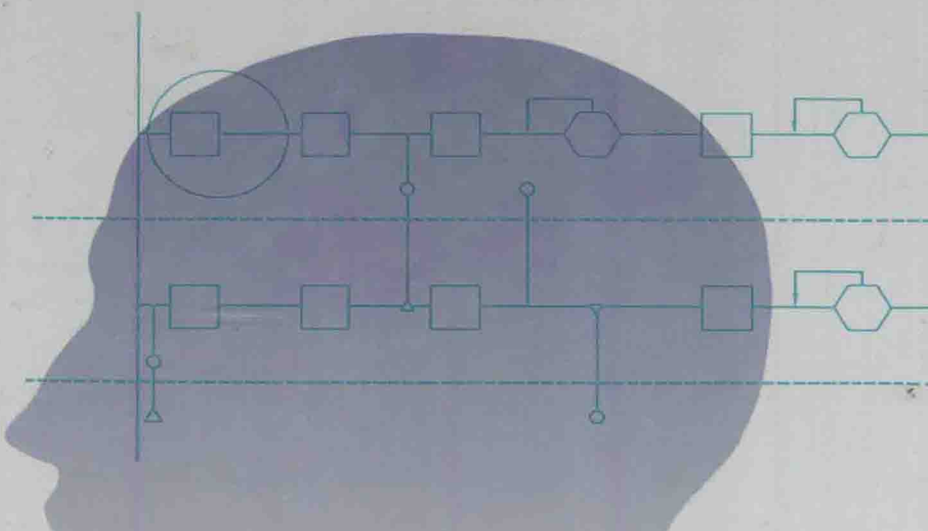
Human Performance Models for Computer-Aided Engineering



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Preface to the New Edition

Because the original publication of this National Research Council report was quickly exhausted, Academic Press has produced this edition in an attempt to make the material more widely available. The present edition follows the original exactly, in keeping with Research Council policy.

This book is concerned with issues of potential interest to a wider community than the study's immediate sponsors. At the broadest level, it touches on the relationship between scientific theories of human performance and practical engineering. This relationship between science and engineering is a general concern in all engineering disciplines and none more so than in human factors. An attempt has been made to inventory and assess the scientific models that bear on a class of human engineering problems. The result of the exercise is a clearer view of the state of at least a part of the scientific base for the human factors discipline. At a more focused level, the book considers the emergence of a new scientific engineering paradigm made possible by the embedding of computational theories in computational design aids. The result here is a clearer view of the possibilities at the present time for computational human factors.

Both of these concerns relate directly to the mission of the Committee on Human Factors of providing new perspectives on the theoretical and methodological bases of human factors and of identifying how to strengthen those bases. The Foreword and Preface of the original edition describe the committee and panel under whose auspices the study was conducted; the members are listed at the end of the book. We hope that the wider publication of this report will contribute to the purposes of the Committee and the human factors community at large.

Jerome I. Elkind, Stuart K. Card,
Julian Hochberg, and Beverly Messick Huey

Foreword

The Committee on Human Factors was established in October 1980 by the Commission on Behavioral and Social Sciences and Education of the National Research Council. The committee is sponsored by the Army Research Institute for the Behavioral and Social Sciences, the Office of Naval Research, the Air Force Office of Scientific Research, the National Aeronautics and Space Administration, the National Science Foundation, and the Army Advanced Systems Research Office. The principal objectives of the committee are to provide new perspectives on theoretical and methodological issues, to identify basic research needed to expand and strengthen the scientific basis of human factors, and to attract scientists both within and outside the field for interactive communication and performance of the necessary research. The goal of the committee is to provide a solid foundation of research as a base on which effective human factors practices can build.

Human factors issues arise in every domain in which humans interact with the products of a technological society. To perform its role effectively, the committee draws on experts from a range of scientific and engineering disciplines. Members of the committee include specialists in such fields as psychology, engineering, biomechanics, physiology, medicine, cognitive sciences, machine intelligence, computer sciences, sociology, education, and human factors engineering. Other disciplines are represented in the working groups, workshops, and symposia. Each of these contributes to the basic data, theory, and methods required to improve the scientific basis of human factors.

Preface

The Panel on Pilot Performance Models for Computer-Aided Engineering was formed by the National Research Council (NRC) in response to a request from the Army Advanced Systems Research Office. The National Aeronautics and Space Administration (NASA) Ames Research Center asked the NRC to conduct a study that would provide advice and guidance in a number of areas important for the Army-NASA Aircrew/Aircraft Integration (A^3I) program which is developing a prototype of a human factors computer-aided engineering (CAE) facility for the design of helicopter cockpits. This study was conducted under the auspices of the Committee on Human Factors within the National Research Council's Commission on Behavioral and Social Sciences and Education.

The objectives of the study were to review current models of human performance; to identify those that would be most useful for the CAE facility; to identify limitations of the models; to provide guidance for the use of these models in the CAE facility; and to recommend research on models and modeling that might overcome existing limitations. The panel focused its attention on the visual and associated cognitive functions required of pilots in the operation of advanced helicopters, which often fly under low-visibility and low-altitude conditions. By limiting the scope of the study in this way, the panel was able to address an important domain of human performance models (vision and associated cognition) in some depth and to gain an understanding of the prospects and problems of using such models in a CAE facility for helicopter design. In addition, the panel's study of these models gave it an appreciation of the difficulties that will be encountered in constructing model-based CAE facilities for the human factors design of complex systems in general and of the types of research that should be undertaken to relieve these problems.

The A^3I CAE facility can be thought of as an evolving set of tools supported by a flexible integration framework. The tools are to be based on models of human performance, and they should be developed to enable analysis and simulation of pilot behavior to aid cockpit design teams in answering specific design questions. The supporting framework should facilitate both the use of these tools by the design team and the integration of new and enhanced tools by users and model builders. The belief is that such a facility would improve the quality of helicopter design and shorten the design process by allowing a larger number of alternatives to be considered and thoroughly evaluated prior to the building of hardware. These benefits are yet to be demonstrated, but experience from engineering disciplines has clearly demonstrated the power of model-based CAE as a way to improve design methodology and designs.

Many people contributed to this study. Loren Hayworth and Jerry Murray of NASA Ames Research Center were very generous with their time as they helped the panel understand the problems often encountered by helicopter pilots in low-altitude, low-visibility flight. They worked with the panel and the authors of the chapters that form a major part of this report to identify the critical problems related to vision, and they provided information describing these problems and the manner in which they are addressed in current helicopter designs. These problems were used by the panel and the authors to identify vision and cognition models relevant to helicopter flight and to evaluate the applicability and limitations of these models to the CAE facility.

A major part of the work of this study was actually performed by a small group of experts from key areas of vision and cognition who wrote many of the chapters in this report. Not only did they provide expertise in areas where the panel itself was not expert, they also contributed their broad experience and knowledge to help the panel structure the study and develop its findings. The panel extends its thanks—for these important contributions, for the many hours donated to make this project successful, and for the insightful review papers—to Irving Biederman, Myron Braunstein, Lynn Cooper, Baruch Fischhoff, Walter Schneider, James Todd, David Woods, and Greg Zacharias.

The panel appreciates the cooperation, support and advice it received from many individuals at the NASA Ames Research Center, including Loren Hayworth, Jerry Murray, James Hartzell, James Larimer, and David Nagel. It is also grateful to Jim Vorhees, Rik Warren, and William Rouse for their presentations to the panel. It is especially appreciative of the contributions of the NRC staff who assisted in beginning this study, nurtured it throughout its execution, and assisted greatly in bringing it to completion. The study began under Stanley Deutsch, who was the second study director of the Committee on Human Factors, and was completed under the auspices of Harold Van Cott, the current study director. Both helped organize the study and participated in the work of the panel. Beverly Huey, Committee on Human Factors staff officer, not only organized and participated in the meetings of the panel, but willingly and effectively took on the task of assembling this report and contributed to its editing. Audrey Hinsman and Carole Foote provided secretarial assistance in preparing this document for review.

Finally, I want to personally acknowledge and thank the panel members for their extensive contributions, their many thoughtful position papers, and their gracious collaboration throughout this study. Special thanks to Julian Hochberg and Stuart Card who undertook the major tasks of organizing and editing the collection of reviews of vision and cognition models and who were enormously influential in determining the course of this study.

Jerome I. Elkind, Chair
Panel on Pilot Performance
Models in CAD/CAE Facilities

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PART III

Part I

1
Introduction

This report discusses a topic important to the field of computational human factors: models of human performance and their use in computer-based engineering facilities for the design of complex systems. It focuses on a particular human factors design problem—the design of cockpit systems for advanced helicopters—and on a particular aspect of human performance—vision and related cognitive functions. By focusing in this way, the authors were able to address the selected topics in some depth and develop findings and recommendations that they believe have application to many other aspects of human performance and to other design domains.

The report is addressed to human factors professionals and others interested in human performance models, human factors design methodology, and design tools. It describes some of the key vision-related problems of helicopter flight and cockpit design as a way of introducing the reader to the design domain on which the report is focused. It discusses issues in the integration of models into a computer-based human factors design facility and the use of such a facility in the design process, and it reviews existing models of vision and cognition with special attention to their use in a computer-based design facility. It concludes with a set of findings about the adequacy of existing models for a computational human factors facility and a related set of recommendations for research that is needed to provide a stronger foundation of models upon which to base such a facility.

A model is a representation or description of all or part of an object or process. There are many different types of models and they are developed for a variety of reasons. In a design context, models can be considered to be a "thing" of which we ask questions about some aspect of a design. Models of human performance have long been used in the human factors design of complex systems to answer questions about the ability of the human to function satisfactorily in the system and the ability of the system to achieve the objectives for which it is being designed. Early models used for human factors design were of necessity verbal, statistical, or mathematical descriptions or theories of some limited aspect of human performance. Sometimes they were narrow, sometimes broad, sometimes shallow, sometimes deep, but rarely broad and deep. It was not possible to cope with the complexity of comprehensive models of human performance.

Modern computer technology is changing this situation and is making it possible to develop models of much greater complexity and comprehensiveness that can represent human performance with greater depth and breadth than was possible with earlier modeling technologies. The impact of computer technology on modeling is sufficiently profound to warrant a distinctive name, computational models, for models that use this technology. Computational models are simply those models that can be, or have been, implemented on a computer. Important properties of computational models are (1) they can be constructed of component models assembled from different sources; (2) they can be integrated into a computer-based facility that provides users with the ability to manipulate these models and apply them to design in a very flexible manner; (3) the models can be made to run using either real or simulated data from the physical environment and thereby provide a simulation of the part of pilot performance being modeled; and (4) since designs can also be represented in a computational form, they can coreside with the computational models and tested against them in a common facility. Computer technology has also fostered new forms of computational models of human performance in the fields of artificial intelligence and cognitive science.

Computational models take many forms, their taxonomy has many dimensions, and it can be structured in many ways depending upon the perspective. For a computer-aided engineering facility, it is of interest to know whether one has a simulation model or an analytic model. Simulation models typically use a computer program to imitate human performance. They are of particular interest for the design of aircraft systems because they allow connection to the physical environment in which the human is to function, have explicit inputs derived from the environment and produce outputs that approximate those produced by the human. These can be fed back to the environment so that the closed-loop behavior of the pilot-vehicle system can be simulated and examined.