

Human Systems Integration (HSI)

Ensuring Design & Development Meet Human Performance Capability Early in Acquisition Process

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Human systems integration (HSI) considers areas such as: *manpower, personnel, training, human factors engineering, system safety, personnel survivability, and health hazards*. In simple terms, HSI focuses on human beings and their interaction with everything in the environment associated with DoD systems. (A sidebar on p. _ describes all seven of these areas in detail.)

HSI is a comprehensive management and technical strategy for human systems integration that is initiated early in the acquisition process to ensure that the design and ultimate development meet human performance capability. These capabilities include cognitive, physical, and sensory skills required for training and using a system. The human-machine interface applies to all C4I [Command, Control, Communications, Computers and Intelligence] systems, automated information systems, and weapons systems.

Each military service has a specific name for the HSI process. For example, the Army's effort (located at the Pentagon) is called MANPRINT [Manpower and Personnel Integration]. The Navy's effort (located at Johnstown, Pa.), formerly called HARDMAN [Hardware/Manpower Integration], is now called HSI—the subject of this article. The Air Force's effort (located at Brooks AFB, Texas), formerly called IMPACTS [Integrated Manpower, Personnel, and Comprehensive Training & Safety], is now also called HSI. The Marine Corps' effort (located at Quantico, Va.) was also called



Commercial and military customers need to be involved throughout the entire design process to ensure their Human Systems Integration (HSI) requirements are met.

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HARDMAN. It too is now called HSI. Regardless of the Service name, all HSI efforts will consider many specific areas. These areas will be described in the objectives of each Service program. For example:

- Influence design for optimum combined human/machine system performance.
- Ensure that system conforms to the capabilities and limitations of the operator, maintainer, and other support personnel.
- Improve control of the total life cycle costs of the system.
- Ensure system safety and compliance with health standards.

Service design goals also include things like minimizing acclimation time for drivers, fast and easy loading of ammunition or equipment, built-in diagnostic and fault isolation, and reducing death and injury through compartmentalization of ammunition and fuel.

Organizational Process

DoD 5000.2-R, *Mandatory Procedures for Major Defense Acquisition Programs (MDAPs) and Major Automated Information System (MAIS) Acquisition Programs*, signed April 5, 2002, suggests that an Integrated Product Team (IPT) be established early in the acquisition process to address HSI. In the past, the Army referred to these teams as MANPRINT Joint Working Groups (MJWG). With the revision of the 5000-series documents in 1996 and again in 2002, the Services should call them HSI IPTs. However, the Army continues to call them MANPRINT IPTs. The Air Force, Navy, and Marine Corps refer to these as HSI IPTs. The Services should develop specific management plans to address HSI for each system being developed.

Some HSI data are initially derived from the Mission Need Statement and the Operational Requirements Document (ORD). Ideally, the HSI Plan should be written before the ORD and used to help formulate the ORD. The Analysis of Alternatives (formerly the Cost & Operational Effectiveness Analysis), the Test

Calculation for System Performance Army Stinger (Using Various Aptitude Categories)		
EQUIPMENT PERFORMANCE (P_e)	HUMAN PERFORMANCE (P_h)	SYSTEM PERFORMANCE (P_s)
(.80) X	AFQT CAT I-III A (.67)	= (.536)
(.80) X	IIIB (.58)	= (.464)
(.80) X	IV (.48)	= (.384)

and Evaluation Master Plan, the Support Plan (sometimes known as the Integrated Logistics Support Plan), and other documents supplement the basic data as the IPT develops the HSI Plan for a system. These plans identify goals and constraints, concerns, tasks, trade-offs, and proposed analyses for the specific system being addressed.

The HSI Plan is a living document that changes as the system evolves. Typical information includes planning for inventory, force structure, standards of grade, skill and knowledge descriptions, anthropometric data, physical qualifications, aptitude descriptions, training history, and task performance. The IPT for HSI will typically be composed of the user and representatives from various disciplines, e.g., safety centers, research labs, health promotion/preventive medicine, engineers/designers, materiel developers, training developers, logisticians, contractors, developmental and operational testers, personnel commands, and Human Factors Engineering (HFE) personnel.

Analytical Process

As our commercial and military system designs become more complex, the aptitude requirements and maintenance problems generally increase. Pratt & Whitney's new PW4098 engine, with over 60,000 parts, is probably the most complex model assembly ever constructed. Many commercial computer aided design (CAD) packages exist to help designers develop a graphics system to display digital products for their customers.

Commercial and military customers need to be involved throughout the en-

tire design process to ensure their requirements are met. Human capability demands the integration of many simple and complex aspects in the operation and support of weapons systems. Some examples are physical demands, sensory demands, and cognitive demands. Each of these demands will change depending on the complexity of the item. For example, the use of hand tools will be different from that of electromechanical machines, and even more difficult for complex human-machine systems. HSI serves to assess these characteristics while still in the concept development.

Each Service has a variety of analytical tools and databases to develop HSI information. For example, in HFE the Army Research Laboratory may use Jack and Hardman III, while the Air Force may use Crewcut. Jack is also available to other Services and even to the private sector for commercial development of HSI. Overall, the tools can range from simple surveys and mock-ups to modeling, simulation, and expert systems. Simple calculations can be performed to predict system performance in various environments.

For example, consider the calculation for system performance for the Army's Stinger using various aptitude categories. The statistics were compiled using test scores from the Armed Forces Qualification Test (AFQT) categories (CAT I through IV) in a training environment. The basic formula is expressed in the sidebar above.

The data reveal that human involvement degrades the Stinger's overall system performance. Therefore, for highly com-

Definitions and Explanations of HSI Terms

MANPOWER—Manpower is defined as the number of human resources, both men and women, military and civilian, required and available to operate and maintain a system. Demographic projections indicate the statistical availability of manpower for the military. For example, a shortage of 18-year-old males was noted for the years 1992 and 1993 only if the force structure had anticipated a need in excess of 2 million military personnel.

PERSONNEL—The definition of personnel is the aptitude, experience, and other human characteristics necessary to achieve optimal total system performance. Human characteristics include four basic areas: Cognitive (aptitude, ability, knowledge); Physical (sex, senses, size, strength, stamina); Psychomotor (coordination, dexterity); and Experience (civilian, military, education, interests).

TRAINING—Training is defined as the requisite knowledge, skills, and abilities needed by available personnel to operate and maintain systems under operational conditions. Some examples of training include formal institutional, on-the-job, embedded, and simulation. Training must also consider the intended target audience, training strategies, and cost impact.

HUMAN FACTORS ENGINEERING—HFE is defined as the comprehensive integration of human characteristics into the system definition, design, development, and evaluation to optimize the performance of human-machine combinations. HFE also is concerned with reducing the probability that a human will make an error in the operation, maintenance, or support of a system; and with the degree to which an individual is able to accomplish a task, or series of tasks, under specific conditions, to meet a specified standard. Some examples of HFE problems are as follows: continuous operations; low light levels; environmental conditions such as cold, heat, noise, or NBC [nuclear, chemical, biological]; disruptive wake/sleep cycles; mental (information) overload; stress; or physical fatigue.

HFE analysis would further refine and attempt to reduce these problems by employing many cognitive and visualization techniques. An illustration of one study, trichromatic vision, noted that prolonged viewing of a computer screen can result in temporary myopia, eyestrain, blurred vision, headaches, and neck aches. To reduce these computer-related problems, HFE data would suggest the following:

- Working in an environment with the correct lighting.
- Using correct posture in relation to the computer.
- Developing a bigger screen or using higher resolution.
- Blinking more often while using the computer.
- Resting the eyes and stretching several times per hour.

In reconciling these hardware and human differences, the HSI and HFE effort would strike a balance between all areas. The balance is the training given to the appropriate users of the equipment. For example, the DoD generally directs training toward those people who fall within the anthropometric range. The anthropometric range accommodates 90 percent of the

population (the 5th to the 95th percentile). However, people outside this range are difficult to train or will not accommodate the equipment used by DoD. For example, anyone under 4'9" is too short to drive a truck or anyone over 6'3" is too tall to drive a tank. Therefore, three scales exist: one for the male population, one for the female population, and one for both populations. Equipment designated for combat organizations (with a male population) will normally use the male scale for equipment development.

SYSTEM SAFETY—System Safety is defined as the inherent ability of a system to be used, operated, and maintained without accidental injury to personnel. System safety is controlled primarily through identifying and "designing-out" problem areas early in the development; and later through accident prevention methods and techniques. HSI IPTs must analyze each component of the CAD design to redesign or remove any potential problem areas.

PERSONNEL SURVIVABILITY—Survivability from an HSI perspective is defined as the characteristic of a system or individual that can reduce fratricide; as well as reduce detection of personnel; prevent damage if attacked; minimize medical injury if wounded; and reduce physical and mental fatigue. For example, efforts to reduce weight, drag, and radar detection on aircraft. The design efforts can potentially increase range, maneuverability, and survivability for future fighter aircraft. Some examples of general personnel survivability include: warning sensors, maneuverability, life support systems, NBC hardening, flak vests, vaccines, prophylactic drugs, eye and ear protection, and radar/acoustic/thermal/microwave detection.

HEALTH HAZARDS—Health Hazards are defined as the inherent conditions in the operation or use of the system that can cause death, injury, illness, disability, or reduced job performance of personnel. Health hazards are found in weapons, munitions, equipment, clothing, training devices, and many other materials. Hazards are classified according to severity, by category:

CATEGORY HAZARD

- I CATASTROPHIC—may cause death or system loss.
- II CRITICAL—may cause severe bodily injury, severe occupational illness, or major system damage.
- III MARGINAL—may cause minor bodily injury, minor occupational illness, or minor system damage.
- IV NEGLIGIBLE—may cause less-than-minor bodily injury, occupational illness, or minor system damage.

These severity categories describe the damage inflicted to people and equipment as a result of acoustical energy, vibration, oxygen deficiency, temperature extremes and humidity, trauma, biological substances, chemical substances, shock, or radiation energy. System safety and health hazards also consider the survivability of the personnel and equipment. These same categories of severity are used extensively in logistical applications (e.g., Failure Modes Effects and Criticality Analysis) to assess personnel and equipment survivability. The combination of safety and survivability are compared against various levels of probability.

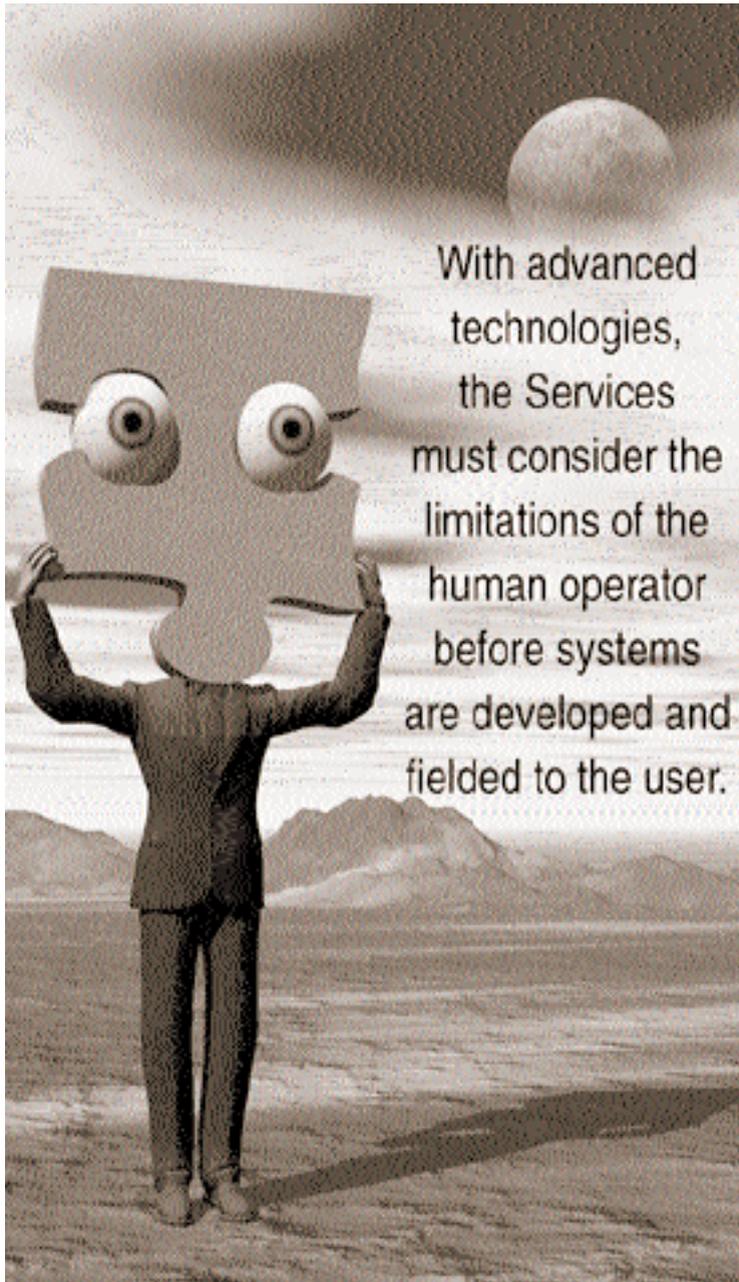
plex weapons systems like the Stinger, some of the alternatives might be as follows:

- Make the design simpler for the operator.
- Train the operators longer.
- Use personnel with higher aptitudes.
- All or none of the above.

Each alternative has merit, but each alternative also has a price. Ultimately, the determining factors in the acquisition process will be cost, schedule, performance, and the trade-offs made between these (and other) parameters.

Another Army example is the T800 engine used in the Comanche helicopter. The human requirement called for no increase in aptitude (from its predecessor engine—the T700 in the OH-58 helicopter) and to reduce the number of maintainers. The resulting HSI effort reduced organizational tool kits from 64 to eight—a substantial accomplishment! The reduction also included a reduction in the number of maintenance tasks. Finally, the manpower manhours were reduced by 14 percent and the reliability of the system was increased. With advanced technologies, the Services must consider the limitations of the human operator before systems are developed and fielded to the user.

To aid in this process, automated modeling processes are used to replicate thinking, perceiving, and acting before systems designs are finalized. For example, Jack is a human factors anthropometric CAD file that uses highly interactive 3D tools to help reduce limitations or find areas needing improvement. Jack looks at posture, reach-



ing, bending, twisting, center of mass, strength, balance, joint limitations, range and motion, eye-to-machine contact, and icon recognition. Jack has the capability to analyze: body weight, mass, size, upper- and lower-area limb evaluations, total body muscle assessments, body area and density, basal metabolic rate analysis, and evaluation of energy allowances.

CAD is capable of incorporating other automated tools and has substantially improved system designs. For example, the Integrated Graphics Robot Instruction Program (IGRIP) and Computer-

Aided Three-Dimensional Interactive Application (CATIA) add extra capabilities to a 3D CAD model by simulating worker functions, predicting desired ergonomic outcomes, helping to reduce start-up and cycle time, increasing reliability of the design model, and reducing risk to the ultimate system. CATIA and IGRIP were of tremendous value developing such major systems as Boeing's 777, the New Attack Submarine, Comanche RAH-66, F-22, Joint Strike Fighter, LPD-17, Enhanced Fiber-Optic Guided Missile, Crusader, Advanced Amphibious Assault Vehicle, AIM-9X, and Ballistic Aerial Target.

Ultimately, HSI data are translated into training manuals, operator and maintainer warnings, and sometimes posted directly on equipment. The physical translation is usually performed by the contractor using a government-approved logistical database (i.e., SLIC/2B, LEADS, ATLAS, DEC, L-BASE, LISA-2B). The contractor integrates all of the data from the government and data generated by

any other contractors to correlate the requested HSI effort.

Without HSI, weapons systems would be less effective and more difficult to operate and maintain. With HSI, soldiers, sailors, airmen, and Marines have a better chance to fight and win with today's highly technical and sophisticated systems. HSI remains a viable and cost-effective program for our military.

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