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FINAL REPORT

AN INVESTIGATION INTO PILOT AND SYSTEM RESPONSE TO CRITICAL IN-FLIGHT EVENTS

VOLUME I

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FOREWORD

This report is prepared in two volumes. Volume I reports the Executive Summary and the findings of the research. Volume II contains the appendices to the final report. The appendices list detailed documentation which supports the research findings. This includes specific materials and procedures used in: a) the open and closed forms of the knowledge tests, b) the full mission simulations, and c) the paper and pencil tests.

EXECUTIVE SUMMARY

A critical in-flight event is a situation which is unexpected, unplanned and unanticipated, and is perceived by the pilot in command to threaten the safety of the aircraft. The CIFE is one which requires pilot judgment beyond routine decision making or a pre-programmed decision structure and where the safety of the aircraft depends more on pilot cognitive processes than skilled motor performance.

Research Objectives

The objectives of this research were to:

1) Describe and define the scope of the critical in-flight event with emphasis on pilot management of available resources.
2) Develop detailed scenarios for both full mission simulation and paper and pencil (P/P) testing of pilot responses to CIFE's.
3) Develop statistical relationships among pilot characteristics and observed responses to CIFE's.

These objectives grew out of a concern with anomalies in reported accidents and incidents in which some pilots or crews seemed better able to handle unusual in-flight events than others. For example, why did a professional crew piloting a Baltimore Colts 727 fail to recognize the symptoms of a frozen pitot system and subsequently enter a fatal stall-spin maneuver? Contrast that event with the performance of an airline pilot who used differential power to overcome a locked elevator problem on his three-engine aircraft. What characteristics of his training and decision making strategy permitted him to develop a successful solution to the problem? Similar questions are raised by events such as a Cessna 206 pilot who experienced engine failure due to fuel exhaustion in one tank, and crashed the aircraft with the second tank nearly full of unused fuel.

Project Development

The project began with an early concern for the dynamics of CIFE's and broad attempts to identify pertinent research issues. The final products were 1) a set of scenarios with associated hardware and techniques for studying CIFE phenomena in a basic general aviation flight simulator; 2) a set of paper and pencil scenarios and associated techniques for studying pilot diagnostic strategies and diversion decision making processes; 3) a set of testing instruments designed to measure a pilot's knowledge of aircraft subsystems and understanding of troubleshooting techniques; 4) a study relating cockpit crew procedural compliance with performance errors. By-products of this research included one M.S. design project, one M.S. thesis, and a Ph.D. dissertation*. Major milestones in the project development are summarized in Figure 1.

Model

A five-phase model of pilot CIFE response is hypothesized on the basis of a) discussions with experts in industry and government and b) observations made about pilot performance in both simulator and paper/pencil scenarios.

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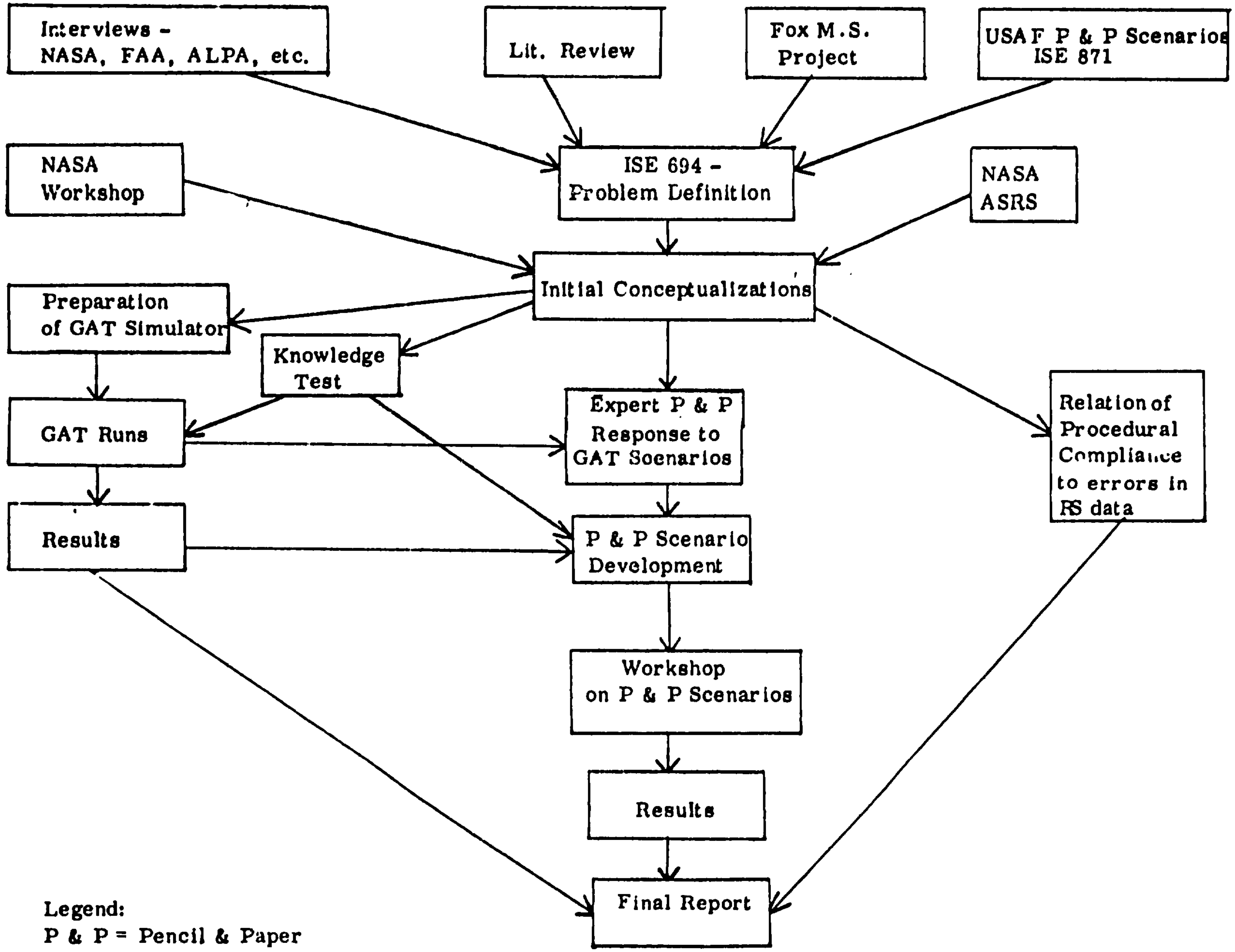
*See Appendix B



Legend:
P & P = Pencil & Paper

Figure 1.

OSU-ISE DEPARTMENT NASA PROJECT DEVELOPMENTS

The five phases are:

1) Detection

2) Diagnosis

3) Option Generation

4) Decision Making

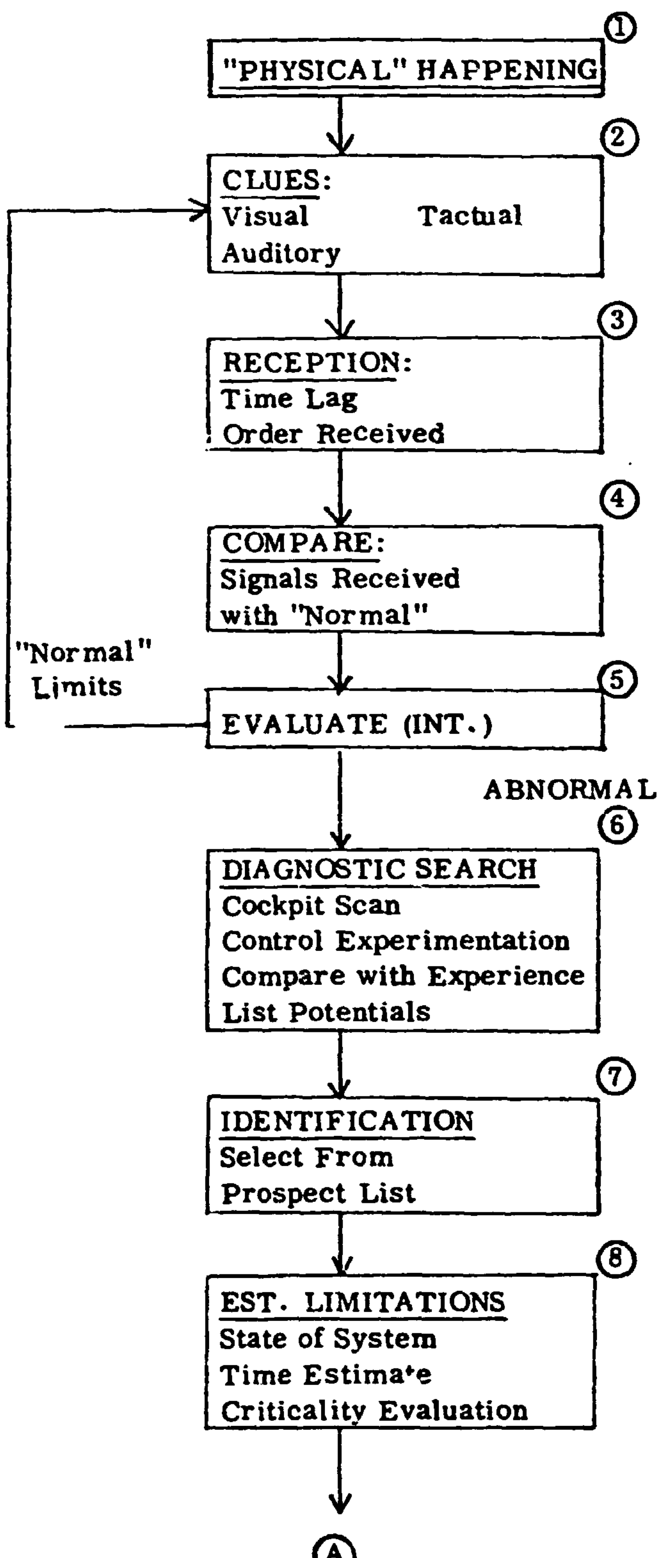
5) Execution

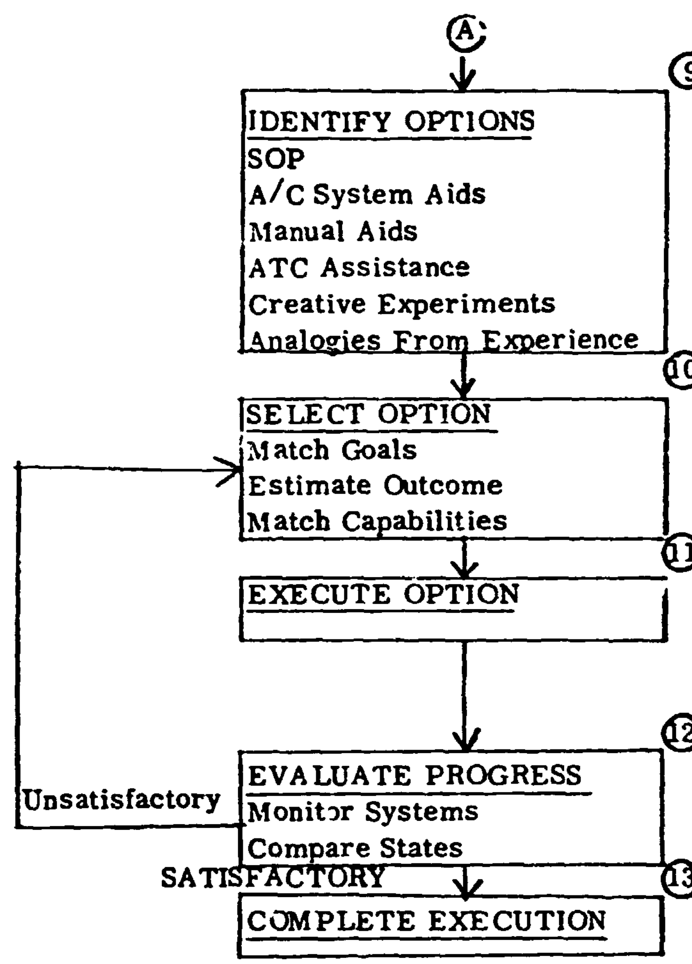
Information seeking activities permeate all five phases of this process. The inter-relationships and feedback among these phases are outlined in Figure 2.

GAT-Scenarios

A Singer GAT-1 flight trainer was modified to permit a variety of extra failure modes and to enhance data collection. Three scenarios were created to be tested in the GAT-1. These scenarios each involved a critical in-flight event imbedded in what was otherwise a routine simulated IFR flight. Subjects went through a pre-flight planning phase involving a complete weather briefing, route planning, and filing of flight plan. Take-off, climb and enroute phase of each scenario began under normal IFR operating conditions. Real time ATC communications, including background conversations, were used to enhance realism. Some 20-30 minutes into each simulated flight one of the following critical events was introduced:

HYPOTHESIZED PILOT CIFE RESPONSE





HYPOTHESIS: 5 Phase Model. Information Seeking Permeates All Phases.

A. DETECTION: Items 1 thru 5

B. DIAGNOSIS: Items 6 thru 8

C. OPTION GENERATION: Item 9

D. DECISION MAKING: Items 10 thru 1

E. EXECUTION: Item 13

Figure 2.

1) Fuel starvation on the active tank (as might be encountered because of a loose fuel cap).

2) Partial power failure (as might be caused by a broken baffle in a muffler).

3) Navaid loss (as might be caused by failure of a single airborne receiver component).

Subject performance was observed through one-way windows on the simulator and recorded by video tape, a 3-channel audio tape and written evaluations by the three experimenters present. These data were later used to measure "stick and rudder" skills and communications techniques as well as to map each pilot's response to the critical in-flight event.

Twelve subjects were selected for testing in the full mission GAT scenarios. Although all were IFR rated, they ranged in age from 20 to 56 years old, in flight experience from 270 to 8800 hours and in certification from private pilot to ATP. Each subject was given two different forms of knowledge survey to complete and was thoroughly debriefed after his flight.

A wide range of cockpit management styles and apparent skill levels were observed. Although it was difficult to quantify, "good performance" was easily recognized by the observers of the experiment. The elements of "good performance" included:

1) professional use of the radio

2) precise heading and altitude control prior to and during the CIFE

3) constant awarenes of the aircraft position along its intended route

4) prompt, but not necessarily instant, response to the on-set of the CIFE (detection)

5) systematic procedure for trouble shooting

6) knowledge and use of available ATC resources

7) diversion decisions which allowed for further potential uncertainties

The sample was too small to indicate anything other than some initial hypotheses concerning pilot performance in such a full-mission setting. However, the following tendencies were noted:

1) Cockpit management style varies widely among pilots. For example, some are extremely self-reliant, others want immediate and extensive help from ATC while still others make the decision making process a joint effort with ATC.

2) Good stick and rudder pilots seem to have excess capability and maintain good stick and rudder performance during and after the CIFE. More marginal stick and rudder pilots, on the other hand, show increased frequency and amplitude of heading and altitude excursions, and experience communication difficulties when faced with a CIFE.

3) Pilots who score well on the knowledge test instruments tend to perform well in problem diagnosis and decision making.

From the observations of the experimenters and comments made by participating subjects, it appears that such a full mission simulation exercise, coupled with an appropriate knowledge survey and debriefing, could be a valuable tool for recurrent training of IFR pilots.

Paper and Pencil Scenarios

Paper and pencil (P/P) scenarios, and associated experimental techniques, were created to streamline the data collection and analysis for pilot responses to critical in-flight events. Although they lacked the high stress environment of the GAT-1 experiments, these scenarios did yield useful data on pilot problem diagnosis and decision making skills and strategies.

The paper and pencil scenarios have the following advantages over the GAT-1 scenarios:

1) Experimental conditions are more easily replicated between subjects.
2) Data collection is more easily accomplished.
3) Diagnostic capabilities and decision making strategies can be more easily isolated.
4) They are much cheaper, in terms of both time and money, which means that a much larger sample size of subjects can be run.

The paper and pencil experiments were conducted in a workshop-type environment. A group of subjects, usually three or four, were seated in a conference room for a common briefing and initial testing. Each subject was asked to complete a background questionnaire, which asked for data on his personal flying experience. Items such as age, ratings, total flying time, recency of experience and type of flying most often done were included. They then were given a 20-question knowledge survey (multiple-choice questions) designed to measure their knowledge of aircraft sub-systems and trouble-shooting skills. After the tests were completed, the group was given a complete briefing on the equipment to be flown, the weather expected, and the airspace in which they would be assumed to be operating for purposes of their CIFE scenarios. At that point the group was disbanded with each subject accompanying a single experimenter to a private room where the scenarios were administered.

Two sets of scenarios were used on each subject. The first set consisted of four scenarios directed toward problem diagnosis. The second set involved two exercises designed to explore diversion-decision making strategies of pilots. (A diversion decision involves choosing an alternate airport when the intended destination airport is unavailable due to a CIFE. At the completion of the paper and pencil experiments the subjects were invited to tour the GAT-1 simulator used in the earlier study and to participate in an informal debriefing. The entire process required about ninety minutes from beginning to end.

For these tests, forty subjects were used. Almost all were current instrument-rated pilots with ages ranging from twenty to sixty-five years, with both civil and military backgrounds, and embracing total flying experience from 270 to 19,000 hours. As a group, these pilots were considered to be above average in experience.

P/P Diagnostic Scenarios

Four separate diagnostic problem situations were presented to each subject. These scenarios centered about problems presumed to be created by:

1) an oil leak at the oil-pressure gauge line
2) a vacuum pump failure
3) a right magneto drive gear failure
4) a frozen static port

After instructions for the diagnosis scenarios were read to the subject, he was given an aircraft instrument panel layout diagram and enroute chart for the first problem. The scenario was then read, concluding with a statement of a major symptom, e.g., "You smell hot engine oil. What would you do?". The subject was given a maximum of four minutes to seek information from the experimenter and conclude his diagnosis of the problem. He could ask for any information available from instruments noted on his panel diagram, response to control inputs or external cues such as oil on the windshield or ice on the wings. The experimenter had a diagnosis information checklist from which he provided information in response to the subject's request. For example, if the subject asked for oil temperature, the experimenter would respond "normal" if that was the entry on his checklist. As each piece of data was requested, its order was noted on the experimenter's checklist. If a diagnosis was not offered by the subject prior to the elapsed time (four minutes) the subject was asked for his best estimate of the diagnosis at that time. At the completion of the allotted time the subject was asked to estimate the criticality (scale of 1 to 7) of the problem as he perceived it. Then he was given the correct diagnosis and was asked to re-estimate the criticality in the light of this perfect information. The same procedure was repeated for each of the four scenarios.

Eight pieces of basic information were extracted from each diagnosis summary sheet. These were:

1) Number of inquiries. (An inquiry represents a request for a single piece of information .)

2) Total tracks of inquiries. (A track represents a single coherent line of questioning which may involve several inquiries; for example, fuel pressure, fuel flow, fuel gauge status.)

3) Unique tracks of inquiries. (A subject may start one track, abandon it, shift to a second track and then return to the first track. Although three total tracks would be noted, only two unique tracks exist.)

4) Correctness score. (A score of 1 to 5 was given which reflected how close the subject's final diagnosis was to the "perfect" solution.)

5) Time to complete the diagnosis.

6) Criticality estimate before the correct diagnosis was revealed. This was a subjective-rating scale, 1-7.

7) Criticality estimate after the correct diagnosis was revealed.

8) Number of control input inquiries. (A control inquiry involves movement of an aircraft control, e.g., "What happens if I advance the throttle?")

These primary data were then used to create a number of compound performance measures including estimates of efficiency and merit. "Efficiency" was measured by the time and number of inquiries required to reach a diagnosis. Subjects who reached their diagnosis quickly (be it right or wrong) and who made relatively few inquiries received high efficiency scores. "Merit" was measured by multiplying correctness and efficiency scores on a given scenario.

P/P Decision Making Scenario

The decision making phase of the paper and pencil experiments was divided into two parts, an information seeking part and a rank ordering of alternatives. The basic scenario used for both phases involved a hypothetical flight in a Cherokee Arrow from Bangor, Maine to Glens Falls, New York for a business meeting. Weather along the route and at the destination was marginal with rain, low ceilings and drizzle signifying instrument meteorological conditions (IMC). The scenario was read to the subject as he was invited to follow the progress of the hypothetical flight along an enroute chart. About midway along the route the aircraft encountered an alternator failure, the diagnosis for which was clearly defined for the subject. An upper limit on the length of time battery power alone would run the required electrical equipment was then given. This maximum time (exact time was uncertain) was less than the time required to reach the primary destination, thus forcing a diversion decision on the pilot.

For the information seeking task the pilot was supplied with a simplified enroute chart with sixteen airports indicated by letters along his flight path. The subject was then given two minutes to ask for information about any of those airports. For each airport questioned, there were six pieces of information the experimenter was prepared to provide:

1) Bearing and distance from his present location.
2) Ceiling at the airport.
3) Visibility at the airport.
4) Approach aids available.
5) ATC services available.
6) Terrain surrounding the airport.

The experimenter provided the pilot with each piece of information requested and the experimenter recorded the sequence in which it was requested. The pilot continued to request information until he had selected an airport (or until forced to select at the end of two minutes) and revealed his choice to the experimenter.

For the ranking of alternatives phase, the pilot was asked to rank each of sixteen alternative airports. He was provided with ATC facilities, ceiling and visibility, time to be reached and approach aids information on all airports. The airports were to be ranked from "most preferable" to "least preferable" given his problem situation. No time limit was imposed for this task. In order to assess his risk-taking tendencies, the experimenter posed a series of questions for the pilot to consider after he had obtained his ranking. The questions asked how far he would go down his list of ranked airports to find one with maintenance facilities to repair his airplane.

The data from the ranking task were used to determine the relative worth structure. The coefficients, or weights, for the variables ATC, weather, time, and approach were obtained by regression analysis according to the techniques of conjoint measurement. The range of values for the coefficients was 0.250 to 4.000. The relative worth coefficients were later used to determine if any relationship existed with pilot background variables, results of the knowledge survey, diagnostic ability, and search pattern exhibited in the information seeking task.

P/P Scenario Generalizations

For purposes of analysis the closed form (multiple choice) knowledge survey was considered to be part of the P/P experiments. This knowledge survey focused on aircraft subsystems and trouble shooting in three major areas: 1) engine and fuel systems, 2) electrical systems and cockpit instrumentation, and 3) weather and IFR operations.

A series of Spearman Rank Correlation studies, stepwise regression analyses and t-tests were performed on the combination of pilot background variables, knowledge survey results, diagnostic scenario performance and decision making measures. Among the observations made from these analyses are the following:

1) There is no correlation between knowledge score and total flight hours.
2) Knowledge score is correlated with pilot ratings held.
3) Pilots good in one section of the knowledge survey tend to be good in all sections.

4) Diagnostic performance is highly correlated with knowledge scores.

5) Knowledge is inversely related to total diagnostic inquiries, e.g., knowledgeable pilots reach conclusions (right or wrong) more rapidly than others.

6) Total diagnostic inquiries is inversely related to correctness. This suggests that undirected experimentation is poor diagnosis style.

7) Total diagnosis correctness score is correlated with efficiency.

8) Civil trained pilots place a higher worth on ATC service in diversion decisions than do military pilots.

9) Private pilots place a higher worth on weather factors in diversion decisions than do commercial and ATP rated pilots.

10) ATP rated pilots place high worth on time in diversion decisions.

11) Pilots with good diagnostic scores place less weight on approach aids in diversion decisions.

12) Pilots with good diagnostic scores place more weight on time in diversion decisions.

13) The pilots with good diagnostic performance were characterized as knowledgeable about aircraft systems, employed few tracks to get at an answer, used few inquiries per track, and emphasized time in their destination diversion decision. They were not differentiated by flight hours, ratings, training, or type of flying.

Procedural Compliance

In support of the general research objectives, Schofield investigated airline cockpit crew operations. For his dissertation he used data generated in an experiment conducted in 1976 by Dr. H. P. Ruffell Smith under the auspices of the NASA-Ames Research Center*. Ruffell Smith used a full mission simulation scenario of a Boeing 747 flight to study crew errors generated during high workload segments of the simulated flight. Schofield used the same data to study routine tasks of flight operations during low workload segments of that flight. He was concerned with:

1) Quantifying routine procedures.
2) Analyzing observed crew errors to identify which particular crew members were the primary causes of such errors.
3) Comparing measures of procedural compliance and operator error.

Schofield identified nineteen separate words and phrases associated with aircrew operations which had procedural connotation. Using that list as the basis for definition he enumerated 97 normal operating procedures which could be identified as standard cockpit activities in a 75-minute flight. This list did not include any abnormal, alternate, irregular or emergency procedures.

Twenty-one crew coordination procedures were separated from the total list for further study. This group was emphasized because those procedures captured the essential ingredients of group leadership, crew management,

*See Appendix B

and behavioral conformity. Schofield sought to examine relationships between meticulous compliance with coordination procedures and the crew errors noted by Ruffle Smith.

Schofield selected ten runs, which had the same set of observers and usable audio data throughout, for detailed procedural analysis. The 21 crew coordination procedures were further subdivided into check lists, call outs, configuration changes and transfers with each of the ten crews evaluated in each subdivision.

The prescribed command-announcement-challenge sequence for check-list procedures was fully executed in only five of fifty opportunities, when the crew members involved were pilot and co-pilot. When the flight engineer was involved, fifteen of thirty opportunities were fully executed. Schofield hypothesized that crew coordination might be improved by making the flight engineer the challenger of all checklists.

One hundred seventy opportunities, among the ten crews, to execute callout procedures were noted. Thirty eight procedural errors were identified, half of which were errors in altitude callouts during climb or descent.

The 104 observed configuration changes, e.g., gear and flap extensions, were well executed in terms of established oral procedures. Verbal indicators of transfer of EGT monitors were also given with few omissions. However, the optional transfer of control procedure was seldom observed even though opportunities existed to use it.

Schofield used stepwise multiple regression techniques to identify the best models relating the independent (procedural) variables to each of the dependent (error) variables in turn. He found that dependent variables which reflect errors by the flying pilot, by the captain, and by the two pilots collectively all have highly significant regression models in which pilot flying checklist commands and non-flying pilot callouts are the common independent variables.

The Schofield study of procedural compliance by aircrews who participated in the Ruffell Smith experiment suggests the following observations:

1) Crew members face an impossible challenge in attempting to mentally catalog all of the standard operating procedures (SOP) published for them.

2) Routine non-compliance with an assortment of SOP's has been documented.

3) Human redundancy by itself does not erradicate personnel errors.

4) A statistical link appears to exist between operator errors and procedural compliance.

ACKNOWLEDGEMENTS

No project of this scope could be undertaken without the assistance of many persons. Graduate students were involved in the conduct of experiments and analysis of data. Technicians were involved in the modification of hardware. Fellow faculty members were involved in evaluating alternative experimental designs. Clerical help were involved in data reduction and document preparation. NASA personnel were involved in project monitoring and control. Members of the flying community were involved as subjects whose performances are reported in this document.

We owe our biggest debt of gratitude to the graduate research associates who worked so hard to make this project a success. Bill Flathers and Dwight Miller were directly responsible for much of the scenario designs and data analysis. Jeff Schofield did all of the crew coordination portion of the study and contributed heavily to the development of the GAT experiments. Mike Burke and Kent Brooks were involved in the early stages of the project. Bill Fletcher contributed to an analysis of available literature.

We are also indebted to our friends in the Department of Aviation at The Ohio State University. Professors Dick Jensen, Dick Taylor, and Stacy Weislogel were valuable resources for testing ideas and initial forms of scenarios. Chuck Ventola together with Cedric Sze of our own department provided the expertise to modify and keep the GAT hardware running.
C. W. "Kelly" Kellenbarger, a retired member of the Department of Aviation, was our expert mechanic who provided the sense of realism to the mechanical problems posed.

The tasks of reducing mounds of data to table and chart format were ably performed by a group of undergraduate engineering students, Dick Romine, Doug Sink, and Bob Savage. The chore of reducing our sometimes illegible scrawl to finished type was very cheerfully and ably performed by Jean Martens.

We also want to thank Drs. Charles Billings and John Lauber of NASA-Ames for their guidance and encouragement throughout this project.

Finally, we want to express our sincere appreciation to all of our pilot friends who gave so generously of their time to participate in these experiments. Without their interest and cooperation there could be no research on critical in-flight events.

T. H. Rockwell
W. C. Giffin

TABLE OF CONTENTS

VOLUME I

APPENDIX		Page

LIST OF FIGURES IN VOLUME I, FINAL REPORT

LIST OF FIGURES IN APPENDIX TO FINAL REPORT

Figure		Page

LIST OF TABLES

Table		Page

I. INTRODUCTION

Departure: 75Y what is your altitude?

N1675Y: Columbus Departure Control, what do you show our altitude on our encoding altimeter?

Departure: I show you at 500 feet. That's why I asked you.

N1675Y: It shows 1000.

Departure: OK. Stop altitude squawk. I show you at 400 feet now. Obviously it's not working right.

N1675Y: 75Y we're having problems with airspeed and everything here--- What do you show our airspeed?

Departure: OK. 75Y do you want vectors back into the airport?

N1675Y: Yeah! Let's do that.

The above brief excerpt of an actual communication between ATC and a pilot experiencing in-flight problems in IFR conditions typifies a persistent dilemma in aviation.[1] We do not (nor does the air traffic controller) understand the true nature of this pilot's problem. How long has he experienced airspeed and altitude problems? Is it a matter of structural ice, mechanical failure or pilot error? If an emergency is to be declared, what does the fact of declaring an emergency mean to the air traffic controller? What does it mean to the pilot? (A confession of incompetence--an invitation to loss of license? Is there a need to specify intentions? Can the pilot provide intentions if he is unaware of the options open to him? How can we avoid those situations in which the pilot relinquishes command to someone on the ground?

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[1]These excerpts from a communications tape are verbatim. Only the aircraft identification number has been changed.

The assessment of the criticality of the situation demands more information, such as the pilot's capability, his training level, his experience with in-flight problems, weather, location, terrain, altitude, etc. Yet this situation is but an example of many such events that occur each year in our national aviation system.

Each year air traffic control provides several thousand assists to pilots. In 1970, of the 4,187 assists, 53% involved lost pilots, but 25% involved fuel problems, navigational failures, and mechanical problems. How many problems went unannounced and resulted in tragic consequences for lack of pilot understanding of how to cope with in-flight problems? How many emergencies were declared which could have been avoided and reduced disruption in air traffic control systems?

Discussions with pilots of various experience levels and ratings reveal little agreement as to when to declare an emergency and the operational and legal consequences of such a declaration. There are instances wherein pilots have risked and lost their lives and those of the passengers to avoid possible suspension of license as a consequence of declaring an emergency when they believed they had violated a regulation. (See NTSB-AAR-71-1). Do the perceptions of the air traffic control personnel differ from that of pilots in this regard? Most importantly, can pilots be trained to handle in-flight problems, provide early assessment and intelligent response to the situation? What should a pilot do if:

a) strange noises occur?

b) the door opens in flight?

c) the ammeter shows a discharge?

d) the radios fail?

e) smoke appears in the cockpit?

f) he cannot determine his location in his flight progress?

g) the weather closes in on him?

Some empirical evidence of pilot perception of threatening experiences is shown in Tables 1 and 2. These data suggest that a pilot's ratings, type of operation, and implied skill level, all serve to alter his perception of critical in-flight events.

What should the "system" be able to do to assist the pilot in properly assessing his real (or perceived) problem? No simple answer exists for these situations nor does past research appear to address these issues. It is hard to imagine the extent of myths and misconceptions about critical in-flight events. Critical events lead to air traffic control disruption, panic, accidents, and perhaps firm resolutions by pilots never to fly again.

In the NASA Aviation Safety Reporting System, 1,497 incidents were submitted in the period of July 15 to October 15, 1976. Of these 3% involved aircraft structure and subsystem factors and about 9% navigation and communication situations. If one assumes that the Reporting System captures only a portion of the total incidents occurring in the system, this statistic also suggests there may be thousands of critical in-flight events each year.

While one objective of this research is to describe and define the scope of the critical in-flight event (CIFE), a definition or set of qualifiers for the purposes of this report is set forth below.

Table I-1. Reported Most Uncomfortable or Threatening Experience During An IFR Flight In Actual IFR Conditions (Reproduced from Study to Determine the Operational Profile and Mission of the Certificated Instrument Rated Private and Commercial Pilot, FAA-RD-70-51 July 1970, p. 125)

Experience	General Avn IFR		Total	
	Number	% of Total*	Number	% of Total**
(1)	(2)	(3)	(4)	(5)
Structural icing	212	29%	331	19%
Thunderstorms	91	12	262	15
Turbulence	41	6	113	6
Communications loss	38	5	82	5
Equipment malfunction	38	5	82	5
Engine failure	28	4	67	4
Feeling behind a situation	25	3	51	3
Deteriorating weather	20	3	77	4
Approach to minimums	20	3	59	3
Spatial disorientation	19	3	73	4
Loss of navigation equipment	18	2	37	2
Near midair and/or unknown traffic	18	2	89	5
Loss of primary flight instruments	13	2	35	2
Communications and navigation loss	13	2	22	1
Unclassified	93	13	257	15
None or no response	52	7	130	7

* Total = 739
** Total = 1767

Table I-2. Most Threatening Experiences Reported by Private Pilots (Reproduced from Study to Determine the Flight Profile and Mission of the Certificated Private Pilot, FAA-DS-68-15, July 1968, pp. 81-82.)

Threatening Experience	Reports: Number	Reports: % of Total 1/
(1)	(2)	(3)
Low visibility	338	28%
Crosswind	290	24
Low ceiling	277	23
Malfunctions	254	21
Landings	247	21
High winds	229	19
In fog or clouds	209	18
Near air collision	198	17
Lost	148	12
Short field	147	12
Fuel supply	139	12
Engine operations	122	10
Forced landing	117	10
Takeoffs	111	9
Unimproved airport	96	8
Mud or snow	96	8
Darkness	92	8
Weight or loading	88	7
Infrequent piloting	87	7
Trees or wires	71	6
Use of radio	64	5
Soft field and high grass	64	5
Different type aircraft	42	4
Preflight operation	38	3
Unavailable preflight information	35	3

Table I-2 (Continued)

Threatening Experience	Reports	
	Number	% of Total 1/
(1)	(2)	(3)
Improper airspeed	30	3
Stalls or recoveries	28	2
Low altitude maneuvering	26	2
Uninformed	23	2
Steep turns	21	2
Flaps	20	2
Handling of aircraft	19	2
Holding altitude	18	2
Check list	14	1
Slow speed flight	13	1
Flight materials (maps, etc.)	13	1
Pontoons or skis	11	1
Slips	10	1
Other	136	11

1/ Total = 1,192

> A critical in-flight event is a situation which is unexpected, unplanned, and unanticipated, and is perceived by the pilot in command to threaten the safety of the aircraft. The CIFE is one which requires pilot judgment beyond routine decision making or pre-programmed decision structure. It may or may not involve communication with ATC. The CIFE assumes alternative courses of action are open to the pilot and some finite period of time is available to the pilot to make an assessment of the situation, enumerate options and make a decision. The safety of the aircraft depends more on pilot cognitive processes than skilled motor performance.

For purposes of this research, emphasis was placed on IFR rated pilots who have sufficient experience to utilize the ATC system when available.

Many examples of the above description can be put forth. The following illustrates a few of these.

a) failure of navigational equipment,

b) failure of electrical systems,

c) failure of hydraulic systems,

d) fuel management problems,

e) flights into unexpected weather,

f) unforecast icing conditions,

g) engine failure (single and multiengine aircraft), and

h) partial pilot incapacitation.

This research was directed towards an understanding of:

a) the nature of critical in-flight events (CIFE), their causes, and how they develop over time;

b) how pilots of different backgrounds might assess and respond to such instances;

c) the psychological stress of in-flight events, appropriate coping processes, and the modeling of such processes;

d) the interaction that exists between air traffic controllers and pilots during CIFE's; and

e) how adequate countermeasures can be developed from the above to minimize the frequency and consequences of CIFE's.

An explicit description of research objectives and discussion of the scope of the project are presented in the next section.

II. RESEARCH OBJECTIVES AND PROJECT SCOPE

The general objectives of the research were:

1. To describe and define the scope of the critical in-flight event with emphasis on characterizing
   a) event development,
   b) event detection,
   c) event assessment,
   d) pilot information requirements, sources, acquisition, and interpretation,
   e) pilot response options,
   f) pilot decision processes,
   g) decision implementation, and
   h) event outcome.
2. To develop detailed scenarios from (1) above for use in
   a) simulators as well as paper and pencil testing for developing relationships between pilot performance and background information, and
   b) an analysis of pilot reaction, decision, and feedback processes.

   The scenarios are viewed as data generating devices for pilot options.

More specific thrusts of this research, related to the general objectives above, were developed on the basis of initial research findings and research capabilities. These involved:

a) emphasis on general aviation IFR pilots in single engine aircraft

b) emphasis on the descriptive character of pilot response to critical in-flight events

c) use of full mission simulation

d) use of paper and pencil scenarios to study pilot problem diagnostic capabilities and destination-diversion decision processes

e) exploration of the relationship between procedural compliance and flight crew errors using the Ruffell-Smith simulation data.

The following chapters place major emphasis on:

1) background activities leading to problem conceptualization (Chapter III)

2) development of knowledge tests on system anomalies (Chapter IV)

3) full mission simulation (Chapter V)

4) paper and pencil scen rio tests (Chapter VI), and

5) analysis of the Ruffell-Smith data for procedural compliance (Chapter VII)

III BACKGROUND

A. Literature Review

Initial project activities centered around the development and implementation of a comprehensive literature search. Because the objectives of the project were rather broad ranged and cross-disciplinary, this search involved a number of topic areas. After an extensive review of search materials available a master list of key words to be used in all literature searches was developed. This list was used for all searches with the exception of pscyhology abstracts which used a controlled vocabulary. This controlled vocabulary can be found in The Searches of Psychological Index Terms, published by the American Psychological Association. The following sources were examined:

a) The Ohio State University Mechanized Information Center (OSU-MIC)

b) Psychology Abstracts

c) FAA Accident Reports

d) Transportation Research Information System (TRIS)

e) National Technical Information Service (NTIS)

f) Department of Defense sources (see Appendix A)

g) Aviation Press Publications, e.g., Flying Magazine, Business and Commercial Aviation, etc.

h) National Transportation Safety Board (NTSB) Accident Reports

While the literature was replete with "never again" stories, surprisingly few documents addressed pilot response to critical in-flight events in sufficient detail to permit pilot response modelling. Indeed, little statistical evidence was available on the relative frequency of various types of incidents.

Appendix B is an annotated bibliography of some of the literature examined. In addition, the dissertation by Schofield and the thesis by Flathers detail further background sources in this area.

B. Results of Interviews With Interested Agencies

At the outset of this project the principal investigators met with several organizations which had both a vital interest in the problem and expertise in pilot behavior. The National Transportation Safety Board (NTSB), The Aircraft Owners and Pilots Association (AOPA), Mitre Corporation, Airline Pilots Association (ALPA), Air Transport Association (ATA), National Aeronautics and Space Administration (NASA), Federal Aviation Administration (FAA), Air Force Office of Scientific Research (AFOSR), and United Airlines (UAL) were all visited to provide consultation with their staffs on their perceptions of the CIFE and to secure whatever data bases were available to document the extent and nature of CIFE and any data on related pilot response. These agencies also suggested other resources for this problem area - either published reports, research in progress or names of individuals who could provide insight into the CIFE problem. Trip summaries and contacts are outlined in Appendices B and C.

In general, all agencies reported a great interest in the problem and were willing to help within their capacities but admitted that the CIFE was largely an unresearched issue. No data bases on pilot response to CIFE's were available. There were, to be sure, many shared experiences, individual examples of CIFE's from FAA and NTSB files and unique perceptions from those interviewed. For general aviation (GA) CIFEs there were little or no data available from NTSB, FAA or NASA/ASRS files. From discussions with these agencies and among the research staff, several hypotheses or constructs were proposed about the CIFE process such as

1) response latency theory
2) social interaction in the cockpit
3) cognitive structuring
4) pilot workload
5) detection of vs. response to CIFE
6) appraisal of CIFE's
7) single channel limitation of the pilot
8) lack of standard work habits
9) lack of real world elements in training and testing of pilots

C. Results of the NASA-ASRS Search

Early in the research, the project team asked NASA-Ames to perform a search of its ASRS data file. Using key words consistent with their data base structure, e.g., emergency, pilot decision making, etc., some two dozen narratives were developed and examined. In general, little value to the project resulted from this search principally because of lack of detail about how the problem developed, how it was diagnosed, what alternatives were considered and other relevant details, e.g., weather and alternate airports available. Because of the NASA policy on anonymity of the reporter it was impossible to trace back an incident to get more information. What would have been necessary would have been to have the analyst follow up immediately on first contact using a supplementary data sheet. Because the thrust of the research was directed towards the GA pilot and the fact that the majority of incidents reported were air carriers, it was decided not to pursue the ASRS data file further.

D. An Initial Conceptual Model

As a result of background information, discussions with experts and a graduate seminar directed to the various facets of the problem, a preliminary model of this process evolved. This is shown in Figure III-1. This conceptualization depicts several key aspects of the problem - the detection phase, information seeking strategies, workload, use of resources, and pilot stress, decision styles and value systems making up his decision making.

Ultimately, pilot response was focused upon:

1) detection of the problem
2) diagnosis of the cause from the symptoms
3) generation of viable options
4) decision making both in terms of problem resolution and destination diversion
5) execution of the decision

Throughout all five phases, pilot information seeking strategies were studied.

A MODEL OF RESPONSE TO A CIFE

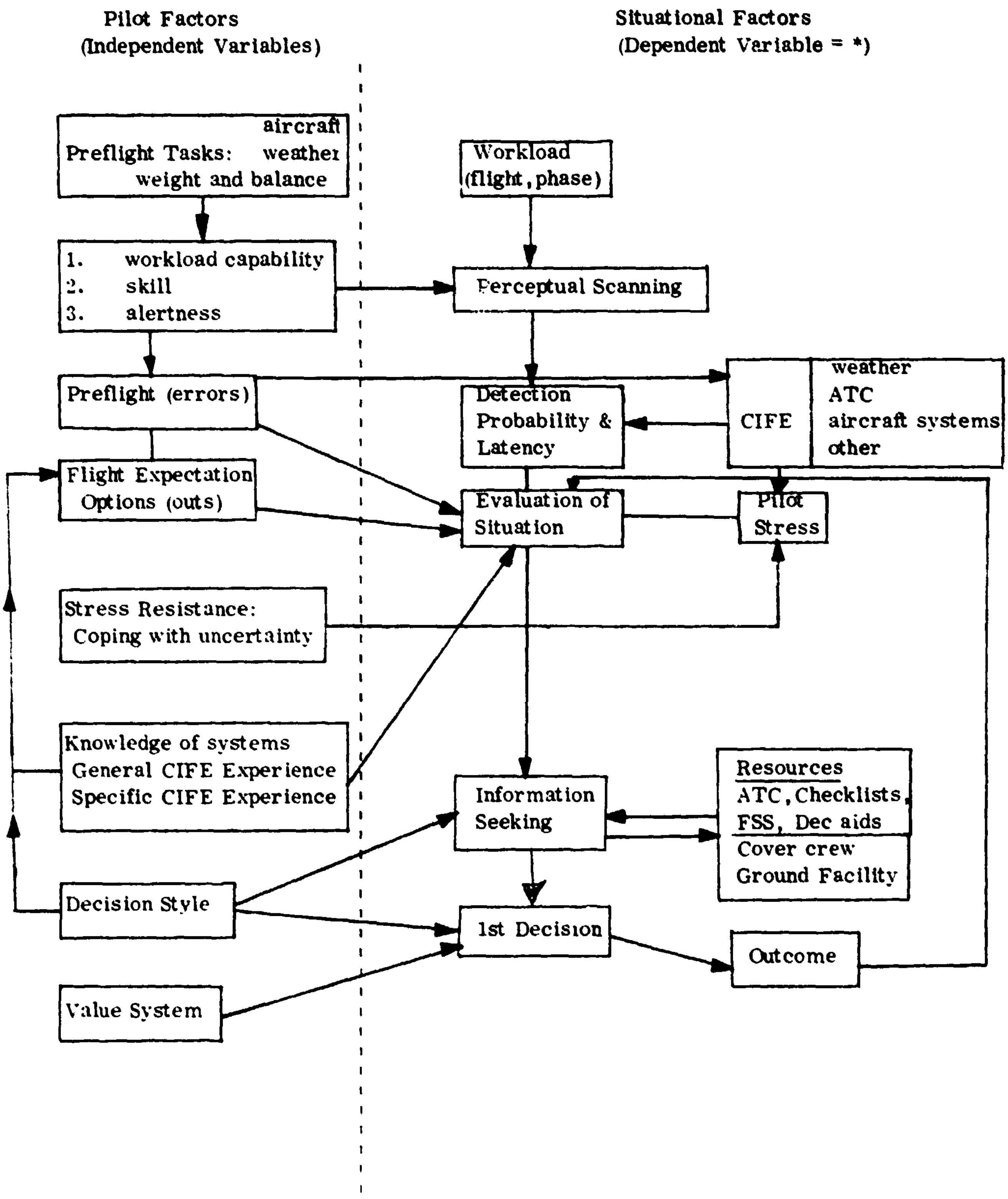


Figure III-1

E. Research Strategy

Figure III-2 depicts the overall strategy undertaken in this research. Above the dotted line are the initial background efforts. These included the aforementioned visitations, literature review, ASRS search and graduate seminar. Prior to the formal research initiation, a graduate project by Fox, "Critical In-Flight Responses", indicated the potential value of using paper and pencil scenarios to study pilot decision making. At the same time, as part of another Industrial and Systems Engineering (ISE) course, USAF pilots were surveyed to arrive at candidate scenarios for future simulation or paper and pencil testing. Both of these exercises provided encouraging results.

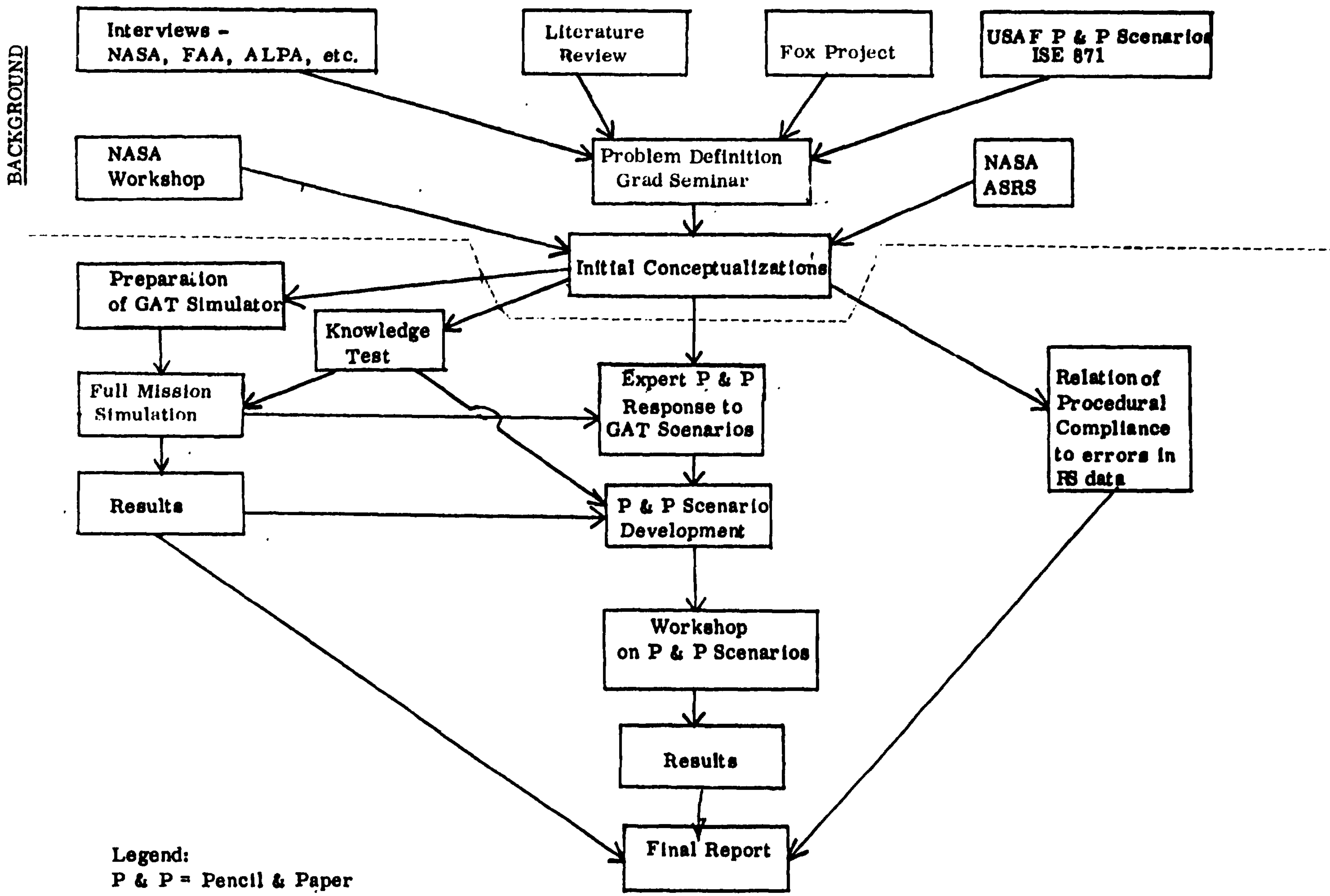
Below the dashed line are the four major fronts of the project:

1) the development of knowledge tests
2) full mission GAT simulations
3) paper and pencil scenario testing
4) the relation of procedural compliance to errors in the Ruffell Smith simulation study

Each of these major fronts is discussed in turn in the chapters which follow.

A comment on the paper and pencil scenario workshop is in order. This was a mechanism to bring pilots together for a general briefing prior to their testing on paper and pencil scenarios. These tests were then conducted with individual experimenters. Hence, about ten small group workshops were held on different days.

Figure III-2.
OSU ISE Department
Critical In-Flight Event Project Developments



IV. EVALUATION OF SUBJECT KNOWLEDGE OF AIRCRAFT SYSTEM ANOMALIES

The evaluation of subject knowledge of aircraft systems and the IFR operating environment was an important element in understanding the ways in which pilots respond to CIFE's. The evolution of the final test instrument involved a series of pre-tests, development of open form questions and finally a closed-form, multiple-choice questionnaire. Contrary to the usual airman certification exam question format, the bulk of the items selected here emphasized aircraft subsystem operation and trouble-shooting.

A. Open Form Survey

A knowledge survey, or inventory, was developed to determine the level of a pilot's knowledge of aircraft systems and the IFR operating environment. An open-form survey was administered to pilots who were participants in the GAT runs. Later a closed-form version was administered to all subjects in the paper and pencil scenarios. The results of the surveys were compared to various measures of pilot performance in the simulations to isolate relationships between pilot knowledge level and measureable aspects of piloting skill. The development of the survey followed a three stage process which included 1) item (question selection and pre-test, 2) construction and test of an open-form survey, and 3) construction and test of a closed-form (multiple choice) exam.

The items for the survey were constructed from information in training texts, government publications, aircraft operating manuals, and other readily available publications. Practice quizzes and examinations commonly used in the certification process placed much emphasis on such areas as regulations, weather, navigation, and weight and balance. Relatively few items on aircraft subsystem operation or trouble-shooting could be found. This is due, in part, to the fact that a modern single engine aircraft may have over 25 independent systems, and some of these systems may be engineered differently by the various manufacturers. For example, while the pitot-static system and gyro-instrument system designs offered by aircraft manufacturers are fairly uniform, other systems such as fuel metering and feed devices are often vastly different. Special care was taken to ensure that items selected for the knowledge survey were representative of the types of systems pilots could be reasonably expected to encounter in their flying careers.

A total of over 60 items were collected and pre-tested on a small group of pilots. Included in this prototype survey were areas such as fuel systems, electrical systems, engine systems and operations, cockpit instrumentation, weather and the flight environment, and general IFR procedures. The pre-test survey items were presented in the form of open-ended questions to which the pre-test subjects responded with short, written answers. Four types of questions were posed. The first type was a simple, straightforward question in which the pilot was asked to define or explain something. In the second type of question, given certain symptoms in terms of instrument indications, noises, visual inspection, and the like, the pilot was asked to identify the most likely cause of those symptoms (Symptom-Cause, or S-C). In the third type of question, the pilot was given a specific condition and was asked to identify symptoms that would most likely arise from that condition (Cause-Symptom, or C-S). In the fourth and final type of question, the pilot was asked what corrective action should be taken if a certain condition was known to exist (Cause-Correction, or C-C).

The correctness of the responses of the pre-test subjects was not as important as the ease with which the subjects understood and responded to the questions. The experience gained in the pre-test was very helpful in determining which questions were not useful and should be eliminated. It was also helpful in determining the way in which the remaining questions should be streamlined to improve clarity. All of the improvements suggested by the pre-test were made and the end result was the refined, open-form knowledge survey which was used in conjunction with the GAT simulation studies.

The open form survey, contained in Appendix D, consisted of 58 questions which called for short, written answers. Thirty questions were of the straightforward type, 11 were of the C-S type, 9 were of the S-C type, and 8 were of the C-C type. The open-form survey measured overall pilot knowledge, as well as knowledge in the six areas listed in Appendix D. Scoring of the survey was performed with the aid of the answer key also provided in Appendix D. Partial credit was awarded for answers which came close to those given in the answer key.

For evaluation of the paper and pencil simulation tests, pilot knowledge about systems was needed. This was accomplished through the use of the closed-form knowledge survey given in Appendix E. The survey consisted of 20 multiple choice questions. Nine of the questions were of the straight-forward type, 6 were of the C-C type, and 5 were of the C-S type. All of the questions came from the open form survey and were selected on the basis of their ability to discriminate between good pilots and marginal pilots. Some of the incorrect responses offered by subjects in the open form survey were used as "dummy" alternatives in the closed, multiple-choice form.

Under the multiple choice format all subjectivity in scoring was removed, and the time spent administering and scoring was greatly reduced. The answer key is given in Appendix E. Scores were provided for the three pilot knowledge subscore areas also given in Appendix E, as well as for overall pilot knowledge. Results of the closed form survey are discussed in Chapter II covering the paper and pencil simulations.

B. General Results of the Closed-Form Knowledge Survey

The closed form knowledge survey was administered to forty pilot-subjects, thirty of whom were also participants in the pilot decision-making workshop. The mean total score for the forty subjects was 12.4 with total scores ranging from five to seventeen. The maximum possible score was twenty.

Statistical tests were performed to determine if any relationships existed between knowledge survey scores and pilot background variables. The Spearman rank coefficient was used as a measure of correlation throughout. A summary of the correlation coefficients between total knowledge survey score and pilot background variables appears in Table IV-1.

Table IV-1

Total Knowledge Score Spearman Correlation Coefficients and Observed Level of Significance (In Parantheses)

Total Flight Hours	.131	(.42)
IFR Hours	.002	(.99)
Single Engine Hours	.467	(.002)*
Rating	.430	(.006)*

*means significant correlations at $p < .05$ level

As seen in Table IV-1, almost no correlation exists between total knowledge survey score and total hours or IFR hours. These lack of relationships suggest that accruing general flight experience or IFR flight experience does not guarantee knowledge will also increase. One possible explanation for this observation, however, is that, as pilots accrue more and more flight time, they tend to advance to more sophisticated aircraft with sharply different operational characteristics. The knowledge survey was aimed at the single pilot IFR operations common in light aircraft. These two relationships may not be as strong, then, because pilots with more flight experience may have moved out of the scope of the knowledge survey.

Substantial positive correlations are seen, in Table IV-1, between total knowledge survey score, and single engine hours and rating. These two relationships lend support to the knowledge survey's validity as a general tool to measure knowledge of single-pilot IFR operations and aircraft systems.

One would expect increased exposure to single engine operations (more single engine hours) would also increase a pilot's knowledge of single engine operations (which was the focal point of the knowledge survey). Additionally, as one's tested level of competence increased, knowledge should also increase.

The knowledge survey was broken into three subcategories: Engine and Fuel Systems, Electrical Systems and Cockpit Instrumentation, and Weather and IFR operations. They were named Category I (CATSCR 1), Category II (CATSCR 2), and Category III (CATSCR 3), and contain 7, 7, and 6 items, respectively. The means and range of scores for each category for the forty subjects are given in Table IV-2.

Table IV-2

Mean Scores and Range of Scores for Categories I, II, and III

	mean	mean % (% of max possible)	range low	range high
Category I (maximum possible = 7)	4.82	68.9	1	7
Category II (maximum possible = 7)	3.750	53.6	2	7
Category III (maximum possible = 6)	3.850	64.2	0	6

The same correlation tests were applied to these scores as were performed on the total knowledge survey score. A summary of the correlation coefficients between the three category scores and pilot background variables is given in Table IV-3.

Table IV-3

Correlation Coefficients and Observed Level of Significance
Category I, II, and III Scores, and
Background Variables (Levels of Significance In Parantheses)

	Total Flight Hours	IFR Hours	SE Hours	Rating
Category I Score	.197 (.22)	.090 (.58)	.474 (.002)*	.273 (.09)*
Category II Score	-.115 (.48)	.194 (.23)	.184 (.26)	.195 (.23)
Category III Score	.120 (.46)	-.001 (.99)	.376 (.017)*	.376 (.017)*

*indicates significant relationships at $p < .10$ level

As evident in this table, Category I score (engine and fuel systems) is positively correlated with single engine hours and ratings, whereas no significant correlation exists between Category I scores and total flight time or IFR flight time. These results may be due, again, to the fact that the knowledge survey was aimed toward single pilot IFR operations. There are sharp differences in powerplants between the sophisticated airplanes experienced pilots are more likely to fly and the simpler, lighter crafts flown in single pilot operations. This is particularly true when one considers the fact that higher performance airplanes are often powered by turbojets or turbopropellers.

Category III score (Weather and IFR operations) is positively correlated, again, with single engine hours and rating, and uncorrelated with total flight time and IFR hours. No correlations were found in any case involving Category II (Electrical Systems and Cockpit Instrumentation).

A summary of individual subject knowledge survey performance, including results for each of the three subscores is found in the Master Data Table, Table VI-4 in Chapter VI.

V. GAT FULL MISSION SCENARIO (FMS) RUNS

Prior to the development of the final paper and pencil experiments, a series of full mission simulation (FMS) experiments were performed. These experiments, which are described below, provided background for designing paper and pencil scenarios and a benchmark which such scenarios could be matched for a rudimentary cost/benefits evaluation.

A. Purpose

A Singer GAT-1 flight trainer was reconfigured to serve as a flight simulator for use in "LOFT" type scenarios. These scenarios each involved a critical in-flight event imbedded within an otherwise normal simulated IFR flight mission. The purpose was to gain an understanding of:

a) how pilots of different backgrounds assess and respond to such instances;

b) the psychological stress of in-flight events, appropriate coping processes, and the modeling of such processes; and

c) the interaction that exists between air traffic controllers and pilots during CIFE's.

In keeping with the full mission scenario approach, each subject went through a pre-flight planning phase involving a complete weather briefing, route planning, and filing of flight plan. Take-off, climb and enroute phases of each scenario began under normal IFR operating conditions. Real time ATC communications, including background conversation were used to enhance realism. A critical event was introduced some twenty to thirty minutes into each simulated flight.

The conduct of an FMS is outlined in the paragraphs which follow. Complete operating instructions and detailed supporting material are contained in the Master Notebook for GAT Scenarios, a copy of which is available in this project's file at NASA-Ames.

B. Experimental Equipment

The primary piece of equipment used in the full mission simulation studies is a Singer General Aviation Trainer (GAT-1) on a motion base. Three degrees of freedom, roll, pitch, and yaw, are provided by the motion base. This machine simulates, both in design and performance, a typical single engine, carbureted, fixed pitch prop, fixed gear aircraft. The avionics equipment includes dual navigation and communication radios, dual VOR indicators (one with glideslope), an automatic direction finder, an audio control panel, and a three-light marker beacon receiver.

Modifications have been made to the standard GAT cockpit. A transponder and a digital clock have been added to the instrument panel. A fuel selector switch has been installed to the left of the pilot's seat. A lapel microphone has been added to pick up the pilot's communications and cockpit sounds. Two floodlights and a closed circuit television camera have been mounted over the pilot's right shoulder to view the instrument panel.

External modifications have also been made to facilitate the experiment. The windows of the GAT have been covered with a one-way reflective film

(Scotchtint) so that the pilot can be observed during the flight without his knowledge. A display for showing which fuel tank is active has been installed, as well as external controls for the ammeter, panel light intensity, and for power (rpm) reduction. These are all new additions to the standard GAT hardware.

The experimenter has the capability to control the operational status of some of the GAT systems, and to determine the values of key parameters. The following can be rendered inoperative: attitude gyro, directional gyro, altimeter, airspeed indicator, turn coordinator, vertical speed indicator, VOR/LOC indicators, automatic direction finder indicator, glideslope, and engine. Additionally, oil pressure, oil temperature, cylinder head temperature, fuel level for each tank, engine sound volume, gross weight, center of gravity, outside air temperature, rough air magnitude, barometric pressure, and wind direction and velocity are subject to continuous control. An X-Y plotter connected to the GAT tracks the progress of the flight on an enroute low altitude chart, and provides the air traffic controller with the equivalent of radar flight monitoring.

Communication channels have been wired to permit two-way communication between the Jumpseat* and the ATC monitoring station. It allows pilot activities such as frequency changes to be relayed to ATC by the Jumpseat observer as augmentation to video monitor viewing. It also provides for ATC cueing of Jumpseat for changes in environmental GAT parameters and introduction of systems failures.

*Jumpseat refers to an experimenter who rides outside the cockpit but who can both observe pilot cockpit behavior and also initiate system failures.

The equipment described above helps to provide fidelity and realism for the subject, adequate experimental control of the flight environment, and audio-visual recording of experimental flight data.

C. FMS Procedures

The following materials support a GAT scenario experimental session from initial contact of subject to raw data collection. Typically, three experimenters are required to execute a session. One (Director) handles subject contact before and after the simulated flight. Another acts as ATC during the run, and a third sits in the GAT Jumpseat to control cockpit conditions and to call out instrument status. The general procedure for a GAT scenario experimental session follows:

1) Subject contacted, explanation of study read, appointment is made, aircraft manual and subject background data form are mailed to Subject.
2) Subject arrives and is met by Director. Subject is taken to a briefing room, where he initiates flight planning.
3) Meanwhile, ATC prepares control station and Jumpseat prepares GAT with detailed checklists.
4) Director prepares GAT room conditions and sees that all checklists are completed.
5) When Subject finishes planning, Director escorts him to GAT room and familiarizes Subject with GAT cockpit.
6) Director has Subject start the engine and closes cockpit door.

Jumpseat controls engine status gauges, winds aloft, and various other environmental conditions as cued by ATC or Director. Jumpseat also monitors and reads instruments that are difficult to read from the video camera. This aids in later review of the video tape and also aids ATC in determining which comm frequency has been selected.

Director fills out data form for the particular run including the clock times for significant events to aid subsequent video tape reviews. He also obtains Subject performance judgments from ATC and Jumpseat at several points in the scenario.

10) After Subject lands the aircraft, Director meets Subject in cockpit and takes Subject to debriefing room.

11) Subject discusses the flight with Director, answering specific questions concerning the CIFE. The debriefing is recorded on audio tape.

12) Meanwhile, ATC and Jumpseat shutdown GAT and supporting hardware, and document and store raw data.

D. FMS Scenarios

Three separate full mission scenarios have been created. Each scenario has accompanying support material in terms of charts, experimenter checklists, ATC scripts, pre-recorded background communication tapes and data forms. Samples of these support materials are contained in the Master Notebook.

Each of the three scenarios features a different type of critical in-flight event. Scenario 1 involves a loss of fuel from one tank. Full power is recoverable by switching tanks at which time the pilot must decide on one of several destination alternatives. Scenario 2 involves a partial power failure. No actions are available to restore full power to the aircraft. The pilot must decide on one of several destination alternatives or an emergency landing. Scenario 3 involves a partial navigation system failure during an ILS approach. The pilot must recognize the failure and select an appropriate alternate approach procedure and/or airport. All scenarios feature weather near IFR minimums and a mix of mountainous, flat, and seacoast terrain. Details of each scenario appear below.

Scenario 1

The objective of this scenario is to reveal how a pilot responds to inadvertent loss of fuel in flight, resulting from the over-wing siphoning of fuel through an improperly sealed filler opening. Of particular interest are, 1) his actions to restore engine power when the fuel supply from the tank in use is depleted, 2) his decision on where to land in view of the unanticipated reduction of remaining fuel and 3) his aircraft control performance prior to and aft the CIFE.

Each subject is instructed to prepare and file an IFR flight plan for a night flight from Seaport Beach to Mountaindale airport. The weather at the point of departure and along the route of flight is IMC (ceilings are less than 1000 feet and visibilities are less than three miles). At the destination airport the weather is marginal VMC. Seaport Beach is on the coast; Mountaindale is surrounded by mountainous terrain.

After takeoff the flight proceeds along a predetermined route as specified in the original clearance (radar vectors to the Seaport 259° radial to Ranch intersection, Victor 97 to Goathill VOR, direct). As the flight continues along this route, the pilot is instructed to contact the appropriate controlling facilities. The fuel supply in the tank in use is reduced gradually, but at a rate much faster than that of normal consumption. When the flight reaches a certain point, the fuel supply in the tank being used is depleted, and the engine sputters and dies. At the time of the engine failure, the flight is in instrument conditions, experiencing moderate turbulence, and not in radar contact.

The only action the pilot can take to regain engine power is to switch fuel tanks. In the course of solving this problem, the pilot must set priorities concerning the activities he deems appropriate. Once the pilot switches tanks, and engine power is restored, normal operations can be continued. However, the flight now has half the original fuel. In view of this new limitation, the pilot must decide on whether to continue or to divert to an alternate. There are three alternatives from which the pilot must choose: he can continue on to his destination, land at a closer airport, or return to the point of departure. The flight has fuel sufficient to fly to and land at any of the alternatives, but his choice is complicated by varying weather conditions at the different airports, the different distances and times to fly to the airports, and the pilot's perception of the problem.

Scenario 2

This scenario simulates the reduction of available engine power due to a broken baffle in the muffler during a cross-country IFR flight.

The mission is to fly from Seaport Beach to Mountaindale. Immediately prior to takeoff, the pilot is cleared along a route approximately parallel to the one which he had filed. At the time of departure the Seaport Beach weather is IMC (ceiling is 1100 feet and visibility is two miles in rain, fog, drizzle) and the Mountaindale weather is marginal VMC.

As the flight progresses, moderate turbulence is encountered near Singer intersection with a tailwind at thirty knots. When the flight proceeds past Thermal intersection, engine power is linearly decreased to 1500 rpm over a period of three minutes. This is accompanied by tachometer indications and a decrease in engine sound. Simultaneously cylinder head and oil temperature are increased to maximum level. The power level is not sufficient to maintain the enroute altitude, so a descent begins as the power loss continues. The problem consists of inadequate power and rising terrain while out of radar contact in instrument conditions.

At this point the available alternatives are: 1) continue to Mountaindale, 2) return to Seaport Beach, 3) land on the immediate terrain, 4) land at Singer, 5) land at Wind Falls, 6) land at Link County, and 7) land at Pelton Naval Air Station. A major decision is whether or not to declare an emergency, especially since the assigned altitude cannot be maintained. Typically the subjects proceed to Mountaindale or return to Seaport Beach.

Scenario 3

The purposes of this scenario are 1) to reveal how a pilot, without the aid of warning lights or flags, determines that an essential part of his approach navigation equipment (localizer) has failed, and 2) to reveal what decisions and actions he makes to complete the flight in view of the aircraft's new status. The pilot is instructed to depart Mountaindale airport, to conduct two ILS approaches at Mountaindale, and to land at Mountaindale after the second approach. His flight plan specifies the route of flight to be "via radar vectors". The local weather conditions during departure and the two subsequent instrument approaches are "ceiling 500 feet overcast, visibility two miles in rain and fog, wind from the east at ten knots."

After takeoff the pilot is vectored along a predetermined route to intercept the localizer course for the runway five ILS approximately five miles from the outer marker. After completion of the first approach, the pilot is vectored around to intercept the localizer for his second, and final approach. As the localizer needle sweeps to the center position during initial interception, it is rendered inoperative. (In this mode the localizer needle remains idle in the center position with a "TO" indication.) At the time of failure, the flight is in instrument conditions, in radar contact, and experiencing light turbulence.

The pilot can use ATC position information, ADF crosschecks, or note that the needle is stationary to determine the localizer needle has failed. Upon confirming its failure, the pilot then must decide what to do next. He could conduct an NDB approach, a VOR approach, or divert to another airport. Of these alternatives, the VOR approach is the only feasible one.

E. Subjects

Twelve subjects were selected for the FMS experiments. Four were used in each of the three scenarios. Their ages ranged from 21 to 56 years old. Although all of the subjects were instrument rated, their licenses covered the spectrum from Private to ATP. Six of the twelve held CFI ratings and five held turbine ratings. In terms of their primary flying activities they were equally divided (six each) into pleasure and professional flying groups. Their total flying hours logged ranged from 270 to 8800 hours. Table V-1 summarizes these data.

Table V-1
FMS Subject Background

Scenario	Subject	Age	Licenses	Total Hours	Type of Flying
1	1	36	Pvt.	420	Pleasure
	2	56	Comm/ CFI	5000	Pleasure
	3	42	Comm	1200	Business
	4	46	ATP	8800	Business
2	5	23	Comm/ CFI	1550	Professional
	6	34	Comm	5000	Pleasure
	7	34	Comm/ CFI	3000	Pleasure/Mil.
	8	30	Pvt.	300	Pleasure
3	9	31	Comm/ CFI	1750	Professional
	10	22	Pvt.	270	Pleasure
	11	21	Comm/ CFI	480	Professional
	12	21	Comm/ CFI	600	Professional

As noted in Table V-1 an attempt was made to obtain a mix of experience and ratings for each of the test scenarios. All subjects were unpaid volunteers from the Columbus, Ohio area.

F. Data Collection

As noted in Figure V 1, three major types of performance data were collected for each FMS run.

1) "Stick and rudder" performance, i.e., basic control of heading, altitude, and airspeed
2) Communications
3) Response to the CIFE

Stick and rudder performance was evaluated both objectively and subjectively. Subjective ratings on a scale of one to seven were given for navigation skills and attitude control by each of the three experimenters present during a run. (All experimenters were qualified pilots as well as researchers.) Subjective rating averages for both navigation and attitude control skills ranged from a low of 1.2 to a high of 6.7. There appeared to be a high correlation between the two ratings, i.e., a subject with good navigation skills also exhibited good attitude control skills as noted in Figure V-2. Only ten subjects were rated due to unscheduled equipment malfunction during a portion of two runs.

A more objective indication of stick and rudder performance was obtained from time traces of altitude, airspeed, and heading deviations covering the period immediately surrounding the introduction of the CIFE. These data

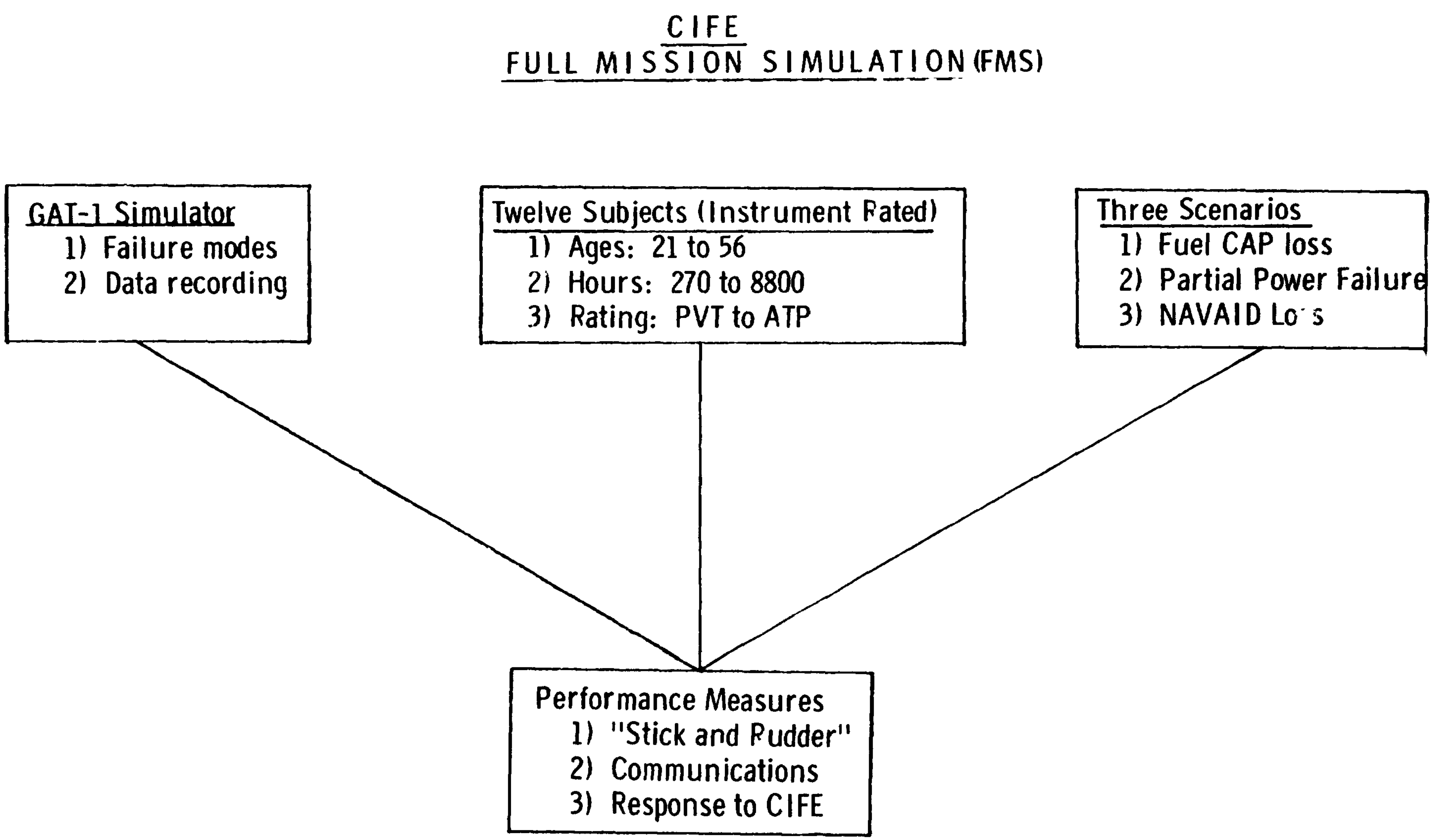

CIFE
FULL MISSION SIMULATION (FMS)
GAT-1 Simulator
1) Failure modes
2) Data recording
Twelve Subjects (Instrument Rated)
1) Ages: 21 to 56
2) Hours: 270 to 8800
3) Rating: PVT to ATP
Three Scenarios
1) Fuel CAP loss
2) Partial Power Failure
3) NAVAID Lo s
Performance Measures
1) "Stick and Rudder"
2) Communications
3) Response to CIFE

Figure V-1

were obtained by analyzing video tapes and coordinated audio tracks for each FMS run. Samples of each data are contained in Figures V-3 and V-4. Plots for all subjects are contained in Appendix F.

Communication skills were also evaluated both subjectively and objectively. Each observer rated each subject on a scale of one to seven. Average scores here ranged from a low of 2.0 to a high of 6.3. In addition to those ratings, which were made at the time of the experiment, complete transcripts of communications were prepared after the fact from the audio tapes. A portion of one such transcript for the second scenario around the time of the CIFE has been reproduced in Figure V-5. These transcripts permitted a detailed analysis of interactions between pilot and controller as well as an indication of the information search by subjects.

The third indication of performance was the actual decision making response of subjects when faced with a CIFE. A standard data sheet was used to summarize the observed behavior of each subject. Problem detection and diagnosis as well as decisions and actions were noted (see Figure V-6). The information used to complete these sheets was obtained by studying the video tapes, consulting observers' data sheets and from a thorough (tape recorded) debriefing of each subject after his FMS run. Observed stress was a subjective estimate (scale one to ten) by the experimenters. Pilot criticality estimates were made by the subjects (scale one to ten) and were intended to indicate the degree of criticality each placed on the CIFE. Flying time estimates were made by the subjects who were asked how long

Figure V-2. Skill Ratings For FMS Subjects

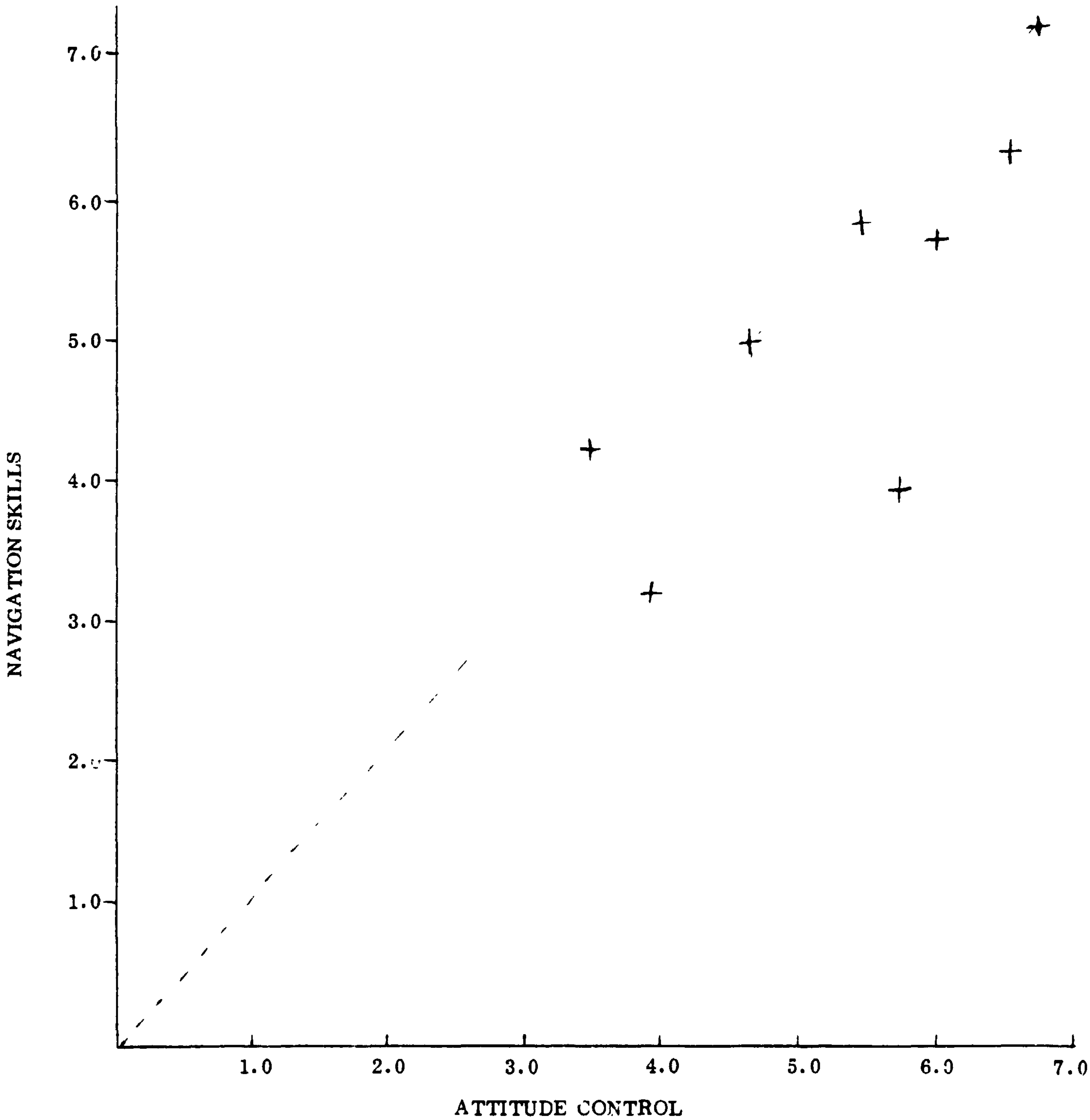


Figure V-3. FMS Poor Stick and Rudder Performance

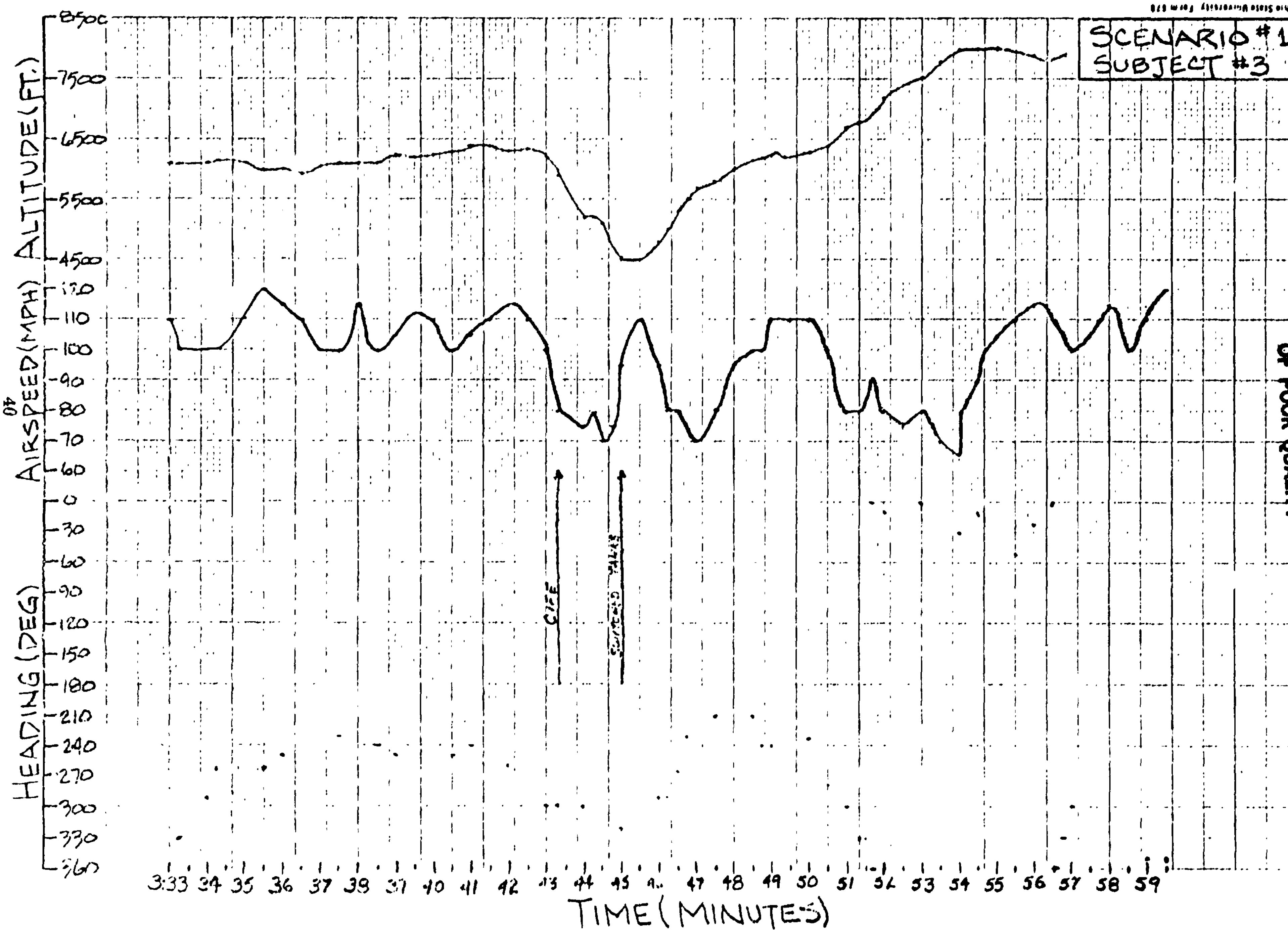


Figure V-4. FMS Good Stick and Rudder Performance

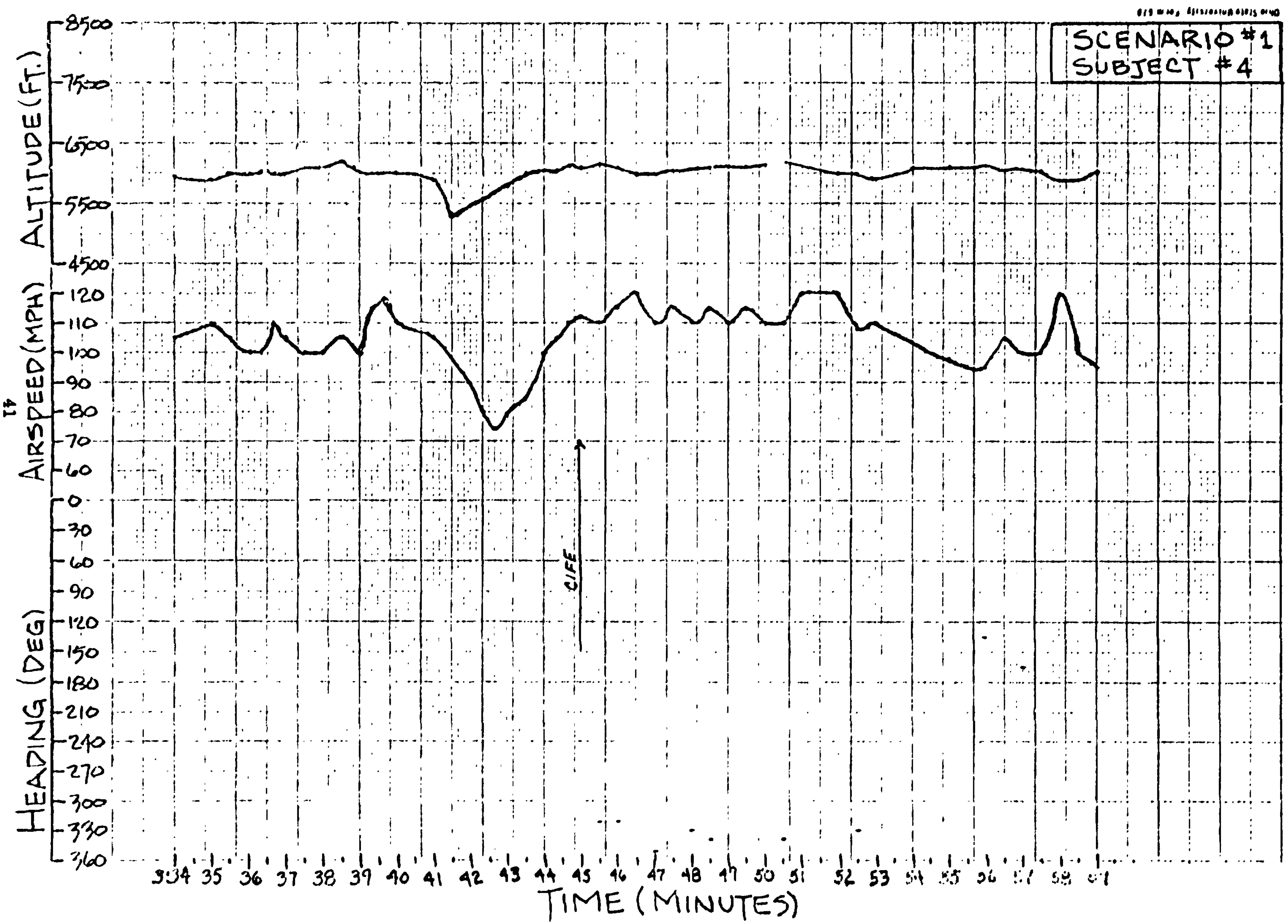


Figure V-5. Communications Transcript, Subject 7, Scenario 2

15.59 C: Japan Air 231, contact East Bay Center, 132.15 heading.
15.71 B: Japan Air 231 to 132.15, good day.
16.28 C: Uh, one niner two golf papa, roger, maintain 6000 (unintelligible).
16.40 P: One niner two golf papa, roger, maintain 6000.
16.71 P: Center, November one niner golf papa reporting Thermal at this time.
16.81 C: Two golf pop's at Thermal intersection. Thank-you, sir.
16.96 B: East Bay Center, United 694 climbing to one-two-zero.
17.06 C: United 694, radar contact, climb unrestricted to flight level three-seven-zero.
17.17 B: Unrestricted to three-seven-zero, United 694.
19.20 C: Uh, one niner two golf papa, radar contact, uh, (unintelligible) two miles north of Thermal intersection.
19.33 P: Uh, roger, one niner two golf papa.
19.45 C: Answer golf papa, you can expect, uh, 8000 in ten miles.
19.52 P: Two golf papa, roger.
19.74 C: King Aire 90 Fox Hotel, contact Seaport Approach 119.6
19.84 B: 119.6 for 90 Fox Hotel.
20.48 B: East Bay Center, Centurion 5343 Foxtrot climbing to 7000.
20.60 C: 43 Foxtrot, East Bay Center, ident.
20.66 B: 43 Foxtrot, roger.
20.73 C: 43 Foxtrot, radar contact, proceed on course.
20.81 B: 43 Foxtrot, on course, roger.
21.96 C: Pacer 62, contact Pelton approach 126.2.
22.07 B: Pacer 62 to 126.2, good day.
22.80 B: Center, this is Baron 3622 Tango. Has anyone reported turbulence on vector two-twenty-two to the northwest here?
22.98 C: 22 Tango, that's negative, sir.
23.05 B: We're in moderate turbulence at 12,000, and picking up mixed ice. Any chance of one four thousand for 22 Tango?
23.22 C: Baron 3622 Tango, climb and maintain one four thousand.
23.31 B: 22 Tango leaving 12,000 for one four thousand.
23.51 P: Center, November one nine two golf papa.
23.59 C: One niner two golf papa, go ahead, sir.
23.65 P: Okay, roger sir, experiencing ,uh, difficulties with my engine. I'm losing RPM and request, uh, immediate descent to the nearest airport.
23.85 C: One niner two golf pop, uh, stand by.
24.07 C: Two golf pop, uh, all the airports in the vicinity are IFR. You're currently, uh, five miles northwest of Thermal.
24.31 P: Uh, roger, what's, uh, what's that weather at Link?
24.40 C: Okay, uh, stand by, I'll have it for you in just a second.
24.82 C: Yeah, two golf pop, uh, Link weather at zero 300. Uh, 500 scattered measured 800 overcast two miles rain and fog. Uh, wind one six zero at ten, altimeter two niner point four five.
25.10 P: Uh, roger, and Center be advised, uh, one niner two golf papa is, uh, losing altitude at this time, unable to maintain altitude, and RPM is dropping off. Uh, request vectors for the clearest weather possible you can find. I'm gonna have to be setting it down.
25.41 C: Uh, two golf papa, understand (unintelligible). Unable to maintain altitude, requesting vectors. All airports in the

Figure V-6. Scenario 1 - CIFE Response

1	Detection mode	heard eng. quit	heard eng. quit	heard eng. quit	fuel gauge
Problem Detection - Diagnosis	Detection time	immediate	immediate	immediate	immediate
	Diagnostic Procedure	knew left tank was low. switched tanks immediately	carb heat switched tanks	carb heat throttle starter switch switched tanks	switched tanks prior to engine failure
	Prepared strategy	none	none	none	identify, allev. before declarin
	Declared emergency?	no	no	yes	no
	Info sources used	none	none	none	fuel gauge
	Perceived cause	drained tank	drained tank	drained tank	drained tank
	Observed stress	1	1	8	1
	Pilot's crit. est.	5	3	9	9
	Relevant experience	same event	same event	lost 1 helo. eng.	sw. aux. to ma
	Est. flying time	2 hrs.	1.6 hrs.	1.6 hrs.	2 hrs.

1	Alternatives considered	Link Co. Seaport	Link Co. Mountaindale	Seaport Mountaindale Link Co.	Mountaindale Link Co.
Decisions and Actions	Decision	Return to Seaport	Continue to Mountaindale	Continue to Mountaindale	Continue to Mountaindale
	Reasons	Had flying time wanted to go home	enough fuel ILS appr.	not discussed	not discussed
	Changes in plan	none	none	Divert to Link Co.	Divert to Link Co.
	Reasons	———	———	VOR Approach good weather	better distance given fuel & good weather
	Flying technique	no change	no change	no change	max. enduranc
	Outcome	Successful NDB with aid of ATC	Successful ILS with aid of ATC	Successful VOR with aid of ATC	Missed VOR successful VOF at Link Co.

Figure V-7. Decision Factors Rating

	Scenario #1	1	2	3	4	Average	Range
Situation	Estimated flying time	7	6	6	7	6.5	2
	Estimated fuel on board	4	4	4	4	4.0	1
	Enroute weather	-	5	-	3	4.0	3
	Destination weather	-	6	1	3	3.3	6

	Scenario #1	1	2	3	4	Average	Range
Decision	Conservatism	4	6	6	7	5.7	4
	Safety	6	7	7	7	6.7	2
	Match with piloting skills	7	6	7	5	6.2	3
	Familiarity with A/C procedures	1	4	7	4	4.0	7
	Familiarity with NAV procedures	1	6	6	4	4.2	6
	Proximity to original intentions	1	7	2	3	3.2	7
	Compliance with FARs	1	6	6	5	4.5	6
	Flying time needed to execute	4	4	4	3	3.7	2

	Scenario #1	1	2	3	4	Average	Range
Influence on decision	A/C condition when decision made	1	7	3	7	4.5	7
	Fuel on board	6	6	5	7	6.0	3
	Enroute weather	1	1	2	1	1.2	2
	Destination weather	5	1	7	7	5.0	7
	Time needed to execute	7	7	4	7	6.2	4
	Familiarity with A/C procedures involved	7	4	7	5	5.7	4
	Familiarity with NAV procedures involved	6	7	4	5	5.5	4
	Proximity to original destination	7	7	2	7	5.7	6
	Compliance with FARs	1	4	1	5	2.7	5
	Other	-	-	3	-	-	-

they thought they could continue to fly after the CIFE. The rest of the data sheet entries were filled by experimental observation or subject statement.

In an attempt to probe their personal rationale, each subject was also asked to complete a rating form covering some 21 separate factors which may have influenced his decision in the face of the CIFE. Each factor was rated by the subject on a scale of one to seven. (Ratings for Scenario 1 are shown in Figure V-7.)

The final piece of information collected was the test score from an open-form knowledge survey. This survey was used as a pilot study to help develop the closed-form knowledge survey used with the paper and pencil scenarios. All subjects for scenarios one and two also participated in the paper and pencil tests. They were identified in the master data sheet with "1" in the GAT column. Complete data summary sheets for all three scenarios are contained in Appendix F.

G. Performance Evaluation

Because of the small sample size and differences across scenarios, it was difficult to develop solid statistical information concerning pilot performance in such full mission simulation studies. However, by analyzing the data mentioned above, it became apparent that the subjects in these experiments possessed a wide range of cockpit management styles and skill levels. Although difficult to quantify, "good performance" was easily recognized by both on-site observers of the FMS runs and others who examined the various data collected from those runs. The elements of "good performance" included:

1) professional use of the radio

2) precise heading and altitude control

3) constant awareness of the aircraft position along its intended route

4) prompt, but not necessarily instant, response to the onset of the CIFE (detection)

5) systematic procedure for trouble-shooting

6) diversion decisions which allowed for further uncertainties

Evidence supporting each of these six characteristics of good performance can be found in Figures V-2 to V-7 above. For example, consider Figures V-3 and V-4 which depict what appear to be good and poor stick and rudder performances. The time traces for subject 4 exhibit very small unplanned deviations in airspeed, altitude and heading both before and after the onset of the CIFE (loss of fuel cap). Subject 3, on the other hand, demonstrates a somewhat unstable control of these three flight parameters even before the onset of the CIFE. Furthermore, during and after the CIFE, his airspeed, altitude and heading excursions appear to increase in both frequency and amplitude which may indicate that he was loaded beyond his ability to cope with the problem at hand. Coincidentally, it is also easy to find evidence that subject 4's performance in each of the six elements listed above was generally superior to that of subject 3. Furthermore, there is supporting evidence that the "good performers" tend to score higher on both forms of the knowledge survey than do the "poor performers".

Since much of the evidence of FMS performance is anecdotal, a brief narrative description of each subject's actions and their characteristics has been prepared. These narratives are contained in Appendix F. These narratives include comments on each subject's background, personal characteristics, and management style. They are perhaps the richest information source for gaining insights into how these twelve subjects made use of available resources in the face of critical in-flight events.

H. FMS Conclusions

The sample was too small to provide anything other than some initial hypotheses concerning pilot performance in such a full-mission setting. However, the following tendencies were noted:

1) Cockpit management style varies widely among pilots. For example, some are extremely self-reliant, others want immediate and extensive help from ATC while still others make the decision making process a joint effort with ATC.

2) Good stick and rudder pilots seem to have excess capability and maintain good stick and rudder performance during and after the CIFE. More marginal stick and rudder pilots, on the other hand, show increased frequency and amplitude of heading and altitude excursions, and experience communication difficulties in the face of a CIFE.

3) Pilots who score well on the knowledge test instruments tend to perform well in problem diagnosis and decision making. (GAT subject performance on the paper and pencil tests are discussed in Section VI-L.)

From the observations of the experimenters and comments made by participating subjects, it appears that such a full mission simulation exercise, coupled with an appropriate knowledge survey and debriefing, could be a valuable tool for recurrent training of IFR pilots.

VI. PAPER AND PENCIL SCENARIO TESTS

The GAT FMS scenarios were extremely valuable in gaining a better understanding of how pilots make decisions in the face of CIFE's. However, they were very expensive to run, in terms of equipment, subject and experimenter time, and the data was difficult to analyze in objective fashion. The paper and pencil scenario concept was developed to provide a more economical way to study the CIFE phenomenon and to reduce the data collection and analysis problems inherent with FMS experiments.

A. Background

The paper and pencil (P/P) concept was tested in two different ways prior to full-scale implementation. First, two pilots, both on the aviation faculty at The Ohio State University and considered to be experts in their field, evaluated several GAT subjects' decisions on two of the three GAT scenarios. The two experts then made their own diagnoses and decisions on the third. From these sessions it became clear that pilots could diagnose problems and make diversion decisions in a P/P format. Furthermore, the expert pilots found the tasks more realistic when they injected themselves into the scenario, rather than playing the role of observer.

A second P/P format pre-test was run with a local aircraft mechanic who is widely respected as an expert. The purpose of this exercise was to determine if someone could diagnose a mechanical failure in an interview situation. The mechanic was given the initial symptoms to the problem and was asked to arrive at an explanation of the cause. He asked questions about the status of various indicators and hypothesized aloud as he systematically eliminated potential causes. The interviewer provided readings from instruments and answers to sundry status inquiries verbally. The mechanic had no trouble diagnosing the problem in the interview format. These results suggested many of the techniques used in the full-scale study. A transcript of part of that interview is contained in Appendix K.

In order to facilitate analysis and to eliminate interactions, it was decided to break the paper and pencil testing into two distinct elements; one set of scenarios directed toward problem diagnosis and a second set directed toward pilot decision making based upon a common diagnosis of the problem.

The diagnosis scenarios were conceived to meet several important criteria: a) a system or component failure that would be nondeteriorating over time, b) insoluble (at least while in the air), but identifiable, c) precipitated by component failure or weather conditions, and d) important enough to require a subsequent diversion decision. There also had to be enough evidence within the available information to unambiguously identify the cause of the problem.

Once the four problems were selected for use, the concomitant symptoms and instrument readings were verified with the expert airplane mechanic referred to earlier. The given symptoms for the problems were selected to lead the subject in the general correct diagnostic direction, but were insufficient for trivial solution. The four scenarios selected involved: 1) an oil leak at the oil pressure gauge line, 2) a vacuum pump failure, 3) a magneto drive gear failure, and 4) a frozen static port. The diversion scenarios designed to illuminate a pilots decision making strategies are discussed in Section E below.

B. The Testing Procedure

The procedure used in the paper and pencil scenario (PPS) testing required about ninety minutes. The period was used for four major data collection inputs:

a) Biographical Data (See Appendix H)

b) Closed-Form Knowledge Test (See Chapter IV)

c) Diagnostic Performance on Four Different Scenarios

d) A Destination-Decision Problem Dealing With Information Seeking Strategies

These will be discussed in detail in the following sections.

Announcements were posted at local flying clubs and fixed base operators (FBOs) to attract volunteer subjects from the flying community. Interested IFR rated pilots called in for details and were scheduled for one of several two-hour sessions. In addition, qualified pilots from The Ohio State University and local communities were called by telephone and invited to participate.

Each session proceeded as follows: Participants gathered in a large conference room. After a brief introduction by one of the principal investigators, subjects filled out the biographical forms and took a closed-form knowledge survey. A briefing statement covering scenario weather, airspace and the airplane to be "flown" was given the subjects while they looked at enroute charts and weather maps (see Appendix H). The subjects then went individually to separate rooms with an experimenter. Here, they went through the problem diagnosis and diversion-decision excercises for about one hour.

The instructions were read to the subjects (see Appendix H) which explained how the four problem diagnosis scenarios would be run. For each problem diagnosis scenario, a brief mission introduction was read, identifying area weather, flight origin and destination, and referring to a low altitude enroute chart with the airports highlighted. Following the introduction, symptoms for the problem were given (e.g. "After twenty minutes of routine flying you notice the smell of hot engine oil"). At this point the subject was signalled to begin his diagnosis by the question, "What would you do?". A stop-watch was started when the subject began his information search, allowing four minutes for completion.

While referring to a modified diagram of the Piper Arrow instrument panel, subjects began to ask the experimenter for pieces of information which could be collected by the pilot if he were actually in the cockpit of a Piper Arrow. In addition to readings from flight instruments, engine gauges and navigation/communication radios, the subject could query the experimenter for information concerning structural ice formation, noise, cabin conditions. status of the cabin interior, and system response to control settings for throttle, mixture, RPM, fuel selector, etc. When queried, the experimenter looked up the information on two sheets of paper which followed a standard format. After finding the requested information and telling the subject, the experimenter then noted the item with a number on the sheet. The numbers denoted the sequence of queries such that the order could be reconstructed. A third sheet was available for noting hypotheses of potential causes mentioned by the subject during the information search. Their position in the sequence was also noted.

The clock was stopped when the subject indicated that he had discovered the cause of the problem. If the four minutes ran out, the subject was asked to make a best guess as to the problem's source. The time taken was recorded and the subject was asked how long he thought the plane would fly with such a problem. He was then asked to judge the criticality of the problem as he had diagnosed it, on a scale of one to seven. An explanation of the cause of the problem was then read to the subject and the final two estimates were repeated. This procedure was repeated for four different scenarios and took about 25 minutes to complete.

Forty volunteer subjects participated in the P/P scenario study. All but one were instrument-rated and with experience ranging from 160 to 19,400 total flying hours. Nineteen had commercial licenses and twelve had Air Transport ratings. Eight of the subjects had participated earlier in the GAT-1 study. Subject background data is shown in Table VI-1. Figures VI-1 to VI-3 depict the flight experience of the subjects. Table VI-2 summarizes subject data for background data by frequency and percent. Figure VI-4 depicts the subjects scores on the closed-form of the knowledge test. It is worth noting that the scores were surprisingly low considering the fact that the mean number of hours experience was 3823 hours.

C. Pilot Background Data and Diagnostic Data Collection

Pilot background data were coded into seven variables. The four continuous numeric variables were: score on the knowledge survey (0-20), total flying hours, total single-engine hours, and total IFR (including actual, simulated and time flown under IFR) hours. The discrete variables were:

Table VI -1

BACKGROUND, DIAGNOSIS, AND TOTALS

SUBJECT	SUBJECT	AGE	RATING	TRAINING	FLYING	RECENCY	TOT HRS	SEHRS	IFRHRS	KNOWLEDG
1	1	2	PRIVATE	CIVILIAN	PLEASURE	3	160	160	15	9
2	2	2	AIR TRANSPORT	CIVILIAN	BUSINESS	1	2500	1800	270	16
3	3	2	AIR TRANSPORT	MILITARY	MILITARY	1	6000	2000	300	8
4	4	3	COMMERCIAL	MILITARY	MILITARY	3	4000	400	1000	5
5	5	3	PRIVATE	CIVILIAN	BUSINESS	1	2000	2000	1500	16
6	6	1	COMMERCIAL	CIVILIAN	AIRLINE	3	1400	400	800	14
7	7	2	COMMERCIAL	CIVILIAN	PLEASURE	1	1800	1500	500	15
8	8	2	COMMERCIAL	CIVILIAN	PLEASURE	1	1085	1088	221	15
9	9	3	PRIVATE	CIVILIAN	PLEASURE	1	800	800	200	9
10	10	1	PRIVATE	CIVILIAN	BUSINESS	1	2100	1700	450	12
11	11	3	COMMERCIAL	CIVILIAN	BUSINESS	3	5000	4000	250	13
12	12	3	COMMERCIAL	MILITARY	BUSINESS	1	15000	1500	2300	7
13	13	3	AIR TRANSPORT	CIVILIAN	COMMERCIAL	1	19400	10000	2500	13
14	14	3	COMMERCIAL	CIVILIAN	BUSINESS	1	2500	2500	250	15
15	15	3	PRIVATE	CIVILIAN	PLEASURE	1	510	510	100	13
16	16	1	COMMERCIAL	CIVILIAN	COMMERCIAL	1	1650	1000	200	17
17	17	1	COMMERCIAL	CIVILIAN	COMMERCIAL	1	980	860	120	15
18	18	2	AIR TRANSPORT	CIVILIAN	COMMERCIAL	2	1960	1700	250	16
19	19	3	AIR TRANSPORT	MILITARY	BUSINESS	2	8000	3000	700	16
20	20	2	AIR TRANSPORT	CIVILIAN	AIRLINE	1	9000	2100	1750	15
21	21	3	COMMERCIAL	MILITARY	BUSINESS	1	5500	4000	500	14
22	22	3	COMMERCIAL	CIVILIAN	BUSINESS	2	485	410	250	12
23	23	1	COMMERCIAL	CIVILIAN	PLEASURE	1	300	300	20	11
24	24	3	PRIVATE	CIVILIAN	PLEASURE	2	3500	3300	280	6
25	25	2	COMMERCIAL	MILITARY	COMMERCIAL	1	6312	2001	540	13
26	26	1	AIR TRANSPORT	CIVILIAN	BUSINESS	1	2260	900	330	10
27	27	2	AIR TRANSPORT	CIVILIAN	COMMERCIAL	1	7000	5000	250	14
28	28	2	PRIVATE	CIVILIAN	MILITARY	1	338	318	162	10
29	29	1	COMMERCIAL	CIVILIAN	COMMERCIAL	1	648	595	32	12
30	30	2	COMMERCIAL	MILITARY	MILITARY	3	2500	200	500	10
31	31	1	AIR TRANSPORT	CIVILIAN	COMMERCIAL	1	1800	1550	150	16
32	32	2	COMMERCIAL	CIVILIAN	COMMERCIAL	1	5000	4000	250	15
33	33	2	AIR TRANSPORT	MILITARY	MILITARY	1	8700	1500	650	13
34	34	2	COMMERCIAL	MILITARY	BUSINESS	2	1500	500	400	9
35	35	2	PRIVATE	CIVILIAN	PLEASURE	2	485	485	61	7
36	36	3	COMMERCIAL	CIVILIAN	COMMERCIAL	2	3000	2000	300	15
37	37	1	AIR TRANSPORT	CIVILIAN	COMMERCIAL	2	2500	2000	200	17
38	38	2	COMMERCIAL	MILITARY	MILITARY	3	3000	250	750	7
39	39	1	PRIVATE	CIVILIAN	PLEASURE	2	180	125	3	13
40	40	3	AIR TRANSPORT	CIVILIAN	COMMERCIAL	1	12000	8000	1200	16

Figure VI - 1

TOTAL FLYING TIME
PERCENTAGE BAR CHART

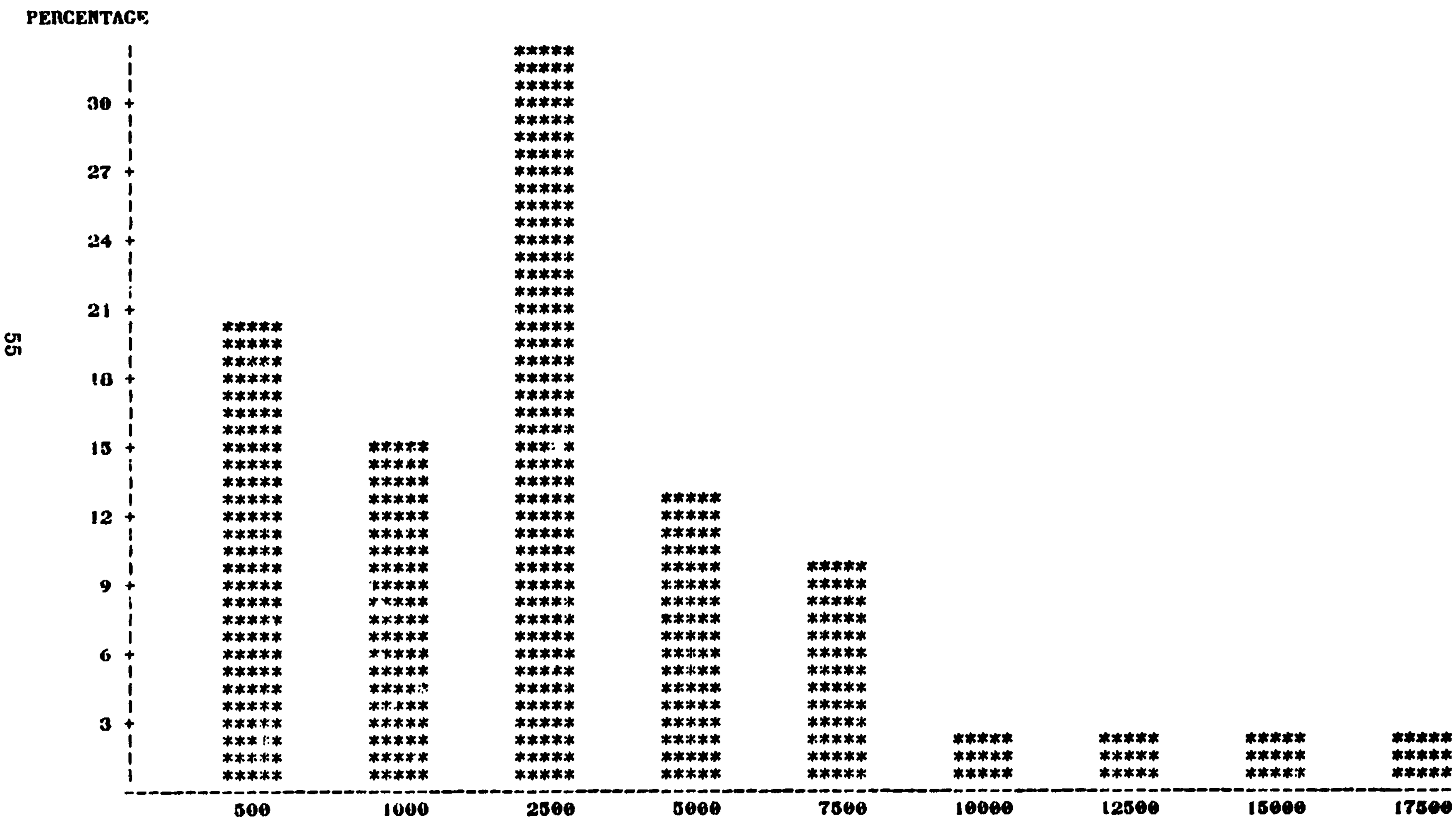


Figure VI -2

SINGLE ENGINE FLYING TIME

PERCENTAGE BAR CHART

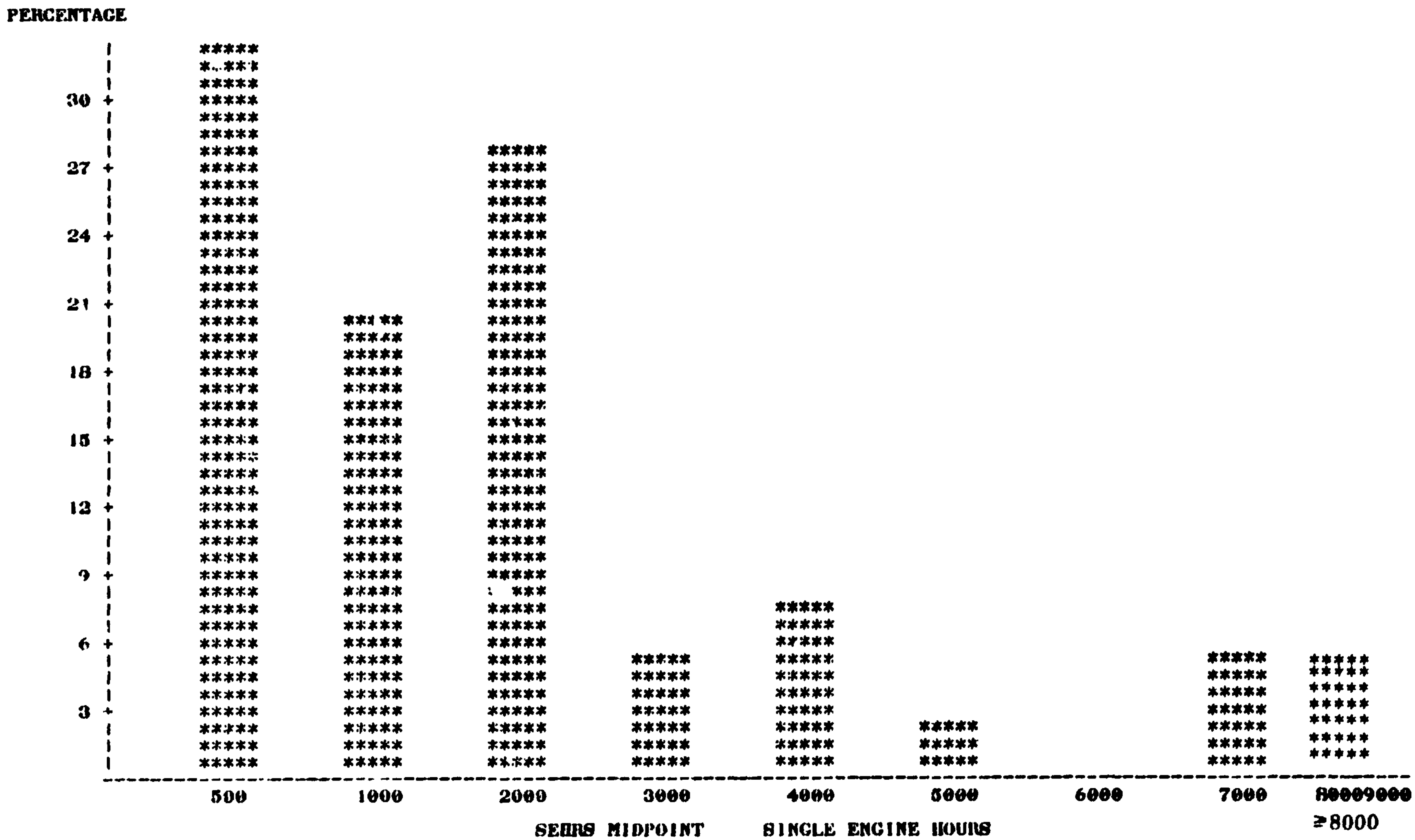


Figure VI -3

IFR FLYING TIME

PERCENTAGE BAR CHART

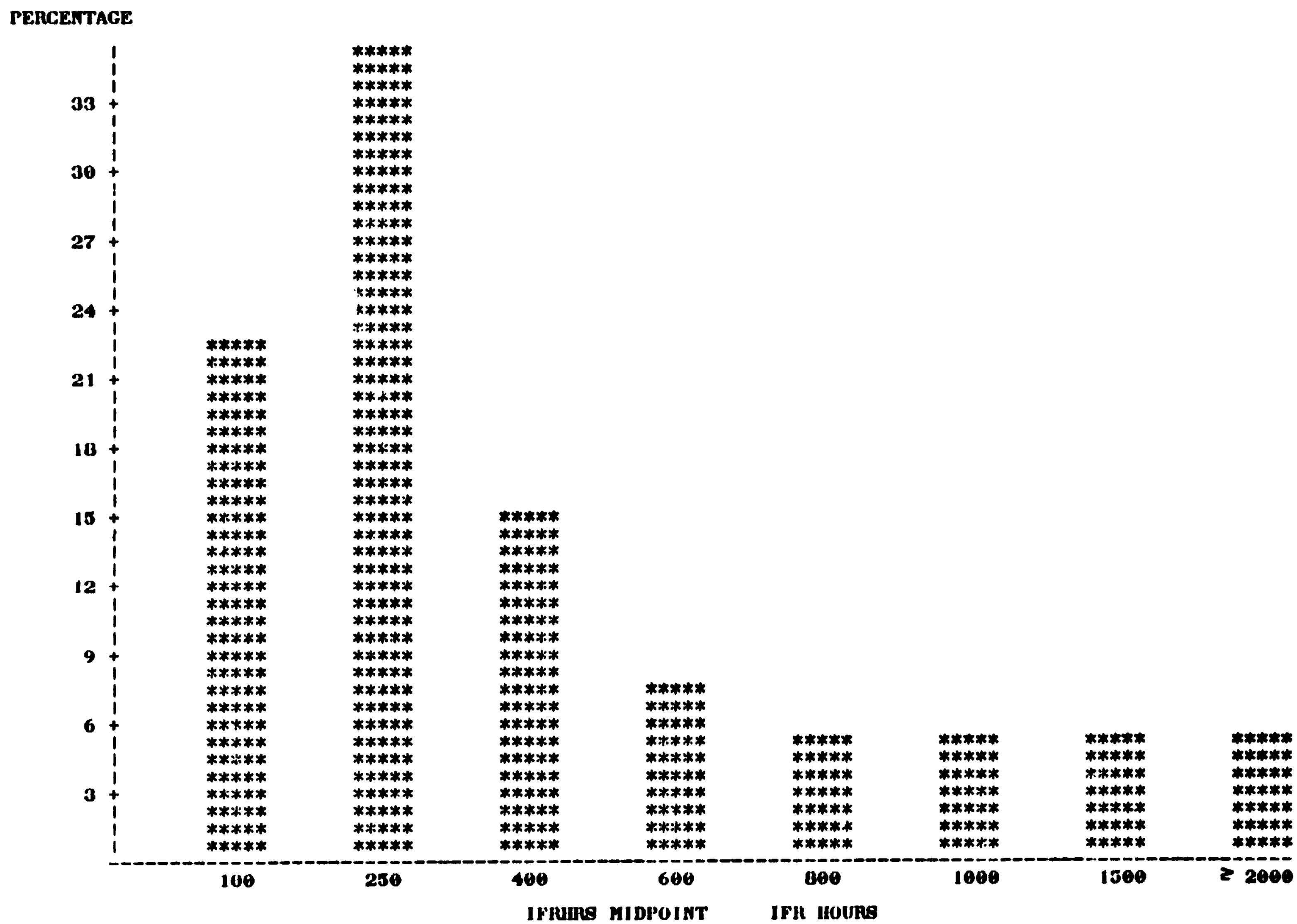


Figure VI-4

KNOWLEDGE SURVEY SCORES

PERCENTAGE BAR CHART

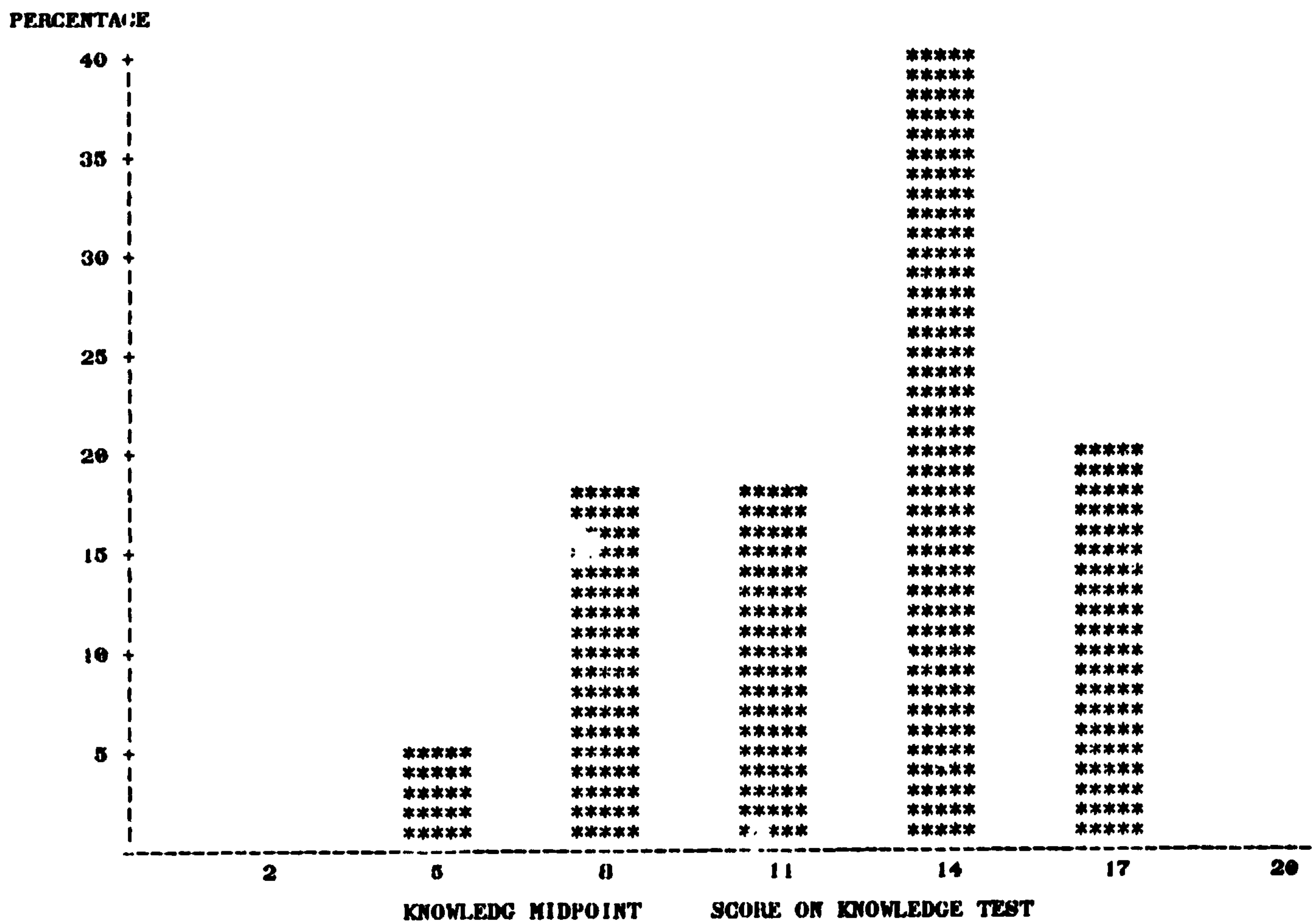


Table VI-2

Frequency Analysis of Pilot Background

	Frequency	Percent
Rating:		
Private	9	22.5
Commercial	19	47.5
Air Transport	12	30.0
Training:		
Military	10	25.0
Civilian	30	75.0
Most Frequent Flying:		
Airline	2	5.0
GA Commercial	12	30.0
Business	11	27.5
Military	6	15.0
Pleasure	9	22.5

rating (private, commercial, and ATP), primary flight training (military or civilian) and the most frequent type of flying (airline, GA comm, business, military, and pleasure).

Diagnosis scenario performance was coded into eight numeric variables for each subject on each scenario. These were:

I	-	number of inquiries or control actions
TT	-	total tracks (lines of coherent questioning)
UT	-	unique tracks (tracks not repeated)
C	-	correctness of final diagnosis (0-5)
Z	-	correctness/total tracks
E	-	efficiency = 25-2 x (minutes required) - I-2
CORINQ	-	correctness/total inquiries
M	-	merit=(C x E)
CB	-	criticality estimate before solution given
CA	-	criticality estimate after solution given
CNTRL	-	number of control actions taken

The totals for these eight variables, summed across the four scenarios were also calculated and named as variables:

TOTINQ	-	I1 + I2 + I3 + I4
TOTTRAKS	-	TT1 + TT2 + TT3 + TT4
TOTUTRKS	-	UT1 + UT2 + UT3 + UT4
TOTCOR	-	C1 + C2 + C3 + C4
ZT	-	TOTCOR/TOTTRAKS
TOTEFF	-	E1 + E2 + E3 + E4

CORINQT	-	TOTCOR/TOTINQ
TOTMERIT	-	M1 + M2 + M3 + M4
TCRITBEF	-	CB1 + CB2 + CB3 + CB4
TCRITAFT	-	CA1 + CA2 + CA3 + CA4

See the Glossary, Table VI-3. The diagnostic data, knowledge scores, pilot background data and decision data (see Section E below) were compiled and used in the total analysis.

D. Diagnostic Performance

Means and standard deviations for all performance variables are listed in Table VI-4. Comprehensive scores of total correct and total merit are shown as percentage distributions in Figures VI-5 and VI-6. The total correct distribution appears somewhat negatively skewed, while that for total merit appears to be normal.

Group performance on the four scenarios improved in terms of correctness and merit with the order of presentation, although all four problems were judged to be equally difficult to diagnose. This fact demonstrates some learning and strategy development by the subjects.

When the pilot sample is broken down by rating, several differences emerge on various diagnostic performance dimensions (see Table VI-5). Total correct and total merit scores increase as the level of certification goes up (Pvt., Comm., ATP) consistent with conventional wisdom. Performance on scenario 1, (the oil leak) seems to run counter to presumed knowledge by the higher certificate holders. However, scenario 2 (vacuum pump failure) and 3 (magneto

Table VI-3

Glossary

1. AGE: Age of the subject - categorized into intervals:
   1) age $<$ 30 yrs.
   2) 30 yrs. $<$ age $<$ 50 yrs.
   3) age $>$ 50 yrs.

2. AIRPORTS: Airports the pilot was willing to pass to locate proper repair facilities.

3. AP: Variable for airports used in computer runs valued (0) if airports ≤ 2 and (1) if airports > 2.

4. APP: Approach attribute of an airport. Includes ILS vs. NDB approach.

5. ATC: Air Traffic Control attribute of an airport (presence of radar).

6. B_{APP}: Pilots importance assessment of approach attribute of an airport.

7. B_{ATC}: Pilots importance assesement of an air traffic control attribute of an airport.

8. B_{TIM}: Pilots importance assessment of time.

9. B_{WX}: Pilots importance assessment of weather.

10. C1: Correctness score on Scenario #1 (possible correct: 0-5).

11. C2: Correctness score on Scenario #2 (possible correct: 0-5).

12. C3: Correctness score on Scenario #3 (possible correct: 0-5).

13. C4: Correctness score on Scenario #4 (possible correct: 0-5).

14. CA1: Subjective criticality estimate of event in Scenario #1 after being provided with the answer (scale 1-7; 1=lowest criticality).

15. CA2: Subjective criticality estimate of event in Scenario #2 after being provided with the answer (scale 1-7; 1=lowest criticality).

16. CA3: Subjective criticality estimate of event in Scenario #3 after being provided with the answer (scale 1-7; 1=lowest criticality).

17. CA4: Subjective criticality estimate of event in Scenario #4 after being provided with the answer (scale 1-7; 1=lowest criticality).

18. CATSCR1: First category score on knowledge survey - knowledge subscore for engine and fuel systems (possible correct: 0-7).

19. CATSCR2: Second category score on knowledge survey - knowledge subscore for electrical systems and cockpit instrumentation (possible correct: 0-7).

20. CATSCR3: Third category score on knowledge survey - knowledge subscore for weather and IFR operations (possible correct: 0-6).

21. CB1: Subjective criticality estimate of event in Scenario #1 before being provided with the answer (scale 1-7; 1=lowest criticality).

22. CB2: Subjective criticality estimate of event in Scenario #2 before being provided with the answer (scale 1-7; 1=lowest criticality).

23. CB3: Subjective criticality estimate of event in Scenario #3 before being provided with the answer (scale 1-7; 1=lowest criticality).

24. CB4: Subjective criticality estimate of event in Scenario #4 before being provided with the answer (scale 1-7; 1=lowest criticality).

25. CNTRL1: Number of inquiries which involved control movements in Scenario #1.

26. CNTRL2: Number of inquiries which involved control movements in Scenario #2.

27. CNTRL3: Number of inquiries which involved control movements in Scenario #3.

28. CNTRL4: Number of inquiries which involved control movements in Scenario #4.

29. CNTRLTOT: Total number of inquiries for all four scenarios which involved control movements

    CNTRLTOT = CNTRL1 + CNTRL2 + CNTRL3 + CNTRL4

30. CORINQ1: Ratio of correctness to inquiries for Scenario #1:

    CORINQ1 = C1/I1

31. CORINQ2: Ratio of correctness to inquiries for Scenario #2:

    CORINQ2 = C2/I2

32. CORINQ3: Ratio of correctness to inquiries for Scenario #3:
CORINQ3 = C3/I3

33. CORINQ4: Ratio of correctness to inquiries for Scenario #4:
CORINQ4 = C4/I4

34. CORINQT: Ratio of total correct to total inquiries for all four scenarios:
CORINQT = (C1 + C2 + C3 + C4)/(I1 + I2 + I3 + I4)

35. DELTAC1: Change in subjective criticality estimate of event for Scenario #1 after being provided with the answer; DELTAC1 = CA1 - CB1

36. DELTAC2: Change in subjective criticality estimate of event for Scenario #2 after being provided with the answer; DELTAC2 = CA2 - CB2

37. DELTAC3: Change in subjective criticality estimate of event for Scenario #3 after being provided with the answer; DELTAC3 = CA3 - CB3

38. DELTAC4: Change in subjective criticality estimate of event for Scenario #4 after being provided with the answer; DELTAC4 = CA4 - CB4

39. DIF1: Difference between number of total tracks and number of unique tracks in Scenario #1: DIF1 = TT1 - UT1

40. DIF2: Difference between number of total tracks and number of unique tracks in Scenario #2: DIF2 = TT2 - UT2

41. DIF3: Difference between number of total tracks and number of unique tracks in Scenario #3: DIF3 = TT3 - UT3

42. DIF4: Difference between number of total tracks and number of unique tracks in Scenario #4: DIF4 = TT4 - UT4

43. DIFT: Difference between number of total tracks and number of unique tracks in all four scenarios: DIFT = TOTTRAKS - TOTUTRKS

44. E1: Efficiency score on Scenario #1: E1 = [25 - 2 (minutes to diagnose) - (I1 -2)]

45. E2: Efficiency score on Scenario #2: E2 = [25 - 2 (minutes to diagnose) - (I2 -2)]

46. E3: Efficiency score on Scenario #3: E3 = [25 - 2 (minutes to diagnose) - (I3 -2)]

47. E4: Efficiency score on Scenario #4: E4 = [25 - 2 (minutes to diagnose) - (I4 -2)]

48. FLY: Computer variable for the variable flying; takes values:
(0) if flying = 1,2,3, or 4 = non-pleasure
(1) if flying = 5 = pleasure

49. FLYING: Most frequent kind of flying.
Valued: (1) Airline
(2) Commercial
(3) Business
(4) Military
(5) Pleasure

50. GAT: Participation in general aviation simulation; 0 = did not participate, 1 = did participate

51. GATK1: Open ended knowledge test on GAT subjects - subscore on engine operations (possible correct: 0-7).

52. GATK2: Open ended knowledge test on GAT subjects - subscore on fuel systems (possible correct: 0-7).

53. GATK3: Open ended knowledge test on GAT subjects - subscore on electrical systems (possible correct: 0-7).

54. GATK4: Open ended knowledge test on GAT subjects - subscore on cockpit instrumentation (possible correct: 0-7).

55. GATK5: Open ended knowledge test on GAT subjects - subscore on weather (possible correct: 0-7).

56. GATK6: Open ended knowledge test on GAT subjects - subscore on IFR procedure (possible correct: 0-7).

57. GATKT: Average of all parts of open ended knowledge GAT test:

$$GATKT = \frac{GATK1 + GATK2 + GATK3 + GATK4 + GATK5 + GATK6}{6}$$

58. GONOGO: Designates whether the pilot would have taken the flight under the given conditions. Valued: (0) - would not go, (1) - would go.

59. I1: Number of inquiries in Scenario #1.

60. I2: Number of inquiries in Scenario #2.

61. I3: Number of inquiries in Scenario #3.

62. I4: Number of inquiries in Scenario #4.

63. IFR: Variable designating upper and lower quartiles of IFR hours:
(0) if IFR hrs. ≤ 175
(1) if IFR hrs. ≥ 700.

64. IFRHRS: Hours of flying under instrument flight rules.

65. INPTR1: Ratio of inquiries to total tracks in Scenario #1: INPTR1 = I1/TT1.

66. INPTR2: Ratio of inquiries to total tracks in Scenario #2: INPTR2 = I2/TT2.

67. INPTR3: Ratio of inquiries to total tracks in Scenario #3: INPTR3 = I3/TT3.

68. INPTR4: Ratio of inquiries to total tracks in Scenario #4: INPTR4 = I4/TT4.

69. INPTRT: Ratio of total inquiries to total tracks for all four scenarios:
INPTRT = TOTINQ/TOTTRAKS

70. KNOW: Variable designating upper and lower quartiles of KNOWLEDG scores:
(0) if KNOWLEDG $\leq$ 9
(1) if KNOWLEDG $\geq$ 16

71. KNOWLEDG: Score on aircraft systems survey (possible correct: 0-20).

72. LATELY: Relative amount of flying done in last year:
(0) if pilot has more than 50 hours
(1) if pilot has less than 20 hours

73. M1: Merit score on Scenario #1: M1 = (C1) x (E1).

74. M2: Merit score on Scenario #2: M2 = (C2) x (E2).

75. M3: Merit score on Scenario #3: M3 = (C3) x (E3).

76. M4: Merit score on Scenario #4: M4 = (C4) x (E4).

77. MECH: Mechanic: (0) = not a mechanic, (1) = mechanic.

78. PROPCON1: Proportion of control movements to inquiries in Scenario #1:
PROPCON1 = CNTRL1/I1

79. PROPCON2: Proportion of control movements to inquiries in Scenario #2:
PROPCON2 = CNTRL2/I2

80. PROPCON3: Proportion of control movements to inquiries in Scenario #3:
PROPCON3 = CNTRL3/I3

81. PROPCON4: Proportion of control movements to inquiries in Scenario #4:
PROPCON4 = CNTRL4/I4

82. PROPCONT: Proportion of total control movements to total inquiries in all four scenarios; PROPCONT = CNTRLTOT/TOTINQ

83. RAT: Substitute variable for RATING used to plot initial data tables. Takes on same values as RATING.

84. RATING: Rating type -
1 = Private
2 = Commercial
3 = Air Transport

85. RATSCORE: Variable dividing ratings into two groups -
0 if private pilots (RATING = 1)
1 if commercial or air transport pilot (RATING = 2 or 3)

86. RECENCY: Relative amount of flying time in past year -
1 = more than 50 hours
2 = between 20 and 50 hours
3 = less than 20 hours

87. S: Specific subjects involved in the GAT experiment -
0 for subject numbers 11, 31, 32, 33
1 for subject numbers 28, 34, 35, 38

88. SEHRS: Hours of flying in a single engine aircraft.

89. SEHRSLOG: Natural logorithm of single engine flying hours;
SEHRSLOG = LOG_E (SEHRS)

90. SHRSRANK: Variable designating upper and lower quartiles for single engine hours;
0 if SEHRS $\leq$ 488.75
1 if SEHRS $\geq$2075.25

91. SUB: Variable dividing subjects -
0 if subject number is $\leq$ 30
1 if subject number is > 30

92. SUBJECT: Subject number (N = 40)

93. T: Variable designating upper and lower divisions for the variable TIM;
0 if TIM < .625
1 if TIM > 1

94. TC: Variable designating upper and lower quartiles of TOTCOR;
0 if TOTCOR $\leq$ 10
1 if TOTCOR $\geq$ 17

95. TDELTAC: Sum of the changes in subjective criticality estimates for all four scenarios; TDELTAC = TCRITAFT - TCRITBEF

96. TE: Variable designating the upper and lower quartiles of TOTEFF;
0 if TOTEFF $\leq$ 42
1 if TOTEFF $\geq$59

97. THRSLOG: Natural logarithm of totaly flying hours;
THRSLOG = LOG_E (TOTHRS)

98. THRSRANK: Variable designating upper and lower quartiles for total flying hours;
0 if TOTHRS $\leq$ 1007
1 if TOTHRS $\geq$ 5375

99. TIM: Time attribute of an alternate airport - flying time to the airport

100. TM: Variable designating upper and lower quartiles for total merit;
0 if total merit $\leq$ 129.25
1 if total merit $\geq$ 235

101. TOTCOR: Total correct score for all four scenarios; TOTCOR = C1 + C2 + C3 + C4 (possible correct = 0-20).

102. TOTCRITAFT: Total of subjective criticality estimates for all four scenarios after being provided with the answers;
TCRITAFT = CA1 + CA2 + CA3 + CA4

103. TCRITBEF: Total of subjective criticality estimates for all four scenarios before being provided with the answers;
TCRITBEF = CB1 + CB2 + CB3 + CB4

104. TOTEFF: Total efficiency score for all four scenarios;
TOTEFF = E1 + E2 + E3 + E4

105. TOTHRS: Total flying hours.

106. TOTINQ: Total number of inquiries for all four scenarios;
TOTINQ = I1 + I2 + I3 + I4

107. TOTMERIT: Total merit score for all four scenarios;
TOTMERIT = M1 + M2 + M3 + M4

108. TOTTRAKS: Total number of tracks for all four scenarios;
TOTTRAKS = TT1 + TT2 + TT3 + TT4

109. TOTUTRKS: Total number of unique tracks for all four scenarios;
TOTUTRKS = UT1 + UT2 + UT3 + UT4

110. TRA: Variable used to plot the TRAINING values in the data tables;
1 = military
2 = civilian

111. TRAINING: Type of training (military or civilian).

112. TT1: Total number of tracks in Scenario #1.

113. TT2: Total number of tracks in Scenario #2.

114. TT3: Total number of tracks in Scenario #3.

115. TT4: Total number of tracks in Scenario #4.

116. UT1: Number of unique tracks in Scenario #1.

117. UT2: Number of unique tracks in Scenario #2.

118. UT3: Number of unique tracks in Scenario #3.

119. UT4: Number of unique tracks in Scenario #4.

120. WX: Weather attribute of an alternate airport; includes ceilings and visibilities.

121. YOUNGOLD: Variable designating the upper and lower divisions of the age category;
0 if age < 30
1 if age > 50

122. Z1: Ratio of correctness to total tracks for Scenario #1;
Z1 = C1/TT1.

123. Z2: Ratio of correctness to total tracks for Scenario #2;
Z2 = C2/TT2.

124. Z3: Ratio of correctness to total tracks for Scenario #3;
Z3 = C3/TT3.

125. Z4: Ratio of correctness to total tracks for Scenario #4;
Z4 = C4/TT4.

126. ZT: Ratio of total correct to total number of tracks for all four scenarios;
ZT = (C1 + C2 + C3 + C4)/(TT1 + TT2 + TT3 + TT4)

drive gear failure) do demonstrate the monotonic relationship to rating one would expect. Scenario 4 (frozen static port) shows mixed results.

Five subjects hold aircraft mechanic licenses (A and P) as well as pilot licenses. In terms of gross measures, the mechanics' performances are superior to the other groups. They have the top scores for knowledge, total correct, total merit and total efficiency. The only inconsistency again shows up in scenario 4 (frozen static port). However, since that problem relates to symptoms more likely to be directly observed in their role as pilot rather than mechanic that result is not totally unexpected. More extensive analysis of the diagnostic performance data will follow in section K.

E. Decision Making Phase of P/P Scenarios

Procedure

The decision making phase of the paper and pencil exercise was divided into two parts: an information seeking part and a rank ordering of alternatives. The goal of the study was to determine the type of decision rule a pilot would use in a given problem, and to determine his worth structure concerning the characteristics of airports to which he might divert if it became necessary. The decision making portion of the experiment was begun after the pilot had completed all four scenarios in the diagnosis phase described above.

One basic scenario was used throughout the decision making phase and is given in Appendix H. The mission of the hypothetical flight was to fly from Bangor, Maine, to Glens Falls, New York, for a business meeting. The flight was to be made in a Cherokee Arrow and the weather at the time of the flight, both along the route and at the destination, was marginal. Though there

Table VI 4
Data Summary

BACKGROUND, DIAGNOSIS, AND TOTALS

VARIABLE	N	MEAN	STD DEV	MEDIAN	MINIMUM	MAXIMUM
KNOWLEDG	40	12.47500000	3.33580037	13.00000000	5.00000000	17.00000000
CATSCR1	40	4.82500000	1.70801279	5.00000000	1.00000000	7.00000000
CATSCR2	40	3.75000000	1.23516842	4.00000000	2.00000000	7.00000000
CATSCR3	40	3.85000000	1.44204271	4.00000000	0	6.00000000
TOTHRS	40	3821.40000000	4216.07414789	2380.00000000	160.00000000	19400.00000000
SEHRS	40	1911.30000000	2062.48192782	1500.00000000	125.00000000	10000.00000000
THRSLOG	40	7.66764530	1.18586123	7.77358246	5.07517382	9.87302835
SEHRSLOG	40	7.05488404	1.06679198	7.31322002	4.82831374	9.21034037
IFRHRS	40	512.60000000	585.37328875	275.00000000	3.00000000	2500.00000000
RATING	40	2.07500000	0.72985773	2.00000000	1.00000000	3.00000000
TRAINING	40	1.75000000	0.43852901	2.00000000	1.00000000	2.00000000
FLYING	40	3.20000000	1.24447497	3.00000000	1.00000000	5.00000000
ATC	39	1.67948718	1.00360980	1.50000000	0.25000000	4.00000000
WX	39	2.29807692	1.29193328	2.00000000	0.75000000	4.00000000
TIM	39	1.63782051	1.26789651	1.37500000	-0.50000000	4.00000000
APP	39	1.87500000	1.28151072	1.62500000	0.25000000	4.00000000
CONOCO	39	0.76923077	0.42683279	1.00000000	0	1.00000000
AIRPORTS	39	4.05128205	2.66506362	4.00000000	1.00000000	14.00000000
AGE	40	2.10000000	0.77789987	2.00000000	1.00000000	3.00000000
RECENCY	40	1.52500000	0.75064075	1.00000000	1.00000000	3.00000000
CATK1	8	4.70000000	1.54849235	5.01499939	2.80000000	6.86000000
CATK2	8	5.85500000	1.21507201	5.91999912	3.50000000	7.00000000
CATK3	8	4.53250000	1.04156133	4.53499985	3.18000000	6.36000000
CATK4	8	3.75750000	1.12685086	3.77499962	1.53000000	5.03000000
CATK5	8	4.94375000	1.52489754	5.59999943	2.10000000	6.30000000
CATK6	8	4.59375000	1.45735511	5.00000000	2.25000000	6.50000000

Table VI-4 (con't.)

BACKGROUND, DIAGNOSIS, AND TOTALS

VARIABLE	N	MEAN	STD DEV	MEDIAN	MINIMUM	MAXIMUM
I1	40	6.37500000	2.70505225	6.00000000	2.00000000	14.00000000
I2	40	8.57500000	3.45585716	9.00000000	2.00000000	16.00000000
I3	40	9.57500000	3.97999807	9.50000000	3.00000000	18.00000000
I4	40	9.12500000	3.61753210	9.00000000	2.00000000	17.00000000
TOTINQ	40	33.65000000	8.94298178	34.00000000	13.00000000	61.00000000
TT1	40	1.80000000	1.24447497	1.00000000	1.00000000	7.00000000
TT2	40	3.75000000	1.82222743	3.00000000	1.00000000	8.00000000
TT3	40	3.85000000	1.88056206	3.50000000	1.00000000	9.00000000
TT4	40	4.10000000	2.10980616	4.00000000	1.00000000	9.00000000
TOTTRAKS	40	13.50000000	4.16333200	13.00000000	5.00000000	23.00000000
UT1	40	1.50000000	0.55470020	1.00000000	1.00000000	3.00000000
UT2	40	2.75000000	0.86971849	3.00000000	1.00000000	5.00000000
UT3	40	3.15000000	1.05125078	3.00000000	1.00000000	5.00000000
UT4	40	3.35000000	1.38767468	3.00000000	1.00000000	6.00000000
TOTUTRKS	40	10.75000000	2.26172160	10.50000000	5.00000000	16.00000000
C1	40	2.67500000	1.68534406	2.00000000	0	5.00000000
C2	40	2.90000000	2.43689588	5.00000000	0	5.00000000
C3	40	3.35000000	2.35937845	5.00000000	0	5.00000000
C4	40	4.02500000	1.67159528	5.00000000	0	5.00000000
TOTCOR	40	12.95000000	0.60740764	14.50000000	2.00000000	20.00000000
E1	40	14.47500000	4.15091896	14.50000000	5.00000000	23.00000000
E2	40	11.80000000	4.94689750	10.50000000	3.00000000	24.00000000
E3	40	11.82500000	5.91342454	11.00000000	3.00000000	23.00000000
E4	40	11.72500000	5.05349587	11.00000000	2.00000000	22.00000000
TOTEFF	40	49.82500000	11.78414297	51.00000000	17.00000000	78.00000000

Table VI-4 (con't.)

BACKGROUND, DIAGNOSIS, AND TOTALS

VARIABLE	N	MEAN	STD DEV	MEDIAN	MINIMUM	MAXIMUM
PROPCON1	40	0.10090965	0.16853223	0	0	0.66666667
PROPCON2	40	0.22999910	0.16978346	0.19999999	0	0.66666667
PROPCON3	40	0.41423853	0.22586742	0.35828871	0.11111111	1.00000000
PROPCON4	40	0.24732450	0.14451400	0.23611110	0	0.66666667
PROPCONT	40	0.24994144	0.09680504	0.23223037	0.10000000	0.50000000
INPTR1	40	4.15059524	1.84931813	3.50000000	1.85714286	9.00000000
INPTR2	40	2.52077381	1.04930555	2.26785660	1.00000000	5.00000000
INPTR3	40	2.68214286	0.92979647	2.50000000	1.28571429	6.00000000
INPTR4	40	2.52206349	1.14337327	2.25000000	1.50000000	8.00000000
I[illegible]RT	40	2.58293242	0.58423896	2.42222118	1.61904762	4.00000000
D[illegible]	40	0.30000000	0.96609178	0	0	5.00000000
DIF2	40	1.00000000	1.37747446	0	0	5.00000000
DIF3	40	0.70000000	1.11401330	0	0	4.00000000
DIF4	40	0.75000000	0.95407359	0	0	3.00000000
DIFT	40	2.75000000	2.50895831	2.00000000	0	10.00000000
Z1	40	1.88797619	1.34738453	2.00000000	0	5.00000000
Z2	40	1.06681548	1.05022473	1.00000000	0	3.00000000
Z3	40	1.17812500	1.01952919	1.00000000	0	2.50000000
Z4	40	1.45362103	1.26995[illegible]3	1.25000000	0	5.00000000
ZT	40	1.10593567	0.61049287	1.00000000	0.12500000	2.60000000
CORINQ1	40	0.52426282	0.42031975	0.38095236	0	1.66666667
CORINQ2	40	0.46615260	0.50024561	0.45454544	0	1.66666667
CORINQ3	40	0.48290309	0.44427174	0.44949490	0	1.66666667
CORINQ4	40	0.56528383	0.38879363	0.55555534	0	1.66666667
CORINQT	40	0.42846449	0.21586358	0.38585603	0.04166667	1.00000000

Table VI-4 (con't.)

BACKGROUND, DIAGNOSIS, AND TOTALS

VARIABLE	N	MEAN	STD DEV	MEDIAN	MINIMUM	MAXIMUM
M1	40	40.07500000	30.28191260	32.00000000	0	108.00000000
M2	40	38.65000000	37.21286654	45.00000000	0	110.00000000
M3	40	46.90000000	40.72156866	42.50000000	0	113.00000000
M4	40	50.82500000	31.82636184	50.50000000	0	110.00000000
TOTMERIT	40	176.45000000	77.64381198	182.00000000	10.00000000	309.00000000
CB1	40	5.05000000	1.75338500	5.50000000	1.00000000	7.00000000
CB2	40	3.67500000	2.17665351	3.50000000	1.00000000	7.00000000
CB3	40	4.35000000	1.64160647	4.50000000	1.00000000	7.00000000
CB4	40	2.70000000	1.68248900	2.00000000	1.00000000	7.00000000
TCRITBEF	40	15.77500000	3.99029271	15.50000000	8.00000000	24.00000000
CA1	39	3.23076923	1.85616382	3.00000000	1.00000000	7.00000000
CA2	40	3.52500000	1.82556630	3.00000000	1.00000000	7.00000000
CA3	40	3.72500000	1.60108137	4.00000000	1.00000000	7.00000000
CA4	40	2.37500000	1.40853625	2.00000000	1.00000000	7.00000000
TCRITAFT	39	12.87179487	4.12425105	13.00000000	4.00000000	22.00000000
CNTRL1	40	0.75000000	1.19292788	0	0	4.00000000
CNTRL2	40	1.87500000	1.18077549	2.00000000	0	5.00000000
CNTRL3	40	3.47500000	1.67924739	3.00000000	1.00000000	8.00000000
CNTRL4	40	1.95000000	0.93232546	2.00000000	0	4.00000000
CNTRLTOT	40	8.05000000	2.84604989	8.00000000	3.00000000	14.00000000
DELTAC1	39	-1.76923077	2.07061570	-1.00000000	-6.00000000	2.00000000
DELTAC2	40	-0.15000000	1.29198714	0	-4.00000000	3.00000000
DELTAC3	40	-0.62500000	1.73482431	0	-5.00000000	4.00000000
DELTAC4	40	-0.32500000	1.22762017	0	-5.00000000	2.00000000
TDELTAC	39	-2.79487179	2.78321555	-3.00000000	-10.00000000	2.00000000

Figure VI-5

TOTAL CORRECT ON 4 SCENARIOS

PERCENTAGE BAR CHART

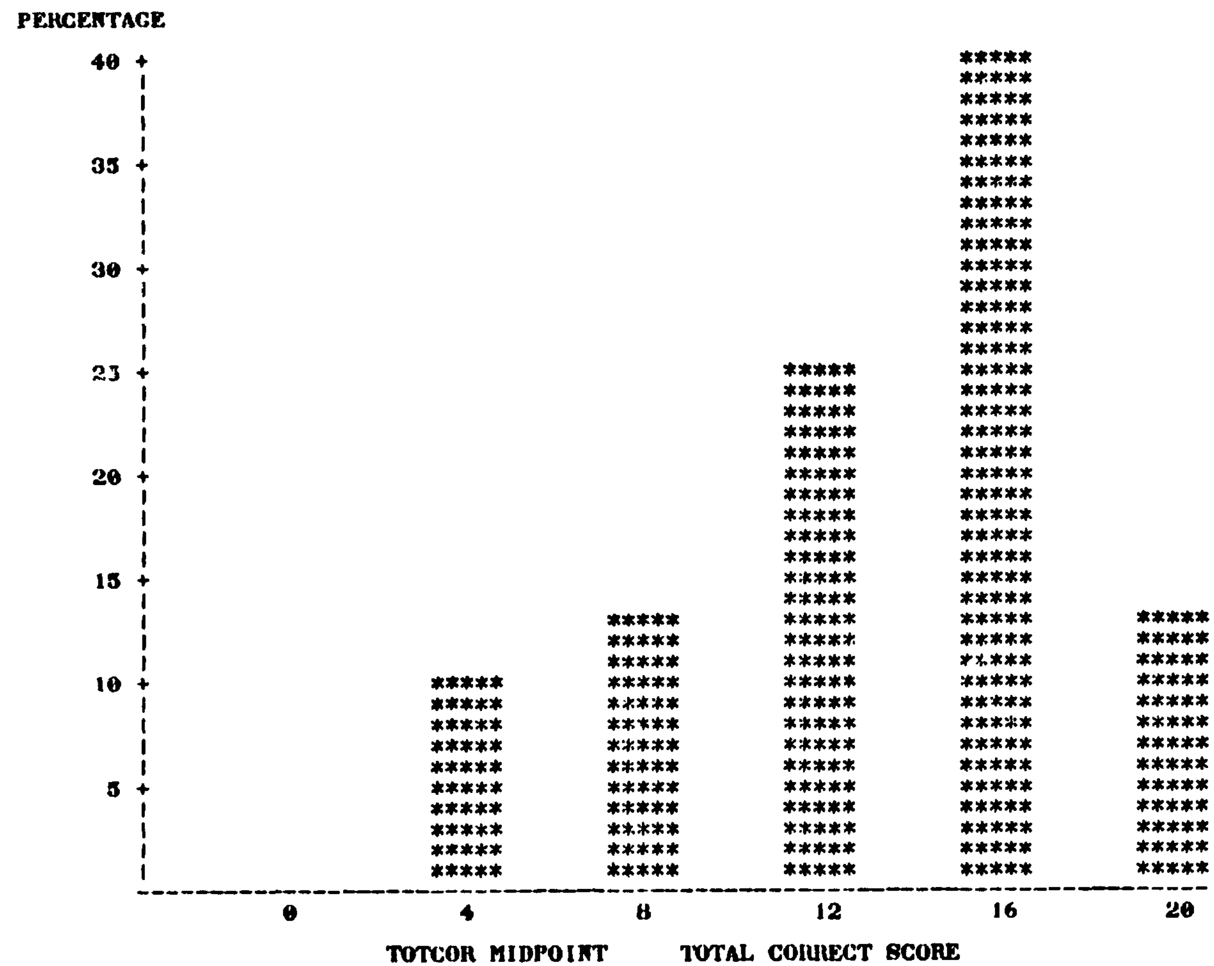


Figure VI-6

TOTAL MERIT SCORES ON 4 SCENARIOS

PERCENTAGE BAR CHART

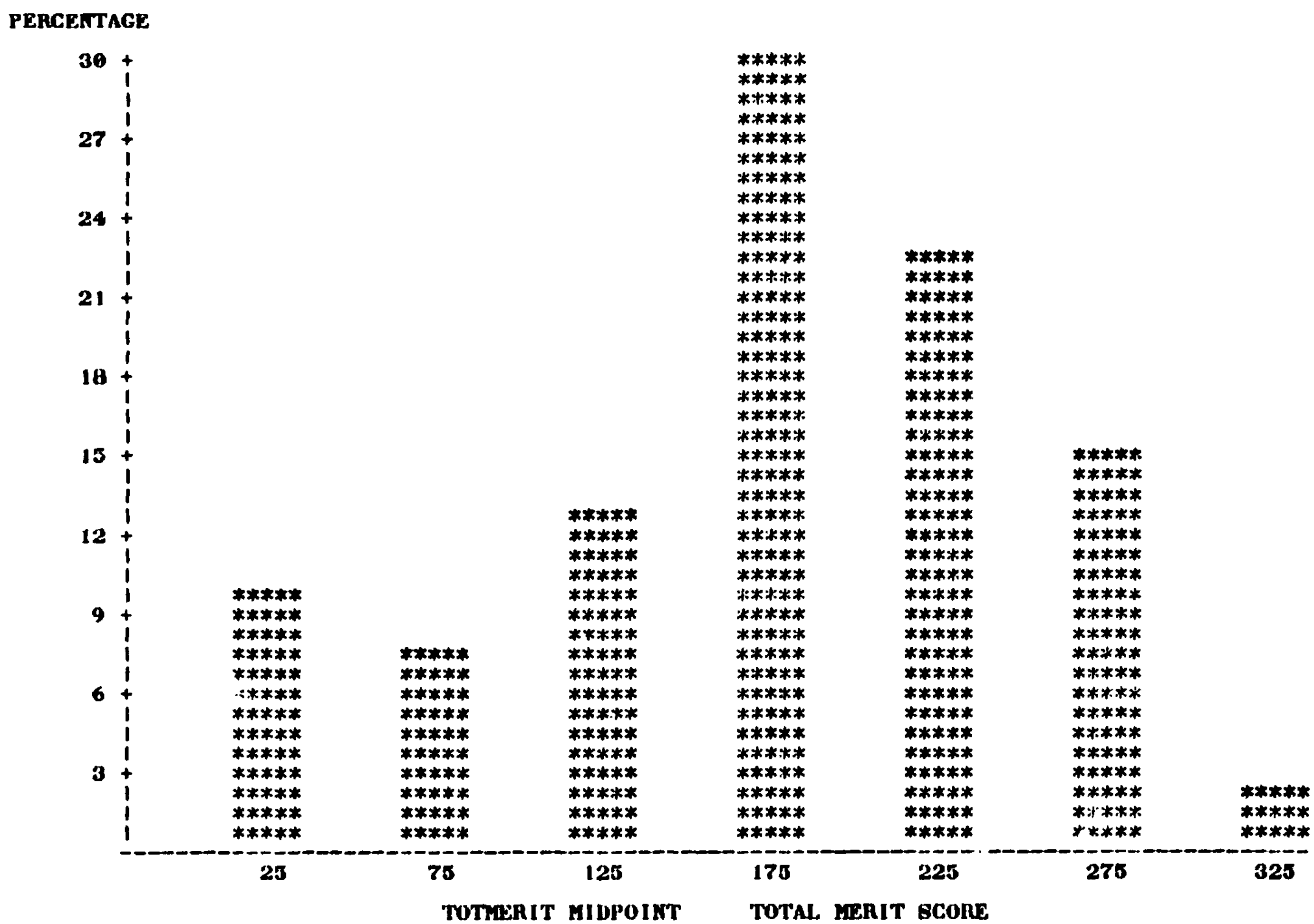


Table VI-5

Diagnosis Performance Means by Rating

	Total Population	PVT	COMM	ATP	A & P
Score on knowledge survey	12.5	10.5	12.3	14.1	14.6
Correct on Scenario 1	2.7	3.2	2.8	2.0	3.4
Correct on Scenario 2	2.9	2.7	2.9	3.0	3.0
Correct on Scenario 3	3.4	2.2	3.4	4.1	4.0
Correct on Scenario 4	4.0	4.1	3.8	4.3	4.0
Total correct	13.0	12.3	12.9	13.4	14.4
Total merit	176.0	156.0	179.0	186.0	203.0
Total efficiency	50.0	45.0	51.0	50.0	53.0

was no severe weather forecast (in the form of thunderstorms, turbulence, or ice), the prevailing rainy and drizzly conditions required the flight to be conducted under Instrument Flight Rules (IFR). In fact, weather conditions were such that the flight would be in instrument meteorological conditions for almost the duration of the time aloft.

After the pilot was given a brief introduction on the mission of the flight, the navigation chart of the area, and the airplane, attention was turned to analyzing the weather in detail and filing a flight plan. The pertinent weather information was given to the pilot in a text written in ordinary English. This text is given in Appendix H. The wording of the text was intended to reproduce what one would normally hear in a telephone conversation with a weather briefer. All of the weather information needed to plan the flight was included. After the pilot confirmed that he had read and understood all of the weather, the next step was to compute and file a flight plan.

In order to save time, the flight plan in Appendix H had already been compiled based on the reported weather, and was shown to the pilot for his approval. The most important features of the flight plan were reviewed by the pilot, including flight routing, cruising altitude, and estimated time en route.

After reviewing all of the information on the airplane, weather, and flight plan, the pilot was asked if he would normally attempt a flight under the stated conditions. He was also asked if there was any other information he would like to have concerning the proposed flight. His responses to these questions were recorded, and it was then time to embark on the flight.

The description of the flight started with a routine lift-off from the Bangor Airport at the planned departure time. Climb-out after departure and the transition to cruising flight was uneventful. The pilot followed the progress of his flight on a very simplified enroute navigation chart (see Appendix H), which portrayed the intended route of flight, radio navigation aids and fixes, and the departure and destination airports.

The flight continued uneventfully until a point about midway along the route. At that point the aircraft encountered a serious problem with its electrical system. The problem was investigated (in the text) and was determined to be an inoperative alternator. After the problem was clearly defined, an upper time limit estimate was provided to indicate how long the aircraft's systems could rely on the reserve electrical power of the battery.

The section of the text in which the problem was introduced and discussed contained several key pieces of information for the pilot. First, the symptoms and the diagnosis set the stage for the need to divert. The straightforward statement of the diagnosis was intended to give each pilot, basically, the same perception of the problem. This was of great importance since the focus of this part of the paper and pencil exercises was on the decision issues rather than diagnosis. If left to their own diagnostic devices, it would have been unlikely that all pilots would have perceived the problem in the same way. Next, the ramifications of the problem were clearly assessed. Having only battery power left to run electrical equipment, the problem was urgent in terms of time. The consequences of flying beyond the lifetime of the battery were serious; the flight would be trapped aloft with no means of communication or navigational guidance. Finally, an estimate of the degree of time urgency was given when the estimated maximum time the battery would be useable was stated as being not longer than fifty minutes.

The paper and pencil scenario had now reached the point where the pilot was called upon to use his own personal decision skills in the problem. The first task was to conduct an information search on the attributes of potential diversion airports. This included ceiling, visibility, navaids, terrain, availability of radar and distance and heading to the diversion airport. The purpose of this task was to determine the search strategy and decision rule the pilot used in shopping for an airport to which to divert. The second task involved ranking a group of sixteen airports from "most preferable" to "least preferable" based on their attributes.

The Information Seeking Task

In this task the pilot was required to search for an airport to which to divert. The pilot was supplied with Figure III (in Appendix H) which portrayed all the airports in the area. (He was cautioned that all the airports shown should not be assumed to be within his range in terms of battery time.) As he viewed the new chart, the pilot was read the instructions given in Appendix H. The experimenter was to act as the air traffic controller and would provide the pilot with the information he requested. The information the experimenter was prepared to give was summarized in Table A4 and shown to the pilot.

In all there were sixteen potential diversion airports and the experimenter had six pieces of information (from four questions) on each. The total store of information maintained by the experimenter is given in Appendix H.

Each pilot was told he had two minutes to conduct his search and to select an airport to which to divert. The mention of the two minute time limit was intended to place a sense of time urgency on the problem, but it was not enforced. In most cases, however, the pilot had finished his search and selected an alternate airport before the two minute limit had expired.

The experimenter provided the pilot with each piece of information that the pilot requested. The experimenter recorded the sequence in which the information was requested. The pilot continued to request information until he had found an airport and revealed his choice to the experimenter. At this point the information seeking task was completed.

F. The Ranking of Alternatives (Decision Phase)

Information from ranking of alternatives was used to interpret the information seeking phase. In this phase the pilot was asked to rank sixteen alternative airports from "most preferable" to "least preferable" given his problem situation. Each airport was described in terms of four attributes, namely, air traffic control (ATC) services at the airport, the weather at the airport, the time to fly from present position to the airport, and the best instrument approach facilities there. These attributes were chosen because they were independent with respect to each other, and also because they were the more pertinent items to consider in this situation.

Each attribute was varied over two levels: a "high" value (in terms of pilot preferability) and a "low value". (For example, weather 1000/3 vs. 500/1.) All possible combinations of high and low attribute levels resulted in a total of sixteen alternatives to be considered. The end product was a 2^4 full-factorial design as shown in Table VI-6.

Each alternative airport was depicted on a 3 x 5 inch card in terms of the four attributes. The sixteen cards were shuffled (prior to the experiment) and laid out before the subject in a random fashion while the experimenter read these instructions:

> "I have a set of cards here; each card describes an airport in terms of ATC services, weather, the flight time from your present position to the airport, and the approach facilities there. I would like you to rank these airports from your "most preferable" to "least preferable", given the situation you are in. Recall that you have, at the very most, fifty minutes of battery time left. You may find it useful to divide the airports into "subgroups", rank the airports in each subgroup, and then reconnect the subgroups as appropriate. Afterwards, make a final check of your rank and adjust it as you think necessary."

Subjects were given as much time as they needed to complete the ranking task, but rarely did it take longer than five minutes. While performing the task, subjects generally appeared quite involved and made meticulous adjustments to the rank before yielding a final ordering. When the subjects had completed the ranking task and were satisfied with their final product, the experimenter recorded the sequence and the ranking task was complete.

In an attempt to estimate how "real" this simulation seemed to the pilot, and to determine the pilot's relative risk taking tendencies, the experimenter posed a series of questions for the pilot to consider. The questions asked

Table VI-6. 2^4 Factorial Layout of Airports

Airports	Attributes			
	ATC	Weather	Time	Approach
A	+	+	+	+
B	-	+	+	+
C	+	-	+	+
D	-	-	+	+
E	+	+	-	+
F	-	+	-	+
G	+	-	-	+
H	-	-	-	+
I	+	+	+	-
J	-	+	+	-
K	+	-	+	-
L	-	-	+	-
M	+	+	-	-
N	-	+	-	-
O	+	-	-	-
P	-	-	-	-

(+ = High value; - = Low value)

Key:

ATC: + = Tower w/radar
- = UNICOM

Time: + = 15 minutes
- = 30 minutes

Weather: + = 1000' ceiling, vis. 3 miles
- = 500' ceiling, vis. 1 mile

Approach: + = ILS
- = NDB

the pilot how far he would go down his list of ranked airports to find one with maintenance facilities to repair his airplane--a question which seeks to find the limit of his diversion options. (The line of questioning used is contained under the Go-No-Go Instructions of Appendix H.) When the pilot finished these questions both the diagnosis and decision making sections of the paper and pencil exercises were completed, and the pilot was invited to participate in other events at the workshop.

Analysis and Results

The analysis proceeded first with the ranks provided by the subjects in the ranking task and then with the information seeking data. The first part of the analysis was aimed at modeling the pilot's worth function and determining if worth functions are related to pilot background variables. The theory of conjoint measurement was used to model the worth functions (Krantz and Tversky, 1971). The second part of the analysis centered on the information search and how it related to worth functions. The analysis which follows was performed on the first 29 subjects.

Results of Ranking Task

A list of the ranks made by the subjects is given in Table VI-7. In this table the "name" of the airport refers to the airport with the same dimensional configuration as shown in Table VI-6. It should be mentioned that the airport name was not revealed to the pilot during the experiment in order to prevent any biasing effects that may have resulted. The numbers in Table VI-7 correspond to the positions in the rank that the airports were assigned by the subject. The convention was adopted that sixteen equals "most preferable". It is evident that most of the pilots agreed airport A was most preferable and airport P was least preferable. However, much variation is seen in the airports in between.

The additive model in Equation (1) below was assumed to be the underlying psychological process in the worth structures and was proven to be the correct choice through a series of axiomatic tests performed on the ranked data. (The ranked data of Subject 4 did not conform to the tests and his data was dropped from further analyses. In effect, the subject showed no logical preferred order. A 65 year old retired pilot, he may not have understood the instructions.)

$$W(X_z) = B_{atc} \cdot ATC_z + B_{wx} \cdot WX_z + B_{tim} \cdot TIM_z + B_{app} \cdot APP_z \tag{1}$$

where $W(X_z)$ is the psychological worth of airport z, and ATC_z, WX_z, TIM_z, and APP_z are the independent variables describing airport z in terms of AT. services, weather, time and approach aids respectively. The independent variables took on a value of +1 for the high level or -1 for the low level of each attribute. The "B"-coefficients are the "weights" each subject assigned to a certain attribute in his ranking scheme. The B-coefficients were obtained by performing a regression analysis where the rank position of airport z was substituted (according to conjoint measurement) for $W(X_z)$. The resulting coefficients are shown in Table VI-8. The range of values for the coefficients is 0.250 to 4.000. An interpretation can be offered if one considers all four coefficients for each subject. The coefficients for Subject 1, for example, are 1.000, 2.000, 4.000, and 0.500 for ATC, weather, time,

Table VI-7. List of Airport Ranks by Subject

FOR AIRPORTS A THROUGH P: 16= MOST PREFERABLE, 1= LEAST PREFERABLE

SUBJECT	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	16	14	12	10	8	6	4	2	15	13	11	9	7	5	3	1
2	16	12	15	11	8	3	6	2	14	10	13	9	7	4	5	1
3	16	15	14	13	8	7	6	5	12	11	10	9	4	3	2	1
4	16	14	6	3	15	5	9	13	12	10	2	1	11	4	8	7
5	16	15	13	12	11	10	8	6	14	7	4	3	9	5	2	1
6	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
7	16	7	12	6	14	4	9	2	15	8	11	5	13	3	10	1
8	16	13	8	6	14	12	7	5	15	9	4	2	11	10	3	1
9	16	11	15	6	14	10	13	2	9	8	5	3	12	7	4	1
10	16	13	11	4	15	12	9	3	14	8	6	2	10	7	5	1
11	16	8	14	7	15	3	13	6	12	5	10	1	11	4	9	2
12	16	12	15	10	14	11	13	9	8	4	7	2	6	3	5	1
13	16	15	12	5	7	6	9	4	13	14	11	2	10	8	3	1
14	16	15	8	7	14	11	6	5	9	12	4	2	13	10	3	1
15	16	14	12	10	6	4	7	3	15	11	13	8	9	1	5	2
16	16	14	12	10	8	6	4	2	15	13	11	9	7	5	3	1
17	16	13	14	10	12	11	9	2	15	5	8	4	7	3	6	1
18	16	11	12	4	14	6	7	3	15	10	9	2	13	5	8	1
19	16	12	14	10	8	6	4	2	11	15	13	9	7	3	5	1
20	16	10	15	11	9	4	8	6	14	13	12	5	7	3	2	1
21	16	12	8	4	15	11	7	3	14	10	6	2	13	9	5	1
22	16	12	14	6	15	7	13	5	11	4	9	2	10	3	8	1
23	16	12	8	4	15	11	7	3	14	10	6	2	13	9	5	1
24	16	12	14	10	15	11	13	9	8	2	5	3	7	4	6	1
25	16	14	10	9	12	11	7	4	15	13	5	2	8	6	3	1
26	16	15	12	10	14	13	11	9	7	4	6	2	8	3	5	1
27	16	12	14	10	15	11	13	9	8	3	6	2	7	4	5	1
28	16	14	8	6	12	11	7	5	15	13	4	2	10	9	3	1
29	16	15	8	6	12	10	4	2	14	13	7	5	11	9	3	1
30	16	15	8	6	12	11	4	2	14	13	7	5	10	9	3	1

Table VI-8. Coefficients of the Additive Worth Function

(SUBJECT 4 DELETED, 29 SUBJECTS REMAINING)

SUBJECT	BSUBATC	BSUBWX	BSUBTIM	BSUBAPP
1	1.000	2.000	4.000	0.500
2	2.000	0.750	4.000	0.625
3	0.500	1.000	4.000	2.000
5	1.125	2.375	2.000	2.875
6	0.500	1.000	2.000	4.000
7	4.000	1.500	1.500	0.250
8	1.250	4.000	0.625	1.625
9	2.500	2.375	0.625	2.375
10	2.500	3.375	0.750	1.875
11	4.000	0.750	0.625	1.750
12	2.000	0.750	0.750	4.000
13	1.625	2.625	2.500	0.750
14	0.625	4.000	0.625	1.750
15	1.875	1.000	3.875	0.500
16	1.000	2.000	4.000	0.500
17	2.375	1.750	2.125	2.375
18	3.250	2.750	1.375	0.625
19	1.250	1.250	4.000	0.500
20	1.875	1.000	3.500	1.375
21	2.000	4.000	0.500	1.000
22	3.500	1.250	0.750	2.500
23	2.000	4.000	0.500	1.000
24	2.000	0.875	0.250	4.000
25	1.000	3.375	2.000	1.875
26	1.375	1.500	0.500	4.000
27	2.000	1.000	0.375	4.000
28	0.875	4.000	1.250	1.375
29	0.875	4.000	2.000	0.625
30	0.750	4.000	2.000	0.750

and approach, respectively. This can be interpreted as follows: the worth of having the time value at the high level (15 minutes) was twice that of having the weather value at the high level (1000 feet ceiling and three miles visibility), four times the worth of having ATC at the high level (tower with radar), and eight times the worth of having the approach at the high level (ILS). In other words, the most important feature about each airport for Subject 1 was time followed by weather, ATC, and approach, respectively.

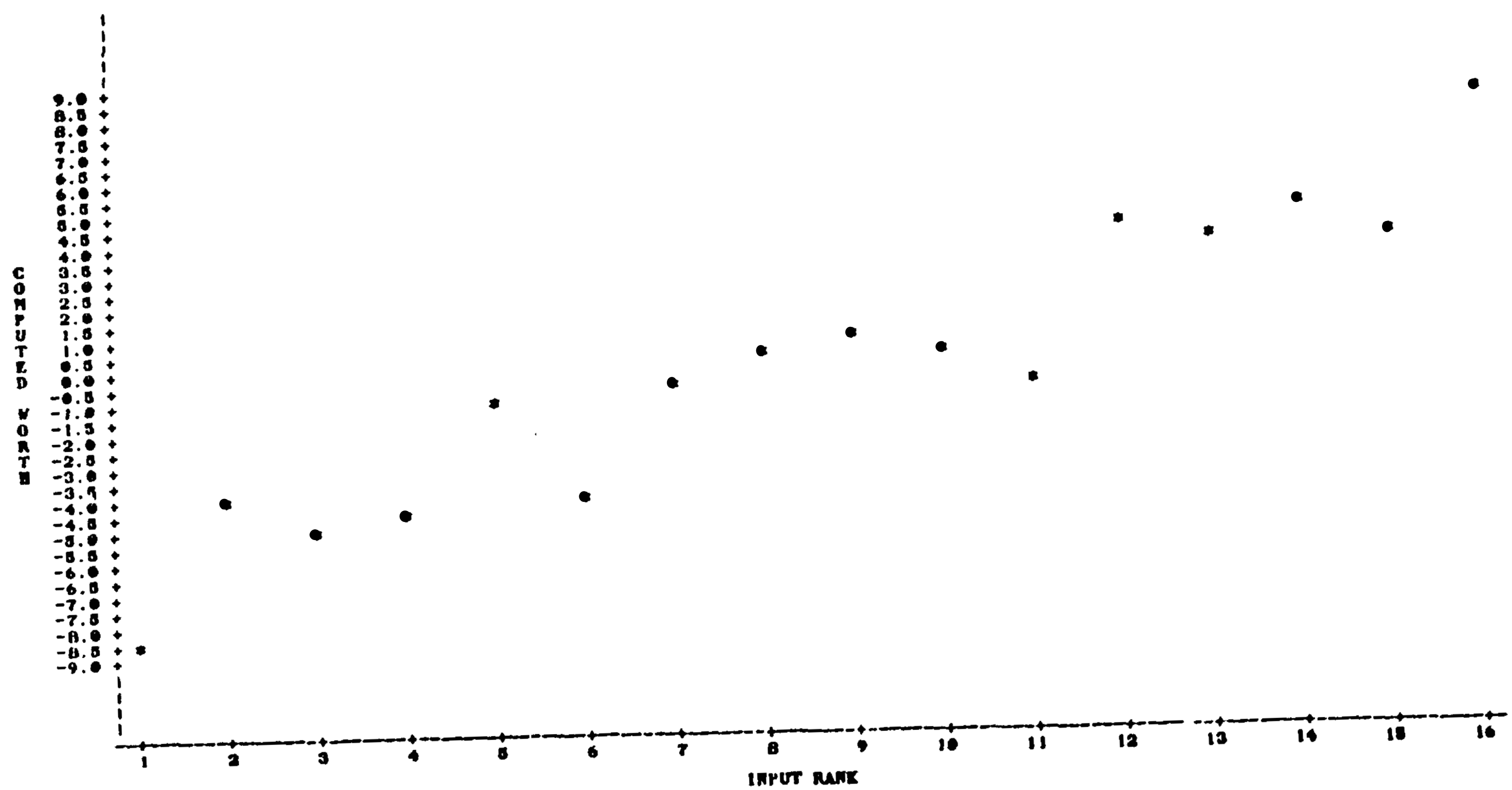
In order to test for the validity of the additivity assumption in the model, the preference ranks determined from equation A for the sixteen airports were plotted against the original preferences for each subject. A Spearman rank correlation was computed to estimate the fit of the model derived ranks with the actual ranks. Figure VI-8 depicts a typical plot. The correlation coefficients ranged from 8.74 to 1.00 for the 29 subjects indicating the model additivity was an acceptable assumption.

The next step was to determine if any relationship existed between the worth function coefficients and pilot background variables. Since no measure of performance exists in this experiment, the data was examined to find relationships or explain differences. The basic approach was to dichotomize the sample population based on several different descriptors of a pilot's background and skill. The means of the coefficients for the resulting two groups were then compared to see if any significant differences occurred as a result of the division. The divisions were performed on the basis of flight experience, training, type of pilot certificate, type of flying most commonly done, and measures of ability determined by the knowledge survey and other

Figure VI-7

PLOT OF COMPUTED WORTH VERSUS INPUT RANK SUBJECT 17

SPEARMAN R= 0.938



means. A summary of coefficient means by pilot category is provided in Table VI-9 along with the criteria used to split the sample population. Significant differences (at the $p < .10$ level) are enclosed in dashed lines.

Analysis of Worth Functions By Subjects and Groups of Subjects

The basic approach in this section is to dichotomize the sample population based on several different descriptors of a pilot's background and skill. The splits are performed on the basis of flight experience, training, type of pilot certificates, type of flying most commonly engaged in, and measures of ability determined by the knowledge survey and other means. The worth coefficients of Table VI-9 become the center of attention in this analysis. This analysis covers the first thirty subjects used in this test.

The first dichotomization is performed on the basis of total flight experience in terms of flight hours. A bar graph representing the distribution of total hours is shown in Figure VI-9. As evident in this graph, the distribution of total hours is in no way "normal", and the criterion used to split the sample is somewhat arbitrary. However, the sample was split at the natural break nearest the 50th percentile. Because the sample is more heavily loaded with experienced pilots (many people consider pilots with 800 or more hours to be "experienced") the search for the natural break in total flight time proceeded from the mean toward the "inexperienced" end. The criterion used to split the pilots was 1100 hours. Nine pilots were in the lower category and 21 pilots in the higher category. A t-test was performed to determine if there were any significant differences between the means of the B coefficients

Table VI-9. Summary of Coefficient Means by Pilot Category

No. of Subjects	Pilot Category	Group Coefficient Means $\overline{B}_{atc}$ I	$\overline{B}_{atc}$ II	$\overline{B}_{wx}$ I	$\overline{B}_{wx}$ II	$\overline{B}_{tim}$ I	$\overline{B}_{tim}$ II	$\overline{B}_{app}$ I	$\overline{B}_{app}$ II
	Total Flight Hours:								
(22)	Category I: Time > 1100 hrs.	1.74	1.90	2.08	2.54	1.80	1.90	1.91	1.41
(8)	Category II: Time < 1100 hrs.								
	Total Single Engine Hours:								
(22)	Category I: Time > 800 hrs.	1.91	1.44	2.05	2.66	1.74	2.04	1.91	1.41
(8)	Category II: Time < 800 hrs.								
	IFR Hours:								
(14)	Category I: Time > 300 hrs.	1.57	1.94	2.13	2.28	2.00	1.68	1.91	1.70
(16)	Category II: Time < 300 hrs.								
	Type of Training:								
(7)	Category I: Military Training	1.25	1.92	2.40	2.16	2.20	1.72	1.68	1.90
(23)	Category II: Civil Training								
	Grade of Certificate:								
(8)	Category I: Airline Transport	1.73	1.80	1.48	2.49	2.53	1.56	1.73	1.80
(22)	Category II: Private or Commercial								

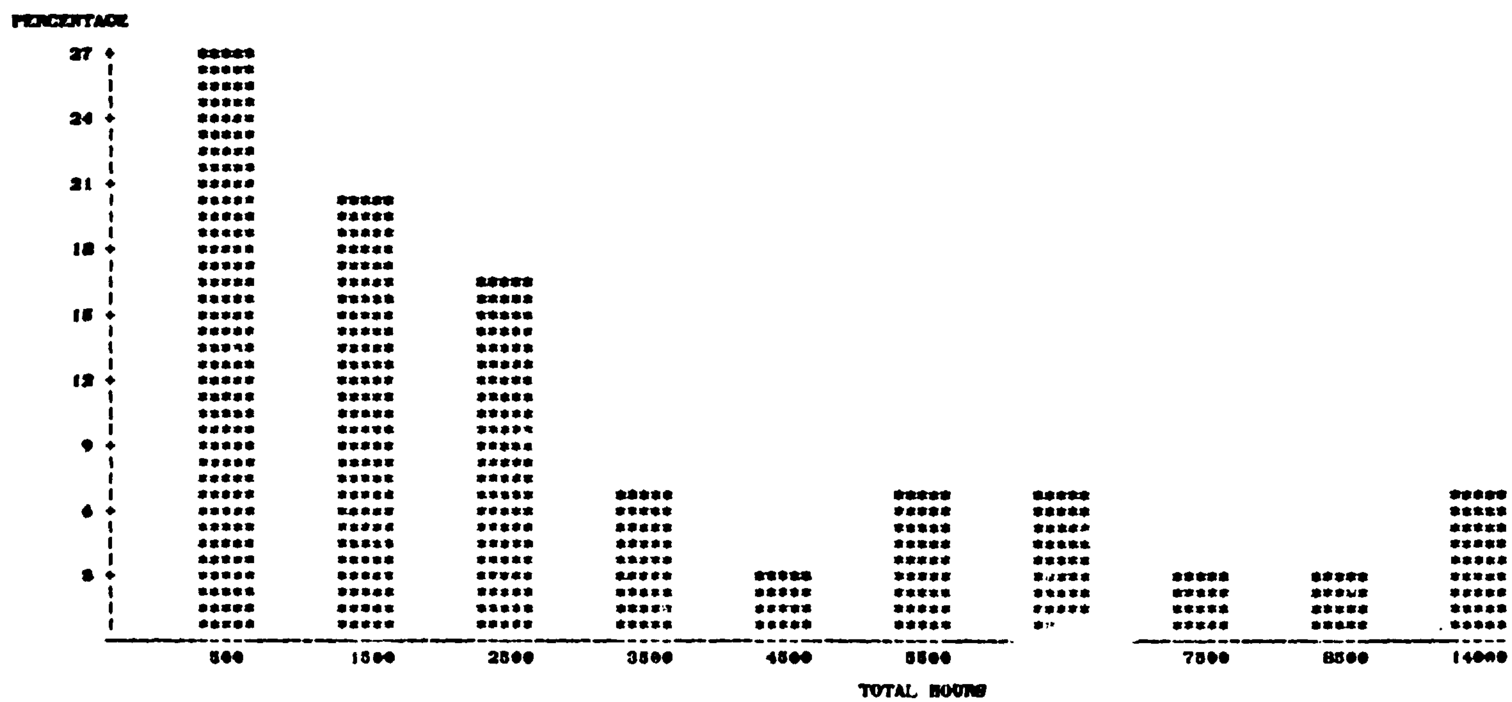
*Significant differences enclosed in dashed lines.

Table VI-9 (con't.)

No. of Subjects	Pilot Category*	Group Coefficient Means							
		$\bar{B}_{atc}$		$\bar{B}_{wx}$		$\bar{B}_{tim}$		$\bar{B}_{app}$	
		I	II	I	II	I	II	I	II
	Type of Flying Mostly Done:								
(5)	Category I: Military or Airline	0.90	1.96	2.20	2.21	2.55	1.67	1.74	1.90
(25)	Category II: Pleasure, GA/Comm, Business								
	Knowledge Survey Score:								
(17)	Category I: Score > 12.5	1.86	1.65	2.06	2.42	2.09	1.45	1.55	2.08
(13)	Category II: Score < 12.5								
	Diagnostic Performance Score:								
(16)	Category I: Score > 13	1.77	1.79	2.25	2.17	2.25	1.37	1.37	2.20
(14)	Category II: Score < 13								
	Would Pilot Attempt Flight?								
(20)	Category I: Pilots said "yes"	1.61	2.15	2.33	1.96	1.61	2.31	2.11	1.01
(10)	Category II: Pilots said "no"								
	Airports Passed for Maintenance:								
(15)	Category I: 4 or more	1.63	1.95	2.60	1.80	1.40	2.28	1.96	1.57
(15)	Category II: 3 or less								

*Significant differences enclosed in dashed lines.

Figure VI-8. Distribution of Total Flight Hours of Sample Population



for the two groups. At the $p = .10$ level, no significant differences were found.

Splits of the sample were made based on the number of Instrument Flight Rules (IFR) hours and single engine airplane hours. A bar graph of the distributions of each are shown in Figure VI-10 and VI-11, respectively. As in the case of total flight hours, these distributions are far from normal, and the "cut" was made in the same manner. At the .10 level, no significant differences were found.

The type of training a pilot received was used as a criterion to split the sample. There were seven military trained pilots and twenty three civil trained pilots. A t-test was performed on the worth coefficients and a difference which was significant at the .10 level ($p = .06$) was observed for the mean value of B_{atc}. (Recall that B_{atc} is a measure of the importance of air traffic control facilities in airport worth evaluation.) For civil trained pilots the mean value of B_{atc} was 1.92 and for military trained pilots it was 1.25.

There are several possible interpretations of this difference, but most allude to the pilot's attitude toward ATC facilities which are formed by previous exposure. In military pilot training programs, much more emphasis is placed on emergency procedures and resolving in-flight problems than in civil pilot training. This may lead to an attitude of greater self-reliance in problem situations on the part of the military pilot, and a reluctance to let too much of the problem "out of the cockpit". Additionally, military trained pilots may feel more strongly that ATC facilities would be of only limited

Figure VI- 9 . Distribution of IFR Hours of Sample Population

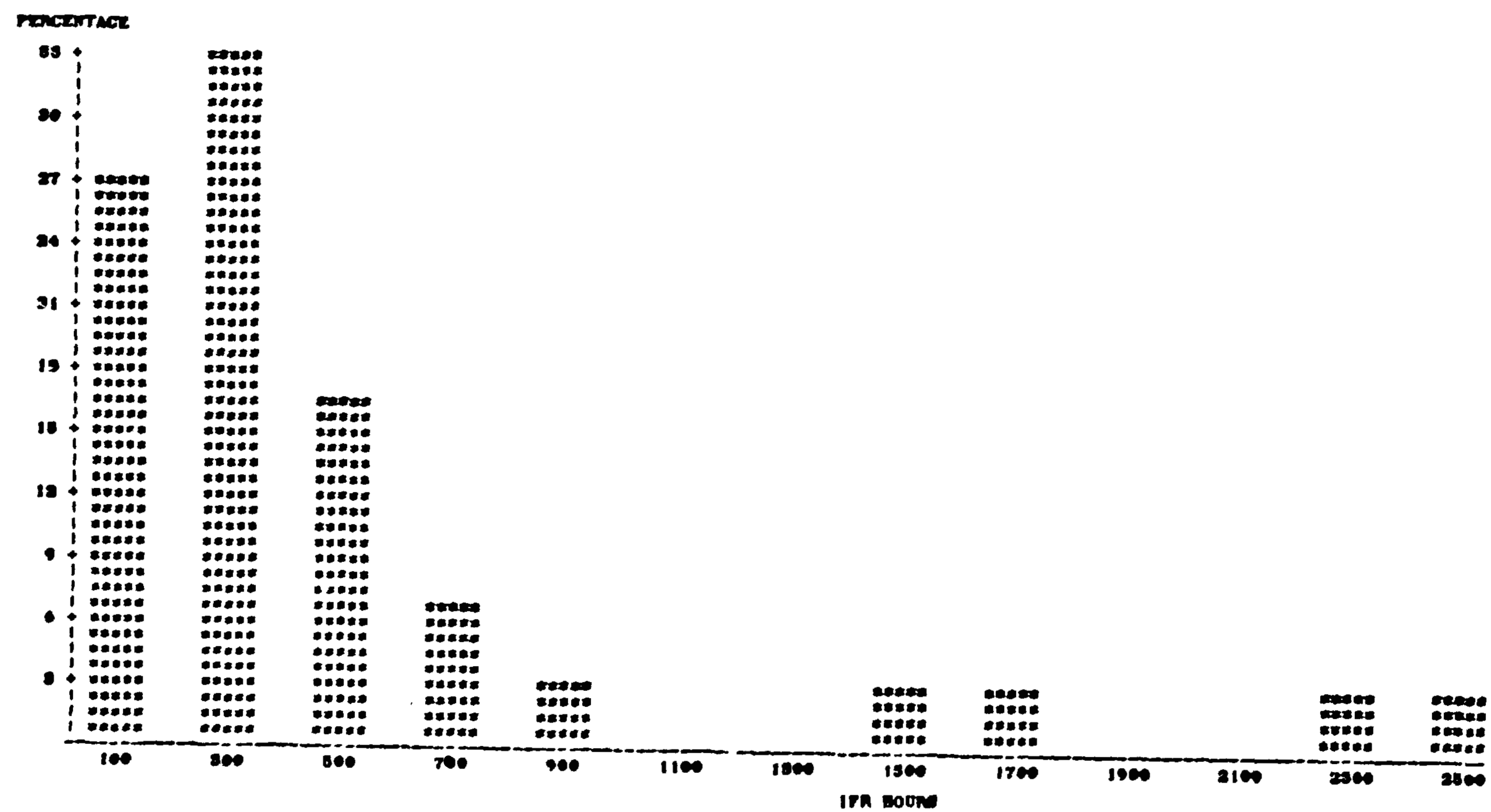
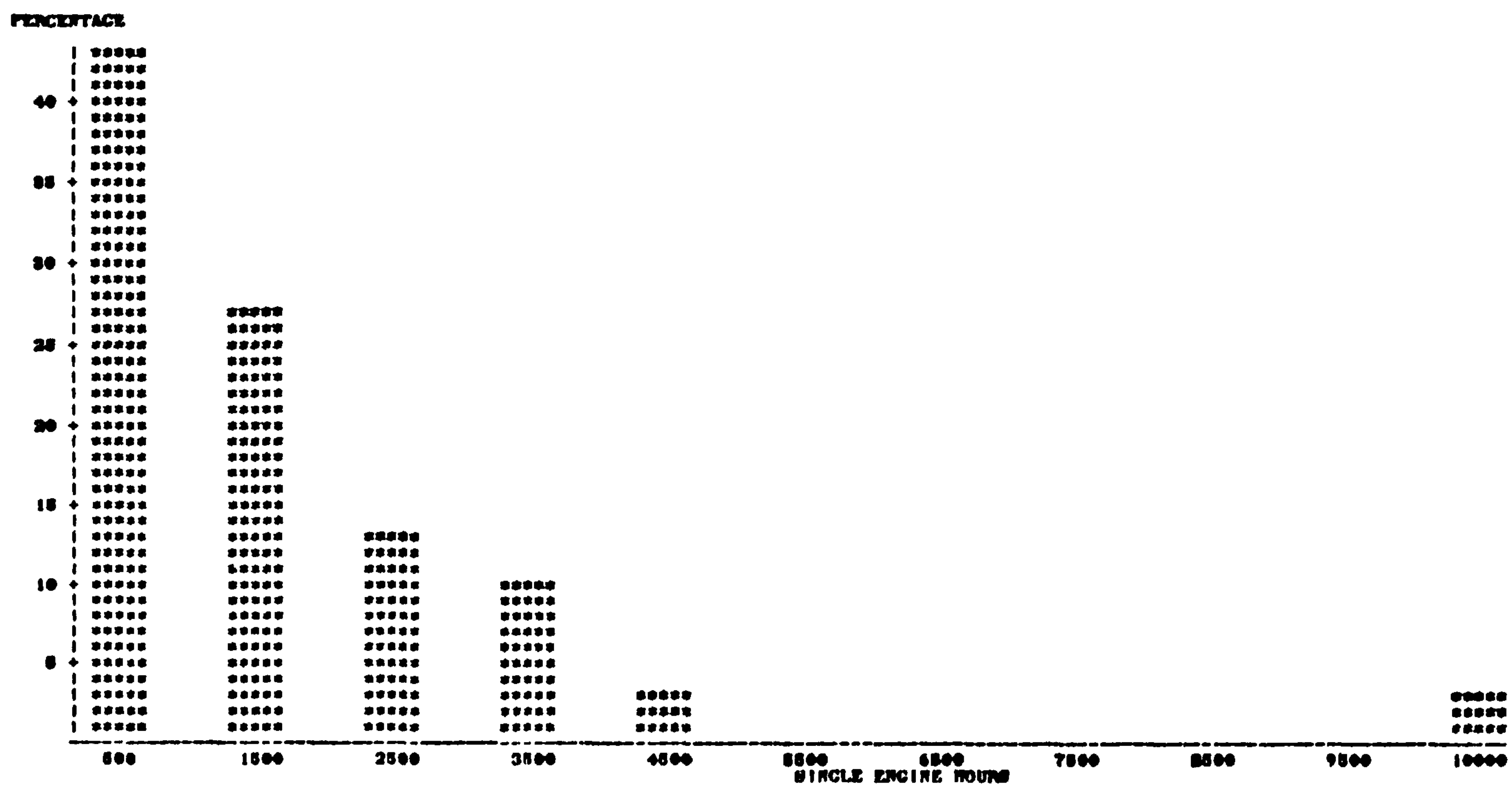


Figure VI-10. Distribution of Single Engine Hours of Sample Population



value in this scenario. Admittedly, if battery power had been depleted and no communications were possible, ATC services would be of no use at all.

The pilot sample was split on the basis of the type of certificate the pilot held. In this case, the twenty one pilots with Private and Commercial certificates made up one group, and the eight pilots with Airline Transport Pilot certificates made up the other group. The split was made in this fashion because the differences between private pilots with instrument ratings and commercial pilots are not great. The experience and proficiency requirements for the issuance of those certificates are nearly the same. In many ways, the commercial pilot training and certification process provides only slight extensions of skill to private pilots with instrument ratings. On the other hand, the stringent eligibility and proficiency requirements for the issuance of the Airline Transport Pilot (ATP) certificate have led to the feeling that ATP airmen are the "cream of the crop". The difference between the two groups of pilots in terms of tested ability is distinct.

Some notable differences were observed when comparing the worth coefficients of these two groups. The mean value of B_{wx}, a measure of the importance of weather to a pilot in this situation, was 2.49 for private and commercial pilots and 1.48 for airline transport pilots. A t-test was performed and this difference was found to be significant ($p = .05$). Another difference, significant at the .10 level, was observed for the value of B_{tim}, a measure of the importance of the time attribute. For airline transport pilots B_{tim} had a mean value of 2.53 and for private and commercial pilots the mean value was 1.56.

The difference in B_{wx} between the two groups is most likely a function of training and the relative "level of preparedness" to fly in adverse weather. Although pilots in both groups are trained in the procedures and maneuvers to be used when flying in bad weather, airline transport pilots are required to perform those maneuvers to much greater accuracy on flight tests. Also, in meeting the greater experience requirements for the ATP certificate, airline transport pilots have been exposed to more poor weather situations than their private and commercial pilot counterparts. In summary, airline transport pilots have reason to feel more confident about their flying skills in relation to marginal weather.

Some interesting comments can be made about the difference in mean values of B_{tim} for the two groups. Because the mean value of B_{tim} was higher for airline transport pilots (2.53) than for private and commercial pilots (1.56), one might casually suggest that airline transport pilots are more cautious. The higher value of time could be interpreted as a desire of airline transport pilots to avoid flirting with the problem by landing quickly. This is the opposite of what one would expect, especially in view of the supposedly "stress hardening" experiences an airline transport pilot faces in his training and career. However, a more probable explanation for the observed difference is that airline transport pilots can take advantage of their skills to consider more airports. They may feel better prepared to conduct flight operations into an airport which is nearby but has poorer weather, and can therefore take advantage of time. Private and commercial pilots, though, may feel that some airports, even though they are close by, are beyond the limits of their skills in terms of weather and facilities. Hence, they sacrifice time for better conditions and services.

The type of flying most commonly done was also used as a basis to divide the pilot sample. Pilots who engaged primarily in business, light commercial, or pleasure flying made up one group. Pilots who were involved with airline or military flying comprised the other group. The split was made in this fashion because the highly structured environments in which airline and military pilots operate are similar in many ways. They are both usually required to fly in and out of busy terminals and heed schedules, policies, and other disciplines. Pilots who fly for business, light commercial, or pleasure concerns, however, operate in a much more relaxed atmosphere and dictate their own policies. Based on this split of the sample population, a significant difference ($p = .024$) was observed for the coefficient B_{atc}. The mean value for business, light commercial, and pleasure flyers was 1.96, while the value for airline and military pilots was 0.90.

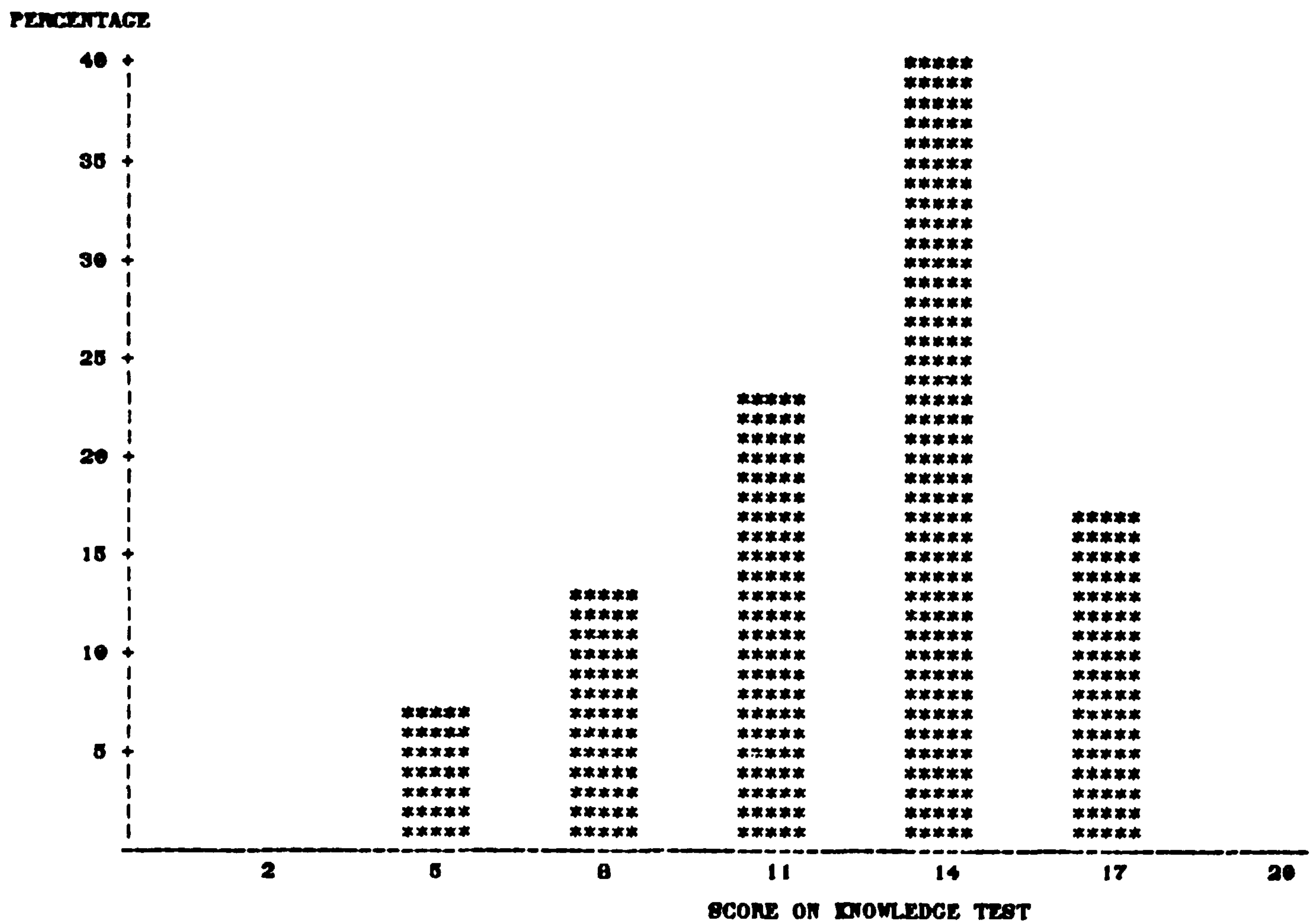
An explanation of this difference could be that military and airline pilots fly much more frequently in congested areas, and are mostly under the surveillance of an ATC facility. Given this day-after-day exposure to ATC, they are more aware of its abilities and limitations. Another potential explanation is the same one noted earlier when contrasting civil trained and military trained pilots. Because of the intensive initial and recurrent training in normal and emergency operations they receive, military and airline pilots may wish to solve in-flight problems with "on-board" resources rather than let too much of the problem outside of the cockpit.

All of the previous comparisons were based on classifications of pilot experience. There were, however, four measures of pilot ability and self-evaluation that were used to classify the pilots as well. The following discussion treats comparisons made on the basis of the pilot's knowledge of aircraft systems, his ability to diagnose problems in flight, and estimates of the perceived risk he assigned to the problem.

The knowledge survey which was administered to the subjects before the experiment was designed to estimate their knowledge of aircraft systems. The mean score was 12.3 out of a maximum of 20, and the distribution of scores was approximately normal, as seen in Figure VI-12. The division was made at the mean and no significant differences were found in the worth coefficients of the resulting two groups at the .10 level.

The pilot's diagnostic ability was estimated in the first half of the decision making workshop. In the four diagnosis scenarios, pilots were scored on the closeness of their diagnoses to the real problems, and these scores were summed up to yield a total correct score. The split was made at the 50th percentile of the total correct score which ranged from 5 to 20. At the .10 level significant differences were observed for two coefficients. Pilots in the lower half of the sample based on the total correct score had a mean value of 2.20 for the B_{app} coefficient, while pilots in the upper half had a mean value of 1.37 (B_{app} is a measure of pilot worth for the instrument approach dimension, and, for this difference, $p = .080$). A possible interpretation of this difference is that diagnostic ability parallels a pilot's perception of his

Figure VI-11. Distribution of Knowledge Survey Scores



flying skills. The NDB approach, aside from being less accurate, requires more headwork and skill than an ILS approach.

The other coefficient in which a .10 level significant difference was observed is B_{tim} ($p = .076$). Pilots in the upper half of the sample had a mean value of 2.25 while those in the lower half had a mean value of 1.37. This difference may again relate to the perceived level of skill. Pilots higher in diagnostic ability may not perceive the problem situation to be any more time critical than pilots in the lower half, but they can take advantage of closer airports more often. They believe they have the skills necessary to meet the challenges of poorer conditions which may accompany the closer airports. The notion that flying skills and diagnostic skills are related should be examined in future research.

During the preflight preparation stage of the decision making scenario, each pilot-subject was asked if he would normally attempt the flight under the stated conditions. Ten of the pilots indicated they would not try it while 20 said they would. A significant difference ($p = .026$) was observed between the two groups for the coefficient for approach aids, B_{app}. Pilots who said they would not attempt the flight had a lower mean value for B_{app} (1.01) than those who said they would try the flight (2.11). This observed difference does not lend itself to a simple, straightforward interpretation. One would expect the relatively cautious pilots who would not attempt the flight to prefer the better approach aid (in this case the ILS) so they could have more in their favor. However, if one looks at the other differences in coefficient means even though they are not significant, some insight is gained. Pilots who would not go on the flight had a higher value for time, and a lower value for weather. This trend leads one to believe that the leery pilots do not wish to push their luck in terms of time. Hence, they put more weight in the time factor and take emphasis away from other factors.

The final dichotomization of pilots was performed on the basis of their responses to the questions on maintenance facilities. In essence, each pilot was asked how far down the list of airports, arranged from most preferable to least preferable, he would go to find the necessary maintenance facilities to repair his plane. Fifteen pilots said 1, 2, or 3 airports and fifteen pilots said 4 or more (the range 1 to 14). The mean value of B_{tim} was 2.28 for pilots who responded with 3 or less (call them "less risky" pilots) while the same measure for the (more risky) pilots who responded with 4 or more airports was 1.40. This was significant at the .10 level ($p = .083$). This difference can be attributed to conservatism of the pilots in the less risky group. In the same manner they are reluctant to take risks by "passing up" too many preferable airports, they are unwilling to pass over a closer airport (in terms of time).

A summary of the results of all the analyses performed in this section is given in Table VI-10. It is interesting to note that significant differences in worth function coefficients were not a result of flight differences, rather, were related to the grade of pilot certificate, the amount and type of initial and recurrent training, and the type of flying most commonly done. This suggests that training and repeated exposure to testing situations are the variables which can predict the general form of a pilot's worth function. A closer examination of the training and certification process is in order.

Once a pilot obtains a private pilot certificate with an instrument rating, there is very little he must legally do to continue exercising the privileges of his certificate. He can continue to accrue many hours of flight time but he is required to demonstrate, on only a sporadic basis, that he is maintaining his basic skills. Airline transport pilots and those pilots who fly for the military or airlines, however, must maintain a higher level of skill regardless of the amount of flight time they have. Many are required to demonstrate proficiency in all sorts of demanding situations and at much more frequent intervals than the biennial flight reviews required of general aviation pilots. The general "level of preparedness" is much higher for military and airline flyers than for the rest of the flying population. All of this lends support to the notion that the total amount of flight experience is not as important as the amount and quality of initial and recurrent training in determining the general worth structure of a pilot.

G. Results of Information Seeking Task

Pilots were referred to the simplified charts of Appendix H when performing information searches. Because of the hypothesized strong winds aloft (out of the southwest at 30 kts.), airports which were closer in terms of distance were not always closer in terms of time. Table VI-10 shows rank orderings of the airports, from nearest to furthest, in terms of both time and distance. Table VI-11 depicts a subject by airport listing of worth values.

Table VI-10. Rank Orderings of Airports In Information Search From Nearest to Furthest

In Terms of Time

1	E	(12 minutes)	I	(23 miles)
2	I	(13)	E	(34)
3	H	(18)	O	(40)
4	N	(19)	N	(40)
5	P	(20)	P	(41)
6	A	(22)	F	(43)
7	J	(22)	H	(49)
8	F	(22)	J	(54)
9	O	(22)	G	(54)
10	L	(23)	B	(54)
11	D	(25)	A	(58)
12	C	(26)	L	(63)
13	M	(28)	C	(63)
14	G	(28)	D	(65)
15	B	(31)	K	(68)
16	K	(32)	M	(69)

Table VI-11. Computed Worth Values and Means by Airports

AIRPORTS A THROUGH P

SUBJECT	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	7.500	5.500	3.500	1.500	-0.500	-2.500	-4.500	-6.500	6.500	4.500	2.500	0.500	-1.500	-3.500	-5.500	-7.500
2	7.375	3.375	5.875	1.875	-0.625	-4.625	-2.125	-6.125	6.125	2.125	4.625	0.625	-1.875	-5.875	-3.375	-7.375
3	7.500	6.500	5.500	4.500	-0.500	-1.500	-2.500	-3.500	3.500	2.500	1.500	0.500	-4.500	-5.500	-6.500	-7.500
5	8.375	6.125	3.625	1.375	4.375	2.125	-0.375	-2.625	2.625	0.375	-2.125	-4.375	-1.375	-3.625	-6.125	-8.375
6	7.500	6.500	5.500	4.500	3.500	2.500	1.500	0.500	-0.500	-1.500	-2.500	-3.500	-4.500	-5.500	-6.500	-7.500
7	7.250	-0.750	4.250	-3.750	4.250	-3.750	1.250	-6.750	6.750	-1.250	3.750	-4.250	3.750	-4.250	0.750	-7.250
8	7.500	5.000	-0.500	-3.000	6.250	3.750	-1.750	-4.250	4.250	1.750	-3.750	-6.250	3.000	0.500	-5.000	-7.500
9	7.875	2.875	3.125	-1.875	6.625	1.625	1.875	-3.125	3.125	-1.875	-1.625	-6.625	1.875	-3.125	-2.875	-7.875
10	8.250	3.750	1.500	-3.000	6.750	2.250	0.000	-4.500	4.500	0.000	-2.250	-6.750	3.000	-1.500	-3.750	-8.250
11	7.125	-0.875	5.625	-2.375	5.875	-2.125	4.375	-3.625	3.625	-4.375	2.125	-5.875	2.375	-5.625	0.875	-7.125
12	7.500	3.500	6.000	2.000	6.000	2.000	4.500	0.500	-0.500	-4.500	-2.000	-6.000	-2.000	-6.000	-3.500	-7.500
13	7.500	4.250	2.250	-1.000	2.500	-0.750	-2.750	-6.000	6.000	2.750	0.750	-2.500	1.000	-2.250	-4.250	-7.500
14	7.000	5.750	-1.000	-2.250	5.750	4.500	-2.250	-3.500	3.500	2.250	-4.500	-5.750	2.250	1.000	-5.750	-7.000
15	7.250	3.500	5.250	1.500	-0.500	-4.250	-2.500	-6.250	6.250	2.500	4.250	0.500	-1.500	-5.250	-3.500	-7.250
16	7.500	5.500	3.500	1.500	-0.500	-2.500	-4.500	-6.500	6.500	4.500	2.500	0.500	-1.500	-3.500	-5.500	-7.500
17	8.625	3.837	5.125	0.375	4.375	-0.375	0.875	-3.875	3.875	-0.875	0.375	-4.375	-0.375	-5.125	-3.875	-8.625
18	8.000	1.500	2.500	-4.000	5.250	-1.250	-0.250	-6.750	6.750	0.250	1.250	-5.250	4.000	-2.500	-1.500	-8.000
19	7.000	4.500	4.500	2.000	-1.000	-3.500	-3.500	-6.000	6.000	3.500	3.500	1.000	-2.000	-4.500	-4.500	-7.000
20	7.750	4.000	5.750	2.000	0.750	-3.000	-1.125	-5.000	5.000	1.250	3.000	-0.750	-2.000	-3.750	-4.000	-7.750
21	7.500	3.500	-0.500	-4.500	6.500	2.500	-1.500	-5.500	5.500	1.500	-2.500	-6.500	4.500	0.500	-3.500	-7.500
22	8.000	1.000	5.500	-1.500	6.500	-0.500	4.000	-3.000	3.000	-4.000	0.500	-6.500	1.500	-5.500	-1.000	-8.000
23	7.500	3.500	-0.500	-4.500	6.500	2.500	-1.500	-5.500	5.500	1.500	-2.500	-6.500	4.500	0.500	-3.500	-7.500
24	7.125	3.125	5.375	1.375	6.625	2.625	4.875	0.875	-0.875	-4.875	-2.625	-6.625	-1.375	-5.375	-3.125	-7.125
25	8.250	6.250	1.500	-0.500	4.250	2.250	-2.500	-4.500	4.500	2.500	-2.250	-4.250	0.500	-1.500	-6.250	-8.250
26	7.375	4.625	4.375	1.625	6.375	3.625	3.375	0.625	-0.625	-3.375	-3.625	-6.375	-1.625	-4.375	-4.625	-7.375
27	7.375	3.375	5.375	1.375	6.625	2.625	4.625	0.625	-0.625	-4.625	-2.625	-6.625	-1.375	-5.375	-3.375	-7.375
28	7.500	5.750	-0.500	-2.250	5.000	3.250	-3.000	-4.750	4.750	3.000	-3.250	-5.000	2.250	0.500	-5.750	-7.500
29	7.500	5.750	-0.500	-2.250	3.500	1.750	-4.500	-6.250	6.250	4.500	-1.750	-3.500	2.250	0.500	-5.750	-7.500
30	7.500	6.000	-0.500	-2.000	3.500	2.000	-4.500	-6.000	6.000	4.500	-2.000	-3.500	2.000	0.500	-6.000	-7.500
MEAN	7.506	4.042	3.155	-0.387	3.931	0.387	-0.495	-4.043	4.043	0.500	-0.387	-3.931	0.387	-3.155	-4.043	-7.506
VARIANCE	0.164	3.817	6.144	6.688	7.573	7.538	9.288	6.150	6.150	9.295	7.538	7.573	6.688	6.144	3.817	0.164

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All twenty-nine subjects considered airport I (i.e., information was requested about I) and twenty-nine considered airports E and K. The frequency of consideration decreases for airports further away. The number of times each airport was chosen as an airport to which to divert in this scenario is given in Table VI-12. The most popular choice was airport N.

Each pilot's search pattern was analysed in an attempt to determine the search and decision logic used when seeking information. Though many pilots displayed definite search patterns, determination of a decision rule was not possible for two reasons. The first is that many pilots reverted to standard ATC information exchange formats. In requesting weather information, for example, they would always request "ceiling" before "visibility" as in the format for such data in weather reports. The second reason is that many pilots estimated bearings and distances directly from the chart, and hence they had information for which no record of request was made.

Some interesting observations can be made, however, when a comparison is made between the results of the ranking task and the information search task. Table VI-13 lists the pilots whose most important attributes were ATC, time, weather, and approach aids, respectively.

Airports N and J were the only ones chosen in the group of pilots who considered "time" to be the most important attribute. Airports N and J are in the top half of the airports ranked according to closeness in terms of time. Pilots who considered other attributes to be the most important, however, chose a much broader range of airports. Pilots in the group who considered

Table VI-12. The Number of Times Each Airport Was Chosen as a Diversion Airport

Airport	Number of Pilots
N	10
J	8
O	3
C	3
A	2
P	2
E	1
M	1
	30

Table VI-13. Most Important Attribute for Pilots
(Subject Numbers Shown)

ATC	Weather	Time	Approach
S7	S8	S1	S5
S9	S10	S2	S6
S11	S13	S3	S12
S17	S14	S16	S24
S18	S21	S17	S26
S22	S23	S19	S27
	S25	S20	
	S28		
	S29		
	S30		

weather to be the most important attribute chose airports A, C, J, M, N, O, P; pilots who thought ATC to be most important chose airports O, N, J, E, and pilots who thought Approach Aids were most important chose airports A, C, J, N. The same trends were apparent in the airports considered by pilots in each group. The general interpretation is that pilots who placed most emphasis on "time" did not venture as far to find a suitable airport as did pilots with other priorities. Pilots who placed emphasis on an attribute other than time, on the other hand, either were forced to search continually for airports with better conditions (and maybe further away), or felt that time was not a serious issue and searches of airports further away were feasible.

H. Analysis of P & P Tests (All Phases)

Since the two major phases of the P & P tests yielded almost ninety measures on each subject (both raw data and derived measures) it became necessary to develop an overall analysis strategy to derive the maximum amount of useful information from such data. Note that the data was divided into four basic categories: The Diagnostic Phase Data, the Decision Phase Data, the Subject Biographical Data and Knowledge Data. Those data bases were individually analyzed for descriptive statistics and derived measures of performance.

In the diagnostic phase the raw data included (for each scenario and for all scenarios) merit, correctness score, efficiency, total inquiries, total unique tracks, total tracks, criticality assessments before and after the diagnosis, use of control inputs and derived measur 7 (correct score/total tracks) and CORINQT (correct score/total inquiries). These variables are defined in the glossary.

For the diagnostic phase, means and variances of these measures both for each subject across the four scenarios and for all subject across each scenario were reported in the Master Data Table (Table VI-14). In addition, the distribution of these data was examined for outliers. Rank correlations were examined to find associative relationships (see Table VI-15). These data were then used in the combined data analysis which is described below.

The decision phase data included subject airport rankings, information seeking profiles, go/no go responses before the flight and the number of airports the subject was willing to pass to locate an aircraft mechanic. As described above, conjoint measurement analysis was employed on the ranking data to derive worth functions. These were expressed as pilot weightings for weather (WX), navigation aids (APP), radar services (ATC), and time to the airport (TIM) (see Glossary). The decision phase data were then used in the combined analysis.

The third major data base involved subject biographical and knowledge data. These are shown in Table VI-14. These data were subjected to descriptive statistical analysis and transformations to adjust for outliers in distributions. Table VI-14 describes the findings from the knowledge and biographical data.

The main thrust was the combined analysis of diagnostic data, decision phase data, and knowledge and biographical data. Sections H, J, and K which

Table VI-14. Master Data Table

STATISTICAL ANALYSIS SYSTEM

SUBJECT	KNOWLEDG	TOTHRS	SEHRS	IFRHRS	RATING	TRAINING	FLYING	ATC	WX	TIM	APP	CATSCR1	CATSCR2	CATSCR3
1	9	160	160	15	1	2	5	1.000	2.000	4.000	0.500	2	4	3
2	16	2500	1800	270	3	2	3	2.000	0.750	4.000	0.625	5	4	5
3	8	6000	2000	300	3	1	4	0.500	1.000	4.000	2.000	1	3	4
4	5	4000	400	1000	2	1	4	1.375	2.375	-0.500	1.625	3	2	0
5	16	2000	2000	1500	1	2	3	1.125	2.375	2.000	2.875	6	4	6
6	14	1400	400	800	2	2	1	0.500	1.000	2.000	4.000	4	6	4
7	15	1800	1500	500	2	2	5	4.000	1.500	1.500	0.250	6	5	4
8	15	1088	1088	221	2	2	5	1.250	4.000	0.625	1.625	5	5	5
9	9	800	800	200	1	2	5	2.500	2.375	0.625	2.375	4	3	2

SUBJECT	I1	TT1	UT1	C1	E1	M1	CB1	CA1	I2	TT2	UT2	C2	E2	M2	CB2	CA2	I3	TT3	UT3	C3	E3	M3	CB3
1	6	2	2	5	16	80	1	1	4	2	2	5	15	75	4	4	13	5	5	0	5	0	6
2	7	1	1	2	12	24	3	1	4	2	2	5	22	110	2	1	6	4	3	5	17	85	1
3	3	1	1	2	19	38	7	1	8	3	3	5	11	55	3	3	11	3	3	0	8	0	7
4	3	1	1	2	19	38	5	1	15	8	4	5	4	20	5	5	6	2	2	5	19	95	2
5	6	2	2	5	13	65	3	3	7	3	3	0	12	0	1	1	11	3	3	0	8	0	5
6	6	3	2	0	13	0	6	2	9	4	4	5	9	45	3	3	4	2	2	5	21	105	3
7	6	1	1	2	15	30	6	3	8	2	2	5	15	75	2	2	14	4	4	5	8	40	3
8	13	7	2	2	6	12	5	2	12	4	3	0	7	0	1	3	4	2	2	5	21	105	6
9	9	1	1	0	11	0	6	6	11	8	3	0	8	0	1	1	6	1	1	0	14	0	5

SUBJECT	CA3	I4	TT4	UT4	C4	E4	M4	CB4	CA4	TOTINQ	TOTTRAKS	TOTUTRKS	TOTCOR	TOTEFF	TOTMERIT	TCRITBEF	TCRITAFT	THRSLOG	SEHRSLOG
1	2	12	8	6	5	8	40	2	2	35	17	15	15	44	195	13	9	5.07517	5.07517
2	1	7	4	4	5	18	90	2	1	24	11	10	17	69	309	8	4	7.824[illegible]5	7.49554
3	3	12	6	5	5	8	40	3	3	34	13	12	12	46	133	20	10	8.69951	7.60090
4	2	8	3	3	3	9	27	2	2	32	14	10	15	51	180	14	10	8.29405	5.99146
5	5	5	2	2	5	19	95	1	1	29	10	10	10	52	160	10	10	7.60090	7.60090
6	3	7	3	3	5	16	80	2	2	26	12	11	15	59	230	14	10	7.24423	5.99146
7	3	6	2	2	5	17	85	2	2	34	9	9	17	55	230	13	10	7.49554	7.31322
8	6	9	4	3	5	12	60	3	2	38	17	10	12	46	177	15	13	6.99210	6.99210
9	5	15	8	6	5	4	20	1	1	41	18	11	5	37	20	13	13	6.68461	6.68461

SUBJECT	MECH	CNTRL1	CNTRL2	CNTRL3	CNTRL4	CAT	CATK1	CATK2	CATK3	CATK4	CATK5	CATK6	CATKT	CONOCO	AIRPORTS	ACE	RECENCY	CNTRLTOT
1	0	0	2	3	4	0	.	.	.	.	.	.	.	1	4	2	3	9
2	0	0	0	3	0	0	.	.	.	.	.	.	.	0	1	2	1	3
3	0	0	2	2	2	0	.	.	.	.	.	.	.	1	3	2	1	6
4	0	2	3	3	3	0	.	.	.	.	.	.	.	0	2	3	3	11
5	0	0	2	2	2	0	.	.	.	.	.	.	.	1	2	3	1	6
6	0	3	5	3	2	0	.	.	.	.	.	.	.	1	4	1	3	13
7	0	0	0	6	2	0	.	.	.	.	.	.	.	0	1	2	1	8
8	0	2	3	2	2	0	.	.	.	.	.	.	.	1	8	2	1	9
9	0	4	3	3	2	0	.	.	.	.	.	.	.	0	8	3	1	12

Table VI-14. Master Data Table (con't.)

S T A T I S T I C A L   A N A L Y S I S   S Y S T E M

SUBJECT	PROPCON1	PROPCON2	PROPCON3	PROPCON4	PROPCONT	INPTR1	INPTR2	INPTR3	INPTR4	INPTRT	DIF1	DIF2	DIF3	DIF4	DIFT	Z1	Z2
1	0.000000	0.500000	0.230769	0.333333	0.257143	3.00000	2.00000	2.60000	1.50000	2.05882	0	0	0	2	2	2.50000	2.50000
2	0.000000	0.000000	0.500000	0.000000	0.125000	7.00000	2.00000	1.50000	1.75000	2.18182	0	0	1	0	1	2.00000	2.50000
3	0.000000	0.250000	0.181818	0.166667	0.176471	3.00000	2.66667	3.66667	2.00000	2.61538	0	0	0	1	1	2.00000	1.66667
4	0.666667	0.200000	0.500000	0.375000	0.343750	3.00000	1.87500	3.00000	2.66667	2.28571	0	4	0	0	4	2.00000	0.62500
5	0.000000	0.285714	0.181818	0.400000	0.206897	3.00000	2.33333	3.66667	2.50000	2.90000	0	0	0	0	0	2.50000	0.00000
6	0.500000	0.535556	0.750000	0.285714	0.500000	2.00000	2.25000	2.00000	2.33333	2.16667	1	0	0	0	1	0.00000	1.25000
7	0.000000	0.000000	0.428571	0.333333	0.235294	6.00000	4.00000	3.50000	3.00000	3.77778	0	0	0	0	0	2.00000	2.50000
8	0.153846	0.250000	0.500000	0.222222	0.236842	1.85714	3.00000	2.00000	2.25000	2.23529	5	1	0	1	7	0.28571	0.00000
9	0.444444	0.272727	0.500000	0.133333	0.292683	9.00000	1.37500	6.00000	1.87500	2.27778	0	5	0	2	7	0.00000	0.00000

SUBJECT	Z3	Z4	ZT	CORINQ1	CORINQ2	CORINQ3	CORINQ4	CORINQT	DELTAC1	DELTAC2	DELTAC3	DELTAC4	TDELTAC	S	TM	TC	TE	SHRSRANK	T	AP	LATELY	THRSRANK	RATSCORE	YOUNGOLD	SUB	FLY	INFR	KNOW
1	0.00000	0.62500	0.88235	0.833333	1.25000	0.00000	0.41667	0.428571	0	0	-4	0	-4	.	.	.	.	0	1	1	1	0	0	.	0	1	0	0
2	1.25000	1.25000	1.54545	0.285714	1.25000	0.83333	0.71429	0.708333	-2	-1	0	-1	-4	.	1	1	1	.	1	0	0	.	1	.	0	0	.	1
3	0.00000	0.83333	0.92308	0.666667	0.62500	0.00000	0.41667	0.352941	-6	0	-4	0	-10	.	.	.	.	.	1	1	0	1	1	.	0	0	.	0
4	2.50000	1.00000	1.07143	0.666667	0.33333	0.83333	0.37500	0.468750	-4	0	0	0	-4	.	.	.	.	0	0	0	1	.	1	1	0	0	1	0
5	0.00000	2.50000	1.00000	0.833333	0.00000	0.00000	1.00000	0.344828	0	0	0	0	0	.	.	0	.	.	1	0	0	.	0	1	0	0	1	1
6	2.50000	1.66667	1.25000	0.000000	0.55556	1.25000	0.71429	0.576923	-4	0	0	0	-4	.	.	.	1	0	1	1	1	.	1	0	0	0	1	.
7	1.25000	2.50000	1.88889	0.333333	0.62500	0.35714	0.83333	0.500000	-3	0	0	0	-3	.	.	1	.	.	.	0	0	.	1	.	0	1	.	.
8	2.50000	1.25000	0.70588	0.153846	0.00000	1.25000	0.55556	0.315789	-3	2	0	-1	-2	.	.	.	.	.	0	1	0	.	1	.	0	1	.	.
9	0.00000	0.62500	0.27778	0.000000	0.00000	0.00000	0.33333	0.121951	0	0	0	0	0	.	0	0	0	.	0	1	0	0	0	1	0	1	.	0

Table VI-14. Master Data Table (con't.)

STATISTICAL ANALYSIS SYSTEM

SUBJECT	KNOWLEDG	TOTHRS	SEHRS	IFRHRS	RATING	TRAINING	FLYING	ATC	WX	TIM	AP	CATSCR1	CATSCR2	CATSCR3	I1	TT1	UT1	CE1	E1	M1	CB1	CA1	I2	TT2	UT2	CE2	E2	M2	CB2	CA2	I3	TT3	UT3	CE3	E3	M3	CB3
10	12	2100	1700	450	1	2	3	2.500	3.375	0.750	1.875	6	4	2	4	1	1	2	21	42	6	2	8	2	2	5	16	80	1	1	16	6	4	5	7	35	1
11	13	5000	4000	250	2	2	3	4.000	0.750	0.625	1.750	7	4	2	7	1	1	2	12	24	6	6	9	5	4	5	10	50	6	6	12	5	3	0	7	0	4
12	7	15000	1500	2300	2	1	3	2.000	0.750	0.750	4.000	2	3	2	6	3	3	2	14	28	6	3	9	5	3	0	10	0	1	4	5	2	2	5	20	100	4
13	13	19400	10000	2500	3	2	2	1.625	2.625	2.500	0.750	5	4	4	6	1	1	2	17	34	6	1	11	6	3	0	9	0	7	7	5	2	2	5	21	105	2
14	15	2500	2500	250	2	2	3	0.625	4.000	0.625	1.750	7	4	4	3	1	1	2	16	32	6	3	11	4	[illegible]	0	8	0	1	2	10	2	2	5	14	70	3
15	13	510	510	100	1	2	5	1.875	1.000	3.875	0.500	5	2	6	10	5	2	2	9	18	7	3	8	4	3	5	13	65	6	6	9	4	4	5	13	65	5
16	17	1650	1000	200	2	2	2	1.000	2.000	4.000	0.500	7	5	5	6	2	2	5	16	80	3	2	3	2	2	5	19	95	6	6	10	4	4	0	9	0	7
17	15	980	860	120	2	2	2	2.375	1.750	2.125	2.375	6	6	3	7	2	2	2	12	24	5	2	3	3	3	5	22	110	4	4	11	5	4	5	8	40	6
18	16	1960	1700	250	3	2	2	3.250	2.750	1.375	0.625	6	5	5	7	2	2	3	12	36	5	3	11	3	3	5	10	50	3	3	6	2	2	5	17	85	4

SUBJECT	CA3	I4	TT4	UT4	CE4	E4	M4	CB4	CA4	TOTINQ	TOTTRAKS	TOTUTRKS	TOTCOR	TOTEFF	TOTMERIT	TCRITBEF	TCRITAFT	THRSLOC	SEHRSLOC	MECH	CNTRLL1	CNTRLL2	CNTRLL3	CNTRLL4	CAT	CATK1	CATK2	CATK3	CATK4	CATK5	CATK6	CATKT	CONOCO	AIRPORTS	ACE
10	1	9	3	3	5	15	75	1	1	37	12	10	17	59	232	9	5	7.64969	7.43838	0	0	2	4	2	0	.	.	.	.	.	.	.	1	4	1
11	4	8	2	2	3	11	33	3	3	36	13	10	10	40	107	19	19	8.51719	8.29405	0	3	3	5	3	1	6.30	7.0	3.34	3.01	4.90	5	5.02	0	3	3
12	4	8	3	3	0	11	0	2	4	28	13	11	7	55	128	13	15	9.61581	7.31322	0	0	3	4	3	0	.	.	.	.	.	.	.	1	5	3
13	2	9	4	3	5	9	45	5	5	31	13	9	12	56	184	20	15	9.87303	9.21034	0	0	4	3	2	0	.	.	.	.	.	.	.	1	2	3
14	3	11	5	4	5	8	40	1	1	35	12	10	12	46	142	11	9	7.82405	7.82405	0	0	2	8	1	0	.	.	.	.	.	.	.	1	3	3
15	5	16	9	6	2	3	6	4	4	43	22	15	14	38	154	22	18	6.23441	6.23441	0	2	0	2	2	0	.	.	.	.	.	.	.	1	3	3
16	6	5	1	1	5	18	90	5	2	24	9	9	15	62	265	21	16	7.40853	6.90776	0	0	2	3	2	0	.	.	.	.	.	.	.	1	3	1
17	2	3	2	2	5	22	110	1	1	24	12	11	17	64	284	16	9	6.88755	6.75693	0	1	0	4	2	0	.	.	.	.	.	.	.	1	2	1
18	5	8	1	1	5	13	65	2	2	32	8	8	18	52	236	14	13	7.58070	7.43838	1	0	2	5	3	0	.	.	.	.	.	.	.	1	7	2

Table VI-14. Master Data Table (con't.)

STATISTICAL ANALYSIS SYSTEM

SUBJECT	RECENCY	CNTRLTOT	PROPCON1	PROPCON2	PROPCON3	PROPCON4	PROPCONT	INPTR1	INPTR2	INPTR3	INPTR4	INPTRT	DIFF1	DIFF2	DIFF3	DIFF4	DIFT	Z1	Z2
10	1	8	0.000000	0.250000	0.250000	0.222222	0.216216	4.0	4.00000	2.66667	3.00000	3.08333	0	0	2	0	2	2.00000	2.50000
11	3	14	0.428571	0.333333	0.416667	0.375000	0.388889	7.0	1.80000	2.40000	4.00000	2.76923	0	1	2	0	3	2.00000	1.00000
12	1	10	0.000000	0.333333	0.800000	0.375000	0.357143	2.0	1.80000	2.50000	2.66667	2.15385	0	2	0	0	2	0.66667	0.00000
13	1	9	0.000000	0.363636	0.600000	0.222222	0.290323	6.0	1.83333	2.50000	2.25000	2.38462	0	3	0	1	4	2.00000	0.00000
14	1	11	0.000000	0.181818	0.800000	0.090909	0.314286	3.0	2.75000	5.00000	2.20000	2.91667	0	1	0	1	2	2.00000	0.00000
15	1	6	0.200000	0.000000	0.222222	0.125000	0.139535	2.0	2.00000	2.25000	1.77778	1.95455	3	1	0	3	7	0.40000	1.25000
16	1	7	0.000000	0.666667	0.300000	0.400000	0.291667	3.0	1.50000	2.50000	5.00000	2.66667	0	0	0	0	0	2.50000	2.50000
17	1	7	0.142857	0.000000	0.363636	0.666667	0.291667	3.5	1.00000	2.20000	1.50000	2.00000	0	0	1	0	1	1.00000	1.66667
18	2	10	0.000000	0.181818	0.833333	0.375000	0.312500	3.5	3.66667	3.00000	8.00000	4.00000	0	0	0	0	0	1.50000	1.66667

SUBJECT	Z3	Z4	ZT	CORINQ1	CORINQ2	CORINQ3	CORINQ4	CORINQT	DELTAC1	DELTAC2	DELTAC3	DELTAC4	TDELTAC	S	TM	TC	TE	SHRSRANK	T	AP	LATELY	THRSRANK	RATSCORE	YOUNCOLD	SUB	FLY	IFR	KNOW
10	0.83333	1.66667	1.41667	0.50000	0.62500	0.31250	0.55556	0.459459	-4	0	0	0	-4	.	.	1	1	.	.	1	0	.	0	0	0	0	.	.
11	0.00000	1.50000	0.76923	0.28571	0.55556	0.00000	0.37500	0.277778	0	0	0	0	0	0	0	0	0	1	0	1	1	.	1	1	0	0	.	.
12	2.50000	0.00000	0.53846	0.33333	0.00000	1.00000	0.00000	0.250000	-3	3	0	2	2	.	0	0	.	.	.	1	0	1	1	1	0	0	1	0
13	2.50000	1.25000	0.92308	0.33333	0.00000	1.00000	0.55556	0.387097	-5	0	0	0	-5	.	.	.	.	1	1	0	0	1	1	1	0	0	1	.
14	2.50000	1.00000	1.00000	0.66667	0.00000	0.50000	0.45455	0.342857	-3	1	0	0	-2	.	.	.	.	1	0	1	0	.	1	1	0	0	.	.
15	1.25000	0.22222	0.63636	0.20000	0.62500	0.55556	0.12500	0.325581	-4	0	0	0	-4	.	.	.	0	.	1	1	0	0	0	1	0	1	0	.
16	0.00000	5.00000	1.66667	0.83333	1.66667	0.00000	1.00000	0.625000	-1	0	-1	-3	-5	.	1	.	1	.	1	1	0	.	1	0	0	0	.	1
17	1.00000	2.50000	1.41667	0.28571	1.66667	0.45455	1.66667	0.708333	-3	0	-4	0	-7	.	1	1	1	.	1	0	0	0	1	0	0	0	0	.
18	2.50000	5.00000	2.25000	0.42857	0.45455	0.83333	0.62500	0.562500	-2	0	1	0	-1	.	1	1	.	.	.	1	.	.	1	.	0	0	.	1

Table VI-14. Master Data Table (con't.)

STATISTICAL ANALYSIS SYSTEM

SUBJECT	KNOWLEDG	TOTHRS	SEHRS	IFRHRS	IRATINNG	TRAINING	FLYING	ATC	WX	TIM	AP	CATSCR1	CATSCR2	CATSCR3	I1	TT1	UTT1	C1	E1	M1	CBA1	CA1	I2	TT2	UTT2	C2	E2	M2	CBA2	CA2	I3	TT3	UTT3	C3	E3	M3	CBA3	CA3	I4
19	16	8000	3000	700	3	1	3	1.250	1.250	4.000	0.500	7	3	6	6	2	2	5	17	85	7	2	11	6	3	3	8	24	2	2	9	4	3	4	10	40	5	5	9
20	15	9000	2100	1750	3	2	1	1.875	1.000	3.500	1.375	6	4	5	7	1	1	2	13	26	5	5	15	5	3	0	4	0	1	1	17	5	5	5	3	45	4	4	5
21	14	5500	4000	500	2	1	3	2.000	4.000	0.500	1.000	6	3	5	5	2	2	5	19	95	5	5	5	4	3	5	18	90	2	2	10	5	4	5	12	60	2	2	11
22	12	485	410	250	2	2	3	3.500	1.250	0.750	2.500	6	2	4	3	1	1	2	17	34	5	2	3	2	2	0	15	0	1	2	5	2	2	5	18	90	4	6	6
23	11	300	300	20	2	2	5	2.000	4.000	0.500	1.000	2	5	4	7	2	2	5	11	55	4	4	6	6	2	0	13	0	7	3	13	6	3	0	6	0	7	5	12
24	6	3500	3300	280	1	2	5	2.000	0.875	0.250	4.000	3	2	1	10	4	2	0	9	0	6	2	11	3	3	5	8	40	1	1	13	3	3	0	6	0	2	2	12
25	13	6312	2001	540	2	1	2	1.000	3.375	2.000	1.875	5	3	5	5	1	1	5	15	60	5	5	10	2	2	5	9	45	5	5	9	4	4	5	12	60	4	4	9
26	10	2260	900	330	3	2	3	1.375	1.500	0.500	4.000	5	2	3	10	2	2	2	9	18	5	4	16	7	4	0	3	0	7	7	18	8	5	5	3	15	4	4	17
27	14	7000	5000	250	3	2	2	2.000	1.000	0.375	4.000	5	4	5	8	2	2	2	13	22	7	7	7	4	1	5	14	70	3	3	8	3	3	5	13	65	5	5	8

SUBJECT	TT4	UTT4	C4	E4	M4	CBA4	CA4	TOTINQ	TOTTRAKS	TOTUTRKS	TOTCOR	TOTEFF	TOTMERIT	TCRITBEF	TCRITAFT	THRSLOC	SEHRSLOC	MECH	CNTRL1	CNTRL2	CNTRL3	CNTRL4	CAT	CATK1	CATK2	CATK3	CATK4	CATK5	CATK6	CATKT	CONOCO	AIRPORTS	ACE	RECENCY
19	4	4	5	10	50	5	5	35	16	12	17	45	199	19	14	8.98720	8.00637	0	0	4	1	1	0	.	.	.	.	.	.	.	0	4	3	2
20	2	2	5	20	100	3	3	44	13	11	12	40	171	13	13	9.10498	7.64969	0	1	1	6	1	0	.	.	.	.	.	.	.	0	1	2	1
21	7	5	5	8	40	4	1	31	18	14	20	57	285	13	10	8.61250	8.29405	0	0	1	5	3	0	.	.	.	.	.	.	.	1	8	3	1
22	4	4	5	13	65	2	1	17	9	9	12	63	189	12	11	6.18415	6.01616	0	0	2	4	2	0	.	.	.	.	.	.	.	1	2	3	2
23	6	3	2	7	14	6	3	38	20	10	7	37	69	24	15	5.70378	5.70378	0	0	2	2	1	0	.	.	.	.	.	.	.	0	14	1	1
24	5	3	0	7	0	1	1	46	15	11	5	30	40	10	6	8.16052	8.10168	0	1	2	2	3	0	.	.	.	.	.	.	.	1	4	3	2
25	4	4	5	12	60	3	3	33	11	11	20	48	225	17	17	8.75021	7.60140	0	1	3	5	3	0	.	.	.	.	.	.	.	1	4	2	1
26	6	5	2	2	4	3	3	61	23	16	9	17	37	19	18	7.72312	6.00239	0	2	2	6	2	0	.	.	.	.	.	.	.	1	4	1	1
27	3	3	5	11	55	7	7	31	12	9	17	51	212	22	22	8.85367	8.51719	0	0	0	2	2	0	.	.	.	.	.	.	.	1	3	2	1

Table VI-14. Master Data Table (con't.)

STATISTICAL ANALYSIS SYSTEM

SUBJECT	CNTRLTOT	PROPCON1	PROPCON2	PROPCON3	PROPCON4	PROPCONT	INPTR1	INPTR2	INPTR3	INPTR4	INPTRT	DIF1	DIF2	DIF3	DIF4	DIFT	Z1	Z2
19	6	0.000000	0.363636	0.11111	0.111111	0.171429	3.00000	1.83333	2.25000	2.25000	2.18750	0	3	1	0	4	2.50000	0.50000
20	9	0.142857	0.066667	0.35294	0.200000	0.204545	7.00000	3.00000	3.40000	2.50000	3.38462	0	2	0	0	2	2.00000	0.00000
21	9	0.000000	0.200000	0.50000	0.272727	0.290323	2.50000	1.25000	2.00000	1.57143	1.72222	0	1	1	2	4	2.50000	1.25000
22	8	0.000000	0.666667	0.80000	0.333333	0.470588	3.00000	1.50000	2.50000	1.50000	1.88889	0	0	0	0	0	2.00000	0.00000
23	5	0.000000	0.333333	0.15385	0.083333	0.131579	3.50000	1.00000	2.16667	2.00000	1.90000	0	4	3	3	10	2.50000	0.00000
24	8	0.100000	0.181818	0.15385	0.250000	0.173913	2.50000	3.66667	4.33333	2.40000	3.06667	2	0	0	2	4	0.00000	1.66667
25	12	0.200000	0.300000	0.55556	0.333333	0.363636	5.00000	5.00000	2.25000	2.25000	3.00000	0	0	0	0	0	5.00000	2.50000
26	12	0.200000	0.125000	0.33333	0.117647	0.196721	5.00000	2.28571	2.25000	2.83333	2.65217	0	3	3	1	7	1.00000	0.00000
27	4	0.000000	0.000000	0.25000	0.250000	0.129032	4.00000	1.75000	2.66667	2.66667	2.58333	0	3	0	0	3	1.00000	1.25000

SUBJECT	Z3	Z4	ZT	CORINQ1	CORINQ2	CORINQ3	CORINQ4	CORINQT	DELTAC1	DELTAC2	DELTAC3	DELTAC4	TDELTAC	S	TM	TC	TE	SHRSRANK	T	AP	LATELY	THRSRANK	RATSCORE	YOUNGOLD	SUB	FLY	INFOR	KNOW
19	1.00000	1.25000	1.06250	0.83333	0.27273	0.44444	0.55556	0.48571	-5	0	0	0	-5	.	.	1	.	1	1	1	.	1	1	1	0	0	1	1
20	1.00000	2.50000	0.92308	0.28571	0.00000	0.29412	1.00000	0.27273	0	0	0	0	0	.	.	.	0	1	1	0	0	1	1	.	0	0	1	.
21	1.00000	0.71429	1.11111	1.00000	1.00000	0.50000	0.45455	0.64516	0	0	0	-3	-3	.	1	1	.	1	0	1	0	1	1	1	0	0	.	.
22	2.50000	1.25000	1.33333	0.66667	0.00000	1.00000	6.83333	0.70588	-3	1	2	-1	-1	.	.	.	1	0	.	0	.	0	1	1	0	0	.	.
23	0.00000	0.33333	0.35000	0.71429	0.00000	0.00000	0.16667	0.18421	0	-4	-2	-3	-9	.	0	0	0	0	0	1	0	0	1	0	0	1	0	.
24	0.00000	0.00000	0.33333	0.00000	0.45455	0.00000	0.00000	0.10870	-4	0	0	0	-4	.	0	0	0	1	0	1	.	.	0	1	0	1	.	0
25	1.25000	1.25000	1.81818	1.00000	0.50000	0.55556	0.55556	0.60606	0	0	0	0	0	.	.	1	.	.	1	1	0	1	1	.	0	0	.	.
26	0.62500	0.33333	0.39130	0.20000	0.00000	0.27778	0.11765	0.14754	-1	0	0	0	-1	.	0	0	0	.	0	1	0	.	1	0	0	0	.	.
27	1.66667	1.66667	1.41667	0.25000	0.71429	0.62500	0.62500	0.54839	0	0	0	0	0	.	.	1	.	1	0	1	0	1	1	.	0	0	.	.

Table VI-14. Master Data Table (con't.)

STATISTICAL ANALYSIS SYSTEM

SUBJECT	KNOWLEDG	TOTHRS	SEHRS	IFRHRS	RATING	TRAINING	FLYING	ATC	WX	TIM	APF	CATSCR1	CATSCR2	CATSCR3	I1	TT1	UT1	C1	E1	M1	CB1	CA1	I2	TT2	UT2	C2	E2	M2	CB2	CA2	I3	TT3	UT3	C3	E3	M3	CB3	CA3
28	10	338	318	162	1	2	4	0.875	4.000	1.250	1.375	3	3	4	10	2	2	5	11	55	2	2	10	2	2	5	9	45	4	4	10	3	3	0	9	0	6	1
29	12	648	595	32	2	2	2	0.875	4.000	2.000	0.625	3	4	5	8	2	2	2	13	26	3	5	12	5	4	5	11	55	3	3	5	2	2	5	21	105	5	5
30	10	2500	200	500	2	1	4	0.750	4.000	2.000	0.750	4	3	3	2	1	1	2	23	46	7	7	6	4	3	0	13	0	4	4	12	5	4	0	7	0	5	3
31	16	1800	1550	150	3	2	2	0.750	0.750	2.000	4.000	7	4	5	7	1	1	0	12	0	1	2	5	2	2	5	19	95	4	4	9	3	3	5	14	70	3	3
32	15	5000	4000	250	2	2	2	0.250	1.125	1.375	4.000	6	5	4	6	1	1	5	13	65	4	4	9	3	3	5	10	50	7	7	5	2	2	5	14	70	5	5
33	13	8700	1500	650	3	1	4	1.500	4.000	0.500	1.500	6	3	4	7	1	1	2	16	32	7	.	12	3	2	0	9	0	7	3	7	2	2	5	19	93	3	3
34	9	1500	500	400	2	1	3	2.000	4.000	0.500	0.500	5	3	1	7	1	1	2	16	24	6	3	8	2	2	0	11	0	3	4	15	9	5	0	4	0	7	3
35	7	485	485	61	1	2	5	2.000	1.000	0.500	4.000	2	2	3	4	2	2	5	20	100	6	6	11	5	4	0	8	0	7	3	16	6	4	5	3	15	4	2
36	15	3000	2000	300	2	2	2	3.750	1.125	2.000	1.125	5	5	5	3	1	1	5	21	105	1	1	5	2	2	5	17	85	6	6	14	6	4	5	6	28	5	5

SUBJECT	I4	TT4	UT4	C4	E4	M4	CB4	CA4	TOTINQ	TOTTRAKS	TOTUTRKS	TOTCOR	TOTEFF	TOTMERIT	TCRITBEF	TCRITAF?	THRSLOG	SEHRSLOG	MECH	CNTRL1	CNTRL2	CNTRL3	CNTRL4	CAT	CATK1	CATK2	CATK3	CATK4	CATK5	CATK6	CATKT	CONOCO	AIRPORTS	ACE	RECENCY
28	9	3	3	5	12	60	1	1	39	10	10	15	41	160	13	8	5.82305	5.76205	0	0	2	2	2	1	3.15	3.50	3.18	3.94	5.95	3.00	3.79	1	5	2	1
29	15	8	5	3	5	15	7	2	40	17	13	15	50	201	18	15	6.47389	6.38856	0	0	1	2	1	0	.	.	.	.	.	.	.	1	9	1	1
30	8	4	3	3	12	36	5	5	28	14	11	5	55	82	21	19	7.82405	5.29832	0	0	1	4	0	0	.	.	.	.	.	.	.	0	1	2	3
31	7	3	2	5	16	80	3	3	28	9	8	15	61	245	11	12	7.49554	7.34601	0	0	0	2	1	1	5.43	5.25	5.41	5.03	5.25	6.50	5.56	1	4	1	1
32	2	1	1	3	17	51	1	1	22	7	7	18	54	236	17	17	8.51719	8.29405	0	0	2	2	1	1	4.90	7.00	6.36	4.94	6.30	5.50	5.00	1	4	2	1
33	14	6	5	5	8	39	3	3	40	12	10	12	52	164	20	.	9.07108	7.31322	1	2	2	2	2	1	6.86	6.16	4.62	4.41	5.95	5.75	5.63	1	1	2	1
34	6	3	3	5	19	93	3	3	36	15	11	7	50	117	19	13	7.31322	6.21461	0	2	2	4	2	1	5.13	5.68	4.13	3.23	3.15	5.00	4.39	1	3	2	2
35	13	5	4	5	11	57	2	2	44	18	14	15	42	172	19	13	6.18415	6.18415	0	0	2	4	4	1	2.80	5.25	4.77	1.53	2.10	2.25	3.12	1	4	2	2
36	12	6	4	5	8	40	2	2	30	15	11	20	52	258	14	14	8.00637	7.60090	1	0	2	8	1	0	.	.	.	.	.	.	.	1	7	3	2

Table VI-14. Master Data Table (con't.)

STATISTICAL ANALYSIS SYSTEM

SUBJECT	CNTRLTOT	PROPCON1	PROPCON2	PROPCON3	PROPCON4	PROPCONT	INPTR1	INPTR2	INPTR3	INPTR4	INPTRT	DIFF1	DIFF2	DIFF3	DIFF4	DIFFT	Z1	Z2
28	6	0.000000	0.200000	0.20000	0.222222	0.153846	5.00000	5.00000	3.33333	3.00000	3.90000	0	0	0	0	0	2.50000	2.50000
29	4	0.000000	0.083333	0.40000	0.066667	0.100000	4.00000	2.40000	2.50000	1.87500	2.35294	0	1	0	3	4	1.00000	1.00000
30	5	0.000000	0.166667	0.33333	0.000000	0.178571	2.00000	1.50000	2.40000	2.00000	2.00000	0	1	1	1	3	2.00000	0.00000
31	3	0.000000	0.000000	0.22222	0.142857	0.107143	7.00000	2.50000	3.00000	2.33333	3.11111	0	0	0	1	1	0.00000	2.50000
32	5	0.000000	0.222222	0.40000	0.500000	0.227273	6.00000	3.00000	2.50000	2.00000	3.14286	0	0	0	0	0	5.00000	1.66667
33	8	0.285714	0.166667	0.28571	0.142857	0.200000	7.00000	4.00000	3.50000	2.33333	3.33333	0	1	0	1	2	2.00000	0.00000
34	10	0.285714	0.250000	0.26667	0.333333	0.277778	7.00000	4.00000	1.66667	2.00000	2.40000	0	0	4	0	4	2.00000	0.00000
35	10	0.000000	0.181818	0.25000	0.307692	0.227273	2.00000	2.20000	2.66667	2.60000	2.44444	0	1	2	1	4	2.50000	0.00000
36	11	0.000000	0.400000	0.57143	0.083333	0.323529	3.00000	2.50000	2.33333	2.00000	2.26667	0	0	2	2	4	5.00000	2.50000

SUBJECT	Z3	Z4	ZT	CORINQ1	CORINQ2	CORINQ3	CORINQ4	CORINQT	DELTAC1	DELTAC2	DELTAC3	DELTAC4	TDELTAC	S	TM	TC	TE	SHRSRANK	T	AP	LATELY	THRSRANK	RATSCORE	YOUNGOLD	SUB	FLY	INFR	KNOW
28	0.00000	1.66667	1.50000	0.50000	0.50000	0.00000	0.55556	0.38462	0	0	-5	0	-5	1	.	.	0	0	.	1	0	0	0	.	0	0	0	.
29	2.50000	0.37500	0.88235	0.25000	0.41667	1.00000	0.20000	0.37500	2	0	0	-5	-3	.	.	.	.	.	1	1	0	0	1	0	0	0	0	.
30	0.00000	0.75000	0.35714	1.00000	0.00000	0.00000	0.37500	0.17857	0	0	-2	0	-2	.	0	0	.	0	1	0	1	.	1	.	0	0	.	.
31	1.66667	1.66667	1.66667	0.00000	1.00000	0.55556	0.71429	0.53571	1	0	0	0	1	0	1	.	1	.	1	1	0	.	1	0	1	0	0	1
32	2.50000	3.00000	2.57143	0.83333	0.55556	1.00000	1.50000	0.81818	0	0	0	0	0	0	1	1	.	1	.	1	0	.	1	.	1	0	.	.
33	2.50000	0.83333	1.00000	0.28571	0.00000	0.71429	0.35714	0.30000	.	-4	0	0	.	0	.	.	.	.	0	0	0	1	1	.	1	0	.	.
34	0.00000	1.66667	0.46667	0.28571	0.00000	0.00000	0.83333	0.19444	-3	1	-4	0	-6	1	0	0	.	.	0	1	.	.	1	.	1	0	.	0
35	0.83333	1.00000	0.83333	1.25000	0.00000	0.31250	0.38462	0.34091	0	-4	-2	0	-6	1	.	.	0	0	0	1	.	0	0	.	1	1	0	0
36	0.83333	0.83333	1.33333	1.66667	1.00000	0.35714	0.41667	0.58824	0	0	0	0	0	.	1	1	.	.	1	1	.	.	1	1	1	0	.	.

Table VI-14. Master Data Table (con't.)

STATISTICAL ANALYSIS SYSTEM

SUBJECT	KNOWLEDC	TOTHES	SEHRS	IFRHRS	RATINC	TRAINNCC	FLYINC	ATC	WIX	TIM	AP	CATSCR1	CATSCR2	CATSCR3	I1	TT1	UT1	C1	E1	M1	CB1	CA1	I2	TT2	UT2	C2	E2	M2	CB2	CA2	I3	TT3	UT3	C3	E3	M3	CB3	CA3
37	17	2500	2000	200	3	2	2	0.50	4	1.50	1.50	5	7	5	4	1	1	0	15	0	4	4	2	1	1	3	24	72	5	5	3	2	2	5	23	113	6	6
38	7	3000	250	750	2	1	4	1.50	4	1.25	0.75	2	2	3	14	3	2	2	5	10	7	7	11	3	3	0	8	0	4	4	11	6	4	0	8	0	5	2
39	13	180	125	3	1	2	5	0.25	3	1.75	2.75	6	4	3	3	1	1	5	22	108	7	3	7	2	2	0	12	0	6	5	6	3	3	5	15	77	3	7
40	16	12000	8000	1200	3	2	2	.	.	.	.	7	4	5	4	1	1	2	16	32	6	1	10	7	5	5	9	45	1	1	9	7	4	0	10	0	6	5

SUBJECT	I4	TT4	UT4	C4	E4	M4	CB4	CA4	TOTINQ	TOTTRAKS	TOTUTRKS	TOTCOR	TOTEFF	TOTMERIT	TCRITBEF	TCRITAFT	THRSLOG	SEHRSLOG	MECH	CNTRL1	CNTRL2	CNTRL3	CNTRL4	GAT	GATK1	GATK2	GATK3	GATK4	GATK5	GATK6	GATKT	CUNOCO	AIRPORTS
37	4	1	1	5	16	80	2	2	13	5	5	13	78	265	17	17	7.82405	7.60090	0	0	0	3	2	0	.	.	.	.	.	.	.	1	5
38	12	4	3	0	7	0	1	3	48	16	12	2	28	10	17	16	8.00637	5.52146	0	4	2	2	3	1	3.03	7	4.45	3.37	5.95	3.75	4.59	1	4
3°	5	3	3	5	19	93	1	1	21	9	9	15	68	278	17	16	5.19296	4.82831	1	0	2	4	1	0	.	.	.	.	.	.	.	1	2
40	11	6	5	0	8	0	1	1	34	21	15	7	43	77	11	8	9.39266	8.98720	1	0	2	2	1	0	.	.	.	.	.	.	.	.	.

Table VI-14. Master Data Table (con't.)

STATISTICAL ANALYSIS SYSTEM

SUBJECT	AGE	RECENCY	CNTRLTOT	PROPCON1	PROPCON2	PROPCON3	PROPCON4	PROPCONT	INPTR1	INPTR2	INPTR3	INPTR4	INPTRT	DIFF1	DIFF2	DIFF3	DIFF4	DIFFT	Z1
37	1	2	5	0.000000	0.000000	1.00000	0.500000	0.384615	4.00000	2.00000	1.50000	4.00000	2.60000	0	0	0	0	0	0.00000
38	2	3	11	0.285714	0.181818	0.18182	0.250000	0.229167	4.66667	3.66667	1.83333	3.00000	3.00000	1	0	2	1	4	0.66667
39	1	2	7	0.000000	0.285714	0.66667	0.200000	0.333333	3.00000	3.50000	2.00000	1.66667	2.33333	0	0	0	0	0	5.00000
40	3	1	5	0.000000	0.200000	0.22222	0.090909	0.147059	4.00000	1.42857	1.28571	1.83333	1.61905	0	2	3	1	6	2.00000

SUBJECT	Z2	Z3	Z4	ZT	CORINQ1	CORINQ2	CORINQ3	CORINO4	CORINQT	DELTAC1	DELTAC2	DELTAC3	DELTAC4	TDELTAC	S	TM	TC	TE	SHRSRANK	T	AP	LATELY	THRSRANK	RATSCORE	YOUNCOLD	SUB	FLY	IFR	KNOW
37	3.00000	2.50000	5.00000	2.60000	0.00000	1.5	1.66667	1.25	1.00000	0	0	0	0	0	.	1	.	1	.	.	1	.	.	1	0	1	0	.	1
38	0.00000	0.00000	0.00000	0.12500	0.14286	0.0	0.00000	0.00	0.04167	0	0	-3	2	-1	1	0	0	0	0	.	1	1	.	1	.	1	0	1	0
39	0.00000	1.66667	1.66667	1.66667	1.66667	0.0	0.83333	1.00	0.71429	-4	-1	4	0	-1	.	1	.	1	0	.	0	.	0	0	0	1	1	0	.
40	0.71429	0.00000	0.00000	0.33333	0.50000	0.5	0.00000	0.00	0.20588	-5	0	-1	0	-6	.	0	0	.	1	0	0	0	1	1	1	1	0	1	1

follow detail the results of this combined analysis. Essentially three types of analysis were involved. First, Spearman Rank Correlations were examined for all data inputs with emphasis on those correlations with major dependent measures. These included merit, efficiency, and correctness measures and their derivatives from the diagnostic phase and weighting functions from the conjoint measurement analysis of the decision phase. The rank correlations provided not only insight into two variable relations but indicated input variables for the stepwise regression analysis which followed.

The stepwise regression analysis predicted dependent measures from the set of independent measures (biographical, knowledge measures and independent performance measures).

Finally, partitions on the independent measures were examined to ascertain differences in performance measures. The splits varied depending on the nature of the variables in question, e.g., pilots with aircraft mechanic (A and P) ratings vs. pilots without A and P ratings, differences in pilot ratings, etc. In addition, some performance measures such as total merit were split into top and bottom quartiles to ascertain differences in other performance indices. The performance measures are listed and defined in the Glossary, Table VI-3.

I. A Rank Correlation Analysis - Combined Data

Table VI-15 depicts the Spearman rank order correlations for the major independent and dependent variables in the analysis. These correlation tests were conducted as a first cut through the data prior to stepwise regression. The correlations enabled the researchers to get an overall view of relationships between the variables of interest. Clearly, some significant correlations resulted because the two variables were related not to each other but through a third variables. These effects were evident with the stepwise regression.

Table VI-15 reports rank correlations for experience variables, knowledge scores and overall tests. Although a log transform of total and single engine hours was employed to adjust for the skewed distribution in these factors, such a transformation has no effect on rank correlation. The comments to follow consider a relationship to be significant if the α value is $\leq .10$.

It is interesting to note that total hours is related only to single engine hours and not to any of the performance measures. Single engine hours is related to knowledge scores. This is to be expected since the knowledge test and its subscores were based on single engine aircraft operation. The negative correlation of the decision factor, weather, with single engine hours suggests that high experience levels lead to less emphasis on weather in the diversion decision.

Knowledge scores are highly related to total merit (α = .0001) - a finding that holds up in the entire analysis. Knowledge about aircraft subsystems definitely affects diagnostic performance in a positive manner. Knowledge is also related to total correctness (α = .005) and total efficiency (α = .003) both of which make up total merit scores. Hence, the knowledgeable pilot is more likely to not only get the right answers in diagnostic tests but also to get

Table VI-15. Rank Correlation Table

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                                          BACKGROUND, DIAGNOSIS, AND TOTALS

                     SPEARMAN CORRELATION COEFF.CIENTS / PROB > |R| UNDER H0:RHO=0 / NUMBER OF OBSERVATIONS

THRSLOG

  THRSLOG SEHRSLOG AIRPORTS       WX  CATSCR1 KNOWLEDG  CATSCR3  CATSCR2 TOTMERIT      APP
  1.00000  0.74575 -0.20945 -0.19835  0.19667  0.13120  0.11968 -0.11479 -0.09300  0.09202
   0.0000   0.0001   0.2006   0.2261   0.2239   0.4197   0.4620   0.4806   0.5682   0.5774
       40       40       39       39       40       40       40       40       40       39

  CORINQT CNTRLTOT
 -0.09064  0.06992
   0.5781   0.6681
       40       40

SEHRSLOG

 SEHRSLOG  THRSLOG  CATSCR1 KNOWLEDG  CATSCR3       WX   TOTCOR  CATSCR2       ZT      APP
  1.00000  0.74575  0.47353  0.46703  0.37575 -0.28740  0.20121  0.18413  0.18068  0.14413
   0.0000   0.0001   0.0020   0.0024   0.0169   0.0761   0.2131   0.2554   0.2646   0.3814
       40       40       40       40       40       39       40       40       40       39

  CORINQT TOTMERIT
  0.14085  0.13787
   0.3860   0.3962
       40       40

KNOWLEDG   SCORE ON KNOWLEDGE TEST

 KNOWLEDG  CATSCR3  CATSCR1  CATSCR2 TOTMERIT       ZT  CORINQT SEHRSLOG   TOTINQ TOTTRAKS
  1.00000  0.75083  0.74191  0.68127  0.58549  0.57338  0.53917  0.46703 -0.46543 -0.45883
   0.0000   0.0001   0.0001   0.0001   0.0001   0.0001   0.0003   0.0024   0.0025   0.0029
       40       40       40       40       40       40       40       40       40       40

   TOTEFF      TIM
  0.45495  0.43533
   0.0032   0.0056
       40       39

CATSCR1

  CATSCR1 KNOWLEDG SEHRSLOG       ZT TOTTRAKS  CATSCR3 TOTMERIT  CORINQT   TOTEFF  CATSCR2
  1.00000  0.74191  0.47353  0.41991 -0.39356  0.37117  0.36750  0.34597  0.33755  0.32448
   0.0000   0.0001   0.0020   0.0070   0.0120   0.0184   0.0197   0.0288   0.0332   0.0411
       40       40       40       40       40       40       40       40       40       40

 AIRPORTS   TOTINQ
 -0.31827 -0.30450
   0.0483   0.0561
       39       40

CATSCR2

  CATSCR2 KNOWLEDG TOTMERIT       ZT  CORINQT   TOTEFF   TOTINQ TOTTRAKS   TOTCOR  CATSCR1
  1.00000  0.68127  0.54161  0.48534  0.47356  0.45462 -0.45000 -0.42639  0.35925  0.32448
   0.0000   0.0001   0.0003   0.0015   0.0020   0.0032   0.0036   0.0061   0.0228   0.0411
       40       40       40       40       40       40       40       40       40       40
```

Table VI-15. Rank Correlation Table (con't.)

BACKGROUND, DIAGNOSIS, AND TOTALS

SPEARMAN CORRELATION COEFFICIENTS / PROB > |R| UNDER H0:RHO=0 / NUMBER OF OBSERVATIONS

CATSCR2

CATSCR3	TIM
0.32219	0.31763
0.0426	0.0488
40	39

CATSCR3

CATSCR3	KNOWLEDG	TIM	CNTRLTOT	TOTCOR	TOTMERIT	SEIRSLOG	CATSCR1	CORINQT	ZT
1.00000	0.75083	0.48210	-0.44103	0.39808	0.39628	0.37575	0.37117	0.36967	0.35974
0.0000	0.0001	0.0019	0.0044	0.0110	0.0114	0.0169	0.0184	0.0189	0.0226
40	40	39	40	40	40	40	40	40	40

CATSCR2	APP
0.32219	-0.26995
0.0426	0.0965
40	39

TOTMERIT TOTAL MERIT SCORE

TOTMERIT	CORINQT	ZT	TOTCOR	TOTEFF	TOTINQ	KNOWLEDG	TOTTRAKS	CATSCR2	CATSCR3
1.00000	0.93193	0.85702	0.85677	0.78284	-0.64515	0.58549	-0.56128	0.54161	0.39628
0.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0003	0.0114
40	40	40	40	40	40	40	40	40	40

TIM	CATSCR1
0.37473	0.36750
0.0188	0.0197
39	40

TOTCOR TOTAL CORRECT SCORE

TOTCOR	TOTMERIT	CORINQT	ZT	TOTEFF	KNOWLEDG	CATSCR3	TOTTRAKS	TOTINQ	CATSCR2
1.00000	0.85677	0.81824	0.80151	0.45644	0.43005	0.39808	-0.38328	-0.36282	0.35925
0.0000	0.0001	0.0001	0.0001	0.0031	0.0056	0.0110	0.0146	0.0214	0.0228
40	40	40	40	40	40	40	40	40	40

CATSCR1	TIM
0.27305	0.27125
0.0882	0.0949
40	39

TOTEFF TOTAL EFFICIENCY SCORE

TOTEFF	TOTINQ	TOTMERIT	CORINQT	ZT	TOTTRAKS	TOTCOR	KNOWLEDG	CATSCR2	CATSCR1
1.00000	-0.86490	0.78284	0.76446	0.69330	-0.67387	0.45644	0.45495	0.45462	0.33755
0.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0031	0.0032	0.0032	0.0332
40	40	40	40	40	40	40	40	40	40

CNTRLTOT	TIM
-0.29990	0.28753
0.0601	0.0759
40	39

Table VI-15. Rank Correlation Table (con't.)

BACKGROUND, DIAGNOSIS, AND TOTALS

SPEARMAN CORRELATION COEFFICIENTS / PROB > |R| UNDER H0:RHO=0 / NUMBER OF OBSERVATIONS

CORINQT

CORINQT	TOTMERIT	ZT	TOTCOR	TOTEFF	TOTINQ	TOTTRAKS	KNOWLEDG	CATSCR2	CATSCR3
1.00000	0.93193	0.90254	0.81824	0.76446	-0.75639	-0.65386	0.53917	0.47356	0.36967
0.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0003	0.0020	0.0189
40	40	40	40	40	40	40	40	40	40

TIM	CATSCR1
0.35363	0.34597
0.0272	0.0288
39	40

ZT

ZT	CORINQT	TOTMERIT	TOTTRAKS	TOTCOR	TOTEFF	TOTINQ	KNOWLEDG	CATSCR2	CATSCR1
1.00000	0.90254	0.85702	-0.83027	0.80151	0.69330	-0.63662	0.57338	0.48534	0.41991
0.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0015	0.0070
40	40	40	40	40	40	40	40	40	40

CATSCR3	TIM
0.35974	0.28368
0.0226	0.0801
40	39

TIM TIME

TIM	CATSCR3	KNOWLEDG	APP	TOTMERIT	CORINQT	TOTINQ	CNTRLTOT	CATSCR2	ATC
1.00000	0.48210	0.43533	-0.38026	0.37473	0.35363	-0.32076	-0.31774	0.31763	-0.31186
0.0000	0.0019	0.0056	0.0169	0.0188	0.0272	0.0465	0.0487	0.0488	0.0533
39	39	39	39	39	39	39	39	39	39

TOTEFF	ZT
0.28753	0.28368
0.0759	0.0801
39	39

APP APPROACH

APP	TIM	WX	CATSCR3	KNOWLEDG	TOTTRAKS	SEHRSLOG	TOTINQ	ATC	CNTRLTOT
1.00000	-0.38026	-0.37606	-0.26995	-0.17561	-0.15176	0.14413	-0.13137	-0.12912	0.11560
0.0000	0.0169	0.0183	0.0965	0.2849	0.3564	0.3814	0.4253	0.4334	0.4834
39	39	39	39	39	39	39	39	39	39

TOTCOR	CATSCR2
-0.11532	-0.10497
0.4845	0.5248
39	39

WX WEATHER

WX	APP	SEHRSLOG	ATC	TIM	AIRPORTS	THRSLOG	TOTINQ	TOTCOR	CORINQT
1.0[illegible]	0.37606	-0.28740	-0.22652	-0.22126	0.21519	-0.19835	0.11938	-0.10991	-0.09347
0.0[illegible]	0.0183	0.0761	0.1655	0.1758	0.1883	0.2261	0.4692	0.5054	0.5714
39	39	39	39	39	39	39	39	39	39

Table VI-15. Rank Correlation Table (con't.)

BACKGROUND, DIAGNOSIS, AND TOTALS

SPEARMAN CORRELATION COEFFICIENTS / PROB > |R| UNDER H0:RHO=0 / NUMBER OF OBSERVATIONS

WX WEATHER

TOTMERIT	TOTTRAKS
-0.07803	0.07198
0.6368	0.6632
39	39

ATC AIR TRAFFIC CONTROL

ATC	TIM	CNTRLTOT	TOTINQ	WX	TOTTRAKS	CATSCR3	ZT	CORINQT	SEHRSLOC
1.00000	-0.31186	0.29194	0.23332	-0.22652	0.20651	-0.19548	-0.16400	-0.15938	0.13718
0.0000	0.0533	0.0713	0.1529	0.1655	0.2072	0.2330	0.3185	0.3325	0.4050
39	39	39	39	39	39	39	39	39	39

APP	KNOWLEDG
-0.12912	-0.10355
0.4334	0.5305
39	39

TOTTRAKS TOTAL # OF TRACKS

TOTTRAKS	ZT	TOTEFF	TOTINQ	CORINQT	TOTMERIT	KNOWLEDG	CATSCR2	CATSCR1	TOTCOR
1.00000	-0.83027	-0.67387	0.66629	-0.65386	-0.56128	-0.45883	-0.42639	-0.39356	-0.38328
0.0000	0.0001	0.0001	0.0001	0.0001	0.0002	0.0029	0.0061	0.0120	0.0146
40	40	40	40	40	40	40	40	40	40

AIRPORTS	TIM
0.33719	-0.22803
0.0358	0.1627
39	39

TOTINQ TOTAL # OF INQUIRIES

TOTINQ	TOTEFF	CORINQT	TOTTRAKS	TOTMERIT	ZT	KNOWLEDG	CATSCR2	TOTCOR	TIM
1.00000	-0.86490	-0.75639	0.66629	-0.64515	-0.63662	-0.46543	-0.45000	-0.36282	-0.32076
0.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0025	0.0036	0.0214	0.0465
40	40	40	40	40	40	40	40	40	39

CNTRLTOT	CATSCR1
0.31692	-0.30450
0.0463	0.0561
40	40

CNTRLTOT

CNTRLTOT	CATSCR3	KNOWLEDG	TIM	TOTINQ	TOTEFF	ATC	TOTMERIT	CORINQT	ZT
1.00000	-0.44103	-0.35232	-0.31774	0.31692	-0.29990	0.29194	-0.25828	-0.24919	-0.23727
0.0000	0.0044	0.0258	0.0487	0.0463	0.0601	0.0713	0.1076	0.1210	0.1404
40	40	40	39	40	40	39	40	40	40

TOTTRAKS	CATSCR2
0.22383	-0.21244
0.1650	0.1882
40	40

Table VI-15. Rank Correlation Table (con't.)

BACKGROUND, DIAGNOSIS, AND TOTALS

SPEARMAN CORRELATION COEFFICIENTS / PROB > |R| UNDER H0:RHO=0 / NUMBER OF OBSERVATIONS

AIRPORTS

AIRPORTS	TOTTRAKS	CATSCR1	TOTEFF	TOTINQ	TIM	WX	THRSLOC	ZT	CNTRLTOT
1.00000	0.33719	-0.31827	-0.28503	0.24834	-0.23218	0.21519	-0.20945	-0.13537	0.13164
0.0000	0.0358	0.0483	0.0786	0.1274	0.1549	0.1883	0.2006	0.4113	0.4244
39	39	39	39	39	39	39	39	39	39

CATSCR2	KNOWLEDG
0.11021	-0.10349
0.5042	0.5307
39	39

the answers more efficiently, i.e. he uses few inquiries to get the answer. As might be expected, Z_t and CORINQT are also highly correlated to knowledge scores since they are derived from total correctness.

One major finding in the correlations (which holds up with subsequent analysis) is the positive relation of knowledge with time (TIM) (α = .0056). This means that more knowledgeable pilots place high emphasis on "time to airport" in the case of a destination diversion decision. With concern for possible additional complications, knowledgeable pilots want to get the aircraft on the ground at the earliest opportunity rather than proceed farther to better weather or facilities.

As expected, total correctness is related to Z_t, CORINQT, total merit, and individual scenario scores. Table VI-15 also indicates pilots who have high correctness scores use fewer tracks and fewer inquiries than those with lower scores (TOTTRKS, α = .0146) (TOTINQ, α = .0214). This again supports the link between diagnostic correctness and efficiency of diagnosis.

Use of control activation related inquiries was negatively related to knowledge (α = .0258), to total efficiency (α = .0601) and to time weights. This was somewhat surprising in light of the value of selected control input tests to find problem causes, e.g., prop cycling to ascertain the locus of low oil pressure readings in scenario 1.

The decision weights show obvious negative intercorrelations with each other since one cannot have high weighting on more than one attribute. The time-knowledge relation described above is again noted. Airports passed to locate mechanics in the decision tests is negatively related to efficiency and knowledge scores and positively to total tracks used. If airports passed represents a crude measure of risk then high risk acceptance pilots have inefficient diagnostic procedures and are less knowledgeable.

J. Regression Analysis

In order to ascertain what factors predict performance measures, a series of stepwise regressions were performed. These are listed in Table VI-16. The table indicates the dependent variable, the R^2, N, and the significant predictor variables from three sets of independent variables - biographical and experience, knowledge, and other independent performance measures. Candidate predictor variables are indicated at the top of the table. The general strategy was to include all predictor (independent) variables, even those which could be related to each other, e.g., DIFT (total tracks - total unique tracks) and total tracks and total unique tracks. The model then selected which of these added the most to the prediction. The model permitted no variable to be introduced if it had been derived from another significant predictor variable.

On the other hand, no predictor variable which formed part of the dependent variable was allowed in the regression. For example, since Z_t = total correct/total tracks, a predictor variable could not be introduced which contained total tracks, e.g., DIFT (DIFT = total tracks - total unique tracks).

When correctness scores on individual scenarios are examined, C1-C4, some interesting results appear. Efficiency is a good predictor of correctness for scenarios 2, 3, and 4. Knowledge subscores are good predictors for C1 and C4 only. Experience variables (training and rating) show up in C1 prediction and (recency) in C3. These are far less significant than efficiency as predictors. Control use is clearly important in scenario 3 as might be expected (this was the rough running engine scenario). The number of inquiries per track is a positive predictor of correctness in scenarios 2, 3, and 4. It seems evident that scenario 1 differs from the other three scenarios probably because of its unique nature, i.e., it required the pilot to seek information about conditions inside the cockpit, but not on the panel. Weather weighting was a negative predictor for C2 and C4.

Pilots with good total correctness scores are characterized by high efficiency, a low number of total inquiries, a low number of tracks, a low DIFT (total tracks - total unique tracks) and thus a high number of inquiries per track. Knowledge is also a good predictor. Note, no biographical and experience factor predicts total correctness.

Individual scenario efficiency scores show little predictability from knowledge test scores. Efficiency on scenario 1 is related to experience variables, i.e., training, rating, and recency - again supporting earlier findings on C1. Most of the efficiency predictors on the scenarios include total tracks (negatively) for E_1, E_2, E_4, and unique tracks for E_3. Interestingly enough, control activation is a good predictor (negative) for E1, E2, and E4.

For total efficiency prediction, total tracks, and total control movements are negatively significant. Total correctness is also a significant predictor, again linking good performance with efficient performance.

Table VI-16

Final Summary of Stepwise Predictions

PREDICTOR VARIABLE	R^2	N	BIOGRAPHICAL & EXPERIENCE	KNOWLEDGE	INDEPENDENT PERFORMANCE VARIABLE
			Age-S.E.Hrs.-Tot Hrs.-Recency-Flying-Rating-Training	CATSCR1 CATSCR2 CATSCR3 KNOWLEDG	C1-C4, E1-E4, UT1-UT4, TT1-TT4, INPTR1-INPTR4, CB1-CB4, CNTRL1-CNTRL4, DIF1-DIF4, TIM, APP, WX, ATC, AIRPORTS, TCRITBEF, TOTEFF, CNTRLTOT, TOTINQ, TOTUTRKS, DIFT, INPTRT
C1	.49	39	Training (.0329)* Rating (.0004)*	CATSCR3 (.0053)	CNTRL1 (.0768)* DIF1 (.0827)*
C2	.46	39			WX (.0041)* UT2 (.0366) AIRPORTS (.0978) INPTR2 (.0015) E2 (.0002)
C3	.70	39	Recency (.0019)*		WX (.0458)* CNTRL3 (.0010) CB3 (.0114)* INPTR3 (.0013)* E3 (.0001)
C4	.60	39		CATSCR1 (.0289) CATSCR2 (.0124)	E4(.0001) INPTR4 (.0385) UT4 (.0001)
TOTCOR	.56	39		KNOWLEDG (.0231)	TOTEFF (.0636) DIFT (.0057)* TOTINQ (.0928)* INPTRT (.0225) TOTTRAKS (.0034)*
E1	.74	39	Training (.0219)* Recency (.0209) Rating (.0091)*		TT1 (.0004)* CNTRL1 (.0001)* CB1 (.0551) DIF1 (.0581)
E2	.63	39		CATSCR2 (.0034)	CNTRL2 (.0007)* TT2 (.0078)*
E3	.84	39			APP (.0023)* UT3 (.0001)* ATC (.0070)* C3 (.0001)
E4	.81	39	Rating (.0040)*		TIM (.0330) CNTRL4 (.0544)* TT4 (.0001)* C4 (.0016)

* Negative B-Value

Table VI-16 (con't.)

PREDICTOR VARIABLE	R^2	N	BIOGRAPHICAL & EXPERIENCE	KNOWLEDGE	INDEPENDENT PERFORMANCE VARIABLE
TOTEFF	.60	39			CNTRLTOT (.0782)* TOTCOR (.0306) TOTTRAKS (.0001)*
TOTMERIT	.56	39		KNOWLEDG (.0001)	DIFT (.0022)*
ZT	.61	39		KNOWLEDG (.0121)	TOTEFF (.0317) TOTUTRKS (.0290)*
CORINQT	.55	39		KNOWLEDG (.0006)	DIFT (.0006)*
CNTRLTOT	.40	[illegible]	SEHRSLOG (.0784) Recency (.0062)		TIM (.0087)* TOTUTRKS (.0097)
TIM	.46	39		CATSCR1 (.0353)* CATSCR2 (.0001)	AIRPORTS (.0027)*
ATC	.20	39	Training (.0793) Age (.0093)		
WX	.35	39	THRSLOG (.0246)* Training (.0020)*		AIRPORTS (.0359) TOTUTRKS (.0418)*
AIRPORTS	.54	39		CATSCR1 (.0555)* CATSCR2 (.0023)	WX (.0905) DIFT (.0001)
KNOWLEDG	.62	39	Flying (.0023)* Training (.0052) Recency (.0292)*		APP (.0042)* TOTTRAKS (.0314)*

* Negative B-Value

In general, efficiency measures led to better prediction than correctness scores (higher R squares). What was surprising was the absence of knowledge, biographical and experience variables as significant predictors for total efficiency.

For total merit prediction, the knowledge score is the best predictor (α = .0001). Later, when extreme scores on total merit are examined through t-tests, knowledge scores differentiate well between high and low merit scores. Total merit is also predicted by DIFT. Low DIFT yield high merit scores which suggests a nonrandom approach by high performance score pilots. Not surprising, Z_t and CORINQT were much like total merit since all three measures are functions of total correctness. Knowledge was a significant predictor for these performance measures. No experience variables were significant. CORINQT was like merit. Z_t revealed total unique tracks and total efficiency as predictors.

Table VI-16 also shows that knowledge scores are significant predictors of time weighting and airports passed in the decision phase. In both cases CATSCR1 was a negative prediction. CATSCR1 deals with engine and fuel systems. CATSCR2 (electrical and cockpit operations) appears to be more germaine to the destination diversion decision. As expected, pilots, who weight time as critical, pass few airports. Pilots who consider weather weightings as critical are willing to pass airports to locate a mechanic. Although the R squares were low, biographical and experience factors appear for weather and ATC weighting. These will be examined later in partition testing.

Since knowledge has bearing on performance it was decided to seek predictors of the total knowledge scores. Table VI-16 reveals that type of flying, training, and recency of flight all are significant predictors. Non-pleasure flying, high recent experience and military training yield higher knowledge scores. Both approach aid weightings and total tracks are good predictors of knowledge in an inverse direction.

K. Tests on Data Partitions

Table VI-17 shows a series of tests on extreme partitions of major independent and key dependent measures to ascertain if differences might exist in extreme cuts through the data as compared to regression of the entire data set. Test candidates for the partitions included twenty-one performance variables. Two state variables are easier to examine in this framework, i.e., mechanics vs. non-mechanics, military vs. civilian training and go vs. no-go preferences for the decision flight. Twenty dependent measures shown in Table VI-16, plus two experience measures were considered for performance differences in the data splits.

Pilots with recent flight experience (over fifty hours in the past year) were more knowledgeable and used less control activations than pilots with less than twenty hours in the past year. Surprisingly enough, diagnostic and decision performance were not different - perhaps due to the small number of low recency pilots.

Total hours of experience ($<$ 1007 hrs. vs. $>$ 5375 hrs.) showed no relation to performance. Separating single engine hours experience revealed greater knowledge for pilots with over 2075 single engine hours vs. those with less than 488 hours. Splits on ratings revealed commercial and ATP rated pilots have more knowledge than private pilots. For training partitions, military training led to higher knowledge scores than non-military training. A split on IFR hours revealed a slight total correctness difference with the two groups (< 175 hrs. vs. > 700 hrs.). In all of the splits above there was little or no performance difference.

When pilots under age thirty are compared to those over fifty, performance differences begin to appear. Younger pilots have higher merit, Z_t and CORINQT scores than older pilots, yet have less experience (total hrs. and single engine hrs.). Type of flying also showed performance effects. Pleasure flying pilots showed less knowledge, less experience, less efficiency, more tracks and larger DIFT than pilots who fly for airline, commercial, business, or military purposes.

When performance measures are split to get profiles of high score pilots vs. low score pilots, many other independent performance effects are noted. Focus is on dependent variables or other measures not related to the partitioner variable. When partitioning on knowledge, the high knowledge scores (≥16) are associated with:

a) higher single engine hours experience

b) higher weightings on time in the decision phase

c) higher correctness and merit scores

d) higher efficiency scores

e) fewer inquiries

f) fewer tracks

g) fewer unique tracks

than pilots with low knowledge scores (less than 10).

Table VI-17

Summary of T-Tests

DATA PARTITIONS ON BIOGRAPHICAL AND EXPEPIENCE AND KEY DEPENDENT MEASURES	N	TEST VARIABLES - CATSCR1 (.0869) (0) means recency differences on CATSCR1 was significant at = .0869. The (0) means high recency group had higher mean values than low recency.
		CATSCR1, CATSCR2, CATSCR3, KNOWLEDG, TOTMERIT, TOTEFF, TOTCOR, ZT, CORINQT, ATC, TIM, APP, WX, PROPCONT, TOTINQ, TOTUTRKS, TOTTRAKS, THRSLOG, SEHRSLOG, TDELTAC, DIFT INPTRT
High Recency vs. Low Recency (0) > 50 hrs. in past yr. (1) < 20 hrs in past yr.	(0)-25 (1)-6	CATSCR1 (.0869) (0) CATSCR3 (.0029) (0) KNOWLEDG (.0110 (0) PROPCONT (.0170) (1) SEHRSLOG (.0040) (0)
Low Total Hrs. vs. High Total Hrs. (0) < 1007 total hrs. (1) > 5375 total hrs.	(0)-10 (1)-10	SEHRSLOG (.0001) (1)
Low Single Engine Hrs. vs. High Single Engine Hrs (0) < 488.75 single hrs. (1) > 2075.25 single hrs.	(0)-10 (1)-10	CATSCR1 (.0011) (1) KNOWLEDG (.0073) (1) THRSLOG (.0001) (1)
Private Rating vs Non-Private Rating (0) - private rating (1) - commercial rating and air transport rating	(0)-9 (1)-31	CATSCR2 (.0776) (1) KNOWLEDG (.0485) (1) THRSLOG (.0004) (1) SEHRSLOG (.0460) (1)
YOUNG vs. OLD (0) < 30 yrs. old (1) > 50 yrs. old	(0)-10 (1)-14	CATSCR2 (.0059) (0) TOTMERIT (.0889) (0) ZT (.0288) (0) CORINQT (.0943) (0) ATC (.0335) (1) THRSLOG (.0140) (1) SEHRSLOG (.0198) (1)

Table VI-17 (con't.)

DATA PARTITIONS ON BIOGRAPHICAL AND EXPERIENCE AND KEY DEPENDENT MEASURES	N	TEST VARIABLES
MECH vs. NON-MECH (0) N=35 (1) N=5	(0)-35 (1)-5	CATSCR1 (.0085) (1)
Military vs. Civilian (1) Military (2) Civilian	(1)-10 (2)-30	CATSCR2 (.0001) (2) KNOWLEDG (.0108) (2) THRSLOG (.0009) (1)
Pleasure vs. Non Pleasure (0) airline commercial business military (1) pleasure	(0)-31 (1)-9	CATSCR1 (.0608) (0) TOTEFF (.0990) (0) TOTTRAKS (.0306) (1) THRSLOG (.0001) (0) SEHRSLOG (.0216) (0) DIFT (.0122) (1)
Low IFR Hrs. vs. High IFR Hrs. (0) < 175 IFR hrs. (1) > 700 IFR hrs.	(0)-9 (1)-9	TOTCOR (.0815) (0) THRSLOG (.0001) (1) SEHRSLOG (.0189) (1)
Low Knowledge Score vs. High Knowledge Score (0) ≤ 9 on knowledge test (1) ≥ 16 on knowledge test	(0)-9 (1)-8	CATSCR1 (.0001) (1) CATSCR2 (.0014) (1) CATSCR3 (.0001) (1) TOTMERIT (.0070) (1) TOTEFF (.0103) (1) TOTCOR (.0436) (1) ZT (.0038) (1) CORINQT (.0064) (1) TIM (.0734) (1) TOTINQ (.0059) (0) TOTUTRKS (.0659) (0) TOTRAKS (.0310) (0) SEHRSLOG (.0127) (1) DIFT (.0519) (0)

Table VI 17 (con't.)

Summary of T-Tests

DATA PARTITIONS ON BIOGRAPHICAL AND EXPERIENCE AND KEY MEASURES	N	TEST VARIABLES	
GO vs. NO GO (0) (1)	 (0)-9 (1)-30	ATC (.0790) (0) APP (.0084) (1)	
Low Total Merit vs. High Total Merit (0)≤ 129.25 TOTMERIT (1)≥235.00 TOTMERIT	 (0)-10 (1)-10	CATSCR1 (.0124) (1) CATSCR2 (.0022) (1) CATSCR3 (.0010) (1) KNOWLEDG (.0001) (1) TOTEFF (.0001) (1) TOTCOR (.0001) (1) ZT (.0001) (1) CORINQT (.0001) (1) TIM (.0061) (1) TOTINQ (.0012) (0) TOTUTRKS (.0199) (0) TOTTRAKS (.0010) (0) DIFT (.0005) (0)	
Low Total Correct vs. High Total Correct (0)≤ 10 total correct (1)≥17 total correct	 (0)-11 (1)-11	CATSCR1 (.0262) (1) CATSCR2 (.0183) (1) CATSCR3 (.0156) (1) KNOWLEDG (.0009) (1) TOTMERIT (.0001) (1) TOTEFF (.0024) (1) ZT (.0001) (1) CORINQT (.0001) (1)	TIM (.0479) (1) TOTINQ (.0281) (0) TOTUTRKS (.0999) (0) TOTTRAKS (.0125) (0) SEHRSLOG (.0752) (1) DIFT (.0097) (0)

Table VI-17 (con't.)

Summary of T-Tests

DATA PARTITIONS ON BIOGRAPHICAL AND EXPERIENCE AND KEY MEASURES	N	TEST VARIABLES	
Low Total Efficiency vs. High Total Efficiency (0)≤42 total efficiency (1)≥59 total efficiency	(0)-10 (1)-9	CATSCR1 (.0125) (1) CATSCR2 (.0090) (1) KNOWLEDG (.0012) (1) TOTMERIT (.0001) (1) TOTCOR (.0028) (1) ZT (.0001) (1) CORINQT (.0001) (1) PROPCONT (.0995) (1)	TOTINQ (.0001) (0) TOTUTRKS (.0068) (0) TOTTRAKS (.0003) (0) DIFT (.0007) (0)
Low Time vs. High Time (0)< .625 time (1)≥ '. time	(0)-13 (1)-16	CATSCR2 (.0705) (1) CATSCR3 (.0035) (1) KNOWLEDG (.0221) (1) TOTMERIT (.0074) (1) TOTEFF (.0125) (1) TOTCOR (.0494) (1) ZT (.0110) (1) CORINQT (.0127) (1) TOTINQ (.0130) (0) TOTTRAKS (.0565) (0) DIFT (.0043) (0)	
Mechanic Help Available Two or Less Airports passed vs. more than two (0) < 3 airports (1) > 2 airports	(0)-11 (1)-28	CATSCR1 (.0862) (0) TOTEFF (.0226) (0) TOTINQ (.0698) (1) TOTUTRKS (.0628) (1) TOTTRAKS (.0163) (1) DIFT (.0310) (1)	

When the top and bottom quartile on merit and correctness scores are examined, an interesting pattern emerges. Members of the upper quartile of performance scores are associated with:

a) more knowledge

b) greater weights or time

c) fewer inquiries

d) fewer tracks

e) fewer unique tracks

f) lower DIFT

g) higher efficiency

h) higher single engine hours (total correctness only and here $\alpha = .07$)

When upper and lower quartiles in total efficiency are examined much the same patterns as indicated above result.

Since time weighting appears to be associated with good diagnostic performance, splits on time weights were made to test for performance effects. High time weightings look again like the list above, i.e., greater knowledge, efficiency, correctness and merit with fewer tracks, fewer inquiries and lower DIFT.

In the regression analysis, airports passed was predicted by knowledge subscores, time weighting, and DIFT. Table VI-17 shows that a split on airports ($2 \leq$ vs. > 2) shows that low number of airports passed is related to higher efficiency and knowledge and lower values for DIFT, unique and total tracks and total inquiries.

L. GAT Subjects in P/P Tests

Eight of the subjects who participated in the FMS experiments also participated in the P/P experiments. All of the subjects from the first GAT scenario (fuel loss) and all from the second GAT scenario (partial power failure) participated. None from the third GAT scenario (partial navigation system failure) participated.

Subjects 11, 33, 34, and 35 were used in the fuel loss FMS experiment. Subjects 28, 31, 32, and 38 were used in the partial power loss FMS experiment.

Some typical performance measures for this group of subjects are highlighted in Table VI-18. The encouraging thing about this comparison is that the results appear to be reasonably consistent. The subjects for each FMS experiment are equally distributed with respect to airman certificates held (one Pvt., two comm., and one ATP in each group) in similar portions to the entire P/P group.

Each GAT subject was ranked from one (best performance) to four (poorest performance) by a subjective evaluation of the experimenter present during all of the GAT runs. Each subject was ranked separately for "Aviating", "Navigating", and "Communicating" for the scenario in which he participated. "Aviating" reflected basic stick and rudder skills. "Navigating" reflected the ability to follow the flight planned course and the subjects awareness of location along the route. "Communicating" reflected the professional nature of the information exchange between pilot and controller. All GAT subjects took

Table VI-18. GAT Subjects P/P Performance

Subject	GAT FMS	Airman Rating	GAT Performance Rank*			Open Knowledge Survey Score GATKT	Closed Knowledge Survey Score KNOWLEDGE	TOTCOR	TOTMERIT
			A	N	C				
11	1	2	2	2	2	5.02	13	10	107
33	1	3	1	1	1	5.63	13	12	164
34	1	2	4	4	4	4.39	9	7	117
35	1	1	3	3	3	3.12	7	15	172
28	2	1	3	4	4	3.79	10	15	160
31	2	3	2	2	3	5.56	16	15	245
32	2	2	1	1	1	5.00	15	18	236
38	2	2	4	3	2	4.59	7	2	10

*A = Aviating
N = Navigating
C = Communicating

the open form knowledge survey prior to the experiment. These data are also noted in Table VI-18.

The first observation to make is that knowledge scores on both forms of knowledge survey seem to agree. Those scoring high on the open-form also score high on the closed-form.

The second observation to make is that GAT performance rank is generally consistent with total correct (TOTCOR) and total merit (TOTMERIT) scores on the P/P scenarios. In GAT scenario 2 the rank order of "Aviating" in exactly the same as the rank order of TOTMERIT. Other rankings are less perfect but still exhibit the same general trends.

Although the sample size is too small to draw definitive conclusions, taken as a group, results for these eight subjects seem to indicate that either FMS or P/P scenario experiments can be used to evaluate pilots with some assurance that relative rankings will be preserved.

M. Summary

The above analyses have found the same pattern running through the data. The three statistical approaches lead to the same conclusions. These are:

1.) Correctness in diagnostic scores is highly related to efficiency in reaching diagnostic answers.

2.) Most biographical and experience variables do not appear to be related to diagnostic performance measures (the exception is the A & P mechanic rating which does appear to be related to diagnostic performance).

3.) Knowledge scores are positively related to both correctness and efficiency in diagnostic performance.

4.) Of the four airport attribute weightings only high time weighting is related to high diagnostic performance.

5.) Patterns of information seeking for high diagnostic performance, i.e., high efficiency and high correctness, involve

a) a minimal number of tracks employed

b) a minimal number of unique tracks employed

c) a minimal number of total inquiries

d) a small number of track repeats, i.e., DIFT (total tracks - total unique tracks) is small.

Although most experience and biographical factors failed to be significant in the analysis, some did appear to be related to knowledge scores - such as high total single engine hours, high recency, military training background and non-pleasure flying.

VII. ANALYSIS OF PROCEDURAL COMPLIANCE

A. Background

At the same time that the GAT and paper and pencil scenarios were being developed for single pilot CIFE's, a parallel study directed toward airline cockpit crew operations was undertaken. The person responsible for this effort was Lt. Col. Jeffrey Schofield who performed the research as his Ph.D. dissertation project. A copy of that dissertation, "Aircrew Compliance With Standard Operating Procedures As A Component of Airline Safety", is on file as part of this project's records at NASA-Ames.

Schofield used data generated in an experiment conducted in 1976 by Dr. H. P. Ruffell Smith under the auspices of the NASA-Ames Research Center. The Ruffell Smith research utilized a full-mission simulation to study the performance of fully qualified airline crews under varying conditions of workload. The cockpit was that of a Boeing 747 which accomodated the usual three-person crew plus two observers, a simulator operator/traffic controller, and an audio coordinator. The full-mission scenario used was built around a charter flight from Dulles Airport to Heathrow Airport (London) with a thirty-minute intermediate stop at Kennedy Airport (New York) for fuel and cargo. The first segment placed relatively low workload on the crews, while the second segment was much higher due to pre-programmed mechanical failures.

Ruffell Smith concentrated on crew errors during the second segment (high workload) of the scenario. He was interested in establishing statistically significant physiological or historical predictors of crew performance during the second leg. Schofield, on the other hand, chose to emphasize the routine or customary tasks of flight operations as exemplified by the first segment of the Ruffell Smith scenario. Furthermore, he was concerned with: 1) quantifying routine crew procedures, 2) analyzing observed crew errors to identify which particular crew members were the primary causes of such errors, and 3) comparing measures of procedural compliance and operator error.

The primary data used by Schofield came from the audio tracks of the FM tapes and handwritten documents generated by the Ruffell Smith study. This information was supplemented by data which was culled from the Aircraft Operating Manual, the Company Operations Manual, the Federal Aviation Regulations, crew handbooks, and assorted navigational documents.

B. Procedures

A procedure is defined as "a symbolic and mnemonic representation of a set of sensory, cognitive, and/or motor activities which, when recalled and executed within determinable tolerances, complete a task as designed". The word "procedure" and its many aliases appear throughout aviation literature. Schofield identifies nineteen separate words and phrases associated with aircrew operations which have procedural conotation.

Schofield enumerates a set of normal operating procedures, as opposed to Abnormal, Alternate, Irregular, or Emergency procedures, which represent an idealized sequence based on the events in the Dulles-JFK segment of the Ruffell Smith experimental scenario. All of his procedures are considered mandatory for normal flight operations in instrument meteorological conditions. Each procedure is identified by published format and the cockpit crew members expected to exhibit active procedural behavior. These are catalogued in Table VII-1.

The astonishing fact in this list is that 97 normal operating procedures can be identified for standard cockpit activities lasting approximately 75 minutes. This lengthy list does not include any "optional" procedures or emergency type procedures. They represent only standard operating procedures for the first leg of the simulated flight scenario.

Schofield has identified several empirical taxonomies which seek to classify these procedures in ways to identify useful relationships among them. One such grouping is the set of 21 crew coordination procedures shown in Table VII-2. Crew coordination procedures are emphasized since they capture the essential ingredients of group leadership, crew management and behavioral conformity. Schofield examines the realtionships between meticulous compliance with coordination procedures and the crew errors noted by Ruffell Smith.

C. Compliance Assessment

Although Ruffell Smith used eighteen crews in his experiment, the quality of the data generated and the observers were not the same for all eighteen simulation runs. Schofield selected ten runs, which had the same set of observers and usable audio data throughout, for detailed procedural analysis. The 21 crew coordination procedures were further subdivided into checklists,

Table VII-1

NORMAL OPERATING PROCEDURES

Index Number	Name	Format[1] codes	Operator[2] codes
1.	Basic ATC communications practices	N	PNF
2.	Preflight Radio Checklist	C,N	P2
3.	Gear pin status report	N	P1
4.	Hydraulic system pressurization	N	P1 & FE
5.	ATIS report	N	U
6.	Clearance Delivery communications	N	PNF
7.	Ground Control communications	N	PNF
8.	Pre-start Checklist	C,N	A
9.	Ground crew report	N	P1
10.	Cabin report	N	P1
11.	Engineer's Start Checklist	C,N	FE
12.	Start Checklist	C,N	A
13.	Engine starting	N	P1 & FE
14.	Ground connections and hand signals report	N	P1
15.	Engineer's Taxi Checklist	C,N	FE
16.	Pre-taxi Checklist	C,N	A
17.	Transfer of EGT monitor	N	P1 & FE
18.	Ground Control communications	N	PNF
19.	Taxi	N	PF
20.	Takeoff and departure briefing	N	PF
21.	Final weight and balance computation	G,N	FE
22.	Taxi Checklist	C,N	A
23.	Tower communications	N	PNF
24.	Passenger pre-takeoff announcement	N	PF
25.	Engineer's Takeoff Checklist	C,G,N	FE
26.	Runway line up	N	PF
27.	Takeoff Checklist	C,N	A
28.	Thrust setting (takeoff power)	G,N	PF & FE
29.	Takeoff	N	PF
30.	Takeoff callouts	N	PNF
31.	Noise abatement departure	G,N	PF
32.	Gear retraction	N	PF & PNF
33.	Departure Control communications (initial contact)	N	PNF
34.	Thrust setting (rated power)	G,N	P1 & FE
35.	Departure Control communication (radar vector)	N	PNF
36.	Flap retraction	G,N	PF & PNF
37.	Altitude callout	N	PNF
38.	Intermediate level off	N	PF
39.	Departure Control communications (climb clearance)	N	PNF

Table VII-1 (con't.)

Index Number	Name	Format codes (1)	Operator codes (2)
40.	Airways navigation practices	N	PF & PNF
41.	Thrust setting (rated power)	G,N	PF & FE
42.	Climb (below 10,000 feet MSL)	N	PF
43.	Company departure report	N	U
44.	ARTCC communications (initial contact)	N	PNF
45.	Seat belt sign	N	U
46.	Climb (above 10,000 feet MSL)	N	PF
47.	After Takeoff Checklist	C,N	PF & FE
48.	Altimeter reset [not applicable for cruising below 18,000 feet]	N	A
49.	ARTCC communications (route clearance)	N	PNF
50.	Cruise data	G,N	FE
51.	Altitude callout	N	PNF
52.	Level off	N	PF
53.	Mach number/airspeed crosscheck	N	FE
54.	Cruise	N	PF
55.	ARTCC communications (radar vector)	N	PNF
56.	Turbulence penetration	N	A
57.	ARTCC communications (radar vector)	N	PNF
58.	Turbulence exit	N	A
59.	ARTCC communications (route clearance)	N	PNF
60.	Fuel systems management	C,N	FE
61.	ARTCC communications (center change; initial contact)	N	PNF
62.	ATIS report	N	U
63.	Company arrival report	N	U
64.	Approach briefing	N	PF
65.	ARTCC communications (sector change; initial contact)	N	PNF
66.	Approach data and speed bugs	G,N	A
67.	Passenger arrival announcement	N	PF
68.	Descent Checklist	C,N	A
69.	ARTCC communications (descent clearance)	N	PNF
70.	Descent (above 10,000 feet MSL)	N	PF
71.	Altimeter reset	N	A
72.	Seat belt sign and landing lights	N	U
73.	Descent (below 10,000 feet MSL)	N	PF
74.	Approach Control communications (initial contact; clearance)	N	PNF
75.	Approach Checklist	C,N	A
76.	Category I Instrument Landing System (ILS) Approach	G,N	PF
77.	Approach radio checks	N	PF & PNF

Table VII-1 (con't.)

Index Number	Name	Format codes (1)	Operator codes (2)
78.	Altitude callout	N	PNF
79.	No smoking sign	N	U
80.	Approach Control communications (radar vector)	N	PNF
81.	Approach flap extension	G,N	PF & PNF
82.	Course bar and glide slope callouts	N	PNF
83.	Approach Control communications (approach clearance)	N	PNF
84.	Landing gear/landing flap extension	G,N	PF & PNF
85.	Landing Checklist	C,N	A
86.	Final approach fix (FAF) communications	N	PNF
87.	FAF instrument crosscheck	N	PNF
88.	Precision approach callout	N	PNF
89.	Ou[illegible] scan and visibility callouts	N	PNF
90.	[illegible]	N	PF
91.	Landing roll callouts	N	PNF & FE
92.	Tower communications	N	PNF
93.	After Landing Checklist	C,N	A
94.	Taxi	N	PF
95.	Ground Control communications	N	PNF
96.	Parking	N	PF
97.	Blocks Checklist	C,N	A

(1) Format Codes: C (Checklist), G (Graphical), N (Narrative)

(2) Operator Codes: A (All), PI (Captain), PZ (Copilot), FE (Flight Engineer), PF (Pilot Flying), PNF (Pilot Not Flying), U (Unspecified)

Table VII-2

CREW COORDINATION PROCEDURES
(To be used for quantitative compliance assessments)

Index Letter	Procedure Name
A.	Pre-start Checklist
B.	Start Checklist
C.	Pre-taxi Checklist
D.	Transfer of EGT Monitor
E.	Taxi Checklist
F.	Takeoff Checklist
G.	Takeoff Callouts
H.	Gear Retraction
I.	Flap Retraction
J.	Altitude Callout
K.	After Takeoff Checklist
L.	Altitude Callout
M.	Transfer of Aircraft Control
N.	Descent Checklist
O.	Approach Checklist
P.	Altitude Callout
Q.	Approach Flap Extension
R.	Landing Gear/Landing Flap Extension
S.	Landing Checklist
T.	Precision Approach Callouts
U.	Landing Roll Callouts

callouts, configuration changes, and transfers. Performance of each of the ten crews was then evaluated for each subdivision.

Pre-start, Start, Pre-Taxi, and Takeoff Checklists are supposed to be initiated upon command of the captain or the flying pilot. The other pilot is then to announce the name of the checklist as a confirmation of the command, and read the opening challenge. Once initiated, checklists may be delayed by interruptions, but ultimately must be resumed and completed in toto.

In every experimental run the requisite challenges and responses were made, even though some of the operator actions and replies were contrary to procedural specifications. However, there were remarkable differences in the patterns of behavior noted among crews for these five checklists. In a total of fifty opportunities over ten flights, the command-announcement-challenge sequence was fully executed only five times. The observed shortcuts raised questions in Schofield's mind about possible degradation in crew cohesion leading to increased uncertainty and lack of internal order.

The five audible checklists conducted by the two pilot crewmembers, were contrasted with three checklist sequences (Descent, Approach, and Landing) in which the flight engineer was the challenger. Exactly half of the observed thirty sequences here began in the prescribed command-announcement-challenge order and only one was missing the initial command. In addition to collectively making more of the prescribed announcements than their pilot counterparts, the flight engineers were more self-consistent. Three engineers omitted all announcements and three others omitted one. They also were more consistent than pilots in following the response to the last challenge statement with the prescribed procedure completion statement. When a pilot was the last challenger, 20% of the time the completion statement was omitted; when an engineer was the last challenger, only 4% were omitted. Schofield hypothesizes that crew coordination might be improved by making the flight engineer the challenger of all checklists.

Callout procedures are fundamentally different from checklists. In the usual format the non-flying pilot acts as a back-up or second-level visual monitor who audibly relays operating information to the flying pilot. Callouts occur during take-off, climb, descent, approach, and landing.

Schofield identifies 170 opportunities, among the ten crews, to execute callout procedures. Thirty-eight procedural errors were noted, half of which were errors in altitude callouts during climb or descent. The errors noted were callouts made by the flying pilot rather than the non-flying pilot (seven cases), late callouts (thirteen cases), and omitted callouts (twenty cases).

Procedures for gear and flap extension/retraction were well executed in terms of established oral procedures. In 104 observed configuration changes one of the two prescribed verbalizations was omitted four times, and one change (from flaps 1 to flaps up) was made without comment from either pilot. However, Schofield noted that aircraft altitude and location over the ground varied considerably at the initiation point of selected configuration change procedures (e.g., the Noise Abatement Departure Procedure), which were to be performed simultaneously.

Verbal indicators of the transfer of Exhaust Gas Temperature (EGT) Monitor and Transfer of Aircraft Control Procedures typify the quality of communications between specific pairs of crew members. In only two of the ten simulated flights does the flight engineer fail to advise the flying pilot when he can relinquish responsibility for monitoring EGT. However, in spite of obvious needs to effect the optional transfer of control procedure, two crews never use it and three crews execute incomplete double transfers. Only one crew uses more than two transfers (4) during the simulated flight.

Schofield further develops the thesis that verbal behaviors dictated by the aforementioned crew coordination procedures can reasonably be expected to enhance crew-coordination and flight safety. He also notes that non-compliance appears to depend more upon the operators involved than on the requirements of the procedures.

D. Errors and Procedural Compliance

Schofield modified and expanded the Ruffell Smith error counts so that every error is identified and individually related to an operator or group of operators. Those data are summarized in Table VII-3. The error categories coded by responsible operator are: pilot flying (PF), pilot not flying (PNF), captain, co-pilot, pilot team, flight engineer (FE), and entire crew. These categories cover all the errors recorded.

The next step was to investigate potential relationships between the enumerative error data and the enumerative procedure compliance data. Because of the limited sample size, relationships noted below should be taken

Table VII-3

RUFFELL SMITH'S ERRORS[a] ATTRIBUTED TO OPERATORS

		Experimental Run Number									
Operator(s)	Code	3	4	5	6[b]	8	10	12[b]	13[b]	14	15
Pilot flying	PF	4	1	1	6	2	0	1	4	0	1
Captain	CAP	4	1	1	6	2	0	3	2	0	1
Pilot not flying	PNF	1	1	0	6	2	2	3	2	4	0
Copilot	COP	1	1	0	6	2	2	1	4	4	0
Pilot team	PTM	1	2	2	4	3	2	2	4	1	2
Flight engineer	FE	0	0	2	0	0	0	0	0	0	0
Entire crew	CRW	1	0	2	3	1	1	1	1	1	1

[a]Error categories and descriptions are individually related to operators in Appendix D.

[b]On runs 6, 12, and 13 the captain is the PNF and the copilot is the PF.

as indications of fruitful directions for further research rather than as definitive results.

A set of fifteen dependent variable categories (error counts) was generated by creating various combinations of six of the categories noted in Table VII-3. A set of seven independent variables (five involving procedural compliance and two involving crew experience) was also generated as noted in Table VII-4. Stepwise multiple regression techniques were then used to identify the best models relating the independent (procedural) variables to each of the dependent (error) variables in turn. Results of that analysis, noting independent variables included and the maximum coefficients of determination, are shown in Table VII-5.

Dependent variables, which reflect errors by the flying pilot (PF, TPF, CPF), by the captain (CAP, TCAP, CCAP) and by the two pilots collectively and individually (PLTs), all have highly significant regression models in which pilot flying checklist commands (PFCK) and non-flying pilot callouts (PNFC) are the common independent variables. That is, pilot errors do appear to be related to those two classes of procedural non-compliance.

E. Procedures Summary

The Schofield study of procedural compliance by aircrews who participated in the Ruffell Smith experiment suggests the following observations:

1) Crew members face an impossible challenge in attempting to mentally catalog all of the standard operating procedures (SOP) published for them.

2) Routine non-compliance with an assortment of SOP's has been documented.

3) Forty-five percent of the enumerated crew errors involved two or more operators, which suggests that human redundancy by itself does not erradicate personnel error.

4) A statistical link appears to exist between operator errors and procedural compliance.

5) Full mission simulation offers new possibilities for studying aircrew behavior in a controlled, high fidelity, operational setting.

6) Altitude callouts, which duplicate functions performed by a machine, produced the highest frequency of non-compliant behavior, suggesting that they may need modification.

7) Lack of unitary leadership and internal coordination was most often observed when the captain was not flying the aircraft, suggesting a need to redefine flying co-pilot responsibilities.

F. Procedures Epilogue

As a follow-on to the Schofield research, a current flight engineer for one of the major carriers (who is also a graduate student at OSU) was invited to critique the study and to suggest a method for scaling criticality of normal operating procedures. The conclusion of the critique was that the Schofield research was a valuable first step in supplementing the standard human-engineering approach used in aircraft accident investigations. Such investigations often

Table VII-4

INDEPENDENT VARIABLES

Variable name	Code	Experimental Run Number									
		3	4	5	6	8	10	12	13	14	15
PF checklist commands	PFCK	5	5	8	1	3	7	3	3	5	8
Pilot checklist announcements	PA	2	2	1	5	0	1	0	0	2	2
FE checklist announcements	FEA	3	3	3	2	0	2	1	0	1	0
PNF callouts	PNFC	11	13	13	9	15	16	15	13	15	14
Aircraft control transfers	TRAN	3	2	4	0	3	6	0	2	4	4
Crew members with more than 1000 hours in B-747	CREX	3	2	2	1	2	3	1	1	2	2
Pilots with more than 1000 hours in B-747	PEX	2	1	1	1	2	2	0	0	1	1

Table VII-5

MAXIMUM COEFFICIENTS OF DETERMINATION

Dependent variable	Independent variables					
	One		Two		Three	
	Code	r^2	Codes	R^2	Codes	R^2
PF	PNFC	.749	PFCK, PNFC	.869	PFCK, FEA, PNFC	.912
CAP	PNFC	.651	PFCK, PNFC	.824	PNFC, TRAN, PEX	.878
PNF	PFCK	.579	PFCK, PA	.709	PFCK, PA, PNFC	.864
COP	PFCK	.513	PFCK, TRAN	.642	PFCK, PA, TRAN	.798
PTM	CREX	.446	CREX, PEX	.626	TRAN, CREX, PEX	.665
TPF	PNFC	.571	FEA, PNFC	.785	PFCK, FEA, TRAN	.848
TCAP	PFCK	.595	PFCK, PNFC	.825	PFCK, FEA, PNFC	.856
TPNF	PFCK	.692	PFCK, PA	.763	PFCK, PA, PNFC	.808
TCOP	PFCK	.567	PFCK, TRAN	.637	PFCK, TRAN, CREX	.789
CRW	PNFC	.317	PFCK, PNFC	.363	FEA, CREX, PEX	.550
CPF	PNFC	.595	PFCK, PNFC	.769	PNFC, CREX, PEX	.820
CCAP	PNFC	.569	PGCK, PMFC	.794	PNFC, CREX, PEX	.852
CPNF	PFCK	.606	PFCK, PA	.710	PFCK, PA, CREX	.743
CCOP	PFCK	.532	PFCK, PA	.624	PFCK, TRAN, CREX	.705
PLTS	PFCK	.597	PFCK, PNFC	.741	PNFC, CREX, PEX	.796

result in "pilot error" accusations which may in fact have strong procedural compliance implications.

Schofield recognized that not all of the 97 normal operating procedures he identified were equally critical to the safety of flight. To obtain some feel for aircrew opinions concerning criticality, and concurrently the implied importance of compliance, a group of five flight engineers were subsequently invited to rate the criticality of these 97 procedures relative to the safety of flight.

The interesting observations here are:

1) There is wide disagreement among flight engineers on the criticality of most procedures.
2) Only four of the procedures are unanimously rated at the maximum (7) criticality. (Takeoff checklist, takeoff, landing checklist and outside scan and visibility callouts.)
3) Noise abatement departure procedures received by far the lowest ratings.
4) There are large differences in the scoring tendencies among engineers, e.g. some have far more high criticality ratings for procedures than others.

VIII. CONCLUSIONS

The project began with an early concern for the dynamics of CIFE's and broad attempts to identify pertinent research issues. The final products were 1) a set of scenarios with associated hardware and techniques for studying CIFE phenomena in a simple flight simulator; 2) a set of paper and pencil scenarios and associated techniques for studying pilot diagnostic strategies and diversion decision making processes; 3) a set of knowledge testing instruments designed to measure a pilot's understanding of aircraft subsystems and troubleshooting; 4) a study relating cockpit crew procedural compliance with performance errors. By-products of this research included one M.S. design project, one M.S. thesis, and a Ph.D. dissertation.

A. Full Mission Simulation

Twelve subjects were selected for testing in the full mission GAT scenarios. Although all were IFR rated, they ranged in age from 20 to 56 years old, in flight experience from 270 to 8800 hours and in certification from private pilot to ATP. Each subject was given two different forms of the knowledge survey to complete and was thoroughly debriefed after his flight.

A wide range of cockpit management styles and apparent skill levels were observed. Although it was difficult to quantify, "good performance" was easily recognized by the observers of the experiment. The elements of "good performance" included:

1) professional use of the radio
2) precise heading and altitude control prior to and during the CIFE

3) constant awareness of the aircraft position along its intended route

4) prompt, but not necessarily instant, response to the on-set of the CIFE (detection)

5) systematic procedure for trouble shooting

6) knowledge and use of available ATC resources

7) diversion decisions which allowed for further potential uncertainties

The sample was too small to indicate anything other than some initial hypotheses concerning pilot performance in such a full-mission setting. However, the following tendencies were noted:

1) Cockpit management style varies widely among pilots. For example, some are extremely self-reliant, others want immediate and extensive help from ATC while still others make the decision making process a joint effort with ATC.

2) Good stick and rudder people seem to have excess capability and maintain good stick and rudder performance during and after the CIFE. More marginal stick and rudder people, on the other hand, show increased frequency and amplitude of heading and altitude excursions, and experience communications difficulties when faced with a CIFE.

3) Pilots who score well on the knowledge tests tend to perform well in problem diagnosis and decision making.

From the observations of the experimenters and comments made by participating subjects, it appears that such a full mission simulation exercise, coupled with an appropriate knowledge survey and debriefing, could be a valuable tool for recurrent training of IFR pilots.

B. P/P Scenarios

For purposes of analysis the closed-form knowledge survey was considered to be part of the P/P experiments. This knowledge survey focused on aircraft subsystems and trouble shooting in three major areas: 1) engine and fuel systems, 2) electrical systems and cockpit instrumentati . and 3) weather and IFR operations.

A series of Spearman Rank Correlation studies, stepwise regression analyses and t-tests were performed on the combination of pilot background variables, knowledge survey results, diagnostic scenario performance and decision making measures. Among the observations made from these analyses are the following:

1) There is no correlation between knowledge score and total flight hours.
2) Knowledge score is correlated with pilot ratings held.
3) Pilots good in one section of the knowledge survey tend to be good in all sections.
4) Diagnostic performance is highly correlated with knowledge scores.
5) Knowledge is inversely related to total diagnostic inquiries, e.g., knowledgeable pilots reach conclusions (right or wrong) m· rapidly than others.
6) Total diagnostic inquiries is inversely related to correctness.

This implies that undirected experimentation is poor diagnosis style.

7, Total diagnosis correctness score is correlated with efficiency.

8) Civil trained pilots place a higher worth on ATC service in diversion decisions than do military pilots.

9) Private pilots place a higher worth on weather factors in diversion decisions than do commercial and ATP rated pilots.

10) ATP rated pilots place high worth on time in diversion decisions.

11) Pilots with good diagnostic scores place less weight on approach aids in diversion decisions.

12) Pilots with good diagnostic scores place more weight on time in diversion decisions.

C. Procedural Compliance

Schofield used data generated in an experiment conducted in 1976 by Dr. H. P. Ruffell Smith to study routine tasks of flight operations involving airline cockpit crews during low workload segments of that flight. He was concerned with:

1) Quantifying routine procedures.

2) Analyzing observed crew errors to identyify which particular crew members were the primary causes of such errors.

3) Comparing measures of procedural compliance and operator error.

The Schofield study of procedural compliance by aircrews who participated in the Ruffell Smith experiment suggests the following observations·

1) Crew members face an impossible challenge in attempting to mentally catalogue all of the standard operating procedures (SOP) published for them.

2) Routine non-compliance with an assortment of SOP's has been documented.

3) Human redundancy by itself does not erradicate personnel errors.

4) A statistical link appears to exist between operator errors and procedural compliance.

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