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Human systems integration: training and education needs analysis

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HUMAN SYSTEMS INTEGRATION:

TRAINING AND EDUCATION NEEDS ANALYSIS

by

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ABSTRACT

Over the past decade, the military (both US and foreign) has developed a wide range of tools, techniques, and technologies for integrating human factors into systems engineering. Human Systems Integration (HSI) came forth as a new multidisciplinary field of study composed of several basic areas including Human Factors Engineering, System Safety, Health Hazards, Personnel Survivability, Manpower, Personnel, Training, and Habitability.

An online survey was designed to examine education and training in HSI. 19 HSI experts responded to the survey. The feedback showed that there is a lack of high qualified practitioners in HSI. Many HSI practitioners are lacking of required skills due to limited resources of education and training in HSI area. A common opinion shared by all the experts is that there are limited programs in HSI or the education programs are not focused on HSI. Many major universities do not have an adequate program. Majority of the HSI programs are focused on mostly Human Factors and are not really on HSI. All aspects of the domains in HSI are not covered in the programs. The experts recommend more applications or hands-on. A series of HSI education and training programs are discussed and recommendations are made to provide a path of future improvement for future students and employers in the field of HSI. Predictions are also made concerning the potential that HSI and Human Factors could be merged into one systematic science that could be used in both industrial and military complex systems.

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1. INTRODUCTION

1.1. WHAT IS HUMAN FACTORS?

Human Factors (HF) is a catch-all term that covers:

- The science of understanding the properties of human capability (Human Factors Science)
- The application of this understanding to the design and development of systems and services (Human Factors Engineering)
- The art of ensuring successful application of Human Factors Engineering to a program [sometimes referred to as Human Factors Integration (HFI)]

The term Human Factors is to a large extent synonymous with the term Ergonomics having separate origins either side of the Atlantic but covering the same technical areas: however, nowadays the terms are used more or less interchangeably.

1.1.1. History of HF. Simply put, Human Factors involves the study of all aspects of the way humans relate to the world around them, with the aim of improving operational performance, and safety, through life costs and/or adoption through improvement in the experience of the end user.

The terms Human Factors and Ergonomics have only been widely known in recent times: the field's origin is in the design and use of aircraft during World War II to improve aviation safety. It was in reference to the psychologists and physiologists working at that time and the work that they were doing that the terms "applied psychology", "applied psychologist" and “ergonomics” were first coined.

Human Factors concerns emerged during World War II as result of the work and experience of a number of specialists involved in the study of then-current manned systems. These systems included those operating on the earth surface, under the sea, and in space. Human Factors studies were made of:

- systems performance
- problems encountered in information presentation, detection, and recognition
- related action controls
- workspace arrangement
- skills required (Sanders & McCormick, 1976)

Research in these areas ensued, with particular emphasis on human operations. This offered the opportunity for early improvements in performance and safety, as significant modifications of equipment were unlikely under wartime circumstances. Attention was focused on operations analysis, operator selection, training, and the environment associated with signal detection and recognition, communication, and vehicle control. Concurrently, Human Factors work in industry was focused on efficiency, task analysis, and time-and-motion studies.

With the coming of peace, Human Factors activity was broadened to include systems design more completely. As a result, Human Factors requirements were incorporated into government phased-procurement contracts with industry. This led to the utilization of Human Factors specialists by industry and gradually resulted in their involvement in nonmilitary systems and equipment. In the decades that followed, Human Factors has continued to broaden its area of concern and activity to include transportation, architecture, environmental design, consumer products, electronics/computers, energy systems, medical devices, manufacturing, office automation, organizational design and management, aging, farming, health, sports and recreation, oil field operations, mining, forensics, education, and speech synthesis.

1.1.2. Definition of HF. Human Factors is designing for human use, interaction between the human and the system. It is also called ergonomics or engineering psychology. Engineering, psychology, computer science and manufacturing are common fields involved in Human Factors.

Some textbook definitions of Human Factors:

- Human Factors is the discipline that tries to optimize the relationship between technology and the human (Kantowitz and Sorkin, 1983).
- The central approach of Human Factors is the application of relevant information about human characteristics and behavior to the design of objects, facilities, and environments that people use (Grandjean, 1980).
- The goal of Human Factors is to apply knowledge in designing systems that work, accommodating the limits of human performance and exploring the advantages of the human operator in the process (Wickens, 1984).

- Human Factors discovers and applies information about human behavior, abilities, limitations, and other characteristics to the design of tools, machines, systems, tasks, jobs, and environments for productive, safe, comfortable, and effective human use (Chapanis, 1985).

The term Human Factors is used as an overall term, but most often it is used to mean the design of hardware and software in order to increase usability, efficiency, performance, and acceptance by the user.

1.2. WHAT IS HSI?

Human Systems Integration is defined as a process that optimizes the human part of the total system equation by integrating Human Factors engineering, manpower, personnel, training, health, safety, survivability, and habitability considerations into the system acquisition process. Human Systems Integration (HSI) is the interaction between people (operators, maintainers, and support) and their systems. The principle goal is to ensure a safe and efficient relationship between the user and the technical system.

1.2.1. Army HSI Programs. The US Army was the first large organization to fully implement and demonstrate the benefits of an HSI approach, by focusing upon the human element. In 1986, the Army created a Manpower and Personnel Integration (MANPRINT) management and technical program designed to improve weapons systems and unit performance. The Army leaders decided it was necessary to change the focus of equipment developers away from "equipment-only" toward a "total system" view—one that considered soldier performance and equipment reliability together as a system. The program was extremely broad, including all Army management, technical processes, products, and related information covering the domains of manpower, personnel, training, Human Factors engineering, system safety, and health hazards. After the Gulf War, largely because of fratricide incidents, the Army added a new domain, soldier survivability, to MANPRINT (Thompson, 1984).

The most unique aspect of the program was effective integration of Human Factors into the mainstream of system definition, development, and deployment. Organizationally, the MANPRINT domain functions were spread throughout the Army with major roles being performed by Army Material Command, Training and Doctrine Command, Office of the Surgeon General, Army Safety Center, Army Research Institute, and the Human Engineering Laboratory. Responsibility for integrating these varied human factors functions into the material acquisition process was with the Deputy Chief of Staff for Personnel (DCSPER) on the Department of Army Staff. The policy that provided the formal definition and various roles and responsibility was presented in Army Regulation 602-2, Manpower and Personnel Integration (MANPRINT) in the material acquisition process (US Army, 1990).

In the latest revisions to the MANPRINT policy (US Army, 2001), several major roles have changed, most significantly with the Army Research Laboratory performing the technical work of all the domains except systems safety (Army Safety Center) and health hazards [Army Center for Health Promotion and Preventive Medicine (CHPPM)]. However, even though the basic philosophy laid out originally has not changed, implementation effectiveness has varied considerably over time.

1.2.2. Other HSI Programs. The desired objectives of the MANPRINT approach to systems integration and the Human Factors domains of the Army program have both been adopted by the US Department of Defense with its HSI program and in the UK Ministry of Defense with its Human Factors Integration (HFI) program. The Federal Aviation Administration (FAA) has also implemented major portions of MANPRINT into its HFI program. The MANPRINT philosophy presented in the original MANPRINT book “MANPRINT: An Approach to Systems Integration” (Booher, 1990) is presented as an HSI philosophy, with the understanding that essentially the same concepts and principles apply whether the term used is HSI, HFI, or MANPRINT. As the HSI philosophy evolves, newer HSI programs (US Air Force, US Navy, UK Ministry of Defense, The Netherlands Applied Scientific Research Organization, and FAA) are making significant contributions both in the development of advanced HSI technology and in procuring new systems with HSI in their systems engineering and management processes.

1.2.3. HSI Definition. Human Systems Integration is primarily a technical and managerial concept, with specific emphasis on methods and technologies that can be utilized to apply the HSI concept to systems integration. As a concept, the top-level societal objectives of HSI are to significantly and positively influence the complex relationships among:

1. People as designers, customers, users, and repairers of technology
2. Government and industrial organizations that regulate, acquire, design, manufacture, and/or operate technology
3. Methods and processes for design, production, operation of systems and equipment

It is believed that most of the technical and managerial advances suggested by the HSI concept can be accomplished within an overall systems integration philosophy that places a special emphasis on how its roles and technology can be included within systems engineering and systems management process. As such, the HSI concept is considered to be an important adjunct to the various levels of systems engineering and management described in the handbook of systems engineering and management (Sage and Rouse, 1999). The HSI concept is fully compatible with those systems engineering processes relevant to systems definition, development, and deployment and their life-cycle phases, as well as the systems engineering method, tools, and technologies.

Organizations that have created programs that adopt certain aspects, wholly or in part, of the HSI concept provide their definitions in programmatic language. The Army has defined it MANPRINT program as a comprehensive management and technical program "which focuses on the integration of human considerations into the system acquisition process to enhance human/system design, reduce life cycle ownership costs, and optimize total system performance. MANPRINT accomplishes this by ensuring that the human is fully and continuously considered as part of the total system in the development and/or acquisition of all systems" (US Army, 2001).

The DoD lists its requirements for HSI under its systems engineering requirements:

For all programs…the PM [program manager] should initiate a comprehensive strategy for HSI early in the acquisition process to minimize ownership costs and ensure that the system is built to accommodate the human performance characteristics of the user population that will operate, maintain, and support the system. The PM shall work with the manpower, personnel, training, safety and occupational health…, habitability, survivability, and HFE [Human Factors Engineering] communities to translate the HSI thresholds and objectives in the ORD [operational requirements document] into quantifiable and measurable system requirements. The PM shall include these requirements in specifications, the TEMP [test and evaluation master plan], and other program documentation, as appropriate, and use them to address HSI in the statement of work and contract. The PM shall identify any HSI related schedule or cost issues that could adversely impact program execution [US Department of Defense, 2001, 5000.2-R, paragraph C5.2.3.5.9. HSI].

As a top-level model, HSI brings two novel features to the systems engineering model. These are (1) the highly concentrated user focus on all aspects of the systems definition, development, and deployment stages and (2) the application of the human-related technologies and the HSI disciplines throughout the systems engineering management and technical processes. No system, product, or equipment inputs can be considered as having had an adequate consideration of the people component if it does not pass through the HSI process modulated with these two inputs.

As a unique concept for integrating people, organizations and technology, HSI can offer a wide range of benefits to an organization. Too often, non-HSI individuals do not appreciate these potential benefits because the benefits have not been communicated in a way that reflects most directly on their particular role in the organization. For example, people who have high levels of responsibility for systems acquisition decisions should be interested in HSI performance measures that help assess quantitatively the human error risk with operational systems. This can be contrasted with those primarily concerned with operational processes within the organization. The latter might be more stimulated by the ability of the HSI professional to help them develop people-oriented procedures that utilize user-centered techniques such as functional and task analyses.

The applicability of HSI varies with sociotechnical systems complexity. Sociotechnical systems can range from very highly complex organizations (such as the DoD) to critical technological human-machine subsystems (such as an aircraft cockpit). The HSI process needs support from the highest levels of an organization but is best applied as a concept to specific technological systems such as an aircraft or a control room. As HSI develops technologically, it will also become more relevant to systems design of more complex sociotechnical organizations that comprise a number of technological systems working in unison, such as an aircraft carrier or a hospital.

1.2.4. Ten HSI Principles. During the past decade, 10 HSI principles have been identified that, to the degree they are applied, seem to assure that large organizations will capture the performance, cost, and safety objectives they desire for their systems. Conversely, to the degree any of these principles are left out entirely or a few are followed only marginally, large organizations risk their systems not meeting their desired system objectives. Moreover, specific systems programs that have followed these principles have been extremely successful, while those that have made compromises have made marginal progress. In some cases, programs have been failed to meet the system objectives; and in these cases, almost always the principles have been poorly followed as well.

The following 10 principles are crucial to effective HSI:

1. Top-level leadership
2. Focus on human-centered design (HCD)
3. Source selection policy
4. Organizational integration of all HSI domains
5. Documentation integration into procurement process
6. Quantification of human parameters
7. HSI technology
8. Test and evaluation/assessment
9. Highly qualified practitioners
10. Education and training program

The 10 HSI principles are a blend between technical and managerial features. Some (such as top-level leadership, source selection, and domains integration) are purely management and organizational factors that can be raised or lowered in maturity through policy decisions. Others (such as quantitative human performance and HSI technology) are primarily technical factors. These tend to progress at the rate science and technology progresses for basic human performance knowledge and techniques. But still others are combinations of managerial applications and technical developments (such as skilled practitioners, and education and training). As technology advances, the organization can speed or impede progress depending on how well it understands and supports maturity development on these principles.

The 10 principles provide a means to assess the organizational maturity of HSI programs. In the 20 years since MANPRINT was first introduced to the Army, there has been significant opportunity to refine the processes and techniques that are important to HSI concepts and show historically how well the Army as an organization has applied the MANPRINT model to its military systems.

1.3. PROBLEMS AND PURPOSE

Given scattered information about HSI, this new area is still less than ideally defined. The following questions should be addressed in this research to contribute to the body of knowledge in HSI:

- What is HSI?
- Who are the HSI practitioners?
- Does current HSI education and training of these specialists meet the needs of their employers?
- What could be done for the future education and training programs of HSI?

2. LITERATURE REVIEW

2.1. HUMAN FACTORS AND SYSTEMS

The increased rate of technological development of recent decades has created the need to consider human factors early in the design phase, and in a systematic manner. Because of the complexity of many new and modified systems it frequently is impractical to make changes after they are actually produced. The cost of retrofitting frequently is exorbitant. Thus, the initial designs of many items must be as satisfactory as possible in terms of Human Factors considerations.

In effect, then, the increased complexities of the things people use (as the consequence of technology) place a premium on having assurance that the item in question will fulfill the two objectives of functional effectiveness and human welfare. The need for such assurance requires that Human Factors be taken into account early in the design and development process.

2.1.1. Systems. A central and fundamental concept in Human Factors is the system. Various authors have proposed different definitions for the term; however, a very simple one is adopted here. A system is an entity that exists to carry out some purpose (Bailey, 1982). A system is composed of humans, machines, and other things that work together (interact) to accomplish some goal which these same components could not produce independently. Thinking in terms of systems serves to structure the approach to the development, analysis, and evaluation of complex collections of humans and machines. As Bailey (1982) states, the concept of a system implies that we recognize a purpose; we carefully analyze the purpose; we understand what is required to achieve the purpose; we design the system's parts to accomplish the requirements; and we fashion a well-coordinated system that effectively meets our purpose.

2.1.2. Human-Machine Systems. A human-machine system can be considered as a combination of one or more human beings and one or more physical components interacting to bring about, from given inputs, some desired output. In this frame of reference, the common concept of machine is too restricted, and we should rather consider a "machine" to consist of virtually any type of physical object, device equipment, facility, thing, or what have you that people use in carrying out some activity that is directed toward achieving some desired purpose or in performing some function. In a relatively simple form, a human-machine system (or what we sometimes refer to simply as a system) can be a person with a hoe, a scissor, or a hair curler. Going up the scale of complexity, we can regard as systems the family automobile, an office machine, a lawn mower, and a roulette wheel, each equipped with its operator. More complex systems include aircraft, bottling machines, computer systems, and automated oil refineries, along with their personnel. Some systems are less delineated and more amorphous than these, such as the servicing systems of gasoline stations and hospitals and other health services, the operation of an amusement park or a highway and traffic system, and the rescue operations for locating an aircraft downed at sea.

The essential nature of people's involvement in a system is an active one, interacting with the system to fulfill the function for which the system is designed. The typical type of interaction between a person and a machine is illustrated in Figure 2-1. This shows how the displays of a machine serve as stimuli for an operator, trigger some

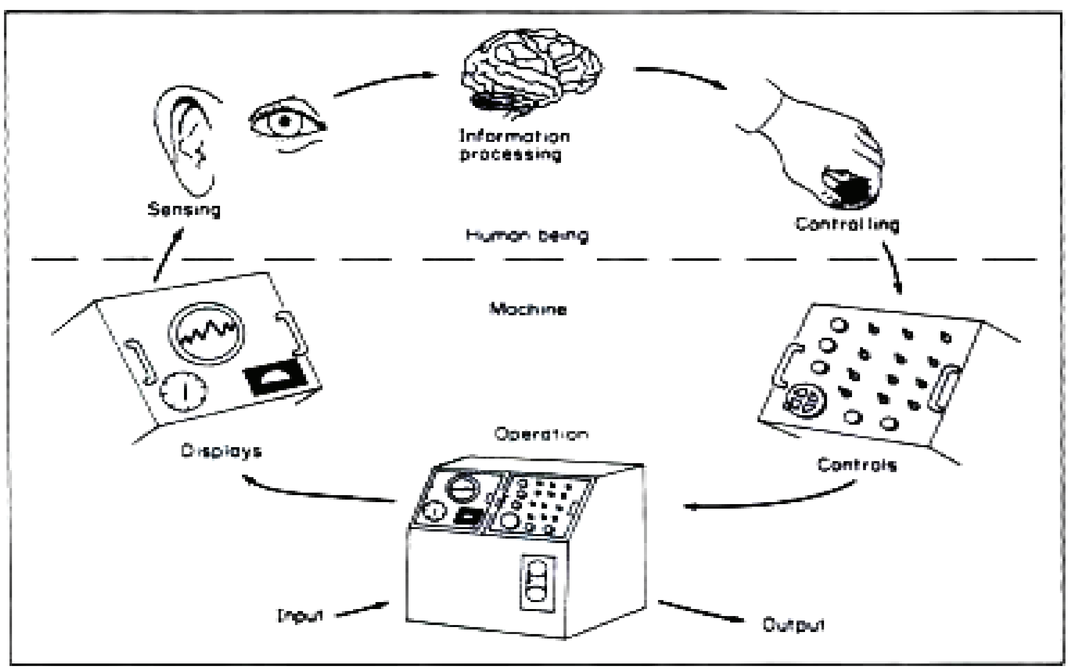

Figure 2-1: Schematic Representation of Human-Machine Systems. (Chapanis, 1985)

type of information processing on the part of the operator (including decision making), which in turn results in some action (as in the operation of a control mechanism) that controls the operation of the machine.

One way to characterize human-machine systems is by the degree of manual versus machine control. Although the distinctions between and among systems in terms of such control are far from clear-cut, systems are generally considered in three broad classes: manual, mechanical, and automatic.

A manual system consists of hand tools and other aids which are coupled by a human operator who controls the operation. Operators of such systems use their own physical energy as the power source.

The mechanical systems (also referred to as semiautomatic systems) consist of well-integrated physical parts, such as various types of powered machine tools. They are generally designed to perform their functions with little variation. The power typically is provided by the machine, and the operator's function is essentially one of control, usually by the use of control devices.

When a system is fully automated, it performs all operational functions with little or no human intervention. Robots are a good example of an automated system. All automated systems require humans to install, program, reprogram, and maintain them. Automated systems must be designed with the same attention paid to human factors that would be given to any other type of human-machine system.

2.1.3. Characteristics of Systems. A few fundamental characteristics of systems, especially as they relate to human-machine systems, are briefly discussed here.

Systems are purposive: in the definition of a system, we stressed that a system has a purpose. Every system must have a purpose, or else it is nothing more than a collection of odds and ends. The purpose of a system is the system goal, or objective, and systems can have more than one (Bailey, 1994).

Systems can be hierarchical: Some system can be considered to be parts of larger systems. In such instances, a given system may be composed of more molecular systems (also called subsystems). When faced with the task of describing or analyzing a complex system, two decisions must be made. First, one has to decide on the boundary of the system, that is, what is considered part of the system and what is considered outside the system. There is no right or wrong answer, but the choice must be logical and must result in a system that performs an identifiable function. The second decision is where to set the limit of resolution for the system. That is, how far down into the system is one to go? At the lowest level of analysis one finds components. A component in one analysis may be a subsystem in another analysis that sets a lower limit of resolution. As with setting system boundaries, there is no right or wrong limit of resolution. The proper limit depends on why one is describing or analyzing the situation.

Systems operate in an environment: The environment of a system is everything outside its boundaries. Depending on how the system's boundaries are drawn, the environment can range from the immediate environment (such as a workstation, a lounge chair, or a computer desk) through the intermediate (such as a home, an office, a factory, or a school) to the general (such as a community, a city, or a highway system). Although the nature of people's involvement with their physical environment is essentially passive, the environment tends to impose certain constraints on their behavior or to predetermine certain aspects of behavior.

Components serve functions: Every component (the lowest level of analysis) in a system serves at least one function that is related to the fulfillment of one or more of the system's goals. One task of human factors specialists is to aid in making decisions as to whether humans or machines (including software) should carry out a particular system function. Components serve various functions in systems, but all typically involve a combination of four more basic functions: sensing (information receiving), information storage, information processing and decision, and action function; they are depicted graphically in Figure 2-2. Since information storage interacts with all the other functions, it is shown above the others. The other three functions occur in sequence.

Systems, subsystems, and components have inputs and outputs: At all levels of a complex system there are inputs and outputs. The outputs of one subsystem or components are the inputs to another. A system receives inputs from the environment and makes outputs to the environment. It is through inputs and outputs that all the pieces interact and communicate. Inputs can be physical entities (such as materials and products), electric impulses, mechanical forces, or information. In a system's analysis all the inputs and outputs required for each component and subsystem to perform its functions are specified. Human factors specialists are especially qualified to determine the inputs and outputs necessary for the human components of systems to successfully carry out their functions.

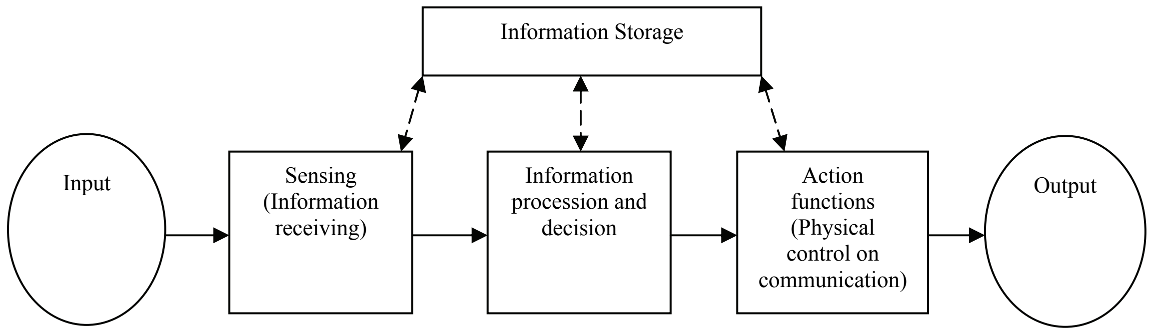

Figure 2-2: Types of Basic Functions Performed by Human or Machine Components of Human-Machine Systems (Thompson, 1987)

2.2. HUMAN FACTORS RESEARCH METHODOLOGIES

Human Factors is in large part an empirical science. The central approach of human factors is the application relevant information about human capabilities and behavior to the design of objects, facilities, procedures, and environments that people use. This body of relevant information is largely based on experimentation and observation.

In addition to gathering empirically based information and applying it to the design of things, human factors specialists also gather empirical data to evaluate the "goodness" of their designs and the designs of others. Thus, empirical data, and hence research, play a dual role in the development of systems: at the front end as a basis for the design and at the back end as a means of evaluating and improving the design.

2.2.1. Overview. Most Human Factors research involves the use of human beings as subjects (Chapanis, 1985), so we focus our attention there. Human Factors research can usually be classified into one of three types: descriptive studies, experimental research, or evaluation research. Actually, not all Human Factors research fits neatly into only one category; often a particular study will involve elements of more than one category. Although each category has different goals and may involve the use of slightly different methods, all involve the same basic set of decisions: choosing a research setting, selecting variables, choosing a sample of subjects, deciding how the data will be collected, and deciding how the data will be analyzed.

2.2.2. Descriptive Studies. Generally speaking, descriptive studies seek to characterize a population (usually of people) in terms of certain attributes. Examples include surveys of the dimensions of people's bodies, hearing loss among people of different ages, people's expectations as to how a knob should be turned to increase the value on a display, and weights of boxes people are willing to lift.

Descriptive studies are very important to the science of human factors. They represent the basic data upon which many design decisions are based. In addition, descriptive studies are often carried out to assess the magnitude and scope of a problem before solutions are suggested. A survey of operators to gather their opinions about design deficiencies and operational problems would be an example. In fact, the Nuclear Regulatory Commission (1981) required such a survey as part of its mandated human factors control room review process.

2.2.3. Experimental Research. The purpose of experimental research is to test the effects of some variable on behavior. The decisions as to what variables to investigate and what behaviors to measure are usually based on either a practical situation which presents a design problem, or a theory that makes a prediction about variables and behaviors. Examples of the former include comparing how well people can edit manuscripts with partial-line, partial-page, and full-page computer displays (Neal and Darnell, 1984) and assessing the effect of seat belts and shoulder harnesses on functional arm reach (Garg, Bakken, and Saxena, 1982). Experimental research of a more theoretical nature would include a study by Hull, Gill, and Roscoe (1982) in which they varied the lower half of the visual field to investigate why the moon looks so much larger when it is near the horizon than when it is overhead.

Usually in experimental research the concern is whether a variable has an effect on behavior and the direction of that effect. Although the level of performance is of interest, usually only the relative difference in performance between conditions is of concern. In contrast, descriptive studies are usually interested in describing a population parameter, such as the mean, rather than assessing the effect of a variable. When descriptive studies compare groups that differ on some variable (such as sex or age), the means, standard deviations, and percentiles of each group are of prime interest. This difference in goals between experimental and descriptive studies has implications for subject selection.

2.2.4. Evaluation Research. Evaluation research is similar to experimental research in that its purpose is to assess the effect of "something." However, in evaluation research the something is usually a system or product. Evaluation research is also similar to descriptive research in that it seeks to describe the performance and behaviors of the people using the system of product.

Evaluation research is generally more global and comprehensive than experimental research. A system or product is evaluated by comparison with its goals; both intended consequences and unintended outcomes must be assessed. Often an evaluation research study will include a benefit-cost analysis. Examples of evaluation research include evaluating a new training program, a new software package for work processing, or an ergonomically designed vehicle cabinet. Evaluation research is the area where human factors specialists assess the "goodness" of designs, theirs and others, and make recommendations for improvement based on the information collected.

2.3. HUMAN SYSTEMS INTEGRATION IN THE CONTEXT OF SYSTEM DEVELOPMENT

The ultimate goal of system development is to deliver a system that satisfies the needs of its operational stakeholders—users, operators, administrators, maintainers, interoperators, and the public—within satisfactory levels of the resources of its development stakeholders—funders, acquirers, developers, suppliers, and others. From the perspective of Human System Integration (HSI), satisfying operational stakeholders' needs can be broadly construed to mean that a system is usable and dependable, permits few or no human errors, and leads to high productivity and adaptability. Developing and delivering systems that simultaneously satisfy all these stakeholders usually requires managing a complex set of risks, such as usage uncertainties, schedule uncertainties, supply issues, requirements changes, and uncertainties associated with technology maturity and technical design. Each of these areas poses a risk to the delivery of an acceptable operational system within the available budget and schedule. End-state operational system risks can be categorized as uncertainties in achieving a system mission, carrying out the work processes, operating within such constraints as cost or personnel, satisfying operational stakeholders, and achieving an acceptable operational return on investment.

2.3.1. Principles for Successful System Development. The five principles critical to the success of human-intensive system development and evolution were evolved and validated by analysis of the critical success factors of many award-winning projects. (Pew and Maver, 2007)

Stakeholder satisficing. If a system development process presents an operational or development stakeholder with the prospect of an unsatisfactory outcome, the stakeholder will generally refuse to cooperate, resulting in an unsuccessful system. Stakeholder satisficing involves identifying the stakeholders critical to success and their value propositions; negotiating a mutually satisfactory set of system requirements, solutions, and plans; and managing proposed changes to preserve a mutually satisfactory outcome.

Incremental growth of system definition and stakeholder commitment. This characteristic encompasses the necessity of incremental discovery of emergent human-system requirements and solutions via such discovery methods as prototyping, operational exercises, and the use of early system capabilities. Requirements and commitment cannot be monolithic or fully prespecifiable for complex, human-intensive systems; understanding, trust, definition, and commitment are achieved through a cyclic process.

Iterative system definition and development. Incremental and evolutionary approaches lead to cyclic refinements of requirements, solutions, and development plans. Such iteration helps projects to learn early and efficiently about operational and performance requirements.

Concurrent system definition and development. Initially, this includes concurrent engineering of requirements and solutions, as well as integrated product and process definition. In later increments, change-driven rework and rebase lining of next-increment requirements, solutions, and plans occur simultaneously with development of the current-system increment. This allows early fielding of core capabilities, continual adaptation to change, and timely growth of complex systems without waiting for every requirement and subsystem to be defined.

Risk management—risk-driven activity levels and anchor point milestones. The level of detail of specific products and processes will depend on the level of risk associated with them. If the user interface is considered a high-risk area, for example, then more design activity will be devoted to this component to achieve stakeholder commitments at particular design anchor points. If, however, interactive graphic user interface (GUI) builder capabilities make it low risk not to document evolving GUI requirements, much time-consuming effort can be saved by not creating and continually updating GUI requirements documents while evolving the GUI to meet user needs.

2.3.2. Principle-Based Comparison of Alternative Process Models. The candidate models include the waterfall, V, spiral, and concurrent engineering process models, plus emerging candidates, such as agile methods (Beck, 1999; Highsmith, 2000), V-model updates (Federal Republic of Germany, 2004), and the spiral model (Boehm and Hansen, 2001).

Table 2-1 indicates that all of the models make useful contributions but exhibit shortfalls with respect to human factors considerations, particularly in explicit guidance for stakeholder satisficing. Pure-sequential implementations of the waterfall and V-models are not good matches for human-intensive systems. Although they are becoming less frequent, they are still often encountered due to the imposition of existing contracting clauses and standards. More recently, the V-Model XT has adopted more risk-driven and incremental approaches that encourage concurrent engineering (Federal Republic of Germany, 2004), but it takes some skill to build in stakeholder satisficing and to avoid overly heavyweight implementations and difficulties in coping with rapid change. Risk-driven evolutionary development is better at coping with rapid change, but it can have difficulties in optimizing around early increments with architectures that encounter later scalability problems. Concurrent engineering explicitly addresses incremental growth, concurrency, and iteration. Although compatible with stakeholder satisficing and risk management, it lacks much explicit guidance in addressing them.

Agile methods are even better at coping with rapid change, but they can have even more difficulties with scalability and with mission-critical or safety-critical systems,

Table 2-1: Principles-Based Comparison of Alternative Process Models (National Research Council, 2007)

Process Models	Design Principles: Stakeholder Satisficing	Incremental Growth	Concurrency	Iteration	Risk Management
Sequential waterfall, V	Assumed via initial requirements; no specifics	Sequential	No	No	Once at the beginning
Iterative, risk-driven waterfall, V	Assumed via initial requirements; no specifics	Risk-driven; missing specifics	Risky parts	Yes	Yes
Risk-driven evolutionary development	Revisited for each iteration	Risk-driven; missing specifics	Risky parts	Yes	Yes
Concurrent engineering	Implicit; no specifics	Yes; missing specifics	Yes	Yes	Implicit; no specifics
Agile	Fix shortfalls in next phase	Iterations	Yes	Yes	Some
Spiral process 2001	Driven by stakeholder commitment milestones	Risk-driven; missing specifics	Yes	Risk-driven	Yes
Incremental commitment	Stakeholder-driven; stronger human factors support	Risk-driven; more specifics	Yes	Yes	Yes

in which fixing shortfalls in the next increment is not acceptable. There is a wide variety of agile methods; some, such as lean and feature-driven development, are better at scalability and criticality than others. The version of spiral development in Boehm and Hansen (2001), with stakeholder satisficing and anchor point milestones, covers all of the principles, but it is unspecific about how risk considerations guide iteration and incremental growth. The analysis of these models indicates primary shortfalls in support of human factors integration and unproven ability to scale up to the future process challenges involving emergent, network-centric, massively collaborative systems of systems (Maier, 1998; Sage and Cuppan, 2001).

2.3.3. The Incremental Commitment Model. An overview of the ICM life-cycle process is shown in Figure 2-3. It identifies the concurrently engineered life-cycle phases; the stakeholder commitment review points and their use of feasibility rationales to assess the compatibility, feasibility, and risk associated with the concurrently engineering artifacts; and the major focus of each life-cycle phase. There are a number of alternatives at each commitment point: (1) the risks are negligible and no further analysis and evaluation activities are needed to complete the next phase; (2) the risk is acceptable and work can proceed to the next phase; (3) the risk is addressable but requires backtracking; and (4) the risk is too great and the development process should be rescoped or halted. These risks are assessed by the system's stakeholders, whose commitment will be based on whether the current level of system definition gives sufficient evidence that the system will satisfy their value propositions.

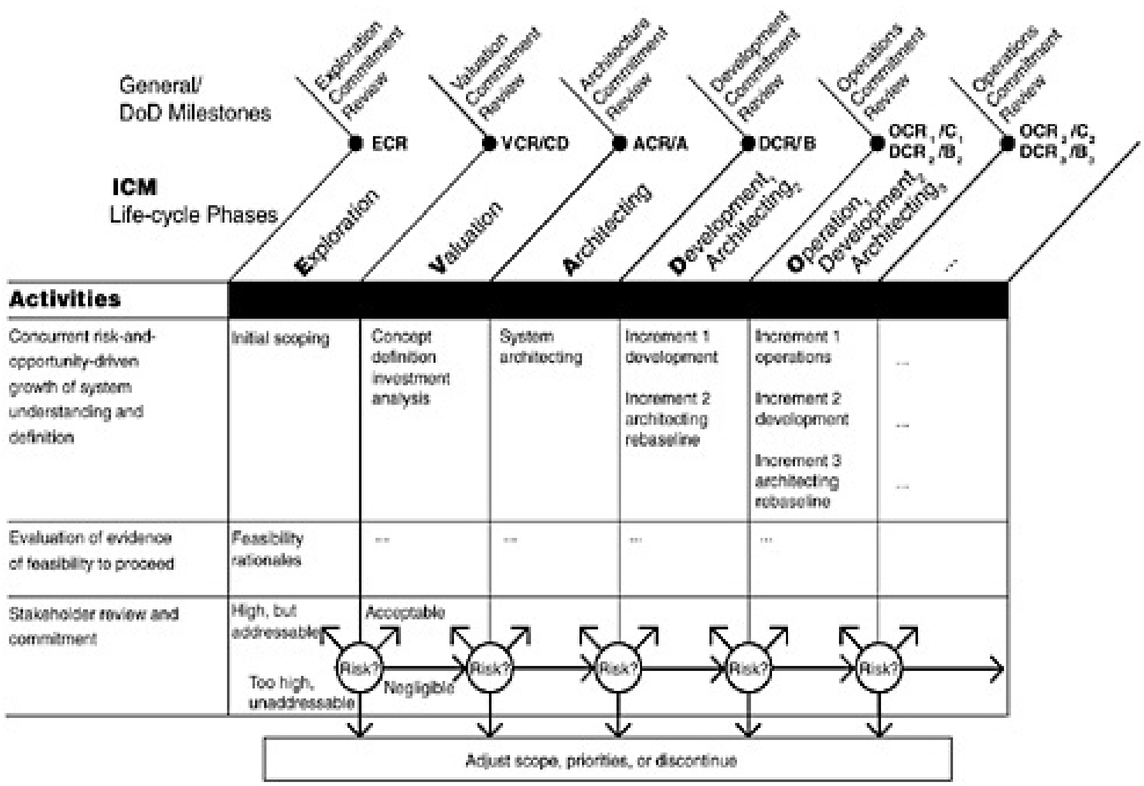

Figure 2-3: Overview of the Incremental Commitment Life-Cycle Process
(Booher, 2003)

The incremental commitment model builds on the early verification and validation concepts of the V-model, the concurrency concepts of the concurrent engineering model, the lighter-weight concepts in the agile and lean models, the risk-driven concepts of the spiral model, the phases and anchor points in the rational unified process (RUP) (Royce, 1998; Kruchten, 1999; Boehm, 1996), and recent extensions of the spiral model to address systems of systems acquisition (Boehm and Lane, 2006). In comparison to the software-intensive RUP, the incremental commitment model also addresses hardware and human factors integration. It extends the RUP phases to cover the full system life cycle: an exploration phase precedes the RUP inception phase, which is refocused on valuation and investment analysis. The RUP elaboration phase is refocused on architecting; the RUP construction and transition phases are combined into development; and an additional operations phase combines operations, production, maintenance, and phase-out. An integration of the RUP and the incremental commitment model is being prepared for use in the open-source eclipse process frameworks.

In comparison to the sequential waterfall (Royce, 1970) and V-models (Federal Republic of Germany, 2004), the incremental commitment model explicitly emphasizes concurrent engineering of requirements and solutions, establishes explicit feasibility rationales as pass/fail milestone criteria; explicitly enables risk-driven avoidance of unnecessary documents, phases, and reviews; and provides explicit support for a stabilized current-increment development concurrently with a separate change processing and rebaselining activity to prepare for appropriate and stabilized development of the next increment. These aspects can be integrated into a waterfall or V-model, enabling projects required to use such models to cope more effectively with systems of the future.

The ICM commitment milestones correspond fairly closely with the Department of Defense (DoD) acquisition milestones as defined in DoD Instruction 5000.2 (U.S. Department of Defense, 2003a). For example, the ICM milestone commitment to proceed into development based on the validated life-cycle architecture package (an operations concept description, requirements description, architecture description, life-cycle plan, working prototypes or high-risk elements, and a feasibility rationale providing evidence of their compatibility and feasibility) corresponds fairly closely with DoD's Milestone B commitment to proceed into the development and demonstration phase.

2.4. HUMAN SYSTEMS INTEGRATION METHODS IN SYSTEM DEVELOPMENT

State-of-the-art methods of human-system integration (HSI) can be used to inform and guide the design of person-machine systems using the incremental commitment model approach to system development. Three general classes of methods are provided to robust representation of multiple HSI concerns and are applicable at varying levels of effort throughout the development life cycle. These broad classes include methods to:

Define context of use. Methods for analyses that attempt to characterize early opportunities, early requirement and the context of use, including characteristics of users, their tasks, and the broader physical and organizational environment in which they operate, so as to build systems that will effectively meet users' needs and will function smoothly in the broader physical and organizational context.

Define requirements and design solutions. Methods to identify requirements and design alternatives to meet the requirements revealed by prior up-front analysis.

Evaluate. Methods to evaluate the adequacy of proposed design solutions and propel further design innovation. (National Research Council, 2007)

Figure 2-4 presents a representative sampling of methods that fall into each activity category and the shared representations that are generated by these methods. A number of points are highlighted in the figure:

The importance of involving domain practitioners—the individuals who will be using the system to achieve their goals in the target domain—as active partners throughout the design process.

The importance of involving multidisciplinary design experts and other stakeholders to ensure that multiple perspectives are considered throughout the system design and evaluation process and that stakeholder commitment is achieved at each step.

The availability of a broad range of methods in each class of activity. Appropriate methods can be selected and tailored to meet the specific needs and scope of the system development project.

The range of shared representations that can be generated as output of each of four HSI activities. These representations provide shared views that can be inspected and evaluated by the system stakeholders, including domain practitioners, who will be the target users of the system. The shared representations serve as evidence that can be used to inform risk-driven decision points in the incremental commitment development process.

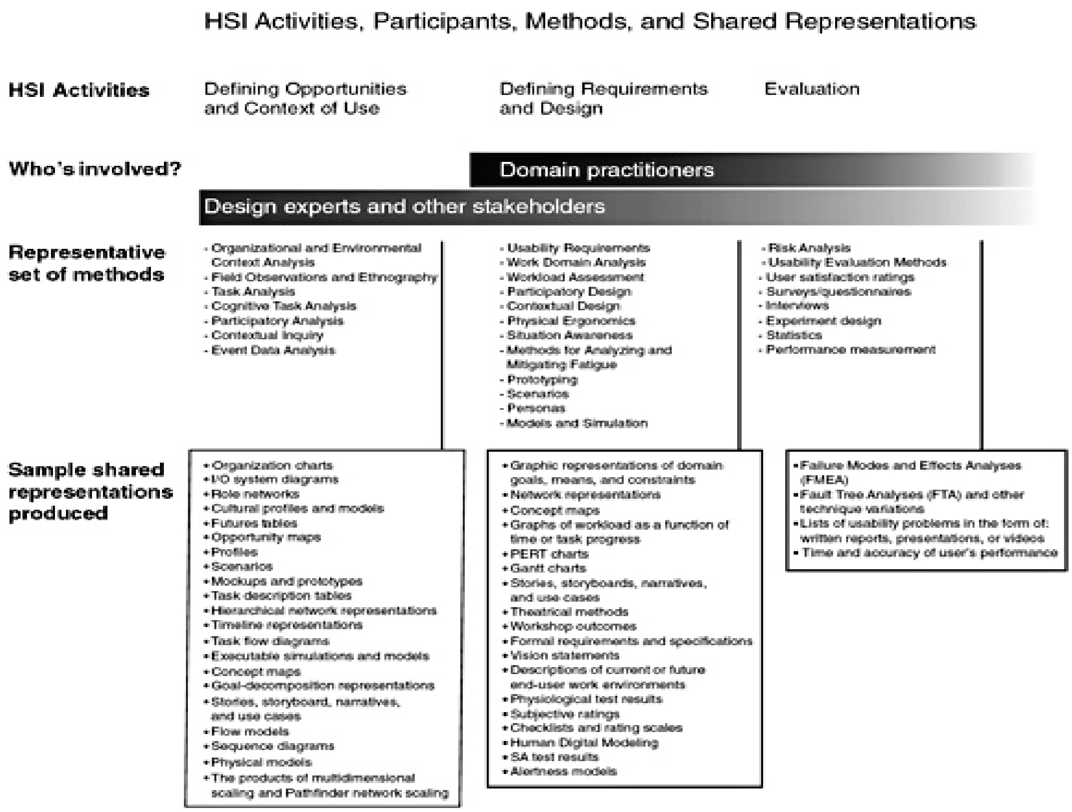

Figure 2-4: HSI Activities, Participants, Methods, and Shared Representations. (National Research Council, 2006)

Function allocation is the assignment of functions to specific software or hardware modules or to human operators or users. In the case of hardware and software, it is a decision about which functions are sufficiently similar in software requirements or interfunction communication to collect together for implementation. In the case of assignment to human users versus software/hardware, it is a matter of evaluating the performance capacities and limitations of the users, the constraints imposed by the software and hardware, and the system requirements that imply users because of safety or policy implications. It is commonly agreed that function allocation is, at the base level, a creative aspect of the overall design process. It's agreed that it requires hypothesis generation, evaluation and iteration. There have been attempts to systematize the process of achieving function allocation (Price, 1985), but they encompass the several parts of the design process that we are discussing in this section and do not add new substantive information.

Performance measurement supports just about every methodology that is applied to human-system integration. Stakeholders are interested in the quality of performance of the systems under development, and they would like to have predictions of performance before the system is built. While they may be most interested in overall system performance—output per unit time, mean time to failure, probability of successful operation or mission, etc.—during the development itself, there is a need for intermediate measures of the performance of individual elements of the system as well, because diagnosis of the cause of faulty system performance requires more analytic measures at lower functional levels. From a systems engineering point of view, one may consider system-subsystem-module as the analysis breakdown; however, when one is concerned with human-system integration, the focus is on goal-task-subtask as the relevant decomposition of performance, because it is in terms of task performance that measures specifically of human performance are most meaningful and relevant.

Since each situation is different, the analyst must consider the context of use under which measurement or prediction is to be undertaken, the goals of the measurement, and the characteristics of the users who will be tested or about whom performance will be inferred, and the level of detail of analysis required in order to select specific measures to be used.

2.5. CONCLUSION

The literature review shows that current research is mainly focused on research methodology and modeling in HSI. The definition of HSI is still not clear. And information about HSI education and training programs is limited. So it's necessary to further study to contribute to the body of knowledge and address problems identified in the previous chapter of this thesis.

3. METHODOLOGY

The chart of the research model is shown in Figure 3-1.

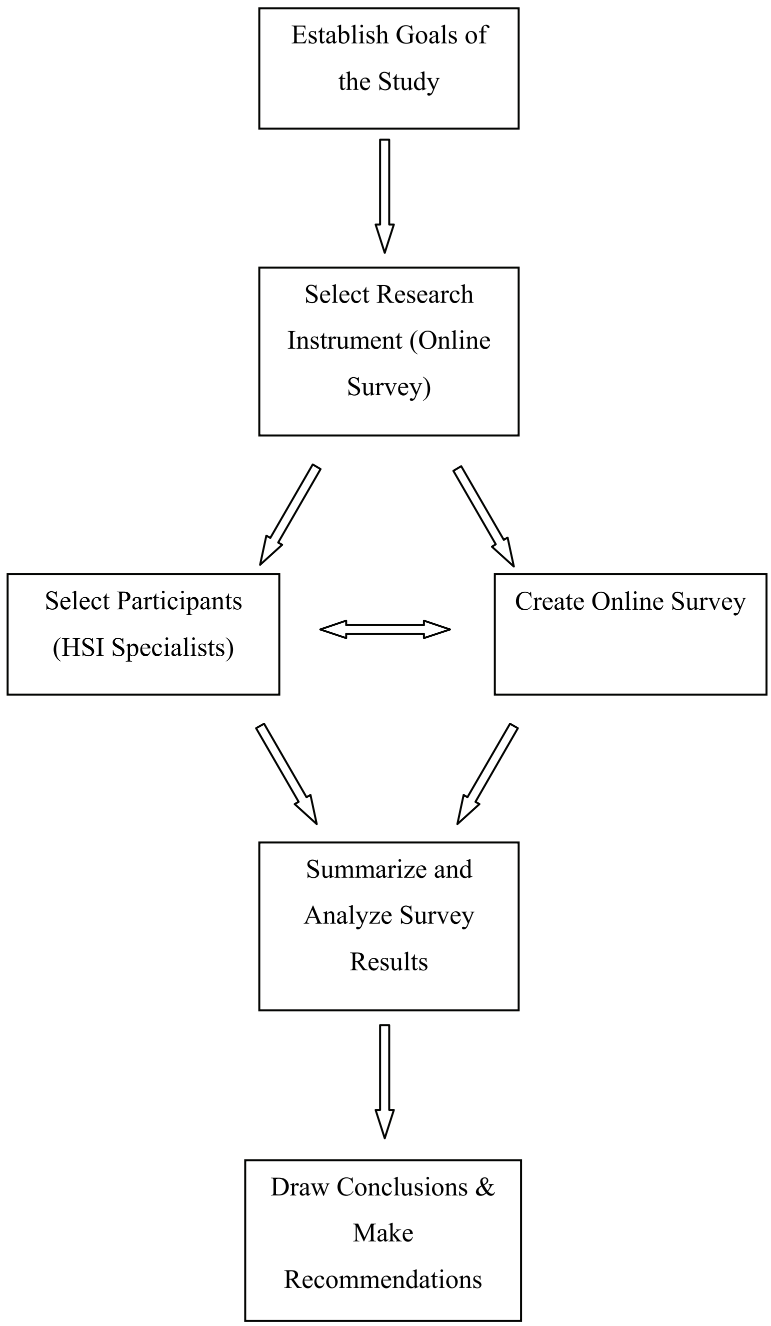

Figure 3-1: Flowchart of the Research Model

The sequence of this research model is:

The objectives of the study are established in the beginning;

Then research instrument (online survey) is selected to address the problems;

A proper group of participants are chosen to do the survey while a list of questionnaires is developed;

Survey results are analyzed after the data is collected online;

Finally, conclusions are drawn and recommendations are made.

3.1. BACKGROUND

Technology is an integral part of modern life. People interact with technology everyday in automobiles, airplanes, boats, banks, supermarkets, industrial plants, schools, hospitals, military systems, homes, and numerous other places. Unfortunately, people have been frustrated, injured, and killed by technical devices that have been incompatible with their human capabilities and limitations or by systems that just perform poorly. The role of Human Systems Integration (HSI) specialists is to overcome these problems by emphasizing and effecting people-oriented design that keeps the human user, rather than technology, central to the design process.

What is a HSI specialist? Where and how are they educated and trained? Where do they work and what do they do? Does the education and training of these specialists meet the needs of their employers? These are the questions that should be addressed in this research.

3.1.1. The Human Systems Integration Specialist. The definition of a professional charged with overseeing this people-oriented design philosophy varies. The term Human Systems Integration Specialist has been selected from a large number of possible terms to name this profession. Terms such as *system engineering, human factors engineering, safety engineering, applied ergonomics, applied experimental psychology, biomechanics, engineering psychology, ergonomics, human engineering, human factors, human performance engineering, industrial ergonomics, industrial engineering and psychotechnology* were used. The three most prevalent terms included human factors, human factors engineering, and system engineering. In the United States human factors tends to be a broad category; human factors engineering tends to emphasize design; and system engineering tends to be concerned with complex working systems.

3.1.2. Origins of the Study. Human Systems Integration requires highly qualified personnel applying their expertise to systems engineering and management processes if potential dramatic improvements in system performance, safety, and affordability are to be realized. An army manpower, personnel, integration (MANPRINT) study on this topic recommended that a national workforce be established for HSI (U.S. Army, 1993). As the demand increases for HSI expertise, the need for education and training programs to provide the necessary qualifications also increases (Van Cott and Huey, 1992). Currently, few education and training avenues exist to provide even minimal qualifications in HSI (Booher, 2003). The HSI workforce cannot increase substantially, therefore, without adequate education and training sources for developing HSI talent. Muchler and Seven (1990) first addressed the central issues of HSI education and training in the context of developing a national MANPRINT workforce: They considered “the kind of skills and knowledge required to conduct the MANPRINT effort”; examined “some of the … institutional systems that educate and train many of the specialties of MANPRINT”, and outlined the various challenges and prospects facing the establishment of a national HSI workforce at the time.

The study will build and expand upon the Muckler and Seven foundation while describing the current HSI requirements and institutional systems available to educate and train HSI specialties. A key purpose of this study is to amplify HSI principles 9 (qualified practitioners) and 10 (HSI education and training).

More specifically, the goals are to:

Outline the HSI competencies needed for qualified HSI specialists;

Describe what is available in HSI practitioner training and education;

Outline the education and training gaps between HSI needs and what is available;

Define what should be included in academic settings to meet HSI qualifications.

3.1.3. Issues. A variety of questions dealing with the education and utilization of Human Systems Integration specialists need to be addressed:

Skill Requirements. What tasks do Human Systems Integration specialists currently perform relevant to the design, development, production, maintenance, and operation of consumer products and military systems? What skills and knowledge are required by Human Systems Integration personnel in order to contribute effectively to the design, development, training, and evaluation of complex systems and operational procedures and to the development of training programs?

Qualifications. To what extent are the Human Systems Integration courses and programs congruent with the task requirements in industry in the behavioral (e.g., cognitive, sensory, learning, performance, social), engineering (e.g., computer science, engineering and industrial design), physiological (e.g., strength, biomedicine, neurophysiology), and interdisciplinary domains? Is there a disparity between job requirements and current education programs? Are Human Systems Integration specialists receiving the type of analytical skills and training needed so that they may adapt appropriately to future requirements?

Training Curricula. How qualified are recent graduates? How extensive are on-the-job training requirements for newly hired graduates? Can postgraduation learning time be reduced without compromising performance? Are modifications or redirection needed for the mode of education or curricula to enhance the contributions of Human Systems Integration specialists in the industrial environment?

Supply and Demand. What is the number of students currently being trained in Human Systems Integration, and what is the projection for the future? Is the supply of educational programs in the various fields adequate to meet current and future needs?

Actions. What actions can governmental and private organizations take to ensure an adequate supply of Human Systems Integration specialists? How can these actions be enhanced? What kind of training and education programs should be provided to meet the HSI needs?

3.2. OBJECTIVES OF THE STUDY

Reliable information is needed in order to address the various issues related to the education and utilization of Human Systems Integration specialists. The results of surveys of HSI specialists will be used as the bases for its discussion and conclusions. Its overall objective was to recommend improvements for the education, training, and utilization of Human Systems Integration specialists in four areas:

Job Definition. Define the jobs and tasks performed by Human Systems Integration specialists involved in the design, development, production, maintenance, operation, and supportability of integrated systems.

Skills and Knowledge. Identify the knowledge and skill requirements of Human Systems Integration specialists.

Education. Evaluate the extent to which Human Systems Integration education and training currently satisfies the needs of industry and government.

Supply and Demand. Assess and project the demand and supply for qualified Human Systems Integration specialists.

3.3. SURVEY METHODOLOGY

During the last decade, web-based surveys have had a profound influence on survey methodology and became a standard method for conducting surveys. "The Internet has truly democratized the survey-taking process. Survey professionals and large organizations are no longer the only people conducting surveys on the Web.” (Couper, 2000). Software, capable of producing survey forms, is available to the general public at an affordable cost, enabling anyone with a web site to conduct a survey without a lot of difficulty. For that reason, the range and the quality of Web-based surveys vary considerably.

3.3.1. Advantages of Web-based Surveys. "There is no other method of collecting survey data that offers so much potential for so little cost as Web surveys". Zanutto (2001) described many of the reasons for the popularity with Web surveys in her presentation for her course in survey design and construction. She explained that Web-based surveys are relatively cheap. An analysis of the cost of paper vs. Web surveys by Schaefer (2001), for the Students Life Experiences Survey conducted at the Illinois Institute of Technology, determined that the average cost of paper surveys was $US2.07 per student compared to the average cost of $US0.88 for Web-based surveys. Zanutto described other advantages of Web surveys as a faster response rate; easier to send reminders to participants; easier to process data, since responses could be downloaded to a spreadsheet, data analysis package, or a database; dynamic error checking capability; option of putting questions in random order; the ability to make complex skip pattern questions easier to follow; the inclusion of pop-up instructions for selected questions; and, the use of drop-down boxes. These are possibilities that cannot be included in paper surveys. Couper (2000) saw the multimedia capability of Web surveys as a real advantage, as well as the option to customize survey options for particular groups of respondents. It is interesting to note that despite many of these advantages of Web surveys, Dillman,Tortora, et al. (1998) found that the response rate was greater for plain rather than fancy surveys that employed tables, graphics, and different colors. This led the authors of this study to question the use of fancy designs and layouts in Web questionnaires.

3.3.2. Concerns with Web-based Surveys. Web-based surveys are not without problems. Zanutto (2001) discussed a number of issues concerning Web surveys:

Questionnaires do not look the same in different browsers and on different monitors. Therefore, respondents may see different views of the same question, and not receive the same visual stimulus.

Respondents may have different levels of computer expertise. This lack of computer expertise can be a source of error or non-response.

The surveyor is faced with concerns about data security on the server.

The sample in a Web survey isn't really a random sample, and there is no method for selecting random samples from general e-mail addresses.

Since information can be collected about respondents without their knowledge or permission, respondents may be concerned with privacy of the data they are entering. The surveyor can determine the time of day the survey was completed, how long the respondent took to complete each question, how long the respondent took to finish the entire survey, what browser was used, and the respondent's IP address.

Although some participants in Web-based surveys might be concerned with privacy issues, Bosnjak and Tuten (2001) saw the metadata that can be collected about participants, without their knowledge through CGI scripts, Java applets, and user log files, as a benefit to the surveyor, and they described the questionnaire design necessary to gather this data. Thus, privacy issues become a double-edged sword: a concern to the respondent, and a benefit to the surveyor.

Jeavons stated that Web surveys are quite unlike other survey methods of data collection in their execution, and this difference can lead to participants acting differently when responding to Web-based surveys. Using an analysis of log files, Jeavons was able to demonstrate the number of failures and number of repeats experienced by respondents to Web surveys with various questions and question types. He noticed that the first questions often caused immediate refusal or confusion with many repeated attempts to answer it.

3.3.3. Design of Web-based Survey. To survey the Human Systems Integration community, a web-based online survey was used to gather data. The purpose of this survey was to question HSI specialists and supervisors about their professional and job-related activities and education. The online survey which consists of both multiple-choice questions and open-ended questions was sent to more than thirty HSI specialists to get feedback. These specialists were selected from an INCOSE interest group, personnel contacts, and referrals. The participants were also encouraged to send the online survey to other HSI experts. The survey was divided into four parts: demographic information, knowledge level of HSI, educational background, and open-ended comments of their opinions about HSI.

The questions used in this survey drew on four sources of information: (a) questions developed by Sanders and his associates (Sanders, Bied, and Curran, 1986) in job-descriptive surveys of members of the Human Factors Society (HFS), (b) studies of the activities of human factors specialists done by American Psychological Association for the Army Research Institute, (c) surveys developed by Human Factors Commission on Behavioral and Social Sciences and Education National Research Council, (d) studies of the HSI techniques and training by Dr. Harold Booher. Different types of employment settings and work in which human factors specialists were also considered in this survey. Survey questions are shown in Appendix A.

4. RESULTS

4.1. OVERVIEW

19 HSI experts finished the survey by the date of this report. The number of responses was affected by the availability of the experts in the field of HSI.

4.2. ROLE OF HSI IN THE WORK SETTING

4.2.1. Type of Employer. The principal workplace of the Human Systems Integration specialists surveyed was in government agencies, with 73.7 percent (14 out of 19) reporting such an organization as their employer. This percentage included those employed by the Army, the Navy, NASA, or other government organizations. Among those remaining, 15.8 percent (3 out of 19) worked for educational institutions and 5.3 percent (1 out of 19) for private business (Figure 4-1). Only 5.3 percent (1 out of 19) reported a place of work in other than one of the three employer categories because he is retired.

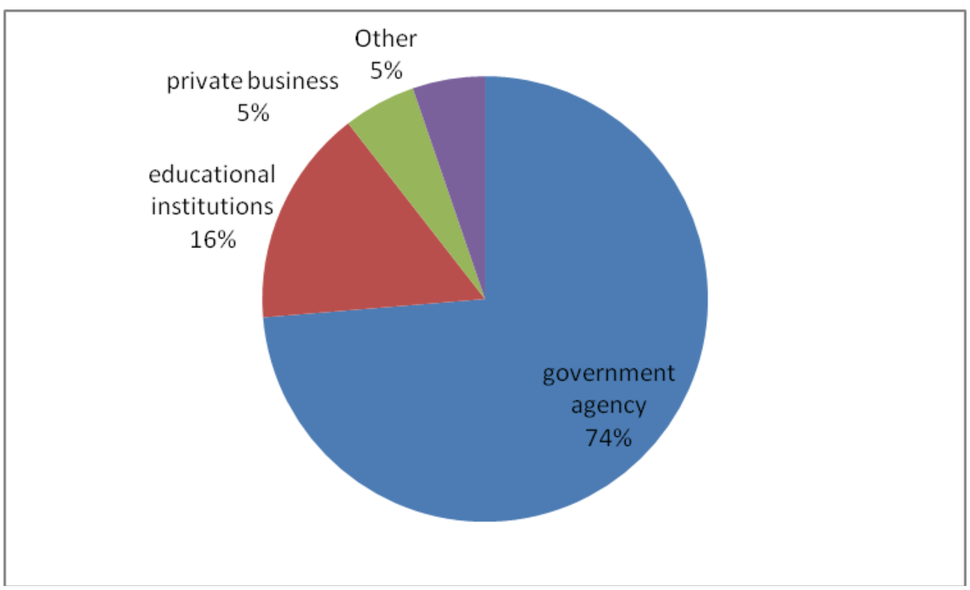

Figure 4-1: Principle Workplace of HSI Specialists

4.2.2. Work History. Most people have been working in the field of Human Systems Integration or human factors for a long time---63.2 percent (12 out of 19) have had their HSI or human factors jobs for 10 years or more, 42.1 percent (8 out of 19) for twenty years or more. Only 36.8 percent (7 out of 19) have been working in HSI or human factors area for less than 10 years (Figure 4-2).

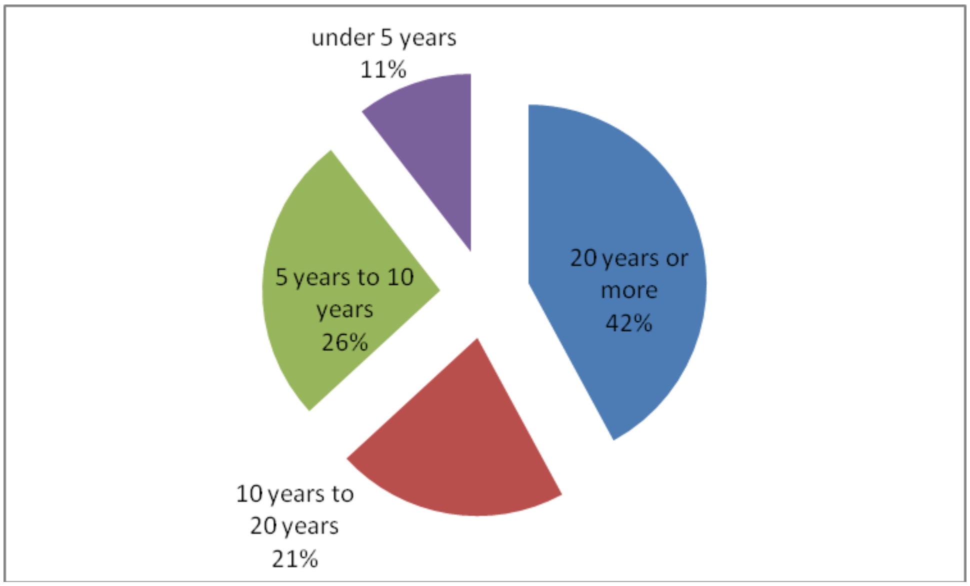

Figure 4-2: Work History in HSI or Human Factors Area

4.2.3. Focus of Work. At the time of the study, all of the respondents' work was related to military systems. 17 of them (89.5%) claimed 100 percent of their own jobs was related to the military systems. Only 2 of them (10.5%) claimed 95 percent of their own work was about military systems.

47.4 percent (9 out of 19) of them are currently working on one or more MANPRINT programs which are the major parts of HSI, and 15.8 percent (3 out of 19) are working on similar programs from the Navy or NASA. Only 36.8 percent (7 out of 19) of them are not related to any MANPRINT programs (Table 4-1).

4.2.4. Self-Perception of Professional Identity. Human Systems Integration specialists were asked the self-perception of professional identity questions. On a scale of

Table 4-1: Percent of HSI Specialists Who Are Working on MANPRINT Programs

8. Are you currently working on any MANPRINT programs?	Response Percent	Response Count
a. No.	**36.8%**	7
b. Yes, one program.	10.5%	2
c. Yes, several programs.	**36.8%**	7
d. Similar programs.	15.8%	3
e. I don't know.	0.0%	0
answered question		**19**

1 through 7, where 1 means very ignorant and 7 means very knowledgeable, 94.7 percent (18 out of 19) of the respondents gave a point of 4 or more in the rating. It means that most people consider themselves to be HSI or human factors experts (Table 4-2).

Table 4-2: Self Rating as HSI or Human Factors Experts

	1-very ignorant	2	3	4	5	6	7 – very knowledgeable	Response Count
About Human System Integration	0.0% (0)	5.3% (1)	0.0% (0)	10.5% (2)	21.1% (4)	26.3% (5)	36.8% (7)	19
About Human Factors	0.0% (0)	5.3% (1)	0.0% (0)	10.5% (2)	21.1% (4)	15.8% (3)	47.4% (9)	19

4.2.5. Perceived Importance of HSI. In the questions of perceived importance of HSI to the jobs, most respondents rate HSI as being important to their jobs on which they spend or have recently spent most of their working times. On a seven-point scale, where 1 means not at all important and 7 means very important, 89.5 percent (17 out of 19) of them used the top two scale positions to indicate the level of importance of HSI to their jobs. Only 10.5 percent (2 out of 19) of them gave low perceived importance of HSI (Table 4-3).

Table 4-3: Perceived Importance of HSI

	1 - Not at all important	2	3	4	5	6	7 - Very important	N/A	Rating Average	Response Count
Rating	0.0% (0)	5.3% (1)	0.0% (0)	5.3% (1)	0.0% (0)	10.5% (2)	**78.9% (15)**	0.0% (0)	6.47	19

In the comment area, the reasons why they thought HSI is so important to their jobs were provided by some respondents:

"It is my job."

"I have the specific responsibility to ensure ship/weapon systems are designed with the human element considered. USN systems designs are still very labor intensive. We have yet to truly embrace technology (both computer H/S and machinery systems) for workload sharing. Additionally, the element of systems safety has yet to be fully addressed."

"HSI and HFE are critical to providing MANPRINT support to DoD."

"I work in the Air Force Human Systems Integration Office (AFHSIO). AFHSIO was established in August 2007 by the Air Force Chief of Staff and is tasked with providing policy, advocacy and oversight to the Air Force for Human Systems Integration (HSI). We have established HSI policy in a new Air Force Policy Document 63/20-1, Acquisition and Sustainment Life Cycle Management and we are working with the domain owners to insert HSI guidance language into appropriate functional Air Force Instructions and Manuals. In other words, Human Systems Integration is our life!"

"The HSI/HF work I have done was for a client in the Air Force. I was only assisting someone in gathering information about HSI/HF related courses at a number of Universities across the country. The Air Force Human Systems Integration Office is interested in establishing and education and training baseline for personnel who are interested in pursuing a Master's degree or certificate in HSI/HF."

"We are building the HSI program for the Air Force - from a blank sheet of paper."

HSI is very important to these experts because it's closely related to their everyday work and life.

4.2.6. Nature of HSI Work. In the nature of HSI work questions, the 55 different types of tasks performed by HSI specialists define what they do. These tasks can be grouped into the seven main domains. The most prominent task performed is Human Factors design which includes specifying human user, operator, or maintainer requirements; assessing mental workload; analyzing the effects of environmental stressors; performing human reliability analyses; applying human factors criteria and principles; verifying design conformance to human factors specifications; designing human-equipment interfaces and other areas in traditional human factors engineering.

The results are shown in Table 4-4, Table 4-5, Table 4-6, and Table 4-7.

As one expert mentioned in a comment, “All domains have relevance to what I do in design. There are some components I do not directly deal with. Therefore those elements are rated lower.” The nature of HSI is consisted by all these 55 different types of tasks performed by HSI specialists.

Table 4-4: Perceived Nature of HSI Work (1 of 4)

	1- Not at all important	2	3	4	5	6	7 - Very important	N/A	Rating Average
11-1. Specify human user, operator, or maintainer requirements?	5.3% (1)	0.0% (0)	0.0% (0)	5.3% (1)	5.3% (1)	15.8% (3)	68.4% (13)	0.0% (0)	6.26
11-2. Assess mental workload?	5.3% (1)	0.0% (0)	0.0% (0)	0.0% (0)	21.1% (4)	26.3% (5)	47.4% (9)	0.0% (0)	6.00
11-3. Assess physical workload?	5.3% (1)	0.0% (0)	5.3% (1)	10.5% (2)	36.8% (7)	10.5% (2)	31.6% (6)	0.0% (0)	5.32
11-4. Analyze the effects of environmental stressors?	5.3% (1)	0.0% (0)	5.3% (1)	5.3% (1)	15.8% (3)	26.3% (5)	36.8% (7)	5.3% (1)	5.67
11-5. Perform human reliability analyses?	5.3% (1)	0.0% (0)	0.0% (0)	21.1% (4)	26.3% (5)	15.8% (3)	26.3% (5)	5.3% (1)	5.28
11-6. Apply human factors criteria and principles?	5.3% (1)	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	31.6% (6)	63.2% (12)	0.0% (0)	6.37
11-7. Verify design conformance to human factors specifications?	5.3% (1)	0.0% (0)	0.0% (0)	0.0% (0)	10.5% (2)	26.3% (5)	57.9% (11)	0.0% (0)	6.21
11-8. Design human-equipment interfaces?	5.3% (1)	5.3% (1)	0.0% (0)	0.0% (0)	15.8% (3)	31.6% (6)	42.1% (8)	0.0% (0)	5.79

Table 4-5: Perceived Nature of HSI Work (2 of 4)

11-9. Design workspace layouts?	10.5% (2)	5.3% (1)	0.0% (0)	5.3% (1)	15.8% (3)	36.8% (7)	21.1% (4)	5.3% (1)	5.17
11-10. Prepare specifications for software?	5.3% (1)	10.5% (2)	5.3% (1)	15.8% (3)	26.3% (5)	26.3% (5)	10.5% (2)	0.0% (0)	4.68
11-11. Design software-user interfaces?	5.3% (1)	5.3% (1)	10.5% (2)	26.3% (5)	21.1% (4)	10.5% (2)	21.1% (4)	0.0% (0)	4.68
11-12. Prepare or review design drawings for conformance to human factors specifications?	5.3% (1)	10.5% (2)	5.3% (1)	21.1% (4)	5.3% (1)	31.6% (6)	21.1% (4)	0.0% (0)	4.89
11-13. Prepare design mockups?	10.5% (2)	10.5% (2)	5.3% (1)	10.5% (2)	10.5% (2)	26.3% (5)	26.3% (5)	0.0% (0)	4.84
11-14. Develop, update, and maintain human factors management plans?	10.5% (2)	5.3% (1)	10.5% (2)	5.3% (1)	5.3% (1)	26.3% (5)	31.6% (6)	5.3% (1)	5.06
11-15. Conduct organization design?	10.5% (2)	15.8% (3)	15.8% (3)	26.3% (5)	5.3% (1)	10.5% (2)	15.8% (3)	0.0% (0)	3.95
11-16. Document changes to organizational structure caused by the introduction of a new system?	10.5% (2)	10.5% (2)	21.1% (4)	0.0% (0)	26.3% (5)	15.8% (3)	15.8% (3)	0.0% (0)	4.32
11-17. Determine numbers of required and authorized personnel for the units and types of personnel that will use, maintain, and support a new system?	10.5% (2)	0.0% (0)	5.3% (1)	5.3% (1)	10.5% (2)	26.3% (5)	36.8% (7)	5.3% (1)	5.44
11-18. Calculate whether a new system will require more personnel than is authorized or required currently?	10.5% (2)	0.0% (0)	5.3% (1)	5.3% (1)	15.8% (3)	10.5% (2)	52.6% (10)	0.0% (0)	5.58
11-19. Document changes to agency personnel, personnel management, and personnel policy caused by the introduction of a new system?	10.5% (2)	0.0% (0)	15.8% (3)	0.0% (0)	31.6% (6)	5.3% (1)	31.6% (6)	5.3% (1)	4.94
11-20. Develop, update, and maintain a description of the equipment operator, user, and maintainer?	10.5% (2)	0.0% (0)	5.3% (1)	5.3% (1)	15.8% (3)	26.3% (5)	36.8% (7)	0.0% (0)	5.42

Table 4-6: Perceived Nature of HSI Work (3 of 4)

11-21. Develop analytical models and methods?	10.5% (2)	0.0% (0)	5.3% (1)	0.0% (0)	15.8% (3)	31.6% (6)	**36.8% (7)**	0.0% (0)	5.53
11-22. Collect data on errors, failures, or accidents?	10.5% (2)	10.5% (2)	0.0% (0)	10.5% (2)	15.8% (3)	21.1% (4)	**31.6% (6)**	0.0% (0)	5.00
11-23. Perform safety analyses?	10.5% (2)	15.8% (3)	0.0% (0)	10.5% (2)	**21.1% (4)**	**21.1% (4)**	**21.1% (4)**	0.0% (0)	4.63
11-24. Conduct root-cause analyses?	10.5% (2)	15.8% (3)	5.3% (1)	21.1% (4)	5.3% (1)	**31.6% (6)**	10.5% (2)	0.0% (0)	4.32
11-25. Perform failure-mode and effects analyses?	10.5% (2)	15.8% (3)	10.5% (2)	**21.1% (4)**	5.3% (1)	**21.1% (4)**	15.8% (3)	0.0% (0)	4.21
11-26. Develop and analyze fault trees?	10.5% (2)	**21.1% (4)**	10.5% (2)	**21.1% (4)**	5.3% (1)	**21.1% (4)**	10.5% (2)	0.0% (0)	3.95
11-27. Develop, update, and maintain system safety plans?	10.5% (2)	21.1% (4)	0.0% (0)	**26.3% (5)**	15.8% (3)	10.5% (2)	15.8% (3)	0.0% (0)	4.11
11-28. Assess performance risks from health hazards categories (noise, contaminants, etc.)?	21.1% (4)	5.3% (1)	10.5% (2)	0.0% (0)	15.8% (3)	21.1% (4)	**26.3% (5)**	0.0% (0)	4.53
11-29. Support product liability litigation?	**31.6% (6)**	10.5% (2)	15.8% (3)	5.3% (1)	10.5% (2)	5.3% (1)	10.5% (2)	10.5% (2)	3.12
11-30. Prepare product warnings?	**26.3% (5)**	10.5% (2)	15.8% (3)	15.8% (3)	10.5% (2)	10.5% (2)	10.5% (2)	0.0% (0)	3.47
11-31. Develop, update, and maintain health hazards prevention plans?	**26.3% (5)**	10.5% (2)	10.5% (2)	5.3% (1)	15.8% (3)	10.5% (2)	10.5% (2)	10.5% (2)	3.53
11-32. Conduct personnel survivability assessments?	15.8% (3)	10.5% (2)	5.3% (1)	10.5% (2)	**26.3% (5)**	5.3% (1)	21.1% (4)	5.3% (1)	4.28
11-33. Support casualty analyses?	15.8% (3)	10.5% (2)	5.3% (1)	5.3% (1)	**31.6% (6)**	10.5% (2)	10.5% (2)	10.5% (2)	4.12
11-34. Develop personnel survivability enhancement procedures?	15.8% (3)	5.3% (1)	10.5% (2)	5.3% (1)	**31.6% (6)**	15.8% (3)	10.5% (2)	5.3% (1)	4.28
11-35. Prepare instructional or procedural documents?	10.5% (2)	0.0% (0)	0.0% (0)	15.8% (3)	21.1% (4)	21.1% (4)	**26.3% (5)**	5.3% (1)	5.17
11-36. Define instructional requirements?	10.5% (2)	0.0% (0)	5.3% (1)	0.0% (0)	26.3% (5)	15.8% (3)	**36.8% (7)**	5.3% (1)	5.39
11-37. Specify training objectives?	10.5% (2)	5.3% (1)	5.3% (1)	0.0% (0)	15.8% (3)	21.1% (4)	**36.8% (7)**	5.3% (1)	5.28
11-38. Assess the effectiveness of training (system, courses, aids, simulators)?	5.3% (1)	0.0% (0)	5.3% (1)	5.3% (1)	26.3% (5)	21.1% (4)	**36.8% (7)**	0.0% (0)	5.58

Table 4-7: Perceived Nature of HSI Work (4 of 4)

11-39. Conduct training?	5.3% (1)	5.3% (1)	5.3% (1)	10.5% (2)	26.3% (5)	15.8% (3)	21.1% (4)	10.5% (2)	5.00
11-40. Design training aids?	5.3% (1)	0.0% (0)	10.5% (2)	10.5% (2)	31.6% (6)	21.1% (4)	15.8% (3)	5.3% (1)	5.00
11-41. Develop training content and instructional methods?	5.3% (1)	5.3% (1)	5.3% (1)	5.3% (1)	26.3% (5)	21.1% (4)	26.3% (5)	5.3% (1)	5.22
11-42. Design simulation system?	10.5% (2)	5.3% (1)	5.3% (1)	15.8% (3)	21.1% (4)	26.3% (5)	15.8% (3)	0.0% (0)	4.74
11-43. Document the changes to agency training strategy, plans, policy, and procedures caused by introduction of a new system?	15.8% (3)	15.8% (3)	5.3% (1)	5.3% (1)	10.5% (2)	26.3% (5)	21.1% (4)	0.0% (0)	4.42
11-44. Specify evaluation objectives?	10.5% (2)	5.3% (1)	5.3% (1)	10.5% (2)	5.3% (1)	26.3% (5)	36.8% (7)	0.0% (0)	5.21
11-45. Plan and coordinate evaluations?	10.5% (2)	0.0% (0)	0.0% (0)	5.3% (1)	21.1% (4)	15.8% (3)	47.4% (9)	0.0% (0)	5.63
11-46. Design evaluations?	10.5% (2)	0.0% (0)	5.3% (1)	10.5% (2)	10.5% (2)	15.8% (3)	47.4% (9)	0.0% (0)	5.47
11-47. Develop criterion measures?	10.5% (2)	0.0% (0)	5.3% (1)	5.3% (1)	21.1% (4)	10.5% (2)	47.4% (9)	0.0% (0)	5.47
11-48. Design data collection procedures and questionnaires?	5.3% (1)	0.0% (0)	15.8% (3)	5.3% (1)	15.8% (3)	15.8% (3)	42.1% (8)	0.0% (0)	5.42
11-49. Prepare design mockups?	5.3% (1)	5.3% (1)	10.5% (2)	26.3% (5)	15.8% (3)	15.8% (3)	21.1% (4)	0.0% (0)	4.74
11-50. Specify or perform data analysis procedures and statistical tests?	5.3% (1)	0.0% (0)	5.3% (1)	15.8% (3)	10.5% (2)	36.8% (7)	26.3% (5)	0.0% (0)	5.42
11-51. Collect data in laboratory settings?	10.5% (2)	5.3% (1)	0.0% (0)	21.1% (4)	15.8% (3)	21.1% (4)	26.3% (5)	0.0% (0)	4.95
11-52. Collect data in field settings?	5.3% (1)	0.0% (0)	10.5% (2)	10.5% (2)	10.5% (2)	15.8% (3)	47.4% (9)	0.0% (0)	5.58
11-53. Interpret test and evaluation results?	5.3% (1)	0.0% (0)	5.3% (1)	10.5% (2)	10.5% (2)	10.5% (2)	57.9% (11)	0.0% (0)	5.84
11-54. Develop hypotheses and theories?	10.5% (2)	5.3% (1)	5.3% (1)	15.8% (3)	5.3% (1)	15.8% (3)	42.1% (8)	0.0% (0)	5.16
11-55. Interpret research results?	5.3% (1)	0.0% (0)	10.5% (2)	15.8% (3)	10.5% (2)	15.8% (3)	42.1% (8)	0.0% (0)	5.42

4.3. TRAINING AND EDUCATION IN HSI

4.3.1. Finding Qualified People in HSI Area. 47.4 percent (9 out of 19) of the respondents have hired new Human Systems Integration (or Human Factors) personnel in the past two years. The number of the new hired ranges from 1 to 4 for different employers.

Among these 9 participants who have hired HSI personnel recently, all of them find it very difficult in finding qualified people to fill these jobs. On a scale of 1 through 7, where 1 means very difficult and 7 means very easy, they gave the lowest two ratings to show the difficulty in finding qualified HSI personnel.

4.3.2. HSI Training. 38.5 percent of the recruited people have received on the job training prior to being hired in HSI positions while only 15.4 percent of them have received formal educational program training (Table 4-8 and Figure 4-3). Most of these hired personnel were found lacking of skills in HSI area.

55.6 percent (5 out of 9) of the employers who have hired HSI personnel rated not satisfied with the HSI training and experiences. On the scale of 1 through 7, where 1 means not at all satisfied and 7 means very satisfied, 2 of them gave the lowest rating and 3 gave the third lowest points (Table 4-9).

Table 4-8: HSI Training Received Prior to Being Hired

	Response Percent	Response Count
a. None	15.4%	2
b. In-House	0.0%	0
c. On the Job Training	**38.5%**	5
d. Some college Human System Integration and/or Human Factors education	15.4%	2

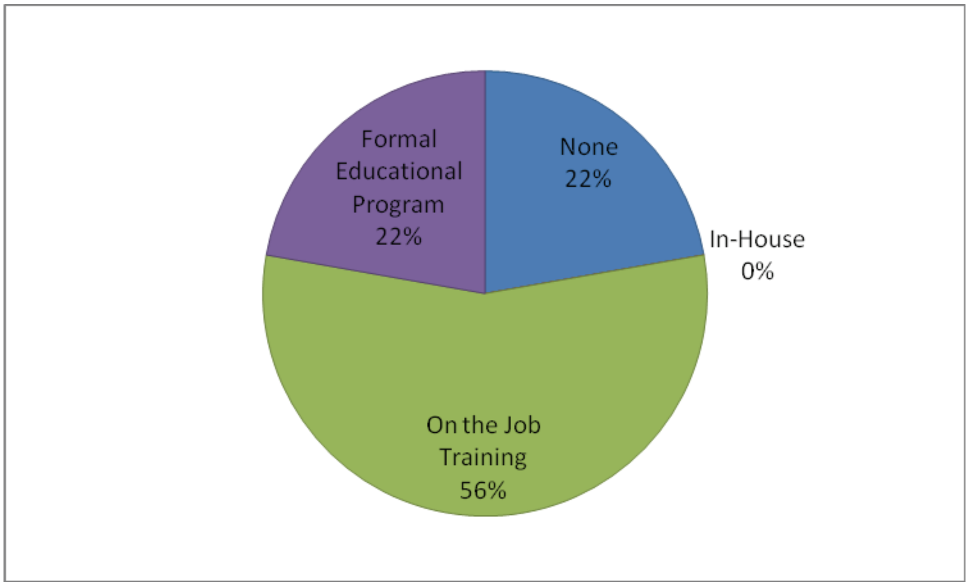

Figure 4-3: HSI Training Received

Systems safety, personnel survivability, manpower analyses, operational risk management, knowledge, skill, ability (KSA) determination, research process, task analysis, Army operational environment, and system engineering were highlighted when the respondents were asked about the lacking skills or abilities for HSI specialists.

Cognitive abilities/degradations, HCI, robotics, environmental safety and occupational health, training, Human Factors, automation, systems engineering/ product life cycle, survivability/habitability were mentioned most to represent the next major Human System Integration thrust by the participants.

Table 4-9: Satisfaction Rating for Hired HSI Personnel

	1- Not at all satisfied	2	3	4	5	6	7 – Very satisfied	N/A	Rating Average	Response Count
Rating:	10.5% (2)	0.0% (0)	15.8% (3)	0.0% (0)	15.8% (3)	5.3% (1)	0.0% (0)	52.6% (10)	3.56	19

4.3.3. Educational Background. Most (78.9%) of the specialists have master's or higher degrees (Figure 4-4). And over 60 percent of them have degrees in industrial engineering. The others have degrees in Psychology, Behavioral Science, Geological Engineering or Sociology.

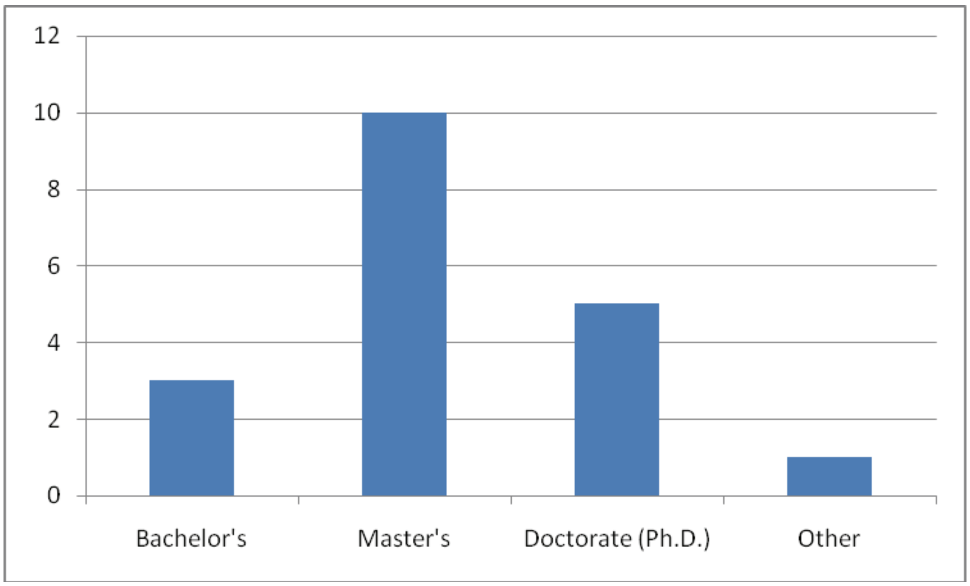

Figure 4-4: Highest Academic Degree Obtained by HSI Experts

All of them pointed out that on the job experiences are the major ways to learn about HSI. And about half of them also mentioned formal education, continuing education, company training or personal study (Figure 4-5).

4.4. SUMMARY OF OPEN-ENDED SURVEY QUESTIONS

Based on the analysis of the numerical data and open-ended comments (Open-ended questions and answers can be reviewed in Appendix B), following points can be made.

4.4.1. Definition of HSI. This is one of the open-ended questions in the survey. It's very important since it's still not very clear what HSI is.

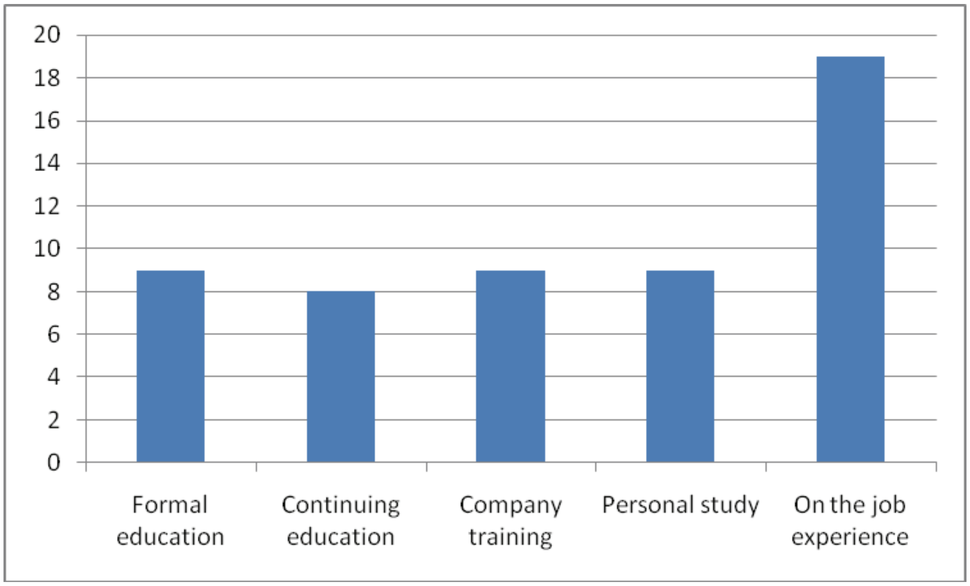

Figure 4-5: Received HSI Education and Training

One of the answers given was “Human Systems Integration is part of the Systems Engineering process, and ensures that the components of manpower, personnel, training, human factors, safety, survivability, and habitability are integrated into a system design.”

Another respondent mentioned, “The application of human factors principles to properly design a system that incorporates the human element based on human capabilities. Capabilities in terms of physical, mental, and environmental constraints would play a key role in defining the user and designing the system to work with the human element.”

“Human Systems Integration (HSI) is the interdisciplinary technical and management processes for integrating human considerations within and across all system elements; an essential enabler to systems engineering practice.”

There are all kinds of definitions about HSI from the experts. HSI could be a part of System Engineering; it could also be the application of traditional Human Factors. It could be used in military environment, or it could also be used in a much broader way (nonmilitary environment).

Although there are variances about this question, some common points still could be summarized from this survey:

- Human elements
- Complex system (usually military environment)
- Seven domains of HSI: manpower, personnel, training, Human Factors, safety, survivability, and habitability
- Integration

These could be the foundations of the future definition or application of HSI.

4.4.2. Definition of Human Factors. Before HSI, Human Factors was commonly used in military applications. It's even stated by some experts that HSI is the military Human Factors program. So it's useful to examine the definition of Human Factors to better understand HSI.

Some typical responses from the experts are summarized below:

"Human Factors is the study and application of information pertaining to human capabilities into a system."

"Human Factors is the field of study of people at work. This includes all cognitive and physical aspects that affect task performance."

"It is usually interchangeable with the term "ergonomics."

"Human factors discovers and applies information about human behavior, abilities, limitations, and other characteristics to the design of tools, machines, systems, tasks, jobs, and environments for productive, safe, comfortable, and effective human use."

Some important opinions the respondents shared are listed below:

- Study of capabilities and limitations of the human
- Improve task performance
- For safe, comfortable, and effective human use
- Closely related to Ergonomics

4.4.3. HSI and Human Factors. Since HSI and human factors share a lot of common elements in this survey, it's important to make sure the relationship between these two areas are understood.

Some of the comparisons are summarized below:

"HSI is making sure that the human is considered part of a system design, while Human Factors is a component of HSI."

“HF is a subset of HSI. In HSI work, I need to consider components from concept to operation. HSI also looks at the skill sets needed to operate an item and the required training needed for that operation. Also there is a strong component for systems safety in HSI.”

“HSI is an application of HF.”

“HSI is focused on engineering solutions to human problems. Human Factors is focused on all things human. The two are not the same.”

It’s clear that these two areas are strongly related while they also have some differences. A comparison table could be shown in Table 4-10, Table 4-11, and Table 4-12.

They share the same history, but HSI was developed from Human Factors for military use and complex systems.

According to NASA, Human Systems Integration is an umbrella term for several areas of "human factors" research that include human performance, technology design, and human-computer interaction. HSI could be an extended discipline within systems engineering that incorporates human-related factors into total system life-cycle design considerations. It also has more focus on Personnel Survivability, Habitability, and Manpower.

Basically, they have the same objectives: Functional effectiveness and human welfare. HSI has all the methodologies that Human Factors has, but it also involves some more tools like Personnel Survivability Methodology.

Human Factors is more focused on manufacturing environments, but it involves almost every aspect in our life; HSI is mainly applied in military, large complex systems. All kinds of organizations could be involved in Human Factors activities; while the government and major Contractors are the major players for HSI right now.

4.4.4. Who Needs to Be Taught HSI? According to the answers by the experts, people who oversee, maintain, test, develop and operate the systems should be taught HSI.

These people may include systems engineers, mechanical engineers, electrical engineers, software engineers, DoD acquisition personnel, researchers working in the HSI domains and behavioral scientists. The Air Force even has a 3x3 model of who needs

Table 4-10: Comparison of HSI and Human Factors (1 of 3)

Factors	HF	HSI
History	Human factors concerns emerged during World War II as a result of the work and experience of a number of specialists involved in the study of then-current manned systems; With the coming of peace and new technologies, human factors activity was broadened to include systems design more completely; Now it's involved in almost every aspect of the society, including industry, business, service, government, and education.	The emergence of human factors out of the US-UK engineering psychology experiences of WWII was its first mile stone; Second was the deliberate broading of the US Army human factors program to Manpower-Personnel Integration (MANPRINT); Now some industrial companies have also joined in HSI development
Research Areas	Engineering Psychology Computer science (HCI) Manufacturing	Human Factors Engineering System Safety Health Hazards Personnel Survivability Manpower Personnel Training Habitability
Research Methodologies	Descriptive Studies Experimental Research Evaluation Research	MANPRINT Methods and Tools; Human Factors Engineering Methods and Tools; System Safety Principles and Methods; Environmental Health Hazard Analysis And Assessment; Personnel Survivability Methodology; Cost Benefit Analysis

Table 4-11: Comparison of HSI and Human Factors (2 of 3)

Factors	HF	HSI
Objectives	Functional effectiveness; human welfare	Human-system integration is concerned with ensuring that the characteristics of people are considered throughout the system development process with regard to their selection and training, their participation in system operation, and their health and safety.
Emphasis	More focused on manufacturing environments	Mainly applied in military, large complex systems
Application	Training, staffing evaluation, communication, task analyses, functional requirements analyses and allocation, job descriptions and functions, procedures and procedure use, knowledge, skills, and abilities; organizational culture, human-machine interaction, workload on the human, fatigue, situational awareness, usability, user interface, learnability, attention, vigilance, human performance, human reliability, human-computer interaction, control and display design, stress, visualization of data, individual differences, aging, accessibility, safety, work in extreme environments including virtual environments, human error, decision making.	Army Systems Acquisition Human Characteristics and Measures in Systems Design Human-Centered Shipboard Systems and Operations Information Systems Training Air Traffic Control and Human Factors Integration New Product Development

Table 4-12: Comparison of HSI and Human Factors (3 of 3)

Factors	HF	HSI
Organizations	Varied: From military to industry; From government to private companies	Government (DoD, NASA); Defense Contractors
Scenarios for the Future	Development and need in more complex environments; Using more System Engineering Methodologies; More and more use in military and industry	An integrated methodology; HSI-led system development and the need for the development of a formal HSI discipline; A set of knowledge-based planning aids that would support HSI activities could be developed in the larger systems engineering context.

to be taught. Three major career areas: the user who generates the requirements and will use/maintain/support the system, the acquisition folks who will carry those requirements through the military procurement cycle and the program managers and systems engineers both in the military and the contractor who will "do" HSI - all three areas at three different levels - simple awareness, those "knowledgeable" with HSI and finally subject matter experts in HSI.

As HSI is becoming more and more important in our life, more and more people should be involved in HSI training and education.

4.4.5. What Needs to Be Taught in HSI? According to the open-ended questions and comments in the survey, all aspects of the domains (Survivability, Occupational Health, Environmental Safety, Habitability, Human Factors, Manpower, Personnel, Training) should be taught in HSI training and education.

Education in HSI should cover: (1) DoD-level requirements for HSI plus service-specific guidelines for implementation of HSI; (2) The DoD systems engineering approach to the Acquisition life cycle (3) Introduction to Systems Engineering (4) Human Factors and Human Performance Analysis (5) Simulation & Training Systems (6)

Environmental Safety, Health Hazards, and Survivability (7) Research Methods & Statistics (8) Human Performance in Test & Evaluation (9) Analytic Methods: Cost Analysis; Cost-Benefit Analysis; Trade Analysis; Optimization. And for the highest level, integration, tools and methods, hands on experience with case studies must be included in the coursework. (Booher, 2003)

4.4.6. Problems in Current HSI Education Programs. A common opinion shared by all the experts is that there are limited programs in HSI or the education programs are not focused on HSI. Many major universities don't have an adequate program. Majority of the HSI programs are focused on mostly Human Factors and are not really on HSI. All aspects of the domains in HSI are not covered in the programs. And more applications or hands-on should be provided for better learning. A master's degree may not be necessary for HSI education, but a certificate consisting of 4 or 5 courses for the core areas in HSI should be used for HSI training and education.

5. CONCLUSIONS

Following conclusions and recommendations can be made according to the analysis in the previous chapter.

5.1. HSI IS INDISPENSABLE

The most distinctive features in HSI could be summarized as follows:

HSI introduces organizational cultural change from one that makes people fit systems to one that makes systems fit people;

HSI introduces a safety culture for anticipating, preventing, and minimizing effects of system error;

HSI conducts risk and cost/benefit analyses to compare systems integration approaches with varying degrees of human performance considerations;

HSI provides ways to measure effectiveness of operational performance that includes human performance;

HSI provides the skills and tools needed to design systems that are user-oriented.

Some of the unique aspects of the HSI philosophy characteristic could be summarized below:

- High-level visibility of people-oriented concepts
- Focus throughout total organization on competence and motivation
- Top-down approach rather than bottom-up
- Multidisciplinary views of design
- Quantification of people variables
- Systematic early warning of human error considerations
- Provides trade-off techniques early in design
- Pushes technology and aids engineering advances
- Inherent part of system-not just supporting role
- Communicates in decision maker’s language
- Encourages resources redirection rather than net increases
- Educates all people in the process

- Reduces demand for manpower, personnel, and training

The benefits of a common focus of management are provided through the practice of top-down leadership and goal setting combined with bottom-up planning and execution. By giving high-level visibility to people-oriented concepts at all levels, the desired wide-sweeping changes have a realistic environment in which to grow. Understanding the concepts at the very top of an organization can bring focus on people throughout and sets up a reward system that instills competence and motivation in its employees.

In HSI, decision makers and facilitators take advantage of technological developments in systems engineering and systems management. Inherent in several of these advances is the capability to quantify and measure human characteristics. These newer methods also allow better decisions to be made early in the design and development process where changes are relatively inexpensive to make.

A fundamental concept of HSI is that people are considered part of any system being developed. At the same time, it is recognized that people issues and recommended actions must be described for decision makers in their own language. Frequently, these issues and actions are in terms of mission, resource, tools, product, and/or process information.

In short, HSI is indispensable and very important for both military and non-military environment use.

5.2. FUTURE OF HSI

5.2.1. Technology Needs. Advances in technology will continue to be one of the primary forces driving our sociotechnical culture into the future. The HSI approach simply provides processes and methods to help assure technology is selected, designed and implemented in such a way that it makes the most of what the decision-makers, designers and implementers intend. When people are the central focus of technology design and usage, system performance can be enhanced, systems can be used more and more safely, and overall system resources can be conserved.

5.2.2. Decision-Maker Needs. The keys to system improvements are in the hands of decision-makers leaders who can decide to apply the processes and methods of HSI. Many of the benefits promised by the HSI approach can become reality for their organizations if the leaders decide to implement some of the concepts outlined in the HSI principles. The two most important decisions for all the activities discussed are 1) defining requirements for new systems in terms of the human user and 2) testing the usefulness of the systems in performance terms. Decision makers need to be aware, however, of the HSI approach and its benefits and methods presented in terms that can be understood economically. Providing the economic case for HSI tailored to decision-maker criteria is the greatest challenge for the systems engineering and Human-Systems Integration communities.

5.2.3. HSI Processes and Methods. When decision-makers understand HSI concepts and see the benefits applicable to their activities, they will need something specific to apply. The state of the art for HSI processes and methods is required as the primary guidance for this purpose. As advanced technology is coming out, the processes and methods in HSI areas would be greatly enhanced and focused with the development of HSI disciplines.

5.2.4. HSI Resources. The quality of HSI implementation is dependent upon the availability and utilization of HSI professionals. The experts interviewed are good sources for additional information on locating qualified HSI professionals. Additionally, as HSI and Human Factors share a lot of similarities, the Human Factors and Ergonomics Society with over 5000 members is also a good source for identifying individuals skilled in various aspects of HSI. The U.S. has over 70 academic institutions teaching human factors and ergonomics. As the number of systems engineering and operations research institutions who teach Human-Systems Integration increase, the availability of HSI professionals will also increase. Now there are not sufficient HSI resources to meet current demands. And the challenge will be greater to meet increases in demand as more decision-makers join the HSI sociotechnical cultural revolution.

5.3. EDUCATION AND TRAINING PROGRAM IN HSI

5.3.1. Highly Qualified Practitioners. Perhaps the most important principle of HSI is the requirement to use highly qualified practitioners. On the buyer's side such individuals will be found as domain representatives for the system working groups, as writers of requirements for statements of work, as proposal evaluators, and as assessors for the test and evaluation process. It goes without saying that the supplier should employ equally qualified individuals. This requirement is often overlooked, for example, when the federal government introduces a large program and the needed skills are not immediately available or affordable.

Consequently, the organization is tempted to try to implement wide-scale changes with insufficiently qualified practitioners. Such attempts will fail to be successful on anything other than a sporadic basis. The issues raised by HSI are nontrivial and not easily solved simply by imposing constraints on the system developer. HSI cannot influence design in any significant way by imposing requirements that cannot be defended by individuals conversant with the technology or operational complexity of the system. And the organization leaders who make decisions, the faculties who teach the HSI education programs, the system engineers who set the design requirements and the others who involved in HSI processes should also take responsibilities to improve the number and quality of HSI practitioners.

5.3.2. Education and Training Program. The HSI principle for education and training is to provide some aspects of HSI for everyone in the acquisition process, including government, industry, and academia. The implementation of this principle may appear so difficult and expensive that the organization will, as with some of the other principles, be tempted to ignore it, hoping benefits can accrue by a few policy changes and that industry will have incentives to provide more use-friendly products. But, wide-sweeping education and training is considered one of the most important principles for long-term institutionalization. Even if all the procedures changes are implemented, systems will not be produced routinely that are significantly better if others throughout the procurement process do not "buy in" to the importance of human performance.

5.3.2.1 Gaps between needs and what is available. Most programs in human factors and ergonomics do not require and many do not offer the array of courses recommended for HSI specialization. Many programs, either intentionally or informally, specialize in a given subarea of HSI. Institutions are only beginning to establish tracks for HSI. Generally, the HSI specialist will need to piece together courses from existing programs to create the appropriate degree of specialization.

As for HSI content areas, the core areas are well represented across programs, but only a few are both broad and detailed enough to provide extensive coverage. Some programs actually specialize in taking a systems approach or provide allied programs such as Macro Ergonomics, but these seem to be the exception, not the rule. It appears, then, that students interested in HSI ought to consider both the breadth and depth of the academic programs before making a selection.

5.3.2.2 Recommended education and training programs. Recommended education and training programs for HSI could be listed by job level from the lowest requirement to the highest:

a) *Continuing Education:* Primarily from nongovernment educational institutions in courses that relate to HSI domains and/or related engineering, analyses, and management fields, this would include courses for individuals completing or already having bachelor's degree. Continuing education should be open to the largest portion of the workforce.
b) *HSI Specialized Education and Training:* The next largest portion of the workforce could participate in HSI specific courses, provided by either the government or civilian educational institutions. If HSI certification is required, it could be acquired by successful completion of specialized HSI coursework.
c) *Professional Development:* This represents a way to improve the quality of HSI practitioners, especially for new and mid-management supervisors. Many of the individuals who end up in supervisory jobs related to HSI may have specialized expertise in one or more domains but need professional development in the other domains and related engineering and management fields.
d) *Advanced-Degree Program:* Individuals who have increasingly greater responsibilities for HSI research, applications, and/or management could be selected as candidates for advanced degrees in related, existing fields, such as

human factors engineering, systems engineering, or operations research and analysis.

e) *HSI Degree:* A master's or doctoral degree in HSI from an accredited institution would be considered the highest educational achievement for the HSI professional. Ideally, when such degrees become attainable, they will serve as a criterion of excellence displayed by the highest level HSI professionals in the federal government.

f) *Executive Seminars:* These are currently available to government senior executives. However, such seminars do not usually have the discipline of HSI integrated into the coursework. For organizations wishing to provide a comprehensive, executive educational program, both specialized HSI seminars and seminars with HSI integrated into their curricula would be part of their educational program.

5.3.2.3 Recommended courses for HSI major. An obvious and important question is what technical content is needed to be a practitioner or user of the HSI approach? Four recommended courses are provided in this section.

5.3.2.3.1 <u>Human Factors Engineering.</u> Human Factors Engineering content refers primarily to cognitive or behavioral issues related to design for human capability and limitation in the interest of better design of tasks, jobs, or related tools and equipment.

Designing for human interfaces essentially postures the designer as a human advocate. The design criterion has to do with finding ways to support the system user to improve performance and well-being. The theory is by supporting operators and maintainers, performance and well-being will be maximized and errors will be reduced. The two principal ways to support a person are to change the system or change the person. Changing the system essentially involves system redesign. Changing the person essentially involves selection and/or training the person. When errors or accidents occur within this human-centered philosophy, the system has broken down in some way. Therefore, it is fruitless and misguided to blame the human operator or categorize mishaps as "human error." In reality, a systems approach is required to rectify the situation. System intervention can focus on system components and/or the interfaces between the human users or operators and the system.

Recommended content areas in Human Factors Engineering can be found in Table 5-1.

Table 5-1: Recommended Content Areas in Human Factors Engineering (Cott, 1992)

Human Factors Engineering
Psychological capability and limitation
Physiological capability and limitation
Sensation and perception
Workplace analysis and design
Cognitive ergonomics
Control/display design
Lifting and handling
Biomechanics and anthropometry
Learning
Skills, knowledge, and abilities analysis
Motivation and reward systems
Work system analysis and design
Function allocation
Organizational design
Automation

5.3.2.3.2 Health and safety. Health and safety tend to be combined in academic courses. System safety content relates to system reliability predictions and the separation of human error from true systemic issues. Within a human-centered philosophy, while the actual error might have come from a person, causes and solutions should be looked for in the system. Human related issues include human reliability, human error, problem personnel, motivation, etc. This content includes the inevitability of system failure and thus includes content related to emergency management, along with risk and risk perception. A systems approach necessarily also takes into account the management aspects of safe and safety programs as well. Military and civilian regulations and standards are also important to the management of health and safety. Liability and legislation are deemed important topics as well. Safety processes and procedures are typically the focus of the personnel subsystem.

From the health perspective, emphasis is on environmental health hazard issues where categories such as human effects from acoustics, chemical substances, and temperature extremes are covered. Topics such as determining hazards, failure minimization, warnings, etc might be included in hazard control and management.

Recommended content areas in health and safety are listed in Table 5-2.

Table 5-2: Recommended Content Areas in Health and Safety (Booher, 2003)

Health and Safety
System reliability analysis
Human error analysis
System safety planning
Safety training
Environmental stressors evaluation
Psychological stressors evaluation
Designing for health and safety
Protective equipment and gear
Controlling workplace hazards
Product reliability and liability

5.3.2.3.3 <u>Human-Computer Interaction (HCI).</u> Processes for acquiring information systems must be revised to capitalize on rapid advances in automation and to meet emerging requirements, especially in the area of adaptable performance. Designing systems for use in highly uncertain, dynamics, and information-rich environment is very challenging.

HCI is the study of interaction between people (users) and computers. It is often regarded as the intersection of computer science, behavioral sciences, design and several other fields of study. Interaction between users and computers occurs at the user interface, which includes both software and hardware. HCI is very useful in information protective equipment and gear systems operations and design of information systems. The long term goal of HCI is to design systems that minimize the barrier between the human's cognitive model of what they want to accomplish and the computer's understanding of the user's task.

Recommended content areas in HCI are listed in Table 5-3.

Table 5-3: Recommended Content Areas in HCI (Sears and Jacko, 2003)

Human-Computer Interaction (HCI)
Information Processing
Computational Perception
Usability Design
User-centered Design
User Interface
Mental Model
Ubiquitous communication
Embedded computation

5.3.2.3.4 <u>HSI methodology.</u> A special emphasis is needed for integration tools and simulation techniques for the HSI practitioner. Methodology is unique for HSI in at least two ways. The first is integration methodology that cuts across the various domains, especially manpower, personnel, and training (MPT); and the second is the integration methodology, which helps make HSI issues quantitatively visible and capable of being introduced into the acquisition process at very early stages.

The primary special methodological content needs for the HSI practitioner are in simulation and modeling methods and tools that include the human component. Use of modeling techniques that have predictive quantifiable results for human performance variables is most helpful in identifying problems early in the design process. It is important that courses on simulation and modeling emphasize methods of quantifying MPT parameters in simulation and modeling processes.

Recommended content areas in HSI Methodology are listed in Table 5-4.

Table 5-4: Recommended Content Areas in HSI Methodology (Booher, 2003)

HSI Methodology
Experimental design
Survey research
HSI techniques
Simulation
Mission, function, and task analysis
Data analysis

5.4. RECOMMENDATIONS FOR FUTURE RESEARCH

Following recommendations are made for future research according to the problems met in this study:

- More HSI specialists can be included in the survey to increase the sample size;
- Some advanced statistics tools can be used to do intensive analysis for more accurate results when the sample size is large enough;

- Another survey for current HSI graduate students or potential practitioners (systems engineers, industrial engineers) can be conducted to compare with the survey for HSI specialists;
- Opinions from universities and research institutes could be gathered to represent their points of view in education and training practice.

APPENDIX A.
SURVEY QUESTIONS

This study is being conducted by Hao Zhang, a graduate student at Missouri University of Science and Technology. The purpose of this study is to evaluate current Human System Integration programs and get information for future HSI training and education. Your responses to this survey will be used in future studies and publication. Your participation in this study is greatly appreciated. For more information, please contact Dr .Susan Murray at murray@mst.edu.

1. Name (Optional):

____

2. If necessary we may contact you for additional information?

   a. No.
   b. Yes.
      Address: ____
      Email: ____

3. Where are you employed?

   a. Private business
   b. Educational institution
   c. Government agency
   d. Other (Specify:____________________)

4. What is the name of your company/university/government agency? (Optional)

____

5. What is your current job title? (Optional)

____

6. How long have you been working in Human System Integration and/or Human Factors area?

__ Years

7. What percentage of your own work is related to military systems?

__ %

8. Are you currently working on any MANPRINT programs?

a. No.
b. Yes, one program.
c. Yes, several programs.
d. Similar programs.
e. I don't know.

9. How knowledgeable do you consider yourself to be about Human System Integration and Human Factors? On a scale of 1 through 7, where 1 means very ignorant and 7 means very knowledgeable, how would you rate yourself?

About Human System Integration

1-very ignorant   2   3   4   5   6   7 – very knowledgeable

About Human Factors

1-very ignorant   2   3   4   5   6   7 – very knowledgeable

10. How important is Human System Integration and/or Human Factors to your job? On a scale of 1 through 7, where 1 means not at all important and 7 means very important, how would you rate its importance?

1- Not at all important   2   3   4   5   6   7 – very important

8- N/A

Comments about your rating:

____

____

____

11. Please rate the importance of the following aspects of Human System Integration to your job using a scale of 1 through 7, where 1 means not at all important and 7 means very important.

1- Not at all important   2   3   4   5   6   7 – very important

8- N/A

11-1. Specify human user, operator, or maintainer requirements?

11-2. Assess mental workload?

11-3. Assess physical workload?

11-4. Analyze the effects of environmental stressors?

11-5. Perform human reliability analyses?

11-6. Apply human factors criteria and principles?

11-7. Verify design conformance to human factors specifications?

11-8. Design human-equipment interfaces?

11-9. Design workspace layouts?

11-10. Prepare specifications for software?

11-11. Design software-user interfaces?

11-12. Prepare or review design drawings for conformance to human factors specifications?

11-13. Prepare design mockups?

11-14. Develop, update, and maintain human factors management plans?

11-15. Conduct organization design?

11-16. Document changes to organizational structure caused by the introduction of a new system?

11-17. Determine numbers of required and authorized personnel for the units and types of personnel that will use, maintain, and support a new system?

11-18. Calculate whether a new system will require more personnel than is authorized or required currently?

11-19. Document changes to agency personnel, personnel management, and personnel policy caused by the introduction of a new system?

11-20. Develop, update, and maintain a description of the equipment operator, user, and maintainer?

11-21. Develop analytical models and methods?

11-22. Collect data on errors, failures, or accidents?

11-23. Perform safety analyses?

11-24. Conduct root-cause analyses?

11-25. Perform failure-mode and effects analyses?

11-26. Develop and analyze fault trees?

11-27. Develop, update, and maintain system safety plans?

11-28. Assess performance risks from health hazards categories (noise, contaminants, etc.)?

11-29. Support product liability litigation?

11-30. Prepare product warnings?

11-31. Develop, update, and maintain health hazards prevention plans?

11-32. Conduct personnel survivability assessments?

11-33. Support casualty analyses?

11-34. Develop personnel survivability enhancement procedures?

11-35. Prepare instructional or procedural documents?

11-36. Define instructional requirements?

11-37. Specify training objectives?

11-38. Assess the effectiveness of training (system, courses, aids, simulators)?

11-39. Conduct training?

11-40. Design training aids?

11-41. Develop training content and instructional methods?

11-42. Design simulation system?

11-43. Document the changes to agency training strategy, plans, policy, and procedures caused by introduction of a new system?

11-44. Specify evaluation objectives?

11-45. Plan and coordinate evaluations?

11-46. Design evaluations?

11-47. Develop criterion measures?

11-48. Design data collection procedures and questionnaires?

11-49. Prepare design mockups?

11-50. Specify or perform data analysis procedures and statistical tests?

11-51. Collect data in laboratory settings?

11-52. Collect data in field settings?

11-53. Interpret test and evaluation results?

11-54. Develop hypotheses and theories?

11-55. Interpret research results?

12a. Have you hired any new Human System Integration (or Human Factors) personnel recently?

a. Yes

b. No (Skip to Q.13a)

12b. IF YES: How many have you hired (in the past two years)?

___ Persons

13. Have you had any difficulty in finding qualified people to fill these jobs?

1- Very difficult   2   3   4   5   6   7 – Very easy

14. For those you have hired, what Human System Integration training have they received prior to being hired?

a. None
b. In-House
c. On the Job Training
d. Some college Human System Integration and/or Human Factors education
e. Other (Specify:___________________________________)

15. Consider the Human System Integration personnel that you have hired in the past two years. Overall, how satisfied were you with their training and experience? If 1 means not at all satisfied and 7 means very satisfied, how would you rate your satisfaction?

1- Not at all satisfied *2* *3* *4* *5* *6* *7 – Very satisfied*

8- N/A

16a. Were there any skills or abilities that they were lacking when first came to work for you?

a. Yes
b. No (Skip to Q.17a)

16b. IF YES: What were those skills?

____

____

____

17a. Are there topics in Human System Integration (or human factors) university degree programs that you feel are not being taught or not being taught well enough?

a. Yes
b. No (Skip to Q.18a)
c. I don't know (Skip to Q.18a)

17b. What topics are these? [TAKE FIRST THREE]

____

____

____

18. What areas do you think represent the next major Human System Integration thrust? [SPECIFIC AREAS]

1) ______________________
2) ______________________
3) ______________________

Now I would like to ask you some questions about your educational background.

19. What is the highest academic degree you've received?

a. Bachelor's
b. Master's
c. Doctorate (Ph.D.)
d. Other (Specify:_____________________________)

20. From what school did you receive this degree?

____

21. In what subject was this degree?

____

22. Where did you learn about Human System Integration (or Human Factors)?

(ACCEPT MULTIPLE RESPONSE)

a. Formal education
b. Continuing education
c. Company training
d. Personal study, or
e. On the job experience
f. OTHER (Specify:______________________)

Now I would like to ask you some open-ended questions about your understanding about HSI and Human Factors.

23. What is your definition of Human System Integration?

____

____

____

24. What is your definition of Human Factors?

____

____

____

25. In your opinion, what's the difference between Human System Integration and Human Factors?

____

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26. What is your prediction about the future of Human System Integration and Human Factors?

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27. Why do we need Human System Integration?

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28. Who needs to be taught Human System Integration?

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29. What needs to be taught?

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30. What training coursework is needed?

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31. What are the pros and cons of the current Human System Integration education programs?

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____

32. What's your suggestion?

____

____

____

APPENDIX B.

OPEN-ENDED QUESTIONS AND ANSWERS

1. What is your definition of Human System Integration (HSI)?

    1) Human Systems Integration is part of the Systems Engineering process, and ensures that the components of manpower, personnel, training, human factors, safety, survivability, and habitability are integrated into a system design.

    2) In the DoD, HSI is the application of information in the 7 (or 8) domains to the system acquisition process. Generating the information in the domains is based on research; applying HSI information is a Systems Engineering process. HSI is defined and mandated in DoD 5000.2 (Encl 7)(2003). It was based on the Army MANPRINT program, which was promulgated approximately 20 years ago. See INCOSE HSIWG for a lengthy email string regarding the definition of HSI. Outside of the DoD definition, there is a large range of opinion. The key item, in my opinion, is that SYSTEMS ENGINEERS need to take "ownership" of human performance as being within the domain of their responsibility. That prevents the aviation system hardware & software developers from claiming that "pilot error" is a satisfactory explanation for a crash. [Implying that is outside of their domain].

    3) Human systems integration is the process that allocates workload to three primary work centers: hardware, software and humans. The HSI specialist will allocate that workload to the work center that bests performs that job.

    4) Human Systems Integration is the collection and integration of seven (arbitrary) domains that are related to improving human performance in a military system. Human Systems Integration is moving towards looking at the human component in all systems, but as such will likely require a broadening of the domains (to include things like reliability, maintainability, etc.)

    5) Human Systems Integration (HSI) acknowledges that the human is a critical component in any complex system. It is an interdisciplinary approach that makes explicit the underlying tradeoffs across the HSI domains, facilitating optimization of total system performance.

    6) The application of human factors principles to properly design a system that incorporates the human element based on human capabilities. Capabilities in terms of physical, mental, and environmental constraints

would play a key role in defining the user and designing the system to work with the human element.

7) Department of Defense Instruction (DODI) 5000.2 defines HSI as the integrated, comprehensive analysis, design and assessment of requirements, concepts and resources for system Manpower, Personnel, Training, Environment, Safety, Occupational Health, Habitability, Survivability and Human Factors Engineering. HSI will be employed across the Air Force, but primary execution will be within the Integrated Defense Acquisition, Technology and Logistics (AT&L) Life Cycle Management Framework. Typically, HSI will be executed as part of the Defense Acquisition System through the systems engineering processes. HSI planning will be summarized in the acquisition strategy and integrate the distinct and interdependent HSI functional domains defined in DoDI 5000.2 and National Security Space Acquisition (NSSA) Policy 03-01.

8) Human Systems Integration (HSI) is the interdisciplinary technical and management processes for integrating human considerations within and across all system elements; an essential enabler to systems engineering practice.

9) HSI is the development of the interface between automation and the human.

10) Human Systems Integration is how humans and systems work together. Humans maintain, analyze, test and develop the systems. Humans explore different ways in which human capabilities can be integrated with systems design in order to create the most effective systems.

11) developing systems with the human and system in mind

12) HSI is the process by which the capabilities and limitations of the human operator is considered during the entire design process of equipment, systems, and organizations.

2. What is your definition of Human Factors?

1) Human Factors focuses on physical and cognitive capabilities and limitations of the human.

2) Human Factors refers to people-related issues in system performance (including human error, safety, and productivity). Human Factors typically includes: (1) Human Factors Engineering (user interface design) (2) Personnel Selection, Screening, and Assignment (3) Training & Training System Design Human Factors applies to the full range of activities including developing data and principles through research, communicating findings in scientific and technical venues (journals, conferences, models, prototypes, etc.), and providing input to design and development teams. [The DoD version of HSI, by contrast, is only responsible for the latter].

3) Human factors is the work directly associated with the capabilities of the human body and cognitive skills. It tends to focus on the takes associated with the human operating something. It also deals with the environmental type conditions, temperature, noise, G forces.

4) Human Factors is the study of human capabilities and limitations to make human performance safer, more efficient, or more effective.

5) "Human factors discovers and applies information about human behavior, abilities, limitations, and other characteristics to the design of tools, machines, systems, tasks, jobs, and environments for productive, safe, comfortable, and effective human use." from Chapanis, 1985

6) Human Factors is the study and application of information pertaining to human capabilities into a system.

7) Human factors is probably the hardest concept to define. It is far too broad in nature to clearly be defined. I would define human factors as any human-related concern or problem that affects the ability of the human to perform a task.

8) The systematic application of relevant information about human abilities, characteristics, behavior, motivation, and performance. It includes principles and applications in the areas of human related engineering,

anthropometrics, ergonomics, job performance skills and aids, and human performance evaluation.

9) For every system, the system performance is a function of the human performance of the human involved in the system. Human Factors is the study of this relationship.

10) Human Factors is more about the aspects of system design directly related to humans, for example health or psychology while developing systems.

11) The understanding of human limitations and capabilities and their effect on the design of systems.

12) Human Factors is the field of study of people at work. This includes all cognitive and physical aspects that affect task performance. I think that it is usually interchangeable with the term "ergonomics."

3. In your opinion, what's the difference between Human System Integration (HSI) and Human Factors?

    1) I see HSI as making sure that the human is considered part of a system design, while human factors is a component of HSI.

    2) HF is a subset of HSI. In HSI work, I need to consider components from concept to operation. HSI also looks at the skill sets needed to operate an item and the required training needed for that operation. Also there is a strong component for systems safety in HSI.

    3) HSI is a much broader field of many domains that touch the human component of the system and their integration. One such domain is Human Factors.

    4) HSI is based within the DoD Lifecycle Acquisition and the Systems Engineering processes. Human Factors is not. Human Factors is but one of the domains of HSI and is generally less constrained by cost, risk, and schedule.

    5) Human Factors is the knowledge used in HSI.

    6) HSI is focused on engineering solutions to human problems. Human factors is focused on all things human. The two are not the same.

    7) Human Factors is but one of the 9 domains of HSI. HSI is more comprehensive, as it includes other human-centered domains like safety, personnel survivability, habitability, environment, occupational health, manpower, training and personnel. Some people want to expand the definition of Human Factors to become HSI, but it is not - the education and training in universities do not support the required skill requirements to understand the tools and methods used by manpower, for instance.

    8) HSI is an application of HF.

    9) Not being well educated in this specific area I would say they are very alike but also have their differences. HSI is the integration of humans and systems, HF are factors affecting humans working with systems.

10) I see HF as more the theory and research of human ability and HSI as the application of that research in system design.

11) They are strongly related. Where the goal of HSI is to maximize performance through knowledge and application of Human Factors, System Safety, and related principles.

4. What is your prediction about the future of Human System Integration (HSI) and Human Factors?

1) These types of activities will continue to be important, although the terminology may change over time.

2) HSI and HF will merge together. This also needs to occur in the professional training. Currently there is a bit of a rift, which makes it a bit difficult to develop a strong design team.

3) HSI will grow through the addition of more domains, consolidation of existing domains, and morph to include a more systems engineering focus. Human Factors will remain a large focus of HSI.

4) HSI must define itself better and distinguish itself from HF or it will be subsumed under either HF or SE. I do believe that there is a niche for HSI separate and distinct from both HSI and SE.

5) I think HSI will become a leader in the Human Factors world. The seamless integration of a human into a system, large or small has a tremendous effect on the overall success of a system. The task of defining a system's user has proven itself to play a key role in system integration as a whole. With this knowledge and design approach the Human Factors community is implementing, HSI will become a valuable and crucial part of product success.

6) The term Human Factors should have left our vernacular years ago. It is far too broad and does not adequately describe anything. I believe the term Human Factors and associated degree programs will eventually go away and be replaced by more specific human-focused displines and degrees. HSI is on the rise but I'm not sure there is a need for degree programs in this area of expertise. I believe focused degree programs in engineering and scientific disciplines should be completed first, followed by credentialing or accreditation in HSI through an appropriate professional organization.

7) HSI is not widely recognized - but hopefully, will be with the new DoD 5000 series policy and guidance that mandates HSI on all acquisitions for the DoD. In spits and spurts, we are gaining ground and recognition, but HSI MUST be called out on contracts - then we mobilize the education

and training arms of the military and civilian public and private universities, service academies, etc., to build a pipeline for HSI professionals. But until HSI has tools and methods, but education and training on tradeoffs, plus respect of the systems engineer and program manager, then we are talking to ourselves. Industry wants guidance and help and education. Human Factors desperately wants to be HSI, without much change - I don't feel that is in the best interest of what we are trying to accomplish with HSI. HF will continue to exist, even if HSI goes away, but it will always be second fiddle in requirements and the first area cut on programs - after all "it's all just common sense, isn't it" ?? - of course, I'm being facetious!

8) HSI and HF will continue to be studied and may grow as a discipline but there will always be those that develop technology for technologies' sake without consideration to the impact on the human or how the system will be most useful to the human.

9) They are becoming more important especially in terms of the environment. I predict people will see HSI/HF as being an area of increasing interest of work and study. The development of degrees or programs specifically related to just HSI/HF would be good.

10) That people will think HSI replaces HF and it will become more of a requirement.

11) Better collaboration between HSI and other design disciplines. Reduce the tendency for HSI as an afterthought. Reduce the attribution of "operator error" as an acceptable accident explanation.

5. Why do we need Human System Integration (HSI)?

1) A systematic approach to communicating Human Performance issues is needed. HSI is an attempt to provide a structure and process for doing that.

2) In the Navy, we cannot afford the manpower trends to continue. Systems design has a significant impact on how, where and why we conduct training. Most of the system engineers I know are not aware of that relationship. That is not promising for Navy ship design. Several of us are using the term human systems engineering. Some staff engineers consider integration to be a menial job. We believe we can appeal to their systems engineering side, by merely adding the human element. This has the potential of reducing the rather significant resistance in the naval architecture community to HSI.

3) Outside of military applications, you don't really need HSI per se. HSI is really an arbitrary break-out of domains based on the existing acquisition processes in the military (i.e., the domains are based on the different communities that work in the military). If the systems engineering community is educated on the integration piece, the existing domains of HSI could remain stand-alone communities. Unfortunately, the existing military climate requires a strong and continuous focus on the human (or they are forgotten), so HSI is an opportunity for us to improve our influence over programs.

4) Systems Engineers have too many other things to consider and are not educated or resourced to be attentive to HSI issues. HF is too narrow (at least at present) to consider all the domains of HSI from cradle to grave.

5) YES! What good is a system that involves a human if the human can't integrate itself into it?

6) As long as humans must interface with machinery to complete tasks, HSI must be accomplished. Appropriate human-centered analysis of new and evolving machines will improve human performance and safety, reduce life cycle costs and reduce negative effects on the environment.

7) First, it is mandated for DoD systems - HSI is the single human voice for the system design and development. The INTEGRATION is key - all the tradeoffs in the domain spaces - how a change in personnel will affect the

design from an HF perspective, safety, training, etc. We will affect the bottom line of total lifecycle cost - manpower costs are killing us on legacy systems. We need to do a better job way up front to consider all aspects of the human interacting with the systems - so not just a user, or pilot, but a maintainer, supporter, all the stakeholders. And hopefully, we'll impact safety and saving lives also.

8) Because system performance is a function of human performance.

9) To understand how humans and systems work together interchangeably.

10) HSI is vital to good system design!

11) Most operational goals are improved through well implemented HSI programs: Safety, Profit (Apple IPhone). Likewise most major disasters have shown a notable failure in their HSI programs, or lack thereof. (NASA, Nuclear Power, Aircraft Crashes, etc...)

6. Who needs to be taught Human System Integration (HSI)?

1) Systems Engineers, Human Resources, Program Managers

2) (1)Systems Engineers (2) Mechanical Engineers (3) Electrical Engineers (4) Software Engineers (5) DoD Acquisition Personnel (6) Researchers working in the HSI Domains (7) Behavioral Scientists interested in practical applications

3) All involved in ship design. That includes program managers and financial types as well. The degree of that instruction should vary by individual duties.

4) Design Engineers/Systems engineers - if you want to do away with the separate field Psychologists/engineers/computer scientists - if you want to keep HSI, so we can ensure multi-disciplined thinking.

5) It must have an interdisciplinary approach in which professionals from all of the HSI domains, as well as Systems Engineering, Acquisition, Cost Estimation, Modeling & Simulation, Org Behavior, etc., etc. contributes their expertise to the educational experience.

6) The HF community, all engineers should be familiar with the concept to better incorporate HSI into their design work.

7) Engineers and scientists.

8) AF has a 3x3 model of who needs to be taught. Three major career areas: the user who generates the requirements and will use/maintain/support the system, the acquisition folks who will carry those requirements through the military procurement cycle and the program managers and systems engineers both in the military and the contractor who will "do" HSI - all three areas at three different levels - simple awareness, those "knowledgeable" with HSI and finally subject matter experts in HSI. Others who need exposure to HSI would include: Congress, OSD, Secretariat of all services, top level staff at a very high, awareness level. Maybe even an exposure to junior high and high school students - be nice if HSI permeated consumer products and became a term that rolled off the tongue like "ergonomically designed" or "lean" or "six sigma."

9) system developers

10) People, who oversee, maintain, test, develop and operate the systems.

11) The importance of HSI, its required presences throughout system design process, it many layers and aspects

12) Aside from those wishing to specialize in the field, almost all engineers and business managers should gain at least some knowledge as to the need for HSI. As an undergrad Mechanical Engineer, it was never mentioned.

7. What needs to be taught?

1) This is a very large question. In short, education in [the DoD version of] HSI should cover: (1) DoD-level requirements for HSI plus service-specific guidelines for implementation of HSI; (2) The DoD systems engineering approach to the Acquisition life cycle (3) Introduction to Systems Engineering (4) Human Factors and Human Performance Analysis (5) Simulation & Training Systems (6) Environmental Safety, Health Hazards, and Survivability (7) Research Methods & Statistics (8) Human Performance in Test & Evaluation (9) Analytic Methods: Cost Analysis; Cost-Benefit Analysis; Trade Analysis; Optimization.

2) Systems engineering safety operational risk management how to transfer technical data into tainting material specification writing performance standards what is like to work at sea.

3) Manpower analyses, Personnel, KSA development, workload measurement, impacts of environmental stressors, training analysis, ergonomics, error measurement, system safety, displays and controls, systems engineering

4) Exposure to all HSI domains. DoD acquisition lifecycle. Systems Engineering. HSI policies across all military services and DoD. How to perform tradeoff analysis (VERY important!!). Research methods. Statistics. Modeling and Simulation. Org Behavior. Negotiation skills. Cost estimation. Test and Evaluation.

5) For the general engineering population the top level concepts should be known with the HF engineers having a more detailed level of understanding and implementation know how.

6) Depends on the level - high level awareness. Knowledgeable - cliff notes version of HSI and finally in depth tradeoffs, understanding of domain issues and how design requirements for the human impact total life cycle costs, but also mission performance.

7) how to account for: mental workload reach fit visual field lighting environmental physical workload fatigue vigilance training experience safety

8) All aspects of the domains (Survivability, Occupational Health, Environmental Safety, Habitability, HF, Manpower, Personnel, Training)

9) EVERYONE who every will participate in the design of a system

10) For the casual engineer: How to identify HSI shortfalls and how to work with an HSI team.

8. What training coursework is needed?

    1) Systems safety risk identification and mitigation. human biology

    2) Manpower analyses, Personnel, KSA development, workload measurement, impacts of environmental stressors, training analysis, ergonomics, error measurement, system safety, displays and controls, systems engineering

    3) Programs that will give Systems Engineers, PEOs, and Program Managers an understanding of what HSI is and how HSI practitioners can assist them.

    4) NOT a master's degree. 4-5 courses - for the highest level - INTEGRATION, tools and methods, hands on experience with case studies

    5) See list above. Some training that covers all those areas and probably a few I forgot.

    6) Hands on learning as well as knowledge of the environment and safety regulations. Some psychology in relation to HSI/HF.

9. What are the pros and cons of the current Human System Integration (HSI) education programs?

1) From above: In the Navy, we cannot afford the manpower trends to continue. Systems design has a significant impact on how, where and why we conduct training. Most of the system engineers I know are not aware of that relationship. That is not promising for Navy ship design. Several of us are using the term human systems engineering. Some staff engineers consider integration to be a menial job. We believe we can appeal to their systems engineering side, by merely adding the human element. This has the potential of reducing the rather significant resistance in the naval architecture community to HSI. I believe you should operate what you are going to design. I would say the majority of academic programs lack some level of introduction to aboard ship work/life.

2) The only program I am familiar with in NPS. They have a pretty good program about to start up - the existing curriculum was just revised. It covers human performance, training, and human factors well. It is weak in manpower (particularly analysis) because they are focused on human resources, not performance.

3) They are focused on mostly on HF and are not really HSI.

4) TOO much HF and not HSI - it is more than HF. A master's degree is overkill, we think.

5) I only have experience with one example and I felt that it was fairly comprehensive. However, I think more application would have helped. I believe this is probably true for all programs. More hands on.

6) Don't know, haven't take any. From what I've seen though, some are very limited and do not cover all aspects of the domains, possibly because it isn't its own field of study.

7) There are some very strong programs nation-wide, but many major universities don't have an adequate program.

10. What's your suggestion?

1) Build a program. Make them develop a training course for whatever they design. Make them teach something. I am a certified instructor in several fields. I also do lectures because I enjoy that work. Not everyone enjoys teaching. But every HSI engineer and systems engineer better know how to get technical drawings to the course authors in a cost effective manner. Otherwise we are stuck with cheap training that does not develop the skill sets we need. Call if you need clarification. This is a good idea. I wish I had more time for comments.

2) Bring in guest lecturers if they are unable to change the curriculum appropriately

3) Form a loose consortium of HSI educators that can share info and content and develop a consistent pedagogical approach to HSI.

4) Require students to complete engineering and scientific degrees at the bachelor and masters levels. Require engineers and scientists that want to work in HSI to complete a focused accreditation or certification program.

5) 4-5 courses - maybe or maybe not a certificate held by INCOSE. The military will use Defense Acquisition University to train the workforce. Contractors can use private or public universities. Whatever is required by the government will be what contractors will seek out to be certified, qualified, etc.

6) Create a field of study for just HSI/HF

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