te technical note techn

Plan for Testing the Methodology for Collecting Vertical Navigational Performance Data (Boulder, CO Winter 1984)

Brian Colamosca

February 1985

DOT/FAA/CT-TN84/6

Document is on file at the Technical Center Library, Atlantic City Airport, N.J. 08405

U.S. Department of Transportation
Federal Aviation Administration

Technical Center
Atlantic City Airport, N.J. 08405

Technical Report Documentation Page

1. Report No. DOT/FAA/CT-TN84/6	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Plan for Testing the Methodology for Collecting Vertical Navigational Performance Data (Boulder, CO Winter 1984)		5. Report Date February 1985
		6. Performing Organization Code
7. Author(s) Brian Colamosca		8. Performing Organization Report No. DOT/FAA/CT-TN84/6
9. Performing Organization Name and Address Federal Aviation Administration Technical Center Atlantic City Airport, N.J. 08405		10. Work Unit No. (TRAIS)
		11. Contract or Grant No.
12. Sponsoring Agency Name and Address U.S. Department of Transportation FAA Technical Center Atlantic City Airport, N.J. 08405		13. Type of Report and Period Covered Test Plan
		14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

As part of the study to reduce vertical separation above Flight Level 290 (29,000 feet), it was determined that testing of the proposed methodology in a more field-like environment than the Wallops Flight Facility would be necessary and testing in a meteorological environment where a noticeable affect on vertical separation might be observed. Accordingly, this paper describes tests conducted over mountainous terrain in the Winter 1984 Test at Longmont, Colorado.

17. Key Words Vertical Separation		18. Distribution Statement Document is on file at the Technical Center Library, Atlantic City Airport, New Jersey 08405	
19. Security Classif. (of this report) UNCLASSIFIED	20. Security Classif. (of this page) UNCLASSIFIED	21. No. of Pages 40	22. Price

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

TABLE OF CONTENTS

	Page
INTRODUCTION	1
Overview	1
Background	3
DISCUSSION	3
Overview of the Methodology to Collect Aircraft Vertical Navigational Performance Data	3
Experience with the Data Collection Methodology During the July-August 1983 Test	6
Objectives of the Winter 1984 Data Collection Methodology Test	11
Organizations Participating in the Test and Their Responsibilities	12
Test Area, Airspace, and Environment	14
Types of Data to be Collected	16
Overall Test Conduct and Daily Test Activities	16
Proposed Daily Test Schedule	21

APPENDICES

A List of Principal Contacts at Organizations Participating in January-February 1984 Test of Vertical Separation Program Data Collection Methodology

B Proposed Pressure-Survey Patterns

C Proposed Patterns for Conducting Atmospheric Research Flights During the January-February Test of the Vertical Separation Program Data Collection Methodology

D Overview of the Daily ERL Forecast of Meteorological Events of Interest During the January-February Test of the Vertical Separation Program Data Collection Methodology

LIST OF ILLUSTRATIONS

Figure		Page
1	Vertical Separation Program Data Collection Methodology	4
2	Pressure Surveying Flight Levels	7
3	Airspace Monitored During Summer 1983 Test of Data Collection Methodology at NASA/Wallops Island	9
4	Airspace to Be Monitored During the January-February Vertical Separation Program Data Collection Methodology Test	15
5	Overview of Communications During Test	26

LIST OF TABLES

Table		Page
1	Types of Data to be Collected During January-February 1984 Test of Vertical Separation Program Data Collection Methodology	17
2	Required Communications Between Organizations Involved in Test of Vertical Separation Program Data Collection Methodology	22
3	Proposed Daily Schedule for Pressure Survey Day's Activities	27

INTRODUCTION

OVERVIEW

As a part of investigating the feasibility of a 1,000-foot vertical separation standard at and above flight level 290, the Federal Aviation Administration (FAA) is developing a methodology to collect data concerning level-flight aircraft vertical navigational performance at high altitude. A thorough test of methodology was conducted during July-August 1983 at the Wallops Flight Facility of the National Aeronautics and Space Administration (NASA) at Wallops Island, Virginia. As the result of suggestions from the Special Committee 150 of the Radio Technical Commission for Aeronautics, an additional test will be conducted in the Greater Boulder Colorado Area from January 16 to February 3, 1984. The test will serve two broad purposes not achieved during the Wallops Island work: (1) demonstration of test methodology at a field location under operational conditions not as controlled as those existent at the Wallops precision test range and (2) collection of meteorological and navigational performance data in airspace over mountainous terrain during winter, with the strong prospect of observing mountain wave and windstorm activities thought by many experts to be vital information in reaching any decision about reducing high-altitude vertical separation.

Organizations participating in the test are:

1. The FAA's Denver Air Route Traffic Control Center at Longmont, Colorado which will provide operational coordination of airspace encompassing Jet Routes 60 and 84-100 in an approximate 80 mile east-west corridor centered over the Continental Divide, and also permit use of its facilities for data collection.

2. NASA/Wallops Flight Facility which is supplying a mobile C-band precision height tracking radar to be located at the Longmont Municipal Airport.

3. The National Center for Atmospheric Research (NCAR) which will provide its North American 265 Series 60 Sabreliner to pressure survey flight levels on Jet Routes 60 and 84-100 and to conduct airborne meteorological research into such relevant atmospheric phenomena as present themselves during the test period.

4. The Environmental Research Laboratories (ERL) of the National Oceanographic and Atmospheric Administration which will forecast the onset of important meteorological events and will also oversee collection of meteorological information from automatic atmospheric profilers (developmental devices aimed to, among other uses, replace meteorological sounding balloons), VHF doppler radars, various observation stations in the Greater Boulder area, and satellite photography of upper atmospheric time-dependent developments.

5. ARINC Research which, under FAA contract, will provide data collection observers and will be responsible for associating registration numbers with all flights observed during the data collection and for obtaining further explanatory information pertaining to any flight observed to have an apparent large deviation from assigned flight level.

6. The FAA Technical Center will supply certain data collection equipment and will have overall responsibility for test conduct. Nominal time for testing is 0800 to 1630, Monday through Friday, with provision to conduct operations at any other time if forecast conditions call for interesting atmospheric phenomena. After test completion, refined data from NASA/Wallops and NCAR will be delivered to the Technical Center; reduced data accompanied by suitable analyses will be forwarded to the Technical Center by ERL. The Technical Center will then complete all analyses and provide interim conclusions and recommendations.

BACKGROUND

At present en route flights in high altitude United States' airspace may normally be conducted only at discrete thousands of feet of pressure altitude, or flight levels. Air traffic control (ATC) practice requires that flight levels from 29,000 to 45,000 feet of pressure altitude (FL290 to FL450) be separated by 2,000 feet. Thus, the only flight levels available within this range are FL290, FL310, FL330, and so on up to FL450.

Considerable evidence indicates that a reduction in required vertical separation to 1000 feet between FL 290 and FL450 would bring about significant economic and operational advantages: more fuel-efficient flying and increased altitudes for ATC planning and tactical employment. Accordingly, the Federal Aviation Administration (FAA) is investigating the feasibility of a 1000-foot vertical separation standard at and above FL290. The Radio Technical Commission for Aeronantics (RTCA), a well established forum for government-industry coorperation, has formed Special Committee 150 (SC 150) in order to develop performance standards supporting the 1000-foot spacing and to offer the FAA advice in conducting its feasibility study. The advantages being apparent to all concerned, study is focused on the effect which a reduced standard would have upon system safey. The system-safety aspect of concern is the risk of midair collision due to the loss of planned vertical separation in the 1000-foot-standard environment. In the FAA approach, collision risk will be modelled using empirical evidence to estimate important safety-related parameters, a principal one of which is present aircraft vertical navigational performance at and above FL 290.

The only information readily available in the ATC system about vertical navigational performance is an aircraft's own estimate of its pressure altitude transponded in reponse to interrogations from ATC radars (nominally every 10 seconds) and rounded to the nearest 100 feet before transmission. This transponded information is often referred to as Mode-C altitude, so called because of the radar interrogation procedures involved. As is apparent upon reflection, the most that could be learned about vertical navigational performance using Mode-C data would be adherence to assigned flight level (as measured onboard an aircraft) on the part of the pilot or automatic flight control system. No information could be obtained either about how well an aircraft's equipment sensed and measured pressure altitude or about the total vertical errors made by an aircraft relative to its assigned flight level. In order to measure this latter quantity (and, within the limits of ambiguity induced by Mode-C pressure altitude granularity, the former), it is necessary to know both an aircraft's geometric height and also the geometric height of the pressure altitude which it is supposed to be flying.

DISCUSSION

OVERVIEW OF THE METHODOLOGY TO COLLECT AIRCRAFT VERTICAL NAVIGATIONAL PERFORMANCE DATA.

The FAA has developed a methodology which it believes is capable of collecting the data necessary to measure total vertical error. Illustrated in figure 1, the methodology calls for use of a specially instrumented aircraft to traverse

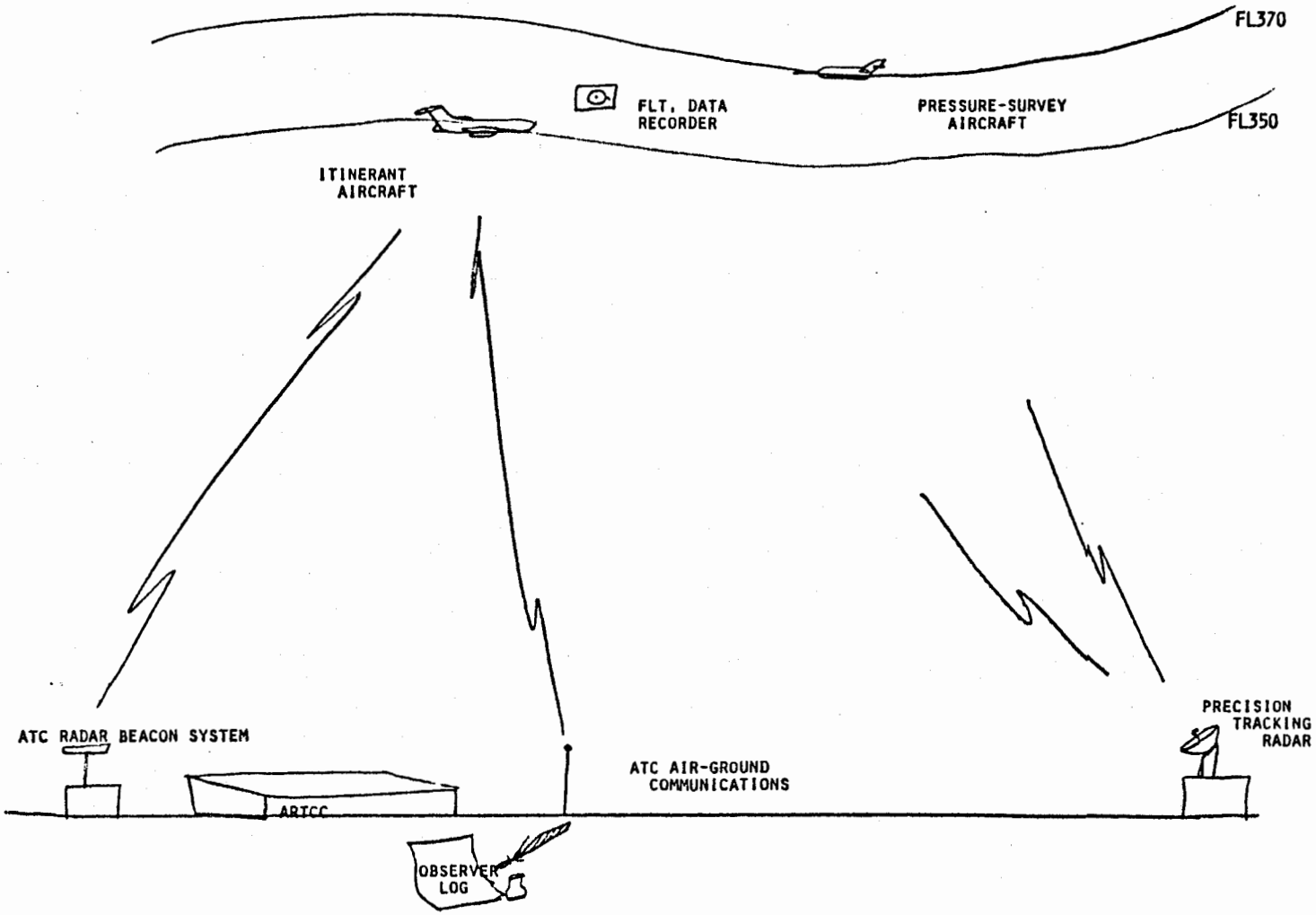


FIGURE 1. VERTICAL SEPARATION PROGRAM
DATA COLLECTION METHODOLOGY

certain flight levels in a given portion of airspace while being followed by a precision three-dimensional tracking radar. The radar is at the lower right in the figure and the aircraft is shown at FL370. Equipment aboard the aircraft measures, with great accuracy, the variables necessary to compute pressure altitude. Thus, post facto, it is possible to very accurately estimate the pressure altitude which the specially instrumented aircraft was flying and, using its precision radar track, in turn to locate the geometric height of the flight level which it was attempting to fly. As this process is repeated for all planned flight levels, a pressure altitude-geometric height survey is developed for the airspace being monitored. Obviously, this survey is good for only one portion of airspace at one time. If the survey process is repeated several times througout the course of a day, the resulting surveys can be used in conjunction with some model of atmospheric behavior to provide an estimate of the pressure altitude-geometric height relationship for any portion of the monitored airspace at any time. Thus, one of the two required elements to measure aircraft total vertical error (the geometric height of an aircraft's assigned flight level) is determined. The second element (an aircraft's actual geometric height) is measured by the same tracking radar. Identification of aircraft to be so tracked is accomplished according to the methodology by monitoring traffic movements using the standard display facilities of the FAA air route traffic control center (shown in the lower left of the figure) having ATC responsibility for the surveyed airspace. When an aircraft of interest (because of its type, class, equipment, or evidenced vertical navigational performance) is noted by a specially assigned observer to be flight planned through the surveyed airspace, it is identified to the precision radar by the observer, acquired and verified as the intended flight before entering surveyed airspace. As the aircraft passes through the surveyed airspace (aircraft at FL350 in figure 1), it is tracked by the precision radar and its geometric height compared in real-time to that of its assigned flight level as determined by the survey aircraft. Should a large difference (say, 300 feet or greater) exist between these two heights, the crew is queried about vertical navigation performance parameters in real-time, if possible, by the air traffic controller responsible for the flight. In any event, the flight's operator is contacted as soon as possible in order to gather any information relevant to explaining the apparent error. Regardless of the error magnitude observed in real-time, the flight becomes part of the data base for the post-facto examination of total vertical error. As shown in figure 1, the flight's Mode-C altitude trace observed by ATC radars and its air-ground voice communications are recorded at the air route traffic control center for later inclusion in the data base. As is also shown, the observer keeps a log of aircraft tracked, including explanatory information, for later use. Also retained are aircraft digital flight data recorder traces, if available, from operators.

The data collection methodology was tested from July 12 to August 11, 1983. The National Aeronautics and Space Administration (NASA) cooperated extensively in the test, making available precision radar tracking installations at its Wallops Flight Facility at Wallops Island, Virginia. Airspace in the immediate region about Wallops was pressure surveyed by a Wallops-based North American 265 Series 60 Sabreliner provided by the National Center for Atmospheric Research of Boulder, Colorado. The airspace was under the jurisdiction of the

Washington Air Route Traffic Control Center (ARTCC) which supplied facilities for an observer and for on-site data collection equipment. The FAA Technical Center assumed overall responsibility for test conduct and was assisted by ARINC Research Incorporated under contract. General results of the test are now being analyzed at the Technical Center.

EXPERIENCE WITH THE DATA COLLECTION METHODOLOGY DURING THE JULY-AUGUST 1983 TEST

The Summer 1983 test had two broad objectives:

1. To evaluate the overall data collection methodology approach with respect to ease of employment and to the achievement of required accuracies by the pressure survey and precision radar measurement components.

2. To obtain an initial sample of aircraft vertical navigational performance.

Data collected during the test is still being processed, so that it is not yet possible to report on the measure of success achieved with respect to required accuracies. However, it is possible to discuss results of actually mechanizing the methodology and to catalog the characteristics of itinerant flights tracked during the five week program.

A preliminary test of certain portions of the methodology, termed Phase 0, had been conducted from December 6 to 9, 1982 at NASA/Wallops and with the cooperation of the Washington ARTCC. During this work, the process of observer identification of flights to be tracked and of acquiring and tracking those flights with NASA precision radars had been demonstrated. Time had also been devoted during this week to evaluating the use of meteorological balloons as a means of pressure surveying flight levels in the monitored airspace. Examination of results indicated that balloons were not satisfactory as a primary source of atmospheric calibration for several reasons: (1) accuracy of pressure altitude measurement was not sufficient to support the analysis of navigationnal performance required for evaluating the feasibility of a 1,000-foot standard, (2) lack of controllability during ascent often resulted in the balloon being far outside of the monitored airspace before passing through the flight levels of interest, and (3) by nature of the balloon survey process, only one measurement of the geometric height of any flight level could be made.

The principal component of the methodology not evaluated during Phase 0 was use of the pressure survey aircraft. Two general questions concerning this facet remained to be tested during the Summer 1983 work: (1) the ease with which an aircraft could survey the flight levels of a busy portion of en route airspace, and (2) the accuracy with which the survey process could be carried out. The latter question is still under active consideration. The NASA/Wallops test did demonstrate, however, that with proper regard for periods of peak itinerant traffic, it is possible to carry out the pressure survey process on a heavily used jet route. Figure 2 shows the sort of to-and-fro by alternating flight

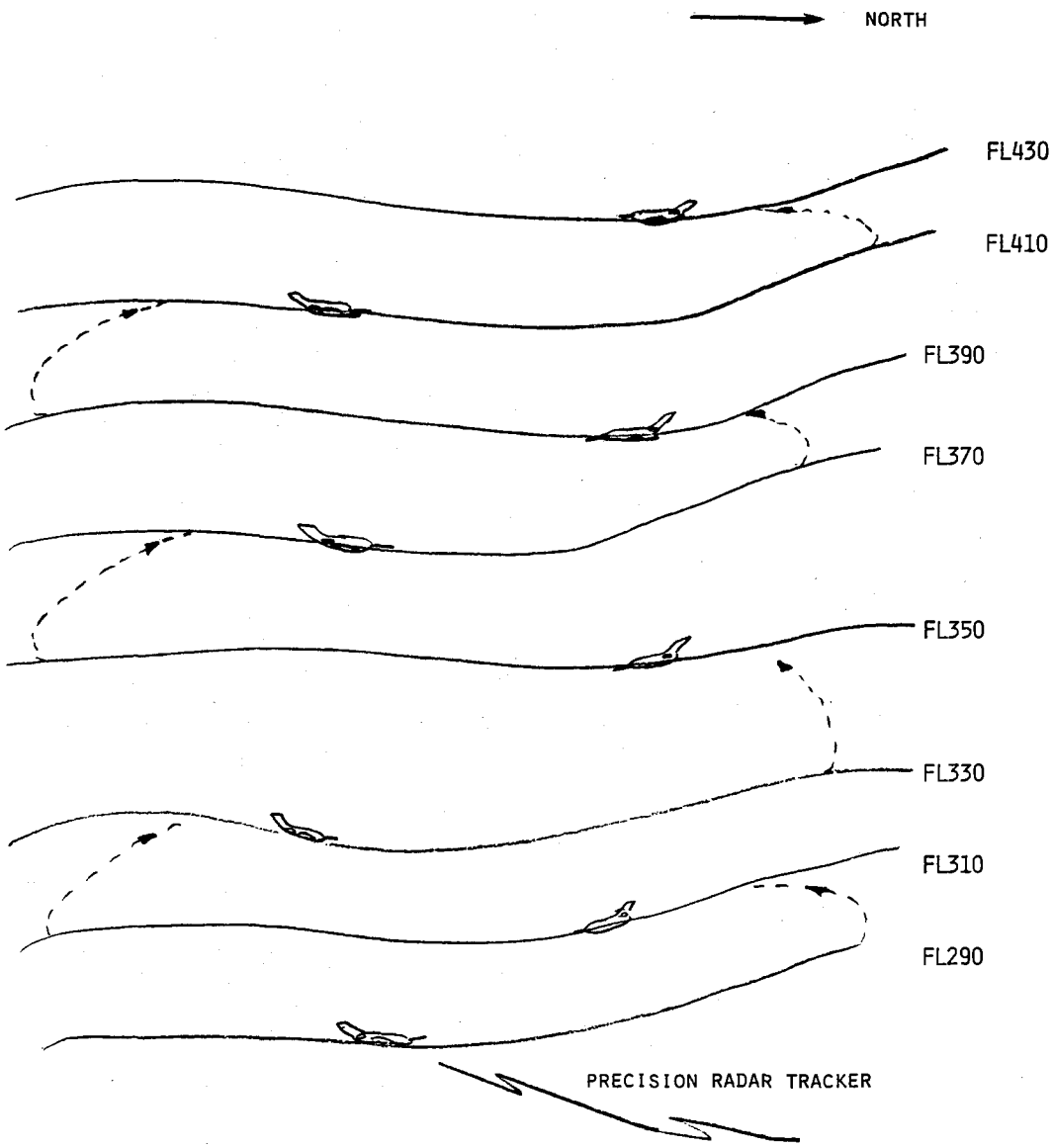


FIGURE 2. PRESSURE SURVEYING FLIGHT LEVELS

level flying which constitutes the pressure survey process. This process was carried out on a portion of Jet Route 79-121 (J79-121) within a 40 nautical mile radius of the Wallops Flight Facility (figure 3). The length of a level flight leg was roughly 25 nautical miles. The NCAR Sabreliner typically flew three pressure surveys per day, five days per week, for five weeks. The daily surveys normally began with takeoffs from Wallops at 0930, 1130, and 1430, Eastern Daylight Time. The morning and afternoon flight profiles were usually abbreviated versions of the full flight level survey shown in figure 2, typically beginning at FL290, thence to FL350, and finishing at FL410. Oftentimes, these morning and afternoon surveys were conducted laterally offset from the centerline of J79-121 by 10 nautical miles in order to avoid conflict with the heavy flow times on these routes--usually 0930 to 1100 and 1400 to 1530, local time. The pressure survey conducted at midday was always flown on route centerline and at all normally available flight levels from FL290 and FL410. Such unrestricted airspace availability was due to the virtual disappearance of itinerant traffic which characterizes J79-121 use between 1130 and 1330 local time each day. On a typical three survey day, the Sabreliner would log about 5.5 flying hours.

The second broad objective of the Summer 1983 test, to obtain an initial sample of aircraft vertical navigational performance, seems to have been amply met--if required measurement accuracies are achieved. Precision radars tracked 579 flights on J79-121. Even with the expected removal of some flights from the sample bacause of, for example, unexpected transitions from level flight while being tracked, it is reasonable to assure that about 550 flights will be available for study.

The July-August test was conducted under atmospheric conditions which must be considered benign by any reasonable reckoning. On all save three days of testing there was neither precipitation nor significant change in the dominant high pressure patterns which produced sea-level daytime temperatures in the 90 degree Fahrenheit range with accompanying 80 per cent humidity readings. When precipitation did occur in the tracking area, it was in the form of thundershowers which caused the itinerant flights to divert far out of range of the precision radars. Upper atmospheric conditions were as changeless and languid as those at sea-level. Winds in the flight level range of interest rarely exceeded 50 knots and temperatures followed expected diurnal change patterns. Typical differences between the geometric hight and pressure altitude of FL410 were in the range of 1800 to 2100 feet, day in and day out.

The NASA/Wallops Flight Facility provides the most extensive and sophisticated precision tracking equipment and support functions available at any known test range. The personnel directing and operating this equipment are highly professional, thoroughly trained and practiced in their craft. There were as many as four precision radars assigned to the test at any time, oftentimes completely absorbing the number of aircraft available for tracking J79-121 with capacity to spare. Support and maintenance for any problems with either radar

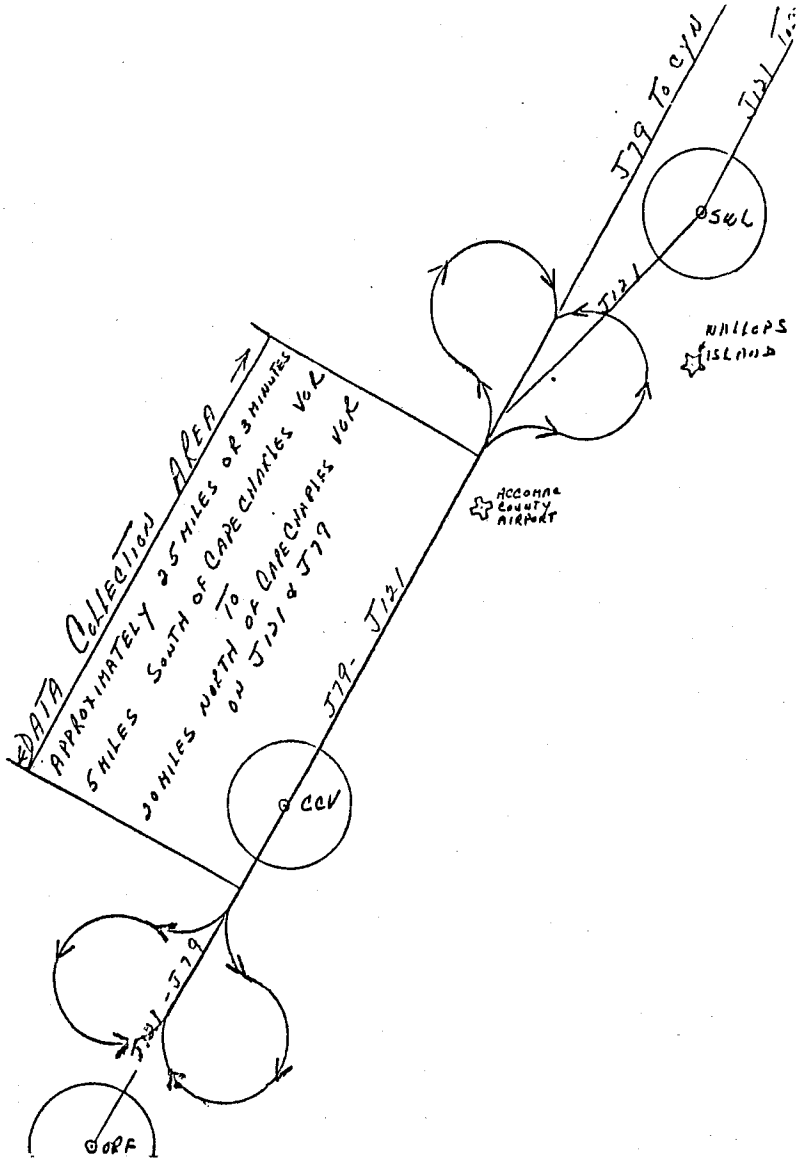


FIGURE 3. AIRSPACE MONITORED DURING SUMMER 1983 TEST OF DATA COLLECTION METHODOLOGY AT NASA/WALLOPS ISLAND

or associated equipments was immediate; no data was lost during the entire test period because of the mechanical or electrical unavailability of NASA/Wallops tracking facilities.

The RTCA's SC-150, as a portion of its contribution to the effort to determine if 1000 feet is a safe vertical separation standard above FL290, had suggested at its Fourth Meeting (September 1983) the advisibility of obtaining some vertical navigational performance data for flights conducted in atmospheric conditions different from those observed during the Summer 1983 test. In particular, experts on the Committee strongly suggested the necessity of observing flights over mountainous terrain in winter, when mountain waves and strong windstorms would likely be present. Working Group III of SC-150, charged with developing performance standards for flight technical error, had preceded the full Committee's recommendation for data on flight in the presence of mountain waves and other possible sources of winter upper atmospheric turbulence. In January, 1983, the Group suggested that the FAA Technical Center attempt collection of Mode C altitude data in the Rocky Mountain area during Winter or Spring 1983 in order to assist the Group in assessing the adequacy of a draft standard which it had developed. Collected in April - May 1983, that data, while instructive, did not prove wholly satisfactory for exploring the effect of mountain waves on navigational performances. In particular, the mode C traces of flights whose crews noted the presence of mountain waves during air-ground communications often failed to show any deviations from assigned flight level. Hence, the necessity for measurements of aircraft vertical position independent of on-board pressure altitude sensing.

Both the advice of SC-150 and the experience with Mode C-based analysis of mountain wave effects point to the necessity of obtaining vertical navigational performance data for winter flying over mountainous terrain in the manner of the data collection methodology. Further impetus for such an undertaking is the necessity to test the methodology under operational conditions primitive relative to the nearly ideal conditions of the Wallops Flight Facility test range.

Accordingly, the FAA intends to carry out a data collection methodology test in the Greater Boulder Colorado area from January 16 to February 3, 1984. The remainder of this document will describe the overall objectives of the test, identify participants, detail the test environment and data to be collected, and provide a general description of intended test procedures and schedules.

OBJECTIVES OF THE WINTER 1984 DATA COLLECTION METHODOLOGY TEST.

The January-February program has four broad goals:

1. To test the data collection methodology at a field site under demanding operational conditions in order to observe any resultant effects upon measurement accuracies and sample yields.

2. To obtain a sample of aircraft high altitude vertical navigation performance in the presence of mountain wave activity, winter windstorms, and other atmospheric activity which may adversely affect vertical position-keeping and which, consequently, should be taken into account during deliberations about the feasibility of a 1,000 foot vertical separation standard at and above FL290.

3. To investigate and record mountain wave and winter windstorm activity using the two basic measurement components of the data collection methodology (a pressure survey aircraft and a precision radar) in conjunction with meteorological observations in order to construct a data base for gauging the possible range and influence of such phenomena relative to the issue of vertical separation reduction.

4. To estimate the generalizability of the data collection methodology and applicability of simpler measurement techniques to other geographic environs.

Testing the data collection methodology in a field location environment will provide valuable information about the possibility of collecting navigational performance measurements in areas of high density air traffic where no instrumentation ranges exist. The effort should lead to identification of minimum equipment, personnel, and training necessary to carry out a large scale data collection effort. Actual navigational performance in the presence of active winter upper atmospheric meteorology will hopefully satisfy a critical need for data required by RTCA's SC-150 to define initial performance specifications to support a 1,000-foot standard. Supplementing this navigational performance with additional empirical evidence about the possible range of phenomena which could influence vertical position-keeping holds out the prospect of not only influencing any final set of performance standards, but also providing initial grounds for basing operational decisions about the propriety of using a 1,000-foot standard under certain atmospheric conditions. It is hoped that a well documented volume of observations will provide further understanding of the influence of known winter meteorology such as mountain waves on vertical navigational performance, allowing more quantitative interpretation of the long-time experience of several operators with such phenomena.

Choosing to conduct the test in the Greater Boulder area permits advantage to be taken of the special expertise of several local research organizations and of their extensive facilities. In addition, FAA operating elements critical to test conduct are also located in the area.

ORGANIZATIONS PARTICIPATING IN THE TEST AND THEIR RESPONSIBILITIES

The FAA's Denver Air Route Traffic Control Center, located in Longmont, Colorado (roughly 12 miles notheast of Boulder) will serve as the ATC center for the test. Through agreements with that facility, a specially dedicated observer will be located within the center to coordinate airspace use, monitor traffic for possible radar tracking, operate Technical Center equipment designed to record Mode-C radar returns and ATC air-ground voice communications, and generally oversee data collection activities at the Denver Center. The observer assigned is an experienced traffic control specialist and will be either in the employ of ARINC Research Incorporated, an FAA contractor, or a member of the FAA Technical Center staff.

The NASA/Wallops Flight Facility is cooperating in the test effort supplying a mobile C-band precision tracking radar to be located at the Longmont Municipal Airport, which is on the western side of the city. The test director who controlled overall operations at the Wallops Flight Facility during the July-August 1983 exercise will again lead the NASA/Wallops effort and will be resident on-site during testing hours with a radar crew complement of three. The radar unit is a self-contained operation, with sensor and data collection equipment housed in a van. Target acquisition range of the radar is well in excess of 150 nautical miles and expected tracking accuracies should support data collection within 60 to 70 nmi the Longmont Municipal Airport.

The NCAR Sabreliner involved in the July-August test at NASA/Wallops will also participate in the January-February work. The aircraft will operate from its home base, Jefferson County Airport in Broomfield, Colorado (roughly 10 miles southeast of Boulder). All precision instruments used in the Summer 1983 program to estimate pressure altitude will again be installed aboard the aircraft. An extensive calibration of the aircraft will be carried out during the program, including installation of a trailing cone system to fix static pressure sensing errors at the flight levels and airspeeds expected to be flown during data collection methodology testing. Flights conducted during the test will be of two general types: (1) pressure surveys of flight levels in a manner similar to those of the Summer 1983 test and (2) atmospheric research flights to be outlined below.

The Environmental Research Laboratories (ERL) of the National Oceanographic and Atmospheric Administration (NOAA) will participate in the test effort, attempting to forecast the occurrence of those upper atmospheric phenomena of interest and actively directing research flying to investigate such phenomena when they do occur. Forecasts will predict the onset of mountain waves, boras, gravity shear wave activity, three-dimensional windstorms, and similar activity 24 hours in advance, using a scale of 1 to 10 to identify the increasing relative likelihood of each event. The ERL staff will further examine events with high likelihoods of occurrence to estimate their expected intensity.

Should such an examination indicate with reasonable probability that an event of interest to the test program will commence within the next 24 hours, ERL will coordinate with NCAR to schedule a Sabreliner flight for purposes of gathering detailed empirical evidence about its occurrence. At present, ERL plans to man the scientist-observer station on the Sabreliner with a member of its staff during such flights. In addition, ERL will coordinate collection of meteorological data relevant to the test from a number of monitoring facilities in the Greater Boulder area. Data from the present profiler net (a developmental system designed to make frequent measurements of wind, temperature, and vapor content of a conical vertical extent of the atmosphere up to the flight levels of interest in the test) will be saved for reduction and later analysis by ERL. This data, collected at the Denver Stapleton Airport (which is equipped with a profiler having a lower altitude capability than the others in the net) and several other locations throughout Colorado, should serve the purpose of providing a wide-ranging rawinsonde-like monitoring of atmospheric conditions for later integration with the more microscopic measurements made by the Sabreliner. Other measurement stations included in the ERL test data collection network are the Boulder Atmospheric Observatory in Erie, Colorado, the Boulder Wind Network, the Microbarograph Array, the vertically pointed VHF radar at Sunset, Colorado, and mesonet data from NOAA's PROFS Research Program. All of this data will be monitored during the test period for significant developments and will be reduced and analyzed post facto.

Research interests of the OSSA organization at NASA Headquarters in Washington have led to scheduling certain flying activities of a NASA/Dryden Flight Research Facility B57 in the Greater Boulder area during the test period. While certain of these interests would have no direct bearing on research into meteorological phenomena pertinent to the vertical separation reduction question and would be best served by low altitude flying, OSSA interest in modeling orographic flows and clear air turbulence is quite consistent with the goals of the data collection methodology test. In turn, precision radar tracks of the B57 will enhance the quality of data interesting to OSSA. As a result, the NASA B57 will devote some of its flying time scheduled in the Greater Boulder area to joint work with the data collection methodology test, being tracked as a pressure survey aircraft complementing the NCAR Sabreliner. Because of the expected higher altitude capability of the B57, such complementary flying should permit pressure surveying of all flight levels normally used by commercial carriers and general aviation in high altitude operations, as well as a significant portion of the airspace used by the United States military.

A member of the ARINC Research Incorporated staff will fly as data collection system monitor on each Sabreliner flight, with responsibility for logging relevant significant events in real-time and for assembling quick-look data from the aircraft's data collection system for post flight analysis. Other

members of the ARINC Research staff will be responsible for obtaining the registration numbers of all flights tracked by the precision radar during the test period and for making detailed inquiries of those operators of flights observed to have possible 300 foot or greater deviations from assigned flight level. When suggested by demonstrated navigational performance, these same staff members will also be in contact with two major commercial operators who have agreed to reduce flight data recorder information for any of their aircraft which evidence non-nominal vertical flight profiles. The ARINC Research staff will also provide elementary data analysis capability on-site during the data collection test period.

The FAA Technical Center will have overall responsibility for directing the test. This responsibility will, in addition to test coordination, involve:

1. Initiating daily coordination of airspace use with the Denver ARTCC.

2. Scheduling the type and duration of Sabreliner flights with NCAR in consort with ERL.

3. Real-time observation of precision radar tracks of the Sabreliner, B57, and itinerant flights.

4. Real-time identification of those aircraft with apparently large vertical navigational errors.

A list of key personnel for the organizations participating in the test can be found in Appendix A.

TEST AREA, AIRSPACE, AND ENVIRONMENT

The airspace to be monitored during the test is shown in Figure 4. It is bounded to the north by J84-100, to the south by J60, to the east by an imaginary north-south line through the Denver (DEN) very high frequency omnidirectional radio ranging (VOR) navigational fix and to the west by an imaginary north-south line through the intersection of J84-100 and the 300 degree radial of the Denver VOR. As can be seen from the figure, Longmont Municipal Airport, the site of the NASA/Wallops mobile tracking radar, is roughly midway between J84-100 and J60, which are separated laterally by about 50 miles. Accuracy constraints imposed by the data collection methodology require that tracked aircraft be within about 60 to 70 nautical miles of the radar before measurements of their positions are useful for analysis purposes.

The test area straddles the Continental Divide by design, so that atmospheric behavior over the precipitous change in topography can be observed and so that the navigational performance of aircraft entering and exiting this airspace can be measured. Pressure surveying of flight levels will be restricted to those portions of J60 and J84-100 within the test area; research-type flights

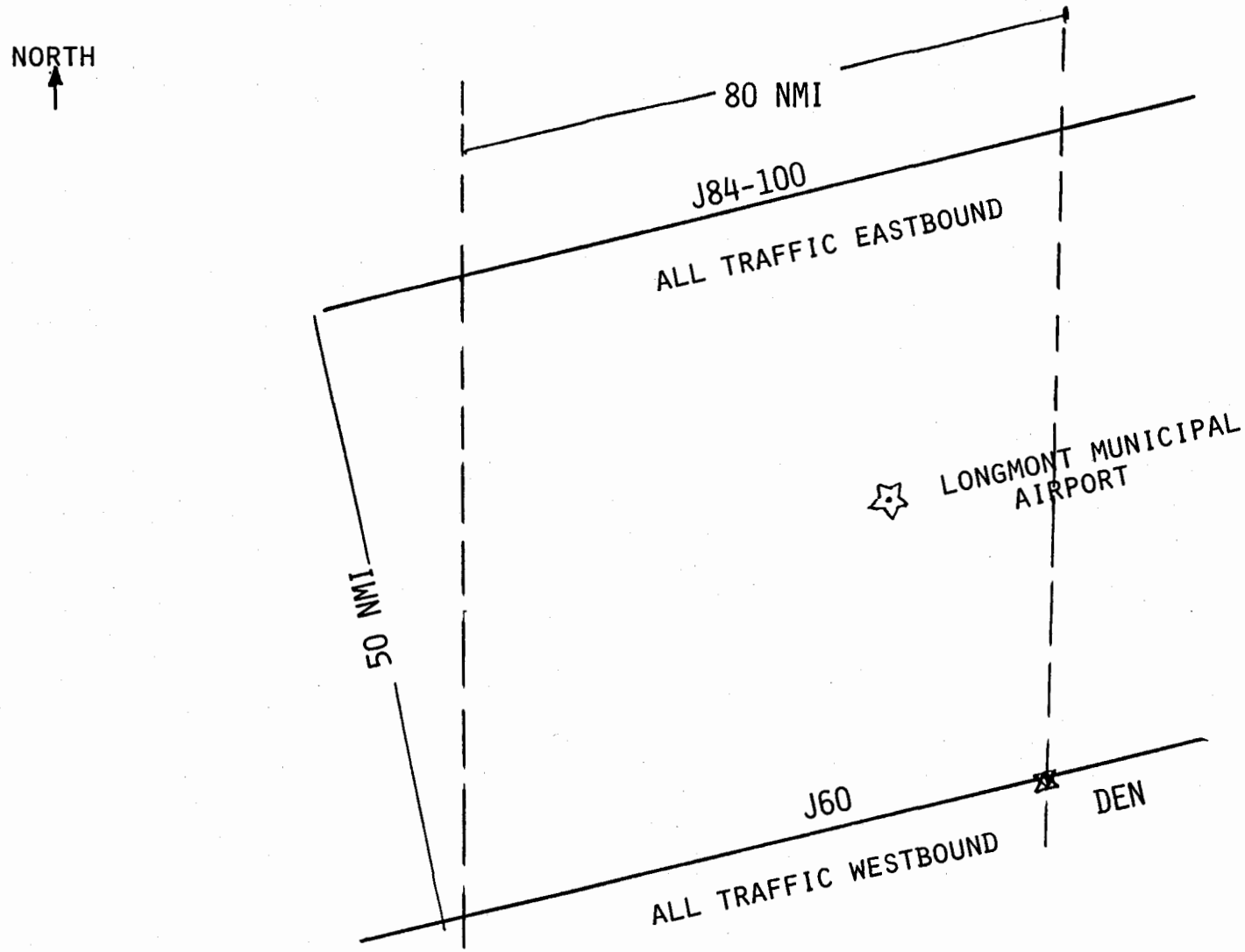


FIGURE 4. AIRSPACE TO BE MONITORED DURING JANUARY-FEBRUARY 1984 VERTICAL SEPARATION PROGRAM DATA COLLECTION METHODOLOGY TEST

will, with rare exception, be conducted solely within the test area, with exact flight plans determined by the meteorology present.

For purposes of the test, Denver ARTCC airspace management personnel have decided that the Center's high-altitude sector 5 will have principal control of Sabreliner and B57 flying in the test area. Normal ATC responsibilities for the general area shown in figure 4 are shared by Sectors 4, 5, 34 and 35. Transition of the pressure survey aircraft into and out of the test area will follow the procedures normal to operations in that airspace.

Traffic flow on J60 is, with some exceptions, entirely westbound; thus, the only flight levels above 290 normally used on the route are 310, 350, 390 and 430. Conversely, J84-100 is used operationally as a one-way route eastbound; the normally employed flight levels of interest in the test are, hence, 290, 330, 370 and 410. Pressure survey flights will be planned with these usual flight level restrictions in mind.

There is very considerable air traffic activity within and immediately below the airspace bounded horizontally by the expanse shown in figure 4 and vertically by FL290 and FL450. Portions of several other jet routes pass through the test area, and key Denver Stapleton approach and departure routes penetrate the area to provide transition paths from and to lower altitudes. As a result, all Sabreliner and B57 flying must be closely coordinated with the Denver ARTCC to ensure maximum yield of test results with minimum inconvenience to the ATC system.

TYPES OF DATA TO BE COLLECTED

Table 1 summarizes in some detail the types of data to be gathered during the test and identifies the corresponding organizational elements responsible for their collection. These data will be supplemented by measurements made aboard the NASA/Dryden B57 and detailed following discussions among OSSA, ERL and the FAA Technical Center after test completion.

With the exception of ERL-provided information, the types of data identified in table 1 were collected during the July-August 1983 test of the data collection methodology. The formats, media and extent of data supplied for that exercise will again suffice for the Winter 1984 test. Specific parameters, sampling frequencies, formats and output media for the reduced ERL data will be defined once the test program has progressed sufficiently to permit observation of some data collection results.

OVERALL TEST CONDUCT AND DAILY TEST ACTIVITIES

There will be five locations where planning and data collection activities will take place during the January-February test:

TABLE 1. TYPES OF DATA TO BE COLLECTED DURING JANUARY-FEBRUARY 1984 TEST OF VERTICAL SEPARATION PROGRAM DATA COLLECTION METHODOLOGY

Type of Data	Source	Responsible Organization/ Data Collection Facility
Aircraft slant range, azimuth, and elevation	Precision radar measurements	NASA/Wallops mobile C-band radar
Ambient temperature, local static pressure, supporting atmospheric and aircraft variables	Airborne precision temperature probes, precision transducers, ancillary devices	NCAR Sabreliner
Aircraft slant range, azimuth, octal identification code, Mode-C altitude	ATC radar beacon system	FAA Technical Center Special purpose radar data recorder*
Air-ground conversations involving tracked aircraft	ATC voice communications	FAA Technical Center Special purpose voice recorder operating in parallel with 152 channel voice communications recorder
Flight plans of tracked aircraft	ATC flight progress strips	FAA Technical Center/ ARINC Research Retention of standard ATC flight progress strips from relevant data collection facilities
Records of tracked flights providing aircraft ID, assigned route and flight level, time in test area, and pertinent remarks	Observer at Denver ARTCC	ARINC Research/FAA Technical Center Specially designed log form

* Operating in parallel with ARTCC Systems Maintenance Monitor Console

TABLE 1 (CONTINUED)

Type of Data	Source	Responsible Organization/ Data Collection Facility
Forecasts of relevant meteorological events	Computer models of future meteorology	ERL Weather Research Pgm
Frequent observations of wind direction, temperature, atmospheric moisture content at altitudes of interest	Sampled data measurements of relevant quantities	ERL Profiler array
Lower atmospheric winds in immediate test area	Remote wind sensors	ERL Boulder Wind Network
General lower atmospheric variables in immediate test area	Sensitive ground level and tower-borne instrumentation	ERL Boulder Atmospheric Observatory
Surface pressure measurements in immediate test area	Sensitive pressure-sensing devices	ERL Microbarograph Array
Measurements of temperature, atmospheric moisture content at altitudes of interest in Continental Divide area	Sampled data measurements	ERL VHF radar at Sunset, Colorado
Semi-continuous visual observations of upper atmospheric meteorology in region surrounding test area	Satellite photography	NOAA--NESDIS, Fort Collins, CO
Mesoscale meteorological observations	Automatic mesoscale data collection network	NOAA-PROFS
Registration numbers of tracked aircraft	Aircraft operators	ARINC Research Next day telephone contact with operators
Explanatory information about apparently larger vertical navigational errors	Aircraft operator records, maintenance logs, calibration reports, aircraft examination and testing	ARINC Research Immediate, thorough follow up of observed larger errors

1. Denver ARTCC-Longmont: location of specially dedicated ATC observer, radar data recorder and ATC voice tape recorder

2. Longmont Municipal Airport-Longmont: site of NASA mobole C-band tracking radar, location of NASA/Wallops test director and FAA Technical Center program manager/coordinator

3. Jefferson County Airport-Broomfield: NCAR Sabreliner base, location of NCAR project manager

4. ERL-30th and Arapahoe, Boulder: Site of ERL forecast station, location of ERL project director

5. Buckley Air National Guard Base, Denver: Staging base for NASA/Dryden B57, location of NASA/Dryden test director

The data collection methodology test will be composed of work-day units. Each such day will be a stand-alone endeavor, in the sense that it will neither serve to continue activities suspended before completion on the previous day nor to initiate activities requiring more than an 8 to 10-hour continuous period to complete. There will, as noted earlier, be two basic types of such work-days:

1. Pressure-survey day: a test day devoted entirely to a combination of precision tracking (a) the Sabreliner (or NASA/Dryden B57) during two or three sorties as it maps the pressure altitude-geometric height relationship of several flight levels on either J60 or J84-100, or both, within the test area, and (b) as many itinerant flights between FL290 and FL450 on these routes as can be accomplished within the time remaining. Initial propositions for the pressure survey patterns are shown in Appendix B. These patterns may well be modified as the test proceeds. The day's activities will normally take place from 0800 to 1630 , local time, from Monday to Friday. There will be an extension of the test period by a few hours on selected days in order to observe early evening meteorology and traffic. These days will be chosen after test initiation in order to take into account achieved Sabreliner flying times for various profiles and traffic mix and flow patterns in later daily hours. At present, there appears to be little value to conducting pressure-survey day activities on weekends.

2. Atmospheric research day: a test day devoted principally to precision tracking either the Sabreliner or B57, or both, while the aircraft conducts flight patterns designed to gather measurements on the important aspects of various types of energetic winter meteorology considered potentially serious obstacles to the unqualified establishment of a 1000-foot vertical separation standard at and above FL290. Unless an especially important and virtually

unique meteorological event occurs elsewhere, these flights will be conducted within the test area. Appendix C contains proposed flight plans for these research sorties. Generally, flying will be restricted to the FL290 to FL450 interval, but, if atmospheric circumstances dictate, could range several thousand feet lower. The specific pattern to be flown will be chosen by ERL and filed appropriately with air traffic control before Sabreliner or B57 takeoff. A research meteorologist from ERL will be aboard the aircraft during such a flight, maintaining FM radio contact with the ERL project director's headquarters in Boulder and exchanging real-time meteorological information with the ERL project team. As a result, the filed pattern may be modified as the flight is progressing. Such modifications will be passed from ERL to the FAA Technical Center program manager and thence to the Denver ARTCC for preplanning purposes as soon as they are contemplated. The changes will also obviously be passed on to ATC according to the established procedures for requesting flight plan modification after takeoff.

Fifty-seven hours of Sabreliner flying are planned for the test. At present, the flying hours are expected to be divided between pressure-surveying and research in the proportion of 4 to 1. There is, however, no rigid requirement to precisely achieve this ratio.

For pre-test planning purposes, every weekday from January 16 to February 3 is now scheduled as a pressure-survey type of test day. Each day at 1000 local time, ERL will forecast the likelihood that meteorological events of interest to the test program will occur in the next 24 hours. The forecast will be recorded and will be available by dialing either FTS 320-6809 or commercial 497-6809 in the Greater Boulder area. Appendix D contains a brief description of forecast details. Should the forecast, in the opinion of the ERL project director and staff, indicate the strong possibility that significant events will occur in the next 24 hours, the pressure survey day will be re-cast as an atmospheric research day. The change may involve rescheduling planned flying for the remainder of the normal work-day, or may entail suspending all work until after normal hours. The scale and duration of the revision will be decided after consultations with all affected organizations. Clearly, execution of an atmospheric research day may entail work at night or on weekends, a prospect accepted by all organizations participating in the test.

The FAA Technical Center program manager will be responsible for temporarily suspending the test if conditions warrant. Any of the three following events will be cause to cancel a given day's test activities:

1. Unavailability of the NASA C-band mobile tracking radar

2. Unavailability of the NCAR Sabreliner

3. High accumulated use time of the Sabreliner coupled with a forecast of meteorologoical conditions already adequately observed during the test

Should the second of the "no-go" conditions pertain when the ERL forecast calls for the likelihood of important events, consideration will be given to conducting a pressure-survey type of day but tracking only itinerants. The third "no-go" condition will be declared by the FAA Technical Center program manager if, at a given point in the test period, a disproportionate amount of the available 57 Sabreliner flying hours have been expended and if the day's meteorology holds out little prospect of adding significantly to knowledge already gained during the test. As with the second condition, consideration will be given to tracking itinerant aircraft on J60 and J84-100 as an alternative to complete suspension of activity.

The decision to conduct or not conduct activities on a given day will be made at the end of the previous day's work after checking the readiness status of the precision tracking radar and the Sabreliner. The decision will then be reviewed at the beginning of the proposed day's activities after conducting similar status checks.

The specific Sabreliner flight times and patterns to be carried out on a given day will be chosen by the FAA Technical Center program manager before the end of the previous day's activities. The choice will be based upon cumulative test results to that time and consultations with the ERL project director. The times and patterns will then be passed to the Denver ARTCC through the test observer at the Center before the end of the previous day's activities and confirmed on the test day prior to the start of activities.

The dispersed locations of the participating organizations makes the timeliness and completeness of communications critical to test success. Table 2 brings together the information transfer links previously noted passim; figure 5 presents the same information pictorially.

PROPOSED DAILY TEST SCHEDULE

Table 3 presents a pre-test proposition for conduct of a pressure-survey type day's activities. Experience during the Summer 1983 test of the data collection methodology at NASA/Wallops indicated the need for considerable flexibility in the pace of the daily routine because of the complexities of both the ATC system environment in which the test was conducted and also because of the availability problems sometimes associated with the sophisticated systems used in the test. Similar flexibility is expected to be required for the Winter exercise. Because of the nature of the atmospheric research-type day's activities, it would be virtually meaningless to propose a rigid sequence and timing of events. Rather, it is reasonable to anticipate that the experience gained previously and during the present work, plus the highly professional capabilities of the organizations involved in the test, will result in successfully adapting to the changing conditions and demands of this type of research.

TABLE 2. REQUIRED COMMUNICATIONS BETWEEN ORGANIZATIONS INVOLVED IN TEST OF VERTICAL SEPARATION PROGRAM DATA COLLECTION METHODOLOGY

Information Source	Information Recipient	Information	When and How Exchanged
FAA Technical Center Program Manager	Denver ARTCC	Next-day test status and proposed next-day Sabreliner flight patterns and times	Near end of previous day's activities through test observer
	Denver ARTCC	Day's test status and confirmed Sabreliner flight patterns and times	Prior to start of day's activities through on-site observer
	NASA/Wallops Test Director	Next-day test status	Near end of previous day's activities verbally
	NASA/Wallops Test Director	Day's test status	Prior to start of day's activities verbally
	NCAR Project Manager	Next-day test status and proposed Sabreliner flying	Near end of previous day's activities by telephone
	NCAR Project Manager	Day's test status and confirmed Sabreliner flying	Prior to start of day's activities by telephone
	NASA/Dryden Test Director	Next-day test status and proposed activities	Near end of previous day's activities by telephone
	NASA/Dryden Test Director	Day's test status and confirmed activities	Prior to start of day's activities by telephone

TABLE 2 (CONTINUED)

Information Source	Information Recipient	Information	When and How Exchanged
FAA Technical Center Program Manager	ERL Project Director	Next-day's test status and proposed Sabreliner flying	Near end of previous day's activities by telephone
	Denver ARTCC On-site Observer	Request for controller contact with aircraft showing 300-foot or greater deviations	At time deviation exhibited on precision radar plotboard by telephone
Denver ARTCC	FAA Technical Center Program Manager	Real-time information from aircraft with 300-foot or greater apparent deviations	As workload permits, as soon as possible after request through on-site observer, by telephone
NASA/Wallops Test Director	FAA Technical Center Program Manager	Precision radar status checks	Near end of previous day's activities and prior to start of day's activities, verbally
	Denver ARTCC On-site Observer	Track acquisition data	After track verification by telephone
NCAR Project Manager	FAA Technical Center Program Manager	Sabreliner status	Near end of previous day's activities and prior to start of day's activities, by telephone

TABLE 2 (CONTINUED)

Information Source	Information Recipient	Information	When and How Exchanged
ERL Project Director	FAA Technical Center Program Manager	Advice on whether to conduct a pressure-survey or atmospheric research-type day, suggestions for Sabreliner flight patterns	When daily forecasts are updated and when atmospheric conditions change unexpectedly, by telephone
	All Participating Organizations	Meteorological conditions for next 24 hours	Forecasts at 1000 local time, by automatic telephone recording on FTS 320-6809, commercial 497-6809
	NCAR Sabreliner	Real-time changes in local meteorological conditions during atmospheric-research type flight	During flight when exchanging information with ERL research meteorologist aboard Sabreliner, by FM radio link
Denver ARTCC On-site Observer	NASA/Wallops Precision Radar Crew	Initial positions for acquiring itinerant aircraft, identification data	During pressure-survey day activities by telephone
	NASA/Wallops Precision Radar Crew	Sabreliner or B57 location and real-time intent	As requested by precision radar crew from ATC voice contact with pressure survey aircraft, by telephone

TABLE 2 (CONTINUED)

Information Source	Information Recipient	Information	When and How Exchanged
NASA/Dryden Test Director	FAA Technical Center Program Manager	B57 status and intended use	Near end of previous day's activities and prior to start of day's activities

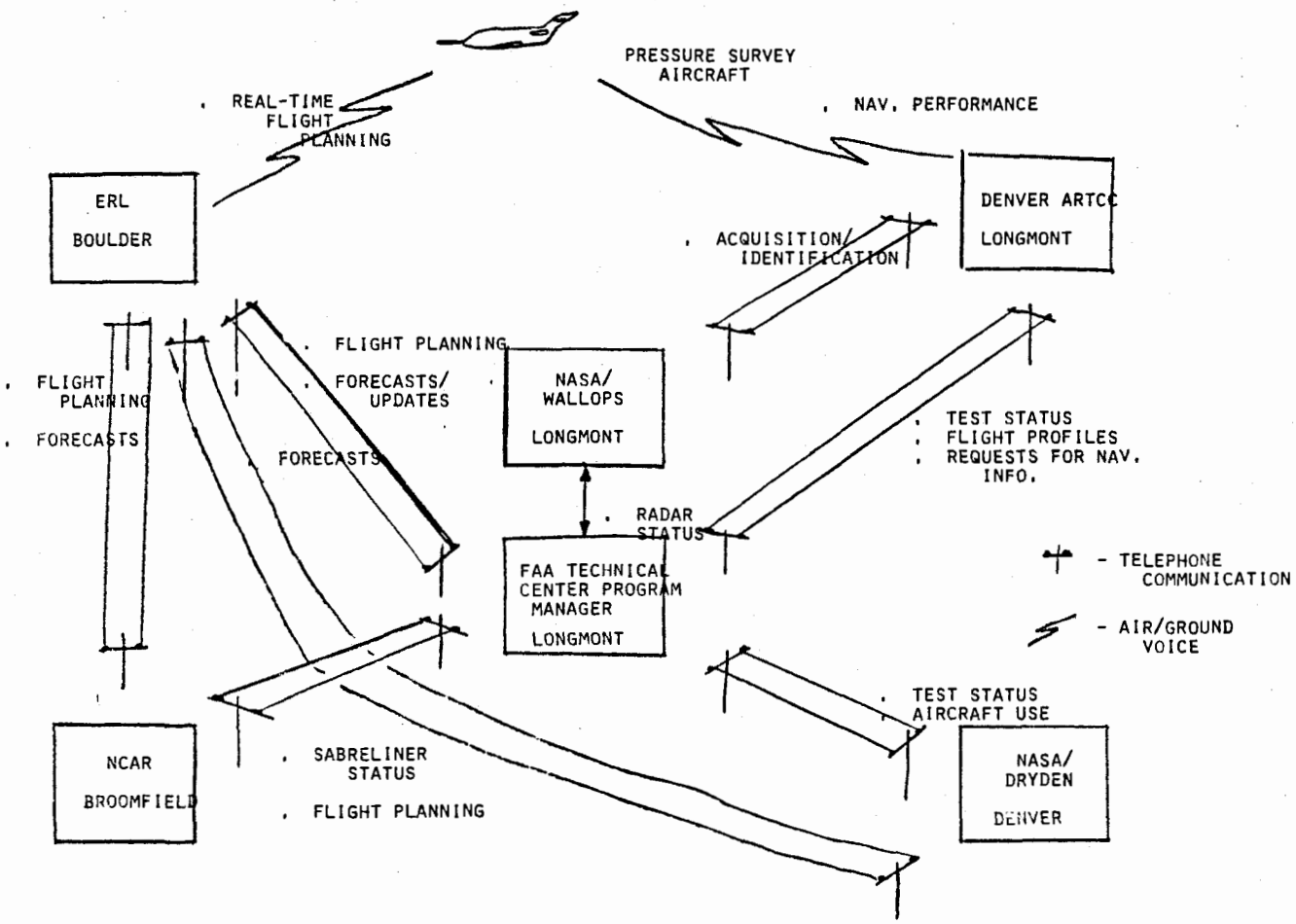


FIGURE 5. OVERVIEW OF COMMUNICATIONS DURING TEST

TABLE 3. PROPOSED DAILY SCHEDULE FOR PRESSURE-SURVEY DAY'S ACTIVITIES

Mountain Standard Time	Activity
0800	Bring up NASA/Wallops precision radar and begin pre-tracking calibrations
0805	Status checks of NASA/Wallops precision radar, NCAR Sabreliner
0810	Check with ERL for significant updates to previously forecast conditions
0815	Decide if scheduled test activities are to go forward, be modified, or be cancelled
	****** ASSUME STATUS CHECKS RESULT IN "GO" CONDITION ******
0820	Inform Denver ARTCC of day's test status and confirm Sabreliner flight patterns through on-site observer
0830	Confirm Sabreliner patterns with NCAR Project Manager
0900	Begin ATC radar and voice recording at Denver ARTCC
0915	Precision radar ready to track
0915	Pressure survey aircraft takeoff
0930	Begin pressure survey
1000	ERL forecast for next 24 hours
1015	End pressure survey
1025	Begin tracking itinerant traffic
1130	End morning precision tracking
1200	Pressure survey aircraft takeoff
1215	Begin pressure survey
1330	End pressure survey

TABLE 3 (CONTINUED)

Mountain Standard Time	Activity
1340	Begin tracking itinerant aircraft
1500	ERL advice for next day's flying
1515	Decide on proposed Sabreliner flight patterns for next day
1520	NCAR Sabreliner status check for next day's activities; identify patterns to be flown in conjunction with NCAR
1530	Inform Denver ARTCC of next day's proposed flying
1545	End afternoon tracking of itinerant aircraft
1550	Begin precision radar post-tracking calibration
1600	End ATC radar and voice recording at Denver ARTCC
1615	NASA/Wallops precision radar status check
PM	Post-test daily debriefing in Longmont, involving NASA/Wallops, ARINC Research and FAA Technical Center with emphasis on identifying larger observed vertical deviations for follow-up and cross-checking identities of itinerant aircraft tracked

APPENDIX A. LIST OF PRINCIPAL CONTACTS AT ORGANIZATIONS PARTICIPATING IN JANUARY-FEBRUARY 1984 TEST OF VERTICAL SEPARATION PROGRAM DATA COLLECTION METHODOLOGY

Name	Title/ Organization	Address	Telephone Home Base/ On-site
Raymond D. Atkins	Test Director NASA/Wallops Flight Facility	Wallops Flight Facility Wallops Island VA 23337	FTS 928-5384/
Al J. Bedard	Project Director Environmental Research Laboratories	U.S. Dept. of Commerce NOAA-ERL 325 Broadway Boulder CO 80303	FTS 320-6508/ Comm 497-6508 Same home and on-site
Edward Brown	Project Manager NCAR-Research Aviation Facility	Natl. Center for Atmospheric Research PO Box 3000 Boulder CO 80307	Comm 497-1033 Same home and on-site
Dennis Camp	Project Manager NASA/Flying Research	Code ED 42 Systems Dynamics Lab Marshall Space Flight Center AL 35812	FTS 872-2087/
Brian Colamosca	Program Manager FAA Technical Center	ACT-220 FAA Technical Center Atlantic City NJ 08405	FTS 482-6233/
Darold Gabel	Area Officer Denver ARTCC	FAA Denver ARTCC 2211 17th Avenue Longmont CO 80501	FTS 323-4203 Same home and on-site
Alex P. Schust	Project Manager ARINC Research Incorporated	ARINC Research Inc 2551 Riva Road Annapolis MD 21401	Comml 301-266-4838/

APPENDIX B. PROPOSED PRESSURE-SURVEY PATTERNS

Figures B.1 through B.4 show the horizontal tracks of proposed pressure survey patterns for J60 and J84-100. Figures B.1 and B.2 present patterns for J60, the difference between the two patterns being the path of the Sabreliner with respect to the centerline of the jet route. During the Summer 1983 test in the busy airspace over the Wallops Flight Facility, flying offset from centerline, as is shown in figure B.2, proved to expedite pressure surveys during periods of high traffic intensity. The offset pattern ensured that ATC had lateral separation between the Sabreliner and co-altitude itinerant route traffic, thus permitting easier manuevering of the aircraft from flight level to flight level during the pressure survey process. It seems prudent to entertain such patterns for the Winter test, even though the nature of traffic patterns are somewhat different in the Denver ARTCC airspace where testing is to be done. Figures B.3 and B.4 show similar centerline and offset tracks for pressure surveying J84-100.

FIGURE B.1
J60 CENTERLINE FULL OR LIMITED PRESSURE SURVEY PATTERN

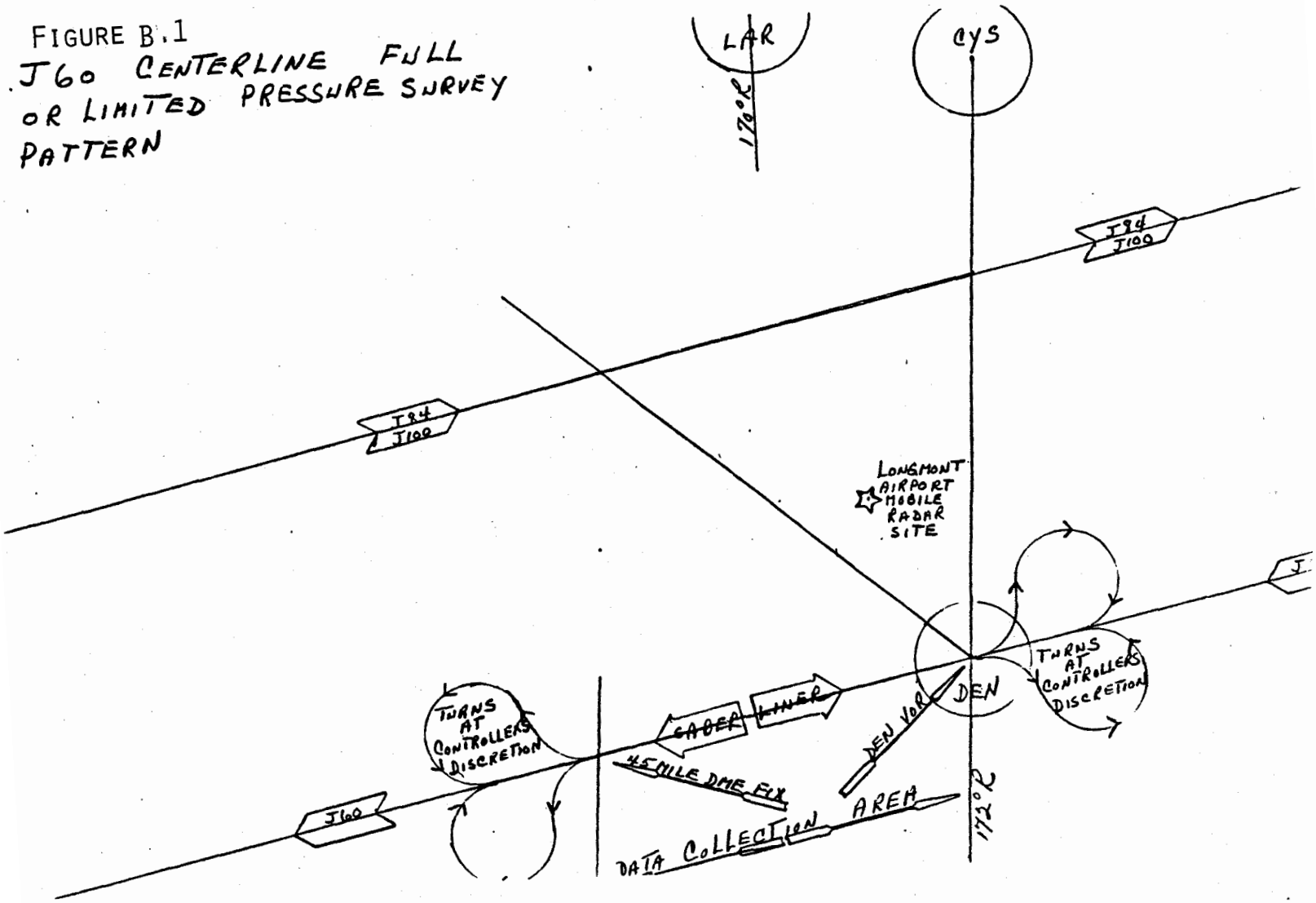


FIGURE B.2
J60 OFFSET NORTH OR SOUTH
FULL OR LIMITED PRESSURE SURVEY

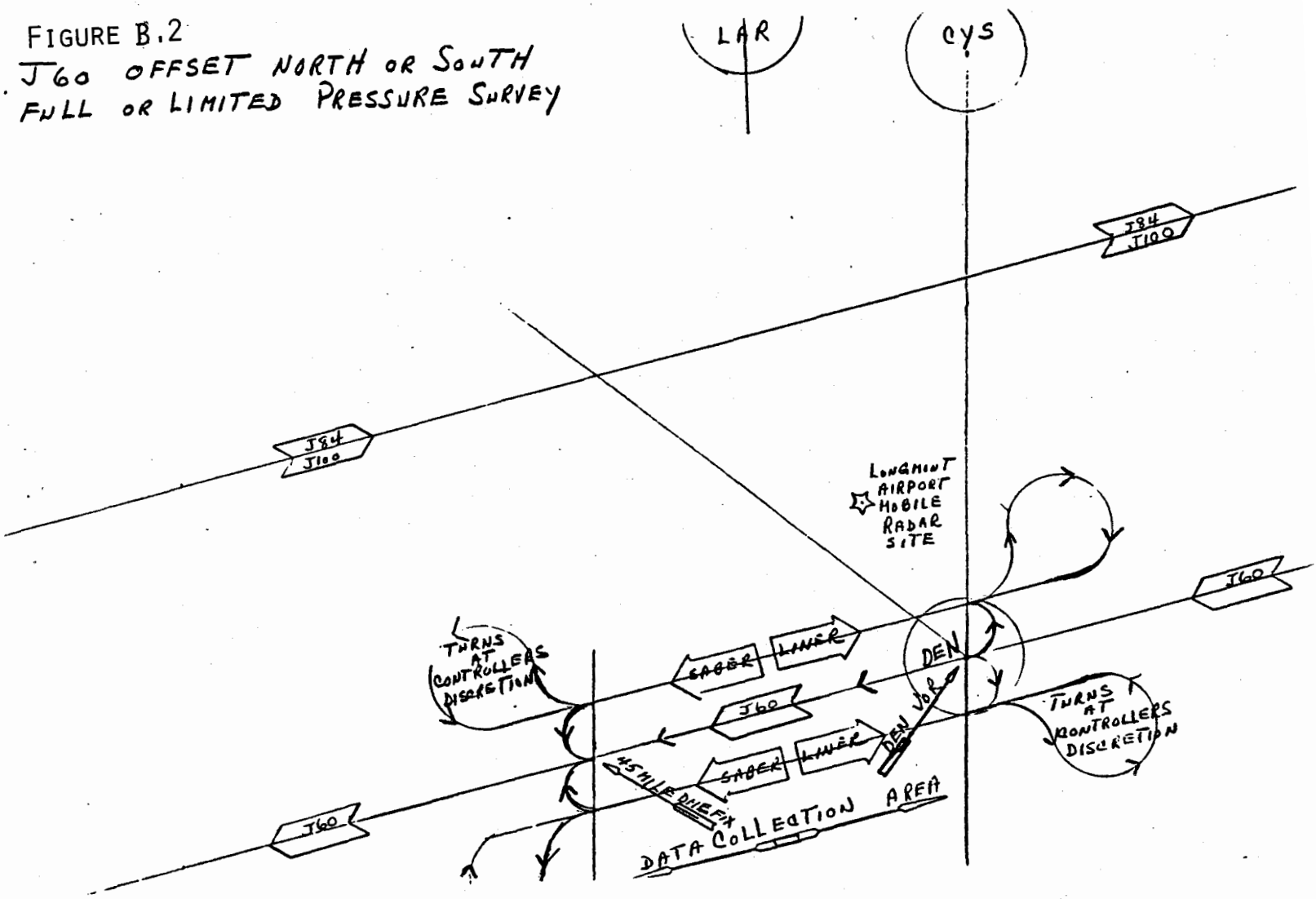


FIGURE B.3
J84 CENTERLINE FULL
OR LIMITED PRESSURE SURVEY
PATTERN

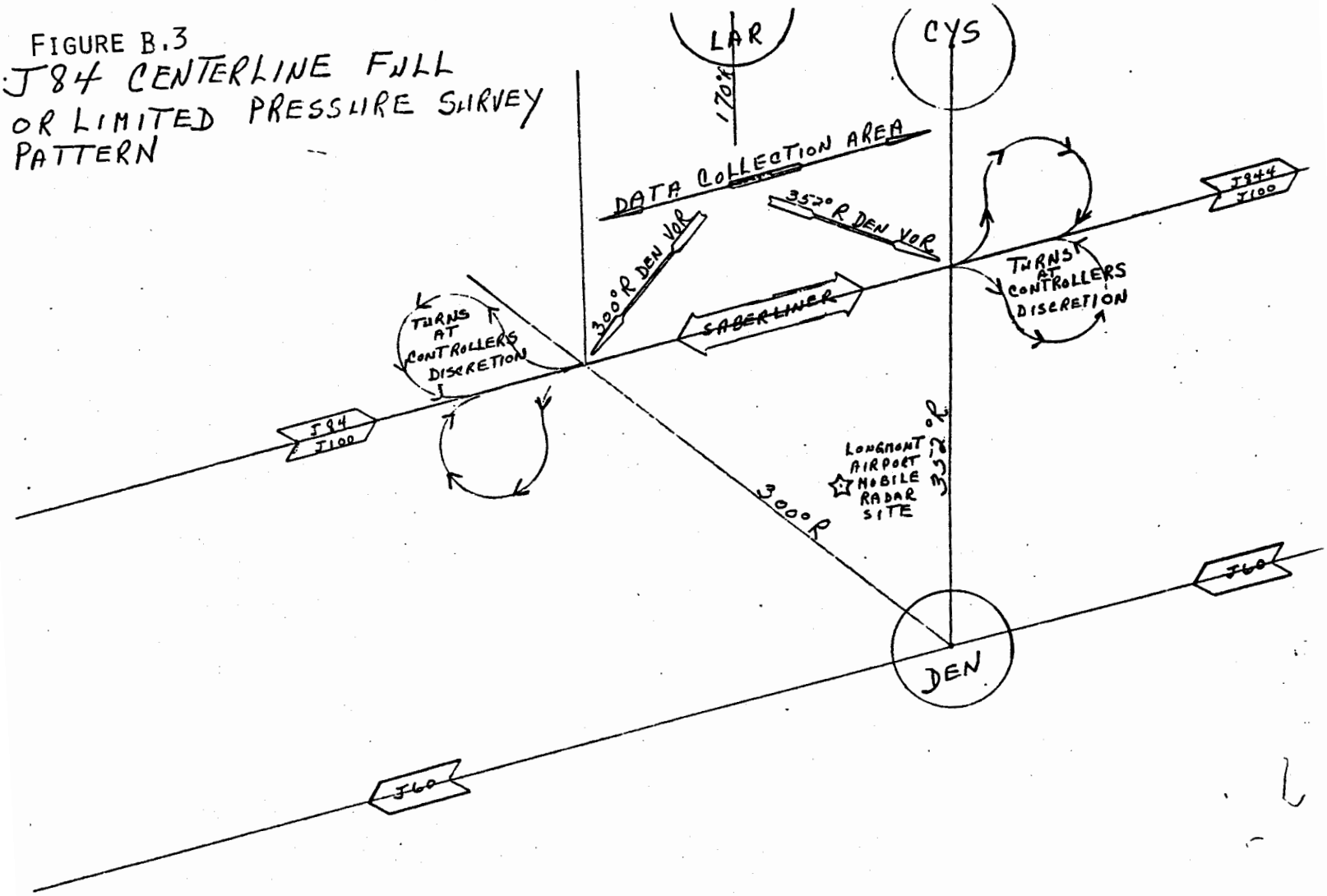
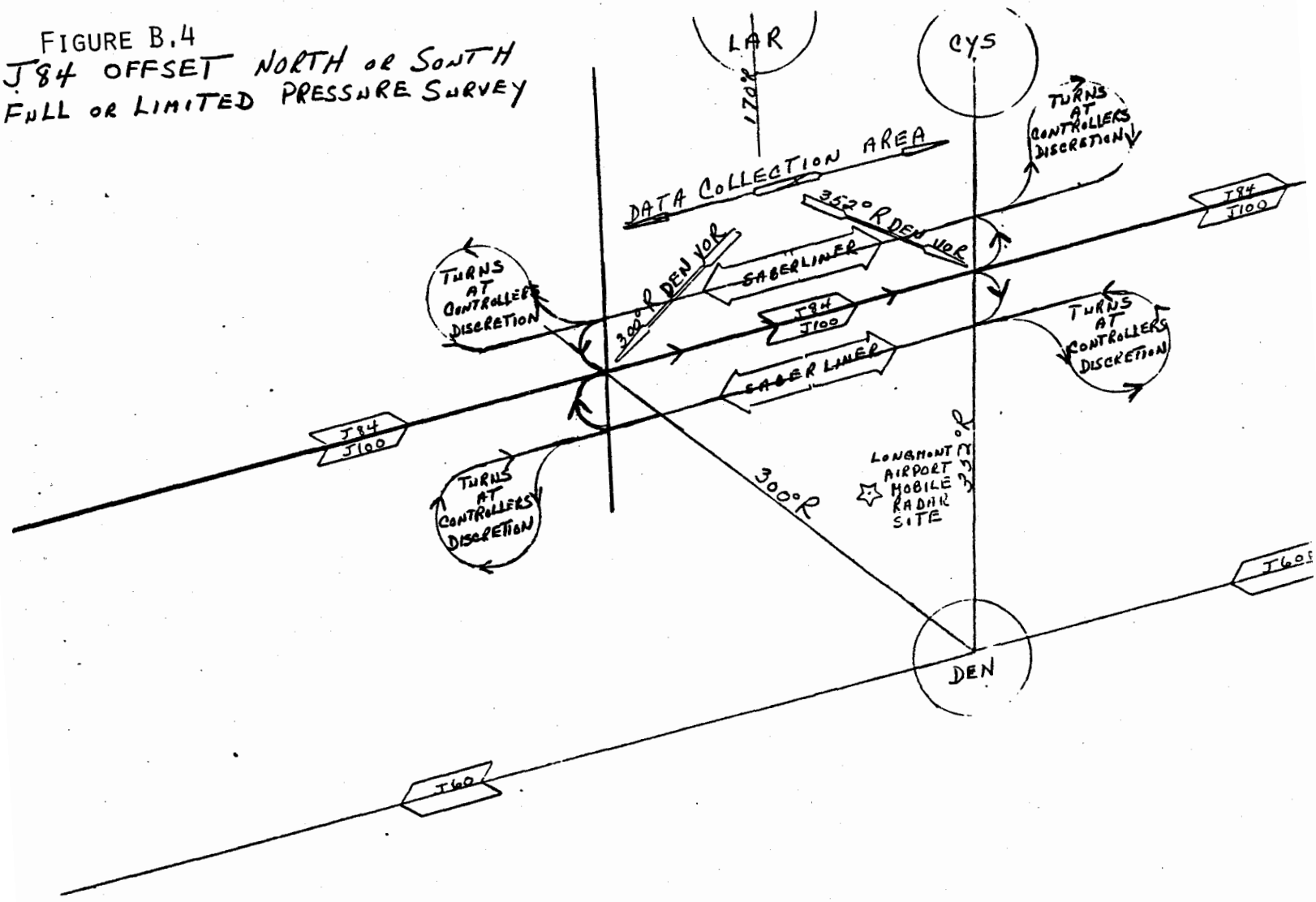


FIGURE B.4
J84 OFFSET NORTH OR SOUTH
FULL OR LIMITED PRESSURE SURVEY



APPENDIX C. PROPOSED PATTERNS FOR CONDUCTING ATMOSPHERIC RESEARCH FLIGHTS DURING THE JANUARY-FEBRUARY TEST OF THE VERTICAL SEPARATION PROGRAM DATA COLLECTION METHODOLOGY

Figures C.1 through C.3 show the horizontal tracks of three flight patterns proposed by ERL to aid in conducting research into meteorologically important phenomena which have reasonable probability of being observed during the test period. The pattern shown in figure C.1 will be flown directly over the north-south portion of the Continental Divide west of Boulder, while that in figure C.2 will consist of parallel tracks beginning roughly 5 nmi east of the Divide, with successive north-south tracks offset by 5 nmi. The pattern shown in figure C.3 is intended to pass back and forth over the Continental Divide, with the east-west legs skewed somewhat to the windward side of the high peaks. All patterns are first approximations of the paths to be flown; actual tracks will be adaptively changed in real-time in order to maximize the prospects of observing the phenomena of interest.

FIGURE C.1
170° RADIAL LAR VOR CENTERLINE
FULL O.R. LIMITED
PRESSURE SURVEY PATTERNS

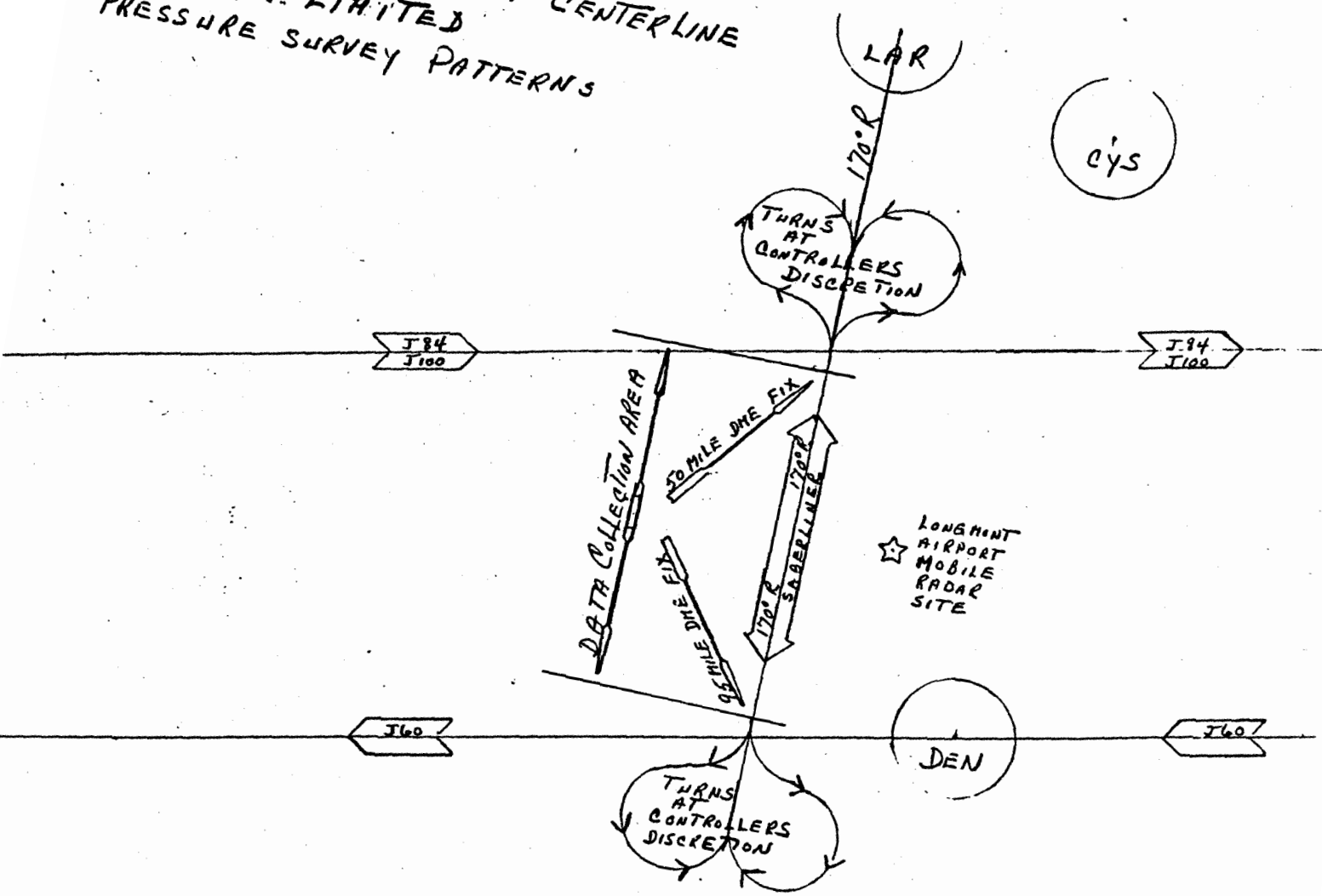


FIGURE C.2

170° RADIAL LAR VOR OFFSETS
EAST AT DISTANCES OF 5-10-15 MILES
FULL OR LIMITED PRESSURE SURVEY PATTERNS

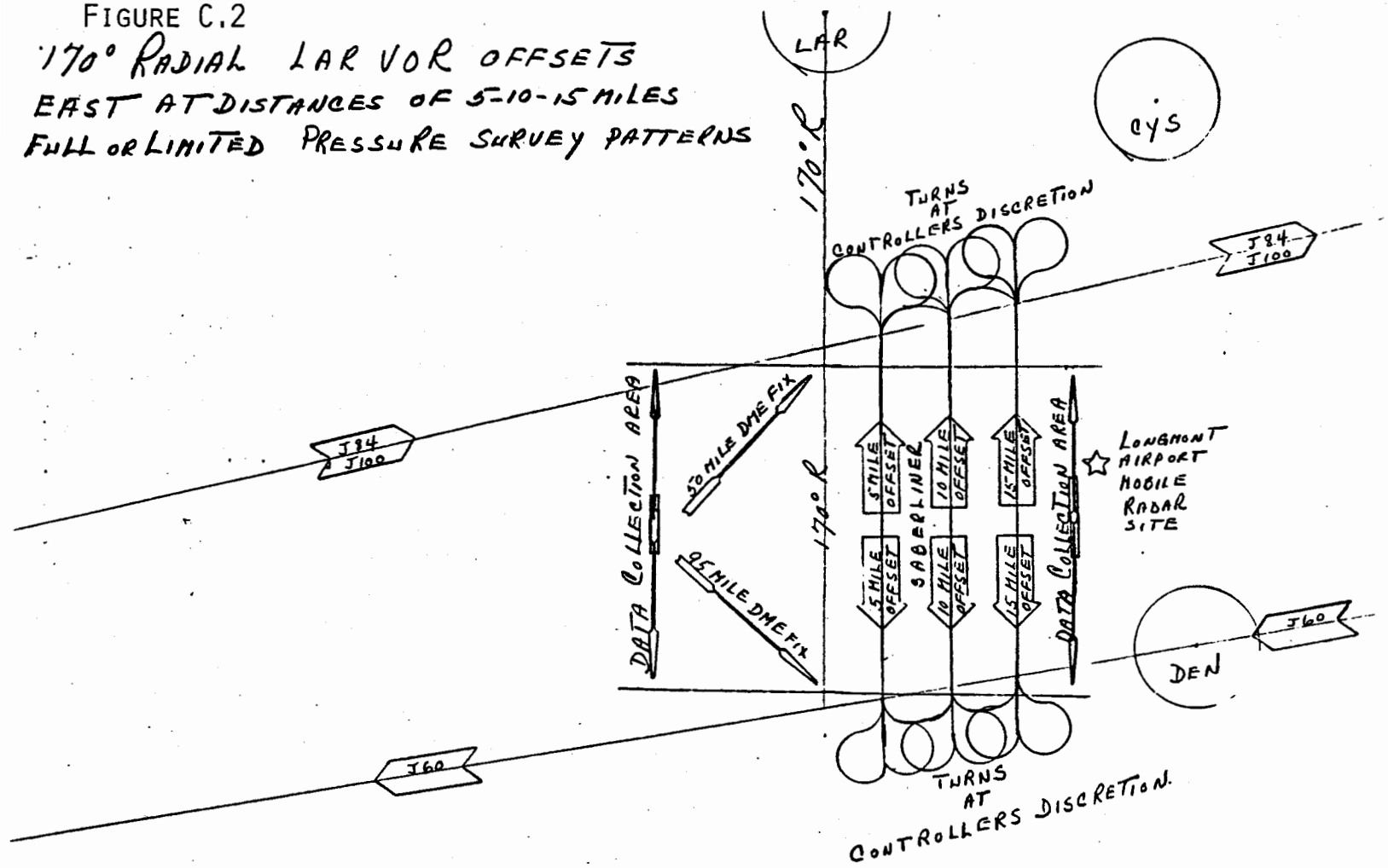
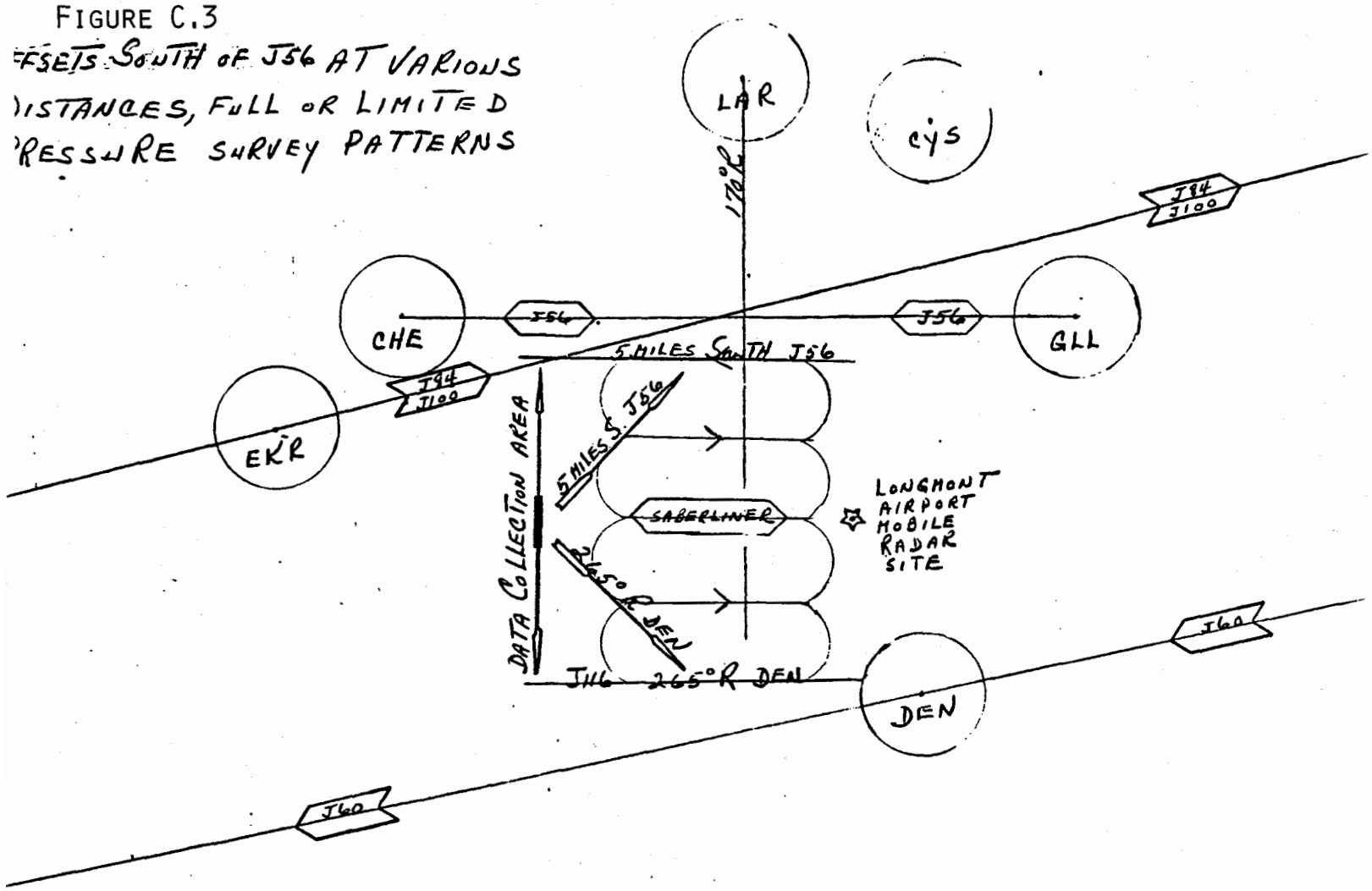


FIGURE C.3
OFFSETS SOUTH OF J56 AT VARIOUS DISTANCES, FULL OR LIMITED PRESSURE SURVEY PATTERNS



APPENDIX D. OVERVIEW OF THE DAILY ERL FORECAST OF METEOROLOGICAL EVENTS OF INTEREST DURING THE JANUARY-FEBRUARY TEST OF THE VERTICAL SEPARATION PROGRAM DATA COLLECTION METHODOLOGY

Figure D.1 is the form used by ERL to compose its daily forecast of meteorological events of interest in the investigation of the feasibilty of a 1000-foot vertical separation standard at and above FL290. The events of interest are explicitly stated on the form.

DATE/TIME (MST) OF FORECAST _____

FORECASTER _____

GENERAL FORECAST:

Potential for Specific Meteorological Phenomena

Time Period	Phenomena	Potential	Comments
_____	Downslope winds - Chinook		
	Downslope winds - Bora		
_____	Wave Clouds		
	3-D flows		
	Gravity/shear waves		
	Frontal interface		

Figure D.1 ERL FORECAST FORM