HANDBOOK OF HUMAN SYSTEMS INTEGRATION

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Edited by

Harold R. Booher

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FOREWORD

If the emergence of human factors out of the US–UK engineering psychology experiences of WWII was its first milestone in the US Defense community; and if the second was the deliberate broadening by Gen. Max Thurman (as Army Deputy Chief of Staff for Personnel) of the U.S. Army human factors program to Manpower-Personnel Integration (MANPRINT); then the publication of this collected work on HSI analysis principles and methods is surely the third major milestone.

From the WWII origin, the tools of the embryonic human factors profession were those of the first practitioners, experimental psychologists. The experimental method with human subjects, system design alternatives as levels of the independent variables, dependent performance measures crafted to illuminate the design differences, an Analysis of Variance framework, and results judged by standards of statistical significance ensured professional rigor.

The reality of the accelerating technological change is pushing the classic HF experiment toward obsolescence as a method of design influence and analysis. The time and other fiscal investments required for deliberate experimentation cannot keep pace with the rate of critical concept and design decisions early in the development of complex, military systems. And the MANPRINT expansion of human factors to include manpower and personnel and other domains raises concept design issues not amenable to people-in-the-loop experimentation. The commonality of the human factors expansion evident in the UK Ministry of Defence Human Factors Integration/MANPRINT program of the mid-1990s and the emerging US Navy interest in Human Systems Integration suggests a change of some permanence for defense human factors.

The organizational context, theoretical bases, and, especially, the concept evaluation tools described in this text give a new reality to this wider view of human factors. As the military services depend on the broadened HF scope to support materiel acquisition decisions, the HF practice will increasingly depend on professionals who are more "engineers"—applying science—than researchers. As such it readily fits into the industrial and systems engineering educational fields. This text is an ideal cornerstone for the education of the new HF professionals.

General Thurman's MANPRINT brought into materiel acquisition decision making all of the issues that might be "human resources" in commercial institutions, e.g., number of operators, maintainers, and support personnel, the relative costs of their abilities and skills, their training, as well as human engineering. Increasingly, we see perennial labor shortages in key sectors of the commercial economy. The next major HF milestone, the fourth, will be adoption of many of these HSI analysis methods for commercial practice where numbers of workers, the costs of necessary aptitude and skills, and training costs will then drive re-design of worker interfaces.

Milestones falling at prominent junctures become landmarks. This comprehensive compilation of HSI principles and methods will soon be viewed as a landmark in the evolution of the human factors discipline.

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PREFACE

Government and industry must change their systems design and development orientation from "technology" driven to "people–technology" driven. Global competition, demographic trends, and high-risk technology demand it. These three forces work together as economic levers to increase demands for products and services while helping to assure their quality and affordability. Systems designed and developed for both military and commercial applications are greatly affected by the interaction of such economic factors, but in the past both business and engineering cultures have tended to view advances in technology as not only the main way to improve systems capability, but for solutions to systems quality and affordability problems as well. For example, greater automation may be seen as the solution to high personnel costs for operating major military systems, but demographics may show personnel and training costs will rise due to the limited availability of skilled people in the work force to operate and maintain highly automated systems. Global competition simply raises the need for all organizations world wide that produce new systems to find the competitive edge which will make their products successful in the market place. Quality programs like Deming's Total Quality Management have raised the standard in commercial manufacturing practices, but have yet to have a major effect in military systems or in such fields as education and medicine. In industries employing high-risk technology as in aerospace, petrochemical, nuclear, and biological environments, the hazards of not fully comprehending the people–technology interfaces all too often result in tragic and costly unintended consequences.

Human Systems Integration is very attractive as a new integrating discipline that can help move business and engineering cultures toward a people–technology orientation. To be effective, however, a cultural change is needed which must start with organizational leadership. At the heart of the need for a cultural change in business and engineering is the fact that human factors engineering as a people–technology interface discipline has, by itself, been largely ineffective at changing ingrained attitudes in government and in most industries.

This point is made clear by Charles Perrow ("The Organizational Context of Human Factors Engineering," *Administrative Science Quarterly*, 1983; Normal Accidents, Basic Books, 1984, 1999) and from my experience with the Army MANPRINT program (discussed in Chapter 1). There is little question of the value of human factors engineering to producing safe and effective products and systems, but even though major human factors programs were introduced in each branch of the Department of Defense and in the Department of Transportation in the 1960s, the nuclear industry was almost completely unaware of the discipline until the Three Mile Island accident. Even when the benefits of human factors are fully appreciated by top leadership, the influence on systems acquisition will tend to erode with changes in leadership. The Army MANPRINT program provided

$3.29 billion cost avoidance on a major aircraft program from efforts initiated in 1985, but by 1994, MANPRINT nearly disappeared from the Army as a result of downsizing and changes in DoD acquisition policy.

I mentioned some of Perrow's findings in the preface to *MANPRINT: An Approach to Systems Integration*, one of which is worth repeating here. In searches to assign blame for accidents with systems employing high-risk technologies, Perrow urges us to seek deeper than the design engineer and to "take into account the pervasive social casual factors inherent in organizations which make and operate our machines." Considering that Perrow came at the problem from an organizational analyst point of view, I stressed "he reminds us that managers and professionals respond to 'rewards and sanctions and prevailing belief systems of top management.' There is nothing to prevent top management, if it wishes, from informing designers about human factors principles. Furthermore, it is top management who 'can require that these principles be utilized.' They alone 'can structure the reward system so that it encourages designers to take these principles into account'."

These organizational "social causal factors" affecting HSI advancement have not gone unnoticed at the congressional level of government. Thanks to Congressman Ike Skelton, who was concerned about the regression of MANPRINT in the Army (see the appendix to the Afterword) HSI began to see a new burst of interest throughout the military and in other sectors at the end of the millennium. It was during this period that the *Handbook of Human Systems Integration* was conceived.

The cover image (created by Heather DuMont) of the *Handbook of Human Systems Integration* symbolizes the theme of the book, which is to provide principles and methods that can help integrate people, technology, and organizations with a common objective toward designing, developing, and operating systems effectively and efficiently. If organizations are to change significantly to take full advantage of the benefits that HSI can offer, I believe this is most likely to be accomplished as an inherent part of systems engineering and management. The publisher, John Wiley and Sons, agrees with us by having the *Handbook* appear in its Systems Engineering Series rather than its Human Factors Series. Human factors and ergonomics are necessary fields for the successful implementation of HSI, as reflected in the large number of contributors to the *Handbook* from those fields. And if one were to try to obtain advanced education in HSI, they would most likely need to acquire it from institutions that teach human factors and ergonomics (see Chapter 5). Human factors and ergonomics are necessary but not sufficient, because they do not fully cover other important human domains that need representation and because of their inability generally to significantly influence organizational decision makers.

The organizations for systems engineering and management are already well institutionalized in government, industry and academia and have the common goal with HSI to produce high performing, safe, and affordable systems. The major component currently missing from systems engineering and management is a detailed description of the principles and methods of human systems. The intent of the *Handbook* is to provide that component.

There are three types of stakeholders in any organization that designs, develops, tests, evaluates, operates, or maintains systems sufficiently complex to employ systems engineering and management processes, who should benefit by using the *Handbook.* These are 1) the HSI practitioners who work with systems using the principles and methods described; 2) systems engineers and managers along with related disciplines such as safety engineering and integrated logistics support who provide the framework for HSI roles and interfaces; and 3) organization decision makers, including program managers who must weight the recommendations of the first two types in making systems acquisition decisions.

The *Handbook* begins where *MANPRINT: An Approach to Systems Integration* (1990) left off. *MANPRINT*... was a basic introduction to an Army concept of integrating various human systems disciplines and technologies in the systems acquisition process. In doing so, it presented the uniqueness of MANPRINT as a systems integration model which focuses directly on the human element both as a critical component of the system and as the primary reason for designing, developing and deploying the system. The original MANPRINT concept has gradually been incorporated into other government system acquisition organizations, both military and commercial, either under the name Human Systems Integration or Human Factors Integration. Those familiar with *MANPRINT*... will be pleased to see the advances made since its publication.

The *Handbook* scope is much broader than *MANPRINT*... covering both public and commercial processes; especially as they interface with systems engineering processes and it provides much greater depth, particularly in presenting the state of the art for tools, techniques, and methodologies utilized by each of the HSI domains. Ninety some contributors, technical advisors and reviewers make up the technical representation from government, industry and academia. Chapters provided by authors from the United Kingdom and Canada represent their government and industry. Three services of the Department of Defense are well represented along with the Federal Aviation Administration and the National Academy of Sciences. Many of the chapters cover both military and non-military applications. The *Handbook* is divided into four parts, which I summarize in the introductory chapter.

I am grateful to the numerous contributors, advisors, and reviewers listed on the pages that follow who are responsible for the bulk of the work that went into this *Handbook.* Without their selfless and timely efforts, a book of this complexity could not have been produced. There are a few individuals, some on those lists and others who are not, who made special contributions to the conception, planning, and execution of the book. I am especially grateful for the services of Robin Keesee, who not only did a technical review of the entire manuscript, but also encouraged a large number of his staff at the Human Research and Engineering Directorate of the Army Research Laboratory to write and review many of the chapters. I also greatly appreciate the additional efforts of Ed Smootz, Glen Hewitt, Bill Rouse, and Andy Sage who formed my inner circle of advisors in handling the numerous issues that arise from a project of this complexity. Others who were particularly important to this project were Nancy Dolan, Arch Barrett, Frank Petho, Bill Natter, Larry Lehowicz, and Jack Wade who helped in a variety of special ways like finding contributors, providing motivational support, and stimulating interests in the *Handbook.*

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