NASA
Space Human
Factors Program
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TABLE OF CONTENTS

Page

INTRODUCTION

The Space Human Factors Program is part of the Life Sciences Division of NASA's Office of Space Science and Applications. Space life sciences research was initiated in 1960 with the goal of enabling human survival in space. Now, in the late 20th century, the program is evolving to ensure human health and productivity on space missions: on the space shuttle in the 1990's, then on Space Station Freedom, and ultimately on the Moon and Mars.

The goal of the Space Human Factors Program is to develop the knowledge base required to understand the basic mechanisms underlying behavioral adaptation to spaceflight and the capabilities and limitations of the crewmember in the unique environments that will be encountered during future missions. This requires an in-depth understanding of psychological and behavioral adaptation to space and the ways in which adaptive behaviors influence or affect performance. The program also develops and validates system design requirements, procedures, and protocols that ensure the psychological well-being, safety, and enhanced productivity of space crewmembers.

The Space Human Factors Program reflects a multifaceted approach to understanding humans in the space environment, utilizing clinical, personality, social, behavioral, experimental, environmental, systems engineering, and psychophysiological methodologies. NASA Space Human Factors in-house research is conducted at Johnson Space Center in Houston, TX and Ames Research Center in Moffett Field, CA. In addition, approximately half of the research funds allocated to the Space Human Factors Program is granted to extramural researchers at universities located in the United States. All intramural and extramural research is peer reviewed to ensure scientific and technical merit. Research supported by the Program involves the collection of qualitative and quantitative data and the development and testing of behavioral and performance models through ground-based studies in laboratories, analogs including the Antarctic and undersea habitat, aviation, mock-ups, and simulations, and during parabolic flights on the KC-135 aircraft, the space shuttle, and Space Station Freedom when available.

In response to NASA's programmatic needs, research is currently being conducted in all space human factors areas to determine the critical limits of performance and to develop design requirements and procedures for the human in the space system. Investigations are being conducted in the following areas: crew selection and training, mission work analysis, sleep and circadian rhythms, workload, small group dynamics, crew communication and coordination, crew composition, automation and computer interaction, EVA glove development, work station design, habitability, noise, stowage and deployment, performance capabilities, perception and cognition, virtual environments, and anthropometrics and biomechanics. The individual research tasks are described in this document.

Research and development activities sponsored by the NASA Space Human Factors Program have resulted in spinoff applications that improve the quality of life for humans on Earth. For example, PLAID software is being used for a variety of modeling and engineering tasks such as equipment design, architectural layout, and traffic patterns; "virtual environment" computer graphics software is now being used commercially and allows the human operator to explore and interact with artificial environments; investigations into the learning and performance of rhesus monkeys have resulted in technologies that have directly benefitted studies of acquired brain damage and recovery of function in young children; and research being conducted on circadian rhythms and the resetting of the human biological clock has direct application to individuals experiencing problems related to work schedules, to situations requiring continuous operations, and to the alleviation of jet-lag difficulties.

NASA's missions in space will be milestones in the history of humankind, accelerating science and technology and greatly expanding our knowledge of our home planet, the solar system, and the universe. Research and development sponsored by the Space Human Factors Program will not only ensure the health, safety, and productivity of humans in space, but will lead to a better life for humans on Earth.

Janis H. Stoklosa, Ph.D.
Manager, Space Human Factors Program

Assessment of Human Factors in Space

Susan Adam
Man-Systems Division
NASA Johnson Space Center
Houston, TX 77058

Human factors evaluations of spacecraft environmental conditions are being conducted on several shuttle missions under the direction of Ms. Adam of Johnson Space Center. Similar to human factors studies completed on Skylab, the techniques used are non-intrusive to existing operations.

Human factors assessments conducted during the STS-40/Spacelab Life Sciences-1 mission included several investigations whose general goal was to understand human productivity in spaceflight. Specific objectives included evaluation of the effects of noise and vibration on crewmember performance, communication, and mission objectives; and the evaluation of equipment stowage and deployment techniques, crewmember restraint techniques, and management of loose cables. Other objectives included evaluations of body posture in microgravity, lighting, and use of electronic procedures. Development of a model to predict the amount of time it takes to complete task components in space was also a goal.
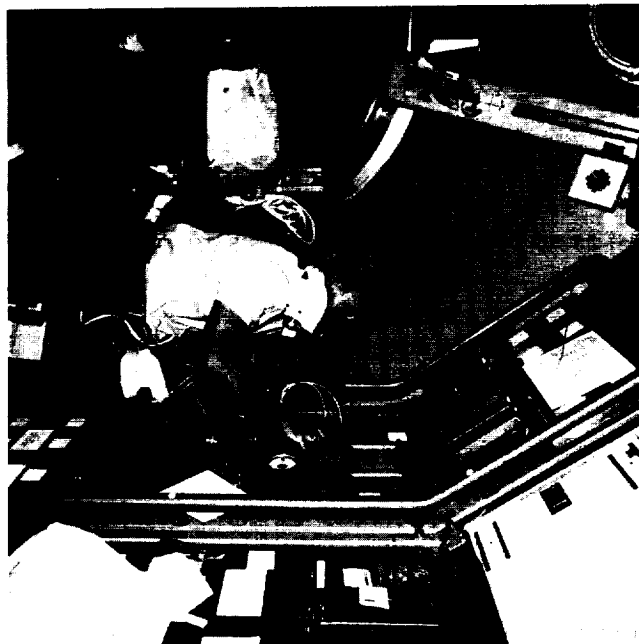
Studies of equipment, crewmember restraint techniques, and management of loose cables were conducted during Spacelab Life Sciences-1.

Similar evaluations are planned for several future shuttle missions. The results of these studies will help guide the design of equipment, organization of procedures, and development of training protocols and timelines for future space missions.
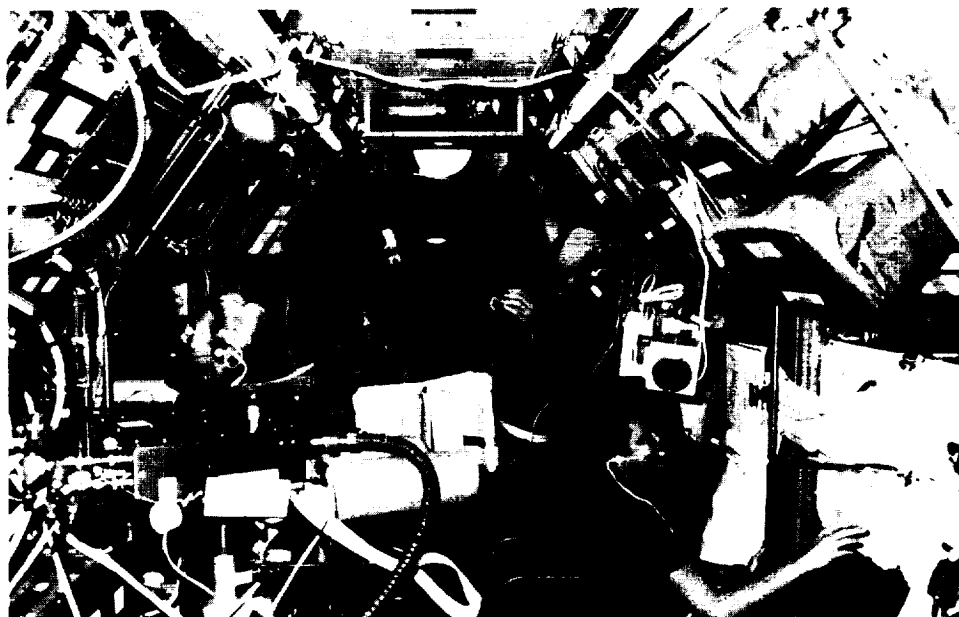
Crewmembers onboard Spacelab Life Sciences-1 performed a variety of activities.

MENTAL WORKLOAD AND PERFORMANCE IN SPACE

Harold L. Alexander
Department of Aeronautics and Astronautics
Massachusetts Institute of Technology
Cambridge, MA 02139

Just as on Earth, a comfortable and stress-free work environment is important for optimal performance and group cohesion among crewmembers in space. In addition, understanding the factors that may limit astronaut performance and productivity is necessary, both to plan for and to ameliorate these effects when designing and planning on-orbit operations. The Mental Workload and Performance Experiment (MWPE), conducted in January 1992 during the International Microgravity Laboratory-1 (IML-1) mission, examined the design of workstations and measured changes in astronaut cognitive and motor performance in orbit.

The anthropometric (workstation design) portion of MWPE used a reconfigurable workstation surface that was able to be freely positioned and oriented by each astronaut. The workstation was used during three classes of activities: MWPE computer interaction sessions, daily shift planning, and planting of seeds for the plant-growth experiment conducted during IML-1. This permitted observation of the workstation configurations used for computer interaction tasks, paperwork, and fine manual work, all of which will be very important for future on-orbit operations.

The MWPE computer interaction tasks combined memorization and recall with fine-positioning control of computer input devices, in order to detect any changes in the astronauts' short term memory and motor dexterity inflight. This represents the first opportunity to quantitatively assess the fundamental effects of microgravity and microgravity adaptation on crewmember cognitive and motor performance.

Results of this experiment will be used by Space Station Freedom designers and planners in creating effective, comfortable work environments for the crew and in anticipating and planning for astronaut productivity on orbit. It also provides for further fundamental understanding of human adaptation to and dependence on gravitational forces.

STABILITY AND PRECISION OF HUMAN PERFORMANCE IN SPACE

Joseph V. Brady and Thomas H. Kelly
Behavioral Biology Research Center
Johns Hopkins University School of Medicine
*Baltimore, MD 21224*

A study of human performance is scheduled to be conducted in 1996 during the Spacelab Life Sciences-3 (SLS-3) mission under the direction of Drs. Brady and Kelly of Johns Hopkins University. Objectives of the study include determination of the stability and accuracy of the daily performance of crewmembers over the duration of the mission, determination of the stability and accuracy of performance across scheduled work periods, determination of the subjective response of crewmembers across both a work period and a mission, identification of the effects of chronic exposure to a reduced gravitational environment on performance and subjective response within a work period and across the mission, and determination of the relationship between subjective responses of crewmembers and their performance before, during, and after spaceflight.

Fifty-minute sessions will occur at the beginning and end of scheduled work periods on days regularly spaced throughout the SLS-3 mission, as well as during flight simulations occurring before and after the mission. During the sessions, each participating crewmember will be performing tasks designed to monitor multiple dimensions of learning and psychomotor performance. Crewmembers, working individually, will choose among four tasks displayed on a computerized menu. When chosen, the crewmember will complete the chosen task for one minute, after which the menu will again be displayed, and another choice will be available. During the session, crewmembers will also be required to learn a new, randomly determined, ten-position sequence of completing the tasks. This procedure is designed to monitor complex learning ability and also to ensure that all four tasks will be completed regularly throughout each session. In addition, at the beginning and end of each session, crewmembers will complete computerized subjective response questionnaires, consisting of the Profile of Mood States and several Visual-Analog scales. Scores on performance tasks will be compared with those on the questionnaires to determine whether change in subjective response is predictive of change in learning or psychomotor performance.

Digit-Symbol Substitution Task
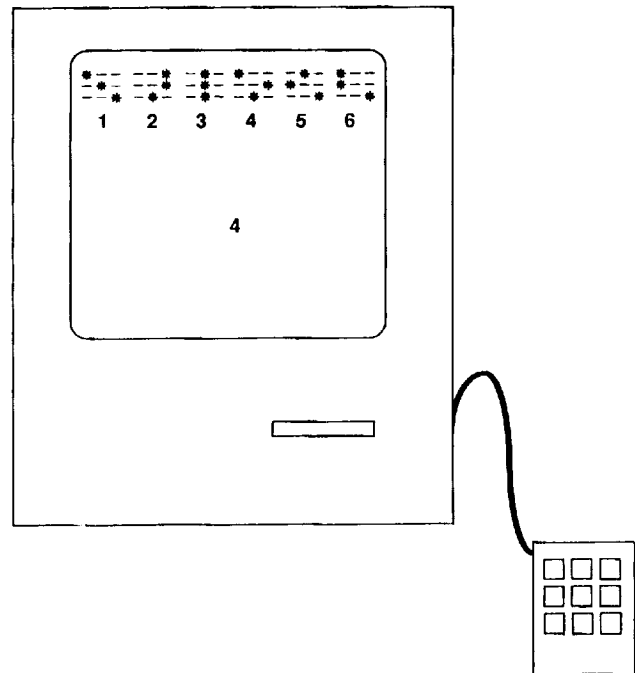
Task Menu
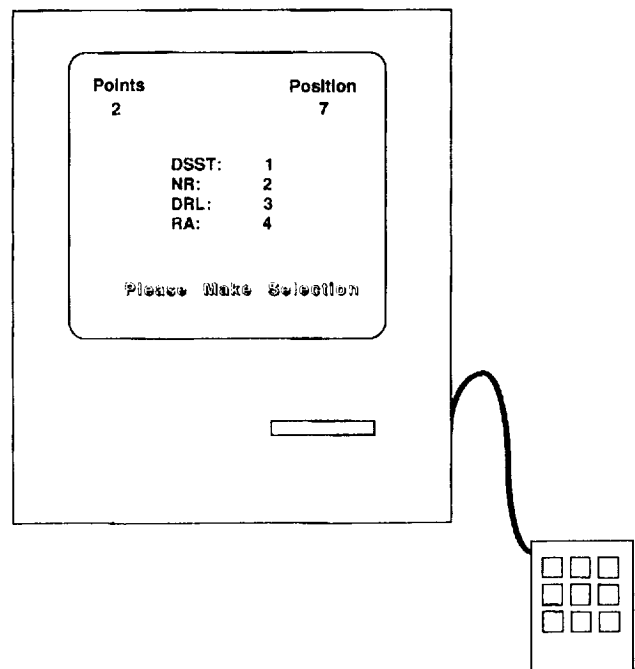
LIGHT EFFECTS ON CIRCADIAN RHYTHMS

Charles A. Czeisler
Center for Circadian and Sleep
  Disorders Medicine
Brigham and Women's Hospital
Harvard Medical School
Boston, MA 02115

Sleep duration, sleep quality, and adequately designed work-rest cycles are especially significant in the stressful and unique environment of space where normal work-rest cycles are often shifted for mission purposes. Dr. Czeisler of Harvard Medical School is investigating the use of bright light in resetting human circadian rhythms. This research involves exposing subjects to 10,000 lux illumination during 8-hour night work shifts and comparing physiological parameters, such as body temperature and plasma cortisol levels, and cognitive performance of test subjects with those of individuals exposed to ordinary room light during the same work shift. Results have shown that bright light treatment adequately shifts these parameters and adapts these individuals to their new work-rest cycle.

On some shuttle missions, crewmembers are required to work around-the-clock in two shifts. Without any alteration in their natural circadian rhythms, crewmembers can experience negative consequences for their well-being and performance, including sleep disturbances, daytime sleepiness, reduced attention, negative mood, slower reaction times, gastrointestinal disorders, and cognitive dullness. An operational protocol developed by Dr. Czeisler has been used successfully to produce a 12-hour circadian phase shift in crewmembers for missions requiring two shifts. Subjective reports from astronauts have indicated that they are able to sleep soundly during the day and remain alert at night. Physiological measurements taken from the astronauts have indicated that shifts in temperature and hormone levels were also successful.

This research utilizes a regimen that may be the first effective technology that can reliably stabilize the human circadian pacemaker and induce complete physiological adaptation to a night duty schedule. Use of this technology could also have a profound effect on the health, productivity, and safety of astronauts during extended duration missions.

Assessment and Workload Measurement in Complex Systems

Emanuel Donchin and Arthur Kramer
Department of Psychology
University of Illinois
Urbana, IL 61820

Drs. Donchin and Kramer of the University of Illinois are examining a number of workload measurement techniques for use in spaceflight. The focus of their research is a complex task, the "space fortress" task, that was developed in the context of a DARPA (Defense Advanced Research Projects Agency) program designed to examine the nature of skill acquisition. A detailed task analysis is available, and how different approaches to practice affect task performance have been documented in detail. Thus, this task provides a useful framework for examining the relationship between workload and performance, along many different dimensions of the task and during different stages of training. In previous work, it was shown that the robustness of the task to interference from concurrent tasks depends on the strategy used in training the subjects.

In the present project, the task has been modified to allow simultaneous recording of physiological and performance measures, on line and in real time, and workload measures will be evaluated using various indices derived from event related brain potential recorded during task performance. The goal of the study is to identify the psychophysiological and performance measures of workload that serve as best predictors of workload associated with different stages of task performance. Results can then be used to determine the proper allocation of responsibility among operators and automated components of the system, assess the robustness of skill acquisition as a function of workload during training, and predict performance of crewmembers during high-pressure episodes of long-duration missions.

SUPER AUDITORY LOCALIZATION FOR IMPROVED HUMAN-MACHINE INTERFACES

Nathaniel I. Durlach
Electrical Engineering and Computer Science
 Department
Massachusetts Institute of Technology
Cambridge, MA 02139

The normal human auditory system suffers from a number of deficiencies in its ability to localize sound sources. However, when localization is considered in the context of human-machine interfaces, such as those employed in teleoperator or virtual environment systems, there is an opportunity to recode source location in a manner that improves localization. In other words, it is possible to transform the acoustical cues available to the listener for determining source location (i.e., alter the manner in which source location is represented in the binaural acoustic stimulus) in such a way that the listener achieves *super localization*.

Research being performed by Mr. Durlach at MIT involves the study of adaptation to a wide range of transformations (rotations, scalings, filterings, asymmetries, exponentiations) using a specially designed virtual-environment system for presenting the transformed localization cues, a variety of training procedures to achieve adaptation, and localization tests to measure adaptation that include detection and localization in multiple-source environments and dynamic tests of localization constancy, as well as discrimination and identification of single sources. To the extent that reliable and reversible adaptation can be demonstrated, the results of this research will provide important new options for improved interface design.

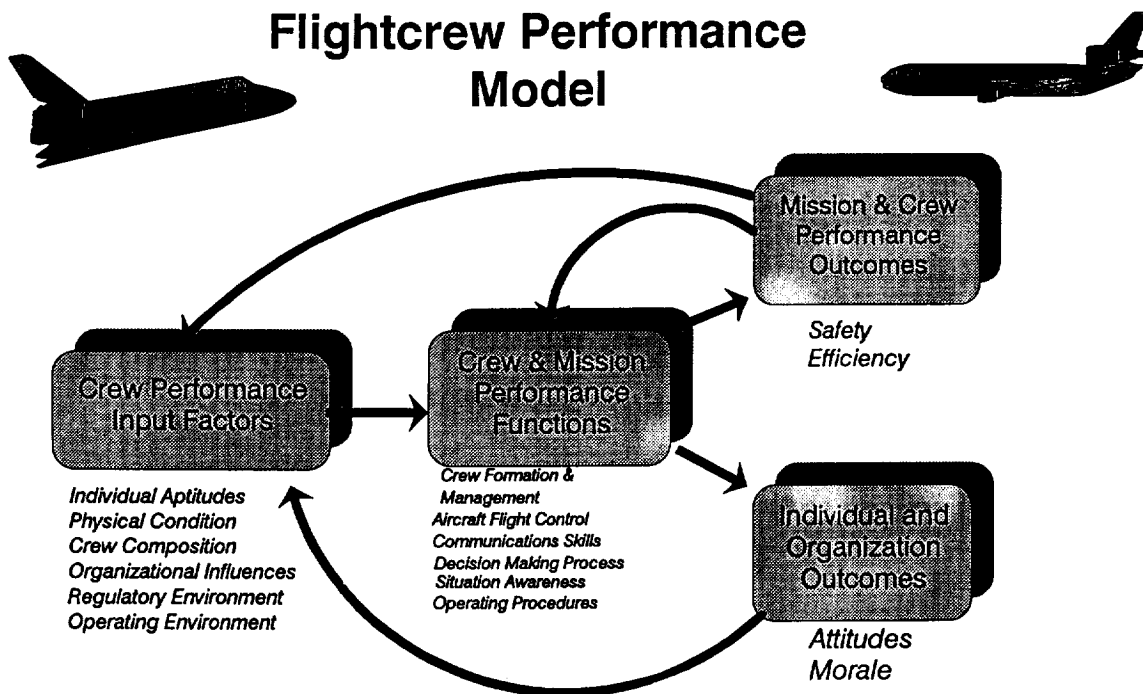# DETERMINANTS OF INDIVIDUAL AND GROUP PERFORMANCE

Robert L. Helmreich
Department of Psychology
University of Texas
Austin, TX 78712

Research being performed by Dr. Helmreich is aimed at studying individual differences and organizational factors that influence group dynamics, cohesion, and performance. Studies focus on personality, demographic variables, and individual differences in task-related skills which characterize members of a group. Studies of social inputs include such variables as group size and group structure, as defined by the distribution of authority and tasks (i.e., social roles). The goal of this research task is to develop optimal selection and training protocols for spaceflight crews.

Specifically, the impact of crew coordination training programs in aviation teams has been studied and validated, showing that group performance can be enhanced through these means. The use of special training programs designed to ensure standardized instructor and evaluator assessments of crew performance has also been extended to astronaut candidates. This research has resulted in the development of rating instruments to evaluate crew coordination and individual and team performance. In addition, decomposition and coding of behavior across time has been developed to capture central elements in interpersonal communication and group processes that can be related to performance and mission success. The final outcome of these research activities will be the isolation of a group of personality constructs that relate to performance in various space missions.

Flightcrew Performance Model

Crew Performance Input Factors:
Individual Aptitudes
Physical Condition
Crew Composition
Organizational Influences
Regulatory Environment
Operating Environment

Crew & Mission Performance Functions:
Crew Formation & Management
Aircraft Flight Control
Communications Skills
Decision Making Process
Situation Awareness
Operating Procedures

Mission & Crew Performance Outcomes:
Safety
Efficiency

Individual and Organization Outcomes:
Attitudes
Morale

From Helmreich and Foushee (in press)

BEHAVIOR PERFORMANCE MODELING FOR EXTENDED SPACE MISSIONS
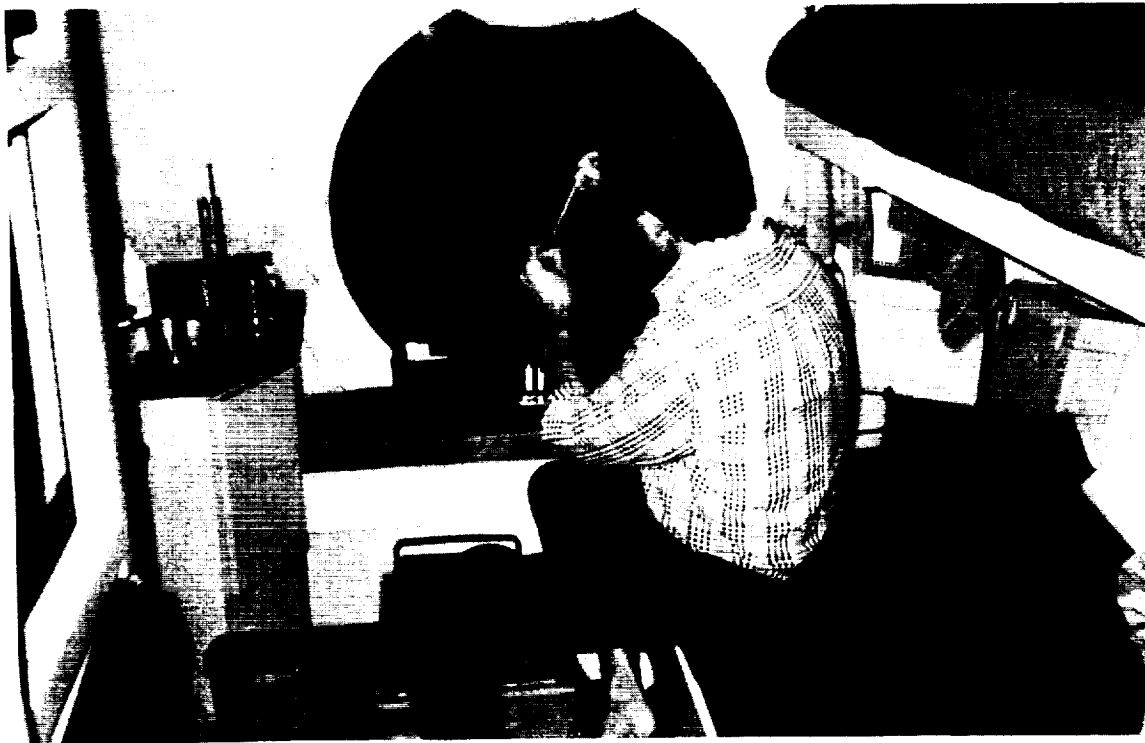
Albert W. Holland
Behavior and Performance Laboratory
NASA Johnson Space Center
Houston, TX 77058

The ability to study the performance of small, semi-autonomous teams operating in remote environments is important for successful long-duration spaceflights. The objectives of this research task are to develop an artificial intelligence-based behavioral performance model and then to verify that model in veteran and current teams in closely-matched analog field settings. The establishment of tools to enable ongoing transfer of emerging behavioral information to operational personnel responsible for mission planning and crew selection and training is also a goal.

Progress to date has included the representation of key team and scenario parameters in an artificial intelligence format. Collection of data in several space analog environments is underway, and future efforts will continue the collection of structured interview and critical incident data. This task represents a viable means of gathering and integrating incongruent data from diverse sources for use in planning long-duration missions.

Data sample being collected in the sleeping area of the La Chalupa-30 test bed, an undersea environment.

Undersea divers are used to study the performance of small, semi-autonomous teams in remote environments.

MULTICULTURAL CREW FACTORS

Albert W. Holland
*Behavior and Performance Laboratory*
NASA Johnson Space Center
Houston, TX 77058

Understanding intercultural crew factors is necessary for future long-duration missions, which will likely involve international cooperation. The goals of this research task are to develop a knowledge base of cross-cultural factors and to identify crew compatibility characteristics that could impact crew cohesion and performance. Research is underway to identify factors that may be unique to the confined, semiautonomous work/habitation environment of Space Station Freedom. Crew training approaches that optimize beneficial cultural differences and minimize problematic ones are also under investigation, and procedures and protocols to improve performance are being developed. Efforts are underway to identify the inflight and ground work tasks that can be optimized through cross-cultural training.

In conjunction with these objectives, data were collected from U.S. astronauts who have flown with international crewmembers, and critical incidents involving multicultural issues were analyzed. Several incidents were reported and the importance of preflight cross-cultural training was emphasized. Future data collection, including data from international astronauts who have flown with Americans, is being planned.
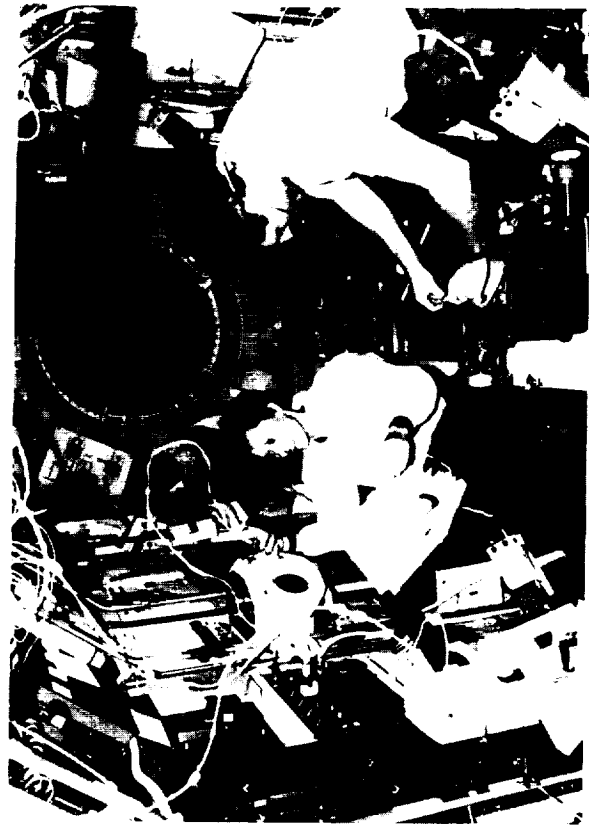
International crewmembers flew aboard the recent International Microgravity Laboratory-1 mission.

# GROUP PRODUCTIVITY ANALYSIS FOR MANNED SPACEFLIGHT

Barbara G. Kanki
NASA Ames Research Center
Moffett Field, CA 94035

Future space missions will involve relatively small groups of individuals living and working for extended periods of time in harsh, stressful environments, which, in many ways, have no counterpart on Earth. Dr. Kanki of Ames Research Center is conducting crew factors research to provide guidance with respect to the design and management of the social, organizational, and task factors that are expected to affect crew productivity and well-being under such conditions. Research is being conducted on how crew factors, such as leader personality and team structure, and task factors, such as level of automation and procedural differences, affect crew coordination, communication, and overall team performance.

The approach of this research is to examine real task-performing teams in operational environments that are analogous in critical ways to space operations (e.g., extended orbiter, space station, and planetary exploration missions). This includes such harsh or stressful environments as those encountered by aviation crews, undersea saturation divers, and mountaineering teams, as well as larger teams that work in complex, high-risk environments such as air and spacecraft maintenance and launch control operations.

This research will contribute to the development of training protocols that can aid crews in reducing errors and in coordinating activities for achieving higher group productivity. It also contributes to the development of selection criteria for composing and structuring teams for optimal performance. Finally, in analyzing the process by which crews execute and manage their tasks, recommendations on designing more human-centered tasks and procedures can be made.
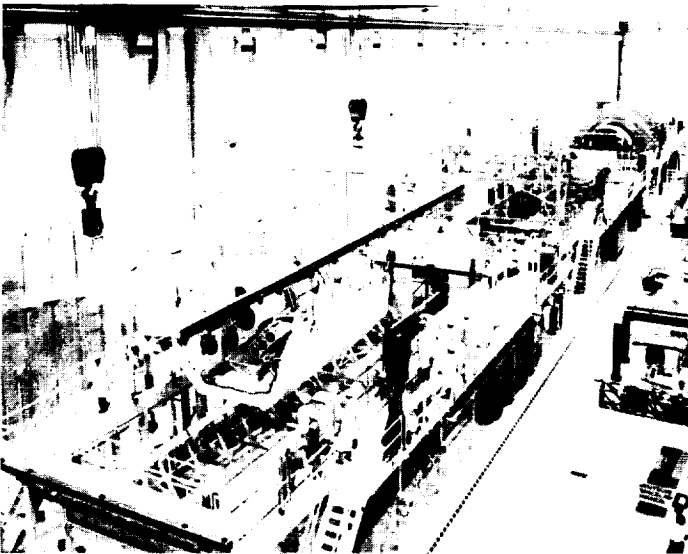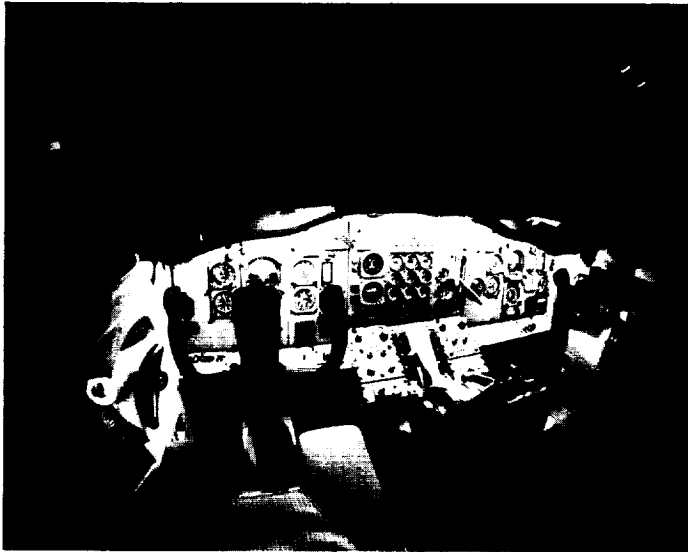
Team performance is studied in a variety of space analog environments including (upper left) aviation, undersea environments (upper right), payload integration teams (lower left), and exploration teams (lower right).

HUMAN PERFORMANCE

Glenn K. Klute
Man-Systems Division
NASA Johnson Space Center
Houston, TX 77058

Human performance in space includes the completion of complex tasks, and knowledge of crewmember capabilities and limitations during such operations is critical. Mr. Klute and the Anthropometry and Biomechanics Laboratory (ABL) staff at Johnson Space Center conduct research to develop a database of anthropometry, range of motion, and strength data from astronauts. In addition, the ABL conducts microgravity tool and restraint system investigations to evaluate astronaut ability to perform extravehicular activity (EVA) and other tasks, and conducts biomechanic studies on exercise countermeasures to aid in determining device effectiveness. These studies provide quantitative measures of performance and equipment.

The ABL conducts studies to quantify astronaut impact on the spacecraft microgravity environment from push off loads and exercising, as well as biomechanical investigations to aid in determining the effectiveness of exercise countermeasures such as the treadmill, rower, and cycle. It documents crewmember operational reach capability in previous and current shuttle flight suits under varying gravitational loads. Results from these investigations will be used to evaluate the effect of increased gravitational loads on reach capability, the impact of the current suit on crew mobility, and the use of ground-based simulators to conduct realistic in-flight emergency training procedures. The ABL also conducts research to quantify crewmember operational reach and force transmission capabilities under various environmental conditions, including comparing the force transmission capability of high pressure space suit prototypes with that of the current shuttle EVA suit. Results from this study will be used to design the next generation suit for exploration missions.

ADVANCED EVA GLOVE DEVELOPMENT

Joseph Kosmo
Crew and Thermal Systems Division
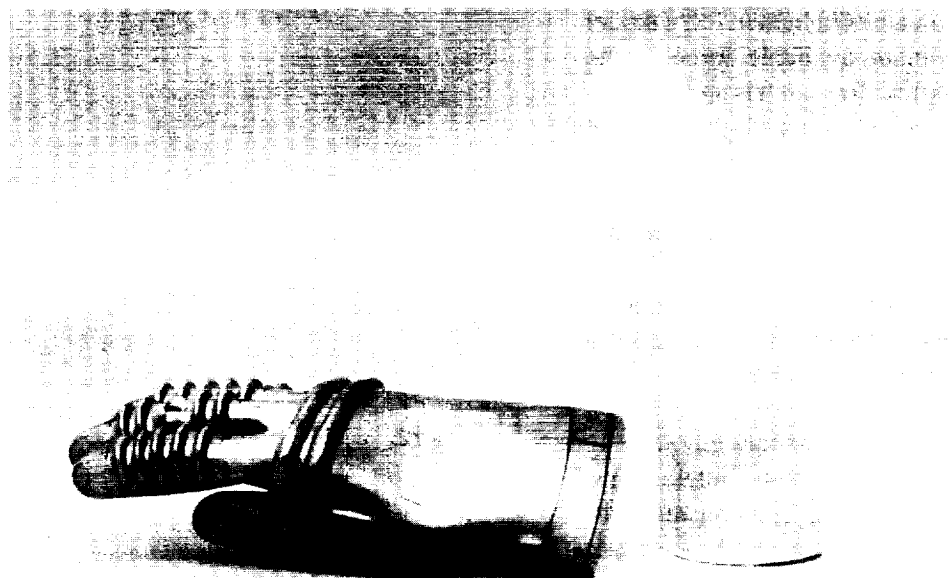*NASA Johnson Space Center*
Houston, TX 77058

Performance of crews during extravehicular activity (EVA) is critical to mission success, and the gloves worn by the astronauts play a key role in this success. Traditionally, however, the gloves can be uncomfortable, lack dexterity, and result in crewmembers performing extended EVAs with a limited ability to perform fine motor functions. In an effort to improve the fabrication process and overall fit of the EVA gloves, Mr. Kosmo of Johnson Space Center is researching the application of advanced laser scanning techniques and stereolithography to develop EVA gloves with enhanced dexterity. The laser scanning technique provides an improved, highly accurate measurement database from which a computer graphic model of the hand can be made. From this process 3-dimensional computer-aided design models are created to define the shape of the glove bladder dipform mold. The mold can then be fabricated using the stereolithography techniques and used to form the innermost layer of the glove. The database model can also be used to generate the flat patterns of the fabric outer restraint layer of the glove.

This approach permits more accurate crewmember hand measurements, resulting in a more comfortable, better fitting glove. This technique also leads to a more accurate placement of mobility joint systems for the hand, decreased fabrication time, reduced overall glove production costs, and improved glove configuration repeatability. All of this will enable crewmembers to perform tasks in space more efficiently and comfortably.
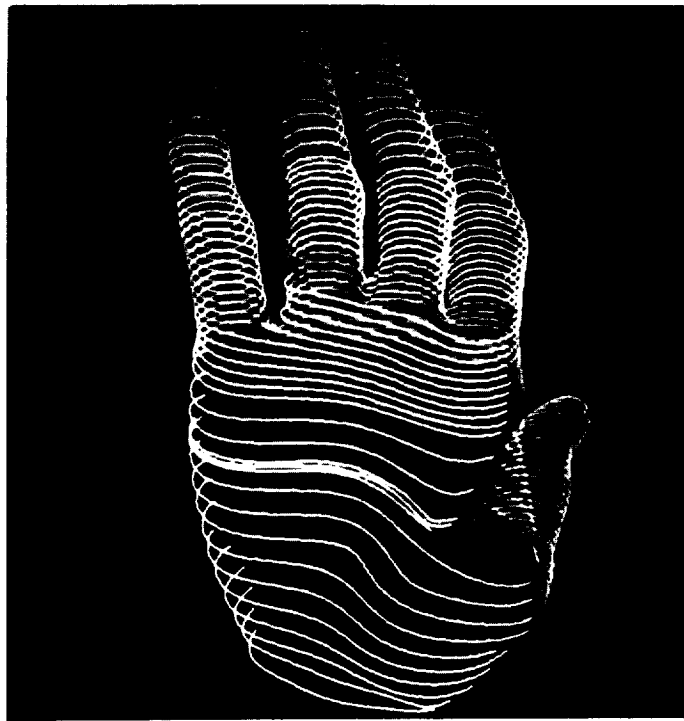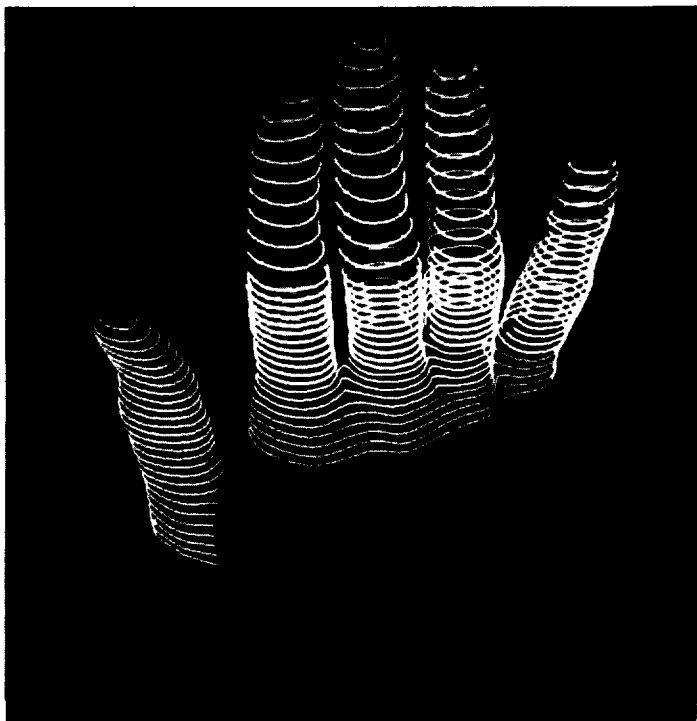
Laser scanned hand image

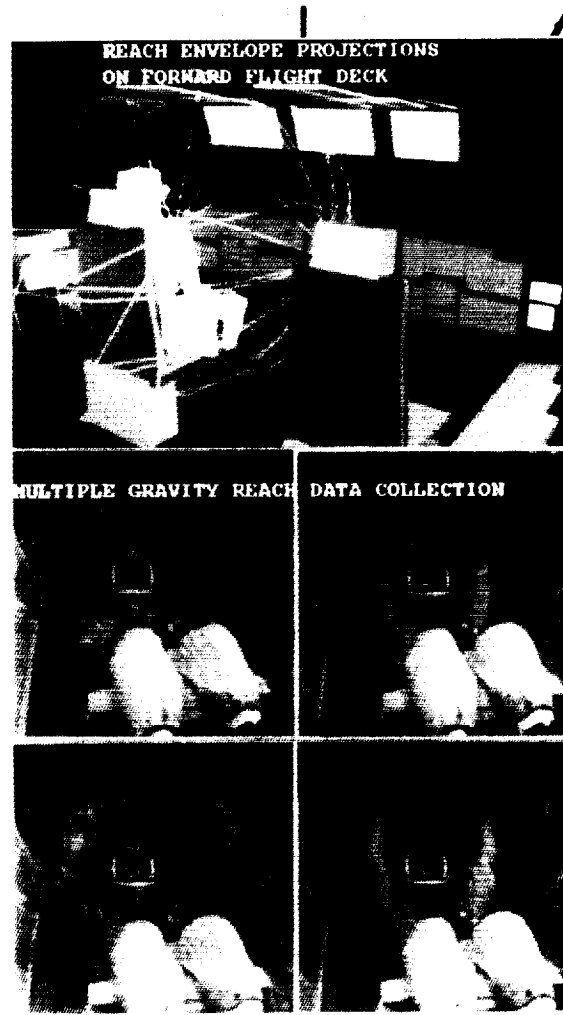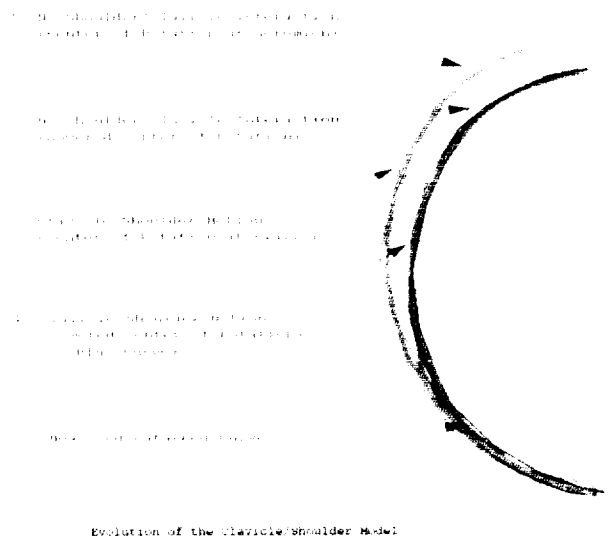Glove bladder dipmold from laser scanned database

HUMAN MODELING

James Maida
Graphics Analysis Facility, Man-Systems
 Division
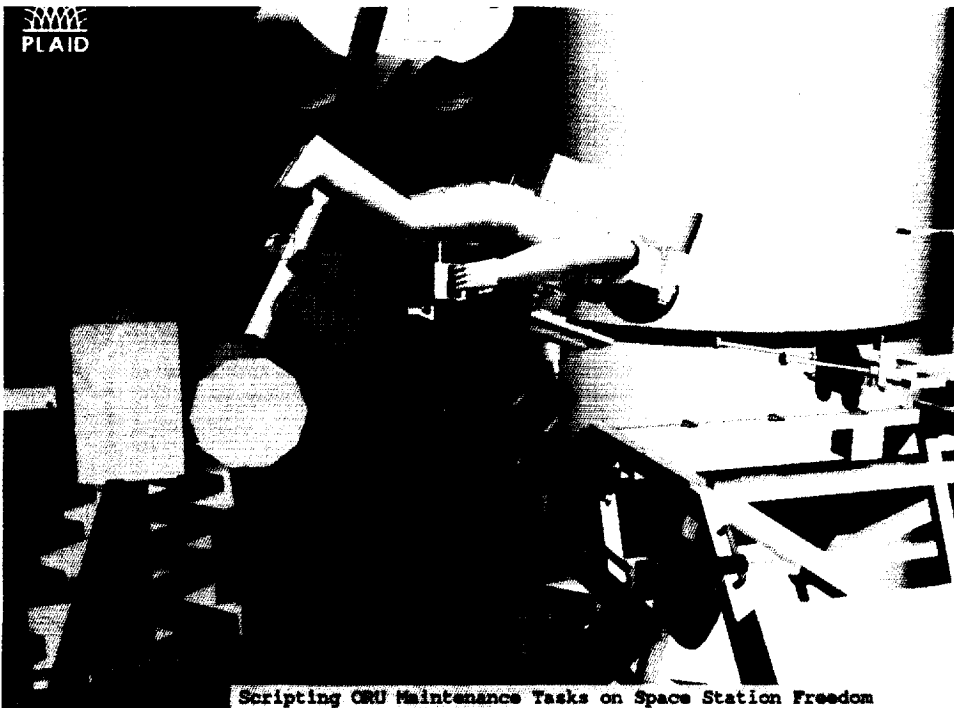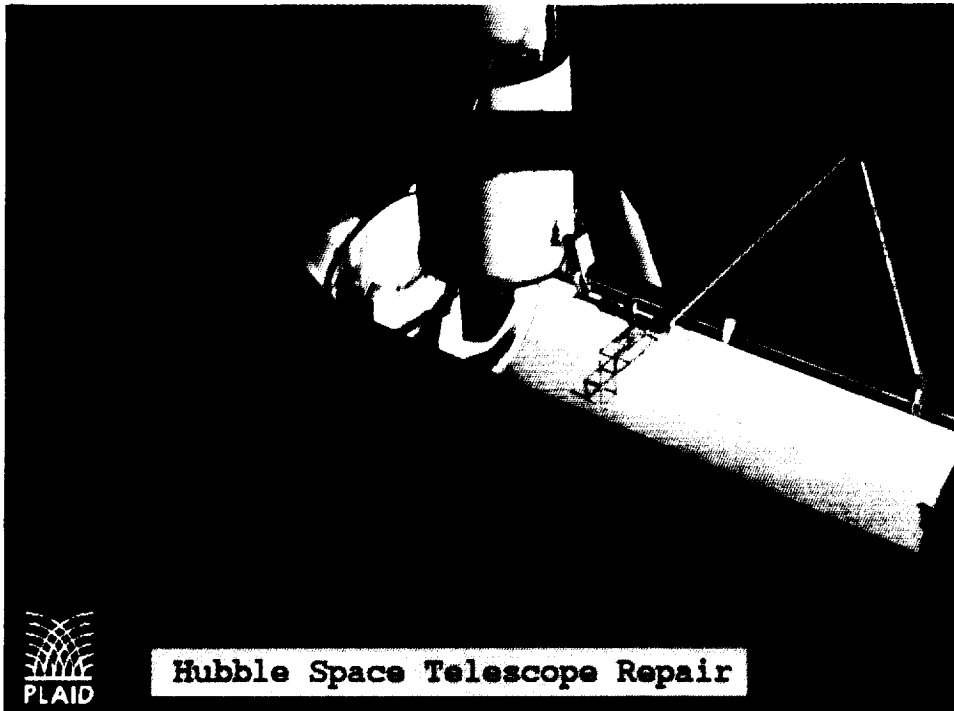*NASA Johnson Space Center*
Houston, TX 77058

Advances in hardware and software technology make it possible to model humans and their environment, thus permitting the simulation, visualization, and analysis of information in new ways to help avoid problems during actual space missions. The Graphics Analysis Facility (GRAF) at Johnson Space Center is developing three-dimensional human models incorporating measured and computed data for strength, reach, vision, body mass, and center of mass. The goal of this research is to develop a validated computer model of a human and the environment characterized by features that allow for improved simulation and analysis.

Recent accomplishments include a validated computer model of the shoulder/clavicle joint with 1 cm accuracy in predicting human reach envelopes, and a validated human force model to predict maximum available force in the human arm complex. Research is underway to develop and validate a computer lighting model for human vision, as well as to study the feasibility of using neural networks and fuzzy logic systems as trainers and drivers for controlling human motion. Future plans include the development of a three-dimensional sound model to predict and adjust sound levels for humans in a computer modeled environment.

Models will be used to conduct engineering evaluations of human-machine interactions, spacecraft configurations, viewing analysis, task performance scenarios, and anthropometric design criteria. Modeling will benefit designers, engineers, and operation planners assessing engineering and human factors concerns for spacecraft design and operations.

Evolution of the Clavicle/Shoulder Model

REACH ENVELOPE PROJECTIONS ON FORWARD FLIGHT DECK

MULTIPLE GRAVITY REACH   DATA COLLECTION

Hubble Space Telescope Repair

Scripting ORU Maintenance Tasks on Space Station Freedom

HUMAN SLEEP, CIRCADIAN RHYTHMS, AND PERFORMANCE IN SPACE

Timothy H. Monk and Daniel Buyssee
Western Psychiatric Institute and Clinic
University of Pittsburgh
Pittsburgh, PA 15213

Adequate sleep and circadian rhythms are essential during spaceflight to ensure high levels of productivity from the crew. Drs. Monk and Buyssee of the University of Pittsburgh will conduct an experiment during the International Microgravity Laboratory-2 mission, scheduled for flight in 1994, on sleep, circadian rhythms, and performance in space. The study will evaluate sleep using polysomnography and sleep diaries. Circadian rhythms will be measured using body temperature, urine volume, and urinary electrolyte and hormone concentration data. Mood and performance will be assessed using subjective measures of global vigor and through a computer-based performance test. Separate analyses will be performed of the two crew shifts, day-shift and night-shift, to study "shift work adaptation" in addition to "time into mission" effects. This experiment will show how circadian rhythms are altered in space; how this alteration is correlated with sleep dysfunction and impairment in mood, vigilance, and performance; and how a phase shift in the sleep-wake cycle in association with spaceflight impacts the above parameters.
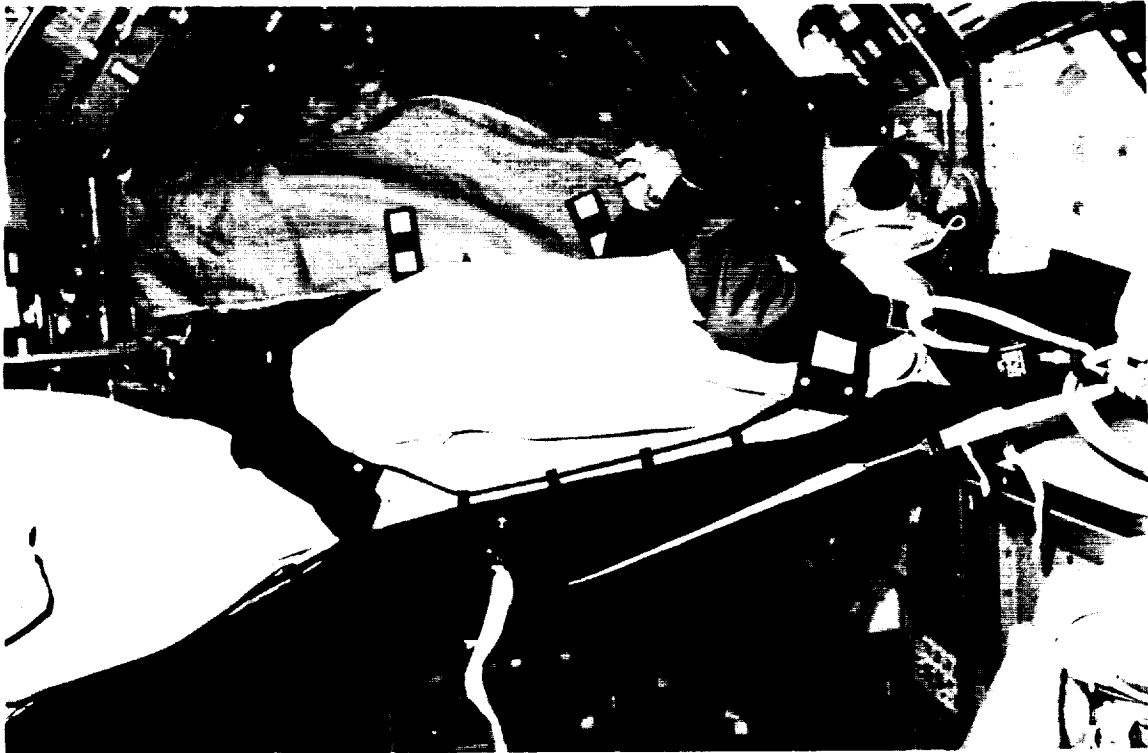
Astronaut sleeps in the Spacelab module during the Spacelab Life Sciences-1 mission.

SHARED MENTAL MODELS AND CREW PROBLEM SOLVING

Judith M. Orasanu
Aerospace Human Factors Research Division
NASA Ames Research Center
Moffett Field, CA 94035

Team problem solving and decision-making strategies will be important for future space missions in which problems may arise for which no packaged solutions are available. Models of crew performance are needed as a foundation for training and design of performance aids. Research performed by Dr. Orasanu of Ames Research Center has led to the development of methods to distinguish between more and less effectively performing crews. The focus of Dr. Orasanu's work is on interactional processes that mediate overall crew performance. These include various aspects of communication, problem solving, decision making, and resource management. Variables that may influence these processes include crew familiarity, crew size, leader personality, gender, fatigue, and situational stressors.

Analysis of full-mission simulations of 2-person and 3-person aviation flight crews has allowed the study of different strategies during abnormal situations. Communication patterns, task allocation, situational awareness, and decision strategies have been found to be important variables for success. Further studies of planning strategies and problem solving in communication between the scientific and support crews in the Aquarius undersea habitat are being planned. The results of this research will advance the development of principles for selecting and designing space crews, guidelines for preparing space crews to cope with unforeseen problems in high-risk environments, techniques for resisting effects of stressors, and principles for designing human-centered systems.

Modeling Human Performance in 3-D Self-Motion and Structure-from-Motion Estimation

John A. Perrone
Department of Psychology
*Stanford University*
Stanford, CA 94305

and

Lee S. Stone
Life Sciences Division
NASA Ames Research Center
Moffett Field, CA 94035

Because the vestibular system does not function normally in space, space crews are forced to rely more heavily on vision for controlling their movements. Therefore a clear understanding of how humans use visual-motion cues to estimate self-motion and depth is critical for anticipating the deleterious effects of microgravity on performance. This fundamental knowledge is also critical for designing visual displays and training paradigms that may minimize or even counteract such effects.

Drs. Perrone and Stone have developed a model of human self-motion estimation that is based on the known properties of motion sensitive neurons in the primate brain. They are now using this model to generate simulations of human perception under a number of sparse visual conditions similar to those encountered during extravehicular activity. They are also conducting human psychophysical experiments to quantify actual human performance in heading and depth estimation tasks under the same sparse visual conditions. Because their model is biologically based and will be psychophysically validated, this research will lead to a better understanding of how the human brain processes self-motion information, to the development of a predictive tool for human performance in various space environments, and to the design of more effective displays and visual interfaces for space environments.
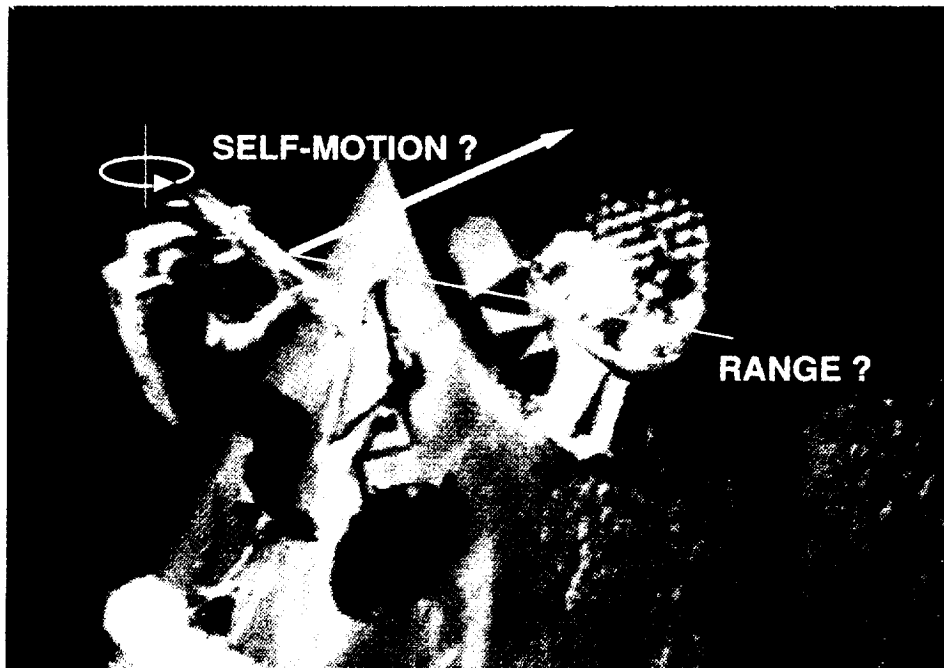
Model of self-motion estimation during extravehicular activity.

# VALIDATION OF PSYCHOLOGICAL "SELECT-IN" CRITERIA FOR SPACE STATION

Robert M. Rose
MacArthur Foundation
Chicago, IL 60603

and

Robert L. Helmreich
Department of Psychology
University of Texas
Austin, TX 78712

Selection criteria are required to ensure crew coordination and optimum crew performance in space. "Select-out" criteria, a process by which unqualified or unfit individuals are removed from the applicant pool, are already established. NASA is now working on the development and validation of "select-in" criteria: identifying positive qualities, and selecting individuals possessing those traits. Researchers Dr. Rose of the MacArthur Foundation and Dr. Helmreich of the University of Texas are investigating characteristics associated with personality and performance measures (both individual and group performance) among astronauts. The overall objective of this task is to identify psychological selection predictors and to validate them against measures of astronaut job performance.

Data are being collected from incoming astronaut trainees and from veteran astronauts on psychological factors, including personality characteristics, psychomotor coordination, and verbal and spatial aptitude, and ratings on nine job-related categories such as job knowledge, job performance, leadership, and teamwork. The validity of these predictors will be established by shuttle performance as represented by peer and supervisor ratings. Preliminary results using NASA astronauts indicate that peer and supervisor ratings provide valid measures of performance. The research in this task should eventually result in a workable method of selecting astronauts for long-duration space missions.
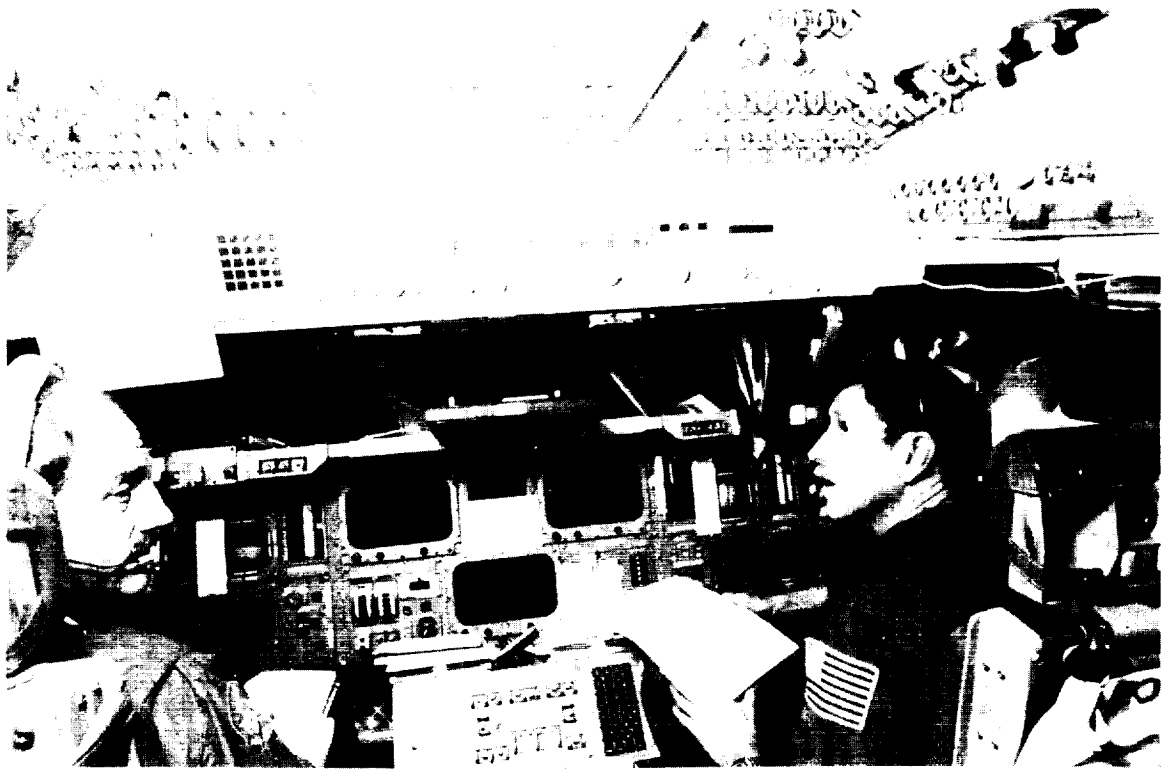
Performance during astronaut training for STS-26 is used to validate "select-in" criteria.

# HUMAN REASONING
(COMPUTER-AIDED MEDICAL DECISION MAKING)

Marianne Rudisill
Man-Systems Division
NASA Johnson Space Center
Houston, TX 77058

During future space exploration missions, crewmembers will be increasingly independent from earth-based support facilities. Therefore, improved human-computer interfaces, especially those for decision support systems, are needed to ensure successful missions. One such system is a computer-based medical decision support system to enable health care delivery during flight by both the crew medical officer and other crewmembers.

Research is being conducted by Dr. Rudisill, John Gosbee and Jurine Adolf of Lockheed, and the Human Computer Interaction Laboratory staff at Johnson Space Center to improve the design of human-computer interfaces during the use of a computer-based medical decision support system, with the goal of enhancing the human decision-making process. The objectives of this task are to develop tools for modeling human reasoning, problem solving, and decision making with tasks conducted in the space environment, and to demonstrate how this information may be used in defining the human-computer interface for decision-aided computer systems.

Research includes employing cognitive models to redesign the interfaces to medical procedures. Preliminary results have shown that human recall of a procedure based on a cognitive modeled interface results in superior performance, compared with traditional medical procedural training. Future research will examine human-computer interface

Model of the Medical Decision Making Process
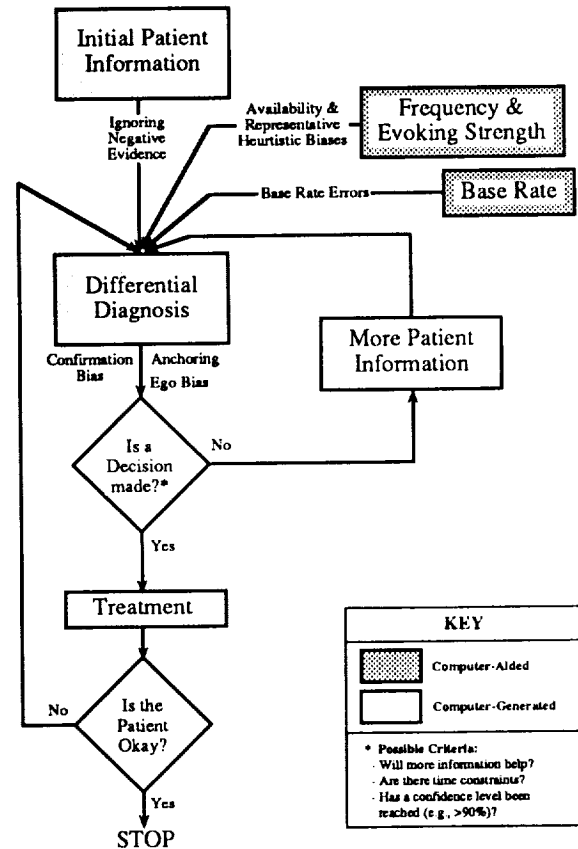
issues, including explanation facility, time consuming data input, trust and acceptance variables, terminology diversity, and decision making errors.

COGNITIVE AND PSYCHOMOTOR PERFORMANCE IN PRIMATES

Duane M. Rumbaugh
Sonny Carter Life Sciences Laboratory
Georgia State University
Atlanta, GA 30303

The behavioral and performance capabilities of rhesus monkeys parallel those of humans and therefore provide important behavioral model data. Drs. Rumbaugh, Washburn, and Richardson of Georgia State University are studying rhesus monkeys to assess the effects of microgravity and spaceflight on rhesus behavioral and psychological functioning.

An interactive, computer-based testing paradigm has been developed that provides highly motivating activity for the animals, while permitting assessment of the effects of spaceflight on their psychomotor functioning, learning, attention, memory, perception, and problem solving. The research will also determine the degree to which these performance measures correlate with corresponding physiological indices of adaptation to microgravity. In addition, it will provide environmental enrichment for the monkeys and continuously assess the psychological well-being of rhesus monkeys maintained for spaceflight or ground-based research. The ground-based data will form the foundation for inflight assessment of basic task performance in rhesus monkeys planned for the Spacelab Life Sciences-3 mission, scheduled for flight in 1996.

A rhesus monkey performs arithmetic as part of the interactive, computer-based research conducted by Dr. Rumbaugh.

MICROGRAVITY EFFECTS ON STANDARDIZED COGNITIVE PERFORMANCE MEASURES

Samuel G. Schiflett
Crew Performance Function, Sustained
  Operations Branch
Armstrong Laboratory
Brooks Air Force Base, TX 78235

Dr. Schiflett of USAF Armstrong Laboratory in San Antonio, Texas, with researchers Douglas Eddy of NTI, Inc., Dayton, Ohio, Jonathan French of Armstrong Laboratory, and Diane Damos of the University of Southern California, are preparing an experiment for the International Microgravity Laboratory-2 (IML-2) Spacelab mission scheduled for flight in 1994. The experiment, which seeks to understand behavioral and performance issues of crews working and living in space, will use six tests selected from the Unified Tri-Service Cognitive Performance Assessment Battery (UTC-PAB). The UTC-PAB was developed by the Office of Military Performance Assessment Technology for the Department of Defense by establishing a set of standardized testing procedures and formats, which was later accepted by NATO. The selection of the tests included in the NASA Performance Assessment Battery was based upon an examination of current theoretical models of human performance, analysis of space mission tasks, and sensitivity to detect hypothesized changes in performance due to microgravity. Experimental protocols will examine decision-making, spatial pattern recognition, divided attention, memory, and perceptual-motor performance in microgravity. The primary objective is identification of the effects of microgravity, separate from those of fatigue and shifts in work/rest cycles, upon specific information processing skills affecting performance.

In a related study, staff at Armstrong Laboratory and the Man-Systems Division at Johnson Space Center have begun a series of investigations aimed at developing workload metrics for assessing the timelines of crew task schedules, evaluating alternative system designs, and quantifying the effects of microgravity and other environmental stressors on human performance in space. A dynamic computer model that describes a task and the characteristics of a human operator will be developed to predict operational flight performance from data acquired from ground-based simulation training exercises. This work, in conjunction with future studies, will serve as the foundation for developing an integrated set of methodologies for the evaluation of human performance and behavior in extended duration spaceflight missions.

Dr. Schiflett performs a test from the NASA Performance Assessment Battery, which will be included in an experiment to be flown on IML-2.

BEHAVIORAL DATA ANALYSIS FROM SPACE ANALOG ENVIRONMENTS

Jack Stuster
Principal Scientist
Anacapa Sciences, Inc.
Santa Barbara, CA 93101

Data from analog environments characterized by extremely long durations, isolation, and potentially hazardous conditions, e.g., remote Antarctic research stations and expeditions of research and discovery, can be used to develop design guidelines and operational recommendations concerning significant behavioral, psychological, and sociological issues associated with long-duration space missions. Dr. Stuster has conducted an analysis of Antarctic mission logs, including pre- and post-mission psychological profiles. Identifying performance measures for remotely monitoring the psychological adjustment of crew personnel to isolation and confinement, and studies of workload have been the focus of this research. This work will provide design guidelines and recommendations for equipment, habitability requirements, and operational procedures to facilitate human performance and productivity in isolated and confined habitats, such as interplanetary spacecraft and lunar outposts.

Amateur theater night aboard the *Alert*, in 1875. Boredom of the crew was one of the principal problems during Arctic naval expeditions of the 18th and 19th centuries. A tradition of staging plays was developed to break the monotony for the icebound crew. The costumes and footlights in this illustration suggest that such productions were considered important.

ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH

Richard E. Byrd, in 1933, preparing a meal at the beginning of his four months of isolation and confinement in a small hut 100 miles from the main base at Little America. After two months Byrd wrote, "Time was no longer like a river running but a deep still pool."

Campsite of the *Discovery* expedition at McMurdo Sound, 1901-1904. Expeditions and Antarctic winter-over experiences resemble in many ways the conditions of isolation and confinement that will be experienced by future space travellers and those who will live and work at lunar and Martian outposts.

Virtual Environments as a Tool for Perceptual and Motor Research

Robert B. Welch
Life Sciences Division
NASA Ames Research Center
Moffett Field, CA 94035

and

Stephen R. Ellis
Aerospace Human Factors
 Research Division
NASA Ames Research Center
Moffett Field, CA 94035

Perception and perceptual-motor control are crucial for adequate human performance in space, but they can be difficult to study in extra-terrestrial and terrestrial settings. Drs. Welch and Ellis at Ames Research Center are using computer-generated "virtual environments" to examine questions about human perception and performance that would prove either impossible or very difficult to test by means of "real-life" physical environments. This research has four specific objectives: (a) to assess the usefulness of the virtual environment as a tool for the study of perception and performance, by examining selected experimental topics in such environments and comparing the results to those obtained in analogous physical environments, (b) to identify the necessary and sufficient stimulus conditions for creating virtual environments that are as functionally similar to physical environments as possible, by directly comparing the responses of subjects to virtual environments and to their physical counterparts, (c) to determine how operations can best use adaptation to overcome the sensory and sensory-motor problems inherent in most virtual environment systems, and

Dr. Ellis repositions a virtual environment display for a perceived eye level experiment.

(d) to extend knowledge about human perception and performance.

Current and planned experiments will measure perceived eye level and body orientation in a variety of virtual environments, and will examine human adaptation to atypical sensory arrangements. Other experiments will examine the degree to which observers can acquire and maintain separate adaptations to two or more mutually conflicting, sensorily rearranged virtual environments. An eventual practical outcome of this research program is the creation of virtual environments for training astronauts to perform effectively in space.

AUTOMATION AND CREW PERFORMANCE

Earl L. Wiener
Department of Management Science
University of Miami
Coral Gables, FL 33124

Dr. Wiener of the University of Miami, along with Tom Chichester, Ev Palmer, and Barbara Kanki of Ames Research Center, Steve Gregorich of San Jose State University, and Renwick Curry of Tycho Systems, are investigating the complex issues associated with the interaction of human crews and automated systems. The goal of this research is to understand, in a real-world setting, how varying levels of automation impact both team performance and group processes. The objectives of this research are to determine human design requirements for automated systems and to develop protocols for training users of automated systems.

Analysis of a full-mission simulation is being conducted, in which performance of air transport crews in a highly automated aircraft (MD-88) has been contrasted with similar performance in an aircraft equipped with older technology (DC-9). This analysis includes overall team performance, incidence and severity of errors, workload ratings, dynamics of group processes, and the factors that contribute to errors and high workload. This line of research will be relevant to the design of space missions and the training of crews for extended spaceflight missions, where onboard automation will be necessary to supply the real-time informational support presently provided from the ground.

For more information regarding the NASA Space Human Factors Program, contact Janis H. Stoklosa, Life Sciences Division, Code SBM, NASA Headquarters, Washington, DC 20546. For more information regarding space human factors research conducted at NASA Johnson Space Center, contact Barbara Woolford, Man-Systems Division, Code SP3, NASA Johnson Space Center, Houston, TX 77058. For more information regarding space human factors research at NASA Ames Research Center, contact Mary Connors, Aerospace Human Factors Division, Mail Stop 239-1, NASA Ames Research Center, Moffett Field, CA 94035.