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Technical Report: NAVTRAEQUIPCEN IH-330

AN ANNOTATED BIBLIOGRAPHY OF OBJECTIVE PILOT PERFORMANCE MEASURES

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Buckout's review in 1962 was the last comprehensive examination of the pilot performance measurement (PPM) literature. This annotated bibliography attempts to: (1) gather the PPM literature written subsequent to 1962 into one source; (2) describe the scenarios and measures used in collecting PPM data; and (3) summarize the major premises and findings of each article.

A variety of sources including computer aided literature search were used to identify candidate articles. Ultimately all referenced material was

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
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SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)* divided into three categories: (1) objective pilot performance measurement; (2) subjective pilot performance measures; and (3) general analysis and review articles.

The objective performance measure category was arranged as follows:

Descriptor		Articles
Field Conditions	Fixed Wing	100-120
	Rotary Wing/VSTOL	120-149
Simulator Conditions	Fixed Wing	200-276
	Rotary Wing/VSTOL	277-287
Laboratory Conditions		300-319
Combination of Field Conditions, Simulator and/or Laboratory Conditions.		400-434

For each of the objective measure articles reviewed the following parameters were reported: subjects, equipment, scenario, measures and summary. For the subjective measures and general analysis and review articles the author's abstract was generally duplicated. In addition to the 189 articles addressing objective performance measurement, 30 articles dealing with subjective measures and 143 related analyses and review articles are contained in the bibliography.

To facilitate the retrieval of articles the following indexes were developed. Author, Subject Matter, Scenario, Performance Measurement, Source and Accession Number. Matrices, which divided the over 200 performance measures into six main classes: physiological aircraft systems, man-machine systems, time, frequency and measures of effectiveness/other, will allow the user to identify articles which use a common performance measure.

The authors hope that the document will (1) provide a means for integrating the PPM literature, and (2) serve as an impetus to develop a systematic approach to PPM.

FOREWORD

The present report is part of the Human Factors Laboratory program to develop performance measurement methods as an essential subsystem of aviation training systems. The work represents a collaborative effort between the Naval Training Equipment Center and Naval Postgraduate School (NAVPGSCOL). Previous research in performance measurement has had two major difficulties: (1) retrieval, and (2) organization of relevant literature. Herein is provided an extensive annotated listing of objective pilot performance measurement research and review articles organized by several meaningful categories. Retrieval from the data base has been facilitated by providing various indexes and matrices. Those reports identified since the present report will be annotated in an NAVPGSCOL report, which will also annotate classified and limited distribution articles. It is intended that the literature on pilot performance will be updated and annotated on a periodic basis.

G.R. Stoffer

G. R. STOFFER
Scientific Officer

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SECTION I

INTRODUCTION

BACKGROUND

The measurement of pilot performance is a "sine qua non." Without measurement one cannot discriminate success from failure, progression from regression. Measurement is a means for determining where one is, where one has been, and potentially where one is going. S. Stevens (1951, p. 1) defined measurement as "the assignment of numerals to objects or events according to rules." This document reviews attempts to assign numerals to pilot activities according to rules. Thus the emphasis is on objective performance measures, i.e., those measures which can be obtained without observer-system interaction.

Some of the areas on which pilot performance measurement (PPM) impacts can be seen by an examination of Figure 1. The areas vary in complexity and criticality yet PPM is essential for progress in these areas.

The advent of the digital computer, particularly in the area of simulators and more recently in the area of airborne systems provided a convenient means for collecting objective data. Indeed, within the Research and Development (R&D) activities of the Department of Defense there has been considerable emphasis on the use of digital computers to objectively quantify performance.

A Department of Defense review (1968) reported that "subjective evaluation was the technique in general use in training programs observed" and had been since before World War II. The study went on to comment that "judgment and experience can be helped by quantitative analytical methods" and that the application of such methods served three purposes:

1. They make it necessary to identify the standards of performance desired for each of the many events the pilot must learn.

2. They determine how many practices or trials a student must accomplish, on the average, to meet the desired standard.

3. They tell the manager how much improvement he normally may anticipate with each additional practice or trial.

This study concluded that "the services should apply objective evaluation techniques where currently feasible in parts of existing training programs..." and "where valid performance data in aircrew training programs can be recorded and stored,

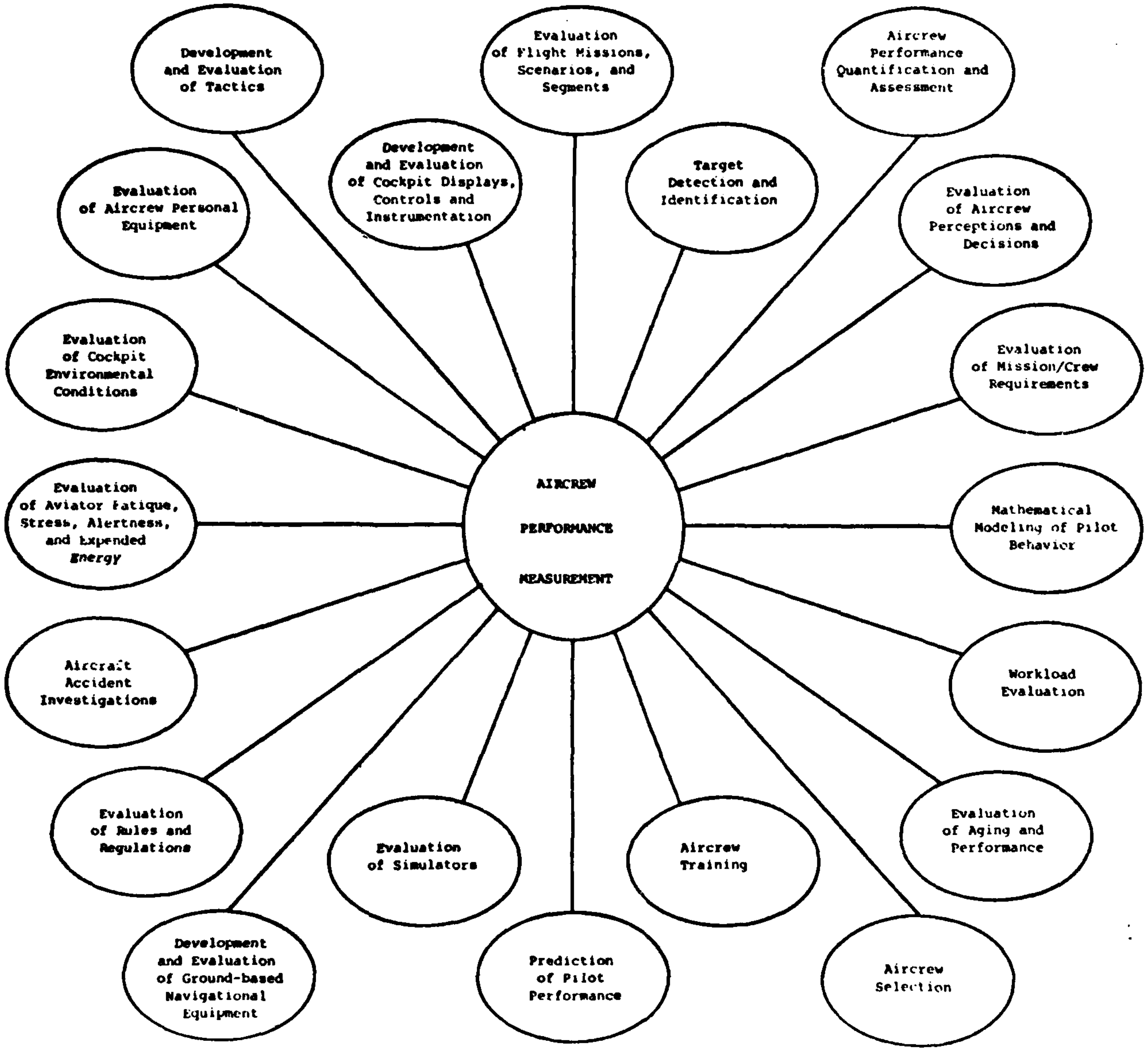

Figure 1. Areas on which Aircrew Performance Measurement Impacts.

quantitative analytical methods should be used to assist the commander in making decisions concerning revising and adjusting the course."

A 1973 study by the Comptroller General of the United States (General Accounting Office) to the Congress on the use of flight simulators in military pilot training programs stated that "simulators could also be used to more accurately measure pilot proficiency by using systematic grading procedures." The study concluded"; objective grading of pilot proficiency using simulators would provide more consistent and accurate results for many phases of flight training and eliminate the possibility of human bias and error associated with the current evaluation method...simulator grading accurately evaluates pilot proficiency for certain flight maneuvers (p. 19)."

Recently, within the applied aviation simulation community there has been an emphasis on the use of objective measures to:

1. Establish performance standards (Campbell, 1976; Rankin and McDaniel, 1980; Mixon, 1981)
2. Evaluate simulators (Knoop, 1968)
3. Evaluate and improve instructor effectiveness (Charles, 1978; Semple, Vreuls, Cotton, Durfee, Hooks and Butler, 1979)
4. Evaluate training effectiveness (Pierce, De Maio, Eddowes, and Yates, 1979; Kelly, Wooldridge, Hennessy, Vreuls, Barnebey, Cotton and Reed, 1979)
5. Identify skill requirements (Pierce, et al., 1979)
6. Improve Instructional Systems Development (Prophet, 1978)

Buckhout's review in 1962 was the last comprehensive examination of the pilot performance measurement literature. Since that time the digital computer has in many ways replaced the analog computer and new techniques for collecting, measuring and analyzing objective performance data have evolved. This annotated bibliography attempts to:

1. Gather the PPM literature written subsequent to 1962 into one source.
2. Describe the scenarios and measures used in collecting and analyzing PPM data.
3. Summarize the major premises and findings of each article.

In addition to the 189 articles addressing objective performance measurement, 30 articles dealing with subjective measures and 143 related analyses and review articles are contained in this bibliography.

The authors hope that the document will (1) provide an integration of the PPM literature and (2) serve as an impetus for the development of a systematic approach to PPM.

SEARCH PROCEDURE

To accomplish a comprehensive search of the scientific literature dealing with objective pilot performance measurement, several sources were used. Potential sources of literature that were searched included books, scientific journals, technical reports, and proceedings of technical meetings. Computer assisted literature search and library searches were used to locate relevant documents.

Primary Search

Computer Assisted Literature Search

Several computerized information search and retrieval systems were used to provide relevant documents on pilot performance measurement. Most of these searches were based on key word accessing of documents contained in the files. The user must develop the key word index and use various combinations of these key words in an iterative fashion too combine words appropriately. The initial list of key words chosen for use included: aviation, pilot, psychometric, measures, performance, flying, skills, scoring forms, training, proficiency, measurement, simulators (flight), and criterion. Subsets of these words were used for the individual computerized searches.

DIALOG System. This nationwide interactive information system was searched through direct telephone access by Dudley Knox Library personnel at the Naval Postgraduate School. The DIALOG system provides approximately 50 computer files pertaining to science, technology/engineering, social sciences, and business/economics.

Three files were searched on DIALOG; COMPENDEX (Engineering Index), National Technical Information Service including Defense Technical Information Center (DTIC), and PSYCHOLOGICAL ABSTRACTS (American Psychological Association). This search provided over 200 titles that contained potential information on objective pilot performance measurement.

DTIC Report Bibliography. The DIALOG system included primarily reports published within the last ten years. To provide a more comprehensive survey of the technical report literature, DTIC files were surveyed using the key words listed above. Literature spanning the years 1959-1979 was searched, resulting in a list of over 200 titles.

DLSIE Report Bibliography. The Defense Logistics Studies Information Exchange (DLSIE) service was also used to provide human performance-related documents not normally found in the open literature. Operated by the U.S. Army Logistics Management Center at Fort Lee, Virginia, DLSIE acquires, organizes, stores, and disseminates logistics and management information on a Department of Defense-wide basis. A selected listing with over 200 abstracts germane to pilot performance was provided.

SABIRS Library Search. A computerized search of all research reports actively maintained by the Naval Postgraduate School (NPS) library, called Semi-Automatic Bibliographic Information Retrieval System (SABIRS), was performed using the key words listed in Table 1. The information provided was in the form of report headings by principal author. Over 75 listings were obtained by this service.

Manual Searches

Computerized searches are not exhaustive due to the limitations imposed by key word accession. This is particularly true for proceedings of professional meetings such as the Human Factors Society and Advisory Group for Aviation Research and Development (AGARD). For material in addition to the computerized searches, an extensive library search was made of several documents including Human Factors, Ergonomics, Aviation, Space, and Environmental Medicine, Proceedings of the Human Factors Society (1972-1980), Air University Library Index to Military Periodicals, and the Applied Science and Technology Index.

In addition to the manual search of library abstracting documents, the subject and corporate author card catalog files of both the Dudley Knox Library at NPS and the Technical Reports Library of the Naval Training Equipment Center, Orlando, Florida, were searched for pilot performance measurement-related material. The results of this search yielded the names of several agencies conducting research in the subject area, as well as numerous documents not previously retrieved by the computer searches.

Secondary Search

Document Retrieval

Once the primary search was completed, documents appearing to meet the selection criteria were ordered from DTIC, NTIS, the NPS and NTEC libraries or if necessary from the author. Every document cited in this bibliography was obtained, examined, and classified before inclusion.

Bibliographies

Several bibliographies appeared in the primary search retrieval that were either directly related to pilot performance measurement or contained subject material that was related. No pilot performance bibliographies were uncovered that had been published after 1962, with Buckhout (1962) and Ericksen (1952) appearing to be the previous major attempts at collecting research material on the subject. Other related bibliographies, e.g., long-term retention of flying skills (Prophet, 1976) and pilot performance and aging (Gerathewohl, 1978), provided source material that had not been uncovered previously in either computer or manual searches.

Human Factors in Aviation, a working bibliography made available by Jack B. Shelnutt of the Seville Research Corporation provided approximately 40 additional source documents. This bibliography was heavily oriented toward civil aviation, and identified source material not found elsewhere.

The last level of bibliographic search was provided by the bibliography of each retrieved document on pilot performance measurement. Locating a potential source report in this manner was accomplished by a computer search for an accession number, and when that failed, by a request to the corporate author.

DATA BASE MANAGEMENT

The large volume of material searched and retrieved required the use of a computer file of material both suitable and unsuitable for inclusion in this bibliography. The initial file contained the following information for each document:

Accession number
Author(s) (2 maximum)
Title of article
Corporate author
Year of publication

Using an IBM 370 computer, this file was then sorted by each category of information, providing cross-indexes of source material that could be instantly referenced to avoid duplication in identification and retrieval of material. As the volume of material grew, a second file was established to accomplish the same organizational structure. This file contained the following categories of information for each document:

Control number (3 digits)
Accession number or source (AD number or agency name)
Author (principal only)
Year and month of publication

Bibliography number (3 digits)
Type of research (experiment or general analysis)

Experimental information:
- Type of measurement
- Flight scenario
- Equipment used

SECTION II

SELECTION CRITERIA

Given the large pool of documents obtained by the combined search procedures, it was necessary to develop a set of criteria for inclusion of a reference in the final bibliography. For a document to be included, it had to satisfy the criteria listed below:

1. Topic. Each document had to be applicable to, deal with, or apply pilot performance measurement concepts. Pilot performance measurement as used here included the observation and quantification of pilot behavior while controlling an airborne vehicle.

2. Date of Publication. Each document included in this bibliography was published during or after 1962.

3. Objective Measurement. Each document included was to address by general analysis or review or by an experimental approach the concept of objective measurement. Objective measurement here is defined as observations where the observer is not required to interpret or judge, but only to record the observation. Some subjective pilot performance measurement studies were provided as contrasts to the objective technique.

4. Availability. A full copy of each document had to exist in print or in copyable form. Documents appearing in summary, or in short abstract only, were not included.

SECTION III

CLASSIFICATION SCHEME

The classification scheme divided all referenced material into three basic categories:

1. Objective Pilot Performance Measures
2. Subjective Pilot Performance Measures
3. General Analysis and Review Articles

OBJECTIVE PILOT PERFORMANCE MEASUREMENTS (Articles 100-434)

The classification scheme used for the objective pilot performance section of the annotated bibliography was developed to provide information to the user or researcher regarding the type or types of objective pilot performance measures employed in the cited document and the specific flight scenario to which the document may be applicable. Additional information for experimental studies is provided in regard to the number of subjects used for research, the equipment utilized, and a summary statement. Each classification item is defined below:

1. Subjects. Number and type of personnel used in the research.
2. Equipment. Each experiment utilized either a laboratory, a flight simulator, or an actual aircraft. The distinguishing line between "laboratory" and "flight simulator" was not always clear; usually if a full-sized aircraft cockpit was employed, this was classified as a "simulation" experiment. When more than one form of equipment was utilized, this was so indicated.
3. Scenario. A broad definition of airborne flight including missions and flight segments.
4. Measures. Observed parameters or variables measured in the objective sense without human perceptions or judgements. These generally fell into six classes; (1) physiological, (2) aircraft systems, (3) man-machine system, (4) time, (5) frequency, and (6) combined measures. Mathematical and statistical transformations applied to each measure are included in parentheses after the measure.
5. Summary. A capsulized synopsis of the purpose of the experiment, experimental conditions, and the results. Brevity was preferred over repetitious statements of facts. No attempt was made to review or critique a document.

Articles were arranged according to the following scheme:

Descriptor		Articles
Field Conditions	Fixed Wing	100-120
	Rotary Wing/VSTOL	121-149
Simulator Conditions	Fixed Wing	200-276
	Rotary Wing/VSTOL	277-287
Laboratory Conditions		300-319
Combination of Field Conditions, Simulator and/or Laboratory Conditions (includes both objective and subjective measures)		400-434

Within each category of fixed or rotary wing, articles were arranged chronologically by scenario, i.e., all carrier landing studies were grouped together in increasing chronological order. Studies of more than one scenario were arranged in order of complexity, i.e., two-, three-, then four-scenario and above studies were arranged chronologically.

SUBJECTIVE PILOT PERFORMANCE MEASURES (Articles 500-530)

A small sample of subjective pilot performance measurement studies (500-530) were included to contrast the pilot rating method with the objective measures reported in Articles 100-434. In addition to the bibliographic data this section contains either the author's original abstract, modified slightly in some cases, or a modification of the sources' introductory material.

RELATED ANALYSIS AND REVIEWS (Articles 600-743)

This section contains articles which, while related to pilot performance measurement did not contain objective or subjective data but rather, addressed related issues such as data analysis, simulation, transfer of training, prediction of pilot performance, etc. In addition to the bibliographic data, this section contains either the author's original abstract, modified slightly in some cases, or a modification of the source's introductory material.

SECTION IV

INDEXES AND MATRICES

To facilitate article retrieval the following indexes were developed:

1. Author Index - lists the author's name and article number
2. Subject Matter Index - a limited search for terms of interest resulted in the development of the Subject Matter Index. Readers are cautioned that the search is only as good as the reviewers' classification scheme and vigilance. Also not all terms of possible interest could be searched for; therefore if a term does not appear in this index the reader should not conclude that the term is not contained in an article in the bibliography.
3. Scenario Index - lists scenario and article number.
4. Performance Measure Index - lists performance measure and article number.
5. Source Index - lists the performing agency and article number.
6. Accession Number Index - lists the document retrieval number as follows:

AD ---- ---	- available from Defense Technical Information Center
ATI ------	- available from Defense Technical Information Center
N -- -----	- available from the NASA source cited with the article

Matrices

A unique feature incorporated into this document are the matrices. A brief explanation of the matrices is appropriate. The matrices are based on articles 100 through 434 inclusive. The pilot performance measures listed across the horizontal axis are identical for all matrices. The measures have been divided into six main classes of measurement; physiological, aircraft systems, man-machine systems, time, frequency, and measures of effectiveness/other. Within each of the six classes the measures have been arranged alphabetically. In order to avoid the complexity of a foldout matrix and to fit within page size constraints (which allow the document to be microfiched) considerable liberty had to be taken in reducing the length of the terms which appear across the vertical axis. The author and number of the article being considered are listed in the leftmost column.

Let us assume that an investigator wished to determine which fixed wing experiments conducted under field conditions used vertical velocity as a metric. The investigator should locate vertical velocity under the man-machine classification (p. 372). By reading down the vertical velocity column he could determine that vertical velocity was used as a metric in articles 105, 110, 111, 113, and 114.

Users of the matrix are advised that when possible, generic descriptors were used as titles of measures and they should therefore review all titles and consider synonyms.

SECTION V

CLASSIFIED PILOT PERFORMANCE MEASUREMENT REPORTS AND BIBLIOGRAPHIC UPDATE

Since this bibliography is intended for general distribution, classified articles of interest were not included. However, an addendum containing abstracts of limited distribution sources is being prepared and will be published as NPS report 55-81-010PR. This addendum will also contain articles which were uncovered too late for inclusion in this report. Appendix A contains references to only those unclassified or unlimited articles reviewed too late for inclusion in this document.

BIBLIOGRAPHIC UPDATE

It is likely that an effort such as this would have inadvertently missed some relevant articles. Therefore, investigators who feel that their article should have been included are invited to send a copy of their article to:

LCDR Lawrence H. Frank, MSC
PPM Update
Naval Training Equipment Center (N-712)
Orlando, FL 32813

If the article is considered appropriate, it will be incorporated into a future update of this bibliography.

SECTION VI

REFERENCES TO SECTIONS I - V

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Stevens, S.S., ed., Handbook of Experimental Psychology. New York: Wiley, 1951.

SECTION VII

ANNOTATED BIBLIOGRAPHY

100. SMIT J., Pilot Workload Analysis Based Upon In-Flight Physiological Measurements and Task Analysis Methods, National Aerospace Laboratory (NLR), The Netherlands, NLR-MP-76001-U, June 1976, 6 pp., AD B026957.

SUBJECTS: 10 pilots.

EQUIPMENT: F-104G "Starfighter" fighter-bomber.

SCENARIO: Low-level ground attack.

MEASURES: Heart-rate signal (ECG; time between successive cardiac events, R-waves), respiration signal, skin resistance level and responses (GSR), pressure altitude, radar altitude, true air speed, ground speed, grid heading, and vertical acceleration.

SUMMARY: The objective of this experiment was to obtain in-flight physiological measures, subjective pilot opinion and objective performance measures to estimate the demand of the low-level ground attack task. Possible results were to develop a method to more quantitatively define man-machine-environment interactions. No conclusions were stated.

101. BURTON, R.R., Storm, W.F., Johnson, L.W., and Leverett, S.D. Jr., "Stress Responses of Pilots Flying High-Performance Aircraft During Aerial Combat Maneuvers," Aviation Space and Environmental Medicine, v. 48(4): p. 301-307, April 1977. Also AD A045629.

SUBJECTS: 8 pilots (F-15) and 9 pilots (F-106).

EQUIPMENT: F-15 and F-106 aircraft.

SCENARIO: Air combat maneuvering (ACM).

MEASURES: Urinary catecholamines were analyzed for epinephrine, norepinephrine, 17-hydroxycorticosterone (17-OCHS), creatine, uric acid, urea, potassium, sodium and phosphate. Subject fatigue checklists were completed before and after each flight.

SUMMARY: This research was conducted to quantify the degrees of fatigue, stress and sympathetic activity experienced by pilots during ACM. The F-106 pilots exerted more relative effort associated with high-G experience than did F-15 pilots. Both groups were equally fatigued following ACM's; F-106 pilot fatigue correlated with the length of the ACM. It was concluded that the F-15 pilots flying ACM are moderately stressed and F-106 pilots are exhilarated during short-duration ACM's.

102. KIBORT, Bernard R., and Drinkwater, Fred J. III, A Flight Study of Manual Blind Landing Performance Using Closed Circuit Television Displays, National Aeronautics and Space Administration, Ames Research Center, Moffett Field, CA, NASA TN D-2252, May 1964, 33 pp.

SUBJECTS: 4 pilots.

EQUIPMENT: DC-3 (R4D) Aircraft with a television display.

SCENARIO: Approach and landing (visual).

MEASURES: Vertical acceleration at ground contact (mean and standard deviation) and landing distance to ideal touchdown point (average absolute, mean and standard deviation).

SUMMARY: The purpose of the report was to evaluate pilot performance while landing with a closed circuit TV system and to compare it with performance while landing under normal visual conditions and when landing with restricted peripheral vision. It was concluded that it was possible to perform a normal visual landing with the two-dimension TV display with no degradation in performance. The most important factor in controlling the basic cues used by the pilot appeared to be the TV lens focal length. The restriction of peripheral vision also had little effect on landing performance once the runway was in sight and the approach was initiated.

103. HASBROOK, A. Howard, and Rasmussen, Paul G., "Pilot Heart Rate During In-Flight Simulated Instrument Approaches in a General Aviation Aircraft," Aerospace Medicine, v. 41(10): p. 1148-1152, October 1970.

SUBJECTS: 8 pilots.

EQUIPMENT: General aviation aircraft (single-engine, four-place).

SCENARIO: Instrument Landing System (ILS) approach.

MEASURES: Heart rate (ECG).

SUMMARY: The purpose of this experiment was to investigate the use of heart rate as an indicator of short-term changes in stress during the approach phase of flight. Ten straight-in ILS landing approaches were performed at ten-minute intervals by each subject. The principal findings showed heart rate increased significantly during each approach, the mean increase in heart rate was 5.2 beats per minute, and the overall mean heart rate level decreased on successive approaches for a total of 11.0 beats per minute for the ten approaches.

104. MILLER, James M., Visual Behavior Changes of Student Pilots Flying Instrument Approaches, Proceedings of the 17th Annual Meeting of the Human Factors Society, Washington, DC, October 1973, p 208-214.

SUBJECTS: 3 student pilots and 2 experienced pilots.

EQUIPMENT: Unspecified general aviation aircraft and corneal reflection eye movement apparatus.

SCENARIO: Instrument Landing System (ILS) approach.

MEASURES: Eye movements; fixation time (mean, number of fixations per minute, percent of fixation time, and inter-fixation interval). Aileron, rudder, throttle, elevator, approach localizer display error, and approach glideslope display error were also measured.

SUMMARY: The purpose of this experiment was to quantitatively measure the changes in a student's psychomotor skill level with increased experience. The design consisted of students performing the ILS approaches at early and late experience levels with the late experience level corresponding approximately to the skill level of the newly licensed private pilot. Results showed that mean fixation times and mean inter-fixation intervals decreased while mean fixation rates increased at the higher student experience level. During the approach as task stress-sensitivity levels increased, mean fixation rates increased. Compared to the glide slope instrument, the localizer instrument had higher fixation rates and percent of fixation time with a lower inter-fixation interval.

105. HASBROOK, A. Howard, Rasmussen, Paul G., and Willis, David M., Pilot Performance and Heart Rate During In-Flight Use of a Compact Instrument Display, Civil Aeromedical Institute, Federal Aviation Administration, Oklahoma City, OK 73125, FAA-AM-75-12, November 1975, 11 pp., AD A021519.

SUBJECTS: 20 pilots.

EQUIPMENT: Beechcraft Bonanza 35A fixed-wing aircraft.

SCENARIO: Instrument Landing System (ILS) approach to minimums (100 feet above runway elevation.)

MEASURES: Heart rate (ECG; stress), approach glideslope display error (mean, range and maximum), approach localizer display error (mean and maximum), airspeed (minimum and mean range), pitch, roll, heading, and vertical velocity.

SUMMARY: The purpose of this report was to conduct an in-flight study of pilot performance while using an experimental Peripheral Vision Flight Display (PVFD). Major findings indicated that pilot performance using the PVFD was equal to performances using conventional instruments, despite little familiarization time and without regard to pilot experiences. No difference in stress (heart rate) was evident between the PVFD and conventional displays. Panel space requirements can be reduced by at least 25 percent by use of PVFD design concept.

106. SCHWIND, G.K., Morrison, J.A., Nylen, W.E., and Anderson, E.B., Flight Evaluation of Two-Segment Approaches Using Area Navigation Guidance Equipment, United Airlines, Chicago, IL 60666, Contract No. NAS2-7475, sponsored by National Aeronautics and Space Administration, Washington, DC 20546, NASA CR-2679, April 1976, 48 pp., N76-20107.

SUBJECTS: 48 pilots.

EQUIPMENT: DC-8 aircraft with an area navigation (RNAV) system.

SCENARIO: Instrument Landing System (ILS) approach modified by an RNAV system into two segments.

MEASURES: Approach glideslope error, approach centerline error, autopilot vertical tracking error, flight director vertical tracking error, airspeed, fuel flow, and engine pressure ratio (EPR).

SUMMARY: The objective of this research was to develop and evaluate an RNAV guided two-segment approach for safety and operational acceptance for use in routine air carrier operations to reduce ground level noise. The system was refined and extensively flight tested, then placed into scheduled airline service for evaluation. The approach was determined to be compatible with the airline operational environment, although operation of the RNAV system in the existing terminal area air traffic control environment was difficult.

107. PERRY, John J., Dana, William H., and Bacon, Donald C. Jr., Flight Investigation of the Landing Task in a Jet Trainer with Restricted Fields of View, Flight Research Center, Edwards AFB, CA, National Aeronautics and Space Administration, Washington, DC, NASA TN D-4018, June 1967, 20 pp., N67-27294.

SUBJECTS: 4 pilots.

EQUIPMENT: T-33A aircraft.

SCENARIO: Landing (field).

MEASURES: Landing distance to ideal touchdown point (long or short) measured in feet (mean and average absolute error).

SUMMARY: The purpose of this study was to determine the relationship between the pilot's field of view and his performance of the landing maneuver. The pilot's task was to fly a 180-degree power-on pattern and final approach and land the aircraft on a predetermined point on the runway. As measured by touchdown error, the performance of the landing task was not appreciably affected by the reduction of the field of view. Pilot comments indicated that even the smallest restrictions of the field of view adversely affected performance.

108. CORKINDALE, K.G., Cumming, F.G., and Hammerton-Fraser, A.M., Physiological Assessment of Pilot Stress during Landing, Proceedings, Annual AGARD Symposium for Measurement of Aircrew Performance, Brooks AFB, TX, Advisory Group for Aerospace Research and Development, Paris, France, AGARD CP No. 56, May 1969, p. 9-1 to 9-4, AD 699934.

SUBJECTS: 4 pilots.

EQUIPMENT: Comet jet transport.

SCENARIO: Approach and landing under clear or fog conditions.

MEASURES: EMG, integrated arm and leg muscle activity, skin resistance activity (GSR), respiratory rate and flow, and heart rate (ECG; mean) which were all integrated over ten-second epochs from 2 minutes prior to touchdown, then further grouped to 30-second periods giving four intervals before touchdown.

SUMMARY: The purpose of the experiment was to investigate the value of physiological measures of pilot stress during landing, in hopes that these measures could be used to augment the current objective and subjective assessments of performance. It was concluded that multivariable physiological assessment of pilot stress in the field is feasible and recommendations were made to develop a more portable digital recording system for further study.

109. GOODE, Maxwell W., O'Bryan, Thomas C., Yenni, Kenneth R., Cannaday, Robert L., and Mayo, Marna H., Landing Practices of General Aviation Pilots in Single-Engine Light Airplanes, Langley Research Center, Hampton, VA 23665, National Aeronautics and Space Administration, Washington, DC, NASA TN D-8283, October 1976, 48 pp., N77-11033.

SUBJECTS: 22 pilots.

EQUIPMENT: 2 single-engine four-place airplanes; one low-wing (stabilator control) and the other high-wing (stabilizer and elevator).

SCENARIO: Approach and landing (field).

MEASURES: Airspeed (mean and standard deviation), pitch attitude, flap deflection (mean), altitude, angle of attack, angle of sideslip, landing distance to ideal touchdown point (median), landing height above runway threshold (median), and landing result (fast approach, float, high and steep, nose-low touchdown, multiple flare, bounce, no flare, over flare, late flare, high flare, and flight-path deviations). Measures were taken every 5 seconds by instruments in the aircraft and from photographs of the approaching aircraft behind a grid that was next to the runway.

SUMMARY: The purpose of this study was to document the methods and techniques used by a group of general aviation pilots during the landing phase of flight. The landings were made on both a long runway (1524 m (5000 ft)) and a short runway (762 m (2500 ft)). The results generally show that most approaches were fast with considerable floating during the flares with touchdowns that were relatively flat or nose-low.

110. BRICTSON, Clyde A. Measures of Pilot Performance: Comparative Analysis of Day and Night Carrier Recoveries, sponsored by Office of Naval Research, Washington, DC, 20360, Contract No. Nonr 4984(00), June 1966, 137 pp., AD 636433.

SUBJECTS: 21 Navy pilots.

EQUIPMENT: F-4 aircraft.

SCENARIO: Carrier approach and landing.

MEASURES: Approach glideslope error (measured in feet from glideslope) and approach centerline error (as a function of range) at 1/2, 1/4 and 1/8 miles and at the ramp. Also measured were vertical velocity, true air speed, closing speed, approach range, carrier deck pitch, approach airspeed, aircraft gross weight, carrier wind-over-deck, and landing result (arrestment wire number).

SUMMARY: The research purpose was to explore the psychophysical differences implied by a day/night carrier landing accident ratio of 1:4. It was desired to define a valid and reliable in-flight measure of pilot landing performance to quantify day and night differences in landings and visual information performance. General results showed pilots tended to approach slower and higher, and land harder and shorter by day than by night. Significant differences were found between day and night pilot altitude performance with night altitude error variability at least twice that recorded during the day. By day, approaches were consistently above glide slope while 25 percent of all night landings were below glide slope. Pilot perceptual ability and experience factors resulted in significant multiple correlations for predicting day lateral error performance.

111. BRICTSON, Clyde A., Hagen, Peter F., and Wulfeck, Joseph W., Measures of Carrier Landing Performance under Combat Conditions, Dunlap and Associates, Inc., Santa Monica, CA, Contract No. Nonr-4984(00), sponsored by Office of Naval Research, Washington, DC 20360, June 1967, 114 pp. AD 654563.

SUBJECTS: Numerous Navy jet pilots.

EQUIPMENT: A-3, A-4, A-5, A-6, and F-4 aircraft.

SCENARIO: Carrier approach and landing under all weather conditions.

MEASURES: Approach glideslope error (variance), vertical velocity, airspeed, ratio of successful carrier arrestments to landing attempts (boarding rate), and ratio of bolters to landing attempts (bolter rate).

SUMMARY: The purpose of this research was to collect and compare empirical measures of day and night carrier landing performance for five types of jet aircraft under combat conditions in order to provide landing performance criteria for the design and evaluation of visual landing aids. It was concluded that the performance measurement system as described above would provide an objective evaluation of existing or proposed visual landing aids.

112\. SECKEL, E., and Miller, G.E., Flight Evaluation of the Effect of Approach Speed on Pilot Performance, Princeton University, Princeton, NJ, 08540, Contract No. NONR-1858-50, sponsored by Naval Air Systems Command, Washington, DC, Princeton University Report No. 831, April 1969, 46 pp., AD 691290.

SUBJECTS: 8 U.S. Navy test pilots.

EQUIPMENT: Princeton Variable Stability Navion (PVSN) airplane (dual controlled).

SCENARIO: Carrier approach and landing.

MEASURES: Landing height (at ramp) and landing touchdown distance (to ramp). Measurements were determined by photographing the approaches. Transformations include means and standard deviations.

SUMMARY: The purpose of this investigation was to determine the effects of approach speed on handling qualities, approach, and touchdown performance with a minimum influence of aircraft dynamics or structural considerations. Conditions evaluated were approach speed (95, 110 and 125 knots) and dynamic response (simulated turbulence). The results indicated the mean height at the ramp and the touchdown distance increase with approach speed. Standard deviation measures did not show a similar trend. No conclusive correlation of carrier landing accident rate with approach speed could be formulated from the data.

113. BRICTSON, Clyde A., Ciavarelli, Anthony P., and Wulfeck, Joseph W., "Operational Measures of Aircraft Carrier Landing System Performance," Human Factors, v. 11(3): p. 281-290, June 1969. Original report is AD 689940. See also Proceedings, Annual AGARD Symposium for Measurement of Aircrew Performance, Brooks AFB, TX, AGARD CP. No. 56, May 1969, p. 7-1 to 7-11, AD 699934.

SUBJECTS: Numerous Navy jet pilots.

EQUIPMENT: A-3, A-4, A-5, A-6, F-4 and F-8 aircraft.

SCENARIO: Carrier approach and landing.

MEASURES: Approach glideslope error, approach centerline error, vertical velocity at the ramp, landing result (arrestment wire), ratio of successful carrier landings to landing attempts (boarding rate), and ratio of bolters to landing attempts (bolter rate).

SUMMARY: This article reviews three years of human factors research on carrier landing system performance in day and night environments. Approximately 1,800 recoveries were recorded for experienced and inexperienced pilots across four aircraft carriers under various environmental conditions. General results indicated several differences in day and night recoveries exist. Greater variability in altitude error, increased altitude performance dispersion at selected ranges, and greater percentage of aircraft flying below glide slope were found at night. Lateral error was found to be the same for both day and night final approaches. The "probability of successful recovery" was established empirically from performance envelopes. The article concludes that the major difference between day and night carrier approach performance was found in altitude error control.

114. KNOOP, Patricia A., and Welde, William L., Automated Pilot Performance Assessment in the T-37: A Feasibility Study, Air Force Human Resources Laboratory, Advanced Systems Division, AFHRL/AS, Wright-Patterson AFB, OH 45433, AFHRL-TR-72-6, April 1973, 463 pp., AD 766446. See also Human Factors, v. 15(6): p. 583-597, December 1973.

SUBJECTS: 4 instructor pilots and 16 student pilots.

EQUIPMENT: T-37B aircraft.

SCENARIO: Aerobatics including lazy 8 and barrel roll.

MEASURES: Basically, 24 flight and engine parameters were digitally recorded by special instrumentation. They included heading, altitude, airspeed, pitch angle, roll angle, vertical acceleration (g force), pitch, roll and yaw rates, lateral and longitudinal (control) stick position, rudder position, left and right engine RPM, left and right throttle position, flap position, landing gear position, speed brake position, thrust attenuator switch in/out, elevator trim tab up or down, time and record number. Parameters were sampled at rates of 10 or 100 per second. Computed parameters were vertical velocity, turn rate, longitudinal and lateral control stick rate, roll rate, yaw rate, pitch rate, and rudder rate.

SUMMARY: The purpose of this study was to develop a capability for quantification and assessment of in-flight pilot performance of undergraduate pilots. An automated, objective performance measurement system with characteristics of reliability, validity, and sensitivity was developed to overcome the traditional disadvantages associated with subjective ratings of a pilot trainee's performance by the instructor pilot. Results indicated that lazy 8 performance assessment can be accomplished using the flight parameters of roll angle, pitch angle, and airspeed. Barrel roll measurement is dependent upon roll angle, pitch angle, acceleration (g force) and roll rate. Criterion values for the two maneuvers were developed by utilizing task analysis data, narrative descriptions, and recorded in-flight maneuver performance of a highly qualified instructor pilot.

115. GEISELHART, Richard, Schiffler, Richard J., and Ivey, Larry J., *A Study of the Task Loading Using a Three Man Crew on a KC-135 Aircraft*, Aeronautical Systems Division, Wright-Patterson AFB, OH 45433, ASD-TR-76-19, October 1976, 47 pp., AD A044257.

SUBJECTS: 3 crews; each consisting of a pilot, copilot and boom operator.

EQUIPMENT: KC-135 aircraft with dual Inertial Navigation System (INS).

SCENARIO: Tanking operations including cell, high latitude, coronet and Emergency War Order (EWO)/Mission Change.

MEASURES: Crew task load data was collected by taped communications and timed events of the crew. Checklist items omitted were noted. The timed events resulted in percentage of time devoted to various functions (radar, outside aircraft, INS, radio, other).

SUMMARY: A series of flight tests were conducted to assess the feasibility of reducing the crew size on a KC-135 from 4 to 3. Crew performance during air refueling operations was assessed using questionnaires and in-flight observations of crew members. The test indicated that on several types of operational refueling missions, a three-man crew composition leads to extremely high crew workloads, resulting in a deletion of many copilot duties.

116. GUNNING, David, and Manning, Michael, The Measurement of Aircrew Task Loading During Operational Flights, Proceedings of the 24th Annual Meeting of the Human Factors Society, Los Angeles, CA, October 1980, p. 249-252.

SUBJECTS: 4 crews of 3 crewmembers each (pilot, copilot and navigator).

EQUIPMENT: KC-135 aircraft and a Datamyte Data Recorder.

SCENARIO: Takeoff, climb, straight and level, aerial rendezvous, air-to-air refueling, descent, and landing.

MEASURES: Pilot activity was dichotomized into monitoring or active tasks. Event times were recorded. Task loading was then computed as time of task execution (percentage) spent on each task.

SUMMARY: The purpose of this study was to investigate the feasibility of measuring in-flight aircrew task loading by the use of a device developed to perform time studies and activity analyses. Each crewmember was observed for two minutes at six-minute intervals during the flights. The technique produced useful data describing crewmember activity and illustrating causes of high task loading.

117. HASBROOK, A. Howard, and Rasmussen, Paul G., In-Flight Performance of Civilian Pilots Using Moving-Aircraft and Moving-Horizon Attitude Indicators, Federal Aviation Administration, Oklahoma City, OK 73125, FAA-AM-73-9, June 1973, 21 pp., AD 773450.

SUBJECTS: 32 pilots.

EQUIPMENT: Beech T-34 aircraft.

SCENARIO: Recovery from unusual attitudes and descending turns.

MEASURES: Means of; number of control reversals, rate of recovery, times to recover, rates of pitch movement, range of excess pitch change during recovery, rates of pitch correction, rates of ranges of pitch changes, and rates of ranges of pitch attitude (during descending turns).

SUMMARY: The purpose of this experiment was to evaluate two attitude indicators by measuring in-flight performance of pilots during typical instrument flying maneuvers. The experimental conditions were indicator (inside-out or moving horizon and outside-in or moving aircraft) and pilot experience level (low or high time). The results differed from previous ground studies which used the same concepts of attitude presentation but did agree in the result of low time pilots exhibiting a narrower range of pitch excursions with the outside-in (moving aircraft) attitude indicator than they did with the inside-out (moving horizon) indicator. This study failed to show any well defined overall advantage between the two indicators.

118. ROSCOE, Stanley N., and Williges, Robert C., "Motion Relationships in Aircraft Attitude and Guidance Displays: A Flight Experiment," Human Factors, v. 17(4): p. 374-387, August 1975.

SUBJECTS: 16 nonpilots.

EQUIPMENT: Beechcraft C-45H airplane.

SCENARIO: Tracking task (disturbed attitude), recovery from unusual attitude, and a tapping task (perceptual-motor workload).

MEASURES: Horizontal tracking error (standard deviation), number of control reversals, and correct control responses.

SUMMARY: The purpose of this experiment was to investigate the effect of visual and vestibular cues in evaluating aircraft attitude presentations. Experimental conditions were attitude presentations (moving horizon, moving airplane, frequency-separated, and kinalog) and flight-director displays (compensatory or pursuit steering guidance). For all attitude presentations, pursuit tracking was superior to compensatory tracking and the order of merit of the four attitude presentations in flight casts doubt upon the validity of previous simulator experiments. It was concluded that the principle of display frequency separation provides at least equivalent pilot steering performance to that obtained with the conventional moving horizon format, while the anticipatory cues it affords tends to reduce the incidence of control reversals under circumstances of subliminal angular acceleration by providing initial direction-of-motion compatibility.

119. BILLINGS, Charles E., Foley, Mary F., and Huie, Charles R., "Physiologicl Effects of Induced Hypoxia During Instrument Flying," Aerospace Medicine, v. 35: p.550-553, June 1964.

SUBJECTS: 20 pilots.

EQUIPMENT Piper "Apache" twin-engine light airplane.

SCENARIO: Straight and level, turns, decelerations, descents, climbs, and an instrument approach.

MEASURES: Means, standard deviations and standard errors of ventilation (respiration), oxygen uptake, and respiratory exchange ratio.

SUMMARY: The purpose of this experiment was to study the metabolic cost of piloting light military and civil aircraft and to examine any tendency of hyperventilation under the combined stress of mild hypoxia and a difficult simulated instrument flying task. Each subject was exposed to four oxygen-nitrogen mixtures providing tracheal oxygen tensions equivalent to those obtained breathing air at sea level, 7,000, 10,000, and 13,000 feet pressure altitude. It was found that the average metabolic cost of performing the simulated approach was approximately 53 percent in excess of the resting oxygen uptake under each condition. Ventilation and respiratory exchange ratios increased as tracheal oxygen tension was reduced, and performance of the task did not tend to prove hyperventilation.

120. HOWITT, J.S., Flight-Deck Workload Studies in Civil Transport Aircraft, Proceedings, Annual AGARD Symposium for Measurement of Aircrew Performance, Brooks AFB, TX, Advisory Group for Aerospace Research and Development, Paris, France, AGARD CP No. 56, May 1969, p. 1-1 to 1-8, AD 699934.

SUBJECTS: Numerous airline pilots.

EQUIPMENT: Various fixed-wing airline jets including the Boeing 707.

SCENARIO: Pilot workload over short periods of time (immediate), e.g., take-off or landing, the entire day (duty-day), and long-term (sequences of days).

MEASURES: For immediate workload, heart rate (ECG) for arousal level and audio recording of significant events (communication). For duty-day workload, urine samples were taken. For long-term workload, time of sleep and work periods were recorded.

SUMMARY: The purpose of this study was to study the effect of the total flying environment on the individual. Results indicated that work could be divided into three distinct areas; immediate, duty-day and long-term workload. For immediate workload, physiological measures provide a reasonable assessment but more research is needed. For duty-day workload, no objective measure was found but a subjective estimate of fatigue is a useful alternative. Long-term workload was measured by sleep patterns in providing valuable information regarding optimum duty sequences.

121. LEES, Michael A., Glick, David D., Kimball, Kent A., and Snow, Allen C. Jr., In-Flight Performance with Night Vision Goggles During Reduced Illumination, U.S. Army Aeromedical Research Laboratory, Fort Rucker, AL 36362, USAARL Report No. 76-27, August 1976, 36 pp., AD A031991.

SUBJECTS: 6 military pilots.

EQUIPMENT: Army JUH-1H helicopter and 40 degree field-of-view (FOV) night vision goggles (NVG'S).

SCENARIO: Stationary three-foot hover.

MEASURES: Utilized Helicopter In-Flight Monitoring System (HIMS) as described in USAARL Report No. 72-11. See article no. 138 for a complete listing of measured and derived variables. Variables selected for analysis (due to equipment malfunction) consisted of pitch (mean [$\bar{X}$], standard Deviation [S], average absolute error [AAE], root mean square [RMS] error, maximum [U], and minimum [L]), roll ($\bar{X}$, S, AAE, RMS error, U, L), heading ($\bar{X}$, S, AAE, RMS error, U, L), and navigational accuracy; X-position ($\bar{X}$, S, AAE, RMS error, U, L) and Y-position ($\bar{X}$, S, AAE, RMS error, U, L).

SUMMARY: This experiment examined man-helicopter system performance across several levels of reduced illumination utilizing NVG's. Because of considerable variability between sets of goggles and conductance of the work at the low side of NVG's capability the results were presented with caution not to generalize to all sets of NVG's. It was concluded that system performance significantly improves over several bands of illumination, but further research is required to provide a more precise demonstration of exactly what level of illumination is required for optimal system performance.

122. LEES, Michael A., Kimball, Kent A., and Stone, Lewis W., The Assessment of Rotary Wing Aviator Precision Performance During Extended Helicopter Flights, Proceedings of the 21st Annual Meeting of the Human Factors Society, p. 426-430, November 1977. Part of article no. 146.

SUBJECTS: 6 pilots.

EQUIPMENT: UH-1H helicopter.

SCENARIO: Stationary hovering task at 3 feet.

MEASURES: Obtained by Helicopter In-flight Monitoring System (HIMS). See article no. 138 for a complete listing of measured and derived variables. Twenty-eight variables were determined to be the most relevant in determining the effects of fatigue on pilot control performance. Eight variables that described changes in the aircraft's stability were derived from measured changes in pitch, roll and yaw axes.

SUMMARY: This report describes changes in aviators' precision hovering skills during five days of extended flight. Results showed the most stable hover performance was observed during the second flight day, with decrements in performance measured by increasing control inputs occurring during subsequent days. Control technique by pilots on the fourth day shifted from active control to one of observed error response.

123. SANDERS, Michael G., Burden, Raymond T. Jr., Simmons, R.R., Lees, M.A., and Kimball, R.A., An evaluation of Perceptual-Motor Workload During a Helicopter Hover Maneuver, U.S. Army Aeromedical Research Laboratory, Fort Rucker, AL 36362, USAARL Report No. 78-14, May 1978, 21 pp., AD A058016.

SUBJECTS: 9 U.S. Army helicopter pilots.

EQUIPMENT: JUH-1H helicopter equipped with a "ministab."

SCENARIO: Hover at 30 feet for 5 minutes under; 1) normal VFR, 2) use of force trim, and 3) use of ministab.

MEASURES: Utilized Helicopter In-Flight Monitoring System (HIMS) as described in USAARL Report No. 72-11. See article no. 138 for a complete listing of measured and derived parameters. Parameters utilized were standard deviations of pitch, roll, heading, and radar altitude, in addition to cyclic, collective and pedal control inputs. Multivariate analyses were performed on the measures.

SUMMARY: The purpose of this research was to examine a method of aiding helicopter MEDEVAC pilots in performing a hover maneuver while perhaps reducing workload. The method uses a modular, four-axes stability augmentation system (Ministab) with integrated rate altitude and heading retention. Results indicated the method using the ministab did not provide a clear-cut improvement in flight performance and workload across all flight parameters.

124. STONE, Lewis W., Sanders, Michael G., Glick, David G., Wiley, Roger W., and Kimball, Kent A., *Night Vision Goggles and In-flight Evaluation of the Inside/Outside Refocusing Problems in a UH-1H Helicopter*, Proceedings of the 22nd Annual Meeting of the Human Factors Society, Detroit, MI, October 1978, p. 230-234.

SUBJECTS: 8 U.S. Army helicopter pilots.

EQUIPMENT: JUH-IH helicopter and AN/PVS-5 Night Vision Goggles (NVG).

SCENARIO: Hovering (ten feet above ground) at night.

MEASURES: Utilized Helicopter In-Flight Monitoring System (HIMS) as described in USAARL Report No. 72-11. See article no. 138 for a complete listing of all measured and derived parameters. For this scenario, measures used were radar altitude (mean [$\bar{X}$] and standard deviation [S]), pitch (S), roll (S), heading (S), cyclic fore-aft control movements ($\bar{X}$ and absolute number per second [ANPS]), cyclic left-right control movements ($\bar{X}$ and ANPS), and pedals ($\bar{X}$ and ANPS).

SUMMARY: The purpose of this experiment was to evaluate three configurations of the NVGs at night using experienced pilots in a hovering maneuver. The experimental conditions were visual (four) and NVG configuration (focus at infinity, bifocal with 14 percent focus at 22 inches, and bifocal with 24 percent focused at 22 inches). Results showed no significant difference among configurations in terms of control movements. Radio measured altitude had large variability with the focus at infinity but stabilized under the bifocal configurations.

125. BARNES, John A., A Review of Individual Performance in Air-to-Ground Target Detection and Identification Studies, U.S. Army Human Engineering Laboratory, Aberdeen Proving Ground, MD 21005, Technical Memorandum 26-78, August 1978, 90 pp.

SUBJECTS: 60 U.S. Army helicopter aircrew (pilots, observers, and gunners).

EQUIPMENT: AH-1 and OH-58 helicopters.

SCENARIO: Target detection and identification.

MEASURES: Number of correct target identifications, slant range at target detection (mean), single glance dwell and fixation times, maximum dwell time, probability of target detection, detection time (mean), identification range (mean), identification time (mean).

SUMMARY: This document is a review of the individual performances of the skilled aviators who participated in the US Army Human Engineering Laboratory Target Acquisition, Camouflage Application and Identification Friend or Foe tests and the Modern Army Selected Systems Evaluation Test, Evaluation, and Review Cobra/Tow Follow-On Evaluation.

One of the most interesting findings of this micro look into individual subject's performance came from the HELCAT and HELIFF eye-movement records. These data showed a considerable difference in the target detection times recorded by the different subjects. Yet, the eye fixations indicated that there was a spread of only a few seconds between the actual visual detections of the targets. The large differences in recorded detection times seemed to be due to each individual's decision making process as shown by the amount of time they spent fixating on the target before reporting the detection.

The major factors that affect the pilot/observer's detection performance against stationary targets were statistically determined. Twenty-five factors were investigated and six were found to be significant; they were the relative bearing between the aircraft and the target, the aircraft's height above the ground, the size of the target, the contrast between the target and its ground, the distance to the target, and the ambient light available.

When moving targets are considered, there are the additional factors of movement and any smoke or dust that is generated. Thus, if one is high enough above the ground and the moving target is well illuminated and contrasts greatly with the ground, there will be no trouble in detecting it at extended ranges within the visual capabilities of the eye. Little difference was found in the amount of time individuals spent fixating on any one item during a search for targets until they find the target; the time was 1/2 second and ± 1/4 second.

The personal statistics of the subjects were correlated with their performance data to determine if any of these would be predictors of target detection performance. There was no correlation between performance in any of these factors. This indicates that the training programs were such that the pilot/observers are at comparable skill levels across subjects and across tactical units. It was found that the mean age of our pilot/observer populations was remaining constant, that is, the mean age of the subjects changed as the year of the test changed. For example, the mean age for the 1976 test was 30; the mean age for the 1972 test was 26.

It was found that the night vision goggles were a necessary item for night target detection. They appeared to be more effective when used with a stationary aircraft as in the pop-up maneuver than when used on the move as in the route reconnaissance work; the subjects only made one detection in 20 trials without the goggles and 13 detections with them.

The identification of targets as friend or foe (IFF) phase of the testing produced one perfect score and 19 of lesser accuracy. The perfect score was tempered by some short observer-to-target ranges; the minimum range was 466 meters. There was a problem of previous misinformation that hampered the subjects who had participated in Reforger 1976. They said that they had been instructed that all of our allies would have US equipment; therefore, if it was not recognized as US, it was enemy and should be fired upon. Without this bias it is possible that these individuals might have had better IFF scores. It can only be surmised that these instructions were meant for the exercise only, but were misunderstood by the individuals and applied to all situations. The overall mean IFF score was 75 percent correct identification. (Modified Author)

126. MORELAND, Stephan, and Barnes, John A., *Exploratory Study of Pilot Performance during High Ambient Temperatures/Humidity*, Proceedings, Annual AGARD Symposium for Measurement of Aircrew Performance, Brooks AFB, TX, Advisory Group for Aerospace Research and Development, Paris, France, AGARD CP No. 56, May 1969, p. 12-1 to 12-24, AD 699934.

SUBJECTS: 4 pilots.

EQUIPMENT: OH-6A light helicopter.

SCENARIO: Precision flight pattern (level flight, standard rate turns), ground target identification, and audio response/reaction.

MEASURES: During the precision flight pattern, performance criteria were established as heading (plus or minus 5 degrees), altitude (plus or minus 50 feet), airspeed (plus or minus 5 knots), and timed turns of 3 degrees per/sec within plus or minus 2 seconds accuracy. An ECG (electrocardiographic) recorder showed heart rate. Body temperature was measured by skin and rectal devices. Perspiration weight loss was determined by weight before and after flight. In addition, reaction time to an audio response was measured in seconds along with number of correct target identifications. Measurement of performance was reduced to:

P_1 = 100-abs(80-A/S)-abs(1100-alt)-abs(hdg error)-abs(torque).

SUMMARY: The objective of this study was to determine if changes in pilot physiological and psychological performance could be detected and correlated with changes in relatively high crew station ambient temperature, humidity, and solar radiation and to also quantitatively assess the pilot's wearing complete combat flight clothing and survival equipment operating in a hot, humid environment. It was concluded that the techniques used during this study did succesfully measure both a large portion of total pilot performance and the cockpit environment. If environmental variables can be accounted for and correlated, the basic approach of inflight measurement of human performance certainly offers the potential of obtaining realistic assessments of new crew station designs and may be the best approach to developing the type of quantified information needed to develop crew station design criteria and standards.

127. **BYNUM, J.A.,** Smart, E.E., Sanborn, F.A., and Matheny, W.G., **Test of a Model of Visual Spatial Discrimination and Its Application to Helicopter Control**, Life Sciences, Inc., **Hurst, TX 76053,** sponsored by U.S. Army Medical Research and **Development Command,** Washington, DC 20314, **LSI-TR-74-1, June 1974, 49 pp., AD A002624.**

SUBJECTS: 4 college students (LAB 1), 6 college students (LAB 2), 6 instructor pilots (Field 1), and 4 instructor pilots (Field 2).

EQUIPMENT: Slide projector display (LAB 1), CRT (LAB 2), and Bell Model 47-J2 Ranger helicopter.

SCENARIO: Stationary hovering task at 3 feet (Field) and visual discrimination performance (LABs).

MEASURES: Deviations from ideal hover point in each of the three translational degrees of freedom as measured by 16 mm movie cameras every two seconds. These deviations were navigational positon; lateral, fore-aft and altitude components transformed by the mean, standard deviation, average deviation about the mean, and average deviation about the standard. Laboratory measures for scene displacement were dichotomous responses categorized as "hits" or "false alarms" (LAB 1). Observer response to an event (dot displacement) was recorded for the CRT experiment (LAB 2).

SUMMARY: This report describes two field studies (Field 1 and Field 2), which tested pilots' abilities to maintain hover control of a helicopter when the visual field was restricted and when referents were specified. Results showed the ability to maintain hover control depended upon the area of the windscreen obscured and on the proximity of the referents. Two laboratory studies (LAB 1 and LAB 2) also were conducted which tested observers' abilities to detect small displacements in one of a pair of stimulus dots on a CRT display and displacements of "real-world" visual scenes when only the scene and/or observer moved in the pitch dimension. Results showed that a small movement of the pilots eye position aided detection of small scene displacements and that ability to detect displacement of a moving dot depends on the direction of movement relative to the stationary dot.

128. LEES, Michael A., Sanders, Michael G., Burden, Raymond T. Jr., and Kimball, Kent A., In-Flight Performance Evaluation of Experimental Information Displays, U.S. Army Aeromedical Research Laboratory, Fort Rucker, AL 36362, USAARL Report No. 79-8, May 1979, 28 pp., AD A071701.

SUBJECTS:	4 U.S. Army helicopter pilots.
EQUIPMENT:	JUH-1H helicopter and AN/PVS-5 night vision goggles.
SCENARIO:	Hover at 30 feet for 2 minutes, straight and level, and level turns.
MEASURES:	Utilized Helicopter In-Flight Monitoring System (HIMS) as described in USAARL Report No. 72-11. See article no. 138 for a complete listing of measured and derived parameters. Parameters utilized were heading error (standard deviation [S], average constant error [ACE], average absolute error [AAE], and root-mean-square [RMS] error), radar altimeter error (S, ACE, AAE, and RMS error), and airspeed error (S, ACE, AAE, and RMS error).
SUMMARY:	The objective of this study was to evaluate a method of displaying information for rapid transmission of flight data to the operator. Viewing conditions were day with unaided eye, night with unaided eye, and night with AN/PVS-5 night vision goggles (NVG's). Several prototype displays were used inside the cockpit as dependent variables. Results indicated the prototype displays have potential for improving mission performance, reducing errors, and providing adequate information across the three lighting conditions.

129. FREZELL, Thomas L., Hofmann, Mark A., Snow, Allen C., and McNutt, Richard P., Aviator Visual Performance in the UH-1-Study II, U.S. Army Aeromedical Research Laboratory, Fort Rucker, AL 36360, USAARL Report No. 75-11, March 1975, 46 pp., AD A007812.

SUBJECTS: 7 Helicopter Pilots.

EQUIPMENT: UH-1 helicopter and a modified EYE NAC Mark Recorder.

SCENARIO: Takeoff, hovering, and landing touchdown.

MEASURES: Utilized Helicopter In-Flight Monitoring System (HIMS) as described in USAARL Report No. 72-11. See article no. 138 for a complete listing of measured and derived parameters. Parameters utilized were absolute values of cyclic fore-aft, cyclic left-right, collective, pedals and roll. Physiological measures obtained were EMG's of the forearm muscle complex and ECG's. Eye movements examined were total time (sec), total number of sectors viewed, number of sector transitions, percent of time spent outside the aircraft, and percent of time spent inside the aircraft.

SUMMARY: The purpose of this investigation was to measure visual and psychomotor performance during incline or slope landings. The pilots visual field was divided into thirteen visual sectors (8 windscreen, 2 chin bubble, 2 side door, and 1 inside cockpit). Results for the EYE NAC recorder indicated that for incline operations, 98.2 percent of visual time is spent outside the cockpit area, supporting the assumption that visual eye information is provided at fairly close ranges. Results of the HIMS control movement data indicated that the controls per unit time for the touchdown were on the order of that found earlier in more demanding Nap-of-the-Earth (NOE) flights.

130. SMIT, J., and Wewerinke, P.H., An Analysis of Helicopter Pilot Control Behaviour and Workload During Instrument Flying Tasks, National Aerospace Laboratory (NLR), The Netherlands, NLR-MP-78003-U, February 1978, 11 pp., AD B031007.

SUBJECTS: 4 military pilots.

EQUIPMENT: Modified Alouette III helicopter.

SCENARIO: Instrument hovering and navigation (tracking).

MEASURES: Physiological variables were heart rate (ECG; beats per minute, root mean square [RMS] successive difference, average band power), respiration frequency, and skin resistance (GSR; level, response). Control activity variables were longitudinal and lateral cyclic control inputs (RMS values), pedal control inputs (RMS values) and collective pitch control inputs (RMS values). Other variables measured were altitude deviation, airspeed, lateral velocity and cross-track error.

SUMMARY: The purpose of this experiment was to develop a mathematical model to describe and analyze the control behavior and attentional workload of a helicopter pilot during instrument flight. A standard sortie (30 min.) consisted of two hover tasks (3 min.) and two navigational tasks (5 min.). Results indicated a control effort model formulated in terms of an optimal control model using state-space optimization, state-space estimation and decision theory offers a suitable framework for the description of control tasks as complex as helicopter instrument flying. A relationship between performance and attention paid to the task was also developed.

131. ANDERSON, David B., and Chiou, Wun C., Physiological Parameters Associated with Extended Helicopter Flight Missions: An Assessment of Pupillographic Data, U.S. Army Aeromedical Research Laboratory, Fort Rucker, AL 36362, USAARL Report No. 77-21, September 1977, 21 pp., AD A052771.

SUBJECTS: 6 helicopter pilots.

EQUIPMENT: Unspecified helicopter and pupillometer equipment.

SCENARIO: Extended helicopter flight (unspecified maneuvers).

MEASURES: Pupil diameter, blink rate, pupillary reflex response, and amplitude of the pupillary response to light.

SUMMARY: The purpose of this study was to analyze pupil size, spontaneous pupillary movements to light during field testing, assess validity of the resulting data, and to assess the value of pupillographic measurements on the evaluation of pilot alertness. Pupillometry data was collected between flights over five days of extended flight. It was found that blinking rate increases and the pupillary amplitude varies as a function of loaded flight task. Pupillary diameter was smaller in the morning as compared to evening. The smallest average pupillary diameter was observed on the third flight day.

132. BILLINGS, Charles E., Eggspuehler, Jack J., Gerke, Ralph J., and Chase, Robert C., "Studies of Pilot Performance: II. Evaluation of Performance During Low Altitude Flight in Helicopters," Aerospace Medicine, v. 39: p. 19-31, January 1968.

SUBJECTS: 4 pilots.

EQUIPMENT: Hiller model 12-E helicopter.

SCENARIO: 4-hour power line surveillance at extremely low altitude.

MEASURES: Rotor RPM, cyclic position, collective position and throttle position were measured at prearranged geographic segments of each flight. Each variable was transformed by mean, standard deviation, integral of the deviations above and below the mean with respect to time, number of control deflections or reversals, average amplitude of reversals, average deviations during the minute, number of turn points observed, (maximum and minimum) and average magnitude of each control movement.

SUMMARY: The purpose of this study was to delineate an objective, quantitative method of evaluating pilot performance in rotary wing aircraft. Results showed rotor RPM was allowed to vary within wider limits by the pilot as flight time increased, control movements of larger amplitude increased toward the latter stages of the mission, and significant differences among pilots appeared positively correlated with previous helicopter flight experience.

133. STERN, John A., and Bynum, James A., "Analysis of Visual Search Activity in Skilled and Novice Helicopter Pilots," Aerospace Medicine, v. 41(3): p. 300-305, March 1970.

SUBJECTS: 26 pilots.

EQUIPMENT: UH-1D helicopter.

SCENARIO: Takeoff, climbs, turns, hover, straight and level, and airways navigation.

MEASURES: Number of saccadic eye movements (horizontal and vertical plane), number of eye blinks per 25-second period, and duration of longest period of no eye movement in the horizontal plane per 25-second period.

SUMMARY: The purpose of this experiment was to evaluate visual search activity of skilled and unskilled pilots while flying for approximately 50 minutes duration. The results demonstrated that skilled pilots engage in significantly more visual search activity in the horizontal plane than do novice pilots. Visual search activity also changed as a function of time on task for both groups. Changes included a decrease in blink rate and horizontal and vertical plane searching, and an increase in the amount of time not engaged in search activity per unit time.

134. SANDERS, Michael G., Simmons, Ronald R., and Hofmann, Mark A., "Visual Workload of the Copilot/Navigator During Terrain Flight," Human Factors, v. 21(3): p. 369-383, June 1979.

SUBJECTS: 10 pilots.

EQUIPMENT: UH-1H helicopter and a modified NAC Eye Mark Recorder.

SCENARIO: Low-level navigation (visual) with initial points (IPs), and a secondary visual free time task (reading random words).

MEASURES: Eye movements; dwell time (mean and percent of total time), number of exits per minute, and link values between visual area.

SUMMARY: The purpose of this experiment was to determine the amount of visual free time the navigator had available during flight over a prescribed course for a nonflight-related task. The visual area of the navigator was divided into 10 sections for analysis. Results indicated that the navigator's normal workload was demanding since the visual free time task was utilized only 3 percent of the total time. Navigation itself required 92.2 percent of the total visual time while engine and flight insturments were utilized the remaining 4 percent of the time.

135. SMITH, Bruce A., *Development and Inflight Testing of a Multi-Media Course for Instructing Navigation for Night Nap-of-the-Earth Flight*, Proceedings of the 24th Annual Meeting of the Human Factors Society, Los Angeles, CA, October 1980, p. 568-571.

SUBJECTS: 32 student pilots.

EQUIPMENT: UH-1 helicopter.

SCENARIO: Nap-of-the-Earth flight (4-km course at night).

MEASURES: Navigation position error (root-mean-square deviation left or right of course). Helicopter positon was plotted by an observation helicopter at approximately 500 feet above ground level.

SUMMARY: The purpose of this study was to investigate the development and evaluate the application of a Map Interpretation, Terrain Analysis and Navigation at Night (MITANN) program of instruction. Two control groups were used (MITANN or no course given) as well as unaided or aided (Night Vision Goggles) flight. The results showed that the group that received MITANN training navigated with significantly greater accuracy than the control group. It was concluded that MITANN provided enough of the skills necessary for successful inflight navigation with very little aircraft time.

136. BARNES, John A., and Doss, N. William, *Human Engineering Laboratory Camouflage Applications Test (HELCAT) Observer Performance*, U.S. Army Human Engineering Laboratory, Aberdeen Proving Ground, MD 21005, Technical Memorandum 32-76, November 1976, 51 pp., AD A034048.

SUBJECTS: 10 military helicopter pilots.

EQUIPMENT: OH-58 Helicopter and AN/PVS-5 Night Vision Goggles.

SCENARIO: Nap-of-the-Earth (NOE) route reconnaissance followed by a series of three or less 60-second pop-up maneuvers for air-to-ground target detection.

MEASURES: Percentage of pilot/observers who detected the camouflaged targets with mean target-detection ranges and mean detection times for each (number of correct target detections).

SUMMARY: The purpose of this report was to investigate air-to-ground target-detection aircrew performance against pattern-painted and augmented-netting camouflaged heavy tanks. The aircrew observers flew the tests under four different conditions: (1) day with no encumbrances; (2) day wearing the Eye-Mark system; (3) night with no encumbrances; and (4) night wearing the AN/PVS-5 Night Vision Goggles (NVG). It was concluded that most aircrews detect pattern-painted tanks at a mean slant range of 710.3 meters and augmented-netting tanks at a mean detection range of 319 meters. Night detections were impossible without the night-vision goggles.

137. KIMBALL, Kent A., Frezell, Thomas L., Hofmann, Mark A., and Snow, Allen C. Jr., Aviator Performance During Local Area, Low Level and Nap-of-the-Earth Flight, U.S. Army Aeromedical Research Laboratory, Fort Rucker, AL 36360, USAARL Report No. 75-3, September 1974, 27 pp. AD A001683.

SUBJECTS: 6 helicopter pilots.

EQUIPMENT: JUH-1H helicopter.

SCENARIO: Local area, low level, and Nap-of-the-Earth (NOE) flights.

MEASURES: Utilized Helicopter In-Flight Monitoring System (HIMS) as decribed in USAARL Report No. 72-11. See article no. 138 for a complete listing of measured and derived parameters. Parameters utilized were pitch (maximum [U] and minimum [L]), roll (U and L), heading (U and L), airspeed (mean and standard deviation), cyclic stick fore-aft (mean time steady states), cyclic fore-aft (mean duration control movements), collective (magnitude of control movements), and pedals (frequency of control movements).

SUMMARY: The purpose of this research was to establish baseline data concerning aviator performance and aircraft state variables during local area, low level and NOE flights. Information was provided concerning differences in control inputs per unit of time across the three flight profiles. The results obtained from the data demonstrated substantial differences among the flight profiles with NOE flight placing more demands on both crews and aircraft than the other two types of flights.

138. LEES, Michael A., Kimball, Kent A., Hofmann, Mark A., and Stone, Lewis W., *Aviator Performance During Day and Night Terrain Fight*, U.S. Army Aeromedical Research Laboratory, Fort Rucker, AL 36362, USAARL Report No. 77-3, November 1976, 30 pp., AD A034898. See also Proceedings of the 19th Annual Meeting of the Human Factors Society, Dallas, TX, October 1975, p. 436-440.

SUBJECTS: 6 pilots.

EQUIPMENT: JUH-1H Research Helicopter.

SCENARIO: Low Level (LL) and Nap-of-the-Earth (NOE) profiles.

MEASURES: Utilized Helicopter In-Flight Monitoring System (HIMS) as described in USAARL Report No. 72-11. Variables selected through cluster analysis for LL flights include cyclic fore-aft control position (mean [$\bar{X}$], standard deviation [S], absolute mean [$|\bar{X}|$], and number of instantaneous control reversals), cyclic left-right control position ($\bar{X}$, S, $|\bar{X}|$, number of instantaneous control reversals, number of control reversals, percent of total time in control steady state), collective control position ($\bar{X}$, S, number of instantaneous control reversals, number of control movements, percent of total time in control steady state), pedal control position ($\bar{X}$, S, number of instantaneous control reversals, number of control movements), pitch ($\bar{X}$, S, root mean square [RMS] error, average absolute error [AAE]), pitch rate ($\bar{X}$, RMS error), roll ($\bar{X}$, S, AAE, RMS error), roll rate ($\bar{X}$, RMS error, AAE error), heading (S, RMS error), Z-axis acceleration ($\bar{X}$, S), X-axis acceleration (S), Y-axis acceleration ($\bar{X}$, S), yaw rate (RMS error, S), and altitude ($\bar{X}$, S). Variables selected through cluster analysis for NOE flights are virtually the same as for the LL with the addition of cyclic fore-aft control position (absolute standard deviation [ISI], absolute average rate standard deviation, mean negative control movement magnitude, mean and standard deviation of negative average control movement rate), cyclic left-right control position (mean and standard deviation absolute average rate, mean positive average rate, mean and standard deviation of negative average control movement rate), collective control position (mean absolute control movement magnitude), pedal control position (I$\bar{X}$I, ISI, mean and standard deviation of positive control movement magnitude, mean and standard deviation of positive/negative average control rate), and yaw rate ($\bar{X}$).

SUMMARY: This experiment compared terrain flight during LL and NOE profiles for day and night flight using night vision goggles. Multiple discriminant analysis techniques were used to determine which measures best discriminated between visual conditions. For LL flight, air speed and frequency of small control inputs best discriminated between visual conditions. For NOE flight, severity of roll angles and frequency and magnitude of control inputs were best.

139. LITTELL, Delvin E., Energy Cost of Piloting Fixed and Rotary Wing Army Aircraft, Proceedings, Annual AGARD symposium for Measurement of Aircrew Performance, Brooks AFB, TX, Advisory Group for Aerospace Research and Development, Paris, France, AGARD CP No. 56, May 1969, p. 2-1 to 2-4, AD 699934.

SUBJECTS: 16 pilots.

EQUIPMENT: OH-6A (light helicopter), UH-1D (utility helicopter), CH-47A (medium helicopter), and U-6A (utility fixed wing).

SCENARIO: Take-off, level flight, hover, holding pattern, descent, and landing.

MEASURES: Energy expenditures were calculated from respiratory expiration minute volume and expired air oxygen content measurements made under basal conditions and during normal flight duties of pilots. An electrocardiograph (ECG) recorded heart rate (number of QRS complexes during 12-second time intervals).

SUMMARY: The purpose of this experiment was to investigate the energy cost of piloting three types of military helicopters and one utility fixed wing aircraft. The data indicated that for level flight in good weather, the energy cost must be classed as very light work, averaging 1.79 Kcal/minute. In three of the four aircraft, the pilot's energy expenditure was greater when ground contact was possible.

140. BILLINGS, Charles E., Bason, Robert, and Gerke, Ralph J., "Physiological Cost of Piloting Rotary Wing Aircraft," Aerospace Medicine, v. 41(3): p. 256-258, March 1970.

SUBJECTS: 4 pilots.

EQUIPMENT: Hiller model UH-12E and UH-12EL helicopters.

SCENARIO: Takeoff, turns, hovering, straight and level, approach, and landing.

MEASURES: Respiration; metabolic rate (aliquots from expired air were analyzed for oxygen and carbon dioxide concentrations). Heart rate (ECG) was also measured.

SUMMARY: This report describes metabolic rates and heart rates during selected maneuvers in helicopters. The experimental conditions were pilots (experienced or inexperienced) and helicopters (boosted controls or nonboosted controls). Results showed heart rates were lower in the boosted control helicopter (12EL) but metabolic rates were identical in both aircraft. No significant differences between pilot groups was apparent. The hovering maneuver exhibited the highest metabolic rate and was accompanied by heart rates of approximately 100 beats per minute.

141. BILLINGS, Charles E., Gerke, Ralph J., Chase, Robert C., and Eggspuehler, Jack J., "Studies of Pilot Performance: III. Validation of Objective Performance Measures for Rotary-Wing Aircraft," Aerospace Medicine, v. 44(9): p. 1026-1030, September 1973.

SUBJECTS:	7 pilots and 2 nonpilots.
EQUIPMENT:	Hiller model 12E helicopter.
SCENARIO:	Hovering, taxiing, approaches during standard rectangular patterns, rapid decelerations, quickstops, and autorotations.
MEASURES:	Primarily engine velocity variability (RPM variability) estimated by engine RPM (standard deviation).
SUMMARY:	The purpose of this study was to validate previous findings of objective and quantitative indicators of performance in rotary-wing and fixed-wing aircraft. It was found that engine (or rotor) velocity variability, as a measure of pilot performance, delineates differences between instructor pilots, differences between instructors and their students, differences among various scenarios, and sequential changes occurring in the course of flight instruction. It was further concluded that engine RPM variability is a valid index of pilot skill in helicopters in which this variable is under direct control of the pilot, and that it may appropriately be used as a partial index of the effects of stress upon pilot performance.

142. FREZELL, Thomas L., Hofmann, Mark A., and Oliver, Richard E., Aviator Visual Performance in the UH-1H. Study I, U.S. Army Aeromedical Research Laboratory, Fort Rucker, AL 36360, USAARL Report No. 74-7, October 1973, 120 pp., AD A032857.

SUBJECTS:	6 U.S. Army helicopter pilots.
EQUIPMENT:	UH-1 helicopter and a modified EYE NAC Mark Recorder.
SCENARIO:	Takeoff, climbs, hovers (stabilized, forward, rearward, sidewards, and turns), approach to hover, and approach to landing.
MEASURES:	Utilized Helicopter In-Flight Monitoring System (HIMS) as described in USAARL Report

No. 72-11. See articles 138 and 129 for a complete listing and specific parameters utilized, respectively, for this experiment. Questionnaires were utilized to collect subjective data on visual information requirements.

SUMMARY: The object of this investigation was to provide information concerning areas of the windscreen not often used by the aviator while flying a number of maneuvers under VFR conditions. The pilots visual field was divided into thirteen visual sectors (8 windscreen, 2 chin bubble, 2 side door, and 1 inside cockpit). Results are given in terms of time and transition data of each sector for each maneuver.

143. BARNES, John A., Tactical Utility Helicopter Information Transfer Study, U.S. Army Aberdeen Research and Development Center, Aberdeen Proving Ground, MD 21005, Technical Memorandum 7-70, March 1970, 96 pp., AD 705594.

SUBJECTS: 11 pilots.

EQUIPMENT: UH-1B helicopter.

SCENARIO: Hovering (spot in/out of ground effect with/without visual references, and 360 degree turn out of ground effect), climbs (vertical, from hover, and 500 feet per minute at 60 or 100 knots), descents (vertical, approach and 500 feet per minute at 60 or 100 knots), straight and level (60 or 100 knots visual or instruments), turns (standard rate at 60 or 100 knots), reverse direction of flight (60 or 100 knots), terrain following (100 knots), and descending turns (180 degrees at 100 knots).

MEASURES: Utilized an eye-movement camera to record eye fixations as a measure of the estimated time spent using each cockpit instrument.

SUMMARY: The object of this research was to analytically determine the information needs of the flight crew of a tactical utility helicopter which could be satisfied by basic flight instrumentation. It was shown what basic flight information the UH-1 pilot felt he needed to perform specific manuevers and what instruments he used to obtain this information. The instruments pilots actually used in flight and the amount of time spent using the instruments during each maneuver was also determined. A need for certain information not now available with present instrumentation was indicated.

144. SIMMONS, Ronald R., Lees, Michael A., and Kimball, Kent A., *Visual Performance/Workload of Helicopter Pilots During Instrument Flight*, U.S. Army Aeromedical Research Laboratory, Fort Rucker, AL 36362, USAARL Report No. 78-6, January 1978, 77 pp., AD A055424.

SUBJECTS: 10 helicopter pilots of which 5 were instrument instructors.

EQUIPMENT: JUH-1H helicopter and a NAC Eye Mark Recorder.

SCENARIO: Flight under instrument flight rules (IFR); instrument takeoff, climb, cruise, descent, climbing turn, descending turn, level turn and instrument landing system (ILS) approach.

MEASURES: Utilized Helicopter In-Flight Monitoring System (HIMS) as described in USAARL Report No. 72-11. See article no. 138 for a complete listing of measured and derived variables. The following measures were derived from HIMS; cyclic fore/aft and left/right (standard deviation [S], movement per second, and percent of steady state), collective (S, movement per second, and percent of steady state), pedals (S, movement per second, and percent of steady state), pitch (S), turn rate (S), vertical velocity (S), heading (S), altitude (S), and airspeed (S). Oculomotor behavior was collected at 16 data points per second and resulted in thirteen areas selected which best described the pilots' visual performance. Basic and derived visual measures were fixation (stationary eye movement for at least 100 milliseconds, number (sum of fixations), time (sum of time spent fixated), link values (visual path from one area to another), dwell time (mean time fixated per area), percent of time (lapse time during a maneuver which was allotted to each area), percent of number (fixations during a maneuver allotted to each area), and scan rate (rate each area was fixated).

SUMMARY: The purpose of this investigation was to measure the visual performance of helicopter pilots during IFR conditons in an attempt to acquire a data base for comparing performance under simulated IFR, visual flight rules (VFR), night, and nap-of-the-earth flights. The results indicated that pilot subjective opinion does not agree with objective data, the attitude indicator and radio compass comprised over 60 percent of the pilots' total visual workload, and aircraft status gauges were monitored less than 10 percent of the total time.

145. GASPARIAN, Richard G., Helicopter Pilot Workload Evaluation, USAF Instrument Flight Center, Randolph AFB, TX 78148, USAFIFC TR-78-2, May 1978, 84 pp., AD A057666.

SUBJECTS: 10 highly experienced helicopter pilots.

EQUIPMENT: TH-1F helicoter.

SCENARIO: Three flight profiles (airways navigation) consisting of climb, interception of an outbound radial, arcing with constant DME, straight and level, turns, descent, deceleration, maintaining course, TACAN approach, climbing turns, descending turns, and autorotation under visual and instrument (hooded) conditions.

MEASURES: The following parameters were maintained for 5 seconds or more to be considered a steady state condition; vertical velocity (plus or minus 200 fpm), roll angle error (plus or minus 5 degrees), altitude error (plus or minus 100 ft), airspeed error (plus or minus 10 kts), and CDI error (plus or minus 1 dot). Other parameters measured were pitch attitude, heading deviation, DME, heartrate (ECG) and urinalysis samples. Activity measures taken were cyclic pitch position, cyclic roll position, collective position and tail rotor position for every second. Steady state criteria of one second was established for the activities, and a Control Frequency Index (CFI) was derived for the four controls. A Performance Activity Ratio (PAR) was defined as the percent time the performance was not "Hi Qual" and multiplying this value by CFI of the associated control, then subtracting this value from the percent of time the performance was "Hi Qual".

SUMMARY: The experimental objective was to determine the level of pilot stress encountered by evaluating the changes in pilot performance, control activity, and biochemical changes that occurred during increasing flight difficulty. As a result of an incomplete data base in all parameters, no definite conclusions were made concerning short duration helicopter pilot workload and stress analysis. Subjective results were that pilots tended to accept a greater range of performance standards for simple tasks and would increase concentration effort by tightening up their own performance standards as task difficulty increased. Pilots were able to accomplish a difficult task while expending a minimum amount of energy.

146\. LEES, Michael A., Stone, Lewis W., Jones, Heber D., Kimball, Kent A., and Anderson, David B., The Measurement of Man-Helicopter Performance as a Function of Extended Flight Requirements and Aviator Fatigue, U.S. Army Aeromedical Research laboratory, Fort Rucker, AL 36362, USAARL Report No. 79-12, July 1979, 68 pp., AD A074541. See also Proceedings of the 21st Annual Meeting of the Human Factors Society, October 1977, p. 426-430.

SUBJECTS: 6 U.S. Army helicopter pilots.

EQUIPMENT: JUH-1H helicopter.

SCENARIO: Hover at 3 feet for 1 minute, 360 degree Pedal turns, slope maneuvers, hover taxi, lateral hover, rearward hover, max-gross takeoff, traffic pattern, shallow approach, normal approach, max performance takeoff, low level flight, confined area landing, climbing turn, straight and level flight, descending turns, decelerations, and accelerations.

MEASURES: Utilized Helicopter In-Flight Monitoring System (HIMS) as described in USAARL Report No. 72-11. See article no. 138 for a complete listing of measured and derived parameters. Biochemical measures used in examining aviator fatigue were urine, biochemical (blood), ECG monitoring, pupilometry measurements, and reaction time to an event (auditory). Subjective assessments of fatigue by each pilot were also recorded.

SUMMARY: The purpose of this research was to observe the impact of fatigue on aviator effectiveness by observing pilots in an actual flight situation. The pilots flew for 11-1/2 hours per day for 5 days with 3.5 hours of sleep per day in all types of weather. It was concluded that this research provided a relevant data base for future research efforts.

147. HARPER, H.P., Sardanowsky, W., and Scharpf, R., "Development of VTOL Flying and Handling Qualities Requirements Based on Mission-Task Performance," Journal of the American Helicopter Society, v. 15(3): p. 57-65, July 1970.

SUBJECTS: 3 pilots.

EQUIPMENT: S-61F helicopter.

SCENARIO: Hovering, hovering turns, air taxi, acceleration, deceleration, and Figure-8 turns.

MEASURES: Offset error and standard deviations (S) of navigational accuracy, altitude, yaw (average integrated error), pitch rate (S), roll rate (S), yaw rate (S), longitudinal and lateral cyclic (average rate, average position, steady time, median frequency, and cutoff frequency), pedals (average rate, average position, and steady time), and power spectral density analyses of control activities. In addition, pilot opinion data on task loadings were collected.

SUMMARY: The purpose of this flight test study was to evaluate the effects of compound configuration on helicopter flying and handling qualities in low-speed flight and to develop task performance evaluation techniques. Experimental conditons were configuration (full compound or wings and horizontal stabilizer removed). Results indicated the effect of wing and horizontal stabilizer was to increase longitudinal stability and to reduce lateral response in forward flight. Pilot work load, pilot opinion, and actual task performance precision information were found to be a requirement for realistic evaluation of task performance capability. No one of these three measures alone covered the information provided by the other two. These results form the basis for further development of mission task performance-oriented design criteria.

148. BARON S., Kleinman, D.L., and Levison, W.H., "An Optimal Control Model of Human Response. Part II: Prediction of Human Performance in a Complex Task," Automatica, v. 6(3): p. 371-383, May 1970.

SUBJECTS: 3 pilots.

EQUIPMENT: XV-5A VTOL aircraft.

SCENARIO: Hovering (complex tracking task).

MEASURES: Mean and variance of control stick input, pitch, pitch rate, navigational position, airspeed, control stick spectra (correlated and uncorrelated), and eye movements (average scan periods and percent of fixation time).

SUMMARY: The purpose of this experiment was to use optimal control theory to model human performance in a simulated VTOL hovering task. The experimental conditions were tracking conditions (six), displays (pitch display or position display), and visual scan (between displays or one display only). The model was able to reproduce essential characteristics of pilots performing the hovering task. Visual scanning behavior was predicted quite well within the same framework. It was concluded that the optimization approach to human operator modelling is promising and the structure is sufficiently general to account for much of the human's behavior in complex tracking tasks.

149. WHITWORTH, William E., Effect of Nap-of-the-Earth Requirements on Aircrew Performance During Night Attack Helicopter Operations, Proceedings of a Conference on Aircrew Performance in Army Aviation Held at U.S. Army Aviation Center, Fort Rucker, Alabama on November 27-29, 1973, Office of the Chief of Research, Development and Acquisition (Army) and U.S. Army Research Institute for the Behavioral and Social Sciences, Arlington, Va 22209, July 1974, p. 153-167, AD A001539.

SUBJECTS: Unspecified number of U.S. Army helicopter pilots.

EQUIPMENT:	AH-1G and OH-58 helicopters.
SCENARIO:	Nap-of-the-Earth navigation and air-to-surface attacks.
MEASURES:	Altitude, navigational accuracy, and subjectively assessed check-rides for different phases of training. Physiological measures were ECG, blood pressure, respiration rate, and urine catecholamines.
SUMMARY:	The purpose of this experiment was to establish the state-of-the art capability to conduct clear night antitank missions by defining a performance baseline for standard unaided helicopters from which techniques of employment could be further developed. It was concluded that the attack helicopter can execute limited clear night antitank missions within 250 feet of the ground but cannot acquire and attack tank targets with current state-of-the art equipment.

200. BERGERON, Hugh P., Kincaid, Joseph K., and Adams, James J., Measured Human Transfer Functions in Simulated Single-Degree-of-Freedom Nonlinear Control Systems, National Aeronautics and Space Administration, Langley Station, Hampton, VA, NASA TN D-2569, January 1965, 42 pp.

SUBJECTS: 6 pilots and 2 nonpilots.

EQUIPMENT: Tracking task simulator with an oscilloscope, control stick, and computer.

SCENARIO: Compensatory tracking task.

MEASURES: Tracking error (root-mean-square).

SUMMARY: The purpose of this research was to investigate a method of determining pilot-control characteristics for nonlinear outputs so as to match a linear model with a nonlinear element. Measured gains were obtained for the linear regions of control and the closed-loop characteristics computed. An analog pilot was made to match or duplicate the pilot's output by an automatic model-adjusting technique such that a representative transfer function of the pilot is obtained. The results showed the pilot does not change his measured gains in direct proportion to changes made in the nonlinear control characteristics. Minor variations that occur implied some change in control technique. It was demonstrated that the single-axis single-loop results could be applicable to a multi-look simulation with minor modification and useful for application to spacecraft flight.

201. SIMPSON, Rae R., The Training of Subjects for UTIAS Research on Dynamics of Human Pilots, Institute for Aerospace Studies, University of Toronto (UTIAS), Canada, UTIAS Technical Note No. 106, March 1967, 49 pp., AD 650163.

SUBJECTS: 12 nonpilots.

EQUIPMENT: CF-100 Mk. 4B flight simulator.

SCENARIO: Compensatory tracking task.

MEASURES: Tracking error of pitch (difference between random input signal and pilot output signal) in terms of mean square error. A "score" was mean square error divided by mean square input times 100. A low score was an indication of high performance.

SUMMARY: The goal of this research was exploratory work in setting up an operating system, training subjects on it, and then varying system parameters and observing subject performance. It was desired to optimize the man-machine system in order to provide a baseline system for research and to train subjects on that system. Results were discussed for input signals, stick sensitivity, performance criteria, and the training procedure.

202. MILLER, G. Kimball Jr., and Riley, Donald R., The Effect of Visual-Motion Time Delays on Pilot Performance in a Simulated Pursuit Tracking Task, National Aeronautics and Space Administration, Hampton, VA 23665, NASA TN D-8364, March 1977, 97 pp., N77-20080.

SUBJECTS: 1 pilot and 1 nonpilot.

EQUIPMENT: Langley visual-motion simulator.

SCENARIO: Tracking task (pursuit).

MEASURES: Tracking error (vertical and horizontal), aileron deflection, and elevator deflection.

SUMMARY: The purpose of this research was to determine the effect on pilot performance of time delays in the visual and motion feedback loops of a simulated pursuit tracking task. Experimental conditions were airplane handling quality, time delays, target frequency, and type of simulator motion cues (full motion, no heave, angular, and no motion). The results showed the greater the task difficulty, the smaller the time delay that could exist without degrading pilot performance. Conversely, the greater the motion fidelity, the greater the time delay that could be tolerated. The effect of motion was pilot dependent.

203. SADOFF, Melvin, A Study of a Pilot's Ability to Control During Simulated Stability Augmentation System Failures, National Aeronautics and Space Administration, Moffett Field, CA, NASA TN D-1552, November 1962, 36 pp.

SUBJECTS 4 NASA test pilots.

EQUIPMENT: Naval Air Development Center (Johnsville, PA) Aviation Medical Acceleration Laboratory (AMAL) human centrifuge.

SCENARIO: Tracking task (pitch attitude).

MEASURES: Tracking error (integral error squared), and pitch attitude error (integral forcing function squared), both presented in a composite of mean square tracking error divided by mean square target motion.

SUMMARY: The objective of this study was to investigate the effects of failure of a stability augmentation system (SAS) on the pilot's ability to control while engaged in a simple tracking task. Experimental conditions included SAS (active or failed), motion (fixed-cab or moving cab), and controller (center-stick or side-arm). It was also desired to apply simplified pilot transfer-function models to the interpretation and prediction of SAS malfunction-related control problems. The result of simulated failures suggested that moving-cab flight simulators provided a more realistic evaluation of the transient effects of SAS failures. Simulator motions generally interfered with the ability of the pilots to adapt to the failures. The side-arm controller proved easier to use than a conventional center stick in coping with pitch damper failures at higher short-period frequencies. The use of pilot models provided encouraging results.

204. JUNKER, Andrew M., and Levison, William H., "Recent Advances in Modelling the Effects of Roll Motion on the Human Operator," Aviation, Space, and Environmental Medicine, v. 49(1): p. 328-334, January 1978. See also Aerospace Medical Research Laboratory, Wright-Patterson AFB, OH, AMRL-TR-77-15, AD A054919.

SUBJECTS: 6 nonpilots.

EQUIPMENT: Multi-axis tracking simulator (MATS).

SCENARIO: Tracking task.

MEASURES: Tracking error (standard deviation), and acceleration (standard deviation). Both were summed for a "cost" score.

SUMMARY: The purpose of this study was to modify the Bolt, Beranek and Newman optimal-control pilot-vehicle model in order to investigate the ability of the model to predict human performance and aid in experimental design. The motion cues considered were commanded vehicle motion and vehicle disturbances. Model predictions and experimental results were compared with a resulting high correlation between the two. The results demonstrated the usefulness of the model to predict pilot-vehicle response for various motion cue conditions and to simplify the experimental design process.

205. McGUINNESS, James, Drennan, Thomas G., and Curtin, James G., Manual Control in Target Tracking Tasks as a Function of Controller Characteristics: A Flight Simulator Investigation - Phase II, McDonnell Douglas Astronautics Company, St. Louis, MO 63166, Contract No. N00014-72-C-0264, sponsored by Office of Naval Research, Arlington, VA 22216, MDC E1148, September 1974, 96 pp., AD A007384.

SUBJECTS: 16 pilots.

EQUIPMENT: Fixed base, part-task simulator configured as an A-7.

SCENARIO: Attitude control (compensatory) tracking and target (pursuit) tracking tasks.

MEASURES: Pitch error (absolute), roll error (absolute), target acquisition time, error at acquisition, initial control reversals, number of overshoots before acquisition, mean absolute tracking error in the X and Y axes, and time on target.

SUMMARY: The purpose of this investigation was to examine the characteristics of tracking controllers which were integrated into an aircraft throttle to derive human engineering guidelines for the improved design of such controllers. Subjects performed the attitude control and target tracking tasks simultaneously under nine experimental conditions varied by three levels of target speed and three levels of control/display ratio (gain). Results indicated the force controller with the step output function yielded better target acquisition and tracking performance than did the displacement controller with the step function, and there were no significant differences in target acquisition and tracking performance between the force and displacement controllers with a linear output function.

206. LOWES, A.L., Ellis, N.C., Norman, D.A., and Matheny, W.G., Improving Piloting Skills in Turbulent Air Using a Self-Adaptive Technique for a Digital Operational Flight Trainer, Life Sciences, Inc., Fort Worth, TX 76118, Contract No. N61339-67-C-0034, sponsored by Naval Training Device Center, Orlando, FL 32813, NAVTRADEVCEN 67-C-0034-2, August 1968, 48 pp., AD 675805.

SUBJECTS: 18 instrument-rated nonjet pilots.

EQUIPMENT: Universal Digital Operational Flight Training Tool (UDOFTT) configured as a high speed Navy jet fighter aircraft.

SCENARIO: Straight and level flight in turbulent air (tracking).

MEASURES: Altitude error ratio (standard minimum altitude error divided by actual error for a given G load), altitude error (average absolute and standard deviation), mach error (average absolute and standard deviation), turbulence intensity (mean and variance), and control stick movement (mean and variance).

SUMMARY: The purpose of this study was to determine the feasibility of applying adaptive principles to flight simulator training functions. Two groups were trained using an adaptive technique or a conventional training technique. The results showed the adaptively trained pilots were more proficient when transferred to a flight simulation representative of an aircraft in turbulent air than the conventionally trained pilots. It was concluded that self-adaptive principles are feasible in the performance of flight simulator training functions.

207. JACOBS, Robert S., Williges, Robert C., and Roscoe, Stanley N., "Simulator Motion as a Factor in Flight-Director Display Evaluation," Human Factors, v. 15(6): p. 569-582, December 1973.

SUBJECTS: 8 pilots.

EQUIPMENT: Link GAT-2 simulator.

SCENARIO: Tracking task (straight and level flight in turbulence).

MEASURES: Tracking error (horizontal steering error). Transformations included root-mean-square (RMS) error and log RMS error.

SUMMARY: The purpose of this experiment was to evaluate various flight-director displays in a moving-base simulator without motion and compare the results to an earlier experiment that utilized motion. The experimental conditions were command steering presentation (compensatory or pursuit), and attitude presentation (moving horizon, moving airplane, kinalog, or frequency separated). Data from the previous experiment that utilized motion was included in the analysis. Results showed that tracking performance was superior when motion was utilized and that a moving airplane attitude presentation and pursuit steering display was superior to all other display combinations. Several conclusions about the results were stated.

208\. MATHENY, W.G., Lowes, A.L., and Bynum, J.A., An Experimental Investigation of the Role of Motion in Ground-Based Trainers, Life Sciences, Inc., Hurst, TX 76053, Contract No. N61339-71-C-0075, sponsored by Naval Training Equipment Center, Orlando, FL 32813, NAVTRAEQUIPCEN 71-C-0075-1, April 1974, 64 pp., AD 778665.

SUBJECTS: 7 pilots.

EQUIPMENT: NTEC R & D simulator (TRADEC) configured as an F-4E with/without motion.

SCENARIO: Straight and level flight in turbulent air.

MEASURES: Altitude (root mean square [RMS] error), heading (RMS value of the sine of deviation angle), and control stick deflection (RMS).

SUMMARY: The purpose of this study was to provide data relevant to the specification of motion requirements for ground-based trainers. Three categories of motion were investigated: (1) no motion, (2) motion correlated with the aircraft equation and visual display output, and (3) random uncorrelated motion. Results indicated that motion did not significantly effect changes in man-machine system performance, however, significant differences were obtained among the pilot performance measures listed above for motion types.

209. LOOSE, Donald R., McElreath, Kenneth W., and Potor, George Jr., Effects of Direct Side Force Control on Pilot Tracking Performance, Aerospace Medical Research Laboratory, Wright-Patterson AFB, OH 45433, AMRL-TR-76-87, December 1976, 26 pp., AD A036083.

SUBJECTS: 2 pilots and 2 nonpilots.

EQUIPMENT: Dynamic Environment Simulator (DES) with an isometric side-arm controller.

SCENARIO: Tracking task simulating an air-to-air environment with target aircraft executing various evasive actions.

MEASURES: Tracking error composed of azimuth error and elevation error (both root-mean-square).

SUMMARY: The purpose of this experiment was to determine the effects of direct side force motion on a pilot's tracking performance in a simulated air-to-air engagement. The pilot could command pitch and lateral velocity during the 45-second runs at various normal G profiles with and without dynamic lateral motion. The results showed some degradation of performance at low normal G levels with side motion, but effective tracking control was easily maintained with plus or minus 2 G's of dynamic lateral acceleration.

210. MILLER, G. Kimball Jr., and Riley, Donald R., Evaluation of Several Secondary Tasks in the Determination of Permissible Time Delays in Simulator Visual and Motion Cues, National Aeronautics and Space Administration, Hampton, VA 23665, NASA TP-1214, August 1978, 65 pp., N78-30089.

SUBJECTS: 1 pilot.

EQUIPMENT: Langley visual-motion simulator.

SCENARIO: Tracking task (pursuit), tapping task (secondary), audio side task, and mental task (arithmetic).

MEASURES: Tracking error (sum of root-mean square vertical and lateral displacements), aileron inputs (root mean square [RMS], elevator inputs (RMS), audio task tracking error (RMS), thumbwheel deflection (RMS), thumbwheel input frequency (RMS), and number of incorrect thumbwheel inputs.

SUMMARY: The purpose of this experiment was to examine the effect of secondary tasks in determining permissible time delays in visual-motion simulation of a pursuit tracking task. Experimental conditions were time delay and secondary tasks (tapping, audio, or adding). The results indicated the permissible time delay was about 250 msec for any secondary task alone and approximately 125 msec less when no secondary task was involved. A power spectral density analysis confirmed the results by comparing the RMS performance measures.

211. ZAITZEFF, L.P., Aircrew Task Loading in the Boeing Multimission Simulator, Proceedings, Annual AGARD Symposium for Measurement of Aircrew Performance, Brooks AFB, TX, Advisory Group for Aerospace Research and Development, Paris, France, AGARD CP No. 56, May 1969, p. 8-1 to 8-3, AD 699934.

SUBJECTS: Unspecified number of pilots and observers.

EQUIPMENT: Boeing Multimission Simulator with a 15-ft. radius screen for visual displays.

SCENARIO: Visual target acquisition.

MEASURES: Target acquisition errors; number of correct target acquisitions, number missed, and number of false identifications. umber missed, and number of false identifications. These were further derived into an empirical "cumulative acquisition probability."

SUMMARY: This study examined performance differences between one- and two-man crews for visual target acquisition. Two specific targets were used. Results indicated that for both targets, the two-man crews were significantly better in sharing the target acquisition load than a one-man crew.

212. KELLOG, Robert S., Prather, Dirk C., and Castore, Carl H., Simulated A-10 Combat Environment, Proceedings of the 24th Annual Meeting of the Human Factors Society, Los Angeles, CA, October 1980, p. 573-577.

SUBJECTS: 7 pilots.

EQUIPMENT: Advanced Simulator for Pilot Training (ASPT) configured as an A-10 aircraft.

SCENARIO: Low-level ground attack (with guns).

MEASURES: Number of correct target detections, number of target kills, number of target misses, number of target detections with no fires, number of ground impacts, vertical acceleration, and percent of time target is destroyed.

SUMMARY: The purpose of this study was to test the feasibility of using the ASPT in training pilots for combat in a simulated hostile environment. The environment included mountainous terrain, enemy surface-to-air missiles (SAM), anti-aircraft artillery (AAA), and a tank target located at random along a roadway. The results indicated combat ready pilots learned and improved offensive and defensive tactics and exhibited favorable responses to this training.

213. KRAFT, Conrad L., and Elworth, Charles L., Flight Deck Work Load and Night Visual Approach Performance, Proceedings, Annual AGARD Symposium for Measurement of Aircrew Performance, Brooks AFB, TX, Advisory Group for Aerospace Research and Development, Paris, France, AGARD CP No. 56, May 1969, p. 11-1 to 11-4, AD 699934.

SUBJECTS: 12 Boeing Company instructors.

EQUIPMENT: Boeing Simulators with a model board visual display.

SCENARIO: Night visual approach.

MEASURES: Pilot-generated altitude (judgement), actual altitude, and visual sightings of other aircraft during the approach (number of correct target detections).

SUMMARY: Research objectives were to determine the degree to which night visual approaches are unsafe, how specific topography features result in inadequate visual information, and to determine how flight deck work load may influence approach performance under night visual conditions. Conclusions were that pilots acquire through training and experience a visual frame of reference that approximates a safe and conventional flight path onto a flat terrain, and that flight deck work load in the form of other traffic to detect and report is a significant variable in affecting altitude and estimated altitudes during penetrations.

214. BRAY, Richard S., "A Study of Vertical Motion Requirements for Landing Simulation," Human Factors, v. 15(6): p. 561-568, December 1973.

SUBJECTS: 4 pilots.

EQUIPMENT: NASA Ames Height Control Test Apparatus (HCTA) configured as a swept-wing jet transport and a TV-terrain model visual system.

SCENARIO: Visual approach and landing.

MEASURES: Vertical velocity (at touchdown), altitude, and vertical acceleration.

SUMMARY: The purpose of this research was to determine the significance of vertical acceleration cues in the simulation of the visual approach and landing maneuver. Several configurations of airplane characteristics and the simulator motion system were varied during the experiment. Test results indicated that vertical motion cues are utilized by the pilot in the landing task and are especially important in the simulation of aircraft with marginal longitudinal-handling qualities. It also appeared that a simulator should have excursion capabilities of at least plus or minus 20 feet to assure vertical motion cues of the desired fidelity.

215. CHASE, Wendell D., "Effect of Display Color on Pilot Performance and Describing Functions," Journal of Aircraft, v. 14(4): p. 333-342, April 1977.

SUBJECTS: 6 airline pilots.

EQUIPMENT: Fixed-base cockpit cab (configured as a DC-8 jet transport), SEL 840 digital computer, and optical collimating lens arrangement.

SCENARIO: Landing approach (visual at night).

MEASURES: Altitude error (mean and standard deviation), time within flight path (glideslope), ratio of pilot control output power to input disturbance power, number of control reversals (open-loop crossover frequency), landing distance to runway threshold, and touchdown vertical velocity.

SUMMARY: The purpose of this study was to determine the effect of chromatic content of the visual display upon pilot performance with a full-spectrum, calligraphic, and computer-generated display system. The experimental conditions were runway approach (dynamic or frozen range), perspective arrays (combination of red and blue), land approach scene and approach lights (red, blue, or red-blue/blue-red), and chromatic describing function flights (2 or 3). The results showed pilots performed best with blue and red/blue displays, and worst with red displays. Describing-function performance measures, vertical performance measures, and pilot opinion supported the hypothesis that specific colors in displays can influence the pilots' control characteristics during the final approach.

216. LEWIS, Mark F., and Mertens, Henry W., Pilot Performance During Simulated Approaches and Landings Made with Various Computer-Generated Visual Glidepath Indicators, FAA Civil Aeromedical Institute, Oklahoma City, OK 73125, FAA-AM-79-4, September 1978, 56 pp. AD A066220.

SUBJECTS: 27 pilots (two experiments).

EQUIPMENT: Convair 580 simulator.

SCENARIO: Visual approach to landing at night.

MEASURES: Altitude error (root mean square [RMS]), approach angle error (RMS), and number of flight path oscillations (number of peaks and troughs over the altitude deviation profile). Experiment two used the frequency of observing responses in 2-bar Visual Approach Slope Indicators (VASI) and the Australian

"T" Visual Approach Systems (T-VASIS) in addition to the measures above.

SUMMARY: The purpose of the two experiments was to quantify the effectiveness of four different visual glidepath indicator systems in the reduced nighttime visual environment by measuring pilot performance. The types of glidepath indicators were standard red/white 2-bar or 3-bar VASI system, the Australian T-VASIS, and a British experimental system called Precision Approach Path Indicator (PAPI). Results showed performance was best with the T-VASIS and decreased with the 3-bar VASI, PAPI, and 2-bar VASI in that order.

217. SMITH, Russell L., Pence, Gail G., Queen, John E., and Wulfeck, Joseph W., Effect of a Predictor Instrument on Learning to Land a Simulated Jet Trainer, Dunlap and Associates, Inc., Inglewood, CA 90301, Contract No. F44620-73-C-0014, sponsored by Air Force Office of Scientific Research, Arlington, VA 22209, AFOSR-TR-74-1731, August 1974, 76 pp., AD A000586.

SUBJECTS: 5 nonpilots.

EQUIPMENT: Cessna T-37 simulation with a predictor display.

SCENARIO: Instrument approach to landing.

MEASURES: Altitude error (integrated about 4.3 degree glideslope), and airspeed error (integrated).

SUMMARY: The purpose of this study was to explore adaptive use of a predictor display to promote rapid and accurate learning on conventional tracking tasks (transfer of training). Experimental conditions were display (with or without predictor) and test trials. Results indicated that use of the predictor display facilitated learning to a great extent as measured by altitude and airspeed error, and appeared to accelerate training substantially.

218. JENSEN, Richard S., and Marsh, Roger W., Simulator Tests of Pilot Performance in Terminal Area Navigation Operations: Effects of Various Airborne System Characteristics, Aviation Research Laboratory, University of Illinois, Savoy, IL 61874, Contract No. DOT-FA71WA-2574, sponsored by Federal Aviation Administration, Washington, DC 20590, FAA-RD-76-99, May 1976, 163 pp., AD A029846.

SUBJECTS:	45 pilots.
EQUIPMENT:	GAT-2 simulator.
SCENARIO:	Instrument approach to landing.
MEASURES:	Horizontal and vertical tracking, airspeed, and procedure performance. Means, standard deviations and root mean square (RMS) transformations were performed.
SUMMARY:	The purpose of this experiment was to assess pilot performance as a function of three turn anticipation techniques (Procedural, Computed, and Electronic Map Display) and three levels of waypoint storage capacity (one, two, and three). Best overall performance was found in the two-waypoint, computed turn anticipation condition. Turn anticipation technique had its greatest effect on horizontal tracking and procedural performance. Waypoint storage effected vertical tracking performance more than other measured variables. The electronic map display improved procedural performance but had little effect on other performance measures.

219. BRAY, Richard S., A Piloted Simulator Study of Longitudinal Handling Qualities of Supersonic Transports in the Landing Maneuver, National Aeronautics and Space Administration, Moffett Field, CA, NASA TN D-2251, April 1964, 30 pp.

SUBJECTS:	4 pilots.
EQUIPMENT:	Fixed-base simulator incorporating visual cues.
SCENARIO:	Instrument Landing System (ILS) approach and landing.
MEASURES:	Vertical velocity (at touchdown), altitude, and landing distance to runway threshold.

SUMMARY: The purpose of this experiment was to study several parameters pertinent to the stability and control characteristics of supersonic transports. Measurements of the landing touchdown performance measures indicated that no severe longitudinal control difficulties were apparent in the flare and touchdown maneuver over the limited flight condition tests. The large distance between cockpit and landing gear did not seem to present a serious problem in height judgment or longitudinal control at touchdown.

220. WEIR, David H., and Klein, Richard H., The Measurement and Analysis of Pilot Scanning and Control Behavior During Simulated Instrument Approaches, Systems Technology, Inc., Hawthorne, CA, Contract No. NAS 2-3746, sponsored by National Aeronautics and Space Administration, Ames Research Center, Mountain View, CA, NASA CR-1535, June 1970, 122 pp., N70-29904.

SUBJECTS: 4 pilots.

EQUIPMENT: NASA fixed-base six degree of freedom simulator configured as a DC-8.

SCENARIO: Instrument Landing System (ILS) approach from the outer marker to the middle marker.

MEASURES: Utilized an eye point of regard for eye movement performance (number of fixations per instrument, total number of fixations on all instruments, dwell time per instrument, mean dwell time, average number of fixations per second, look rate per instrument, percent of fixations per instrument, percent of time per instrument, and look interval). Other parameters measured were approach glideslope error (root mean square [RMS]), pitch attitude (RMS), elevator response (mean square), and aileron response (mean square).

SUMMARY: The primary purpose of this research effort was to further develop and validate the theory of manual control displays requiring simultaneous eye movement and pilot response data in flight control tasks under realistic instrument conditions. Two manual configurations and a flight director configuration were tested. Results indicated that scan rates were greater for manual ILS runs than for flight director runs, dwell fractions (percent of time fixating) were larger for the flight director than with the manual ILS configuration, and scan patterns were more scattered for the flight director configurations. Performance data results showed glideslope errors and pitch attitude errors were less with the flight director than with the manual ILS configuration. Other conclusions were listed.

221. GOLD, Robert E., and Kulak, Linton L., "Effect of Hypoxia on Aircraft Pilot Performance," Aerospace Medicine, v. 43(2): p. 180-183, February 1972.

SUBJECTS: 7 pilots.

EQUIPMENT: Link GAT-1 simulator.

SCENARIO: Instrument Landing System (ILS) approach.

MEASURES: Airspeed (mean [$\bar{X}$], absolute average error [AAE], standard deviation [S], and root mean square error [RMS]), altitude (AAE, S, and RMS), heading (AAE, S, and RMS), vertical velocity (AAE, S, and RMS error), approach centerline error ($\bar{X}$, AAE, S, and RMS error), approach glideslope error ($\bar{X}$ AAE, S, and RMS) and positions of elevator, aileron, rudder, and throttle. Pitch and roll were also measured.

SUMMARY: The purpose of this experiment was to use methods of pilot performance to determine the effects of hypoxia at an altitude region of 12,000 to 15,000 feet. The results indicated the 15,000 feet altitude showed a marked performance decrement as measured by airspeed, heading, vertical velocity, localizer and glide slope. Performance decrements at 12,300 feet were not apparent due to the variability among pilots and number of experimental runs. These results indicated the need for supplemental oxygen at or above 12,000 feet for any crew member involved in a complex or dangerous task.

222. SIMONELLI, Nicholas Michael, An Investigation of Pictorial and Symbolic Aircraft Displays for Landing, Proceedings of the 22nd Annual Meeting of the Human Factors Society, Detroit, MI, October 1978, p. 213-217.

SUBJECTS: 16 flight instructor pilots.

EQUIPMENT: Singer-Link GAT-2 simulator.

SCENARIO: Instrument Landing System (ILS) apaproach.

MEASURES: Approach glideslope error and approach centerline (lateral) error. Transformations included means, variances, and root-mean-square (RMS) error.

SUMMARY: The purpose of this experiment was to evaluate four different approach to landing displays using experienced pilots. The displays were; conventional ILS with no pictorial information, "glideslope localizer" (GSL) with a pictorial runway but no scale type error indications, a combination of the above two displays (ILS + GSL), and a runway-only pictorial display with no glideslope or localizer information other than the runway shape itself. Best performance overall was achieved with the combination display (ILS + GSL). No reliable lateral performance difference was found among the displays but vertical performance was best on those displays that contained a vertical deviation scale and pointer irrespective of the presence of a pictorial runway. It was concluded that pictorial runway information aids in stabilizing lateral control but was not adequate for guidance cues in maintaining precise vertical control.

223. RUOCCO, Joseph N., Vitale, Patrick A., and Benfari, Robert C., Kinetic Cueing in Simulated Carrier Approaches, Grumman Aircraft Engineering Corporation, Bethpage, Long Island, NY, Contract No. N61339-1432, sponsored by U.S. Naval Training Device Center, Port Washington, NY 11050, NAVTRADEVCEN 1432-1, April 1965, 91 pp., AD 617689. See also NAVTRADEVCEN 1432-1-S1, AD 618756.

SUBJECTS: 12 pilots.

EQUIPMENT: Motion simulator configured as a high performance jet with a model board and television viewing screen.

SCENARIO: Carrier approach and landing.

MEASURES: Control stick displacement in roll and pitch (mean, root mean square [RMS]), percent of time within flight path (in seconds), altitude error (mean, RMS, absolute mean), and airspeed (mean and RMS about nominal value). Terminal (touchdown) parameters were vertical position (plus or minus 8 feet), landing distance to ideal touchdown point, roll angle, pitch angle, yaw angle, and vertical velocity.

SUMMARY: The purpose of this study was to determine whether the gross effects of kinetic cueing have objectively measurable consequences upon pilot training to control a vehicle and to gain insight into the mechanism by which kinetic cueing augments the visual system. Conditions tested were static and kinetic cockpit motion. Results showed kinetic cueing significantly improved performance in terms of percentage of successful landings, altitude error, time outside flight path, and variability of pilot inputs. Kinetic cueing appears to be a valuable and desirable adjunct to flight airborne simulation systems.

224. GOLD, T., and Perry, R.F., Research in Visual Perception for Carrier Landing, Sperry Rand Corporation, Great Neck, NY 11020, Contract No. NOnr-4081(00), sponsored by Office of Naval Research, Washington, DC 20360, Sperry report No. SGD-5265-0327, December 1969, 84 pp., AD 706036.

SUBJECTS: 3 pilots.

EQUIPMENT: Carrier Landing Simulator with a visual model board.

SCENARIO: Carrier approach and landing.

MEASURES: Approach glideslope error, landing aim point, and visual performance. Visual performance was measured by pilot bias (mean estimates of position estimation), variability (standard deviation of position estimate), and sensitivity (rate of change of median response for position estimate).

SUMMARY: The purpose of this study was to determine the accuracy and consistency with which Navy pilots can judge position on the glide slope and flight path during final approach to the carrier. Conditions studied were ambient lighting, ship conditions (static, dynamic, with/without Fresnel Lens Optical Landing System [FLOLS]), positions on the glide slope, and range from the carrier. The results showed pilots' mean estimates of position when on glide slope and on-course are within a small fraction of a degree of being correct under dusk and night conditions, with a static or moving carrier, and with and without the FLOLS. Variability in judgement was high under all test conditions and consistently higher at night than at dusk. Pilots tend to overestimate the aim point at far ranges and change to an undershoot near the carrier under all conditions. Other results are listed.

225. COOPER, Fred R., Harris, William T., and Sharkey, Vincent J., The Effect of Delay in the Presentation of Visual Information on Pilot Performance, Analysis and Design Branch N-2211, Naval Training Equipment Center, Orlando, FL 32813, NAVTRAEQUIPCEN IH-250, December 1975, 78 pp., AD A021418.

SUBJECTS: 12 pilots.

EQUIPMENT: NTEC R & D simulator (TRADEC) configured as an F-4.

SCENARIO: Carrier approach and landing.

MEASURES: For the preliminary experiment (1), a successful landing was defined as; landing gear down; landing distance to ideal touchdown point within parameters, and 64 to 69 feet above sea level in altitude; vertical velocity less than or equal to 1000 feet per minute at touchdown; pitch between 2 degrees down and 18 degrees up from horizontal; and roll left or right less than 15 degrees from horizontal. A task was considered learned if three successful arrestments in a row were made (trials to criterion). Experiment 2 sampled stabilator control stick deflection and force, aileron control stick deflection and force, and rudder pedal deflection and force. The mean and variance of each parameter was derived.

SUMMARY: The purpose of the experiments was to determine the effect of a 100 millisecond delay of visual presentation on pilot learning performance and the change that occurs in piloting skills when visual stimuli are delayed. The main conclusion from experiment 1 was that an introduction of a 100 millisecond delay in the presentation of visual information had no effect on learning the scenario by the subjects. Experiment 2 determined that pilot subjects manipulated their flight controls differently both in displacements and in control force when the visual stimuli were delayed 100 milliseconds, and that these differences are indicated by a trend towards greater control activity variance and by the differences in the frequency spectra for the Delayed and Non-Delayed conditions.

226. COLLYER, S.C., Ricard, L., Anderson, M., Westra, D.P., and Perry, R.A., Field of View Requirements for Carrier Landing Training, Naval Training Equipment Center, Orlando, FL 32813, and Air Force Human Resources Laboratory, Williams AFB, AZ 85224, NAVTRAEQUIPCEN IH-319/AFHRL-TR-80-10, May 1980, 45 pp., AD A087012.

SUBJECTS: 21 U.S. Air Force instructor pilots.

EQUIPMENT: Advanced Simulator for Pilot Training (ASPT).

SCENARIO: Carrier circling approach and landing.

MEASURES: Instantaneous measures were angle of attack, altitude, navigational accuracy (X and Y position), roll angle, approach glideslope error, and approach centerline error. Continuous measures were pilot control inputs and time-within-tolerance combined measures (glideslope error, centerline deviation, and angle of attack). Landing success measures were ramp centerline deviation and landing height at carrier ramp, roll, pitch, vertical velocity, and landing result (wire caught, ramp strike, bolter, or waveoff). Subjective ratings were an LSO score and the landing performance score (LPS) developed by Brictson, Burger, and Wulfeck (see article no. 410).

SUMMARY: The purpose of this study was to investigate simulator visual field-of-view (FOV) requirements in conjunction with two approaches to training daytime carrier circling approach and landing. Three groups of pilots were trained under different conditions to execute a landing on a simulated USS Forrestal (CVA-59) aircraft carrier. The experimental conditions were wide visual FOV (300 degrees horizontal/150 degrees vertical), a narrow FOV (48 degrees horizontal/36 degrees vertical), circling approach, and a straight-in approach. Results indicated there were no clear training advantages of a wide-angle visual display for carrier circling approaches and landings. Practice on straight-in approaches, using a narrow-angle visual display, appeared to be the most cost-effective use of simulators for training that task.

227. Wewerinke, P.H., A Simulator Experiment to Investigate a Lateral Rate Field Display, National Aerospace Laboratory (NLR), The Netherlands, NLR-TR-74093-U, April 1974, 45 pp., AD B010200.

SUBJECTS: 4 pilots.

EQUIPMENT: Hawker Hunter Mk. 12 simulator.

SCENARIO: Tracking task and secondary audio task (autopaced).

MEASURES: Tracking error (variance of lateral displacement), control stick activity (mean squared aileron deflection), eye movements (percent of time per instrument, and scan rate or looks per second), attentional workload index (based on critical instability level), and a subjective rating of the workload by the pilots.

SUMMARY: The goal of this experiment was to evaluate a linear rate field display. The experimental conditions were display (status display or flight director configurations containing raw ADI information) and the secondary audio task. The results showed the flight director configuration was superior to the status display configuration in terms of system performance and pilot workload. Rate information was useful for the task considered, especially when presented peripherally by means of a moire pattern.

228. RILEY, Donald R., and Miller, G. Kimball Jr., Simulator Study of the Effect of Visual-Motion Time Delays on Pilot Tracking Performance with an Audio Side Task, National Aeronautics and Space Administration, Hampton, VA 23665, NASA TP-1216, August 1978, 71 pp., N78-30090.

SUBJECTS: 2 pilots.

EQUIPMENT: Langley vision-motion simulator configured as a fighter-type aircraft.

SCENARIO: Tracking task (pursuit tracking in two dimensions), and an audio side task.

MEASURES: Tracking error (root mean square [RMS]), aileron movements (RMS), elevator movements (RMS), thumbwheel input (RMS), and tone error.

SUMMARY: The purpose of this study was to reexamine the effect of time delay in the visual and motion cues of a flight simulator on pilot performance in a visual tracking task with a different side task. The results of the study indicated that about the same acceptable time delay (250 msec) was obtained for a single aircraft (fighter type) for both fixed-base and motion-base conditions. Use of the audio side task provided quantitative data for the subject's work level.

229. QUEIJO, M.J., and Riley, Donald R., Fixed-Base Simulator Study of the Effect of Time Delays in Visual Cues on Pilot Tracking Performance, National Aeronautics and Space Administration, Hampton, VA 23665, NASA TN D-8001, October 1975, 77 pp., N76-10087.

SUBJECTS: 2 nonpilots.

EQUIPMENT: Langley visual-motion simulator.

SCENARIO: Tracking task (pursuit) and a secondary tapping task.

MEASURES: Number of taps on the side task, and tracking error (vertical, horizontal, and total).

SUMMARY: The purpose of this study was to examine the effects of time delay in the visual cues presented to the subject in a simulator. Experimental conditions were time delays and aircraft handling qualities with the secondary task employed to maintain the workload constant and to insure the pilot was fully occupied. Results showed a positive correlation between improved aircraft handling qualities and a longer acceptable time delay.

230. GEISELHART, Richard, Jarboe, Joseph K., and Kemmerling, Paul T. Jr., Investigation of Pilots' Trcking Capability Using a Roll Command Display, Aeronautical Systems Division, Wright-Patterson AFB, OH, ASD-TR-71-46, December 1971, 64 pp., AD A009590.

SUBJECTS: 10 U.S. Air Force pilots.

EQUIPMENT: F-111A flight simulator.

SCENARIO: Tracking using a roll command display during a medium altitude route to a target.

MEASURES: Time, airspeed (true and indicated), yaw, pitch, roll, ADI displacement, course error command, altitude, mach, angle of attack, navigational accuracy (latitude and longitude), vertical velocity, wind, and lateral control stick (position and forces).

SUMMARY: The purpose of the experiment was to establish baseline normative data for pilot tracking performance. The route was flown at 450 knots and 6000 feet altitude. It was concluded that by employing state-of-the-art avionic systems, tracking errors of less than 4 milliradian are attainable by pilots when steering an aircraft about the vertical axis.

231. CURTIN, J.G., Emery, J.H., and Drennen, T.G., Investigation of Manual Control in Secondary Flight Tracking Tasks, McDonnell Douglas Astronautics Company, St. Louis, MO 63166, Contract No. N00014-72-C-0264, sponsored by Office of Naval Research, Arlington, VA 22217, MDC E0890, August 1973, 58 pp., AD 766070.

SUBJECTS: 16 pilots.

EQUIPMENT: Part-task simulator (F-4B cockpit).

SCENARIO: Straight and level, and secondary radar tracking task.

MEASURES: Pitch error, roll error, and airspeed error. Target tracking measures were acquisition time, percent time on target, and X-Y tracking error. In addition, subjective ratings of the configurations were taken.

SUMMARY: The purpose of this experiment was to evaluate four radar control configurations in terms of target acquisition and tracking in order to control simplification.

Experimental variables were types of control action (displacement or force), location (integrated into throttles or independent), and personal equipment (gloves or no gloves). Results showed the integrated secondary control configurations were significantly better in terms of tracking performance. Type of control action significantly affected initial target acquisition time with displacement control action producing better scores. Best tracking performance was obtained with the integrated tracking controls. Flight gloves had no effect upon performance.

232. PRICE, Dennis L., "The Effects of Certain Gimbal Orders on Target Acquisition and Workload," Human Factors, v. 17(6): p. 571-576, December 1975. See also Proceedings of the 18th Annual Meeting of the Human Factors Society, Huntsville, AL, October 1975, p. 153-157.

SUBJECTS: 18 pilots.

EQUIPMENT: Martin Marietta simulator and terrain model.

SCENARIO: Target detection, recognition, identification, and a secondary monitoring task (reading digits aloud when they appear; a workload measure).

MEASURES: Number of digits repeated correctly (correct responses) and in sequence (mean), and mean slant-range to target for detection, recognition, and identification.

SUMMARY: The purpose of this study was to measure the effects of visual scenes produced by three different gimbal orders on target detection, recognition, and identification tasks. Experimental conditions were gimbal orders (roll-pitch, pitch-yaw, and yaw-pitch). It was concluded that gimbal order affected target detection, recognition, and identification performance with pitch-yaw best and roll-pitch poorest. Operator workload was highest with roll-pitch gimbal order.

233. KRAUS, Emmett F., and Roscoe, Stanley N., Reorganization of Airplane Manual Flight Control Dynamics, Proceedings of the 16th Annual Meeting of the Human Factors Society, Los Angeles, CA, October 1972, p. 117-126.

SUBJECTS: 16 pilots.

EQUIPMENT: Link GAT-1 simulator.

SCENARIO: Area navigation on VOR airways and a secondary adaptive task (response to presented digits).

MEASURES: Procedural errors and information processing rate (bits per second as measured on the secondary task).

SUMMARY: The purpose of this experiment was to evaluate the effectiveness of a system providing direct control over aircraft maneuvering performance. Experimental conditions were waypoint storage capacity (1, 2, 4 or 8), control mode (normal or performance control), and side-task loading (with or without). Results showed the flight performance controller yielded greater precision of maneuvering control, fewer procedural errors, and an increased level of residual pilot attention.

234. VANDERKOLK, Richard J., and Roscoe, Stanley N., Simulator Tests of Pilotage Error in Area Navigation with Vertical Guidance: Effects of Descent Angle and Display Scale Factor, Proceedings of the 17th Annual Meeting of the Human Factors Society, Washington, DC, October 1973, p. 229-239.

SUBJECTS: 8 pilots.

EQUIPMENT: Link GAT-2 simulator.

SCENARIO: Area navigation (straight and level and descents), and a secondary workload task (response to lights).

MEASURES: Crosstrack error, altitude error, airspeed error, number of correct responses (to secondary task), and procedural errors. Transformations included root-mean-square (RMS) error and standard deviations.

SUMMARY: The purpose of this study was to assess the effects of pilot experience, display scale factor, angle of descent, and practice upon steady-state performances under more nearly routine flight conditions involving flight-path variations in the vertical plane only. The results showed that altitude tracking errors increase with descent angle and decrease as display scale factor becomes more sensitive. For most conditions tested, airline transport pilots had reliably smaller altitude error than for commercial instrument pilots.

235. ELLIS, N.C., Lowes, A.L., Matheny, W.G., and Norman, D.A., Pilot Performance, Transfer of Training, and Degree of Simulation: III. Performance of Non-Jet Experienced Pilots Versus Simulation Fidelity, Life Sciences, Inc., Fort Worth, TX 76118, Contract No. N61339-67-C-0034, sponsored by Naval Training Device Center, Orlando, FL 32813, NAVTRADEVCEN 67-C-0034-1, August 1968, 65 pp., AD 675825.

SUBJECTS: 18 instrument-rated non-jet pilots.

EQUIPMENT: Universal Digital Operational Flight Training Tool (UDOFTT) configured as a high speed Navy jet fighter aircraft.

SCENARIO: Level turn and climbing turn.

MEASURES: Altitude (absolute error [AE] and algebraic average error [ALGE]), heading (AE and ALGE), mach (AE and ALGE), and position/variance of fore-aft control stick, aileron, elevator, elevator trim, aileron trim, lateral control stick trim, and lateral control stick.

SUMMARY: The purpose of this study was to determine the training feasibility of using degraded levels of simulation fidelity in an Operational Flight Trainer (OFT). Simulation fidelity was varied by varying aerodynamic equation coefficients into rigid and flexible conditions. It was concluded that the feasibility of rigid coefficients for OFT training was demonstrated but the flexible coefficients were of doubtful value.

236. WOLF, James D., Crew Workload Assessment. Development of a Measure of Operator Workload, Honeywell Systems and Research Center, Minneapolis, MN 55413, Contract No. F33615-77-C-3065, sponsored by Air Force Flight Dynamics Laboratory, Wright-Patterson AFB, OH 45433, AFFDL-54-78-165, December 1978, 94 pp., AD A068616.

SUBJECTS: 8 pilots.

EQUIPMENT: Honeywell simulator configured as an F-4 aircraft.

SCENARIO: Instrument landing approach with a secondary audio stimulus task (Sternberg fixed-set procedure).

MEASURES: Root mean square (RMS) of pitch, roll, airspeed, approach glideslope error, and approach centerline error. Secondary task variables were reaction time and number of correct responses (percent). Visual response variables were pupil diameter and fixation location. Physiological variables were electrocardiogram (ECG), forehead electromyogram (EMG), forearm EMG, and respiration. Subjective opinion variables of workload were comparative judgements of task difficulty and scalar ratings of difficulty.

SUMMARY: The objective of this study was to develop a practical empirically-based tool for crew-staion workload evaluation, and to further develop alternative workload metrics based on analysis of physiological-response, task-performance, and opinion data. Three levels of flight task difficulty were formed by a composite of gust level and flight control system mode (nominal versus degraded) and thus defined distinguishable differences in performance errors and judged task difficulty. Resulting data for selective physiological and visual response variables were applied in a stepwise regression-analysis procedure to the prediction of a composite performance/opinion measure. An operationally-defined metric for information processing workload was presented.

237. CHARLES, John P., and Johnson, Robert M., Automated Training Evaluation, Logicon, Inc., San Diego, CA 92110, Contract No. N61339-70-C-0132, sponsored by Naval Training Device Center, Orlando, FL 32813, NAVTRADEVCEN 70-C-0132-1, January 1972, 165 pp., AD 736932.

SUBJECTS: 12 pilots.

EQUIPMENT: NTEC R & D simulator (TRADEC) configured as an F-4.

SCENARIO: Ground controlled approach and emergency procedures.

MEASURES: Approach path performance (landing gear down, full flaps, speed brake in, heading, angle of attack, and altitude) and gate score (lateral displacement from the approach course centerline, vertical displacement from approach glideslope, angle of attack error, turn rate, and angle of attack rate). These measures w overall single score for input to the sampling plan.

SUMMARY: The purpose of this study was to investigate the implementation of automated weapon system training and demonstration of technical feasibility in terms of computer programs and crew station development within realistic and practical constraints. The methodology involved problem definition, analysis, design and development, implementation and debug, and test and evaluation. The results indicated that automated weapon system training was feasible and acceptable by operational personnel.

238. BRECKE, Fritz H., Gerlach, Vernon S., and Shipley, Brian D., *Effects of Instructional Cues on Complex Skill Learning*, Arizona State University, Tempe, AZ 85281, Contract No. AFOSR-71-2128, Air Force Office of Scientific Research, Arlington, VA 22209, AFOSR-TR-75-0201, August 1974, 147 pp., AD A004465.

SUBJECTS: 11 student pilots.

EQUIPMENT: T4-G simulator.

SCENARIO: Vertical S-A (straight and level, climbs, and descents).

MEASURES: Altitude, power, vertical velocity, pitch, heading, and airspeed. Transformations included percent time within criterion, number of times outside or inside criterion limits, and error amplitude about the criterion limit.

SUMMARY: The purpose of this study was to ascertain the effectiveness of an operationally defined mediator, the instructional cue, on the acquisition of an instrument maneuver flying skill. Experiment conditions were current operational cues, systematically developed cues, or no cues. It was found through analysis of techniques and graphic analysis that the instruction cue is a powerful and effective variable. Pretraining which included instructional cues resulted in better subsequent perceptual-motor performance and less within group variance than did pretraining without instructional cues.

239. HAGIN, William V., Herrington, Scott S., and Haygood, Robert C., Measuring Pilot Proficiency on an Instrument Training Maneuver, Arizona State University, Tempe, AZ 85281, Contract No. AFOSR-76-2900, sponsored by Air Force Office of Scientific Research, Bolling AFB, DC 20332, AFOSR-TR-78-0211, August 1977, 40 pp., AD A050972.

SUBJECTS: 30 student pilots.

EQUIPMENT: Advanced Simulator for Pilot Training (ASPT).

SCENARIO: Vertical S-A (straight and level, climbing, and descending).

MEASURES: Heading deviation (mean [$\bar{X}$]), airspeed deviation ($\bar{X}$), vertical velocity ($\bar{X}$), and time of maneuver deviation ($\bar{X}$).

SUMMARY: The purpose of this study was to develop an observer-recording form for the instrument training maneuver Vertical S-A in order to increase observer reliability and decrease dependence on automatic scoring methods. It was concluded that trained observers can use a well-designed recording form as a means of objectifying pilot performance measurement in support of training methods, research, and hardware evaluations where both the maneuver and criteria can be conveniently described in terms of instrument readings.

240. SHIPLEY, Brian D., An Automated Measurement Technique for Evaluating Pilot Skill, Arizona State University, Tempe, AZ 85281, Contract No. AFOSR-76-2900, sponsored by Air Force Office of Scientific Research, Bolling AFB, DC 20332, AFOSR-TR-76-1253, February 1976, 120 pp., AD A033920.

SUBJECTS: 2 pilots and 39 student pilots (3 empirical investigations).

EQUIPMENT: T4-G simulator.

SCENARIO: Vertical S-A (straight and level, climbing, and descending).

MEASURES: Used an algorithmic performance state evaluation model with performance times and deviations from a standard flight path as indicators of skill. Parameters or components of the model were error amplitude, total time, maximum altitude, and ten "state" or "sum" times.

SUMMARY: The purpose of this study was to develop and apply specific indicators of performance skill to pilot training. A "performance state" model was constructed to evaluate pilot skill. The results of stepwise regression analysis supported the hypothesis that a small set of specific indicators could be used to replace a summary indicator of variability in performance. With the present maneuver, the model allowed for superior evaluations with fewer data points.

241. GERLACH, Vernon S., Cues, Feedback and Transfer in Undergraduate Pilot Training, Arizona State University, Tempe, AZ 85281, Contract No. AFOSR-71-2128, sponsored by Air Force Office of Scientific Research, Bolling AFB, DC 20332, AFOSR-TR-76-0056, August 1975, 51 pp., AD A033219.

SUBJECTS: 11 student pilots.

EQUIPMENT: T4-G flight simulator.

SCENARIO: Vertical S-A maneuver (climbs, descents, and straight and level).

MEASURES: Airspeed, heading, vertical velocity, altitude, pitch, roll, elevator deflection, and throttle (percent of maximum power). These parameters were transformed by means of raw scores, means of error scores, area scores, and percent time on criterion.

SUMMARY: The purpose of this study was to present past research efforts in order to generate prescriptive statements or guidelines for designing effective training materials and procedures for undergraduate pilot training in both simulated and natural environments. A series of studies were conducted and are presented in which selected dependent variables related to instructional cues, feedback, and transfer were studied as they affected flying training. Results of the series of studies provided a basis for the development of a model for generating instructional cues based on a set of procedures for an objective task analysis, the demonstration of systematically generated cues, and the effects of the amount of practice during cue learning and type of instructional cue. Substantial research was also devoted to developing objective and automated procedures for measuring complex flying skills in an advanced simulator.

242. SHIPLEY, Brian D., Gerlach, Vernon S., and Brecke, Fritz H., Measurement of Flight Performance in a Flight Simulator, Arizona State University, Tempe, AZ 85281, Contract No. AFOSR-71-2128, sponsored by Air Force Office of Scientific Research, Bolling AFB, DC 20332, AFOSR-TR-75-0208, August 1974, 145 pp., AD A004488.

SUBJECTS: 11 student pilots.

EQUIPMENT: T4-G simulator.

SCENARIO: Vertical S-A (straight and level, climbing, and descending).

MEASURES: Altitude, airspeed, vertical velocity, heading, pitch, power, and throttle movements. Scoring procedures included time-on-criterion (normalized root-mean-square error and hit-rate) and error amplitudes.

SUMMARY: The purpose of this study was to investigate the relationship between the form of instructional cues given to a novice pilot and the resulting performance of that pilot. Methods of collecting, transforming, and analyzing data collected are discussed and evaluated. It was concluded that time-on-criterion scores and error amplitude methods are potentially useful as efficient estimators of general differences in pilot performance quality.

243. SCHWANK, Jock C.H., Bermudez, John M., Smith, Bruce A., and Harris, Dickie A., Pilot Performance During Flight Simulation with Peripherally Presented Visual Signals, Proceedings of the 22nd Annual meeting of the Human Factors Society, Detroit, MI, October 1978, p. 222-226.

SUBJECTS: 48 U.S. Air Force student pilots.

EQUIPMENT: Singer-Link GAT-1 simulator.

SCENARIO: Vertical S-A maneuver (straight and level, ascents, and descents), and a secondary mental task (digit canceling).

MEASURES: Heading (plus or minus 10 degrees), airspeed, vertical velocity, number of heading crossovers (270 degree baseline), and number of correct responses to the digit canceler.

SUMMARY: This report is a culmination of two experiments that investigated the effectiveness of 3 types of instrument displays during flight in a GAT-1 simulator. Both experiments showed no decrement in pilot performance during the complex instrument maneuver involving normal and peripheral displays. Subjects were less prone to deviate from a given compass heading using the peripheral display. The secondary task (digit canceling) used to simulate secondary tasks involved in actual flight also did not diminish performance across displays. These results are consistent with a dual theory of visual processing and the notion of non-obtrusive prompting.

244. WOODRUFF, Robert R., Longridge, Thomas M. Jr., Irish, Philip A. III, and Jeffreys, Richard T., Pilot Performance in Simulated Aerial Refueling as a Function of Tanker Model Complexity and Visual Display Field-of-View, Air Force Human Resources Laboratory, Williams Air Force Base, AZ 85224, AFHRL-TR-78-98, May 1979, 24 pp., AD A070231.

SUBJECTS: 12 pilots.

EQUIPMENT: Advanced Simulator for Pilot Training (ASPT) with simulated KC-135, A-10, F-4, B-52, and F/FB-111 aircraft.

SCENARIO: Aerial refueling, takeoff, and landing.

MEASURES: Elapsed time to criterion, number of refueling disconnects (mean), aileron (power, root-mean-square [RMS] position, and RMS movement), and amount of oscillation of the receiver aircraft receptacle around the center point of the acceptable boom movement envelope during contact (aircraft/boom oscillations).

SUMMARY: The purpose of this experiment was to determine the effects of tanker model level of detail on the performance of pilots in the context of several display systems involving visual field-of-view. Number, location, and complexity of four field-of-views were examined. It was concluded that aerial refueling performance varies as a function of both field-of-view size and tanker detail level. The larger the field-of-view or the more detailed the tanker model, the better the performance.

245. PFEIFFER, Mark G., Clark, W. Crawford, and Donaher, James W., *The Pilot's Visual Task: A Study of Visual Display Requirements*, Courtney and Company, Philadelphia, Pa, Contract No. N61339-783, sponsored by U.S. Naval Training Device Center, Port Washington, NY, NAVTRADEVCEN 783-1, March 1963, 119 pp., AD 407440.

SUBJECTS: 10 pilots.

EQUIPMENT: F-100/151 fixed gunnery flight simulator.

SCENARIO: Formation flight with/without an external horizon, single aircraft flight with/without an external horizon, and inside/outside cockpit visual performance.

MEASURES: Reaction time to emergencies (cockpit or inside and intruder aircraft or outside) and altitude.

SUMMARY: The purpose of this experiment was to investigate the improvement in pilot time-sharing using a visual display, determine the training potential of a flight simulator with a nonprogrammed display, and determine what kinds of visual time-sharing behavior are observed and the implications of that behavior with regard to training to improve performance. In general it was found that pilots improved their performance with training for the different scenarios of flight as well as the visual performance tasks. Performance was better while flying singly than while flying in formation. The addition of an external visual horizon had no overall effect on emergency detection behavior, but did make a difference for aircraft control behavior despite its being difficult to see. The pilots who performed best in terms of emergency detection did not necessarily perform best in terms of aircraft control, implicating the need for time-sharing training.

246. WEWERINKE, P.H., Human Control and Monitoring-Models and Experiments, National Aerospace Laboratory (NLR), The Netherlands, NLR-MP-76015-U, May 1976, 25 pp., AD B026958.

SUBJECTS: 4 pilots.

EQUIPMENT: Fixed-base simulator configured as a DC-8.

SCENARIO: Instrument Landing System (ILS) approach, monitoring task, and auditory tracking task.

MEASURES: Tracking performance was measured in terms of approach ILS error (variance [S^2]), flight director error (S^2), and airspeed deviations (S^2), control stick activity (S^2), audio display deviation (S^2). For decision-making tasks, a theoretical model was used to determine total decision error. Workload was estimated by fractional attention to a particular task and subjective ratings.

SUMMARY: The objective of this study was to describe human monitoring behavior and to determine how it is affected by performing other tasks (interference). Human operator models utilized included decision making models (perceptual and subjective expected utility model), a task interference model, a multivariable monitor model, and a multivariate workload model. The results demonstrated the multivariable monitor model adequately described human behavior for the experimental tasks, and a multivariate workload model was developed.

247. EPHRATH, A.R., Tole, J.R., Stephens, A.T., and Young, L. R., Instrument Scan - Is it an Indicator of the Pilot's Workload? Proceedings of the 24th Annual Meeting of the Human Factors Society, Los Angeles, CA, October 1980, p. 257-258.

SUBJECTS: 3 pilots.

EQUIPMENT: NASA-Langley Research Center Terminal Configured Vehicle (TCV) fixed-base flight simulator and an oculometer system.

SCENARIO: Microwave Landing System (MLS) approach, a mental loading task (arithmetic), and a workload measuring side task (response to lights).

MEASURES: Number of correct responses (workload side task and mental loading task), and eye movements; fixation location, fixation-sequences, and probability of a fixation-sequence.

SUMMARY: The purpose of this experiment was to investigate the relationship between the pilot's visual scanning of instruments and his level of mental activity during a simulated approach and landing. The experimental conditions were traffic (presence or absence), side task lights (presence or absence), and mental loading task (no loading, 20-sec intervals and 10-sec intervals). Results of the side task showed a definite increase in workload when the arithmetic task was introduced. The three instruments used most in the scan were the EADI, EHSI, and air-speed indicator. Preliminary results of fixation-sequences suggested a monotonic trend in entropy values as mental loading increased.

248. IRISH, Philip A. III, and Buckland, George H., Effects of Platform Motion, Visual and G-Seat Factors Upon Experienced Pilot Performance in the Flight Simulator, Air Force Human Resources Laboratory, Williams AFB, AZ 85224, AFHRL-TR-78-9, June 1978, 44 pp., AD A055691. See article no. 263 for a similar study.

SUBJECTS: 5 pilots.

EQUIPMENT: Advanced Simulator for Pilot Training (ASPT).

SCENARIO: Aileron Roll, Barrel Roll, Loop, 360` overhead pattern, and Ground Controlled Approach (GCA).

MEASURES: Utilized Auto[illegible] Performance Measurement System (APMS). [illegible]iations were measured based on tolerance bands established by instructor pilots during each maneuver for: pitch angle and rate, bank in, bank out, roll angle and rate, roll acceleration, groundtrack, vertical velocity, altitude, bank, airspeed, approach glideslope error, approach centerline error, landing distance to ideal touchdown point, landing heading, and centerline. Pilot input parameters were elevator, aileron, and rudder. Composite scores were derived for segments and scenarios.

SUMMARY: The objective of this study was to empirically assess the performance of experienced pilots in the ASPT under varying platform motion, G-seat, field-of-view, and visibility/ceiling. The results indicated that expert performances were affected by motion, field-of-view, and visibility/ceiling variables and were often manifested as changes in control behavior rather than vehicle performance.

249. VREULS, Donald, Obermayer, Richard W., and Goldstein, Ira, Trainee Performance Measurement Development Using Multivariate Measure Selection Techniques, Manned Systems Sciences, Inc., Northridge, CA 91324, Contract No. N61339-73-C-0066, sponsored by Naval Training Equipment Center, Orlando, FL 32813, NAVTRAEQUIPCEN 73-C-0066-1, September 1974, 53 pp., AD 787594. See also Proceedings, NTEC/Industry Conference, Orlando, FL, NAVTRAEQUIPCEN IH-240, November 1974, p. 227-236, AD A000970.

SUBJECTS: 4 pilots.

EQUIPMENT: NTEC R & D simulator (TRADEC) configured as an F-4.

SCENARIO: Straight and level, climbs, descents, turns, climbing turns, and descending turns.

MEASURES: Elevator control stick (range [R], crossover power [CP], and mean displacement [$\bar{X}$]), aileron control stick (R, CP, $\bar{X}$), angle of attack (R, standard deviation [S]), pitch (R, S, root mean square error [RMS]), roll (R, RMS), heading (R, RMS), altitude (R, average absolute error [AAE]), vertical velocity (R, AAE), and airspeed (R, AAE).

SUMMARY: The purpose of this study was to extend a descriptive structure for measuring human performance during training to a fixed-wing, high-performance aircraft simulation and to develop performance measure selection statistical techniques. The methodology included definition of candidate performance measures, development of computer programs to acquire raw data and to produce candidate measures, and to develop methods to reduce the resulting candidate measures to a small and efficient set which reflects the skill change that occurs as a function of training. Two measure selection methods were developed; one based in part on a multiple discriminant analysis model and the other based in part on a canonical correlation model. The results showed the multiple discriminant procedure reduced measures to an efficient set that discriminated between early and later training performance and produced weights for the summation of individual measures into a composite score. The canonical method produced similar results but needed additional criteria in the selection of predictive measures.

250. GOLDBERG, Bernard, and Eldredge, Donald, RNAV Procedural Turn Anticipation Techniques Experiment No. 2, GAT-2A. Phase III. - 2 and 4 NMI Offset Tracking Procedures, Federal Aviation Administration, Atlantic City, NJ 08405, FAA-RD-78-110, September 1978, 76 pp., AD A060501.

SUBJECTS: 8 pilots.

EQUIPMENT: Link GAT-2A simulator.

SCENARIO: Takeoff, climb, straight and level, Standard Terminal Arrival Route (STAR), and RNAV approach to landing.

MEASURES: Total system crosstrack error (transition from one segment to the next segment within 2 nmi before and after the waypoint), flight technical error (steady state tracking data), and Course Deviation Indicator (CDI) displacement. These variables were basically horizontal tracking error, airspeed control, and procedural errors.

SUMMARY: The purpose of this research was to establish a data base to assess pilot performance for; (1) anticipation of turns while maintaining a desired offset, and (2) steady state parallel offset tracking proficiency. The results indicated no differences exist betwen the offset turn data and the offset steady state data in terms of the performance variables measured.

251. ELLIS, N.C., Lowes, A.L., Matheny, W.G., Norman, D.A., and Wilkerson, L.E., Pilot Performance, Transfer of Training and Degree of Simulation. II. Variations in Aerodynamic Coefficients, Life Sciences, Inc., Fort Worth, TX, Contract No. N61339-1889, sponsored by Naval Training Device Center, Orlando, FL, NAVTRADEVCEN 1889-1, May 1967, 109 pp., AD 655837.

SUBJECTS: 18 pilots.

EQUIPMENT: Universal Digital Operational Flight Trainer Tool (UDOFTT) configured as a jet fighter aircraft.

SCENARIO: Straight and level, climbs, descents, turns, and climbing turns.

MEASURES: Altitude, mach number, heading, pitch rate, roll rate, aileron motion, and elevator motion. Transformations included average absolute deviations and maxiumum absolute deviations.

SUMMARY: The purpose of this research was to investigate the potential training utility of rigid airframe equations and least squares approximations for the reduction of simulation complexity and the corresponding relationship to pilot performance. Three transfer of training investigations were conducted. Experiment one incorporated the aerodynamic coefficients by rigid coefficients and least squares approximations to the coefficients in the longitudinal mode, experiment two incorporated the coefficient changes in the lateral mode, and experiment three combined longitudinal and lateral modes. It was concluded that feasibility of these reduced simulations as conditions for training had been demonstrated in terms of the performance measurements taken.

252. GAINER, Charles A., and Obermayer, Richard W., "Pilot Eye Fixations While Flying Selected Maneuvers Using Two Instrument Panels," Human Factors, v. 6(5): p. 485-501, October 1964.

SUBJECTS: 16 U.S. Air Force pilots.

EQUIPMENT: Link MG-5 Simulator configured as a high performance jet.

SCENARIO: Instrument flight maneuvers; climbout, level-off, turns, straight and level, fast rate letdown, penetration outbound, penetration turn, and low approach.

MEASURES: For system performance; root mean square (RMS) error of altitude, heading, Mach, vertical velocity, and airspeed was measured only when that parameter was steady state during a maneuver. For each maneuver, pilot eye movement performance was measured by number of eye fixations, total time spent between fixations, time per fixation, percent fixation on each instrument, and percent fixation between each instrument.

SUMMARY: The primary purpose of this study was to investigate eye fixations as they occurred while flying instruments in two panel configurations. One panel was a conventional dial type and the other was equipped with vertical moving tape instruments. Results showed certain differences which demonstrated statistical significance in favor of the circular instruments while other differences favored vertical instruments. Scale expansion was concluded as a possible critical factor in any existing differences. Eye movement results showed the attitude director indicator (ADI) was the most frequently fixated instrument on both panels. Very low correlations between RMS error and eye fixations were obtained, leading to the result that any relationship between the two was not yet demonstrated.

253. IAMPIETRO, P.F., Melton, C.E. Jr., Higgins, E.A., Vaughan, J.A., Hoffman, S.M., Funkhouser, G.E., and Saldivar, J.T., "High Temperature and Performance in a Flight Task Simulator," Aerospace Medicine, v. 43(11): p. 1215-1218, November 1972.

SUBJECTS: 12 pilots.

EQUIPMENT: Link GAT-1 simulator.

SCENARIO: Straight and level, VOR navigation, turns, and an Instrument Landing System (ILS) approach.

MEASURES: System measure was heading. Physiological measures were skin temperature, rectal temperature, ECG (heart rate), perspiration weight loss, and urine samples.

SUMMARY: The purpose of this experiment was to determine the effects of high cockpit temperatures on performance of pilots flying a general aviation type simulator. Experimental conditions were temperatures of 25 degrees C, 43.3 degrees C, and 60 degrees C. Flights lasted 50 minutes. Results showed significant decrements in performance for three segments of flight as a function of increasing temperature.

254. MCDOWELL, Edward D., The Development and Evaluation of Objective Frequency Domain Based Pilot Performance Measures in ASUPT, Oregon State University, Corvallis, OR 97331, Contract No. AFOSR-77-3294, sponsored by Air Force Office of Scientific Research, Bollings AFB, DC 20332, AFOSR-TR-78-1239, April 1978, 40 pp., AD A059477.

SUBJECTS: 20 student pilots and 10 instructor pilots.

EQUIPMENT: Advanced Simulator for Undergraduate Pilot Training (ASUPT).

SCENARIO: Straight and level (2 minutes), turn to heading, Vertical S Delta (UPT maneuver), and formation flight.

MEASURES: Aileron, elevator and throttle positions were measured in terms of a minimum, a maximum, and the first four moments. An ASPT automatic performance measurement total score (percent of total time the pilot maintains his aircraft within prescribed tolerance limits) was used as follows; (1) straight and level - altitude, airspeed and heading, (2) turn to heading - altitude, airspeed, roll, and heading, (3) vertical S Delta - airspeed, bank, vertical velocity, heading, and altitude, and (4) formation - X, Y and Z position (navigational accuracy).

SUMMARY: The objective of this research was to determine if the pilot's control movement relative power spectra would shift to higher frequencies as experience was gained, to identify the pilot's control movement measures which vary significantly as a function of experience, and to estimate the degree to which the control movement measures discriminated pilot experience levels. The results indicated that frequency domain based measures of a pilot's control movements do discriminate between pilot experience levels and may be useful for developing an automated objective pilot performance measurement system.

255. DEMAREE, Robert G., Norman, Don A., and Matheny, William G., An Experimental Program for Relating Transfer of Training to Pilot Performance and Degree of Simulation, Life Sciences, Inc., Fort Worth, TX, Contract No. N61339-1388, sponsored by U.S. Naval Training Device Center, Port Washington, NY, NAVTRADEVCEN 1388-1, June 1965, 65 pp., AD 471806.

SUBJECTS: 3 U.S. Navy pilots.

EQUIPMENT: Universal Digital Operational Flight Trainer Tool (UDOFTT) configured as a jet fighter aircraft.

SCENARIO: Straight and level, climbs, descents, and turns.

MEASURES: Altitude, vertical velocity, mach number, pitch angle and rate, roll angle and rate, heading, turn rate, angle of attack, and yaw angle. Parameters used for pilot workload were aileron, elevator, rudder, and throttle deflection. Transformations included mean square error, absolute error, and maximum/minimum deviation of a parameter from its reference value.

SUMMARY: The objective of this research was to determine the relationship between the degree of simulation and the carry-over effects of learning which occurs in one situation to learning in another situation. Results of this study and earlier investigations have provided a basis for the methodology, rationale, and design of a series of UDOFTT experiments on the relationship in question.

256. HENRY, Peter H., Fluek, James A., and Lancaster, Malcolm C., Laboratory Assessment of Pilot Performance Using Nonrated Subjects at Three Alcohol Dose Levels, USAF School of Aerospace Medicine, Brooks AFB, TX 78235, SAM-TR-74-27, December 1974, 223 pp., AD A007727. See also article nos. 257 and 258.

SUBJECTS: 22 nonpilots.

EQUIPMENT: Link GAT-1 trainer (simulator).

SCENARIO: Takeoff, climbs, turns, straight and level, descents, climbing and descending turns, approach, and landing.

MEASURES: See article no. 258 for a complete listing of man/machine output parameters (CSTE). Other variables measured were elevator, rudder, aileron, throttle, and flap position. In addition, a secondary task for reaction time was added to the flight task.

SUMMARY: The purpose of this study was to present research efforts in the effects of drugs and environmental stresses on pilot psychomotor performance. Specifically, three experiments were described to assess the acute effects of three measured blood alcohol levels of 25, 55 and 85 mg percent on pilot performance. Results showed statistically significant performance decrements for all three dose levels. The decrements were small at the low dose, showed a progressive increase with the moderate dose, and became substantial at the high dose. Other tests conducted on the Multidimensional Pursuit Task and Complex Coordinator gave comparable results.

257. HENRY, P.H., Davis, T.Q., Engelken, E.J., Triebwasser, J.H., and Lancaster, M.C., Alcohol-Induced Performance Decrements Assessed by Two Link Trainer Tasks Using Experienced Pilots, USAF School of Aerospace Medicine, Brooks AFB, TX 78235, SAM-TR-74-323, October 1974, 12 pp., AD A000982. See also Aerospace Medicine, v. 45(10): p. 1180-1189, October 1974. See article nos. 256 and 258 for similar studies.

SUBJECTS: 12 U.S. Air Force instructor pilots.

EQUIPMENT: Link GAT-1 trainer (simulator).

SCENARIO: Takeoff, climbs, turns, straight and level, descents, climbing and descending turns, approach, and landing.

MEASURES: See article no. 258 for a complete listing of man/machine output parameters (CSTE).

SUMMARY: The purpose of this experiment was to quantify the degrading effects of ethanol (ETOH) on performance of two separate tasks developed in the GAT-1 trainer. The subjects were tested at three measured blood alcohol levels of approximately 30, 60, and 100 mg percent. Results indicated a significant performance decrement for only the moderate and high alcohol doses. The decrement magnitudes were found to closely correspond to previous experimental results (see article no. 256) using the same test conditions but with nonpilot subjects.

258. **HENRY, Peter H.**, Subject Instruction Manual for the Pilot Performance Evaluation System, USAF School of Aerospace Medicine, Brooks AFB, TX 78235, SAM-TR-74-40, October 1974, 37 pp., AD A003433. See also article nos. 256 and 257.

SUBJECTS: 22 student pilots and 16 U.S. Air Force pilots.

EQUIPMENT: Link GAT-1 trainer (simulator).

SCENARIO: Takeoff, climbs, turns, straight and level, descents, climbing and descending turns, approach, and landing.

MEASURES: Combined total seconds of error (CTSE) computed as a combination of separate error-seconds for: (1) altitude (plus or minus 40 feet), (2) heading (plus or minus 1 degree), (3) airspeed (plus or minus .5 mph), (4) vertical velocity (plus or minus 20 fpm), (5) turn rate (plus or minus .25 degrees per second), and (6) ball angle (plus or minus 2 degrees vertical).

SUMMARY: The purpose of this study was to develop an automated system to assess performance in a Link GAT-1 trainer and to provide an instruction manual for the basic functions, controls, and test requirements. The methodology included describing the GAT-1 controls and instruments, developing scoring criteria, testing the scoring criteria, and recommending strategies for superior performance within the scoring criteria. Also included is a set of instruction cards describing the maneuvers to be executed during the course of the hour-long test.

259. **VREULS, Donald, Wooldridge, A. Lee**, Obermayer, Richard W., Johnson, Robert M., Norman, Don A., and Goldstein, Ira, Development and Evaluation of Trainee Performance Measures in an Automated Instrument Flight Maneuvers Trainer, Canyon Research Group, Inc., Westlake Village, CA 91361, Contract No. N61339-74-C-0063, sponsored by Naval Training Equipment Center, Orlando, FL 32813, NAVTRAEQUIPCEN 74-C-0063-1, October 1975, 112 pp., AD A024517.

SUBJECTS: 15 civilian pilots.

EQUIPMENT: NTEC R & D Simulator (TRADEC).

SCENARIO: Straight and level, climbs, descents, turns, climbing turns, and descending turns.

MEASURES: Elevator control stick (range [R], crossover power [CP], and mean displacement [$\bar{X}$]), aileron control stick (R, CP, and $\bar{X}$), rudder pedal (R, CP, and $\bar{X}$), angle of attack (R and standard deviation [S]), pitch (R and S), roll (absolute average error [AAE] and root mean- squared [RMS] error), heading (R and RMS error), altitude (AAE and R), airspeed (AAE and R), vertical velocity (AAE and R), turn rate (RMS error and AAE), sideslip (RMS error), and right throttle (R).

SUMMARY: The purpose of this experiment was to improve training performance measurement selection methods, apply the results to an automated flight training system and conduct an evaluation of resulting measurement during automated training of four instrument flight maneuvers. Training sessions for each scenario were pooled to result in 144 possible observations for each scenario on a given training day. Early and late training days were then compared by using multivariate discriminant analysis techniques with three matched groups of five subjects each. Results showed that time-to-train was reduced 34-40 percent for pilots training with empirically derived measures over the original scoring algorithm. The discriminant measures demonstrated the ability to select and properly weight important student variables along with system performance. Potentially serious inefficiencies with linear, single score adaptive logics were observed and discussed.

260. LEMASTER, W. Dean, and Gray, Thomas H., Ground Training Devices in Job Sample Approach to UPT Selection and Screening, Air Force Human Resources Laboratory, Williams Air Force Base, AZ 85224, AFHRL-TR-74-86, December 1974, 58 pp., AD A009995.

SUBJECTS: 128 student pilots.

EQUIPMENT: A/F37A-T-40 Instrument Trainer.

SCENARIO: Straight and level, pitch control, accelerate, decelerate, climbs, descents, turns, rate climb or descent, complex turn, steep turns, vertical "S" Alpha, and vertical "S" Delta.

MEASURES: Basically, three types of measures were obtained; (1) aircraft control-airspeed, altitude, heading, pitch, roll, pitch/roll coordination (displayed wing tip position on the artificial horizon), vertical velocity, and roll rate, (2) systems management - used a light box (secondary task) for amount of time required to solve and accuracy of the solution, and (3) flying procedures - power setting, VOR course intercept (navigational accuracy), VOR holding, takeoff procedures, number of turns to assigned headings, number of successful recoveries from unusual attitudes, and simple radio communications (all recorded as correct/incorrect).

SUMMARY: The purpose of this study was to develop a screening procedure for undergraduate pilot training (UPT). The methodology utilized a ground-based instrument trainer in a highly standardized and tightly controlled environment to evaluate UPT candidates naive to flying. The job sample approach proved highly successful in predicting student performance in a later T-37 phase of UPT but did not satisfactorily predict attrition due to causes other than a lack of flying skill.

261. LONG, George E., and Varney, Nicholas C., Automated Pilot Aptitude Measurement System, McDonnell Douglas Astronautics Company, St. Louis, MO 63166, Contract No. F41609-73-C-0037, sponsored by Air Force Human Resources Laboratory, Lackland AFB, TX 78236, AFHRL-TR-75-58, September 1975, 134 pp., AD A018151.

SUBJECTS: 178 student pilots.

EQUIPMENT: Link GAT-1 trainer simulator.

SCENARIO: Straight and level, climbs, descents, turns, climbing turns, descending turns, takeoff, and approach traffic pattern.

MEASURES: Utilized an Automatic Pilot Aptitude Measurement System (APAMS). Parameters measured were altitude, pitch angle, vertical velocity, heading, roll angle, turn rate, airspeed, sideslip, and navigational accuracy (distance right or left of desired track).

SUMMARY: The purpose of this study was to address the problem of predicting success in undergraduate pilot training (UPT) through the measurement of performance on a learning sample of flight tasks administered prior to the initiation of training. The technique was proposed as a means for reducing attrition rates during UPT. Learning tasks and/or flight maneuvers were selected so as to reflect individual differences in basic psychomotor abilities, learning rate, multi-task integration, and performance under overload. The performance measures from 5 hour flights were compared with performance (subjective) during subsequent T-41 and T-37 phases of UPT. The results showed grades given by instructors in T-41 training were highly correlated with performance measures on the learning sample. In addition, eliminated candidates from both phases could also be discriminated. It was concluded that the learning sample approach could contribute substantially to existing pilot selection procedures in reducing current attrition rates in UPT.

262. GABRIEL, Richard F., Burrows, Alan A., and Abbott, Paul E., Using a Generalized Contact Flight Simulator to Improve Visual Time-Sharing, Douglas Aircraft Company, Inc., Long Beach, CA, Contract No. N61339-1428, sponsored by Naval Training Device Center, Port Washington, NY, NAVTRADEVCEN 1428-1, April 1965, 74 pp., AD 619047. See also Human Factors, v. 10(1): p. 33-40, February 1968.

SUBJECTS: 30 pilots.

EQUIPMENT: A-4 flight simulator with visual attachment (2F76).

SCENARIO: Straight and level, climbs, descents, turns, navigation, dive-bombing, climb-out, penetration, and target tracking.

MEASURES: Detection of emergencies (mean probability, frequency), detection of targets (time), tracking error (mean), heading error, altitude error, scan time-sharing patterns (eye movement), and reaction time to emergencies (mean).

SUMMARY: The purpose of this experiment was to perform a follow-up study to a previous study (Pfeiffer, Clark, and Donoher, 1963, article no. 245) in order to provide a more extensive test of the effectiveness of time-sharing training as well as determine if a simplified device could be used for such training. The 30 pilots were given time-sharing training sessions while a control group was not. Both groups were then tested under the experimental conditions. Results showed the visual-time sharing trained group had significantly greater ability to detect outside-the-cockpit (intruder) emergencies without compromising performance on other flight tasks. Optimum scanning patterns acquired by practice were also found to transfer from one maneuver to another.

263. IRISH, Philip A. III, Grunzke, Paul M., Gray, Thomas H., and Waters, Brian K., The Effects of System and Environmental Factors Upon Experienced Pilot Performance in the Advanced Simulator for Pilot Training, Air Force Human Resources Laboratory, Williams AFB, AZ 85224, AFHRL-TR-77-13, April 1977, 60 pp., AD A043195.

SUBJECTS: 3 pilots.

EQUIPMENT: Advanced Simulator for Pilot Training (ASPT).

SCENARIO: Takeoff, climb, 360` overhead pattern, slow flight, aileron roll, Ground Controlled Approach (GCA), and landing.

MEASURES: Utilized Automated Performance Measurement System (APMS). Deviations were measured based on tolerance bands established by instructor pilots during each maneuver for: heading, pitch, course, airspeed, approach centerline error, approach glideslope error, pitchout altitude, roll, slip indicator, and roll acceleration. Pilot input parameters were elevator, aileron, and rudder power. Composite scores for percent-time-within-criteria were derived for each scenario.

SUMMARY: The objectives of this study were to assess the relative contribution of platform motion, G-seat, and visual factors to pilot performance, and to acquire information on the relationships between system output and pilot input measures. In addition, it was desired to evaluate the utility of economical multifactor designs for research in the ASPT. Experimental conditions were platform motion, G-seat, field-of-view (FOV), turbulence, wind, and visibility/ceiling. Results showed platform motion cueing produced a concomitant decline in performance. G-seat effect demonstrated a strong interactive potential often with a visually oriented independent variable. The FOV variable showed extreme maneuver-specific effects. All variables showed complex interactions that were difficult to isolate.

264. HILL, John W., and Goebel, Ronald A., Development of Automated GAT-1 Performance Measures, Stanford Research Institute, Menlo Park, CA 94025, Contract No. F41609-70-C-0041, sponsored by Air Force Human Resources Laboratory, Williams AFB, AZ 85224, AFHRL-TR-71-18, May 1971, 33 pp., AD 732616.

SUBJECTS: 30 subjects with various levels of flying experience.

EQUIPMENT: Link GAT-1 trainer.

SCENARIO: Tracking task (two-dimensional), straight and level, turns, ascents, descents, ascending and descending turns, decelerations, accelerations, and ILS approach.

MEASURES: Airspeed, altitude, roll, pitch, heading, vertical velocity, approach glideslope error, and approach centerline error. Transformations included means, standard deviations, correlation coefficients, gain shifts, and phase shifts for the tracking tasks.

SUMMARY: The purpose of this study was to systematically search for flight parameters that correlate with pilot proficiency. The experiment had four tasks of increasing difficulty: a holding task, a holding task with power change, a five-part flight profile, and the Instrument Landing System (ILS) approach. Analysis of variance and multivariate discriminant analysis were used to select and determine which variables contributed most to differences in pilot experience. It was found that 27 variables significantly contributed to the separation of the subjects into three experience groups from which they were chosen. A single linear weighted sum of these 27 flight parameters was a criterion variable suggested as a measure of pilot proficiency.

265. HILL, John W., and Eddowes, Edward E., Further Development of Automated GAT-1 Performance Measures, Stanford Research Institute, Menlo Park, CA 94025, Contract No. F41609-72-C-0012, sponsored by Air Force Human Resources Laboratory, Williams AFB, AZ 85224, AFHRL-TR-73-72, May 1974, 77 pp., AD 783240.

SUBJECTS: 30 pilots of varying experience.

EQUIPMENT: Link GAT-1 simulator.

SCENARIO: Roll and pitch tracking, accelerations, decelerations, climbs, turns, slow flight, descents, descending turns, Instrument Landing System (ILS) approach, roll tracking, roll, pitch, and yaw tracking, and altitude and position tracking.

MEASURES: Airspeed, altitude, vertical velocity, roll, pitch, yaw, approach glideslope error, approach centerline error, turn rate, power rudder, elevator, aileron, and heading deviation. Transformations included means, standard deviations, correlations, and tracking parameters. Experiment 1 had 326 performance parameters while Experiment 2 had 2436 parameters.

SUMMARY: The purpose of this research was to investigate a systematic, statistically-directed search for automated flight measurements that correlate with pilot proficiency. The subjects were divided into three groups by experience level, and two experiments were conducted. Analysis of variance, canonical analysis, and multivariable analysis techniques were used to discriminate among the three groups. Results showed there is little difficulty in obtaining measurements that correlate with experience and over five percent of the variables of each experiment were statistically significant (0.01 level). Applying canonical variables to repeated measurements of the second experiment allowed several deductions about the best selection procedures to be made.

266. KELLY, Michael, J., Wooldridge, Lee, Hennessy, Robert T., Vreuls, Donald, Barnebey, Steve F., Cotton, John C., and Reed, John C., Air Combat Maneuvering Performance Measurement, Canyon Research Group, Inc., Westlake Village, CA 91361, Contract No. F33615-77-C-0079, sponsored by Naval Training Equipment Center, Orlando, FL 32813, and Air Force Human Resources Laboratory, Brooks Air Force Base, TX 78235, NAVTRAEQUIPCEN IH-315/AFHRC-TR-79-3, September 1979, 142 pp. See also Proceedings of the 23rd Annual Meeting of the Human Factors Society, 1979, p. 324-328.

SUBJECTS: 30 fighter pilots.

EQUIPMENT: Simulator for Air-to-Air Combat (SAAC) configured as an F-4 aircraft.

SCENARIO: One-vs-one air combat maneuvering.

MEASURES: Altitude rate (mean), opponent out of view (percentage of time opponent out of pilot's field of view), airspeed (mean), speedbrake (mean deflection), fuel flow (mean), relative altitude use (ratio of altitude standard deviations), energy management index (function of remaining fuel, fuel flow, airspeed and altitude), offensive time (sight angle less than 60 degrees), offensive time with advantage, throttle percentage time (idle, LO MIL, HI MIL, and afterburner), heading (root-mean-square and absolute average), lead time, time within range, roll rate, maneuvering rate (roll rate times altitude rate), ACM plane of action (composite of X, Y and Z), defensive time, angle of attack (percentage of time greater than 28 units), and aircraft kills (percentage of engagements ending in an AIM-9 success, gun success, ground impact, over-g or fuel exhaustion).

SUMMARY: The goal of this study was to develop a preliminary measurement structure and measurement set for an automated Air Combat Maneuvering Performance Measurement (ACMPM) system which could be implemented on the SAAC. The measurement system was to provide valid and diagnostic performance information in real time. Using multivariate analysis, a measurement model containing 13 variables accounted for 51 percent of the performance variance and was able to discriminate between pilots of high and low skill with an accuracy of 92.1 percent. It was recommended that further analyses, developmental testing, and weighted sum of these 27 flight parameters was a criterion variable suggested as a measure of pilot proficiency.

265. HILL, John W., and Eddowes, Edward E., Further Development of Automated GAT-1 Performance Measures, Stanford Research Institute, Menlo Park, CA 94025, Contract No. F41609-72-C-0012, sponsored by Air Force Human Resources Laboratory, Williams AFB, AZ 85224, AFHRL-TR-73-72, May 1974, 77 pp., AD 783240.

SUBJECTS:	30 pilots of varying experience.
EQUIPMENT:	Link GAT-1 simulator.
SCENARIO:	Roll and pitch tracking, accelerations, decelerations, climbs, turns, slow flight, descents, descending turns, Instrument Landing System (ILS) approach, roll tracking, roll, pitch, and yaw tracking, and altitude and position tracking.
MEASURES:	Airspeed, altitude, vertical velocity, roll, pitch, yaw, approach glideslope error, approach centerline error, turn rate, power rudder, elevator, aileron, and heading deviation. Transformations included means, standard deviations, correlations, and tracking parameters. Experiment 1 had 326 performance parameters while Experiment 2 had 2436 parameters.
SUMMARY:	The purpose of this research was to investigate a systematic, statistically-directed search for automated flight measurements that correlate with pilot proficiency. The subjects were divided into three groups by experience level, and two experiments were conducted. Analysis of variance, canonical analysis, and multivariable analysis techniques were used to discriminate among the three groups. Results showed there is little difficulty in obtaining measurements that correlate with experience and over five percent of the variables of each experiment were statistically significant (0.01 level). Applying canonical variables to repeated measurements of the second experiment allowed several deductions about the best selection procedures to be made.

266. KELLY, Michael, J., Wooldridge, Lee, Hennessy, Robert T., Vreuls, Donald, Barnebey, Steve F., Cotton, John C., and Reed, John C., *Air Combat Maneuvering Performance Measurement*, Canyon Research Group, Inc., Westlake Village, CA 91361, Contract No. F33615-77-C-0079, sponsored by Naval Training Equipment Center, Orlando, FL 32813, and Air Force Human Resources Laboratory, Brooks Air Force Base, TX 78235, NAVTRAEQUIPCEN IH-315/AFHRC-TR-79-3, September 1979, 142 pp. See also Proceedings of the 23rd Annual Meeting of the Human Factors Society, 1979, p. 324-328.

SUBJECTS: 30 fighter pilots.

EQUIPMENT: Simulator for Air-to-Air Combat (SAAC) configured as an F-4 aircraft.

SCENARIO: One-vs-one air combat maneuvering.

MEASURES: Altitude rate (mean), opponent out of view (percentage of time opponent out of pilot's field of view), airspeed (mean), speedbrake (mean deflection), fuel flow (mean), relative altitude use (ratio of altitude standard deviations), energy management index (function of remaining fuel, fuel flow, airspeed and altitude), offensive time (sight angle less than 60 degrees), offensive time with advantage, throttle percentage time (idle, LO MIL, HI MIL, and afterburner), heading (root-mean-square and absolute average), lead time, time within range, roll rate, maneuvering rate (roll rate times altitude rate), ACM plane of action (composite of X, Y and Z), defensive time, angle of attack (percentage of time greater than 28 units), and aircraft kills (percentage of engagements ending in an AIM-9 success, gun success, ground impact, over-g or fuel exhaustion).

SUMMARY: The goal of this study was to develop a preliminary measurement structure and measurement set for an automated Air Combat Maneuvering Performance Measurement (ACMPM) system which could be implemented on the SAAC. The measurement system was to provide valid and diagnostic performance information in real time. Using multivariate analysis, a measurement model containing 13 variables accounted for 51 percent of the performance variance and was able to discriminate between pilots of high and low skill with an accuracy of 92.1 percent. It was recommended that further analyses, developmental testing, and validation testing be undertaken to produce an effective ACMPM system usable by instructor pilots on the SAAC.

267. PROUHET, Edward P., and Kulwicki, Philip V., High Acceleration Cockpit Simulator Evaluation Summary Report, McDonnell-Douglas Corporation, St. Louis, MO 63166, Contract No. F33615-75-C-5087, sponsored by Aerospace Medical Research Laboratory, Wright-Patterson AFB, OH 45433, AMRL-TR-75-123, June 1977, 17 pp., AD A045165.

SUBJECTS: 4 military fighter pilots.

EQUIPMENT: Manned Air Combat Simulator (MACS).

SCENARIO: One-vs-one air combat maneuvering.

MEASURES: Relative heading (positional advantage), offensive time (nose to tail quadrant), radar and heads-up display (HUD) time-to-envelope and time within envelope, missile and gun opportunities (time spent with launch or fire parameters), number of hits (within 15 feet), and number of kills (cumulative probabilities of a time-based Markov process).

SUMMARY: The purpose of this experiment was to investigate the improved combat capability projected for a High Acceleration Cockpit (HAC) design and estimate its tactical utility in the air combat scenario. In each of the 144 missions flown, the pilots were instructed to aggressively seek the offensive advantage and deliver the appropriate weapon (guns or missiles). The results showed the HAC-equipped aircraft improved engagement control, had earlier firing opportunities, more "hits," and had a greater kill advantage. It was recommended that the HAC concept be evaluated in a future tactical aircraft.

268. RIIS, Erik, Measurement of Performance in F-86K Simulator, Proceedings, Annual AGARD Meeting of the Aerospace Medical Panel, Toronto, Canada, Advisory Group for Aerospace Research and Development, Paris, France, AGARD Conference Proceedings No. 14, Assessment of Skill and Performance in Flying, September 1966, p. 49-56, AD 661165.

SUBJECTS: 8 pilots.

EQUIPMENT: F-86K Simulator.

SCENARIO: One-vs-one air combat maneuvering (tracking task).

MEASURES: Deviations from ideal flight path measured in azimuth and distance.

SUMMARY: The purpose of this study was to review the development of a standardized flying program, practicing up to a maximum level of performance, adding different types of workload to the standard program, and observing performance under the influence of alcohol. No definite conclusions could be made because of the experimental conditions and small sample size.

269. LOENTAL, Diane G., Feasibility of Implementing Specific Performance Measurement Techniques, Quest Research Corporation, McLean, VA 22101, Contract No. F33615-73-C-4121, sponsored by Aerospace Medical Research Laboratory, Wright-Patterson AFB, OH 45433, March 1976, 111 pp., AD A025945.

SUBJECTS: 9 operators with various levels of experience with the simulator.

EQUIPMENT: F-106 coplanar attack simulator.

SCENARIO: Spotlight (pre-lock-on), lock-on, and attack modes of one-vs-one air-to-air combat.

MEASURES: Tracking error and rate, amount of deviation from the flight trajectory, roll angle, and "transition score" matrices based on steady-state Markov processes.

SUMMARY: The objective of this study was to determine what operator actions produce superior performance as distinguished from actions which produce less than superior performance. Several suggested operator models were used to represent the various pilot steering error controls for tracking. It was concluded that; (1) the nonlinear modeling technique is useful for generating pilot models that are representative of any nonlinear control policy, (2) performance can be measured by the amount of deviation between the actual flight trajectory and the model trajectory, (3) the transition modeling technique provides performance scores, transitions characteristic of a specific performance level, and state distributions that are applicable to any error-error rate state space performance measurement problem, and (4) operator flight control policies tend to become unstable when radar lock-on is attempted and when time-to-go is less than 20 seconds.

270. SOLIDAY, S.M., and Schohan, B., A Simulator Investigation of Pilot Performance During Extended Periods of Low-Altitude, High-Speed Flight, North American Aviation, Inc., Columbus, OH, Contract No. NASW-451, sponsored by National Aeronautics and Space Administration, Washington, DC, NASA CR-63, June 1964, 94 pp.

SUBJECTS: 8 pilots.

EQUIPMENT: Dynamic Flight Simulator with an A-5A G-seat and either a conventional center-stick or a side-stick controller.

SCENARIO: Low altitude terrain-following flight.

MEASURES: Altitude error (variance [S^2], root-mean-square [RMS]), pitch error (mean, standard deviation [S], S^2), vertical acceleration (RMS), heading errors per minute (mean and S^2). Physiological parameters were urinary catecholamines, biochemical (blood) analysis, ECG (heart rate), and respiratory rates. Control input measures were longitudinal control stick displacement.

SUMMARY: The purpose of this experiment was to investigate flight stresses imposed by low-altitude high-speed flight over extended periods. The relative merits of a side-stick versus a center-stick controller were also investigated. It was concluded that the performance measures taken indicated various levels of stress for the terrain-following mission. The side-stick controller reduced task performance errors, total G, and heart and respiratory rates but increased fatigue effects.

271. SOLIDAY, Stanley M., Effects of Task Loading on Pilot Performance During Simulated Low-Altitude High-Speed Flight, North American Aviation, Inc., Columbus, OH, Contract No. DA 44-177-AMC-66(T), sponsored by U.S. Army Transportation Research Command, Fort Eustis, VA, USATRECOM Technical Report 64-69, February 1965, 79 pp., AD 614243. See also Human Factors, v. 7(1): p. 45-53, February 1965.

SUBJECTS: 3 pilots.

EQUIPMENT: Dynamic Flight Simulator (G-Seat).

SCENARIO: Low altitude terrain-following flight for 3 hours.

MEASURES: Altitude error (average and root-mean-square [RMS]), heading error (average and RMS), vertical acceleration (RMS), longitudinal control stick movements (RMS), reaction time to an event (reset master warning light), time to complete a task (emergency procedure), and time to complete computation of fuel remaining.

SUMMARY: The purpose of this study was to investigate the effects of task loading on pilot performance during simulated low-altitude high-speed terrain-following flight. It was concluded that average altitude was higher going up slopes than going down slopes, heading maintenance was no problem, and pilot alertness or vigilance as measured by reaction times was very high across all conditions. No evidence of fatigue was noted throughout the experiment.

272. SCHOHAN, Ben, Rawson, Harve E., and Soliday, Stanley M., "Pilot and Observer Performance in Simulated Low Altitude High Speed Flight," Human Factors, v. 7(3): p. 257-265, June 1965.

SUBJECTS: 6 pilots and 4 observers.

EQUIPMENT: Dynamic Flight Simulator (G-seat).

SCENARIO: Low altitude high speed (LAHS) mission with altitude holding, navigation, out-of-cockpit surveillance, in-cockpit surveillance, and instrument monitoring tasks.

MEASURES: Pilot performance was measured by; navigational accuracy (number of checkpoints found), detection of ECM warnings, number of correct target identifications, and identification of in-cockpit presentations. Also measured were altitude error (RMS), vertical acceleration (RMS), missile kills (exceeding 1000 feet in altitude), number of ground impacts (less than 0 feet altitude), and reaction time (response to the ECM warning light). Observers were scored subjectively on navigation, by the number of seconds to respond to the ECM warning light, and target identifications.

SUMMARY: The purpose of this study was to investigate pilot and observer performance in pilot, navigational, and surveillance tasks under simulated LAHS conditions. Three-hour missions were flown at 500 feet altitude with different degrees of simulated atmospheric turbulence. Results showed pilot's flying ability decreased when airspeed increased but target identification remained unimpaired by either turbulence or airspeed. Observer target identification decreased as airspeed increased. Overall performance efficiency on all tasks did not deteriorate from beginning to end for both pilots and observers.

273. SOLIDAY, Stanley M., and Milligan, James R., "Terrain-Following with a Head-up Display," Human Factors, v. 10(2): p. 117-126, April 1968.

SUBJECTS: 6 U.S. Air Force pilots.

EQUIPMENT: Dynamic Flight Simulator configured as an F-4C, with a pilot's Head-up Display installed.

SCENARIO: Low altitude high speed (LAHS) mission with altitude holding and course maintenance subtasks.

MEASURES: Altitude error (absolute), heading error (absolute), and vertical acceleration (standard deviation). Physiological parameters were heart rate (ECG) and respiratory rate.

SUMMARY: The purpose of this study was to evaluate a Head-up Display (HUD) as an aid to the pilot in flying LAHS missions. Experimental conditions included airspeed, terrain type, visibility and display mode (HUD, no HUD) over 30 minute flights. The results showed terrain-following with the HUD was better than with typical in-cockpit instruments, and that terrain-following efficiency varied with type of terrain, airspeed, and visibility.

274. SOLIDAY, Stanley M., "Navigation in Terrain-Following Flight," Human Factors, v. 12(5): p. 425-433, October 1970.

SUBJECTS: 12 U.S. Air Force pilots.

EQUIPMENT: Dynamic Flight Simulator with a visual attachment.

SCENARIO: Navigation in the low altitude high speed (LAHS) terrain-following flight with altitude holding, turns, and checkpoint navigation.

MEASURES: Altitude error (standard deviation [S]), navigational accuracy at checkpoint (S), vertical acceleration (S), number of course corrections, number of checkpoints found, and time to correct an emergency (time of task execution).

SUMMARY: This study investigated navigational problems in LAHS terrain-following flight. Experimental conditions included navigational and terrain-following displays (Head-up Display, conventional instruments, and destination direction and range information), visibility (VFR or IFR), and aircraft type (high-performance jet fighter-bomber or swept wing fighter-bomber) for a 90-minute flight. The results showed the pilots navigated with much greater efficiency when they had information from a simulated inertial guidance system than when they did not have this information. Navigation was better in mountainous terrain with a HUD than when conventional in-cockpit instruments were used and better in the aircraft with more desirable handling qualities.

275. OSTERHOFF, William E., and McGrath, James J., Geographic Orientation in Aircraft Pilots: Contemporary Charts and Pilot Performance, Human Factors Research, Inc., Santa Barbara, CA, Contract No. Nonr 4218(00), ONR Authority Identification NR 213-028, sponsored by the Joint Army-Navy Aircraft Instrument Research (JANAIR) Committee, Office of Naval Research, Washington DC, Technical Report 751-6, May 1966, 41 pp., AD 635384.

SUBJECTS: 22 U.S. Marine Corps pilots.

EQUIPMENT: A-4 cockpit, rear projection screen and recording apparatus.

SCENARIO: Visual low-level at 200 feet altitude and 300 knots airspeed.

MEASURES: Absolute error of response (distance in nautical miles between perceived and actual position), offset error (perpendicular distance in nautical miles) after a time correction is made), and time error (distance in nautical miles after a lateral offset correction is made).

SUMMARY: The purpose of this study was to evaluate three different aeronautical charts in terms of their relative effectivenes as visual navigation aids. Charts used were the Sectional Aeronautical Chart (SAC), the Operational Navigation Chart (ONC), and the Pilotage Chart (PC). Results showed pilots using the SAC performed as well as or better than those using either the PC or the ONC for the low-level routes flown. It was concluded that the relative effectiveness of aeronautical charts is specific to the terrain over which pilots must navigate.

276. GEISELHART, Richard, Kemmerling, Paul, Cronburg, James G., and Thorburn, David E., A Comparison of Pilot Performance Using a Center Stick VS Sidearm Control Configuration, General Precision, Inc., Binghamton, NY, Contract No. F-33-615-68C-1097, sponsored by Aeronautical Systems Division, Wright-Patterson AFB, OH, Technical Report ASD-TR-70-39, November 1970, 45 pp., AD 720846.

SUBJECTS: 6 U.S. Air Force pilots.

EQUIPMENT: F-111 flight simulator with three degrees of motion.

SCENARIO: Takeoff, low-level navigation profile using terrain-following radar, turns, and Instrument Landing System (ILS) approaches.

MEASURES: Course steering deviation, airspeed deviation, pitch deviation and ILS evaluation scores (airspeed, approach glideslope and approach centerline errors). Transformations included absolute average error, mean, and standard deviations.

SUMMARY: The purpose of this study was to compare the performance of a group of pilots under low-altitude, high-speed conditions as a function of three configurations of control sticks;

conventional center stick, dual side sticks, and single side stick. Pilot acceptance of each control configuration was also surveyed. It was concluded that side stick controllers are feasible for the scenarios examined, and that dual side sticks are preferable to single side sticks.

277. DUFFY, Timothy W., An Analysis of the Effect of a Flight Director on Pilot Performance in a Helicopter Hovering Task, Master's Thesis, Naval Postgraduate School, Monterey, CA 93940, March 1976, 53 pp. AD A025680.

SUBJECTS: 4 pilots.

EQUIPMENT: UH-1H simulator with control stick and collective.

SCENARIO: Stationary hovering task at 40 feet.

MEASURES: Longitudinal and vertical deviation from an initial equilibrium position were measured in terms of root mean square (RMS) error (deviations from an ideal flight path).

SUMMARY: Test subjects performed 90-second precision hovering tasks utilizing two cockpit displays. The displays were differentiated by the addition of a flight director indicator. Data from RMS performance and numerical pilot opinion ratings indicated significant improvement in performance when the flight director indicator was used.

278. WHEAT, Luther W., A Comparison of Optimal Control Theory Predictions with Actual Pilot Performance in a Helicopter Longitudinal Tracking Task, Master's Thesis, Naval Postgraduate School, Monterey, CA 93940, June 1975, 43 pp., AD A016441.

SUBJECTS: 1 pilot and 1 nonpilot.

EQUIPMENT: UH-1H simulator with control stick and collective.

SCENARIO: Helicopter landing approach.

MEASURES: Perturbation flight velocity (airspeed) along x stability axis in ft/sec, perturbation pitch angle about y axis in radians, altitude deviation from reference position in ft, cyclic pitch control input in ft, and collective pitch control input in ft. Root mean square (RMS) error for each run was computed and then normalized for all runs. The normalized RMS scores were then summed to provide a single scalar index of performance.

SUMMARY: Test subjects performed ten 90-second tracking runs while utilizing two cockpit displays for longitudinal control during landing approach. Real pilot performance was compared with pilot model predictions. The displays were normal and quickened horizon bar and aircraft reference for pitch control along with a glidescope deviation indicator. The use of quickening in the cockpit display significantly reduced control motion and improved pilot peformance, as measured by normalized RMS error scores.

279. STAVE, Allan M., "The Effects of Cockpit Environment on Long-Term Pilot Performance," *Human Factors*, v. 19(5): p. 503-514, October 1977.

SUBJECTS: 5 pilots.

EQUIPMENT: Fixed-base, commercial helicopter simulator.

SCENARIO: Airways navigation and Instrument Landing System (ILS) approach.

MEASURES: Course error (root mean square) and number of degrees off glideslope (approach angle error).

SUMMARY: The purpose of this experiment was to explore the effects of noise and vibration on pilot performance. Experimental conditions were flight periods (3 to 8 hours), noise (74 to 100 dB), and vibration (at 17 Hz ranging from 0.1 to 0.3g). Results showed performance tended to improve as environmental stress increased despite reports of extreme fatigue during the long flights. Subjects did suffer from lapses of short duration (seconds) occurring at unpredictable times that resulted in abnormally poor performance.

280. WAUGH, John D., *Pilot Performance in a Helicopter Simulator*, U.S. Army Human Engineering Laboratory, Aberdeen Proving Ground, MD 21005, Technical Memorandum 23-75, September 1975, 336 pp., AD A017441.

SUBJECTS: 6 helicopter pilots.

EQUIPMENT: GAT-2H helicopter simulator.

SCENARIO: Climbs, descents, turns, and straight and level (BRAVO precision flight pattern).

MEASURES: Altitude, vertical velocity, airspeed, heading, lateral cyclic (roll) position, longitudinal cyclic (pitch) position, collective (power) position, pedal (yaw) position, ground track position, and maneuver execution time.

SUMMARY: The purpose of this experiment was to approach pilot performance from the standpoint of measuring accuracy of precision flight and to investigate the measurement of pilot workload. Experimental conditions were aerodynamic variables (thrust to weight ratios, control sensitivity, and cyclic centering spring force gradients. Results showed no significant differences among pilots, and that no differences existed along the trials dimension indicating further learning or fatigue and boredom trends. Analysis of the measures for the three experimental conditions showed they had no significant effect on the error scores. Also found was an unexpectedly large variation exhibited by each pilot which was presumed responsible for masking any significant effects which the experimental conditions may have had on accuracy of task performance. It was noted that an incomplete balanced-block design was used due to lack of available pilots and this may have reduced the power available from using a complete design.

281. CHILDS, Jerry M., The Development of Objective Inflight Performance Assessment Procedures, Proceedings of the 23rd Annual Meeting of the Human Factors Society, Boston, MA, October 1979, p. 329-333.

SUBJECTS: 12 student pilots.

EQUIPMENT: UH-1 helicopter simulator.

SCENARIO: Straight and level, climbing and descending turns, accelerations, decelerations, and unusual attitude recovery.

MEASURES: Airspeed, altitude, and heading. Data was collected by instructors with either a criterion level method or a segmental manuever method.

SUMMARY: The purpose of this study was to develop and test methods for objectively evaluating Initial Entry Rotary Wing (IERW) pilot performance in flight. Two inflight procedures were developed and tested.

Procedure 1 employed time-based sampling while procedure 2 evaluated segments of maneuvers without strict adherence to time. The results indicated procedure 1 was overly constraining in terms of recording attention for the instructor but did detect and quantify differences in performance among and within students across training days. Procedure 2 was more practical but not as effective in discriminating performance levels due to lack of standardization in its use.

282. VREULS, Donald, Obermayer, Richard W., Goldstein, Ira, and Lauber, John K., Measurement of Trainee Performance in a Captive Rotary-Wing Device, Manned Systems Sciences, Inc., Northridge, CA 91324, Contract No. N61339-71-C-0194, sponsored by Naval Training Equipment Center, Orlando, FL 32813, June 1973, 88 pp., AD 764088.

SUBJECTS: 2 nonpilots.

EQUIPMENT: Jaycopter (similar to a helicopter on a fixed boom).

SCENARIO: Yaw to boom, pitch to level, roll to level, forward translation, sideways translation, liftoff, hover, climbs, descents, and constant heading.

MEASURES: Boom azimuth, pitch, roll, yaw relative to boom, collective control movement, rudder pedal movement, altitude, airspeed, cyclic roll, torque, heading, cyclic pitch, windspeed, and wind direction. Univariate and multivariate analyses were then performed on these parameters.

SUMMARY: This study was conducted to define and implement an exploratory approach to quantitative, machine-derived measures of human training performance in a complex manned vehicle. Using univariate and multivariate analysis techniques, performance was compared between trainees and instructors for over 846 analytically derived measures. The results showed the approach could produce measures that discriminated between trainee and instructor performance. In general, the multivariate procedures produced a set which was more closely aligned with analytic expectation than the univariate method.

283. FEDERMAN, P.J., and Siegel, A.I,, Communications as a Measurable Index of Team Behavior, Applied Psychological Services, Inc., Wayne, PA, sponsored by U.S. Naval Training Device Center, Port Washington, NY, NAVTRADEVCEN 1537-1, October 1965, 83 pp., AD 623135. See also article no. 284.

SUBJECTS:	12 teams/2 crews per team/3 members per crew.
EQUIPMENT:	Helicopter simulator (Device 15R10).
SCENARIO:	Tactical multi-aircraft ASW problems (varied submarine course) that involved straight and level, turns, hovers, climbs, descents, and weapon drops.
MEASURES:	See article no. 284 for communication variables. System parameters were number of lost target contacts, time to detect target, time to initiate each jump from a hover position, dip to dip accuracy error, time to complete a vector attack, dip to target error, and mission results (number of target hits or misses).
SUMMARY:	The purpose of this research was to investigate the relationship between anti-submarine warfare (ASW) helicopter team performance and the content and flow of communications within the team during a simulated attack. Of primary concern was the development of communication measures to assess team behavior during a training mission. Results showed fourteen distinct communications variables were correlated with miss distance and further factor analyis reduced it to four factors. The four factors were probabilistic structure, evaluative interchange, hypothesis formulation, and leadership control. The findings suggest the value of developing scaled performance measures as diagnostic devices for evaluating inflight crew behavior, as predictors of future success, and as end-of-course measures.

284. SIEGEL, Arthur I., and Federman, Philip J., Increasing ASW Helicopter Effectiveness Through Communications Training, Applied Psychological Services, Inc., Wayne PA, Contract No. N61339-66-C-0045, sponsored by Naval Training Device Center, Orlando, FL, NAVTRADEVCEN 66-C-0045-1, October 1968, 190 pp., AD 682498. See also article no. 283.

SUBJECTS: 12 teams/2 crews per team/3 members per crew.

EQUIPMENT: Helicopter simulator (Device 14H4).

SCENARIO: Two ASW detect, track and attack problems. Both used two submarines that maneuvered in various directions. Flight maneuvers were straight and level, turns, hovers, climbs, descents, and weapon drops.

MEASURES: Intra and inter-helicopter communications were recorded and classified as; voluntary information, directing, information, request, furnishes voluntary information, objective, provides information, extrapolation, phenomenological, evaluative, concordant, interpolation, activity, corroborated, progressive, discordant, repeated messages, potency, regressive, requests opinion, risk, provides opinion, invitational, requests for directions, intuition, and non-risk. The effectiveness measure was miss distance (between target and impact point of weapon).

SUMMARY: The primary purpose of this study was to verify previous findings that investigated communications as a component affecting inflight ASW helicopter mission success. Another purpose was to develop, administer, and evaluate a course to train ASW helicopter pilots in the use of verified communications factors. Four factors of communication previously identified were probabilistic structure, evaluative interchange, hypothesis formulation, and leadership control. A trained group and a control group flew the ASW problems and their performance was compared in terms of communications and mission effectiveness. The results showed the trained group performed more proficiently than the control group by a significant increase in a problem solving level without any negative effect on problem solving time or on navigational accuracy. The trained group's communications contained twice as many factor related communications as the control group.

285. MURPHY, Miles R., Individual Differences in Pilot Performance, Proceedings of the 6th Congress of the International Ergonomics Association, College Park, MD, July 1976, p. 403-409.

SUBJECTS: 6 pilots.

EQUIPMENT: Bell UH-1B fixed-base simulator (V/STOL).

SCENARIO: Instrument approach and landing.

MEASURES: Root mean square (RMS) error and variability of; approach glideslope error, approach centerline error, ground speed, vertical velocity, roll, pitch, and yaw. RMS error was also measured for cyclic and collective controls and rudder pedal movement.

SUMMARY: The purpose of this research was to evaluate three electronic displays for potential application to V/STOL zero-visibility landings and to study differences in pilot behavior. The six pilots flew data runs using each of the three displays with six degree and fifteen degree flight-path angles with varying wind conditions. The results indicated that relative performance levels of individual pilots vary with particular situations as defined by combinations of tracking parameters, glide-slope segment, or speed requirements. This variance appeared to be superimposed on general differences in skill level and may reflect individual tracking styles. Selected literature on individual differences in pilot performance was also reviewed.

286. GRODSKY, Milton, A., and Tutmann, C.C., "Pilot Reliability and Skill Retention for Space Flight Missions," Air University Review, v. 16(4): p. 22-32, May-June 1965.

SUBJECTS: Three 3-man crews of U.S. Air Force pilots.

EQUIPMENT: Command module simulator and lunar excursion module simulator.

SCENARIO: Lunar landing, flight control, switching, procedural tasks, navigation, and information handling.

MEASURES: Pilot variability and error during flight control, failure to throw a switch, throwing the wrong switch, false-alarm switching, number of digits of information handled correctly, number of deviations from established procedures, and navigational error (number of degrees between a star's absolute position and the pilot's subjective position).

SUMMARY: The purpose of this research was to experimentally determine the reliability of pilots in an integrated mission simulation of a long-duration space flight mission. Skill retention was examined over 30 or 60 days of non-activity for the crews. Results showed minimal loss in pilot skill retention in all task categories for the 30-day group while the 60-day group experienced some loss in pilot retention of tasks in the complex phase of braking, hovering, and in switching tasks during an integrated post-time mission.

287. SENDERS, John W., A Study of the Attentional Demand of VFR Helicopter Pilotage, Proceedings of a Conference on Aircrew Performance in Army Aviation Held at U.S. Army Aviation Center, Fort Rucker, Alabama on November 27-29, 1973, Office of the Chief of Research, Development and Acquisition (Army) and U.S. Army Research Institute for the Behavioral and Social Sciences, Arlington, VA 22209, July 1974, p. 175-187, AD A001539.

SUBJECTS: 2 pilots and 2 student pilots.

EQUIPMENT: Jaycopter (similar to a helicopter on a fixed boom).

SCENARIO: Mirror hover and constant heading.

MEASURES: Altitude (plus or minus 5 feet), heading (plus or minus 15 degrees), and intervals between viewing observations (mirror hover).

SUMMARY: The purpose of this study was to assess the utility of an experimental approach and its underlying theoretical basis for the evaluation of skill in the piloting of a helicopter and for the measurement of change in skill level with continuing practice. The approach utilized a model of attentional demand that was predicated on the notion that attention is directed by a need on the part of the observer to reduce uncertainty about the information source attended to. A visual occlusion technique that was employed appears to be a useful and simple way to assess skill in complex perceptual motor tasks.

300. RYACK, Bernard L., and Krendel, Ezra S., Experimental Study of the Natural Pilot Flight Proficiency Evaluation Model, U.S. Naval Training Device Center, Port Washington, New York, NAVTRADEVCEN 323-2, April 1963, 38 pp., AD 414666.

SUBJECTS:	24 male college students.
EQUIPMENT:	Analog computer, rotary control, and a display.
SCENARIO:	Compensatory tracking task.
MEASURES:	Root mean Square (RMS) tracking error during the final minute of a tracking run for controlled element dynamics and intermittency. A time score (percent time on target) was also computed.
SUMMARY:	The purpose of this study was to evaluate the ability of the human operator to adapt to changes in controlled element dynamics and to perform under different rates of target intermittency, and the effects of tracking training upon these abilities. The assumptions were that human adaptability and economy of effort as understood in the context of servo-mechanism theory are important parameters of flying proficiency, and serve to differentiate proficient ("natural") from poor ("mechanical") operators. The results showed a considerable relationship between generalized tracking ability and each of the two factors of adaptability and economy of effort, and also revealed the two are independent.

301. STAPLEFORD, R.L., McRuer, D.T., and Magdaleno, R., Pilot Describing Function Measurements in a Multiloop Task, Systems Technology, Inc., Hawthorne, CA, Contract No. NA52-1868-3, sponsored by National Aeronautics and Space Administration, Mountain View, CA, NASA CR-542, August 1966, 33 pp., N66-33461.

SUBJECTS:	1 pilot.
EQUIPMENT:	Cockpit with aileron and rudder controls, cathode ray tube, and analog computer.
SCENARIO:	Tracking task (compensatory).
MEASURES:	Tracking error (mean squared), and yawing velocity (mean squared).

SUMMARY: This experiment was undertaken to provide data essential for the development of detailed adjustment rules, loop closure criteria, and refinement of a pilot model for a multiloop situation. Experiment conditions included display gain and scaling and dutch roll damping. Results showed that quasi-linear pilot model and adjustment rules evolved for single-loop systems are applicable to the multiloop system command loop for control situations with an integrated display. Other conclusions are stated.

302. LASHBROOK, Daniel Floyd, Dissection and Analysis of Electroencephalograms of Subjects Doing a Simulated Pilot's Task, Master's Thesis, Naval Postgraduate School, Monterey, CA 93940, March 1977, 69 pp., AD A039925.

SUBJECTS: 1 pilot.

EQUIPMENT: Control stick, visual display, and EEG biofeedback display.

SCENARIO: Simulated aircraft attitude control (compensatory tracking) task.

MEASURES: Electroencephalograms (EEG) readings (tegules), and a running plot of the radial displacement of the pip from the center of an error display (tracking error).

SUMMARY: The purpose of this experiment was to investigate and establish a relationship between preferred EEG frequencies and the performance of a simulated piloting task. It was concluded that the generation of frequencies in the 70 to 95 Hz band is a physiological trait common to people engaged in a simulated piloting task, and that in-flight monitoring of a pilot's EEG could provide valuable information about visual evoked responses, state of alertness, and instrument scan performance.

303. ALLEN, R.W., and Jex, H.R., An experimental Investigation of Compensatory and Pursuit Tracking Displays with Rate and Acceleration Control Dynamics and a Disturbance Input, Systems Technology, Inc., Hawthorne, CA, Contract No. NAS 2-3746, sponsored by National Aeronautics and Space Administration, Mountain View, CA, NASA CR-1082, June 1968, 71 pp., N68-28272.

SUBJECTS: 4 pilots.

EQUIPMENT: Control stick and cathode ray tube (CRT).

SCENARIO: Tracking task (compensatory and pursuit).

MEASURES: Tracking error (absolute average), remnant content, control activity (absolute average), open-and closed-loop describing functions (error/input, output/error, and output/command), and subjective assessments of task difficulty.

SUMMARY: The purpose of this investigation was to validate previous results and to provide a sounder data base for a theory of manual control displays. Experimental controls included tracking task (compensatory or pursuit), controlling dynamics (rate or acceleration), and display mode (coventional or "pursuit-plus-disturbance"). Results showed that all pilots learned quickly to perform equally well with all displays when controlling rate dynamics but took longer to learn and had greater variability with acceleration dynamics. Error performance was insensitive to display mode while describing function data showed that differences in pilot behavior did occur. The independent disturbance input proved that a compensatory loop closure does exist during pursuit tracking and that its closure parameters may be different from the purely compensatory display case.

304. LAYTON, Donald M., A Simulator Evaluation of Pilot Performance and Acceptance of an Aircraft Rigid Cockpit Control System, Naval Postgraduate School, Monterey, CA 93940, NPS-57LN7071A, July 1970, 100 pp., AD 711296.

SUBJECTS: 87 pilots and 18 nonpilots.

EQUIPMENT: Research Education Device for Basic Aeronautics (RED BARON) with an analog computer, timers, cathode ray tube, and a counter.

SCENARIO: Tracking task (two-dimensional).

MEASURES: Tracking error (percent time on target or within criteria limits). Subjective opinion of which controls were better was also obtained.

SUMMARY: The purpose of this experiment was to evaluate pilot performance using four separate control sticks - two moveable and two rigid. Results showed the rigid systems were superior from both performance and opinion. The experiment was controlled for pilot bias, learning, fatigue, or adaptation. Test limitations included low stick-force levels employed and lack of aircraft vibration effects.

305. KENNEDY, John Patrick, Time-Sharing Effects on Pilot Tracking Performance, Master's Thesis, Naval Postgraduate School, Monterey, CA 93940, September 1975, 47 pp., AD A016378.

SUBJECTS: 20 U.S. military pilots.

EQUIPMENT: Research Education Device for Basic Aeronautics (RED BARON) with an analog computer, timers, cathode ray tube, and a counter.

SCENARIO: Tracking task (two-dimensional).

MEASURES: Tracking error (percent time within criteria), number of incorrect responses, and reaction time to secondary task. "Efficiency scores" were computed as an average of total reaction time plus number of incorrect responses, both times a constant.

SUMMARY: The purpose of this experiment was to examine time-sharing performance of experienced military pilots and to investigate differences in performance by pilots of different type aircraft. Experimental conditions were levels of difficulty (five), stimulus presentation rates (two), and a secondary task (lights and toggle switches). Results showed that correlation between elements of a complex task is weak, performance levels decrease as task difficulty increases, and virtually no differences existed between the pilot groups. Dual-crew fighter/attack jet pilots took significantly longer than other pilot types to respond to the secondary task stimuli when time-sharing.

306. RODRICK, Peter T., Vibration Effects on Pilot Tracking Performance Using a Rigid Control Stick, Master's Thesis, Naval Postgraduate School, Monterey, CA 93940, March 1972, 64 pp., AD 745193.

SUBJECTS: 4 pilots and 1 nonpilot.

EQUIPMENT: Rigid control stick, CRT display, and aircraft simulator components.

SCENARIO: Two-dimensional tracking task while being subjected to vibration.

MEASURES: The time a pip was within a predetermined distance of the CRT center was recorded. Error was measured as normalized time outside this predetermined distance (time within criterion).

SUMMARY: Subjects were required to keep a CRT display pip centered by proper movement of a control stick while being subjected to vibratory motion for trials of one minute in length. Performance scores for whole body vibration were lower than those for control stick only vibration. All subjects experienced greater discomfort on the whole body vibration tests.

307. BENJAMIN, Peter, "A Hierarchical Model of a Helicopter Pilot," Human Factors, v. 12(4): p. 361-374, August 1970.

SUBJECTS: 7 nonpilots.

EQUIPMENT: Computer simulation, control stick (cyclic), and oscilloscope.

SCENARIO: Tracking task (simulated hover).

MEASURES: Altitude, airspeed, roll, and control stick deflections.

SUMMARY: The purpose of this study was to propose and validate a new model of the human operator in a man-vehicle control loop and to use a computer simulation to investigate man-vehicle control. The model is based on a hierarchical controller that interprets quantified input, decides which loop to close, and determines the mode of tracking to be utilized in the control of the closed loop. It uses a dual-level bang-bang tracking and simple tracking (gain plus lead) for each loop, depending upon the stability level of the closed loop. Model validation was provided by comparison of tracking records obtained from a simulation of the vehicle with the tracking records of human operators.

308. LEVISON, William H., and Tanner, Robert B., A Control-Theory Model for Human Decision-Making, Bolt, Beranek and Newman, Inc., Cambridge, MA 02138, Contract No. NAS 2-5884, sponsored by National Aeronautics and Space Administration, Washington, DC 20546, NASA CR-1953, December 1971, 112 pp., N72-17079.

SUBJECTS: 4 nonpilots.

EQUIPMENT: Computer model, oscilloscope display, and response buttons.

SCENARIO: Tracking task (compensatory), single decision tasks, and two-decision tasks.

MEASURES: Number of correct decisions, number of incorrect decisions (false alarms and miss rates), and tracking error (mean squared).

SUMMARY: The goal of this study was to develop and experimentally test a model for human decision-making. The model is an adaptation of a previously developed model for optimal-control of pilot/vehicle systems. The model contains concepts of time delay, observation noise, optimal prediction, and optimal estimation. Results indicated that prediction of single-task and two-task decision performance was accurate within 10 percent. Agreement was less accurate for a simultaneous decision and control situation and did not allow a conclusive test of the predictive capability of the model for that situation.

309. ADAMS, James J., Bergeron, Hugh P., and Hurt, George J. Jr., Human Transfer Functions in Multi-axis and Multi-loop Control Systems, Langley Research Center, Langley Station, Hampton, VA, National Aeronautical and Space Administration, Washington, DC, NASA TN D-3305, April 1966, 44 pp., N66-22272.

SUBJECTS: 4 pilots.

EQUIPMENT: Fixed-base multi-axis simulator with a three-axis eight-ball display instrument, side-arm controller, and rudder pedals.

SCENARIO: Compensatory tracking of a random disturbance and information processing capacity.

MEASURES: Amplitude and break frequency of filtered disturbance signals were compared to a model-matching automatic-parameter-tracking analog computer. The tracking error (in volts) was then transformed to root mean square values.

SUMMARY: A measurement of the response of a human pilot in multi-axis tracking tasks was designed to analytically obtain the closed-loop system characteristics and multiloop manually controlled characteristics. The results showed that the pilot changes the response so that system frequency is reduced as additional axes requiring control are added to the work load. These results are correlated with the theory of maximum information processing capacity for a pilot.

310. JAMES, Ronald Edward., Investigation and Evaluation of a Zero Input Tracking Analyzer (ZITA), Master's Thesis, Naval Postgraduate School, Monterey, CA 93940, March 1976, 47 pp., AD A025431.

SUBJECTS: 6 U.S. Navy pilots, all currently qualified.

EQUIPMENT: ZITA (Zero Input Tracking Analyzer); consisted of a signal processor, an error analyzer, a display recorder unit, and a two- or three-position hand control stick.

SCENARIO: Four tracking tasks with increasing levels of difficulty.

MEASURES: Displacement (tracking) error from a display spot to the center of a scale was rectified and summed over a 60-second cycle, and was presented in tenths of millimeters.

SUMMARY: This study was designed to evaluate the ZITA and its qualities as a psychomotor testing device for possible consideration as a prediction device in the selection of applicants for the U.S. Navy aircrew training program. The results showed consistent results in distinguishing between subjects with respect to this particular psychomotor task. Two cited disadvantages of the ZITA were length of learning curve level-offs (2 hours) and the rate at which learning curves are developed.

311. RICARD, G.L., and Norman, D.A., Adaptive Training of Manual Control: Performance Measurement Intervals and Task Characteristics, Naval Training Equipment Center, Orlando, FL 32813, NAVTRAEQUIPCEN IH-252, November 1975, 20 pp., AD A019233.

SUBJECTS:	68 male college students.
EQUIPMENT:	Side-arm controller and visual display.
SCENARIO:	Aircraft attitude control training task.
MEASURES:	Absolute integrated roll error (under 3 degrees for two sequential trials; trials to criterion).
SUMMARY:	The purpose of this experiment was to investigate the relationship between the phugoid (reciprocal of the airframe's long-period longitudinal resonant frequency) and the performance measurement interval (PMI). Also investigated was the relation between the measurement of trainee performance and parameters of the simulated airframe of an adaptive, aircraft roll-control, training task. Results showed that when the PMI was shorter than the break frequency ($1/T_R$) of the lateral transfer function, subjects experienced greater difficulty in developing criterion-level control than when longer PMI's were used. These data indicated relations do exist between rules of the adaptive logic and parameters of the simulated airframe.

312. LEVISON, William H., Elkind, Jerome I., and Ward, Jane L., Studies of Multivariable Manual Control Systems: A Model for Task Interference, Bolt Beranek and Newman, Inc., Cambridge, MA, Contract No. NAS 2-3080, sponsored by National Aeronautics and Space Administration, Washington, DC 20546, NASA CR-1746, May 1971, 229 pp., N71-26160.

SUBJECTS: 4 pilots.

EQUIPMENT: Oscilloscope displays, analog computer, and control sticks.

SCENARIO: Tracking tasks (multi-axis).

MEASURES: Tracking error (mean square, variance), fractional remnant power, fractional variational power, control input (variance), and a "workload index" defined as the fraction of a controllers' capacity that is required for him to perform a given task to some specified (criterion) level of performance. Eye movement was recorded by electro-oculographic techniques.

SUMMARY: The objectives of this study were to investigate human performance in multivariable control and monitoring situations, to develop models for the controller in these situations, and to develop a metric for pilot workload. Experimental conditions included four-axis tracking tasks, multi-axis tracking tasks, displays (single, multiple, fixation, or foveal and peripheral viewing), controlled-element dynamics, and forcing functions. Multi-axis behavior was shown to be consistent with single-axis results. A model was presented for interference among multiple control tasks based upon the assumption that multiple tasks are performed in parallel and that the human must share a fixed amount of central-processing capacity among the tasks. Validation was provided by comparison of the model predictions with experimental results. A metric based upon the model for pilot workload was suggested.

313. SMITTLE, John H., "Current" vs. "Stagnant" Jet Pilots' Response Times: A Comparison, Master's Thesis, Naval Postgraduate School, Monterey, CA 93940, March 1973, 39 pp., AD 761463.

SUBJECTS: 22 U.S. Navy pilots, 11 currently qualified.

EQUIPMENT: Visual slides of an AAI (Aircraft Attitude Indicator) with 12 different aircraft attitudes, a control stick, and a timer.

SCENARIO: Recovery from an unusual attitude.

MEASURES: Reaction time to an event (presentation of a slide to final control stick position); measured in thousandths of a second.

SUMMARY: The experiment was designed to determine if the piloting skill of response time to a critical situation is lost during prolonged periods of nonflying. Two groups of jet Naval aviators were distinguished by recent flying experience and designated as "current" or "stagnant." The results found no significant difference in response time between the groups. Further analysis revealed "more experienced" (in terms of total flight hours) aviators had smaller response times than "less experienced" aviators.

314. BERNSTEIN, Bernard R., "Detection Performance in a Simulated Real-Time Airborne Reconnaissance Mission," Human Factors, v. 13(1): p. 1-9, February 1971.

SUBJECTS: 54 nonpilots.

EQUIPMENT: Flying spot scanner, photomultiplier tube, video processor, and a television type display.

SCENARIO: Detection of targets on a TV or laser display by aircrew.

MEASURES: Number of targets correctly detected (percentage of total), and number of false positives.

SUMMARY: The purpose of this experiment was to investigate subjects' abilities to detect targets presented on a cathode-ray-tube (CRT) display simulating the presentation of visual information on a display as it would appear in a low-light-level TV or laser system mounted in a relatively slow-moving aircraft. Experimental conditions were time available for search (image rate of motion), display scale factor (display size), display resolution (number of active scan lines), target type and size (target area/display area), and target-to-background contrast. Results indicated that probability of detection was sensitive to variations in target type, target-to-background contrast, and image rate of motion. False positive rate was affected only by available search time.

315. KREBS, Majorie J., Scanning Patterns in Real-Time FLIR Displays, Proceedings of the 19th Annual Meeting of the Human Factors Society, Dallas, TX, October 1975, p. 418-422.

SUBJECTS:	24 nonpilots.
EQUIPMENT:	Forward looking infrared (FLIR) imagery, hood oculometer, and sequence boards.
SCENARIO:	Target detection.
MEASURES:	Time and accuracy for the number of target detections, classifications, and identifications were taken. Eye movement measures were fixation location, fixation time, interfixation distance, and fixation rate.
SUMMARY:	The purpose of this experiment was to investigate the effects of prior task-related experience and imagery characteristics for target detections using FLIR displays. Actual FLIR imagery taken by a P2-V aircraft was recorded and presented to the 24 subjects, of which 6 were experienced FLIR instructors. For both groups the sequence of fixations and the distribution of fixation densities were different for each scene and dependent on specific content. Subjects appeared to systematically explore areas within a scene in terms of some estimated probability of a target being present. Eye movement data differentiated between groups with the experienced group having shorter fixation times and shorter "target, no target" decision times.

316. FREITAG, M., Hilgendorf, R.L., and Searle, R.G., Simulated Helo Ground Target Acquisition under Different Sun Angles and Ground Fixtures, Proceedings of the 19th Annual Meeting of the Human Factors Society, Dallas, TX, October 1975, p. 473-479.

SUBJECTS:	30 nonpilots.
EQUIPMENT:	Terrain model with subject seated behind a curtain for 30-second viewing times.

SCENARIO: Target detection during simulated pop-up maneuver.

MEASURES: Target detection time (search time), slant range at detection, and number of false detections.

SUMMARY: The goal of this study was to determine the influence of target surface texture and sun angle on acquisition performance with target and background factors fixed at nominal values. The experimental conditions were sun angle (three levels) and terrain location (two levels). Results showed effects of sun angle and terrain texture on slant range and total search time were not significant but were highly interacting in a reliable manner. It was also found that hilly portions of the terrain required longer search times and shorter slant ranges for target detection with the sun at right angles to the target.

317. ANDERSON, P.A., and Toivanen, M.L., Effects of Variations in System Data Rates and Measurement Accuracies on Pilot Performance in the Helicopter IFR Formation Flight Mode, Honeywell Inc., Minneapolis, MN 55413, Contract No. N0014-66-C-0362, sponsored by Office of Naval Research, Department of the Navy, Washington, DC 20360, JANAIR Report 68048, April 1969, 187 pp., AD 688200.

SUBJECTS: 4 helicopter pilots.

EQUIPMENT: Honeywell hybrid simulation facility (UH-1 vehicle) with a quickening display.

SCENARIO: Heavy Right instrument flight rules (IFR) formation with; acceleration, climbs, turns, descents, deceleration, and straight-and-level.

MEASURES: Positional errors in terms of longitudinal (X), lateral (Y), vertical (Z), and range (R) using the command position as a reference (further transformed by mean, standard deviation, and root mean square [RMS] errors). Relative aircraft attitude stability was measured by integrated squares of pitch and roll attitude over time. Other measures were number of collisions with other formation aircraft (less than 60 feet hub-to-hub) and number of catastrophic control losses (exceeding attitude limits).

SUMMARY: The primary objective of this study was to relate total system performance to variations in data rate and accuracy for the manual IFR helicopter formation flight mode. Results showed that pilot performance degrades approximately linearly with a decrease in data accuracy, a data rate as low as 4 updates/second yielded adequate performance results for this experiment, and that the optimal quickening model and the data filtering model for a specific helicopter formation flight system is a function of that system's data rate and accuracy.

318. STAPLEFORD, Robert L., Craig, Samuel J., and Tennant, Jean A., Measurement of Pilot Describing Functions in Single-Conroller Multiloop Tasks, Systems Technolgoy, Inc., Hawthorne, CA, Contract No. NAS 2-3144, sponsored by National Aeronautics and Space Administration, Ames Research Center, Mountain View, CA, NASA CR-1238, January 1969, 95 pp., N69-15372.

SUBJECTS: 2 pilots.

EQUIPMENT: Fixed wing simulator with CRT display and manipulator stick.

SCENARIO: Attitude and altitude control with elevator in a simulated landing approach.

MEASURES: Analog pilot model output was compared to real pilot output for overall performance. Altitude in average absolute error (AAE) and pitch attitude AAE were measured over 100 sec intervals. A Crossover Model Parameter Tracker provided an on-line continuous estimate of the pilot's crossover frequency in the outer control loop.

SUMMARY: The objective of this study was to investigate techniques for measuring pilot describing functions in multi-loop tasks and to verify and possibly revise an existing quasi-linear pilot model being utilized. The experimental results show that measurement of multi-loop describing functions (where the pilot is controlling two or more response variables with a single manipulator) is feasible although considerably complex. The current quasi-linear model is supported by the results and shows that the inner-loop (attitude) closure is quite similar to that for single-loop attitude tracking.

319. WULFECK, Joseph W., Prosin, Daniel J., Burger, William, and Kennedy, Robert S., Effect of a Predictor Display on Carrier Landing Performance - Part I Experimental Evaluation, Dunlap and Associates, Inc., Inglewood, CA, Contract No. N00014-71-C-0252, sponsored by Office of Naval Research, Arlington, VA 22217, June 1973, 93 pp., AD 767982.

SUBJECTS: 6 pilots.

EQUIPMENT: Laboratory simulator configured as an F-4.

SCENARIO: Carrier approach and landing.

MEASURES: Altitude error, approach centerline error, landing distance to ideal touchdown point (no. 3 wire), vertical velocity, roll angle, pitch angle, yaw angle, and airspeed.

SUMMARY: The purpose of this research was to explore the possibility of using a predictor display to aid the pilot during the approach and landing of an aircraft on an aircraft carrier. Approaches were flown with a baseline display, the predictor display, and a glideslope reference element of the predictor display. The predictor display was the combination of a rectangular glideslope reference "tunnel" representing a specified flight envelope about the 3.5 degree glideslope and a flat, roadway-like, continuous predictor presentation of future aircraft trajectory. The results showed the predictor display superior to the baseline display for all performance criteria. Approaches with it appeared far better than approaches observed in the fleet when compared on altitude error and Fresnel envelope criteria. It was recommended that the display be introduced for fleet use after development and refinement.

400. BUCKLAND, George H., *Flight Simulator Runway Visual Textural Cues for Landing*, Proceedings of the 24th Annual Meeting of the Human Factors Society, Los Angeles, CA, October 1980, p. 285-287.

SUBJECTS: 12 pilots.

EQUIPMENT: Advanced Simulator for Pilot Training (ASPT) and the T-37 aircraft.

SCENARIO: Visual approach and landing.

MEASURES: Vertical velocity (mean).

SUMMARY: The purpose of this experiment was to study the effect of visual textural patterns superimposed upon the runway touch-down zone area as a potential factor in excessive vertical velocity at touchdown during flight simulation. Experimental conditons included six simulated daytime runways with varying degrees of textural cues and one night runway scene. Simulator vertical velocity at touchdown was compared to actual T-37 touchdown vertical velocity. Results showed the textural patterns produced significant differences in simulated vertical velocity at touchdown and improved pilot performance, but were not sufficient by themselves to completely solve excessive vertical velocity at touchdown problems.

401. BARON, Sheldon, and Levison, William H., "Display Analysis with the Optimal Control Model of the Human Operator," *Human Factors*, v. 19(5): p. 437-457, October 1977.

SUBJECTS: Unspecified number of pilots.

EQUIPMENT: Terminal Configured Vehicle configured as a Boeing 737-100 and an optimal pilot control model.

SCENARIO: Instrument Landing System (ILS) approach.

MEASURES: Altitude error, vertical velocity, pitch error, pitch rate, pitch angle error, pitch angle rate, approach centerline error, drift, roll, roll rate, track angle error, and track angle rate.

SUMMARY: This research evaluated the application of the optimal control model of the human operator to problems in display analysis.

The experimental conditions were two modes of control wheel steering (Attitude Control Wheel Steering and Velocity Control Wheel Steering) and displays (baseline and advanced). Results showed the optimal control model of the human operator was valid and applicable to determining what information is needed and how it should be displayed for meeting performance objectives with reasonable attentional workload.

402. WICK, Robert L., Billings, Charles E., Gerke, Ralph J., and Chase, Robert C., Aircraft-Simulator Transfer Problems, Ohio State University, Columbus, OH, Contract No. F3315-72-C-1308, sponsored by Aerospace Medical Research Laboratory, Wright-Patterson AFB, OH 45433, AMRL-TR-74-68, September 1974, 69 pp., AD A002140.

SUBJECTS: 5 pilots.

EQUIPMENT: Cessna 172 aircraft and Link GAT-1.

SCENARIO: Instrument Landing System (ILS) approaches.

MEASURES: Approach centerline error (root mean square [RMS]), approach glideslope error, (RMS), airspeed deviations (RMS), and subjectively assessed and recorded procedural errors.

SUMMARY: The purpose of this research was to examine the performance decrements induced by sodium secobarbital in experienced pilots flying either a light airplane or a surrogate flight simulator. Each pilot flew eight approaches when under the influence of a placebo, 100 mg, and 200 mg of secobarbital for a total of 24 approaches. Results showed the simulator to be more sensitive to drug effects, and some learning effects indicating that skilled airplane pilots are not necessarily skilled simulator pilots as well. Within the experimental limits, simulators appear to be an effective tool for the assessment of stress effects on pilots, require asymptotic performance by pilots for the evaluation, and demand a much different strategy to fly than is required by the aircraft for which it is a substitute.

403. **ARONSON, Moses,** Pilot Performance in the Visual Carrier Landing Task - Simulator vs. Flight, First Interservice/Industry Training Equipment Conference, sponsored by Naval Training Equipment Center, Orlando, FL 32813, NAVTRAEQUIPCEN IH-316, November 1979, p. 337-334.

SUBJECTS: 6 pilots.

EQUIPMENT: T-28 flight simulator with a visual attachment and T-28 aircraft.

SCENARIO: Carrier approach and landing.

MEASURES: Landing attitude (at touchdown), elevator movement, aileron movement, landing distance ratio (landing distance divided by distance from known point), and probability of a successful landing given touchdown distance from the ramp.

SUMMARY: The purpose of this research was to validate previous findings of simulator and aircraft carrier landings. The basic premise was that the proper method for evaluating a visual attachment to a flight simulator was to measure pilot effort in performing a specific task in the simulator and compare it with the effort expended doing the same task in an aircraft. Performance in the simulator was compared to pilots' performance obtained in landings on board carriers. The results showed that errors in the simulation did contribute to differences in pilot performance. Principal simulation errors were identified as vertical location of the Fresnel Lens Optical Landing System (FLOLS) and lack of texture in the water.

404. **JENSEN, Richard S., Vander Kolk, Richard J., and Roscoe, Stanley N.,** Pilotage Error in Area Navigation: Effects of Symbolic Display Variables, University of Illinois, Savoy, IL 61874, Contract No. DOT-FA71WA-2574, sponsored by Federal Aviation Administration, Washington DC 20590, FAA-RD-72-29, January 1972, 149 pp., AD 750178.

SUBJECTS: 8 pilots (simulator experiments) and 8 pilots (aircraft experiment).

EQUIPMENT: Singer-Link GAT-2 flight simulator and a Beechcraft C-45H aircraft.

SCENARIO: Straight and level, turns, and airways navigation.

MEASURES: Crosstrack error (positional in terms of root mean square [RMS] error), altitude (RMS error), and procedural errors (setting digits into instruments, failure to notice way point passage, interpretational errors, etc.)

SUMMARY: Pilotage errors in area navigation terminal operations were measured in flight and in a flight simulation laboratory. Experimental display variables included scale factor of course deviation indications, whether course deviation is presented in linear or angular fashion, and whether or not either actual or relative heading is presented integrally with course deviation. The major task variable was the angle between successive route segments. The results of systematically controlled laboratory and flight experiments support and amplify preliminary conclusions based on earlier, less formal laboratory and flight tests. Measured horizontal pilot steering errors indicate that the values assumed for terminal area operations in the Federal Aviation Administration's Advisory Circular AC 90-45 are conservative. Independent of the display used, it was also found that altitude control deteriorated as the horizontal turn angle increased. Relatively frequent procedural blunders occurred in the operation of currently typical area navigation controls during the experiments conducted in flight.

405. BERINGER, Dennis B., Williges, Robert C., and Roscoe, Stanley N., The Transition of Experienced Pilots to a Frequency-Separated Aircraft Attitude Display: A Flight Experiment, Proceedings of the 18th Annual Meeting of the Human Factors Society, Huntsville, AL, October 1974, p. 62-70.

SUBJECTS: 24 pilots.

EQUIPMENT: Beechcraft C-45H aircraft and Link GAT-2 simulator.

SCENARIO: Unusual attitude recovery, disturbed attitude tracking, completion of an area navigation course, and a mental secondary task (response to lighted digit).

MEASURES: Pitch angle, roll angle, aileron position, altitude, crosstrack error, distance to or from waypoint (DME), airspeed, and number of correct secondary task responses.

SUMMARY: The purpose of this experiment was to evaluate three attitude displays using experienced pilots. The attitude displays evaluated were moving horizon, moving airplane, and frequency-separated. Data from the C-45H aircraft showed superior performance of both the frequency-separated and moving horizon displays when compared to the moving airplane display during unusual attitude recoveries. During disturbed attitude tracking, the frequency-separated display was superior to all other displays. It was concluded that experienced pilots perform equally as well or better during transition to a frequency-separated flight attitude presentation than to the conventional moving horizon presentation.

406. **EMERY, J.H., Sonneborn, W.G.O.,** and Elam, C.B., A Study of the Validity of Ground-Based Simulation Techniques for the UH-1B Helicopter, Bell Helicopter Company, Fort Worth, TX, Contract No. DA 44-177-AMC-463(T), sponsored by U.S. Army Aviation Material Laboratories, Fort Eustis, VA, USAAVLABS Technical Report 67-72, December 1967, 70 pp., AD 667988.

SUBJECTS: 7 pilots.

EQUIPMENT: UH-1B helicopter and simulator.

SCENARIO: Hover, acceleration, deceleration, maximum power takeoff, straight and level, climbs, descents, six-degree glideslope landing approach.

MEASURES: Cyclic control fore/aft and lateral position, directional (pedal) control position, pitch, roll, and heading. These parameters were subjected to autocorrelation and cross correlation functions. Control efficiency was measured by sum of absolute error, sum of absolute error multiplied by the control rates, and the sum of absolute error multiplied by the sum of the rates.

SUMMARY: The work explored the characteristics of some simulator and flight data which were collected in UH-1B helicopter and a ground-based simulated version of the same.

Analytical treatments are described and applied to these data. They are autocorrelation and cross correlation functions, pilot error and pilot efficiency.

Two basic questions of simulation are considered. First, is the extent to which one can generalize or extrapolate upon the results of a simulator study to the actual system being simulated. The results of the study show that: (1) The aerodynamic characteristics of a given aircraft's flying qualities must be accurately represented in the ground-based simulator in order to produce a high correlation between a pilot's control behavior in the simulator and the aircraft. (2) Simulator motion in forward flight maneuvers is important when large attitude changes are required. In steady-state forward flight, platform motion is less important. (3) Simulator motion is helpful in hovering. Simulation of the offset of the pilot's seat with respect to the UH-1B helicopter center of gravity does not appear to produce better steady-state hover attitude control. In transition maneuvers, however, pilots reported that the c.g. offset was helpful. (4) The type of primary visual display that is included in ground-based simulators is very important. Maneuvers which require large attitude changes also require a wide display field-of-view.

The second question considers what events are important and how they should be measured in order to predict the usefulness of the system based upon the occurrences in the simulator. It was found that advantages of the various measurement techniques depend greatly upon what is to be emphasized from the data, such as control precision, pilot workload, lead-lag time constants, all of which are associated with the overall definition of handling-qualities problems. (Author)

407. GROSSLIGHT, J.H., Fletcher, Harold J., Masterton, R. Bruce, and Hagen, Richard, "Monocular Vision and Landing Performance in General Aviation Pilots: Cyclops Revisited," Human Factors, v. 20(1): p. 27-33, February 1978.

SUBJECTS: 13 private pilots.

EQUIPMENT: Beech Sport training aircraft.

SCENARIO: Visual approach to landing.

MEASURES: Landing distance to runway threshold and altitude. Both were measured and recorded by observers.

SUMMARY: The purpose of this experiment was to evaluate the performance of low-time pilots during monocular and binocular visual landings and compare the results to previous research performed in the same area. Each pilot flew 36 landings each in a random sequence of monocular and binocular visual ability. The results indicated that monocular-visioned pilots were more anxious, flew higher approaches, tended to land longer, and considered the landings to be relatively poorer than binocular-visioned landings.

408. **NICHOLSON, A.N.**, Borland, R.G., and Hill, L.E., Studies on Subjective Assessment of Workload and Physiological Change of the Pilot During Let-Down, Approach and Landing, Proceedings, Annual AGARD Symposium for Measurement of Aircrew Performance, Brooks AFB, TX, Advisory Group for Aerospace Research and Development, Paris, France, AGARD CP No. 56, May 1969, p. 5-6, AD 699934.

SUBJECTS: Unknown number of British Overseas Airways Corporation pilots.

EQUIPMENT: Boeing 707 aircraft.

SCENARIO: Penetration, approach and landing during day and night visibility conditons.

MEASURES: Pilots used the "10 cm line" technique to subjectively assess the overall difficulty of the particular scenario. Other measures were ECG (mean r-r interval) and finger tremor.

SUMMARY: The purpose of the study was to subjectively assess pilot workload while measuring the physiological change in the pilot during the evolution. Observations were made during thirty-four landings into international airports while noting the aircraft configuration, navigational aids, meteorological conditions, physical features of the airports, and air traffic control procedures. It was concluded that mean r-r interval around touch-down reflects the workload of the cruises, penetration, approach and landing whereas changes in finger tremor are associated with unexpected events during the approach.

409. BILLINGS, C.E., WICK, R.L. Jr., Gerke, R.J., and Chase, R.C., "Effects of Ethyl Alcohol on Pilot Performance," Aerospace Medicine, v. 44(4): p. 379-382, April 1973.

SUBJECTS: 16 pilots.

EQUIPMENT: Cessna 172 aircraft.

SCENARIO: Instrument Landing System (ILS) approaches (night).

MEASURES: Approach centerline error, approach glideslope error, percent change from control, and procedural errors (subjectively assessed by an observer pilot as catastrophic or major). Electrocardiogram (ECG) readings were also recorded.

SUMMARY: The purpose of this study was to investigate the role of alcohol as a contributory or causative factor in alcohol-related aircraft accidents. Experimental conditions were pilot groups (experienced or inexperienced) and blood alcohol levels (0, .04, .08, and .12% v/v). Results showed procedural errors increased significantly in frequency and potential seriousness with increasing blood alcohol level. Tracking error and variability also increased with alcohol levels and were more pronounced in less experienced pilots. Even very low blood concentrations of alcohol cause significant performance decrements in flights.

410. BRICTSON, C.A., Pilot Landing Performance Under High Workload Conditions, Dunlap and Associates, Inc., La Jolla, CA 92037, Contract No. N00014-73-C-0053, sponsored by Office of Naval Research, Arlington, VA 22217, April 1974, 12 pp., AD A001802. See also Proceedings on Simulation and Study of High Workload Operations, Advisory Group for Aerospace Research and Development, Paris, France, AGARD Conference Proceedings No. 146.

SUBJECTS: 51 U.S. Navy pilots.

EQUIPMENT: F4J and A-7 aircraft.

SCENARIO: Carrier approach and landing.

MEASURES: Accident rate, boarding rate, and landing result (wire arrestment number, waveoffs, and bolters). The Landing Signal Officers (LSO) subjective grade was combined with objective measures which resulted in a Landing Performance Score (LPS).

SUMMARY: The purpose of this research was to examine the longitudinal performance of pilot carrier landings and describe the influence of prolonged operations on pilot performance. Pilot and squadron performance and workload were measured and compared over time. Three levels of cumulative workload were defined based on recent flying experience. Results showed pilot landing performance improved over time with greater improvement found in night recovery performance than in day. The influence of practice on carrier landings is discussed in relation to high cumulative workload. High and low proficient pilots were identified and diagnostic training information was provided.

411. PIERCE, Byron J., De Maio, Joseph, Eddowes, Edward E., and Yates, David, Airborne Performance Methodology Application and Validation: F-4 Pop-Up Training Evaluation, Air Force Human Resources Laboratory, Williams AFB, AZ 85224, AFHRL-TR-79-7, June 1979, 20 pp., AD A072611. See also Proceedings of the 23rd Annual Meeting of the Human Factors Society, p. 320-324, November 1979.

SUBJECTS: 21 pilots.

EQUIPMENT: F-4.

SCENARIO: Visual pop-up dive bombing.

MEASURES: Circular bomb error, and subjective pilot performance ratings of the maneuver by instructor pilots.

SUMMARY: The purpose of this study was to validate the pop-up performance rating methodology and to generate information identifying specific areas of pilot performance/non-performance. Results indicate that instuctor pilot ratings of individual stages of the delivery yield a reliable index of the quality of performance on the maneuver and identified the proficiency levels attained on certain flying skill areas critical to mission readiness.

These results enabled an examination of the relationship between pilot learning and training program design.

412. BROWN, James E., and Rust, Steven K., Undergraduate Pilot Training Task Frequency Study, Air Force Human Resources Laboratory, Williams AFB, AZ 85224, AFHRL-TR-75-19, August 1975, 60 pp., AD A017472.

SUBJECTS: 121 student pilots.

EQUIPMENT: T-37 and T-38 aircraft.

SCENARIO: Undergraduate Pilot Training (UPT) maneuvers from takeoff to landing.

MEASURES: Students were subjectively assessed as unable to perform (U), fair (F), good (G), or excellent (E), by instructors. Task repetition data (trials to criterion) were collected and evaluated in terms of a mean, standard deviation, median, mode, and range (minimum and maximum).

SUMMARY: The objectives of this research were to determine the number of training task repetitions required for a UPT task, and to determine the total number of task repetitions that UPT students receive for each maneuver. Two studies were discussed; the first involved the development of data collection procedures while the second describes the operational implementation of improved data collection procedures. The results are presented in summary tables and should be useful to the Air Training Command for UPT syllabus development.

413. LEWIS, Ronald E.F., Navigation of Helicopters in Slow and Very Low Flight. A Comparison of Solo and Dual Pilot Performance, Proceedings, Annual AGARD Meeting of the Aerospace Medical Panel, Toronto, Canada, Advisory Group for Aerospace Research and Development, Paris, France, AGARD Conference Proceedings No. 14, Assessment of Skill and Performance in Flying, September 1966, p. 29-34, AD 661165.

SUBJECTS: 6 pilots.

EQUIPMENT: Hiller CHIIZ helicopter.

SCENARIO: Low-level navigation at slow speed.

MEASURES: Number of turn points reached (criterion distance of one-eighth mile was set) and heading error at the beginning of a leg. Performance was subjectively recorded by a chase helicopter flying from approximately 300 feet away on the routes.

SUMMARY: The purpose of this study was to investigate the navigational performance of dual versus solo piloted helicopters and to determine the effects of eliminating pre-flight route briefing. Results showed no differences between dual and solo performance in terms of endpoints reached. Dual teams did exhibit smaller landing deviation errors, fewer initial heading errors, and fewer enroute "sit downs."

414. FINEBERG, Michael L., Navigation and Flight Proficiency under Nap of the Earth Conditions as a Function of Aviator Training and Experience, Proceedings of the 18th Annual Meeting of the Human Factors Society, Huntsville, AL, October 1974, p. 249-254. See article no. 417 for a similar study.

SUBJECTS: 14 U.S. Army helicopter pilots.

EQUIPMENT: UH-1H helicopter.

SCENARIO: Nap-of-the-Earth (NOE) flight.

MEASURES: Number of initial points (IPs) missed, number of landing zones (LZs) missed, number of 250-meter excursions from the course line, and number of 1000-meter excursions (navigational accuracy). These were transformed into probability of finding IP, and probability of finding LZ. Weights were applied to each measure (first four above) by analytical results to give a single objective mission success score (OMSS). Performance on navigation, mission planning, and flying capability were subjectively assessed by an instructor pilot.

SUMMARY: The goal of this study was to determine the present level of NOE performance among U.S. Army aviators and to measure the effects of additional terrain analysis training and flight exlperience. It was also desired to develop and apply a quantified NOE performance measurement technique. The experimental conditions were presence or absence of terrain-analysis training and the pilot's level of flight experience. Results showed those pilots given additional terrain-analysis training appeared to perform the mission more effectively than the group which did not recieve additional training. Pilots with greater flight experience performed slightly less effectively than pilots who were less experienced.

415. FARRELL, John P., and Fineberg, Michael L., "Specialized Training versus Experience in Helicopter Navigation at Extremely Low Altitudes," Human Factors, v. 18(3): p. 305-308, June 1976.

SUBJECTS: 21 U.S. Army helicopter pilots.

EQUIPMENT: UH-1H helicopters.

SCENARIO: Nap of the Earth (NOE) flight.

MEASURES: See article no. 414 for a list of measures used.

SUMMARY: The purpose of this experiment was to determine if general navigation skills acquired in normal rotary-wing flight are transferable to the NOE or very low level flight situation and if the transfer could be matched by specialized training. The subjects were grouped according to experience (14 pilots with a minimum of 2000 hours flight time and 7 pilots with 200 hours flight time) and training (the 7 pilot group had completed a 15 hour NOE course while the other 14 did not). Results showed the only significant difference between groups was on flight planning. It was concluded that skill transfer from one situation to another may not be as extensive as expected, and short periods of specialized training may be more effective than generally recognized.

416. STAMPER, David A., Leibrecht, Bruce C., and Lloyd, Andree J., Honest I: Personality, Heart Rate, Urinary Catecholamine, and Subjective Fatigue Measures Related to Night Nap-of-the-Earth Flying, Letterman Army Institute of Research, Presidio of San Francisco, CA 94129, LAIR Institute Report No. 51, January 1978, 40 pp., AD A054888.

SUBJECTS: 8 Army helicopter pilots.

EQUIPMENT: OH-058 and AH-IG helicopter.

SCENARIO: Night Nap-of-the-Earth (NOE) flying.

MEASURES: California Psychological Inventory (CPI), Eysenck Personality Questionnaire and General States Questionaire, (for personality), urinary catecholamines (free and total norepinephrine, free and total epinephrine) and heart rate (ECG; mean).

SUMMARY: Personality, subjective fatigue, urinary catecholamines, and heart rate measures were evaluated to determine if a relationship between the variables and night NOE flying exists. Results showed scores on the CPI were significantly above the mean for pilots rated as above average ability. Some CPI scores were related to urine catecholamine levels. Heart rate levels were related to epinephrine, but not to norepinephrine. There were no significant increases in perceived anxiety, as measured by the General States Questionnaire. The lack of increase in perceived anxiety may be explained by the processes of dissociation and the general adaptation syndrome.

417. FINEBERG, Michael L., Meister, David, and Farrell, John P., An Assessment of the Navigation Performance of Army Aviators Under Nap-of-the-Earth Conditions, U.S. Army Research Institute for the Behavioral and Social Sciences, Alexandria, VA 22333, Research Report 1195, August 1978, 28 pp., AD A060563. See article no. 414 for a similar study.

SUBJECTS: 35 U.S. Army pilots.

EQUIPMENT: UH-1H aircraft.

SCENARIO: Nap-of-the-Earth (NOE) flight where altitude and airspeed are variables in close proximity to the ground. Aviators were to navigate a specified route starting from an initial point and identify all landing zones while staying within 250 meters of the course line.

MEASURES: Number of initial points (IPs) missed, number of landing zones (LZs) missed, number of 250-meter excursions from the course line and number of 1000-meter excursions (navigational accuracy). These were further transformed into probability of finding IP (number of

IP's found divided by total number of IP's), probability of finding LZ (number of LZ's found divided by total number of LZ's), total distance traveled and percentage of distance traveled off-course (250 or 1000 meters). Performance was also subjectively assessed by instructor pilots who rated navigational effectiveness as complete failure, partial success, or complete success.

SUMMARY: The goals of this research were to determine present levels of NOE performance, develop and evaluate a qualitative NOE performance measure, and measure the effects of additional training and experience on proficiency level. All 35 aviators navigated at least six NOE routes ranging from 23 to 25 kilometers in length. The results indicated that NOE navigation skill can be improved with training while flight experience (total flight hours) did not result in improved NOE navigational skills.

418. WILSON, Wayne Bruce, The Effect of Prolonged Non-Flying Periods on Pilot Skill in Performance of a Simulated Carrie Landing Task, Master's Thesis, Naval Postgraduate School, Monterey, CA 93940, September 1973, 41 pp., AD 769696.

SUBJECTS: 15 pilots.

EQUIPMENT: Carrier Approach Landing Simulator composed of an analog computer, digital computer, control stick, throttle quadrant, and graphic display.

SCENARIO: Carrier approach and landing.

MEASURES: Airspeed, approach centerline error, vertical velocity, and landing result (bolter, wire caught, or crash). Criterion limits were subjectively assigned and a resultant "score" was composed of weighted variables.

SUMMARY: The purpose of this experiment was to determine if a significant loss of basic pilot skill occurs during prolonged periods of non-flying. Aviators were grouped according to length of time since "qualified" as pilots or by actual flight hours (experience). Results showed no significant difference in overall performance among the "currency" groups, with no loss of continuous (tracking) skills in evidence for non-flying periods of up to 30 months. A significant difference was noted among "experience" groups, with more experienced pilots exhibiting better performance.

419. KOONCE, Jefferson M., and McCloy, Thomas M., Cognitive Styles and the Acquisition of a Complex Aerial Maneuver, Proceedings of the 24th Annual Meeting of the Human Factors Society, Los Angeles, CA, October 1980, p. 578-580.

SUBJECTS: 45 male and 43 female nonpilots.

EQUIPMENT: Pacer MK IId desk-top flight simulator.

SCENARIO: "Chandelle" (straight and level, descents, climbing turns, and turns).

MEASURES: Each trial was subjectively scored by an instructor pilot. Trials to criterion was then utilized to measure performance.

SUMMARY: The purpose of this experiment was to investigate the relationship of various cognitive factors to the rate of acquisition of a complex aerial maneuver. The subjects had been previously tested for several cognitive and perceptual-motor areas and were trained to criterion level on four basic instrument flight maneuvers. Results indicated cognitive factors were significant in predicting complex maneuver performance.

420. WAAG, Wayne L., Eddowes, Edward E., Fuller, John H. Jr., and Fuller, Robert R., ASUPT Automated Objective Performance Measurement System, Air Force Human Resources Laboratory, Williams AFB, AZ 85224, AFHRL-TR-75-3, March 1975, 15 pp., AD A014799.

SUBJECTS: 23 pilots.

EQUIPMENT: Advanced Simulation in Undergraduate Pilot Training (ASUPT).

SCENARIO: Straight and level, acceleration, deceleration, climbs, descents, and turns.

MEASURES: Altitude, airspeed, heading, control stick movement, throttle movement, elevator stick force, pitch rate and acceleration, roll rate and acceleration, vertical velocity, vertical acceleration, and subjective ratings of each maneuver by instructor pilots.

SUMMARY: The purpose of this study was to document the approach taken for the development of performance measures and to present data collected from two preliminary evaluations. The results indicated that objectively derived measures highly correlate with instructor ratings and discriminate between pilots of different experience levels. It was suggested that instructor evaluations are a useful criterion for developing objective measures that are valid. The measurement scheme provided some insight into the manner in which instructors assign grades.

421. GOEBEL, Ronald A., Baum, David R., Hagin, William V., Using a Ground Trainer in a Job Sample Approach to Predicting Pilot Performance, Air Force Human Resource Laboratory, Flying Training Division, Williams AFB, AZ 85224, AFHRL-TR-71-50, November 1971, 16 pp., AD 741747.

SUBJECTS: 142 undergraduate pilots.

EQUIPMENT: Link B-Model GAT-1 trainer.

SCENARIO: Tracking (circle, square, sine wave, bullseye, and vertical line), slow flight entry, slow flight coordination, and an Instrument Landing System (ILS) approach.

MEASURES: For tracking tasks, a beam of light on the trainer's nose traced a pattern on the target screen. Measures taken were number of errors (track deviations) and accumulated time off track. Derived measures for tracking tasks were percent time on target (accuracy), mean error (corrective ability), error interval (control ability), average track and a "speed score." Slow flight entry measures were entry time, altitude (time off), and airspeed (time off). Slow flight coordination measures were altitude (time off), airspeed (time off), ball position (time off), and roll angle (time on). ILS measures were groundtrack (time off) and airspeed (time off).

SUMMARY: The purpose of this study was to investigate the utility of a ground trainer in effecting a "job sample" approach to pilot screening. Three findings were reported: (a) job sampling appears to be valid; (b) the T-41 continues to predict subsequent performance in jet pilot traiing; and (c) the ground trainer is useful for predicting pilot success and should be given further study to assess its proper role in jet pilot screening.

422. CHARLES, John P., Johnson, Robert M., and Swink, Jay R., Automated Flight Training (AFT) Instrument Flight Maneuvers, Logicon, Inc., San Diego, CA 92138, Contract No. N61339-71-C-0205, sponsored by Naval Training Equipment Center, Orlando, FL 32813, NAVTRAEQUIPCEN 71-C-0205-1, February 1973, 96 pp., AD 759366.

SUBJECTS:	4 trainees (3 pilots and 1 nonpilot).
EQUIPMENT:	NTEC R & D simulator (TRADEC) configured as an F-4.
SCENARIO:	Straight and level, climbing and diving turns.
MEASURES:	Altitude (plus or minus 200 feet), airspeed (plus or minus 10 knots), vertical velocity (plus or minus 500 feet per minute), turn rate (plus or minus 1 degree per second), roll angle (plus or minus 5 degrees), heading (plus or minus 10 degrees).
SUMMARY:	*The purpose of this study was* to explore and demonstrate conceptual and technical possibilities for applying adaptive training techniques to basic instrument flight maneuvers. Performance evaluation techniques were developed to permit real-time assessment of student performance. A computer controlled voice system was employed for verbal briefings, instructions, and feedback. The results indicated that these techniques can be effectively applied to both initial skill acquisition and proficiency training with particular emphasis on identifying skill deficiencies and adaptation of the training course to meet individual training needs.

423. MARTIN, Elizabeth L., and Waag, Wayne L., Contributions of Platform Motion to Simulator Training Effectiveness: Study I - Basic Contact, Air Force Human Resources Laboratory, Williams AFB, AZ 85224, AFHRL-TR-78-15, June 1978, 40 pp., AD A058416.

SUBJECTS:	24 student pilots.
EQUIPMENT:	Advanced Simulator for Pilot Training (ASPT).

SCENARIO: Straight and level, turn to heading, steep turns, climbs, descents, accelerate, decelerate, slow flight, takeoff, approach, and overhead pattern.

MEASURES: For each scenario, the following parameters were measured: (1) straight and level - altitude (ALT) and heading (HD), (2) turn to heading - ALT, HD, and airspeed (IAS), (3) steep turns - ALT, IAS, and roll, (4) climbs and descents - ALT, IAS and HD, (5) accelerations and decelerations - ALT, IAS, and HD, (6) slow flight - ALT, IAS and inclinometer, (7) takeoff - ALT, HD, and climb-out attitude (pitch), (8) straight-in approach - ALT, IAS, and approach centerline error on glidepath, and (9) overhead pattern - ALT, bank, IAS, approach glideslope error, and approach centerline error. In addition, instructor pilots subjectively assessed student performance in the ASPT on a 12-point scale.

SUMMARY: The purpose of the experiment was to evaluate the contributions of simulator training with and without motion to the acquisiton of basic contact, approach, and landing skills. The same amount of training on each task was given to Motion and No-Motion subjects. Major findings indicated no difference was found between the performance of the Motion and No-Motion groups for any tasks subsequently flown in a T-37.

424. ENOCHS, Edgar R., An Investigation of Possible Correlations Between Individual Pilot Performance and Neurological Functions, Trident Scholar Project Report, U.S. Naval Academy, Annapolis, MD 21402, Report No. 84(1977), May 1977, 86 pp., AD A045372.

SUBJECTS: 12 pilots.

EQUIPMENT: Singer-Link GAT-1B simulator.

SCENARIO: Instrument flight (straight and level, turns, and checkpoint navigation).

MEASURES: Electroencephalogram (EEG) recordings, altitude (percent of time within criterion), and a subjective grade assessed by a safety observer.

SUMMARY: The purpose of this study was to determine whether a meaningful correlation exists between some quantifiable element of a pilot's neurological activity and his performance at the controls of an aircraft. Results showed significant changes in pilot performance and neurological functions as a result of sleep deprivation and an apparent trend was observed relating changes in pilot performance to changes in a pilot's pre-flight neurological state described in terms of cross correlation and coherence function analysis of evoked potential tests.

425. GUNNING, David, Time Estimation as a Technique to Measure Workload, Proceedings of the 22nd Annual Meeting of the Human Factors Society, Detroit, MI, October 1978, p. 41-45.

SUBJECTS: 16 U.S. Air Force pilots.

EQUIPMENT: C-130 simulator.

SCENARIO: Takeoff, straight and level, airdrop preparation, airdrop, and a secondary time estimation task (workload).

MEASURES: Course error, altitude, airspeed, and subjective time estimates (10 seconds). Pilots also subjectively assessed workload during each scenario.

SUMMARY: The purpose of this study was to determine the avionics requirements for a two-pilot transport aircraft by measuring aircrew workload. Each subject was instructed to produce several 10-second time estimates during each of four flights. It was found that time estimation as a measure of aircrew workload correlated highly with subjective workload ratings for this particular scenario. Several problems were addressed, including the large number of incomplete estimates (25 percent) and a low correlation between copilot subjective workload ratings and the time estimation results.

426. CARTER, Vernon E. Development of Automated Performance Measures for Introductory Air Combat Maneuvers, Proceedings of the 21st Annual Meeting of the Human Factors Society, October 1977, p. 436-439.

SUBJECTS: Seven F-4J student pilots and six F-4J instructor pilots.

EQUIPMENT: LAS/WAVS air combat simulator configured as an F-4J aircraft.

SCENARIO: One-vs-one air combat maneuvering (against a preprogrammed, nonintelligent target).

MEASURES: Over 552 "objective" performance measures and 35 "subjective" performance measures were obtained on each run but not listed in this publication. "Ideal" flight paths with "tolerance windows" were flown by expert instructor pilots in runs which were judged to be error-free. Student performance was measured in terms of the student's distance from the center of this funnel-shaped envelope, or in terms of the number of excursions or percent of time within the envelope.

SUMMARY: The objectives of this study were to identify a preliminary set of automated measures which could be used to augment instructor evaluation of performance in introductory air-to-air tactics and to assess the relative effectiveness of alternative statistical techniques for the measure identification process. The method consisted of maneuver selection, development of specific behavioral objectives, development of augmented instructor evaluation techniques, measure analyses, measure definition, software development, data collection and reduction, and measure selection. It was concluded that the performance measurement system developed could be used to augment and facilitate instructor evaluation and diagnosis in introductory air-to-air tactics.

427. MOORE, Samuel B., Meshier, Charles W., and Coward, Robert E., The Good Stick Index. A Performance Measurement for Air Combat Training, First Interservice/Industry Training Equipment Conference, sponsored by Naval Training Equipment Center, Orlando, FL 32813, NAVTRAEQUIPCEN IH-316, November 1979, p. 145-154.

SUBJECTS: 80 student pilots.

EQUIPMENT: Vought Air Combat Simulator configured as F-4E.

SCENARIO: One-versus-one air combat maneuvering.

MEASURES: Tracking error (in mils), pointing angle advantage (mean percentage time), ratio of offensive to defensive time, and time to first kill (mean with gun or heat missile). These four measures were part of a predictor equation called the Good Stick Index (GSI) and had been reduced from over 80 original variables by discriminant analysis. In addition, students were subjectively ranked by instructors and these rankings were compared to the objective data results.

SUMMARY: The purpose of this experiment was to empirically investigate the predictive ability of a formulated index to determine the outcome of a simulated one-versus one free engagement. The data were collected during normal training sessions which culminated in a double elimination competition. The results showed the GSI predicted student pilot performance comparable to the instructors' subjective predictions with 75 percent accuracy. Prediction improved 80 percent when available subjective and objective measures were added.

428. KESTON, Robert, Doxtader, Donald, and Massa, Ronald J., "Visual Experiments Related to Night Carrier Landing," Human Factors, v. 6(5): p. 465-473, October 1964.

SUBJECTS: 3 nonpilots.

EQUIPMENT: Laboratory setup of a darkened room and a horizontal lighted bar.

SCENARIO: Visual perception during carrier approach.

MEASURES: Subjective judgements of altitude along with actual altitude were obtained.

SUMMARY: The purpose of the experiment was to evaluate visual performance during a simulated carrier approach at night. Major variables investigated were the structure of the visual field and the motion of the stimulus array (horizontal bar). The results showed errors as large as 1 degree (corresponding to 8 ft at a range of 500 ft from touchdown) occur frequently, indicating the inadequacy of direct visual contact unaided by artificial display devices. An artificial horizon present dramatically reduced altitude variability and demonstrated the importance of a visual frame of reference or structure.

429. LEWIS, Gregory W., and Rimland, Bernard, Hemispheric Asymmetry as Related to Pilot and Radar Intercept Officer Performance, Navy Personnel Research and Development Center, San Diego, CA 92152, NPRDC TR 79-13, March 1979, 34 pp., AD A068087.

SUBJECTS: 28 pilots and 30 radar intercept officers (RIOs).

EQUIPMENT: EEG equipment, visual presentation, and a keyboard.

SCENARIO: Information processing task.

MEASURES: Uses visual evoked potential (VEP) for brain wave analysis. Eight channels of brain wave activity were recorded from scalp contact electrodes. The subjects were subjectively rated by the squadron operations officer in terms of performance. Information processing was measured by the number of correct responses (bits/sec). VEP data were transformed by means and standard deviations by groups.

SUMMARY: The objective of this study was to determine whether VEP analysis could provide measures of right and left hemisphere functioning that may be used to predict on-the-job performance of aviators requiring fast, high-level cognitive skills. Differences were found between pilot and RIO groups in VEP. Asymmetry differences were shown for higher rated versus lower rated pilots and higher rated RIOs versus lower rated RIOs. It was concluded that the technology under development was promising as a means of improving the selection and classification of aviator training applicants.

430. GRAY, Thomas H., and Fuller, Robert R., Effects of Simulator Training and Platform Motion on Air-to-Surface Weapons Delivery Training, Air Force Human Resources Laboratory, Williams AFB, AZ 85224, AFHRL-TR-77-29, July 1977, 50 pp., AD A043649.

SUBJECTS: 24 student pilots.

EQUIPMENT: F-5B aircraft and Advanced Simulator for Pilot Training (ASPT).

SCENARIO: Visual dive bombing.

MEASURES: Circular bomb error, number of qualifying bombs (circular error less than 105 feet for 10- and 15-degree dive angles and 140 feet or less for 30-degree dive angles), and number of scorable bombs were effectiveness variables. ASPT performance variables were release heading, altitude, airspeed, vertical acceleration, and dive angle. The F-5B performance was subjectively assessed by an instructor pilot on a scale of 0 to 4.

SUMMARY: The objectives of this research were to determine: (1) the extent to which generalized, conventional, air-to-surface (A/S) weapons delivery training in the ASPT transferred to a specific aircraft; (2) the contribution of six-degree-of-freedom platform motion to the transfer of training from simulator to aircraft; and (3) the differential effects of that simulator training on student pilots of differing ability levels. Experimental conditions were simulator training and platform motion. The results showed that simulator training significantly increased air-to-surface weapons delivery skills (measured by number of qualifying bombs and circular error). Platform motion did not contribute in that process. Novice student pilots of greater initial ability benefited most from such simulator training when a minimum fixed number of trials was used.

431. NATAUPSKY, Mark, Waag, Wayne L., Weyer, Douglas C., McFadden, Robert W., and McDowell, Edward, Platform Motion Contributions to Simulator Training Effectiveness: Study III - Interaction of Motion with Field-of-View, Air Force Human Resources Laboratory, Williams AFB, AZ 85224, AFHRL-TR-79-25, November 1979, 30 pp., AD A078426.

SUBJECTS: 32 student pilots.

EQUIPMENT: T-37 aircraft and Advanced Simulator for Pilot Training (ASPT).

SCENARIO: Takeoff, turns, slow flight, and straight-in visual approach and landing.

MEASURES: Altitude (minimum [L] and maximum [U], airspeed (L, U), roll (V,L), heading (U,L), pitch (U,L), takeoff position error, and touchdown point (landing distance from threshold). ASPT used the Automated Pilot Measurement System (APAMS) whereas the pilots in the T-37 were subjectively graded for each parameter and scenario.

SUMMARY: The objective of this study was to determine the effects of platform motion cueing, visual field of view (FOV), and their interaction upon learning in the simulator and as a subsequent transfer of training to the aircraft for basic contact maneuvers in the T-37 aircraft. Experimental conditions were platform motion (full or none) and FOV (full or limited). Results provided no conclusive evidence of differential transfer effects resulting from motion cueing, size of the visual FOV, or their interaction. Platform motion cueing does not significantly enhance transfer of learning for basic contact tasks in the T-37 aircraft. The major implication from the findings is that a fixed-base, limited FOV simulator configuration provides sufficient cueing for basic contact skills normally trained during Undergraduate Pilot Training.

432. CARO, Paul W., Isley, Robert N., and Jolley, Oran B., Research on Synthetic Training: Device Evaluation and Training Program Development, Human Resources Research Organization, Alexandria, VA 22314, Contract No. DAHC 19-C-73-0004, sponsored by Office of the Chief of Research and Development (Army), Washington, DC 20310, HumRRO TR-73-20, September 1973, 53 pp., AD 768923.

SUBJECTS: 40 student pilots.

EQUIPMENT: T-42 aircraft and Singer GAT-2 simulator.

SCENARIO: Takeoff, recovery from unusual attitudes, single engine procedures, traffic pattern, landing (visual), straight and level, turns, climbs, descents, and Instrument Landing System (ILS) approach.

MEASURES: Procedural errors (proper or improper selections), altitude (plus or minus 100 feet), airspeed (plus or minus 10 knots), ground track (plus or minus 5 degrees), heading (plus or minus 10 degrees), and ILS position errors (mean frequency and percent deviation from approach centerline and glideslope).

SUMMARY: The purpose of this research was to evaluate a fixed-wing instrument procedures training device and to develop a training program for use with the device. The experimental conditions were training or no training in the simulator for two randomly selected groups of 20 trainees each. Results showed the trainees who received training in the device tended to perform more satisfactorily than those who did not. Their attrition rate was lower and they were more likely to be rated above average by instructors. Performance on procedural tasks tended to be superior during check rides as measured by subjective pilot ratings and scored objective photographic records. The administration of the training program that was developed resulted in a 40 percent reduction in number of flight hours required to attain transition and instrument flight objectives of the course under study.

433. CARO, Paul W. Jr., Isley, Robert N., and Jolley, Oran B., The Captive Helicopter as a Training Device: Experimental Evaluation of a Concept, Human Resources Research Office, Ft. Rucker, AL, Contract No. DA 44-188-ARO-2, sponsored by Office of Chief of Research and Development (Army), Washington, DC 20310, HumRRO Technical Report 68-9, June 1968, 47 pp., AD 673436.

SUBJECTS: 132 Warrant Officer Candidate aviation students.

EQUIPMENT: Whirlymite Helicopter Trainer (WHT) and OH-23D helicopter.

SCENARIO: Hover (60 sec), turns (tethered, slack, and precision), slack hover, tracking (with tether and rectangular), and altitude control (four and fourteen-inch) for the WHT. Primary helicopter training was also utilized.

MEASURES: For the WHT: time of task execution (complete a maneuver), trials to complete a maneuver, absolute time to complete a maneuver criterion, cumulative time to complete a maneuver criterion, number of errors to criterion, tracking time on target, tracking frequency off target, turn error, number of contacts per trial on 14-inch hoop, number of errors per trial, number of correct trials, and number of trial series performed. Aircraft training effectiveness variables were attrition rate, time to flying proficiency (criterion), and subjective grading by instructors.

SUMMARY: The research objective was to determine the effectiveness of new device concept for helicopter contact flight training and the usefulness of such a device for predicting performance during subsequent flight training. The device was a commercially available captive helicopter attached to a ground effects machine. Two experimental groups of trainees received 3-1/4 or 7-1/4 hours of device training prior to primary helicopter training. In comparison with control groups, both device trained groups (a) were significantly less likely to be eliminated from subsequent flight training for reasons of flying deficiency; (b) required less flight training to attain the proficiency required to solo the helicopter; and (c) received higher grades during early training. Trainees who performed well on the training device tended to perform well during subsequent flight training. Instructors using devices such as this one need not be proficient in the helicopter used for subsequent flight training. (Author)

434. ISLEY, Robert N., Caro, Paul W. Jr., and Jolley, Oran B., Evaluation of Synthetic Instrument Flight Training in the Officer/Warrant Officer Rotary Wing Aviator Course, Human Resources Research Office, Ft. Rucker, AL, Contract No. DA 44-188-ARO-2, sponsored by Office of Chief of Research and Development (Army), Washington, DC 20310, HumRRO Technical Report 68-14, November 1968, 43 pp., AD 680586.

SUBJECTS: 60 student pilots.

EQUIPMENT: Quasi-rotary-wing training device (1-CA-1), OH-23D helicopter, and TH-55A helicopter. Cockpit parameters were measured by photographic cameras.

SCENARIO: Inbound tracking, station passage, turns, descending turns, climbs, outbound passage, and a tactical instrument check-ride.

MEASURES: Airspeed, pitch, roll, altitude, engine RPM, ADF, heading, vertical velocity, and trim. These parameters were assigned control standards and tolerance levels. Tactical instrument check-rides were subjectively assessed by instructor pilots.

SUMMARY: The objective was to determine the training value of synthetic instrument flight training given in the Tactical Instrument Phase of the Army's Officer/Warrant Officer Rotary Wing Aviator Course. Synthetic training in that course is administered in a modified fixed wing instrument training device. One group of trainees received the standard 20-hour synthetic instrument flight training program, a second group received 10 hours, and a third group received no synthetic training. The synthetic training given in the modified fixed wing training device did not increase trainee helicopter instrument flight proficiency in terms of aircraft control and procedural skills. In addition, there were no significant differences among the three groups in attrition, instructor-assigned daily grades, amount of flight instructional time required to complete the phase, and final checkride grades. (Author)

500. BOOTH, Richard F., and Berkshire, James R., Factor Analysis of Aviation Training Measures and Post-Training Performance Evaluations, Naval Aerospace Medical Institute, Pensacola, FL 32512, NAMI-1050, October 1968, 13 pp., AD 681794.

The purpose of this study was to relate the factor structure of naval air training measures to the performance of Marine pilots in operational squadrons. Although several similar factor analytic studies have been conducted previously, none has investigated the relationship of resulting factors to the post-training performance of naval aviators.

Five post-training criteria were developed for this analysis. Four of these were Commanding Officer (C.O.) nominations of junior officers for hypothetical special assignments, and the fifth was a general satisfactory/ unsatisfactory C.O. evaluation of each junior officer's squadron performance.

Academic ability, flying skill, and systems comprehension factors were found in separate analyses for jet and helicopter pilots. The four C.O. nominations were loaded on a single nomination factor that was essentially unrelated to training measures in either sample. The satisfactory/ unsatisfactory criterion, however, was directly related to a jet pilot's over-all flying skill and inversely related to the performance of a helicopter pilot early in flight training. (Author)

501. HORNER, Walter R., Radinsky, Thomas L., and Fitzpatrick, Robert, The Development, Test, and Evaluation of Three Pilot Performance Reference Scales, American Institutes for Research, Pittsburgh, PA 15213, Contract No. F33615-9-C-1366, sponsored by Air Force Human Resources Laboratory, Williams AFB, AZ, AFHRL-TR-70-22, August 1970, 62 pp., AD 727024.

This report describes the results of a study to develop pilot performance reference scales based upon audio-video recordings of in-flight performances of students undergoing T-37 undergraduate pilot training. The study included scale development as well as the test and evaluation of each scale. All the maneuvers contained on the in-flight recordings were analyzed, and constituent performance elements observable on the video replay were identified. Three maneuvers, Final Turn to Landing, Vertical S "A," and Lazy Eight, were selected for the final scaling effort. Ten performance elements each were identified for the Lazy Eight and Vertical S "A" maneuvers, and twelve elements for the Final Turn to Landing. A performance reference scale was developed for each maneuver. Each scale consisted of a series of subscales for rating performance on each of the elements of the maneuver and an additional subscale for rating the overall performance of the maneuver. Although some elements were common to more than one maneuver, the rating scales for these elements were tailored in each case to the maneuver involved. Each subscale consisted of a ten-point rating line (a row of ten boxes) representing the full range of performance from "unsatisfactory" to "excellent" and, beneath, four graded verbalizations describing different levels of performance. No verbalizations were presented, however, with the subscale used for rating overall performance. Final versions of the scales were subjected to a test and evaluation through their utilization by experienced instructor pilots. These pilots assigned levels of performance based upon what they observed on video replays of selected maneuver examples. The results showed the overall reliability of scales for the three maneuvers was high but that the majority of the individual element scales were of a relatively low to medium degree of reliability. The results are believed to justify more in-depth analysis of the data and continued development efforts to refine and increase the scope of scale application. (Author)

502. SCHRADY, David A., and Hanley, Michael J., A Comparative Analysis of Proficiency Aviator Skill, Knowledge, and Satisfaction, Naal Postgraduate School, Monterey, CA 93940, NPS 55S071031A, March 1971, 123 pp., AD 721222.

Data reflecting the knowledge, skill, and satisfaction of aviators in combat readiness training (CRT) flight status, was collected. The aviator sample consisted of one group flying 4-hours per month and another flying 8-hours per month in the T-1A aircraft. The data collection methods are described, and the results and conclusions from a comparative analysis are noted. (Author)

503. HOFFMAN, David Wesley, A Method for Predicting Carrier Qualification Success in the Combat Replacement Air Wing, Master's Thesis, Naval Postgraduate School, Monterey, CA 93940, March 1971, 23 pp., AD 721233.

A method for predicting Replacement Air Wing Carrier Qualification grades is examined. The data were supplied by Fighter Squadron One-Twenty-One, and subjected to multiple regression analyses in search of important variables that may be used in the prediction. Such have been identified and applied to the data. The results are extremely encouraging and a follow on study applied to a broader data base is suggested. Applicability and some economic factors are discussed. (Author)

504. POVENMIRE, H. Kingsley, and Roscoe, Stanley N., "An Evaluation of Ground-Based Flight Trainers in Routine Primary Flight Training," Human Factors, v. 13(2): p. 109-116, April 1971.

The relative benefits of different types of flight training equipment were evaluated in a routine instructional situation with no particular constraints placed upon the instructor as to how he used the equipment and without interfering with the normal course of flight training. The specific objectives of this research program were: (1) to evaluate the flight instructors' ability to predict success in private pilot training on the basis of students' initial performances in each of two ground trainers as opposed to actual aircraft, (2) to determine the relative value of 11 hours of flight instruction in two different ground trainers, and (3) to develop an objective scale for checking flight proficiency. There was a significant positive correlation of 0.50 between predictions based on two hours of training in the ground-based trainers and actual hours required to pass the flight check, but a nonsignificant negative correlation of 0.22 for predictions based on two hours in the aircraft. The ground trainer groups passed their flight checks with an average of slightly more than an hour greater total time than those trained exclusively in the aircraft. On the basis of equivalent levels of group performance, 11 hours of training in the AN-T-18 resulted in a saving of 9 hours of flight time thereby yielding a transfer effectiveness ratio of 0.8. Eleven hours of training in the GAT-1 resulted in a saving of 11 hours of flight time, yielding a transfer effectiveness ratio value of 1.0. The transfer effectiveness ratio is a new measure that directly relates the saving in learning one task to the amount of training on another. (Author)

505. SHANNON, Richard H., and Waag, Wayne L., Toward the Development of a Criterion for Fleet Effectiveness in the F-4 Fighter Community, Proceedings of the 16th Annual Meeting of the Human Factors Society, Los Angeles, CA, October 1972, p. 335-337. See also NAMRL-1173, December 1972, 13 pp., AD 755184.

In a previous investigation, an attempt was made to isolate the most critical skills and procedures within each of the stages comprising replacement air group (RAG) training in the F-4 aircraft. For each of the stages analyzed, a small set of graded items were selected on the basis that they could adequately discriminate among replacement pilots according to their final RAG grade. The resulting set of items were found to be highly predictive of both the stage grade from which they were obtained and the final RAG grade. The present investigation attempted to replicate these findings with data obtained from a different squadron. For the items common to both squadrons, a multiple R of .852 was obtained for the initial sample using the final RAG grade as the criterion. Using the beta weights obtained from the initial sample, predictions were derived for pilots in the new sample. The resulting correlation between predicted and observed RAG grades was .776. Such findings suggest that skills and procedures can be effectively isolated which are highly predictive of pilot performance in the RAG. It is suggested that such "critical" items should form the basis from which an adequate measure of fleet performance might be developed. (Author)

506. HOLLISTER, Walter A., LaPointe, Arthur, Oman, Charles M., and Tole, John R., Identifying and Determining Skill Degradations of Private and Commercial Pilots, Massachusetts Institute of Technology, Cambridge, MA 02139, Contract No. DOT-FA72WA-2767, sponsored by Federal Aviation Administration, Washington, DC 20590, FAA-RD-73-91, June 1973, 76 pp., AD 771101.

The aeronautical skills of a sample of non-instrument rated, private and commercial pilots, were studied to determine the effect of experience factors. A sample of 55 pilots, chosen to be representative of the total pilot population in terms of age and experience, each flew three flights with an evaluator in a Cessna 150. On the average, subjects received higher scores on skills employed most often. They received the lowest average scores on skills seldom practiced such as stalls and simulated instrument flight. A step-wise regression analysis indicated that an individual's latent skill accounts for 30% of the variance between pilots. Experience factors accounted for 25% of the variance. The most predictive of these experience factors were Recency and the logarithm of total time. Recency is the average rate at which a pilot flies. It is the most important experience factor and the one which the pilot can vary most easily. The logarithm of the total time was the second most important experience factor. The logarithmic dependence causes changes of total time to be more important for pilots with low total time. Skill degradation with years since certification was the third most important experience factor. A .15 hour per week increase in flying Recency or a 10% increase in total time is required to offset the effect of a year since certification. (Author)

507. YOUNG, Linda L., Jensen, Richard S., and Treichel, Curtis W., Uses of a Visual Landing System in Primary Flight Training, Proceedings of the 17th Annual Meeting of the Human Factors Society, Washington, DC, October 1973, p. 265-271.

An exploratory study was made to determine the potential usefulness of a visual landing system in a primary flight training program and to determine design and instructional changes which may be necessary to optimize the landing trainer. Thirty-eight flight-naive student-subjects were divided into three groups, each receiving a different type of simulator landing instruction: Visual Landing System (VLS), Standard GAT-1 (SG), and Control (C). The VLS and SG Groups each received two hours of simulator landing instruction in their respective simulators, and the C Group received no simulator landing instruction. The criterion was three consecutive unassisted landings in a Cherokee 140. The primary measure was flight instruction time needed to reach criterion. No reliable differences were found among the three groups leading to the conclusions that more instructional time is needed in the simulator and a considerable amount of experimental control is needed to produce significant results. However, comments from flight instructors and students who used it demonstrated an attitude of high optimism concerning the potential of the VLS as an aid to teaching landings. (Author)

508. POVENMIRE, H. Kingsley, and Roscoe, Stanley N., "Incremental Transfer Effectiveness of a Ground-Based General Aviation Trainer," Human Factors, v. 15(6): p. 534-542, December 1973.

Link trainers and similar synthetic flight-training devices have been used with varying effectiveness since before World War II. Currently available ground-based flight trainers differ widely in their degree and fidelity of simulation and in their associated costs. To provide a rational basis for trainer procurement, a method of assessing their cost effectiveness is needed.

An experiment was conducted to establish the incremental transfer effectiveness of a representative ground-based general aviation trainer to serve as a basis for the evaluation of its incremental cost effectiveness. Four groups of student pilots were given, respectively, 0, 3, 7, and 11 hours of instruction in the Link GAT-1 concurrently with flight instruction in the Piper Cherokee airplane. Average flight times for the four groups to reach the private pilot criterion reflected the postulated negatively decelerated nature of the incremental transfer effectiveness function. (Author)

509. KOONCE, Jefferson M., Effects of Ground-based Aircraft Simulator Motion Conditions upon Prediction of Pilot Proficiency. Parts I and II, Doctoral dissertation, University of Illinois, Savoy, IL 61874, Contract No. F44620-70-C-0105, sponsored by Air Force Office of Scientific Research, Arlington, VA 22209, AFOSR-TR-74-1292, April 1974, Part I, 213 pp., AD 783256; Part II, 103 pp., AD 783257.

Three groups of thirty pilots with multi-engine and instrument ratings performed a simulated flight mission in a General Aviation Trainer - 2 (GAT-2) on each of two days. The experimental conditions for the groups differed in terms of GAT-2 motion (Group I - no motion; Group II - sustained linear, scaled-down analog motion; Group III - washout motion). Each group of pilots then flew the same mission in a light twin-engine aircraft representative of the class of aircraft simulated by the GAT-2.

The mission consisted of five maneuvers representative of those usually performed under instrument flight rules (IFR) without visual reference to the outside world and five maneuvers usually performed with outside visual contact under visual flight rules (VFR). In the simulator, all of the maneuvers were performed without outside visual reference.

Two trained observers, one of whom was also the safety pilot for the mission, recorded pilot performance on each mission in a specially designed booklet. The order of assignment of observers to the missions permitted recording of a pilot's performance on a single mission by two independent observers and also the recording of the pilot's performance on two successive missions by the same observer and two independent observers.

The results indicated that the proficiency of aircraft pilots can be predicted to a high degree from ground-based simulator performance measures. Of the three simulator motion conditions used greater prediction of operator performance from a simulator to flight can be obtained using sustained cockpit motion than by using washout motion or no motion. There was no significant difference between the predictive validities of performance with no motion and washout motion.

The experiment demonstrated that very high observer-observer reliabilities (r = .771 to .971) on the same mission can be obtained by recording performance on scales that are well defined and easy to follow, descriptive of the maneuver and behavior being recorded, and not too demanding upon the person doing the recording of performance. The performance measures taken in the simulator tended to be more reliable than those taken in the aircraft because of the elimination of degrading environmental factors and the reduction of safety oriented duties frequently imposed upon safety observers.

Simulator motion tends to increase subject acceptability of the device, lower performance error scores, and reduce the workload on the subjects and observers through the aiding effects of the motion onset cues. But the differential effects of motion on two performance trials in the simulator do not transfer to performance in flight. In the prediction of operator performance in flight the magnitude of the error scores resulting with the use of one motion system as opposed to another is not as important as the stability of the subjects' performance from one day to the next. Increasing the fidelity of the simulator motion system may bring much of the variability of flight into the simulated environment which was used to escape the variability of the operational environment.

The recorded pilot performance measures correlated very highly with the observers' overall subjective ratings of the missions (r = .726 to .878). The observers' overall ratings correlated slightly higher with performance on instrument flight maneuvers than with performance on visual flight maneuvers. Other possible indices of pilot proficiency, such as the amount of multi-engine land, instrument or total flight time logged in the past six months, did not correlate very well with mission performance scores, in fact they correlated about as well as age. (Author)

510. HENGGELER, William M., and Ovalle, Nestor K., A Study to Determine a Relationship Between Flying Hours and Flying Proficiency for the KC-135A/Q Aircraft, Master's Thesis, Air Force Institute of Technology, Wright-Patterson AFB, OH 45433, August 1975, 93 pp., AD A016035.

The United States Air Force's operational readiness posture is a function of flying proficiency. Flying time is an important factor in achieving and maintaining an optimal level of flying proficiency. This study attempted to measure the effect of flying hour reductions (resulting from energy conservation and fuel reduction programs) on flying proficiency in order to determine if a statistical correlation can be applied for use as a predictor of flying proficiency as a function of flying time. This study was primarily concerned with the KC-135A/Q aircraft which are in operational use in the Strategic Air Command's 8th and 15th numbered Air Forces. The study encompassed the time period from January, 1973 through June, 1974 in order to provide a comparison of proficiency analysis before flying hours were significantly reduced and after their reduction. The study did not determine any statistically significant effect on flying proficiency. The methodology and analysis of this study could be used to generate future studies on all types of aircraft, and, therefore, extend the analysis to the effects of flying time on proficiency throughout the Air Force. (Author)

511. ONTIVEROS, Robert J., Effectiveness of a Pilot Ground Trainer as a Part Task Instrument Flight Rules Flight-Checking Device Stage I, Federal Aviation Administration, Atlantic City, NJ 08405, FAA-RD-75-36, September 1975, 50 pp., AD A015722.

The first stage of a two-stage experiment was conducted at the National Aviation Facilities Experimental Center (NAFEC) to determine the effectiveness of a pilot ground trainer for training noninstrument-rated pilots in instrument approaches and related instrument flight procedures. Ten private pilots were trained to perform very high frequency omnirange station (VOR), automatic direction finder (ADF), and instrument landing system (ILS) approaches. The pilot ground trainer represented a single-engine general aviation aircraft. The subjects' flight performance capability, achieved through ground trainer instruction, was evaluated by a flight check in an instrument-equipped Cessna 172. The results of this first stage of investigation indicate a positive transfer of training between observed pilot performance in the ground trainer and observed pilot performance in the aircraft for performing instrument flight approaches. The report provides information about trainer equipment and capabilities which contributed to the positive transfer. Procedural maneuver situations which resulted in minimal training transfer are discussed in terms of desirable ground trainer capabilities which could enhance the effectiveness of the pilot ground trainer for performing instrument flight approaches. With the stage I confirmation of pilot ground trainer effectiveness in an instrument training situation, a planned second stage of experimentation will determine if a ground trainer can be used effectively as a flight-checking device for pilots to demonstrate their ability to perform instrument approaches in lieu of performing these procedures on their initial instrument flight test in an aircraft. (Author)

512. REID, Gary B., "Training Transfer of a Formation Flight Trainer," Human Factors, v. 17(5): p. 470-476, October 1975.

The present research was conducted to measure transfer of training from a formation simulator to aircraft formation flying. Evidence in support of positive transfer was obtained by comparing students trained in the formation simulator with students who were essentially untrained and with students trained in the aircraft. This design provided data for a direct comparison of five simulator sorties with two aircraft sorties, in an effort to establish quickly a training cost/transfer comparison. The results indicate that simulator training has at least the effectiveness of two aircraft sorties. (Author)

513. JACOBS, Robert S., and Roscoe, Stanley N., Simulator Cockpit Motion and the Transfer of Initial Flight Training, Proceedings of the 19th Annual Meeting of the Human Factors Society, Dallas, TX, October 1975, p. 218-226.

Transfer of flight training from a Singer-Link GAT-2 training simulator, modified to approximate a counterpart Piper Cherokee Arrow airplane, was measured for independent groups of nine flight-naive subjects, each trained in one of three simulator cockpit motion conditions: normal washout motion in bank with sustained pitch angles, washout banking motion in which the direction of motion relative to that of the simulated airplane was randomly reversed 50% of the time as the cab passed through a wings-level attitude, and a fixed-base condition. Subjects received predetermined fixed amounts of practice in the simulator on each of 11 flight maneuvers drawn from the Private Pilot flight curriculum. Transfer performance measures, including flight time and trials to FAA performance criteria and total errors made in the process, showed reliable transfer for all groups with differential transfer effects and cost-effectiveness implications depending upon the type of simulator motion. (Author)

514. BERGMAN, Craig A., "An Airplane Performance Control System: A Flight Experiment," Human Factors, v. 18(2): p. 173-182, April 1976.

Pilot performance and preference measures were obtained for 12 pilots in actual flight operations using a twin-engine general aviation aircraft with both conventional controls and a Performance Control System (PCS). The PCS provides zero-order control of aircraft bank angle and vertical speed over the ranges of ±60` and ±457.2 m/min, respectively. An information-processing side task was also used. With the PCS, flight error scores were reliably lower than with conventional aircraft controls. Pilot preferences, using a six-point scale, ranging from "slight" to "moderate" to "strong" preference for each of the two control systems, showed a "moderate preference for the PCS" as the median response. (Author)

515. ONTIVEROS, Roberrt J., Effectiveness of a Pilot Ground Trainer as a Part Task Instrument Flight Rules Flight-Checking Device Stage II, Federal Aviation Administration, Atlantic City, NJ 08405, FAA-RD-76-72, June 1976, 67 pp., AD A 026754.

The second stage of a two-stage experiment was conducted at the National Aviation Facilities Experimental Center

(NAFEC) to determine if a pilot ground trainer (PGT) could be used to flight check instrument-pilot applicants on instrument approaches in lieu of performing these tasks in an aircraft on their initial instrument flight check. Stage I defined the capabilities and equipment of PGT's considered essential for training pilots to perform instrument approaches and related instrument procedures. Based on the comparative PGT and aircraft performance scores of a control and experimental group, the results of Stage II indicate that an appropriately equipped PGT may be used to flight check instrument-pilot applicants on the automatic direction finder (ADF) very high frequency omnidirectional radio range (VOR), and instrument landing system (ILS) approaches. The report lists the equipment and capabilities required for the ground trainer to be effective as a part-task flight-checking device for accomplishing these tasks. Significant differences between PGT and aircraft performance scores are disccussed. Factors contributing to the performance differences are identified. (Author)

516. WOODRUFF, Robert R., Smith, James F., Fuller, John R., and Weyer, Douglas C., Full Mission Simulation in Undergraduate Pilot Training: An Exploratory Study, Air Force Human Resources Laboratory, Williams AFB, AZ 85224, AFHRL-TR-76-84, December 1976, 18 pp., AD A039267.

Eight undergraduate pilot training students were trained to specified levels of performance in all major areas of basic pilot training using the Advanced Simulator for Undergraduate Pilot Training (ASUPT); half were trained using the platform motion system and half without. Subsequently, they completed basic pilot training (to Air Training Command (ATC) phase standards) in T-37 aircraft. Training hours required and check ride scores were compiled for each subject. Similar data were collected for a control group of eight subjects trained using the conventional ATC syllabus. Using data obtained from both groups, estimates of transfer of training percentages, and training effectiveness ratios were computed.

Simulator trained students required fewer aircraft hours in all areas of basic UPT and achieved check ride scores equal to or better than the control group. No significant or practical differences were documented between performances of the motion and no-motion trained groups for any category of maneuvers.

This was a first effort to incorporate a full mission simulator into an operational pilot training program. Several problem areas were identified which must be solved before full success can be achieved. These same problems should be relevant to application of other full mission simulators in other training programs. In addition, some ASUPT deficiencies were identified. (Author)

517. BROWNING, Robert F., Ryan, Leonard E., and Scott, Paul G., Utilization of Device 2F87F OFT to Achieve Flight Hour Reductions in P-3 Fleet Replacement Pilot Training, Training Analysis and Evaluation Group, Orlando, FL 32813, TAEG Report No. 54, April 1978, 44 pp., AD A053650.

This study continued the investigation of the training effectiveness of Device 2F87F in fleet replacement training. The study examined:

1. comparative data on first-tour pilots trained on principal P-3 flight tasks without correlative simulator training,
2. training trials required to achieve proficiency in the flight simulator and in the aircraft,
3. performance in the flight simulator as a predictor of later performance in the P-3.

The analyses considered:

1. the number of in-flight hours required to complete the Familiarization/Instrument phase of Fleet Readiness Squadron (FRS) without previous training in Device 2F87F,
2. transfer effectiveness ratios for Device 2F87F,
3. benefits of landing practice in Device 2F87F, and
4. correlations between undergraduate pilot training (UPT) flight averages, UPT flight hours, and FRS performance. (Author)

518. DAMOS, Diane L., "Residual Attention as a Predictor of Pilot Performance," Human Factors, v. 20(4): p. 435-440, August 1978.

Sixteen student pilots performed a task combination designed to measure residual attention. Scores on this combination were correlated with performances on flight checks administered periodically during flight training. The multiple correlation between performances on the flight checks and the task combination increased as the students progressed through flight training. The usefulness of residual attention as a predictor of pilot performance is discussed. (Author).

519. MARTIN, Elizabeth L., and Waag, Wayne L., Contributions of Platform Motion to Simulator Training Effectiveness: Study II - Aerobatics, Air Force Human Resources Laboratory, Williams AFB, AZ 85224, AFHRL-TR-78-52, September 1978, 32 pp., AD A064305.

A transfer of training design was used to evaluate the contributions of simulator training with synergistic six-degrees-of-freedom platform motion to the acquisition of aerobatic skills in the novice pilot. Thirty-six undergraduate pilot trainees with no previous jet piloting experience were randomly assigned to one of three treatment groups (n = 12): (a) Motion, (b) No-Motion, and (c) Control. Those students assigned to the Control group received the standard syllabus of preflight and flightline instruction. The students in the two experimental conditions received five sorties, in the Advanced Simulator for Pilot Training (ASPT), covering instruction on basic and advanced aerobatic tasks. All students received the same amount of training on each task, that is, a fixed number of repetitions per task. Student performance in the ASPT was evaluated periodically throughout the pretraining phase by the use of Instructor Pilot ratings for overall task performance and of special data cards. Following three missions of instruction in the ASPT on the basic aerobatics tasks (Aileron Roll, Split "S," Loop, Lazy 8), the student advanced to the flightline for T-37 instruction. Upon completion of the basic block, the students returned for 2 ASPT instructional sorties on the advanced aerobatic tasks (Barrel Roll, Immelman, Cuban 8, and Clover Leaf). The ASPT training was followed by the corresponding aircraft instructional block. Airborne performance was evaluated by the flightline instructor pilot using the same data card format used during the ASPT phase. The resulting data produced the following findings: (a) using IP ratings, no differences in simulator performance emerged between the Motion and No-Motion groups, (b) using the special data cards, no consistent differences emerged between the Motion and No-Motion groups, although several of the measures produced statistically significant effects, (c) significant learning occurred during simulator training for both groups, (d) the two groups trained in the ASPT performed significantly, although modestly, better in the T-37 than the control group; and (e) no significant differences emerged in T-37 performance between the Motion and No-Motion groups. This study indicates the need for developing better procedures for the training of acrobatic tasks in flight simulators. Although the data failed to reveal any significant or practical enhancement of training effectiveness as a result of the addition of platform motion, the modest degree of transfer makes the question of platform motion more academic than practical. (Author)

520. TROLLIP, Stanley R., "The Evaluation of a Complex Computer-Based Flight Procedures Trainer," Human Factors, v. 21(1): p. 47-54, February 1979.

Skills such as flying holding patterns are taught in planes or simulators. An alternative method is to use computer-assisted instruction (CAI) which emphasizes training requirements rather than physical fidelity. Such a program was written and evaluated. Traditional ground school methods were compared with the CAI method. All subjects completed a training sequence in a ground trainer. Those taught by computer performed better and attained criterion quicker with significantly fewer critical errors. Results indicate that CAI offers an effective alternate to the costly trainers currently in use. (Author)

521. KOONCE, Jefferson M., "Predictive Validity of Flight Simulators as a Function of Simulator Motion," Human Factors, v. 21(2): p. 215-223, April 1979.

Ninety multi-engine instrument rated pilots were assigned to no motion, sustained linear scaled down analog motion, and washout motion in a GAT II simulator for determining the effects of degree of motion upon the predictive validity of flight simulators. Five instrument and five contact maneuvers were flown in the simulator followed by flight in a Piper Aztec aircraft. Performances were recorded by two observers and the interobserver reliability coefficients were 0.962 and 0919 for instrument maneuvers and 0.879 and 0.613 for contact maneuvers in the simulator and aircraft, respectively. The condition of no motion resulted in greater error than the other two groups in the simulator, but there were no significant differences in the aircraft. Correlations of aircraft performance from the simulator maneuvers were 0.763 (no motion), 0.911 (sustained motion), and 0.651 (washout motion). Simulator motion did not result in better aircraft performance, and higher predictive validity was found with very basic sustained motion. (Author)

522. DAMOS, Diane L., and Lintern, Gavan, A Comparison of Single- and Dual-task Measures to Predict Pilot Performance, University of Illinois, Urbana, IL 61801, Contract No. F44620-76-C-0009, sponsored by Air Force Office of Scientific Research, Bolling AFB, DC 20332, AFOSR-TR-80-0325, May 1979, 24 pp., AD A084237.

An experiment comparing the predictive validity of single- versus dual-task measures is reported. Fifty-seven males received two trials on each of two identical one-dimensional compensatory tracking tasks. The subjects then attempted to perform the tasks concurrently for 25 trials. Finally, they performed each task alone for one trial. The subjects then were given a short basic flight course consisting of ground instruction and practice in a GAT-2 simulator. After completing the course, the subjects were asked to perform four repetitions of a descent, a descent followed by a stall, and a level turn. Performance was scored by an instructor and an observer. Performance in the simulator then was correlated with performance on each tracking trial. The predictive validity of the early single-task scores decreased with practice while the dual-task validity increased throughout the testing session. However, the predictive validity of the late single-task scores was almost as large as that of the late dual-task scores. Possible explanations for the results are given. (Author)

523. LINTERN, Gavan, "Transfer of Landing Skill after Training with Supplementary Visual Cues," Human Factors, v. 22(1): p. 81-88, February 1980.

An aircraft simulator, with a closed-loop computer-generated visual display, was used to teach flight-naive subjects to land. A control training condition in which subjects learned to land with reference to a skeletal airport scene consisting of a horizon, runway, centerline, and aiming bar was tested against training with constantly augmented feedback, adaptively augmented feedback, and a flightpath tracking display. A simulator-to-simulator, transfer-of-training design showed that adaptively trained subjects performed best in a transfer task that was identical to the control group's training condition. Several subjects attempted six landings in a light airplane after they had completed their experimental work in the simulator. They performed better than another group of subjects that had not had any landing practice in the simulator. (Author)

524. GREER, George D. Jr., Smith, Wayne D., and Hatfield, Jimmy L., Improving Flight Proficiency Evaluation in Army Helicopter Pilot Training, Human Resources Research Office, Ft. Rucker, AL, Contract No. DA 44-188-ARO-2, sponsored by Department of the Army, Washington, DC, HumRRO TEchnical Report 77, May 1962, 47 pp., AD 276115.

Improvement in the efficiency of the Army's primary helicopter training program depends to a large degree on the reliability of flight training evaluation. The traditional flight check has consisted of an evaluation of the flight by the check pilot not on the basis of a uniform series of maneuvers and measures, but on the basis of his personal specifications. It seemed probable that the unreliability of the traditional method of evaluation, which had been repeatedly demonstrated, was due primarily to this lack of standardization. This study was initiated to develop a more reliable system of evaluating helicopter pilots' flight performance, by emphasizing standardized and objective measures which also provide a diagnostic record of student performance.

Training grades and check flight grades were analyzed for Army helicopter pilots at both the U.S. Army Aviation School (USAAVNS), Fort Rucker, Ala., in 1956-57 and at the U.S. Army Primary Helicopter School (USAPHS), Camp Wolters, Tex., in 1957. In general, the relationships between the training grades and the corresponding test grades proved to be little better than zero. In another analysis, it was found that ratings of students' flight performance reflected the standards of evaluation applied by individual check pilots more than they did the students' flying skill.

The first step in the development of a more effective method of flight evaluation was an analysis of the light helicopter training program content into fundamental training maneuvers and maneuver components. Simple scales of several types were developed for use by the check pilot in recording the students' performance on each of these components. Where it was possible, direct instrument observations were recorded. However, many evaluations are necessarily based on individual judgment, to a lesser or greater degree; where judgments were required, the performance being evaluated was defined as specifically as possible at each point on the scale in order to narrow the range of personal interpretation in assigning ratings.

The next step was the development of a format for an Intermediate and an Advanced Pilot Performance Description Record (PPDR). Each PPDR was based on a standard ride, that is, the same maneuvers flown in the same sequence. The scales included as PPDR items were those judged to be most critical to successful performance in each maneuver. The number of scales that an expert check pilot could safely observe and record during a check ride was used as the basis for setting the total number of PPDR items (most items were recorded as the operation was being accomplished, but on operations that are considered hazardous, recording was delayed until completion of the dangerous portion).

The PPDR's were then tested by administering check rides to 40 Intermediate and 35 Advanced students at the Primary Helicopter School (Camp Wolters) in 1957. Each student was administered one ride by a LIFT research staff pilot and one ride by a military check pilot assigned to USAPHS.

The PPDR's were revised on the basis of experience in the first administration, and the revised PPDR's were evaluated in 1958. Check pilots were given one week of training in the use of the PPDR system, with emphasis placed on identification and reduction of check pilot differences in scoring standards. Two successive rides, each with a different USAPHS check pilots, were given to 50 Intermediate and 50 Advanced students.

Several approaches to summarizing the data on student performance which the PPDR check rides provided were explored. One was simply to total the number of errors recorded on the PPDR in a check flight. A second weighted items according to difficulty. In another approach ("error pattern-weighted") the pilot rated the student's over-all performance on a maneuver segment, taking into consideration not only errors but their sequence and combination; these segment ratings were weighted according to difficulty and importance of the maneuver. Finally, the check pilot assigned an over-all judgmental rating, based upon a review of the detailed PPDR record of the student's performance, and comparable to the "traditional" score.

It was concluded that: (1) The PPDR flight evaluation system can provide an evaluation of helicopter students' flight performance that is at an acceptable level of reliability. The resulting diagnostic data provide the basis for determining flight deficiencies of individual students and for maintaining uniform standards for both instruction and evaluation, (2) To maximize the effectiveness of the PPDR system, it is necessary that personnel serving as check pilots be trained in the concepts, objectives, and techniques of the system, and in administering and scoring the PPDR's. (Modified author).

525. GREER, George D. Jr., Smith, Wayne D., Hatfield, Jimmy L., Colgan, Carroll M., and Duffy, John O., PPDR Handbook. Use of Pilot Performance Description Record in Flight Training Quality Control, Human Resources Research Office, Ft. Rucker, AL, Contract No. DA 44-188-ARO-2, sponsored by the Department of the Army, Washington, DC 20310, December 1963, 58 pp., AD 675337.

The purpose of this handbook is to provide a method of describing and evaluating helicopter student pilot performance that is more reliable and yields more complete descriptions of the student's performance than does the traditional system, and to provide a program for instructing appropriate personnel in its use.

The device for measuring student proficiency - the Pilot Performance Description Record (PPDR) - described in this handbook, does not overcome all the difficulties encountered in flight training evaluation. It has, however, when properly utilized, been shown to be capable of effecting a substantial improvement over the traditional method.

Research data clearly show that the traditional methods of evaluating flying proficiency are too general and have resulted in the loss of much descriptive information. This finding has been shown to be generally true of flight proficiency evaluation methods in Air Force, civilian, and Army flight training programs. This is not to say that the Army's program or the other flight training methods have failed to produce satisfactory aviators. However, in the interests of obtaining more effective training per dollar spent, these shortcomings in flying proficiency evaluation deserve attention. Utilization of the evaluation system described herein has proved effective at the U.S. Army Primary Helicopter School (USAPHS), Fort Wolters, Tex., and has provided the basis for a training quality control program at that School. Adoption of this system can be expected to result in more efficient evaluation and also to provide a basis for objective detail about student performance and quality. (Author)

526. LOCKE, Edwin A., Zavala, Albert, and Fleishman, Edwin A., "Studies of Helicopter Pilot Performance: II. The Analysis of Task Dimensions," Human Factors, v. 7(3): p. 285-301, June 1965.

Measures of helicopter pilot proficiency were obtained on several hundred student pilots in the Primary and Basic training phases. Measures were based on students' performance on 75 and 76 tasks (items) for the Primary and Basic phases, respectively. Intercorrelations of tasks in each phase were subjected to factor analysis. The 12 factor rotation solutions were presented in detail for each phase, and the 18 and 24 factor rotations solutions were described briefly. In almost all cases the same tasks (e.g., RPM: Altitude) tended to cluster together across different maneuvers. The factors are interpreted in terms of the operations performed for each task, and the theoretical and practical implications of the findings are discussed. (Author)

527. ZAVALA, Albert, Locke, Edwin A., Van Cott, Harold P., and Fleishman, Edwin A., "Studies of Helicopter Pilot Performance: I. The Analysis of Maneuver Dimensions," Human Factors, v. 7(3): p. 273-283, June 1965.

Measures of helicopter pilot proficiency were obtained on samples of student pilots in two training phases. Measures were based on students' performance on 16 and 12 separate maneuvers in the Primary and Basic training phases respectively. Intercorrelations of maneuvers in each phase were subjected to factor analysis. In both phases maneuver performance could be described in terms of six or seven clearly interpretable common factors. The results were discussed in terms of the implications for understanding the structure and measurement of skilled psychomotor performance. (Author)

528. CARO, Paul W., Transfer of Instrument Training and the Synthetic Flight Training System, Human Resourcees Research Organization (HumRRO), Alexandria, VA 22314, Contract No. DAHC 19-70-C-0012, sponsored by Office of Chief of Research and Development (Army), Washington, DC 20310, HumRRO-PP-7-72, March 1972, 10 pp., AD 743155.

One phase of an innovative flight training program, its development, and initial administration is described in this paper. The operational suitability test activities related to a determination of the transfer of instrument training value of the Army's Synthetic Flight Training System (SFTS) Device 2B24. Sixteen active Army members of an Officer Rotary Wing Aviator Course who had completed primary training and 9 Instructor Pilots participated in the study.

Instrument training was conducted in the SFTS on a proficiency basis. Aircraft checkrides were administered by independent evaluator personnel. Checkride times and grades showed that much of the training now conducted in aircraft could be conducted more efficiently on the ground. (Author)

529. WEITZMAN, Donald O., Fineberg, Michael L., and Compton, George L., Evaluation of a Flight Simulator (Device 2B24) for Maintaining Instrument Proficiency Among Instrument--rated Army Pilots, U.S. Army Research Institute for the Behavioral and Social Sciences, Alexandria, VA 22333, Technical Paper 298, July 1978, 30 pp., AD A060557. See also Human Factors, v. 21(6): p. 701-710, December 1979.

The research aims to evaluate the operational suitability of Device 2B24, which simulates the UH-1H helicopter, for facilitating UH-1H instrument proficiency training and proficiency assessment among instrument rated pilots. The present data indicate that substantial amounts of UH-1H time can be substituted by Device 2B24 time in instrument proficiency training and proficiency assessment. With simulators, the Army has the opportunity to establish an instrument training program that can maintain and assess instrument proficiency year round and at a reasonable cost. A reasonable conclusion from this study is that a realistic instrument training program that includes simulator training would reduce accidents and enhance combat readiness among instrument rated pilots. (Author)

530. NORTH, Robert A., and Gopher, Daniel, "Measures of Attention as Predictors of Flight Performance," Human Factors, v. 18(1): p. 1-14, February 1976.

A new technique for measuring individual differences in basic attention capabilities and the validity of these differences in predicting success in flight training were investigated. The testing system included a digit-processing, reaction-time task and a one-dimensional compensatory tracking task. Comparisons were made between separate and concurrent performances of these tasks, with both equal and shifting task priorities. Adaptive techniques were employed to obtain maximum performance levels for each subject in the single-task condition and to maintain dual-task difficulty within subjects. Consistent individual differences in basic attention capabilities were observed and several dimensions of attention capabilities are suggested. A preliminary validation study compared scores for flight instructors asnd student pilots. In addition, the student sample was dichotomized based on performance in training. There were reliable differences for both groups on dual-task performance efficiency. (Author)

600. ERICKSEN, Stanford C., A Review of the Literature on Methods of Measuring Pilot Proficiency, American Institute for Research, Pittsburgh, PA, Contract No. AF 33(038)-23183, sponsored by Human Resources Research Center, Lackland AFB, San Antonio, TX, Research Bulletin 52-25, August 1952, 24 pp., ATI No. 169181.

An increasingly large number of research problems directed at improving methods of pilot selection and training are becoming more and more severely bottlenecked by the fundamental need for improved methods of measuring pilot proficiency. The review of the literature, which follows, represents a general summary of the research contributions which should be recognized when dealing with problems of proficiency measurement at different levels of flying training or in specialized pilot tasks.

While the making of an historical review is an almost automatic procedure for the careful research worker, it is equally important to survey the contemporary contributions of colleagues working in offices and laboratories more distant than the end of the hall. There really are no simple psychological research problems, and, in the maturing structure of aviation psychology, one must be doubly sensitive to whatever evidence and guiding principles are being made available in the current scene.

No guarantee is made for providing coverage of all relevant research projects. The bibliography includes many items not referred to in the body of the report. How many additional items might have been included cannot be said since no central agency was located which could provide bibliographic reference to the many studies and reports not presented in professional journals, published military reports, and other accessible sources. The bibliographic search was ended as of 31 December 1951. (Author) Includes 53 references.

601. SMODE, Alfred F., Gruber, Alin, and Ely, Jerome H., The Measurement of Advanced Flight Vehicle Crew Proficiency in Synthetic Ground Environments, Dunlap and Associates, Stamford, CN, sponsored by 6570th Aerospace Medical Research Laboratories, Wright-Patterson AFB, OH, MRL-TDR-62-2, February 1962, 121 pp., AD 27

This report is devoted to the presentation and discussion of major considerations in the design of systems for measuring the proficiency of advanced flight vehicle crews in synthetic ground environments. Emphasis is given throughout to the logic of proficiency measurement and the general problems involved rather than to the analysis of specific details. Successive portions of the report deal with general measurement concepts, procedures and steps in designing measurement systems, an example application of the material presented, and the anticipated characteristics of advanced flight vehicle simulation equipment related to proficiency measurement. In addition, a historical overview of aircrew proficiency measurement emphasizing early work and a list of study references on rating methods are appended. As it provides a considerable background of information on proficiency measurement, this report will be of interest to individuals directly concerned with simulator training programs, proficiency evaluation and standardization, training standards, and training equipment procurement for advanced flight systems. (Author)

602. BUCKHOUT, Robert, A Bibliography on Aircrew Proficiency Measurement, Aerospace Medical Division, Wright-Patterson AFB, OH, MRL-TDR-62-49, May 1962, 25 pp., 234 references, AD 283545.

This bibliography addresses the problem of assessing the level of proficiency of Air Force personnel in performing their jobs as combat aircrew members. This report supports research on the potential value of using the electronic flight simulator as an aircrew personnel testing and measurement tool. Present aircrew proficiency measurement programs make limited use of the flight simulator, since it is usually possible to evaluate performance in flight. However, there is a growing realization that the hazards and high costs of operating future weapon systems may curb, if not eliminate, the use of special flights solely for the purpose of training and proficiency measurement. Thus, ground-based simulators will probably have an added requirement to produce detailed, reliable, and valid indices of proficiency, upon which predictions of subsequent performance in aerospace flight can be made.

The 234 reports are organized in six sections. Section I (First Order Measurement) deals with research on measuring proficiency on single task elements, behavioral components, and isolated job segments. Reports of proficiency measurement of more inclusive job segments, total job performance, and the combining and weighting of scores are presented in Section II (Combination Measures). In Section III (Validation) reports on the reliability and validity of various proficiency measurement techniques and criterion measures are compiled. In Section IV (Measurement Equipment) reports on some of the equipment and techniques involved in testing, recording, and scoring human performance in the context of flight are listed. Literature surveys, summaries of World War II proficiency evluation programs, theoretical papers, and general reports on the measurement problem are compiled in Section V (General Analyses and Reviews). Finally, in Section VI (Background Reports) reports providing background information on psychomotor performance and on transfer of training are included. (Modified author).

603. KRENDEL, Ezra S., and Bloom, Joel W., The Natural Pilot Model for Flight Proficiency Evaluation, Franklin Institute, Philadelphia, PA, Contract No. N61339-323, sponsored by U.S. Naval Training Device Center, Port Washington, NY, NAVTRADEVCEN 323-1, April 1963, 70 pp., AD 410805.

This report presents the development and rationale for a new approach to pilot proficiency measurement in operational flight trainers. It is based on a "natural pilot model" that identifies three criteria as being of prime importance to the understanding and measurement of pilot performance: consistency of system performance, human adaptability, and least effort in skilled performance. By means of these criteria - which arose from an effort to apply the servomechanism theory of skilled performance to the study of pilot proficiency - the investigators believe that the traditional impediments to valid measurement will be removed; and that the characteristics that most crucially differentiate the good from the poor pilot will be measured. Ways of quantifying these criteria and the implications to training and further research are discussed. (Author)

604. McCOY, William K. Jr., "Problems of Validity of Measures Used in Investigating Man-Machine Systems," Human Factors, v. 5(4): p. 373-377, August 1963.

The human engineer, in his role as consultant to system design teams, is confronted with problems of measuring system performance in such a way that various elements of the system can be evaluated. The validity of such measurement techniques is often questioned but little data concerning the validation of such measurement techniques is available.

Analysis of the problems involved in validating measures used in investigating man-machine systems suggest that the concepts of validity as adhered to in modern psychology might not be adequate for use by a human engineer confronted with a system in its development stage. The general approach to system evaluation and the concepts of validity are discussed in terms of the problems involved in determining the validity of measurement schemes commonly used in investigating the properties of a man-machine system. (Author)

605. Groth, Hilde, and Lyman, John, "Measurement Methodology for Perceptual-Motor Performance under Highly Transient Extreme Heat Stress," Human Factors, v. 5(4): p. 391-401, August 1963.

The existing state of the art for handling human performance under transient heat stress has been reviewed. It was concluded that it is necessary to develop a new methodology based on "micro-performance" measurements to assess severe localized transient heat stresses relevant to contemporary flight problems.

The test procedure proposed is based on the rationale that a primary task, with difficulty that can be varied according to subject error in order to maintain a relatively constant subject performance level, can be used as a measure of the moment-to-moment perceptual load. In addition to the primary task, secondary tasks are suggested to help simulate problems in decision-making and verbal communication. (Author)

606. UHLANER, J.E., and Drucker, A.J., "Criteria for Human Performance Research," Human Factors, v. 6(3): p. 265-278, June 1964.

The heart of human factors performance research is the development of an appropriate criterion or effectiveness measure. Typical criteria employed in research from 1941 to 1963 by the U.S. Army Personnel Research Office have included grades, ratings, and situational performance measures, each selected for use according to critical methodological, operational, and administrative considerations. Emphasis is placed upon predicting individual effectiveness.

Today's military manager desires an evaluation of a system or subsystem as a totality and is likely to give more wholehearted acceptance to that research product expressed in quantitative units reflecting his goals and mission. Examples are given of the roles human factors scientists play today in helping develop the systems output criterion, similar to human factors performannce criteria in some respects but which requires more attention to the need for simulation and to decisions with respect to laboratory vs. field experimentation. A framework of human factors oriented systems research is presented. (Author)

607. OBERMAYER, R.W., and Muckler, F.A., Performance Measurement in Flight Simulation Studies, Martin Company, Baltimore, MD, Contract No. NASw-718, sponsored by National Aeronautics and Space Administration, Washington, DC, NASA CR-82, July 1964, 19 pp.

An analysis of guidance and control performance measurements was made for five basic types of flight simulations studies: feasibility demonstrations; subsystem comparisons; studies of quantitative models of man-machine performance; handling qualities investigations; and, full-mission and total-system performance evaluations. Six studies illustrate the variety of possible measurement approaches which can be taken. General measurement criteria are derived from the evaluation considerations for any manned guidance and control system: stability; response; reliability; adaptability; and, acceptability. The selection of specific measures and some basic measurement problems were discussed. (Author)

608. PICKREL, E.W., and McDonald, T.A., "Quantification of Human Performance in Large, Complex Systems," Human Factors, v. 6(6): p. 647-662, December 1964.

A method for the identification of human-induced equipment failures in complex systems is presented. This method requires a description of the tasks to be performed, the determination that the tasks can be performed in the time available and finally a specification of task criticality. The probability of error occurrence and estimation of the effect of potential errors are also major parts of the analysis. Efforts for further reduction are concentrated on errors most likely to occur and to affect the system negatively. (Author)

609. RABIDEAU, Gerald F., "Field Measurement of Human Performance in Man-Machine Systems," Human Factors, V. 6(6): p. 663-672, December 1964.

Field evaluation of human performance is rapidly assuming a role of major importance in system measurement. However, the special conditions under which such ecological tests must be performed impose certain limitations upon the evaluator which must be recognized. These limitations involve restrictions on the opportunity to manipulate variables, which lead to greater use of subjectively oriented data collections tools: e.g. the human observer, the interview and checklists. Factors to be considered in the planning of a field test are discussed. (Author)

610. WARE, Claude T. Jr., "Individual and Situational Variables Affecting Human Performance," Human Factors, v. 6(6): p. 673-674, December 1964.

The purpose of this article was to examine present methods for the measurement and prediction of operator performance. A very rough distinction can be made between two types of variables affecting human performance: individual and situational. Individual variables describe such parameters as age, sex, skill level and personality. Situational variables describe task characteristics, system organization, test characteristics, physical environment etc. Certain variables are intermediate between individual and situational since they are produced by situational factors but given expression through individual responses. Thus, morale as a condition of the test environment tending to produce better or worse performance is a situational variable; while motivation (as reflected in individual attitudes etc.) is an individual one.

Both sets of variables mediate human performance (i.e. they act as intervening variables), but they do not directly control it. For that reason one cannot expect to find a linear relationship between any one variable and the performance of a particular task. In addition, any two or more of these variables may have an interactive effect on task performance (i.e. where one of them alone may be insufficient, one can enhance the influence of the other to produce a significant effect). The action of these variables may be to increase or decrease the probability of successful performance, depending on specific values given these variables. All of this complicates the task of measurement and prediction of human performance.

This paper is a plea that the theory and method of performance quantification should involve consideration of these variables, or at least the most *a priori* promising of them. The first task in insuring such consideration is for researchers in human performance to specify in detail the characteristics of their test situations, particularly as they influence the subject, so that pertinent variables can be identified from these descriptions. Researchers can then indicate the nature of the individual and situational factors they utilize in their test situations. If this were done, it might be possible to place the variables in any one test situation on some sort of continuum and to at least scale their relative effect on performance. Until some concerted effort is made to include these variables systematically in performance testing, our efforts at performance quantification will be seriously lacking. (Author)

611. SWAIN, Alan D., "Some Problems in the Measurement of Human Performance in Man-Machine Systems," Human Factors, v. 6(6): p. 687-700, December 1964.

Quantification of human performance in man-machine systems is receiving more and more attention in human factors work. Obstacles to such quantification include: (1) complexity and subjectivity of available quantification methods, (2) grossness of assumptions behind these methods, and (3) resistance of some psychologists. Research is needed (1) to develop an improved human performance data bank, (2) to develop improved models and methods, and (3) to validate quantification data, models and methods. Some research is being done in these areas. (Author)

612. BOWEN, Hugh M., Bishop, Edward W., Promisel, David, and Robins, James E., Study, Assessment of Pilot Proficiency, Dunlap and Associates, Inc., Darien, CT, Contract No. N61339-1614, sponsored by U.S. Naval Training Device Center, Port Washington, NY, NAVTRADEVCEN 1614-1, August 1966, 128 pp., AD 637659.

This project studied the role of the Operational Flight Trainer (OFT) in a navy squadron teaching qualified pilots to fly A4 aircraft prior to joining fleet operations. The principal objective was to determine appropriate objective scoring devices and associated procedures that can be used in future OFTs to enhance the training experience of student pilots and to afford a reliable basis for assessing pilot proficiency.

Two classes of ten men each were studied. The data analyzed included previous history as a pilot, squadron scores, a variety of OFT measures, and measures of proficiency in landing an aircraft during FMLP (Field Mirror Landing Practice) and CARQUAL (Carrier Qualification). During the study of EFT training, one class was subjected to an intense regimen of augmented feedback (derived from a prototype group of objective scoring devices), while the other class received essentially customary training.

The chief conclusions of the study are: (1) augmented feedback in the form of objective scores tends to heighten performance; (2) OFT scores of proper sequencing of procedures, control of aircraft to prescribed settings, and response time to unexpected situations are independent measures of pilot skill; (3) these scores are predictive of proficiency at landing the aircraft and indicate that OFT performance can provide valid pilot proficiency assessment data; however, the predictive relationship from measured OFT performance to actual flight is not simple and seems to depend upon there being an adequate correspondence between the requirements imposed on the student in the OFT and in the air; (4) and it is, therefore, inferred from this study that it is important for the student in the OFT to experience the plurality of events that can occur in real flight missions. Scores extracted during performance of such missions, or mission segments, will indicate the degree to which the student has acquired the necessary skills and the ability to deploy them effectively and appropriately against actual flight requirements.

Recommendations are made for scoring devices and procedures to be used with future OFTs, and it is suggested that effective use of the trainers depends upon their credibility in the eyes of the user. For this purpose, the ingredients which serve the end of user acceptance should be examined. (Author)

613. GRODSKY, Milton A., "The Use of Full Scale Mission Simulation for the Assessment of Complex Operator Performance," Human Factors, v. 9(4): p. 341-348, August 1967.

This report describes the use of full-scale high fidelity simulation as a technique for the evaluation of the performance of the human operator in an aerospace vehicle context. The specific implementation of this approach used an Apollo simulation with highly trained aerospace research pilots as subjects. The major advantages of the approach are considered to derive from the relative ease with which generalizations can be made from the research vehicle to the vehicle being simulated. The ultimate criterion, in-flight validation, is not as yet attainable, but the prediction is made that this approach would be fully supported by the outcome of such an evaluation. A requirement exists for the examination of this approach in relation to more commonly employed laboratory situations and tasks so that a tie in with such research can be established. (Author)

614. FLEISHMAN, Edwin A., "Performance Assessment Based on an Empirically Derived Taxonomy," Human Factors, v. 9(4): p. 349-366, August 1967.

This report reviews and discusses a number of the methodological questions relating to the application of an experimental-correlational approach to the problem of assessing complex performance. The basic point of departure is the specification of the requirements for a task taxonomy and an analysis of the value of factor analytic investigations in combination with experimental methods in providing the framework for such a taxonomy. The way in which this approach has been applied in the past and the expected benefits of its successful implementation are discussed. It is concluded that experimental-correlational studies offer considerable promise in attacking complex performance but that a more extensive research program is needed. The general outlines of such a program is described. (Author)

615. PARKER, James F. Jr., "The Identification of Performanace Dimensions Through Factor Analysis," Human Factors, v. 9(4): p. 367-373, August 1967.

The problems encountered in trying to relate factor-analytically derived performance measures to real world, complex work situations are described. A particular implementation of this approach to the problem of assessing the performance capabilities of the on-orbit astronaut is described in relation to the task demands of the predicted space vehicle performance requirements. The general approach as outlined here is restricted to the measurement of perceptual motor functions of the sort traditionally looked at by factor analysis in relation to the ability requirements of aircraft operators. Relatively mild stressors - sleep loss and heat - have not resulted in significant alterations of performance on these tasks. (Author)

616. ALLUISI, Earl A., "Methodology in the Use of Synthetic Tasks to Assess Complex Performance," Human Factors, v. 9(4): p. 375-384, August 1967.

The application of synthetic tasks to the assessment of complex performance is discussed in relation to the trade-offs involved in achieving adequate levels of face validity and in specifying the exact changes in psychological functions that may result from particular environmental manipulations. It is argued that the multiple-task performance battery approach can provide levels of face validity adequate to maintain the motivation of subjects while at the same time permitting the identification of changes in specific performance functions. The characteristics of this approach are discussed in relation to a program of research on the effects of confinement and demanding work-rest schedules on crew performance. (Author)

617. BILLINGS, Charles E., "Studies of Pilot Performance: I. Theoretical Considerations," Aerospace Medicine, v. 39: p. 17-19, January 1968.

This report describes criteria established by the investigators for the evaluation of methods and techniques of performance assessment in the flight environment. It appears on the basis of previous studies and our own research that the following are desirable criteria for such performance measures.

Objectivity: The ideal measure of performance is one which does not involve a human observer at any point.

Quantitation: Acceptable performance measures must yield quantitative data, since it is clear that performance can vary quantitatively within the range of safe operation of an airplane.

Relevance: A useful measure of performance should reflect accurately the real and important tasks the pilot must perform in the course of a mission.

Safety: No acceptable performanc assessment method should require unsafe actions of the pilot, nor should it require undue attention on the part of an observer or safety pilot.

Additional criteria include broad applicability of the techniques across missions and specific aircraft types. It is also believed that acceptable measurement techniques should be passive with respect to the pilot being studied: ideally, they should require neither the pilot's cooperation nor even knowledge that he is under study. (Author)

618. KELLEY, Charles R., "The Measurement of Tracking Proficiency," Human Factors, v. 11(1): p. 43-64, February 1969.

The problem of measuring tracking proficiency is reviewed and analyzed. The five classes of measurements discussed are:

(1) single-axis error amplitude scores;
(2) multi-axis error amplitude scores;
(3) simple frequency scores; control effort;
(4) special engineering measurement techniques
(5) adaptive tracking measurements.

The most widely used score in psychological investigations, time on target, is shown not to be an interval measurement of tracking error amplitude and, in addition, is shown to be unreliable. Seventeen equations for the measurement of tracking skill are described. Adaptive tracking measurement techniques are shown to be more effective than are techniques employing fixed-difficulty tasks. (Author)

619. STEYN, D.W., "The Criterion - Stagnation or Development? A Selective Review of Published Research Work on Criterion Problems," Psychologia Africana, v. 12(3): p. 193-211, March 1969.

A few definitions of the criterion are furnished and the absence of a conceptual framework in criterion studies is pointed out.

Various methods of assessing one-the-job performance are discussed with special emphasis on reliability. Ratings and the problems connected with them are given consideration.

The dimensional aspect of the criterion is re-emphasized and the dynamic character of the criterion is pointed out.

A few avenues for further exploration are indicated and a specific approach to the criterion is recommended. Includes 113 references. (Author)

620. ISLEY, Robert N., and Caro, Paul W., Jr., "Use of Time-Lapse Photography in Flight Performance Evaluation," Journal of Applied Psychology, v. 54(1): p. 72-76, January 1970.

A time-lapse photographic technique for recording and scoring the inflight performance of helicopter aviator trainees during a hypothetical tactical instrument mission is described. Data were derived from 16-mm. films of the instrument panel readings of the TH-13T helicopter. Advantages, disadvantages, and other possible applications of the film technique are also discussed. (Author)

621. MATHENY, W.G., Patterson, G.W. Jr., and Evans, G.I., Human Factors in Field Testing, Life Sciences, Inc., Fort Worth, TX 76118, Contract No. N00014-67-C-0315-P002, sponsored by Office of Naval Research, Washington, DC, LS-ASR-70-1, May 1970, 61 pp., AD 716438.

The objective of this study is to develop methods and techniques for evaluating operator performance during field testing of Navy systems.

The procedure adopted has been to develop and test the evaluation techniques using a particular Navy system. After examination of various sytems the pilot station of the P-C3 Anti-Submarine Warfare (ASW) aircraft system was selected for use in development and trial.

A detailed description of the information flow through the operator is basic to the development of human factors evaluation measures. The field evaluator must have such a descriptive technique in his repertoire to update prior descriptions or generate his own. The Mission Time Line Analysis (MTLA) has been used and evaluated in this study with a bar chart time related format.

From the MTLA evaluative judgments regarding workload per block of mission time, task concurrency and delayed or indeterminate feedback can be made. The MTLA also provides the basis for measurements of errors in carrying out task sequences and procedures. An important use of the MTLA is in identification of measurement points within the system at which human operator performance may be reliably and practically assessed.

Due to the importance of the Tactical Coordinator (TACCO) crew position in the system and the information handling type of task involved it was concluded and recommended that this position be analyzed and used in the development of evaluative procedures. In carrying out this development it is recommended that the Weapons System Trainer which provides a quite complete simulation of the tasks of the TACCO be used and evaluated as a test and evaluation tool in which error data may be collected under systematically varied and controlled conditions. It is also concluded that inflight data be obtained during Board of Inspection and Survey (BIS) trials and Operational Evaluation (OPEVAL) flights to validate the evaluative judgments drawn from the MTLA and the Weapon System Trainer trials. (Author)

622. CHRISTIANSEN, Julien M., and Mills, Robert G., "What Does the Operator Do in Complex Systems," Human Factors, v. 9(4): p. 329-340, August 1970.

An effort was made to locate representative data on human activities in complex operational systems. Very little operational data were found which were suitable for our purposes. Therefore, this requirement was compromised and activity data from tests and paper and pencil analyses were used. These data were then classified by two raters according to an adopted taxonomy. It was generally concluded that where activity data have been gathered under operational conditions, they have been useful to design engineers, human factors specialists and systems analysts. It is further noted, however, that additional effort must be devoted to the development of better methods for obtaining data and corresponding criteria of human performance under operational conditions. A discussion of the taxonomy and other techniques indicated that collection of activity data should be feasible under operational conditions. In addition it is suggested that increased standardization and use of operational definition in the development of these techniques might result in improvement of their general applicability. (Author)

623. PROPHET, Wallace W., Performance Measurement in Helicopter Training and Operations, Human Resources Research Organization, Alexandria, VA 22314, Contract No. DAHC 19-70-C-0012, sponsored by Office of Chief of Research and Development (Army), Washington, DC 20310, HumRRO-PP-10-72, April 1972, 15 pp., AD 743157.

For almost 15 years, HumRRo Division No. 6 has conducted an active research program on techniques for measuring the flight performance of helicopter trainees and pilots. This program addressed both the elemental aspects of flying (i.e., maneuvers) and the mission- or goal-oriented aspects. A variety of approaches has been investigated, with the stress on nonautomated techniques feasible for operational use. This paper describes the work and illustrates its application to and implications for training management, quality control, manpower resources management, and operational capability. Automated human performance monitoring in flight simulators and its implications for automated training is also described. (Author)

624. BAUM, David R., Smith, James F., and Goebel, Ronald A., Selection and Analysis of UPT Maneuvers for Automated Proficiency Measurement Development, Air Force Human Resources Laboratory, Williams AFB, AZ 85224, AFHRL-TR-72-62, July 1953, 56 pp., AD 767580.

A program exists within the Air Force Human Resources Laboratory to develop techniques for automated assessment of pilot performance. To insure that quantitative assessment capabilities are available for the evaluation of the Advanced Simulator for Undergraduate Pilot Training (ASUPT) and to make efficient use of existing resources, measurement development is being limited initially to six aircraft maneuvers. These are (a) Lazy 8, (b) Barrel Roll, (c) Normal Pattern and Landing, (d) Cloverleaf, (3) Normal Spin, and (f) Split-S. The rationale for selection of these particular maneuvers is discussed in the first part of this report. Subsequent to selection, extensive maneuver analyses were performed. The analysis format was chosen specifically for the purpose of supporting automated proficiency measurement development. The categories of information which constitute the analyses are described and the proceedures whereby the information was obtained are detailed. (Author).

625. FARRELL, John P., Measurement Criteria in the Assessment of Helicopter Pilot Performance, Proceedings of a Conference on Aircrew Performance in Army Aviation held at U.S. Army Aviation Center, Fort Rucker, Alabama on November 27-29, 1973, Office of the Chief of Research, Development and Acquisition (Army) and U.S. Army Research Institute for the Behavioral and Social Sciences, Arlington, VA 22209, July 1974, p. 141-148, AD A001539.

The purpose of this paper is to describe the factors to be considered in selecting a method for measuring pilot flight performance, especially in regards to nap-of-the earth (NOE) flight. To illustrate some of the relevant considerations, the pilot performaance NOE research currently being performed by ARI at Fort Rucker, Alabama is described. This field experimentation is designed to provide parametric information on pilot performance at NOE and also to test the effects of certain variables on NOE performance. This paper deals with the necessary aspects of performance criteria and assessment. (Author)

626. VREULS, Donald, and Obermayer, Richard W., Selection and Development of Automated Performance Measurement, Proceedings of a Conference on Aircrew Performance in Army Aviation held at U.S. Army Aviation Center, Fort Rucker, Alabama on November 27-29, 1973, Office of the Chief of Research, Development and Acquisition (Army) and U.S. Army Research Institute for the Behavioral and Social Sciences, Arlington, VA 22209, July 1974, p. 168-174, AD A001539.

Performance measurement produces information needed for a specific purpose, such as the evaluation of aircrew performance or the conduct of aircrew training. Performance measurement is therefore vital to improved evaluation or improved training. Aircrew performance measurement involves the processing of large quantities of continuously varying information; consequently such measurement is beyond the capabilities of manual processes and simple measurement devices, and thus must be automated.

Automation, however, places certain demands on succinct definition of measurement and the specific conditions during which measurement takes place. Historically, the problem of defining a sufficient and useful set of measures for human performance assessment has been a major technical challenge. The process of measurement definition may be analytic, empirical, or some combination of analytic and empirical approaches.

One may attempt to define measures analytically, using examples from the literature along with common task analytic techniques. The skills involved in performance can be identified and described as well as analytically possible, leading to measurement when used to compare performance to prior criteria. Specific task and mission objectives can be identified, again leading to measurement but at a man-machine system performance level. Obviously, analytic definition of measurement is a mandatory step in developing measurement.

When analytical means are exhausted, the measurement remaining is likely to be overabundant, unwieldy, and perhaps impossible to completely implement in an operational setting. The large quantities of measurement thus produced for each important part of flight missions are likely to include (1) alternative forms of measurement (e.g., different ways to measure the same behavior), and (2) measurement of behavior and system performance which may prove to be relatively unimportant during later utilization. Furthermore, there have been several studies which have emphasized that analytic methods alone fail to satisfactorily define measurement.

It seems necessary, therefore, to seek other sources of information for further reduction and improvement of analytically defined candidate measures. The approach adoped herein is to implement the candidate measurement in a trial fashion, collect empirical data with human subjects in environments approximating the operational setting, and to exercise mathematical selection techniques.

The empirical approach requires the collection of sufficient quantities of data in order to produce an over-abundance of candidate measures from which further reduction is desired to produce a smaller, more efficient set. Computer techniques are mandatory. Therefore, flexible programs are needed to easily define a wide range of mathematical measurement relationships and to iterate as more information becomes available about ways to improve the measurement.

Much of the work upon which this paper is based was oriented to the use of measurement within automated adaptive training systems. Therefore, it was desired that the resultant measurement have the capability of discriminating between different levels of proficiency and the capability to predict later performance based on measures of current performance. Consequently, mathematical selection techniques may require some modification, when used with other problem areas, but it is believed that the measurement development process is generally applicable. (Modified author)

627. SPINDELL, William A., and Knirk, Frederick G., Baseline Performance Measurement for Human Performance Evaluation, Proceedings of the 18th Annual Meeting of the Human Factors Society, Huntsville, AL, October 1974, p. 429-432.

The problem of determining baselines for human performance measurement is neither peculiar to people concerned with military system performance nor to those associated with educational systems. It has traditionally been easier to compare performance of, for example, the experimental group to the control group or system "a" to system "b," than it has been to determine some base of performance characteristic of a group of people and then to measure the effect of change from there.

In education, the question of not only philosophical but very practical consequence is how do we know when someone is working at his level? Do attempts to standardize presentation methodology and time consider performer variations adequately? In engineering, the human factors specialist is also concerned with workload and overload in terms of system performance decrement. If the pilot of a high performance tactical fighter must perform a precise tracking task, and at the same time navigate and monitor his aircraft systems while subject to intense "g" loadings, and if he fails to do so, the concern is with the increment which resulted in this failure - i.e., which added duty or which increment of psychological or physiological stress was the last straw?

Baseline performance measurement is confounded by other problems as well. The largest of these is the tremendous reserve capacity for both continued performance and dramatic performance increase found among humans at all age and ability levels. This is clearly a motivational artifact because, when so motivated, people can program their activities in such a way as to have enormously increased capacities for work or cognition. The overloaded pilot, suddenly faced with a fire warning indication, in seconds becomes a far more sophisticated analog computer than anything he has on-board, rapidly relegating certain tasks to low priority (e.g., navigation or energy management) and others to the highest priority (e.g., fault isolation, logic assessment of spurious indications). The child in the classroom, plodding along at one moment, is, in the next moment, able to take on vast increases in information when his interest is sparked.

Over the years, techniques have developed in response to such engineering questions as: will control system "a" result in a greater workload than system "b"? These were typically performance based questions, since what was ultimately desired was some statement of how the above would influence mission performance. Similarly, educators have devised systems of measuring learner activity levels, but most dramatically, recent innovations in remote measurement of psychophysiological states perhaps may provide some breakthroughs. This paper will trace the development of baseline performance measurement techniques from human factors task loading studies to those of brain wave and physiological state measurements and offer several recommendations for further study. (Author)

628. DICKMAN, Joseph L., Automated Performance Measuring, Proceedings of the Seventh NTEC/Industry Conference Held on 19-21 November 1974, sponsored by Naval Training Equipment Center, Orlando, FL 32813, NAVTRAEQUIPCEN IH-240, November 1974, p. 87-95, AD A000970.

The purpose of this article was to describe automated performance measurement with specific applications to flight simulation.

There are several benefits from automation in the field of student evaluation. An obvious one is economy of personnel. The one-to-one ratio between instructors and students that is usually encountered in flight simulator training programs is luxurious by any standards.

Perhaps the greatest benefit from automation is its contribution to standardization. Automation substitutes accurate, objective, uniform measurement by a computer for -- all to often -- imprecise, subjective, erratic observations by a human instructor.

A well-written training exercise should have standards for every leg of the "hop"; the values to be measured and the allowable tolerances from prescribed standards can vary throughout the flight, but the computer can evaluate every aspect, from deviation from the runway heading on the takeoff roll to height above or below the glide path on the ILS approach for final landing.

The designer of scenarios for Automated Performance Measuring is primarily concerned with insuring that the important parameters of a maneuver, from a training viewpoint, are monitored.

Scenario design contains a number of pitfalls that the designer must continually watch out for. The first of these is premature advancing of the computer program. The basic cause for premature advancing is the pilot making an error and achieving an end condition at the wrong time. Another pitfall is failure to advance. A third pitfall is the charging of invalid errors, i.e., the computer believes the pilot is making a mistake when in fact he is not. Premature advancing and failure to advance will produce invalid errors, but there are other ways, through careless design, that they can be caused.

The future possibilities of Automated Performance Measuring, coupled with some form of adaptive training, are virtually unlimited. Complete do-it-yourself training is not inconceivable, especially for organizations without a substantial number of instructor pilots always available. Since at present there is a large number of trainers in operation without Automated Performance Measuring, it might be possible to design a relatively economical module that could be attached to these trainers to modernize their training capability without requiring an expensive modification to the trainer itself. Furthermore, the basic concepts of Automated Performance Measuring and adaptive training can be used in other than flight simulators; sonar trainers, ECM trainers, and radar intercept trainers are only a few of the possibilities. The fact is, any form of training in which success can be expressed in numerical values, such as miss distance, angular error, or correct versus incorrect procedures, is amenable to Automated Performance Measuring. (Modified author).

629. CONNELLY, Edward M., Bourne, Francis J., and Loental, Diane G., Computer-Aided Techniques for Providing Operator Performance Measures, Quest Research Corporation, McLean, VA 22101, Contract No. F33615-72-C-2094, sponsored by Air Force Human Resources Laboratory, Wright-Patterson AFB, OH 45433, AFHRL-TR-74-87, December 1974, 84 pp., AD A014330. See also Proceedings of the 18th Annual Meeting of the Human Factors Society, Huntsville, AL, October 1974, p. 359-367.

This report documents the theory, structure, and implementation of a performance measurement processor (written in FORTRAN IV) that can accept performance demonstration data representing various levels of operator's skill and, under user control, analyze data to provide candidate performance measures and validation test results. The processor accepts two types of information: (1) Sample performance data on magnetic tape, and (2) User information reflecting knowledge about features of the performance that are considered to be important to measurement. The sample performance data input is smoothed by the processor in order to remove or reduce noise factors in acordance with information provided by the user. Criterion performance functions are, optionally, provided by the user or are computed by the processor using skilled performers' data. The processor then develops a discrete representation of the continuous performance data based on observed deviations from the criterion functions. This discrete representation, in turn, is used to model each performance using state-space techniques. The processor operates on the state-space model to compute vectors which form generators of various conceivable measure spaces. Candidate performance measures are then generated by operating on the vectors with multiple regression algorithms. Empirical validation tests of several types are applied to the candidate measures for assessment of their validity-likelihood.

The processor can be applied to measurement problems where the human operator working with his equipment obtains demonstrations of various levels of performance. These potential applications include those situations where criterion performance cannot be quantitatively predefined and/or the existing definitions are ambiguous.

Demonstration of some portions of the processor was accomplished using limited flight demonstration data from an instrumented T-37B aircraft for five undergraduate pilot training (UPT) maneuvers: (1) Barrel Roll, (2) Lazy 8, (3) Cloverleaf, (4) Split S, and (5) Normal Landing. (Author)

630. CONNELLY, Edward M., Bourne, Francis J., Loental, Diane G., Migliaccio, Joseph S., Burchick, Duane A., and Knoop, Patricia A., Candidate T-37 Pilot Performance Measures for Five Contact Maneuvers, Quest Research Corporation, McLean, VA 22101, Contract No. F33615-72-C-2028, Air Force Human Resources Laboratory, Wright-Patterson AFB, OH 45433, AFHRL-TR-74-88, December 1974, 88 pp., AD A014331.

The objective of this program was to develop candidate pilot performance measures for five undergraduate pilot training (UPT) contact training maneuvers flown in the T-37B aircraft. The work included development and application of a method of analyzing operator performance tasks for purposes of identifying candidate measures. This resulted in sectoring of each T-37B maneuver into functional segments, wherein the dominant measurement variables are consistent, and task segments, wherein the relationships among the dominant measurement variables are consistent. Several types of measures were then defined which, collectively, satisfy measurement needs over all task segments. Specific candidate measurement formulae were developed for each segment in accordance with the analysis results. Computer programs (FORTRAN IV) were developed and implemented to: (1) smooth, printout, and plot data recorded on-board a T-37B aircraft; (2) automatically detect task segment boundaries; (3) compute criterion functions from skilled performer's data; (4) compute measures specified at run-time by the user; and (5) perform and print results of several empirical validation tests of the candidate measures for subsequent researcher analysis. (Author)

631. ALLUISI, Earl A., "Optimum Uses of Psychobiological, Sensorimotor, and Performance Measurement Strategies," Human Factors, v. 17(4): p. 309-320, August 1975.

The selection of a criterion, index, or output to measure, when an experiment is planned will influence not only the conduct of the study, but also the findings and the generalizations that can properly be made on the basis of the results. Guidelines for making such selections among psychobiological, sensorimotor, and performance measurement domains are presented, based on the summary findings of research in four areas: the behavioral effects of (1) occupational exposure to inorganic lead; (2) exposure to carbon monoxide; (3) sleep loss; and (4) infectious disease. Three dimensions that must be considered in order to optimize the selection are: (1) the purpose, immediate and distal, of the specific study; (2) the degree of specificity vs. generality of the organismic changes involved; and (3) the desired area(s) of generalization of the results or findings of the study. (Author)

632. HOPKINS, Charles O., Human Performance in Aviation Systems, University of Illinois, Savoy, IL 61874, Contract No. F44620-76-C-0009, sponsored by Air Force Office of Scientific Research, Bolling AFB, DC 20332, AFOSR-TR-78-0080, July 1977, 55 pp., AD A050078.

Activities and accomplishments are summarized for six research tasks involving various aspects of human performance in the operation of aviation systems. The program has produced information relevant both to the selection and training of pilots and the design of systems and operational procedures. (Author)

633. VREULS, Donald, and Wooldridge, Lee, Aircrew Performance Measurement, Proceedings of the Symposium on Productivity Enhancement: Personnel Assessment in Navy Systems, Naval Personnel Research and Development Center, San Diego, CA, October 1977, 38 pp.

Aircrew performance measurement is described in terms of the aircrew environment, an approach to measurement development and future research needs. A global view of the aircrew environment barely touches a few of the variables and considerations involved in the training process, the aircraft and weapon system environment and operational environment. One approach to measurement development is used to examine some of the considerations, progress and methodological issues in selected areas of analysis for measurement, measurement system design, date collection, measure selection techniques, and product and system effectiveness testing. Future research needs for more empirical data, better analytic methods, measurement standardization and personnel are highlighted. Aircrew performance measurement has come a long way in the past several years, but there is much more to do if we are going to be fully responsive to the needs. (Author)

634. SWEZEY, Robert W., "Aspects of Criterion-Referenced Measurement in Performance Evaluation," Human Factors, v. 20(2): p. 169-178, April 1978.

Four measurement models for use in performance evaluation (norm, criterion, domain, and objectives-referenced measurement) are presented and the contingent relationships among them are discussed. An argument is made for the use of criterion-referenced measurement in performance testing. Literature on two major problem areas in criterion-referenced measurement, reliability and validity, is briefly reviewed; and a recent example of criterion-referenced performance test development in an applied training context is described. (Author)

635. COTTON, John C., Airborne Performance Measurement Concepts, Canyon Research Group, Inc., Westlake Village, CA 91361, Contract No. N61339-77-C-0140, sponsored by Naval Training Equipment Center, Orlando, FL 32813, NAVTRAEQUIPCEN 77-C-0140, September 1978, 257 pp.

Aircrew Performance Measurement is emerging from a research venture to the realms of emerging technology. Initially, the technology is being developed for the quantitative assessment of undergraduate pilot skills as they transition from training airplanes to the more sophisticated operational types. The report covers a universal approach to the system development of a production airborne measurement system for the performance measurement of aviation pilots. (Author)

636. SWINK, Jay R., Butler, Edward A., Lankford, Harry E., Miller, Ralph M., Watkins, Hal, and Waag, Wayne L., Definition of Requirements for Performance Measurement System for C-5 Aircrew Members, Logicon, Inc., San Diego, CA 92138, Contract No. F33615-76-C-0056, sponsored by Air Force Human Resources Laboratory, Williams AFB, AZ 85224, AFHRL-TR-78-54, October 1978, 76 pp., AD A063282.

This study identified and defined C-5 aircrew tasks and performances essential to the effective operation of the aircraft on a typical, representative mission. It described present capabilities of C-5 simulators to determine how these capabilities might be implemented or augmented for measuring crew performance. The results of the above efforts were synthesized into a description of the requirements for a C-5 aircrew performance measurement subsystem. The study also identified the applicability of these C-5 simulator performance measures to the airborne environment. The capabilities of the C-5 aircraft systems to provide necessary data are described, and the results are synthesized into a functional description for a C-5 inflight performance measurement system. (Author)

637. DREYFUS, Hubert L., and Dreyfus, Stuart E., The Psychic Boom: Flying Beyond the Thought Barrier, University of California, Berkeley, CA 94720, Contract No. AFOSR-78-3594, sponsored by Air Force Office of Scientific Research, Bolling AFB, DC 20332, UC report ORC-79-3, March 1979, 13 pp., AD A071336.

Except in unfamiliar circumstances, the highly skilled performer responds to holistically perceived situations with previously learned appropriate actions. The analytic mind is thus by-passed in the production of performance. We examine four possible roles of the by-passed analytic mind, and conclude that the highest level of masterful performance is achieved when the analytic mind is quiet and the performer is totally absorbed in his activity. (Author)

638. UHLANER, J.E., and Drucker, Arthur J., "Military Research on Performance Criteria: A Change of Emphasis," Human Factors, v. 22(2): p. 131-139, April 1980.

This paper discusses trends in development and use of performance measures to meet complex needs of the U.S. Army. Examples from the programs of the Army Research Institute for the Behavioral and Social Sciences include typical major criteria of individual effectiveness (school grades, ratings, performance tests); measures of unit effectiveness more recently developed (tactical engagement simulation); and measures dealing with human factors problems encountered in systems analysis in the Army. The way in which performance criteria have changed over the years is emphasized. (Author)

639. VREULS, D., and Cotton, J.C., Feasibility of Aircrew Performance Measurement Standardization for Research, Canyon Research Group, Inc., Westlake Village, CA 91361, Contract No. F49620-79-C-0072, sponsored by Air Force Office of Scientific Research, Bolling AFB, DC 20332, April 1980, 31 pp.

With the emergence of practical human performance measurement methods and techniques, all three military services are developing automated, multiple measurement systems as an integral part of future aviation training devices and aircraft. Aircrew performance measurement is a rapidly expanding and evolving technology. The training and operational need for better measurement is so great that the technology is being proliferated by popular demand without common direction, guidelines and standards.

The lack of guidelines and standards "guarantees" duplication of effort across programs. Without standards, detailed measurement results of any one program will not be comparable to the results of any other program, unless the same investigators are involved. It is unlikely that all future measurement efforts will be performed by the same investigators because the need is just too great to be fulfilled by a few government laboratories and contractors.

The problem of measurement sttandardization was discussed with informed researchers at the Naval Training Equipment Center, the Army Research Institute Field Unit at Fort Rucker, and at the Air Force Human Resources Laboratory, Flying Training Division. There was substantial agreement that there are today a number of common flight tasks, mission segments, measure segments and certain measures that a group of experienced measurement investigators and subject matter experts would agree are essential. Standards for these measures could be defined by a project that is organized specifically for the purpose.

This document is the first product of a Working Group. It represents the humble beginning of an on-going program that holds future potential for standard measurement of flight crew performance. The authors took the position that the document would evolve from being a record of the aviation behavioral research communities' considered opinions into a specification used almost exclusively by flight training personnel. Therefore, the structure of the document from its inception should offer the end user a flight task analysis repertoire and a natural pre-programming format for the measurement problem at hand. (Modified author).

640. North Atlantic Treaty Organization, Assessment of Skill and Performance in Flying, Proceedings of the 23rd Annual Meeting of the AGARD Aerospace Medical Panel, Toronto, Canada, Advisory Group for Aerospace Research and Development, Paris, France, AGARD Conference Proceedings No. 14, Assessment of Skill and Performance in Flying, September 1966, 128 pp., AD 661165.

This volume contained 13 papers:

Luehrs, R.E., Human Error Research and Analysis Program
Hitchcock, L. Jr., The Analysis of Human Performance within the Operational Flight Environment

Hartman, B.O., and Cantrell, G.K., Sustained Pilot Performance Requires More Than Skill
Whiteside, T.C.D., Sleep Rhythms in Transatlantic Civil Flying
Lewis, R.E.F., Navigation of Helicopters in Slow and Very Low Flight: A Comparison of Solo and Dual Pilot Performance
Gillingham, K.K., Development of the Spatial Orientation Trainer
Riis, E., Measurement of Performance in F-86K Simulator
Huddleston, H. F., Measuring the Pilot's Contribution in the Aircraft Control Loop
Brown, J.M., Prior Learning and Age in Relation to Pilot Performance
Polis, B.D., Martorano, J.J., Schwarz, H.P., Polis, E., and Dreisbach, L., Plasma Phospholipid Composition as a Biochemical Index to Stress
Squires, R.D., The Electroencephalogram as a Physiological Criterion of Performance
Benson, A.J., and Rolfe, J.M., The Use of Psycho-Physiological Measures in the Assessment of Operator Effort
Scano, A., Mazza, G., And Caporale, R., Influence of Mild Hypoxia on Visual Perception During Post-Rotatory Nystagmus

641. PROPHET, Wallace W., Human Factors in Aviation: Some Recurrent Problems and New Approaches, Human Resources Research Office, Alexandria, VA 22314, Contract No. DA 44-188, ARO-Z, sponsored by Office of Chief of Research and Development, U.S. Army, Washington, DC 20310, HumRRO Professional Paper 30-67, June 1967, 20 pp., AD 656971.

Three areas of human factors concern in aviation - performance assessment, prediction of performance, and simulation in training - are discussed. Emphasis is placed on the necessity for providing objective and standardized evaluation of flight trainees, rather than using the unreliable subjective evaluation methods. Methods for predicting trainees' performance, particularly in combat situations, are being sought. Use of simulation in training helicopter pilots has been minimal, but recently two devices have been developed to provide better transfer of training from the device to the actual helicopter situation. (Author)

642. PROPHET, Wallace W., The Human Factor in Army Aviation, Human Resources Research Office, Alexandria, VA 22314, Contract No. DA 44-188-ARO-2, sponsored by Office of Chief of Research and Development (Army), Washington, DC 20310, HumRRO Professional Paper 43-67, September 1967, 3 pp. See also U.S. Army Aviation Digest, v. 13(8): August 1967.

In an article in observance of the 25th anniversary of U.S. Army aviation, some research activities are described to illustrate the attention being given to the most important factor in Army aviation - the human factor. Research in subareas that are part of the human factors field, such as personnel selection, training methods, prediction of performance, performance assessment, training devices, simulation, and human engineering, is also described. (Author)

643. PROPHET, Wallace W., Prediction of Aviator Performance, Human Resources Research Office, Alexandria, VA 22314, Contract No. DA 44-188-ARO-2, sponsored by Office of Chief of Research and Development, U.S. Army, Washington, DC 20310, HumRRO Professional Paper 5-69, February 1969, 14 pp., AD 686619.

Approaches to the prediction of three specific kinds of aviator performance are discussed: (1) in flight training or school, (2) in combat, (3) with respect to career decision. Within the school setting the psychometric reliability of flight performance evaluation is treated, as in the prediction of flight performance on the basis of trainee performance on a captive helicopter training device. The interaction of self-confidence in dangerous situations with the acquisition of flight skills and with effective performance under combat stress is discussed; flight trainee volunteers are more self-confident than similar, but non-aviation trainees, and degree of confidence is related to pass-fail in flight training. Integration of many diverse quantitative descriptors of aviator performance into a multiple predictor system is described. The aim of the system would be to provide time and usable information to Army personnel management and training decision-makers. (Author)

644. LAUSCHNER, Erwin A. (Editor), Measurement of Aircrew Performance: The Flight Deck Workload and Its Relation to Pilot Performance, Proceedings, Annual AGARD Symposium for Measurement of Aircrew Performance, Brooks AFB, TX, Advisory Group for Aerospace Research and Development, Paris, France, AGARD CP No. 56, May 1969, 55 pp., AD 699934.

The purpose of this report was to provide the opportunity for the mutual exchange of information among workers in the field of the quantitative assessment of workload. The following articles are contained herein:

Howitt, J.S., Flight-deck Workload Studies in Civil Transport Aircraft.
Littell, Delvin E., Energy Cost of Piloting Fixed and Rotary Wing Army Aircraft.
Jones, R. Douglas, Psychomotor Performance under Thermal Stress: A Critical Appraisal
Nicholson, A.N., Borland, R.G., and Hill, L.E., Studies on Subjective Assessment of Workload and Physiological Change of the Pilot During Let-down, Approach and Landing.
Brictson, Clyde A., Operational Measures of Pilot Performance During Final Approach to Carrier Landing.
Zaitzeff, L.P., Aircrew Task Loading in the Boeing Multimission Simulator.
Corkindale, K.G., Cumming, F.G., and Hammerton-Fraser, A.M., Physiological Assessment of Pilot Stress During Landing.
Kraft, Conrad L., and Elworth, Charles L., Flight Deck Work Load and Night Visual Approach Performance.
Moreland, Stephen, and Barnes, John A., Exploratory Study of Pilot Performance During High Ambient Temperatures/ Humidity.

645. DUNING, Kenneth E., Hickok, Craig W., Emerson, Kenneth C., and Clement, Warren F., Control-Display Testing Requirements Study, Collins Radio Company, Cedar Rapids, IO 52406, Contract No. F33615-72-C-1022, sponsored by Air Force Flight Dynamics Laboratory, Wright-Patterson AFB, OH, AFFDL-TR-72-122, December 1972, 182 pp., AD 759539.

Results of a survey of Air Force operational commands concerning anticipated utilization of the MLS are summarized. Control-display problems in terminal area navigation and zero visibility landing are identified along with related considerations for control laws and computations and requirements for sensors. Test and development program plans for research, development, and testing of controls and displays for full utilization of the capabilities of the MLS are presented. The program plans are categorized by priority for Air Force operations, by the level of modification of existing systems, and by phase of flight. Criteria and measurements for development and testing controls and displays are discussed. Procedures for evaluation of system performance, pilot performance, pilot acceptance, and safety are included. Alternative techniques for measuring pilot workload are outlined. Coordinated use of theoretical analysis, simulation, and flight test for development and testing of control-display systems is discussed. (Author)

646. U.S. Army Chief of Research, Development and Acquisition, Aircrew Performance in Army Aviation. Proceedings of a Conference that Convened November 27-29, 1973, at the U.S. Army Aviation Center, Fort Rucker, Alabama, U.S. Army Research Institute for the Behavioral and Social Sciences, Arlington, VA 22209, July 1974, 205 pp., AD A001539.

The purpose of the conference on Aircrew Performance in Army Aviation, held on 27-29 November 1973, was to explore the behavioral problems affecting pilots of Army helicopters, with special emphasis on Nap-of-the Earth (NOE) flight. The technical papers included in this Proceedings deal with the nature of the future combat environment, next generation helicopters, cockpit configuration, map aids, avionics systems, night vision devices, training and simulation requirements and measurement criteria. Included also is a recommended behavioral research program to support Army aviation. (Author)

647. ROSCOE, Stanley N., and Hopkins, Charles O., Enhancement of Human Effectiveness in System Design, Training, and Operation: July 1974-June 1975, University of Illinois, Savoy, IL 61874, Contract No. F44620-70-C-0105, sponsored by Air Force Office of Scientific Research (NL), Bolling AFB, DC 20332, AFOSR-TR-76-0476, July 1975, 35 pp., AD A023941.

Substantial contributions were made through research that extended empirical knowledge and conceptual formulations of divided attention and time-sharing behavior. This work, which was done as a part of the research on residual attention, information load, and pilot performance has resulted in (1) general rules and prediction equations for evaluation of task load and operator efficiency, (2) discrimination of individual differences in attention and assessment of their predictive validity to operational performance, (3) development of training procedures for timesharing, and (4) application of feedback control theory to operator tracking performance in timesharing. Investigation of adaptive logic in the acquisition of perceptual-motor skills included (1) a critical review of research literature on adaptive training with emphhasis on current theoretical models of perceptual motor skills included (1) a critical review of research literature on adaptive training with emphasis on current theoretical models of perceptual motor skills and (2) a theoretical framework for investigation of adaptive training concepts. Initial experiments were designed to investigate the role of proprioceptive and visual response-produced feedback after the same or after different amounts of practice. The completion of programmatic research was concerned with extension of response surface methodology through perceptual research applications and an investigation of the relationship between the motion cue fidelity provided by a flight simulator and transfer effectiveness in a basic flight training context. (Author)

648. PASSEY, George E., and McLavrin, William A., Perceptual-Psychomotor Tests in Aircrew Selection: Historical Review and Advanced Concepts, Lockheed-Georgia Company, Contract No. AF 41(609-2796, sponsored by Personnel Research Laboratory, Lackland AFB, TX PRL-TR-66-4, June 1966, 245 pp., AD 636606.

This report reviews the literature reflecting the employment of perceptual-psychomotor tests for selection of aircrew members since World War II and provides behavioral concepts for consideration as possible future test development area. The review considers the use of flight experience as well as perceptual-psychomotor screening devices and comments on the results of the programs in which such experience is intentionally used. The fundamental importance of criterion definition to development and validation of selection devices is discussed. Recent research is reviewed leading to the derivation of behavioral concepts recommended for consideration as principles on which new perceptual-psychomotor tests may be based. The merits of simple tests as opposed to complex tests in which numerous facets of performance are concurrently assessed are considered and the latter approach is recommended. References are included in support of the review and critical items are annotated. (Author)

649. NORTH, Robert A., and Griffin, Glenn R., Aviator Selection 1919-1977, Naval Aerospace Medical Research Laboratory, Pensacola, FL 32508, NAMRL-SR-77-2, October 1977, 57 pp., AD A048105.

The potential for increased success in predicting aviator performance is high. The fact that current selection tests normally account for less than half of the total variance associated with aviator success (in training) suggests that there are additional factors associated with aviator performance which are not now being adequately assessed. The lack of any prominent breakthrough in perceptual/cognitive paper-and-pencil testing since the war years (WWII) suggests that non-paper-and-pencil performance tests should be investigated more fully to determine their relationship to aviator performance in both a training and operational setting.

Relating aviator performance to better and more appropriate performance measurement criteria is a continuing psychological assessment goal. New technological advancements such as the Navy and Air Force Air Combat Maneuvering Ranges have the potential to identify and reliably measure relevant physical and psychological human attributes which may provide more accurate and valid prediction of aviator operational performance.

Still, such obviously valid criteria as ACMR performance pose an interesting assessment problem. It is unclear whether the prediction variables presently utilized in aviation selection to predict successful performance in undergraduate training are related to successful performance in postgraduate operational environments.

It is suggested that research be oriented toward the identification of highly relevant criterion-oriented performance measures for use as criteria in the evaluation of present and new selection prediction variables and identification and development of non-paper-and-pencil performance prediction measures to improve prediction of criterion performance in undergraduate training, and in postgraduate operational flying environments. Examples of non-paper-and-pencil performance prediction measures recommended for future study are Selective and Divided Attention, Stress and Anxiety Motivational Measurement, and Perceptual Psychomotor skill assessment. (Author)

650. BROWN, J.M., Prior Learning and Age in Relation to Pilot Performance, Proceedings, Annual AGARD Meeting of the Aerospace Medical Panel, Toronto, Canada, Advisory Group for Aerospace Research and Development, Paris, France, AGARD Conference Proceedings No. 14, Assessment of Skill and Performance in Flying, September 1966, p. 71-78, AD 661165.

An attempt was made in this paper to break away from the traditional emphasis by psychologists and others on the establishment of arbitrary selection, training, and performance standards for pilots. As important as they are, they are essentially negative in nature. If we are to enhance learning during pilot training, reduce flying accidents, and improve the operational effectiveness of pilots, our research effort cannot be restricted to the prediction of pilot performance but must move on to a more positive emphasis on the modification of pilot behaviour through training. To accomplish this aim we must strive for a better understanding of the complex variables which account for the wide range of individual differences found in the assessment of pilot skill.

Some of the effects of two of these variables, prior learning and age, on pilot performance and flying accidents are discussed. Supporting evidence is drawn from the extensive experience of the RCAF in the training of Canadian, NATO, and other foreign national pilots. (Author)

651. PROPHET, Wallace W., Long-Term Retention of Flying Skills: An Annotated Bibliography, Human Resources Research Organization, Alexandria, VA 22314, Contract No. F44620-76-C-0106, sponsored by U.S. Air Force Headquarters (AF/SAA), Washington, DC 20332, HumRRO FR-ED(P)-76-36, October 1976, 143 pp., AD A036114.

In support of USAF Saber Wings II study, a survey of the state of behavioral science knowledge with reference to long-term retention of flying skills was conducted. Various literature sources were surveyed, as well as selected agencies and knowledgeable individuals. Abstracts or annotated references are presented for 120 references. Literature is grouped as: flight skill retention studies; non-flight skill retention studies; miscellaneous aviation studies; and literature reviews and references. Abstract length varies from three pages to a single paragraph. An additional 80 references are given as reviewed, but not pertinent. (Author)

652. PROPHET, Wallace W., Long-Term Retention of Flying Skills: A Review of the Literature, Human Resources Research Organization, Alexandria, VA 22314, Contract No. F44620-76-C-0106, sponsored by U.S. Air Force Headquarters (AF/SAA), Washington, DC 20332, HumRRO FR-ED(P)-76-35, October 1976, 94 pp., AD A036077.

In support of USAF Saber Wings II study, a survey of the state of behavioral science knowledge with reference to long-term retention of flying skills was conducted. Various literature sources were surveyed, as well as selected agencies and knowledgeable individuals. Results of the review suggest that basic flight skills can be retained fairly well for extended periods of nonflying, but some decrement of concern does occur, particularly for instrument and procedural skills. Retraining of basic flying skills is judged not to be a major USAF problem, and must of the proficiency maintenance/retraining requirements can be met through the use of training devices and simulators. The review suggests, however, that little is known about the retention, maintenance, and retraining of higher level pilot skills that characterize the professional USAF pilot in tactical units. It is retention and retraining of these higher level skills that is the major concern in establishing manpower management policies with reference to USAF rated supplement pilots. Literature dealing with the nature of these higher level pilot skills is discussed. Conclusions are drawn with reference to flight skills maintenance and retraining, and with reference to management of the rated force. In addition, areas in need of additional research are identified. It is concluded that the general state of knowledge is inadequate to USAF current and future needs and that a better base of data on which to develop policies is needed. (Author)

653. GERATHEWOHL, Siegfried J., Psychophysiological Effects of Aging - Developing a Functional Age Index for Pilots. II. Taxonomy of Psychological Factors, Federal Aviation Administration, Washington, DC 20591, FAA-AM-78-16, April 1978, 74 pp., AD A054356.

One of the major objectives of gerontological aviation psychology is to determine the psychological variables, functions, abilities, skills, and factors that underlie, constitute or are associated with pilot performance and proficiency. They must be identified, analyzed, and measured if functional age is to be substituted for chronological age as a criterion for terminating an aviator's career.

Three methodological approaches are being used in this study to determine the psychological and psychophysiological factors, which are thought to be representative of and essential to effective pilot performance. They consist of (a) the analysis of successful pilot behavior as displayed under simulated and operational conditions, (b) the analysis of unsuccessful pilot behavior (pilot error) as related to aircraft accidents, (c) the evaluation of pilot performance during the selection and training procedures as reported in the literature. By means of factor analyses, logical deductions, and clinical interpretations of the results obtained by various investigators, 14 factors are identified and described, namely (1) perception, (2) attention, (3) reaction, (4) orientation, (5) sensorimotor, (6) stamina, (7) cognition/mentation, (8) interpersonal relations, (9) decision making, (10) experience, (11) learning, (12) personality, (13) mechanical ability, and (14) motivation.

No attempt is made to assign weights to these factors or to rank them in accordance with their importance to flying proficiency. However, their relationship to age and the aging pilot is discussed. (Author)

654. GERATHEWOHL, Siegfried J., Psychophysical Effects of Aging - Developing a Functional Age Index for Pilots: III. Measurement of Pilot Performance, Federal Aviation Administration, Washington, DC 20591, FAA-AM-78-27, August 1978, 59 pp., AD A062501.

If a functional age index for pilots is to be developed that can be used as a criterion for extending or terminating an aviator's career, means for the assessment of pilot proficiency must be available or devised. There are two major approaches used today; the qualitative evaluation of performance based mainly on subjective ratings, and the quantitative assessment of performance through objective recordings of pilot action and aircraft response. The qualitative rating procedure, which is still the official method authorized by the Federal Aviation Administration and other Government agencies abroad, is still popular, generally accepted, and operationally rather effective. The most advanced concept of measuring pilot performance is based on automated data recording and processing independently of or in conjunction with the judgment and interpretation of an instructor, examiner, or inspector. With all the computers and automatic data processing equipment around, pilot performance indeed can now be measured automatically, accurately, and rather reliably. Measurements already obtained this way discriminate effectively among different levels of operational requirements, demands, skills, and proficiency and are accepted by the pilots. Owing to the capability of simultaneously monitoring the performance of the human operator and the aircraft, automatic inflight monitors are the ultimate in systems design and application. Their implications for the development of a functional age index for pilots are discussed. (Author)

655. EDDOWES, Edward E. DeMaio, Joseph C., Eubanks, James L., Lyon, Don R., Killion, Thomas H., and Nullmeyer, Robert T., Flying Skill Maintenance, Proceedings of the 24th Annual Meeting of the Human Factors Society, Los Angeles, CA, October 1980, p. 167-168.

A skills maintenance and reacquisition training (Project SMART) research program has been developed to improve Air Force continuation flying training. Project SMART consists of four phases: 1. Preliminary evaluation of research concepts and procedures, 2. Identification and definition of critical flying skills and development of skill measures, 3. Evaluation of skill maintenance and reacquisition training program alternatives, and 4. Measurement of skill retention. The program is sponsored by Air Force Headquarters and is being accomplished by the Air Force Human Resources Laboratory with participation by the Strategic Air Command and the Tactical Air Command. Selected studies completed during Phases 1 and 2 are reported. (Author) The papers listed below were delivered during the interactive session:

Eddowes, Edward E., U.S. Air Force Human Resources Laboratory, Identifying and Defining Critical Flying Skills.
Eubanks, James L., University of Dayton Research Institute, Air Combat Maneuvering Performance Measurement.
Killion, Thomas H., University of Dayton Research Institute, Measurement of Electronic Warfare Officer Performance.
Lyon, Don R., University of Dayton Research Institute, Ground Attack Skill Measurement.

Nullmeyer, Robert T., University of Dayton Research Institute, Radar Navigator Bombing Performance Measures.
DeMaio, Joseph C., U.S. Air Force Human Resources Laboratory, Measuring Low Altitude Tactical Formation Flying.

656. BENENATI, A.T., Hull, R., Korobow, N., and Nienaltowski, W., Development of an Automatic Monitoring System for Flight Simulators, Curtiss-Wright Corporation, East Paterson, NJ, Contract No. AF 33(616)-6891, sponsored by Aerospace Medical Research Laboratories, Wright-Patterson AFB, OH, MRL-TDR-62-47, May 1962, 102 pp., AD 283008.

The design study of an automatic monitoring system for flight simulators is presented. System basic functions are:

1. Recording and playback
2. Evaluation and scoring

The recording and playback facilities allow the recording of pertinent parameters of a simulated flight mission. The recording of any part or all of the mission can be played back into the flight simulator for re-enactment at any desired time.

Objective evaluation and scoring of the trainee is accomplished by comparison of monitored parameters to the programmed criteria. Student errors in performance are printed by the device onto a cue sheet readily accessible to the instructor. Functional flexibility, the degree of automation required, size, and complexity of the simulator to be monitored are the factors that most affect the design. (Author)

657. ANGELL, D., Shearer, J.W., and Berliner, D.C., Study of Training Performance Evaluation Techniques, American Institute for Research, Palo Alto, CA, sponsored by U.S. Naval Training Device Center, Port Washington, NY, NAVTRADEVCEN 1449-1, October 1964, 76 pp., AD 609605.

The report discusses performance evaluation in the training environment, specifically in training situations involving the use of simulators and other complex training equipment. The important variables involved in developing a system of performance evaluation are seen as (1) types of behaviors, (2) types of measures or mensural indices, and (3) types of instruments for recording performance. Factors relating to these variables are discussed, and some of their interrelationships are delineated. Matrices which facilitate the consideration of interrelationships among the three variable are presented. An illustrative application of an automatic training/evaluation system is given. (Author)

658. WALLIS, Kenneth B., Ewart, Warren L., and Kaufman, Roger A., "Instructional System Approach to Flight Crew Training," Human Factors, v. 8(2): p. 173-178, April 1966.

This paper discusses the rationale for analysis and definition of flight crew training requirements. Using the Instructional System Approach, the concept of flight crew performance from a management aspect is presented together with methods for determining detailed flight crew training requirements. (Author)

659. KELLEY, Charles R., and Wargo, Michael J., Adaptive Techniques for Synthetic Flight Training Systems, Dunlap and Associates, Inc., Santa Monica, CA, Contract No. N61339-68-C-0136, sponsored by Naval Training Device Center, Orlando, FL, NAVTRADEVCEN 68-C-0136-1, October 1968, 43 pp., AD 678536.

This report is concerned with the application of adaptive training techniques to Synthetic Flight Training Systems (SFTS) in general, and to the 2B24 SFTS in particular. The report is divided into four major sections. The first section discusses the basic elements for any adaptive training system, which are: valid and reliable performance measures; one or more system, task or environmental variables that directly affect task difficulty; and, an adaptive logic which automatically adjusts task difficulty on the basis of the relation of measured performance to a preset criterion of performance. The second section of the report is addressed to the major problem areas associated with application of adaptive principles to the SFTS: selection of valid and reliable performance measures and the combining of performance measurements in several degrees of freedom to provide for a single continuum of adaptation. Specific suggestions for the application of adaptive techniques to the 2B24 SFTS are detailed in the third section of the report. The fourth and final section is concerned with an experimental program for the determination of the 2B24 SFTS adaptive training parameters. (Author)

660. FACONTI, V., Mortimer, C.P.L., and Simpson, D.W., Automated Instruction and Performance Monitoring in Flight Simulator Training, Singer-General Precision Systems, Inc., Binghamton, NY 13901, Contract No. F33615-69-C-1159, sponsored by Air Force Human Resources Laboratory, Wright-Patterson AFB, OH, AFHRL-TR-69-29, February 1970, 365 pp., AD 704120.

This report documents research in the area of Automated Instruction and Performance Monitoring. One objective of the research was to develop modular approaches to implementing eight individual automated training capabilities in flight simulators. Several approaches to each area are identified and briefly investigated. More complete investigation, including programming flow diagrams and hardware and software estimates, is presented on those approaches in each capability area which appeared to be most feasible. Two integrated systems, i.e., systems which include all eight automated training capabilities, are "designed." Selection of the components for each of the systems is made by assigning levels of relative complexity to each approach in each area. System one is designed by using the lowest complexity approach in each area while system two consists of the highest. Several methods of implementation, in relation to the computer complex, are presented. These varied from including the instructional system in the basic simulation programs to the addition of satellite computers to handle the instructional function.

Estimated implementation costs are given for the two systems for each selected computer configuration and two display system options (system two). These estimates include Engineering (and Programming) cost estimates, special-purpose hardware costs, peripheral device costs and computer implementation costs. (Author)

661. VREULS, Donald, and Obermayer, Richard W., Emerging Developments in Flight Training Performance Measurement, from U.S. Naval Training Device Center 25th Anniversary Commemorative Technical Journal, Orlando, FL 32813, November 1971, p. 199-210.

This paper reviews critical examples of past and present performance measurement for flight training. Emerging concepts, methods, and techniques in training performance measurement are presented in the areas of: automated and adaptive training, abilities and task measurement, development of multi-dimensional algorithms, training state measures, utility analysis, and measurement technology. (Author)

662. PROPHET, Wallace W., Caro, Paul W., and Hall, Eugene R., Some Current Issues in the Design of Flight Training Devices, Human Resources Research Organization, Alexandria, VA, HumRRO-PP-5-72, March 1972, 11 pp., AD 743270. See also U.S. Naval Training Device Center 25th Anniversary Commemorative Technical Journal, Orlando, FL 32813, November 1971.

This paper develops the rationale that training equipment should be selected or designed to furnish what the student needs to know and to be able to do to perform successfully on the operational job. Several considerations relevant to training equipment design from the systems engineering standpoint are examined. Suggested design features based upon particular student learning needs and on student learning characteristics are presented. Training equipment design features for particular categories of training objectives and for levels of training (e.g., initial training of aviators vs. transition training) are considered. Also discussed is the criticality of the synthetic training program with respect to the total training engineering process. (Author)

663. BERGMAN, Brian A., and Siegel, Arthur I., Training Evaluation and Student Achievement Measurement: A Review of the Literature, Applied Psychological Services, Inc., Wayne, PA, Contract No. F41609-71-C-0025, sponsored by Air Force Human Resources Laboratory, Lowry AFB, CO 80230, AFHRL-TR-3, January 1972, 57 pp., AD 747040.

The purpose of this paper is to review the training evaluation and student achievement measurement literature with primary emphasis being placed on studies reported in the last ten years.

Recent trends in training evaluation and student achievement measurement are presented. Because of the obvious interaction between both training evaluation and student measurement, on the one hand, and such topics as statistical methods, course development methods, training techniques, learning styles, motivation, and moderator variables, on the other hand, these and similar considerations are also included.

Where new methods of training evaluation and student achievement measurement appeared in the literature, detailed presentations were given. Among these procedures were cost-effectiveness or cost-benefit analysis, criterion-referenced testing, sequential testing, confidence testing, convergent and discriminant validity, and computer assisted branched testing.

Systematic approaches to evaluation and course development are receiving more and more attention. Most systems begin with a job analysis in order to derive a list of behaviorally oriented job requirement from which training objectives can be formulated. The new techniques in evaluation and measurement have resulted from attempts to determine whether training objectives have been realized. (Author)

664. OBERMAYER, R.W., and Vreuls, D., Measurement for Flight Training Research, Proceedings of the 16th Annual Meeting of the Human Factors Society, Los Angeles, CA October 1972, p. 377-384.

Training research goals are identified to point up the need for objective quantitative performance measures and a performance measurement system. To show what is involved to produce the needed information, a performance measurement system is defined based on combat-crew flight training. The steps for defining performance measures are outlined. The performance measurement system is presented in detail including data acquisition and processing hardware/software, the personnel subsystem, facilities, implementation steps and costs. It is concluded that comprehensive measurement, though costly, is essential if quantitative studies of flight training effectiveness are to be performed. (Author)

665. STANLEY, Maurice Dudley Jr., A Method for Developing a Criterion for Combat Performance of Naval Aviators, Master's Thesis, Naval Postgraduate School, Monterey, CA 93940, June 1973, 56 pp., AD 765679.

Current Naval aviator selection and screening procedures are based on the individual's statistical probability of completing flight training and do not determine the capability of the student to adapt to an operational environment. The resultant failure of some student aviators to complete the advanced stages of training and the ineffective performance of others in operational missions have caused a considerable financial loss and a lessening of combat readiness.

A critical incident study, using 30 aviators who have combat experience, indicates that there are 10 categories of behavior which characterize effective and ineffective Naval aviators. Procedures to identify these categories early in flight training are discussed. (Author)

666. CARO, Paul W., "Aircraft Simulators and Pilot Training," Human Factors, v. 15(6): p. 502-509, December 1973.

Flight simulators are built as realistically as possible, presumably to enhance their training value. Yet their training value is determined by the way they are used. Traditionally, simulators have been less important for training than have aircraft, but they are currently emerging as primary pilot training vehicles. This new emphasis is an outgrowth of systems engineering of flight training programs, and a characteristic of the resultant training is the employment of techniques developed through applied research in a variety of training settings. These techniques include functional context training, minimizing over-training, and objective performance measurement. Programs employing these and other techniques, with training equipment ranging from highly-realistic simulators to reduced-scale paper mockups, have resulted in impressive transfer of training. The conclusion is drawn that a proper training program is essential to realizing the potential training value of a device, regardless of its realism. (Author)

667. PROPHET, Wallace W., and Caro, Paul W., Simulation and Aircrew Training and Performance, Human Resources Research Organization, Alexandria, VA 22314, sponsored by Office of the Chief of Research and Development (Army), Washington, DC 20310, HumRRO-PP-4-74, April 1974, 11 pp., AD 780688. See also Aircrew Performance in Army Aviation, Proceedings of a Conference that Convened November 27-29, 1973 at the U.S. Army Aviation Center, Fort Rucker, Alabama, July 1974, p. 130-136, AD A001539.

This paper outlines some major areas of use of simulation in Army Aviation and comments on current research. Equipment development, crew performance studies, concept development and training are discussed. Only in the training area has the Army made substantial progress. A broad program of simulation research with emphasis on engineering and behavior is suggested toward the goal of improving aircrew performance. There are significant simulation research problems unique to the Army which need to be worked out. (Author)

668. WIERWILLE, W.W. and Williges, B.H., An Annotated Bibliography on Operator Workload Assessment, Systemetrics Inc., Blacksburg VA 24061, sponsored by Naval Air Test Center, Patuxent River, MD 20670, SY-27R-80, March 1980, 411 pp., AD A083686.

An annotated bibliography on operator mental workload is presented with supporting information. This bibliography is based upon two literature searches, one performed in 1977 in support of a survey and analysis catalog (AD A059-501) and one performed in 1979 as an update.

Each literature citation presented contains reference information, an abstract, a numerical workload technique category classification, a numerical operator behavior classification, and a group of word descriptors. Workload methods are divided into 28 specific techniques in four major categories: opinion, spare mental capacity, primary task, and physiological. Applicable operator behaviors are similarly divided into categories.

The descriptors associated with each citation designate the general workload classification, the specific workload classification, the type of presentation, the type of facilities used, and the potential aircrew application. Over 600 citations are presented. Two indexes are also provided. The first is a workload technique index and the second is an experimental facility index. It is concluded that periodic updating of the bibliography will be required and that attention should be directed toward computerizing future workload bibliographies.

669. EDDOWES, Edward E., A Cognitive Model of What is Learned During Flying Training, Air Force Human Resources Laboratory, Williams AFB, AZ 85224, AFHRL-TR-74-63, July 1974, 12 pp., AD A000046.

The cognitive model of what is learned during flying training presents an alternative to the familiar concept of flying skill as hand-eye coordination. The model relates the growth of pilot ability to the student's increasingly refined cognitive discriminations about his flying performances made possible by his improved familiarity with the phenomena of flight gained practicing aircraft control tasks.

As the student pilot becomes familiar with his flying tasks, he anticipates his control requirements. Consequently, his performance improves. This leads to better error discriminations, increased aircraft control effectiveness and more familiarity with the phenomena of flying, which is in turn followed by another incremental cycle. This interpretation views the acquisition of flying skill as a spiral-type expanding cognitive process rather than a linear-type perceptual motor skill refinement process. (Author)

670. MEYER, Robert P., Laveson, Jack I., Weissman, Neal S., and Eddowes, Edward E., Behavioral Taxonomy of Undergraduate Pilot Training Tasks and Skills: Executive Summary, Design Plus, St. Louis, MO 63132, Contract No. F41609-73-C-0040, sponsored by Air Force Human Resources Laboratory, Williams AFB, AZ 85224, AFHRL-TR-74-33(I), December 1974, 26 pp., AD A008771.

This report summarizes the development and application of a behavioral taxonomy of undergraduate pilot training (UPT) tasks and skills. The taxonomy specifies the fundamental flying abilities which comprise the training objectives of UPT. Its purpose is to provide a broadly applicable conception of UPT that obviates the need to continually study each specific training task or aircraft to determine the requirements for training hardware and software in research on and the development of optimized flying training programs. (Author)

671. MEYER, Robert P., Laveson, Jack I., and Weissman, Neal S., Behavioral Taxonomy of Undergraduate Pilot Tasks and Skills: Surface Task Analysis, Taxonomy Structure, Classification Rules and Validation Plan, Design Plus, St. Louis, MO 63132, Contract No. F41609-73-C-0040, sponsored by Air Force Human Resources Laboratory, Williams AFB, AZ 85224, AFHRL-TR-73-33(II), July 1974, 106 pp., AD A000053.

The objective was to analyze and specify the fundamental flying abilities which comprise the training objectives of Undergraduate Pilot Training (UPT). The results of this analysis will be used as a foundation for structuring research on and recommendations for improvements in Air Force flying training programs. The Phase I effort focused on a review of literature relevant to the development of a taxonomy of flying tasks and skills, a surface analysis of fundamental flying tasks, generation of a basic taxonomic structure and classification rules and planning for an evaluation of the taxonomy. Reports of the results of previous taxonomic studies were reviewed to avoid duplication of effort in the present research. Analyses of relevant flying tasks were reviewed and used in producing task analysis. A concept of the pilot-aircraft system operation was evolved and subsequently applied in configuring both the surface analysis and the taxonomy structure. Examination of previous task and skill taxonomies failed to provide a useable basis for the present effort. The surface task analysis was developed on the basis of a breakdown of task elements according to the cue, mental action and motor action involved. The flying tasks analyzed were found to fall into three caegories: fundamental transitions, composite transitions and continuous transactions. The surface task analysis was organized so the more complex flying maneuvers could be accommodated by a sequence of two or more of the three categories of task types identified. A cubic taxonomic structure was developed with cue, motor action and mental action dimensions. A set of classification rules were provided for locating any flying training task in a specific "pigeon hole" within the taxonomic structure. A procedure for evaluating the validity of the taxonomic system was established for use during Phase II of this program. (Author)

672. MEYER, Robert P., Laveson, Jack I., Weissman, Neal S., and Eddowes, Edward E., Behavioral Taxonomy of Undergraduate Pilot Training Tasks and Skills: Taxonomy Refinement, Validation and Operations, Design Plus, St. Louis, MO 63132, Contract No. F41609-73-C-0040, sponsored by Air Force Human Resources Laboratory, Williams AFB, AZ 85224, AFHRL-TR-74-33(III), December 1974, 217 pp., AD A008201.

The objective was to analyze and specify the fundamental flying abilities which comprise the training objectives of Undergraduate Pilot Training (UPT). The results of this study will be used as a basis for structuring research on and recommendations for improvements in Air Force flying training programs. The flight training maneuvers of UPT were analyzed according to a breakdown of task elements into the cues, mental actions and motor actions required to accomplish them. Flying tasks analyzed were found to fall into three categories: fundamental transitions, composite transitions and continuous transitions. A set of classification rules were developed to locate any flying training task element in a specific "pigeon hole" within a taxonomic cubic structure with a cue, motor actions and mental actions serving respectively as the vertical, horizontal and depth axes of the cube.

The taxonomic cubic structure was refined and subsequently validated by having flying training personnel who had not participated in development of the taxonomy's classification rules and procedures use them to classify several sample tasks. The validation test resulted in an overall agreement of 82% among the test raters. This outcome was interpreted as indicating that the taxonomy could be used for the purposes for which it was developed, that is, to describe an orderly relationship between the flying tasks analyzed and the skills required in their execution.

During this phase of the study, 22 additional flight tasks were analyzed supplementing the 14 tasks analyzed previously. All the tasks analyzed were classified and the resulting skill data were further categorized according to a hierarchy of taxonomic rules. The taxonomic hierarchy was adapted to a matrix system of information categorization which was found to provide for simplified data retrieval. (Author)

673. MEYER, Robert P., Laveson, Jack I., Weissman, Neal S., and Eddowes, Edward E., Behavioral Taxonomy of Undergraduate Pilot Training Tasks and Skills: Guidelines and Examples for Taxonomy Application in Flying Training Research, Design Plus, St. Louis, MO 63132, Contract No. F41609-73-C-0040, sponsored by Air Force Human Resources Laboratory, Williams AFB, AZ 85224, AFHRL-TR-74-33(IV), December 1974, 191 pp., AD A008897.

This report presents the results of the third phase of a research program to develop a behavioral taxonomy of undergraduate pilot training (UPT) tasks and skills. The Phase III effort consisted of the continued development of surface analyses to include instrument flight maneuvers, the classification of the resulting surface analysis information and its integration within the taxonomic data system, an analysis of future UPT objectives in terms of present and future flying training requirements and the development of four applications of the taxonomic data system to flying training research problems. The illustrative examples dealt with skill comparisons among different tasks, the determination of skill difficulty within and between tasks, developing standard training tasks and generating new training tasks to teach specific flying skills. (Author)

674. HAYGOOD, Robert C., Leshowitz, Barry, Parkinson, Stanley R., and Eddowes, Edward E., Visual and Auditory Information Processing Aspects of the Acquisition of Flying Skill, Arizona State University, Tempe, AZ 85281, Contract No. F41609-72-C-0037, sponsored by Air Force Human Resources Laboratory, Williams AFB, AZ 85224, AFHRL-TR-74-79, December 1974, 62 pp., AD A007721.

The result of a number of experimental studies of human auditory and visual information processing behavior and their possible relationship to the student pilot's acquisition of flying skill were explored in terms of the conceptual model developed for this study. The results were interpreted in terms of the potential interfering effects of the intake of and response to information processed during flying tasks and in terms of the student pilot's nonoptimal information processing strategies during his acquisition of flying skill. It was concluded that the experimental procedures employed could be adapted successfully for research in the area and that the relationships found between information processing and flying skill warranted their further study. (Author)

675. LESHOWITZ,Barry, Parkinson, Stanley R., and Waag, Wayne L., Visual and Auditory Information Processing in Flying Skill Acquisition, Arizona State University, Tempe, AZ 85281, Contract No. F41609-74-C-0002, sponsored by Air Force Human Resources Laboratory, Williams AFB, AZ 85224, AFHRL-TR-74-103, December 1974, 20 pp., AD A009636.

This document summarizes a series of experiments conducted to study further refinements in the development of experimental paradigms for the investigation of information processing skills relevant to pilot training. A series of tasks have been developed and studied which attempt to measure the individual's information processing capacity as well as his susceptibility to performance degradation resulting from the introduction of interfering stimuli. Data suggest performance on these tasks to be highly dependent upon individual differences, therefore, making them good candidates for use as tools in the investigation of information processing skills in flying training. Implications for direct application to flying training research are discussed. (Author)

676. MATHENY, W.G., Training Research Program and Plans: Advanced Simulation in Undergraduate Pilot Training, Life Sciences, Inc., Hurst, TX 76053, Contract No. F41609-73-C-0038, sponsored by Air Force Human Resources Laboratory, Williams AFB, AZ 85224, AFHRL-TR-75-26 (II), June 1975, 102 pp., AD A016486.

In this study, a survey was made among experts in pilot training to determine the important training research problems to be undertaken in order to increase training effectiveness in beginning pilot training. The highest priority problems were examined in the light of the research equipment capabilities of the Air Force Human Resources Laboratory, Flying Training Division and administrative constraints. The initial experiments in the area of training methodology and training simulator requirements are recommended and outlined. The performance equivalence approach to research in these areas is described.

Studies are suggested designed to evaluate the concept and its use in training research. (Author)

677. FEURZEIG, Wallace, Cohen, Dan, Lukas, George, and Schiff, Martin, Research on High-Level Adaptive Training Systems, Bolt Beranek and Newman, Inc., Cambridge, MA 02138, sponsored by Naval Training Equipment Center, Orlando, FL 32813, NAVTRAEQUIPCEN 74-C-0081-6, November 1975, 115 pp., AD A022291.

The long term objective of this research is to develop an automated system for instrument flight training which incorporates capabilities for recognizing malfunction patterns and diagnosing the trainee's underlying difficulties. This is necessary because individual trainees experience distinctly different conceptual problems. As the core of such a system, a computer-based instrument flight training simulator, ORLY, was designed. To aid in its development and use, a critical review was made of the literature on adaptive training models and applications. Computer program implementations of the ORLY simulator were made on the Bolt Beranek and Newman PDP-10 and the Naval Training Equipment Center PDP-9 computation facilities. ORLY-based protocol experiments with trainees and instructor pilots were designed to elicit and characterize trainees' malperformance patterns and instructors' diagnostic procedures and strategies. (Author)

678. ROSCOE, Stanley N., Review of Flight Training Technology, University of Illinois, Savoy, IL 61874, project No. 2Q162107A745, sponsored by U.S. Army Research Institute for the Behavioral and Social Sciences, Research Problem Review 76-3, July 1976, 32 pp., AD A076641.

The state of the art of aircrew training technology, particularly in simulation, was reviewed as part of a program to identify areas in which nap-of-the-earth (NOE) aircrew training might be most readily improved.

Ground-based devices that simulate flight are both effective and cost-effective for initial flight training; with time, as a student's skill increases, the simulator becomes decreasingly cost-effective compared with actual flight. The more complex and costly the simulator, the sooner it will cease to be cost-effective but the more realistic its simulation is likely to be. Optimum fidelity must be determined for each training objective; although more realistic simulation does not necessarily produce more effective transfer of training generally, exact fidelity is vital in teaching procedural skills.

Present flight simulators are much less useful in NOE training than in general helicopter pilot training because they cannot properly reproduce the visual field outside the cockpit. They might be used to train pilots in procedures to cope with NOE-altitude emergencies; however, a combination of cinematic simulation and air training appears to be the most promising cost-effective method of developing NOE visual perception skills.

Of other innovations in pilot training, computer-assisted instruction can be used for any lecture-type training; measurement of residual attention could be useful in assessing NOE pilot performance. Automatically adaptive training methods are not presently suitable for NOE. Automatic performance measurement could be very useful to provide objective assessments once the pivotal measures that correlate highly with total performance are identified.

The conclusions of this review of existing technology were used in conjunction with training objectives derived from task analyses to suggest improvements for NOE aircrew training. These suggestions, validated by the results of ARI's field research program, were used as the basis for the experimental MAP Interpretation Terrain Analysis Course (MITAC)) now being evaluated at the Army Aviation School, Fort Rucker, Alabama. (Author)

679. KLEIN, Gary A., Phenomenological Approach to Training, Air Force Human Resources Laboratory, Wright-Patterson AFB, OH 45433, AFHRL-TR-77-42, August 1977, 16 pp., AD A043920.

Current approaches to training attempt to break complex tasks into simple, discrete steps. This attempt while valuable for teaching procedural tasks, may not be optimal for teaching complex perceptual and motor tasks; it is valuable for initial stages of training, but may not be optimal for training to highly proficient levels of performance. The assumptions behind current approaches to training are questioned. A phenomenological approach is discussed as a means for supplementing the traditional methods, and for accomplishing high proficiency training of complex perceptual-motor tasks. A phenomenological approach would emphasize wholistic features of tasks, and shifts in perspective that develop with competence. Such an approach could provide a theoretical framework for the use of modelling, demonstrations, prediction displays, and other instructional methods. (Author)

680. CHARLES, John P., and Johnson, Robert M., Automated Weapon System Trainer: Expanded Module for Basic Instrument Flight Instruction, Appli-Mation, Inc., Orlando, FL 32803, Contract No. N61339-74-C-0141-1, sponsored by Naval Training Equipment Center, Orlando, FL 32813, NAVTRAEQUIPCEN 74-C-0081, August 1977, 200 pp., AD A048498.

Previous studies have demonstrated the conceptual and technical feasibility of automated and adaptive aviation simulator training. This study was concerned with exploring the impact of operational syllabi and training requirements on these advanced techniques. The Advanced Jet Instrument Training syllabus was selected and analyzed. A demonstration of the application of automated and adaptive techniques to the syllabus was conducted utilizing the R&D simulator at the Naval Training Equipment Center. Several new approaches to performance measurement, syllabus structuring and training control were developed to meet the syllabus requirement and training objectives. The techniques and applications were successfully demonstrated. (Author)

681. MEYER, Robert P., Laveson, Jack I., Pape, Gary L., and Edwards, Bernell J., Development and Application of a Task Taxonomy for Tactical Flying, Design Plus, St. Louis, MO 63141, Contract No. F33615-77-C-0020, sponsored by Air Force Human Resources Laboratory, Williams AFB, AZ 85224, AFHRL-TR-78-42(I), September 1978, 198 pp., AD A061387. Volume II; 66 pp. AD A061388. Volume III; 240 pp., AD A061478.

A taxonomy of tactical flying skills was developed as a user-oriented skill-task analysis sytem for practical application in solving TAC continuation training problems and for a behavioral data base for skill maintenance and reacquisition training research and development. Sixteen representative tactical air-to-air and air-to-surface maneuvers were analyzed and classified within the system with provision for later expansion. A classification system was developed to accommodate the complexities of tactical flying. A data system was organized with sufficient flexibility to objectively address many areas of tactical flying. The taxonomy system also included methodology for addressing on-going training problems and requirements. (Author)

682. SEMPLE, Clarence A., Vreuls, Donald, Cotton, John C., Durfee, D.R., Hooks, J. Thel, and Butler, Edward A., Functional Design of an Automated Instructional Support System for Operational Flight Trainers, Canyon Research Group, Inc., Westlake Village, CA 91361, Contract No. N61339-76-C-0096, sponsored by Naval Training Equipment Center, Orlando, FL 32813 NAVTRAEQUIPCEN 76-C-0096-1, January 1979, 116 pp., AD A065573.

Functional requirements for a highly automated flexible, instructional support system for aircrew training simulators are presented. Automated support modes and associated features and capabilities are described. Hardware and software functional requirements for implementing a baseline system in an operational flight training context are presented. The importance of an effective man-machine interface is discussed as it relates instructor acceptance and system utility. (Author)

683. CARO, Paul W., The Relationship between Flight Simulator Motion and Training Requirements, Seville Research Corporation, Pensacola, FL 32505, Contract No. F96620-77-C-0112, sponsored by Air Force Office of Scientific Research, Bolling AFB, DC 20332, Seville TP 79-10, August 1979, 9 pp., See also Human Factors, v. 21(4): p. 493-501, August 1979.

Flight simulator motion has been demonstrated to affect performance in the simulator, but recent transfer of training studies have failed to demonstrate an effect upon in-flight performance. However, these transfer studies examined the effects of motion in experimental designs that did not permit a dependency relationship to be established between the characteristics of the motion simulated and the training objectives or the performance measured. Another investigator has suggested that motion cues which occur in flight can be dichotomized as maneuver and disturbance cues, i.e., as resulting from pilot control action or from external forces. This paper examines each type cue and relates it analytically to training requirements. The need to establish such relationships in simulator design is emphasized. Future transfer studies should examine specific training objectives that can be expected to be effected by motion. (Author)

684. MITCHELL, David R., Trainee Monitoring, Performance Measuring, Briefing, and Debriefing, First Interservice/Industry Training Equipment Conference, sponsored by Naval Training Equipment Center, Orlando, FL 32813, NAVTRAEQUIPCEN IH-316, November 1979, p. 117-121.

The purpose of this paper was to present some of the methods that are being employed in today's state-of-the-art digital flight simulators to monitor trainee performance and provide simulator instructors with effective briefing and debriefing tools. Typical methods and system hardware that are being employed are presented. (Author)

685. HITCHCOCK, Lloyd Jr., The Analysis of Human Performance within the Operational Flight Environment, Proceedings, Annual AGARD Meeting of the Aerospace Medical Panel, Toronto, Canada, Advisory Group for Aerospace Research and Development, Paris, France, AGARD Conference Proceedings No. 14, Assessment of Skill and Performances in Flying, September 1966, p. 9-14, AD 661165.

The laboratory detection and evaluation by psychophysical measurements of deterioration in a man's ability to pilot a modern aircraft are subject to four important limitations: (a) an arbitrary standard generally must be assumed; (b) available techniques provide data bearing on no more than two dimensions but these data must then be applied to the full six degrees of freedom of the flight environment; (c) the choice of parameters of performance to be measured will strongly influence the conclusions and interpretations; (d) the same data may lead to conflicting interpretations, depending on the statistical procedures employed. This paper summarizes some of the more popular procedures and attempts to classify them with respect to their dimensional capabilities and the assumptions which define when and how they may be used. (Author)

686. POLIS, B. David, and Martorano, J.J., Plasma Phospholipid Composition as a Biochemical Index to Stress, Proceedings, Annual AGARD Meeting of the Aerospace Medical Panel, Toronto, Canada, Advisory Group for Aerospace Research and Development, Paris, France, AGARD Conference Proceedings No. 14, Assessment of Skill and Performance in Flying, September 1966, p. 79-90, AD 661165.

On the premise that diverse physiological reactions to stress have common chemical parameters, changes in phospholipid composition were investigated in various stress conditions using blood plasma of the human as source material. Exposure of humans to acceleration stress from head-to-foot $(+G_z)$ for a time sufficient to induce grey-out or black-out significantly increased the total plasma phospholipid content by about 70%. But more marked was the fourfold increase in phosphatidyl glycerol. Centrifugation of subjects in chest-to-back positions $(+G_x)$ for time periods insufficient to induce cyanosis showed no marked changes in total phospholipid, but some increase in phosphatidyl glycerol. Subjects laboring under the stress of schizophrenia gave the highest observed levels of phospholipid. In these subjects, both lecithin and sphingomyelin were outstandingly elevated compared to normals.

These data suggest that the phospholipid composition of the human blood plasma reflects the action of cerebral metabolic control factors. The resolution of these factors and the bioenergetic role of phospholipids like phosphatidyl glycerol offer an investigative approach, both to biochemical recognition of biological response to stress and to a protective methodology. (Author).

687. SQUIRES, Russell D., The Electroencephalogram as a Physiological Criterion of Performance, Proceedings, Annual AGARD Meeting of the Aerospace Medical Panel, Toronto, Canada, Advisory Group for Aerospace Research and Development, Paris, France, AGARD Meeting of the Aerospace Medical Panel, Toronto, Canada, Advisory Group for Aerospace Research and Development, Paris, France, AGARD Conference Proceedings No. 14, Assessment of Skill and Performance in Flying, September 1966, p. 91-102, AD 661165.

Indications of physiological changes within the central nervous system concomitant with psychologically measured deterioration in performance can be obtained from the electroencephalogram (EEG). Continuous monitoring of selected frequency components of the EEG has been found to provide an objective estimation of an individual's level of wakefulness as well as an evaluation of the extent and duration of his visually directed attention. Equipment designed for such studies has recently been developed in this laboratory. It is now being used in evaluating the effect of certain metabolites and drugs on sleep-walking cycles and on the level of intensity of visual attention. (Author)

688. BENSON, A.J., and Rolfe, J.M., The Use of Psychophysiological Measures in the Assessment of Operator Effort, Proceedings, Annual AGARD Meeting of the Aerospace Medical Panel, Toronto, Canada, Advisory Group for Aerospace Research and Development, Paris, France, AGARD Conference Proceedings No. 14, Assessment of Skill and Performance in Flying, September 1966, p. 101-114, AD 661165.

The level of activity in physiological systems which are under the control of the autonomic and somatic nervous system, may be considered to reflect, inter alia, the mental and physical "effort" demanded by the task.

As the operator attempts to maintain control to a prescribed standard, variations in task dynamics, display or output characteristics may not be revealed by measures of performance on the basic task, although the loads imposed by the task differ. Attempts have been made to assess operator load using both psychological and physiological techniques.

In psychological terms one method has been to use a secondary task. Such a technique is founded upon an assumption of a fixed performance capacity of the human oeprator. It is argued by the experimenter that differences in the demand placed upon the subject by variations in the experimental task will be shown by the level of performance the subject is able to produce on the secondary task whilst maintaining the required level of performance on the experimental task. A second method of measuring operator "effort" is provided by recording physiological activity (e.g. heart rate, skin resistance, muscle activity, respiratory rate and ventilation).

The result of experiments on subjects who performed simple closed sequence control tasks, and those of greater complexity provided by the simulated and actual flying task, are described. The limitations of psychophysiological measures in behavioral studies also are discussed. (Modified author).

689. GOMER, Frank E., Beideman, Larry R., and Levine, Sheldon H., The Application of Biocybernetic Techniques to Enhance Pilot Performance During Tactical Missions, McDonnell Douglas Corporation, St. Louis, MO 63166, Contract No. MDA-903-78-C-0181, sponsored by Defense Advanced Research Projects Agency, MDC E2046, October 1979, 165 pp.

This report describes a rather novel means of enhancing man's performance in highly complex, crew station environments. Specifically, we have related the benefits of on-line evaluation of physiological data to projected mission requirements for a 1990 tactical aircraft.

The salient role that tactical air power must continue to play in the structure of U.S. defense forces has engendered a sophisticated technological approach to weapon system development. Therefore, we begin with an overview of the components of a "high technology" weapon system - real-time command and control, advanced crew station and avionics design, effective defense suppression, sensor aided target acquisition, and precision-guided ordnance. Although a reliance upon advanced technology and a trend toward greater automation of aircraft functions are clearly evident, the importance of the human element should not be underestimated. This is especially true if the system is to retain the capacity to anticipate and respond to unpredictable threats. Herein lies the present dilemma. Man-in-the-loop assures that tactical aircraft will have an inherent flexibility. However, if man is unable to perform increasingly complex tasks both rapidly and accurately under all combat situations, he may severely limit, and perhaps even undermine, the inventive technology of the system he controls.

It may be possible to solve this problem by taking advantage of the same improvements in digital computation and signal processing that currently influence hardware development. That is, we may enhance the pilot's effectiveness if we monitor momentary fluctuations in attentiveness and in his ability to process information and make appropriate decisions. The report summarizes research which has demonstrated that these mental activities are manifest in distinct electrophysiological signals, and that such signals, recorded noninvasively and unobtrusively, can be analyzed and interpreted in real-time.

For a variety of mission segments we then outline the courses of action which can be taken to unburden or assist the pilot if biological signal processing has forewarned an imminent deterioration in his capacity to perform.

The recording and analysis of electrophysiological data also may permit a direct coupling of the pilot with aircraft subsystems from a control standpoint. At issue is whether it will be possible to interpret bioelectric patterns related to different thought commands, whereby the pilot can "think" to activate control surfaces.

We are aware that a great deal more must be accomplished (in computer technology, software development, and the design of physiological monitoring equipment) before it is both feasible and practical to apply biocybernetic techniques in dynamic, operational environments. Nonetheless, we have attempted to clarify important basic research issues and to recommend reasonable priorities for future investigations. (Author)

690. BERGERON, Hugh P., "Pilot Response in Combined Control Tasks," Human Factors, v. 10(3): p. 277-282, June 1968.

Pilot response in a multi-task simulation, which consisted of a primary control task combined with one or two secondary or side control tasks, was investigated. A general description of the response characteristics of each of these tasks was obtained and this information was used to determine the work-load requirements of the tasks. Two different control tasks were used as the primary control task, either a fixed-base simulation of a lunar letdown or a simplified multi-loop tracking task which was similar to the end portion of the lunar letdown. The simplified tracking task was used in lieu of the more complicated lunar letdown because it could be represented and reproduced analytically. The secondary or side tasks consisted of a system failures task and a motor response task. The system failures task was incorporated from those systems present in a vehicle known as the Mercury Procedures Trainer. The motor response task was similar to that presented by the late Dr. Fitts of the University of Michigan. The task consisted of using a pencil-like device to make impacts on two separated, restricted columns.

An evaluation of the pilot's capability in controlling the multi-task simulation and a determination of the inter-task correlation was made. It was shown that either of the two side tasks produced similar effects on the primary task. Quality measurements were made of all three tasks in all possible combinations. The degradation of each, when in the combined task tests, was then correlated to the other task(s) of the same test. A simple relationship was found by which one could predict the time required of a human operator to perform the particular task(s) in question. This relationship could be used to determine the workloading qualities of the task when performed either alone or combined. An analytical representation for the degraded pilot response in the multi-loop tracking task was also obtained. (Author)

691. SIMMONS, Ronald R., Kimball, Kent A., and Diaz, Jamie J., Measurement of Aviator Visual Performance and Workload During Helicopter Operations, U.S. Army Aeromedical Research Laboratory, Fort Rucker, AL 36362, USAARL Report No. 77-4, December 1976, 32 pp., AD A035757. See also Human Factors, v. 21(3): p. 353-367, June 1979.

This report was initiated to review the techniques and modifications developed by the U.S. Army Aeromedical Research Laboratory for assessing visual performance/workload of pilots during helicopter operations. Although the corneal reflection technique for gathering eye movement data is not new, innovative modifications had to be developed to permit accurate data collection in this flight environment. This study reports on these techniques, modifications, and applications. (Author).

692. CHILES, W. Dean, Objective Methods for Developing Indices of Pilot Workload, Federal Aviation Administration, Oklahoma City, OK 73125, FAA-AM-77-15, July 1977, 43 pp., AD A044556.

This paper discusses the various types of objective methodologies that either have been or have the potential of being applied to the general problem of the measurement of pilot workload as it occurs on relatively short missions or mission phases. Selected studies that have dealt with the workload measurement problem or some similar problem are reviewed in relation to their applicability to securing answers to operational questions. The types of methods are classified as: laboratory, analytic and synthetic, simulator, and in-flight. The paper concludes with a general discussion of the relative merits and some of the cautions to be observed in attempting to apply these methods and in trying to interpret the results with a view toward generalizing to operational situations. (Author)

693. CHILES, W. Dean, Ellis, George A., and Roscoe, Alan H., Assessing Pilot Workload, Advisory Group for Aerospace Research and Development, Paris, France, AGARDograph No. 233, February 1978, 84 pp., AD A051587.

The assessment of levels of pilot workload associated with the various phases and sub-phases of flight is important in the design, development, and evaluation of aircraft handling qualities and of display and guidance systems. This AGARDograph, written primarily for flight test engineers and pilots, is intended as a guide to the different methods available for estimating workload and in particular to those techniques suitable for use in aircraft. An introductory chapter briefly reviews the various concepts and classifications of workload; the former tend to fall into two main areas, those related to workload as task-demands and those to workload as pilot-effort. In Chapter 2, subjective assessment, at present the most used method, is discussed from the viewpoint of the test pilot. Physiological methods in general are reviewed in Chapter 3 with those techniques available for use in flight being discussed in more detail. Chapter 4 describes various objective methods and presents examples of their practical application. Whereas the methods in Chapter 2 and 3 are appropriate only to workload as effort, objective methods contain techniques appropriate to workload as task-demands as well as to effort. The former techniques are particularly valuable for providing data which can be used to construct models and to predict levels of workload. Different modelling techniques will be discussed in a proposed supplement entitled Engineering Methods. (Author)

694. GERATHEWOHL, S.J., Brown, E.L., Burke, K.A., Kimball, K.A., Lowe, W.F., and Stackhouse, S.P., "Inflight Measurement of Pilot Workload: A Panel Discussion," Aviation, Space, and Environmental Medicine, v. 49(6): p. 810-822, June 1978.

A group of U.S. scientists engaged in inflight measurements of pilot workload discussed the problems and aspects of workload; the techniques used for inflight measurements; the various workload models, such as design-oriented, operational, psychological, and physiological concepts; different experimental approaches; and experiences, results and further plans, during the 48th Annual Scientific Meeting of the Aerospace Medical Association in Las Vegas, NV, on May 10, 1977. The contributions by the chairman and the five panel members are summarized. (Author)

695. WIERWILLE, Walter W., and Williges, Robert C., Survey and Analysis of Operator Workload Assessment Techniques, Systemetrics, Inc., Blacksburg, VA 24060, Contract No. N00421-77-C-0083, sponsored by Naval Air Test Center, Patuxent River, MD 20670, S-78-101, September 1978, 206 pp., AD A059501. (See also Article 668).

Over 400 references relating to operator mental workload were selected and classified according to a two-dimensional scheme including workload methodology and universal operator behavior. Twenty-eight specific techniques of assessing workload by means of subjective opinions, spare mental capacity, primary task, and physiological measures were cataloged. This catalog summarizes critical criteria that need to be considered in the flight test and evaluation environment and describes each technique in terms of theory and background, description of necessary method/apparatus, area of application and example, limitations, and suggested RDT&E follow-ups. (Author)

696. CHILES, W. Dean, and Alluisi, Earl A., "On the Specification of Operator or Occupational Workload with Performance-Measurement Methods," Human Factors, v. 21(5): p. 515-528, October 1979.

Five system-output or performance-measurement methods have been described in the literature for use in operator or occupational workload specifications: laboratory, analytic, synthetic, simulation, and operational-system methods. A review and analysis of these methods indicates that laboratory methods, where appropriate, are the methods of choice, with the synthetic-work technique especially well suited to examinations of general workload questions. Analytic and synthetic methods appear to yield reasonable results, but both rest on relatively fragile data bases; with correction of this deficiency and further research on time-sharing behavior or function interlacing, these methods should prove to be quite helpful, especially in systems designs and workload allocations. Simulation methods have the potential of providing quite useful information on operator workload, but simulators have not generally been employed for this purpose, and some of the difficulties implicit in their use are discussed. Operational-system methods, except for some possible safety limitations, can be used on virtually any workload-specification problem suitable for investigation in a simulator, but the problems of data recording can be substantial, and often there is little agreement on what should be measured as criteria of good performance. The need for reliable, valid, quantitative criteria to reflect system performance is stressed, and a potentially useful paired-comparisons scaling procedure is described. (Author)

697. OGDEN, George D., Levine, Jerrold M., and Eisner, Ellen J., "Measurement of Workload by Secondary Tasks," Human Factors, v. 21(5): p. 529-548, October 1979.

The post-1965 literature on the use of secondary tasks in the assessment of operator workload was surveyed. Twelve classes of tasks were identified; the most frequently used were choice reaction time, memory, monitoring, and tracking. The literature review did not suggest a single best task or class of tasks for the measurement of workload. Limitations in using secondary tasks are discussesd, and directions for future research are presented. (Author)

698. WILLIGES, Robert C., and Wierwille, Walter W., "Behavioral Measures of Aircrew Mental Workload," Human Factors, v. 21(5): p. 549-574, October 1979. (See also Article 668 and 695).

Behavioral research literature pertaining to the measurement of aircrew workload was classified into general categories of subjective opinion, spare mental capacity, and primary task metrics. Fourteen specific classes of workload measures related to these general categories were reviewed specifically in regard to aircrew workload assessment in the flight test and evaluation. Each class of measures was summarized in terms of background, applications, and implications for research and implementation. It was concluded that no one, single measure can be recommended as the definitive behavioral measure of mental workload. Due to the multidimensionality of workload, it appears that the most promising assessment procedure should include multiple measures of subjective opinions, spare mental capacity, and primary task measures as well as physiological correlates. (Author)

699. WIERWILLE, Walter W., "Physiological Measures of Aircrew Mental Workload," Human Factors, v. 21(5): p. 575-593, October 1979. (See also Article 668 and 695).

Physiological measures of aircrew mental workload were divided into fourteen specific classes. Each class was then summarized in terms of background, applications, and implications for research and implementation. It is concluded that several physiological measures appear promising, but that more research is needed to provide convincing evidence of viability. Physiological techniques can, however, be combined with other workload assessment techniques to provide a more complete understanding of the workload associated with given aircrew tasks. (Author)

700. ADAMS, James J., and Bergeron, Hugh P., Measured Variation in the Transfer Function of a Human Pilot in Single-Axis Tasks, National Aeronautics and Space Administration, Hampton, VA, NASA TN D-1952, October 1963, 56 pp.

Measurements of the variations in the transfer function of a human pilot, relating visual stimuli to stick controller output, in a single-degree-of-freedom fixed-base simulator have been made by using an automatic model matching technique. Variations in subjects, controlled dynamics (from simple amplifiers to a double integration), display sensitivity, control sensitivity, and type of task (from compensatory tracking to pursuit tracking) were included in the tests.

The results show that the pilot changes his transfer function whenever any element in the control loop is changed. Whereas wide variations in the transfer functions were measured, variations in the closed-loop characteristics were much more restricted. (Author)

701. BERGERON, Hugh P., and Adams, James J., Measured Transfer Functions of Pilots During Two-Axis Tasks with Motion, National Aeronautics and Space Administration, Hampton, VA, NASA TN D-2177, March 1964, 40 pp.

Measurements of human transfer functions, made by matching an analog pilot to a human pilot, have been obtained in tests where the variables were the number of axes being controlled, and operation with and without cockpit angular motion corresponding to the indicated error. The analog pilot contained three gains which were automatically adjusted to match the pilot. The tests were made with a gimbal-mounted simulator in which the simulated dynamics represented an inertia system with linear damping and control 2/s(s + 1) where s is the LaPlace transform.

The results show that although a pilot operates in a manner similar to a linear mechanism with constant gains when in a fixed-base, single-axis control loop, the addition of a second axis to his task causes him to operate with time-varying gains. The further addition of motion to the simulation greatly reduces the amount of time variation in the measured gains of the pilot. The tests show that the measuring method promises to be a very useful means for obtaining data on human characteristics. (Author)

702. BARON, Sheldon, and Kleinman, David L., The Human as an Optimal Controller and Information Processor, Bolt Beranek and Newman, Inc., Cambridge, MA, Contract No. NAS 12-104, sponsored by National Aeronautics and Space Administration, Washington, DC, NASA CR-1151, September 1968, 71 pp., N 68-33304.

A mathematical model of the human operator in multivariable control tasks is developed by considering the human as a control and information-processing system. The model contains elements for describing the operator's inherent physiological limitations as well as his instrument-monitoring, data-reconstruction and control behavior. Special emphasis is placed on the instrument-monitoring aspects of the model.

The human's limitations are modelled by combining them into an equivalent perceptual time delay and an equivalent observation noise. The main assumption underlying the subsequent theoretical investigations is that the well-trained, well-motivated operator behaves in a near optimal manner, subject to the constraints imposed by the above limitations. Thus, the operator's control behavior is assumed to be that of an ideal feedback controller. The human's data-reconstruction process is chosen so as to obtain a "best" estimate of the state of the controlled element based on information obtained from "sampling" the various instruments. The data reconstructor consists of a Kalman estimator and a predictor in tandem, its structure is fixed but it depends, parametrically, on the sampling behavior.

Instrument-monitoring behavior depends explicitly on the control task and on the control actions. Provision is made for the ability to obtain information from the peripheral visual field and there are no restrictions on signal coupling. The visual sampling model also includes means for constraining instrument scanning rates. The specific characteristics of the operator's visual sampling behavior are predicted by solving a nonlinear optimization problem. This problem is precisely formulated and methods for its solution are discussed. By changing the variances of the observational noises it is possible to predict the effects that changes in the visual display panel will have upon the human's sampling behavior. Finally, instrument sampling characteristics for a simple two-axis compensatory tracking task are obtained. The results exhibit the general characteristics one would expect from a human operator performing a similar task. (Author)

703. ASKREN, William B., and Regulinski, Thaddeus L., "Quantifying Human Performance for Reliability Analysis of Systems," Human Factors, v. 11(4): p. 393-396, August 1969.

A general mathematical model of the probability of errorless human performance was derived and equated to human reliability for time-continuous tasks. The application of this model and the implications of the time-to-first-human-error (TTFHE) concept were tested with data collected using a laboratory vigilance task. The error data were ordered, and through classical inference theory the underlying density functions were isolated and tested for goodness of fit. Weibull, gamma, and log-normal distributions emerged as relevant; normal and exponential distributions were rejected. The relevant distribution parameter values were applied to the general mathematical model, and predictions were made of human performance reliability for the task. It was concluded that this is a feasible and meaningful way to quantify human performance for time continuous tasks for use in reliability analyses of systems. (Author)

704. KLEINMAN, David L., and Baron, Sheldon, Manned Vehicle Systems Analysis by Means of Modern Control Theory, Bolt Beranek and Newman, Inc., Cambridge, MA 02138, Contract No. NAS12-104, sponsored by National Aeronautics and Space Administration, Washington, DC 20546, NASA CR-1753, June 1971, 194 pp., N71-31373.

Modern control and estimation theory is used to provide a framework for the analysis of manned-vehicle systems. By assuming that the human behaves "optimally" in some sense, subject to his inherent psychophysical limitations, a quantitative model is developed for the response characteristics of the human operator. The resultant model can be used to predict task performance, scanning behavior and frequency doman characteristics. The model is described in detail and is used to predict experimentally measured quantities in both single and multi-axis compensatory tracking tasks. Remarkable agreement between measured and predicted quantities is obtained, demonstrating the value and potential of the optimization approach to manned-vehicle systems analysis. (Author)

705. BARON, Sheldon, and Berliner, Jeffrey E., The Effects of Deviate Internal Representations in the Optimal Model of the Human Operator, Bolt Beranek and Newman Inc., Cambridge, MA 02138, DA Project No. I 362303A214, sponsored by U.S. Army Missile Research and Development Command, Redstone Arsenal, AL 35809, Technical Report TD-CR-77-3, July 1977, 22 pp., AD A045003.

This report gives some of the issues and equations involved in predicting closed-loop man-machine performance for situations in which the human operators' knowledge of the system and/or environment are imperfect. Several examples to demonstrate some of the effects to be expected when such is the case are then given. (Author)

706. ENGLER, Harold F., Davenport, Esther L., Green, Joanne, and Sears, William E. III, Human Operator Control Strategy Model, Georgia Institute of Technology, Atlanta, GA 30332, Contract No. F33615-77-C-0042, sponsored by Air Force Human Resources Laboratory, Wright-Patterson AFB, OH 45433, AFHRL-TR-79-60, April 1980, 140 pp., AD A084695.

Present measures of performance during training are inadequate for sensitively describing cue utilization, for assessing individual differences, and for predicting transfer of training to other tasks. The present research attempted to approach this problem by developing a computer simulation of continuous motor control learning, including a representation of control strategy, and applying the simulation to measurement of human control strategy. Initial demonstration and validation tests indicate that the simulation is able to identify aspects of human control strategy, and that such identification may provide a more sensitive measure of performance. (Author)

707. HUDDLESTON, H.F., Measuring the Pilot's Contribution in the Aircraft Control Loop, Proceedings, Annual AGARD Meeting of the Aerospace Medical Panel, Toronto, Canada, Advisory Group for Aerospace Research and Development, Paris, France, AGARD Conference Proceedings No. 14, Assessment of Skill and Performance in Flying, September 1966, p. 57-69, AD 661165.

Engineers and designers are continuously aware of the need to specify the form of the pilot's input to an airborne weapons system, if good design guidelines are to be obtained for research and development purposes. Unfortunately, the fact that the biological sciences frequently have to deal with more complex material than do the physical sciences means that human factors workers are often not prepared to propose or accept a closely quantified description of human control function. In particular, individuals are known to differ between themselves in piloting skill and controlling strategy, and any given individual can vary widely over time, in poorly understood ways which are apparently the result of interaction of an embarrassingly large family of factors.

During research in simulated flight over the last 2 years, the author has been at pains to develop measurement techniques which do not obscure inter-pilot differences in manual control style, but which, at the same time, reduce the data to manageable proportions. On the basis of this research, it is proposed that pilot control strategies may be considered, to a first approximation, as a function of four primary inter-related factors. These are: (1) the ability to erect and test alternative decision hypotheses;

(2) the amount of information felt to be required to reach decision; (3) the perceived urgency of decision; and (4) the sense-data available in the situation for sampling and decision modelling. (Author)

708. KINKADE, Robert G., and Ranc, Maurice P., "The Effect of Conflicting Instructions and Feedback Specificity on Tactical Decision Performance," Human Factors, v. 9(3): p. 257-262, June 1967.

The ultimate goal of study programs concerning tactical decision making is to furnish a set of behavioral principles which will serve as a guideline for designers of command and control systems. Conceptually, tactical decision making may be viewed as a two stage process: the first stage involves perceiving a need for changing existing, or potential, environmental conditions and the second stage involves selecting an action from a more or less well defined set of action alternatives which will change the environmental conditions in the desired direction.

This study was conducted to investigate how the quality of tactical decision performance is affected by a conflict between the decision maker's instructions about his task and the feedback he receives during the task when the specificity of feedback is varied.

The results of this study indicate that instructions which are diametrically opposed to the actual situation will decidedly degrade the quality of decision making performance regardless of the specificity of feedback. The decision maker apparently will continue to perform in accordance with the relationships outlined in his instructions. Although there are isolated historical instances which show that this result has some precedence in operational decision making situations, the dynamics involved are poorly understood.

Similar results were obtained in a previous experiment in this series. This finding supports the view that a decision maker attempts to refine his concept concerning the relationships between his information about the environment and the available decision alternatives on the basis of his feedback. These results lead to the conclusion that when correct instructions are provided, the decision maker modifies his behavior on the basis of his feedback, but when incorrect instructions are provided the decision maker does not modify his behavior. This decision behavior does not appear to be consistent and the reasons for this phenomenon should be investigated further. (Modified author)

709. HAMMELL, Thomas J., Pesch, Alan J., and Lane, William P., Decision-Making Performance Measurement for a Command and Control Training System, Proceedings of the 19th Annual Meeting of the Human Factors Society, Dallas, TX, October 1975, p. 315-320.

A technique has been developed to provide measurement of tactical decision-making performance. A comprehensible mathematical model of the system provides an estimate of the system's effectiveness with regard to accomplishing specific interim and ultimate training and tactical objectives. The effectiveness estimate is based on particular system and situation parameters. The relationship between the operator/trainee's behavior and changes in the system parameters enables the system effectiveness values to provide a relative measure of human performance. (Author)

710. ROSCOE, Stanley N., "Assessment of Pilotage Error in Airborne Area Navigation Procedures," Human Factors, v. 16(3): p. 223-228, June 1974.

In 1969, by specifically including "pilotage error" in the error budget for area navigation system certification, the Federal Aviation Administration legally attached economic premiums and penalties to human, as well as equipment, performance in man-machine system design. To establish the accuracy of use and freedom from pilot blunders associated with systems employing various configurations of displays and controls requires both simulator and flight experimentation. An automatically adaptive cockpit side task provides a saturating level of pilot workload and allows the sensitive, orderly, and statistically reliable measurement of a pilot's residual attention as a common metric for area navigation system assessment. (Author)

711. LEWIS, Ronald E.F., Navigation at Very Low Level: Methods of Evaluation, Proceedings of a Conference on Aircrew Performance in Army Aviation Held at U.S. Army Aviation Center, Fort Rucker, Alabama, on November 27-29, 1973, Office of the Chief of Research, Development and Acquisition (Army) and U.S. Army Research Institute for the Behavioral and Social Sciences, Arlington, VA 22209, July 1974, p. 149-152, AD A001539.

The Canadian Forces have been interested for about a decade in the results of behavioral research in nap-of-the-earth (NOE) flying. The Defence and Civil Institute of Environmental Medicine in Toronto undertook to study the navigational problems associated with this kind of flying.

This paper discusses two issues. First, it argues for more field trial research in matters related to NOE. Second, questions are posed that may, if answered, make operational NOE flying more effective.

The writer concludes that behavioral research can ease the lot of the NOE aviator if some salient questions are answered by means of carefully designed field trials.

In summary, more field trials, carefully designed and of a fairly extensive nature, should be used to complement experiments done in the laboratory. These trials have limitations but often unexpected observations can be made concerning incidents which may escape notice when more conventional methods are used. (Modified author)

712. FITZGERALD, Joe A., Wise, John A., Rutkowski, Robert E., and Biolchini, Paul D., An Application of Manned Simulation in Crew Station Conceptual Development, Proceedings of the 24th Annual Meeting of the Human Factors Society, Los Angeles, CA, October 1980, p. 286-388.

The McDonnell Aircraft Company's Manned Air Combat Simulator is being used in the early design and evaluation phases of an advanced real-time reconnaissance aircraft. The cockpit arrangement and control logic have been implemented in the engineering development simulator. To date there have been two formal human factors evaluations of th system under simulated operational conditions. This presentation outlines the procedures used, the results, and their impact upon the design. (Author)

713. VREULS, Donald, and Obermayer, Richard W., Study of Crew Performance Measurement for High-Performance Aircraft Weapon System Training: Air-to-Air Intercept, Manned Systems Sciences, Inc., Northridge, CA 91324, Contract No. N61339-70-C-0059, sponsored by Naval Training Device Center, Orlando, FL 32813, NAVTRADEVCEN 70-C-0059-1, February 1971, 218 pp., AD 727739.

A study was undertaken to develop performance measurement and methods for deriving performance measurement for F-4J air-to-air intercept training in an envisioned adaptive and automated training environment. It was found that a combined analytic-empirical test method was mandatory for defining measurement for adaptive training. The functional relationships between measures, the tasks and the adaptive variables must be known in order to properly design an adaptive logic. Single measure feedback control for adaptive training of multi-dimensional tasks did not appear feasible. A simplified method to handle multi-dimensional measurement based on tolerance bands was suggested. Using this approach a set of candidate measures for the Pilot, for the Radar Intercept Officer, and for the Crew composed of both were analytically derived. Further tests of the measures were recommended. It was concluded from a measurement viewpoint that an automated weapon system trainer was feasible provided that empirical tests of the measurement relationships to the task and adaptive variables are conducted. All measurement algorithms must be tested throughout the entire operating range because idiosyncratic behavior of the trainee cannot be predicted by analysis. (Author)

714. BURGIN, George H., Fogel, Lawrence J., and Phelps, J. Price, An Adaptive Maneuvering Logic Computer Program for the Simulation of One-on-One Air-to-Air Combat, Decision Science, Inc., San Diego, CA 92109, Contract No. NAS1-9115, sponsored by National Aeronautics and Space Administration, Washington, DC 20546, NASA CR-2582, September 1975, 73 pp., N75-30817.

A novel technique for computer simulation of air combat is described. Volume I describes the computer program and its development in general terms. Two versions of the program exist. Both incorporate a logic for selecting and executing air combat maneuvers with performance models of specific fighter aircraft. In the batch processing version the flight paths of two aircraft engaged in interactive aerial combat and controlled by the same logic are computed. The real-time version permits human pilots to fly air-to-air combat against the Adaptive Maneuvering Logic (AML) in Langley Differential Maneuvering Simulator (DMS). Volume II consists of a detailed description of the computer programs. (Author)

715. de LEON, Peter, The Peacetime Evaluation of the Pilot Skill Factor in Air-to-Air Combat, The Rand Corporation, Santa Monica, CA 90406, Contract No. F44620-73-C-0011, sponsored by U.S. Air Force Headquarters, Washington, DC 20330, Rand report R-2070-PR, January 1977, 64 pp., AD A039880.

An attempt was made to develop an objective measure for peacetime evaluation of a fighter pilot's air-to-air combat skills. Previous research and combat data from Korea and North Vietnam suggest that the skill of the individual pilot is crucial in the outcome of an aerial engagement. However, it has not been possible to estimate the actual effect or to identify what makes him superior. The Air Force cannot currently evaluate its pilots' air-to-air skills objectively during either their training or operational assignments. This report proposes four research areas that address the effectiveness and evaluation of these pilots: the selection of the prospective pilot from his undergraduate pilot training program, the air-to-air portions of his combat crew training squadron curriculum, the more efficient management of pilot resources, and an examination of the costs and benefits of dissimilar air combat training. It also proposes the development of a pilot skill index. (Author)

716. CIAVARELLI, Anthony P., and Brictson, Clyde A., Air Combat Maneuvering Range (ACMR): Has Operational Performance Measurement Entered a Golden Age? Proceedings of the 22nd Annual Meeting of the Human Factors Society, Detroit, MI, October 1978, p. 365-368.

Three years of aircrew performance measurement related to air combat effectiveness using the Navy's Air Combat Maneuvering Range (ACMR) are described. Performance assessment methods were based on air combat engagement outcomes (i.e. wins, losses, draws), weapon delivery accuracy measures, and metrics derived from antecedent events. When used in an operational setting, the aircrew assessment methods have been used to identify squadron performance differences, evaluate competitive exercises, and provide diagnostic training feedback to operational users. The use of continuously recorded quantitative measures from systems such as ACMR represents a 'Golden Age' in the performance measurement field. The availability of objective performance criteria promises to be of substantial benefit to both the operational user and the research community in such areas as pilot selection and training, fleet combat readiness and pilot workload and stress. (Author)

717. CIAVARELLI, A.P., Williams, A.M., and Krasovic, F., Operational Performance Measures for Air Combat: Development and Application, Proceedings of the 24th Annual Meeting of the Human Factors Society, Los Angeles, CA, October 1980, p. 560-564.

The content of this paper summarizes four years of research designed to develop valid and reliable performance criteria for the Navy's Tactical Aircrew Combat Training System (TACTS). Performance measurement methods for assessing missile envelope recognition and air combat engagements have been developed and applied in an operational setting. TACTS measures used in performance assessment were selected on the basis of their operational importance and their demonstrated statistical relationship to successful completion of such air combat tasks as missile launch success and engagement outcomes. A measurement framework has evolved and may be appropriately applied to estimate overall air combat effectiveness, and to provide diagnostic performance analysis of critical air combat tasks. The resulting measurement framework has been applied operationally to evaluate U.S. Navy competitive air combat exercises and to provide diagnostic performance feedback to aircrews undergoing TACTS training. More recently, these measures and assessment methods have been incorporated in a computer-based TACTS debrief system called the Performance Assessment and Appraisal System (PAAS). The PAAS is representative of an emerging technology which uses automated performance measurement methods for enhancing the training process. (Author)

718. REEDER, John P., and Kolnick, Joseph J., A Brief Study of Closed-circuit Television for Aircraft Landing, National Aeronautics and Space Administration, Hampton, VA, NASA TN D-2185, February 1964, 7 pp.

A brief study was made of a closed-circuit television mounted in a trainer-type airplane to provide forward view during landing. The results of 45 landings by seven pilots under good visual conditions but with the pilot entirely dependent on the television for vision showed that television provided adequate forward view during the approach, flare, and ground roll. In addition, three take-offs were made which showed that television provided adequate forward view during the ground roll and climb to about 500 feet. Some problems connected with the use of the television for forward view were discussed and some recommendations were made for a practical system. (Author)

719. GRAHAM, Dunston, Clement, Warren F., and Hofmann, Lee Gregor, Investigation of Measuring System Requirements for Instrument Low Visibility Approach, Systems Technology, Inc., Hawthorne, CA 90250, Contract No. F33615-69-C-1904, sponsored by Air Force Flight Dynamics Laboratory, Wright-Patterson AFB, OH, AFFDL-TR-70-102, February 1971, 185 pp., AD 722773.

A practical method of determining measuring system requirements for instrument low visibility approach is presented. The method is made to depend on system analysis of the airplane, its control system, and the guidance system, as well as on atmospheric turbulence inputs and radio guidance system fluctuation noise. Requirements on the system are set in terms of a low value of the accident exposure multiplier which is related to the probability of a missed approach in the assumed environment.

The application of the method is demonstrated in connection with two examples: manual-flight director approach in the A-7D attack airplane, and automatically coupled approach with an advanced "windproof" flight control system in the DC-8 transport aircraft. The results, including particularly the implied requirements on scan rate for a scanning beam instrument low visibility approach system, demonstrate the interconnections between scanning rate, flight control, and overall system performance. (Author)

720. HYATT, Christopher J., and DeBerg, Oak H., A Scoring System for the Quantitative Evaluation of Pilot Peformance During Instrument Landing System (ILS) Approaches and Landings, Aeronautical Systems Division, Wright-Patterson AFB, OH 45433, ASD-TR-74-19, July 1974, 16 pp., AD A000422.

In the course of various studies, starting with a comparison of center and side control sticks in 1970, the Crew Station Design Facility (CSDF) at Wright-Patterson AFB, Ohio, has had need of an objective and quantitative method of evaluating pilot performance during ILS approaches and landing. To meet this need, the CSDF, in conjunction with the facility operating and maintenance contractor, the Singer Company, Simulation Products Division, has designed and implemented a numerical scoring system which reads out directly from the facility's simulator in real time. Its use in various studies and comparison with other measures of performance has demonstrated its repeatability and indicates that the scores are meaningful.

This paper describes the principle of the system, and gives an outline of the form in which is it currently being used. (Modified author).

721. PUIG, J.A., Johnson, R.M., and Charles, J.P., Evaluation of an Automated GCA Flight Training System, Proceedings of the Seventh NTEC/Industry Conference Held on 19-21 November 1974, sponsored by Naval Training Equipment Center, Orlando, FL 32813, NAVTRAEQUIPCEN IH-240, November 1974, p. 269-276, AD A000970.

The principal objective of this evaluation is to measure the training effectiveness of an advanced training concept using an Automated Flight Training System (AFTS) GCA Module. This module, developed by Logicon, Inc., was installed at NAS Chase Field, Beeville, Texas for use with a TA-4J Operational Flight Trainer (Device 2F90).

In addition to training effectiveness, per se, curriculum design and its effect on cost-effectiveness of the student training will be examined. As a result of the reset capability of the GCA module, it is possible to run a greater number of students and cover more material in a shorter period of time than with conventional methods. Substitution of trainer time for ground control approach flight training will also be investigated.

Comparisons of training with the GCA module and with conventional techniques will be made. In addition, a transfer of training evaluation will be made to determine how learning by the different techniques is carried over to the operational situation. (Author)

722. HYATT, Christopher J., and DeBerg, Oak H., A Scoring System for the Quantitative Evaluation of Pilot Performance During Microwave Landing System (MLS) Approaches, Aeronautical Systems Division, Wright-Patterson AFB, OH 45433, ASD-TR-75-17, August 1975, 22 pp., AD A025782.

The Crew Station Design Facility's scoring system for ILS approaches and landings has been extended for use with Microwave Landing System (MLS) approaches. The philosophy of scoring systems is briefly discussed, and the rationale for this application is developed. (Author)

723. ROSCOE, Stanley N., "When Day is Done and Shadows Fall, We Miss the Airport Most of All," Human Factors, v. 21(6): p. 721-731, December 1979.

Both the effectiveness of pilot training and the safety of flight can be influenced by the distribution of texture in the visual scene, the distance to which the eyes accommodate, and the associated shifts in the apparent size and distance of objects in central and peripheral vision. Studies reviewed and original results presented indicate that these factors are involved in various misjudgments and illusions experienced by pilots: (1) when searching for other airborne traffic or targets, (2) when making approaches to airports over water at night, (3) when breaking out of low clouds on a final approach to a landing by reference to head-up or head-down displays, and (4) when practicing simulated approaches and landings or air-to-surface weapon deliveries by reference to synthetically generated visual systems. (Author)

724. LEVISON, William H., and Kleinman, David L., Analysis of Pilot/System Performance in Carrier Approach, Bolt Beranek and Newman, Inc., Cambridge, MA 02138, Contract No. N62269-71-C-0015, sponsored by Naval Air Development Center, Warminster, PA 18974, BBN Report No. 2169, September 1971, 114 pp., AD 888283.

An analysis procedure has been developed for predicting pilot/system performance in carrier approach. This procedure, which has the acronym SMAC (Simulated Manual Approach to Carrier), is built upon the optimal-control model for pilot/system behavior developed previously by Bolt Beranek and Newman Inc. It is designed to treat in an explicit manner the range-dependent characteristics of the disturbance inputs and of the pilot's monitoring and control strategy that are peculiar to the carrier approach task. SMAC requires inputs that relate to the system configuration, to performance requirements, and to the pilot's limitations; outputs include predictions of the mean time history of each system variable, of the rms variability of each variable at all points along the approach path, and of pilot as well as open-loop describing functions. Numerical results are presented to demonstrate the capability of this analysis procedure. Cases are selected to illustrate the effects on pilot/vehicle performance of: (a) the carrier air wake, (b) temporary loss of visual feedback to the pilot, and (c) ship motion. (Author)

725. PROSIN, Daniel J., Burger, William J., and Wulfeck, Joseph W., Effect of a Predictor Display on Carrier Landing Performance - Phase B (Display Mechanization and Preliminary Evaluation), Dunlap and Associates, Inc., Santa Monica, CA 90404, Contract No. N00014-71-C-0252, sponsored by Office of Naval Research, Arlington, VA 22217, August 1972, 22 pp., AD 750294.

Phase B of a three-phase program was designed to determine the effect of a predictor display on carrier landing performance; in cooperation with the Human Factors Division, Naval Missile Center, Point Mugu.

Phase A identified pilot information display and display interface requirements during final approach to an aircraft carrier landing; demonstrated a small-scale laboratory mechanization of a fast-time, predictive model of F-4 aircraft dynamics; and developed selected predictor display symbologies and formats. A report, "Effect of a Predictor Display on Carrier Landing Performance-Phase A (Display Development)," concluded Phase A.

Phase B mechanized a unique six degree-of-freedom, fast-time, predictor model of the F-4 aircraft and a six degree-of-freedom, forward-looking, predictor cockpit display, based upon the requirements established in Phase A. A "base-line" display for comparison with the predictor was mechanized as a closed-circuit, gantry-driven, TV system viewing a scale model of a carrier with deck and edge lights, and FLOLS, illuminated in scale to appear as they would at night. The displays of both systems were mounted in the cockpit of a static simulator at Point Mugu programmed for F-4 flight and control dynamics. Informal trials were run with research staff and carrier-qualified pilots to evaluate realism of the displays; amount of training required; sensitivity and reliability of simulation and measurement systems; and recording systems, including a computer program to reduce the data.

The report concludes with a detailed design for formal experimental comparison of the predictor vs the "base-line" display in Phase C using carrier qualified pilots as subjects. (Author)

726. LINTERN, G., Westra, D., Iavecchia, H., and Hennessy, R., Visual Technology Research Simulator (VTRS) Human Performance Research: Phase II, Canyon Research Group, Inc., Westlake Village, CA 91361, Contract No. N61339-78-C-0060, sponsored by Naval Training Equipment Center, Orlando, FL 32813, NAVTRAEQUIPCEN 78-C-0060-2, April 1980, 95 pp.

This report summarizes the research projects in progress for which Canyon Research Group, Inc. have a major responsibility under the VTRS Human Performance Research Contract. Work has continued on Multifactor Performance Testing with carrier landings. A project is also planned to examine relationships between performance and transfer data. Other experiments to test a glideslope rate-cueing display to aid glideslope control, and to test alternative display concepts for teaching basic contact flying skills have been completed. Progress on analysis of data for both of these experiments is reported here. (Author)

727. BRICTSON, Clyde A., and Breidenbach, Steven T., Description of a LSO Carrier Landing Training Aid: Automated Performance Assessment and Remedial Training System (APARTS), Dunlap and Associates, Inc., La Jolla, CA 92037, contract No. N61339-77-C-0166, sponsored by Naval Training Equipment Center, Orlando, FL 32813, NAVTRAEQUIPCEN 77-C-0166-1, April 1980, 36 pp.

A conceptual plan designed to aid the Landing Signal Officer (LSO) in training pilot carrier landing skills is described. The plan, named the Automated Performance Assessment and Remedial Training System (APARTS) employs basic principles of learning in integrating the Night Carrier Landing Trainer (NCLT) with Field Carrier Landing Practice (FCLP). Application of the APARTS conceptual plan resulted in the development of two computer programs, PADDLES and GRADER, which are described and documented. The two computer programs process, store and summarize LSO grades and comments of a pilot's landing performance during FCLP. Individualized training is accomplished through diagnostic training feedback provided by program printouts. NCLT remedial instruction is specified to correct a pilot's landing technique problems identified during FCLP. Future development and integration of APARTS for improved carrier landing training effectiveness is outlined. (Author).

728. BRICTSON, Clyde A., Breidenbach, Steven T., and Stoffer, Gerald R., Operational Performance Measures for Carrier Landing: Development and Application, Proceedings of the 24th Annual Meeting of the Human Factors Society, Los Angeles, CA, October 1980, p. 565-567.

Fifteen years of carrier landing performance criteria development and applications are described. An offshoot of the research resulted in the emergence of an automated performance measurement and appraisal system designed to enhance the effectiveness of night carrier landing. (Author)

729. KUSEWITT, J.B., Development of Criteria and Methods for Evaluating Trainer Aircraft Effectiveness, LTV Aerospace Corporation (Vought Aeronautics Division), Dallas, TX 75222, Contract No. NOw-66-0410-f, sponsored by Naval Air Systems Command, Washington, DC, Report 2-55100/7R-50392, March 1967, 228 pp., AD 651421.

The purpose of this study was to develop a method for determining objective measures of trainer aircraft effectiveness for use in evaluating trainer aircraft program alternatives. The scope of the study was limited to training of pilots for fleet fighter and attack type aircraft.

The training effectiveness of a given aircraft is measured in terms of the productive training flight hours in a total training program context. The fundamental problem which had to be solved in this study was to establish quantitative time-difficulty (complexity) relationships, especially those pertaining to trainer aircraft phasing.

The method developed in the study for the measurement of training difficulty and its several components, including task and aircraft components, has been given the name of Time Demand. The concept is predicated on calculating indices of difficulty (complexity) for the various training situations based on the ratio of time required to the time available. The method was applied at the individual subtask - incremental time level employing human time and deviation distribution terms, aircraft motion terms, and task parameters.

Representative samples of training situation complexities were calculated for all stages of training. From the results it became apparent that the landing approach operation was the primary determinant of aircraft phasing in training. This stems from the fact that this operation is the one in which aircraft complexity increases training complexity in a fully additive fashion. In other training situations the aircraft has less effect on total training difficulty, either because task requirements are relaxed to partially or fully compensate for increased aircraft complexity, or because the aircraft is of lesser contribution to training situtation difficulty. Significantly, the landing approach task is also the training situation attended by the greatest penalty for failure (accidents).

The study also draws a number of conclusions with respect to the nature of flight training, the relative contribution of aircraft and task to the training situation, simulator training, discrete vs continuous components, accident causes, transfer of training, and other facets of the flight training problem.

The Time Demand methodology evolved in this study appears to have potential future application to related problems such as more detailed training analysis, detailed man-machine engineering of weapons systems, and weapons system probability of mission success evaluations. (Author).

730. BLAIWES, Arthur S., Puig, Joseph A., and Regan, James J., "Transfer of Training and the Measurement of Training Effectiveness," Human Factors, v. 15(6): p. 523-533, December 1973.

Transfer of training research has been conducted on actual training systems to determine: (1) the effectiveness of present training; (2) whether the training can be improved; and, (3) how the training might be improved. The present paper includes some major methodological and analytical considerations in performing this research - the experimental and descriptive models to use in investigating and expressing transfer, cost effectiveness evaluations, and aspects of the training system to be included in the study. A number of conclusions are derived from the transfer research and some popular research themes are identified. Desirable features for an applied research program for military training purposes are presented. Problems arising from the use of the transfer of training model are traced to operational constraints placed on experimental manipulation and control, and to the inadequacy of performance measurement systems. Solutions to these problems are discussed. One solution provides alternate methods to the transfer of training model for evaluating the effectiveness of a training system. Another approach recommends the employment of laboratory simulations of training or operational situations for transfer research. (Author).

731. WILLIGES, Beverly H., Roscoe, Stanley N., and Williges, Robert C., "Synthetic Flight Training Revisited," Human Factors, v. 15(6): p. 543-560, December 1973.

Critical issues in the development and use of synthetic flight trainers are reviewed. Degree of simulation and fidelity of simulation are discussed as key design considerations. Problems in measurement of original learning, transfer, and retention are presented. Both transfer effectiveness and cost effectiveness are described as critical factors in the evaluation of flight trainers. Recent training innovations, such as automatically adaptive training, computer-assisted instruction, cross-adaptive measurement of residual attention, computer graphics, incremental transfer effectiveness measurement, and response surface methodology, are discussed as potential techniques for improving synthetic flight training. It is concluded that broader application of simulation is necessary to meet the new demands of pilot training, certification, and currency assurance in air transportation. (Author)

732. MATHENY, W. Guy, Training Simulator Characteristics: Research Problems, Methods, and Performance Measurements, Proceedings of a Conference on Aircrew Performance in Army Aviation Held at U.S. Army Aviation Center, Fort Rucker, Alabama on November 27-29, 1973, Office of the Chief of Research, Development and Acquisition (Army) and U.S. Army Research Institute for the Behavioral and Social Sciences, Arlington, VA 22209, July 1974, p. 137-140, AD A001539.

Three major areas may be identified as being of prime importance to the effective functioning of a man/machine system such as an aircraft in nap-of-the-earth flight. Attention to these, how they interact, and the trade-offs which may be made for their most appropriate combination, can result in the most effective system at least cost. These areas are: (1) system design including the procedures for system operation, (2) operator selection for those basic abilities and skills most compatible with system operation requirements, and (3) operator training. As a practical matter, in developing a system and getting it to work, these major areas interact, there are trade-offs among them, and there is a pushing and pulling among them throughout the life of the system. This discussion addresses the area of training. Specifically, it centers upon a proposed method whereby training research may be expedited and the results of that research made available for configuring training systems at reduced time and cost.

A method which can give definitive answers to training method and trainer design questions in less time and at substantially less cost than is required by classical transfer-of-training experiments is proposed. By training method research is meant how the training simulator is used. Training device research refers to the trainer configuration in respect to characteristics such as motion, visual attachments, equations of motion, and the like.

The substitution of a perceptual equivalence concept in training research for the classical transfer-of-training paradigm provides a criterion device against which a broad spectrum of training methods, devices, procedures and methods of performance measurement, and training simulator configurations may be evaluated. (Modified author)

733. SHELNUTT, Jack B., Smillie, Robert J., and Bercos, James, A Consideration of Army Training Device Proficiency Assessment Capabilities, Defense Sciences Laboratories, Fort Benning, GA 31905, Contract No. DAHC 19-77-C-0011, sponsored by U.S. Army Research Institute for the Behavioral and Social Sciences, Alexandria, VA 22333, ARI-TR-78-A20, June 1978, 73 pp., AD A056191.

This report reviews the procedures and problems involved in the assessment of the use of training devices as a cost-effective alternative to the use of operational equipment for the evaluation of individual and collective proficiency in the U.S. Army. A review of the literature was conducted as well as an informal survey of personnel in other agencies who are involved in the use of training devices for proficiency assessment. This information was employed to: (a) review the use of training devices in proficiency assessment programs by agencies other than the Army; (b) to summarize aspects of proficiency test programs in the Army which are relevant to the present problem; and (c) to discuss issues which need to be considered in the assessment of the utility of using training devices for proficiency assessment. Recommendations were provided for future research planning. (Author)

734. DE BOTTON, Isaac, "Human Factors Evaluation of Head-Up Display and Flight Performance by Photography and Data-Reduction Methods," Human Factors, v. 10(1): p. 41-52, February 1968.

A photographic method is presented which can determine flight parameters, and many measures of the quality of an electronic Head-Up Display which uses Microvision^{RI} and an electronic horizon as real world information. In conjunction with pilot input factors and pilot acceptance and evaluative factors which can be obtained through other means, there are enough parameters to relate the quality of the display to good flight performance. One method proposed involves the taking of motion pictures through the head-up display while the pilot is using it to fly the airplane. With the use of a film reader, the x and y coordinates of 12 points are obtained as the raw data. This, in turn, through simplified approximate formulas, can be converted to flight parameters and quality of the display which, in turn, can be related to flight performance. (Author)

735. ROSCOE, Stanley N., "Airborne Displays for Flight and Navigation," Human Factors, v. 10(4): p. 321-332, August 1968.

This paper deals with certain types of airborne displays, specifically, those used in navigating and flying aircraft.

Consideration is given to the nature of the crew's flight task, to certain principles of flight display, and to some of the experimental evidence bearing on principles of display. (Author)

736. KNOWLES, William B., Burger, William J., Mitchell, Meredith B., Hanifan, Donald T., and Wulfeck, Joseph W., "Models, Measures, and Judgements in System Design," Human Factors, v. 11(6): p. 577-590, December 1969.

This paper assumes increasing use of analytical models in system design. Some characteristics of such models and requirements for human performance data compatible with them are discussed. Methods of obtaining human performance data for use in design models are considered. The use of expert judges to generate performance measures is reviewed. Two new studies are reported in support of the proposition that expert judgments may offer a practical method of obtaining performance measure with potentially wide application in analytical modeling efforts. (Author)

737. JOHNSON, Steven L., and Roscoe, Stanley N., "What Moves, the Airplane or the World?" Human Factors, v. 14(2): p. 107-129, April 1972.

The literature pertaining to motion-relationship variables in the display of airplane flight attitude and steering commands and their effects upon pilot performance is reviewed. Factors considered include: (1) figure and ground relationships, (2) control-display relationships, (3) whether the airplane or the horizon is the moving element of the display, and (4) whether the presentation of steering commands result in pursuit or compensatory tracking. The frequency-separation principle is an unexplored approach to the solution of display motion relationship problems. A concluding set of requirements for future research is based on problems encountered in previous investigations of display motion relationships. (Author).

738. SCANLAN, L.A., and Carel, W.L., Human Performance Evaluation of Matrix Displays: Literature and Technology Review, Hughes Aircraft Company, Culver City, CA 90230, Contract No. F33615-74-C-4083, sponsored by Aerospace Medical Research Laboratory, Wright-Patterson AFB, OH 45433, AMRL-TR-76-39, June 1976, 205 pp., AD A029932.

In recent years a number of different types of "flat-panel" displays have been developed which utilize large arrays of discrete display elements for the presentation of symbolic and sensor information. These displays offer several advantages over the conventional cathode ray tube, including reductions in display volume, weight, and power requirements. Included in this class of matrix displays are light emitting diode (LED) arrays, flat panel cathode ray tubes (e.g., the Digisplay), AC plasma and liquid crystal displays. This spectrum of displays allows the designer a new freedom in selecting the most appropriate display type for a given task and environment. To make such decisions successfully, designers need data relating specific display design parameters to measures of system performance. The most critical information that a designer needs concerns those parameters that affect the performance of the operator using the displays. The operator must be able to obtain from the display the information he needs to perform his task(s), to some minimum level of acceptability, under the poorest expected operational circumstances.

Little of the mass of literature on display design parameters and human performance research has been oriented to this new class of matrix displays. Therefore, a comprehensive evaluation of advanced display technology, in terms of its effects on human performance and the resultant human factors requirements thus implied, was needed to provide display systems designers with appropriate direction, design criteria, and trade-off data.

The objective of this program was, therefore, to identify the functional relationships between design aspects of advanced displays and human performance. This was accomplished through a survey of the current and forecasted electronic display state-of-the-art and a critical review of relevant human factors data. This survey and review covered the design aspects of symbolic and sensor data displays. (Author).

739. HELM, Wade R., and Donnell, M.L., System Operability: Concept and Measurement in Test and Evaluation, Proceedings of the 22nd Annual Meeting of the Human Factors Society, Detroit, MI, October 1978, p. 46-50. Pacific Missile Test Center, Pt. Mugu, CA 930440, PMTC TP 79-31, October 1979, 77 pp.

During system test and evaluation a human factors specialist may be required to evaluate man-system compatibility as related to mission success. A problem emerges, however, whenever one progresses from this broadly stated requirement to the specifics of how it is to be accomplished. For example, if one examines the criterion of mission success he discovers that missions are subdivided into phases and each phase has its own goals and objectives. Also these goals and objectives are themselves criteria and their relation to the criterion of mission success may be of differential importance. Thus the criterion of mission success quickly emerges as one that is more complex than first assumed. Compounding this criterion problem is the complex nature of man and systems. Considering that each of them has its own subsystems and multilevel criteria, one begins to realize the problems faced by the human factors specialist in attempting to adequately conceptualize the problem. Assuming the human factors specialist can overcome these difficulties and develop a satisfactory conceptual model of the problem, he can then begin to consider the other major issues inherent in evaluation. That is, how will he measure his concepts, how will he design for optimal data collection and, finally, how will he ascertain that the results can be interpreted in a meaningful and useful manner?

This paper will present a technique currently being developed, Mission Operability Assessment Technique (MOAT), which is a tool for assessing man-system compatibility as related to mission success. In developing this tool each of the major methodological issues mentioned above has been incorporated into the technique. The emphasis of this paper will be on how the issues of conceptualization and measurement are reflected in the technique. (Author)

740. PRUITT, V.R., Moroney, W.F. and Lau, C., Energy Maneuverability Display for the Air Combat Maneuvering Range/Tactical Training System (ACMR/TACTS), Naval Aerospace Medical Research Laboratory, Pensacola, FL 32508, SR 80-4, August 1980, 36 pp.

Over the past decade, emphasis has been placed on designing fighter aircraft to energy maneuverability criteria. These criteria have indeed increased fighter performance, but they have also presented analysts and pilots with new tasks in fully utilizing this improved capability. In the development of tactics, the energy maneuverability capability of a potential adversary's aircraft must be compared with the maneuvering capability of one's own aircraft. A major factor which determines the outcome of aerial combat is the pilot's ability to maximize the maneuvering capability of his aircraft. This report describes the development of an integrated analog display (turn rate vs calibrated airspeed) for use as a debriefing aid on the Air Combat Maneuvering Range (ACMR).

The ACMR gathers in-flight data from the aircraft while they are engaged in air combat maneuvering. Upon returning from the ACMR, aircrew are presented with 1) a pictorial display of the engagement, and 2) a digital printout of selected encounter parameters (e.g., velocity, "g," altitude of each aircraft, range between aircraft). The display integrates these relevant energy maneuverability data into an analog format, thus providing an immediate comparison of the performance of each aircraft with respect to the maneuvering envelope of that aircraft and that of the opponent. The display also allows the aircrew to recognize very rapidly whether they are gaining or losing energy and the rate of gain or loss. The maneuvering envelopes of the

F-14, F-4, A-4, and F-5 aircraft can be displayed in this dynamic format. It is expected that this new format 1) will provide a better means for pilots to determine how well they have maximized the performance of their aircraft, and 2) may serve as an aid in tactics development.

A brief discussion of the nature of energy maneuverability is contained in an Appendix.

It is proposed that the effectiveness of the energy maneuverability (EM) display and the companion instructional videotape should be evaluated. The potential incorporation of the display into other ACMRs/ACMIs and ACM simulators should also be considered.

741. PRUITT, V.R., and Moroney, W.F., Energy Maneuverability Displays for Air Combat Training. Society of Automotive Engineers, Aerospace Exposition and Congress, Warrendale, PA 15096, SAE 801185, October 1980, 8 pp.

Two types of energy maneuverability displays have been developed for use in air combat maneuvering (ACM) training. One type of display is used on the ground in connection with the U.S. Navy's Tactical Air Combat Training System (TACTS) facility and the other is a helmet-mounted display for use during inflight air combat training. Both displays employ energy maneuverability concepts which show the key maneuvering parameters of maximum sustained turn rate, minimum sustained turn radius, corner turn, and areas of energy gain and loss as functions of aircraft performance and structural limits. Both have shown significant potential for enhancing ACM training effectiveness.

742. DEFENSE DOCUMENTATION CENTER, Performance Measurement, DTK, Cameron Station, Alexandria, VA 22314, September 1976, 550 pp. AD 029850.

This bibliography contains studies which aid in measuring and assessing data relevant to human performance. Training devices, aptitude and achievement tests, special clothing and equipment are all employed to establish the criteria used in these studies. There are also references on the environmental, physical and stress factors, which not only evaluate performance, but under certain conditions may predict it. A Subject Index is included.

743. ROSCOE, S.N., Ed., Aviation Psychology, Iowa State University Press, Ames, Iowa 50010, 1980, 304 pp.

This text addresses human performance in the operation of flight systems. It is divided into six sections as outlined below.

21. "Adaptive Perceptualmotor Training," Gavan Lintern and Stanley N. Roscoe.
22. "Computer-Assisted Flight Training," Stanley R. Trollip and Stanley N. Roscoe.

VI. RESEARCH LESSONS

23. "The Evolution of Operational Systems," Dennis B. Beringer and Stanley N. Roscoe.
24. "Galileo and the Marketing Manager," Stanley N. Roscoe.

SECTION VIII

BIBLIOGRAPHIC LISTING

SECTION VIII

BIBLIOGRAPHIC LISTING

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SECTION X

MATRICES

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Smit	100			X					X				X				
Burton	101															X	
Kibort	102																
Hasbrook	103			X													
Miller	104						X										
Hasbrook	105			X													
Schwind	106																
Perry	107																
Corkindale	108			X		X			X				X				
Goode	109																
Brictson	110																
Brictson	111																
Seckel	112																
Brictson	113																
Knoop	114																
Geiselhart	115		X														
Gunning	116																
Hasbrook	117																
Roscoe	118																
Billings	119												X				
Howitt	120		X	X											X	X	

		PHYSIOLOGICAL															
AUTHOR	ART. NO.	Biochemical analysis (blood)	Communications/Speech	Cardiovascular (ECG, BP)	Electroencephalogram (EEG)	Electromyogram (EMG)	Eye movements	Finger tremor	Galvanic Skin Response (GSR)	Metabolic rate	Perspiration weight loss	Pupillography	Respiration	Temperature	Time of sleep	Urinary catecholamines	Visual Evoked Potential (VEP)
Lees	121																
Lees	122																
Sanders	123																
Stone	124																
Barnes	125						X										
Moreland	126			X							X			X			
Bynum	127																
Lees	128																
Frezell	129			X		X	X										
Smit	130			X					X				X				
Anderson	131											X					
Billings	132																
Stern	133						X										
Sanders	134						X										
Smith	135																
Barnes	136																
Kimball	137																
Lees	138																
Littell	139			X									X				
Billings	140			X						X			X				
Billings	141																
Frezell	142			X		X	X										
Barnes	143						X										
Simmons	144						X										
Gasparian	145			X												X	
Lees	146	X		X								X				X	
Harper	147																
Baron	148						X										
Whitworth	149			X									X			X	

		PHYSIOLOGICAL															
		Biochemical analysis (blood)	Communications/Speech	Cardiovascular (ECG, BP)	Electroencephalogram (EEG)	Electromyogram (EMG)	Eye movements	Finger tremor	Galvanic Skin Response (GSR)	Metabolic rate	Perspiration weight loss	Pupillography	Respiration	Temperature	Time of sleep	Urinary catecholamines	Visual Evoked Potential (VEP)
Bergeron	200																
Simpson	201																
Miller	202																
Sadoff	203																
Junker	204																
McGuinness	205																
Lowes	206																
Jacobs	207																
Matheny	208																
Loose	209																
Miller	210																
Zaitzeff	211																
Kellog	212																
Kraft	213																
Bray	214																
Chase	215																
Lewis	216																
Smith	217																
Jensen	218																
Bray	219																
Weir	220						X										
Gold	221																
Simonelli	222																
Ruocco	223																
Gold	224																
Cooper	225																
Collyer	226																
Wewerinke	227						X										

		PHYSIOLOGICAL															
		Biochemical analysis (blood)	Communications/Speech	Cardiovascular (ECG, BP)	Electroencephalogram (EEG)	Electromyogram (EMG)	Eye movements	Finger tremor	Galvanic Skin Response (GSR)	Metabolic rate	Perspiration weight loss	Pupillography	Respiration	Temperature	Time of sleep	Urinary catecholamines	Visual Evoked Potential (VEP)
Riley	228																
Queijo	229																
Geiselhart	230																
Curtin	231																
Price	232																
Kraus	233																
Vanderkolk	234																
Ellis	235																
Wolf	236			X		X	X					X	X				
Charles	237																
Brecke	238																
Hagin	239																
Shipley	240																
Gerlach	241																
Shipley	242																
Schwank	243																
Woodruff	24																
Pfeiffer	245																
Wewerinke	246																
Ephrath	247						X										
Irish	248																
Vreuls	249																
Goldberg	250																
Ellis	251																
Gainer	252						X										
Iampietro	253			X							X			X		X	
McDowell	254																
Demaree	255																

		PHYSIOLOGICAL															
		Biochemical analysis (blood)	Communications/Speech	Cardiovascular (ECG, BP)	Electroencephalogram (EEG)	Electromyogram (EMG)	Eye movements	Finger tremor	Galvanic Skin Response (GSR)	Metabolic rate	Perspiration weight loss	Pupillography	Respiration	Temperature	Time of sleep	Urinary catecholamines	Visual Evoked Potential (VEP)
Henry	256																
Henry	257																
Henry	258																
Vreuls	259																
Lemaster	260		X														
Long	261																
Gabriel	262						X										
Irish	263																
Hill	264																
Hill	265																
Kelly	266																
Prouhet	267																
Riis	268																
Loental	269																
Soliday	270	X		X									X			X	
Soliday	271																
Schohan	272																
Soliday	273			X									X				
Soliday	274																
Osterhoff	275																
Geiselhart	276																
Duffy	277																
Wheat	278																
Stave	279																
Waugh	280																
Childs	281																
Vreuls	282																
Federman	283		X														
Siegel	284		X														
Murphy	285																
Grodsky	286																
Sanders	287																

		PHYSIOLOGICAL															
		Biochemical analysis (blood)	Communications/Speech	Cardiovascular (ECG, BP)	Electroencephalogram (EEG)	Electromyogram (EMG)	Eye movements	Finger tremor	Galvanic Skin Response (GSR)	Metabolic rate	Perspiration weight loss	Pupillography	Respiration	Temperature	Time of sleep	Urinary catecholamines	Visual Evoked Potential (VEP)
Ryack	300																
Stapleford	301																
Lashbrook	302				X												
Allen	303																
Layton	304																
Kennedy	305																
Rodrick	306																
Benjamin	307																
Levison	308																
Adams	309																
James	310																
Ricard	311																
Levison	312						X										
Smittle	313																
Bernstein	314																
Krebs	315						X										
Freitag	316																
Anderson	317																
Stapleford	318																
Wulfeck	319																

		PHYSIOLOGICAL															
AUTHOR	ART. NO.	Biochemical analysis (blood)	Communications/Speech	Cardiovascular (ECG, BP)	Electroencephalogram (EEG)	Electromyogram (EMG)	Eye movements	Finger tremor	Galvanic Skin Response (GSR)	Metabolic rate	Perspiration weight loss	Pupillography	Respiration	Temperature	Time of sleep	Urinary catecholamines	Visual Evoked Potential (VEP)
Buckland	400																
Baron	401																
Wick	402																
Aronson	403																
Jensen	404																
Beringer	405																
Emery	406																
Grosslight	407																
Nicholson	408			X				X									
Billings	409			X													
Brictson	410																
Pierce	411																
Brown	412																
Lewis	413																
Fineberg	414																
Farrell	415																
Stamper	416			X												X	
Fineberg	417																
Wilson	418																
Koonce	419																
Waag	420																
Goebel	421																
Charles	422																
Martin	423																
Enochs	424				X												
Gunning	425																
Carter	426																
Moore	427																
Keston	428																
Lewis	429																X
Gray	430																
Nataupsky	431																
Caro	432																
Caro	433																
Isley	434																

		AIRCRAFT SYSTEMS																																
AUTHOR	ART. NO.	ADI displacement	Aileron	Aircraft gross weight	Angle of attack	Glideslope display error	Localizer display error	Automatic Dir. Find. (ADF)	Autopilot vert. track. error	Ball angle	CDI error	Collective	Control stick	Cyclic	DME	Elevator	Engine Pressure Ratio (EPR)	Engine RPM	Flaps	Flight director error	Fuel flow	Heading	Inclinometer	Landing gear	Pedal (helicopter)	Radar altimeter error	Rotor RPM	Rudder	Speed brake	Tail rotor position	Throttle	Thrust attenuator	Thumbwheel inputs	Trim
Smit	100																					X												
Burton	101																																	
Kibort	102																																	
Hasbrook	103																																	
Miller	104		X			X	X									X												X			X			
Hasbrook	105					X	X															X												
Schwind	106								X								X			X	X													
Perry	107																																	
Corkindale	108																																	
Goode	109				X														X															
Brictson	110			X																														
Brictson	111																																	
Seckel	112																																	
Brictson	113																																	
Knoop	114												X					X	X			X		X				X	X		X	X		X
Geiselhart	115																																	
Gunning	116																																	
Hasbrook	117												X																					
Roscoe	118												X																					
Billings	119																																	
Howitt	120																																	

		AIRCRAFT SYSTEMS																																
AUTHOR	ART. NO.	ADI displacement	Aileron	Aircraft gross weight	Angle of attack	Glideslope display error	Localizer display error	Automatic Dir. Find. (ADF)	Autopilot vert. track. error	Ball angle	CDI error	Collective	Control stick	Cyclic	DME	Elevator	Engine Pressure Ratio (EPR)	Engine RPM	Flaps	Flight director error	Fuel flow	Heading	Inclinometer	Landing gear	Pedal (helicopter)	Radar altimeter error	Rotor RPM	Rudder	Speed brake	Tail rotor position	Throttle	Thrust attenuator	Thumbwheel inputs	Trim
Lees	121																					X												
Lees	122																																	
Sanders	123											X		X								X			X									
Stone	124													X								X			X									
Barnes	125																																	
Moreland	126																					X												
Bynum	127																																	
Lees	128																					X				X								
Frezell	129											X		X											X									
Smit	130											X		X											X									
Anderson	131																																	
Billings	132											X		X													X				X			
Stern	133																																	
Sanders	134																																	
Smith	135																																	
Barnes	136																																	
Kimball	137											X		X								X			X									
Lees	138											X		X								X			X									
Littell	139																																	
Billings	140																																	
Billings	141																	X																
Frezell	142											X		X											X									
Barnes	143																																	
Simmons	144											X		X								X			X									
Gasparian	145										X	X		X	X							X								X				
Lees	146																																	
Harper	147													X											X									
Baron	148												X																					
Whitworth	149																																	

		AIRCRAFT SYSTEMS																																
AUTHOR	ART. NO.	ADI displacement	Aileron	Aircraft gross weight	Angle of attack	Glideslope display error	Localizer display error	Automatic Dir. Find. (ADF)	Autopilot vert. track. error	Ball angle	CDI error	Collective	Control stick	Cyclic	DME	Elevator	Engine Pressure Ratio (EPR)	Engine RPM	Flaps	Flight director error	Fuel flow	Heading	Inclinometer	Landing gear	Pedal (helicopter)	Radar altimeter error	Rotor RPM	Rudder	Speed brake	Tail rotor position	Throttle	Thrust attenuator	Thumbwheel inputs	Trim
Bergeron	200																																	
Simpson	201																																	
Miller	202		X													X																		
Sadoff	203																																	
Junker	204																																	
McGuinness	205																																	
Lowes	206												X																					
Jacobs	207																																	
Matheny	208												X									X												
Loose	209																																	
Miller	210		X													X																	X	
Zaitzeff	211																																	
Kellog	212																																	
Kraft	213																																	
Bray	214																																	
Chase	215												X																					
Lewis	216																																	
Smith	217																																	
Jensen	218																																	
Bray	219																																	
Weir	220		X													X																		
Gold	221		X													X						X						X			X			
Simonelli	222																																	
Ruocco	223												X																					
Gold	224																																	
Cooper	225												X											X				X						
Collyer	226				X								X																					
Wewerinke	227		X										X																					

		AIRCRAFT SYSTEMS																																
AUTHOR	ART. NO.	ADI displacement	Aileron	Aircraft gross weight	Angle of attack	Glideslope display error	Localizer display error	Automatic Dir. Find. (ADF)	Autopilot vert. track. error	Ball angle	CDI error	Collective	Control stick	Cyclic	DME	Elevator	Engine Pressure Ratio (EPR)	Engine RPM	Flaps	Flight director error	Fuel flow	Heading	Inclinometer	Landing gear	Pedal (helicopter)	Radar altimeter error	Rotor RPM	Rudder	Speed brake	Tail rotor position	Throttle	Thrust attenuator	Thumbwheel inputs	Trim
Riley	228		X													X																	X	
Queijo	229																																	
Geiselhart	230	X			X								X																					
Curtin	231																																	
Price	232																																	
Kraus	233																																	
Vanderkolk	234																																	
Ellis	235		X										X			X						X												X
Wolf	236																																	
Charles	237				X														X			X		X					X					
Brecke	238																					X												
Hagin	239																					X												
Shipley	240																																	
Gerlach	241															X						X									X			
Shipley	242																					X									X			
Schwank	243																					X												
Woodruff	244		X																															
Pfeiffer	245																																	
Wewerinke	246												X							X														
Ephrath	247																																	
Irish	248		X													X						X						X						
Vreuls	249		X		X								X			X						X						X						
Goldberg	250										X																							
Ellis	251		X													X						X												
Gainer	252																					X												
Iampietro	253																					X												
McDowell	254		X													X						X									X			
Demaree	255		X		X											X						X						X			X			

AUTHOR	ART. NO.	AIRCRAFT SYSTEMS																																
		ADI displacement	Aileron	Aircraft gross weight	Angle of attack	Glideslope display error	Localizer display error	Automatic Dir. Find. (ADF)	Autopilot vert. track. error	Ball angle	CDI error	Collective	Control stick	Cyclic	DME	Elevator	Engine Pressure Ratio (EPR)	Engine RPM	Flaps	Flight director error	Fuel flow	Heading	Inclinometer	Landing gear	Pedal (helicopter)	Radar altimeter error	Rotor RPM	Rudder	Speed brake	Tail rotor position	Throttle	Thrust attenuator	Thumbwheel inputs	Trim
Henry	256									X						X			X			X						X			X			
Henry	257									X												X												
Henry	258									X												X												
Vreuls	259		X		X								X			X						X						X			X			
Lemaster	260																					X												
Long	261																					X												
Gabriel	262																					X												
Irish	263		X													X						X						X						
Hill	264																					X												
Hill	265		X													X						X						X						
Kelly	266				X																X	X							X		X			
Prouhet	267																																	
Riis	268																																	
Loental	269																																	
Soliday	270												X									X												
Soliday	271												X									X												
Schohan	272																																	
Soliday	273																					X												
Soliday	274																																	
Osterhoff	275																																	
Geiselhart	276																																	
Duffy	277																																	
Wheat	278											X		X																				
Stave	279																																	
Waugh	280											X		X								X			X									
Childs	281																					X												
Vreuls	282											X		X								X			X									
Federman	283																																	
Siegel	284																																	
Murphy	285											X		X											X									
Grodsky	286																																	
Sanders	287																					X												

		AIRCRAFT SYSTEMS																																
AUTHOR	ART. NO.	ADI displacement	Aileron	Aircraft gross weight	Angle of attack	Glideslope display error	Localizer display error	Automatic Dir. Find. (ADF)	Autopilot vert. track. error	Ball angle	CDI error	Collective	Control stick	Cyclic	DME	Elevator	Engine Pressure Ratio (EPR)	Engine RPM	Flaps	Flight director error	Fuel flow	Heading	Inclinometer	Landing gear	Pedal (helicopter)	Radar altimeter error	Rotor RPM	Rudder	Speed brake	Tail rotor position	Throttle	Thrust attenuator	Thumbwheel inputs	Trim
Ryack	300																																	
Stapleford	301																																	
Lashbrook	302																																	
Allen	303												X																					
Layton	304																																	
Kennedy	305																																	
Rodrick	306																																	
Benjamin	307												X																					
Levison	308																																	
Adams	309																																	
James	310																																	
Ricard	311																																	
Levison	312												X																					
Smittle	313																																	
Bernstein	314																																	
Krebs	315																																	
Freitag	316																																	
Anderson	317																																	
Stapleford	318																																	
Wulfeck	319																																	

		AIRCRAFT SYSTEMS																																
AUTHOR	ART. NO.	ADI displacement	Aileron	Aircraft gross weight	Angle of attack	Glideslope display error	Localizer display error	Automatic Dir. Find. (ADF)	Autopilot vert. track. error	Ball angle	CDI error	Collective	Control stick	Cyclic	DME	Elevator	Engine Pressure Ratio (EPR)	Engine RPM	Flaps	Flight director error	Fuel flow	Heading	Inclinometer	Landing gear	Pedal (helicopter)	Radar altimeter error	Rotor RPM	Rudder	Speed brake	Tail rotor position	Throttle	Thrust attenuator	Thumbwheel inputs	Trim
Buckland	400																																	
Baron	401																																	
Wick	402																																	
Aronson	403		X													X																		
Jensen	404																																	
Beringer	405		X												X																			
Emery	406													X								X			X									
Grosslight	407																																	
Nicholson	408																																	
Billings	409												X																					
Brictson	410																																	
Pierce	411																																	
Brown	412																																	
Lewis	413																					X												
Fineberg	414																																	
Farrell	415																																	
Stamper	416																																	
Fineberg	417																																	
Wilson	418																																	
Koonce	419																																	
Waag	420												X									X									X			
Goebel	421									X																								
Charles	422																					X												
Martin	423																					X	X											
Enochs	424																																	
Gunning	425																																	
Carter	426																																	
Moore	427																																	
Keston	428																																	
Lewis	429																																	
Gray	430																					X												
Nataupsky	431																					X												
Caro	432																					X												
Caro	433																																	
Isley	434								X										X				X												

		MAN-MACHINE SYSTEM																																	
AUTHOR	ART. NO.	Acceleration	ACM plane of action (X,Y,Z)	Aircraft/boom oscillations	Airspeed	Altitude	Altitude (pitchout)	Altitude (radar)	Approach angle error	Approach centerline error	Approach glideslope error	Approach range	Checklist errors	Circular bomb error	Closing speed	Course error	Crosstrack error	Dev. from ideal flight path	Dip to target error (ASW)	Distance traveled	Dive angle at bomb release	Drift	Emergency detections	Energy Mgmt. Index (EMI)	Ground speed	Ground track	Landing aim point	Landing attitude	Ldg. dist. to ideal touchpt.	Ldg. dist. to rwy. threshold	Ldg. ht. at rwy. threshold	Landing result (bolter...)	Lateral acceleration	Lateral velocity	Mach number
Smit	100				X	X		X																	X										
Burton	101																																		
Kibort	102																												X						
Hasbrook	103																																		
Miller	104																																		
Hasbrook	105				X																														
Schwind	106				X					X	X																								
Perry	107																												X						
Corkindale	108																																		
Goode	109				X	X																							X		X	X			
Brictson	110				X					X	X	X			X																	X			
Brictson	111				X						X																								
Seckel	112																													X	X				
Brictson	113									X	X																					X			
Knoop	114				X	X																													
Geiselhart	115												X																						
Gunning	116																																		
Hasbrook	117																																		
Roscoe	118																																		
Billings	119																																		
Howitt	120																																		

		MAN-MACHINE SYSTEM																																	
AUTHOR	ART. NO.	Acceleration	ACM plane of action (X,Y,Z)	Aircraft/boom oscillations	Airspeed	Altitude	Altitude (pitchout)	Altitude (radar)	Approach angle error	Approach centerline error	Approach glideslope error	Approach range	Checklist errors	Circular bomb error	Closing speed	Course error	Crosstrack error	Dev. from ideal flight path	Dip to target error (ASW)	Distance traveled	Dive angle at bomb release	Drift	Emergency detections	Energy Mgmt. Index (EMI)	Ground speed	Ground track	Landing aim point	Landing attitude	Ldg. dist. to ideal touchpt.	Ldg. dist. to rwy. threshold	Ldg. ht. at rwy. threshold	Landing result (bolter...)	Lateral acceleration	Lateral velocity	Mach number
Lees	121																																		
Lees	122																																		
Sanders	123							X																											
Stone	124																																		
Barnes	125																																		
Moreland	126				X	X																													
Bynum	127					X																													
Lees	128				X																														
Frezell	129																																		
Smit	130				X	X											X																	X	
Anderson	131																																		
Billings	132																																		
Stern	133																																		
Sanders	134																																		
Smith	135																																		
Barnes	136																																		
Kimball	137				X			X																											
Lees	138	X				X																											X		
Littell	139																																		
Billings	140																																		
Billings	141																																		
Frezell	142																																		
Barnes	143																																		
Simmons	144				X	X																													
Gasparian	145				X	X																													
Lees	146																																		
Harper	147					X																													
Baron	148				X																														
Whitworth	149					X																													

		MAN-MACHINE SYSTEM																																	
AUTHOR	ART. NO.	Acceleration	ACM plane of action (X,Y,Z)	Aircraft/boom oscillations	Airspeed	Altitude	Altitude (pitchout)	Altitude (radar)	Approach angle error	Approach centerline error	Approach glideslope error	Approach range	Checklist errors	Circular bomb error	Closing speed	Course error	Crosstrack error	Dev. from ideal flight path	Dip to target error (ASW)	Distance traveled	Dive angle at bomb release	Drift	Emergency detections	Energy Mgmt. Index (EMI)	Ground speed	Ground track	Landing aim point	Landing attitude	Ldg. dist. to ideal touchpt.	Ldg. dist. to rwy. threshold	Ldg. ht. at rwy. threshold	Landing result (bolter...)	Lateral acceleration	Lateral velocity	Mach number
Bergeron	200																																		
Simpson	201																																		
Miller	202																																		
Sadoff	203																																		
Junker	204	X																																	
McGuinness	205																																		
Lowes	206					X																													X
Jacobs	207																																		
Matheny	208					X																													
Loose	209																																		
Miller	210																																		
Zaitzeff	211																																		
Kellog	212																																		
Kraft	213					X																													
Bray	214					X																													
Chase	215					X																								X					
Lewis	216					X			X																										
Smith	217				X	X																													
Jensen	218				X																														
Bray	219					X																								X					
Weir	220										X																								
Gold	221				X	X				X	X																								
Simonelli	222									X	X																								
Ruocco	223				X	X																							X						
Gold	224										X																X								
Cooper	225																												X						
Collyer	226					X				X	X																				X	X			
Wewerinke	227																																		

		MAN-MACHINE SYSTEM																																		
AUTHOR	ART. NO.	Acceleration	ACM plane of action (X,Y,Z)	Aircraft/boom oscillations	Airspeed	Altitude	Altitude (pitchout)	Altitude (radar)	Approach angle error	Approach centerline error	Approach glideslope error	Approach range	Checklist errors	Circular bomb error	Closing speed	Course error	Crosstrack error	Dev. from ideal flight path	Dip to target error (ASW)	Distance traveled	Dive angle at bomb release	Drift	Emergency detections	Energy Mgmt. Index (EMI)	Ground speed	Ground track	Landing aim point	Landing attitude	Ldg. dist. to ideal touchpt.	Ldg. dist. to rwy. threshold	Ldg. ht. at rwy. threshold	Landing result (bolter...)	Lateral acceleration	Lateral velocity	Mach number	
Riley	228																																			
Queijo	229																																			
Geiselhart	230				X	X																													X	
Curtin	231				X																															
Price	232																																			
Kraus	233																																			
Vanderkolk	234				X	X											X																			
Ellis	235					X																													X	
Wolf	236				X					X	X																									
Charles	237					X				X	X																									
Brecke	238				X	X																														
Hagin	239				X																															
Shipley	240					X												X																		
Gerlach	241				X	X																														
Shipley	242				X	X																														
Schwank	243				X																															
Woodruff	244			X																																
Pfeiffer	245					X																														
Wewerinke	246				X					X	X																									
Ephrath	247																																			
Irish	248				X	X				X	X															X			X							
Vreuls	249				X	X																														
Goldberg	250				X												X																			
Ellis	251					X																													X	
Gainer	252				X	X																													X	
Iampietro	253																																			
McDowell	254					X																														
Demaree	255					X																													X	

		MAN-MACHINE SYSTEM																																		
AUTHOR	ART. NO.	Acceleration	ACM plane of action (X,Y,Z)	Aircraft/boom oscillations	Airspeed	Altitude	Altitude (pitchout)	Altitude (radar)	Approach angle error	Approach centerline error	Approach glideslope error	Approach range	Checklist errors	Circular bomb error	Closing speed	Course error	Crosstrack error	Dev. from ideal flight path	Dip to target error (ASW)	Distance traveled	Dive angle at bomb release	Drift	Emergency detections	Energy Mgmt. Index (EMI)	Ground speed	Ground track	Landing aim point	Landing attitude	Ldg. dist. to ideal touchpt.	Ldg. dist. to rwy. threshold	Ldg. ht. at rwy. threshold	Landing result (bolter...)	Lateral acceleration	Lateral velocity	Mach number	
Henry	256				X	X																														
Henry	257				X	X																														
Henry	258				X	X																														
Vreuls	259				X	X																														
Lemaster	260				X	X																														
Long	261				X	X																														
Gabriel	262					X																	X													
Irish	263				X		X			X	X					X																				
Hill	264				X	X				X	X																									
Hill	265				X	X				X	X																									
Kelly	266		X		X	X																		X												
Prouhet	267																																			
Riis	268																	X																		
Loental	269																	X																		
Soliday	270					X																														
Soliday	271					X																														
Schohan	272					X																														
Soliday	273					X																														
Soliday	274					X																														
Osterhoff	275																																			
Geiselhart	276				X					X	X					X																				
Duffy	277					X												X																		
Wheat	278				X	X																														
Stave	279								X							X																				
Waugh	280				X	X																				X										
Childs	281				X	X																														
Vreuls	282				X	X																														
Federman	283																		X																	
Siegel	284																																			
Murphy	285									X	X														X											
Grodsky	286																																			
Sanders	287					X																														

		MAN-MACHINE SYSTEM																																	
AUTHOR	ART. NO.	Acceleration	ACM plane of action (X,Y,Z)	Aircraft/boom oscillations	Airspeed	Altitude	Altitude (pitchout)	Altitude (radar)	Approach angle error	Approach centerline error	Approach glideslope error	Approach range	Checklist errors	Circular bomb error	Closing speed	Course error	Crosstrack error	Dev. from ideal flight path	Dip to target error (ASW)	Distance traveled	Dive angle at bomb release	Drift	Emergency detections	Energy Mgmt. Index (EMI)	Ground speed	Ground track	Landing aim point	Landing attitude	Ldg. dist. to ideal touchpt.	Ldg. dist. to rwy. threshold	Ldg. ht. at rwy. threshold	Landing result (bolter...)	Lateral acceleration	Lateral velocity	Mach number
Ryack	300																																		
Stapleford	301																																		
Lashbrook	302																																		
Allen	303																																		
Layton	304																																		
Kennedy	305																																		
Rodrick	306																																		
Benjamin	307				X	X																													
Levison	308																																		
Adams	309																																		
James	310																																		
Ricard	311																																		
Levison	312																																		
Smittle	313																																		
Bernstein	314																																		
Krebs	315																																		
Freitag	316																																		
Anderson	317																																		
Stapleford	318					X																													
Wulfeck	319				X	X				X																			X						

		MAN-MACHINE SYSTEM																																	
AUTHOR	ART. NO.	Acceleration	ACM plane of action (X,Y,Z)	Aircraft/boom oscillations	Airspeed	Altitude	Altitude (pitchout)	Altitude (radar)	Approach angle error	Approach centerline error	Approach glideslope error	Approach range	Checklist errors	Circular bomb error	Closing speed	Course error	Crosstrack error	Dev. from ideal flight path	Dip to target error (ASW)	Distance traveled	Dive angle at bomb release	Drift	Emergency detections	Energy Mgmt. Index (EMI)	Ground speed	Ground track	Landing aim point	Landing attitude	Ldg. dist. to ideal touchpt.	Ldg. dist. to rwy. threshold	Ldg. ht. at rwy. threshold	Landing result (bolter...)	Lateral acceleration	Lateral velocity	Mach number
Buckland	400																																		
Baron	401					X				X												X													
Wick	402				X					X	X																								
Aronson	403																											X	X		X				
Jensen	404					X											X																		
Beringer	405				X	X											X																		
Emery	406																																		
Grosslight	407					X																								X					
Nicholson	408																																		
Billings	409									X	X																								
Brictson	410																															X			
Pierce	411													X																					
Brown	412																																		
Lewis	413																																		
Fineberg	414																																		
Farrell	415																																		
Stamper	416																																		
Fineberg	417																			X															
Wilson	418				X					X																						X			
Koonce	419																																		
Waag	420				X	X																													
Goebel	421				X	X																				X									
Charles	422				X	X																													
Martin	423				X	X				X	X																								
Enochs	424					X																													
Gunning	425				X	X										X																			
Carter	426																	X																	
Moore	427																																		
Keston	428					X																													
Lewis	429																																		
Gray	430				X	X								X							X														
Nataupsky	431				X	X																								X					
Caro	432				X	X				X	X															X									
Caro	433																																		
Isley	434				X	X																													

		MAN-MACHINE SYSTEM (CONTINUED)																													
AUTHOR	ART. NO.	Maneuvering rate	Miss distance (ASW)	LAT/LONG	Pitch	Pitch/roll coordination	Pointing angle advantage	Position estimation	Positional error (form. flt.)	Power	Prob. of find. turn point	Prob. of target acq.	Prob. of target detect.	Procedural errors	Range at target detect.	Range at target ID	Range at target recog.	Rate of info. processing	Ratio: carrier accidents	Ratio: carrier bolters	Ratio: carrier bolter rate	Reaction to an event	Roll	Sideslip	Takeoff position error	Torque	Tracking error	Turn errors	Turn rate	Vertical acceleration	Vertical velocity	Yaw
Smit	100																													X		
Burton	101																															
Kibort	102																													X		
Hasbrook	103																															
Miller	104																															
Hasbrook	105				X																		X								X	
Schwind	106																															
Perry	107																															
Corkindale	108																															
Goode	109				X																			X								
Brictson	110																														X	
Brictson	111																			X	X										X	
Seckel	112																															
Brictson	113																			X	X										X	
Knoop	114				X																		X						X	X	X	X
Geiselhart	115																															
Gunning	116																															
Hasbrook	117				X																											
Roscoe	118																										X					
Billings	119																															
Howitt	120																															

		MAN-MACHINE SYSTEM (CONTINUED)																														
AUTHOR	ART. NO.	Maneuvering rate	Miss distance (ASW)	LAT/LONG	Pitch	Pitch/roll coordination	Pointing angle advantage	Position estimation	Positional error (form. flt.)	Power	Prob. of find. turn point	Prob. of target acq.	Prob. of target detect.	Procedural errors	Range at target detect.	Range at target ID	Range at target recog.	Rate of info. processing	Ratio: carrier accidents	Ratio: carrier bolters	Ratio: carrier bolter rate	Reaction to an event	Roll	Sideslip	Takeoff position error	Torque	Tracking error	Turn errors	Turn rate	Vertical acceleration	Vertical velocity	Yaw
Lees	121			X	X																		X									
Lees	122				X																		X									X
Sanders	123				X																		X									
Stone	124																						X									
Barnes	125												X		X	X																
Moreland	126																															
Bynum	127			X																		X										
Lees	128																															
Frezell	129																						X									
Smit	130																															
Anderson	131																															
Billings	132																															
Stern	133																															
Sanders	134																															
Smith	135			X																												
Barnes	136														X																	
Kimball	137				X																		X									
Lees	138				X																		X							X		X
Littell	139																															
Billings	140																															
Billings	141																															
Frezell	142																						X									
Barnes	143																															
Simmons	144				X																								X		X	
Gasparian	145				X																		X								X	
Lees	146																															
Harper	147			X	X																		X									X
Baron	148			X	X																											
Whitworth	149			X																												

		MAN-MACHINE SYSTEM (CONTINUED)																												
AUTHOR	ART. NO.	Maneuvering rate	Miss distance (ASW)	LAT/LONG	Pitch	Pitch/roll coordination	Pointing angle advantage	Position estimation	Positional error (form. flt.)	Power	Prob. of find. turn point	Prob. of target acq.	Prob. of target detect.	Procedural errors	Range at target detect.	Range at target ID	Range at target recog.	Rate of info. processing	Ratio: carrier accidents	Ratio: carrier bolters	Ratio: carrier bolter rate	Reaction to an event	Roll	Sideslip	Takeoff position error	Torque	Tracking error	Turn errors	Turn rate	Vertical acceleration	Vertical velocity	Yaw
Bergeron	200																										X					
Simpson	201				X																						X					
Miller	202																										X					
Sadoff	203				X																						X					
Junker	204																										X					
McGuinness	205				X																		X				X					
Lowes	206																															
Jacobs	207																										X					
Matheny	208																															
Loose	209																										X					
Miller	210																										X					
Zaitzeff	211											X																				
Kellog	212																													X		
Kraft	213																															
Bray	214																													X	X	
Chase	215																														X	
Lewis	216																															
Smith	217																															
Jensen	218													X													X					
Bray	219																														X	
Weir	220				X																											
Gold	221				X																		X								X	
Simonelli	222																															
Ruocco	223				X																		X								X	X
Gold	224							X																								
Cooper	225				X																		X								X	
Collyer	226			X	X																		X								X	
Wewerinke	227																															

		MAN-MACHINE SYSTEM (CONTINUED)																														
AUTHOR	ART. NO.	Maneuvering rate	Miss distance (ASW)	LAT/LONG	Pitch	Pitch/roll coordination	Pointing angle advantage	Position estimation	Positional error (form. flt.)	Power	Prob. of find. turn point	Prob. of target acq.	Prob. of target detect.	Procedural errors	Range at target detect.	Range at target ID	Range at target recog.	Rate of info. processing	Ratio: carrier accidents	Ratio: carrier bolters	Ratio: carrier bolter rate	Reaction to an event	Roll	Sideslip	Takeoff position error	Torque	Tracking error	Turn errors	Turn rate	Vertical acceleration	Vertical velocity	Yaw
Riley	228																										X					
Queijo	229																										X					
Geiselhart	230			X	X																		X								X	X
Curtin	231				X																		X				X					
Price	232														X	X	X															
Kraus	233													X				X														
Vanderkolk	234													X																		
Ellis	235																															
Wolf	236				X																		X									
Charles	237																												X			
Brecke	238				X					X																					X	
Hagin	239																														X	
Shipley	240																															
Gerlach	241				X																		X								X	
Shipley	242				X					X																					X	
Schwank	243																														X	
Woodruff	244																															
Pfeiffer	245																															
Wewerinke	246																															
Ephrath	247																															
Irish	248				X																		X								X	
Vreuls	249				X																		X								X	
Goldberg	250													X																		
Ellis	251				X																		X									
Gainer	252																														X	
Iampietro	253																															
McDowell	254			X																			X								X	
Demaree	255				X																		X						X		X	X

		MAN-MACHINE SYSTEM (CONTINUED)																												
AUTHOR	ART. NO.	Maneuvering rate	Miss distance (ASW)	LAT/LONG	Pitch	Pitch/roll coordination	Pointing angle advantage	Position estimation	Positional error (form. flt.)	Power	Prob. of find. turn point	Prob. of target acq.	Prob. of target detect.	Procedural errors	Range at target detect.	Range at target ID	Range at target recog.	Rate of info. processing	Ratio: carrier accidents	Ratio: carrier bolters	Ratio: carrier bolter rate	Reaction to an event	Roll	Sideslip	Takeoff position error	Torque	Tracking error	Turn errors	Turn rate	Vertical acceleration	Vertical velocity	Yaw
Henry	256																												X		X	
Henry	257																												X		X	
Henry	258																												X		X	
Vreuls	259				X																		X	X					X		X	
Lemaster	260			X	X	X				X				X									X								X	
Long	261			X	X																		X	X			X		X		X	
Gabriel	262																															
Irish	263				X																		X	X								
Hill	264				X																		X								X	
Hill	265				X					X													X						X		X	X
Kelly	266	X																					X									
Prouhet	267																															
Riis	268																															
Loental	269																						X				X					
Soliday	270				X																									X		
Soliday	271																													X		
Schohan	272																					X								X		
Soliday	273																													X		
Soliday	274			X																										X		
Osterhoff	275			X																												
Geiselhart	276				X																											
Duffy	277																															
Wheat	278				X																											
Stave	279																															
Waugh	280																														X	
Childs	281																															
Vreuls	282				X																		X			X						X
Federman	283																															
Siegel	284		X																													
Murphy	285				X																		X								X	X
Grodsky	286			X										X				X														
Sanders	287																															

MAN-MACHINE SYSTEM (CONTINUED)

AUTHOR	ART. NO.	Maneuvering rate	Miss distance (ASW)	LAT/LONG	Pitch	Pitch/roll coordination	Pointing angle advantage	Position estimation	Positional error (form. flt.)	Power	Prob. of find. turn point	Prob. of target acq.	Prob. of target detect.	Procedural errors	Range at target detect.	Range at target ID	Range at target recog.	Rate of info. processing	Ratio: carrier accidents	Ratio: carrier bolters	Ratio: carrier bolter rate	Reaction to an event	Roll	Sideslip	Takeoff position error	Torque	Tracking error	Turn errors	Turn rate	Vertical acceleration	Vertical velocity	Yaw
Ryack	300																										X					
Stapleford	301																										X					X
Lashbrook	302																										X					
Allen	303																										X					
Layton	304																										X					
Kennedy	305																										X					
Rodrick	306																															
Benjamin	307																						X									
Levison	308																										X					
Adams	309																										X					
James	310																										X					
Ricard	311																						X									
Levison	312									X																	X					
Smittle	313																															
Bernstein	314																															
Krebs	315																															
Freitag	316														X																	
Anderson	317				X				X														X									
Stapleford	318				X																											
Wulfeck	319				X																		X								X	X

		MAN-MACHINE SYSTEM (CONTINUED)																														
AUTHOR	ART. NO.	Maneuvering rate	Miss distance (ASW)	LAT/LONG	Pitch	Pitch/roll coordination	Pointing angle advantage	Position estimation	Positional error (form. flt.)	Power	Prob. of find. turn point	Prob. of target acq.	Prob. of target detect.	Procedural errors	Range at target detect.	Range at target ID	Range at target recog.	Rate of info. processing	Ratio: carrier accidents	Ratio: carrier bolters	Ratio: carrier bolter rate	Reaction to an event	Roll	Sideslip	Takeoff position error	Torque	Tracking error	Turn errors	Turn rate	Vertical acceleration	Vertical velocity	Yaw
Buckland	400																														X	
Baron	401				X																		X								X	
Wick	402													X																		
Aronson	403																															
Jensen	404													X																		
Beringer	405				X																		X									
Emery	406				X																		X									
Grosslight	407																															
Nicholson	408																															
Billings	409													X																		
Brictson	410																		X		X											
Pierce	411																															
Brown	412																															
Lewis	413																															
Fineberg	414			X							X																					
Farrell	415			X							X																					
Stamper	416																															
Fineberg	417			X							X																					
Wilson	418																														X	
Koonce	419																															
Waag	420				X																		X							X	X	
Goebel	421																						X				X					
Charles	422																						X						X		X	
Martin	423				X																		X									
Enochs	424																															
Gunning	425																															
Carter	426																															
Moore	427						X																				X					
Keston	428																															
Lewis	429																															
Gray	430																													X		
Nataupsky	431				X																		X		X							
Caro	432													X																		
Caro	433																											X				
Isley	434				X																		X								X	

		TIME																										
AUTHOR	ART. NO.	Combined Total Sec. of Error	Defensive time	Lead time	Offensive	Offensive with advantage	Opponent out of view time	Ratio: offensive/defensive	Reaction time to an event	Time	Estimation	Of event	Of task execution	On criterion	On target	To acquire target	To criterion	To detect target	To envelope	To first kill	To identify target	To recover from unusual att.	To turn	Within criterion	Within envelope	Within flight path	Within gun range	Within missile range
Smit	100																											
Burton	101																											
Kibort	102																											
Hasbrook	103																											
Miller	104																											
Hasbrook	105																											
Schwind	106																											
Perry	107																											
Corkindale	108																											
Goode	109																											
Brictson	110																											
Brictson	111																											
Seckel	112																											
Brictson	113																											
Knoop	114											X																
Geiselhart	115											X	X															
Gunning	116											X	X															
Hasbrook	117																					X						
Roscoe	118																											
Billings	119																											
Howitt	120																											

		TIME																										
AUTHOR	ART. NO.	Combined Total Sec. of Error	Defensive time	Lead time	Offensive	Offensive with advantage	Opponent out of view time	Ratio: offensive/defensive	Reaction time to an event	Time	Estimation	Of event	Of task execution	On criterion	On target	To acquire target	To criterion	To detect target	To envelope	To first kill	To identify target	To recover from unusual att.	To turn	Within criterion	Within envelope	Within flight path	Within gun range	Within missile range
Lees	121																											
Lees	122																											
Sanders	123																											
Stone	124																											
Barnes	125																	X			X							
Moreland	126								X														X					
Bynum	127																											
Lees	128																											
Frezell	129																											
Smit	130																											
Anderson	131																											
Billings	132																											
Stern	133																											
Sanders	134																											
Smith	135																											
Barnes	136																	X										
Kimball	137																											
Lees	138																											
Littell	139																											
Billings	140																											
Billings	141																											
Frezell	142																											
Barnes	143																											
Simmons	144																											
Gasparian	145																											
Lees	146								X																			
Harper	147																											
Baron	148																											
Whitworth	149																											

		TIME																										
AUTHOR	ART. NO.	Combined Total Sec. of Error	Defensive time	Lead time	Offensive	Offensive with advantage	Opponent out of view time	Ratio: offensive/defensive	Reaction time to an event	Time	Estimation	Of event	Of task execution	On criterion	On target	To acquire target	To criterion	To detect target	To envelope	To first kill	To identify target	To recover from unusual att.	To turn	Within criterion	Within envelope	Within flight path	Within gun range	Within missile range
Bergeron	200																											
Simpson	201																											
Miller	202																											
Sadoff	203																											
Junker	204																											
McGuinness	205														X	X												
Lowes	206																											
Jacobs	207																											
Matheny	208																											
Loose	209																											
Miller	210																											
Zaitzeff	211																											
Kellog	212																											
Kraft	213																											
Bray	214																											
Chase	215																									X		
Lewis	216																											
Smith	217																											
Jensen	218																											
Bray	219																											
Weir	220																											
Gold	221																											
Simonelli	222																											
Ruocco	223																									X		
Gold	224																											
Cooper	225																											
Collyer	226																											
Wewerinke	227																											

		TIME																										
AUTHOR	ART. NO.	Combined Total Sec. of Error	Defensive time	Lead time	Offensive	Offensive with advantage	Opponent out of view time	Ratio: offensive/defensive	Reaction time to an event	Time	Estimation	Of event	Of task execution	On criterion	On target	To acquire target	To criterion	To detect target	To envelope	To first kill	To identify target	To recover from unusual att.	To turn	Within criterion	Within envelope	Within flight path	Within gun range	Within missile range
Riley	228																											
Queijo	229																											
Geiselhart	230									X																		
Curtin	231														X	X												
Price	232																											
Kraus	233																											
Vanderkolk	234																											
Ellis	235																											
Wolf	236																											
Charles	237																											
Brecke	238																											
Hagin	239											X																
Shipley	240																									X		
Gerlach	241													X														
Shipley	242													X														
Schwank	243																											
Woodruff	244																X											
Pfeiffer	245								X																			
Wewerinke	246																											
Ephrath	247																											
Irish	248																											
Vreuls	249																											
Goldberg	250																											
Ellis	251																											
Gainer	252																											
Iampietro	253																											
McDowell	254																											
Demaree	255																											

		TIME																										
AUTHOR	ART. NO.	Combined Total Sec. of Error	Defensive time	Lead time	Offensive	Offensive with advantage	Opponent out of view time	Ratio: offensive/defensive	Reaction time to an event	Time	Estimation	Of event	Of task execution	On criterion	On target	To acquire target	To criterion	To detect target	To envelope	To first kill	To identify target	To recover from unusual att.	To turn	Within criterion	Within envelope	Within flight path	Within gun range	Within missile range
Henry	256	X							X																			
Henry	257	X																										
Henry	258	X																										
Vreuls	259																											
Lemaster	260												X															
Long	261																											
Gabriel	262								X									X										
Irish	263																									X		
Hill	264																											
Hill	265																											
Kelly	266		X	X	X	X	X																				X	X
Prouhet	267				X														X						X		X	X
Riis	268																											
Loental	269																											
Soliday	270																											
Soliday	271								X				X															
Schohan	272								X																			
Soliday	273																											
Soliday	274												X															
Osterhoff	275																											
Geiselhart	276																											
Duffy	277																											
Wheat	278																											
Stave	279																											
Waugh	280												X															
Childs	281																											
Vreuls	282																											
Federman	283												X					X										
Siegel	284																											
Murphy	285																											
Grodsky	286																											
Sanders	287																											

AUTHOR	ART. NO.	TIME																										
		Combined Total Sec. of Error	Defensive time	Lead time	Offensive	Offensive with advantage	Opponent out of view time	Ratio: offensive/defensive	Reaction time to an event	Time	Estimation	Of event	Of task execution	On criterion	On target	To acquire target	To criterion	To detect target	To envelope	To first kill	To identify target	To recover from unusual att.	To turn	Within criterion	Within envelope	Within flight path	Within gun range	Within missile range
Ryack	300														X													
Stapleford	301																											
Lashbrook	302																											
Allen	303																											
Layton	304														X									X				
Kennedy	305								X															X				
Rodrick	306																							X				
Benjamin	307																											
Levison	308																											
Adams	309																											
James	310																											
Ricard	311																											
Levison	312																											
Smittle	313								X																			
Bernstein	314																											
Krebs	315																											
Freitag	316																	X										
Anderson	317																											
Stapleford	318																											
Wulfeck	319																											

		TIME																								
AUTHOR	ART. NO.	Combined Total Sec. of Error	Defensive time	Lead time	Offensive	Offensive with advantage	Opponent out of view time	Ratio: offensive/defensive	Reaction time to an event	Time	Estimation	Of event	Of task execution	On criterion	On target	To acquire target	To criterion	To detect target	To envelope	To first kill	To identify target	To recover from unusual att.	To turn	Within criterion	Within envelope	Within flight path	Within gun range	Within missile range
Buckland	400																											
Baron	401																											
Wick	402																											
Aronson	403																											
Jensen	404																											
Beringer	405																											
Emery	406																											
Grosslight	407																											
Nicholson	408																											
Billings	409																											
Brictson	410																											
Pierce	411																											
Brown	412																											
Lewis	413																											
Fineberg	414																											
Farrell	415																											
Stamper	416																											
Fineberg	417																											
Wilson	418																											
Koonce	419																											
Waag	420																											
Goebel	421														X													
Charles	422																											
Martin	423																											
Enochs	424																							X				
Gunning	425										X																	
Carter	426																								X			
Moore	427							X												X								
Keston	428																											
Lewis	429																											
Gray	430																											
Nataupsky	431																											
Caro	432																											
Caro	433												X		X		X											
Isley	434																											

		FREQUENCY (NO. OF)																																	
AUTHOR	ART. NO.	Aircraft ground impacts	Collisions (formations)	Control losses	Control reversals	Correct decisions	Correct responses	Corr. target acquisitions	Corr. target classifications	Corr. target detections	Corr. target identifications	Correct trials	Course corrections	Crossovers	Errors per trial	Errors to criterion	False target detections	False target identifications	Gun hits/kills	Incorrect control inputs	Incorrect decisions	Lost target contacts (ASW)	Missile hits/kills	Overshoots	Refueling disconnects	Qualifying (criterion) bombs	Scorable bombs	Successful unusual att. rec.	Taps (secondary task)	Target detections (no fires)	Target hits	Target kills	Target misses	Times inside criterion	Times off target
Smit	100																																		
Burton	101																																		
Kibort	102																																		
Hasbrook	103																																		
Miller	104																																		
Hasbrook	105																																		
Schwind	106																																		
Perry	107																																		
Corkindale	108																																		
Goode	109																																		
Brictson	110																																		
Brictson	111																																		
Seckel	112																																		
Brictson	113																																		
Knoop	114																																		
Geiselhart	115																																		
Gunning	116																																		
Hasbrook	117				X																							X							
Roscoe	118				X																							X							
Billings	119																																		
Howitt	120																																		

AUTHOR	ART. NO.	FREQUENCY (NO. OF)																																	
		Aircraft ground impacts	Collisions (formations)	Control losses	Control reversals	Correct decisions	Correct responses	Corr. target acquisitions	Corr. target classifications	Corr. target detections	Corr. target identifications	Correct trials	Course corrections	Crossovers	Errors per trial	Errors to criterion	False target detections	False target identifications	Gun hits/kills	Incorrect control inputs	Incorrect decisions	Lost target contacts (ASW)	Missile hits/kills	Overshoots	Refueling disconnects	Qualifying (criterion) bombs	Scorable bombs	Successful unusual att. rec.	Taps (secondary task)	Target detections (no fires)	Target hits	Target kills	Target misses	Times inside criterion	Times off target
Lees	121																																		
Lees	122																																		
Sanders	123																																		
Stone	124																																		
Barnes	125										X																								
Moreland	126										X																								
Bynum	127																																		
Lees	128																																		
Frezell	129																																		
Smit	130																																		
Anderson	131																																		
Billings	132				X																														
Stern	133																																		
Sanders	134																																		
Smith	135																																		
Barnes	136									X																									
Kimball	137																																		
Lees	138				X																														
Littell	139																																		
Billings	140																																		
Billings	141																																		
Frezell	142																																		
Barnes	143																																		
Simmons	144																																		
Gasparian	145																																		
Lees	146																																		
Harper	147																																		
Baron	148																																		
Whitworth	149																																		

AUTHOR	ART. NO.	FREQUENCY (NO. OF)																																	
		Aircraft ground impacts	Collisions (formations)	Control losses	Control reversals	Correct decisions	Correct responses	Corr. target acquisitions	Corr. target classifications	Corr. target detections	Corr. target identifications	Correct trials	Course corrections	Crossovers	Errors per trial	Errors to criterion	False target detections	False target identifications	Gun hits/kills	Incorrect control inputs	Incorrect decisions	Lost target contacts (ASW)	Missile hits/kills	Overshoots	Refueling disconnects	Qualifying (criterion) bombs	Scorable bombs	Successful unusual att. rec.	Taps (secondary task)	Target detections (no fires)	Target hits	Target kills	Target misses	Times inside criterion	Times off target
Bergeron	200																																		
Simpson	201																																		
Miller	202																																		
Sadoff	203																																		
Junker	204																																		
McGuinness	205				X																			X											
Lowes	206																																		
Jacobs	207																																		
Matheny	208																																		
Loose	209																																		
Miller	210																			X															
Zaitzeff	211							X										X																	
Kellog	212	X								X																				X		X	X		
Kraft	213									X																									
Bray	214																																		
Chase	215				X																														
Lewis	216																																		
Smith	217																																		
Jensen	218																																		
Bray	219																																		
Weir	220																																		
Gold	221																																		
Simonelli	222																																		
Ruocco	223																																		
Gold	224																																		
Cooper	225																																		
Collyer	226																																		
Wewerinke	227																																		

		FREQUENCY (NO. OF)																																	
AUTHOR	ART. NO.	Aircraft ground impacts	Collisions (formations)	Control losses	Control reversals	Correct decisions	Correct responses	Corr. target acquisitions	Corr. target classifications	Corr. target detections	Corr. target identifications	Correct trials	Course corrections	Crossovers	Errors per trial	Errors to criterion	False target detections	False target identifications	Gun hits/kills	Incorrect control inputs	Incorrect decisions	Lost target contacts (ASW)	Missile hits/kills	Overshoots	Refueling disconnects	Qualifying (criterion) bombs	Scorable bombs	Successful unusual att. rec.	Taps (secondary task)	Target detections (no fires)	Target hits	Target kills	Target misses	Times inside criterion	Times off target
Riley	228																																		
Queijo	229																												X						
Geiselhart	230																																		
Curtin	231																																		
Price	232						X																												
Kraus	233																																		
Vanderkolk	234						X																												
Ellis	235																																		
Wolf	236						X																												
Charles	237																																		
Brecke	238																																	X	
Hagin	239																																		
Shipley	240																																		
Gerlach	241																																		
Shipley	242																																		
Schwank	243						X							X																					
Woodruff	244																								X										
Pfeiffer	245																																		
Wewerinke	246																																		
Ephrath	247						X																												
Irish	248																																		
Vreuls	249																																		
Goldberg	250																																		
Ellis	251																																		
Gainer	252																																		
Iampietro	253																																		
McDowell	254																																		
Demaree	255																																		

AUTHOR	ART. NO.	FREQUENCY (NO. OF)																																	
		Aircraft ground impacts	Collisions (formations)	Control losses	Control reversals	Correct decisions	Correct responses	Corr. target acquisitions	Corr. target classifications	Corr. target detections	Corr. target identifications	Correct trials	Course corrections	Crossovers	Errors per trial	Errors to criterion	False target detections	False target identifications	Gun hits/kills	Incorrect control inputs	Incorrect decisions	Lost target contacts (ASW)	Missile hits/kills	Overshoots	Refueling disconnects	Qualifying (criterion) bombs	Scorable bombs	Successful unusual att. rec.	Taps (secondary task)	Target detections (no fires)	Target hits	Target kills	Target misses	Times inside criterion	Times off target
Henry	256																																		
Henry	257																																		
Henry	258																																		
Vreuls	259																																		
Lemaster	260						X																					X							
Long	261																																		
Gabriel	262																																		
Irish	263																																		
Hill	264																																		
Hill	265																																		
Kelly	266																		X				X												
Prouhet	267																		X				X												
Riis	268																																		
Loental	269																																		
Soliday	270																																		
Soliday	271																																		
Schohan	272	X									X																								
Soliday	273																																		
Soliday	274												X																						
Osterhoff	275																																		
Geiselhart	276																																		
Duffy	277																																		
Wheat	278																																		
Stave	279																																		
Waugh'	280																																		
Childs	281																																		
Vreuls	282																																		
Federman	283																					X									X		X		
Siegel	284																																		
Murphy	285																																		
Grodsky	286																																		
Sanders	287																																		

		FREQUENCY (NO. OF)																															
AUTHOR	ART. NO.	Aircraft ground impacts	Collisions (formations)	Control losses	Control reversals	Correct decisions	Correct responses	Corr. target acquisitions	Corr. target classifications	Corr. target detections	Corr. target identifications	Correct trials	Course corrections	Crossovers	Errors per trial	Errors to criterion	False target detections	False target identifications	Gun hits/kills	Incorrect control inputs	Incorrect decisions	Lost target contacts (ASW)	Missile hits/kills	Overshoots	Refueling disconnects	Qualifying (criterion) bombs	Scorable bombs	Successful unusual att. rec.	Taps (secondary task)	Target detections (no fires)	Target hits	Target kills	Target misses	Times inside criterion	Times off target
Ryack	300																																		
Stapleford	301																																		
Lashbrook	302																																		
Allen	303																																		
Layton	304																																		
Kennedy	305						X																												
Rodrick	306																																		
Benjamin	307																																		
Levison	308					X															X														
Adams	309																																		
James	310																																		
Ricard	311																																		
Levison	312																																		
Smittle	313																																		
Bernstein	314									X							X																		
Krebs	315								X	X	X																								
Freitag	316																X																		
Anderson	317		X	X																															
Stapleford	318																																		
Wulfeck	319																																		

		FREQUENCY (NO. OF)																																	
AUTHOR	ART. NO.	Aircraft ground impacts	Collisions (formations)	Control losses	Control reversals	Correct decisions	Correct responses	Corr. target acquisitions	Corr. target classifications	Corr. target detections	Corr. target identifications	Correct trials	Course corrections	Crossovers	Errors per trial	Errors to criterion	False target detections	False target identifications	Gun hits/kills	Incorrect control inputs	Incorrect decisions	Lost target contacts (ASW)	Missile hits/kills	Overshoots	Refueling disconnects	Qualifying (criterion) bombs	Scorable bombs	Successful unusual att. rec.	Taps (secondary task)	Target detections (no fires)	Target hits	Target kills	Target misses	Times inside criterion	Times off target
Buckland	400																																		
Baron	401																																		
Wick	402																																		
Aronson	403																																		
Jensen	404																																		
Beringer	405						X																												
Emery	406																																		
Grosslight	407																																		
Nicholson	408																																		
Billings	409																																		
Brictson	410																																		
Pierce	411																																		
Brown	412																																		
Lewis	413																																		
Fineberg	414																																		
Farrell	415																																		
Stamper	416																																		
Fineberg	417																																		
Wilson	418																																		
Koonce	419																																		
Waag	420																																		
Goebel	421																																		
Charles	422																																		
Martin	423																																		
Enochs	424																																		
Gunning	425																																		
Carter	426																																		
Moore	427																																		
Keston	428																																		
Lewis	429						X																												
Gray	430																									X	X								
Nataupsky	431																																		
Caro	432																																		
Caro	433											X			X	X																			X
Isley	434																																		

AUTHOR	ART. NO.	FREQ. (CONT'D)			MEASURES OF EFFECTIVENESS/OTHER								
		Times outside criterion	Turn points found	Turns to assigned heading	Auto.Perform.Meas.Sys.(APMS)	Autopilot Apt.Meas.Sys.(APAMS)	Carrier deck pitch	Carrier wind-over-deck	Good Stick Index (GSI)	Helo In-Flt. Mon. Sys. (HIMS).	Lndg. Performance Score (LPS)	Obj. Mission Success Score	Trials to criterion
Smit	100												
Burton	101												
Kibort	102												
Hasbrook	103												
Miller	104												
Hasbrook	105												
Schwind	106												
Perry	107												
Corkindale	108												
Goode	109												
Brictson	110						X	X					
Brictson	111												
Seckel	112												
Brictson	113												
Knoop	114												
Geiselhart	115												
Gunning	116												
Hasbrook	117												
Roscoe	118												
Billings	119												
Howitt	120												

AUTHOR	ART. NO.	FREQ. (CONT'D)			MEASURES OF EFFECTIVENESS/OTHER								
		Times outside criterion	Turn points found	Turns to assigned heading	Auto.Perform.Meas.Sys.(APMS)	Autopilot Apt.Meas.Sys.(APAMS)	Carrier deck pitch	Carrier wind-over-deck	Good Stick Index (GSI)	Helo In-Flt. Mon. Sys. (HIMS)	Lndg. Performance Score (LPS)	Obj. Mission Success Score	Trials to criterion
Lees	121									X			
Lees	122									X			
Sanders	123									X			
Stone	124									X			
Barnes	125												
Moreland	126												
Bynum	127												
Lees	128									X			
Frezell	129									X			
Smit	130												
Anderson	131												
Billings	132		X										
Stern	133												
Sanders	134												
Smith	135												
Barnes	136												
Kimball	137									X			
Lees	138									X			
Littell	139												
Billings	140												
Billings	141												
Frezell	142									X			
Barnes	143												
Simmons	144									X			
Gasparian	145												
Lees	146									X			
Harper	147												
Baron	148												
Whitworth	149												

AUTHOR	ART. NO.	FREQ. (CONT'D)			MEASURES OF EFFECTIVENESS/OTHER								
		Times outside criterion	Turn points found	Turns to assigned heading	Auto.Perform.Meas.Sys.(APMS)	Autopilot Apt.Meas.Sys.(APAMS)	Carrier deck pitch	Carrier wind-over-deck	Good Stick Index (GSI)	Helo In-Flt. Mon. Sys. (HIMS)	Lndg. Performance Score (LPS)	Obj. Mission Success Score	Trials to criterion
Bergeron	200												
Simpson	201												
Miller	202												
Sadoff	203												
Junker	204												
McGuinness	205												
Lowes	206												
Jacobs	207												
Matheny	208												
Loose	209												
Miller	210												
Zaitzeff	211												
Kellog	212												
Kraft	213												
Bray	214												
Chase	215												
Lewis	216												
Smith	217												
Jensen	218												
Bray	219												
Weir	220												
Gold	221												
Simonelli	222												
Ruocco	223												
Gold	224												
Cooper	225												X
Collyer	226										X		
Wewerinke	227												

		FREQ. (CONT'D)			MEASURES OF EFFECTIVENESS/OTHER								
AUTHOR	ART. NO.	Times outside criterion	Turn points found	Turns to assigned heading	Auto.Perform.Meas.Sys.(APMS)	Autopilot Apt.Meas.Sys.(APAMS)	Carrier deck pitch	Carrier wind-over-deck	Good Stick Index (GSI)	Helo In-Flt. Mon. Sys. (HIMS)	Lndg. Performance Score (LPS)	Obj. Mission Success Score	Trials to criterion
Riley	228												
Queijo	229												
Geiselhart	230												
Curtin	231												
Price	232												
Kraus	233												
Vanderkolk	234												
Ellis	235												
Wolf	236												
Charles	237												
Brecke	238												
Hagin	239												
Shipley	240												
Gerlach	241												
Shipley	242												
Schwank	243												
Woodruff	244												
Pfeiffer	245												
Wewerinke	246												
Ephrath	247												
Irish	248				X								
Vreuls	249												
Goldberg	250												
Ellis	251												
Gainer	252												
Iampietro	253												
McDowell	254												
Demaree	255												

AUTHOR	ART. NO.	FREQ.(CONT'D)			MEASURES OF EFFECTIVENESS/OTHER								
		Times outside criterion	Turn points found	Turns to assigned heading	Auto.Perform.Meas.Sys.(APMS)	Autopilot Apt.Meas.Sys.(APAMS)	Carrier deck pitch	Carrier wind-over-deck	Good Stick Index (GSI)	Helo In-Flt. Mon. Sys. (HIMS)	Lndg. Performance Score (LPS)	Obj. Mission Success Score	Trials to criterion
Henry	256												
Henry	257												
Henry	258												
Vreuls	259												
Lemaster	260			X									
Long	261						X						
Gabriel	262												
Irish	263				X								
Hill	264												
Hill	265												
Kelly	266												
Prouhet	267												
Riis	268												
Loental	269												
Soliday	270												
Soliday	271												
Schohan	272		X										
Soliday	273												
Soliday	274		X										
Osterhoff	275												
Geiselhart	276												
Duffy	277												
Wheat	278												
Stave	279												
Waugh	280												
Childs	281												
Vreuls	282												
Federman	283												
Siegel	284												
Murphy	285												
Grodsky	286												
Sanders	287												

		FREQ. (CONT'D)				MEASURES OF EFFECTIVENESS/OTHER								
AUTHOR	ART. NO.	Times outside criterion	Turn points found	Turns to assigned heading		Auto.Perform.Meas.Sys.(APMS)	Autopilot Apt.Meas.Sys.(APAMS)	Carrier deck pitch	Carrier wind-over-deck	Good Stick Index (GSI)	Helo In-Flt. Mon. Sys. (HIMS)	Lndg. Performance Score (LPS)	Obj. Mission Success Score	Trials to criterion
Ryack	300													
Stapleford	301													
Lashbrook	302													
Allen	303													
Layton	304													
Kennedy	305													
Rodrick	306													
Benjamin	307													
Levison	308													
Adams	309													
James	310													
Ricard	311													X
Levison	312													
Smittle	313													
Bernstein	314													
Krebs	315													
Freitag	316													
Anderson	317													
Stapleford	318													
Wulfeck	319													

		FREQ. (CONT'D)				MEASURES OF EFFECTIVENESS/OTHER								
AUTHOR	ART. NO.	Times outside criterion	Turn points found	Turns to assigned heading		Auto.Perform.Meas.Sys.(APMS)	Autopilot Apt.Meas.Sys.(APAMS)	Carrier deck pitch	Carrier wind-over-deck	Good Stick Index (GSI)	Helo In-Flt. Mon. Sys. (HIMS)	Lndg. Performance Score (LPS)	Obj. Mission Success Score	Trials to criterion
Buckland	400													
Baron	401													
Wick	402													
Aronson	403													
Jensen	404													
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Emery	406													
Grosslight	407													
Nicholson	408													
Billings	409													
Brictson	410											X		
Pierce	411													
Brown	412													X
Lewis	413		X											
Fineberg	414		X										X	
Farrell	415		X										X	
Stamper	416													
Fineberg	417		X											
Wilson	418													
Koonce	419													X
Waag	420													
Goebel	421													
Charles	422													
Martin	423													
Enochs	424													
Gunning	425													
Carter	426	X												
Moore	427									X				
Keston	428													
Lewis	429													
Gray	430													
Nataupsky	431						X							
Caro	432													
Caro	433													X
Isley	434													

APPENDIX A

PARTIAL LIST OF REPORTS CONTAINED IN ADDENDUM

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