SEARCH FOR TRAINING AND HSI TECHNOLOGIES: ANALYSIS OF DoD LIVEWARE SURVEY

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ABSTRACT

How can the United States (US) military achieve more with the human resources it will have after completing the current downsizing efforts? By improving training effectiveness and Human Systems Integration (HSI), the DoD can leverage the people it has. To achieve this goal, the DoD has mandated a series of HSI analyses throughout the defense acquisition process. Now Government and contractor employees alike must find training and HSI technologies that help achieve better consideration of human issues during acquisition and better integration of the human into each defense system developed or modified. Recently, there has been an explosion of affordable HSI and training technologies. Despite this new emphasis, it is very difficult to identify the most appropriate technology for training development and HSI analyses. Defense acquisition managers, their contractors, and the HSI research and development community need a database of information about HSI and training tools, databases, and test facilities. They need help in identifying the technology already available in each of the Liveware domains of Manpower, Personnel, Training, (MPT) Safety, Health Hazard Prevention, and Human Factors Engineering (HFE). However, no comprehensive catalog of HSI and training technology exists. Under the sponsorship of the Office of the Assistant Secretary of Defense (Force Management and Personnel) HSI office and North Atlantic Treaty Organization (NATO) Research Study Group.21 (RSG.21), ARL-HRED-STRICOM and CSERIAC have surveyed the HSI and training communities to obtain a comprehensive database of HSI and training technologies. This paper presents highlights of the resulting Liveware database, and discusses Liveware survey collection methods, findings, and implications of this landmark survey. More than 500 HSI and training technologies have been catalogued in the Liveware database. Special emphasis will be placed on technologies critical to maintaining US military superiority while reducing manpower and training costs.

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BACKGROUND

Importance of Effective Training and HSI

The US and NATO militaries are downsizing during the post-Cold War era, while other nations are taking advantage of inexpensive military hardware and brainpower to expand their militaries. Economic pressures to spend less on military preparedness increase while tyrants and ethnic conflicts increase. Meanwhile, our training and weapon systems need to be refocused on the kinds of wars likely in the future. We are all caught up in a period of dramatic change in which it is easy to become disoriented. As acquisition people, we need to focus on how to be prepared with fewer people. To improve the people-related cost-effectiveness equation, we must find better ways to include HSI issues and technologies in the Defense materiel acquisition process, and we must leverage our investment in our people by increasing their training quality.

DoD Directives Contain HSI Requirements

Recognizing the need for more effective human-materiel interrelationships, the DoD defense systems acquisition instruction (DoDI 5000.2) documents a series of HSI analyses and data requirements to be analyzed and furnished to the Defense Acquisition Board throughout the acquisition process. Pressures to accomplish more with smaller defense forces, and the widening interest and direction in HSI as a means to this end, have accelerated the need for comprehensive information about available HSI tools, databases, techniques, and test facilities. Department of Defense Instruction (DoDI) 5000.2, *Defense Acquisition Management Policies and Procedures*, requires the "effective integration of human considerations in the design effort to improve total system performance and reduce life-cycle cost." Objectives for the human components of a system are to be established at Milestone I, and addressed, refined, and updated throughout acquisition. This DoDI enumerates appropriate HSI studies, analyses, plans, and milestone issues to be addressed at each phase of the Defense acquisition process.

Need for Available HSI and Training Technologies

To meet the challenge of these changing times and the requirements of directives, Defense acquisition personnel and their contractors need to have a set of proven HSI technologies readily available to use during each phase of acquisition. Systems development personnel need tools, data, and methods for determining HSI impacts and influencing the design process for increased human efficiency, safety, and to minimize hazards. These HSI technologies are so critical to the US technological lead that the Director of Defense Research and Engineering (1992, July) listed "human-system interfaces" and "design automation" which includes representation of people-related issues, and "environmental effects" as three of the top 11 DoD key technologies. The goal of these technologies is to help US fighting personnel perform more effectively under stressful conditions. Our people must be prepared to do more with fewer people, while remaining more protected from "harm's way". HSI and training technologies exist for just that reason, yet sometimes there seems to be a disconnect between the developer of HSI technology and the potential user. For this reason, the OASD(FM&P) HSI Office commissioned the DoD Liveware survey. The goal is to take stock of HSI technologies and index them for easy access.

NATO RSG.21

Across NATO, other nations are awakening to similar needs for easy access to HSI technology. Member countries are finding that HSI processes

can be effective in improved development/ modification of defense systems. NATO Defense Research Group Panel 8, *Defense Applications of Human and Bio-medical Sciences,* established Research Study Group 21 (RSG.21). This group, designated ***Liveware Integration in Weapon System Acquisition***, was chartered to study how the human-machine interface was addressed and how these issues were resolved during acquisition. Participant nations are listed in Figure 1. RSG.21 is chaired by Mr. Michael Pearce of the Office of the Assistant Secretary of Defense (OASD), Force Management and Personnel (FM&P)/Requirements and Resources (R&R), Total Force Requirements (TFR), HSI office.

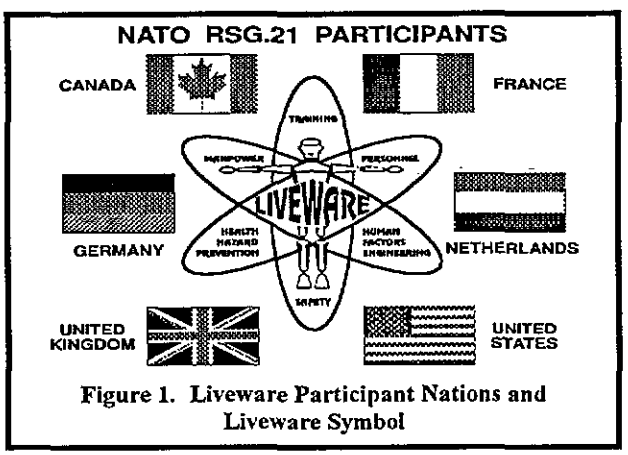

Figure 1. Liveware Participant Nations and Liveware Symbol

Liveware Defined. As RSG.21 wrestled with the difficulty in communicating concepts like Army MANPRINT, Navy HARDMAN, and AF IMPACTS -- acronyms for programs that implement HSI in the respective Services -- they coined a new term, "Liveware." ***Liveware*** collectively describes all acquisition disciplines that directly affect humans in defense systems. Liveware domains include MPT, Safety, Health Hazard Prevention, and HFE, the same disciplines involved in the DoDI 5000.2 definition of HSI. Figure 1 also displays the logo that symbolizes the Liveware concept of six domains integrated in an *atom structure, with the human in the center.* A bio-mechanical humanoid mannequin symbolizes the computer-aided design technology which allows integration of human issues into the design engineer's workplace, midst the creative process.

Tasking. RSG.21 was tasked to (1) identify, define, and describe the tools, techniques, and databases that enhance early consideration and integration of HSI issues into the total system; (2) evaluate these findings; and (3) identify gaps and voids for future research and development (R&D) efforts. Moving to meet this NATO-wide need, the OASD(FM&P) HSI Office tasked the Defense Training and Performance Data Center (TPDC) to develop a comprehensive database of "Liveware" information.

Project Overview and Implementers

TPDC. To build the Liveware database, TPDC developed the survey instrument to collect essential information from HSI technology owner/developers, users, and distributors. Liveware survey questions were reviewed by RSG.21 members. Since this involved translating across Service, nation, language, and scientific discipline, developing a consensus was no small challenge. Each country was to survey its own HSI community and share results with TPDC, for input into the Liveware database.

ARL-HRED-STRICOM. Shortly after initiating the Liveware survey, TPDC was disestablished and the responsibility for data collection and input was moved to ARL-HRED-STRICOM.

CSERIAC. After the survey instrument was finalized, CSERIAC's assistance was obtained as subject matter experts in the area of Human Factors, Human System Integration, and survey analysis. CSERIAC helped identify prospective technologies and Points of Contact (POCs) from literature searches and their expert network.

Liveware Project Goals

The primary goal of the Liveware survey is to be the most comprehensive study of HSI technology yet accomplished. It is to document tools, databases, methods, and facilities in all Liveware domains. The Liveware database will be available on-line and on diskette to the Government and Industry acquisition communities. This database will support effective use of HSI tools and databases throughout the acquisition process. In addition, it will store the results provided by other NATO nations. Liveware database analyses will help identify HSI technology gaps and set the research agenda to improve these technologies. The overall objective is to help DoD and NATO acquisition personnel and their contractors identify and use HSI technologies. By making HSI technologies easier to locate, we hope that they will more likely be used in producing the most cost-effective defense systems possible.

Previous Studies and Background Searches

Earlier Studies. CSERIAC performed a background/literature search to determine the ex-

tent to which HSI technology had been studied before. Nine studies were identified that covered parts of the Liveware domains (see Gentner & Crissey 1992, May) . In discussions with study authors, they identified these factors as limiting the scope of their studies: (1) the study intended to cover only one or a few domains, or one service component; (2) the breadth of the study was limited by funding or expertise; (3) participation from all domains and Services was not forthcoming and/or time was not available to personally encourage developers to submit input; and (4) the organizational infrastructure and technology did not exist within the Services during the study's timeframe (especially in the case of health hazards prevention).

Difficulties Locating Needed Technology. Comprehensive HSI technology review and comparisons are rare in the Literature. In addition, it is difficult to find POCs for HSI existing technology from literature searches. While some technical references do exist to many of these technologies, Liveware technologies are not easily located in existing technical reference databases. Often multiple cross-references are needed to find one single technology that can serve a specific need, even if the searcher is knowledgeable of the technological jargon. This dearth of easily-accessible information about HSI technologies reinforces the need for a "living" Liveware database. One could easily spend hours finding an appropriate HSI technology, just to learn that it was never completed or is no longer maintained.

METHOD

Survey Content

Survey questions were divided into the three sections. The information available from the Liveware database is listed below:

General Program Information. Section I consists of ten major areas. *Program Identification* captures the program name, acronym, description, type of technology, country of origin, community *sector, state of development, availability, accessibility,* and portability. The *Purpose and Acquisition Phase* covers mission area, system area, system and force level, and acquisition phase. The next three areas cover *Hardware Requirements, Software Requirements,* and *Linkages* to other tools/databases. *Documentation* captures the names and dates of the technical reference and user instruction documents, data output mode, and availability of data field descriptions and data record layout. The *Validity* area has product validation information. The three final areas are text fields covering *Assumptions, Limitations,* and *Remarks.*

Descriptive Information. Section II identifies the Liveware domains addressed by the program, applicable categories within each domain, and environmental areas of concern to safety and health hazard programs. In addition, if the program integrates several domains, the method of integration (vertical and/or horizontal) is specified.

Owner/User Information. *Section III covers* multiple areas. Not only is the owning organization identified with a POC, but multiple users and their organizations can also be identified. For each POC, the following information is collected: organization name, address, and telephone number, user work discipline, domains applied, and frequency of use. For a more detailed description of the survey, see Gentner & Crissey (1992, May).

Survey Administration Strategy

Maximum publicity was sought by publishing and presenting papers/articles at technical forums and in professional publications, such as the National Aerospace and Electronics Conference (NAECON), Human Factors Society, Interservice/ Industry Training Systems and Education Conference (IITSEC), DoD Human Factors Engineering Technical Group (DoD HFE TG), *CSERIAC Gateway,* and other conference/ workshop proceedings. The CSERIAC specialized literature searches identified potential technology POCs, who were sent Liveware surveys, followed-up by phone and fax. As surveys arrived, CSERIAC used "networking" techniques to identify other technologies and POCs. For those technologies with no POC participation, existing literature was used to develop a survey entry. When possible, those literature entries were coordinated with the POC.

Survey Database and Analyses

Prototype Databases. Survey results were entered in a prototype PC FOCUS database, and later into a Folio Views hypertext *infobase.* The database displayed matrix-type (cross-tabulation) printouts of survey variables. The infobase enabled instant word combination searches.

Survey Analyses. Survey analyses were conducted by Frank Gentner, Dave Kancler, and Dr. Mona Crissey using matrixed printouts from the Liveware database. Descriptive statistics were used to highlight the existence of technologies in various categories and to look for trends. At press time, detailed analyses of these 3 following

Table 1
TECHNOLOGIES IN LIVEWARE DATABASE
BY SERVICE/INDUSTRY
(As of April 15, 1993)

LIVEWARE DOMAIN	UNITED STATES AIR FORCE	ARMY	NAVY/ MARINES	OTHER GOVT.	INDUSTRY	UNIVERSITIES	TOTAL BY DOMAIN
MANPOWER	54	44	15	25	103	7	248
PERSONNEL	43	44	12	25	99	8	231
TRAINING	68	52	37	33	126	8	324
SAFETY	27	18	8	19	87	6	165
HEALTH HAZARDS	21	16	7	18	71	4	137
HUMAN FACTORS ENGINEERING	48	42	11	30	112	11	254
INTEGRATION	38	23	15	23	79	8	186
NUMBER OF TECHNOLOGIES IN DATABASE	116	85	52	60	174	13	500

NOTE: Each technology can impact more than one domain

groups have been conducted: Total HSI Survey (579 participants, 500 technologies, and 295 users), Human Factors Engineering-related technologies (301 HFE total participants, 254 HFE-related technologies, and 137 HFE users), and Training-related technologies (378 total participants, 324 training technologies, and 198 training users). This paper will (1) examine the representativeness of the survey sample, (2) present results of the total HSI survey, then (3) concentrate on the training technology findings, comparing them with the total HSI findings.

RESULTS

Adequacy of Survey Sample

Participants Outnumber Technologies. Liveware survey participation as of April 15, 1993 totaled 579 owners, developers, users, and distributors covering 500 technologies. Since more than one user could participate for each technology, the number of participants exceeds the number of technologies in the database by 79.

Number by Domain and Service/Other. Table 1 presents a listing of technologies by Service/other organization and by Liveware domain. The Training domain has had the greatest number (324) of programs listed. The HFE and Manpower domains are next with 248 and 254 programs, respectively. The lowest numbers of technologies by domain are in the Safety and Health Hazards domains, but they still have achieved 165 and 137 "hits" respectively. Participation by DoD Service shows the AF has 116 and the Army 85 technologies, while the Navy/ Marine Corps grouping has 52 technologies listed. It is possible that the Navy is either underrepresented, or that it has fewer HSI technologies than the AF and Army. When we contacted personnel from a Navy lab that specializes in MPT issues, they indicated there was no HSI-related research going on at that lab, or anywhere in the Navy to their knowledge. The showing from Industry is quite good, with 174 technologies listed. The least participation came from academia, with only 13 listed. Academia coverage could be sparse for one of these reasons: Academicians did not make the connection between their technologies and defense systems acquisition; they were not interested (and some stated so); or maybe they might not have many HSI tools. Thus, if this sample is deficient, it probably would be in Navy and university-developed technologies.

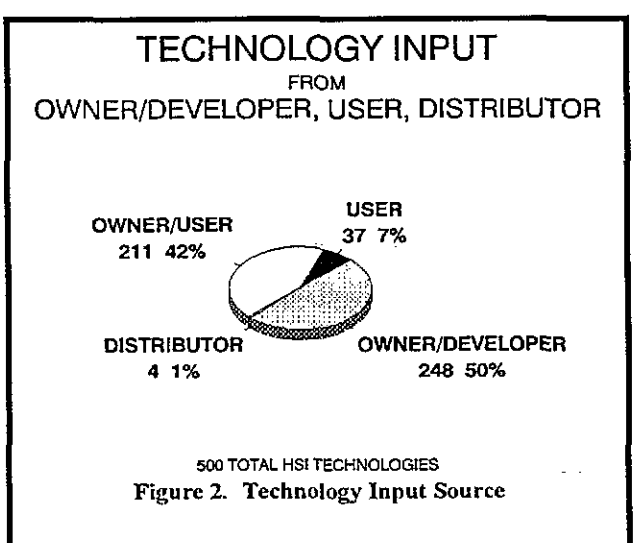

Figure 2. Technology Input Source

Technology Descriptions Come Primarily from Owner-Developer-Users. Figure 2 presents the technology input source. Over 50 percent of the input used to describe each technology came from owner/developers, 42 percent from owner/users, one percent from distributors, with less than seven percent or 37 technology inputs coming only from users (without developer/owner input). Thus, the source of the information contained in the Liveware survey appears to be authoritative, with more than 93 percent input from owner-developers, owner-users, and distributors.

Total HSI Survey Findings

The number of technologies identified as supporting each Liveware domain is displayed in Figure 3. Specific definitions of these domains are presented in last year's IITSEC Liveware paper (Crissey and Gentner, 1992, November), and are similar to those in DoDI 5000.2.

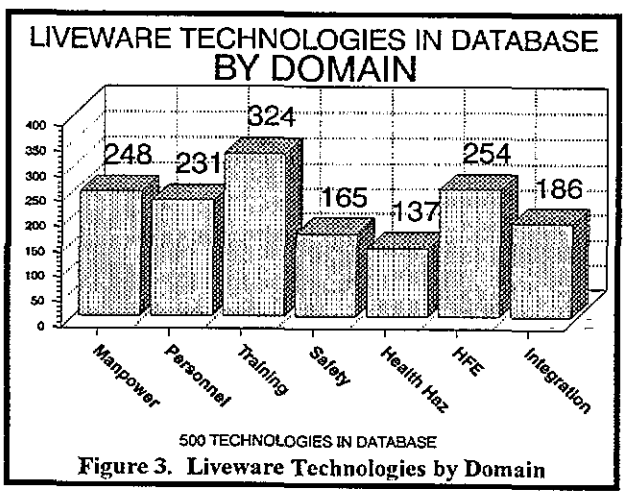

Figure 3. Liveware Technologies by Domain

Manpower. Of the 248 manpower-related technologies, 194 assisted the development of operator manpower, 181 maintenance manpower, 114 support manpower, 99 instructor manpower, with only 28 technologies supporting casualty estimates (see Table 2). The number of existing tools, databases, techniques that already exist appears quite adequate on the surface, However, by examining the technology listing, one can see that these technologies range from very specialized models good for only one class of weapon system, to ones that are so generic that to use them involves labor-intensive development of the databases and task network models to provide a manpower estimate. Some of these models simply project the number of authorizations needed to field weapon systems once the manpower per system or unit has been developed, and thus, ac-

TABLE 2
HSI Technologies by Domains & Subdomains

DOMAIN / Subdomain	NUMBER OF TECHNOLOGIES
MANPOWER	**248**
Operator	194
Maintainer	181
Support	114
Instructor Trainer	99
Casualty Estimates	28
PERSONNEL	**231**
Occupational Classification	106
Selection	89
Skills, Knowledge, Ability	178
High Driver Tasks	90
TRAINING	**324**
Methods/Media	132
Op Tempo	36
Effectiveness	85
Skill Decay	56
Training Resources	153
ISD	174
Special Training including: (Simulators, CBT, Embedded)	194
Instructional Systems Development	**174**
Analysis	19
Development	11
Design	1
Implementation	9
Evaluation	7
Combined Steps	127
SAFETY	**165**
Human Safety	154
Equipment Safety	100
Thermal (heat, cold, humidity)	60
Mechanical (shock, vibration)	106
Radiation & Directed Energy	61
Chemical Threats	64
Electrical	85
Atmospheric Pressure	51
HEALTH HAZARD PREVENTION	**137**
Psychological	48
Physical	125
Thermal	52
Mechanical	93
Radiation & Directed Energy	54
Chemical Threats	62
Electrical	85
Atmospheric Pressure	46
HUMAN FACTORS ENGINEERING	**254**
Mission, Function, Task Analysis	136
Task Performance & Workload	177
Human-Machine Interface	139
Information Transfer	88
Workspace & Anthropometry	86
Environment, Life Support	78
INTEGRATION	**186**
Vertical (only)	35
Horizontal (only)	53
Both	84
Unspecified	14

complish only one piece of the manpower estimation job.Other technologies counted here include those that only tangentally assist with development of manpower figures and primarily belong in another domain. (For each of the Liveware domains and subdomain descriptions, see Table 2 for the number of technologies in each category.)

Personnel. While the 231 technologies purport to assist with personnel decisions, many of these are, in fact, training tools that assist with skill, knowledge, and abilities (178) and few enable the projection of the skill requirements driven by a particular design solution. Other personnel technologies assist with occupational classification (106), personnel selection (89), and identification of high driver tasks (90).

Training. Of the 324 training-related technologies, most (194) were associated with special training systems (e.g., simulators, etc.), Instructional Systems Development (ISD) (174), training resources (153), and method/media (132). Relatively few (36) were associated with OP Tempo, skill decay (56), or training effectiveness (85). Table 2 also presents the number associated with each phase of ISD. Most technologies covered multiple ISD phases.

Safety. One hundred sixty-five safety-related tools supported both human (154) and equipment (100) safety. Mechanical (106) and electrical (85) were the areas most addressed, with atmospheric pressure addressed by 51.

Health Hazards Prevention. Of the 137 Health Hazard Prevention technologies, only 48 were psychological, while 125 were concerned with physical aspects. The most supported areas were mechanical and electrical hazard prevention, and least supported was atmospheric pressure.

Human Factors Engineering. HFE enjoyed the second largest participation. Of the 254 HFE technologies, 177 were associated with performance and workload and 136 with mission, function, and task analysis. The fewest HFE technologies were associated with life support (78).

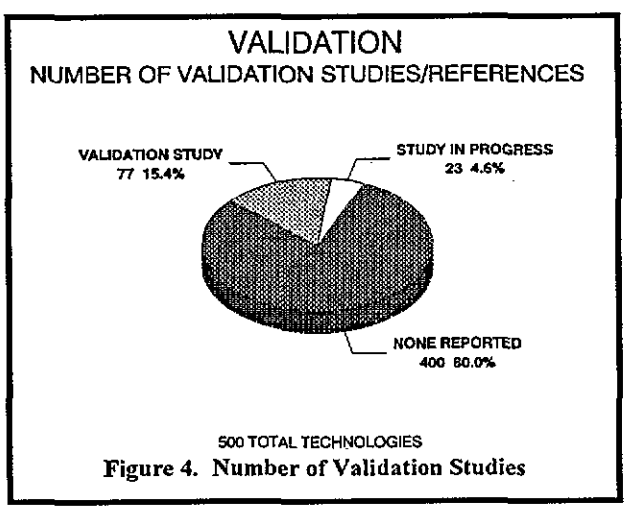

Figure 4. Number of Validation Studies

Integration. Among the most important functions of HSI tools is integration. Over 180 technologies claimed to achieve some form of integration (general category). Varying numbers addressed horizontal (35), vertical (53), or both types of integration (84). Notable is that fewer than 45 technologies integrated all domains.

Validation of Few. Of the 500 technologies, only 77 were validated and 23 had validation studies in progress for a total of 20 percent. This means (see Figure 4) that 80 percent did not have or report validation studies, a major deficiency in developing the credibility of HSI tools.

Training Findings & Comparisons to Total HSI

Technology Ownership. Most Liveware training and technologies were owned by the military (about 50% for both) and other government organizations (13-14 %), while 34-38 percent were commercial tools. Slightly more training technologies were proprietary than were other HSI tools (33 % versus 29%) leaving nearly 70 percent of technologies listed in the Liveware database as non-proprietary (see Figure 5).

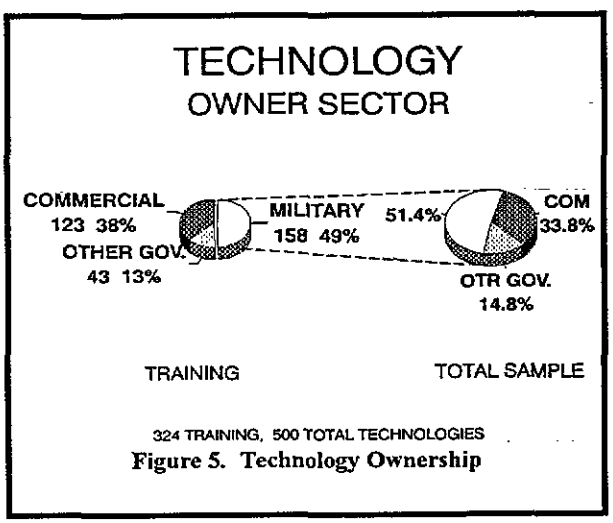

Figure 5. Technology Ownership

Technology Type. Seventy-one percent of training technologies were tools, compared to 62 percent of overall HSI tools. A lower percentage of training technologies was databases (17%) compared with HSI databases (25%). Techniques were about the same percentage (12%) in both areas (see Figure 6.)

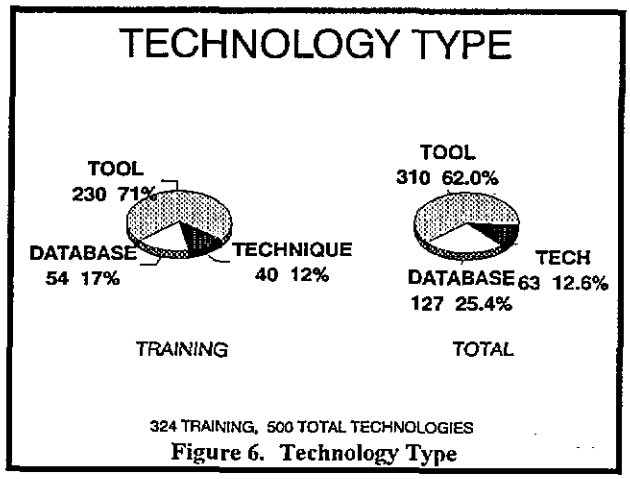

Figure 6. Technology Type

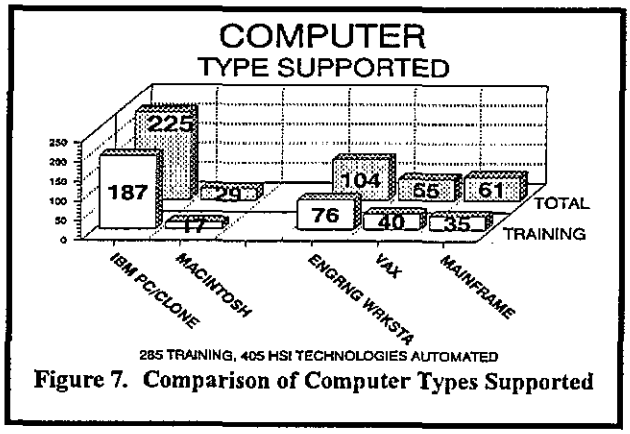

Figure 7. Comparison of Computer Types Supported

Computer Type Supported. Of 405 automated technologies, the most supported computer types were the IBM PC/clone (225) and engineering workstation (104). Only 29 technologies were identified as Macintosh-based, despite an intensive literature and expert network search for Mac-based tools. Training technologies followed suit. Most were PC-supported with about the same percentage of other computer support as the total sample, except that they had relatively fewer mainframes (see Figure 7).

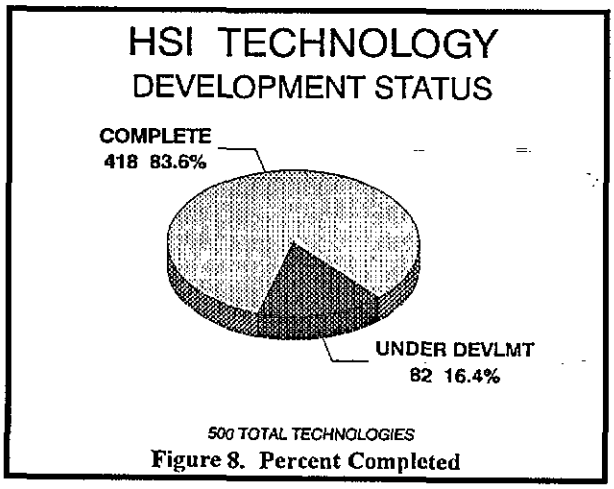

Figure 8. Percent Completed

Development Status. More than 80 percent of both training and HSI technologies listed in the Liveware database are complete and ready for use. This should quell the rumors that HSI technology is all "vaporware" (see figure 8).

System Areas Addressed. Both training and HSI tools addressed all system areas in high numbers and nearly equal proportions. Aircraft systems were the most addressed (see figure 9).

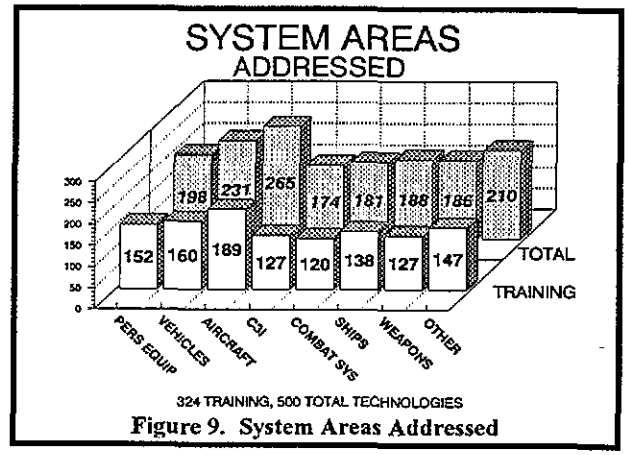

Figure 9. System Areas Addressed

System Levels Addressed. For both training and HSI technology, single systems are most addressed, with mixed systems and missions, and component level least addressed. (see Figure 10).

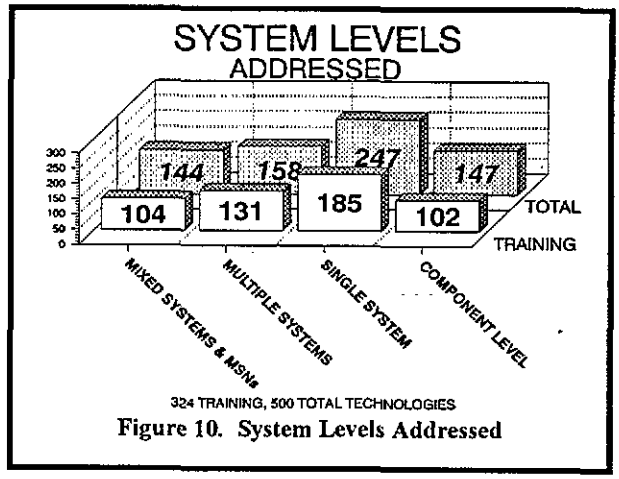

Figure 10. System Levels Addressed

Mission Areas Served. All major mission areas were served, with greatest emphasis on air and land (as one might expect, given the lower participation by the Navy. (see Figure 11).

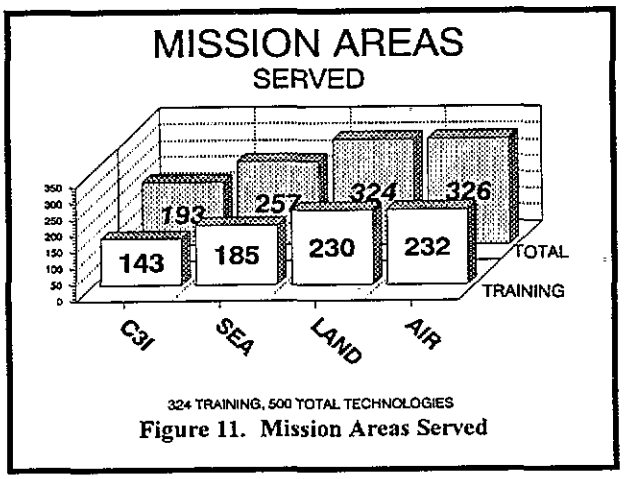

Figure 11. Mission Areas Served

Acquisition Phase Applicable. Both training and HSI technologies supported all phases of acquisition. The most frequently supported phase was design and development (to use US terminology, Engineering and Manufacturing Development). (see Figure 12).

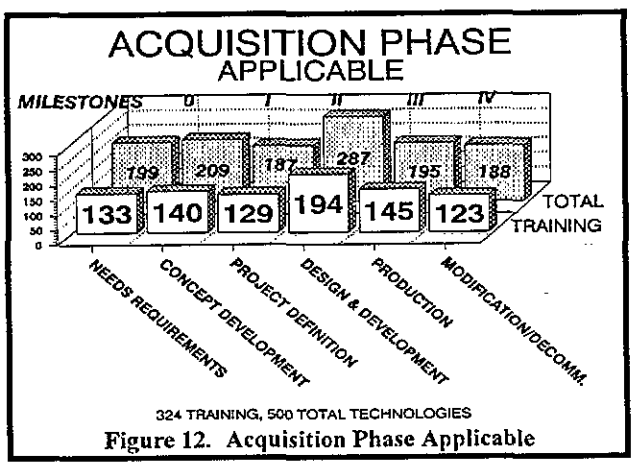

Figure 12. Acquisition Phase Applicable

About the User

User Work Discipline. Figure 13 presents user work discipline. The largest number of HSI and training technology users in the survey was engineers and designers (60 and 31, respectively). Scientists and researchers were second, with 55 and 27, respectively. In addition, for both HSI and training-specific tools, users reported using their technologies most frequently in either "daily" or "as required" categories.

DISCUSSION

Coverage of Liveware Tools

Although a considerable number of tools that cover all domains, subdomains, system areas and levels, missions, and acquisition phases, some gaps were found in the survey data.

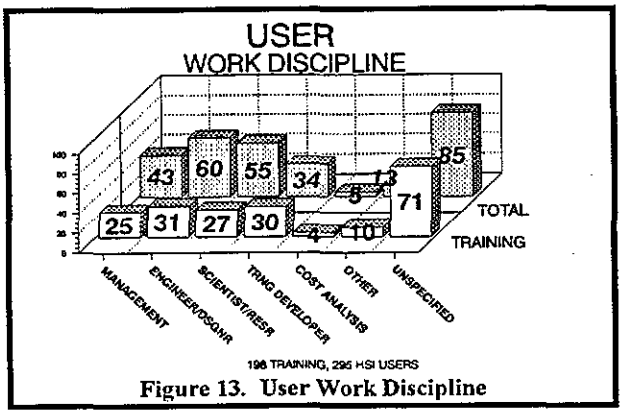

Figure 13. User Work Discipline

Integration. While 186 technologies indicate that they accomplish some form of integration, a maximum of 84 can specify the type (vertical or horizontal). Although one could argue that respondents didn't understand the question, it is more likely that the entire HSI area lacks a thorough network of integrated tools and databases. One clue to the need for integration and linkage could have been the linkage question; however, very few answered the questions (60) and their answers appeared as though the question was misunderstood. The literature is full of complaints about the number of HSI tools that have no database on which they can be run, or databases that are too expensive to build. It will take a study to show the input, process and output of these tools to determine the extent of integrated tools for HSI. The Liveware survey could be extended to accomplish this level of analysis, using the present data as a start.

Utility. The actual gaps occur in the utility of a technology and how cost-effective it is to use. The Liveware survey did not ask evaluative or cost-benefits questions about the technologies. Later versions, with special mailings to HSI technology users could help answer the question of cost-benefits, and disconnects in using this technology during acquisition.

Missing Details. All areas addressed in the survey appear to be covered except integration, the categories used in the Liveware survey were broad. For example, the Human Factors area had only six subcategories, while the CSERIAC taxonomy of human factors includes 15 major areas with thousands of subcategories. To determine whether there was adequate coverage, one would need to make a multidimensional matrix of the type of analysis by the type of system and level, Service, and by type of person (operator, maintainer, trainer, etc.) to see which

cells of the matrix were inadequately supported. Because the categories in the Liveware survey were broad, it is difficult to identify missing tools from the present dataset. If the Liveware survey were considered a first step toward identifying an optimal taxonomy of technologies for use in HSI, future versions could more carefully define each element of the taxonomy and could better characterize tools.

Missing Validity Studies. Perhaps the most significant finding of the study is the fact that 80 percent or more of the HSI technologies reported no existing or in-progress validity study. To develop and maintain credibility with program offices and the user of the technology, validity studies need to be planned and executed to demonstrate the worth of HSI technology. For those technologies that have published validity studies, the Liveware database can help find easy access to these documents, as well as differentiate those validated technologies from others.

Uses of Liveware Survey Database

Assessment Aid. Survey data, displayed and analyzed using the Liveware database, can help identify the technology available. To the extent that missing technologies can be compared with those existing in the Liveware database, deficits can be identified. This will provide a basis to marshal R&D resources. Information will be shared NATO-wide, thus making maximum use of existing technology wherever it exists. This could ultimately save HSI technology development costs.

Technology Choice Aid. The Liveware database does not rate or rank individual technologies, nor does it provide descriptive information in great detail. It does provide enough information to the analyst, program manager, or developer to narrow the list of appropriate technologies to those of value for a particular domain, task, or acquisition phase. By providing a broad range of information in an easily-queried summary format, the user can quickly narrow searches for appropriate tools. By providing POC information about tool developers and users, the pursuit of in-depth information about tools is easily accomplished.

Secondary Benefits. By making the database available and widely advertised to the acquisition community, it is likely that the Liveware program will have these positive benefits. It will (1) promote state-of-the-art information sharing; (2) help potential users of HSI technology easily find what they need; (3) encourage the use of HSI tools and databases; (4) help identify available technology and gaps; and (5) help set and substantiate the HSI research agenda.

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