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

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Ames Research Center
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June, 1981

FINAL REPORT

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

VOLUME II - APPENDIX TO FINAL REPORT

Supported By

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Principal Investigators:

Thomas H. Rockwell

and

Walter C. Giffin

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.

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APPENDIX A

DOD Interest In The CIFE Problem

I. Literature: mostly event or problem specific articles (e.g., engine failures, electrical system failures, thunderstorm penetration, wind shear, low visibility approaches, etc.) but some studies containing generalizations on workload, perception, distraction, simulation, stress measurement, etc.

A. Indices (and Repositories*)

1. Air University Index of Military Periodicals (Air University Library*)
2. Defense Documentation Center (DDC)*
3. National Technical Information Services (NTIS)*
4. Transportation Research Information Services (TRIS)

B. Selected Journals

1. Aviation, Space, and Environmental Medicine
2. Aerospace Safety
3. MAC Flyer
4. TAC Attack
5. Combat Crew
6. Interceptor
7. Soviet Military Review
8. Journal of Human Stress
9. U.S. Army Aviation Digest
10. Approach (U.S. Navy)
11. TIG (The Inspector General) Brief

II. Examples of Recent/Current Research

A. Air Force Flight Dynamics Laboratory - mission management techniques for large aircraft (pilot workload, stress, and decision making in relation to automatic flight control systems)

B. Aerospace Medical Research Laboratory - pilot workload assessment: measures of human operator performance in operational stress environments

C. AF Human Resources Laboratory - evaluation of an emergency procedures training program

D. AF Office of Scientific Research - divided attention and task workload in control failure detection and decision making

E. Savoy Aviation Research Laboratory (Univ. of Illinois) - enhancement of human effectiveness in system design, training, and operation

F. Perceptronics, Inc. - emergency procedures training packages

G. AF School of Aerospace Medicine - stress factors in aviation

III. Air Force Accident/Incident Data Bases (available to us but restricted "For Official Use Only")

A. Hazardous Air Traffic Reports - narrative of accidents that did not happen (similar to ASRS)

B. Main Frame Computer File - lengthy description of what happened and findings of the accident investigation board, 1962 to present

C. Management Information Technical System (MITS) (the "one liner liner report") aircraft data, phase of flight, time, weather, fatalities, fire damage, parts failure, cause codes (up to two), ejection data, accountability code, and brief remarks, 1962 to present.

D. Accident Investigation Reports - a complete report on each accident including who, what, where, when, how, and sometimes, why; includes personal testimony if available

IV. Current Air Studies

A. "Change Pace" - by AF Safety Center, looks at causes for increase in accident rate during 1976-78 time frame, tries to answer the "why" question as well as summarize what happened

B. Project Hasty Blue - by Air Training Command and the AF Human Resources Laboratory, deals with selection criteria for candidates to enter USAF pilot training

V. Additional Methodologies for CIFE Research (not previously discussed)

A. Heuristic programming of a robot - ref. "Questionnaire Theory: Modelling of the Pilots Mental Load" by Dominique Soulatges, Office National d'Etudes et de Recherches Aerospatiales, Paris

B. Deriving weights for a set of activities according to several criteria via a pairwise comparison matrix and analyzing a decision maker's consistency - ref. A Scaling Method for Priorities in Hierarchical Structures by Thomas L. Saaty

APPENDIX B

Annotated Bibliography

(1) The National Transportation Safety Board's "Annual Review of Aircraft Accident Data" for U.S. General Aviation, Calendar Year 1977, was reviewed to verify that the literature searched is pertinent. Fatal and non-fatal accident data including causes/factors cited by accident type were reviewed. It was easily verified that pilot judgment was the underlying element in a large percentage of accidents. What is not present are the results of near-accidents and train of thought prior to any accident.

(2) Billings, Charles E., Ralph J. Gerke, and Robert L. Wick, Jr., "Comparisons of Pilot Performance in Simulated and Actual Flight" in Clinical Medicine, March, 1975, performed in-flight and simulator experiments with experienced pilots. Under varying doses of secobarbital, the subjects flew multiple ILS approaches. The data were more strongly associated with the drug level in the simulator than in the airplane. The drug related effects were more consistent in the simulator. Improvement in performance suggestive of learning effects were seen in the simulator but not in actual flight.

The most important conclusion was the the GAT-1 simulator is a useful and sensitive device for studies of the effects of mild stress on pilot performance, but extrapolation of simulator data to the flight environment must be approached with considerable caution.

(3) Bolz, Eric H. and Janice E. Eisele, "General Aviation IFR Operational Problems", in NASA Contractor Report 159022, April, 1979, have presented general aviation IFR operational problems as more of an overview which defines problems than as a system analysis. Significant is the discussion of cockpit workload and stress. (Also significant the lack of footnoting for direct and derived data: We are left to assume the data are properly treated.) This paper is an effort to review all the factors influencing the general aviation pilot in the world of IFR and considers future developments currently in planning. It is an interesting point to start considering critical in-flight events.

(4) Bruggink, Gerald M., "Managing Emergencies", in The MAC Flyer, April, 1980, in his discussion of managing emergencies, speaks of problems of crew coordination in crew-served aircraft. He cites decision-making in a true emergency situation as an area that cannot be simulated. He claims that relying on the pat procedures in an established checklist is a gateway to a dead end road when a "non-standard" emergency develops. He identifies smoke, fire, takeoff and landing problems as real emergencies where immediate action must be taken. Other problems, at altitude, allow more time for analysis and correction. This article is basically a call for aviation safety through operating intelligence and conscience; it is not a technical treatise.

(5) Butterbaugh, Larry C., "Crew Workload - Technology Review and Problem Assessment", in AF Flight Dynamics Laboratory Technical Memorandum AFFDL-TM-78-74-FGR, has reviewed and discussed the applications and resulting technical requirements of pilot/crew workload measurement/prediction methods.

In addition, existing pilot/crew workload measurement/prediction technology is identified and reviewed. An assessment of the adequacy of these techniques relative to the identified requirements is performed. Generally, the state of workload measurement/prediction technology is not sufficiently developed for measuring/predicting total mission-derived workload, but is sufficient for part-task applications.

(6) Cavalli, Daniel, "Discrete-Time Pilot Model". The objective of this paper was to demonstrate the originality of his approach with regards to already existing pilot models and to present recently obtained results. He considers the pilot's behavior as a discrete-time process where the decision making has a sequential nature. This model contrasts very clearly with previous approaches, namely the quasi-linear model which follows from classical control theory and the optimal control model which considers the human operator as a Kalman estimator-predictor. He also considers that the pilot's objective may not be adequately formulated as a quadratic cost functional to be minimized, but rather as a more fuzzy measure of the closeness with which the aircraft follows a reference trajectory.

All model parameters, in the digital program simulating the pilot's behavior, have been successfully compared in terms of standard-deviation and performance

with those of professional pilots in IFR configuration. The first practical application of the pilot model has been the study of its performance degradation when the aircraft model static margin decreases.

Of significance in his model of the human sensor/decision/action loops is his observation that there is only a single loop in operation at a given time. It is noted that this is a most fundamental difference between a human pilot and an autopilot. This may be a valuable consideration when designing various decision making scenarios.

(7) Ceausu, Valeriu, "The Decision In the Flight Activity", Revue Raumainte Des Sciences Sociales-Serie De Psychologie, Vol. 15, #2, 1971. Ceausu makes an involved, text-like analysis of pilot decision making. His major input to the CIFE analysis is not just the various laboratory models he develops but is the concept of present time versus future time. The tests used present time without anticipatory capabilities available to the subject. He acknowledges the constraining effect on his subject. It is suggested that even the principles of laboratory psychological investigation be revised to accomodate the "temporal dimensions".

(8) Connor, T. M. and Hamilton, C. W., "Final Report on Evaluation of Safety Programs With Respect to the Causes of Air Carrier Accidents" to the FAA, May 16, 1979. Connor and Hamilton cite, among other things, a need to emphasize efforts at system level programs aimed at optimizing operator performance in specified temporal and spatial conditions. New program initiatives are required that address human error problems in behavioral terms at detailed cause factor levels. This will provide a very broad knowledge base upon which further research, programs, and data can grow.

(9) Honeywell Systems and Research Center, "Crew Workload Assessment - Development of a Measure of Operator Workload", Technical Report AFFDL-TR-78, June 1977-September 1978. Honeywell developed a quantitative measure of operator information processing workload for use in crew-station evaluation. A conceptual relationship between task performance,

task difficulty, and operator workload was formulated which predicts a positive correlation between performance and workload over an intermediate range of task difficulties.

After statistical evaluation, it was found that the forearm electromyogram amplitude, respiration amplitude, and respiration duration metrics have ordinal scale characteristics which can be used to compare design options relatively. But further analysis is needed to generalize this or a related metric to workload estimation in real-world flight tasks.

(10) Curry, Renwick E., John K. Lauber and Charles E. Billings, "Experiments In Pilot Decision-Making During Simulated Low Visibility Approaches". Curry, et. al., have devised a way to simulate stress in the laboratory with significant correlation to pilot decision making during low visibility approaches. They observe that despite a vast accumulation of operational experience with the conduct of low visibility instrument approaches, little is understood about the decision-making behavior of pilots who fly these approaches. Likewise, there is little information regarding the man, system, and task-related factors which influence this decision-making behavior. Such information is essential for the rational design of new systems, or for the redesign of existing systems in order to correct known deficiencies.

They have assumed that it is necessary to use a simulation task which incorporates both kinds of variables, informational and psychological, to successfully study pilot decision-making behavior in the laboratory. Their paper describes the preliminary experiments in the measurement of decisions and the inducement of stress in simulated low visibility approaches.

(11) Damos, Diane L., "Residual Attention as a Predictor of Pilot Performance", Human Factors, 1978. Damos discusses an experiment where sixteen student pilots performed a task combination designed to measure residual attention. Scores on this combination were correlated with performances on flight checks administered periodically during flight training. The multiple correlation between performances on the flight checks and the task combination increased as the students progressed through flight training. The usefulness of residual attention as a predictor of pilot performance is discussed.

It is suggested that future research in this area should be concerned primarily with determining the long-range predictive validity of measures of residual attention. The paper does not address judgment training.

(12) DeMaio, Joseph, Stanley R. Parkinson, and John V. Crosby, "A Reaction Time Analysis of Instrument Scanning", Human Factors, 1978.
DeMaio, et. al., have made a study of instrument scanning reaction time. Detection and latency performance of instructor pilots and students pilots was compared in a task which required searching an aircraft instrument display for target deviations from a desired course. Performance of instructors was superior to that of students on both detection and latency measures. The use of stable fixation queues was reflected in the latency performance of students. The latency performance of instructors was much less affected by the use of such queues. Results were interpreted to suggest that experienced pilots are able to place a greater reliance on peripheral vision in scanning instrument displays.

(13) Dieterly, Duncan L., "Problem Solving and Decision Making: An Integration", NASA-Ames Research Center Report, AFHRL-TR-78, May, 1978.
Dieterly reviewed the areas of problem solving and decision-making to determine if a central approach could be identified. The approach would then be applied to training others in those areas. However, in the face of no model standardization, synthesis of research proved ineffective. The basic structure developed in Dieterly's research may be the basis upon which this structure could be developed but that was not within the scope of his project. He submits that a training program embodying such concepts would be an effective tool in decision/problem resolution training.

(14) Dieterly, Duncan L., "Accident Analysis: Application of the Decision/Problem State Analysis Methodology", NASA-Ames Research Center Report, AFHRL-TR-78, August, 1978. In a subsequent paper Dieterly developed and applied a methodology for analyzing the decision/problem state. This methodology was developed to improve the present capability to explain the causes of human error accidents.

He assumed that a successful outcome may be obtained only through the management of the decision/problem state. The decision/problem state is the set of decision/problem conditions that must be resolved to obtain an outcome. In the example he provides, the element of state management is not apparent in the available record. The approach he suggested provides a more systematic and comprehensive method for studying one major aspect of human error in accidents. It is another step in model standardization.

(15) Boeing Aerospace Company, WAM User's Manual, September 30, 1976 through June 30, 1977, Report #D180-20247-3. Boeing has published, under contract, a document which is the User's Manual for a computer program called WAM (Workload Assessment Model). The manual contains a technical description of the analytical functions of the model: instructions for the preparation of input data; instructions for the retrieval of WAM outputs; a description of the deck structure and control cards required for WAM execution; and a description of diagnostic messages generated by WAM.

WAM is used by human engineering analysts to study crew workloading at a task or subtask level. Estimates of workload, for a given temporal interval, are based upon the time available versus the time required to perform all tasks within the interval. WAM provides both printed and plotted workload data for each operator as a function of several workload channels (i.e., vision, hands, feet, cognitive, auditory, verbal). A task shifting option is provided which automatically shifts tasks to reduce workload when overload conditions are encountered.

WAM is one of several computer models developed under the Computer Aided Function-Allocation and Evaluation System (CAFES) Program. WAM is written in Fortran IV for use on the CDC 6600 computer with the KRONOS 2.1 Operating System and the RUN Compiler.

(16) FAA General Aviation News, June, 1978, "Don't Give Up The Ship".
In the FAA General Aviation News two separate critical in-flight events (in a twin Beech and a Learjet) were discussed. They happened to the same 19,000 hour pilot. He summarized both events by saying, "The one thing I'm sure of is that the experience shook me up enough to make me realize something important: none of us pilots is so calm and cool and collected but that in a moment of intense crisis we are liable to start worrying and stop searching for the answer that may be right under our nose. In my case (for the second event) the answer was a little to the right and below my nose, but it was there all the time".

But it was there all the time . . . The editor noted the key point: "This pilot's confidence in his training enabled him to solve a critical in-flight problem". Here, then, are the two problem areas pertinent to this report, the quality of training tempered by experience, and confidence in some.

(17) Forsyth, Donna L. and John D. Shaughnessy, "Single Pilot IFR Operating Problems Determined From Accident Data Analysis", NASA Technical Memorandum, September, 1978. Forsyth and Shaughnessy made an examination of Single Pilot Instrument Flight Rule (SPIFR) operations from 1964-75 NTSB accident files. They concluded that problem areas exist in pilot workload, low visibility at night due to fog and low ceilings, icing on aircraft not deicer equipped, imprecise navigation, failure to remain above minimum altitudes, mismanagement of fuel and low instrument time. Some suggested areas of research include new types of deicing or anti-icing equipment, standardized navigation instrument displays, improved fuel management systems and better methods for pilots to safely acquire experience and increase proficiency in SPIFR operations.

(18) Gartner, Walter B and Miles R. Murphy, "Pilot Workload and Fatigue: A Critical Survey of Concepts and Assessment Techniques", a Technical Note published by NASA. Gartner and Murphy have an in-depth literature review on pilot workload and fatigue. It is rigorous enough for them to be able to draw conclusions on the way the problem should be addressed, measured, and managed. They look at measurement of pilot effort, cognition, and other studies in sleep research.

The overall study, then, addresses the principal unresolved issues in conceptualizing and measuring pilot workload and fatigue. These issues are seen as limiting the development of more useful working concepts and techniques and their application to systems engineering and management activities. A conceptual analysis of pilot workload and fatigue, an overview and critique of approaches to the assessment of these phenomena, and a discussion of current trends in the management of unwanted workload and fatigue effects are presented. Refinements and innovations in assessment methods are recommended for enhancing the practical significance of workload and fatigue studies.

(19) Kowalsky, Nestor B, Richard L. Masters, Richard B. Stone, Gary L. Babcock, and Eugene W. Rypka, "An Analysis of Pilot Error-Related Aircraft Accidents", NASA Contractor Report Final #CR-2444, June, 1974. Kowalsky, et. al., present an in-depth analysis of air carrier accident investigation problems, techniques, and solutions. They propose and apply a systematic methodology to examine the characteristics of flights prior to accidents (environmental factors, aircraft systems, pilot performance, facilities, policies, procedures). They also include the contingencies pertaining at the time of the accident, to afford consideration of all the elements interfacing and interacting in the operation of a complex aeronautical system. Of significance is their underlying treatment of decision making.

(20) Levit, Robert A., "Human Behavior In Extreme Situations: Generalizations From a Review of the Disaster Literature", Proceedings of the Human Factors Society 22nd Annual Meeting, 1978. Levit provides a short review of disaster literature and some exemplary human factors studies. He makes generalizations on principles of disaster management from the standpoint of human factors professionals. The items relevant to the flight regime are from a study by Keating and Loftus on voice alarm systems (VAS): (1) The system must emphasize the communication of what is happening, why and what to do about it, (2) Messages should be unambiguous and communicated in a manner which instills a sense of confidence, order and control in the recipients, (3) Messages should be delivered before emergency cues have reached a large segment of the populace, (4) All essential information should be repeated twice using relatively common words, and (5) The attentional value of emergency messages is enhanced if segments are delivered by alternating male and female voices.

(21) Hart, Sandra G., "A Cognitive Model of Time Perception", presented at the 56th Annual Meeting of the Western Psychological Association, April, 1976. Hart defines the terms and basic model used in the research and papers described below.

(22) Hart, Sandra Gail and Duncan McPherson, "Airline Pilot Time Estimation During Concurrent Activity Including Simulated Flight", presented at the 47th Annual Meeting of the Aerospace Medical Association, May, 1976. In further developing the utility of pilot time estimation, Hart and McPherson clarify the functional relationships between the length and variability of time estimates and concurrent task variables. This is one way to provide an unobtrusive and minimally loading additional task that is sensitive to differences in flying conditions and aircraft instrumentation associated with complex piloting tasks.

(23) Hart, Sandra Gail, Duncan McPherson and Leslie L. Loomis, "Time Estimation As A Secondary Task to Measure Workload: Summary of Research", presented at the 15th Annual Manual, 1978. Hart, McPherson, and Loomis have outlined the results of a longer series of experiments designed to evaluate the utility of time estimation as a secondary measure of piloting workload. Actively produced intervals of time were found to increase in length and variability, whereas retrospectively produced intervals decreased in length although they also increased in variability with the addition of a variety of flight-related tasks. If pilots counted aloud while making a production, however, the impact of concurrent activity was minimized, at least for the moderately demanding primary tasks that were selected. The effects of feedback on estimation accuracy and consistency were greatly enhanced if a counting or tapping production technique was used. This compares with the minimal effect that feedback had when no overt timekeeping technique was used.

Actively made verbal estimates of sessions filled with different activites decreased in length as the amount and complexity of activities performed during the interval were increased. Retrospectively made verbal estimates, however, increased in length as the amount and complexity of activities performed during the interval were increased. These results support the suggestion that time estimation provides a useful index of the workload involved in performing concurrent tasks.

(24) Jensen, Richard S., "Pilot Judgment: Training and Evaluation". Jensen covers a large area in the state-of-the-art of pilot decision making. He examines various techniques and measures of training and testing effectiveness, defines judgment in two ways, and considers the problems in teaching judgment.

In looking at learning principles, available training media, computer-aided instruction and situational emergency training, Jensen leads into the problem of judgment evaluation. Many points are made which could lead to scenario development for evaluating and training in situational emergencies.

(25) Murphy, M. R., "Analysis of Eighty-four Commercial Aviation Incidents: Implications for a Resource Management Approach to Crew Training", in the 1980 Proceedings Annual Reliability and Maintainability Symposium Manual. Murphy considers air crew performance from a resource management viewpoint. He observes that resource management training should be concentrated on: (1) Interpersonal communications, with Air Traffic Control (ATC) information of major concern, (2) Task management, mainly setting priorities and appropriately allocating tasks under varying workload levels, (3) Planning, coordination, and decision making concerned with preventing and recovering from potentially unsafe situations in certain aircraft maneuvers. Problem solving and leadership skills were implicated as factors in a sufficient number of incidents to require further study. Leadership, social skills, and role-issue effects may be under-reported in voluntarily submitted incident data: more systematic study is recommended. Some problem areas are identified for which design changes are apparently in order, particularly the ATC interface.

(26) NASA Aviation Safety Reporting System: Ninth Quarterly Report, NASA Technical Memorandum 78608. This report publishes the results of a study on Distraction - A Human Factor in Air Carrier Hazard Events. As a frequent contributor or cause of hazardous events, distraction incidents (where attention is diverted from aircraft management, such as heading control) can be type-classified. Both air and ground operations suffer accidents where the normal crew coordination designed as a human-engineered series of tasks is interrupted. By following established cockpit priorities, reformatting charts, SIDS, approaches, etc., reading distractions can be reduced. Autopilot monitoring ("who's flying the airplane?"), improved air/ground communications, weather, passenger problems, controller inputs, and many other items are considered as distractions. Reducing the cockpit workload results in more time for vigilance and anticipation of events requiring judgment. The underlying theme of the report is that a good train of thought is easily and often disturbed through distraction.

(27) Roscoe, Alan H., "Stress and Workload in Pilots", Aviation, Space, and Environmental Medicine, April, 1978. Roscoe observes that several studies have highlighted the increase in physiological activity which occurs in pilots during flight and especially during takeoffs and landings. For example, it has been clearly demonstrated that pilots' heart rates increase during the landing approach to reach a peak at or just before touchdown. These changes have been attributed to workload and to psychological or emotional stress. This paper examines a number of test pilots' heart rate responses recorded during various flight trials involving different types of aircraft. Examples include ramp takeoffs in a VTOL fighter, automatic landings in fog, supersonic flight through monsoon rain, and a sortie in which the pilot developed acute appendicitis. It is concluded that heart rate responses in experienced pilots are influenced almost entirely by workload-related factors and not by emotional stressors, such as risk and anxiety. Because of the emotional overtones of the word "stress", it is suggested that the term workload should be used when referring to the reason for increased cardiovascular activity in pilots.

(28) Thorpe, Jack A, Elizabeth L. Martin, Bernell J. Edwards, and Edward E. Eddowes, "Situational Emergency Training: F-15 Emergency Procedures Training Program", Interim Report for Air Force Systems Command, July 1975 - January 1976. Thorpe, et. al., discuss the comparative strengths and weaknesses of Situational Emergency Training (SET) versus Boldface checklist reactions. Since the latter is simply the critical steps that must be taken to reduce an emergency, there is room for pilot error in maintaining control of the aircraft, developing another emergency, and losing positional awareness. There is little thought (judgment) applied, just immediate actions.

The objective of their work was to develop and evaluate an emergency procedures training program for the F-15. The three applicable in all emergency/abnormal situations specified for F-15 operations are: (a) maintain aircraft control, (b) analyze the situation and take the proper action, and (c) land as soon as practicable. The traditional emergency procedures common to other USAF weapons systems featuring Boldface procedures which must be committed to memory do not exist for the F-15.

The strengths and weaknesses of both approaches were noted. Five conclusions were derived from this comparative analysis: (a) the traditional Boldface approach has several deficiencies which may reduce the probability that judgment will be exercised when needed, (b) SET is more comprehensive than Boldface, encourages the development of judgment, and centers training around all three emergency rules listed above, (c) the underlying concept of SET is situational training, an approach which systematically manipulates the important dimensions of the emergency situation. The pilot is taught to discriminate the relevant from the irrelevant dimensions of the situation, a discrimination process which is fundamental to exercising judgment, (d) pilots report a positive attitude towards SET training sessions, which in turn has resulted in what supervisors feel is a more productive training program, and (e) by using a scenario development procedure, it is hypothesized that SET can be more effective.

(29) Trollip, Stanley R., "The Evaluation of a Complex Computer-Based Flight Procedures Trainer", Human Factors, 1979. Skills such as flying holding patterns are taught in planes or simulators. An alternative method is to use computer-assisted instruction (CAI) which emphasizes training requirements rather than physical fidelity. Such a program was written and evaluated. Traditional ground school methods were compared with the CAI method. All subjects completed a training sequence in a ground trainer. Those taught by computer performed better and attained criterion quicker with significantly fewer critical errors. Results indicate the CAI offers an effective alternate to the costly trainers currently in use.

(30) Verstynen, Harry A., "A Possible Role For the Pilot in the Future ATC System", presented at the fall conference of the Air Traffic Control Association, October, 1978. Verstynen presents an overview of the role of the pilot in the future ATC system. He admits to bias and seeks the reader's judgment of validity. He poses some interesting problems and possible outcomes. He concludes that the role of the pilot in the future ATC system is likely to be substantially changed from the role of the pilot today. The two major factors effecting this role will be the shifting of certain ATC functions from the ATC system to the pilot and the development of onboard processing capabilities which will relieve the pilot of many of the functions to which machines are better suited than humans.

The pilot will progressively become less of a control manipulator and more of a manager of a system which combines traditional outer loop tasks such as navigation, planning, and resource management with new roles as a tactical situation manager.

(31) Walden, Rex S. and William B. Rouse, "Queueing Model of Pilot Decision-making In a Multitask Flight Management Situation", IEEE Transactions On Systems, Man, and Cybernetics, Vol. SMC-8, December, 1978. Walden and Rouse model pilot decision making as a queueing problem.

Allocation of decisionmaking responsibility between pilot and computer is considered, and a flight management task, designed for the study of pilot-computer interaction, is discussed. A queueing theory model of pilot decision making in this multitask control and monitoring situation is presented. An experimental investigation of pilot decision making and the resulting model parameters are discussed.

They conclude that the queueing formulation of the control and monitoring situation presented is attractive. With the exception of the control task service rate, the parameters of the model are "eminently measureable", at least in controlled experiments. Whether this is transferrable to the real world is not discussed.

APPENDIX C

Trip Summary Outline - W.C. Giffin, T.H. Rockwell, J. Schofield

1. NTSB - March 12, 1979

   A. Participants

      1. James Danaher, Chief Operational Factors Division
      2. Gerrit Walhout, Chief Human Factors Division
      3. Dave Kelly, Chief Information System Division

   B. Suggested Contacts

      1. Al Diehl, Human Factors Engineering - NTSB
      2. Ward Edwards, Prof. (?) (Fighter Pilot Decisions)
      3. Jim Loomis, Battelle (NTSB Data)
      4. Emil Spieza, Fort Rucker (Viet Nam Data)

   C. Interesting Data

      1. 80 man hours to report BA accident
      2. "In-House" documents behind blue cover reports
      3. Danaher list of resource management accidents for future study
      4. 65 pilot factors in NTSB data
      5. Accident identified by "nearest post office"
      6. Two years cases at NTSB - rest in archives
      7. FAA training approval through air carrier training office (ATCO)
      8. Fort Rucker factor analysis of Viet Nam data

2. ATA - March 12, 1979

   A. Participants

      1. H.G. (Grady) Gatlin, Director of Operations
      2. Frank Brady, Director NAS Systems Engineering (ATA)
      3. Larry Gillespie, MGR, DF FLT. OPS.
      4. Vern Ballenger, Director of Engineering
      5. Bob Smith, ATC
      6. Peter Duprey

   B. Suggested Contacts

      1. Airline Safety Directors (see Gatlin letter 3/13/79)
      2. Dave Thomas, GAMA

3. Jim Gannet, Boeing Human Factors
4. Flight Safety Foundation
5. NASA/Langley (Air Crew Performance Evaluation)
6. ICAO, (Accident/Incident Report for INTN'L)
7. Captain H.T. Nunn, Northwest (Loft)

C. Interesting Data

1. Line oriented flight training
2. ASRS - best hope for incident data
3. Gatlin "horror show" of unreported incidents
4. American Airlines BAC III - record of human factors information (24 parameters)
5. United Airlines - Safety Awareness Program

3. Mitre Air Transport Division - March 12, 1979

A. Participants

1. Dr. J.S. Matney
2. Dr. Glen Kenney - ATC Human Factors
3. Pat McKay - Division Chief

B. Interesting Data

1. Gear study to FFS modernization program? (e.g., natural for computer aid to distressed pilot)
2. Lovelace report - on site air carrier pilot analysis
3. ATC system errors - 600/yr. - in-house monitoring
4. Improve work habits to reduce system errors
5. Problem with unreported errors
6. System error causes
   i. Lack of controller awareness of own limitations
   ii. Lack of standard work habits
   iii. Delay action (reluctant to tell A/C what to do)

4. ALPA - March 13, 1979

A. Participants

1. Bill Edmunds, Human Performance Specialist
2. Dick Stone, Delta Captain and Chairman of Committee

B. Suggested Contacts

1. Homer Mouden, Flight Safety Foundation (703-820-2777)
2. Topmiller, WPAFB
3. J.D. Smith, United
4. Mack Eastburn, United

C. Interesting Data

1. Simulator; demonstration of proficiency for FAA only
2. Ask pilot "what scares you?"
3. CIFE - events which take A/C out of normal flight envelope
4. Crew often unaware of participation in CIFE
5. False alarms compromise warning systems
6. Training not consistent with real world
7. Difference between success and failure is information
8. ALPA gold medal award (annual)
9. Lovelace report (stone involved)
10. United and Allegheny good sources
11. Competition in cockpit - who can solve problem first
12. Crew lounge interviews
13. Resources management - why give decision maker manipulative functions?

5. AOPA - March 13, 1979

A. Participants

1. Russel Lawton

B. Suggested Contacts

1. John Shaughnessy - NASA/Langley (804-827-3917) (time line analysis for single pilot IFR)

C. Interesting Data

1. AOPA market survey might include CIFE questions
2. Plantation party seminar
3. AOPA has docket on member accident reports
4. Lawton working on paper "Pilot Distress"
5. Royal A/F - pilot workload/stress

6. DSR - Bolling AFB - March 13, 1979 (J. Schofield)

A. Participants

1. Jack Thorpe

B. Suggested Contacts

1. Dr. Wayne Waag - AFHRL/FT, Williams AFB (8-474-6945) (C-5 Pilot Performance Measures Project)
2. Hans Heinrich and Lt. Col. Rudy Hartzog - SAC/Instructional Systems Development (8-271-2674/3015)

C. Interesting Data (AFOSR Contracts and Grants)

1. Herbert A. Colle (Wright State University) - a capacity theoretic approach to workload assessment
2. Diane Damos (State University of New York) - training efficient multiple-task strategies
3. Herbert Land and Stuart E. Dreyfus (University of California, Berkeley) - formal versus situational models of expert decision-making
4. Daniel Gopher - task load and operator attention capacity in time-sharing performance
5. Gary S. Krahenbuhl (Arizona State University) - stress and learning in the flying training environment
6. Luigi Lucaccini, Amos Freedy, and Rosemarie Hopl-Weichel (Perceptronics, Inc.) instructional system development and evaluation of situational emergency training

7. United Airlines - April 19, 1979

A. Participants

1. J.D. Smith, Vice President
2. Tom Dawe, Flight Operations Safety Task Force

B. Interesting Data

1. NASA contract with UAL to bring SST into ATC system
2. UAL involved in basic program for ASRS - foreign and domestic
3. UAL internal report system
   a) co. immunity
   b) 180 reports 1977-1979
   c) ATC incidents, equipment malfunctions, procedures
   d) all United reports go to ASRS

4. monitored approach concept - crew coordination
5. 24 hr. maintenance function avail to patch for help
6. Navy study - Dr. Alkov - fatals came from "best" pilots who couldn't cope with marital, budget, etc. problems
7. command training module - how to train decision makers
8. "irregularity" reports - UAL has 5000/yr.
9. cardinal sin - operating by assumption

APPENDIX D

Open Form Knowledge Survey with Answer Key
and Description of Six Pilot Knowledge Areas

You have been asked to help the OSU Systems Research Group develop a means of testing pilot knowledge of aircraft sub-system operation. Please give a short answer to each of the following questions in the space provided. If you need more space, use the back of that page.

Although this questionaire will not be graded, you may wish to compare your responses to our own answer key.

Thank you for your help and cooperation.

1. What is the only method to assure the fuel boost pump is operating?

2. Name a few design innovations intended to minimize "sloshing" in a fuel tank.

3. Name a source in the cockpit of determining the amount of usable fuel an airplane is capable of carrying (other than the Aircraft Operating Manual).

4. Does a turn coordinator and a turn-and-bank indicator provide you with identical information? If no, what is the difference?

5. Should ammeter indications fluctuate with changes in engine RPM with an alternator system?

6. What would be an indication of an alternator malfunction?

7. Aircraft operating manuals usually suggest the fuel boost pump be turned on for take-offs and when conducting low altitude (less than 1000' AGL) operations (on airplanes that require them). What is the reason for this?

8. What is the function of a voltage regulator?

9. Is structural icing considered a likely event above the clouds? Why?

10. What is the standard adiabatic lapse rate?

11. What indications would tell the pilot his alternator system is operating normally, or "acceptably"? Do the indications of "normal operation" change during the course of a flight?

12. Define IAS, CAS, TAS.

13. If an alternator is removed from the rest of the electrical system by an automatic circuit protection device (i.e., an auto-reset circuit breaker), how can the pilot attempt to bring the alternator back into service?

14. If smoke is noticed in the cabin, what indicators would tell the pilot it is "electrical" in origin? What should he do?

15. When the battery power is sufficiently "run down", an "alternator restart" may be impossible. What does this mean and why does it happen?

16. What does an ammeter tell the pilot?

17. What does the term "unusable fuel" mean?

18. What could cause a sharp, sudden decrease in RPM, and pronounced engine roughness?

19. What range of temperature and atmospheric conditions is most likely to to cause carburetor ice?

20. What airspeed and altimeter errors are associated with the use of an interior alternate static air source in unpressurized airplanes?

21. What is "detonation" and when does it occur?

22. If it becomes necessary to continue operation with the use of full carburetor heat, what action should be taken to insure smooth engine operation?

23. What does a suction gauge, or instrument air gauge, indicate?

24. In what temperature range should carburetor heat not be used?

25. What is the reason for not using carburetor heat during ground operations?

26. Periodically, an ordinary directional gyro needs to be reset to keep its indications consistent with that of the magnetic compass. Why is this so?

27. What do ground based weather and airborne weather radar systems detect and display?

28. What are the symptoms indicating the onset of carbon-monoxide poisoning?

29. Is there any ground-assisted instrument approach procedure, other than PAR or ASR, which can be made in an emergency? (Ground-assisted assumes that all the pilot needs is a two-way radio).

30. What is the difference between a "slaved" directional gyro and a non-slaved one?

31. Which gyro flight instrument is most likely to tumble last?

32. How can a pilot determine that his alternator is operating properly (before he takes off)?

33. Master switches, on aircraft with alternator systems, usually consist of two switches labeled BATTERY and ALTERNATOR which can be turned ON or OFF. Which of these two switches, when turned OFF, automatically turns off the other side as well?

34. Describe the possible ways a pilot could remove the alternator from the rest of the electrical field, and operate solely on battery power.

35. What causes a gyroscopic flight instrument to tumble, i.e., give grossly erroneous or nonsense information?

36. Name all of the "unsafe gear" indications you can recall, that a manufacturer uses in airplanes with retractable gear.

37. In an airplane equipped with retractable landing gear, what guidelines normally determine the point of retraction?

38. Explain your procedure for power application and power reduction in an airplane equipped with a constant-speed propeller

39. What determines the configuration of cowl flaps during a climb?

40. Define the terms "service ceiling" and "absolute ceiling".

41. Are airspeeds marked on the airspeed indicator in terms of IAS, CAS, or TAS?

42. If there is a loss of oil pressure, how would a constant-speed propeller be affected?

43. Begin with the slowest "V" speed shown on an airspeed indicator and describe each in order, including its' significance.

44. Some gyro flight instruments are "vacuum" driven. What does this mean?

45. Where does carburetor ice form (induction ice)?

46. How can a pilot usually tell when detonation occurs?

47. What would you do if you encountered severe turbulence in IFR conditions?

48. Assume you encounter instrument conditions immediately after lift-off. A short time later you notice your airspeed indicator showing a steady decrease, altimeter still shows field elevation, and your VSI shows a zero rate of change. (Attitude indicator still shows normal climb). What is your response?

49. What is the cause of most engine failures in flight?

50. How is vacuum system pressure differential kept at a constant value throughout the range of normal operating RPMs and altitudes?

51. Suppose your pitot tube became totally and rapidly blocked (i.e., ice) at 5000' while you were climbing to 10,000'. Assuming the aircrafts true airspeed remained the same during the climb through 5000', what indications would you expect from your airspeed indicator, altimeter, and vertical speed indicator?

52. Assuming the failure of all gyroscopic flight instruments, how can a pilot directionally control an airplane in a decent through an overcast?

53. At what altitude should leaning be attempted under normal cruising power (less than 75%), in a direct drive, fixed pitch, float type carburetored airplane?

54. In what free air temperature range would expected structural icing?

55. If you suspect your air filter has become obstructed or iced-over in flight, what action should you take and why?

56. What is the best method for temporarily correcting preignition and detonation?

57. What could cause a gradual drop in RPM and engine roughness (float type carburetor)?

58. What flight instruments would be affected by a total blockage of the static port?

Answer Key To Open Form Knowledge Survey

1. Turn on the fuel pump before starting the engine. There should be an increase in fuel pressure as indicated on fuel pressure gauge.

2. Baffles and Rubber Bladders.

3. On the Fuel Selector valve or the Fuel Shut-off valve.

4. No. A turn and bank indicator reveals direction and rate of turn. A turn coordinator provides that information plus the rate and direction of roll. Both instruments have "balls" which tell the quality of coordinated flight.

5. No.

6. An excessively high rate of charge, any discharge, illumination of an over-voltage light, if equipped, or a tripped alternator circuit breaker.

7. This is done to insure an uninterrupted flow of fuel to the engine in the event the mechanical pump fails. Engine failure at such a critical altitude may not allow enough time for a successful restart.

8. To regulate the rate of charge of the battery, and to place electrical load on the alternator.

9. No, visible moisture is necessary.

10. 2° C/1000 ft.

11. A zero rate or a slightly positive rate of charge indicates a normal operation. Yes, normal indications do change during the course of a flight: after engine start, charge rate is slightly higher than at other times.

12. IAS = Indicated Air Speed = speed read directly from indicator.
    CAS = Calibrated Air Speed = IAS corrected for position and instrument errors.
    TAS = True Air Speed = calibrated air speed correct for nonstandard temperature and pressure.

13. Turn off alternator switch for a moment, then turn back on.

14. Smells like burning insulation. Turn off all switches and isolate faulty equipment by turning switches on one at a time.

15. It occurs because the battery power is insufficient to close the relay to bring the alternator into the electrical field. If this happens it means the battery will not charge even if the airplane is jump started.

16. The rate of battery charge or discharge, or the amount of electrical load assumed by the alternator.

17. Fuel remaining in the tanks which cannot be relied upon for use in all normal flight attitudes or conditions.

18. Magneto malfunction or internal engine failure.

19. 32° to 80° F with relative humidity 50% or more.

20. Airspeed reads higher than actual and altimeter reads higher than actual, and there is more of a lag in indications.

21. Detonation is the uncontrolled explosion of fuel in the power stroke caused by overheating or improper grades of fuel.

22. Lean the mixture.

23. The difference between pressure inside the system (vacuum network) and the pressure outside the system.

24. Below 15° F.

25. Unfiltered air enters the carburetor with the carburetor heat "on".

26. It is due to precession from motion and drag in the bearings.

27. Precipitation.

28. Feelings of sluggishness, tightness across forehead, warmth, headaches, throbbing, pressure at the temples.

29. Yes, an emergency D.F. approach.

30. A slaved directional gyro continuously corrects itself with respect to a remote magnetic compass, whereas a non-slaved one must be reset manually.

31. A turn-and-bank indicator or a turn coordinator.

32. Turn on landing light (or other high load device). For a charge-discharge ammeter, needle should flicker and return to original position. For a load type ammeter, needle should indicate higher than originally.

33. Battery.

34. Turn off alternator master switch, or trip the alternator circuit breaker.

35. They tumble when they are forced beyond their mechanical limits, or when there is an insufficient rate of rotation.

36. Gear horn, gear-in-transit lights, unlit gear down light, "barber poles", gear position indicator, or gear emergency extension handle.

37. Retract at point in take-off where insufficient runway ahead remains for landing.

38. Adding power prop forward then throttle; reducing power, throttle back then prop.

39. Cylinder head temperature.

40. Service ceiling is the altitude at which maximum rate of climb is 100 fpm. Absolute ceiling is altitude where maximum rate of climb is zero.

41. CAS.

42. Prop would move to high RPM (low pitch).

43. V_{S0} = stall speed - landing configuration.

    V_{S1} = stall speed - gear and flaps retracted

    V_{FE} = maximum speed with flaps extended

    V_{NO} = maximum structured cruising speed

    V_{NE} = never exceed speed

44. Air is sucked out of instrument case by a vacuum and incoming air is directed at rim of gyro rotor, causing it to spin.

45. Throttle plate and walls of carburetor venturi.

46. Under normal circumstances he can not.

47. Reduce speed below V_A, maintain level attitude.

48. You should select an alternate static source.

49. Fuel starvation or mismanagement.

50. By a suction relief valve.

51. Airspeed would increase, altimeter and VSI remain unaffected.

52. Use a magnetic compass on a heading of south. Or "home" to a distant station on ADF.

53. Any altitude.

54. 32° F or colder.

55. Apply full carburetor heat to provide alternate source of air for the carburetor.

56. Enrich mixture, open cowl flaps, reduce power.

57. Carburetor ice.

58. Altimeter, VSI, and airspeed indicator.

Six Pilot Knowledge Areas Covered In Open Form Survey

Area	
I. Engine and Engine Operations	18, 19, 21, 22, 24, 25, 38, 39, 42, 45, 46, 49, 53, 56, 57
II. Fuel Systems	1, 2, 7, 17
III. Electrical Systems	5, 6, 8, 11, 13, 14, 15, 16, 32, 33, 34
IV. Cockpit Instrumentation	3, 4, 12, 20, 23, 26, 30, 31, 35, 41, 43, 44, 48, 50, 51, 58
V. Weather	9, 10, 27, 28, 54
IV. General and IFR Procedures	29, 36, 37, 40, 47, 52, 55

APPENDIX E

Closed Form Knowledge Survey With Answer Key and Description of Three Pilot Knowledge Areas

A/C SYSTEMS SURVEY

Circle Correct Answer

_____
(Name)

1. What is the standard adiabatic lapse rate?

   a. 2°F per 1000 feet
   b. 2½°F per 1000 feet
   c. 3°F per 1000 feet
   d. 3½°F per 1000 feet
   e. 4°F per 1000 feet

2. Do the indications of a normally operating alternator system change during the course of a flight? (Assume charge-discharge ammete

   a. Yes: Ammeter shows more charge when electrical equipment turned on.
   b. Yes: Ammeter shows less charge when electrical equipment is turned on.
   c. After engine start, the ammeter shows a higher than normal rate of charge and gradually declines to normal rate.
   d. No, does not change.

3. If an alternator is removed from the rest of the electrical system by an automatic circuit protection device (i.e., an auto reset circuit breaker), how can the pilot attempt to bring the alternator back into service?

   a. Turn off the alternator and turn it back on.
   b. Turn off all switches and push reset button.
   c. Turn off switches one by one and push the reset after each switch is turned off.
   d. Just push the reset button.

4. If smoke is noticed in the cabin, what indicators would tell the pilot that it is electrical in origin?

   a. Discharge on ammeter
   b. Odor
   c. Erratic instrument indications
   d. Circuit breaker popped

5. In what range of temperatures is one most likely to encounter carburetor ice?

   a. 32°F or below
   b. 20-40°F
   c. 32-80°F
   d. 50-80°F

6. What airspeed and altimeter errors are associated with the use of an interior alternate static source in unpressurized airplanes?

   a. Airspeed and altitude read higher than actual
   b. Airspeed and altitude read lower than actual
   c. Airspeed reads higher and altitude reads lower than actual
   d. Airspeed reads lower and altitude reads higher than actual

7. If it becomes necessary to continue operation with the use of full carburetor heat, what action, if any, should be taken to insure smooth engine operation?

   a. Enrich mixture
   b. Lean mixture
   c. Avoid high power settings
   d. No action required

8. What do ground based and airborne weather radar systems detect and display?

   a. Precipitation
   b. Clouds
   c. Thunderstorms
   d. Turbulence

9. Which gyro flight instrument is most likely to be the last to tumble?

   a. Artificial horizon
   b. Turn and bank indicator
   c. Directional gyro
   d. Depends on maneuver

10. Master switches, on aircraft with alternator systems, usually consist of two switches labeled "battery" and "alternator," which can be turned on or off. Which of these two switches, when turned off, automatically turns off the other side as well?

a. Battery

b. Alternator

c. Neither: both must be turned off

11. What determines the configuration of cowl flaps during a climb?

a. Cylinder head temperature

b. Exhaust gas temperature

c. Oil temperature

d. Outside air temperature

12. Which of the following is the best definition of the service ceiling of an aircraft?

a. Maximum altitude at which the A/C can maintain level flight

b. Maximum altitude at which the A/C can climb 100 fpm

c. Maximum altitude at which the A/C can climb 500 fpm

d. Maximum altitude to which the A/C can climb

13. If there is a loss of oil pressure, how would a constant speed propeller be affected? (Assume a non-counterweight type propeller)

a. It would not be affected

b. It would move to high rpm

c. It would move to low rpm

d. It would vary between high and low rpm

14. Which of the following is the best procedure if you encounter severe turbulence in IFR conditions?

a. Reduce speed below V_A, maintain level altitude

b. Reduce speed below V_A, pull on carb heat

c. Reduce speed below V_A, maintain level attitude

d. Maintain speed and level altitude

e. Maintain speed and level attitude

15. Suppose your pitot tube became totally and rapidly blocked (i.e., ice) at 5000 feet while you were climbing to 10,000 feet. Assuming the aircraft's true airspeed remained the same during the climb from 5000 feet, what indications would you expect from your airspeed indicator, altimeter, and vertical speed indicator?

a. Airspeed decrease altimeter and VSI show climb

b. Airspeed increase altimeter and VSI show climb

c. Airspeed decrease altimeter 5000 and VSI zero

d. Airspeed increase altimeter 5000 and VSI zero

16. Assuming the failure of all gyroscopic instruments, how can pilot directionally control an airplane in a descent through an overcast?

a. Reduce power, trim for 500 fpm descent

b. Use turn and bank indicator for directional control

c. Call approach control for vectors

d. Use magnetic compass on a heading of south

17. At what altitude should leaning be attempted under normal cruising power (less than 75%) in a direct drive, fixed pitch, float type carburetored airplane?

a. 3000 feet MSL

b. 5000 feet MSL

c. 6000 feet MSL

d. Any altitude

18. In what free air temperature would a pilot expect structural icing to occur

a. 32°F or below

b. 32°to +40°F

c. -10 to 32°F

d. Above 32°F

19. If you suspect that your air filter has become obstructed or iced-over in flight, what action should you take and why?

a. Apply full carburetor heat to melt ice

b. Apply full carburetor heat to provide alternate source of air

c. Lean mixture so less air would be required

d. Land immediately: can't melt ice on filter

20. What is the best method for temporarily correcting pre-ignition and detonation?

a. Lean mixture and reduce power

b. Enrich mixture and reduce power

c. Lean mixture and increase power

d. Enrich mixture and increase power

ANSWER KEY FOR CLOSED FORM SURVEY

1. D	11. A
2. C	12. B
3. A	13. B
4. B	14. C
5. C	15. B
6. A	16. D
7. B	17. D
8. A	18. A
9. B	19. B
10. A	20. B

Three Pilot Knowledge Areas Covered In Closed Form Survey

Area	Pertinent Questions	Code*
I. Engine and fuel systems	5,7,11,13,17,19,20	CATSCR 1
II. Electrical systems and cockpit instrumentation	2,3,4,10,6,9,15	CATSCR 2
III. Weather and IFR operations	1,8,18,12,14,16	CATSCR 3

*For reference to data in Chapter VI, also see Glossary Table VI-3.

APPENDIX F

GAT-1 FMS Performance Profiles

SCENARIO: #1
SUBJECT: #1

ACTION: 1) Returned to Seaport 2) Shot ADF approach

Subject #1 is a low-time (400 hours) GA private pilot with very little instrument experience (7 hours actual). He flies infrequently and strictly for pleasure.

Subject #1 exhibited difficulty in performing basic stick and rudder skills. He has difficulty holding altitude and heading and devoted much of his cockpit attention to scanning charts. He appeared nervous as exhibited by a constant stream of remarks to himself and occasional whistling. When power failure occurred he immediately reached for the fuel selector and restored power. During debriefing he stated that he noticed that the fuel gauge was reading low. Furthermore he had had a similar experience before which accounted for his fast diagnosis.

Subject #1 was quick to inform ATC of his difficulties and required considerable guidance to successfully complete the mission. His overriding concern seemed to be to return "home" just as quickly as possible.

Subject #1's management style might be characterized as 1) reactive (he did not seem to have well thought out alternatives); 2) dependent (he asked for and received considerable aid from ATC); 3) repetitive (he returned to his departure point because he viewed that as a "conservative" and was familiar with current procedures and weather at that point).

SCENARIO: #1
SUBJECT: #2

ACTION: 1) Proceeded direct to Mountaindale per flight plan

Subject #2 is a high-time GA pilot (5000 hours) with most of his flight experience being in single engine aircraft operating in VFR conditions. Although he once flew professionally his activities in recent years have been limited to pleasure flying and occasional business trips in a C172.

Subject #2 exhibited a high degree of stick and rudder competence. His only pre-CIFE difficulties stemmed from failure to note a change in clearance and garbled communications. The onset of the CIFE was initially diagnosed as an icing problem. When carb heat failed to restore power he immediately went to the fuel selector and successfully restored power.

Subject #2 was extremely self-reliant. At no time did he inform ATC that he was having difficulty. He had faith in his diagnosis of fuel siphon on one tank only and in his calculated fuel consumption (evidenced in debriefing). He continued to his planned destination without consulting the area chart for potential alternates.

Subject #2's management style might be characterized as one which involves 1) thorough pre-flight preparation; 2) rigid adherence to plans (he carried through the entire mission as planned); 3) self-reliance; and 4) minimum external source information seeking.

SCENARIO: #1
SUBJECT: #3

ACTION: 1) Divert to Link Co 2) Shot VOR approach at Link

Subject #3 is a medium time pilot (1200 hrs.) with most of his experience in military helicopters and fixed-wing single engine aircraft. His current GA flying is related to occasional business trips in a C-182.

Subject #3 exhibited extreme difficulty in basic aircraft control. Aircraft heading and altitude excursions had both high frequency and high amplitude. He appeared to be overloaded and expressed that feeling during debriefing. His first reaction at the time of engine failure was to declare an emergency and dial in the emergency transponder code. He lost nearly 1600 feet altitude before he was able to restore power to the aircraft.

Subject #3 did not seem to be well prepared with basic operating information and skills. During his preflight planning he commented that he was not familiar with ILS procedures. He elected to shoot a VOR approach at an uncontrolled airport because it appeared simpler than an ILS. Furthermore he noted that the ILS equipped airport was in an area on the chart with many airways and VOR stations which he viewed as complications, not aids.

Subject #3's management style could be characterized as 1) reactive (he did not have preplanned alternatives and was unsure of his position); 2) dependent (his first act after the CIFE was to declare an emergency and ask for help); and 3) perceptually basic (he elected an alternative which looked simplest on the charts).

SCENARIO: #1
SUBJECT: #4

ACTION: 1) Started for Mountaindale, 2) Returned to Link, 3) Shot one missed approach

Subject #4 is a professional GA and military pilot with nearly 9000 hours PIC time. He is currently active, flying a King Air and military helicopters. He is also rated as a mechanic (AI) and has built his own homebuilt aircraft.

Subject #4 exhibited a high degree of stick and rudder competence in addition to being constantly aware of the state of the system. He frequently cross-checked his position and asked for enroute weather updates. He was well prepared concerning operating information. As noted in the debriefing session he knew precisely what the MEA's were at the point of the CIFE, what radial he was crossing and what his theoretical fuel consumption should have been. He was monitoring the fuel gauges and suspected a fuel leak prior to actual engine failure.

Subject #4 was self-reliant. He never declared an emergency and only informed ATC of his difficulties after he had diagnosed the problem and selected an execution strategy.

Subject #4's management style might be characterized as one which involves 1) thorough preparation, (memorized critical numbers from charts and manual); 2) constant information seeking and comparing; 3) flexibility (changed options in light of new information concerning weather and fuel consumption); and 4) personal control limits (executed missed approach because flight parameters were out of his personal tolerances).

SCENARIO: #2
SUBJECT: #5

Subject #5 is a commercial pilot with multi- and single engine land and certifed flight instructor ratings with fifty hours in the last ninety days of which four were instrument hours. He has a total of 1550 hours. He is in his late 20's and is employed as a flight instructor.

The pilot departed from Seaport Beach airport. He experienced a decrease in power at Thermal Intersection and proceeded to land at Singer Airport.

The flight proceeded routinely from Seaport to Thermal intersection. The pilot's ground track was good. He exhibited good stick and rudder performance. Difficulties were experienced with communication. At the first report of turbulence, the pilot decreased power to slow the aircraft down. North of Thermal intersection the pilot experienced a subtle rpm loss. This was detected by the pilot visually. He was also sensitive to the fact that the temperature gauges were changing; both the cylinder head temperature and oil temperature. Upon debriefing the pilot indicated that he was very slow to incorporate diagnostic changes to isolate or fix the problem, though eventually he did switch tanks, switch the mags and adjust mixture and carburetor heat. In fact, he left the carburetor heat on throughout the flight. The aircraft began to have altitude problems immediately. The pilot declared an emergency. He was convinced the airplane would not fly much longer and proceeded to ask for an off-airport landing. Airspeed was maintained at about 75-80 mph. The pilot pulled the throttle back because he didn't want to full bore a sick engine. The rpm decrease was stabilized at 1500 rpm. As the pilot began to lose altitude, the researchers decided to open Singer airport for a landing and after much persuasion by the air traffic controller convinced the pilot to attempt to fly to Singer where he successfully landed the aircraft.

During the debriefing the pilot felt that he was not in complete control despite his familiarity with this kind of equipment. He exhibited deviations in headings, and, as indicated above, made no attempt to keep the aircraft at the maximum altitude. His diagnosis was that the aircraft probably had induction icing, which is the reason that he kept the carburetor heat on. His management style might be characterized as becoming convinced that the airplane could not fly much longer and setting himself for an emergency landing regardless of the potential to use altitude trade-offs to get to nearby airports.

SCENARIO: #2
SUBJECT: #6

Subject #6 is a 5,000 hour commercial aircraft, single, multi-engine, land-rated pilot. He has had experience in turbine aircraft. He has had two hundred hours total instrument, ten hours in the last thirty days and fifty hours in the last ninety days. His most recent IFR training flight was June, 1979. He typically flys a Cessna 182RG. He has over 1500 multi-engine, single pilot experience. He also is an air traffic controller.

Subject #6 took off IFR from Seaport to Mountaindale. At Thermal Intersection he encountered power difficulties. He proceeded on and landed at Mountaindale airport.

The pre-CIFE part of the flight was normal with the pilot exhibiting good stick and rudder control. He was very conscious of weather and frequently asked for weather updates at Mountaindale throughout his flight. As he began to encounter moderate turbulence south of Thermal, he requested and received clearance to 9,000 feet. As he climbed through 8500 the CIFE was initiated with a gradual reduction in rpm. The pilot noted that the rpm did not return to the initial level. Thus he began to assess the fact that the aircraft was losing power. He initiated immediate action in terms of changing fuel selector switch, switching the mags and using carburetor heat. He was conscious of the increased temperature for cylinder head and oil but was relieved that there was no change in oil pressure. This led him to believe that the problem was not basically an engine problem, or at least an oil loss problem. The pilot's flying strategy changed at the time of the CIFE to very slow flight, 60 mph, in order to maintain his altitude as much as possible. He had made his own decision to proceed direct to Mountaindale, but alerted the air traffic controller of his problems. (Incidently, he felt the air traffic controller was not particularly sympathetic or helpful to his problem. For example, he was concerned with the minimum vectoring altitude around Mountaindale, which he claimed he never received.) He was conscious of wind conditions being in his favor throughout most of the flight and decided that he had a good twenty to thirty minutes with the aircraft operating at 1500 to 1700 rpm.

The pilot stated upon debriefing that he knew he could maintain 2,000 or 3,000 feet with 1700 rpm. His main concern was getting over the mountains.

One interesting aspect of the flight occurred when the pilot reached the Mountaindale area. He elected to pull the power to lose altitude rather than to trade altitude for air speed. His decision was explained on the basis that he wanted to make his approach as slow as possible because he did not want to execute a missed approach. This pilot's management style was 1) sticking to his original flight plan, 2) eliminating turning back into the wind by returning to Link or to Seaport, and 3) determining it was unacceptable to seek a landing elsewhere since the area was IFR.

SCENARIO: #2
SUBJECT: #7

This subject was a 3,000 hour commercial CFI instrumented rated pilot who had had considerable experience in Navy jets, multi- and single engines. He had had limited experience in light aircraft and only four hours of total flying in the last ninety days, of which there were no hours of instrument flying. His last instrument proficiency check was two years ago.

His initial preparation time before the flight was approximately forty minutes, which subsequently he argued was insufficient for his current experience in IFR flying. Examination of the pilot controller tapes and initial pre-CIFE navigation and flight control indicates that the pilot did a good job in complying with his clearance, in communication and navigation and was rated high in terms of aircraft attitude control.

Twenty-five minutes into the flight, after reaching Thermal Intersection, the pilot experienced a gradual decrease in rpm from 2500 to 1500. At that time he was cruising at 6,000 feet. He asked for an immediate descent to the nearest airport but was reminded by Center that the area was currently IFR. As he proceeded to lose altitude, holding his airspeed at approximately 85 mph, he reported at 5,000 feet, at which time the controller asked him if he wished to declare an emergency, upon which he agreed. Analysis of his ground track showed erratic heading maneuvers, including a 360° maneuver northwest of Thermal.

The pilot, after asking for weather, and rejecting the idea of continuing the flight over the mountains to Mountaindale decided to divert to Link County airport. At that time he was losing altitude and was at 4500 feet. Because of the concern by the research staff of his ability to get to Link, with his current air speed and rate of descent, it was decided to have another light aircraft report out of Singer airport that it was turning VFR. At the Center's suggestion the pilot opted to go direct to Singer. His altitude at that time was approximately 3,500 feet.

The pilot, four minutes after the CIFE, reported his concern that the engine instruments were reading high and said that he could "anticipate" engine failure. Upon the direct clearance to Singer, the pilot requested both vector and headings distance to Singer, as well as field elevation in the event of possible radio failure. The pilot proceeded direct to Singer at 3,500 feet, and successfully landed the aircraft.

The debriefing of this pilot is particularly insightful and indicates that the pilot had an acute sense of the failure of his own performance in this situation. His major concern was his lack of preparation for procedures to handle what he conceived to be an icing problem. He detected the rpm loss visually, not

aurally and confirmed it upon application of carburetor heat, in which case the rpm did not return to its original level. He was particularly conscious of air speed and altitude; so much so that he "admitted" that he lost his scan capability. As a result of this his heading became erratic immediately after the CIFE. The pilot admitted, upon debriefing, that he literally turned the navigation of the airplane over to Center.

His immediate concern following the CIFE was to get the aircraft on the ground as soon as possible. After the aircraft maintained 1500 rpm for several minutes he believed he could maintain 1500 rpm and 3,500 feet in proceeding to his new destination. He was not particularly conscious of his air speed. The relatively high air speed the he selected (85) caused a descent rate that prompted the researchers to open up an emergency landing field for the pilot.

Since his problem occurred right after switching the tanks, his first concern was that there was a fuel problem. However, the fact that the rpm could be maintained at 1,500 dissuaded him from this particular position. The pilot, on debriefing, was not sure why he did not slow up the airplane for altitude. He was ashamed that he was not aware of the position of Singer airport on his chart. The pilot was sensitive to increasing temperatures for cylinder head and oil temperature, and this created a sense of urgency on his part for getting the airplane down. He tried to get out the flight manual for the aircraft to determine proper procedures for icing. He was resigned to bringing the aircraft to an off airport landing.

This pilot diagnosed his problem to be one of inadequate preflight preparation in terms of alternate airports and preparation for handling procedures in the event of icing (which he had diagnosed as his problem). Thus, with the introduction of the CIFE he became overly absorbed in his altitude control, lost his basic scan pattern and proceeded to develop heading problems. With all of this workload upon him the pilot essentially opted to turn the navigation decision over to Center. Indeed, it was the controller who recommended Singer airport as an alternate for the pilot. The pilot had agreed with the debriefer that the situation was very realistic and, in fact, was worried that he might develop vertigo with his heading diversions immediately following the CIFE.

SCENARIO: #2
SUBJECT: #8

Subject #8 is a newly-minted IFR pilot with approximately 250 hours. He is thirty years old and took up flying after graduation from college. Most of his experience has been in fixed wing, fixed pitch, fixed gear aircraft. He currently flies a 172. He has had considerable experience in the simulator. His preflight might be considered extremely ponderous and slow as the pilot sat in the cockpit for almost fifteen minutes before initiating takeoff. He seemed very meticulous in terms of organization of cockpit housekeeping.

The pilot was IFR from Seaport to Mountaindale. Upon the initiation of the CIFE eventually he was radar-vectored to Singer airport for a landing.

His pre-CIFE flight might be characterized as average in terms of stick and rudder control. The pilot apparently had only minimum consciousness of his position in the air space. This was illustrated by his inability to know the Link VOR frequency, one of the major VORs along his path. The aircraft was cruising at 8,000 feet near Thermal Intersection when the CIFE was initiated. The CIFE was a gradual decrease in rpm. The pilot detected this aurally and initiated carburetor heat action. It was clear that the pilot became rapidly overloaded and lost scan patterns because there was considerable drifting in heading. His first request was for a precautionary landing at the nearest airport. When advised that the situation was IFR, the pilot attempted to proceed on to Mountaindale. He was reminded by air traffic control of the MEA in the region. As his altitude began to fall, the pilot exhibited extreme measures in air speed to keep altitude, frequently tripping the stall alarm, and at approximately 7,000 feet the pilot, at the point of declaring an emergency, clearly turned the navigation part of the flight over to the air traffic controller, with a statement, "Get me down". At this point it was decided to open up Singer airport VFR so that vectors could be given to him to proceed directly there.

The debriefing of this pilot suggests that he was unprepared for the emergency and admittedly was overloaded. His concern with altitude and air speed and rpm resulted in him spending a considerable amount of time giving information to the air traffic controller, seemingly looking for the air traffic controller to provide not only recommendations on where to go but what to do. It was the air traffic controller who made the decision not to proceed up into the mountains with decreasing altitude. It was the air traffic controller who was conscious of the MEA. It was the air traffic controller who ultimately had to suggest to the pilot that he might proceed to Singer, even though this information was now available to the pilot. His management style of the CIFE might be characterized as one of total preoccupation with one or two aircraft parameters and the inability to "put together" a reason/decision about the nature of his problem and what to do about it. He admitted on debriefing that he tried to do what he could to get some more rpm and when he concluded that there was nothing that he could do about it he was less concerned about the possible diagnosis of the failure.

SCENARIO: #3
SUBJECT: #9

ACTION: 1) used ATC to confirm failure, 2) attempted one VOR approach; missed, 3) 2nd VOR approach was successful

Subject #9 is a flight engineer for a major airline. The majority of his flight experience was gained in the military where he piloted single-engine turbojet aircraft. He is still active in military aviation as an Air Guard pilot and instructor. In GA aircraft he has earned FAA certification as a flight instructor.

Subject #9's basic stick and rudder skills were highly refined. His movements of controls were well planned and smoothly executed. Excursions from assigned headings and altitudes were minimal, even during the CIFE. Beyond the basic piloting of the aircraft, he had plenty of spare capacity to perform navigation and communication duties. During the first ILS approach he understood and complied with all ATC instructions, and conducted the approach down to the decision height before executing the missed approach. During the first approach, deviations from the glide slope and localizer centerlines were small, and the entire approach was conducted in a stabilized condition.

The CIFE started as the flight was being radar vectored for a second approach. The flight was given a final heading to intercept the localizer course when the localizer needle was covertly rendered inoperative. (In the failed mode the localizer needle moves to the center and remains motionless and there are no other cues that indicate the localizer has failed.) When he first saw the needle in the center, he thought he may have already intercepted the localizer course and was passing through it. Just a few seconds later, however, he asked ATC for his position relative to the localizer course, and, noting the discrepancy, became suspicious of the instrument. Using radar vectors and position updates, the subject confirmed that the needle had failed within 1 1/2 minutes after the onset of the problem, and reported his situation to ATC.

Subject #9's next action was to choose an alternate type of approach. His first choice was an ASR approach, but that was not available at Mountaindale. He next considered an NDB approach, but because of intermittent and inaccurate ADF indications he decided to proceed to the VOR and shoot the VOR approach. Before making this decision, he checked the local winds at Mountaindale to see if this approach would be feasible.

Subject #9 conducted one VOR approach but executed a missed approach early in the procedure when he became suspicious of the VOR needle indications. His suspicions were unfounded, however, and he successfully completed a second approach and landed.

Subject #9's management style might be characterized as "aviate, navigate, communicate". Precise control of the aircraft was maintained at all times. He was always aware of his geographical position and used all navigation aids "in concert" to follow his progress. He also made use of ATC services in an efficient and organized manner. His relationship with the radar controller was one of a cooperative effort, but he always reserved final responsibility for the operation of the aircraft. The authoritative manner in which he requested ATC assistance was indicative of his understanding of the ATC system and it's capabilities and limitations. It was also evidenced that he used ATC resources as an aid, rather than as a means to "bail him out".

SCENARIO: #3
SUBJECT: #10

ACTION: 1) did not use ATC to aid in diagnosis, 2) tried NDB approach but went far off-course, 3) wanted another NDB but persuaded to do otherwise by ATC, 4) successfully completed VOR approach.

Subject #10 is a private pilot with an instrument rating who has very little experience. He has a total of almost 300 flight hours, all of which has been in light single-engine aircraft. At the time of this experiment, he had only recently acquired his instrument rating and did not have any instrument experience beyond that required for the rating.

Subject #10's basic stick and rudder skills were considered to be fair, with occasional deviations from assigned headings and altitudes observed during unstressed periods. At times when cockpit workload and distraction were higher, larger deviations were observed. His communication skills were also fair. He understood most transmissions and acknowledged using standard phraseology. His navigation skills, however, were somewhat less than polished. On the first ILS approach, he had much difficulty bracketing the localizer course, and misinterpreted glide-slope indications. During the post-flight briefing, he mentioned that he thought an "up" glide-slope needle meant a "down" correction was needed to get back on the glide-slope. (This is the reverse of what is true.) Following this notion he continued to descend to intercept the glide-slope. As a result, he was always below the glide-slope during the first approach. After the glide-slope needle had not wavered from its full "up" indication for awhile, he thought it might be faulty and asked for clearance to conduct a localizer approach. When the flight was about one mile outside the outer marker, it was so cleared. The flight reached the outer marker near the localizer course and 300 feet below the minimum altitude published in the chart. From that point, the subject was unable to track the localizer and wandered well to the right of course while reaching the MDA. Finally, when still about two miles from the airport, he confessed to the tower controller that he was "totally off course and lost track of time" and that a missed approach would be necessary.

During the second approach, the CIFE was introduced as the localizer was secretly failed as the flight was given a heading to intercept the localizer course. Shortly after the localizer was failed, the subject sensed something was wrong. He noticed the localizer needle was centered and motionless. (For a pilot who was totally unable to center the needle during the previous approach, this indication was, understandably, a cause for suspicion.) He switched frequencies on his localizer receiver, and, noting no change in needle position, assumed the system had failed.

Because of his position relative to other navigation aids, the subject chose to proceed to the beacon and conduct an NDB approach. The approach controller cleared the flight for an NDB approach and advised the pilot that field conditions were "500 feet overcast and two miles visibility with rain and fog". Though the stated visibility was above the legal minimums for landing, the low reported ceiling made visual contact with the ground during the approach unlikely. Nevertheless, the flight proceeded to the beacon, crossed it 350 feet below the published minimum altitude, and commenced a descent to the MDA. Shortly thereafter the flight had wandered well to the right of course and was 260 feet below the MDA. The pilot was not aware of how seriously he was straying from the approach procedure and executed a missed approach only after he was instructed to do so by ATC.

Still not aware that the weather was not suitable for such an approach, the pilot requested another NDB approach. As the flight was preparing for a second NDB approach, the radar controller advised the flight that current weather conditions (500-2) were not favorable for the successful completion of the approach. At this point the pilot decided to proceed to the VOR and execute a VOR approach. The flight was given vectors for the final approach course, and completed the approach and landing in a routine manner.

The subject displayed no clear management style or priority during either the routine phase of the flight or the CIFE. Although basic aircraft attitude control was adequate (i.e. the aircraft was never in serious danger of stalling or assuming a critical attitude), on two occasions he did allow the aircraft to wander into dangerous situations by not adhering to course and altitude restrictions. His ability to conduct ILS approaches was severely hampered, of course, by the erroneous impression he had about the way glide-slope information is presented. Also, the last and eventually successful approach (the VOR approach) was the only one where he did not stray far from the approach course. It was interesting to note that the subject did not request any special ATC assistance to determine the nature of his problem or how to resolve it. Though he appeared to be familiar with most of the phraseology, communications were limited to the customary exchanges between pilots and controllers. In radio conversation and from the direct observation of pilot activity during the simulation, he did not exhibit any outward sign of nervousness, anxiety or being overloaded.

In summary, it seems that although the subject was able to communicate and control the aircraft at, at least, a minimally acceptable level, he was unable to make crucial navigation decisions in terms of heading and altitude selection. This inability could be attributed to inexperience, poor training, or the pilot merely having a bad day.

SCENARIO: #3
SUBJECT: #11

ACTION: 1) ATC was largely responsible for pilot's detection of problem, 2) pilot chose the VOR approach to complete mission, 3) while enroute to VOR, pilot thought localizer needle was operating properly again and wanted to shoot another ILS approach, 4) due to anticipated delays, pilot changed mind again to the VOR approach, executed it, and landed.

Subject #11 is a relatively new pilot who holds a commercial pilot certificate with instrument and multi-engine ratings. He is also a certified flight instructor and works part-time as such for OSU's Department of Aviation. He has acquired about 500 hours of total flight time, but his instrument flight experience does not extend far beyond that required for the instrument rating.

The subject was fairly proficient at the basic control, navigation, and communication skills. Control of the aircraft was maintained in a smooth and coordinated manner. Deviations from assigned headings and altitudes were slight. Though some difficulty with radio communication equipment was encountered, the subject usually did understand, reply, and respond properly to radio transmissions. His ability to navigate was also at an acceptable level. On his first ILS approach, he had captured the localizer course and glide-slope after the usual bracketing maneuvers. From that point, the first approach was conducted to within 100 feet of the decision height, with a few deviations occurring around the glide-slope and localizer course.

On the second approach, the CIFE was introduced just as the flight was getting established on the localizer. The failure of the localizer needle was so subtle that the pilot never noticed it, continued to the outer marker, and intercepted the glide-slope. Still thinking all was well and that he was on the localizer course (from the indications of the instrument in the failed mode), he continued to descend on the glide-slope to the vicinity of the middle marker. On at least two occasions during this descent, the flight turned to the right to headings which should have resulted in off-course indications from the localizer needle. In addition, the subject received three ATC warnings, since crossing the outer marker, that the flight was observed, on radar, to be well off course. The subject, however, continued to descend and executed a missed approach only after he was instructed to do so by ATC. When he started his missed approach he was less than 200 feet from the decision height, crossing the middle marker, and was well to the right of course.

As he was climbing on his missed approach, the subject informed the radar controller that his localizer must have failed and that he was requesting the VOR

approach. A few minutes later, however, he thought the localizer might have resumed normal operation and wanted to make the ILS approach. After being informed of traffic delays for the ILS, he decided again on the VOR approach and landed without further incident.

Though he seemed proficient in the basic skills, the way in which he managed this problem raises a few questions. In the post-flight briefing, he said he first felt something was wrong when ATC first advised him he was off course while his own localizer needle indicated he was on course. He also said he made a few slight turns to see if the localizer needle moved. It is not clear, then, why the subject continued to descend another 600 feet in the one minutes that followed the first ATC warning, or why he continued to descend after the second and third warnings. Presumably, the additional warnings should have lent more support to the hypothesis that some serious navigation problems existed. Also unclear is the reason why he thought the localizer may have started working again after he initiated the missed approach, and why he wanted to try another ILS. (Recall that he was discouraged from trying the ILS approach due to traffic delays.)

The subject's apparent style of flight system management was to assume everything was operating until there was substantial proof otherwise. Until he had the evidence to prove beyond doubt that the localizer had failed, he continued to trust it and to descend on an approach into a mountainous area. Also, he first had to be convinced that the localizer was inoperative before he considered other alternatives. Even after three ATC warnings and being instructed to execute a missed approach, he was not overwhelmingly convinced that the localizer had failed because he considered shooting the ILS again. From this, one must conclude that either the subject did not lend much credence to the ATC warnings, or he really wanted to believe his localizer was still working.

This school of thought is not an entirely healthy one, and it contradicts the more conservative philosophies prevalent in flight training circles. In flight training it is desirable for the student to gain a basic level of suspicion about the airworthiness of an aircraft and its systems. This is not intended to undermine the trust a pilot has in his aircraft. It does serve, however, as an incentive for the pilot to require proof of the integrity of aircraft instruments and systems through preflight checking, crosschecking indicators, and monitoring trends.

SCENARIO: #3
SUBJECT: #12

ACTION: 1) became suspicious of localizer needle but continued approach, 2) assumed localizer failure when ATC told flight it was off-course, 3) chose to conduct VOR approach and completed it (with difficulty)

Subject 12 is a pilot of average experience. He holds a commercial pilot certificate with an instrument rating. He is also a certified flight instructor and is employed part time as such for OSU's Department of Aviation. All of his flight experience has been in light single-engine aircraft, and his instrument experience extends slightly beyond that required for the rating.

Subject #12 was not very proficient in the basic communication, navigation, and aircraft control skills. On a few occasions he missed entire radio messages which were intended for him even though there were no apparent problems with his airborne equipment. At other times he did understand and comply with the bulk of the instructions but it was necessary to repeat some of the details for him. In controlling the aircraft he allowed some fair-sized oscillations to occur around assigned headings and altitudes. He did maintain general control but it was not precise. The subject also had difficulty in navigating. On his first ILS approach he had trouble bracketing and staying on the localizer course. This problem was compounded by his feeling that he had an oil pressure problem. (In fact, no problem existed. Subject #12 may have been looking for problems to occur, given the nature of the study.) A short time after crossing the outer marker, the flight had deviated well to the right of course, when he announced his missed approach and his intentions to try another ILS.

The CIFE occurred on the second approach in the form of a localizer failure as the flight was being vectored to the final approach course. About 1 1/2 minutes after the failure occurred, the subject became suspicious of his instrument and asked the radar controller if he showed the flight established on the localizer course. (During the post-flight briefing he said the apparent insensitivity of the needle to changes in position led to this suspicion.) The flight was advised that it was near the centerline, but, on its present heading, would not intercept the localizer centerline for another two miles. The flight then assumed a heading which paralelled the localizer but kept it slightly to the south of course. About two minutes later the flight was advised it was one mile from the outer marker, slightly to the south of course, and it was instructed to change frequencies. As the flight crossed the outer marker it turned to headings (40° to 50° to the right of course) which should have resulted in off-course indications from the localizer needle. The flight began to descend on the glide-slope but continued digressing from the localizer course. At the first suggestion from ATC that the flight was significantly off-course, Subject #12 initiated a missed approach and advised the controller that his localizer must have failed. The subject chose to execute the VOR approach to complete the

flight but had much difficulty doing so. A great deal of ATC assistance was required to get the flight on the VOR final approach course. Once established, however, the flight completed the approach and landed without further incident.

It was not clear what Subject #12's method of managing the CIFE was from observing his actions. During the post-flight briefing he did mention that, once the localizer failure was suspected, he decided to continue the approach until he was certain of the failure. Once the problem was confirmed, he said his next action was to climb to a safe altitude and then decide what to do next. It was apparent at several points in the flight that he was being taxed by different situations to near the limits of his piloting resources. As he crossed the outer marker on both ILS approaches, for example, (a point where workload is usually higher), heading and aircraft control became progressively more erratic. This overloading, no doubt, had an effect on his perception of the problem and the way he managed it. This may explain why the flight continued for several minutes in attempting the ILS approach after a localizer failure had been suspected. It may also have been the reason why the subject did not continue with any diagnostic activity once he suspected the failure. (The 40° to 50° heading deviations with no needle change should have been enough evidence.) It was not until the advisory from ATC that the flight was off-course that his suspicions were confirmed.

APPENDIX G

GAT-1 Performance Data

Figure G1: Scenario #1, Data Summary Sheet

1	Pilot	#1	#2	#3	#4
Experience	Licenses	ASEL/INSTR	CFI/A & I	COMM	ATP/FW & RW
	Ratings	———	———	Rotary	Turbine
	Total hrs.	420	5000	1200	8800
	Single engine/sim	420/0	4640/0	400/40	4000/190
	Total IFR/sim	7/53	38/156	50/150	750/250
	Last 90 days/instr.	9/0	0/0	2/0	45/2
	Type of flying	Pleasure	Pleasure	Business	Business
1	Survey - overall (7 pts.)	3.12	5.02	4.39	5.63
Knowledge	Instrumentation	1.53	3.61	3.23	4.41
	Fuel system	5.25	7.00	5.68	6.16
	Engine & operation	2.80	6.30	5.13	6.86
	Electrical system	4.77	3.34	4.13	4.62
	Procedures - IFR ops	2.25	5.00	5.00	5.75
	Weather & environment	2.10	4.90	3.15	5.95
1	Flight planning	30 min.	40 min.	50 min.	35 min.
Pre-Cliff Flight	Cockpit preparation	2.5	5.0	2.5	———
	Communication skills	2.0	4.3	3.0	———
	Navigation skills	1.5	3.7	1.2	———
	Attitude control	1.5	5.7	1.2	———
	Problems	540° turn to Seaport	forgot to fly clnc. radio squelch	behind A/C reversed VOR	none

Figure G2: Scenario #1, CIFE Response

1					
Problem Detection - Diagnosis	Detection mode	heard eng. quit	heard eng. quit	heard eng. quit	fuel gauge
	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 declari
	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 main
	Est. flying time	2 hrs.	1.6 hrs.	1.6 hrs.	2 hrs.

1					
Decisions and Actions	Alternatives considered	Link Co. Seaport	Link Co. Mountaindale	Seaport Mountaindale Link Co.	Mountaindale Link Co.
	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. endurance
	Outcome	Successful NDB with aid of ATC	Successful ILS with aid of ATC	Successful VOR with aid of ATC	Missed VOR successful VOR at Link Co.

Figure G3: Scenario #1, 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	-	-	-

Figure G4: Scenario #2, Data Summary Sheet

2	Pilot	#5	#6	#7	#8
Experience	Licenses	COMM/ASMEL/CFI	COMM/ASMEL	COMM/CFI/HEL	ASEL/INSTR.
	Ratings	2+	Turbine	2+, Jet, Rot	——
	Total hrs.	1550	5000	3000	300
	Single engine/sim	1480/19	3000/6	2200/40	270/30
	Total IFR/sim	51/41	200/180	300/200	14/30
	Last 90 days/instr.	150/10	50/0	4/0	40/10
	Type of flying	Professional	Pleasure	Pleasure/X-Mil	Pleasure
2	Survey - overall	5.56	5.00	4.59	3.79
Knowledge	Instrumentation	5.03	4.94	3.37	3.94
	Fuel system	5.25	7.00	7.00	3.50
	Engine & operation	5.43	4.90	3.03	3.15
	Electrical system	5.41	6.36	4.45	3.18
	Procedures - IFR ops	6.50	5.50	3.75	3.00
	Weather & environment	5.25	6.30	5.95	5.95
2	Flight planning	25 min.	25 min.	40 min.	
Pre-CIFE Flying Perf.	Cockpit preparation	5.2	6.0	6.2	
	Communication skills	4.7	5.7	5.5	
	Navigation skills	5.5	5.2	6.0	
	Attitude control	5.5	6.0	6.5	
	Problems	communications poor	——	——	

Figure G5: Scenario #2, CIFE Response

2	Detection mode	Tach, Oil Temp.	A/C performance	Tach	
	Detection time	1.3 min	1.5 min	1.0 min	
	Diagnostic Procedure	carb heat mixture eng. gauges magnetos throttle	mixture carb heat magnetos switched tanks	throttle carb heat	
	Prepared strategy	none	none	none	
	Declared emergency?	yes	yes	yes	
	Info sources used	ATC			
	Perceived cause	induction ice	internal malf.	icing	
	Observed stress	5	5	5	
	Pilot's crit. est.	7	8	6	
	Relevant experience	carb. icing	power loss	pitot icing	
	Est. flying time	1.6 hrs.	45 min	——	

	Alternatives considered	find field to land	Link Co. Singer	Mountaindale Seaport Link	
	Decision	put down off-airport	continue to Mountaindale	divert to Link Co.	
	Reasons	wanted power for landing	poor weather in East, no appr. at Singer	Mountaindale elevation too high	
	Changes in plan	land at Singer	——	land at Singer	
	Reasons	ATC suggested within range	——	ATC suggested within range	
	Flying technique	reduce pwr., head into wind for landing	slow flight tried flaps	over controlled flew for airspeed, then altitude	
	Outcome	successful VFR landing at Singer	successful ILS landing at Mountaindale	successful VFR landing at Singer	

Figure G6: Scenario #2, Decision Factors Rating

Scenario #2	5	6	7	8	Average	Range
Estimated flying time	6	3			4.5	4
Estimated fuel on board	5	4			4.5	2
Enroute weather	4	2			3.0	3
Destination weather	4	4			4.0	1

Scenario #2	5	6	7	8	Average	Range
Conservatism	6	4			5.0	3
Safety	7	3			5.0	5
Match with piloting skills	5	7			6.0	3
Familiarity with A/C procedures	3	7			5.0	5
Familiarity with NAV procedures	7	6			6.5	2
Proximity to original intentions	1	7			4.0	7
Compliance with FARs	6	4			5.0	3
Flying time needed to execute	2	3			2.5	2

Scenario #2	5	6	7	8	Average	Range
A/C condition when decision made	7	5			6.0	3
Fuel on board	2	2			2.0	1
Enroute weather	4	7			5.5	4
Destination weather	1	7			4.0	7
Time needed to execute	6	7			6.5	2
Familiarity with A/C procedures involved	4	5			4.5	2
Familiarity with NAV procedures involved	5	5			5.0	1
Proximity to original destination	6	7			6.5	2
Compliance with FARs	4	1			2.5	4
Other ATC	7	-			7.0	1

Figure G7: Scenario #3, Data Summary Sheet

	Pilot	#9	#10	#11	#12
	Licenses	COMM/CFI/FE	PVT/INSTR.	CFI/ASMEL	COMM/CFI
	Ratings	2+, Turb., Jet	Turbine	———	———
	Total hrs.	1750	270	480	660
	Single engine/sim	1300/300	265/5	430/37	660/0
	Total IFR/sim	500/200	200/180	5/24	13/55
	Last 90 days/instr.	50/15	8/0	70/1	35/3
	Type of flying	Prof./Mil.	Pleasure	Professional	Professional
3	Survey - overall	---	3.9	---	4.9
	Instrumentation	---	3.1	---	5.0
	Fuel system	---	6.1	---	2.6
	Engine & operation	---	3.5	---	4.9
	Electrical system	---	4.4	---	4.1
	Procedures - IFR ops	---	3.0	---	6.5
	Weather & environment	---	3.1	---	6.3
	Flight planning	20 min.	35 min.	20 min.	25 min.
	Cockpit preparation	6.7	4.3	5.3	5.5
	Communication skills	6.3	5.0	6.0	3.5
	Navigation skills	6.7	3.0	4.7	4.0
	Attitude control	6.7	4.0	4.7	3.5
	Problems	———	———	———	temporary low oil pressure

Figure G8: Scenario #3, CIFE Response

3	Detection mode	CDI frozen	CDI position	ATC advice	CDI positio
Problem Detection - Diagnosis	Detection time	0.5 min	1.5 min	5.0 min	2 min
	Diagnostic Procedure	ck. aud. ID, ck. OFF flag, observed CDI on final appr.	freq. selector fuses	LOC failure on course, pilot flew LOC well until MM when ATC advised off course	
	Prepared strategy	none	none	none	continue until failure verifie
	Declared emergency?	no	no	no	no
	Info sources used	none	none	ATC	ATC fix
	Perceived cause	faulty needle	radio malf'cn	radio malf'cn	radio malf'cr
	Observed stress	3	1	2	5
	Pilot's crit. est.	5	7	4	6
	Relevant experience	none	none	none	ILS failure
	Est. flying time	2 hrs.	2 hrs.	2 hrs.	2 hrs.

3					
Decisions and Actions	Alternatives considered	NDB appr. VOR appr.	continue but execute NDB, missed appr. examine others	missed appr., NDB, VOR, Seaport	another airpo VOR appr.
	Decision	missed appr. execute VOR	attempt NDB	missed appr. attempt NDB	missed app execute VO
	Reasons	trouble with ADF	not yet to outter marker	?	only feasible alternative
	Changes in plan	———	missed appr. attempt VOR	attempt VOR appr.	———
	Reasons	———	———	15 min. delay for NDB	———
	Flying technique	no change	no change	no change	no change
	Outcome	successful VOR landing at Mountaindale	successful VOR landing at Mountaindale	successful VOR landing at Mountaindale	successful VOR landing at Mountain

Figure G9: Scenario #3, Decision Factors Rating

Scenario #3	9	10	11	12	Average	Range
Estimated flying time	7	7	7	7	7.0	1
Estimated fuel on board	7	4	5	3	4.7	5
Enroute weather	-	-	-	-	-	-
Destination weather	4	3	3	3	3.2	2

Scenario #3	9	10	11	12	Average	Range
Conservatism	4	3	6	5	4.5	4
Safety	6	4	7	6	5.7	4
Match with piloting skills	2	4	7	5	4.5	6
Familiarity with A/C procedures	4	2	6	4	4.0	5
Familiarity with NAV procedures	7	5	6	7	6.2	3
Proximity to original intentions	4	6	1	6	4.2	6
Compliance with FARs	6	2	1	7	4.0	7
Flying time needed to execute	1	1	3	1	1.5	3

Scenario #3	9	10	11	12	Average	Range
A/C condition when decision made	7	1	6	5	4.7	7
Fuel on board	1	1	7	6	3.7	7
Enroute weather	-	2	4	6	4.0	5
Destination weather	6	1	1	6	3.5	6
Time needed to execute	3	6	2	7	4.5	6
Familiarity with A/C procedures involved	1	5	5	7	4.5	7
Familiarity with NAV procedures involved	6	2	5	2	3.7	5
Proximity to original destination	7	5	-	6	6.0	3
Compliance with FARs	4	4	1	6	3.7	6
Other	7	5	6	-	6.0	3

Figure G10: GAT Subject Performance

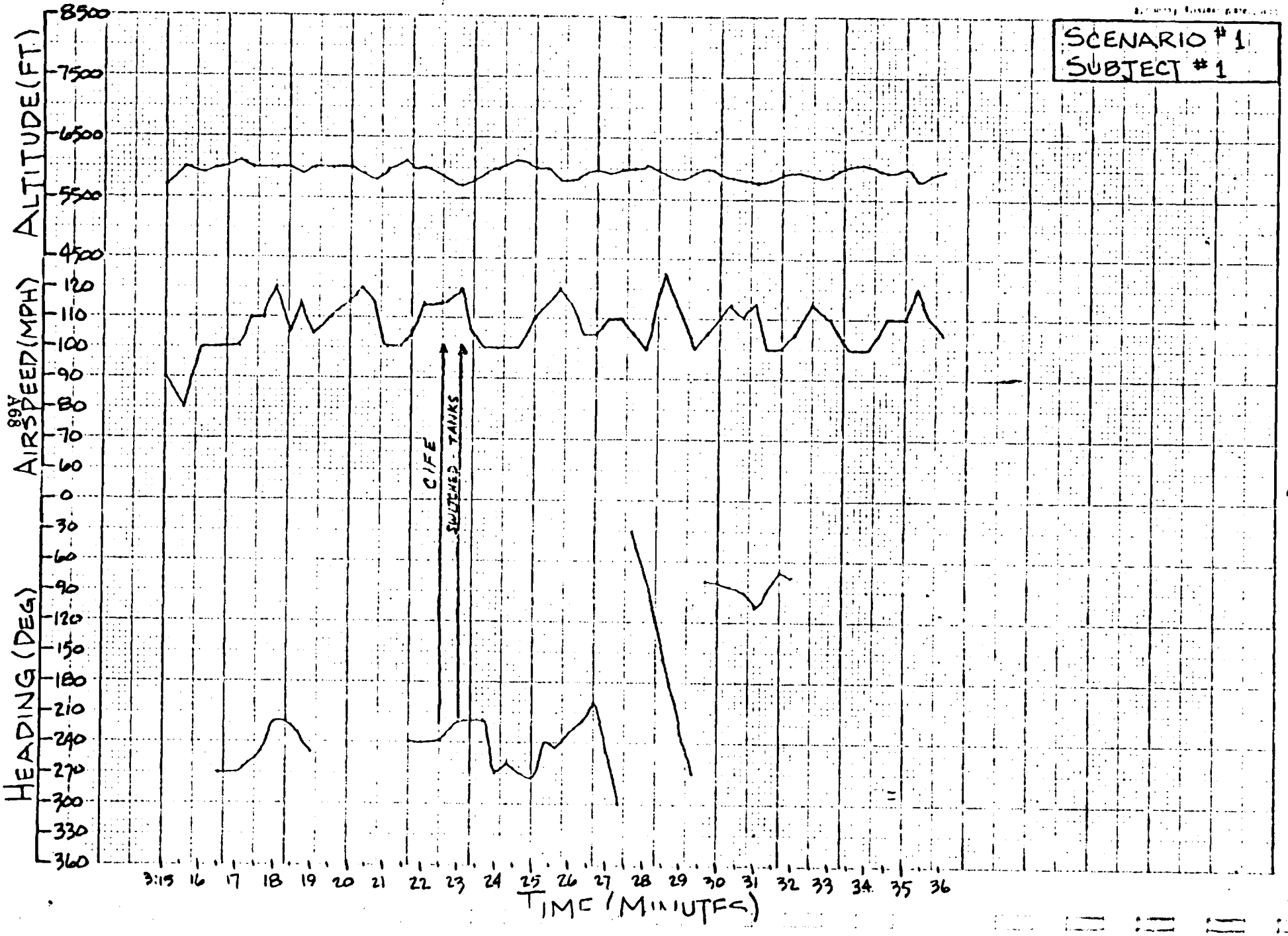

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Figure G11: GAT Subject Performance

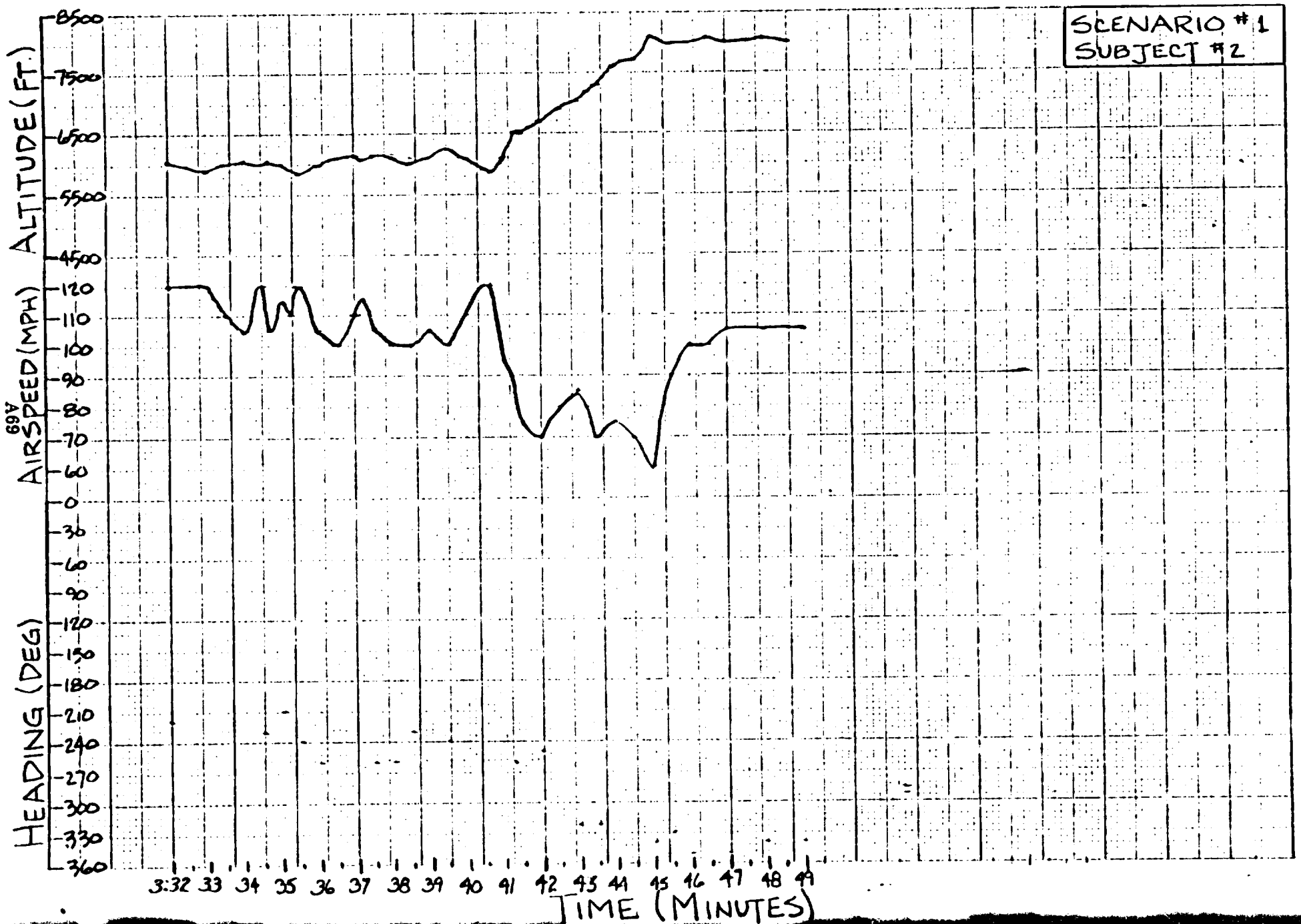

Figure G12: GAT Subject Performance

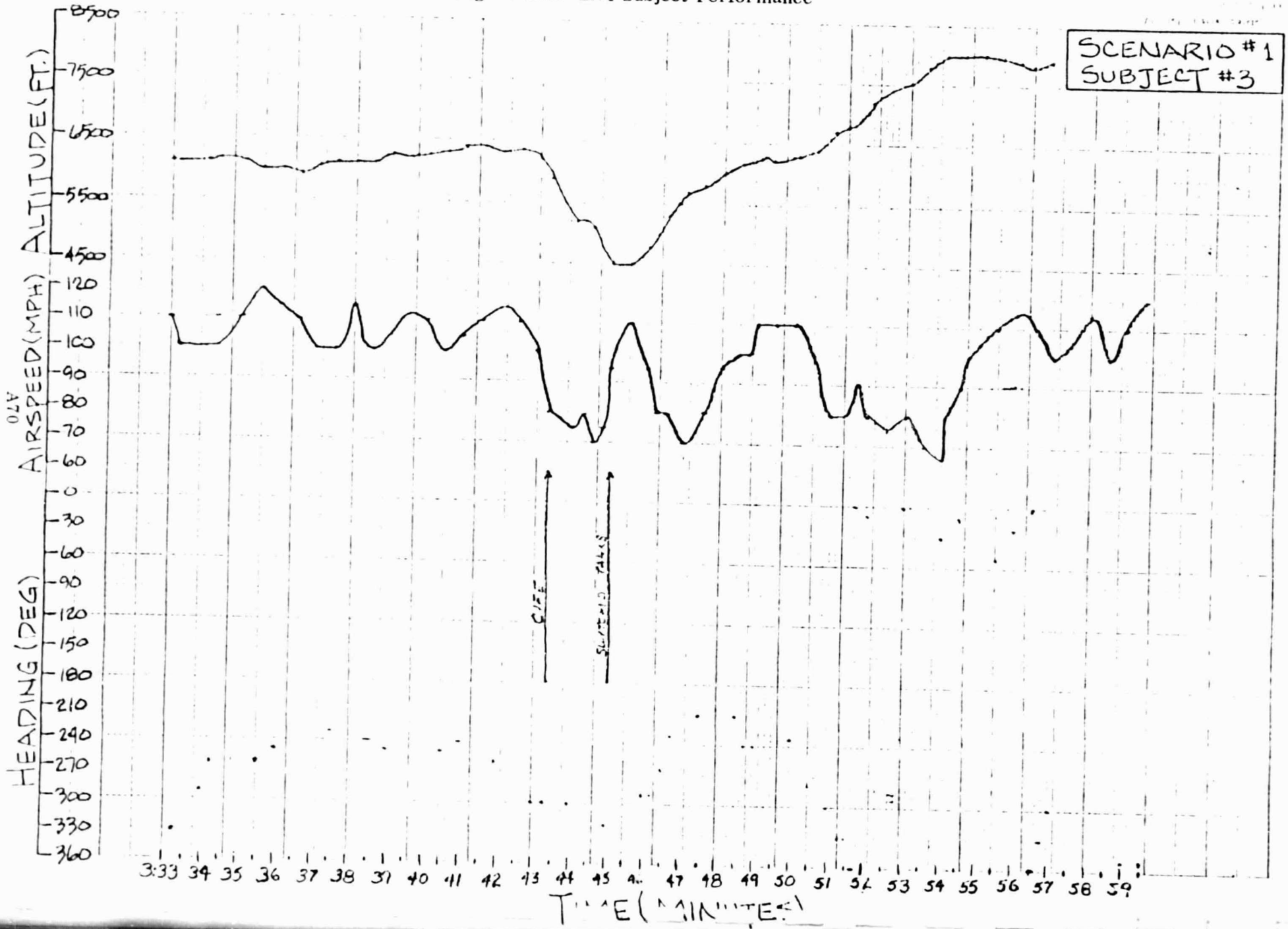

Figure G13: GAT Subject Performance

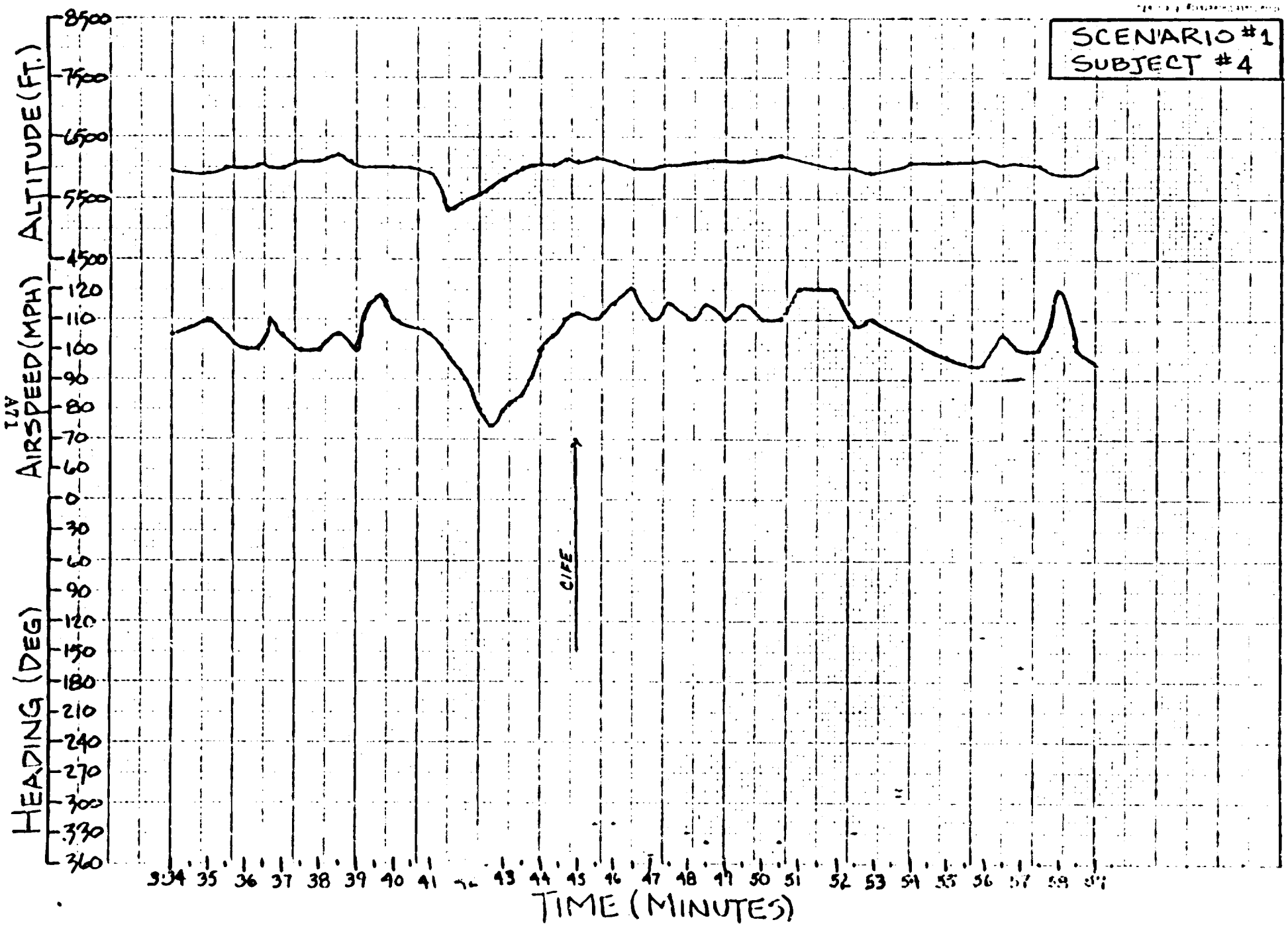

Figure G14: GAT Subject Performance

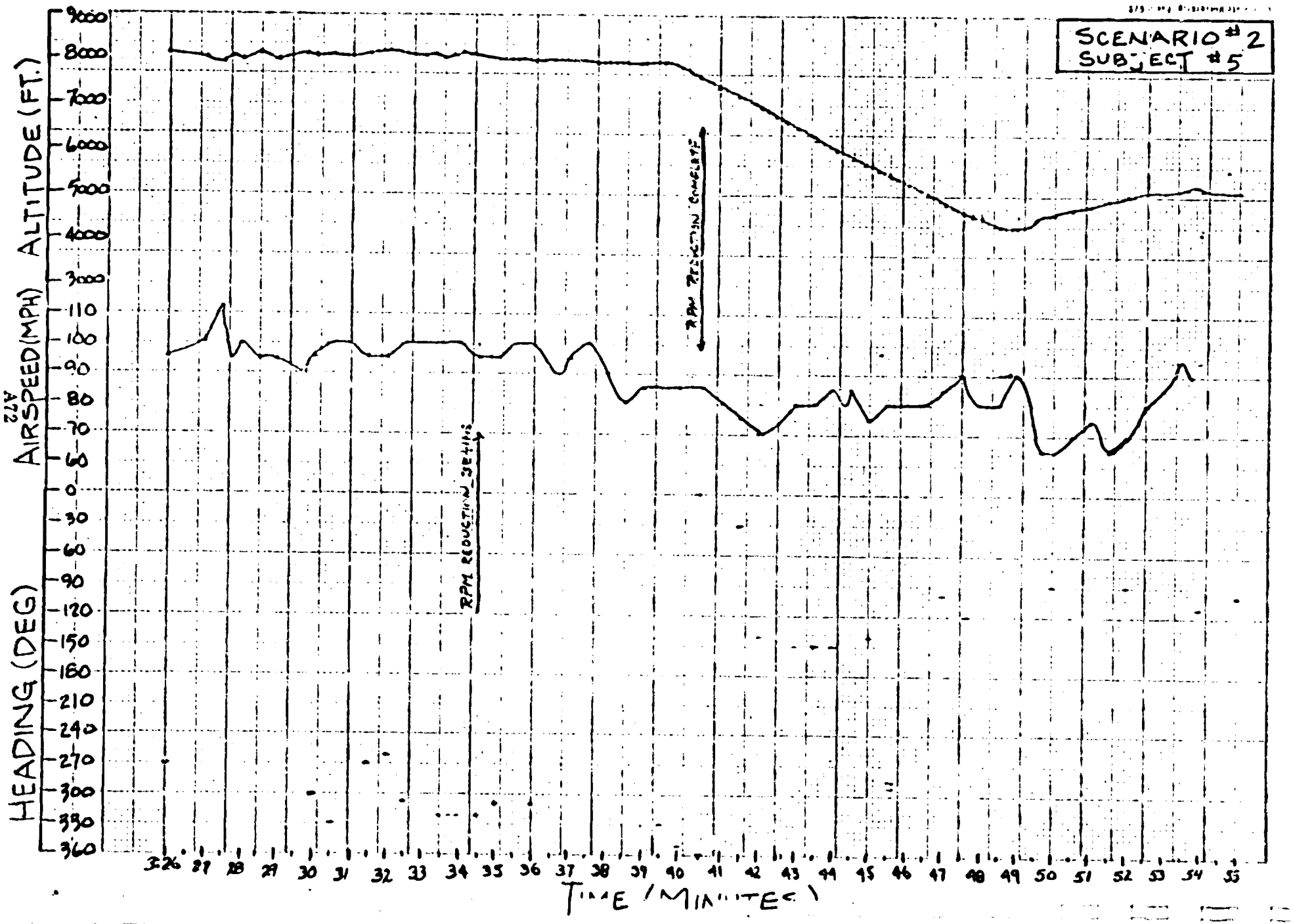

Figure G15: GAT Subject Performance

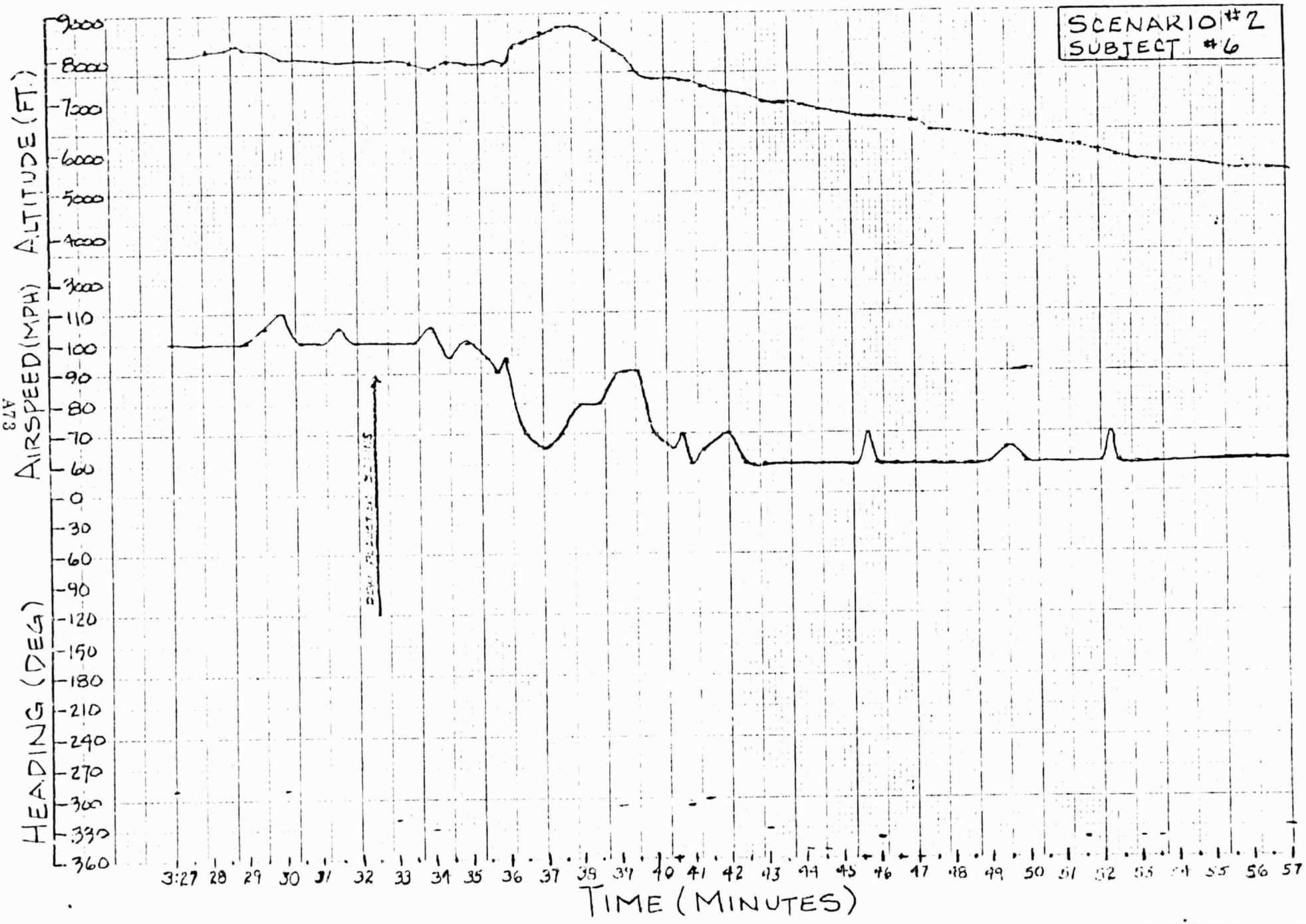

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Figure G16: GAT Subject Performance

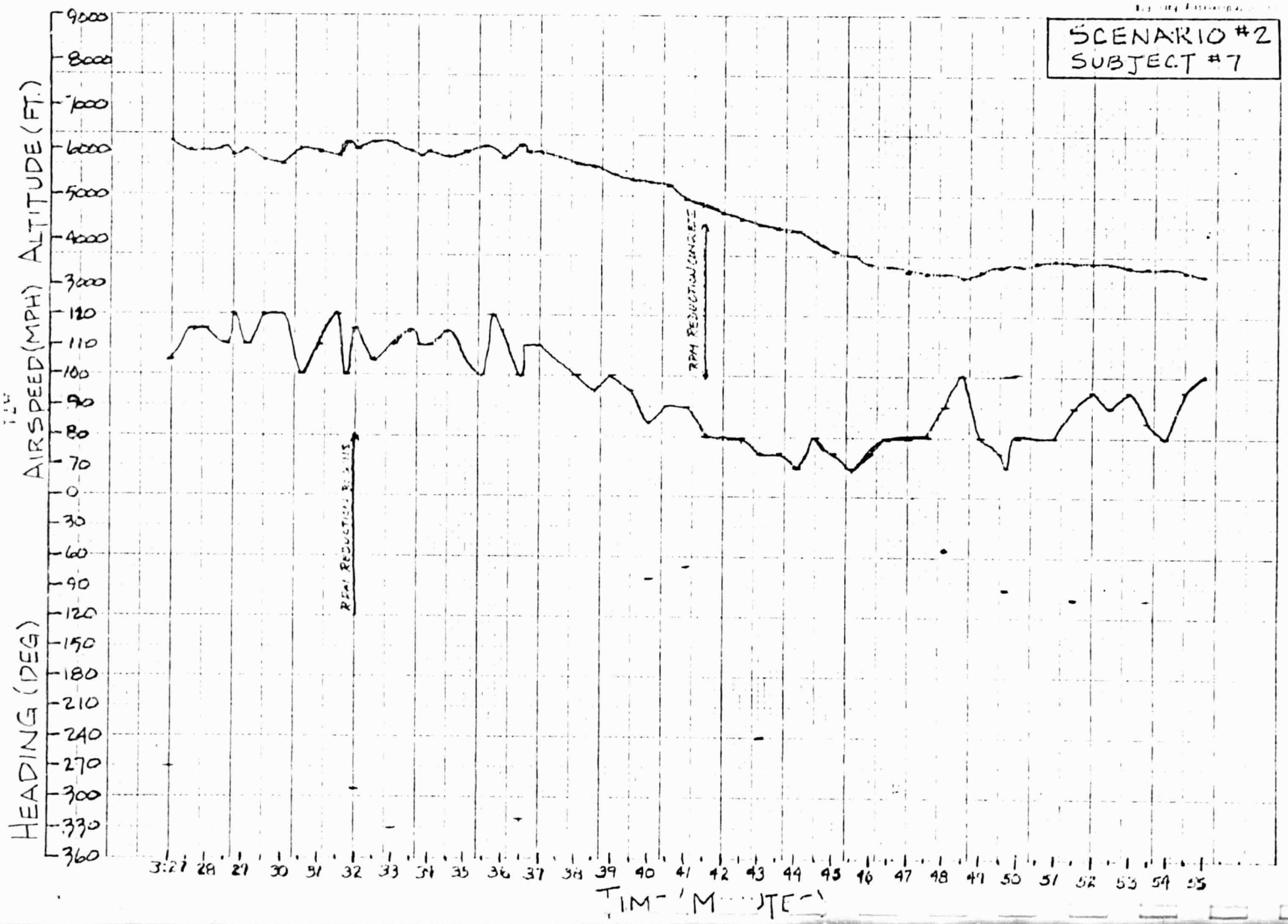


Figure G17: GAT Subject Performance

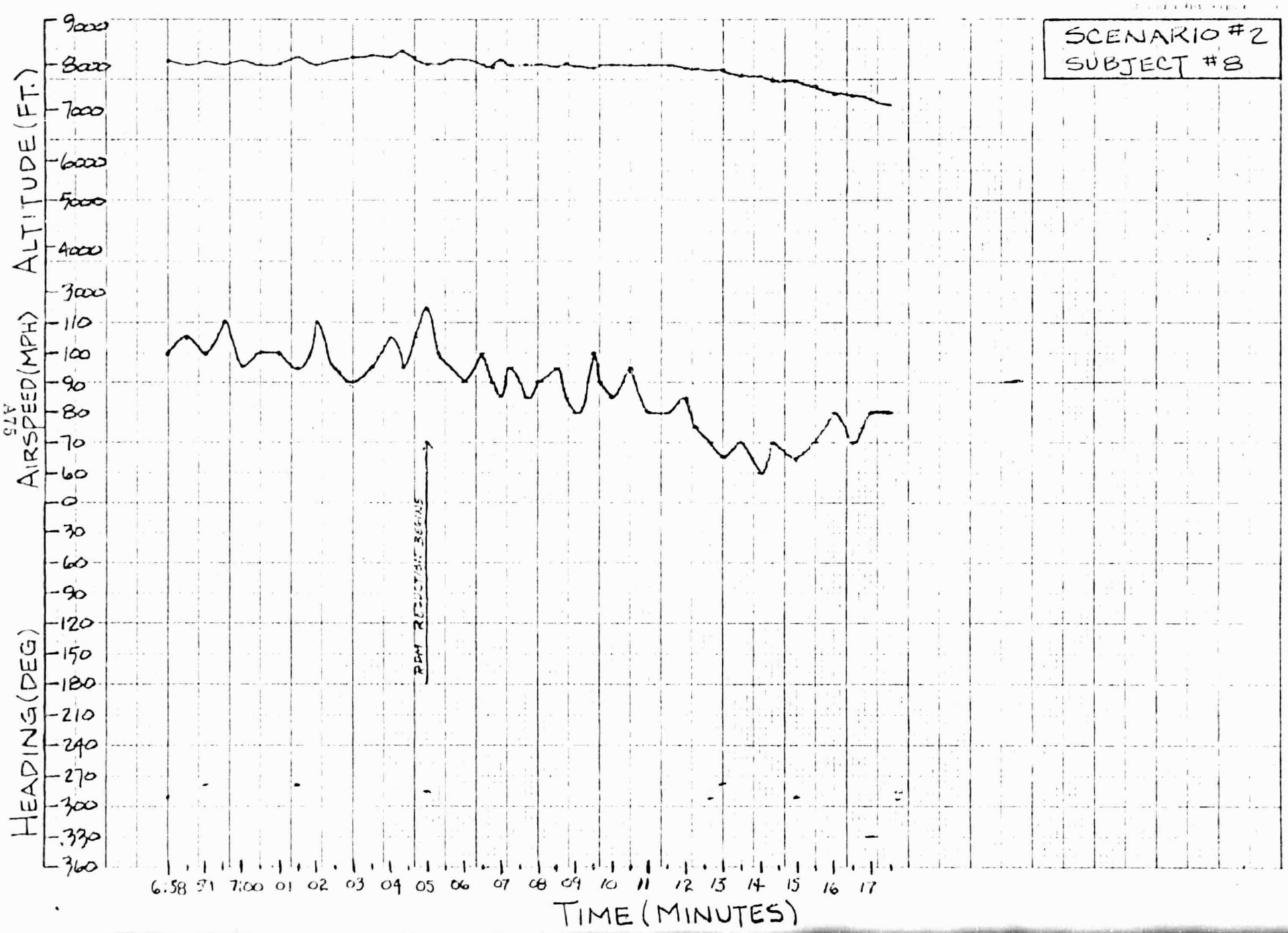


Figure G18: GAT Subject Performance

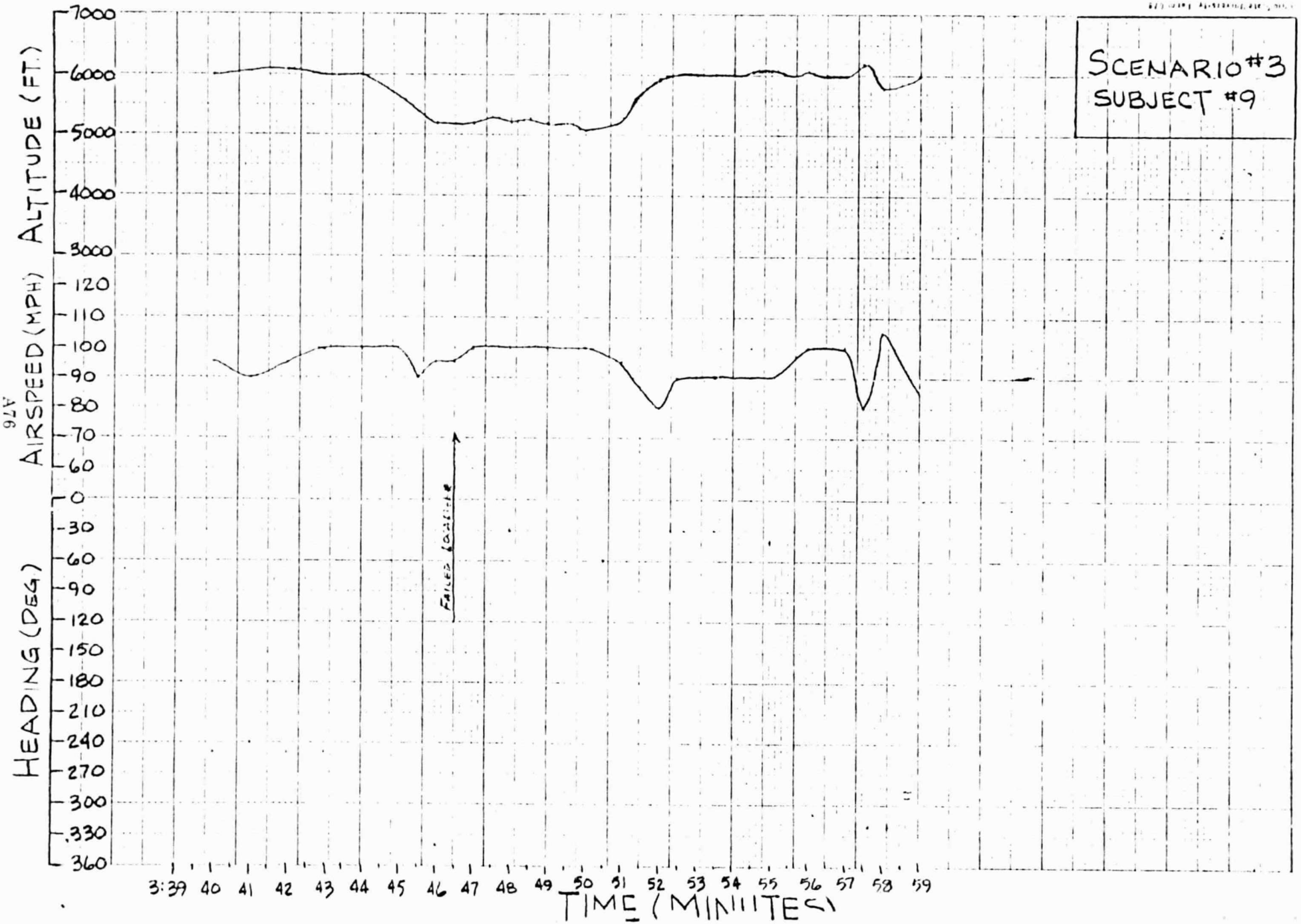


Figure G19: GAT Subject Performance

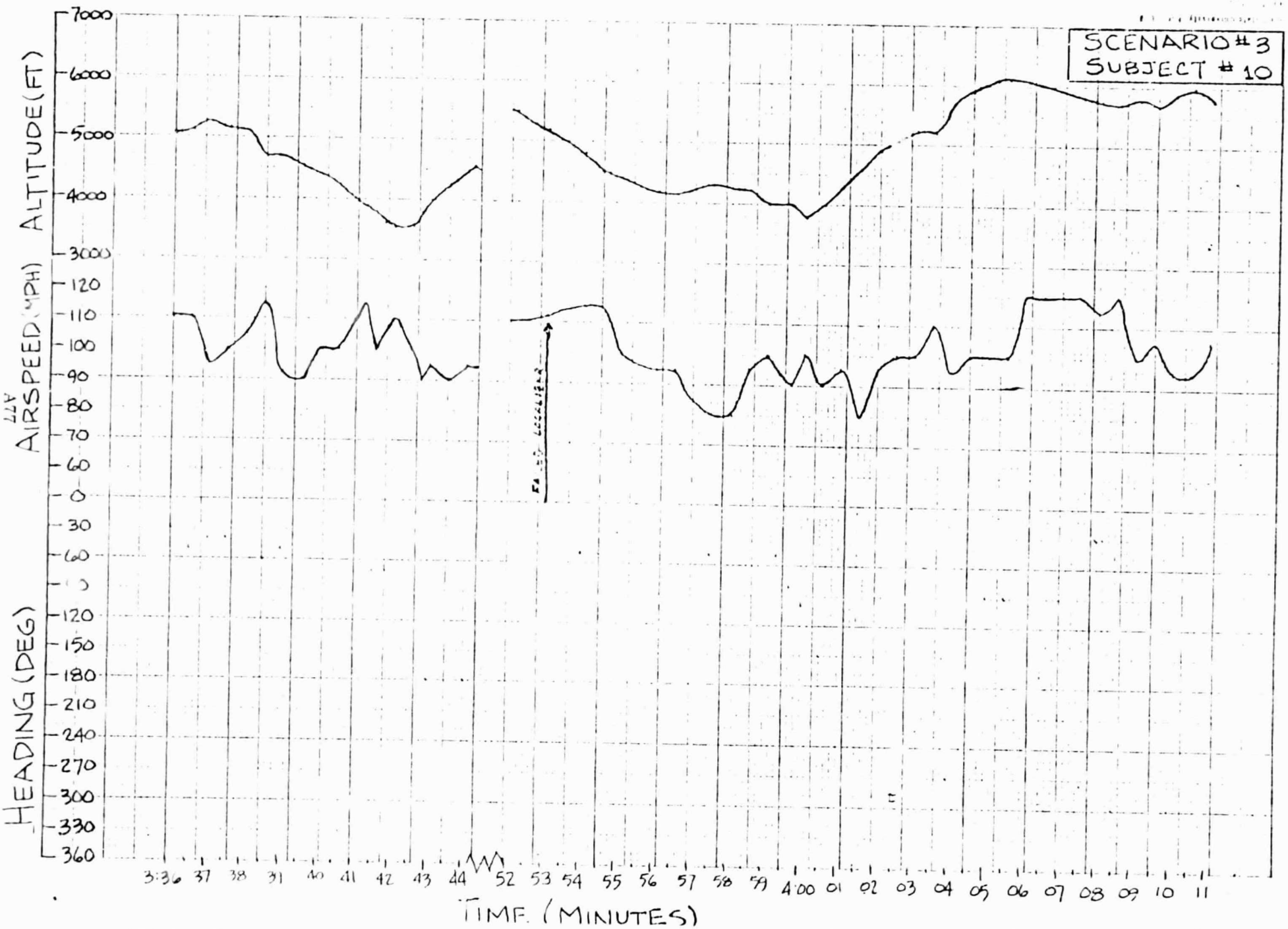


Figure G20: GAT Subject Performance

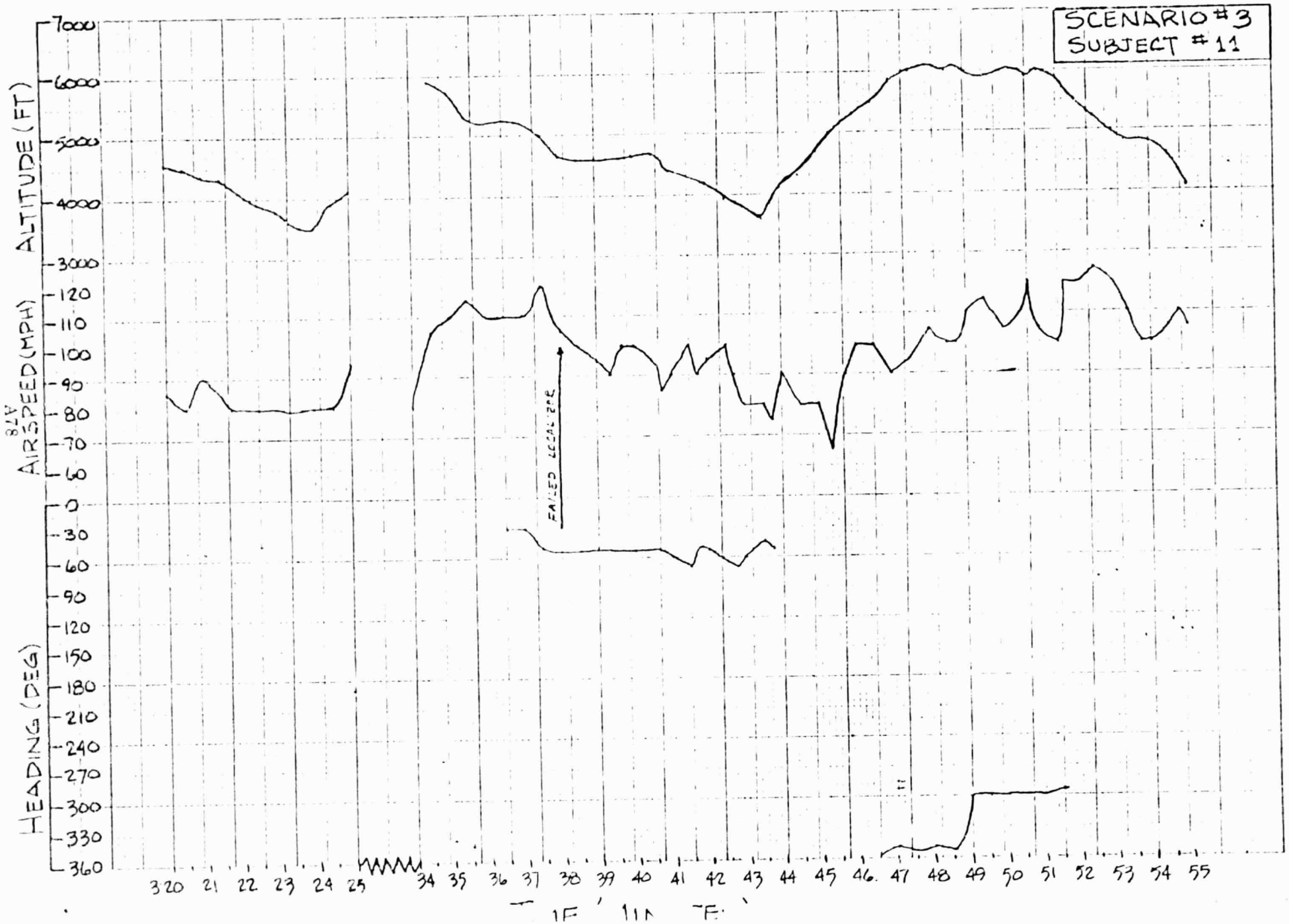
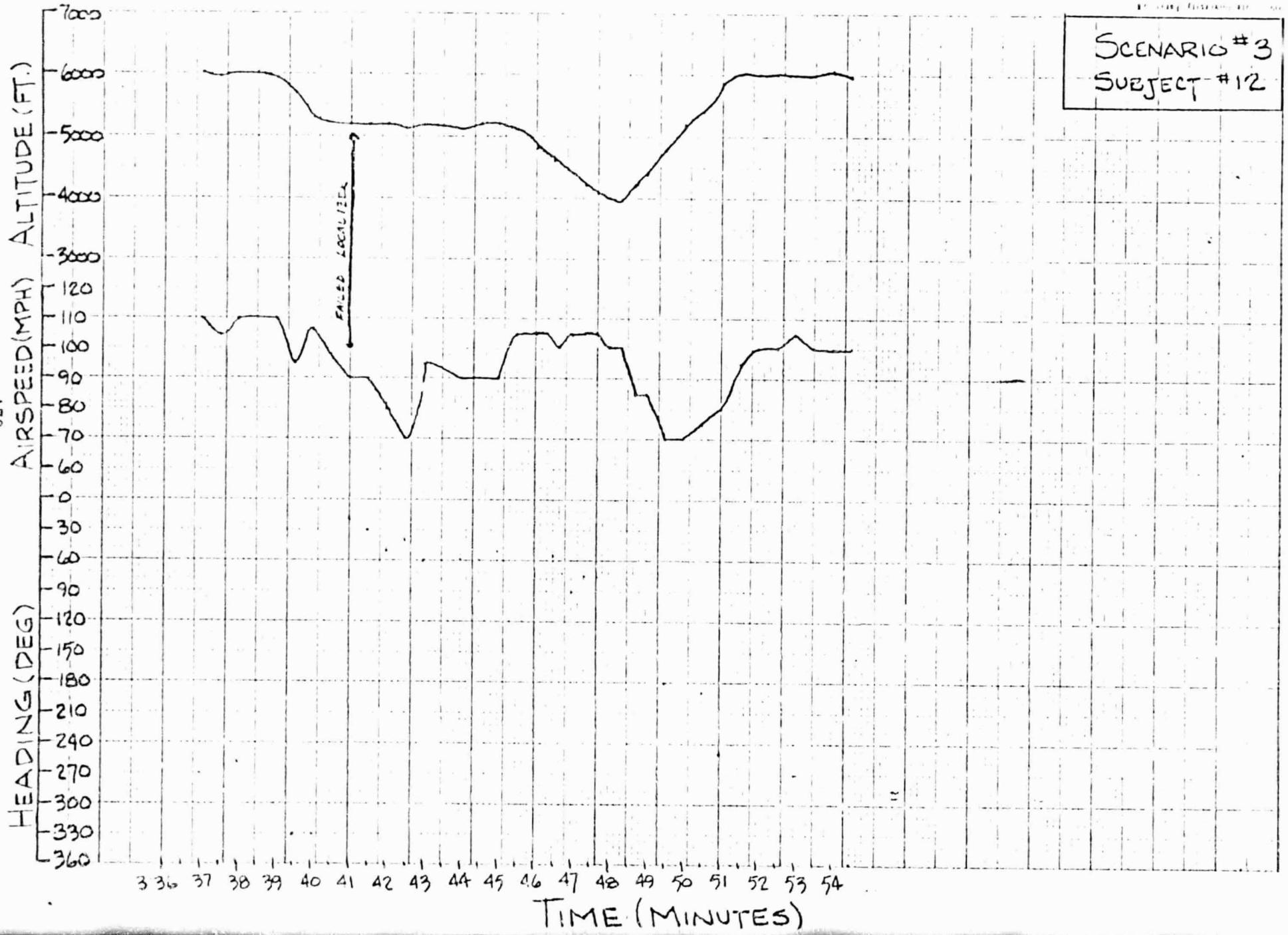


Figure G21: GAT Subject Performance



APPENDIX H

Paper and Pencil Testing Materials

PILOT BACKGROUND DATA

Subject #: _____

Date: _____

Time: _____

Pilot licenses held: _____

Ratings and limitations: _____

Primary flight training: ☐ military ☐ civilian

Type of flying done most often:

☐ airline ☐ GA comm ☐ business ☐ military ☐ pleasure

Total flying time: _____ hrs.

Total small, single engine: _____ hrs.

Total IFR: _____ hrs.

GENERAL INTRODUCTION

Today we would like you to participate in a few paper and pencil scenarios. We will be considering a series of hypothetical flights which will take place in the Northeastern United States. The booklet in front of you contains some information which we will proceed through in a step-wise fashion.

Page 1 shows a map of the Northeastern and Northcentral United States, and Southeastern and Southcentral Canada. All of the hypothetical flights we will consider will take place in the area surrounded by the dashed lines. You can see this includes Vermont, New Hampshire, and parts of Maine, Massachusetts, New York, and Quebec.

Page 2 is a simplified weather chart of the same region. Pictured on this chart are the major weather systems prevalent during the time of these flights. As you can see, a low pressure system is centered over Michigan and Lake Huron, and it is moving very slowly eastward. A warm front extends from the low center northeastward, and a cold front extends from the low center southward. Our area of concern is the region within the dashed lines. The weather in this area has been caused by the warm front and is generally rainy and drizzly, with light southeast winds and reduced visibilities. There is no severe weather in this area. Although the cold front is approaching the area, it is a relatively dry front and should not be a factor during the time we will be flying.

A weather depiction chart is shown on page 3. It shows the areas where visibilities are less than 3 miles and/or the ceilings less than 1000' by enclosing these areas in a solid line. Scalloped lines surround the areas where ceilings are between 1000' and 5000', and visibilities are greater than 3 miles. You can see

that IFR conditions prevail over most of our area of concern, except over northeastern New York, where conditions are slightly better.

These charts are intended to give you a brief overview of the "big" weather picture. More detailed information on the weather will be provided when appropoiate.

The airplane you will be flying is a Cherokee Arrow. This is a typical four-place plane with retractable landing gear and constant speed propellor. It is powered by a 200 HP, fuel injected engine. The airplane is equipped with standard IFR instrumentation and avionics. This should be ample information for you to begin our paper and pencil scenarios.

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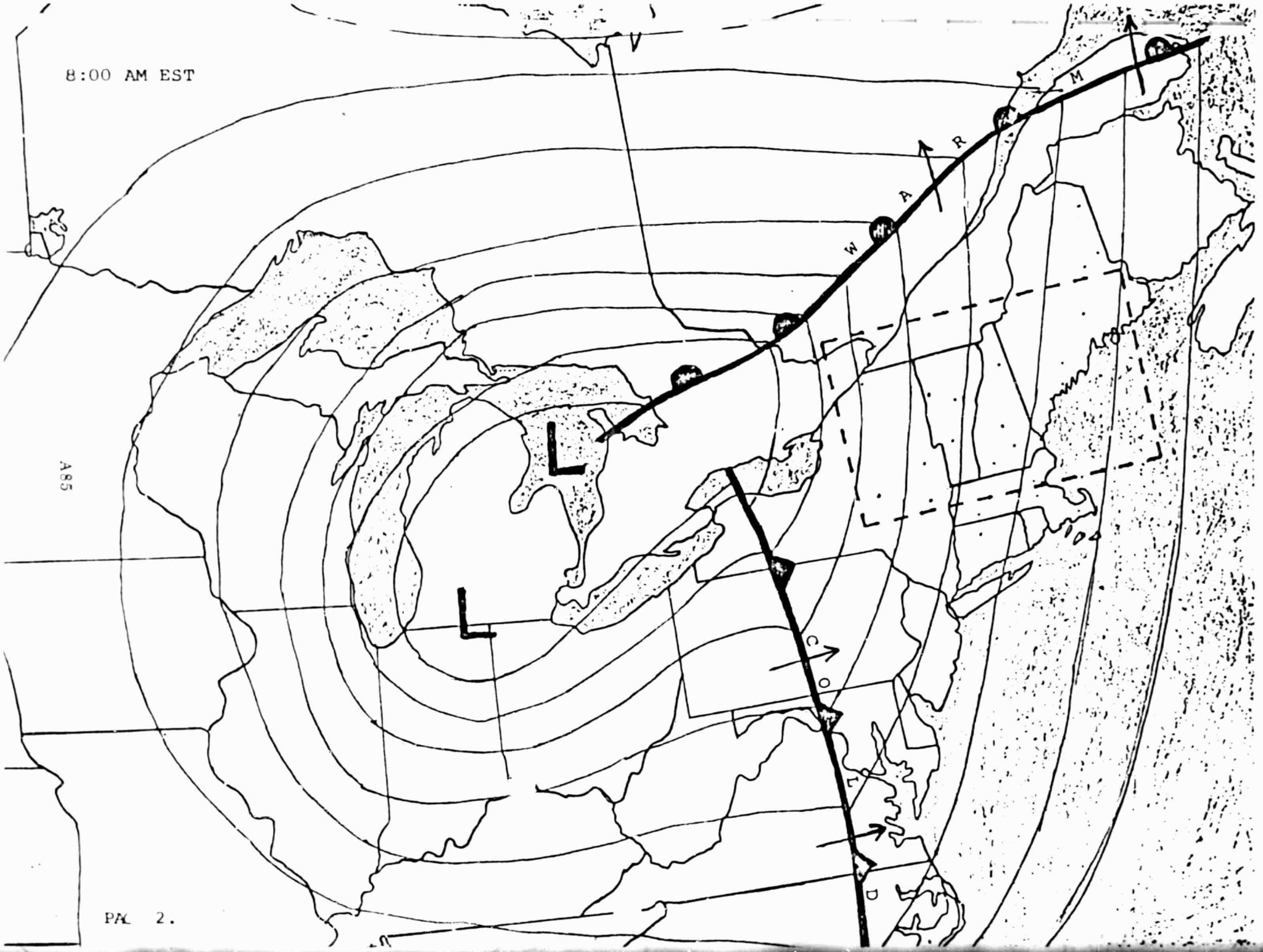
8:00 AM EST
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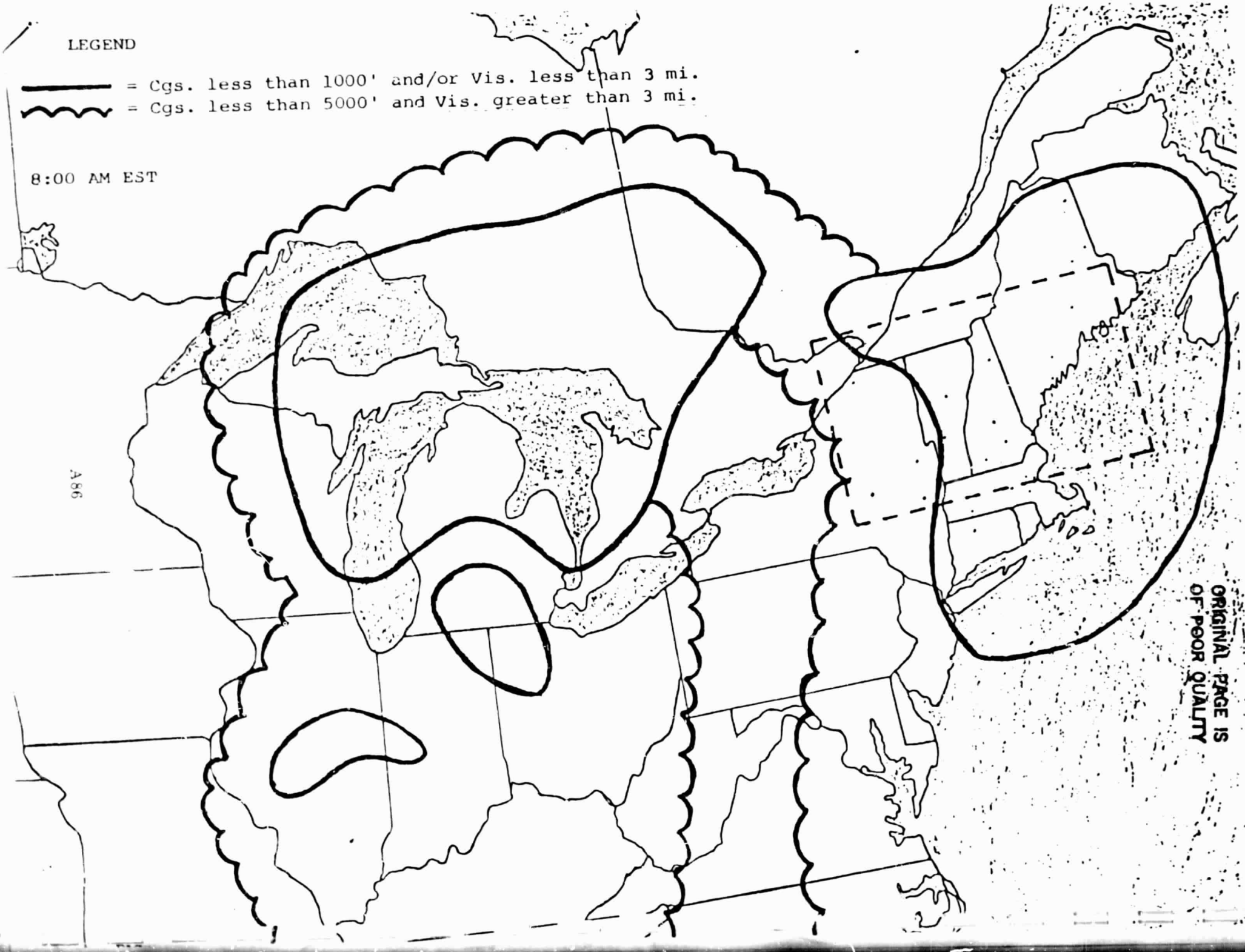

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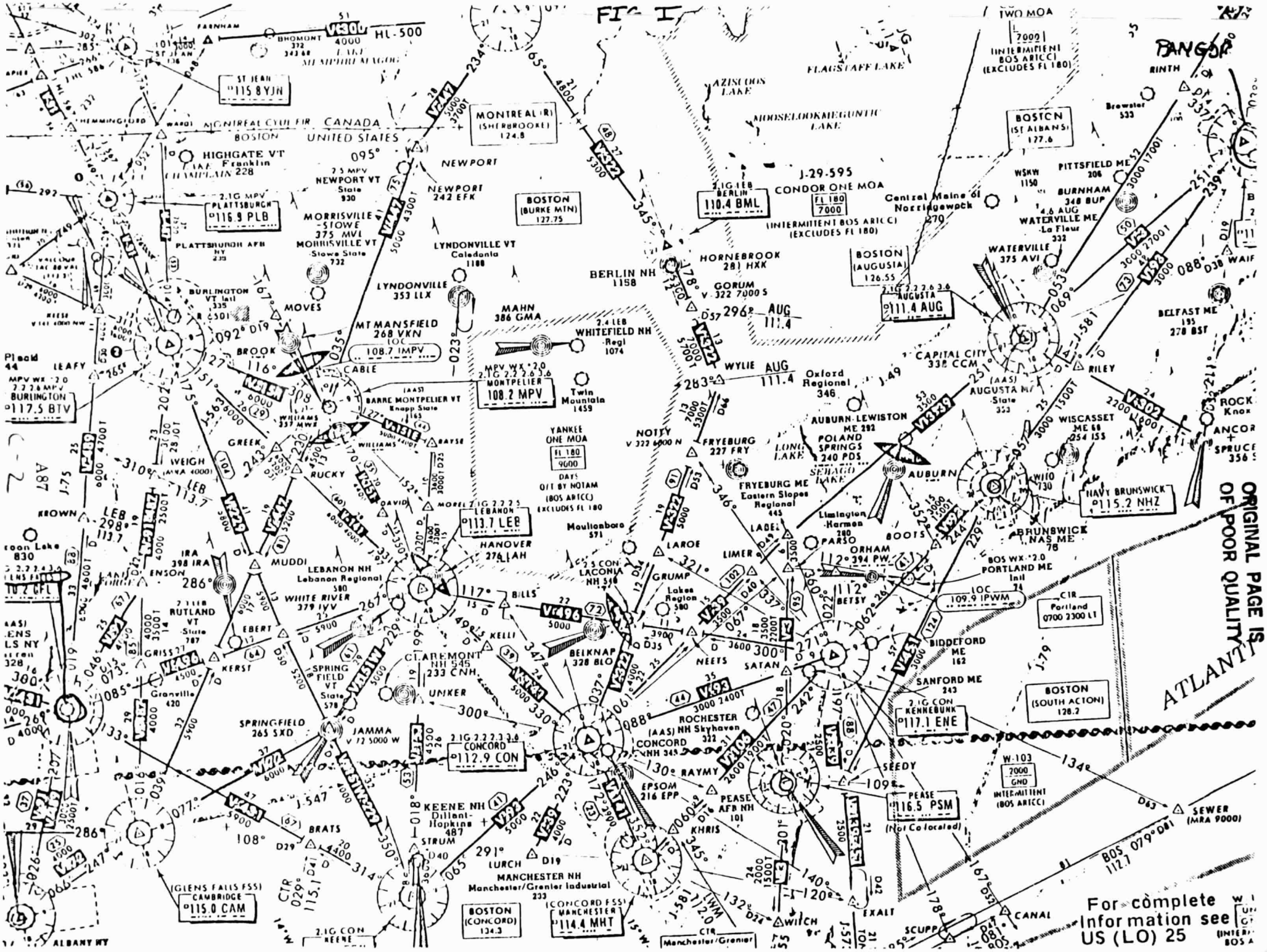
FIG I
CANADA
UNITED STATES
MONTREAL CYUL FIR
BOSTON
HIGHGATE VT
Franklin
CHAMPLAIN 228
PLATTSBURGH
116.9 PLB
PLATTSBURGH AFB
NEWPORT VT
State
930
MORRISVILLE-STOWE
375 MVL
MORRISVILLE VT
Stowe State
732
NEWPORT
NEWPORT
242 EFK
MONTREAL (R)
(SHERBROOKE)
124.8
BOSTON
(BURKE MTN)
127.75
LYNDONVILLE VT
Caledonia
1188
LYNDONVILLE
353 LLX
MOVES
MT MANSFIELD
268 VKN
108.7 IMPV
BROOK
CABLE
BARRE MONTPELIER VT
Knapp State
165
108.2 MPV
BURLINGTON
117.5 BTV
GREEK
RUCKY
WEIGH
KROWN
IRA
398 IRA
MUDDI
LEBANON NH
Lebanon Regional
580
WHITE RIVER
379 IVV
RUTLAND VT
State
787
EBERT
KERST
SPRINGFIELD
265 SXD
JAMMA
CONCORD
112.9 CON
KEENE NH
Dillant-Hopkins
487
BRATS
STRUM
LURCH
MANCHESTER NH
Manchester/Grenier Industrial
233
CAMBRIDGE
115.0 CAM
BOSTON
(CONCORD)
134.3
MANCHESTER
114.4 MHT
CTR
Manchester/Grenier
MAHN
386 GMA
WHITEFIELD NH
Regl
1074
Twin Mountain
1459
YANKEE
ONE MOA
FL 180
9000
DAYS
OFF BY NOTAM
(BOS ARTCC)
EXCLUDES FL 180
LEBANON
113.7 LEB
HANOVER
276 LAH
Moultonboro
571
LACONIA NH
Lakes Region
580
BELKNAP
328 BLO
CLAREMONT NH
233 CNH
UNKER
ROCHESTER
(AAS) NH Skyhaven
322
CONCORD
NH 345
EPSOM
216 EPP
PEASE AFB NH
101
KHRIS
BERLIN NH
1158
HORNEBROOK
281 HXK
GORUM
V 322 7000 S
WYLIE
AUG
111.4
Oxford Regional
346
FRYEBURG
227 FRY
NOTTY
V 322 6000 N
LARDE
LIMER
GRUMP
BILLS
KELLI
NEETS
SATAN
RAYMY
LARDE
BETSY
BERLIN
110.4 BML
CONDOR ONE MOA
FL 180
7000
(INTERMITTENT BOS ARTCC)
(EXCLUDES FL 180)
J-29-595
AZISCOOS LAKE
MOOSELOOKMEGUNTIC LAKE
FLAGSTAFF LAKE
Central Maine of Norridgewock
270
BOSTON
(AUGUSTA)
126.55
AUGUSTA
111.4 AUG
AUBURN-LEWISTON
ME 292
POLAND SPRINGS
240 PDS
LONG LAKE
SEBAGO LAKE
FRYEBURG ME
Eastern Slopes Regional
445
Limington-Harmon
280
PARSO
ORHAM
394 PW
AUBURN
BOOTS
BRUNSWICK
NAS ME
78
NAVY BRUNSWICK
115.2 NHZ
PORTLAND ME
Intl
109.9 IPWM
CTR
Portland
0700 2300 LT
BIDDEFORD
ME
162
SANFORD ME
243
BOSTON
(SOUTH ACTON)
128.2
KENNEBUNK
117.1 ENE
W-103
2000
GND
INTERMITTENT
(BOS ARTCC)
PEASE
116.5 PSM
(Not Co-located)
SEEDY
EXALT
SCUPP
CANAL
SEWER
(MRA 9000)
BOS 079°
112.7
TWO MOA
7000
(INTERMITTENT
BOS ARTCC)
(EXCLUDES FL 180)
BANGOR
BOSTON
(ST ALBANS)
127.6
PITTSFIELD ME
206
BURNHAM
348 BUP
WATERVILLE ME
La Fleur
332
WATERVILLE
375 AVI
CAPITAL CITY
338 CCM
AUGUSTA ME
State
353
RILEY
BELFAST ME
195
278 BST
WISCASSET ME
68
254 ISS
ROCK
Knox
ANCOR
SPRUCE
ATLANTI
For complete
Information see
US (LO) 25
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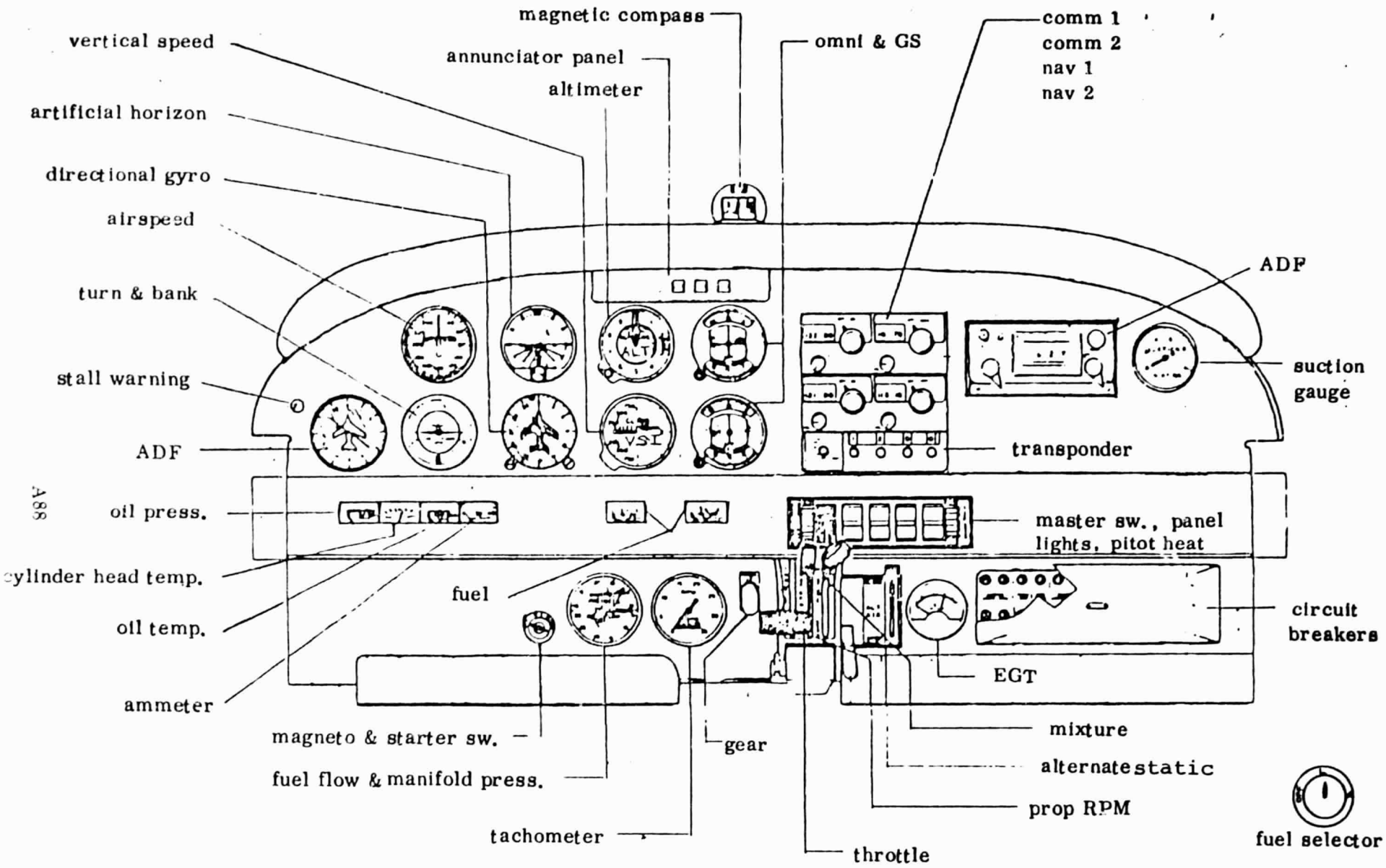


Notes:

Other information available from interviewer:
- visible plane exterior
- outside air temperature
- interior cabin condition

Diagnosis Problem _____
Subject # _____
Experimenter _____

Instructions for P/P Diagnosis:

You have been given a brief rundown on the plane, airspace and current weather. The next phase of our study will proceed as follows: First, I will read you an introduction to a flight you will be taking. Then I will read to you some symptoms which will indicate some form of problem with the plane you are flying. After that, I will start the clock and you will have 4 minutes to diagnose the problem. Referring to your diagram of the ARROW instrument panel, and your knowledge of aircraft systems, you can ask me for individual readings from the instruments and controls shown. I will respond by telling you the status or reading of the chosen instrument or control. You can then write this information somewhere on your panel diagram if you wish (you'll get a clean sheet for each problem). Any actions you may want to take to improve the safety of the situation or to test the plane's reaction should also be mentioned in the sequence you would normally use. I will explain the effect of your actions in sequence. No multiple, simultaneous actions will be possible.

Please think out loud as to what the possible cause of the problem might be at any point in your diagnosis, even if you have several potential causes in mind.

You are working against the clock. Ask for information only if you think it will help your diagnosis. The information available from me concerning your panel and the cockpit environment is adequate for complete and unambiguous diagnosis of the given problem. Any information "not available" will not influence the problem. Any information termed "normal" means that the instrument reading is in its normal range or that the response of the plane to a control input is typical for that phase of the flight.

Once you are certain that you know what the problem is tell me and I will verify your diagnosis. If you are wrong, you can continue until you've identified the cause or until time is up. If time runs out, you can make a best guess. In any case, I will explain the cause of the problem when the diagnosis period is over.

We will be trying 4 different problems. Any questions?

FLIGHT INTRODUCTION FOR DIAGNOSIS

Diagnosis Scenario 1

You are making a day trip from Albany, NY to Burlington, VT. You fly out of Albany at 9:00 a.m., cleared Victor-91, Burlington. You climb to a cruising altitude of 7000 ft. After 20 minutes of routine flying you notice the smell of hot engine oil. What would you do?

[READ SLOWLY - repeat any portion necessary for pilot's full understanding]

EXPLANATION OF CAUSE FOR SCENARIO 1

A small crack developed in the oil line feeding the oil pressure gauge. This crack reduced the oil pressure reading drastically, but did not seriously affect the actual lubrication of the engine. A small pool of oil began to form on the floor of the cabin, pilot's side. Assuming that the cracked line would not deteriorate quickly into a complete break, you were in no immediate danger of engine seizure.

FLIGHT INTRODUCTION FOR DIAGNOSIS

Diagnosis Scenario 2

You are making a day trip from Augusta, Maine to Lebanon, New Hampshire. You fly out of Augusta at 9:00 a.m., cleared Victor 39 to Neets Intersection, Victor 496 to Lebanon. You climb to a cruising altitude of 6000 feet. After 15 minutes of routine flying in instrument conditions, your instruments indicate an increase in airspeed and steadily decreasing altitude while maintaining level flight attitude. What is the first thing you would do?

EXPLANATION OF CAUSE FOR SCENARIO 2

Your vacuum pump failed as indicated by the low reading of the suction gauge. The vacuum pump drives the attitude and directional gyros. As the artificial horizon lost its drive it started to sag to the right and you compensated by turning left, leveling the artificial horizon and putting the plane in a slow, descending left bank. The airspeed increase was due to the slight nose-down attitude.

FLIGHT INTRODUCTION FOR DIAGNOSIS

Diagnosis Scenario 3

You are making a day trip from Keene, New Hampshire to Montpelier, Vermont. You fly out of Keene at 10:30 a.m., cleared Victor-151 to Montpelier. You climb to a cruising altitude of 5000 feet. After 20 minutes of routine cruise your engine suddenly starts running extremely rough, shaking the whole plane and losing about 20% of its cruise power. What is the first thing you would do?

EXPLANATION OF CAUSE FOR SCENARIO 3

Your engine suffered a broken drive gear in the right magneto. The resultant untimed ignition conflicted with the remaining good ignition and caused the extremely rough engine and backfiring. Switching from "both" to the left magneto would have resulted in a smooth running engine with slightly less power than normal cruise.

FLIGHT INTRODUCTION FOR DIAGNOSIS

Diagnosis Scenario 4

You are making a day trip from Sanford, Maine to Messena, New York. You fly out of Sanford at 8:30 a.m., cleared Victor-496 to Lebanon, Victor 141 to Messena. You climb to an initial cruise altitude of 6000. After about 20 minutes, Boston Center instructs you to climb and maintain 10,000 feet. You acknowledge and begin your enroute climb between layers. After 2 minutes of climb, you notice your indicated airspeed dropping off steadily from 100 kts., maintaining constant pitch attitude. What would you do?

EXPLANATION OF CAUSE FOR SCENARIO 4

As you climbed through 6500 feet, the static port froze over as the outside air temperature dropped below 32° F. This caused the airspeed indicator to decrease as altitude increased and the VSI and altimeter to read low. Several corrective actions were possible: return to your previous altitude of 6000 feet; open the alternate static source; break the VSI glass.

DECISION PHASE

Checklist for Each Subject

A. Have these materials ready and in the following order:

1. Figure I (Lo Enroute Chart)
2. Tables I, II, III, and IV (Stapled)
3. Figure II (Route Chart)
4. Figure III (Airport Chart)

B. Have Subject number, Experimenter name, and date filled out on the "Information Sheet" and be prepared to collect data on this sheet.

SCENARIO E

You are at the Bangor International Airport in Bangor, Maine, and desire to fly to Glens Falls, New York, for a 1:00 p.m. business meeting (shown in Fig. I). The current time is 9:00 a.m. and you feel you can be ready for departure by 10:00 a.m. after you conduct all necessary preflight activities. The plane you will be flying today is your company's Cherokee Arrow (N8086W). You have flown this particular plane several times before and regard it as a reliable airplane. A brief list of the important performance figures and IFR equipment on board is shown in Table I. (pause) The aircraft's fuel tanks are full, and after a very thorough preflight inspection, you conclude that it is operationally and legaily ready for the flight.

Now your attention turns to the weather and filing a flight plan. You call the nearest Flight Service Station on the telephone and obtain the weather information in Table II. (pause) After compiling a navigation log for the flight, you file the flight plan in Table III. (pause)

Based on the information you have received so far, would you normally attempt this flight? ("Yes" or "No" - Circle on Information Sheet, Question I.)

What bits of information would you like to have which you don't already have? (List on Information Sheet, Question II.) We realize you may not have all the information you would like for this flight, but for the purposes of the scenario, assume you are satisfied and we will proceed.

(*Remove Fig. I and replace with Fig. II)

DESCRIPTION OF THE FLIGHT

Use Fig. II to follow the progress of your flight.

You were cleared to the Glens Falls airport "as filed". You lifted off from Bangor at 10:00 a.m., and your departure was routine. At 10:14 (14 minutes after departure) you reached your cruising level of 8000 feet and were established on V3 northeast of the Augusta VOR. At 10:34 (34 minutes after departure) you crossed the Augusta VOR within one minute of your ETA. You proceed on V39 and cross Label, Limer, and Neets intersections all very close to your ETA's. You have been in instrument conditions since departure but the flight has been smooth. At 11:21 (1 hour 21 minutes after departure) you cross Grump intersection. One minute later you hear a short burst of static noise over your radio speakers. At the same time you notice your VOR needles and their "on-off" flags flicker unsteadily and return to normal indications. Curious to know what caused these events, you glance over the instrument panel and find a "zero" reading on the ammeter. You actuate the landing light and notice no change in ammeter indications. From this information you conclude the alternator has failed. You follow the procedures in the manual but your attempts to bring the alternator back into service are unsuccessful. Therefore, you turn off the alternator, minimize the electrical load, and operate solely on battery power.

The battery, by itself, can supply the required power to operate your radios for only a limited time. The amount of time you have depends on the

size and condition of the battery, and the power requirements of the essential electrical equipment you use. Even under ideal conditions battery power is not expected to last longer than 50 minutes.

You are at an altitude of 8000 feet, just west of Grump intersection. The time is now 11:23 and you have been airborne for 1 hour and 23 minutes. Winds are out of the southwest at 30 knots.

Clearly there is a need to divert from the planned flight and to land somewhere else. Glens Falls, your destination, is beyond your range in terms of battery time. Your task now is to find a suitable place to land.

We will replace Figure II with Figure III which is a simplified version and includes all the airports in the area. (It should not be assumed that all these airports are within your range). I will act as the air traffic controller and provide you with information about the airports as you request it. The information which I am prepared to give you about each airport is listed in Table IV. PAUSE You request each piece of information by stating the airport name (i.e. "C") and the particular information you desire about that airport (i.e. "bearing and distance"). You can ask for only one piece of information at a time. You will have two minutes to conduct your search and select an airport to divert to. You will be able to fly to that airport and shoot one approach only.

Ranking Exercise Instructions

You have just finished choosing an airport to divert to in the face of a serious problem. Now we would like you to consider yourself to be in that same situation again. 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. We would like you to rank these airports from your "most preferable" to "least preferable," given the same situation. Recall that you have, at the very most, 50 minutes of battery time left. You may find it useful to divide the airports into "sub-groups," rank the airports in each sub-group, and then reconnect the sub-groups as appropriate. Afterwards, make a final check of your complete rank and adjust it as you think necessary.

Go - No Go Instructions

You have just finished ranking these airports from "most preferable" to "least preferable." The airport on the top of this deck is the one you like the most, and the airport on the bottom is the one you like the least. Presumably, you would choose to land at this "top" airport first, in this situation, given these airports.

Now assume that maintenance facilities to repair your airplane are not available at the top airport. If you land where maintenance services are not available, you will probably be delayed an extra day or so in order to make arrangements to have your aircraft repaired. If you knew airport "2" had maintenance facilities, would you "pass up" airport "1" for airport "2"?

(If subject responds "Yes") Now assume maintenance services are not available at airport 2. If maintenance was available at airport 3, would you pass up airport 2 in favor of airport 3?

(If subject responds "Yes" continue this routine until he says "No". Record the rank order (3rd letter of the code in lower right corner of card) and the Go - No Go point (by placing a slash in the rank between the "go" and "no go" points)).

TABLE I

Important Specs. and Performance Figures

Cruise Speed	=	135 KTAS (65% pwr. @ 7000 feet)
Fuel Flow (65% pwr.)	=	10 GPH
Usable Fuel Capacity	=	48 gallons
Endurance	=	4.8 hours (no reserve)
Range	=	648 nautical miles (no wind, no reserve)

IFR Equipment on Board

2 NAV/COMMs

2 VOR/ILS indicators

1 ADF

1 Three-light marker beacon receiver

1 Transponder (not encoding)

1 Single axis autopilot

TABLE II

for Glens Falls (New York): The weather is currently "1000 feet overcast and 3 miles visibility in rain." It is forecast to stay that way until 1:00 p.m., local time, when it should improve to 1500 overcast and 5 miles visibility.

for Bangor (Maine): The weather is currently "1000 feet overcast and 3 miles visibility in rain and fog." It is forecast to remain unchanged except for a chance of 500 feet overcast and 1 mile visibility in rain, drizzle, and fog.

for Albany (New York): The weather is currently "1000 feet overcast and 4 miles visibility in light rain." It is forecast to remain the same until 1:00 p.m., at which time it should improve to "1500 overcast and 4 miles."

Winds aloft: from the southwest (200°) at 30 knots at all altitudes up to 9000 feet.

Icing Level: 10,000 feet.

No PIREPs reported for the route.

TABLE III.

Form Approved: OMB No. 04-R0072

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

FLIGHT PLAN

CIVIL AIRCRAFT PILOTS. FAR Part 91 requires you file an IFR flight plan to operate under instrument flight rules in controlled airspace. Failure to file could result in a civil penalty not to exceed $1,000 for each violation (Section 901 of the Federal Aviation Act of 1958, as amended). Filing of a VFR flight plan is recommended as a good operating practice. See also Part 99 for requuements concerning DVFR flight plans.

1. TYPE	2. AIRCRAFT IDENTIFICATION	3. AIRCRAFT TYPE/ SPECIAL EQUIPMENT	4. TRUE AIRSPEED	5. DEPARTURE POINT	6. DEPARTURE TIME PROPOSED (Z)	6. DEPARTURE TIME ACTUAL (Z)	7. CRUISING ALTITUDE
VFR / X IFR / DVFR	N8086W	PA 28R-200/T	135 KTS	BGR	10:00 EDT 1400 Z		8000

8. ROUTE OF FLIGHT

V3 to Augusta VOR V39 to N[illegible] intersection V496 to Glens Falls

9. DESTINATION (Name of airport and city)	10. EST TIME ENROUTE HOURS	10. EST TIME ENROUTE MINUTES	11. REMARKS
GFA (Glens Falls)	2	15	

12. FUEL ON BOARD HOURS	12. FUEL ON BOARD MINUTES	13. ALTERNATE AIRPORT(S)	14. PILOT'S NAME, ADDRESS & TELEPHONE NUMBER & AIRCRAFT HOME BASE	15. NUMBER ABOARD
4	50	Albany	—	1

16. COLOR OF AIRCRAFT	
Red on white	CLOSE VFR FLIGHT PLAN WITH _____ FSS ON ARRIVAL

FAA Form 7233-1 (5-77)

TABLE IV

ATC has the following information on each airport:

-ATC Services: tower w/radar (not GCA), tower, FSS, or none.

-Visibility: Visibility in statute miles reported by an authorized weather observer.

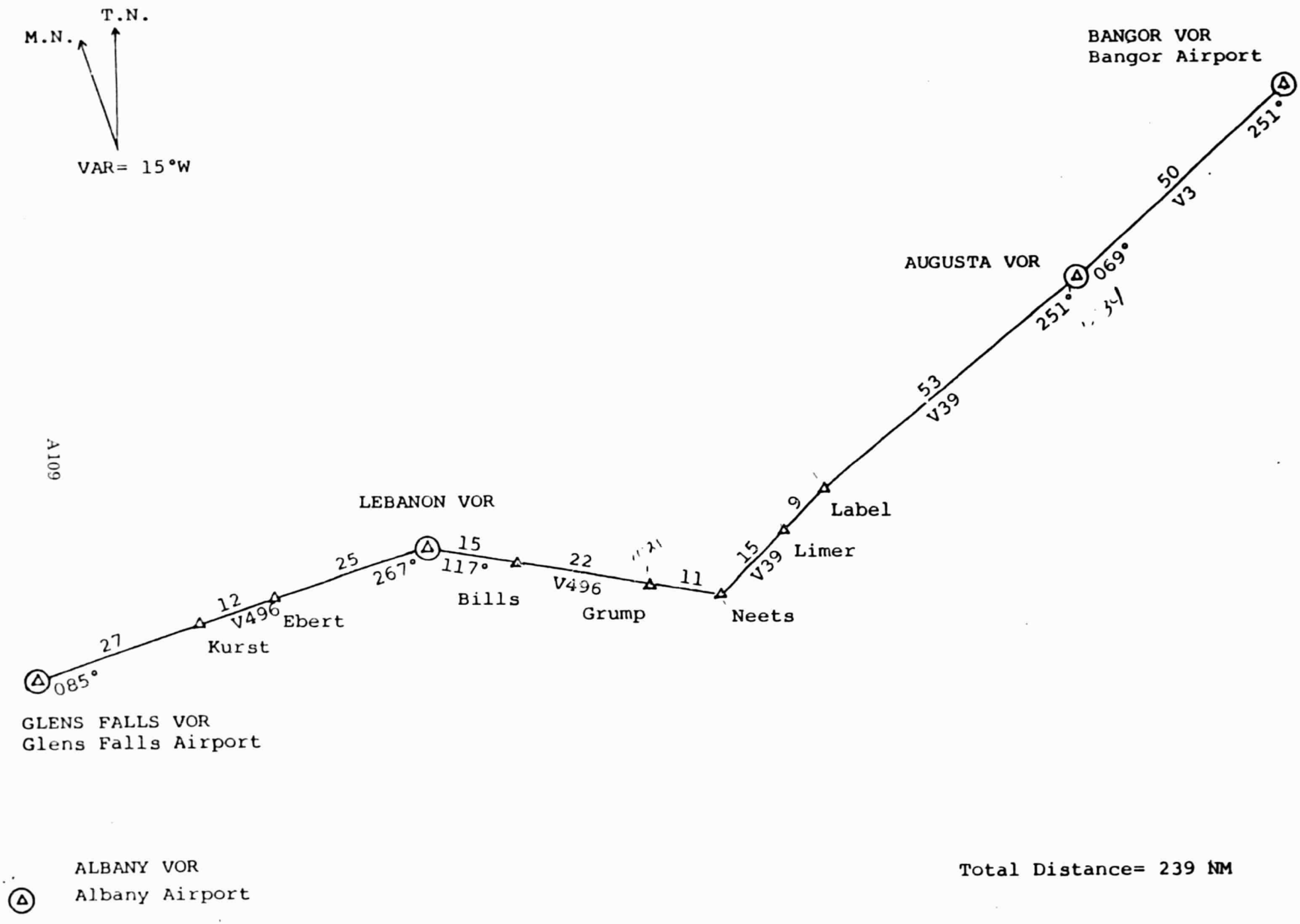
-Magnetic Bearing and Distance: From present position to the airport in nautical miles.

-Ceiling: Height of lowest cloud cover (feet, AGL) reported by an authorized weather observer.

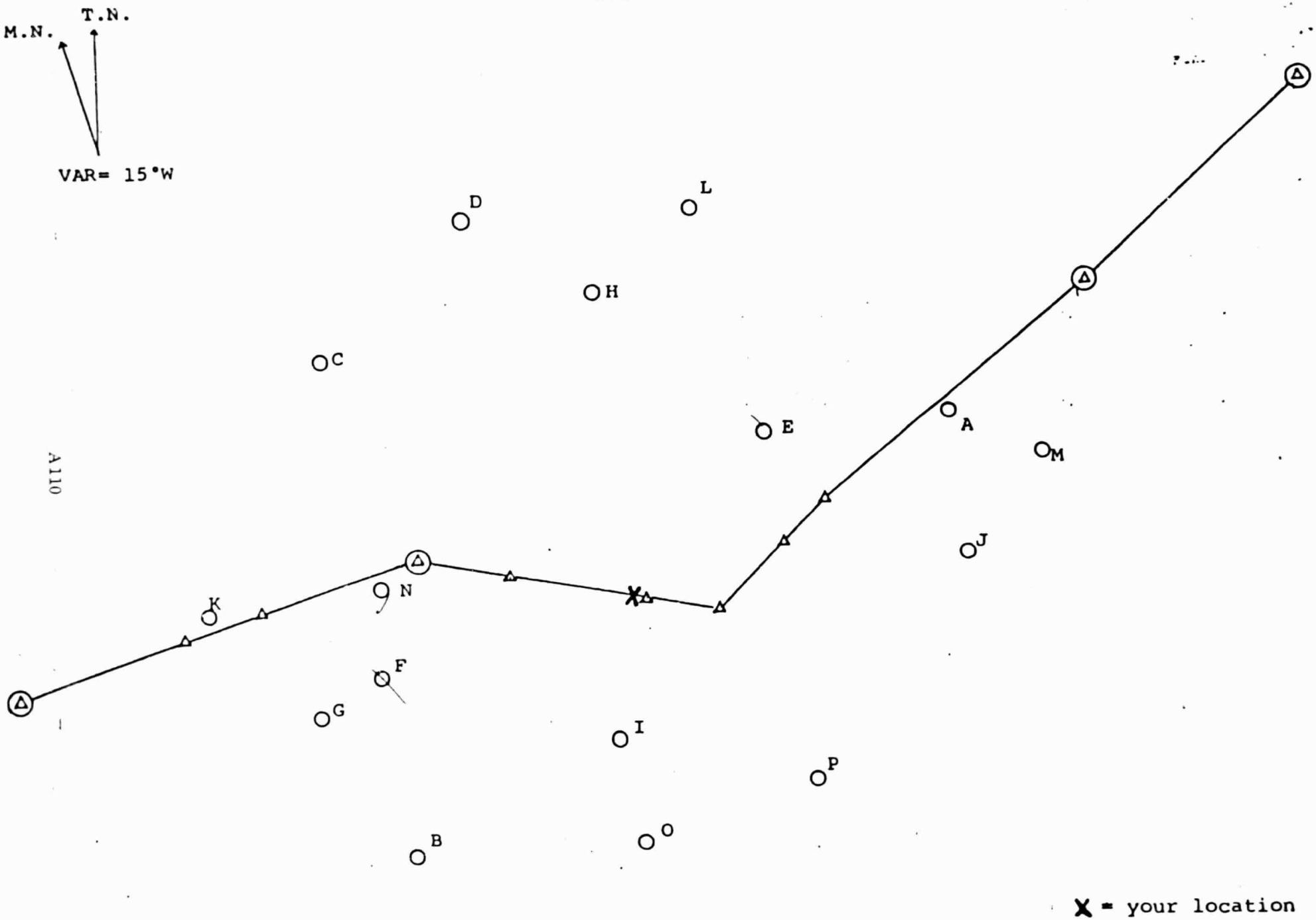
-Terrain: Brief description of the topography of the land surrounding the airport (i.e. level, hilly, or Mountainous, etc.).

-Approach Aids: The most accurate type of approach at that airport (i.e. ILS, LOC, VOR, NDB, etc.).

FIGURE II


T.N.
M.N.
VAR= 15°W
BANGOR VOR
Bangor Airport
251°
50
V3
AUGUSTA VOR
069°
251°
53
V39
Label
9
Limer
15
V39
Neets
11
Grump
22
V496
Bills
15
117°
LEBANON VOR
267°
25
Ebert
12
V496
Kurst
27
085°
GLENS FALLS VOR
Glens Falls Airport
ALBANY VOR
Albany Airport
Total Distance= 239 NM

FIGUI 1II.



INFORMATION SHEET

SUBJECT #: EXPERIMENTER: DATE:

AIRPORT	BEARING DISTANCE	CEILING	VISIBILITY	APPROACH AIDS	ATC SERVICES	TERRAIN	AIR-PORT	COMMENTS
A	080° 60	500	2	ILS	TWR	LEVEL	A	
B	230° 50	700	1	ILS	NONE	HILLY	B	
C	330° 60	1000	3	VOR	TWR (R)	HILLY	C	
D	350° 35	500	1	NDB	NONE	HILLY	D	
E	060° 35	700	2	NDB	NONE	MOUNT	E	
F	270° 40	700	2	NDB	NONE	MOUNT	F	
G	270° 50	500	2	ILS	NONE	MOUNT	G	
H	010° 50	700	2	NDB	NONE	MOUNT	H	
I	200° 35	500	1	NDB	FSS	HILLY	I	
J	100° 55	500	1	ILS	TWR(R)	LEVEL	J	
K	290° 65	700	2	ILS	NONE	MOUNT	K	
L	030° 60	1000	3	ILS	NONE	MOUNT	L	
M	090° 70	1000	2	ILS	TWR(R)	LEVEL	M	
N	290° 35	700	2	VOR	TWR	MOUNT	N	
O	190° 40	700	2	ILS	TWR	HILLY	O	
P	150° 40	500	1	VOR	TWR(R)	LEVEL	P	

QUESTION I: YES NO (CIRCLE) COMMENTS:

QUESTION II: (LIST HERE)

QUESTION III: (SUBJECT ESTIMATE OF FLYING TIME)

SUBJECT RANK (ENTER 3RD LETTER OF CODE)

— — — — — — — — — — — — — — — —

PLACE SLASH (/) BETWEEN "GO-NO GO"

COMMENTS:

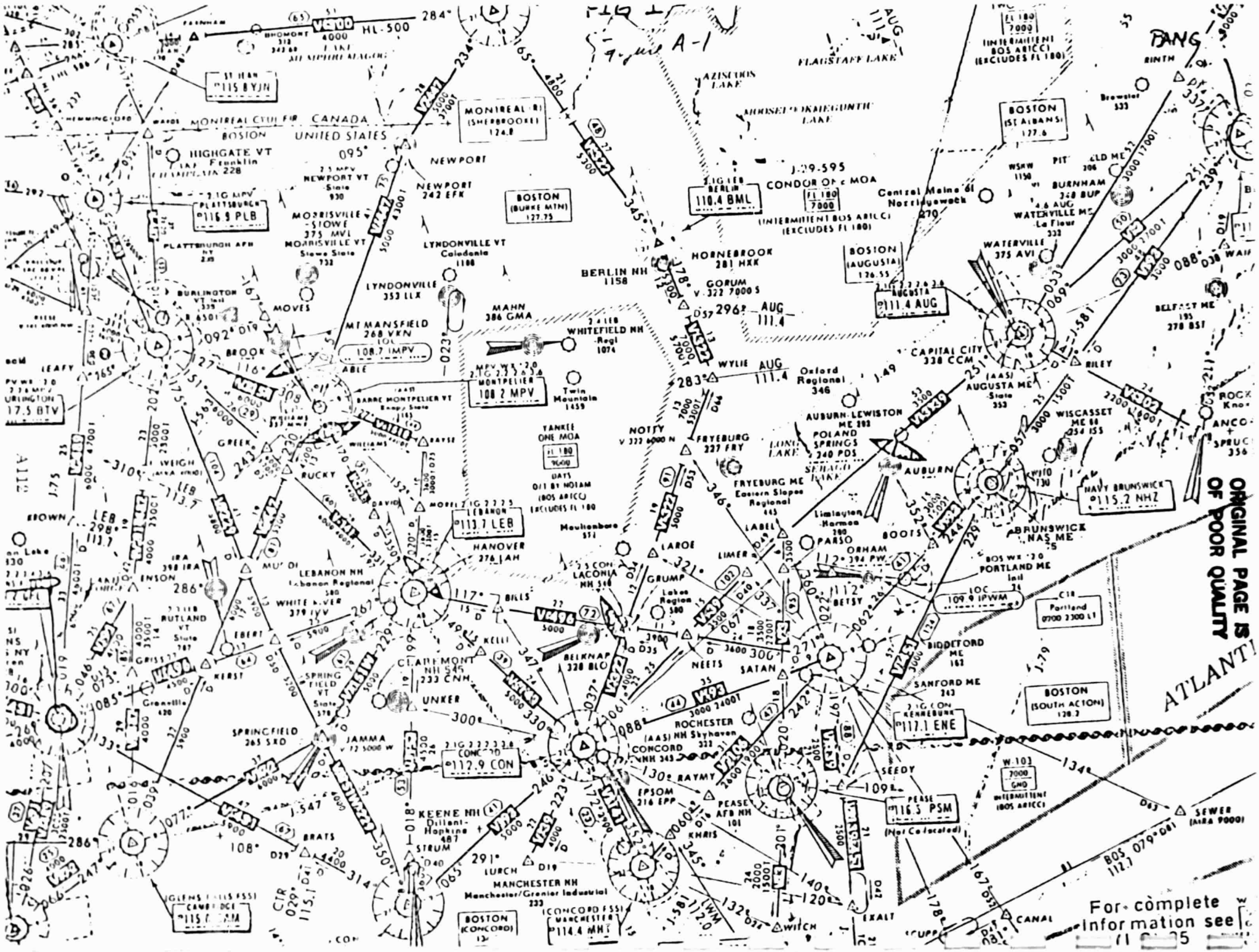


Figure A-1
CANADA
UNITED STATES
MONTREAL CTUL FIR
BOSTON
HIGHGATE VT
Franklin
NEWPORT VT
State
NEWPORT
NEWPORT
MORRISVILLE-STOWE
MORRISVILLE VT
Stowe State
PLATTSBURGH
PLATTSBURGH AFB
LYNDONVILLE VT
Caledonia
LYNDONVILLE
MT MANSFIELD
BURLINGTON
BERLIN NH
MAHN
WHITEFIELD NH
MONTPELIER
BARRE MONTPELIER VT
Twin Mountain
YANKEE ONE MOA
CONDOR ONE MOA
HORNEBROOK
GORUM
WYLIE
Oxford Regional
AUGUSTA
CAPITAL CITY
AUGUSTA ME
AUBURN-LEWISTON
POLAND SPRINGS
FRYEBURG
FRYEBURG ME
Eastern Slopes Regional
Limington-Harmon
PARSO
ORHAM
LACONIA NH
GRUMP
Lakes Region
BELKNAP
NEETS
SATAN
LEBANON NH
Lebanon Regional
HANOVER
WHITE RIVER
RUTLAND VT
State
CLAREMONT NH
SPRINGFIELD VT
State
UNKER
SPRINGFIELD
JAMMA
CONCORD
ROCHESTER
(AAS) NH Skyhaven
CONCORD NH
RAYMY
EPSOM
PEASE AFB NH
KEENE NH
Dillant-Hopkins
STRUM
BRATS
LURCH
MANCHESTER NH
Manchester/Granier Industrial
BOSTON (KONCORD)
MANCHESTER
BOSTON (BURKE MTN)
BOSTON (ST ALBANS)
BOSTON (AUGUSTA)
BOSTON (SOUTH ACTON)
BURNHAM
WATERVILLE
WISCASSET ME
NAVY BRUNSWICK
BRUNSWICK NAS ME
PORTLAND ME
BIDDEFORD ME
SANFORD ME
SEEDY
PEASE
EXALT
CANAL
SEWER
BOS 079° 061
112.7
ATLANTI
BANG
ORIGINAL PAGE IS OF POOR QUALITY
For complete Information see

Diagnosis Problem 1
Subject #
Experimenter

DIAGNOSIS INFORMATION

AIRFRAME

- [ ] wings & flaps - normal
- [ ] cowl - normal
- [ ] windscreen - normal
- [ ] external noise - normal
- [ ] outside air temp. - normal (34° F)
- [ ] cabin - oil drops on floor in front of pilot

PANEL INSTRUMENTS

Attitude & Performance

- [ ] airspeed - N - 135 kts.
- [ ] turn & bank - N - level
- [ ] art. horizon - N - level
- [ ] directional gyro - N - 040
- [ ] vertical speed - N - ϕ
- [ ] altimeter - N - 7000'
- [ ] mag. compass - N - 040
- [ ] stall warning - N - off
- [ ] suction gauge - N

Navigation & Communication

- [ ] transponder - normal
- [ ] omni 1 - normal
- [ ] omni 2 - normal
- [ ] comm 1 - normal
- [ ] comm 2 - normal
- [ ] ADF - normal

Engine Gauges

- [ ] tachometer - normal
- [ ] fuel - normal
- [ ] oil pressure - extremely low - near peg.
- [ ] oil temp. - normal
- [ ] cyl. head temp. - normal
- [ ] manifold press. - normal
- [ ] ammeter - normal
- [ ] exhst. gas temp. - normal
- [ ] fuel flow - normal

Other

- [ ] panel lights - normal
- [ ] circuit breakers - normal
- [ ] annunciators - normal

Information Not Listed

- [ ] _____
- [ ] _____
- [ ] _____

Diagnosis Problem 1
Subject # _____
Experimenter _____

COCKPIT CONTROLS

- [ ] throttle - normal
  - [ ] increase - normal R
  - [ ] decrease - normal R
- [ ] mixture - normal
  - [ ] increase - normal R
  - [ ] decrease - normal R
- [ ] propeller RPM - normal
  - [ ] increase - normal R
  - [ ] decrease - normal R
- [ ] gear selector - up
  - [ ] gear down - normal R
- [ ] yoke - trimmed for cruise
  - [ ] pitch up/down - normal R
  - [ ] turn left/right - normal R
  - [ ] pitch trim - normal R
- [ ] master switch - on
  - [ ] off - power lost
- [ ] magneto & starter sw - both
  - [ ] left - RPM drop
  - [ ] right - RPM drop
  - [ ] off - engine quits
- [ ] fuel selector - left
  - [ ] right - no change
  - [ ] left - no change
  - [ ] off - engine quits
- [ ] alternate static source- closed
  - [ ] open - no change
- [ ] control actions not listed
  - [ ] pitot heat - no change
  - [ ] _____
  - [ ] _____

NAVIGATION AND COMMUNICATION

- [ ] transponder - normal
  - [ ] off - normal R
  - [ ] chk. CB - normal R
  - [ ] change code - normal R
- [ ] omni 1 - normal
  - [ ] off - normal R
  - [ ] chk. CB - normal R
- [ ] omni 2 - normal
  - [ ] off - normal R
  - [ ] chk. CB - normal R
- [ ] comm 1 - normal
  - [ ] off - normal R
  - [ ] chk. CB - normal R
- [ ] comm 2 - normal
  - [ ] off - normal R
  - [ ] chk. CB - normal R
- [ ] ADF - normal
  - [ ] off - normal R
  - [ ] chk. CB - normal R

Diagnosis Problem 2
Subject # _____
Experimenter _____

DIAGNOSIS INFORMATION

AIRFRAME

- [ ] wings & flaps - N
- [ ] cowl - N
- [ ] windscreen - N
- [ ] external noise - engine speed increasing
- [ ] outside air temp. - N (37° F)
- [ ] cabin - N

PANEL INSTRUMENTS

Attitude & Performance

- [ ] airspeed - increased by 10 kts. to 145 kts.
- [ ] turn & bank - slight left bank
- [ ] art. horizon - level, no movement
- [ ] directional gyro - no movement (250°)
- [ ] vertical speed - increasing negative
- [ ] altimeter - decreasing slowly from 6000°
- [ ] mag. compass - rotating slowly (230°)
- [ ] stall warning - off
- [ ] suction gauge - extremely low, near peg

Navigation & Communication

- [ ] transponder - N
- [ ] omni 1 - N
- [ ] omni 2 - N
- [ ] comm 1 - N
- [ ] comm 2 - N
- [ ] ADF - N, moving

Engine Gauges

- [ ] tachometer - slight increase
- [ ] fuel - N
- [ ] oil pressure - N
- [ ] oil temp. - N
- [ ] cyl. head temp. - N
- [ ] manifold press. - N
- [ ] ammeter - N
- [ ] exhst. gas temp. - N
- [ ] fuel flow - N

Other

- [ ] panel lights - N
- [ ] circuit breakers - N
- [ ] annunciators - N

Information Not Listed

- [ ] _____
- [ ] _____
- [ ] _____

Diagnosis Problem 2
Subject # _____
Experimenter _____

COCKPIT CONTROLS

- [ ] throttle - N
  - [ ] increase - NR
  - [ ] decrease - NR
- [ ] mixture - N
  - [ ] increase - NR
  - [ ] decrease - NR
- [ ] propeller RPM - N
  - [ ] increase - NR
  - [ ] decrease - NR
- [ ] gear selector - up
  - [ ] gear down - NR
- [ ] yoke - slightly forward, slightly left
  - [ ] pitch up/down - NR
  - [ ] turn left/right - NR
  - [ ] pitch trim - NR
- [ ] master switch - on
  - [ ] off - power lost
- [ ] magneto & starter sw - both
  - [ ] left - RPM drop
  - [ ] right - RPM drop
  - [ ] off - engine quits
- [ ] fuel selector - left
  - [ ] right - no change
  - [ ] left - no change
  - [ ] off - engine quits
- [ ] alternate static source- closed
  - [ ] open - no change
- [ ] control actions not listed
  - [ ] pitot heat - no change
  - [ ] _____
  - [ ] _____

NAVIGATION AND COMMUNICATION

- [ ] transponder - N
  - [ ] off - NR
  - [ ] chk. CB - NR
  - [ ] change code - NR
- [ ] omni 1 - N
  - [ ] off - NR
  - [ ] chk. CB - NR
- [ ] omni 2 - N
  - [ ] off - NR
  - [ ] chk. CB - NR
- [ ] comm 1 - N
  - [ ] off - NR
  - [ ] chk. CB - NR
- [ ] comm 2 - N
  - [ ] off - NR
  - [ ] chk. CB - NR
- [ ] ADF - N
  - [ ] off - NR
  - [ ] chk. CB - NR

Diagnosis Problem 3
Subject # _____
Experimenter _____

DIAGNOSIS INFORMATION

AIRFRAME

- [ ] wings & flaps - N
- [ ] cowl - N
- [ ] windscreen - N
- [ ] external noise - rough, vibrating engine with backfiring
- [ ] outside air temp. - N - (40° F)
- [ ] cabin - being shaken

PANEL INSTRUMENTS

Attitude & Performance

- [ ] airspeed - decrease of 10 kts.
- [ ] turn & bank - N - level
- [ ] art. horizon - N - level
- [ ] directional gyro - N - 360°
- [ ] vertical speed - N - 0
- [ ] altimeter - N - 5000'
- [ ] mag. compass - N - 360°
- [ ] stall warning - N - off
- [ ] suction gauge - N

Navigation & Communication

- [ ] transponder - N
- [ ] omni 1 - N
- [ ] omni 2 - N
- [ ] comm 1 - N
- [ ] comm 2 - N
- [ ] ADF - audio crackling, needle wandering

Engine Gauges

- [ ] tachometer - RPM drop of 200
- [ ] fuel - N
- [ ] oil pressure - N
- [ ] oil temp. - N
- [ ] cyl. head temp - slight decrease
- [ ] manifold press. - slight increase
- [ ] ammeter - N
- [ ] exhst. gas temp. - large fluctuations
- [ ] fuel flow - very slight decrease

Other

- [ ] panel lights - N
- [ ] circuit breakers - N
- [ ] annunciators - N

Information Not Listed

- [ ] _____
- [ ] _____
- [ ] _____

Diagnosis Problem 3
Subject # _____
Experimenter _____

COCKPIT CONTROLS

- [ ] throttle - N
  - [ ] increase - NR
  - [ ] decrease - NR
- [ ] mixture - N
  - [ ] increase - NR
  - [ ] decrease - NR
- [ ] propeller RPM - N
  - [ ] increase - NR
  - [ ] decrease - NR
- [ ] gear selector - up
  - [ ] gear down - NR
- [ ] yoke - N
  - [ ] pitch up/down - NR
  - [ ] turn left/right - NR
  - [ ] pitch trim - NR
- [ ] master switch - on
  - [ ] off - power lost
- [ ] magneto & starter sw - both
  - [ ] left - engine runs smooth
  - [ ] right - engine sputters, quits
  - [ ] off - engine quits
- [ ] fuel selector - left
  - [ ] right - no change
  - [ ] left - no change
  - [ ] off - engine quits
- [ ] alternate static source - closed
  - [ ] open - no change
- [ ] control actions not listed
  - [ ] pitot heat - no change
  - [ ] _____
  - [ ] _____

NAVIGATION AND COMMUNICATION

- [ ] transponder - N
  - [ ] off - NR
  - [ ] chk. CB - NR
  - [ ] change code - NR
- [ ] omni 1 - N
  - [ ] off - NR
  - [ ] chk. CB - NR
- [ ] omni 2 - N
  - [ ] off - NR
  - [ ] chk. CB - NR
- [ ] comm 1 - N
  - [ ] off - NR
  - [ ] chk. CB - NR
- [ ] comm 2 - N
  - [ ] off - NR
  - [ ] chk. CB - NR
- [ ] ADF - audio crackling, needle wandering
  - [ ] off - NR
  - [ ] chk. CB - NR

Diagnosis Problem 4
Subject # _____
Experimenter _____

DIAGNOSIS INFORMATION

AIRFRAME

- [ ] wings & flaps - N
- [ ] cowl - N
- [ ] windscreen - N
- [ ] external noise - N
- [ ] outside air temp. - N (30° F)
- [ ] cabin - N

PANEL INSTRUMENTS

Attitude & Performance

- [ ] airspeed - slowly decreasing from 100 kts.
- [ ] turn & bank - N - level
- [ ] art. horizon - N - climb
- [ ] directional gyro - N - (300°)
- [ ] vertical speed - sluggish, low (100 ft./min.)
- [ ] altimeter - low - only 6300'
- [ ] mag. compass - N - (300)
- [ ] stall warning - N - off
- [ ] suction gauge - N

Navigation & Communication

- [ ] transponder - N
- [ ] omni 1 - N
- [ ] omni 2 - N
- [ ] comm 1 - N
- [ ] comm 2 - N
- [ ] ADF - N

Engine Gauges

- [ ] tachometer - N
- [ ] fuel - N
- [ ] oil pressure - N
- [ ] oil temp. - N
- [ ] cyl. head temp. - N
- [ ] manifold press. - N
- [ ] ammeter - N
- [ ] exhst. gas temp. - N
- [ ] fuel flow - N

Other

- [ ] panel lights - N
- [ ] circuit breakers - N
- [ ] annunciators - N

Information Not Listed

- [ ] _____
- [ ] _____
- [ ] _____

A118A

Subject # _____

Experimenter _____

COCKPIT CONTROLS

- [ ] throttle - N
  - [ ] increase - NR, no airspeed increase
  - [ ] decrease - NR, no airspeed increase
- [ ] mixture - N
  - [ ] increase - NR
  - [ ] decrease - NR
- [ ] propeller RPM - N
  - [ ] increase - NR
  - [ ] decrease - NR
- [ ] gear selector - up
  - [ ] gear down - NR
- [ ] yoke - N
  - [ ] pitch up/down - up - airspeed decreases faster; down - airspeed stabilizes
  - [ ] turn left/right - NR
  - [ ] pitch trim - NR
- [ ] master switch - on
  - [ ] off - N - power lost
- [ ] magneto & starter sw - both
  - [ ] left - N - RPM drop
  - [ ] right - N - RPM drop
  - [ ] off - N - engine quits
- [ ] fuel selector - left
  - [ ] right - N - no change
  - [ ] left - N - no change
  - [ ] off - N - engine quits
- [ ] alternate static source - closed
  - [ ] open - airspeed suddenly increases, vert. speed reads correctly but sluggish
- [ ] control actions not listed
  - [ ] break airspeed case -
  - [ ] break VSI case - ____
  - [ ] break altimeter case -

  } airspeed returns to normal
  - [ ] pitot heat - no change

NAVIGATION AND COMMUNICATION

- [ ] transponder - N
  - [ ] off - NR
  - [ ] chk. CB - NR
  - [ ] change code - NR
- [ ] omni 1 - N
  - [ ] off - NR
  - [ ] chk. CB - NR
- [ ] omni 2 - N
  - [ ] off - NR
  - [ ] chk. CB - NR
- [ ] comm 1 - N
  - [ ] off - NR
  - [ ] chk. CB - NR
- [ ] comm 2 - N
  - [ ] off - NR
  - [ ] chk. CB - NR
- [ ] ADF - N
  - [ ] off - NR
  - [ ] chk. CB - NR

P/P DIAGNOSIS SUMMARY

Diagnosis Problem _____
Subject # _____
Experimenter _____

Potential causes mentioned and sequence location

☐ _____

☐ _____

☐ _____

☐ _____

☐ _____

☐ _____

Best guess on final diagnosis _____

Time of final diagnosis _____, or time out ☐

Is guess or diagnosis correct? ☐ yes ☐ no

Estimated time plane would fly _____

Judged criticality (scale 1-7) _____

After pilot knows correct cause of problem:

estimated time plane would fly _____

judged criticality (scale of 1-7) _____

APPENDIX I

Conditions for the Use of the Additive Model

Conditions For the Use of the Additive Model

It has long been recognized in the conjoint measurement approach that situations could exist where numerical "goodness-of-fit" metrics would not be able to determine if the proposed composition rule is actually the best. Conjoint measurement addresses the issues of composition and measurement simultaneously. If, however, the dependent variable does not follow the stated composition rule to a suitable degree, it may be because either the composition rule is invalid, or the numerical scales are inadequate. At this point an analysis of the ordinal input data is required to determine which of the possible explanations holds. Krantz and Tversky (1971) outlined several testable properties of ordinal input data which could be used to determine which of the various composition rules describes the actual process. They intended for their "axiomatic" approach to be considered in a complementary fashion with numerical goodness-of-fit approaches.

In cases where any factor is varied over two levels, the property of ordinal independence is the only one required for the additive model to be considered as feasible. This is not to be confused with the property of orthogonality between attributes. An explanation of this independence property is given in the words of Krantz and Tversky:

> "The essence of ordinal independence is that the ordering of the dependent variable can be used to order some of the independent variables (i.e., factors) in a manner that does not depend on the remaining variables." (Krantz and Tversky, 1971).

A mathematical representation of ordinal independence can be developed in the following way. If the two levels for each of the four attributes are described as in Equation E2,

$$x_1 = a \text{ or } b,$$
$$x_2 = g \text{ or } f,$$
$$x_3 = p \text{ or } q, \text{ and}$$
$$x_4 = y \text{ or } z, \qquad \text{(E2)}$$

then each alternative could be defined by the attribute values which are assigned to it (for example, (a,g,q,y) is the alternative where $x_1 = a$, $x_2 = g$, $x_3 = q$, and $x_4 = y$). If $(a,g,p,y) \geq (b,g,p,y)$, and $(a,f,p,y) \geq (b,f,p,y)$ and, in general, if $(a,x_2,x_3,x_4) \geq (b,x_2,x_3,x_4)$ for all possible combinations of the values of x_2, x_3, x_4, then x_1 is said to be ordinally independent of x_2, x_3, and x_4. Independence of the other attributes is defined in the same fashion.

One problem that must be considered when testing any axiom is the presence of error in the raw (ranked) data. In most cases, the data are regarded as

"fallible" in the sense that slight fluctuations or local errors occur in the ranks. This can lead to refuting an ordinal property on a strict basis, even though the property is largely satisfied. Unless the compliance criterion is relaxed to include those cases where the property is strongly though not strictly obeyed, no composition rule can be supported by these tests.

In order to account for the effects of fallible data, Krantz and Tversky propose that ordinal independence be expressed probabilistically to take on the view of statistical independence. Required ordinal properties can be interpreted as statistical hypotheses and tested accordingly. This would minimize the effects of slight inconsistencies in the ranked data on the selection of a composition rule.

A sensitivity analysis was performed to see how many inconsistencies could be introduced to the rank before the additive model became excessively distorted. The approach taken was to start with a rank which was in strict accordance with the Krantz-Tversky tests and progressively alter it. At each point the relative importance of each attribute was compared with that of the original rank (the relative importance of the attributes was determined from the coefficients obtained by the regression procedure outlined in Chapter 5). The initial rank for airports A through P was as follows:

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1

The numbers refer to the position each airport received in the order of preference where sixteen means "most preferable". Because the extremes in the preference positions (for example the positions of 16, 15, 2, or 1) have the most influence on the resulting coefficients, it was decided to move one of them around in a systematic fashion. The sixteenth position was progressively assigned to airports B, C, D, E and so on. After making the first alteration the rank appeared as follows:

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
15	16	14	13	12	11	10	9	8	7	6	5	4	3	2	1

The relative importance of the attributes was preserved and virtually 100% of the variation was accounted for by the model. The second and third alterations were made as follows:

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
15	14	16	13	12	11	10	9	8	7	6	5	4	3	2	1

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
15	14	13	16	12	11	10	9	8	7	6	5	4	3	2	1

Still the relative importance of the attributes was maintained, and the model accounted for nearly 100% of the response variation. It wasn't until airport G was assigned the sixteenth position that the first change in relative importance of attributes was observed.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
15	14	13	12	11	10	16	9	8	7	6	5	4	3	2	1

The additive model however still accounted for 95% of the variation. This analysis continued and, except for two more instances, the original relative importance of attributes was maintained, and the model accounted for a good portion of the variation.

This exercise is indicative of the ability of conjoint measurement and the additive model to absorb minor blemishes in the ranked data and still faithfully reveal the subject's general ranking policy. It should be noted that the inconsistencies found in the actual data were all much less serious than those introduced in the sensitivity analysis.

APPENDIX J

Master Summary of Data for the
Destination Diversion Scenario

MASTER SUMMARY OF DATA

The Master Summary of Data is given on the following page. The meaning of each category abbreviation is given below.

BSUBATC is the value of the coefficient, B_{atc}.

BSUBWX is the value of the coefficient, B_{wx}.

BSUBTIM is the value of the coefficient, B_{tim}.

BSUBAPP is the value of the coefficient, B_{app}.

KNOWLEDG is the score received on the knowledge survey.

TOTHRS is the total flying experience in hours.

SEHRS is the total flight experience in single-engine airplanes, in hours.

IFRHRS is total flight experience under Instrument Flight Rules, in hours.

RATING is the grade of pilot certificate (PRIV= Private, COMM= Commercial, and ATP= Airline Transport).

TRAINING is the type of basic training received (CIV= Civilian, MIL= Military).

FLYING is the type of flying most commonly done (GA/ COMM= General Aviation, Commercial).

SPEAR is the value of the Spearman correlation coefficient for the computed value-input rank pairs.

MAINT is the number of airports the subject would "pass-up" in search for an airport with maintenance services.

WOULDGO is the response the pilot gave to the question on whether he would attempt the flight or not.

TOTALCOR is the score received on the four diagnosis scenarios conducted prior to the diversion-decision scenario.

MASTER SUMMARY OF ALL PERTINENT DATA BY SUBJECT

(SEE PREVIOUS PAGE FOR LEGEND)

SUBJECT	BSUBATC	BSUBWX	BSUBTIM	BSUBAPP	KNOWLEDG	TOTHRS	SEHRS	IFRHRS	RATING	TRAINING	FLYING	SPEAR	MAINT	WOULDCO	TOTALCOR
1	1.000	2.000	4.000	0.500	9	160	160	15	PRIV	CIV	PLEASURE	1.000	4	NO	15
2	2.000	0.750	4.000	0.625	16	2500	1800	270	ATP	CIV	BUSINESS	0.991	1	NO	17
3	0.500	1.000	4.000	2.000	8	6000	2000	300	ATP	MIL	MILITARY	1.000	3	YES	12
4	1.375	2.375	-0.500	1.625	5	4000	400	1000	COMM	MIL	MILITARY	0.688	1	NO	15
5	1.125	2.375	2.000	2.875	16	2000	2000	1500	PRIV	CIV	BUSINESS	0.953	2	YES	10
6	0.500	1.000	2.000	4.000	14	1400	400	800	COMM	CIV	AIRLINE	1.000	4	YES	15
7	4.000	1.500	1.500	0.250	15	1800	1500	500	COMM	CIV	PLEASURE	0.979	1	NO	17
8	1.250	4.000	0.625	1.625	15	1088	1088	221	COMM	CIV	PLEASURE	0.985	8	YES	12
9	2.500	2.375	0.625	2.375	9	800	800	200	PRIV	CIV	PLEASURE	0.909	8	NO	5
10	2.500	3.375	0.750	1.875	12	2100	1700	450	PRIV	CIV	BUSINESS	0.987	4	YES	17
11	4.000	0.750	0.625	1.750	13	5000	4000	250	COMM	CIV	BUSINESS	0.968	3	NO	10
12	2.000	0.750	0.750	4.000	7	15000	1500	2300	COMM	MIL	BUSINESS	0.997	5	YES	7
13	1.625	2.625	2.500	0.750	13	19400	10000	2500	ATP	CIV	GA/COMM	0.874	2	YES	12
14	0.625	4.000	0.625	1.750	15	2500	2500	250	COMM	CIV	BUSINESS	0.965	3	YES	12
15	1.875	1.000	3.875	0.500	13	510	510	100	PRIV	CIV	PLEASURE	0.965	3	YES	14
16	1.000	2.000	4.000	0.500	17	1650	1000	200	COMM	CIV	GA/COMM	1.000	3	YES	15
17	2.375	1.750	2.125	2.375	15	980	860	120	COMM	CIV	GA/COMM	0.938-	2	YES	17
18	3.250	2.750	1.375	0.625	16	1960	1700	250	ATP	CIV	GA/COMM	0.985	7	YES	18
19	1.250	1.250	4.000	0.500	16	8000	3000	700	ATP	MIL	BUSINESS	0.944	4	NO	17
20	1.875	1.000	3.500	1.375	15	9000	2100	1750	ATP	CIV	AIRLINE	0.935-	1	NO	12
21	2.000	4.000	0.500	1.000	14	5500	4000	500	COMM	MIL	BUSINESS	1.000	8	YES	20
22	3.500	1.250	0.750	2.500	12	485	410	250	COMM	CIV	BUSINESS	0.988	2	YES	12
23	2.000	4.000	0.500	1.000	11	300	300	20	COMM	CIV	PLEASURE	1.000	14	NO	7
24	2.000	0.875	9.250	4.000	6	3500	3300	280	PRIV	CIV	PLEASURE	0.988	4	YES	5
25	1.000	3.375	2.000	1.875	13	6312	2001	540	COMM	MIL	GA/COMM	0.974	4	YES	20
26	1.375	1.500	0.500	4.000	10	2260	900	330	ATP	CIV	BUSINESS	0.976	4	YES	9
27	2.000	1.000	0.375	4.000	14	7000	5000	250	ATP	CIV	GA/COMM	0.997	3	YES	17
28	0.875	4.000	1.250	1.375	10	338	318	162	PRIV	CIV	MILITARY	0.971	5	YES	15
29	0.875	4.000	2.000	0.625	12	648	595	32	COMM	CIV	GA/COMM	0.997	9	YES	15
30	0.750	4.000	2.000	0.750	10	2500	200	500	COMM	MIL	MILITARY	0.997	1	NO	5

APPENDIX K

Reduced Power Diagnosis Interview

The following interview was conducted with a widely known and respected aircraft mechanic. It demonstrates the feasibility of system problem diagnosis from verbal description of symptoms and the information seeking and problem solving logic used by an expert to narrow the list of plausible causes.

REDUCED POWER DIAGNOSIS

P = Pilot (Brooks) C = Consultant (Kellenbarger) A = Auxilliary (Giffin)

P Okay, I just noticed that I was cruising along at 2400 RPM, and my power started coming back--I've got an RPM loss. Do you have any idea what might be wrong? Or what we can do about it?

C Have you tried carburetor heat?

P No, okay we can try that. No effect.

C No effect. Do you have a drop; Can you pull heat on?

P Yes

C And you push it back off and does it raise back up to normal or above normal?

P It comes back up to the reduced level to which it had dropped. To--below 24.

C Oil pressure, oil temperature normal?

P Well, let's take a look. Okay we notice the pressure appears to be normal. I've got a little advanced cylinder head temperature and oil temperature creeping up - it appears.

C Is your mixture control full in?

P Okay, we had leaned for cruise at altitude, so we can richen the mixture. And we get no significant improvement.

C How about reducing the mixture control a little bit more than you had--what does that do?

P Okay, we can try that and it doesn't seem to help. We have a very slow loss in RPM and the temperature gauges are both creeping up.

C Have you switched tanks yet on your fuel tank?

P Okay, we can try that, and we get no effect.

C What happens if you lose a little altitude? Does this have anything to do with your temperature?

P Okay, we're on an IFR plan, so we're nailed at altitude, and we haven't talked to Center about this yet other than calling for help, so we could try to request a lower altitude.

C Well, just a small amount to increase your air speed, what will that do?

P Okay, it seems that the effect of the power loss is advancing faster than the improvement we're getting from possibly going down.

A (At this point you're beginning to be unable to hold altitude, too.)

P Right, that's going to happen real soon.

C Okay, have you played with the throttle in any amount--increase or decrease the throttle to see if that has any bearing on it?

P Okay, we try fire-walling it and we get an increase in RPM's, but it's not going up to what it normally should go to. In other words, instead of getting maybe 2650, we get 25 now "flat out".

C I would say move the throttle back and forth abruptly, at least 5-10 hundred RPM's and see what happens and then leave it settle down.

P Okay, we cycle throttle, and at this point, too, we've lost so much power that we're unable to hold altitude. And the throttle cycles--the RPM cycles, but it's still not going up to normal cruise. I'd say now we're down below 2000.

A (2000 RPM, not 2000 feet?)

P Right.

C I'd say here you might switch mags and see what effect one mag has against the other one. See if you have one mag going bad and it's getting out of time for one reason or another. Be careful when you do this that you don't go over to a dead mag and leave it on too long . . .

P Lose everything? Okay, we switch mags, we get a little differential between them, but just as would be expected. We're definitely coming down now--200 feet per minute.

C Do you have any indication of oil leaks on the cowling that you can recognize?

P Nothing apparent. Now the oil temperature and cylinder head temperature gauges are pegged.

C I'd declare an emergency and proceed to the closest landing strip--I guess.

P Okay, you wouldn't try to go over the mountains?

C Not losing altitude.

P Do you think it would be better to try to put it down at on an off-airport landing--try to go over and poke around in the soup at the airport with no tower and no reported weather or go back to the destination airport--that's 50 miles away, can we make it? It would take 30 minutes from here.

C I think I'd head over to a destination that I'd know - knew it didn't have mountains in it.

P So that means going back to Seaport?

C Yeah.

P Okay, there's nothing else we can do in here?

C Not unless it changes somewhere along the line in going back. When you change altitude it would have something to do with it.

P Okay, in the last minute or two that we've been talking, the RPM has stablized at somewhere between 1300 and 1400, and apparently with our loss in altitude, we've been able to go down to a point where we can stablize here. It looks like the cylinder head and oil temperature gauges are still pegged. Our RPM loss is stablized here, we can hang on with this power level--and our airspeed is very low. Does this have any effect on the decision?

C No, I would say that you ought to get to the ground as soon as possible or change altitude due to temperature--this may have some effect on what is wrong with your engine.

P Okay, we can't go up at this point, we can only stay where we are or come down, so we may be able to hold 3000 feet to Seaport--just above stall.

C Okay, I'd proceed to that destination.

P Okay.

APPENDIX L

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 assessment 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. $\leq$ 175
(1) if IFR hrs. $\geq$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 ≤ 9
(1) if KNOWLEDG ≥ 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;
$ZT = (C1 + C2 + C3 + C4)/(TT1 + TT2 + TT3 + TT4)$

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15. Supplementary Notes

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16. Abstract

The objectives of this research were to describe and define the scope of the critical in-flight event (CIFE) with emphasis on pilot management of available resources; to develop detailed scenarios for both full-mission simulation and paper and pencil testing of pilot response to CIFE; and to develop statistical relationships among pilot characteristics and observed responses to CIFE(s). This report includes a description of a model developed to describe pilot response to CIFE(s). Also described are the results of an analysis of professional flight crews' compliance with specified operating procedures and the relationships with in-flight errors.

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