A BETTER IDEA
HUMAN SYSTEMS INTEGRATION (HSI) METHODS AND TOOLS

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ABSTRACT

With the issuance of DoD Instructions 5000.1 and 5000.2 in February, 1991, the DoD radically changed the way it addresses Human issues in system acquisition. A new concept called Human Systems Integration (HSI) encompasses the integration of manpower, personnel, training, human factors engineering, system safety, and health hazard concerns. In the wake of the DoD directives establishing the requirements for HSI, the need is for a standardized and formalized approach to HSI implementation. Tools and methods to implement this approach are also needed. This paper describes a set of automated tools to meet this need, designated the HSI Integrated *Decision/Engineering Aid or IDEA.*

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INTRODUCTION

Human Issues Come of Age. The world of military system acquisition experienced a transformation in February 1991 with the release of DoD Directive 5000.1, DoD Instruction 5000.2, and 5000.2M. The impact of the acquisition philosophy embodied in these documents on HSI is profound. With DoD Instruction 5000.2, the DoD has recognized that the human is indeed an element of the system, something that human factors and training professionals have been preaching for years, and a point of view which favors the full application of HSI in system acquisition. With the 5000 series, however, the DoD goes far beyond conceding that concern for the human user is important in system acquisition. The stated purpose of these documents is to establish a disciplined management approach for acquiring military systems and materiel that satisfy the operational user's needs (DoDD 5000.1 A-1, page 1). The DoD is explicitly and clearly establishing the needs of the user as the first priority in system acquisition. The user includes the command, the organization, the tactical unit, down to the individual soldier, sailor, airman, and marine who use the system or equipment as intended and who must be trained to operate and maintain the equipment.

Users Must Be Included. The DoD Directive 5000.1 also notes that the user plays a critical role in acquisition through the translation of the broadly stated needs into operational performance parameters and minimum acceptable operational requirements for the proposed system. (Part 1, page 1-1). The impact of this acquisition philosophy is that not only must the user be considered in the design of the system and trained in system operation and maintenance, but the requirements of the user are pivotal in determining the direction that the system design, including training device design, will follow.

Key Objectives. The system acquisition policies in DoD Directive 5000.1 address three major objectives:

1) translating operational needs into stable, affordable programs;

2) acquiring quality products; and

3) emphasizing efficiency and effectiveness in acquisition management.

Translating operational needs into stable, affordable programs involves a

process of phases and milestones and emphasizes affordability in acquisition. The acquisition of quality products emphasizes early identification of performance objectives, coupled with the requirement that the user participate in the development of operational performance objectives. The concern for quality products also involves:

1) concurrent engineering to achieve a balance among system design requirements;

2) an emphasis on use of non-government standards and commercial item descriptions; and

3) the assessment and reduction of risks, notably cost, schedule, and design risks.

Finally, in organizing for efficiency and effectiveness, the DoD is seeking to facilitate decision making, foster uniformity in acquiring military systems, and emphasize reliance on automated processes and tools.

HUMAN SYSTEMS INTEGRATION (HSI)

Basic HSI References. The major parts of DoD 5000.2 which impact those of us in the human factors, systems safety, and training arenas are: Part 7 Section B, "Human Systems Integration"; Part 6 Section H "Human Factors Engineering"; and Part 6 Section I "System Safety, Health Hazards, and Environmental Impact." With the HSI section, DoD 5000.2 replaces DoD Directive 5000.53, "MPTS In the Defense System Acquisition Process." It establishes the basis for effective integration of human factors engineering (HFE); manpower, personnel, and training (MPT); and health hazards and safety considerations into the acquisition of defense systems. It directs that human considerations shall be effectively integrated into the design effort for defense systems to improve total system performance and reduce costs of ownership by focusing attention on the capabilities and limitations of the soldier, sailor, airman, or marine. Furthermore, the instruction requires that objectives of the human element of the system shall be initially established at Milestone I, Concept Demonstration Approval, and shall be traceable to readiness, force structure, affordability, and wartime operational objectives. They shall be subsequently refined and updated at successive milestone decision points.

Tools are Needed. Surveys of personnel already involved in HSI and Army MANPRINT have pointed to the need for a standard process describing what must be done in applying HSI and automated tools and data bases to support standardized processes. For a full implementation of an HSI program, the need therefore is for: 1) an HSI process; 2) automated tools which facilitate and support the achievement of specific steps of the HSI process; and 3) readily accessible data to support HSI design decisions. The HSI process essentially comprises a standardized and formalized procedures for accomplishing HSI at each phase of the acquisition process. It includes all activities needed to apply HSI at each phase; and it is integrated with the activities, events, and products of the acquisition process. In the performance of specific steps of the process, there

is a need for automated tools which reduce the time, effort, and costs associated with HSI analysis activities.

INTEGRATED DECISION/ENGINEERING AID (IDEA)

Joint Development. The U.S. Army Human Engineering Laboratory (USAHEL) and Carlow International Incorporated have been developing automated processes, tools, and data for integrating HSI into each phase of the Army's materiel acquisition process. More recently the USAHEL has been joined by the U.S. Navy Space and Naval Warfare Systems Command (SPAWAR) and the U.S. Naval Sea Systems Command (NAVSEA) in extending the scope of the standard processes and tools for Army MANPRINT also to address processes, tools, and data for Navy HSI. The automated processes and tools are designated the HSI Integrated Decision/Engineering Aid or IDEA.

The Basic Idea. IDEA is a set of automated processes, tools, and data bases developed specifically to enable HSI analysts in the Army and Navy meet the requirements of the DoD 5000 series documents as well as service specific regulations and directives (Army Regulation 602-2; Naval Sea Systems Command Instruction 3900.8). The guiding principle behind the design of the IDEA software is that the HSI analyst should have at his or her fingertips all of the requirements, guidance, instructions, processes, procedures, methods, tools, and data needed to conduct a timely and complete HSI effort and should be provided with a report generator for preparation of HSI reports.

Nine Building Blocks. Application of HSI must address the requirements described in the appropriate sections of DoD 5000.2. Nine major requirements imposed on HSI which permeate the 5000 series and form the basic building blocks for IDEA are:

HSI must influence and support

1) system design,
2) affordability assessment,
3) system risk management,
4) quality of acquired products,
5) concurrent engineering,
6) the use of commercial products and standards,
7) program security,
8) prototyping, simulation, and modeling, and
9) system operational performance objectives.

How IDEA processes, tools, and data (the IDEA system) address each of these building blocks follows:

System Design. The primary objective of the IDEA system, and the primary objective of MANPRINT and HSI, is to influence design. The way in which this is accomplished in IDEA is through several initiatives:

1) making sure that HSI issues and concerns are addressed early in system acquisition;

2) attention to defining the roles of humans in system operations and maintenance early in system development;

3) identification of deficiencies and lessons learned in baseline comparison systems;

4) early application of simulation and prototyping; and

5) through human-centered test and evaluation activities.

Affordability Assessment. The issue of affordability is addressed in DoD 5000.2 Part 4 Section D. The issue takes center stage in the IDEA processes due to the importance of manpower, personnel, and training as drivers of life- cycle costs and due to the importance of reducing human error, the leading cause of accidents and system failures. The HSI inputs to the Affordability Assessment include the results of assessments of the implications of HSI for each candidate Acquisition Strategy and Alternative Design Concept. This analysis involves determination of life-cycle resource requirements for operational and maintenance manpower; training; personnel non-availability due to accident; expected human error rates; expected time to repair; requirements for supportability; and requirements resulting from expected system downtime. The Affordability Assessment will also determine if the proposed acquisition strategy is in line with Defense Planning Guidance and long-range modernization and investment plans. The Assessment will define the adjustments required of the proposed acquisition strategy due to HSI affordability factors and will recommend changes to the acquisition strategy or alternative acquisition strategies to resolve problems due to HSI affordability factors. The Affordability Assessment will assess alternative design concepts on HSI affordability factors, will identify alternative design concepts having problems with HSI affordability factors, and will recommend changes to alternative design concepts to improve the performance of HSI affordability factors.

The IDEA Assessment tool addresses the requirements for providing HSI inputs to the Affordability Assessment.

System Risk Management. In the realm of risk management (5000.2, Part 5, Section B), the IDEA processes and tools are focused on efforts to identify, prioritize, and reduce cost risks, schedule risks, design risks, and technology risks. The activities in this realm address reduction of risk and the conduct of tradeoffs.

HSI Risk Assessment involves identification of critical human system factors in design alternatives that will have a significant impact on readiness, life-cycle costs, schedule, or performance. These include tasks, task sequences, task complexity estimates, environments and environmental controls, equipment design features, maintenance requirements, information requirements, user-computer interface features, manning requirements, workloads, personnel skill levels, training requirements, and hazards.

HSI tradeoff decisions are required at each milestone. Tradeoffs include role of man vs. automation; approaches to reduced manning including improved design, task simplification, decision-aiding, automation, or cross-training; design, manning, or training approaches to reduce high drivers; alternative man-machine interface design concepts; hazard elimination, guarding, warning, or

training; training vs. job aiding; required skill levels of personnel; school house training vs. organic training; and training media-fidelity/cost tradeoffs.

The IDEA thrust in risk management is to identify HSI risks in alternative design concepts and to determine the requirements for reducing these risks to an acceptable level.

Acquiring Quality Products. Concerning the need for maximizing the quality of acquired products (DoD 5000.1 Part C), application of the IDEA tools links the notion of affordability with that of product quality from an HSI perspective. The underlying concerns in product quality include efforts to ensure usability, reliability, maintainability, supportability, and safety of products.

Concurrent Engineering. Concerning concurrent engineering, DoD 5000.1 requires that program plans provide for a systems engineering approach to the simultaneous design of the product and its associated manufacturing, test, and support processes (5000.1 page 1-4). This concurrent engineering approach is viewed as essential to achieving a careful balance among system design requirements (e.g. operational performance, producibility, reliability, maintainability, logistics, human factors engineering, safety, survivability, interoperability, and standardization). IDEA focuses on concurrent engineering through

1) its integration of human factors engineering; system safety and health; and manpower, personnel, and training;

2) its emphasis on supportability considerations in system design; and

3) its reliance on test and evaluation throughout all phases of the HSI process.

Commercial Products and Standards. DoD 5000.1 requires that maximum practical use be made of commercial and other nondevelopmental items, non-Government standards, and commercial item descriptions (page 1-4). IDEA emphasizes the comprehensive evaluation of the human performance and safety impacts of commercial products and standards through HSI test and evaluation. IDEA also provides guidance on the application of HSI methods, techniques, and data to the acquisition of nondevelopment items (NDI).

Program Security. DoD 5000.2 Part 5 Section F requires that an overall protection program from hostile intelligence collection threat for acquisition activities will be established and maintained by integrating security disciplines into a coherent program. IDEA addresses the process for establishing the role of the human in security operations, including design of human-machine interfaces; determination of manning needs; and development of training system requirements, concepts, and criteria.

Prototyping. The role of prototyping, simulation, and modeling in system acquisition is seen in DoDI 5000.2 mainly as a technique for assessing and reducing risks associated with integrating available and emerging technologies into a system design approach (Part 5 Section D). In IDEA, prototyping and simulation serve to

ensure that human concerns are addressed early in system acquisition and also as a technique for reducing developmental costs, thereby enhancing affordability.

System Performance. As stated in DoD 5000.1, performance objectives must satisfy operational needs and be verifiable through testing; and they must include critical supportability factors such as reliability, availability, and maintainability (Page 1-5). The major contributions of the HSI IDEA to the achievement of system operational performance objectives include the following:

1) identification of design deficiencies and lessons learned in existing systems which adversely impact personnel performance and safety;

2) development of design, manning, and training options to resolve personnel performance, safety, and readiness problems identified in existing systems;

3) determination of the optimum role of the human vs. automation in system operation and maintenance;

4) development of system, subsystem and component design concepts and criteria;

5) integration of personnel selection criteria, personnel skill requirements, and human performance standards in the development of personnel performance and readiness criteria;

6) application of standardized, requirements-driven, front-end analysis techniques which address personnel quantity and quality demands as well as human-machine interface design requirements;

7) reductions of required manning, workloads, training, and skills and task simplification through HSI application;

8) reductions of human error potential and enhancement in error detection and recovery in emerging systems;

9) reductions in accident rates and health hazards, and enhancement of human performance and safety in adverse environments;

10) reductions in the risks associated with personnel capability, availability, performance, productivity, and safety;

11) attention to development and implementation of HSI technology; and

12) significant cost avoidance due to reduced error rates, reduced accident rates, reduced system redesign requirements.

The IDEA Tool Locker

IDEA tools include analysis tools, design and evaluation tools, analyst productivity tools, and information tools.

Analysis Tools Completed. The IDEA automated HFE/MANPRINT analysis tools which have been identified for the early phases of the IDEA process, and which are already completed and are undergoing field testing at this time include

1) an IDEA Comparability Analysis (ICAN) tool which supports the identification of high driver tasks/conditions and lessons learned from predecessor systems;

2) an IDEA Role-of-MAN (ROMAN) tool which supports function allocations and determination of alternate feasible roles of the soldier in system operation and maintenance;

3) IDEA Task Analysis (I-TASK) Tool based on MIL-H-46855 and MIL-STD 1478;

4) a cognitive task analysis tool (I-COG) focused on the decision aspects of tasks, designated the IDEA Decision Analysis (IDA) tool;

5) a functional flow/task sequencing tool, designated NETWORK, for graphically establishing the relationships and dependencies among functions and tasks;

6) a simulation model for assessing multi-operator task networks and evaluating alternate role of man concepts, and system design alternatives in terms of impacts on human performance and workload, designated SIMWAM (Simulation for Workload Assessment and Modeling);

7) an IDEA HFE/MANPRINT Issue Tracking Tool (ISSUE) which is not only a system for monitoring the status of specific HFE/MANPRINT issues throughout the design process but also an institutional memory, a repository of the history of issues and their resolution, pertaining to HFE/MANPRINT; and

8) an IDEA Tradeoff Analysis (ITALIC) tool to support the evaluation of alternative design, manning and training approaches, prioritization of tradeoff criteria, and assessment of the performance of each alternative on each criterion measure.

Analysis Tools Under Development. Analysis tools associated with later phases of the IDEA process and which are at earlier stages of development include

1) an IDEA Timeline Tool (I-TILT) which enables a graphic representation of timeline data imported from the task analysis tool, NETWORK, or other sources of information concerning tasks;

2) an IDEA Safety and Health Hazard Analysis Determination and Evaluation (I-SHADE) tool which enables the user to identify hazards, track the hazards, categorize the hazards, assign priorities, and develop hazard resolution plans;

3) an IDEA Error Analysis Tool (ERA) which expands on the error analysis section of the task analysis tool;

4) an IDEA Training Requirements Evaluation and Analysis Tool (I-TREAT) which expands on the training requirements analysis section of the task analysis tool;

5) the IDEA HFEA Tool (I-HFEAT) which supports the conduct and documentation of the Army's HFEA; and

6) the Operational Procedures

Requirements Analysis tool (OPERA) for determination of requirements, concepts and criteria for operational procedures.

These tools are integrated to the point that they enable the analyst to export and import data between tools rather than creating a data base specific to each tool. For example, task data generated in the application of the IDEA Comparability Analysis tool can be exported to the task analysis, NETWORK, and SIMWAM tools.

Design and Evaluation Tools. IDEA design and evaluation tools currently under development include

1) Automated IDEA HEDGE T&E Tool (I-HEDGE);

2) HFE Experimental Testbed (VISTA);

3) IDEA Maintainability Analysis Tool (I-MAT); and

4) IDEA Display Requirements Optimization Prototyper (I-DROP).

Productivity Enhancement Tools. The IDEA HFE/MANPRINT analyst productivity enhancement tools which are currently undergoing field testing include

1) a hypertext version of MIL-STD-1472D;

2) special computational aids such as visual field of view calculation and anthropometrics; and

3) a means of accessing standard office productivity software (wordprocessing, spreadsheet, database, etc.)

Information Tools. IDEA Information Tools include

1) an HSI glossary accessible from any location in IDEA;

2) an automated HSI points of contact information system;

3) an IDEA automated, status-reporting system for each *materiel system under analysis;*

4) an information system containing surveys of all known HFE tools and models;

5) an HSI Planning Tool; and

6) an HSI Assessment Tool.

Distinguishing Features

The distinguishing features of the HSI IDEA system are its level of integration, its usability, and its relatively low development costs.

Integration. Integration is the central design theme in the HSI IDEA. First of all, the acquisition requirements in DoD 5000.15000.2, and 5000.2M are integrated into the HSI IDEA process. The HSI IDEA process is integrated into the specific phases of the system acquisition process. Automated HSI tools and data bases are integrated among themselves and with the HSI IDEA process through data import and export. Finally, the specific elements of HSI, including HFE, manpower, personnel and training, system safety,

and health hazard reduction, are integrated among themselves.

Usability. The high level of usability of the HSI IDEA software are the result of its design philosophy and its architecture. The design philosophy as dictated by the USAHEL, incorporates the requirement that the HSI IDEA user will have at his or her fingertips, in one location and readily accessible, all the procedures, guidelines, tools, methods, models, and data needed to apply HSI in the acquisition of a military system.

The usability of the HSI IDEA system also springs from its architecture. In terms of IDEA software architecture, it should be noted that a significant finding of a survey of HFE tools was that the human factors engineering community identified the microcomputer of choice for advanced HFE tools as the Apple Macintosh. This preference also facilitates the development of a predominantly graphic-based architecture such as is required for IDEA.

Low Cost. The relatively low development cost of IDEA is in part the result of the decision to select the Macintosh environment. Not only does the Apple Macintosh enable development of software that is more usable and learnable as compared with other environments, it also results in reduced development costs since a large proportion of the software commands and protocols are already included in the Macintosh toolbox. The IDEA system is also more affordable due to another feature of the IDEA design philosophy: the system will enable application of tools written for any operating system. Thus the IDEA system, using off-the-shelf software packages, is fully capable of emulating tools and data bases written for other environments.

Future Directions. The HSI IDEA processes and tools are currently undergoing field testing at the USAHEL field units, at the DoD HSI Office, and at the Naval Sea Systems Command's HSI Division (SEA 55W5). IDEA Beta testing is also proceeding at several European organizations, including the French Army's L'Etablissement Technique D'Angers (ETAS), the Netherlands Institute for Perception, the UK MANPRINT Office, and British Aerospace. The development of HSI IDEA processes has been completed through acquisition milestone IV.

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