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PREVIOUS EXPERIENCE IN MANNED SPACE FLIGHT: A SURVEY OF HUMAN FACTORS LESSONS LEARNED

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INTRODUCTION

Previous experience in manned space flight programs can be used to compile a data base of human factors lessons learned for the purpose of developing aids in the future design of inhabited spacecraft. The objectives of this study are to gather information available from relevant sources, to develop a taxonomy of human factors data, and to produce a data base that can be used in the future for those people involved in the design of manned spacecraft operations. A study is currently underway at the Johnson Space Center with the objective of compiling, classifying, and summarizing relevant human factors data bearing on the lessons learned from previous manned space flights. The research reported here defines sources of data, methods for collection, and proposes a classification for human factors data that may be a model for other human factors disciplines.

PERSPECTIVE

Three major manned space programs have been conducted since the mid-1960s: the Apollo, Skylab, and Space Shuttle programs. Each program has contributed significant new data to the field of human factors and to gaining a greater understanding of how humans operate, function, behave, and adapt to the environment encountered in space. Because of various circumstances, including time constraints, human factors data collected during the past two decades of manned space flight have been transferred in a way such that the data remain scattered in various locations and do not reside in a single central location that is accessible to interested individuals, including those that might be involved in future advanced spacecraft design. Difficulties encountered in the systematic collection of past data are compounded because new data and technology appear frequently and must also be stored for easy use by appropriate individuals.

METHODS

The technique for data collection involves identifying information sources including technical reports, films, or video tapes, minutes of meetings, and records of in flight and postflight debriefings. A taxonomy is imposed on these data and the taxonomy may be a model for other human factors research activities. Data are transferred to an appropriate data archival/retrieval system that serves as a resource from which individuals involved in spacecraft design can draw relevant human factors data. Data sources include documents, published and unpublished technical reports, individuals, transcripts of meetings, audio and visual recording media, and computer-stored information, and may be supplemented with information acquired in interviews or from questionnaires. Systematic collection of data from these identified sources involves establishing a way of coding, tabulating, and cataloging the data before incorporating it into a data management application for use. Since human factors data are so diverse, a scheme for classifying data helps impose a meaningful structure on the data and renders the data more easily incorporated into an appropriate data base.

Commercially available software packages have been evaluated as candidate applications for the development of the computer-based retrieval system. These packages generally fall into two categories: data base management systems and hypertext-based text/graphics handling tools. Data base management systems correspond to the traditional linear and hierarchical method of storing data. This form of data archival and retrieval system does not take advantage of complex interconnected Links between textual/graphical data and, as a result, data browsing can be cumbersome and slow. Hypertext (and hypermedia) systems allow for complex organization of data (text and graphics) by allowing machine-supported references from one data unit to another by taking advantage of the ability of a computer to perform interactive branching and dynamic display (Conklin, 1987). In this fashion, hypertext systems allow a user to jump from one data unit to another through links. Data browsing becomes simple and efficient.

PROPOSED CLASSIFICATION SCHEME

The need for a classification system of human factors data has been recognized for years (Melton and Briggs, 1960), yet attempts to produce such a classification have been few. The main reason appears to be the belief that such a task would require enormous amounts of time and effort because of the quantity of literature and data available. The classification proposed here relates to human-machine interaction in the context of manned space flight but some aspects should be applicable to other endeavors.

The classification proposed here builds upon a previous one used to systematically categorize Skylab man-machine data. The groupings are operationally based. The following 19 categories are suggested to classify human factors lessons learned in previous manned spaceflight programs: Architecture, Communications, Crew Activities, Environment, EVA-suited activities, Food Management, Garments, Housekeeping, Locomotion, Logistics management (including failure management and the logistics and procedures involved in coping with system anomalies), Maintenance (scheduled and unscheduled), Manual dexterity, Mobility/restraint, Off-duty activity, Personal hygiene, Personal equipment, Physiological data, Tool inventory, and Waste management. Within each of these categories are other, less broad and more specific categories. The number of categories may appear large, yet previous studies have had to use many categories. Meister and Mills (1971), for example, created 18 categories in their attempt to determine requirements for and the elements of a human performance reliability data base. The number of categories must be large, given the large number of activities encompassed by human-machine interaction. Other workers (Chiles, 1967; Christensen and Mills, 1967) have indicated the difficulties involved in establishing a taxonomy of human factors.

DISCUSSION

Previous studies attempting to classify human factors data (Fleishman, Kinkade, and Chambers, 1968; Chambers, 1969; and Meister and Mills, 1971) have relied less on operational categories and more on behavioral and performance criteria. Meister and Mills (1971), for example, developed a taxonomy based on functional behavior and established categories such as auditory perception, tactile perception, and motor behaviors. This taxonomy reflected the goal of the study: to develop a data base of human behavior (behavioral data acquired during actual experimentation) for predicting human-machine performance. The taxonomy presented here reflects a different purpose: to develop a data base of human operator experience (operational experience data acquired as the result of various activities in space) for the purpose of providing a source of data to be used in the future design of manned-spacecraft operations.

Evaluations of presently available text/graphics software applications suggest that certain criteria must be considered when a data archival and retrieval system such as this one is developed. One fundamental criterion is the degree to which the system successfully retrieves relevant articles. The precision ratio (Lancaster, 1968) is one way of measuring this success. The ratio, developed in the context of information theory, is defined as R/L x 100 where R is the number of relevant documents retrieved in a search and L is the total number of documents retrieved in a search. A retrieval application should have a high precision (at least 80% or above) to prove useful. To achieve such reliability, design of the application software and the data itself are critical. Flexibility, nearly unlimited growth potential, and the ability to effectively handle increasingly complex links that are established within the network are some attributes a viable application should possess.

Results presented here have significance in the establishment and design of a Space Station, lunar base, and Martian colony. The methods developed in the collection and systematic archival of human factors data during the course of this study may also bear directly on questions of ways in which to systematically compile and characterize human factors data in other areas of research including design of aircraft, automobiles, manned sea-faring vessels, and other similar activities. Research in human factors engineering has escalated in recent years and tremendous amounts of data are being generated (see, for example, Huchingson, 1981 or Woodson, 1981). Appropriate archival and retrieval systems will need to be developed to store this data.

Results of this work could have at least three possible applications: (1) other workers with large data sets might be able to use the collection methods developed in this study, (2) the taxonomy of human factors data developed will be applicable to other human factors research and might be used in instances where large volumes of unsystematically collected data exist, and (3) future research in the definition and design of human factors requirements may be able to benefit from the methods, taxonomy, and data organization techniques developed in this study.

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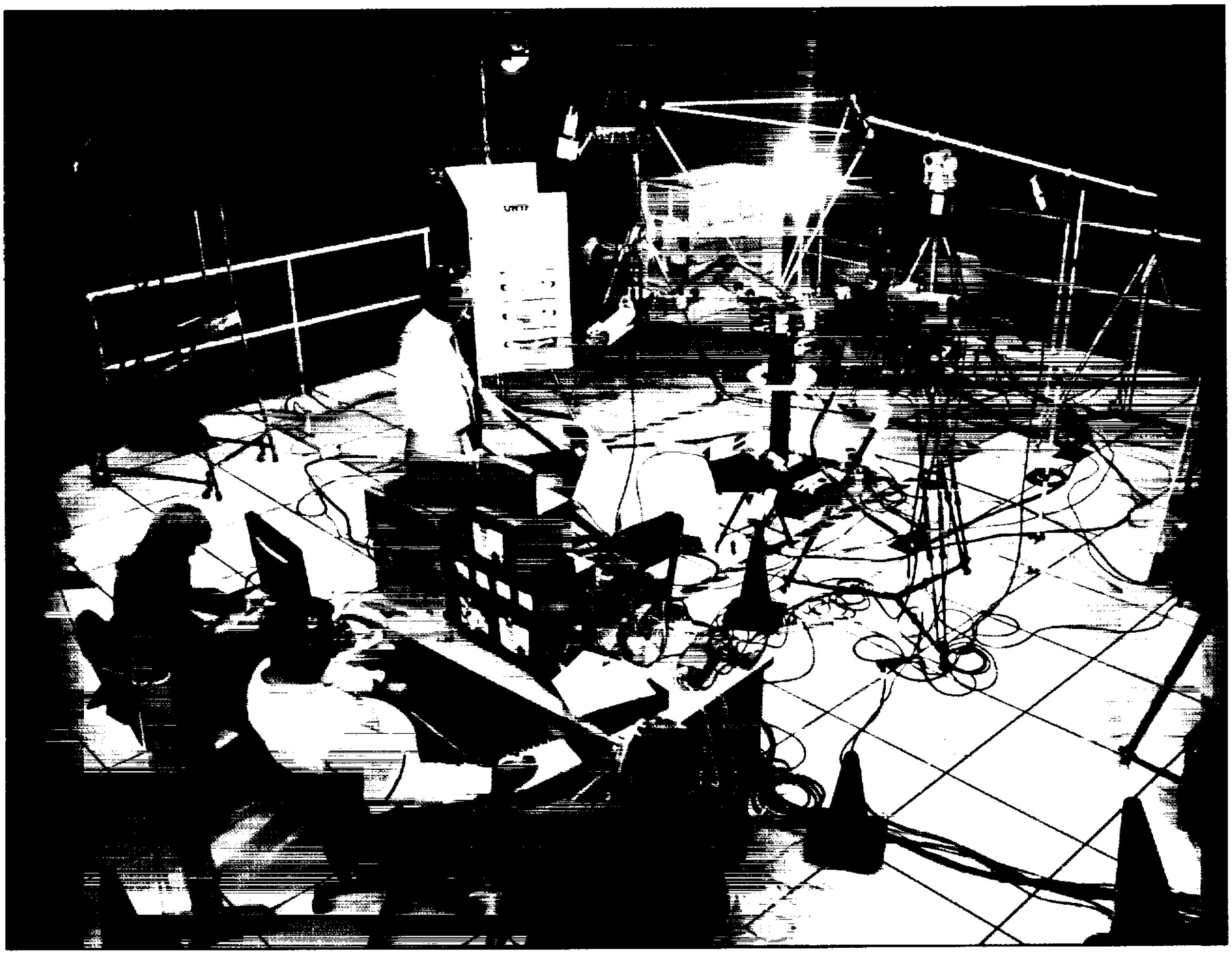
Remote Operator Interaction



In the Remote Operator Interaction Lab, researchers design and conduct experiments and evaluations dealing with human informational needs during the use of telerobots and other remotely operated systems. Operators use various hand controllers with television and direct visual feedback to perform remote manipulation tasks.