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THE DEVELOPMENT OF HUMAN FACTORS RESEARCH OBJECTIVES FOR CIVIL AVIATION

Theodore J. Post

Prepared for

Biotechnology and Human Research Division
Office of Advanced Research and Technology
National Aeronautics and Space Administration

Prepared by

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Eastern Operations Division
2001 Jefferson Davis Highway
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Arlington, Virginia 22202

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FOREWORD

This study was performed by Serendipity, Inc., Eastern Operations Division, under National Aeronautics and Space Administration (NASA) contract number NASW 1825. The work was done under the auspices of the Office of Advanced Research and Technology, NASA Headquarters, specifically for the Biotechnology and Human Research Division.

The objective of the study was to identify human factors research programs which would support civil aviation and be suitable for accomplishment by NASA research centers. Aviation problems formed the basis for the research program recommendations and, accordingly, problems were identified, ranked and briefly defined in an informal report to the project monitor and other cognizant NASA personnel. The sources for this problem foundation were literature reviews and extensive interviews with NASA and non-NASA personnel. An overview of these findings is presented as the first chapter of this report.

Research recommendations were developed by considering national aviation issues in concert with high ranking problems mentioned above. These considerations generated twenty research program recommendations covering the fields of:

Information Technology,
Crew Factors,
Training,
Psychological-Physiological Research, and
Supporting Research.

Chapters II and III of this report deal respectively with the Development of Human Factors Programs and Research Program Resumes. An Appendix provides detailed information on the civil aviation problems which formed the basis for the human factors research recommendations. Specific coverage includes: complete listing of all problems considered as candidates; the method and data used to select those problems warranting research attention; and, brief discussions, including references, of the human factors aspects of the selected problems.

A special NASA committee provided guidance to the efforts of the study team. Committee members included:

Mr. Steven E. Belsley	Ames Research Center
Dr. Charles Lewis	Flight Research Center
Mr. Robert P. Taylor	Langley Research Center
Mr. James Patton	Langley Research Center
Dr. Randall Chambers	Langley Research Center
Mr. Richard Miner	Electronic Research Center
Mr. Allan Merkin	NASA Headquarters

Many other technical personnel from the NASA gave extensively of their time to contribute to the development of the research objectives reported in this document.

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CHAPTER I

HUMAN FACTORS PROBLEMS IN CIVIL AVIATION

GENERAL

It was intended that the human factors research program resulting from this study be responsive to the problems confronting civil aviation. Accordingly, the initial work focused on identifying and ranking aviation problems. The steps used in developing this problem foundation are listed below and discussed in the remainder of this chapter.

1. Review trade journal literature to obtain a nucleus of problems to support initial interviews.

org. & names

2. Interview non-NASA experts to expand and validate the preliminary problem listing.
3. Interview NASA experts to obtain their views on the developed listing.
4. Administer questionnaires and open-ended mailings to augment the interview data.
5. Select the most critical problems on the basis of frequency of mention by:
   a. Trade journal literature, and
   b. NASA and non-NASA interviews and mailing results.
6. Review all problems for possible combination on the basis of technical relationship.
7. Associate most critical problems with aircraft types of concern.
8. Describe each problem in terms of the cost, safety and effectiveness factors which justify its inclusion as an item in the research foundation.

Brief amplifications of these steps and the results of applying them are discussed briefly in the remainder of this chapter and more extensively in the Appendix, Human Factors Problems in Civil Aviation.

AVIATION PROBLEM IDENTIFICATION

A nucleus of aviation problems was compiled through a review of trade journal literature. Expert opinion, obtained through interview and questionnaire, was used to verify existing listings, provide additional listings and to obtain criticality data on all listed items. The process of developing this problem listing was facilitated by the following classification scheme.

Category	No. of Problems
Crew-Aircraft Interface	(39)
Air Traffic Control	(9)
Aviation-Community Interface	(14)
Medical-Psychological	(35)
Selection and Training	(16)
Maintenance	(2)
Crash Survivability	(7)
Miscellaneous	(9)
Total	131

Descriptive titles for specific problems of each category are presented in Section I of the Appendix.

SELECTION OF MOST CRITICAL PROBLEMS

A concensus of literature and expert opinion similar to that used in the initial identification of problems was used to select from the entire problem listing those which were most worthy of research attention. Thirty-eight of the 131 problems received significant percentages of the literature and interview votes. The small number of votes and their relatively even distribution across problems precluded a precise ranking. However, the selected problems are listed below in the order indicated by the voting scheme. Section II of the Appendix discusses the selection technique, presents the voting data, and the results of consolidating three separate rankings.

PROBLEM LISTING (In Order of Ranking)

Rank	Problem Title	Original Number
1.	Air Traffic Controller Workload	(II-1)
2.	Approach and Landing	(I-18)
3.	Collision Avoidance	(I-17)
4.	Cockpit Instrumentation	(I-28)
5.	Handling Characteristics	(I-2)
6.	Allocation of Functions	(I-1)
7.	Passenger Comfort and Convenience	(III-13)
8.	Pilot Assist Devices	(I-9)
9.	Compatibility of Regulations with User Needs	(VIII-2)
10.	Enroute and Terminal Information	(I-8)
11.	Crashworthiness	(VII-1)
12.	Human Factors Design Principles/Data	(I-12)
13.	Aviation Weather	(I-21)
14.	Pilot Proficiency and Procedural Knowledge	(V-2)
15.	Performance Decrement and Environmental Factors	(I-39)
16.	Standardization	(I-10)
17.	Non-adherence to Standard Operating Procedures	(I-35)
18.	Maintenance Ineffectiveness	(III-3)
19.	Hijacking and Bomb Threats	(III-9)
20.	Required Simulator Improvements	(V-10)
21.	Pilot Manpower Shortage	(III-1)
22.	Fatigue	(IV-7)
23.	Aircraft Noise	(III-6)
24.	Turbulence	(I-3)
25.	Sonic Boom	(III-5)
26.	Insufficient Emphasis on Social Factors in Aviation	(III-14)
27.	Attentiveness	(IV-15)
28.	Pilot Workload	(I-7)
29.	Stress	(IV-8)

PROBLEM LISTING (In Order of Ranking) (Contd.)

Rank	Problem Title	Original Number
30.	Human Factors Involvement in Aircraft Certification	(I-25)
31.	Use of Simulators in Checkouts and Proficiency	(V-3)
32.	Task and Aircraft Design Simplicity	(I-29)
33.	Faulty Cockpit Layout	(I-15)
34.	Voice Communications	(I-11)
35.	Readiness Self-Test	(IV-14)
36.	Ego as an Accident Cause	(IV-31)
37.	Accident/Incident Feedback	(V-7)
38.	Aircraft Handbooks	(V-8)

HUMAN FACTORS PROBLEM STATEMENTS

Generally speaking, the problems selected by the majority as most pressing were aviation problems with implied human factors issues. It was, therefore, necessary to explicate the human factor themes within each problem. The results of this explication are presented in Section III of the Appendix as brief human factors problem statements.

In their present form, the problems are quite general and association with aircraft type is one means of providing more detail. For example, Problem I-39, Performance Decrement Attributable to Environmental Factors, can be thought of as emphasizing vibration and noise in helicopters; anoxia in light aircraft; and humidity and temperature in transport types. Or if Problem I-21, Aviation Weather, is associated with light aircraft, the research area concerns training and education; when considered in the context of helicopters, the research theme could be avionics; and with air carrier operations, the research concern might be terminal area visibility.

Table 1 summarizes the applicability of the selected problems to one or more of seven aircraft types.

TABLE 1. MATRIX OF PROBLEMS BY AIRCRAFT APPLICABILITY

	(1) Light Aircraft	(2) Heli-copter	Subsonic Jet Transport (3) Conven-tional	Subsonic Jet Transport (4) Jumbo	(5) VTOL	(6) SST	(7) HST
I-1 Allocation					X	X	X
I-2 Handling Characteristics	X	X	X	X	X	X	X
I-3 Turbulence				X		X	X
I-7 Pilot Workload	X	X			X*	X	X
I-8 Enroute & Terminal Information	X	X	X	X	X	X	X
I-9 Pilot Assist Devices	X	X			X	X	X
I-10 Standardization			X	X		X	X
I-11 Communications			X	X	X		
I-12 Human Factors Design Principles/Data	X	X	X	X	X	X	X
I-15 Faulty Cockpit Layout	X						
I-17 Collision Avoidance	X	X	X	X	X	X	X
I-18 Landing Accidents	X		X	X	X	X	X
I-21 Aviation Weather	X	X	X	X	X	X	X
I-25 Human Factors Involvement in A/C Cert.	X	X	X	X	X	X	X
I-28 Cockpit Instrumentation	X	X	X	X	X	X	X
I-29 Simplicity	X	X	X	X	X	X	X
I-35 Non-adherence to Standard Oper. Proc.	X		X	X			
I-39 Perf. Decrement & Environ. Factors	X	X	X	X	X	X	X
II-1 Air Traffic Controller Workload	(Not applicable)						
III-1 Pilot Manpower Shortage			X	X	X	X	X

* Emphasis is placed on the circled items.

TABLE 1. MATRIX OF PROBLEMS BY AIRCRAFT APPLICABILITY (CONTD.)

	(1) Light Aircraft	(2) Heli-copter	Subsonic Jet Transport (3) Conven-tional	Subsonic Jet Transport (4) Jumbo	(5) VTOL	(6) SST	(7) HST
III-3 Maintenance Ineffectiveness	X	X	X	X	X	X	X
III-5 Sonic Boom						X	X
III-6 Aircraft Noise		X	X	X	X	X	X
III-7 Hijacking & Bomb Threats			X	X		X	X
III-13 Passenger Comfort & Convenience		X	X	X	X	X	X
III-14 Insuff. Emphasis on Social Factors in Aviation	X	X	X	X	X	X	X
IV-7 Fatigue		X	X	X	X	X	X
IV-8 Stress	X	X	X	X	X	X	X
IV-14 Readiness Self-Test	X*						
IV-15 Attentiveness	X	X	X	X	X	X	X
IV-31 Ego as an Accident Cause	X	X	X	X	X	X	X
V-2 Pilot Prof. & Procedural Knowledge	X						
V-3 Use of Simul. in Checkouts & Prof.	X	X	X	X	X	X	X
V-7 Accident/Incident Feedback	X	X	X	X	X	X	X
V-8 Aircraft Handbooks	X	X	X	X	X	X	X
V-10 Required Simulator Improvements			X	X	X	X	X
VII-1 Crashworthiness	X	X	X	X	X	X	X
VIII-2 Compat. of Regulation with User Needs	X	X	X	X	X	X	X

* Emphasis is placed on the circled items.

SUMMARY OF INITIAL STUDY EFFORT

The result of this initial study effort is a set of aviation problems whose underlying human factors issues have been extracted and described in the Appendix. Where identifiable, the cost, safety and effectiveness implications of these problems are included in these descriptions.

The second half of this study transformed this problem foundation into human factors research programs. The results of this transformation are reported in Chapters II and III of this report dealing respectively with the Development of Human Factors Research Programs and Resumes of the Recommended Research Programs.

CHAPTER II

THE DEVELOPMENT OF HUMAN FACTORS RESEARCH PROGRAMS

TECHNIQUE ILLUSTRATION AND SUMMARY RESULTS

The recommended research programs presented in this chapter were based on: expert opinions obtained during interviews and via literature reviews; the concept of national aviation issues; new developments in aviation; and the top-ranked problems emerging from the initial study effort. The largest influence in developing the research recommendations was a systematic consideration of problems and the following national issues:

- Approach and Landing
- Air Traffic Control
- Collision Avoidance
- Crashworthiness
- Training and Proficiency
- Aircraft Noise and Sonic Boom
- Congestion

An illustration of this "issue -- problem interplay" is presented below for Approach and Landing. The numbered items are some of the relevant top-ranked problems, and the notes indicate the background material suggested by their combination with Approach and Landing.

APPROACH AND LANDING

1. Cockpit Instrumentation - new development of third generation ILS, Pilot Factor study, display problem study by Human Research Laboratory, USAF

2. Handling Characteristics - new rating scale, general aviation stall/spin accident rates, C. W. Harper on future aircraft systems, and reports linking handling with landing accidents

3. Visual Illusions - Vision studies by Boeing, FAA and Fitts.

4. Fatigue, Stress - "Landing Short" paper, ATA/Aero-med paper, FRC studies on stress

5. Aviation Weather - NASA and FAA All weather landing work, ALPA paper on breakout

The systematic consideration of national issues, aviation problems (emphasizing the concensus set), and the relevant research resulted in the following twenty research program recommendations.

HUMAN FACTORS RESEARCH
PROGRAM RECOMMENDATIONS

A. Information Technology
   1. All Weather Landing Studies
   2. Collision Avoidance
   3. Advanced Display Concepts
   4. Data Link Displays
   5. Air Traffic Controller Information Processing

B. Crew Factors
   1. Man-Computer Interactions
   2. Human Factors Influencing Handling Characteristics Assessment
   3. Visual Cues in Landing
   4. Variability of Manual Aircraft Control
   5. See and Be-Seen Improvements
   6. Fatigue, Stress and Workload

C. Training
   1. Advanced Simulator Employment Concepts
   2. Visual and Motion Advancements
   3. Training for Cognitive Performance
   4. Training Requirements Guidelines

D. Psychological-Physiological Research
   1. Human Response to Aircraft Noise and Sonic Boom
   2. Personnel Impact Protection
   3. User Needs in Air Travel

E. Supporting Research
   1. Human Factors Data Techniques
   2. Man-Machine Allocation

RESEARCH PROGRAM ORGANIZATION

The charter of NASA's aeronautical research is currently under study by the Civil Aviation Research and Development (CARD) committee.* While no formal pronouncements have been made as yet, it would seem that NASA's aviation research will continue to stress basic research, applied studies, and proof of concept or product feasibility efforts. A human factors version of these types of research and development is presented in Figure 1 and discussed briefly below.

Human Performance Technology

Objectives of this research area are to develop and experimentally investigate hypotheses (suggested by basic research findings) on new roles for man in aviation. This category also includes the development of techniques and apparatus to support these objectives.

Man-Rated Mechanizations

The ultimate applications of many engineering innovations either support human performance or are controlled by a human operator. This area establishes the compatibility of these advanced mechanizations with the capabilities and limitations of man. The objectives are to assess compatibility in terms of total system performance attainable (acceptable or

* As described in the minutes of the January 1970 meeting of the NASA Research and Technology Advisory Committee on Aeronautics.

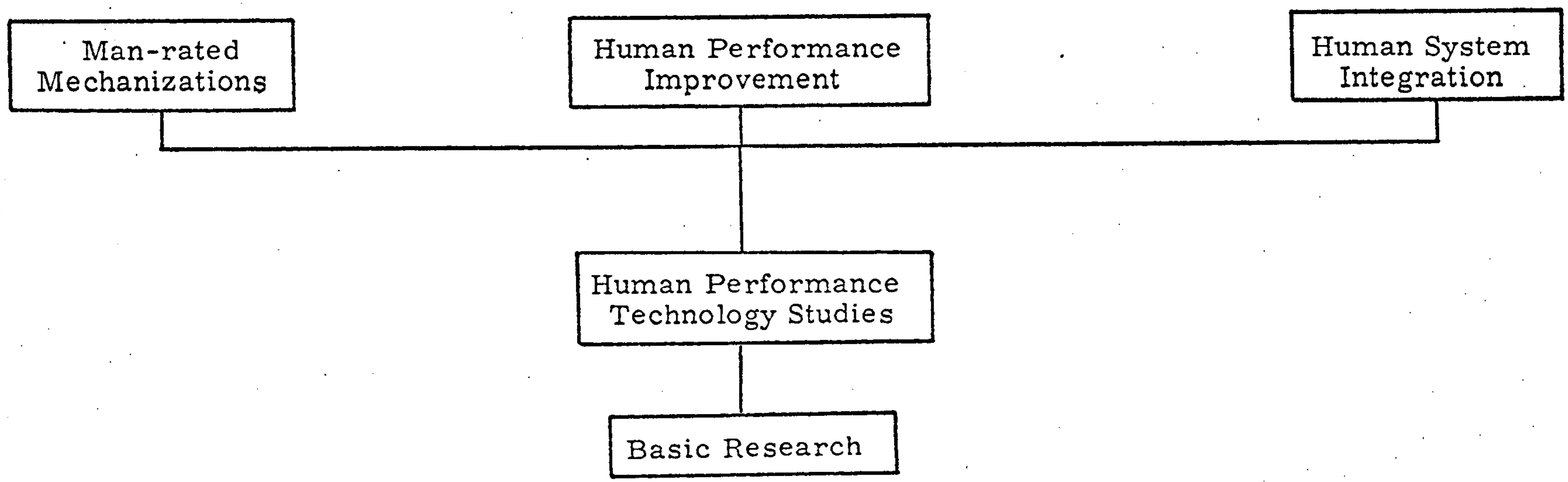

FIGURE 1. RECOMMENDED PROGRAM STRUCTURE

marginal) and to provide recommendations for modification where appropriate.

Human Performance Improvement

This area is an advanced version of human performance technology. The concern remains with the man but the products sought are human factors design standards and principles as opposed to hypotheses or research issues. The intention is to develop these products to be supportive of aviation system design, test, and certification.

Human-System Integration

This research area is responsible for determining the degree to which man's and the community's needs are met by aviation systems and where mismatches are found to provide authorities with evidence of the fault and principles for resolution.

These statements of scope for each research area are necessarily quite broad. A more definitive indication of the program's intent is realizable by associating the twenty research program recommendations with the appropriate research category. The results of this association are shown in Figure 2. While the development of basic research programs was not a requirement of this study, illustrative types of human basic research were taken from a Navy study* and are included in Figure 2 for comprehensiveness. Resumes of the twenty research programs recommended in this study are presented in the next and final chapter of the report.

COMPARISON OF RECOMMENDED RESEARCH AND AVIATION PROBLEMS

The aviation problems presented in the initial part of this report were intended to be requirements for the research programs being developed.

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* A Study of Human Factors Research and Development Activities in the Navy's RDT and E Program, DCNO (Development), November 1962, Tolcott, et al.

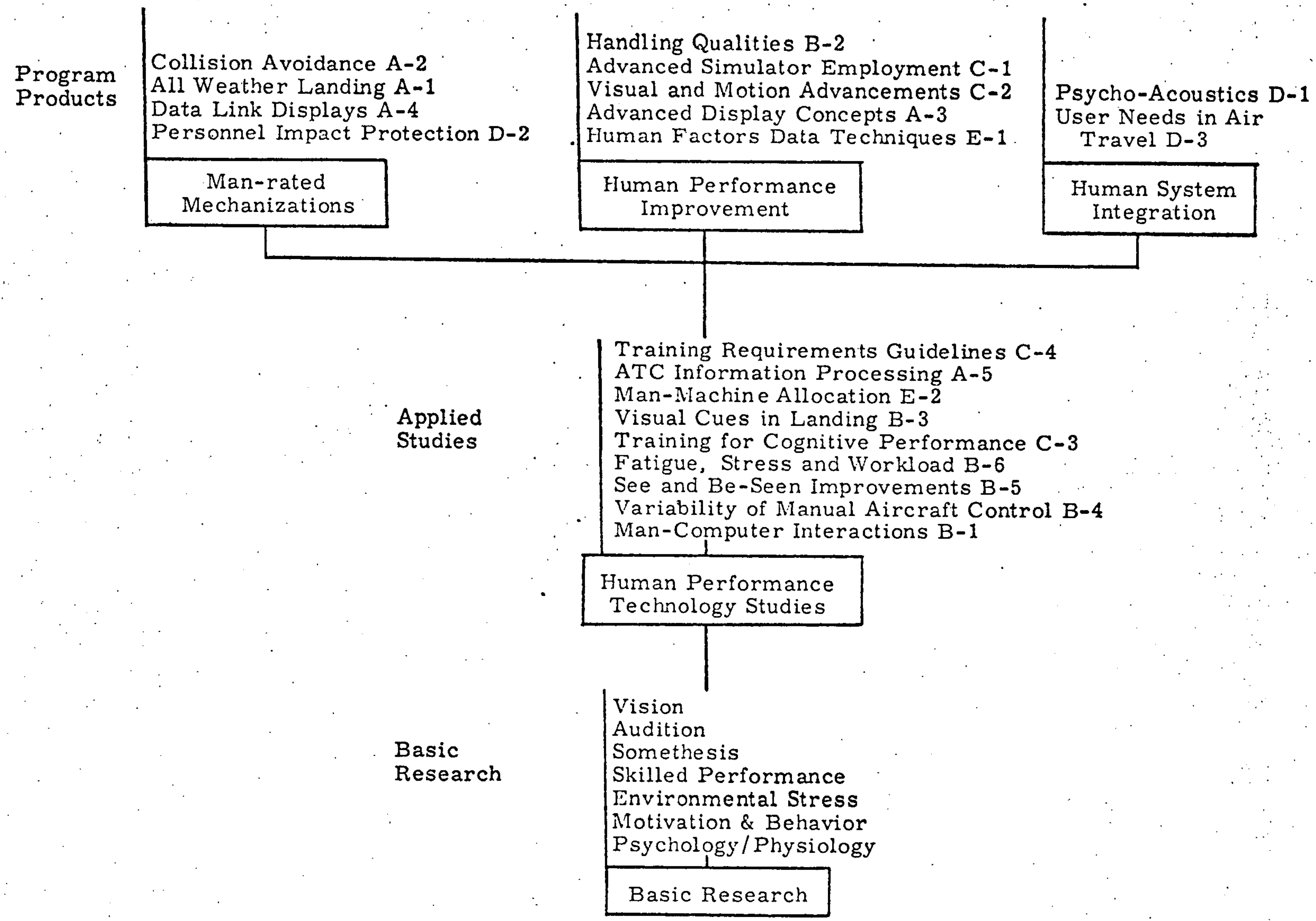

FIGURE 2. SPECIFIC RESEARCH PROGRAMS

The degree to which the recommended research responded to these requirements is indicated in Table 2, a research program x aviation problem matrix. The recommended research programs satisfy or respond to relevant problems in varying degrees. Some accounting of this variation is shown in the body of the matrix of Table 2 through the use of the following legend:

X - full or direct relationship between problem and research as in All Weather Landing System studies and Aviation Weather problems.

P - recommended research covers only a part of the problem, e.g., handling characteristics research is only one aspect of the turbulence problem and even then the recommended research is not specifically directed toward turbulence.

G - indicates a general relationship wherein the recommended research could be directed to solve the referenced problem.

The research programs interact with 28 of the 38 aviation problems. Four of the ten omitted problem statements are so broad and interacting that the overall intent of the recommended research might be thought of as responsive. These problems are:

1. Human Factors Design Principles and Standards
2. Standardization
3. Human Factors in Aircraft Certification
4. Task and Aircraft Design Simplicity

Four* of the remaining six problems appear more compatible with the research charters of other government agencies such as Department of Transportation and Department of Labor. The fifth and sixth problems, Maintenance Ineffectiveness, and Aircraft Handbooks, are symptoms of poor information technology and training both of which are addressed at a general level in the overall research program.

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*Hijackings and Bomb Threats, Pilot Manpower Shortage, Readiness Self-Test, and Ego as an Accident Cause

TABLE 2. RECOMMENDED RESEARCH VS. AVIATION PROBLEMS

Aviation Problems	A-1 All Weather Landing Studies	2 Collision Avoidance	3 Advanced Display Concepts	4 Data Link Displays	5 ATC Information Processing	B-1 Man-Computer Interactions	2 HF Influencing Hndlg. Char. Asses	3 Visual Cues in Landing	4 Variability of Manual A/C Control	5 See & Re-Seen Improvements	6 Fatigue, Stress and Workload	C-1 Advanced Simul. Employ. Concepts	2 Visual and Motion Advancements	3 Trng. for Cognitive Performance	4 Trng. Requirements Guidelines	D-1 Psycho-Acoustics	2 Personnel Impact Protection	3 User Needs in Air Travel	E-1 Human Factors Data Techniques	2 Man-Machine Allocation
Air Traffic Controller Workload					X	G														
Approach and Landing	X			P		G	X	X			G									
Collision Avoidance		X								X										
Cockpit Instrumentation	G	P	X	P																
Handling Characteristics							X		X											X
Allocation of Functions						X														X
Passenger Comfort & Convenience																		X		
Pilot Assist Devices						X			X											X
Regulations and User Needs																		G/P		
Enroute & Terminal Information	P		G	P																
Crashworthiness																	X			
H. F. Design Principles/Data		NO SPECIFIC PROGRAM COVERAGE																		
Aviation Weather	X																			
Pilot Prof. & Procedural Knowledge														G	G					
Perf. Decrement & Environ. Factors											P									
Standardization		NO SPECIFIC PROGRAM COVERAGE																		
Non-adherence to SOP																			X	
Maintenance Ineffectiveness		NO SPECIFIC PROGRAM COVERAGE																		
Hijacking & Bomb Threats		NO SPECIFIC PROGRAM COVERAGE																		
Required Simulator Improvements												X	X							
Pilot Manpower Shortage		NO SPECIFIC PROGRAM COVERAGE																		
Fatigue											X									
Aircraft Noise																X				
Turbulence							P													
Sonic Boom																X				
Insuff. Emphasis on Social Factors in Aviation																		G/P		
Attentiveness											X			X						
Pilot Workload						G					X									X
Stress											X									
H. F. Involvement in a/c Certification		NO SPECIFIC PROGRAM COVERAGE																		
Use of Simul. in Checkouts & Prof.												X								
Task & A/C Design Simplicity		NO SPECIFIC PROGRAM COVERAGE																		
Faulty Cockpit Layout			G						G											
Voice Communications				P																
Readiness Self-Test		NO SPECIFIC PROGRAM COVERAGE																		
Ego as an Accident Cause		NO SPECIFIC PROGRAM COVERAGE																		
Accident/Incident Feedback																			X	
Aircraft Handbooks		NO SPECIFIC PROGRAM COVERAGE																		

CHAPTER III

RESUMES OF RESEARCH PROGRAM RECOMMENDATIONS

INTRODUCTION

The recommended research programs identified in the preceding chapter are discussed in some detail in the following text. Specific topics covered in each resume are a statement of objective including justification and a suggested research approach. Each program writeup includes supporting references which were chosen for their accessibility as well as for their relevance.

A. INFORMATION TECHNOLOGY

1. All Weather Landing System (AWLS) Studies

2. Determine Pilots' Role and Information Requirements for Collision Avoidance Systems (CAS)

3. Advanced Display Concepts and Principles

4. Determine the In-Cockpit Requirements Associated With ATC Data Link Concepts For the 1980s

5. Air Traffic Controller Information Processing

A-1 ALL WEATHER LANDING SYSTEM (AWLS) STUDIES

Objective

Among the many National Airspace System (NAS) capabilities prescribed by the Alexander report, scanning beam micro-wave ILS[1] is slated to play an important role in increasing the capacity of high density airports by permitting reduced spacing between parallel runways and between landing aircraft. The objective of the AWLS research program is to begin definition of the cockpit configuration for this advanced landing system and to continue work on perfecting displays, control dynamics, and procedures for the conventional AWLS.

Approach

I. Conventional AWLS

The Ames Research Center has begun a series of simulator projects[2] to develop and test solution concepts (changes in flight instrumentation, crew preparation, and system operating procedures) for flight management tasks which are suspect when supported only by the baseline low visibility landing system. Accordingly, suggested approaches are not provided.

II. Cockpit Requirements for Advanced ILS

(1) Review the operating concepts and characteristics of the scanning beam micro-wave ILS[3] and devise candidate display-control configurations for the airborne element.

(2) Recommend modifications to existing simulators, and develop scenarios and experimental designs to exercise the hypotheses of the candidate configurations.

(3) Conduct experimentation, analyze data, and provide recommendations in the following areas:

- Crew roles/procedures
- Cockpit configuration (control systems, presentation systems)

- System performance projections, e.g.,
  - touchdown variability
  - vertical control
  - azimuth control
  - increased airport capacity

A-2 DETERMINE PILOTS' ROLE AND INFORMATION REQUIREMENTS FOR COLLISION AVOIDANCE SYSTEMS (CAS).

Objective

Current CAS developments[4, 5] focus on feasibility of engineering approaches and, while experimental cockpit displays have been developed additional effort appears warranted to define the crew's role with particular emphasis on the information content and format required to support this role.

Approach

1. Develop "man-in-the-loop" concepts for CAS in coordination with current FAA, ATA, and NASA efforts.[6, 7, 8] Desirable features might include:

   (a) Alternative modes of operation as a function of such factors as traffic, flight phase and altitude.

   (b) Full or partial display of the state of automatic functions (i.e., targets held, % suspect, caution sector).

   (c) Coordination with other cockpit needs and ease of use, (i.e., false alerts, combining with R-Nav or ATC data link command displays).

2. Devise alternative CAS display mechanizations and subject to comparative tests for effectiveness and preference.

3. Prepare recommendations/findings to include:

   (a) Additional tests and evaluations;

   (b) Recommended characteristics for CAS information presentation.

A-3 ADVANCED DISPLAY CONCEPTS AND PRINCIPLES

Objective

Current cockpit display concepts are considered inadequate for present day operation, e.g., Willis'[9] false hypothesis theory involving inadequate, misinterpreted, or missing information; Beck's[10] citation of load stress and speed stress errors due to data saturation; and Harper's[11] call for better information transfer to the crew concerning aircraft state. The need for advanced concepts of information presentation will become more urgent as the pilot's role evolves into one of an off-line, monitor/optional operator.

Approach

1. Identify candidate presentation concepts[12, 13] in terms of:
   (a) Functional areas (communication, flight safety, and flight management).
   (b) Types of information needed (e.g., projection, rate, options, states).
   (c) Formats and modes (e.g., graphic, command, audio, visual).
   (d) Mechanization concepts (e.g., computer-assisted, passive monitor with call up capability, multi-mode CRT).

2. Design experimentation to determine feasibility from the pilot/operator point of view. Plans should include presentation hypotheses, measures of effectiveness, and apparatus requirements for significantly different aircraft types[14] (e.g., VTOL, SST).

3. Conduct experimentation and data analysis. Prepare recommendations to include:
   (a) Instrumentation principles;
   (b) Crew roles and constitution; and,
   (c) Required research.

A-4 DETERMINE THE IN-COCKPIT REQUIREMENTS ASSOCIATED WITH ATC DATA LINK CONCEPTS FOR THE 1980's

Objectives

The Alexander report on ATC problems and needs envisions an evolutionary system beginning with an upgraded version of the current National Airspace System to serve through the 1980's. Central to the upgraded system is a data link[15] capability providing at least one way command/control from a ground-based computer to the airborne element. The cockpit configuration to accommodate these input commands (i.e., spacing, sequencing, conflict detection and resolution) requires development and test against human factors standards and requirements.

Approach

1. Establish the requirements for information exchange between ground and airborne elements under different ATC concepts (for example, see Thomas[16] and Schriever[17]). Specific concept differences should include variations attributable to airborne vs. ground control.

2. Devise data link information presentation concepts with due consideration to interacting and supporting techniques (station-keeping, R-NAV, Flight Director, back-up equipment) for each of the allocation concepts of (1) above.

3. Prepare experimental plan to exercise and evaluate these cockpit presentation concepts. Plan should include:
   - (a) basic simulator;
   - (b) display apparatus; and,
   - (c) experimental design.

4. Conduct experiments and prepare data link content and format recommendations for use in the following areas:
   - (a) Communication system.
   - (b) Cockpit instrumentation.
   - (c) Crew requirements under normal and degraded system conditions.

A-5 AIR TRAFFIC CONTROLLER INFORMATION PROCESSING

Objective

Projected traffic volumes and the resulting controller workloads are causing major reassessment of the controllers' role in processing aircraft. Changes under consideration involve reassignment of certain functions to the airborne element[18] coordinated with a change in the controllers' method of operation from direct control to management by exception. This research program will use the new set of ground functions as a basis for developing and validating information requirements for the various controller positions which emerge from this reallocation.

Approach

(Note: The preliminary work for this research recommendation is similar to its in-cockpit counterparts, see items A-1 and A-4).

1. On the basis of ATC concepts projected for the 1980s (e.g., navigation and separation functions assigned to the airborne element, speed class sequencing, data link, etc.) establish information requirements for various controller positions.

2. Devise prototype information formats and presentation means and prepare experimental plan to determine the human and total system performance fostered by these prototypes.

3. Conduct experimentation and interpret the data in terms of:

- information presentation recommendations
- controller crew configuration
- operating procedures and criteria

B. CREW FACTORS

1. Determine Requirements and Techniques for Crew Interaction With On-Board Computers

2. Human Factors Variables in Handling Quality Assessment

3. Visual Factors in the Approach-Landing Process

4. Variability of Private Pilot Control Input

5. Human Factors Improvements for See-And-Be-Seen Collision Avoidance

6. Research in Workload, Fatigue and Stress

B-1 DETERMINE REQUIREMENTS AND TECHNIQUES FOR CREW INTERACTION WITH ON-BOARD COMPUTERS

Objectives

A variety of computer-based cockpit systems are under development or evaluation, i.e., Airborne Integrated Data System, Flight Management, R-NAV, All Weather Landing System and Collision Avoidance. Some research activity[19] has addressed the pilot-computer interface with the crew acting as receptors of computer-generated commands, but more effort[20] is required to develop advanced concepts for two-way interaction with the crew interrogating for such information as system status, projection data, or clerical computations.

Approach

1. Review pilot information requirements studies for advanced aircraft for the purpose of determining those flight segments and information needs where on-board computers might be brought to bear.

2. Devise experiments and identify apparatus necessary to support investigations of the areas identified in (1) above.
   - (a) Methods for simulating computer functions.
   - (b) Input/Output devices.
   - (c) Performance hypotheses and scenarios.

3. Procure apparatus and implement experiments; prepare recommendations for:
   - (a) future experimentation;
   - (b) cockpit hardware principles; and,
   - (c) crew roles and procedures.

B-2 HUMAN FACTORS VARIABLES IN HANDLING QUALITY ASSESSMENT

Objective

A significant amount of research[21, 22] is being conducted to improve the handling qualities of conventional and advanced aircraft. Much of this research relies heavily on the evaluation of aircraft dynamics (simulated or actual) by test pilots. However, too little is known about the variables[22] which a pilot considers when formulating his assessment. Further, his assessment comments are not usually consistent with engineering terminology involved in control system design and test. To improve upon the communication between designers and pilots it is necessary to isolate the factors used by the pilot during this assessment and to gather data to establish the roles and relative influence of each of these factors.

Approach

1. Develop an experimental set of human factors variables* (and terminology) which appears to influence a pilot's assessment of handling qualities. The intent[21, 22] is to increase the type and number of variables considered during a pilot's assessment of handling qualities and, where possible, to establish relationships with engineering characteristics** of flight control systems.

* For example: control/display features, external visual cues, motion, acceleration, and vibration.

** For example: force trimming, dynamic/static friction, and force gradients.

2. Conduct a series of experiments to evaluate, modify, and validate the experimental assessment structure.

3. Apply validated assessment techniques to man-rate experimental control systems-cockpit configurations.

B-3 VISUAL FACTORS IN THE APPROACH-LANDING PROCESS*

Objective

An annual review of air transport accident statistics reported by Flight Safety Foundation (FSF)[23] indicates that 5 of 7 landing accidents occurred at night at airports without glide slope service. Ground and onboard landing aids to combat this problem are not expected to be available for some years and consequently a better understanding of the visual approach is required. The research objective presented here seeks to extend recent simulator investigations of the night VFR approach and to begin work on visual problems under IFR breakout conditions.

Approach

Two coordinated programs should be considered. The first would depart from the results of recent simulator investigations of night VFR approaches[24] and should be coordinated with pending work of DOT[25].

Suggested areas of emphasis should include:

- isolation of circumstances which constitute a hazard for night VFR approaches.
- principles for advanced instrumentation, procedures, charts, and training.

The second[26] effort is a series of visual perception and decision-making studies of the IFR breakout circumstance conducted under various decision heights and aircraft offsets, cloud cover, terrain, and landing aid configurations.

Conclusions to be drawn from such investigations should cover:

Crew role/procedures/criteria

Cockpit and ground aids required for normal, night and low visibility landing systems.

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* See research recommendations A-1 and B-5 for related programs.

B-4 VARIABILITY OF PRIVATE PILOT CONTROL INPUT

Objective

Stall/spin accidents in private aviation continue to occur at a high rate[27] indicating that the user pilots' behavior is not congruent[28] with the manufacturers' test programs or the FAA certification process. This research is intended to reduce this discrepancy by defining the variability of control inputs by private pilots so as to be useful to the designers of improved control systems.

Approach

1. Prepare a data gathering plan for the purpose of defining aircraft control "performance envelopes"[29] for typical users. Scope of the experimental plan should be defined in terms of concepts for measuring control input, pilot populations, aircraft and flight control types, flight segments, and flight conditions.

2. Implement data collection using ground simulators adapted to this purpose; include inflight verification as necessary.

3. Prepare findings in terms of "performance envelopes" or safety margins which are representative of normal-emergency conditions, various levels of pilot experience and critical portions of the flight profile.

B-5 HUMAN FACTORS IMPROVEMENTS FOR SEE-AND-BE-SEEN COLLISION AVOIDANCE

Objective

Detailed reviews[30] of recent mid-air collisions indicate that a surprisingly large percentage occur in the landing pattern where workload is highest and vigilance lowest. These factors combine with visibility problems to restrict the visual-cognitive capability required for effective use of the see and be seen concept. The objective of this program is to identify and demonstrate the feasibility of one or more human factors solution concepts which are compatible with but beyond the scope of sensing devices such as Proximity Warning Indicators and Collision Avoidance Systems.

Approach

1. Determine through survey and experimentation the degree to which the see and be seen concept is comprised by non-awareness of the techniques[31] and ineffectualness of properly applied techniques[32].

2. Compare improvements proposed for see and be seen operations (for example, see AOPA[33] recommendations) against:

   (a) Results of (1) above, and
   (b) Newly identified collision characteristics[34].

3. Conduct test and evaluation of most promising solutions.

B-6 RESEARCH IN WORKLOAD, FATIGUE AND STRESS

Objective

Problems arising from this array of human factors considerations include: increases in requests for early medical retirement traced to boredom, emotional stress about proficiency and fatigue;[35] indictment of emotional stress as accident cause;[36] and, inhibited progress on advanced aircraft designs due to inadequate workload measurement techniques and standards.[37] The research recommended concerns selection of measurement functions, development of instrumentation, and the collection of data which can be translated into principles and standards.

Approach

Three specific study areas are recommended:

1. Desynchronosis.[38] Conduct a controlled experiment to quantify the symptoms of desynchronosis as a lead to precautionary and remedial measures research. Experiment should be characterized by:
   - pre-, post- and in-flight subject assessment,
   - comparison of severe and mild time zone changes,
   - basic medical parameter coverage.

2. Workload.[39] Gather experimental data on psychophysiological measures alone and in combination with subsidiary task measures and subjective opinion to determine their utility as an index of pilot workload.

3. Physical Stress.[40] Conduct simulator studies to determine threshold sensitivity to angular accelerations typical of advanced jet transport and attempt to define the visual-vestibular interactions which may be the cause of disorientation in airline pilots.

C. TRAINING

1. Development of Human Factors Techniques to Improve the Efficiency of Simulator Employment

2. Training Benefits of Motion and Visual Capabilities in Simulators

3. Demonstrate Training Techniques for Cognitive Performance

4. Training Requirements Guidelines

C-1 DEVELOPMENT OF HUMAN FACTORS TECHNIQUES TO IMPROVE THE EFFICIENCY OF SIMULATOR EMPLOYMENT

Objective

Increased reliance on simulator usage has been responsible for significant reductions in the time required to qualify pilots in transition and upgrade training[41]. Despite these advancements, it has been estimated that simulator usage is only 50% as efficient as it could be[42]. The purpose of this research is to investigate advanced human factors methods of simulator utilization which offer promise of further increasing the efficiency and effectiveness of the training process.

Approach

1. Employ recent research advances to develop new training concepts which utilize the simulator as the nucleus. Illustrative content of the total concepts might include:

    (a) Proficiency indications via onboard monitoring equipment[43].

    (b) Private practice, automatic data generation, and self-confrontation[44].

    (c) Adaptive training with instructor diagnosis of preprocessed data[45].

2. Design experimental settings and apparatus modifications to be used in demonstrating the feasibility and benefits of the results of (1) above.

C-2 TRAINING BENEFITS OF MOTION AND VISUAL CAPABILITIES IN SIMULATORS

Objective

Data is readily available which purport to show the training advantages of motion or visual capability in simulators[46]. However, the "full cycle" has not always been investigated, i.e., more accurate tracking in motion simulators does not necessarily equate with superior training. This research program is intended to develop training benefit hypotheses for simulator advancements (primarily motion and visual attachments) and to conduct experimentation[47] to bear out or invalidate the contentions.

Approach

1. Review simulator/training advances as a basis for the development of hypotheses and the preparation of experimental concepts/plans.

2. Using modified simulators gather data on the degree to which simulator advances can benefit training. Identify the problems which the new capabilities bring to the training arena[48].

3. Interpret data to determine:
   (a) need for additional research; and,
   (b) principles for applying motion and visual simulators in training programs.

C-3 DEMONSTRATE TRAINING TECHNIQUES FOR COGNITIVE PERFORMANCE

Objective

A training problem consistently reported by many researchers[49] concerns the lack of objective criterion measures to assess complex performance especially in the higher level cognitive tasks. In addition to the assessment problem many of these cognitive performances (vigilance, decision making, judgement) are not included in current training curricula. This lack of coverage is all the more disconcerting in view of the suspicion that these types of performance are frequently involved in pilot error accidents. This research area is intended to examine these types of performance for the purpose of associating them with potential training techniques and to conduct feasibility demonstrations where warranted.

Approach

1. Based on accident data and a review of flight crew performances, identify cognitive tasks and behavioral traits which should receive treatment but are not now covered in standard training curricula. Examples[50] of such performance are: vigilance or state of awareness, reactive capacity, consistency of performance, adaptability and accuracy of expectancies.

2. Review the potential of existing training methods and performance criteria to address the requirements of (1) above.

3. Conduct feasibility demonstrations where existing techniques permit and recommend training research where voids are found.

C-4 TRAINING REQUIREMENTS GUIDELINES

Objective

A major and continuing problem[51] of training specialists is the determination of what should be taught and to what level of understanding. Total reliance on the traditional task analysis is too theoretical and time consuming. The training specialist needs guidelines to aid in selecting the tasks to be trained, the quality of performance sought, and the conditions under which the crew should be able to perform at this level. Observational studies[52, 53] of inflight performance of crews are recommended to collect the data which will serve as the basis for developing these guidelines.

Approach

1. In close coordination with ATA and ALPA representatives, design the observational study program referenced above. Minimum scope of the data plan should include:
   - (a) performance areas of interest and conditions of accomplishment,
   - (b) statistical requirements,
   - (c) personnel variables (e.g., experience, proficiency, age).

2. Implement data collection plan including pretest, modification and data collection phases.

3. Analyze data to define principles for establishing training requirements covering such areas as:
   - (a) Skills most susceptible to error under normal conditions.
   - (b) Skills/performances most susceptible to deterioration through disuse.
   - (c) Signs of performance deterioration by performance type.
   - (d) Performances most susceptible to load or speed stress.

D. PSYCHOLOGICAL - PHYSIOLOGICAL RESEARCH

1. Passenger/Crew Protection Against Impact Injury

2. Human Response to Aircraft Noise and Sonic Boom

3. User Needs in Air Travel

D-1 PASSENGER/CREW PROTECTION AGAINST IMPACT INJURY

Objective

A study of 153 U.S. air carrier accidents in years 1955-1964 concluded that 1628 occupants died from impact forces, 297 died from fire, and 30 from miscellaneous causes[54]. "The rate at which (air carrier) accidents lead to fatalities is increasing. For the years 1961-1964, the number of fatal accidents per million landings was 0.27, 0.88, 1.06, and 1.27 respectively."[55] The objective of this research program is to develop and demonstrate impact protection means as the heart of an integrated crash survival system, i.e., including delethalization, evacuation factors and toxicity considerations.

Approach[56]

1. Develop and validate a mathematical model of the dynamic response of the human vertebral column to impact forces in the magnitude and directions represented by new aircraft types.

2. Validate and exercise the model to provide data for the complete design of crew and passenger seat support and restraint systems.

3. Devise total protection concepts based on impact protection means of (1) and (2) above; determine through study and experimental investigations the survivability improvements expected.

D-2 HUMAN RESPONSE TO AIRCRAFT NOISE AND SONIC BOOM

Objective

Negative public reaction to noise and sonic boom are potential deterrents to new transport modes such as VTOL and attempts to reduce the negative reaction has aggrevated congestion (90 movements per hour at JFK with noise abatement vs. 150 movements per hour at O'Hare without noise abatement[57]) and created concern over safety. The purpose of this research program is to determine the psychological-acoustical impacts of aircraft noise and sonic boom on flight crew and community. The intent is to provide data to authorities for use in establishing guidelines and standards.

Approach

Continue[58] to gather data to develop an information base having applications: to the establishment of international noise standards, to future aircraft/airport operations, and to the evaluation of aircraft noise reduction approaches. Specific study coverage should include subjective noise comparison tests, absolute judgment tests, sleep interference tests, auditory and non-auditory tests, task performance tests, and acoustic-vibration tests.

D-3 USER NEEDS IN AIR TRAVEL

Objective

User dissatisfaction with air travel is represented by such diverse areas as uncomfortable ride qualities contributing to non-acceptance of some vehicles[59], passenger congestion and ground processing difficulties with their potential back-up into the ATC system[60], and the users' impression of air safety and its impact on the selection of mode of travel[61]. The objective of this research area is to develop techniques and data which will improve the degree to which users' needs are met in new transport technology.

Approach

Develop and test analytical trade-off techniques involving the following areas:

- user acceptance factors (vibration, space, noise, perceived safety, enroute time)
- engineering variables (wing loading, angle and speed of approach, handling characteristics)
- employment concepts (satellite airport, load factor, cabin capacity).

The development and test process should include:

- studies to define factors and theoretical relationships (ride quality and angle/speed of attack)
- a series of data gathering efforts to quantify the factors and validate the relationships.

E. SUPPORTING RESEARCH

1. Develop Human Factors Data Collection Techniques Appropriate For Inclusion in the Accident/Incident Investigation Process

2. Data For Support of Man-Machine Allocations

E-1 DEVELOP HUMAN FACTORS DATA COLLECTION TECHNIQUES APPROPRIATE FOR INCLUSION IN THE ACCIDENT/INCIDENT INVESTIGATION PROCESS

Objective

Historical accident data reveal an extremely high percentage of pilot error accidents (51% primary causes and 28% secondary causes[62]). Yet the accident investigative data being accumulated do not seem to provide the researcher with the basis for preventive or corrective programs, i.e., an extensive review[63] of landing accident data was unable to isolate causes and suggests a massive data collection program to overcome this void. Development of suitable techniques to accumulate and analyze such data is the objective of this research program.

Approach

1. Define scope of the problem to include at least the following areas of concern:

   (a) Human factors information desired and techniques applicable to its collection during investigation of accidents/incidents[64].

   (b) Screening and analysis of data from new sources such as onboard[65] monitoring systems and training data pools.

   (c) Data exchange capability[66] emphasizing human factors aspects of operation, training, and design.

2. Conduct feasibility efforts for each of these areas of concern working with relevant agencies and organizations such as:

   NTSB
   ALPA
   NSF (Information Exchange)
   ATA

3. Evaluate results of feasibility studies and recommend changes, discontinuance or implementation plans.

E-2 DATA FOR SUPPORT OF MAN-MACHINE ALLOCATIONS

Objective

Many of the aviation research programs being conducted involve an allocation of system functions between air and ground elements or between men and machines. A recent study[67] provided a brief history of the technical inadequacies of this allocation process and outlined the actions necessary to eliminate many of the resulting problems. This research program is intended to implement the outlined actions as a means of providing design and certification agencies with the appropriate principles and standards.

Approach

1. Develop a methodology for conducting man-machine allocations and establishing roles, size and operating procedures for the crew.

2. In coordination with related military efforts[68], develop the data base on man's capabilities and limitations required to support the allocation methodology; this development must include formats and retrieval concepts for the elements of the data base.

3. Conduct a proof-of-concept effort on a specific, future vehicle such as the VTOL aircraft.

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APPENDIX

HUMAN FACTORS PROBLEMS IN CIVIL AVIATION

CONTENTS

LIST OF TABLES AND FIGURES

LIST OF TABLES AND FIGURES (CONTD.)

I. DEVELOPMENT OF PROBLEM LISTING

INTRODUCTION

Unstructured interviews were held first with non-NASA and then with NASA technical personnel for the purpose of developing a listing of human factors problems in civil aviation. A preliminary listing of candidate problems, obtained from the literature, was furnished to the interviewees to serve as a guide and stimulus. Interviewees were asked to comment (pro-/con-amplifications) on only those problems for which they felt they had reasonable technical knowledge. Specific effort was made to have the interviewees add problems to the list either directly (e.g., human factors problems they felt should be on the list but were not) or indirectly by indicating new aeronautical technology or aviation problems with human factors overtones.

Two additional types of problem information were obtained. Questionnaires were distributed to each member of a NASA coordinating committee, and open-ended requests were mailed to 100 people soliciting their opinion on the top "several" human factors problems. The address list for the mailing was compiled largely from the Human Factors Society membership directory and included only those people whose areas of stated interest covered both human factors and aviation.

As the problems were being identified, it became clear that a categorization would facilitate the interviews and generally aid in keeping track of collected information. The following categories evolved during the problem development process:

I	Crew-Aircraft
II	Air Traffic Control
III	Aviation-Community Interface
IV	Medical/Psychological
V	Selection and Training
VI	Maintenance

VII	Crash Survivability
VIII	Miscellaneous

The list of problems resulting from the process described above is presented on the following pages. The check marks indicated those problems added to the list relatively late in the development process.

It should be noted that the list as it appears here was used primarily as an interview aid, and therefore some of the "problems" suggest research recommendations (e.g., Need for Measurement Techniques and Standards for Pilot Workload); some are techniques which if not properly applied will result in problems (e.g., Allocation of Functions); and there is much overlap (e.g., Approach and Landing Accidents and Cockpit Instrumentation). These inconsistencies were deliberately allowed to remain in order to elicit the broadest range of comments possible from each of the diverse elements of the interview population.

LIST OF HUMAN FACTORS
PROBLEM AREAS IN AVIATION

Category I. Crew-Aircraft

1. Allocation of functions between crew members, man and machine, air and ground.

2. Measurement and standards for aircraft handling characteristics.

3. Structural overload deriving from pilot reaction to low frequency turbulence.

4. Physical characteristics of airports as they relate to piloting activities.

5. Aircraft control systems compatible with natural pilot response.

6. Need for improved stability and control augmentation systems.

7. Lack of measurement techniques and standards for pilot workload.

8. Presentation of enroute and terminal information.

9. Principles for pilot assist devices applicable to flight control, approach and landing, and flight management.

10. Aircraft standardization in the crew and passenger compartments, and for maintenance.

11. Excessive requirements for voice communication.

12. Inadequate employment of human factors principles in the design of aviation systems.

13. Acceptable methods and standards for determining crew size.

14. Proliferation of cockpit displays.

15. Faulty cockpit layout as an accident factor.

16. Pilot errors induced by aircraft design.

17. Visual collision avoidance.

18. The approach and landing phase of flight.

19. Cockpit noise.

20. Exceeding aircraft design limits by pilots.

21. The factor of weather in aviation accidents.

22. Instrument panel vibration.

23. Questionable safety of noise abatement procedures.

24. Obstruction marking.

25. Human factors involvement in aircraft certification.

26. Pilot warning indicators.

27. Aircraft lighting and marking.

*28. Inadequacies of current cockpit instruments.

*29. Task and aircraft design simplicity.

*30. Need to reconsider aircraft controls.

*31. Stall-spin accidents.

*32. Private pilot limitations in dealing with airspace congestion.

*33. Judgment and poor airmanship as an accident cause.

*34. Terminal area visibility requirements.

*35. Lack of standardized procedures or non-adherence to standard procedures.

*36. Desirability of automating checklist.

*37. Efficacy of direct lift controls.

*38. Collation and compensation of "faulty" information from cockpit displays.

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* Asterisked items are problems which were added to the list relatively late in the development process.

*39. Performance decrement from mechanical or environmental factors, e.g., vibration, noise, acceleration.

Category II. Air Traffic Control

1. Excessive air traffic controller workload.

2. Definition of air traffic controller assist devices.

3. Allocation of ATC functions between air and ground, man and machine, and amongst positions.

4. Ground control of aircraft.

5. Controller training.

6. Controller proficiency.

7. Lack of human factors principles in design of ATC workspace.

* 8. Determination of information requirements and instrumentation.

* 9. Capacity of ATC as a function of personnel factors.

Category III. Aviation-Community Interface

1. Adequacy of number of qualified pilots.

2. Adequacy of number of qualified controllers.

3. Adequacy of number of qualified aviation support personnel.

4. Intermodal transportation problems.

5. Sonic boom effects on people.

6. Aviation noise.

7. The basis for public choice of transportation mode.

8. Means for quantifying the benefits of human factors program.

9. Bomb threats, aircraft hijacking, and sabotage.

10. Congestion problems for processing and loading passengers.

11. Aviation-caused air pollution.

12. International flight complexities, e.g., language, antiquated facilities.

*13. Passenger comfort and convenience.

*14. Necessity to emphasize social factors in air transport development.

Category IV. Medical/Psychological

1. Circadian rhythm.

2. Early detection of disease in aviation personnel.

3. Prediction and detection of solar flares.

4. Anoxia.

5. Explosive decompression.

6. Ageing.

7. Fatigue and effect on performance.

8. Emotional stress.

9. Vibration-induced back injuries.

10. Hearing impairments attributable to aviation noise.

11. In-aircraft medical care.

12. Sanitation onboard aircraft.

13. Updating of physical requirements for pilots.

14. A readiness self-test.

15. Attentiveness and its variations in different parts of the flight profile.

16. Visual illusions.

17. Rapid transition from light to dark in SST profiles.

18. Need for display of anticipatory information, e.g., imminent events for automatic systems.

19. Effect of off-duty activities on performance.

20. Turbulence-induced visual deterioration.

21. Negative reaction of pilots to assist devices such as automatic gear extenders.

22. Negative reaction of air traffic controllers to assist devices.

23. Controller morale.

24. Attitude of the general aviation pilot (non-professional) to weather.

25. Mass behavior under emergency crash conditions.

26. Complacency of aircrews.

27. Controller-pilot relationship.

28. Vertigo/disorientation.

*29. Cockpit-derived health problems.

*30. Cigarette smoking, anoxia and "veiling".

*31. Ego involvement in accidents.

*32. General health habits.

*33. Crew interchangeability and emergency effectiveness.

*34. Difficulty of obtaining rest before and during (extended) trips.

*35. "Get-out-itus" for senior pilots.

Category V. Selection and Training

1. Private pilot certification requirements.

2. Pilot proficiency and procedural knowledge.

3. Use of simulators in training and check-outs.

4. Selection and training techniques and standards.

5. Measures of effectiveness for air safety educational programs.

6. Ground classroom training improvements.

7. Feedback of accident information.

8. General aviation aircraft manuals.

* 9. Poor weather instructional techniques.

*10. Required simulator advancements.

*11. Controller selection criteria.

*12. Human factors benefits of variable stability aircraft.

*13. Need to quantify human performance criteria.

*14. Realism in simulation scenarios.

*15. Hazards of training role reversals (in flight).

*16. Lack of understanding of differences between research and training simulators.

Category VI. Maintenance

1. New techniques to foster maintenance technician performance (e.g., training methods, job aids).

2. Accidents attributable to maintenance error.

Category VII. Crash Survivability

1. Crashworthiness.

2. Restraint.

3. Injurious environment.

4. Energy absorption.

5. Post crash behavior.

* 6. Trade-off criteria for evacuation versus aerodynamic factors.

* 7. Toxicity.

Category VIII. Miscellaneous

1. Semantics.

2. Compatibility of regulations with user needs.

3. Communication of information to users.

4. Protection of private pilot from self without excessive restrictions.

5. The need for better (human factors) aviation statistics.

* 6. Validity of research settings and results.

* 7. Alcohol and flathatting.

* 8. Lack of measures to establish quality of man-machine combination.

* 9. Expense of avionics as a deterrent to light aircraft operators.

II. RANKING DATA AND PROBLEM DISPOSITION

INTRODUCTION

During the development of the aviation problem listing information was sought to support a "frequency-of-mention" ranking of the candidate problems. The purpose was not to obtain a precise numerical ranking for each problem; rather, the intention was to distinguish between the most and least severe problems on the basis of expert opinion. The following six sources of information were used for this application:

1. Approximately 600 articles from trade-journal literature.

2. Technical reports (approximately 175) resulting from two literature search requests of the Defense Documentation Center.

3. Information resulting from the interviews of non-NASA technical personnel (16 individuals).

4. Information resulting from the interviews of NASA technical personnel (35 individuals).

5. Responses to an open-ended request for human factors problems (20 responses from 100 mailings).

6. Questionnaire data obtained from NASA coordinating committee members plus project principals.

RANKING TECHNIQUE

These sources of information were used in the following fashion to select the aviation problems which warranted research attention. The interviewees were asked to comment within their technical field on the candidate problems which they felt to be most pressing. The results of these interviews (i. e., frequency of mention) were compiled for NASA, for non-NASA (including the mailing) and for the trade-journal literature. Figures A-1, A-2 and A-3 present the resulting distributions of problem mentions. *

The NASA and non-NASA "votes" were added and the top one third of the problems was selected tentatively. These problems were then compared against the literature distribution. Problems for which both groups (interviewees and literature) were in agreement were retained for inclusion on the list. The remainder of the problems were treated in one of the following ways.

1. A low vote problem could be absorbed by a high vote problem precluding elimination.

2. A problem could be retained despite a low vote if a case could be developed to show impact on safety, cost or effectiveness.

3. If neither of these options was possible the problem was eliminated from the final listing.

---

*No attempt was made to interpret similarities or discrepancies.

Table A-1 summarizes the voting data and the disposition of problems. Columns 2 and 3 present the numbers of interviewed persons or groups who chose to comment on each problem. Columns 4 and 5 show whether this frequency of mention was sufficient for placement in the top one third of the problems. Columns 6 through 9 indicate disposition of each problem according to the following legend:

Column 6 - check indicates that problem was included in the final listing on the basis of commentary, i. e., NASA, non-NASA and literature.

Column 7 - entry indicates that the problem of column 1 was absorbed by the indicated problem.

Column 8 - entry indicates that problem was retained on basis of:
S = Safety, C = Cost or E = Effectiveness.

Column 9 - check indicates that problem was eliminated.

TABLE A-1 RANKING DATA AND DISPOSITION OF CANDIDATE PROBLEMS

Prob. No.	No. of Interviewees Commenting		Top 1/3 by Commentary	Top 1/3 by Literature	Disposition			
					Included on Basis of:			Eliminated
	NASA	Non-NASA			Commentary	Absorption	Rationale	
I-1	7	7	Yes	Yes	X			
I-2	7	2	Yes	Yes	X			
I-3	4	1	Yes	Yes	X			
I-4	1	2	No	Yes		I-18		
I-5	3	0	No	No		I-2 & I-29		
I-6	4	3	Yes	No		I-2		
I-7	5	3	Yes	Yes	X			
I-8	3	8	Yes	Yes	X			
I-9	3	6	Yes	Yes	X			
I-10	2	9	Yes	No			C	
I-11	0	5	Yes	Yes	X			
I-12	5	2	Yes	No			E	
I-13	2	2	No	No		I-1		
I-14	4	6	Yes	No		I-28		
I-15	1	2	No	No			S	

TABLE A-1 RANKING DATA AND DISPOSITION OF CANDIDATE PROBLEMS (CONTD)

Prob. No.	No. of Interviewees Commenting		Top 1/3 by Commentary	Top 1/3 by Literature	Disposition			
					Included on Basis of:			
	NASA	Non-NASA			Commentary	Absorption	Rationale	Eliminated
I-16	1	0	No	No		I-15		
I-17	5	10	Yes	Yes	X			
I-18	5	11	Yes	Yes	X			
I-19	1	3	No	No				X
I-20	0	0	No	No				X
I-21	3	4	Yes	Yes	X			
I-22	0	2	No	No				X
I-23	0	1	No	Yes		III-6		
I-24	1	1	No	No		I-18		
I-25	3	4	Yes	No			S	
I-26	2	1	No	No		I-28		
I-27	2	2	No	No		I-17		
I-28	4	7	Yes	Yes	X			
I-29	1	2	No	No			S	
I-30	0	0	No	No		I-2		
I-31	2	0	No	No		I-2		

TABLE A-1 RANKING DATA AND DISPOSITION OF CANDIDATE PROBLEMS (CONTD)

Prob. No.	No. of Interviewees Commenting		Top 1/3 by Commentary	Top 1/3 by Literature	Disposition			
					Included on Basis of:			
	NASA	Non-NASA			Commentary	Absorption	Rationale	Eliminated
I-32	0	0	No	No		VIII-2		
I-33	0	0	No	No		I-18		
I-34	0	0	No	No		I-21		
I-35	3	1	No	No			S	
I-36	1	1	No	No		I-1		
I-37	0	0	No	No		I-18		
I-38	0	0	No	No		I-18		
I-39	1	0	No	No			S	
II-1	1	10	Yes	Yes	X			
II-2	0	9	Yes	No		II-1		
II-3	1	8	Yes	No		II-1		
II-4	0	5	Yes	No				X
II-5	0	1	No	No				X
II-6	1	1	No	No				X
II-7	1	1	No	No				X

TABLE A-1 RANKING DATA AND DISPOSITION OF CANDIDATE PROBLEMS (CONTD)

Prob. No.	No. of Interviewees Commenting		Top 1/3 by Commentary	Top 1/3 by Literature	Disposition			
					Included on Basis of:			
	NASA	Non-NASA			Commentary	Absorption	Rationale	Eliminated
II-8	0	0	No	Yes		II-1		
II-9	0	0	No	No		II-1		
III-1	2	1	No	No			S	
III-2	0	2	No	Yes		II-1		
III-3	0	4	No	No			S	
III-4	2	5	Yes	Yes		III-13		
III-5	3	2	Yes	Yes	X			
III-6	2	5	Yes	Yes	X			
III-7	2	0	No	Yes		III-14		
III-8	0	1	No	No				X
III-9	0	4	No	No			S	
III-10	0	4	No	Yes		III-13		
III-11	0	1	No	No				X
III-12	0	2	No	No				X

TABLE A-1 RANKING DATA AND DISPOSITION OF CANDIDATE PROBLEMS (CONTD)

Prob. No.	No. of Interviewees Commenting		Top 1/3 by Commentary	Top 1/3 by Literature	Disposition			
					Included on Basis of:			
	NASA	Non-NASA			Commentary	Absorption	Rationale	Eliminated
III-13	4	1	Yes	Yes	X			
III-14	3	1	No	Yes			E	
IV-1	1	1	No	No				X
IV-2	0	4	No	No				X
IV-3	0	3	No	No				X
IV-4	0	5	Yes	No		I-39		
IV-5	0	2	No	No				X
IV-6	0	2	No	No		III-1 & II-1		
IV-7	2	5	Yes	No			S	
IV-8	4	1	Yes	No			S	
IV-9	0	1	No	No		IV-4		
IV-10	1	2	No	No		IV-4		
IV-11	0	2	No	No				X
IV-12	0	1	No	No				X

TABLE A-1 RANKING DATA AND DISPOSITION OF CANDIDATE PROBLEMS (CONTD)

Prob. No.	No. of Interviewees Commenting		Top 1/3 by Commentary	Top 1/3 by Literature	Disposition			
					Included on Basis of:			
	NASA	Non-NASA			Commentary	Absorption	Rationale	Eliminated
IV-13	0	1	No	No				X
IV-14	0	6	Yes	No			S	
IV-15	2	5	Yes	No		I-35		
IV-16	2	3	Yes	No		I-17, 18		
IV-17	0	1	No	No				X
IV-18	1	1	No	No		IV-21 & I-28		
IV-19	0	2	No	No		IV-7		
IV-20	1	2	No	No		I-3		
IV-21	5	2	Yes	No		I-9		
IV-22	0	0	No	No		I-9		
IV-23	0	1	No	No				X
IV-24	0	0	No	No		I-21		
IV-25	0	1	No	No		VII-1		
IV-26	0	3	No	No		IV-15		
IV-27	0	2	No	No		IV-8		
IV-28	1	3	No	No		I-21		

TABLE A-1 RANKING DATA AND DISPOSITION OF CANDIDATE PROBLEMS (CONTD)

Prob. No.	No. of Interviewees Commenting		Top 1/3 by Commentary	Top 1/3 by Literature	Disposition			
					Included on Basis of:			
	NASA	Non-NASA			Commentary	Absorption	Rationale	Eliminated
IV-29	0	1	No	No		I-39		
IV-30	0	1	No	No				X
IV-31	2	0	No	No			S	
IV-32	0	0	No	No				X
IV-33	0	0	No	No				X
IV-34	0	0	No	No		IV-7		
IV-35	1	0	No	No		IV-6		
V-1	2	2	No	Yes		VIII-2		
V-2	3	9	Yes	Yes	X			
V-3	1	5	Yes	Yes	X			
V-4	0	2	No	No		III-1		
V-5	0	2	No	No				X
V-6	0	2	No	No				X
V-7	0	1	No	Yes			S	
V-8	1	2	No	No			S	

TABLE A-1 RANKING DATA AND DISPOSITION OF CANDIDATE PROBLEMS (CONTD)

Prob. No.	No. of Interviewees Commenting		Top 1/3 by Commentary	Top 1/3 by Literature	Disposition			
					Included on Basis of:			
	NASA	Non-NASA			Commentary	Absorption	Rationale	Eliminated
V-9	0	3	No	No		I-21		
V-10	3	3	Yes	Yes	X			
V-11	0	0	No	No				X
V-12	0	0	No	No				X
V-13	1	2	No	No				X
V-14	2	2	No	No		VIII-6 & V-10		
V-15	0	0	No	No				X
V-16	1	1	No	No				X
VI-1	1	1	No	Yes				X
VI-2	0	0	No	No		III-3		
VII-1	2	4	Yes	Yes	X			
VII-2	1	0	No	No		VII-1		
VII-3	1	2	No	No		VII-1		

TABLE A-1 RANKING DATA AND DISPOSITION OF CANDIDATE PROBLEMS (CONTD)

Prob. No.	No. of Interviewees Commenting		Top 1/3 by Commentary	Top 1/3 by Literature	Disposition			
					Included on Basis of:			
	NASA	Non-NASA			Commentary	Absorption	Rationale	Eliminated
VII-4	1	0	No	No				X
VII-5	0	4	No	No		VII-1		
VII-6	1	0	No	No				X
VII-7	0	0	No	No				X
VIII-1	0	1	No	No				X
VIII-2	1	3	No	Yes			E	
VIII-3	1	3	No	No				X
VIII-4	1	2	No	No		VIII-2		
VIII-5	0	3	No	Yes		VIII-2		
VIII-6	3	1	No	No			S	
VIII-7	0	1	No	No				X
VIII-8	3	0	No	No				X
VIII-9	2	0	No	No				X

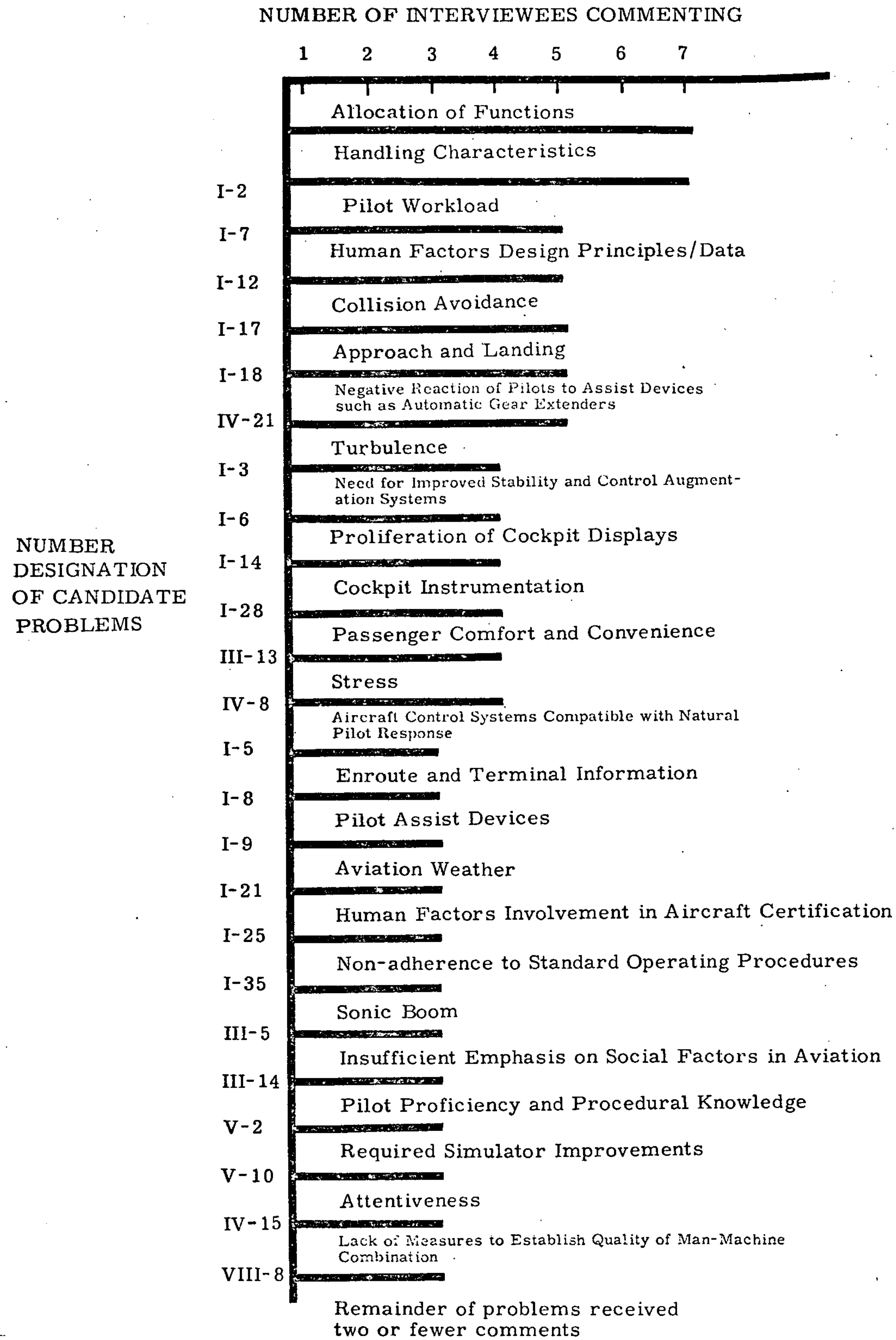
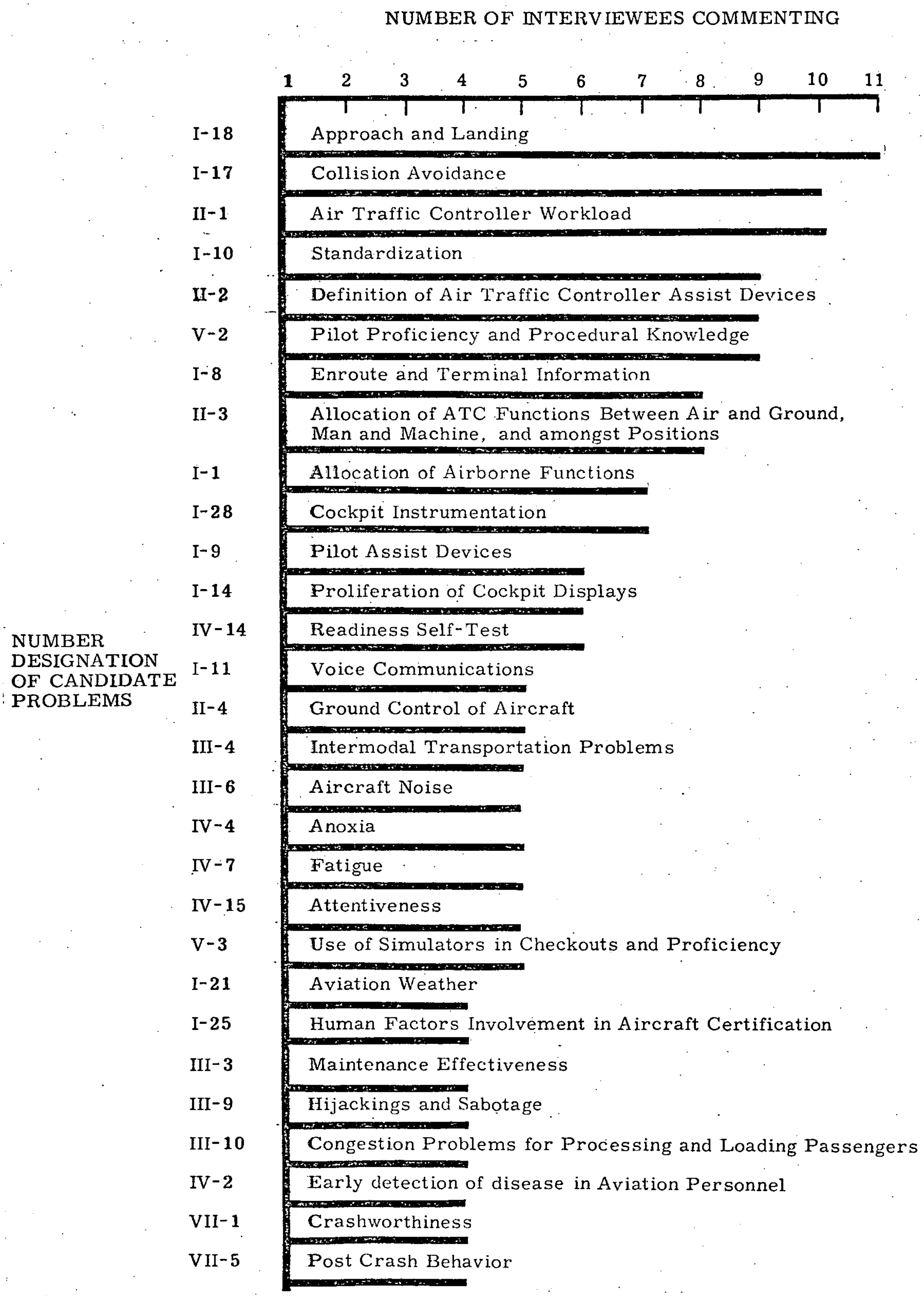
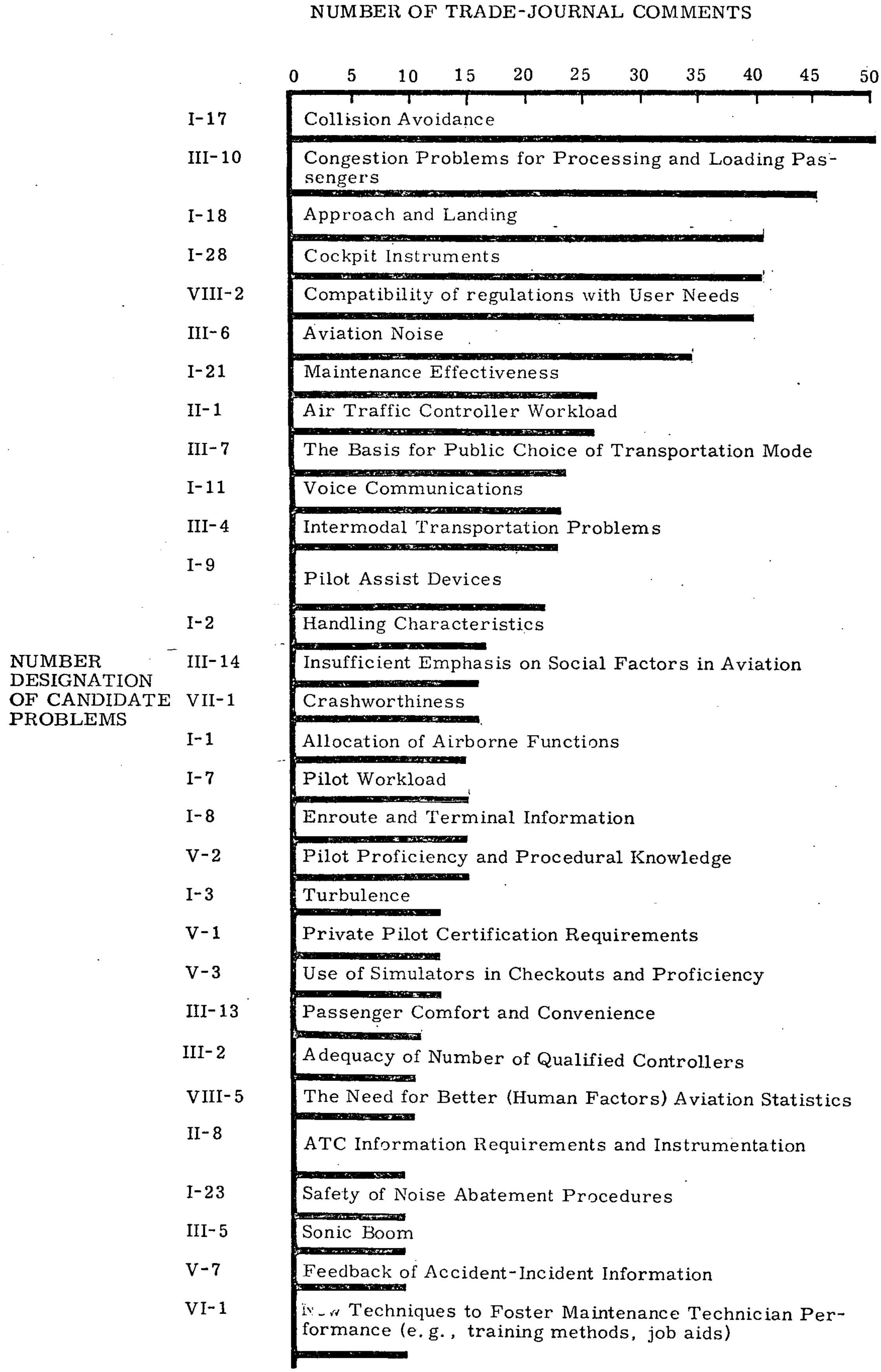


FIGURE A-1 PROBLEM STANDINGS BASED ON NASA INTERVIEWEE COMMENTS



Remainder of problems received three or fewer comments

FIGURE A-2 PROBLEM STANDINGS BASED ON NON-NASA INTERVIEWEE COMMENTS



Remainder of problems received ten or fewer comments

FIGURE A-3 PROBLEM STANDINGS BASED ON TRADE JOURNAL LITERATURE

III. DESCRIPTIONS OF THE SELECTED PROBLEMS

The thirty-eight problems selected as most worthy of research attention are described briefly in this chapter to include:

1. Statement of scope;
2. Cost, safety and effectiveness considerations; and,
3. Ranking by NASA, non-NASA and literature sources.

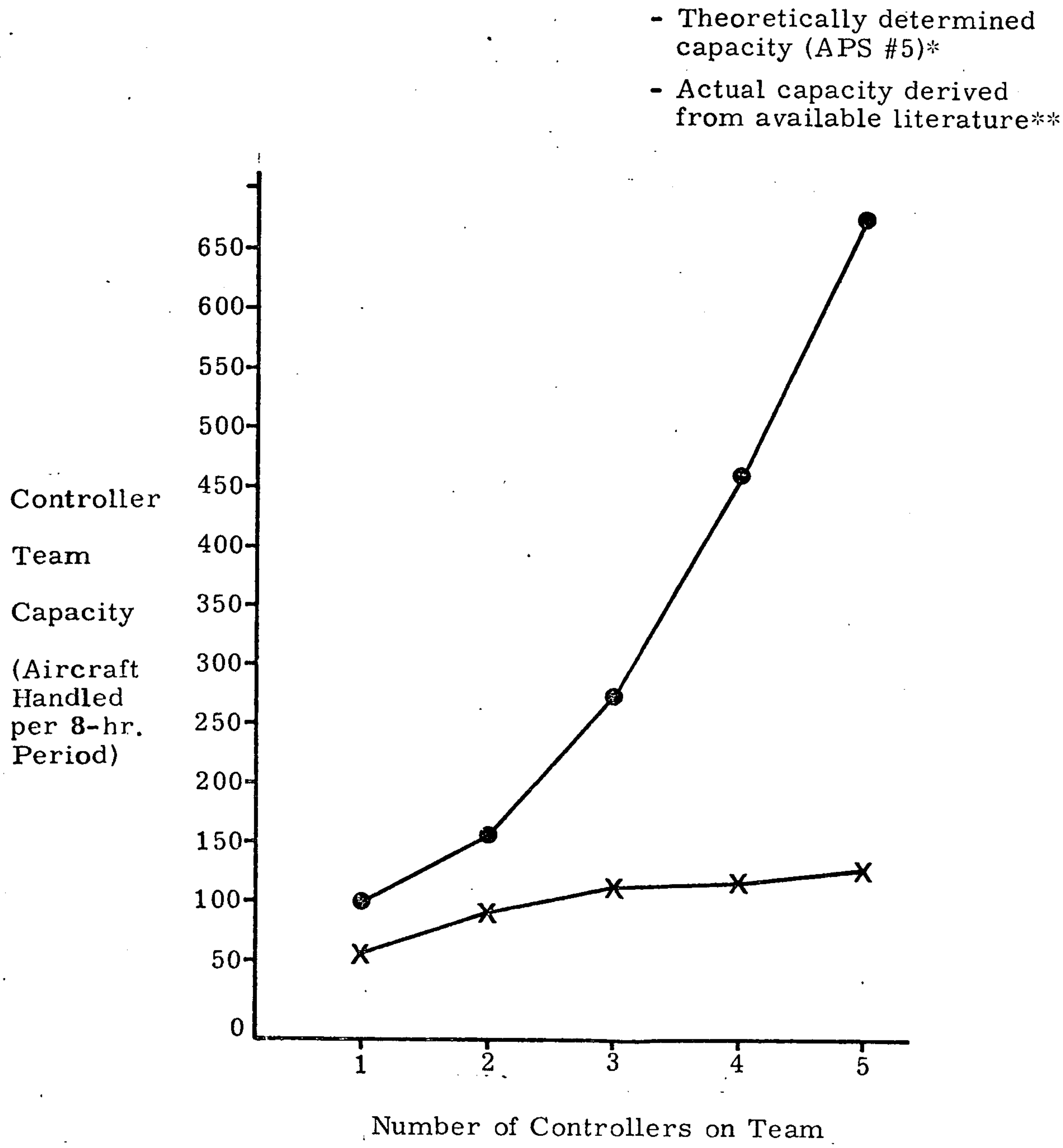
A list of references to support these descriptions appears at the end of this section.

1. Air Traffic Controller Workload (II-1)

The capacity of air traffic control systems is a function of personnel factors such as number, specialties, organization, and operating policy (see Figure A-4). Current man-machine configurations (now in the process of installation) will not handle the predicted traffic volumes (140 million in the near future) without radical decentralization of functions from the ground to the airborne elements and the provision of controller assist techniques (see Table A-2).

Effectiveness — Current congestion problems are attributed in part to a shortage of controllers and increasing traffic volumes. These factors combine to impose a severe workload on the controller staff and the condition is expected to worsen in the near future.

	NASA	NON-NASA	LITERATURE
RANKING:	Top 1/3	Top 1/3	Top 1/3



* Maximum capability curves = $20x^2 + 20x + 40$ where x = number of journeymen controllers.

** These values illustrate only a general relationship and should not be taken as findings.

FIGURE A-4 COMPARATIVE RELATIONSHIP OF TEAM SIZE AND AIRCRAFT HANDLING CAPACITY FROM THEORETICAL AND ACTUAL DETERMINATIONS DERIVED FROM CURRENT LITERATURE[1]

TABLE A-2 INCREASING AIRPORT CAPACITY*[2]

Runway Configuration	Present ATC Scheduling		Speed-Class Sequencing (SCS)		SCS Plus Computer-Aided Approach Spacing(CAAS)		CAAS & SCS With 60-Sec Maximum Separation	
	Long Haul Jets In Mix (Percent)							
	60	20	60	20	60	20	60	20
One @ 3500 ft.	33	38	34	40	36	42	39	45
Two @ 3500 ft.	67	69	69	72	81	84	96	99
Three @ 5000 ft	77	86	80	89	85	94	89	101
Six @ 5000 ft (2 skew)	133	137	139	144	103	168	173	193

* IFR aircraft handled per hour, assuming a 4-min (average) delay for arrivals or departures, whichever occurs first. Maximum capacities are about 20 percent higher than the values shown.

A key technique in comparing alternatives to air terminal improvements is summarized in this table of tradeoffs between concrete runways and auotmated traffic control procedures. Present hourly IFR capacities for four runway configurations are shown in the first column for two different mixes of aircraft. Two 3500-ft. parallel runways handle about twice the traffic of a single 3500-ft. runway, but the increase in capacity enjoyed by traffic going to three parallel 5000-ft. runways is not nearly proportional to the added concrete. Total capacity, in fact, is less than that of the two 3500-ft. runways equipped with CAAS and SCS; the payoff here is in automation, not concrete. The reason for this anomaly and others in the table is that the approach airspaces for parallel runways overlap and the traffic controllers must then manually sequence the traffic. Some gains for concrete, however, are achieved by placing the third runway skew to the parallel pair.

2. Approach and Landing (I-18)

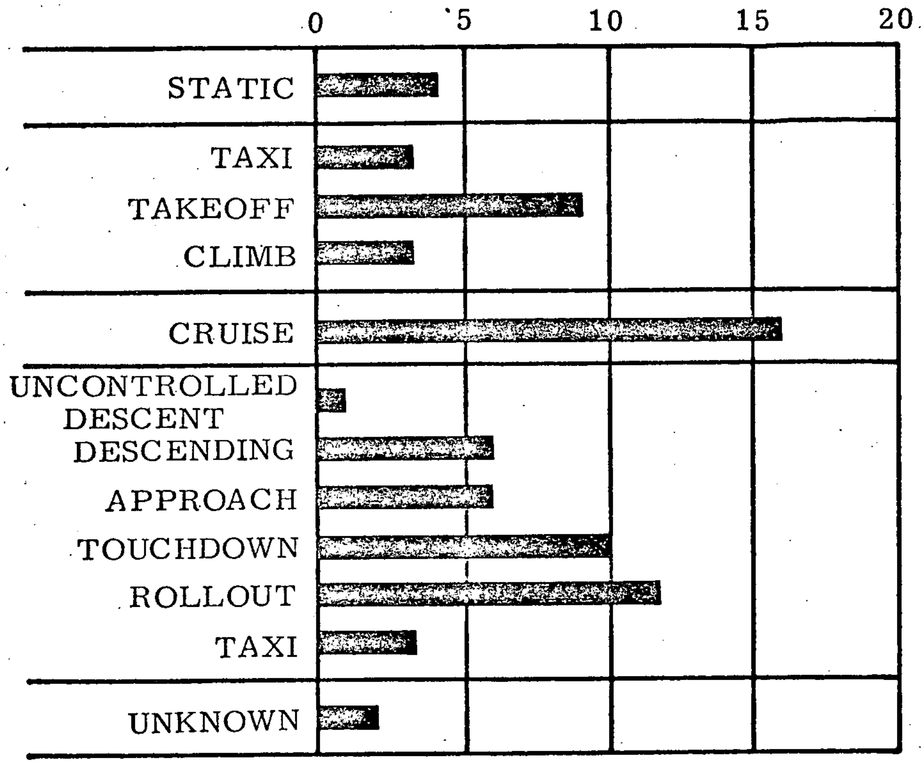
As in the case of at least two other problems (allocation of functions/air and human factors principles and data) the approach/landing problem permeates many of the other problems. Recommendations to eliminate this problem because its difficulties were covered in other problems were resisted for two major reasons. First, the "high stress" aspects of the approach and landing tend to flush out problems which are not so apparent in the milder environments. Therefore, its retention on the list is intended to emphasize its potential for identifying researchable issues. Second, a large research payoff is represented by this phase and giving it visibility is intended to encourage its use as a research setting and as a guage for measuring research and development results.

Safety — The landing and approach phase accounts for about 1/2 of the air carrier accidents (see Figure A-5) and the rate at which these accidents lead to fatalities is increasing. For the years 1961 - 1964 the number of fatal accidents per million landings was 0.27, 0.88, 1.06, and 1.27 respectively.[4]

	NASA	NON-NASA	LITERATURE
RANKING:	Top 1/3	Top 1/3	Top 1/3

3. Collision Avoidance (I-17)

The 586 fatalities in 225 mid-air collisions over a 12-year period (see Table A-3) are a measure of this problem's severity and by all accounts it will get worse. The human factors aspects of this problem, on the one hand, derive from the fact that a large proportion of the collisions occur under see-and-be-seen conditions implicating attentiveness and cockpit visibility to name just two areas. On the other hand, engineering solutions are under development (Proximity Warning Indicators and Collision



The unit of transport productivity (passenger-miles), a valid yardstick for measuring economic growth or profitability, is not valid for measuring safety because not every mile of a flight is equally safe. FAA data on accidents involving commercial carrier aircraft during 1966 show that the cruise regime, in which largest numbers of seat-miles or passenger-miles are clocked up, is generally safer than taxiing, takeoff, and climb; and that the takeoff-climb regime is safer than taxiing, takeoff, and climb; and that the takeoff-climb regime is safer than descent, approach, and landing. Since every flight, irrespective of its length or the number of passengers carried, goes through each phase from taxiing out through taxiing back in, numbers of trips (or flights, or flight-segments, or departures) would appear to be a sounder base for statistical evaluation. Further, casualties per unit of transport productivity is a meaningless figure to people, who measure their lives in units of time, or in events. An airline may consider a passenger in terms of ton-miles or passenger-miles; but he thinks of his trip as an event, either a singular incident or as a number of elapsed hours. (Source: FAA)

FIGURE A-5 CARRIER AIRCRAFT ACCIDENTS (1966)[3]

TABLE A-3 MIDAIR COLLISIONS - U.S. CIVIL AVIATION[a] [5]

	Accidents		Fatalities	Accidents by Aviation-Class				
	Total	Fatal		Carrier/ Carrier	Carrier/ General	Carrier/ Military	General/ Military	General/ General
1956	17	11	161	1	1	0	1	14
1957	15	6	19	0	0	1	4	10
1958	16	12	86	0	0	2	2	12
1959	13	10	20	0	0	0	3	10
1960	26	10	152	1	4	0	2	19
1961	20	10	22	0	0	0	0	20
1962	19	9	27	0	0	0	5	14
1963	13	3	6	0	0	0	2	11
1964	15	7	12	0	0	0	2	13
1965	47	14	30	1	0	0	2	44
1966	24	9	51	0	1	0	3	20
1967	NA	NA	NA	0	2	1	NA	27
Total[b]	225	101	586	3	6	3	26	187

[a]NTSB & FAA. [b]1967 not included.

General aviation aircraft crash into each other in the air with astonishing frequency; they also hit carrier and military aircraft more often than seems statistically probable.

Avoidance Systems) which have some major and minor human factors problems themselves, e.g., information presentation, acceptance of automatic evasive maneuvers and compatibility with man's limited visual capabilities.

Safety

General aviation is involved in more mid-air collisions than seems statistically probable; while collisions are relatively infrequent their fatality toll is high.[5]

	NASA	NON-NASA	LITERATURE
RANKING:	Top 1/3	Top 1/3	Top 1/3

4. Cockpit Instrumentation (I-28)

Three examples of the need for improving cockpit information presentation are: 1) Willis' false hypothesis theory involving inadequate, misinterpreted or missing information; 2) Beck's citation of load stress and speed stress errors due to data saturation; and 3) Harper's call for better information transfer to the crew concerning aircraft state. The inadequate state of current instrumentation is widely recognized but specific recommendations for improvement are either not being generated, or are experiencing difficulty in dislodging the existing techniques, e.g., taped instruments, head-up display, flight directors, etc.

Safety

False Hypothesis - "Probably more common than is realized; may be the cause of a substantial number of inadequately explained accidents; involves erroneous estimation of glide path, etc.; based on inadequate or misinterpreted information, compounded by the absence of 'corrective' information."[6]

"With present day instrumentation and workloads, flight crews may well be approaching a point of 'data saturation' which will result in a deterioration of performance leading to errors through 'speed stress' or 'load stress.'"[7]

Effectiveness — Information transfer must be improved if the full advantage of certain current (e.g., all-weather helicopter) and many advanced designs (VTOL, SST) can be realized.[8] Cockpit instrumentation improvements demanded by users but mutually acceptable concepts do not seem available.[9]

	NASA	NON-NASA	LITERATURE
RANKING:	Top 1/3	Top 1/3	Top 1/3

5. Handling Characteristics (I-2)

The human factors involvement in the problem annotations listed is an inadequate understanding of the variables (cues/senses) used in assessing flight characteristics.

Safety — Poor handling characteristics of some general aviation aircraft, especially in the stall region;[10] suggestion of handling characteristics as a factor behind the increase in jet transport landing accidents.[11]

Effectiveness — Apparent conflict between the aerodynamic need for stability and control augmentation systems on advanced aircraft and pilot's desire to minimize their usage.[12, 13]

	NASA	NON-NASA	LITERATURE
RANKING:	Top 1/3	Mid 1/3	Mid 1/3

6. Allocation of Functions (I-1)

This problem relates to the technique for generating alternative sets of man-machine responsibilities; experimentation to identify the optimum set; translating the results into crew size and procedures; and providing inputs to subsequent functions such as training and instrumentation.

Safety — Apparent link between crew size, crew coordination and approach/landing accidents;[14] compatibility between man's capabilities and his role in automatic all-weather landing systems in particular and "automatics" in general.[15]

Cost — A major factor in crew size disputes is cost, especially for the supplemental carrier using short haul jets where crew costs average about 40-45 percent of total.[16]

	NASA	NON-NASA	LITERATURE
RANKING:	Top 1/3	Top 1/3	Top 1/3

7. Passenger Comfort and Convenience (III-13)

The problem has two parts: in-flight conditions (riding qualities) and ground activities. The former is quite obvious and is highly related to problem I-3 - Turbulence, but from the passenger's view rather than safety of flight. The ground activities phase is threatening to overwhelm even the air traffic control system and is concerned with loading and processing passengers and intermodal/nodal considerations: "... intersections of human and vehicular traffic, both of which must be guided and controlled -- the first by psychology, sociology and information technology, the second by the engineering of the interrelations among devices."[17]

Effectiveness	Passenger congestion at terminals, loading points, and nodes may back up into ATC system;[18] riding quality of some current (Helo) and projected (VTOL) aircraft is suspect.[19]

	NASA	NON-NASA	LITERATURE
RANKING:	Top 1/3	Bottom 1/3	Top 1/3

8. Pilot Assist Devices (I-9)

During system development, allocation of functions and the development of pilot assist devices are conducted in an integrated fashion and it might seem natural to combine these two problems. The reason behind keeping them separate in this list is to distinguish the methodological need of the allocation problem from the "proof of concept" need regarding pilot assist devices.

Safety	"Aircraft are getting to the point where pilot skill alone is not enough to control them during landings particularly in bad weather;"[20] light aircraft accidents/incidents could be reduced by availability of safety assist devices, e.g., roll stability for inadvertent weather entry.[21, 22]
Effectiveness	Without inclusion of acceptable man-in-the-loop features (e.g., input/output facility for onboard computer, inclusion of operability information, etc.) resistance to automatic systems will continue.[23]

9. Compatibility of Regulations with User Needs (VIII-2)

The most popular issues of this problem derived from congestion and the regulatory attempts to ease the situation. Other aspects included training requirements (both private and air carrier), technical data disclosure (test and accident) and certification requirements (private only). The common denominator for all these aspects is a lack of statistics or technical data to support or invalidate one regulatory action over another (i. e., aircraft noise, private pilot certification and proficiency measures, crew size in 737, simulator efficacy, etc.).

Effectiveness — Concern is for the basis, fairness and understandability of regulatory attempts to control airspace usage, training requirements and technical data disclosures.

	NASA	NON-NASA	LITERATURE
RANKING:	Bottom 1/3	Top 1/3	Top 1/3

10. Enroute and Terminal Information (I-8)

The initial scope of this problem included only the clutter and cumbersome handling of charts. It was expanded, however, to include all non-aircraft information necessary to plan and conduct a flight, e. g., weather, regulations/procedures, navigational and NOTAMS. The major justifications for this problem are: 1) complexity of information is moderate to high for even the professional pilot and the trend is toward much more IFR flying on the part of the light aircraft pilots (it is estimated that 70% of instrument approaches will be made by general aviation in 1980); and 2) to capture the congestion, workload and communication benefits of R-NAV, a new network of airways and attendant operating criteria will be required beyond that of the already complex system.[24]

Safety — Distraction of chart handling was posed as an accident factor in a jet transport crash.[25]

	NASA	NON-NASA	LITERATURE
RANKING:	Top 1/3	Top 1/3	Top 1/3

11. Crashworthiness (VII-1)

The areas included within this problem are concerned with impact (delethalization and restraint), heat, smoke and toxicity protection, and evacuation standards.

Safety

153 U. S. air carrier accidents were caused by or resulted in fire in years 1955-1964; the study of these accidents concluded that 1628 occupants died from impact forces, 297 died from fire, and 30 from miscellaneous causes.[26] "The rate at which (air carrier) accidents lead to fatalities is increasing. For the years 1961-1964, the number of fatal accidents per million landings was 0.27, 0.88, 1.06, and 1.27 respectively.[27]

12. Human Factors Design Principles/Data (I-12)

Studies have shown[28] and expert opinion support the findings[29] that human factors design principles are not finding their way into aviation systems. Causes have been theorized but activity toward verifying cause, developing and validating corrective measures has not been forthcoming. The specific problem concerns the validity and utility of research results and the meaningfulness with which they are made available to the user populations.

	NASA	NON-NASA	LITERATURE
RANKING:	Top 1/3	Mid 1/3	Bottom 1/3

13. <u>Aviation Weather (I-21)</u>

In general aviation the underlying theme is lack of knowledge about and respect for the hazards of weather. The major weather problem regarding air carrier operations concerns the crew's ability to cope with: 1) the visual problems (approach light ambiguity, pattern recognition, etc.) upon breaking out in "ragged" IFR conditions, and 2) the concomitant team decision requirements.

<u>Safety</u> During 1965 . . . 250 (45%) of the 550 (general aviation) accidents involving weather were directly or indirectly caused by the pilot . . ." (see Figure A-6).

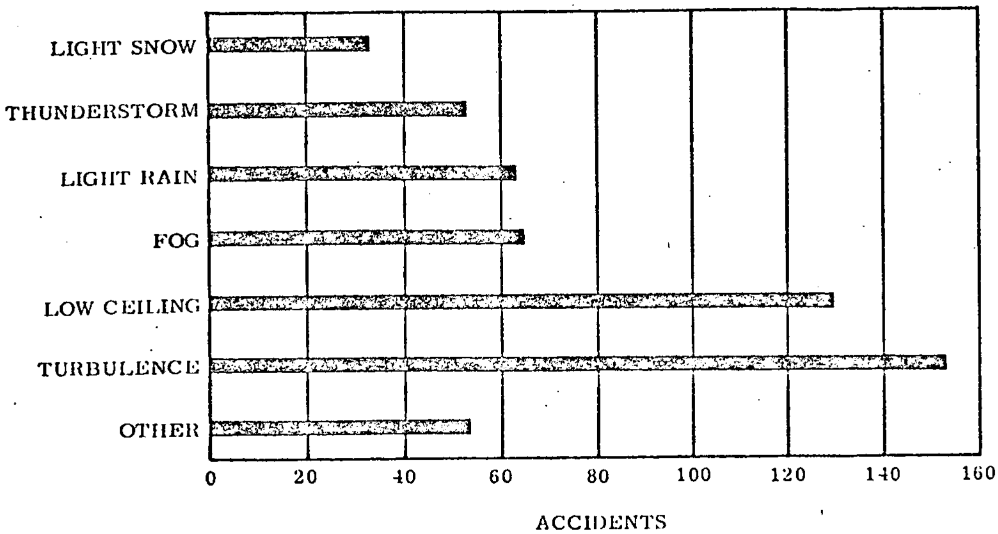
<u>Effectiveness</u> Terminal area visibility and breakout conditions (approach light ambiguity and uncontrollability) are not understood well enough to support all weather landing operations (see Figure A-7).

	NASA	NON-NASA	LITERATURE
RANKING:	Top 1/3	Top 1/3	Top 1/3

14. <u>Pilot Proficiency and Procedural Knowledge (V-2)</u>

In the context of air carrier operations this problem addresses the difficulty (imprecision) of assessing pilot proficiency. The impetus in this case is detection of marginal cases with reasonable cost. For general aviation (private pilots) the problem is oriented more to safety, stressing the need to instill and maintain, in the pilot, an appropriate level of capability.

<u>Safety</u> "The biggest single factor in the failure to reduce the constantly increasing number of aircraft accidents and fatalities in general aviation



Data developed by Flight Safety Foundation indicate that weather is major causal factor in cruise-phase accidents, because pilots exhibit faulty judgment in evaluating their own competence to handle adverse weather. Turbulence, low ceiling, fog and light rain -- marginal conditions rather than outright bad weather -- are chiefly to blame: apparently many noncommercial pilots think they are more competent in such conditions than they really are.

FIGURE A-6 WEATHER FACTORS IN NON-COMMERCIAL ACCIDENTS[30]

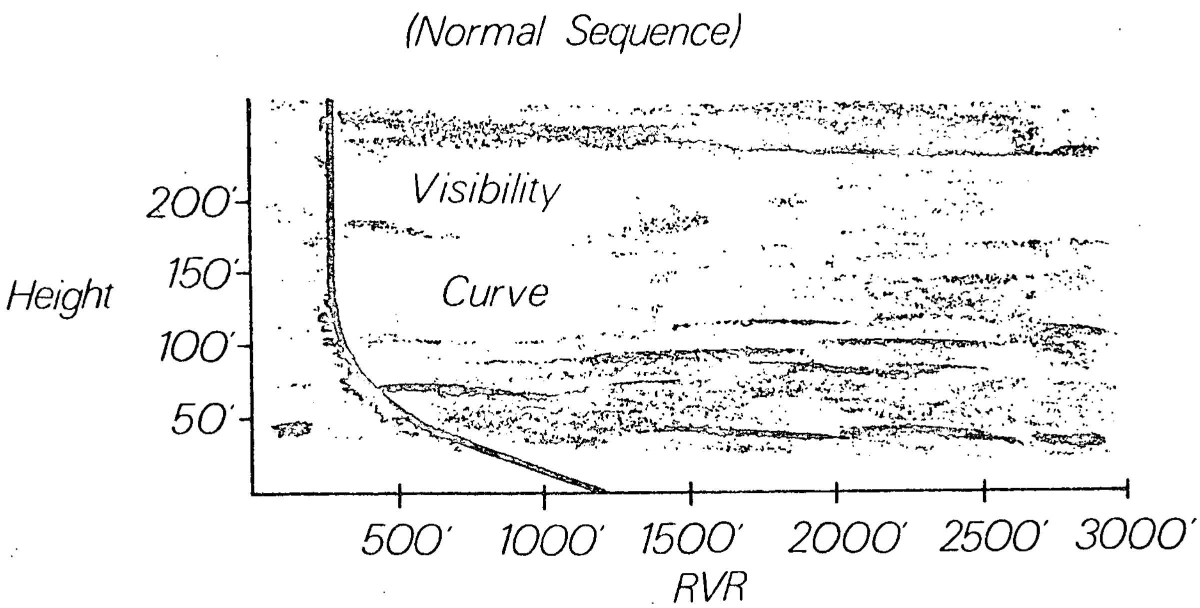


FIGURE A-7 MATURE RADIATION FOG[31]

is attributed directly to the lack of pilot proficiency and procedural knowledge . . . lack of pilot proficiency and procedural knowledge was behind 80% of the more than 5000 general aviation accidents last year" (see Figure A-8); accident reviews showed that many pilot error accidents (general aviation) were attributable to "deterioration of basic airmanship and skills and the pilot's failure to keep abreast of new developments and procedures."[33]

	NASA	NON-NASA	LITERATURE
RANKING:	Top 1/3	Top 1/3	Top 1/3

15. Performance Decrement and Environmental Factors (I-39)

The air carrier version of this problem relates to the long term impact of cockpit environmental factors such as humidity, noise and vibration, with emphasis on the effects of combinations of these factors. In general aviation it is restricted to anoxia in high performance aircraft and the distraction of cockpit noise.

Effectiveness: Some cockpits claimed to be the source of medical problems, i.e., hearing impairment, vibration-induced back injury, dehydration.

	NASA	NON-NASA	LITERATURE
RANKING:	Bottom 1/3	Top 1/3	Bottom 1/3

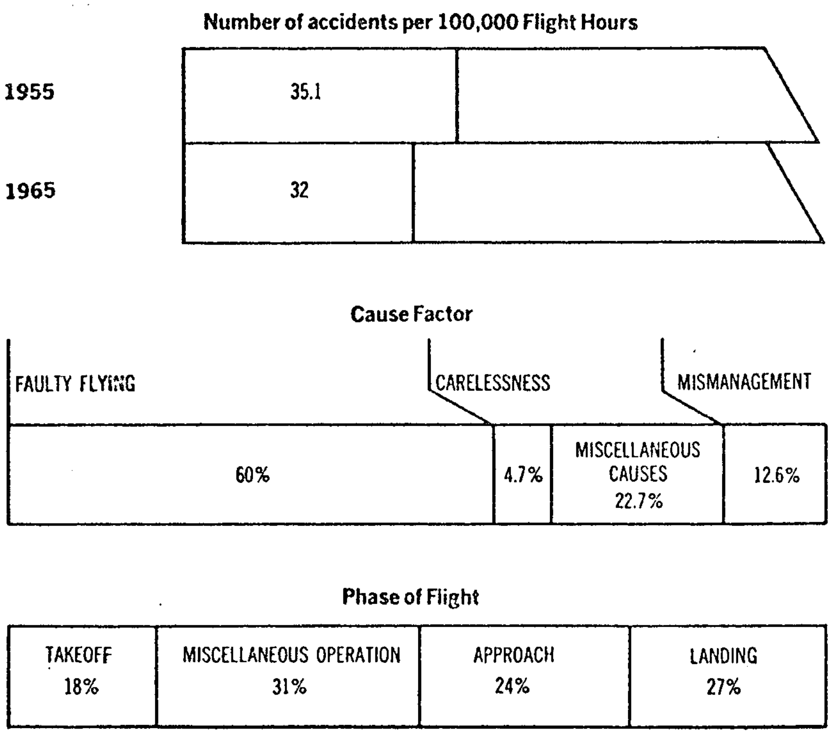


FIGURE A-8 GENERAL AVIATION ACCIDENT RATES AND CAUSES[32]

16. Standardization (I-10)

Standardization of maintenance features, cockpit instrumentation and passenger cabin interiors can result in reduced initial aircraft cost and reduced operating costs via inter-line pooling arrangements. The problem from the human factors standpoint is not to prove that standardization is beneficial but rather to generate standard configurations which meet all user's needs.

Safety	Standardize emergency features in passenger cabin to foster familiarity;[34] model differences cited as contributing factor in jet crash.[35]
Effectiveness	Financial feasibility of advanced aircraft may depend on standardization in cockpit, passenger cabin and on maintainability features as a means of encouraging inter-line exchange agreements.[36]

	NASA	NON-NASA	LITERATURE
RANKING:	Mid 1/3	Top 1/3	Mid 1/3

17. Non-adherence to Standard Operating Procedures (I-35)

This problem refers to errors of commission (shortcuts, faulty technique, etc.) and omission occurring in both air carrier and general aviation.

Safety	Omitted flight procedures are a relatively frequent occurrence in air carrier operations;[37] "one major category of pilot error (landing) accidents: failure to carry out established procedures (in many cases shortcuts intended to ensure completing an approach . . .)."[38]

	NASA	NON-NASA	LITERATURE
RANKING:	Top 1/3	Bottom 1/3	Bottom 1/3

18. Maintenance Effectiveness (III-3)

The original scope of this problem was narrowed from all support personnel to include only maintenance technicians; it was then extended to cover maintenance effectiveness and its implications to safety of flight. This latter expansion was prompted by work of Willis,[39] and recent pronouncements by the National Transportation Safety Board.[40]

Safety — The maintenance factor may be 10 times that of pilot error as a cause of accidents/incidents;[41] "If the current mechanic production trend for general aviation continues, there will be 1/2 as many mechanics per plane by 1975 - and safety in-flight is no better than mechanical condition of the aircraft."[42]

Effectiveness — General aviation will need about 183,500 mechanics and air carriers will require about 95,000 during the 1965-1980 time period.[43]

	NASA	NON-NASA	LITERATURE
RANKING:	Bottom 1/3	Top 1/3	Middle 1/3

19. Hijackings and Sabotage (III-9)

The efforts to deal with this problem concern human factors in two ways: 1) attempting to "profile" perpetrator for interdiction as well as preparing crew to cope with such a person; and, 2) the impact on the flying public of the threat and the attempts at cures, i.e., searches.

Safety	Threat of hijackings to passenger safety; 13 bomb destructs and many more hoaxes since 1933.[44]
Cost	Claims for sabotage accidents; $20,000 estimate per diversion due to bomb hoax.[45]
Effectiveness	Ill-will of traveling public because of personal search; threatened IFALPA strike.

	NASA	NON-NASA	LITERATURE
RANKING:	Bottom 1/3	Top 1/3	Mid 1/3

20. Required Simulator Improvements (V-10)

The predominant theme in the trade literature is achievement of specific improvements requested by simulator users, i.e., primarily motion and visual attachment fidelity. Interview comments agree in general but urge that proof of utility or pay-off be obtained to guard against fidelity for fidelity's sake.

Effectiveness	To support more realistic research settings and handling qualities research, and to permit more widespread usage of simulators, improvements are needed in simulator technology; most notable needs relate to vision and motion.[46]

C2

RANKING:	NASA	NON-NASA	LITERATURE
	Top 1/3	Top 1/3	Top 1/3

21. Pilot Manpower Shortage (III-1)

The original problem concerned the "shortage" of pilots for air carrier operations. In general aviation this seems to be somewhat true of instructor pilots (i. e., insufficient number of check pilots to administer a recent FAA proficiency plan) but at least in the air carrier context it does not seem to be a pressing issue. However, there appears to be an inability to predict the roles and qualifications of future flight crews for use as a foundation for current recruitment, selection and training practices.

Effectiveness . Junior captains are purported to have the widest experience variability in the airline's history; early "medical" retirements are increasing; airlines are contemplating reaching into the junior ranks for their SST crews; and younger crews seem more amenable to the "automatics" appearing on the scene.[47]

RANKING:*	NASA	NON-NASA	LITERATURE
	Bottom 1/3	Bottom 1/3	Mid 1/3

22. Fatigue (IV-7)

The scope of this problem extends from the difficulty of obtaining rest before and during extended trips (see Figure A-9), to its implication in pilot error accidents, to its being cited as a symptom for boredom and a cause for medical/discharge/retirement.

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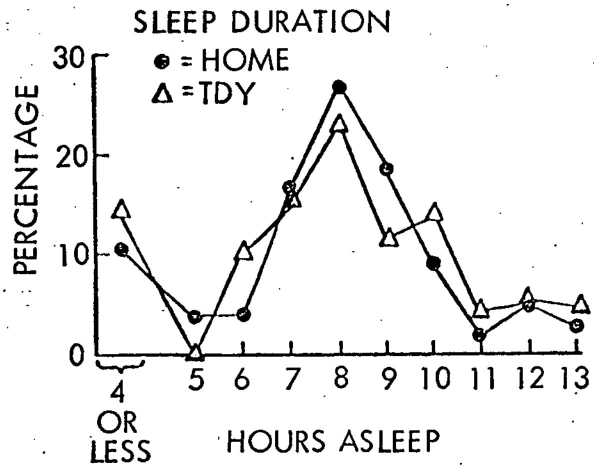
* This problem as described above was not evaluated by interviewees, but emerged as a result of analyzing interview results.

C2



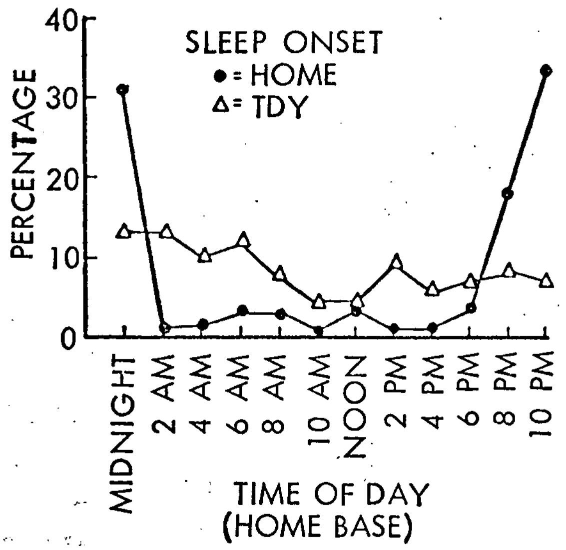


FIGURE A-9 COMPARISON OF SLEEP DURATIONS AND ONSET TIMES AT HOME AND ON AN EXTENDED MISSION[48]

Safety — Estimated as being a factor in between 5% and 10% of pilot error accidents.[49]

Effectiveness — Increase in requests for early medical retirement related to boredom as a cause and fatigue as the symptom.[50]

	NASA	NON-NASA	LITERATURE
RANKING:	Mid 1/3	Top 1/3	Mid 1/3

23. Aircraft Noise (III-6)

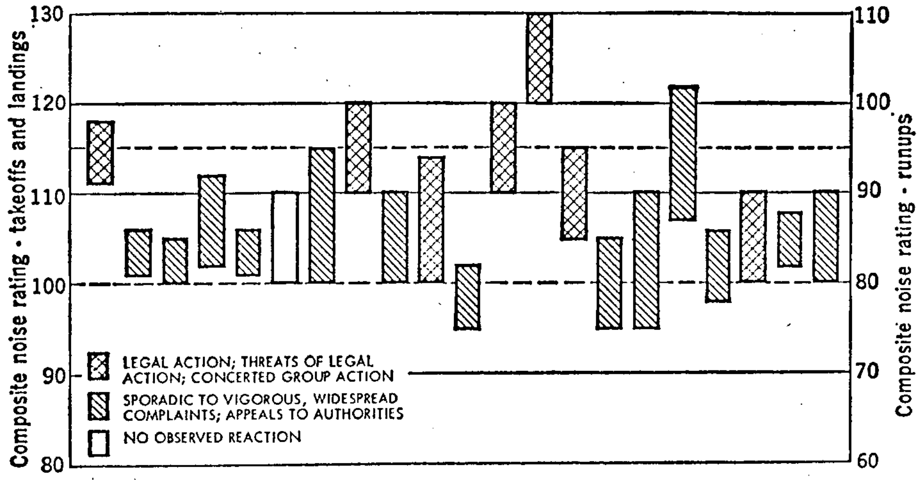
This problem is similar to the sonic boom but was kept separate on the basis of its technical uniqueness. The human factors aspects include: (1) audition phenomena, (2) measurement techniques, (3) acceptability and tolerance standards; and, (4) consequences of control efforts (i.e., safety implications of noise abatement flight procedures).

Safety — "From both safety and flying qualities standpoint (of the SST), the two-step noise abatement method is absolutely intolerable;"[51] "Abatement procedures may have contributed to several major accidents in the past 5 years."[52]

Effectiveness — Negative public reaction* to noise may deter new transport modes (VTOL) and inhibit congestion solutions (i.e., satellite airports; 90 movements per hour at JFK (with noise abatement) vs. 150 movements per hour at O'Hare (without noise abatement).[53]

	NASA	NON-NASA	LITERATURE
RANKING:	Mid 1/3	Top 1/3	Top 1/3

*See figures below.



Note: The height of the bars represents the range of CNR values taken over a given neighborhood. Twenty-four additional cases are available.

FIGURE A-10 REACTIONS OF PEOPLE IN COMMUNITIES EXPOSED TO AIRCRAFT NOISE ENVIRONMENTS OF DIFFERENT COMPOSITE NOISE RATING (CNR) VALUES[54]

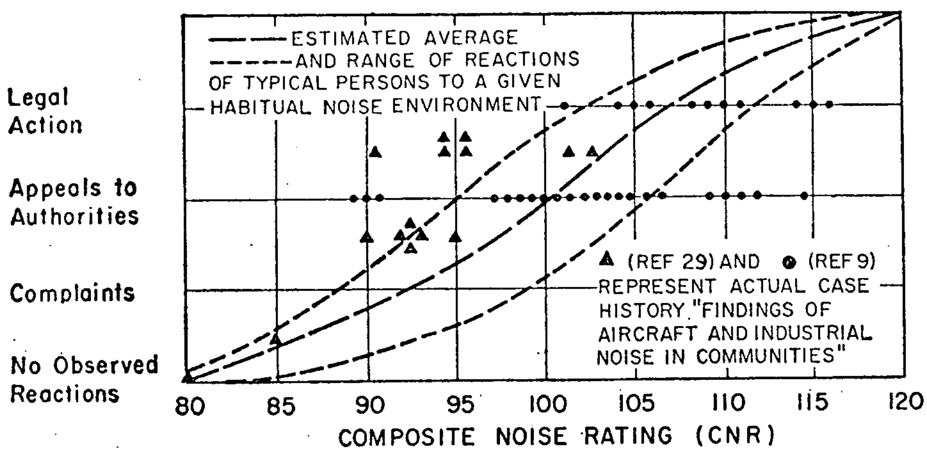


FIGURE A-11 GENERAL RELATION BETWEEN COMMUNITY RESPONSE TO AIRCRAFT OR OTHER NOISES AND COMPOSITE NOISE RATING[54]

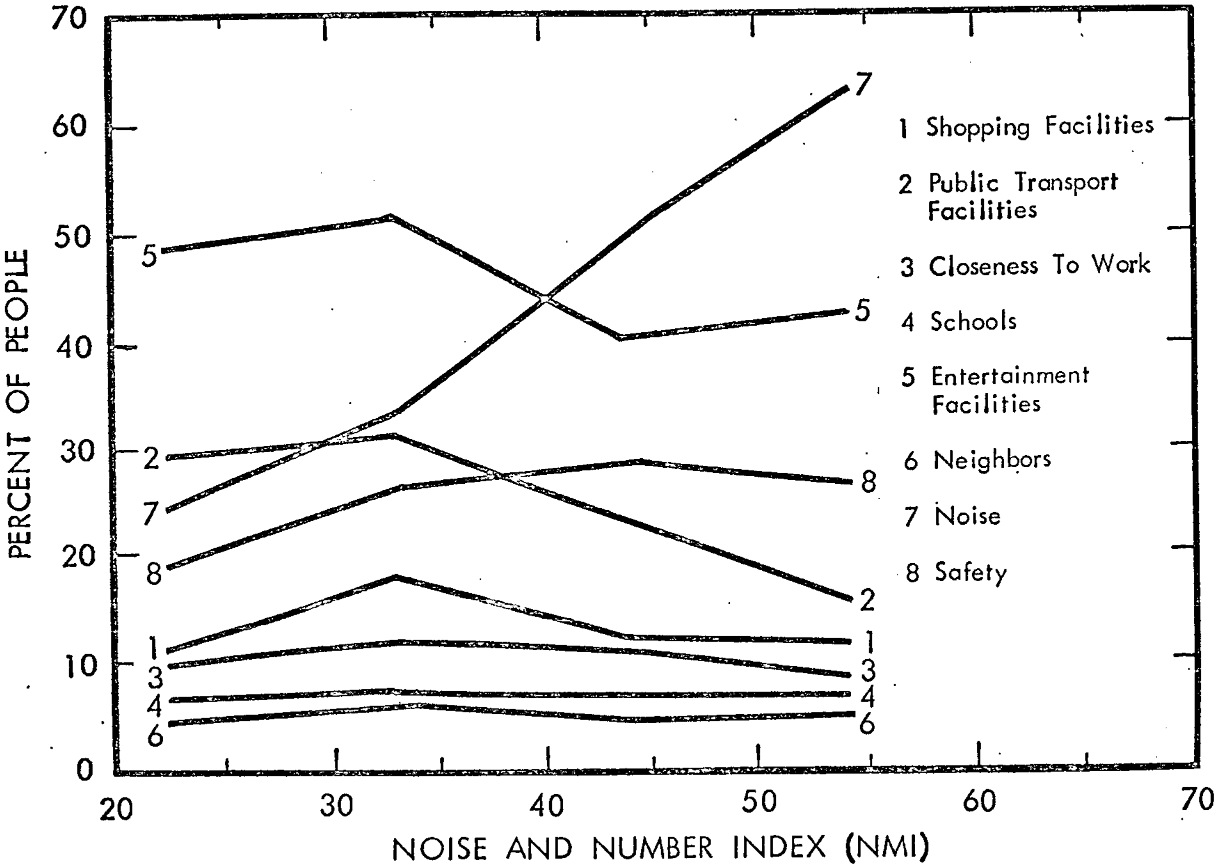


FIGURE A-12 RESULTS OF INTERVIEWS IN COMMUNITIES WITHIN A 10-MILE RADIUS OF HEATHROW AIRPORT, LONDON, SHOWING PERCENTAGES OF PEOPLE RATING THEIR AREA AS A POOR, OR VERY POOR, PLACE TO LIVE FOR VARIOUS REASONS[54]

24. Turbulence (I-3)

The scope of this problem covers jet upsets and suspected pilot/turbulence-induced structural overload. While jet upset problems seem to be contained in current aircraft, doubt was expressed about the applicability and effectiveness of solutions to future aircraft.

Safety	Visual deterioration under certain conditions of turbulence;[55] turbulence/pilot induced structural overload;[56] jet upsets and involvement of piloting technique.[57]
Effectiveness	Passenger comfort with respect to ride quality (see Problem 26 for discussion).

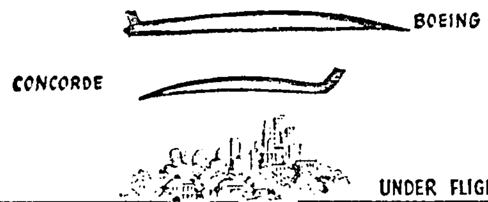
	NASA	NON-NASA	LITERATURE
RANKING:	Top 1/3	Top 1/3	Top 1/3

25. Sonic Boom (III-5)

The boom consequences of commercial SST operations (overland) have been estimated at $37-86 million annually in damage claims. The key, of course, is the word estimated; too little is known about how people will react to the phenomenon, and research to date has been criticized as being unrealistic and inconclusive (i.e., pre-warned subjects, no vibration; 34% felt 8-10 booms per day to be acceptable).

Cost	Financial claims resulting from boom damage are estimated at between $37 and $86 million annually (see Figure A-13).
Effectiveness	Reaction of 25% - 50% of the people exposed to the anticipated boom would include extreme annoyance, complaints to authorities, and legal action (see Figure A-14).

POSSIBLE OVERLAND SST OPERATIONS



1. MEDIAN BOOM INTENSITIES	UNDER FLIGHT PATH		12.5 MILES TO SIDE OF FLIGHT PATH	
	TRANSSONIC	CRUISE	TRANSSONIC	CRUISE
BOEING	2.1 psf (est)	1.8 psf (est)	1.6 psf (est)	1.3 psf (est)
CONCORDE	2.0 psf (est)	1.9 psf (est)	1.5 psf (est)	1.4 psf (est)

2. 50% OF LONG HAUL U.S. AIR TRAVEL ON SST WOULD PRESENT 10-20 BOOMS PER DAY TO;
   a. GREAT CIRCLE ROUTES
      65.5 MILLION PEOPLE (WITHIN 25 MILE BOOM PATH)
   b. CIRCUITOUS ROUTES
      35 MILLION PEOPLE (WITHIN 25 MILE BOOM PATH)

GENERAL CONCLUSIONS

1. WIDE SPREAD POLITICAL AND LEGAL ACTION AGAINST BOOM FROM SST SEEMS CERTAIN WHEN RESULTS OF BOOM-NOISE JUDGEMENT TESTS ARE RELATED TO REACTION OF PEOPLE NOW LIVING NEAR AIRPORTS AND IN VIEW OF OBSERVED COMMUNITY ATTITUDES TO ACTUAL SS OVERFLT
2. "BEST ESTIMATES" OF ANNUAL PAID DAMAGES (BASED ON 50% OF ACTUAL PAID DAMAGE RATE EXPERIENCED TO DATE)
   a. GREAT CIRCLE ROUTE – $86,000,000
   b. CIRCUITOUS ROUTE $37,000,000

NOTE: COST OF PROCESSING CLAIMS NOT INCLUDED

STRONG POINT OF RESEARCH DATA

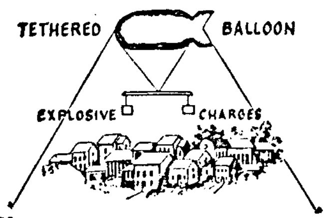
DATA FROM LABORATORY, FIELD, AND COMMUNITY RESPONSE STUDIES CONSISTENT WITH EACH OTHER

WEAK POINTS IN DATA

1. LABORATORY AND FIELD SUBJECTS NOT IN OWN HOMES OR ENGAGED IN TYPICAL ACTIVITIES
2. REACTIONS OF PEOPLE IN COMMUNITIES TO SUBSONIC JET NOISE AND BOOMS POSSIBLY NOT SUFFICIENTLY MEASURED.

FIGURE A-13 SONIC BOOM PROBLEM FROM THE SUPERSONIC TRANSPORT AND RESEARCH CONCLUSIONS[58]
(Note: Sonic boom intensity is given in pounds per square foot (psf).)

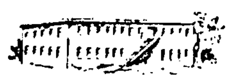
1. U.K. PROJECT YELLOW HAMMER, (20)



RESULTS

- ANNOYANCE DECREASED WITH FAMILIARITY OF BANGS
- INCREASE IN ANNOYANCE WITH DOUBLING OF INTENSITY OF BANGS SAME AS WITH INCREASE OF 2½ TIMES NUMBER OF BANGS

2. U.K. PROJECT WESTMINISTER, (30)



RESULTS

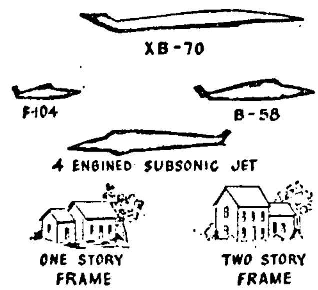
NOTE: ALL PHYSICAL MEASUREMENTS MADE OUTDOORS

- GOVERNMENT PERSONNEL SUBJECTS (N=61)

BOOM	NOISE EQUAL TO BOOM	
1.7 psf	INDOORS	OUTDOORS
SS FIGHTER	110 PNdB	105 PNdB

Variability of judgments of Boom vs. Aircraft Noise was such that a change of about 0.3 psf in boom or 3 PNdB in Noise Intensity caused a significant change in the subjective judgments of the subjects.

3. U.S.A. EDWARDS AIR FORCE BASE STUDIES, (8)



RESULTS

NOTE-ALL PHYSICAL MEASURES OUTDOORS

- EDWARDS AIR FORCE BASE SUBJECTS (N=120)

SUBSONIC AIRCRAFT

NOMINAL PEAK	BOOM	NOISE EQUAL TO BOOM INDOORS	NOISE EQUAL TO BOOM OUTDOORS
1.40 psf	F-104	108 PNdB	97 PNdB
1.69 "	B-58	109 " "	105 " "
1.36 "	XB-70	107 " "	98 " "

- FONTANA CITY SUBJECTS (N=98)

		INDOORS	OUTDOORS
1.69 psf	B-58	119 PNdB	109 PNdB

- REDLAND CITY SUBJECTS (N=148)

		INDOORS	OUTDOORS
1.69 psf	B-58	118 PNdB	107 PNdB

- EDWARDS AIR FORCE BASE SUBJECTS (N=120)

		INDOORS	OUTDOORS
2.80 psf	F-104	121	117
1.40 "	F-104	107	97
0.75 "	F-104	99	88

*

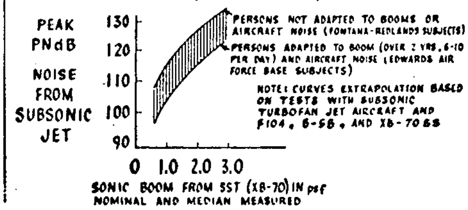


FIGURE A-14 SONIC BOOM FIELD TESTS CONDUCTED IN THE UNITED KINGDOM AND IN THE UNITED STATES[58]
(Note: Sonic intensities are given in pounds per square foot (psf).)

	NASA	NON-NASA	LITERATURE
RANKING:	Top 1/3	Mid 1/3	Top 1/3

26. Insufficient Emphasis on Social Factors in Aviation (III-14)

Public acceptance problems with current and proposed elements of the air transport system are beginning to emerge -- the classic case of course is noise. However, the problem is broader involving rejection of rotor equipped aircraft in favor of other modes, concern over safety and current safety trends, and the "worth of" size and speed, i.e., 747 and SST. The problem appears to be a lack of data and methods by which it could be collected and applied in the design of air transport technology.

Effectiveness — Design engineers of advanced aircraft must become more conscious of employment factors and utility of their products;[59] "Passenger acceptance of rotor-equipped aircraft versus other types is a really fuzzy area, and we can't get a handle on it"; gnawing doubts about the acceptability of jumbo size.[60]

	NASA	NON-NASA	LITERATURE
RANKING:	Top 1/3	Bottom 1/3	Top 1/3

27. Attentiveness (IV-15)

Safety — Errors in control operation, substitution and forgetting apparently account for 35% of pilot errors;[61] lack of cockpit discipline cited as a possible factor in surge in landing accidents;[62] omitted procedures found in recent air carrier test.[63]

	NASA	NON-NASA	LITERATURE
RANKING:	Top 1/3	Top 1/3	Top 1/3

28. Pilot Workload (I-7)

Excessive or heightened workload has been implicated as an involved factor in landing accidents for all aircraft and in weather accidents for private pilot. However, it is felt that excessive workload is not the cause of accidents but rather the result of other factors at work. Therefore, the reason for retaining this problem is not its status as an accident cause but rather its utility in exploring other areas such as handling characteristics, instrumentation, control configurations, etc., for new aircraft and systems.

Safety — Heightened workload identified as a factor in approach and landing accidents.[64]

Effectiveness — Lack of workload measurement techniques and standards is inhibiting progress on advanced design aircraft generally[65] and their handling characteristics in particular.[66]

	NASA	NON-NASA	LITERATURE
RANKING:	Top 1/3	Mid 1/3	Top 1/3

29. Stress (IV-8)

The problem concerns the relationship between physical (danger) and non-physical (emotional) stress and its effect on immediate and long-term human performance (see Figure A-15). Included are:

Sandia Scale	P Scale	z Scale
10	0.994	-2.5
	0.992	-2.4
	0.989	-2.3
	0.986	-2.2
	0.982	-2.1
9	0.977	-2.0
	0.971	-1.9
	0.964	-1.8
	0.955	-1.7
	0.945	-1.6
8	0.933	-1.5
	0.919	-1.4
	0.903	-1.3
	0.885	-1.2
	0.864	-1.1
7	0.841	-1.0
	0.816	-0.9
	0.788	-0.8
	0.758	-0.7
	0.726	-0.6
6	0.692	-0.5
	0.655	-0.4
	0.615	-0.3
	0.579	-0.2
	0.540	-0.1
5	0.500	0
	0.460	0.1
	0.421	0.2
	0.382	0.3
	0.345	0.4
4	0.308	0.5
	0.274	0.6
	0.242	0.7
	0.212	0.8
	0.184	0.9
3	0.159	1.0
	0.136	1.1
	0.115	1.2
	0.097	1.3
	0.081	1.4
2	0.067	1.5
	0.055	1.6
	0.045	1.7
	0.036	1.8
	0.029	1.9
1	0.023	2.0
	0.018	2.1
	0.014	2.2
	0.011	2.3
	0.008	2.4
0	0.006	2.5

Sandia Scale bands*:

- 10–8: HER 0.23 (0.15-0.30) EXTREME STRESS
- 8–6: HER 0.18 (0.10-0.25) VERY HIGH STRESS
- 6–4: HER 0.14 (0.05-0.20) HIGH STRESS
- 4–2: HER 0.07 (0.01-0.15) MODERATE STRESS
- 2–0: HER 0.02 (0.01-0.10) MILD STRESS

Emergencies	Obtained Values
Fire in cabin or bomb bay during takeoff	-1.8554
Fire in cabin or bomb bay at altitude	-1.4870
Engine loss on takeoff	-1.3223
Engine fire at altitude	-0.8890
Controls iced up	-0.8716
Landing gear failure during takeoff	-0.7416
Tire fails during takeoff or landing	-0.3812
Partial power loss on takeoff roll	-0.3712
Fire in cabin or bomb bay during taxi	-0.3306
Brakes fail while landing	-0.2922
Live bomb hangs up on bomb run	-0.1466
All engines iced up	-0.1333
Abnormal control indications at altitude	-0.0191
Propeller malfunction on takeoff	-0.0106
Fuel leak during in-flight refueling	0.0214
Landing gear fails to extend	0.0750
Wing surfaces iced up	0.0772
Extreme turbulence	0.0853
Propeller malfunction while landing	0.1764
Propeller malfunction at altitude	0.1888
Abnormal oil indications at altitude	0.2419
Blister cracks while pressurized at alt.	0.2729
Gen. failure of electrical system at alt.	0.2918
Runway covered with ice while landing	0.3554
Hydraulic system failure at altitude	0.4327
Gen. failure of pressurization system at alt.	0.5841
Engine loss while at altitude	0.6751
Abnormal fuel indication at altitude	0.6952
Partial power loss at altitude	0.7478
Failure of single radio system	1.4811
Landing gear fails to retract	1.4817
Loss of visual contact with ground	1.9667

*HER = mean human error rate per task per level of stress, with likely overlap shown in parentheses.

The Sandia aircraft emergency scale.

FIGURE A-15 RELATIONSHIP OF HUMAN ERROR RATES AND LEVELS OF STRESS FOR AIRCRAFT EMERGENCY SITUATION[67] identification of indicators and measurement techniques as well as the definition (data) of the relationships. Evidence of the importance/utility of this topic to aviation is represented by some British work which defines heart rate differentials between aircraft types, weather conditions, and sophistication of airfield landing aids, all of which have possible implications for equipment design and operating criteria (e.g., should less credit be given for VFR day, flights?)

<u>Safety</u> The relationship between congestion-caused stress in pilots/ground crews and unsafety is not known;[68] contributing factor in recent crash was emotional state brought on by preflight interaction of ground and flight crew;[69] relationship of pilots' "activity peak", strain of flying and likelihood of performance errors.[70]

	NASA	NON-NASA	LITERATURE
RANKING:	Top 1/3	Bottom 1/3	Bottom 1/3

30. Human Factors Involvement in Aircraft Certification (I-25)

The occurrence of hearing impairments, vibration-induced back ailments, dehydration problems, etc. may be cited as evidence that inadequate consideration is given to human factors in the certification process. The solution lies in 1) the development of adequate human factors <u>standards</u>, and 2) their <u>inclusion</u> as criteria in the certification of new aircraft.

<u>Safety</u> Human factors inadequacies have caused pilot-induced error accidents and have not been identified during the certification process;[71] flight test does a marginal job of identifying hazardous (to be avoided) portions of the flight envelopes.[72]

	NASA	NON-NASA	LITERATURE
RANKING:	Top 1/3	Top 1/3	Bottom 1/3

31. Use of Simulators in Checkouts and Proficiency (V-3)

Operating costs, safety restrictions, and occasional accidents during training are factors which mitigate against using line aircraft for training applications. The problem is to provide factual evidence to support an orderly transition from present air carrier practices to a more complete use of simulator/synthetic trainers for all training and checkout functions 10-15 years from now. While not so formally stated the same goals seem appropriate to general aviation emphasizing refresher and upgrading applications.

Safety — Use of general aviation simulators may offer a means of updating and checking private pilot proficiency. The cost and lack of check pilots mitigates against doing this in the air.

Cost — In air carrier operations the high cost (and hazards) of using line aircraft for training is forcing new uses of "synthetic" ground trainers.[73]

	NASA	NON-NASA	LITERATURE
RANKING:	Bottom 1/3	Top 1/3	Top 1/3

32. Task and Aircraft Design Simplicity (I-29)

In general aviation there appear to be two issues involved: 1) simplification as a means of reducing accidents/incidents, and 2) simplification so as to encourage a broader usage of the private

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aircraft, i.e., reduce the amount of initial training and proficiency requirements. Regarding air carrier applicability comments were made about the complexity of the regulations (for both ground controllers and aircrews); the National Transportation Safety Board has recently called for simplification of crew duties during the descent before landing phase; and NASA personnel urged caution regarding the use of "apparently" job simplifying automation.

Safety	As a result of increased landing accidents, National Transportation Safety Board calls for simplifying crew duties;[74] simplicity called for in aircraft design and operating procedures to improve safety;[75] pilots question the benefits versus added complexity of proposed automation.[76]
Effectiveness	Simplification of private aviation to decrease proficiency requirement and encourage more widespread usage.[77]

	NASA	NON-NASA	LITERATURE
RANKING:	Mid 1/3	Top 1/3	Top 1/3

33. Cockpit Layout (I-15/16)

A recent government study compared accident/incident rates of a large number of general aviation aircraft, and one of the factors implicated in the high rate aircraft was faulty cockpit layout (i.e., human engineering). In air carriers numerous "convenience" complaints are still being made about current aircraft although these have purportedly been rectified for the upcoming generation.

Safety — Cockpit layout (i.e., location and design of controls and instrumentation) has been isolated as a contributing factor in certain light aircraft accidents/incidents.[78]

RANKING:	NASA	NON-NASA	LITERATURE
	Bottom 1/3	Bottom 1/3	Bottom 1/3

34. Voice Communications (I-11)

Current and near future air traffic control concepts involve: (1) a large amount of communications, i.e., Northeast Corridor operations require a full-time crew member to handle communications; and 2) a high chance for error. In addition to the hazard, workload and crew size consequences, this situation limits the rate at which air traffic control can process aircraft in the terminal area. The human factors aspects are of two types: 1) establishing information exchange requirements, and 2) participating in the selection and development of improved means, e.g., data link.

Safety — Excessive error possibilities in traffic control directions via voice communications.[79]

Cost — Full-time crew member required to man the radio during corridor operations.[80]

Effectiveness — One of the limitations in terminal area capacity is the time-consuming nature of current communication concepts; high ground and air workload is also a consequence.[81]

RANKING:	NASA	NON-NASA	LITERATURE
	Bottom 1/3	Top 1/3	Top 1/3

35. Readiness Self-Test (IV-14)

No information was found on this topic in the sample of literature; however, several apparently independent interview sources expressed need to develop such a technique. Its suggested scope varied from purely medical, to psycho-motor, to mental set; its main purpose was, of course, safety and the self-administration aspect addresses the question of how do you protect the (private) pilot from himself without excessive restrictions?

	NASA	NON-NASA	LITERATURE
RANKING:	Bottom 1/3	Top 1/3	Bottom 1/3

36. Ego as a Factor in Aviation Accidents (IV-31)

The definition of this problem includes motivation (i.e., desire to do well and inclination to "push" the limits to succeed) and the foolishness acts of "flat hatting". In the first sense the problem is applicable to all aircraft types; the second application is limited to the private pilot.

Safety — Over-extending oneself because of desire to do well;[82] inability to diagnose this factor may be confounding accident conclusions.[83]

	NASA	NON-NASA	LITERATURE
RANKING:	Bottom 1/3	Bottom 1/3	Bottom 1/3

37. Feedback of Accident-Incident Information (V-7)

Interest was not especially high for this problem but it was retained for its strong safety implications and in view of a new incident reporting program being initiated by the National Transportation Safety Board. The crux of the problem is not so much the free exchange of accident/incident data, which some sources think should be enhanced, but rather an identification of the kinds of information that would be both obtainable and useful to operators and designers.

Safety — As a means of educating the private pilot;[84] as a diagnostic technique for aircraft design and air carrier operations.[85]

	NASA	NON-NASA	LITERATURE
RANKING:	Bottom 1/3	Bottom 1/3	Top 1/3

38. Operating and Training Manuals (V-8)

Regarding general aviation the problem relates to omitted, incomplete or misleading information concerning hazardous portions of the operating envelope and emergency procedures. For air carrier applications the problem appears to be concerned more with identification of relevant information. In both cases the issue is information requirements.

Safety — The problem is inadequate communication to the user; specifically, ommitted, incomplete or misleading information in the owner's handbook.[86]

	NASA	NON-NASA	LITERATURE
RANKING:	Low 1/3	Low 1/3	Low 1/3

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