CHAPTER 5

Human Systems Integration Education and Training

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5.1 INTRODUCTION

Human systems integration (HSI) 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. Unfortunately, very few qualified people are currently available in the national pool for organizations to draw upon the needed expertise.[1] Three critical ingredients are required to increase the size and talent of the HSI personnel pool. First is greater demand for their talents, which is reflected in an increasing number of projects that mention HSI and jobs that require HSI qualifications. But demand for HSI jobs is not likely to increase until the need for the skills and methods outlined in this book are fully appreciated by organizations that procure, produce, and/or use systems. Second, 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 (Hollis, 1995; U.S. Army, 1995). The HSI workforce cannot increase substantially, therefore, without adequate education and training sources for developing HSI talent. Third, even if demand rises and education and training programs are available, something more is needed to motivate people to seek out such programs. To be sufficiently motivated to become a highly qualified HSI practitioner, individuals need to see the career potential of the HSI field. The demand for HSI practitioners and the development of qualification programs must progress together within an overall national vision of long-term careers for HSI specialists.

An army manpower, personnel, integration (MANPRINT) study on this topic recommended that a national workforce be established for HSI[2] (U.S. Army, 1993), which, if done, would bring together the second and third ingredients needed to solve the HSI

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personnel supply problem.[3] An essential first step would need to be made by the U.S. federal government (U.S. Army, 1993, p. ES-1):

> The need to integrate human issues or concerns into the engineering design process ... has been recognized by the Department of Defense (DoD) and other agencies of the Federal Government.... A series of the Congressional studies, General Accounting Office reports, and experiences of the [military] services ... identified a number of problems which illustrated the overriding fact [that] government agencies are designing, building, and buying systems ... [they] cannot easily use. A root cause of these problems is the lack of trained and qualified people in the workforce who understand how to integrate human issues into the process of research, design, development, and system implementation.

The army study recognized, however, that the federal government could not accomplish such a demanding challenge on its own: "Although, the Federal Government discharges a key and essential role in establishing and building a national [HSI] workforce, it is essential to involve academia and industry as well [as] the Federal Government" (U.S. Army, 1993, p. ES-1). The study also found that there was sufficient demand for the government to establish a formal job series and career progression within it. If this were done, it would be a major step toward attracting and retaining highly qualified personnel for both the managerial and technical work needed in HSI. Unfortunately, the third ingredient is so intertwined with the second that the federal government is reluctant to formalize its processes until education and training programs needed for a formal career in HSI are available.

The focus of this chapter therefore, is on the second ingredient, national education and training for HSI. Muckler 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 (p. 519).

This chapter 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 the chapter is to amplify HSI principles 9 (qualified practitioners) and 10 (HSI education and training) described in Chapter 1.

More specifically, the objectives of the chapter are to:

- outline the HSI competencies needed for qualified HSI specialists,
- define what is available in academic settings to meet HSI qualifications,
- describe what is available in HSI practitioner training courses,
- summarize what HSI information is available in technical handbooks and textbooks,
- outline the education and training gaps between HSI needs and what is available,
- discuss special issues with establishing an HSI career path.

5.2 HSI COMPETENCIES NEEDED

Many of the competencies needed to perform HSI tasks in occupations have been identified. Past DoD studies (U.S. Army, 1993, 1995) provide a consensus of HSI practitioners and education and training specialists on job competency requirements for HSI personnel. These efforts investigated the types of work being conducted in the army MANPRINT jobs and identified related jobs in other federal agencies. The different contexts in which nearly all of the MANPRINT- or HSI-related work was being performed could be classified into four major categories (or functions):

- research,
- engineering,
- acquisition, and
- regulatory and policy.

Research jobs involve working in laboratory or field settings with responsibilities to determine such things as determining basic, quantitative effects of environmental stimuli on human behavior or performance. Research jobs also entail such work as the development of new HSI technology that is usually considered applied research. As such, HSI research is primarily concerned with producing results that advance the state of the art for HSI principles 6 (quantitative human parameters) and 7 (HSI technology).

Engineering jobs involve design, development, and testing of hardware and software. Acquisition jobs involve documenting and supporting a system or product program through the various acquisition stages discussed at length in several chapters in this book. For the HSI specialist, the engineering acquisition jobs categories are usually implemented through the systems engineering and management processes but may also be part of logistics support, training, safety, and test and evaluation processes, depending on the organization's engineering management structure. The regulatory and policy jobs frequently involve setting (or applying) standards and practices for technical HSI domains [usually human factors engineering (HFE), system safety (SS), or health hazards (HH) domains]. In HSI mature organizations, the entire HSI program and the other domains will also have HSI policy jobs.

Based on the typical task assignments and levels of competency required for these four job functions and on surveys of active MANPRINT practitioners, the U.S. Army (1993) developed lists of HSI task activities and personnel competencies. The following describes and updates these lists in discussing

- levels of competency and functional assignments, and
- core HSI competency requirements.

5.2.1 Levels of Competency and Functional Assignments

An HSI professional workforce can be envisioned as operating at three levels of competency. A career path for a HSI practitioner will tend to progress through three levels, with varying job requirements by level:

- Level I: HSI domain expert.
- Level II: System integrator; knowledgeable in all HSI domains.
- Level III: Overall HSI Manager and/or policymaker.

Specific job assignments can be defined at each level for each of the four job functions. Table 5.1 provides a matrix of job titles appropriate to each level and function.

The personnel competencies that are needed for the various jobs vary by both function and level. Table 5.2 shows some of the kinds of competencies that are frequently required for the four major functions.

Table 5.3 lists the types of tasks HSI practitioners might be asked to perform for a new system acquisition. Categorized by the seven HSI domains, most of these tasks were obtained from a MANPRINT practitioners survey conducted by the U.S. Army (1993). Although reflecting actual task domain requirements, the tasks itemized in Table 5.3 are only representative and not meant to be exhaustive of the tasks that can be required for the various domains. This listing of tasks does, however, indicate a number of characteristics of HSI jobs:

1. HSI requirements tend to mix management and technical tasks.
2. There is some overlap between domain requirements (e.g., both training and HFE do task analyses).
3. Some domains (e.g., HFE) show greater analytical and design requirements than others (e.g., manpower). This is more a function of domain maturity, than the need for the domain activity. For example, as HSI research and development provides more manpower analysis and design tools, the manpower domain plays a greater technical role.

In addition to specialized domain requirements, all HSI practitioners need to play a role in integration, both among domains and among the other acquisition process fields, such as systems engineering, safety engineering, integrated logistics support, etc. Consequently, an overall integration category needs to be added to the individual domains to cover the various analytical and managerial competencies listed in Table 5.2 below the domains.

5.2.2 Core HSI Competency Requirements

The army (Hollis, 1995; U.S. Army, 1993) developed an initial set of core requirements for the HSI professional to cover the broad functional competencies (Table 5.2) needed to do the sample HSI tasks (Table 5.3). We have modified the original list based on lessons learned from contributors writing this handbook, allowing us to compile a new list of core competencies, reflected in the key words of Table 5.4. Full descriptions of the topics are covered in the chapters that discuss them. (See, e.g., Chapters 4 and 10 for systems engineering and integration models, Chapter 6 for requirements determination, Chapter 8 for human performance measures, and Chapter 11 for HSI technology.)

Table 5.4 illustrates many of the competencies likely to be needed for those HSI practitioners working in one or more domains in the acquisition process. The major categories are (a) HSI domains and (b) systems engineering and integration. As might be expected, HSI competencies start with expertise in the HSI domains. Domain expertise at the entry level is required only for the domain in which the individual works, along with a familiarity of the particular systems engineering and integration functions associated with the entry job position. However, to progress in an HSI career path, expertise will be needed in more than one domain, and a working knowledge of most of the systems engineering and integration items listed in Table 5.4 will be required.

TABLE 5.1 Job Titles by Level and Function

Research	Applied Engineering	Acquisition	Policy/Regulatory
	Level I		
Research and development (R&D) laboratory staff	Junior engineer	Combat development (CD) staff	Regulatory agency staff
Research psychologist	Cost analyst	Training development (TD) staff	Acquisition policy staff
Anthropometrician	Safety engineer	Program management (PM) staff	Cost accounting standards staff
Operations research analyst	Industrial hygienist	Testing and evaluation (T&E) staff	Agency inspector
Operational medicine	Engineering psychologist	Integrated logistics support (ILS) staff	
	Industrial engineer		
	Level II		
R&D team leader	Design engineer	CD/TD branch chief	Regulatory agency branch chief
Senior scientist	Human factors engineer	Training system manager	Acquisition policy senior staff
	Test engineer	PM branch chief/senior staff position	
		Senior ILS position	
		T&E branch chief	
	Level III		
R&D branch chief	System engineer	Program manager	Regulatory division director
R&D laboratory director	Program engineer	T&E director	Acquisition policy director
Chief scientist	HSI chief engineer	HSI program manager	
Technical director			

TABLE 5.2 Job Competencies by Function

Competencies	Research	Application Engineering	Regulatory	Acquisition
Domains	•	•	•	•
HFE and system safety	•	•	•	•
Manpower and personnel	•	•	•	•
Training	•	•	•	•
Health Hazards	•	•	•	•
Analytical techniques	•	•	•	•
Information management	•	•	•	•
Acquisition management		•		•
Regulatory management		•	•	
Integrated logistic support	•	•		•
System engineering	•	•	•	•
Research and development	•	•	•	•
Testing and evaluation	•	•	•	•
Procurement				•
Cost analysis	•	•	•	•
Program funding				•
Program management				•
Organizational integration	•			•
Operations research	•	•		•

The core competencies are those needed collectively by all HSI jobs, levels I, II, and III and for all relevant functions—research, engineering, acquisition, and regulatory. These then become the basic list of knowledge, skills, and abilities (KSAs) for curriculum developers, education and training delivery systems, and students to focus upon in meeting HSI competency needs. A full-blown HSI career package would, of course, include all the advanced and specialized KSAs to cover all functional assignments. The academic coursework and special training courses to develop HSI expertise covered in the next sections will use the core competencies shown in Table 5.4 as the basic requirements for the HSI practitioner. It is understood, of course, that HSI is continually maturing and that this list is only something to start a dialog among the various stakeholders interested in enhancing the systems acquisition process and the HSI profession.

5.3 ACADEMIC EDUCATION

This section discusses HSI academic offerings. It begins with a review of currently available curricula that include coursework related to HSI requirements. It then covers two areas of special interest to HSI–human systems interface technology and new content trends—to help provide a broad perspective to the considerations involved in making up an HSI academic major. This is followed by a brief discussion on the content gaps between what is currently available and what is needed. Finally, perhaps the most important part of the chapter is a discussion of specific HSI course content. This is complemented by two hypothetical but plausible graduate-degree tracks focused on HSI.

TABLE 5.3 HSI System Acquisition Tasks by Domain[a]

Domain	Task
Manpower	• Document changes to organizational structure caused by the introduction of a new system • Determine numbers of required and authorized personnel for the units and types of personnel that will use, maintain, and support a new system • Calculate whether a new system will require more personnel than is authorized or required currently
Personnel	• Specify human user, operator, or maintainer requirements (aptitudes and experience) • Document changes to agency personnel, personnel management, and personnel policy caused by the introduction of a new system • Develop, update, and maintain a description of the equipment operator, user, and maintainer
Training	• Prepare instructional or procedural documents • Define instructional requirements • Specify training objectives • Assess the effectiveness of training (systems, courses, aids, simulators) • Conduct training • Design training aids • Develop training content and instructional methods • Design simulation systems • Document the changes to agency training strategy, plans, policy, and procedures caused by introduction of a new system
Human factors engineering	• Assess mental workload • Assess physical workload • Analyze effects of environmental stressors • Perform human reliability analyses • Apply human factors criteria and principles • Verify design conformance to human factors specification • Design human–equipment interfaces • Design workspace layouts • Design software–user interfaces • Prepare/review drawings for conformance to human factors specifications • Develop, update, and maintain human factors management plans
System safety	• Develop analytical models and methods • Collect data on errors, failures, or accidents • Perform safety analyses • Conduct root-cause analyses • Perform failure-mode and effects analyses • Develop and analyze fault trees • Develop, update, and maintain system safety plans
Health hazards	• Assess performance risks from health hazards categories (noise, contaminants, etc.) • Support product liability litigation • Prepare product warnings • Develop, update, and maintain health hazards prevention plans
Personnel survivability	• Conduct personnel survivability assessments • Support casualty analyses • Develop personnel survivability enhancement procedures

[a]This table is a sampling of types of tasks assignable to the various domains for a new system acquisition.

TABLE 5.4 HSI Core Competencies

HSI domains	Systems Engineering and Integration
• Statistics	• Acquisition process models
a. Experimental design	a. Traditional
b. Regression methods	b. Streamlined
c. Nonparametrics	c. Nondevelopmental items
• Sensory and perceptual processes	d. Materiel improvement
• Cognition and decision making	• Requirements determination
• Physical abilities and limits	a. Systems requirements analysis
• Anthropometry and work physiology	b. HSI issues and criteria
• Simulation methodology	c. MPT trade-offs
• Human system modeling	• Systems design and management
• Human performance measurement	a. Human-centered design
• Design of displays, controls, and workstations	b. Requests for proposal, proposal development, and evaluations
• Skill acquisition	c. HSI assessments
• Personnel selection	d. Program management
• Team performance	• Testing and evaluation
• Environmental health hazards	a. Measures of effectiveness and performance
• System safety	b. HSI in test design plans
• Human survivability in hostile environments	c. HSI in test reports
	• HSI technology research and development
• Organization design	• Operations research
• Analytical techniques	• Integrated logistics support processes
a. Early comparability analysis	• Safety engineering and management
b. Manpower staffing analysis	• Training approaches and methodologies
c. Information requirements analysis	• Economic and cost analyses
d. Task, function, and workload analysis	
e. Training effectiveness analysis	
f. HSI domain trade-off analysis	
g. Accident analysis	
h. Human error and reliability analyses	

5.3.1 Currently Available Curricula

Due to its similarity with HSI content, a content analysis was performed on program descriptions of human factors/ergonomics (HF/E) academic programs in the United States and Canada [Human Factors and Ergonomics Society (HFES), 2000a]. As illustrated in Table 5.5, there are 83 programs listed by the HFES (2000a). These 83 programs reside on 72 campuses. Therefore, 11 campuses offer human factors programs in multiple departments. Several additional campuses have integrated their multiple offerings into a single program. Seventy-eight percent of the programs offer doctoral degrees. Thirty-six percent of the programs are in psychology departments while 36% are in industrial engineering departments. This is an interesting statistic because there are twice as many psychologists as engineers in the HFES, yet these disciplines have the same number of programs. The remaining 28% of programs are from either integrated departments or departments other than psychology or industrial engineering.

TABLE 5.5 Graduate Programs in North America

Program	Number of Faculty	Department	Degrees Offered
Arizona St.	8	School of Design	MS
Auburn	3	Industrial and Systems Engineering	MS, MISE, PhD
Cal. St., Long Beach	4	Psychology	MAR
Cal. St., Northridge	8	Psychology	MA
Catholic	5	Psychology	MA, PhD
Central Michigan	8	Psychology	MS, PhD
Clemson	12	Psychology	MS
Cornell	5	Design and Env. Analysis	MS
Embry-Riddle	7	Human Factors and Systems	MS
FIT	9	Space Coast Center for HF Research	MS
Florida International	2	Industrial and Systems Engineering	MS
George Mason	5	Psychology	MA, PhD
Georgia Tech.	6	Psychology	MS, PhD
Iowa St.	2	Industrial and Manufacturing Systems	MS, PhD
Kansas St.	2	Industrial and Manufacturing Systems	MSIE, PhD
Kansas St.	6	Psychology	MS, PhD
Louisiana St.	10	Industrial Engineering	MSIE, PhD
Marquette	5	Mechanical and Industrial	MS, PhD
Marshall	5	Safety Technology	MS, MA
Mississippi St.	3	Industrial Engineering	MS, PhD
Mississippi St.	9	Psychology	PhD
MIT	8	Aeronautics and Astronautics	MS, PhD
Miami of Ohio	10	Psychology	MS, PhD
NJIT	3	Industrial and Manufacturing Engineering	MS
New Mexico St.	7	Psychology	MA, PhD
NYU	5	Occupational Therapy/ Environmental Medicine	MA, PhD
NC A&T	1	Industrial Engineering	MS
NC St.	5	Industrial Engineering	MS, MIE, PhD
NC St.	10	Psychology	MS, PhD
Northeastern	4	Mechanical, Industrial and Manufacturing	MS, PhD
Ohio St.	10	Industrial and Systems	MS, PhD
Ohio St.	5	Psychology	MA, PhD
ODU	10	Psychology	MS, PhD
Oregon St.	3	Industrial and Manufacturing Engineering	MS, PhD
Penn St.	3	Industrial and Manufacturing Engineering	MS, PhD

(*continued*)

TABLE 5.5 (*Continued*)

Program	Number of Faculty	Department	Degrees Offered
Purdue	6	Industrial Engineering	MS, PhD
RPI	6	Psychology, Philosophy and Cognitive Sciences	MS
Rice	3	Psychology	MA, PhD
San Jose	8	College of Graduate Studies	MS
SUNY Buffalo	3	Industrial Engineering	MS, PhD
Texas A&M	5	Nuclear Engineering	MS, PhD
Texas Tech	3	Industrial Engineering	MS, PhD
Texas Tech	7	Psychology	MA, PhD
Tufts	2	Mechanical Engineering	MS, PhD
Tufts	3	Psychology	MS, PhD
U. of Alabama-Huntsville	1	Psychology	MA
U. of Alabama-Tuscaloosa	2	Industrial Engineering	MS
U. of Calgary	9	Psychology	MS, PhD
U. California-Berkeley	7	School of Health/Bioengineering	MS, PhD
U. California-Berkeley	7	Vision Science	MS, PhD
U. Central Florida	9	Psychology	PhD
U. Cincinnati	5	Mechanical, Industrial and Nuclear Engineering	MS, PhD
U. Cincinnati	24	Psychology	MA, PhD
U. Conn.	6	Psychology	MA, PhD
U. Dayton	7	Psychology	MA
U. Houston	5	Industrial Engineering	MS, PhD
U. Idaho	3	Psychology	MS
U. Illinois-Urbana-Champaign	8	Psychology and Mechanical and Industrial Engineering	MA/MS, PhD
U. Iowa	10	Industrial Engineering	MS, PhD
U. Kentucky	4	Psychology	PhD
U. Louisville	5	Industrial Engineering	ME, PhD
U. Mass-Amherst	13	Mechanical and Industrial Engineering, Exercise Science and Psychology	MS, PhD
U. Mass-Lowell	3	Work Environment	MS, ScD
U. Miami	13	Industrial Engineering	MS, PhD
U. Michigan	7	Industrial and Operations Engineering	MS, PhD
U. Minnesota	15	Graduate Studies	MS, PhD
U. Nebraska-Lincoln	4	Industrial and Management Systems Engineering	MS, PhD
U. Oklahoma	2	Industrial Engineering	MS, PhD
U. South Dakota	7	Psychology	MA, PhD
U. Texas-Arlington	8	Industrial Engineering	MS, PhD
U. Toronto	4	Mechanical and Industrial Engineering	MEng, MS
U. Utah	6	Mechanical Engineering	MS, PhD
U. Virginia	3	Systems Engineering	ME, MS, PhD

TABLE 5.5 (*Continued*)

Program	Number of Faculty	Department	Degrees Offered
U. Waterloo	6	Kinesiology	MS, PhD
U. Waterloo	4	Systems Design Engineering	MS, PhD
U. Wisconsin-Madison	9	Industrial Engineering	MS, PhD
VPI & SU	8	Industrial and Systems Engineering	MS, PhD
WV U.	7	Industrial and Management Systems Engineering	MS, PhD
Wichita State	4	Industrial and Manufacturing Engineering	MS, PhD
Wichita State	8	Psychology	MA, PhD
Wright State	6	Biomedical, Industrial and Human Factors Engineering	MS, PhD
Wright State	11	Psychology	MS, PhD
York U.	3	Psychology	MA, PhD

Source: Reprinted with permission from *Directory of Human Factors/Ergonomics Graduate Programs in the United States and Canada*.

Programs that are offered in such departments as environmental design (e.g., Cornell) tend to concentrate on the human–environment interface. Many psychology programs tend not to focus on the larger system or holistic issues primarily because they have a sister industrial/organizational (I/O) psychology program that focuses on organizational issues. An example would be Clemson. There are still several HF/E programs that are offered in both psychology and engineering departments at the same institution. Examples include Clemson and North Carolina State. Many of these campuses do coordinate and collaborate with respect to their offerings. Programs that offer human factors or ergonomics as a concentration within industrial engineering tend to promote a systems approach. The analogous situation for psychology departments is to promote linkage with I/O programs or departments.

Many departments have integrated appropriate faculty from departments other than the primary degree-granting department. In some cases, as in the case of Iowa, these faculty members are referred to as "affiliated faculty." In other cases, the descriptions do not differentiate between affiliated and regular faculty, but the listing includes both. Still others operate by integrating several departments. An example would be the 15 faculty listed for the University of Minnesota who span eight different departments. Care therefore should be taken when evaluating the number of faculty per program. Indeed, it is difficult to evaluate the extent to which an institution has made a fixed-cost commitment to ergonomics.

It is also somewhat difficult to evaluate the human factors offerings per university by evaluating individual programs. In several cases (e.g., Wichita State), programs exist in multiple departments. Most typically, this involves a program in both psychology and engineering. At Wichita State, for example, psychology lists eight faculty positions and industrial and manufacturing lists four faculty members. Together, 12 faculty participants are quite respectable for an HF/E program at a university.

5.3.2 Human–System Interface Technology

Scientific disciplines can most readily and distinctly be defined by the nature of their unique technology (Hendrick and Kleiner, 2001). Based on its survey of HF/E internationally, the Strategic Planning Committee of the HFES identified the unique technology of HF/E as human–system interface technology. Included are the interfaces between the people portion of systems and the other sociotechnical system components. This includes jobs, hardware, software, internal and external environments, and work system structures and processes. As a science, HF/E involves the study of human performance capabilities, limitations, and other characteristics. These data then are used to develop human–system interface technology. The technology takes the form of interface design principles, guidelines, specifications, methods, and tools. As a practice, HF/E professionals apply the technology to the design, analysis, test and evaluation, standardization, and control of systems. The general objective of the discipline is to improve the human condition, including health, safety, comfort, productivity, and quality of life (HFES, 2000b).

Human–system interface technology has at least five clearly identifiable subparts, each with a related design focus (Hendrick and Kleiner, 2001, 2002) as follows:

- *human–machine* interface technology or hardware ergonomics,
- *human–environment* interface technology or environmental ergonomics,
- *human–software* interface technology or cognitive ergonomics,
- *human–job* interface technology or work design ergonomics, and
- *human–organization* interface technology or macroergonomics.

The first four of these technologies are focused on the individual or, at best, the subsystem level. Thus, they constitute the technologies of what often is referred to in the literature as *microergonomics*. The fifth is focused on the overall work system level and, accordingly, is the primary technology of *macroergonomics*.

5.3.3 Content Trends

Imada and Kleiner (2000) identified emerging educational topics for educating human factors engineering and ergonomics professionals (Table 5.6). These might have implications for the new HSI professional. Traditionally, a broad educational program will provide coverage of such basic areas as human–machine systems design, human sensation and perception, cognitive processing and decision making, psychomotor response, display and control layout/design, applied anthropometry and biomechanics, materials handling, environmental effects, control of dynamic systems, research methodology and experimental design, and workplace design. The demands imposed by modern systems, expansion of information technology, increases in government and other regulations concerning ergonomics and safety, increased environmental concerns, increased attention to special user populations, and constant pressure of litigation constitute some examples of why additional knowledge and skill might be needed (as illustrated in Table 5.6).

TABLE 5.6 Content Trends for Educational Programs

Information and communications systems design
Virtual reality
Usability testing and evaluation
Green design
Ergonomics standards and regulations
Forensics
Professional certification
Macroergonomics
Security

With increases in digitization comes the need to accelerate human–computer interaction work. Whatever can be automated is being automated without particular regard to people. The impact of digitization will affect the HSI practitioner as well. One particular area of this is virtual reality (VR). Virtual reality and augmented reality (AR) systems are being used for training, product test and evaluation, even medical applications such as surgery. Again, human interface issues warrant attention to avoid technology-driven systems. One area that helps address these concerns is usability testing and evaluation. Training in the latest methods of usability testing is therefore helpful to the HSI specialist.

Environmentally conscious design is increasingly a concern for ergonomists. Thus, the HSI professional should be aware of how system design impacts the larger ecological balance. Related to the environment, but spanning well beyond its borders, are ergonomics standards and regulations. While these are changing in a dynamic political environment, the HSI professional needs to understand the relevant standards and regulations. Related to these issues is the frequency with which ergonomists find themselves involved with legal matters. Students need basic coursework information in tort law, professional ethics, forensic responsibilities of the ergonomics expert, and forensic research and data collection techniques. Professional certification is also an important goal for the HSI specialist to consider. Certification as offered in North America by the Board of Certified Professional Ergonomists (BCPE) can provide credibility to the HSI expert. Ergonomics curricula should include discussions of the need for professional certification and how to achieve it and encourage graduates to seek this goal as practicing ergonomists.

Ergonomists have for some time realized it was possible to do a good job of ergonomically designing a system's components, modules, and subsystems yet not attain relevant systems effectiveness goals because of inattention to the macroergonomic design of the overall work system (Hendrick 1984, 1986a, b). Macroergonomics has been shown to increase productivity, improve health and safety, and improve the competitiveness of organizations (Hendrick and Kleiner, 2001). In the laboratory, the science of macroergonomics continues to develop, with new knowledge being created about personnel, technological, and environmental work system factors. Several formal academic programs and courses exist, and given the compatibility with HSI content and philosophy, the HSI student is encouraged to gain as much exposure to macroergonomics as possible.

Finally, September 11, 2001, created a new trend—security. It is predicted that increasingly HSI will be seen as an invaluable approach to integrating the various system components necessary to create and maintain a level of safety and security in many types of critical systems.

5.3.4 What Are 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 ergonomics. 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 listed in Table 5.4 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 macroergonomics, 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.

Based on the core competencies needed for HSI, seven broad content areas (Table 5.7) are recommended for HSI education. Using these content areas as a guide, the student has a checklist for programmatic content that can be drawn from available course. Ideally, the curriculum would also be sensitive to the emerging trends outlined in Section 5.3.3.

5.3.5 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? This section describes in more detail the seven content areas listed in Table 5.7.

Human Factors Engineering 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. We limit our operational definition here to single user–machine interactions and primarily cognitive demands.

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, the system has failed and 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.

When automating, special attention is paid to allocating function between human and machine. While automation is desirable for a number of tasks (e.g., repetitive, hazardous, etc.), as long as the human is needed within the system, it is important to proactively decide his or her role. When the human’s role becomes too passive, he or she might not be able to appropriately operate or intervene should the conditions warrant an increased role at some point in the system’s life cycle. Therefore, attention should be paid to building and

TABLE 5.7 Recommended Content Areas for HSI Education

Human Factors Engineering
Psychological capability and limitation
Sensation and perception
Workplace analysis and design
Cognitive ergonomics
Control/display design
Ergonomics
Physiological capability and limitation
Lifting and handling
Biomechanics and anthropometry
Training
Learning
Training transfer
Instructional design
Training technology
Training evaluation
Training models
Personnel
Skills, knowledge, and abilities analysis (SKA)
Selection
SKA/training trade-offs
Performance measurement and evaluation
Motivation
Reward systems
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
Forensics
Macroergonomics and Systems
Sociotechnical system design
Work system analysis and design
Participatory ergonomics
Function allocation
Organizational design
Collaborative/group work systems
Group task analysis
Methodology
Experimental design
Survey research
Simulation
Mission, function, and task analysis
Data analysis

maintaining an appropriate mental model during system operation. (See Chapter 13 for greater discussion of HFE content.)

Ergonomics Relative to the term *human factors*, we use the term *ergonomics* to cover physiological demands. Ergonomics content refers to physiological issues related to design for human capability and limitation in the interest of better design of tasks, jobs, or related tools and equipment. Physical work is typically the beneficiary of ergonomics intervention or prevention. For example, a worker injured through lifting heavy loads could lead to an ergonomic analysis of the job to identify risk factors. This analysis in turn could lead to a redesign effort. As in human factors engineering, intervention is likely to focus on changing the operator or changing the system. Again, selection and training are the major methods for changing the person.

The lower back is one targeted area for risk and injury reduction, especially in work that requires lifting and/or twisting. Repetitive-motion injuries such as carpal tunnel syndrome characterize maladies of the hands and wrists. Slips and falls relate to dynamic movement issues having to do with gait, balance, floor surface interaction, etc. In addition to physical injury and accidents, physical fatigue and workload are areas of concern as well.

Training Training as used here refers primarily, but not exclusively, to skills training. It is recognized that knowledge acquisition is a necessary part of most skills training, but we are not referring to higher education per se, which is broadly covered throughout this chapter. It is recognized that most skills training involves some knowledge acquisition as well. There are various types of training approaches, training schedules, and other logistical issues to consider. One special consideration is team training. Here, one must be cognizant of both individual and group developmental needs. An assumption cannot be made that a properly trained individual will necessarily make a good team member. In fact, this highlights the distinction we can make between technical skills and social skills training. Both are needed to operate within an organization, especially a team-based organization.

If anything, the emphasis on technological systems for training has increased over time. Augmented reality and VR systems, for example, represent extremely sophisticated technologies currently being used in training. For example, distance learning technologies and computer-based training are now the norm for training rather than the exception. Web-based courses also exist, but their results are unknown at this juncture. What is known is that purely Web-based courses are quite difficult to develop and complex to deliver. (See Chapters 11, 12 and 22 for more information on training issues and techniques.)

Personnel In many educational institutions, "personnel" and "manpower" are combined, thus converging much of the content for both domains. This content includes skill, knowledge, and ability attributes of people. Motivational issues are also included. "Manpower," or "person-power," as it is often referred to today, includes person-power demands and costs of acquiring, operating, and maintaining a system or systems.

Determining and maintaining manpower requirements is a staple skill in project and human resource management. What is less straightforward is how to develop and maintain a proper level of motivation in an organization. Traditional motivational approaches include extrinsic reward systems such as pay for performance approaches. However, these behavioral approaches have been scrutinized. The theory is that behavioral reward systems only lead to temporary compliance at best and feelings of inadequacy and punishment at worst. An alternative philosophy is to compensate people well, get their focus off pay and other extrinsic rewards, and then let the work itself intrinsically motivate people. Anything less than intrinsic motivation will be transient and unworkable in the long term. (See Chapter 11 for greater detail on the HSI tools and techniques used for manpower and personnel systems analysis.)

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. Again, within a human-centered philosophy, while the actual error might have come from a person, we look to the system for causes and solutions. 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 safety 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 technical subsystem whereas the roles of safety personnel are 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. Such items as protective garments and gear are included. This category is broad, covering other relevant topics such as product liability and forensics. Hazard control and management might include such topics as determining hazards, providing safeguards, fail-safe designs, failure minimization, monitoring, warnings, failure minimization, etc. (See Chapters 14 and 15 for detailed coverage of health and safety.)

Macroergonomics Conceptually, macroergonomics may be defined as a top-down sociotechnical systems approach to the design of work systems and the carry-through of the overall work system design to the design of the human–job, human–machine, and human–software interfaces in creating a fully harmonized work system (Hendrick, 1997; Hendrick and Kleiner, 2001).

Macroergonomics covers multiuser and organizational scenarios. The central purpose of macroergonomics is to optimize work system design (Hendrick and Kleiner, 2001). This is what distinguishes it from both microergonomics and organizational psychology, making it a particularly valuable contribution to HSI. Macroergonomics is accomplished through a systematic consideration of the relevant sociotechnical system variables in the ergonomics analysis, design, implementation, evaluation, and control process. These variables relate to three basic, empirically identified sociotechnical system components: the technical (technological) subsystem, social (personnel) subsystem, and the external environment. A fourth sociotechnical system element, job (and task) design, falls within the purview of microergonomics but is influenced by and interacts with design of the work system. In reality, macroergonomic design of the work system helps determine many of the characteristics that should be designed into individual jobs for joint optimization of the total system. Work system design, thus, includes both the structure and related processes of the entire work system.

As well as a top-down process, macroergonomics includes bottom-up and middle-out analysis, design, and evaluation processes (Hendrick and Kleiner, 2001). Top-down, an overall work system structure, may be prescribed to match the organization's sociotechnical characteristics. Middle-out, an analysis of subsystems and work process, can be assessed both up and down the hierarchy from intermediate levels and changes made to ensure a harmonized work system design. Bottom-up most often involves identification of opportunities by employees and lower level supervisors that result from higher level work system structural or process design. A true macroergonomics intervention effort thus requires employee participation at all levels of the organization.

Technically, macroergonomics is a human–organization interface technology. The empirical science underlying this discipline is concerned with factors in the technological subsystem, personnel subsystem, external environment, and their interactions as they impact work system design. As a perspective, certain guiding principles assist the ergonomist. These include participation, flexibility, joint optimization, joint design, system harmonization, and continuous improvement of processes.

Methodology The last category in Table 5.7 is concerned with basic methods and techniques. Each content area previously described also has specific methods and techniques, but 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); the second is integration methodology, which helps make HSI issues quantitatively visible and capable of being introduced into the acquisition process at very early stages. Chapter 11 describes the state of the art for MPT integration methodology, and Chapter 13 describes the manner in which human factors engineering methods and tools help quantify HSI issues for early acquisition process decisions.

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, thus allowing a range of possible solutions for consideration that would be unlikely options if introduced later in the acquisition cycle.

It is important that courses on simulation and modeling emphasize methods of quantifying MPT parameters in simulation and modeling processes. For example, methods and tools should demonstrate ways that MPT trade-offs in resources and system performance can be applied to system requirements, design, development, and test and evaluation.

5.3.6 Two Hypothetical HSI Graduate-Degree Tracks

To illustrate how an existing academic program could take the aforementioned recommended course content and develop a graduate program focused on HSI, we developed hypothetical HSI graduate-degree tracks from two institutions that currently teach large portions of the needed HSI content. These are Virginia Tech and the Naval Postgraduate School (NPS). Many of the institutions listed in Table 5.5 could undoubtedly produce acceptable HSI tracks, but these two are most familiar to the authors and have had extensive review for feasibility by faculty at these institutions. At the time of this writing, one institution has already approved a two-year master's HSI track, and the other expects to have an approved track in the near future. Should other educational institutions decide to create graduate degrees for HSI, the information provided here should be useful models for programs to meet military and commercial educational needs.

Virginia Tech Most of the degree tracks from Virginia Tech appear in its published graduate manual (http//www.ise.vt.edu). At Virginia Tech, the M.S. and Ph.D. degrees in the HF/E option emphasize both methodology and content areas. Using the master's program as an example, students are required to complete five core courses, a minimum of four elective courses, and six hours of thesis work. The core courses are Human Information Processing, Human Factors System Design I, Human Physical Capabilities, Human Factors Research Design I, and Integrated Systems Design. Students then can select preapproved "tracks" in order to specialize beyond the core. Currently, these tracks include Cognitive Ergonomics, Human–Computer Interaction, Macroergonomics, Methods, Occupational Biomechanics, Sensory and Perception, Safety, Telecommunications, Transportation, and Work-Related Musculoskeletal Disorders.

In consulting Table 5.7, the core master's-level courses cover the following domains: human factors engineering, ergonomics, and methodology. The four electives would then be selected to provide coverage of the remaining content areas as well as provide a single course that covers the breadth of HSI. The other electives then could be in the areas of training, safety, and macroergonomics. Table 5.8 illustrates a currently hypothetical but potential program of study for an HSI master's-degree specialization. As an HSI program, some modifications from the Human Factors Engineering and Ergonomics (HFEE) option would be recommended. As examples, some of the most prominent modifications would include the following:

- One of the core courses (Integrated Systems Design) might be replaced with Usability Engineering.

TABLE 5.8 Hypothetical HSI Masters Program—Virginia Tech

Course Type	Course Title	Credit Hours
Core	Human Information Processing	3
Core	Human Factors System Design I	3
Core	Human Physical Capabilities	3
Core	Human Factors Research Design I	4
Core	Usability Engineering[a]	3
Research	Research Thesis	6
Elective	Human Systems Integration[b] or Macroergonomics	3
Elective	Simulation Modeling[c] or Modeling Processes in Operations Research[c]	3
Elective	Training Systems or Human Computer Systems	3
Elective	System Safety, Industrial Health and Safety,[d] Occupational Safety, or HSI in Security Operations[e]	3
Total hours		34

[a]Replace current core course.
[b]Create new course.
[c]Add HSI Modeling.
[d]Add Personnel Survivability.
[e]Create new course.

- A new course on HSI principles and methods should be developed and offered as an elective.
- The personnel survivability domain is not represented currently by any Virginia Tech courses. Some content on personnel survivability could be added to one of the safety or health courses.
- The operations research courses in simulation modeling and modeling processes in operations research should be modified to include HSI trade-off models.
- A new course on HSI and national security could be developed and offered as an elective.

Table 5.9 provides descriptions of several representative courses drawn from the 2001 graduate manual of Virginia Tech. Suggested additions to existing courses for HSI modeling and personnel survivability are provided in italics but are not current offerings. The strength of these courses would be the application to industrial settings that could apply to both military and nonmilitary systems and products.

Naval Postgraduate School Most of the degree tracks at the NPS are shown in its general catalog. Degrees include master of arts (MA), master of science (MS), engineer, and doctor's degrees. The MS options are most relevant for an HSI track. Depending on the course of study, MS degrees range from one year (four quarters) to two years (eight quarters). The minimum for any MS thesis degree is 48 quarter hours for a one-year program. Numerous courses are currently taught at NPS that, properly organized, could provide the HSI academic requirements. These are primarily in the Operations Research Department and the Systems Management Department. Two academic groups—Systems Engineering/Integration and Modeling, Virtual Environments and Simulation (MOVES)—also have courses of study that would be relevant to an HSI degree track. Table 5.10 provides a hypothetical one-year HSI master's program at NPS[4] that would draw from the Operations Service and Operations Analysis courses in the Operations Research Department, courses in the System Management Department, and courses from the two academic groups. At least six of the courses would be core requirements, with six others drawn from the electives. A new course on HSI principles and methods should be developed as part of the track.

Table 5.11 provides descriptions of several representative courses drawn from the 2001 NPS catalog. With the exception of a new survey course in HSI, the NPS has sufficient current courses that could be applied to an HSI track without major modifications. Its strength for DoD students would be the direct military applications in all of the coursework.

5.4 TEXTBOOKS

Another perspective on the information available for training is in terms of source books and texts. Muckler and Seven (1990) reviewed seven human factors textbooks for their coverage of the six MANPRINT domains. As stated in Muckler and Seven (1990), the comparisons reviewed here are presented to offer an alternative view of national education and training resources and are in no way intended to serve as a critical comparison of these texts.

TABLE 5.9 HSI Course Descriptions—Virginia Tech

Course Title	Course Description
Human Information Processing	An examination of present human engineering design criteria, principles, and practices to achieve mission success through integration of the human into the system, subsystem, equipment, and facility design in order to achieve effectiveness, simplicity, reliability, and safety of system operation, training, and maintenance.
Human Factors System Design I	Human factors input into manned-system design, development, testing, and evaluation. Emphasis on the systems approach to human–machine interfacing, with discussion and application of specific methodologies and analytical techniques. Display and control design and selection fundamentals with engineering modeling of manual control systems.
Human Physical Capabilities	An examination of human physical attributes in human–machine systems with an emphasis on models of anthropometry and biomechanics, intero- and exteroceptors and on the work environment; force fields (transitory and sustained), sound, light, climate.
Human Factors Research Design I	Procedures for conducting human factors experiments, including research methodology, multifactor design alternatives, field research, designs for reducing data collection, empirical model building, and sequential research procedures.
Usability Engineering	An overview of the development process of interactive software interfaces, including iterative life-cycle management, systems analysis, design representation techniques, prototyping, and formative user-based evaluation. Integrative and cross-disciplinary approach with main emphasis on usability methods and user interaction development process.
Macroergonomics	The optimization of work system design through consideration of relevant personnel, technological, and environmental variables and their interactions. Emphasis is on the theoretical background, research methods, analysis, design, development and application of work system, and relationship between macro- and microergonomics.
Simulation Modeling	Introduction to discrete-event digital simulation, including development of simulation models, random-number and random-variable generation, model validation and testing, analysis of model output, and an overview of simulation languages. *Emphasizes the use of human systems simulation modeling in decision making through a series of projects involving manpower, personnel, and training trade-off problems*.
Modeling Processes in Operations Research	Introduction to and demonstrations of the phases and activities involved in the development, validation, and use of models in the solution of management decision problems. *Emphasizes the methods of quantifying manpower, personnel, and training parameters in modeling processes*.
Training Systems Design	A systems approach to the design and development of training with an emphasis on techniques to conduct training needs analysis, a survey of training methodology with an emphasis on computer-assisted techniques and training simulators, and procedures to evaluate training effectiveness.

TABLE 5.9 (*Continued*)

Course Title	Course Description
Human–Computer Systems	A survey of human factors procedures used in the design of computer-based systems. Consideration is given to the iterative interface design process, hardware interface design, software interface design, and workplace design.
Industrial Health and Safety	Addresses the identification, analysis, and control of biological, chemical, radiation, and fire hazards in industrial settings. *Instruction on personnel survivability would be included for HSI students*.
System Safety Analysis	Review of the systems safety analytical techniques and documentation requirements to protect against product liability and to provide proper design of equipment and systems.

The texts reviewed by Muckler and Seven (1990) were Huchingson (1981), Oborne (1982), Kantowitz and Sorkin (1983), Wickens (1984), Salvendy (1987), Sanders and McCormick (1987), and Adams (1989). Salvendy's (1987) *Handbook of Human Factors* was a major source book for human factors at the time of the Muckler and Seven review, and with 68 technical chapters and nearly 2000 pages it is still widely regarded as the most

TABLE 5.10 Hypothetical HSI Master's Curricula—Naval Postgraduate School

Course Type	Course Title	Credit Hours
Operations service (E)	Human Factors Engineering	4QHR
	Manpower Requirements Determination	4QHR
	Man–Machine Interaction	4QHR
	Human Factors in Information Warfare	4QHR
Operations service (R)	Manpower and Personnel Models	4QHR
Operations analysis (R)	Human Factors in System Design I	4QHR
	Human Factors in System Design II	4QHR
Operations analysis (E)	Human Performance Evaluation	4QHR
	Skilled Operator Performance	4QHR
	Special Topics in Human Performance	4QHR
	Test and Evaluation	4QHR
	Cost Estimation	4QHR
Operations analysis (R)	Human Systems Integration	4QHR
Systems management (E)	Principles of Acquisition and Program Management	4QHR
	Training Foundations	4QHR
	Personnel Testing and Selection	4QHR
Systems management (R)	Job Analysis and Personnel Selection	4QHR
Systems engineering integration (R)	Systems Engineering I	4QHR
MOVES (E)	Human Factors of Virtual Environments	4QHR
	Training in Virtual Environments	4QHR
Thesis (R)	—	8QHR

Abbreviations: R = required; E = elective; QHR = quarter hours; MOVES = modeling, virtual environments and simulation academic group; MS degree = 48 QHR plus thesis.

TABLE 5.11 HSI Course Descriptions—Naval Postgraduate School

Course Title	Course Description
Human Factors Engineering	Introduction to human factors engineering. Designed to give an appreciation of human capacities and limitations and how these can affect optimum design of human–machine systems. Emphasis on integration of human factors into the system development cycle.
Manpower Requirements Determination	Utilize the tools of industrial engineering to determine quantity and quality of manpower required in military systems. Techniques include motion-and-time study, work sampling, time standards, work design and layout, materials handling, procedure review, and process design.
Manpower and Personnel Models	Covers the major types of manpower and personnel models for estimating the effects of policy changes on the personnel system. Topics include longitudinal and cross-sectional models, optimization models, and data requirements and validation.
Human Factors in Systems Design I	Provide foundation to understand, explain, and predict human behavior. Students develop techniques in understanding how to ask a question and methodological procedures for collecting data and interpreting results. Laboratory exercises and field surveys to determine and demonstrate human strengths and limitations in the workplace.
Human Factors in Systems Design II	Includes selected topics on human engineering and psychophysics in measuring human performance as part of overall systems performance. Investigate sensory perceptual deficits associated with simulators, virtual environments, and other human–machine devices.
Test and Evaluation	Relates the theory and techniques of operations research to the problems associated with system test and evaluation. Examples of exercise design, reconstruction, and analysis are examined.
Cost Estimation	Advanced study in the methods and practice of systems analysis with emphasis on cost analysis; cost models and methods for total program structures and single projects; relationship of effectiveness models and measures to cost analysis.
Principles of Acquisition and Program Management	Introduce fundamental principles of DoD systems acquisition and program management. Covers planning, programming, and budgeting processes; acquisition strategies; contractual decisions; and program management. Key functional areas explored are research and development, testing and evaluation, contracting, funding and budgeting, logistics support, systems engineering, and legal issues.
Personnel Testing and Selection	Study of methods for evaluating and predicting training and work performance in organizations. Special emphasis on testing concepts and models for Armed Services Vocational Aptitude Battery, equal employment opportunity, and selection decisions based on cost–benefit analysis.
Job Analysis and Personnel Selection	Study of job analysis and its use in determining training requirements. Consideration of instructional systems development and training pipeline management. Attention to cost–benefit issues involving training in regard to selection, equipment design, changing job requirements, and career development.

TABLE 5.11 (*Continued*)

Course Title	Course Description
Systems Engineering/ Integration	Study the systems engineering process and studies to include knowledge of systems design, development, and deployment; technical and economic trade-offs; human-in-the-loop issues; project management; systems acquisition; and the planning, programming, and budgeting system (PPBS).
Human Factors of Virtual Environments	Study issues in virtual environments on human performance, perception, cognition, multimodal interfaces, locomotion, wayfinding, object selection and manipulation, visualization, simulator sickness, and individual differences.

comprehensive summary of the field (see revised edition: Salvandy, 1997). Muckler and Seven briefly summarized the other six books reviewed for their relative coverage of the six MANPRINT domains. They concluded that Huchingson (1981) provides a "highly applied human factors engineering point of view" showing strong coverage of human factors engineering and health hazards, but purposely excludes "selection and training of personnel in favor of design-oriented material" (Muckler and Seven, 1990, p. 536). Wickens (1984), on the other hand, provides a somewhat basic engineering psychology point of view with only a few of the domain content areas covered to any depth. Each of the other texts reviewed by Muckler and Seven fell somewhere between these two views with a fairly good presentation of HF/E content and scattered coverage of the other HSI domains. The principal findings of Muckler and Seven were as follows:

1. None of the texts showed "any apparent interest in the manpower area."
2. The texts covered "personnel variables only insofar" as they interacted "with human engineering design problems."
3. The texts showed concern with training devices, but so far as training variables in general, they were covered only if they interacted with system design variables.
4. Collectively, the texts concentrated on "three major areas: human factors engineering, system safety, and health hazards."

Our review for this chapter restructured the domains and content areas examined by Muckler and Seven, reexamined their texts, and added several newer texts. When we look at all the texts today, the first finding is still true—the human factors texts do not generally show interest in the manpower area. We have eliminated manpower, therefore, in our textbook examination. There does, however, seem to be some coverage of the personnel and training domains in several of the texts as well as the major areas of human factors engineering, system safety, and health hazards.

Table 5.12 presents our combined review of those texts examined by Muckler and Seven and 10 more recent textbooks. These newer texts include Kroemer and Grandjean (1997), Pulat (1997), Tayyari and Smith (1997), Wickens et al. (1998), Hollands and Wickens (2000), Niebel and Freivalds (1999), Konz and Johnson (2000), Hendrick and Kleiner (2001), Kroemer et al. (2001), and Hendrick and Kleiner (2002).

The text by Kroemer and Grandjean (1997) focused on the physical side of work but does contain some interesting related topics such as control and display design. Pulat

TABLE 5.12 Textbooks for HSI Domains

Domains	H 1981	O 1982	K/S 1983	W 1984	S 1987	S/M 1987	A 1989	K/G 1997	P 1997	T/S 1997	W/G/L 1998	N/F 1999	H/W 2000	K/J 2000	H/K 2001	K/K/K 2001	H/K 2002
Human factors engineering	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Psychological capability and limitation	×	×	×	×	×	×	×		×		×		×			×	
Sensation and perception					×				×	×	×		×			×	
Workplace analysis and design	×	×	×		×	×	×	×	×	×	×	×		×	×	×	×
Cognitive ergonomics					×			×	×		×		×			×	
Control/display design	×	×	×	×	×	×	×	×	×	×	×		×	×		×	
Ergonomics	0	0	0	0	0	0	0	0	0	0	0			0		0	
Physiological capability and limitation	×	×	×	×	×	×	×	×	×	×	×			×		×	
Lifting and handling								×	×	×	×			×		×	
Biomechanics and anthropometry								×	×	×	×			×		×	
Training	0			0	0		0		0		0	0	0				
Learning					×		×				×		×				×
Training transfer				×	×		×				×		×				×
Instructional design				×	×		×				×						×
Training technology	×				×		×				×						
Training evaluation					×		×		×		×	×					×
Training models					×		×				×						
Personnel	0	0	0	0	0	0	0		0		0	0			0		
Skills, knowledge, and abilities (SKA) analysis			×	×	×		×					×					
Selection					×				×		×						
SKA analysis/training trade-offs	×																
Performance measurement and evaluation	×	×	×	×	×	×	×		×			×			×		×
Motivation					×										×		×
Reward systems					×										×		×
Health and safety	0	0	0	0	0	0	0		0	0	0		0	0	0		
System reliability analysis					×		×		×		×		×				×
Human error analysis	×	×	×	×	×	×	×		×		×		×	×			
System safety planning					×	×											×

(continued)

TABLE 5.12 (*Continued*)

Domains	H 1981	O 1982	K/S 1983	W 1984	S 1987	S/M 1987	A 1989	K/G 1997	P 1997	T/S 1997	W/G/L 1998	N/F 1999	H/W 2000	K/J 2000	H/K 2001	K/K/K 2001	H/K 2002
Safety training	×				×												×
Environmental stressors evaluation	×	×	×		×	×					×						×
Psychological stressors evaluation	×	×	×	×	×								×				
Designing for health and safety	×	×			×						×			×	×		×
Protective equipment and gear	×				×						×						
Controlling workplace hazards	×		×		×		×			×							×
Product reliability and liability	×		×		×		×				×						
Forensics	×		×		×	×											
Macroergonomics	0	0	0	0	0	0	0						0		0	0	0
Sociotechnical system design					×	×	×								×		×
Work system analysis and design					×										×		×
Participatory ergonomics	×	×	×	×	×	×	×								×		×
Function allocation	×				×	×							×		×		×
Organizational design					×										×		×
Collaborative/group work systems															×	×	×
Group task analysis															×		×
Methodology	0				0				0		0	0			0		0
Experimental design	×				×										×		×
Survey research															×		×
Simulation	×				×												×
Mission, function, and task analysis	×				×						×				×		×
Data analysis									×			×			×		

Abbreviations: 0 = some treatment given to major area; × = in-depth treatment given to subtopic identified. Column headings: A = Adams; H = Huchingson; H/K = Hendrick–Kleiner; H/W = Hollands–Wickens; K/G = Kroemer–Grandjean; K/J = Konz–Johnson; K/K/K = Kroemer–Kroemer–Kroemer; K/S = Kantowitz–Sorkin; N/F = Niebel–Freivalds; O = Oborne; P = Pulat; S = Salvendy; S/M = Sanders–McCormick; T/S = Tayyari–Smith; W = Wickens; W/G/L = Wickens–Gordon–Liu.

(1997) offers a wide variety of topics. Like the other texts reviewed, it has excellent resource information in the physical ergonomics area. However, this book also has very good cognitive information and other related topics. As is typically the case, little information is provided relative to macroergonomic or HSI issues.

The Tayyari and Smith (1997) text is heavily oriented towards physical ergonomics. However, the text also provides excellent treatment of some cognitive ergonomics issues such as design of controls and displays. It also uniquely has a section on the management of ergonomics programs, a topic usually associated with macroergonomics. Wickens et al. (1998) present a very broad, excellent introductory human factors perspective that covers several of the key informational areas important to establish the HSI knowledge base. The Hollands and Wickens (2000) book bears the same title as that of Wickens (1984) (*Engineering, Psychology and Human Performance*.) It is an excellent text for the domain of human cognitive performance and error and related subjects. While it covers manual control quite well, it does not seek to cover the more traditional topics in physical ergonomics or cover the more recent domains such as macroergonomics. Niebel and Freivalds (1999), as their title (*Methods*, *Standards and Work Design*) implies, focuses upon work design from a standards and methods perspective. While it does not directly address the more traditional topics associated with the HF/E aspects of HSI, the text does provide good information with respect to methods, data collection, and analysis. Konz and Johnson (2000) present another work design text that offers some interesting additional topics such as "cumulative trauma" and "managing change." Hendrick and Kleiner (2001) focus almost exclusively on macroergonomics in the first treatment of the subject in a textbook. Kroemer et al. (2001) offer a broad treatment of industrial ergonomics. Both Kroemer et al. and Konz and Johnson provide at least a brief treatment of macroergonomics. Finally, Hendrick and Kleiner (2002) provide an in-depth coverage of several topics within the macroergonomics domain but again do not directly address many of the HSI specialized topics.

5.5 HSI TRAINING COURSES

Academic institutions cannot provide all HSI specialist course needs, especially for short, non-degree-focused curricula. Much of the training needed by the HSI professional is in areas not HSI specific. In particular, these include non-degree courses to improve KSAs in acquisition management, systems engineering, logistics engineering and management, operations research, and safety engineering. The government, especially the DoD, provides a number of training opportunities for the HSI professional to acquire KSAs in these well-established fields. But in addition, specialized training is needed for HSI. This section summarizes the questions and findings of a recent training needs analysis conducted for HSI training (Booher, 2001).

Who Needs to Be Taught HSI? Within the military, the target audience for HSI is the same general audience as has been in existence since the inception of the army's MANPRINT program. This audience is frequently divided into four major categories:

1. Organizational leaders (e.g., senior executive service (SES), generals/admirals, political appointees),

2. MANPRINT and HSI practitioners (or action officers),
3. MANPRINT and HSI managers, and
4. Non-MANPRINT and HSI acquisition process participants.

The major change needed for new HSI courses is to expand the target audience from being primarily army personnel to include the other services and government agencies that procure, operate, and/or regulate systems and equipment. Human systems integration is now part of the DoD requirements in the DoD 5000 series under Systems Engineering. All DoD government and contractor personnel who are affected by this regulation need some education and training in HSI.

What Needs to Be Taught? The specific content for each course that should be developed to meet the target audience needs is beyond the scope of this chapter. However, models for courses both in the government and at academic institutions do exist. The best military example of coursework is that taught by the Army Logistics Management College (ALMC) for MANPRINT. This coursework provides short modules to address target audiences 2, 3, and 4 above. Numerous short courses are available for some of the domains of HSI (as human factors, safety), but no training courses outside the army are currently available. As discussed in the previous section, numerous educational academic institutions have coursework that provides various domain expertise, but institutions are only beginning to consider coursework in HSI specifically. It is assumed that the other services will need as a minimum the type of coursework currently available to the army.

What Coursework on HSI Currently Exists? Since so little training coursework exists beyond that provided by army MANPRINT, we can for all practical purposes be confident that what exists for MANPRINT is all that is currently available for HSI training. The primary existing formal army coursework is provided by the ALMC. This comprises

1. an eight-day MANPRINT action officer's course;
2. three- to five-day MANPRINT applications course—tailored and derived from the action officer's course;
3. numerous two-hour modules for about six other army courses; and
4. CD ROM on MANPRINT for individual instruction.

In addition to ALMC coursework, materials for a short course on MPT is available from the Army Research Laboratory's Human and Research Directorate (ARL-HRED); an e-learning course on HSI is being developed by the U.S. Air Force; the U.S. Navy offers a one-day introduction to HSI[5]; and the Federal Aviation Administration (FAA) has developed a short course on human factors for acquisition. Also, this handbook has been designed to help fill gaps in HSI principles and methods training coursework.

What Training Coursework Is Needed? The two principal needs for new training coursework identified by Booher (2001) are

1. expanding the current ALMC coursework to cover other agencies and
2. developing new specialized short courses for HSI practitioners—focused on known methods and principles. Table 5.13 shows a five-day HSI course curriculum that could be developed and taught by an institution such as ALMC to meet this need.

5.6 HSI CAREERS

As mentioned in the introduction to this chapter, individuals need to see the career potential of the HSI field if they are to become sufficiently motivated to develop the skills required. There are a number of actions the federal government would need to take in order to establish a career field for an HSI workforce. Those addressed in the HSI national workforce study (U.S. Army, 1993) include the following:

- HSI professional workforce vision,
- HSI personnel job series and skill code, and
- HSI certification/licensing.

5.6.1 HSI Professional Workforce Vision

As discussed above, the demand for HSI practitioners and the development of qualification programs should progress together. In order for this to happen, there needs to be an overall

TABLE 5.13 HSI Applications Course

Curriculum	Course Hours
Day 1	
HSI overview: HSI concept and model, 10 principles of HSI, case examples	2
Systems engineering overview: systems engineering framework; systems trade-off analyses	2
Systems acquisition process and HSI interfaces: requirements; testing and evaluation; performance measures; reporting documents	2
Day 2	
Manpower, personnel, and training (MPT) domains: definitions and concepts; methods and tools; MPT trade-off analyses	3
MPT group exercises/case studies/demos	3
Day 3	
Human factors engineering (HFE) domain: definitions and concepts; HFE methods and tools; program planning and execution	3
HFE group exercises/case studies/demos	3
Day 4	
Health hazards domain: types of hazards; health hazards analysis	2
System safety: accident analysis; risk assessment	2
Personnel survivability: parameter assessment list (PAL); survivability case examples	2
Day 5	
System integration domain tradeoffs exercise	2
Course Review	2
Total:	28

national vision and implementation of a career path for HSI professionals. We believe that the vision and initial implementation must come from the federal government. It is encouraging that a practical approach to a career path has already been provided in the studies mentioned above. An overview of the concept for an HSI government career path is illustrated in Figure 5.1, which shows a hierarchy of HSI government jobs progressing from junior to midmanagement positions to senior manager, HSI integrator positions.

Personnel could come into HSI jobs from any of the job series indicated on the left side of the figure. These job series currently relate to various individual HSI domains (MPT, human factors engineering, health and safety) and related engineering and analysis fields. Entry could be at any level in the hierarchy. Minimum entry requirements for each level are shown in Table 5.14. Individuals would need specialized experience and education in at least one of the HSI domains. Entry could be from any federal agency or from outside the federal government, so long as minimum qualifications were met.

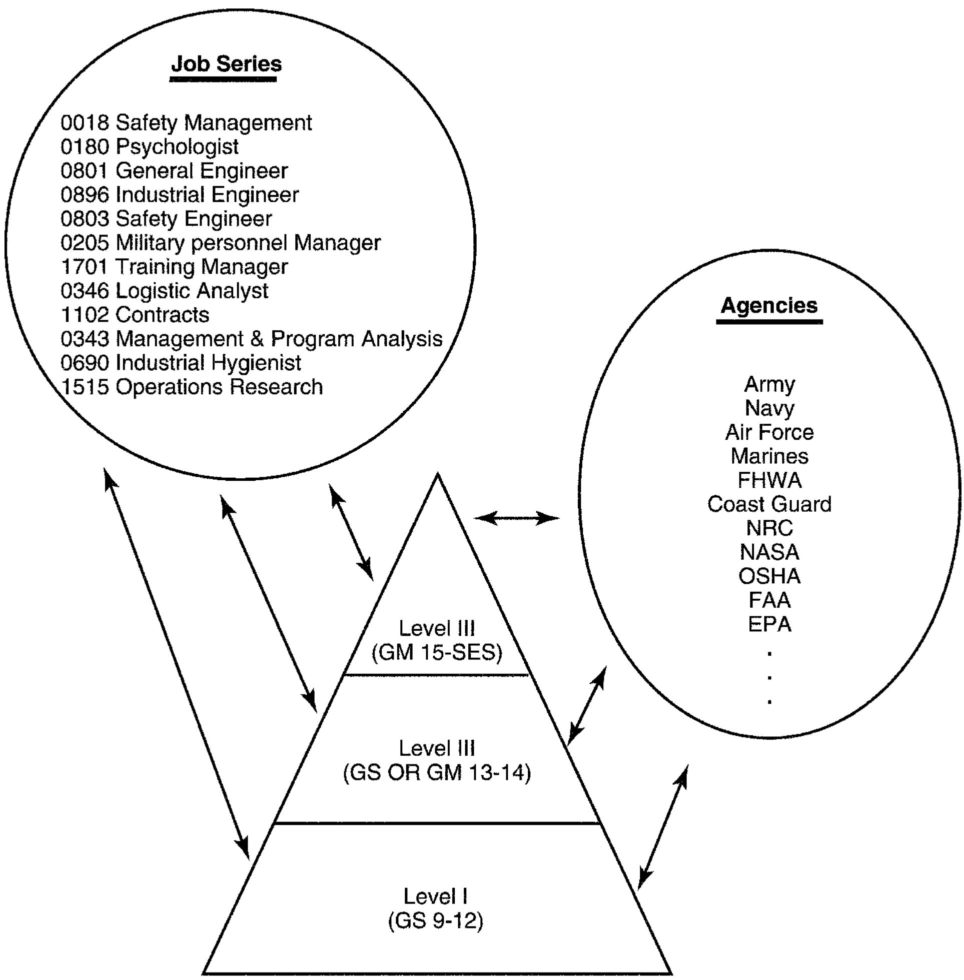

Figure 5.1 HSI professional workforce hierarchy (federal government).

TABLE 5.14 HSI Job Entry Requirements

Level	Grade	Experience	Education	Training
I	Junior to mid-technical, GS 9-12	M—one domain, experience 1 yr D—acquisition, experience 1 yr	D—baccalaureate degree	M—HSI basic course M—certification D—interdisciplinary courses D—acquisition management courses
II	Mid to senior technical or mid-management, GS or GM 13/14	M—HSI, experience 2 yr D—acquisition or applied engineering, experience 2+ yr	D—master's degree	M—HSI advanced course M—analytical techniques course M—certification D—interdisciplinary training D—acquisition training D—program manager course
III	Senior management, GM 15 and above	M—HSI, experience 4 yr, 2 of which in mid-management M—acquisition, experience 2 yr	D—master's degree or doctoral	M—certification D—executive training seminars

Note: M = mandatory; D = desired.

Note that entry at each level requires a combination of experience, education, and training requirements. Some of the requirements are mandatory, whereas others are desired. Some trade-offs among the requirements would be expected. For example, an individual seeking to meet entry Level I requirements might have a bachelor's degree in one of the domains but no experience. It is likely the education (which is desired) could be substituted for the mandatory one year of experience for entry at the lowest level (GS-9).

Note also that HSI certification is considered highly important in the government vision. This is because there are currently no educational institutions that provide formal HSI degrees; thus, at least some of the KSAs needed to enter the field must be made up with government training. Successfully completing HSI training can be the primary criterion for certification.

The federal government study on establishing a national workforce proposed a comprehensive education option as part of the career path. We have slightly modified this option, as illustrated in Figure 5.2, to include training. The major features of a comprehensive education and training program for HSI would include the following major features:

- ***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 degrees. Continuing education is shown as open to the largest portion of the workforce primarily for improving KSAs for level I jobs.
- ***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

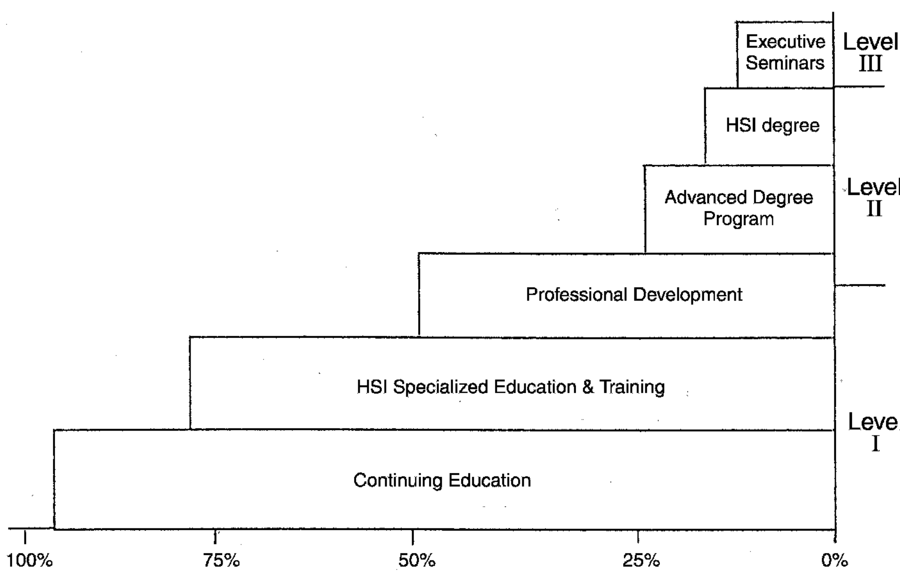

Figure 5.2 HSI education and training by job level and percentage of workforce.

by successful completion of specialized HSI coursework. Nongovernment personnel would also be eligible to acquire certification through this coursework.

- ***Professional Development*** This represents a way to improve the KSAs for 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.
- ***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. For every year spent in such a program at government expense, three years of government service in HSI would generally be required.
- ***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.
- ***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.

5.6.2 HSI Personnel Job Series and Skill Code

The study on establishment of a HSI career workforce (U.S. Army, 1993, p. 2-1) concluded that a viable career professional development program in the federal government must consist of the following personnel system components:

1. authorized full and part-time positions with job descriptions and grade requirements within the workforce structure;
2. a group of full-time HSI professionals that can be considered the HSI corps; and
3. a management system that facilitates recruiting new talent, providing them with required, sequential HSI-specific training and additional academic education, and assigning them to authorized positions.

As was shown in Figure 5.1, the HSI professional workforce career ladder hierarchy can have three levels. Typical job assignments for the levels in the four functional contexts are illustrated in Table 5.1. Currently, the military services have some full- and part-time positions that attempt to carry out HSI responsibilities. This is not done with any formal career structure, and none of the services has a personnel management system that facilitates the identification and assignment of individuals and their skills. There is no ability within the federal government to track personnel with HSI skills, so consequently it cannot evaluate any return on education and training investment to develop such skills.

In order to satisfactorily fulfill any of the three desired personnel system components, two fundamental decisions need to be made by federal agencies. The first is the determination of acceptable job series options for HSI personnel; the second is the development of approved job descriptions for HSI functions. The Office of Personnel Management (OPM) is the authority for establishing a new job series, but each agency has considerable latitude in utilizing existing job series and creating job descriptions.

The primary choices for HSI job series are (1) creating and assigning HSI personnel positions within existing job series as determined by the specific agency need; (2) creating and assigning HSI personnel positions within existing job series augmented by an HSI appendix;[6] (3) creating and assigning HSI personnel positions within existing job series, augmented by job skill codes;[7] or (4) creating a specialized HSI job series for HSI positions.[8] The national workforce study examined the advantages and disadvantages of each option. Essentially, the advantages of having a federal workforce that can be identified, tracked, and managed increase as one moves from option 1 to option 4. For example, as shown in Table 5.15, none of the existing job series is fully satisfactory to meet the job demands of an HSI position, making option 4 the preferred option. However, options 2 and 3 would be better than option 1 by providing greater controls over existing job series when used for HSI positions.

The disadvantages of implementing the options, however, increase in just the opposite direction (due to increased cost and coordination requirements). Currently, option 1 is the only choice being exercised.

Agencies can make some improvements in the career workforce simply by exercising some of the choices at each agency's disposal. For example, Table 5.15 shows that three of the existing job series do have strong technical requirements. These are engineering psychologist (180), general engineer (801), and operations research (1515). Options 2 and 3 could be exercised by augmenting these three job series either with an HSI appendix or a job skill code inserted into the position description. Table 5.16 illustrates a draft of what the national workforce study considered an acceptable job description for the HSI job series (option 4), but it could also be the basis for augmenting existing job series for any of the other options.

5.6.3 Certification and Licensing

The issues of certification and licensing of HSI practitioners have not changed since first examined by Muckler and Seven (1990). Their discussion on this topic was so enlightening that it is worth repeating in its entirety (pp. 540–542 with kind permission of Kluwer Academic Publishers):

> Once a labor pool of highly skilled professionals is established, a way of indicating to the public that they are (1) skilled and (2) skilled in something specific may be inevitable. The issue is certification and/or licensing of human factors/MANPRINT/[HSI] professionals where "certification" usually is the weaker form of regulation and restricts the use of a professional title. "Licensing," on the other hand, usually implies some specific kind of skill level and requires some form of examination.
>
> The basic purpose of certification and licensing is said to be the protection of the public. The practice goes back at least 3,000 years to Hammurabi and the Babylonians (Oates, 1979, pp. 180–183, on the practice of medicine). It should be understood that this is an extraordinarily controversial subject, and that there are those who argue that certification and licensing protects no one except guild members and may operate to the detriment of the public as well as practitioners (cf., Danish and Smyer, 1981; Gross, 1978; Koocher, 1979; Wiens and Menne, 1981; Herbsleb, Sales, and Overcast, 1985). It has been an issue of major concern to human

TABLE 5.15 Pros and Cons of Job Series for HSI Careers

Job Series	Title	Pros	Cons
0018	Safety and Occupational Health Management	Strong integrated look at personnel health and safety	Lacks MPT knowledge
0180	Psychologist[a]	Most human factors engineers are now in this series	Restricted to those with psychology degrees and has no integration focus
0205	Military Personnel Management	Strong view of manpower and personnel issues	No technical requirements or engineering background
0343	Management and Program Analysis	Emphasis on integration and management	No technical requirements or background
0346	Logistics Analysis	Requires integration skills; relates to logistic part of acquisition	Too narrow a focus and weak in technical requirements
0801	General Engineering[a]	Engineering perspective and background helps interactions with design engineers	Lacks MPT background
0803	Safety Engineer	Engineering perspective and background helps interactions with design engineers	Lacks MPT background
0845	Industrial Engineer	Strong human factors orientation	Weakest in personnel areas
1102	Contracting	Relates well to acquisition process	Not technical enough
1515	Operations Research[a]	Good analytical skills that apply across all domains	Weak in human factors, health hazards, safety
1701	Training Manager	Strong human performance orientation	No technical or engineering background
XXXX	Human Systems Integration (new)	Tailored for HSI mission	Requires new job series

[a]Series with technical grounding.

factors practitioners (cf. Siegel, 1980; Blanchard, 1985). Perhaps the best that can be done here is to describe some of the difficult issues raised by certification and licensing.

- It is possible to apply the process either to individuals or organizations. Normally, it is the individual who will be certified or licensed. An alternative would be blanket approval

TABLE 5.16 Draft Definition of HSI Job Series

Personnel in the HSI job series are primarily concerned with integrating the human component into the design, development, and acquisition of new systems or modifications of existing systems. System is defined in its broadest organizational context and includes equipment, people, and the procedures they use.

Individuals in this job series will perform in a number of environments, to include research and development, applied engineering, acquisition, and regulatory.

HSI professionals would perform the following principal functions:

- Develop HSI goals and constraints
- Develop and validate designs to meet HSI goals and constraints and performance requirements
- Trade off alternate design options to optimize (validate) compliance with requirements
- Validate design compliance
- Develop demographic and anthropometric description of workforce
- Identify critical usability issues for test and evaluation
- Prepare input to government solicitation documents
- Participate in source selection
- Identify issues for research and development
- Monitor contractor and/or government performance

Individuals in the HSI job series must be capable of conducting a variety of analyses in support of the procurement of hardware or software or the regulation of the end products. The analyses include but are not limited to the following:

Human–machine interface	Workload	Training
Organization workflow	Organization productivity	Anthropometric analysis
Manpower requirements	Health and safety analysis	Life-cycle analysis

The results of these analyses are included in government regulation requirement and procurement documents (request for proposal, request for information, and request for quote) to which industry is required to respond.

HSI personnel are further responsible for evaluating the technical quality and consistency of industry response to government solicitations and requirements and supervising and evaluating contractor performance in the following functional areas:

Manpower	Human factors engineering	Occupational health and safety
Personnel	Health hazards	Personnel survivability
Training	Systems safety	Habitability

for all those who graduate from an accredited educational program. What agency would do the accreditation has been the subject of disagreement.

- For individuals making their initial entry into a field, there is the question of what kinds of requirements should be established for either certification or licensing. For example, some fields require a formal, written, and often very rigorous, examination. Another alternative would be an oral examination of some form. Further, it may probably be assumed that some minimum level of experience and/or education would be required.
- There must be some written set of standards or ethics for what constitutes good and bad practice. There should be some form of statement as to what constitutes "harmful" activity. The American Psychological Association (APA) has a detailed code of ethics and defines at length acceptable and unacceptable behavior. The Human Factors Society

has also recently ratified a statement of ethics. [The Human Factors Society has changed its name to the Human Factors and Ergonomics Society. As of 2003, it still retains a statement of ethics for its members.]

- There have been many questions as to who should perform the certification and licensing. Paramount is the legal desire of the state. If the state deems the profession potentially harmful to the public, the state will probably provide formal mechanisms for certification and licensing. Even then, the state rarely does so without the approval and assistance of professional societies and organizations. In some cases, there will be both professional and public representation. For many professions (e.g., medicine) the state provides certification and licensing which may create some problems in jurisdiction when practicing in different states (cf., Henderson and Hildreth, 1965) or in standardization of requirements.
- One useful question is: What do the people in the field want? Rarely are current practitioners asked, but in one case they were. Siegel (1980) queried human factors professionals. His findings are interesting. First, current professionals preferred certification over licensing, principally on the practical grounds of the investment required to do licensing. Second, a master's degree was felt to be a sufficient level of education for certification (even then, 10% of the respondents felt that degrees were either not required or "immaterial"). Third, there was little agreement on the most appropriate background. Fourth, practitioners felt that experience should be substituted for formal education where appropriate. Perhaps the last two items reflect, in part, the fact that several major contributors to the field of human factors have not come from traditional educational backgrounds.
- A final issue is how frequently an individual should be assessed for his or her competency. For some, initial assessment is sufficient. But there has been a growing social feeling that more frequent assessments might be useful to see if competence is maintained. There appears to be no particular agreement on what form of assessment might be best. One could require formal, written, and/or oral examinations. Another method could be the submittal of performance and achievements to an assessment board. A third way could be a requirement to return to an educational institution at certain prescribed times for certain required number of courses.

5.7 HSI PROFESSIONAL PERSONNEL SUPPLY

Finally, an important aspect of establishing an HSI career workforce is having a reliable supply of professional personnel. One way of predicting the supply and composition of HSI professionals for the future is by examining the historical trends of groups having interest in applying human factors to the design of systems and equipment. Therefore, we wrap up our discussion on education and training of an HSI career workforce by examining the HFES membership by academic specialty and highest degree held (HFES, 2000b).

As can be seen in Figure 5.3, psychologists dominate the membership of the HFES (45 percent). This group includes general, experimental, industrial, engineering, cognitive, and other psychologists such as physiological, social, and clinical psychologists. The next largest group is comprised of engineers (23 percent). This includes general, industrial, mechanical, electrical, aeronautical/astronautical, and other engineers, including system engineering and biotechnology. The "other" category (discussed shortly) is almost as large as engineering (21 percent). Members with degrees in human factors or ergonomics constitute 11 percent of the HFES. This group includes general, psychology, and

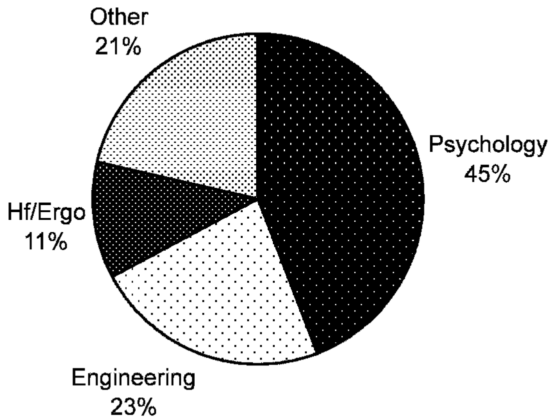

Figure 5.3 Major academic specialties (adapted with permission from HFES, 2000b).

engineering specialists. Detailing the "other" category further, it becomes obvious that the HFES is diverse indeed. Figure 5.4 illustrates the composition of the 21 percent "other" in Figure 5.3.

As can be seen in Figure 5.4, there are many constituencies in HFES. The "other" category includes a variety of specialties such as physics, anthropology, sociology, architecture, industrial management, and operations research (HFES, 2000b). Academic specialties are not listed separately by HFES unless they constitute 0.8 percent of the total membership.

Regarding degrees of professionalism, the highest degree held analysis is interesting as well. As illustrated in Figure 5.5, there are almost as many members with master's degrees (37.7 percent) as those with Ph.D. degrees (38.4 percent). Members with a bachelor's degree account for 15.5 percent. Nondegreed members account for 0.75 percent of the total membership. Other undergraduates constitute 2.16 percent, and 5.54 percent did not declare.

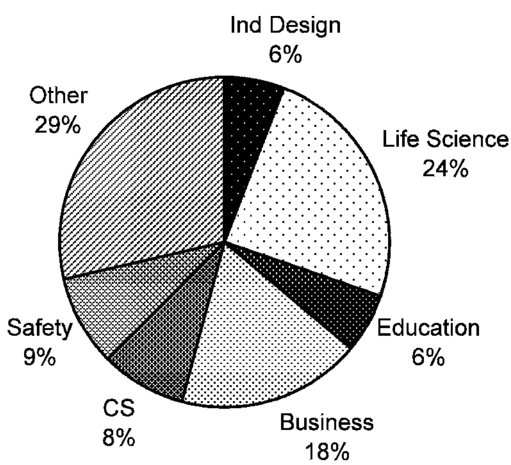

Figure 5.4 Breakdown of "other" category (adapted with permission from HFES, 2000b).

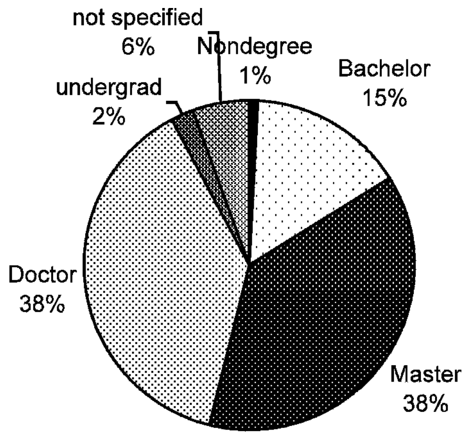

Figure 5.5 Highest degree held (adapted with permission from HFES, 2000b).

As illustrated in Figure 5.6, the largest single membership group is comprised of general psychologists with Ph.D. degrees (12.11 percent). There are approximately half as many Ph.D.s in Industrial Engineering, the next largest group (6.53 percent). Those with a Master's in Experimental Psychology make up the next group (6.25 percent), followed by industrial engineers with MS degrees (5.70 percent) and those with a Bachelor's in General Psychology (4.90 percent). Together, these five groups comprise 35.49 percent of the membership. The majority of members is comprised of very small groups outside these five, reflecting the tremendous diversity of professional populations making up the HFES.

Figure 5.7 illustrates the growth of the HFES from 1960 until 2000. The HFES has grown from approximately 500 members in the 1960s to well over 5000 in 2000. Student membership has also increased but not so sharply.

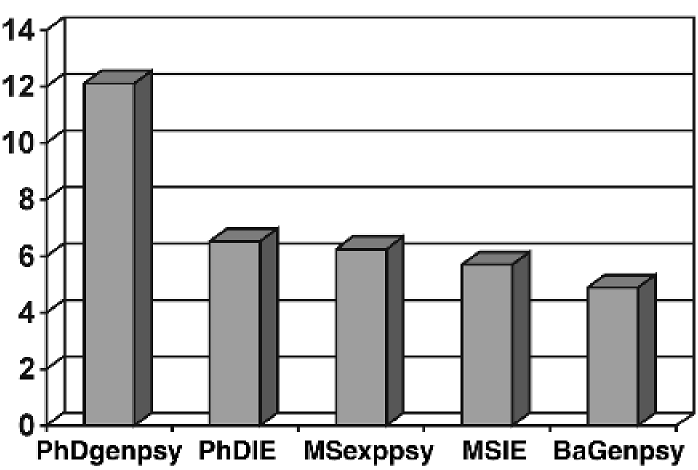

Figure 5.6 Largest member groups in HFES (adapted with permission from HFES, 2000b).

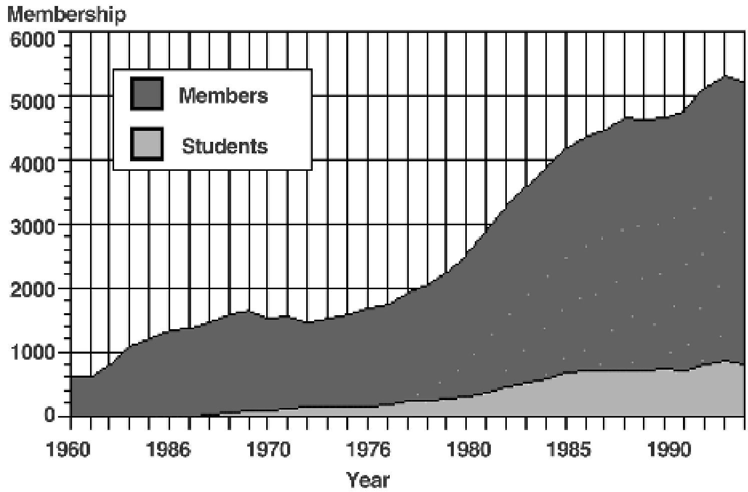

Figure 5.7 Membership trends in 1960–2000 (HFES, 2001).

It is clear that the HF/E professional domain offers a diverse environment and home for the HSI professional. Since certification appears to be a trend that will continue, HSI professionals should consider BCPE certification or a comparable designation. Unless and until dedicated HSI degree programs are developed, multiple degrees, even from multiple disciplines, are appropriate. Potential degree programs include macroergonomics, systems engineering, industrial engineering, human resources, and I/O psychology.

5.8 SUMMARY AND CONCLUSIONS

In this chapter, we first outlined the core competencies needed for qualified HSI specialists. This included a discussion of levels of competency and functional assignments. We then explored the academic environment in which HSI study can be pursued. Current curricula in several institutions were reviewed to illustrate the state of the educational environment for HSI pursuit. We then identified the recommended content areas for HSI education and illustrated through two hypothetical examples how a student might pursue an advanced degree in HSI. Textbook coverage of HSI content areas and the status of practitioner-training coursework were also discussed. In addition to academic education, specialized training for the HSI professional is also important, so the issues and status of HSI training were addressed as well. Since education and training development of HSI professionals is closely linked to careers in HSI, several issues regarding the development of an HSI career path were discussed. These covered a professional workforce vision, personnel job series and job descriptions, and certification and licensing. Finally, we examined the composition of the most likely supply of HSI professionals through membership data from the HFES. We have attempted to address questions that would interest three readers: (1) HSI professionals, (2) teachers and developers of HSI courses and materials, and (3) those involved with the system acquisition process. Common to all readers is material on the issues and options involved in acquiring KSAs in HSI principles and methods. For the HSI professional, whether it is through emerging HSI courses or obtaining advanced degrees or on-the-job experience, the authors are hopeful these readers will pursue life-long HSI careers.

NOTES

1. The U.S. Army (1993, 1995) national workforce studies for MANPRINT identified the situation then, and military downsizing since has further diminished the national pool of HSI professionals: "Few qualified people ... having needed expertise" should not be construed that there are not a large number of individuals with many of the skills important to HSI. Neither does it mean that to be qualified requires an individual to have expertise in all the HSI domains. However, HSI as a profession is still immature and is discovering that it needs certain expertise (such as that which meets the unique management and technical integration requirements discussed in Chapter 1; see Table 1.1) not widely available. Currently, few people could have acquired full HSI qualifications through either experience or academic institutions. This is because the number of work opportunities has been low and the definition of unique educational requirements has not fully evolved.
2. The study was for a MANPRINT national workforce, but outside the army, the program is better known as HSI (see Chapter 1).
3. It is understood that there would be no need for the second and third ingredients if sufficient demand were not present.
4. The NPS does have an approved two-year master's HSI track.
5. The one-day navy HSI course, Human Factors and Safety Engineering, is sponsored by the American Society of Naval Engineers (ASNE) and sanctioned by Virginia Tech.
6. An HSI appendix would be information on HSI skills and functions that could be appended to each related job series descriptions in the government personnel manual (X-118). It would be available to managers to help in defining position descriptions.
7. Job skill codes are a way of formalizing experience or training that reflect qualifications needed for the job that are not reflected in the job series. For example, individuals could obtain a skill code in HSI by meeting specified criteria such as working in an HSI position, attending HSI training, or becoming certified in HSI. Skill codes are controlled by each agency and are not standard across agencies.
8. A separate job series for HSI could be designated from existing job series or created as a totally new series, but its functional contexts would include acquisition, regulation, research, and applied engineering. Although agency coordination across all federal agencies would be required, the creation of a new job series in HSI would have a very positive effect on individual career opportunities, motivating universities and industry to support the workforce, improving the availability and quality of HSI professionals, and allowing the management of the workforce.

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