

AD/A-004 309

MEASUREMENT AND ANALYSES OF ASR-4 SYSTEM ERROR.
PART III. SUMMARY

Allen C. Busch, et al

National Aviation Facilities Experimental Center
Atlantic City, New Jersey

December 1974

**Reproduced From
Best Available Copy**

DISTRIBUTED BY:

NTIS

National Technical Information Service
U. S. DEPARTMENT OF COMMERCE

20000 726 056

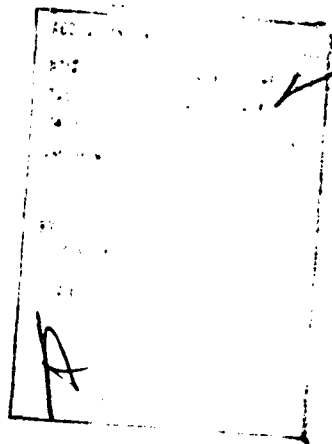
1. Report No. FAA-RD-73-62, III	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle MEASUREMENT AND ANALYSES OF ASR-4 SYSTEM ERROR PART III: SUMMARY	5. Report Date December 1974	6. Performing Organization Code
7. Author's Allen C. Busch Paul W. Bradbury	8. Performing Organization Report No. FAA-NA-74-8	10. Work Unit No. (TRAIS)
9. Performing Organization Name and Address Federal Aviation Administration National Aviation Facilities Experimental Center Atlantic City, New Jersey 08405	11. Contract or Grant No. 142-177-010	13. Type of Report and Period Covered Final December 1969 - March 1970
12. Sponsoring Agency Name and Address U.S. Department of Transportation Federal Aviation Administration Systems Research and Development Service Washington, D.C. 20590	14. Sponsoring Agency Code	
15. Supplementary Notes		
16. Abstract The positional accuracy of aircraft radar targets displayed in an air traffic control airport surveillance radar system (ASR-4) was measured as one of the inputs essential for determining aircraft separation standards. Using radar track input from the Atlantic City (New Jersey) ASR-4, radar targets of two test aircraft executing flight patterns of varying relative spacing were photographed as displayed in both beacon and primary radar modes on scan-converted and plan position indicator (PPI) displays. The displayed positions were related to simultaneous precision track from single-target instrumentation radars, and a data bank was developed of error measures for range, azimuth, and separation. The extensive analysis program employed a "least squares" analysis of variance. The data clearly demonstrated the strong interdependency of the individual components that contribute to radar system separation error. Further, it was noted that the tails of the distribution of the radar separation error response measure were not normally distributed. In this report, Part III: Summary, data has been pooled for all like system response measures from two extensive data sets previously reported out as Phase I Data and Phase II Data (reflecting a difference in measurement instrumentation) in the associated report, Part II: Analyses, and an analysis of variance was then performed for the pooled expressions. In general, the pooled data shows a tendency to be more homogeneous and less subject to extraneous effects.		
17. Key Words Airport Surveillance Radar Radar Error Air Traffic Control		18. Distribution Statement Document is available to the public through the National Technical Information Service, Springfield, Virginia 22151
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 73
		22. Price 4.25/2.25

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
US Department of Commerce
Springfield, VA 22151

PRICES SUBJECT TO CHANGE

NOTICE

This document is disseminated under the sponsorship of the Department of Transportation in the interest of information exchange. The United States Government assumes no liability for its contents or use thereof.



PREFACE

Technical reporting of the measurement and analyses of ASR-4 terminal radar system error under project 142-177-010 is organized into three parts. To facilitate independent or exclusive use of either report, each contains a sufficient description of methodology, data bank development, and the analyses which are reported.

PART I: OVERVIEW

This report is intended to present a general, nontechnical description of a limited set of the results which were developed in multivariate, multidimensional experiments using a large data sample. To achieve maximum clarity and simplify reader understanding of the overall effort, a very minimum of statistical data is presented in this report, and basic trends are described without expansion to describe or explain anomalies. More detailed treatments are presented in the associated reports.

PART II: ANALYSES

This is the main study, and it consists of three independent data collection programs and independent analyses. The report describes in detail the results of extensive data analysis and presents tables of summary statistical values for the two major data sets, which are categorized as "Phase I Data" and "Phase II Data."

PART III: SUMMARY

The Summary is a compendium and consolidation of the numerous analyses and subsets of data appearing in the main report, "Part II: Analyses." To relieve the reader of nonsignificant differences that result in three independent studies on a common problem, all similar system response measures were pooled, and combined into a single expression; and analysis of variance was then performed for the pooled expressions. The general effect was that the data thus becomes more homogeneous, and less subject to extraneous effects.

The extensive and complex nature of data collection and data analysis for these studies involved many participants whose individual contributions merit commendation, which can be made only generally. However, a few individuals must be specially cited.

We appreciate the direction and consultation provided by Mr. Walter Faison, for Systems Research and Development Service, and Mr. William Broadwater, for Air Traffic Service, who largely developed the program's conceptual approach.

We are very pleased to acknowledge the guidance and technical assistance of Dr. J. Stuart Hunter, of the Princeton University School of Engineering, for his painstaking and enthusiastic support in the statistical analysis and modeling effort.

TABLE OF CONTENTS

	Page
INTRODUCTION	1
Purpose	1
Background	1
PROJECT METHODOLOGY	2
Method of Approach	2
Data Collection	2
Data Reduction	5
Data Bank Tape	9
EXPERIMENTAL DESIGN AND ANALYSIS	11
Sample Airspace	11
Altitudes	11
Flight Patterns	11
Range Blocking	15
Test Design	15
Measurements	15
Circular Probable Error	17
ANALYSIS	18
Control Variables	18
Response Variables	18
System Performance Measures	19
Imbalance In Number of Observations	20
Modification of the Test Design	22
Replication, Phase II Data	23
Pooled Data - Combined Phase I and Phase II	24
Use of Correlation Coefficients	25
RESULTS	26
General	26
Interpretation of Statistical Significance	26
How to Read the Tables	27
Application of the Results	28
Analysis of Main Effects	29
Analysis of Two-Way Interactions	33
Analysis of Response Variables	34
REFERENCES	42

LIST OF ILLUSTRATIONS

Figure		Page
1	Measurement Instrumentation	3
2	Radar Displays with Camera Installations	4
3	EAIR Facility Data Flow Diagram	6
4	TAIR Facility Data Flow Diagram	7
5	Telereadex Film Reader Equipment	8
6	Data Reduction Flow Chart	10
7	Airspace Sampled	12
8	Flight Patterns	14
9	Test Design	16
10	Probable Distribution of Relative Position Error - Range Block Q1	36
11	Probable Distribution of Relative Position Error - Range Block Q2	37
12	Separation Error Residuals on Double-Exponential Paper	38

LIST OF TABLES

Table			Page
I	Overview of System Response Measures		43
II-1	PE Mean	Position Error Mean	44
II-2	PE ln Var	Position Error Log Variance	44
II-3	SE Mean	Separation Error Mean	45
II-4	SE ln Var	Separation Error Log Variance	45
II-5	RE Mean	Range Error Mean	46
II-6	RE ln Var	Range Error Log Variance	46
II-7	AE Mean	Azimuth Error Mean	47
II-8	AE ln Var	Azimuth Error Log Variance	47
II-9	COR R to A	Correlation, Range Error Versus Azimuth Error	48
II-10	COR R1 to R2	Correlation Range Error Versus Range Error	48
II-11	COR A1 to A2	Correlation, Azimuth Error Versus Azimuth Error	49
II-12	RSQ R, A, on SE	Multiple Correlation, Range and Azimuth Error on Separation Error	49
II-13	RSQ R1, R2, A1, A2, on SE	Multiple Correlation, Range Error 1 and 2 and Azimuth Error 1 and 2 on Separation Error	50
III-1	DXT Averages	Display Type by Radar Mode Averages	51
III-2	DXR Averages	Display Type by Radial Averages	52
III-3	DXQ Averages	Display Type by Range Block Averages	53
III-4	DXF Averages	Display Type by Flight Pattern Averages	54
III-5	DXA Averages	Display Type by Altitude Averages	55
III-6	TXR Averages	Radar Mode by Radial Averages	56
III-7	TXQ Averages	Radar Mode by Range Block Averages	57
III-8	TXF Averages	Radar Mode by Flight Pattern Averages	58
III-9	TXA Averages	Radar Mode by Altitude Averages	59
III-10	RXQ Averages	Radial by Range Block Averages	60
III-11	RXF Averages	Radial by Flight Pattern Averages	62
III-12	RXA Averages	Radial by Altitude Averages	63
III-13	QXF Averages	Range Block by Flight Pattern Averages	64
III-14	QXA Averages	Range Block by Altitude Averages	65
III-15	FXA Averages	Flight Pattern by Altitude Averages	66

INTRODUCTION

PURPOSE

The technical objective of this project was to conduct measurements of system error in the air traffic control terminal area radar system and to perform analyses to provide a more quantitative basis for related decision making.

BACKGROUND

The Federal Aviation Administration (FAA) Air Traffic Service (ATS) requested from the FAA Systems Research and Development Service (SRDS) a quantitative analysis of the errors in range, azimuth, geographic position, and separation which are associated with aircraft position information derived by a typical terminal area search radar system.

Data collection was performed at the National Aviation Facilities Experimental Center (NAFEC), Atlantic City, New Jersey, by tracking two test aircraft with instrumentation radars, photographing radar targets displayed by the field-operational Atlantic City ASR-4, and then comparing the related target position reports from these two sources. Extensive analyses were performed by the Analysis Branch at NAFEC supported by computer services at Princeton University.

The SRDS project objective specified that an airport surveillance radar (ASR) which was operational in an ATS field facility would be used to conduct measurements of the positional accuracy of the radar targets displayed on two types of radar indicators, the standard plan position indicator (PPI) and the scan-converted radar bright display equipment (RBDE). Measurements were specified to include the positional accuracy of the displayed target for a set of altitudes and ranges, measurements of range and azimuth resolution through a range of altitudes, and under conditions of losing resolution and then regaining it, and that such measurements would consider both raw radar and beacon (primary and secondary radar respectively).

These specifically defined measures were to be used to provide a series of statistical estimates showing the probability of various values of measured separation of aircraft, both relative and geographical, through a range of critical values.

The key interest may be expressed, "What is the separation error between aircraft targets displayed in an air traffic control terminal area radar system?"

PROJECT METHODOLOGY

METHOD OF APPROACH

The basic measurement sought in response to the Air Traffic Service request was the difference between displayed aircraft position and actual aircraft position. This difference was considered to be the system error in positional accuracy of the aircraft radar target.

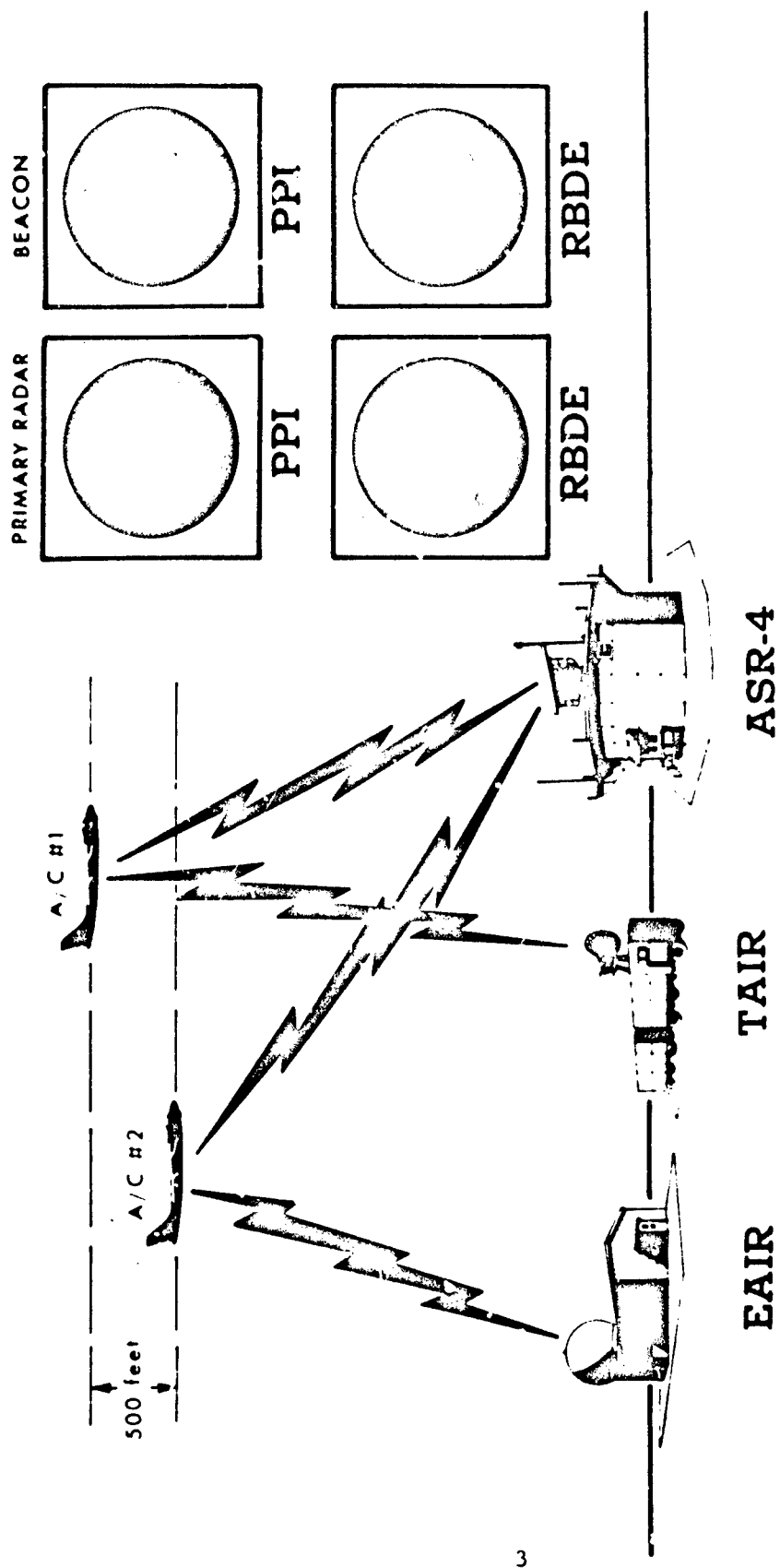
The difference between the displayed aircraft target position and the true geographical position of the aircraft was treated as the total system error and was measured at the point of service. This is to say that component errors of the electronic system which produces and displays the aircraft radar target are not considered independently. The measurement data was collected at that point in the air traffic control system where the air traffic controller observes aircraft target position relative to other aircraft radar targets (or known obstructions), and uses this positional information as a basis for his judgments in the exercise of air traffic control service. Moreover, no consideration was made of human factors, such as the controllers' visual acuity or response lag.

To treat the system error thus defined, it was necessary (1) to acquire an adequate data sample, (2) to compute its statistical characteristics, (3) to estimate therefrom population parameters relating to accuracy and precision, and (4) to develop predictive statements about the expectancy of various kinds and amounts of error.

DATA COLLECTION

Measurement of displayed aircraft radar target position was made by photographing radar displays which used input from the Atlantic City ASR-4 airport surveillance radar system. Four displays were photographed in each data run. Two of these displays were scan-converted RBDE-5 displays, and two were PPI displays. One display of each pair presented the radar targets of interest in beacon radar mode, and one display of each pair presented the targets of interest in raw radar mode (figure 1). The acquired film data thus fulfilled the specified requirements for information from both primary radar and secondary radar displays and also from both scan-converted and PPI displays.

Each radar display was equipped with a camera, frame-mounted to record total display scope coverage and automatically triggered to expose one frame of film for each scan of the surveillance radar antenna, one frame of film each 4 seconds (figure 2). For time correlation with other measurement data, each display was equipped with a presentation of clock time which would be recorded on film to the nearest 0.1 seconds of camera trigger.



74-8-1

FIGURE 1. MEASUREMENT INSTRUMENTATION

PAGES 4, 5
ARE
MISSING
IN
ORIGINAL
DOCUMENT

EXTENDED AREA INSTRUMENTATION RADAR

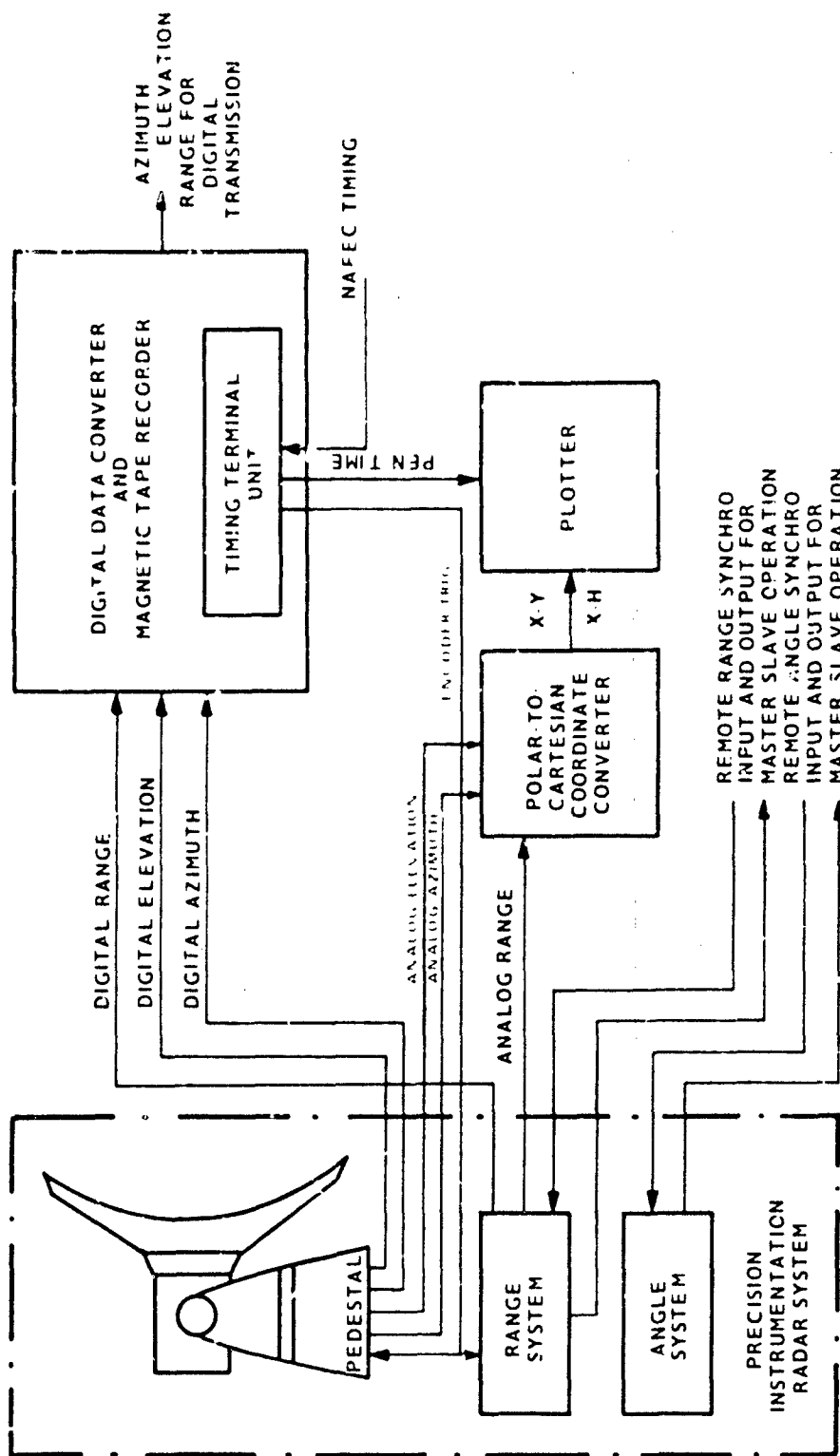


FIGURE 3. EAIR FACILITY DATA FLOW DIAGRAM

74-8-3

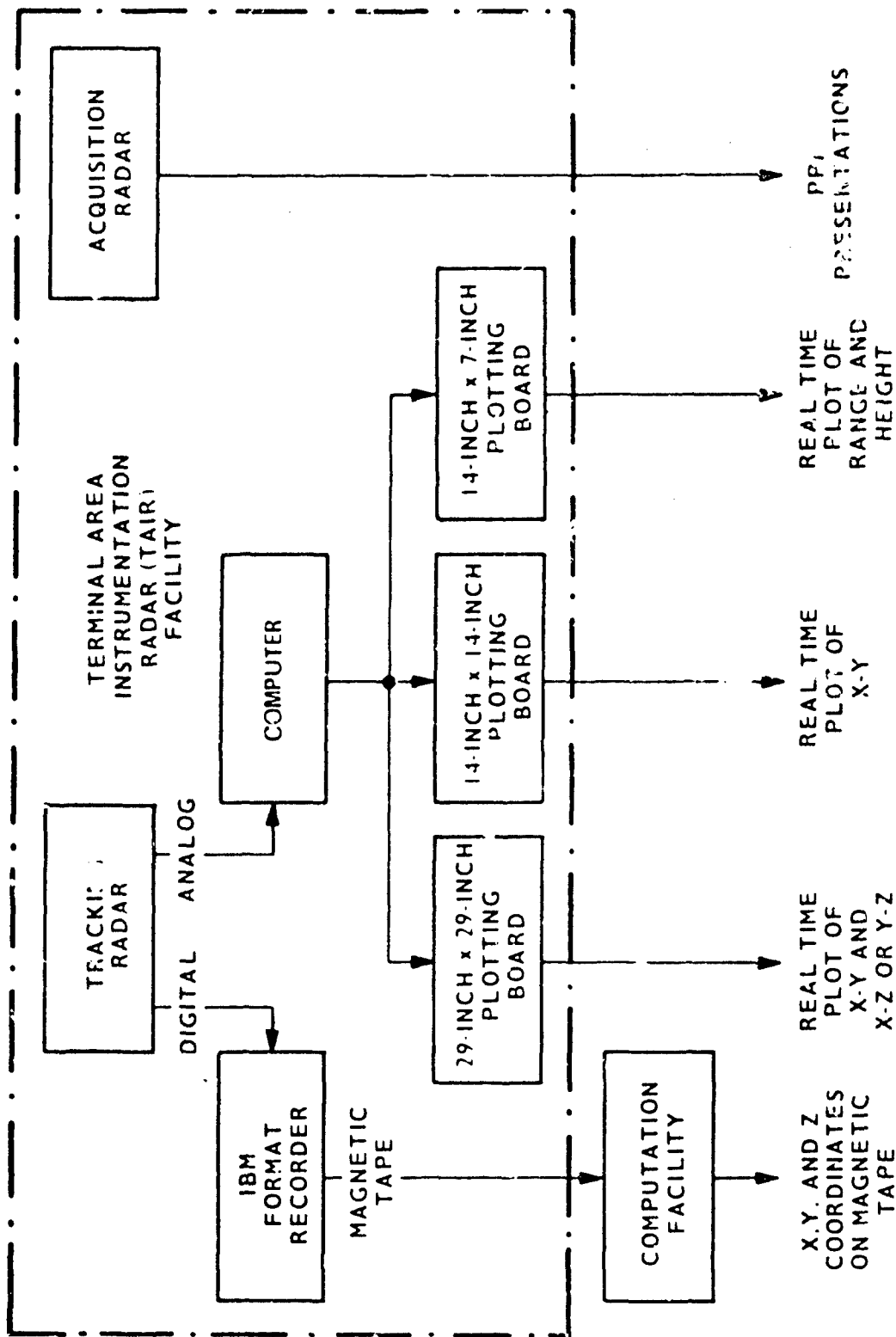


FIGURE 4. TAIR FACILITY DATA FLOW DIAGRAM

74-8-4

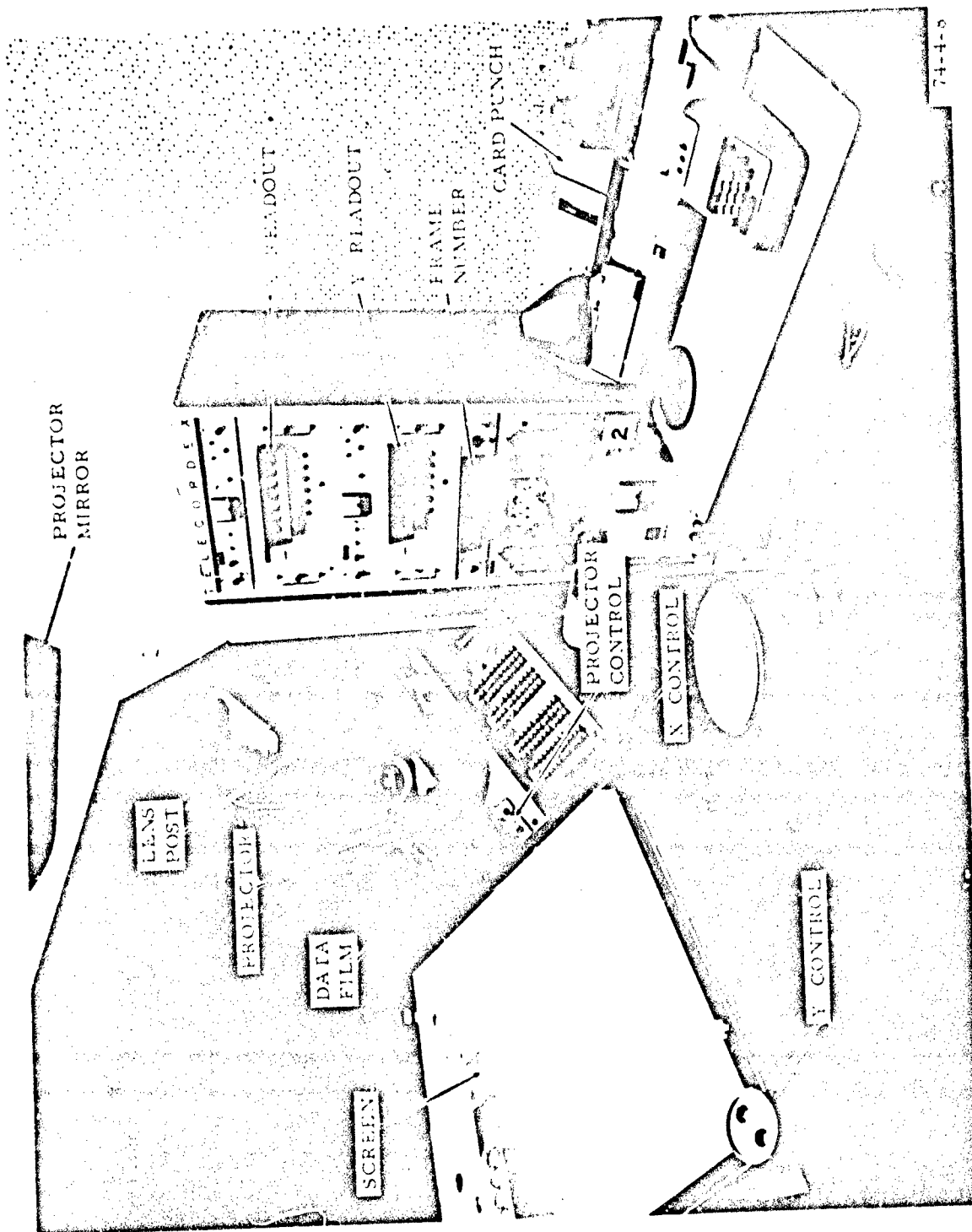


FIGURE 5. TELEREADEx FILM READER EQUIPMENT

tapes, this data was computer processed to translate and rotate the measurements from the source points of the EAIR and TAIR radar antennas to the source point of the Atlantic City ASR-4 surveillance radar antenna, and the data was converted from rho-theta to X and Y.

DATA BANK TAPE

A special computer program was developed to combine the position-time-space data from EAIR/TAIR magnetic tapes and Telereadex punched card output (figure 6) and to record the following basic measures on master data bank tapes for use in statistical analysis:

1. Aircraft One, precision radar track position (from TAIR);
2. Aircraft One, film position, primary radar mode, PPI display;
3. Aircraft One, film position, beacon radar mode, PPI display;
4. Aircraft One, film position, primary radar mode, RBDE display;
5. Aircraft One, film position, beacon radar mode, RBDE display;
6. Aircraft Two, precision radar track position (from EAIR);
7. Aircraft Two, film position, primary radar mode, PPI display;
8. Aircraft Two, film position, beacon radar mode, PPI display;
9. Aircraft Two, film position, primary radar mode, RBDE display;
10. Aircraft Two, film position, beacon radar mode, RBDE display.

The project data reduction program also developed for the master data bank tapes the following calculated measures:

1. Aircraft One Slant Range Error
2. Aircraft One Azimuth Error
3. Aircraft One Composite Error
4. Aircraft One Geographic Error
5. Aircraft One Composite-Geographic Error
6. Aircraft One Ground Range
7. Aircraft Two Slant Range Error
8. Aircraft Two Azimuth Error
9. Aircraft Two Composite Error
10. Aircraft Two Geographic Error
11. Aircraft Two Composite-Geographic Error
12. Aircraft Two Ground Range
13. Separation Error (between Aircraft One and Aircraft Two)

The data bank tape consists of one data record for each 4-second period of live flight data collection, except where deleted in quality control data editing. Each record includes the basic and calculated measures listed above as well as clock time. Records are blocked into data "cases," equivalent to flight on one radial, in one direction at one altitude and flight pattern.

From the data bank, the various system response variables were calculated and analyzed according to the experimental design.

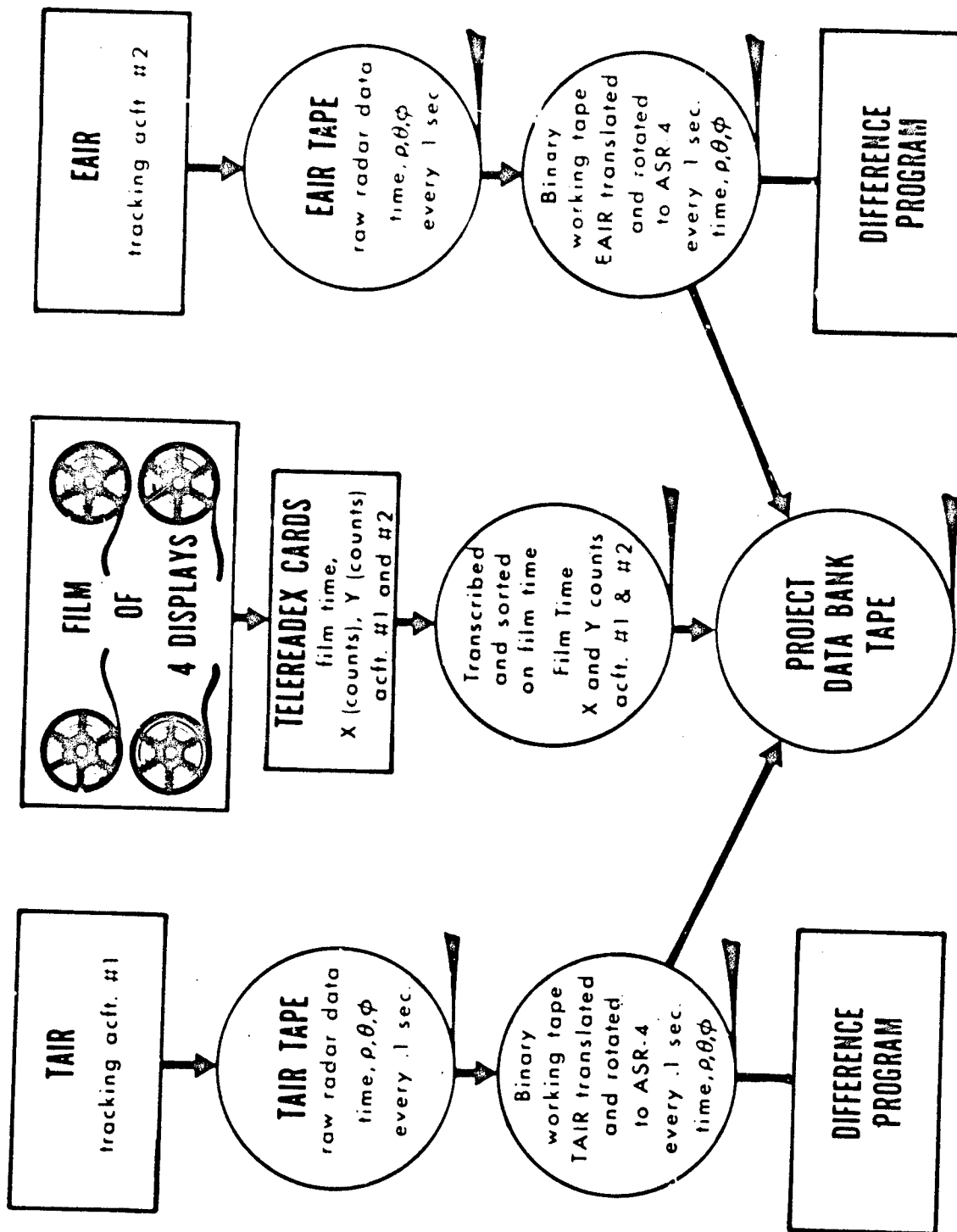


FIGURE 6. LTA REDUCTION FLOW CHART

EXPERIMENTAL DESIGN AND ANALYSIS

SAMPLE AIRSPACE

A cylindrical airspace 50 nautical miles in radius from the Atlantic City ASR-4 radar antenna (sited at NAFEC) and from ground level (14 feet mean sea level) to 20,000 feet mean sea level was selected as the area to be sampled (figure 7). The radius of 50 nautical miles was established from consideration of present operational and jurisdictional interests of air traffic control terminal area facilities. Operational field facilities which provide radar service very commonly use a range setting of 30 nautical miles on their radar displays. However, recent developments in terminal area air traffic control service have extended the area of interest for the terminal area air traffic controller.

Within the selected sample area, observations were sought in each of the four quadrants. Flight paths for the test aircraft were aligned with the approximate bisectors of the four quadrants defined by the cardinal points of the compass. The natural fall of terrain was so oriented to the prescribed flight paths that it was possible to sample possible effects on radar accuracy in relation to over-land, over-water, and over-marsh (mixed) conditions.

The course bearings from the Atlantic City ASR-4 radar antenna site which define the flight paths of the data runs were 050°, 140°, 230°, and 320°. These were designated (in data labelling, etc.) "radials" 1, 2, 3, and 4 respectively, in clockwise order from true north. Navigation was actually accomplished by flying the corresponding radials of the Atlantic City VORTAC station, very closely adjacent to the ASR-4 antenna site.

ALTITUDES

Test flights for data collection were performed at flat altitudes of 20, 14, 8, and 3 thousand feet. Altitude separation of 500 feet vertical spacing was assigned so that the maneuvering aircraft could cross under the nonmaneuvering aircraft without varying its own constant altitude. Otherwise, vertical spacing was of no interest as a test objective, since displayed aircraft radar targets vary in only the two horizontal dimensions.

FLIGHT PATTERNS

Specified flight patterns for each data run were designed to consider either range separation (spacing) or azimuth separation between radar targets when presented on a radar display. Three flight patterns were specified to be flown at each of the assigned altitudes, starting at the 50-nautical-mile periphery of the sample area and proceeding inbound to overhead the radar antenna site, and thence outbound on the reciprocal course to the opposite 50-nautical-mile point. For purposes of test replication, the same patterns were subsequently flown on the opposite headings (figure 8).

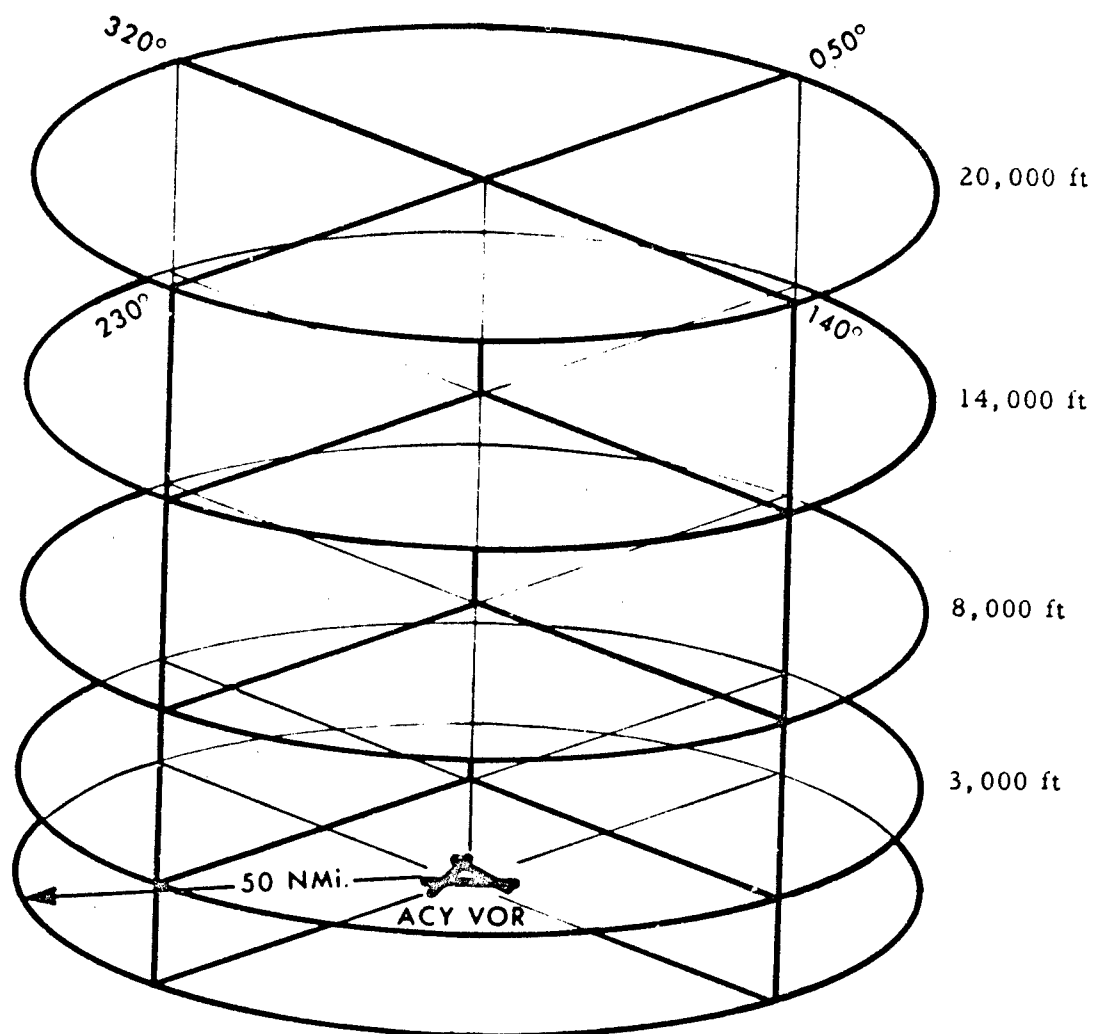


FIGURE 7. AIRSPACE SAMPLED

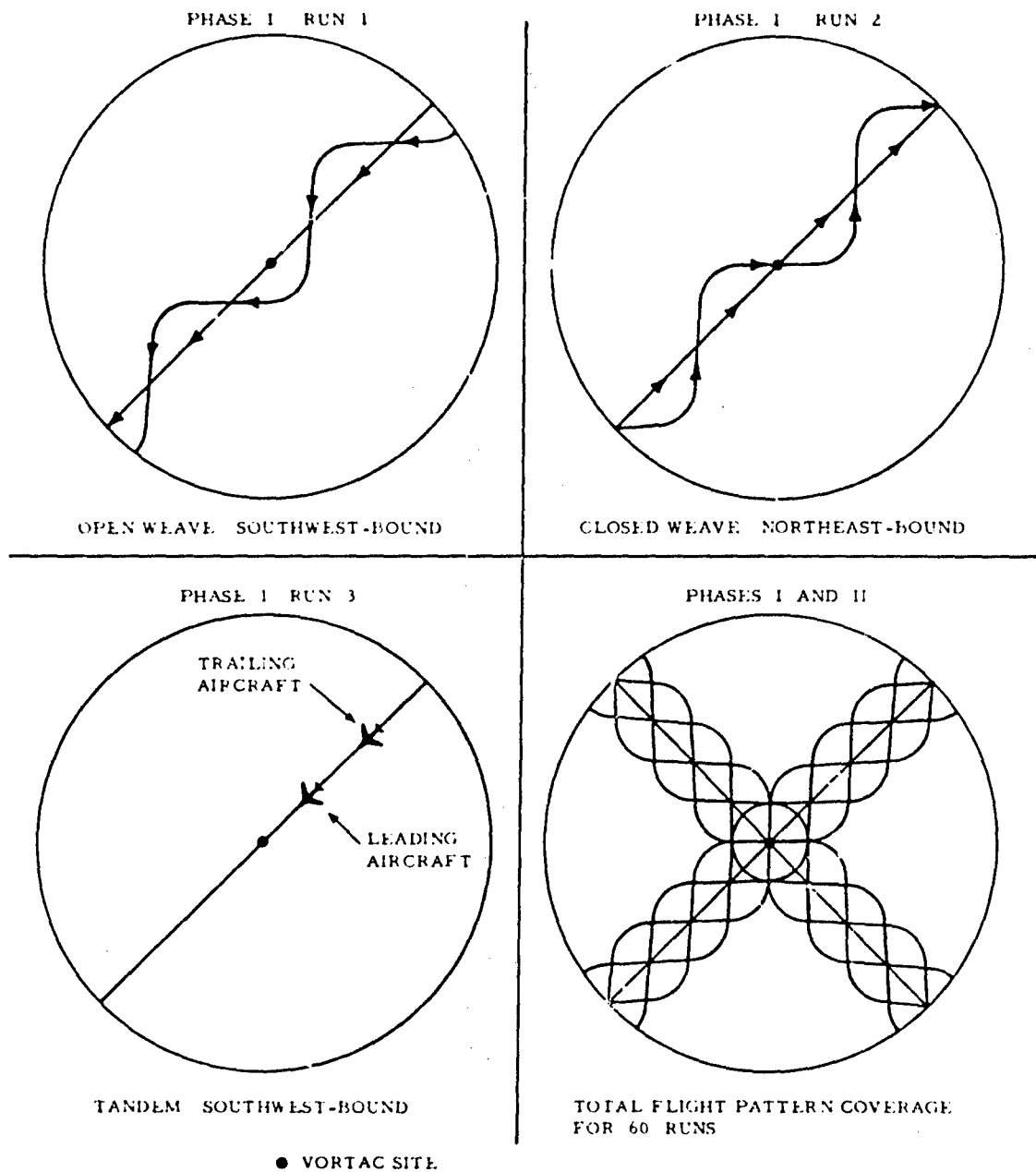


FIGURE 8. FLIGHT PATTERNS

In the tandem flight pattern (for the 050° radial and its reciprocal course 230° for example), the "lead aircraft" (nonmaneuvering aircraft) started the test run at assigned altitude and at the 50-nautical-mile DME fix on the 050° radial of the Atlantic City VORTAC heading inbound, thence navigated a straight course on the 050° radial to overfly the radar antenna, and then navigated outbound on the 230° radial to termination of the data run at the 50-nautical-mile DME fix of the 230° radial. The maneuvering aircraft, trailing the lead aircraft along the same radials, made speed adjustments to vary the longitudinal spacing between the two aircraft from 7 nautical miles to zero, and then back to the maximum of 7 nautical miles. This alternate catch-up and fall-back maneuver along defined VORTAC radials was intended to vary range spacing while maintaining as nearly as practicable a constant azimuthal relationship between the target aircraft.

The other two specified flight patterns, open weave and closed weave, were designed to vary the azimuthal relationship between the two test aircraft while maintaining a minimum difference in their respective ranges from the radar antenna throughout each run.

In both of the weave patterns, the lead aircraft navigated in the same manner as in the tandem pattern, in a straightline course inbound from a 50-nautical-mile DME fix on one of the specified radials, to over the radar antenna site, thence outbound to the 50-nautical-mile DME fix on the reciprocal radial.

In the open weave pattern, the maneuvering aircraft, maintaining throughout the run as closely as possible the same range from the VORTAC as the lead aircraft, initiated the data run inbound at a range of 50 nautical miles from the VORTAC, but 7 nautical miles laterally from the lead aircraft. Thence, the maneuvering aircraft executed a series of weaves about the lead aircraft such that a crossover beneath the lead aircraft was executed at ranges of 37.5 and 12.5 nautical miles (these equatable with zero azimuthal spacing) and lateral spacing of 7 nautical miles was reestablished about 25 nautical miles on each side of the antenna site, passing the antenna site, and at the outbound 50-nautical-mile DME fix.

The closed weave flight pattern was performed identically to the open weave flight pattern, except that maximum lateral spacing was specified for ranges of 37.5 and 12.5 nautical miles, and minimum lateral spacing (cross-under) was specified to occur at 50 nautical miles and 25 nautical miles on both sides of the antenna site, and overhead the antenna site.

Each of the three flight patterns was executed on the 140°/320° radials as well as on the 050°/230° radials. For purposes of test replication, all three flight patterns were also executed in a subsequent data set (Phase II) on aircraft headings reciprocal to those used in the first data set (Phase I).

RANGE BLOCKING

Radar displays in the ground environment test laboratory were set for a range of 50 nautical miles while the aircraft were beyond 30 nautical miles inbound and 25 nautical miles outbound, and were switched to a range setting of 30 nautical miles when the aircraft were within these limits.

It should be noted that, while this variable of the test conditions is described in terms of display radar range setting, the effect is to change the scale on the display. All the radar displays used in these tests, whether PPI or scan-converted (RBDE-5), were types specified as 22-inch; the effective display face diameter being slightly less than this dimension. The impact of the scale change (range-setting change) on the measurements should be expected in the range block variable Q1 (zero to 25-nautical-mile range) and Q2 (25- to 50-nautical-mile range).

TEST DESIGN

The six basic test conditions, with their various treatment levels, comprised a factorial test design which was multidimensional as well as multivariate. To recapitulate, the conditions were as follows:

<u>Variable</u>	<u>Treatment Levels</u>	<u>Data Code</u>
Radar Mode	2	T
Display Type	2	D
Flight Pattern	3	F
Radial (Course)	4	R
Altitude	4	A
Range Block	2	Q

A graphic matrix of the complete test design (figure 9) depicts the schematic relationship of the various test conditions and treatment levels.

MEASUREMENTS

Four types of error measurements were derived from the basic data bank: (1) range error; (2) azimuth error; (3) position error, which is the vector derived from the range error and the azimuth error; and (4) the relative separation error. In this report, these measurements are all expressed in terms of nautical miles.

A4 Altitude 3 Thousand									
A3 Altitude 8 Thousand									
A2 Altitude 14 Thousand									
A1 Altitude 20 Thousand									
		D1 Scan Converted				D2 PPI			
Radar Mode		T1		T2		T1		T2	
Range Block		Q1	Q2	Q1	Q2	Q1	Q2	Q1	Q2
F1	R1	x	x	x	x	x	x	x	x
	R2	x	x	x	x	x	x	x	x
	R3	x	x	x	x	x	x	x	x
	R4	x	x	x	x	x	x	x	x
F2	R1	x	x	x	x	x	x	x	x
	R2	x	x	x	x	x	x	x	x
	R3	x	x	x	x	x	x	x	x
	R4	x	x	x	x	x	x	x	x
F3	R1	x	x	x	x	x	x	x	x
	R2	x	x	x	x	x	x	x	x
	R3	x	x	x	x	x	x	x	x
	R4	x	x	x	x	x	x	x	x

matrix cells 1-96

matrix cells 97-192

matrix cells 193-288

matrix cells 289-384

Legend:

Radar Mode	T1, Primary; T2, Beacon
Display Type	D1, Scan-converted; D2, PPI
Flight Pattern	F1, Tandem; F2, Open Weave; F3, Closed Weave
Radial (Course)	R1, 050°; R2, 140°; R3, 230°; R4, 320°
Altitude	A1, 20; A2, 14; A3, 8; A4, 3 thousand feet
Range Block	Q1, zero-25 nmi; Q2, 25-50 nmi

74-8-9

FIGURE 9. TEST DESIGN

CIRCULAR PROBABLE ERROR

Two principal unique factors emerge after examining previous programs of radar analysis and studies of aircraft separation standards derived for navigation systems. The first such factor is that the use of circular probable error calculation is not applicable. In this regard, our approach differs from that of other studies of radar error distribution. The two principal components of the horizontal position error of an aircraft are the range error and the azimuth error. To treat these as the X and Y coordinate errors around the antenna can lead to erroneous calculations.

The assumption in the use of circular probable error is that the variances of X and Y are equal. The horizontal error around an aircraft radar target is more probably an ellipse. However, if this ellipse is rotated, or moved 360° around the radar antenna in such a way that the range and azimuth components maintain their true orientation, then the X and Y coordinates alternate between being principally determined by the range error to being determined by the azimuth error. Thus, when an aircraft is due north (or due south) of the radar antenna, the range error in the displayed radar target position is completely defined by the Y vector; whereas, the range error is completely defined by the length of the X vector when the aircraft is due east (or west) of the antenna.

Moreover, since range error and azimuth error are not completely independent of each other, their variances are not statistically independent; therefore, no simple combination of the summary of range and azimuth errors, or summary of the X and Y errors, can be made.

The second factor is that, when two aircraft are within a few miles of each other, the range error and the azimuth error of each aircraft are likely to have a statistically significant positive correlation between them. Thus, the separation error is not defined by the overlap of the assumed independent error distributions of the two adjacent aircraft, but by a more complex function of the error distributions.

In the case of an analogue radar system, when two points in space (such as two aircraft) approach convergence into one point (the two aircraft approach minimum lateral separation), the characteristics of their errors in range and azimuth approach identity, represented by a positive correlation coefficient of 1.0. In this study, to collect data so that the nature of this relationship is correctly interpreted, it was necessary to fly two aircraft and to have them tracked by independent tracking radars.

This concern of positive correlation between errors is of particular importance when digital radar data is being examined. Since there is the possibility that the radar signals might not be processed in a completely time-coherent fashion, the cross-correlation function could be decreased when measured from the radar display scope.

ANALYSIS

CONTROL VARIABLES

The basic analysis for this program consisted of viewing an air traffic control terminal radar system as if it were comprised of a set of six (6) independent control variables:

1. Radar types (T) -- primary and secondary (raw and beacon);
2. Display types (D) -- scan-converted (RBDE) and PPI;
3. Flight patterns (F) -- tandem, open weave, closed weave;
4. Radials (R) -- representative of bisectors of the four quadrants of the sample airspace, or flight courses bearing approximately 50°, 140°, 230°, and 320° from the radar antenna site;
5. Altitudes (A) -- representative of horizontal sampling of the terminal airspace at its upper and lower boundaries and at two intermediate levels (approximately 20, 14, 10, and 3 thousand feet); and
6. Range blocking (Q) -- from minimum range to 25 nautical miles (approximately), and from 25 nautical miles to maximum range (50 nautical miles).

The test design was laid out as a $2^3 \times 3 \times 4^2$ factorial experiment, by virtue of two levels each for variables T, D, and Q, plus three levels of F, and four levels each of R and A. The design goal was to perform a set of 384 experimental runs.

RESPONSE VARIABLES

The responses, or system performance measures, were time traces (that is, scan-by-scan determinations) for each of two independently tracked aircraft of similar characteristics for each cell in the design matrix.

For each of the 384 experiments, or cells within the design matrix, these time traces provided a set of primary responses as follows:

- Y_1 -- the arithmetic average ($\bar{X}$) and variance (s^2) of the slant range error for each aircraft, in nautical miles -- calculated on a scan-by-scan basis by subtracting the measured slant range (precision track) from the displayed slant range (photographed track);
- the arithmetic average ($\bar{X}$) and variance (s^2) of the azimuth error of each aircraft, in nautical miles -- calculated on a scan-by-scan basis by subtracting the measured azimuth (precision track) from the displayed azimuth (photographed track).

The Y_1 measures of range error provided a set of four responses characterizing the range error for each cell within the design matrix:

- R_1 -- the range error of Aircraft One;
- R_2 -- the range error of Aircraft Two;
- R_1 Var -- the variance for range error R_1 ; and
- R_2 Var -- the variance for range error R_2 .

The Y_1 measures of azimuth error were transformed from angular terms (degrees) to nautical miles so as to provide a consistent metric to describe the response measures and so as to provide a linear form of the data. These measures provided a set of four responses characterizing the azimuth error for each cell within the design matrix:

- Az_1 -- the azimuth error of Aircraft One;
- Az_2 -- the azimuth error of Aircraft Two;
- Az_1 Var -- the variance of azimuth error Az_1 ; and
- Az_2 Var -- the variance of azimuth error Az_2 .

SYSTEM PERFORMANCE MEASURES

From the eight response measures of system performance just described, the following set of system performance measures were derived:

1. Separation error -- the straight-line distance derived from the position of the two aircraft depicted on the display minus the straight-line distance between the two aircraft as calculated from the position determination of the two independent tracking radars. This calculation was made on a scan-by-scan basis, providing an average separation error and variance for each cell in the design matrix (Se and Se Var).
2. Correlation coefficient between the range error of Aircraft One with the range error of Aircraft Two, on a per scan basis. This provided a measure of the independence of the range error when two aircraft are in geographical proximity to each other (COR $R_1 R_2$).
3. Correlation coefficient between the azimuth error of Aircraft One with the azimuth error of Aircraft Two, on a per scan basis. This provided a measure of the independence of the azimuth error when two aircraft are in geographical proximity to each other (COR $A_1 A_2$).

4. Correlation coefficients between the range error of Aircraft One with the azimuth error of Aircraft One, on a per scan basis, and the same for Aircraft Two. These provided measures of the independence of the two components which account for the overall position error of a single target (COR R₁ A₁ and COR R₂ A₂).

5. Multiple correlation coefficients derived from the range error and the azimuth error of Aircraft One with separation error between the two aircraft, on a per scan basis. Similarly the range error and the azimuth error of Aircraft Two were regressed on the same separation error. This response measure provides information about the dependence of separation error on the individual error values for just one aircraft; or, looking at it another way, this measure is indicative of how well you can predict the separation error from a set of range errors and azimuth errors derived for just one aircraft (RSQ 13 and RSQ 24).

6. Multiple correlation coefficient derived from range error and azimuth error of Aircraft One and the range error and azimuth error of Aircraft Two, on a per scan basis. This measure provides information about the dependence of separation error upon a set of values for range error and azimuth error when two aircraft are in proximity to each other (RSQ 1234).

IMBALANCE IN NUMBER OF OBSERVATIONS

Some 94 experimental trials are missing from the planned program of 384 cells in the $2^3 \times 3 \times 4^2$ experimental design. Some of the cells are empty (or effectively so) because of holes in the radar coverage, either by the ASR-4 airport surveillance radar, or by either of the track radars. For example, the 3° angle of elevation on the ASR antenna intersects the 50-nautical-mile boundary of the sample airspace just above the 8,000-foot level; and data for the 3,000-foot altitude is missing from mid-range (25 nautical miles) to that boundary, all of range block Q2. Data missing because of holes in the radar coverage had no serious effect upon the data results.

However, there are an appreciable number of random missing cells, missing primarily because of faulty data recording equipment and/or human error. This type of missing data did impact the analysis of variance in several analyses where the two-way tables were very seriously imbalanced.

For example, a cell in the two-way table either had zero data, or the number of data entries was less than a one-third to one-quarter of the average number of entries in the rest of the table. Where this happens in the series of data tables at the end of this report it will be called to the reader's attention.

To illustrate the wide range in number of observations by test design data cell, the complete listing for two-way cells is as follows:

NUMBER OF OBSERVATIONS FOR TWO-WAY CELLS
(Combined N's for Phase I and Phase II)

D X T (Displays by Radar Mode)				D X R (Displays by Radials)			
	T1	T2			R1	R2	R3 R4
D1	199	194		D1	93	102	98 100
D2	206	202		D2	104	101	102 101
D X Q (Displays by Range Block)				D X F (Displays by Flight Pattern)			
	Q1	Q2			F1	F2	F3
D1	237	156		D1	134	134	125
D2	240	168		D2	135	140	133
D X A (Displays by Altitude)							
	A1	A2	A3 A4				
D1	117	98	108 70				
D2	112	98	125 73				
T X R (Radar Mode by Radial)				T X Q (Radar Mode by Range Block)			
	R1	R2	R3 R4		Q1	Q2	
T1	104	101	100 100	T1	236	169	
T2	93	102	100 101	T2	241	155	
T X F (Radar Mode by Flight Pattern)				T X A (Radar Mode by Altitude)			
	F1	F2	F3		A1	A2	A3 A4
T1	135	140	130	T1	114	100	119 72
T2	134	134	128	T2	115	96	114 71
R X Q (Radial by Range Block)				R X F (Radial by Flight Pattern)			
	Q1	Q2			F1	F2	F3
R1	118	92		R1	57	85	55
R2	120	83		R2	75	49	79
R3	122	78		R3	62	75	63
R4	117	84		R4	75	65	61
R X A (Radial by Altitude)							
	A1	A2	A3 A4				
R1	46	59	44 48				
R2	68	40	64 31				
R3	47	65	61 27				
R4	68	32	64 37				
Q X F (Range Block by Flight Pattern)				Q X A (Range Block by Altitude)			
	F1	F2	F3		A1	A2	A3 A4
Q1	160	160	157	Q1	118	112	120 127
Q2	109	114	101	Q2	111	84	113 16
F X A (Flight Pattern by Altitude)							
	A1	A2	A3 A4				
F1	78	71	80 40				
F2	87	68	69 50				
F3	64	57	84 53				

As a consequence of this imbalance in the number of observations in each cell, a standard orthogonal analysis of the results was not possible. A full non-orthogonal analysis of these data, taking into account all main effects and the interactions, proved insufferably large. Also, there was little interest in or expectation that the higher order interactions would be statistically significant.

MODIFICATION OF THE TEST DESIGN

The statistical study concerns the analysis of the basic three recorded responses (slant range error, azimuth error, and separation error) for each of the 290 experiments (or cells in the design matrix) that were eventually performed.

Each of the response variables, or performance measures, was used for conducting an analysis of variance for determining the effect of the six independent variables on the response variables. The analysis that was finally selected required the estimation of the parameters in 15 separate mathematical models. Each model was accompanied by an analysis of variance table, each table in turn requiring the solution of a set of normal equations for nonorthogonal data. The details of these computations are explained in appendix A of the Part II report.

The results of these analyses were displayed by plotting the averages associated with the different treatments along with their reference, 95-percent confidence "t" gate (see appendix B of the Part II report).

The 15 separate mathematical models resulted from the determination to examine the six main effects (independent control variables) and the 15 two-way tables composed by considering the six independent variables, two at a time.

The analysis selected was to estimate the parameters in the mathematical model of the form --

$$Y_{ijk} = \mu + \rho_i + \tau_j + \rho\tau_{ij} + e_{ijk}$$

where: Y_{ijk} = observations

μ = grand mean

ρ_i = effect of rows

τ_j = effect of columns

$\rho\tau_{ij}$ = effect of row and column interaction

e_{ijk} = residual error, assumed to be NID ($\mu=0$).

This model was approximate for the six main effects analyses and for each of the 15 possible two-way effects.

To say that the model is an approximation means that the effect of each of the six control variables is estimated five times as it is paired with or affected by the other five variables. Rather than partial out the effect of all of the five main effects, all 15 two-way interactions, all three-way interactions, all four-way interactions, and the five-way interactions, the alternative scheme already described was selected. Furthermore, because of missing data, there were instances when the matrix for three-way and higher interactions had zero cells, making an analysis all but impossible. The conclusions obtained from the model which was used provide a conservative estimate of the effects described.

Since 15 analyses were done for each response variable, we obtained five estimates of the significance of each main effect. In our analyses, we will occasionally see cases where main effects are declared statistically significant in some of the two-variable analyses and nonsignificant in others. Once a main effect is found to be significant, we should declare it significant. The failure to be significant on all occasions is due to the presence of bias in the error mean square, this bias coming from main effects not taken out in the two-way analysis (that is, variables omitted from the two-way analysis). These enter into the error term, causing it to be inflated, which results in an under-estimation of the significance of the main effect.

In determining whether real differences exist between the treatment averages (for main effects), the reference distribution is constructed using an estimate of variances with the role of the main effects and all interactions swept out (to the degree possible in this nonorthogonal analysis). In fact, we employed the smallest mean square error obtained from all the two-way analyses in constructing the reference distribution. Even here, the error mean square is conservative, since it does not exclude all effects.

The analysis of variance tables are unique in that they give the sums of squares for each effect independent of all other effects considered. Because of the nonorthogonal matrix, the experimental designs of these independent sums of squares do not add up to the total sum of squares. The computer program used was the F4STAT, and the work was performed at the Princeton University Computer Center.

REPLICATION, PHASE II DATA

Since this analysis program was of such a magnitude and comprised of such a large set of response variables and dependent variables, a partial replication was conducted. With so many main effects and two-way effects to examine for the 17 different response variables, it was very probable that a reasonable number of statistically significant signals might appear in the analysis by pure chance. The replication (Phase II) consisted of redoing the original design matrix with only two principal differences:

1. The direction of flight of the aircraft as they flew a radial was reversed. For example, for the 8,000-foot altitude, tandem flight pattern, radial number 3, if the aircraft flew inbound to the antenna for the first run series (Phase I), it flew outbound in the corresponding run of the replication series (Phase II). Besides providing a replication, this reversal provided data concerning the possible effect of approach velocity on the radar.

2. The second precision tracking radar (TAIR) was not used and a time/frequency, air-to-air ranging equipment (ASMS) was used to determine the measured aircraft separation. This means that, instead of the 17 response variables available in the Phase I portion, only eight response variables were available in the Phase II portion.

The following response variables were not available from Phase II: mean range error and variance for Aircraft Two, azimuth error and variance for Aircraft Two, the correlation coefficient between the range error of Aircraft One and Aircraft Two, the correlation coefficient between the azimuth error of Aircraft One and Aircraft Two, the correlation coefficient between the range error and the azimuth error of Aircraft Two, the multiple correlation coefficient of the range error and azimuth error of Aircraft Two with separation error, and the multiple correlation coefficient of the range error and azimuth error of Aircraft One and Aircraft Two with separation error.

Again the basic design was $2^3 \times 3 \times 4^2$ factorial, only with fewer response variables to analyze. Of the 384 expected cells in this design matrix, only 221 contained experimental results. Thus, the complex analysis procedure was replicated for Phase II.

Included in the analysis of this data was an examination of the distribution of the three principal response variables:

1. The slant range error of the tracked aircraft,
2. The azimuth error of the tracked aircraft, and
3. The separation error between the two test aircraft.

POOLED DATA - COMBINED PHASE I AND PHASE II

Since this data collection program resulted in a large data set extensively sampling the terminal radar environment, it provided a good opportunity, with a sufficient data base empirically derived, to analyze the nature of central tendency and the nature of the tails of the distribution of these three response variables.

For this report, all similar system response measures were pooled and combined into a single measure. For example, range error of Aircraft One and range error of Aircraft Two for the Phase I data sets were pooled with range error of Aircraft One for the Phase II data set into a single expression of range error (there being no data track for Aircraft Two in Phase II from which to derive a separate measure of range error for Aircraft Two, Phase II). An analysis of variance was then performed for the pooled expression.

The reader can therefore expect some minor differences in data interpretation (from the Part II interpretation, previously published), because this report is in fact based on separate analyses.

Generally speaking, as the data sets are pooled, the data should in fact become more homogeneous and less subject to extraneous effects.

USE OF CORRELATION COEFFICIENTS

The analysis performed included the use of correlation coefficients and multiple correlation coefficients viewed as response variables. The correlation coefficient is a measure that is bounded by the limits $-1 < \rho < +1$. The comparison of correlation coefficients is thus made awkward, particularly in those cases where values of ρ are close to the bounds. Changes of ρ close to the bounds are not equivalent to equal changes in the middle of the interval. For example, change in the correlation coefficient of say 0.50 to 0.51 is of much less practical importance than a change of 0.90 to 0.91, and this change is in turn much less significant than a change of 0.98 to 0.99.

The intent in the use of multiple correlation coefficients is to maximize ρ or to increase its value to as close to +1.00 as possible. Thus, the correlation measure is simply inappropriate for comparisons or use in an analysis of variance program.

To avoid this handicap when comparing correlation coefficients, it is usual to transform the correlations into a measure that does not have either -1 or +1 as its bounds. The accepted transformation is the one suggested by R. A. Fisher, i.e., $Z = 1/2 \ln \frac{1+\rho}{1-\rho}$. All analyses involving comparisons between correlations

as a function of the experimental parameters have been performed in the transformed scales.

Some of the basic sets of response variables previously described were the variances of the range error, the azimuth error, and the separation error. Because the mean response was expected to be positively correlated with the variance, the logarithmic transformation of the variance, when used as a response variable in the analysis of variance, was used. However, the final reported results and the two-way tables have been re-expressed in terms of the natural metric -- variance or standard deviation.

RESULTS

GENERAL

The results will be presented in terms of the effect of the six main control variables:

1. Radar mode (T) -- primary radar (T1), and secondary radar (T2);
2. Display type (D) -- scan-converted, RBDE (D1), and PPI (D2);
3. Radials (R) -- representing slight geographical effects of primarily over water versus primarily over flat terrain; 050° (R1), 140° (R2), 230° (R3), and 320° (R4), each R-block consisting of data from two data runs, one in each direction of flight, for both tracked aircraft in Phase I, and for the tracked aircraft in Phase II;
4. Range blocking (Q) -- from minimum range (4 to 7 nautical miles) to approximately 25-nautical-miles range or when the range setting was changed (Q1), and from 25 nautical miles to 40- to 47-nautical-mile range where tracking data ceased to be sufficient (Q2);
5. Altitude (A) -- 20,000 feet (A1), 14,000 feet (A2), 8,000 feet (A3), and 3,000 feet (A4); and
6. Flight pattern (F) -- tandem (F1), open weave (F2), and closed weave (F3) -- representing the different angular relationships of two aircraft as they converge and diverge in close proximity to each other.

Because of the quantity and details of the whole analysis of this project, this report addresses itself to a summary and analysis of the pooled data set. For a more detailed presentation, including tables of data results prior to pooling, the reader should refer to Part II of this report, published separately.

The discussion of the results will center principally on the data in tables I, II, and III in this report. Only those differences that were assessed as being statistically significant for the main effects and for the two-way interactions will be presented in this discourse. However, the reader may determine the exact level of all effects by examining Part II.

INTERPRETATION OF STATISTICAL SIGNIFICANCE

For purposes of discussion, a "true" difference, or statistically significant difference, between two or more conditions (subsets) is said to exist if the statistical significance in the probability level is .05 or smaller. The determination of the existence of significant differences is made on the basis of comparing the means of the responses for that set of conditions. For

comparing k means, we are attracted to the $k(k-1)/2$ possible differences. The Student's "t" reference distribution approach (see appendix B in Part II, under separate cover) provides a convenient device for making these many comparisons.

HOW TO READ THE TABLES

The tables need some explanation. To assist the reader in this regard, the following statement is provided.

Table I presents an "overview" of all the tables in the table II series. Table II indicates which of the system control variables (D, T, R, Q, F, A -- display type, radar mode, radial, range block, flight pattern, altitude) statistically affected the system response measures (position error, separation error, etc.).

Reading across table I, the first line of tabular entries informs us that the effect of the control variable D (radar display type) on the magnitudes of the system response measures was (**) in columns 2, 3, 4, 6, 7, 8, 9, 10, 11, 12) statistically significant for mean position error, for position error variance, for mean separation error, for mean range error, for range error variance, for mean azimuth error, for azimuth error variance, for correlations between range error and azimuth error of aircraft (tracked), for correlations of range error Aircraft One to range error Aircraft Two, and to correlations between azimuth error Aircraft One to azimuth error Aircraft Two. Similarly this first line of tabular entries informs us that the effect of control variable D on magnitudes of system response measures was (ns in columns 5, 13, 14) not significant for separation error variance, nor for multiple correlations between range errors (of both aircraft independently) and azimuth errors (of both aircraft independently) regressed on separation error (between the two aircraft).

Reading down the fifth column, the effects of each of the other control variables in turn on magnitudes of separation error variance (s^2) were statistically significant (**); but for all two-way interactions (DXT, DXR...FXA), the effects on separation error variance were not statistically significant (ns).

Table II (series) should be read across the rows, not down the columns. The left-hand column reading down, D, T, R, Q, F, AFA, lists the letter designators for main effects and two-way effects. The values across the rows show the significance level (probability) extracted from the analysis of variance.

There are five values for each main effect because of the fact that it was estimated every time a two-way effect was estimated. Thus, reading from table II-1, we see that the D main effect (display main effect) was statistically significant, and greater than the .000X probability level; the T (radar mode) main effect was not statistically significant, as indicated by .798, .806, .634, .770, and .561 levels respectively, through the FXA (flight pattern by altitude) effect being not statistically significant at the .746 level. The reader is enjoined to examine table III to find the corresponding magnitude of the difference between the appropriate means that resulted in the probabilities in

table II. For example, table II-1 indicates a significant difference between displays for aircraft position error (.000X), and table III-1 shows that the RBDE displays (D1) had a mean position error of 0.602 nautical miles, whereas the PPI displays (D2) had a mean position error of 0.762 nautical miles. This difference of 0.160 nautical miles was very statistically significant, with the RBDE displays having the smaller mean position error.

APPLICATION OF THE RESULTS

The reader should be aware that the results reported here are not exactly the same as summary results published in the Part II report, even though the same data were used for both reports. The results in Part II are derived from analyses of three independent data sets and a comparison/summary thereof. The results in this report are derived from a statistical pooling of these three sets of data, and the analyses of variances in this report were calculated on this pooled data. This should result in a more homogeneous and normal distribution of the subsets of data. However, where the analysis of variance matrices had an imbalance in the number of entries, this would still hold true (e.g., in the QXA -- Range Block by Altitude analysis, the second range block and minimum altitude data set still has an abnormally small number of entries as contrasted to the rest of the matrix).

This report is addressed to a statistical characterization of the response variables (i.e., range error or azimuth error for each aircraft, position error per aircraft, separation error between the two aircraft, and the related variances, correlation coefficients and multiple correlation coefficients) of a typical ASR-4 system. ("Typical" implies representative of the population of airport surveillance radar systems of ASR-4 type which were in operational service at field facilities of FAA air traffic control.)

This report does not attempt, nor does the project effort as a whole, to determine any cause and effect of the magnitude of the responsive variables, nor of their relationships. The writers are fully aware that some of the results were determined by the specific design and/or engineering status of the system, and that if these were changed, some of the results might be affected. Thus, the results are relative to the specific system operating conditions. Therefore, any broad generalizations to another population of radar systems should be made only with due caution.

While, from a viewpoint of correct experimental design, one would seek a specific evaluation of each radar system (such as ASR-5 and ASR-7), certain generalizations from this study can be expected to apply. Within the family of airport surveillance radars applied in the federal air traffic control system, design changes have been most conservative with respect to factors affecting target position and separation. Mainly, design changes have affected quality of detection and control of noise.

It is anticipated that the effects due to the primary control variables (type of display system, radar mode, target bearing, range blocking, flight pattern, and target altitude) are generalizable to radars other than ASR-4: however, the absolute magnitudes of range error and azimuth error, or their products, are not generalizable. Thus, we would expect the relative difference of a response variable, say range error for range block 1 versus range error for range block 2, in all likelihood would be generalizable, but the absolute magnitude of the range error, in this case 0.0567 nautical miles for range block 1, is likely to vary from one system test to another.

Furthermore, the introduction of digital processing of radar signals is such that generalization from this study of broadband radar to digitized, narrowband radar systems is not expected to be valid, and specific evaluations of those systems should be conducted.

ANALYSIS OF MAIN EFFECTS

DISPLAYS (D) -- SCAN-CONVERTED (D1) AND PPI (D2). The data indicates that the PPI displays exhibit a statistically larger position error and position error variance than did the RBDE (scan-converted) displays. Also, the PPI displays exhibit a statistically larger separation error than did the RBDE's. Since the processed radar signals feeding these two sets of displays were essentially equivalent, the RBDE's could be considered a preferred display for determinations of both position error and separation error, inasmuch as a minimum error in these respective variables is desirable.

The data indicates that the PPI displays exhibited a statistically larger mean range error and azimuth error than the RBDE displays: however, only the range error variance was significant, with the PPI again having the larger range error variance.

The data shows that the RBDE tended to display the range of the aircraft as less than the true range; whereas, the PPI tended to display the range as greater than the true range.

The mean azimuth error for the RBDE's was, for all intents and purposes, zero; whereas, the PPI tended to displace the target towards the radar leading edge or at a greater angle than true azimuth. Thus, the indication is that the RBDE displays performed with a minimum range and azimuth error.

The correlation coefficients between (1) the range error of two aircraft in proximity to each other, (2) the azimuth error of two aircraft in proximity to each other, and (3) the range error and azimuth error of a single aircraft all were significantly larger for the PPI's than for the RBDE's. This indicates that the PPI displays tended to preserve the relative spatial relationship between two adjacent targets better than did the RBDE displays. That is, when an aircraft tended to vary from its true position on a PPI, an aircraft target in proximity to the first target tended to vary in the same direction and magnitude. Furthermore, the within-target consistency (i.e., the relative relationship between the magnitude of a target's range error and azimuth error tended to vary in a monotonic manner) was better preserved on a PPI display than on an RBDE display.

RADAR MODE (T) -- PRIMARY RADAR (T1), AND BEACON (T2). The radar mode selected, raw radar or beacon (primary and secondary radar respectively), did not appear to significantly affect the magnitude of position error, position error variance, or separation error, although variance of the separation error was significantly larger for the beacon radar mode. This means, for the beacon radar mode, that for 95 percent of the time, the aircraft could be expected to be between 0.292 nautical miles less than, to 0.436 nautical miles more than actual separation [mean error (0.072 nautical miles) $\pm 1.96 s \sqrt{.0346}$]. For comparison, the 95-percent confidence limit for the primary target is -0.224 nautical miles to +0.324 nautical miles.

Neither radar mode evidenced significantly different mean range error or range error variance, although the primary radar indicated a significantly greater mean azimuth error, with the beacon radar having the larger azimuth error variance.

The data indicates that the primary radar exhibited a significantly larger positive correlation coefficient between range error and azimuth error, range error and range error, and azimuth error and azimuth error than did the beacon radar.

RADIALS (R). Radials represented more of a random variable of the environment which we could treat as a control variable and determine some effects on the system response variables. In general, the radials represented the effect of flying (1) almost exclusively over the ocean, (2) almost exclusively over flat terrain, and (3) over surface of mixed character between marsh, water, and flat terrain.

For the radials variable, there was a very significant effect on the mean and variance of the position error and on the mean and variance of the separation error. For interpretation, however, no clear cut effect can be attributed to the over-land condition versus over water. Thus we conclude merely that the data results substantiate that terrain surrounding a radar site apparently affects radar target position.

The data indicates that the radials had a significant effect upon the mean range error, and, since the order of the mean range error by radial shifted for the various data collection phases, it suggests that a possible mixture of topographic effect and weather effect occurred. There was a tendency for the radials over marsh and bayshore (R1 and R3) to have a larger mean range error than those over ocean (R2) and flat terrain (R4). The variability of the range error was not significantly affected.

The only correlation coefficient that had a significant radial effect was the simple correlation between the range errors of two adjacent aircraft targets.

RANGE BLOCKING (Q). Q1, MINIMUM RANGE TO ABOUT 25 NAUTICAL MILES, AND Q2, 25 NAUTICAL MILES TO MAXIMUM RANGE. This control variable represented a mixture of two parameters, distance from the radar antenna, and distance from the center of the display. The minimum observed range was from 4 to 7 nautical miles, and the maximum observed range varied from 40 to 47 nautical miles.

The data indicates that the range blocking had a significant effect upon the mean range error, with Q1, the range block closer to the antenna, as expected, having the smaller error. No effect on the range error variability was observed.

The mean azimuth error and the variance of the azimuth error were significantly affected by the range blocking, again with the inner range block, Q1, having the smaller mean and variance.

The data indicates a significantly smaller mean position error and mean separation error, with correspondingly smaller variances, for the Q1 range blocks. When an aircraft is within 25 nautical miles of the radar antenna, its displayed position can be expected to be (on the average) 0.525 nautical miles away from its true position; and when an aircraft is farther than 25 nautical miles from the radar antenna, its radar target can be expected to be 0.917 nautical miles (on the average) from its true position. When the two aircraft were displayed as 3 nautical miles apart, they were (on the average) 2.957 nautical miles apart in range block Q1 and 2.912 nautical miles apart in range block Q2. While true separation was slightly less than displayed separation, the difference appears to be below the threshold of discernibility to the eyes of a radar controller using displays of this scale.

Since the means and variances for these response variables were significantly different for Q1 and Q2, the following is illustrative of the data:

1. Position error (given the true position of an aircraft) --
Q1 displayed position average error = 0.525 nautical miles,
Q2 displayed position average error = 0.917 nautical miles;

Probable variability of the average displayed position error
(99 percent of the time) --
Q1 = -0.265 to +1.315 nautical miles,
Q2 = -0.245 to +2.079 nautical miles;

2. Separation error (given that 3 nautical miles is the true separation) --
Q1 average displayed separation = 2.957 nautical miles,
Q2 average displayed separation = 2.912 nautical miles;

Probable variability of the average displayed separation
(99 percent of the time) --
Q1 = 2.597 to 3.317 nautical miles,
Q2 = 2.408 to 3.417 nautical miles.

The difference in variances between Q1 and Q2 is apparent when the respective data results are substituted into the expression

$$\bar{X} \pm t \sqrt{s^2}, \text{ where } t = 2.576 \text{ for the 99-percent confidence interval:}$$

Most probable (99-percent confidence) variability of the position error mean --

$$\begin{aligned} Q1 &= 0.525 \pm 2.576 \sqrt{.0941} , \\ Q2 &= 0.917 \pm 2.576 \sqrt{.2035} ; \end{aligned}$$

Most probable (99-percent confidence) variability of the separation error mean --

$$\begin{aligned} Q1 &= 2.957 \pm 2.576 \sqrt{.0195} , \\ Q2 &= 2.912 \pm 2.576 \sqrt{.0384} . \end{aligned}$$

The correlation coefficient between the range error of an aircraft and the azimuth error of that aircraft was significant, as was the cross correlation between the azimuth errors of two adjacent aircraft.

The multiple correlation coefficient of the two range errors and the two azimuth errors on separation error was significantly larger for range block Q2, the outer range block.

ALTITUDE (A) -- 20,000 (A1), 14,000 (A2), 8,000 (A3), 3,000 (A4). The data indicates that the altitude of the aircraft had a very significant effect upon the mean position error, the mean separation error, and their associated variances. The effect was generally in the expected direction that is, maximum mean error and variance associated with maximum altitude (A1), and minimum mean error and variance associated with minimum altitude (A4). However, the function was not as smooth as desired.

The mean range error and associated variance were significantly affected by the altitude. Again, the magnitude of the error was in the expected direction, but the function was not as smooth as expected.

The only other variable significantly affected by the control variable, altitude, was the simple correlation coefficient between range error and azimuth error.

FLIGHT PATTERN (F) -- TANDEM (F1), OPEN WEAVE (F2), AND CLOSED WEAVE (F3).

These three flight patterns were included in the test design principally to provide a random sampling of angular convergence and divergence of aircraft. Since data results included a significant effect by this (F) control variable upon a number of response variables, we feel obligated to present these results. Since the design intent was to include flight pattern as a random variable, just as radar propagation effects and environmental effects, which would all be included in the error term when testing for significant main effects, it was so included here.

The mean separation error and its associated variance were very significant, with the tandem flight pattern having the significantly larger separation error. This is not surprising, since the separation between the test aircraft in the tandem flight pattern was determined principally by range error, which was significantly larger than azimuth error. Correspondingly, the separation between the test aircraft in the open weave and closed weave flight patterns was principally determined by the azimuth component of the separation vector; and the weave patterns had the smaller separation error. The position error variance and the separation error variance also were significant, however no clear-cut relationship existed here.

The data indicates that the correlation coefficient between the range error of the two aircraft and the multiple correlation coefficient of separation error on the two range errors and two azimuth errors were significantly affected by the flight pattern control variable. Again, no consistent effect is observable.

ANALYSIS OF TWO-WAY INTERACTIONS

So far in the presentation of results, only the statistically significant results due to the main effects have been presented. Thus, we have stated that six control variables were employed in the series of experiments, and that each control variable had at least two treatment levels. For example, the treatment levels for the control variable D (displays) were scan-converted RBDE (D1) and PPI (D2). When a main effect was declared statistically significant, this meant that changing of the level of the variable significantly affected the response.

Now the significance of any two-way interactions will be presented. Declaring a two-way interaction to be significant means that a change in the level of one variable had an effect upon a second variable even though the level of the second variable did not change, or it means that one of the levels of a specific variable, when in the presence of just one level of a second variable, resulted in a change in the response such that no simple additive effect can account for the change.

Since only a few of the two-way interactions have any operational utility associated with them, these will be singled out for discussion.

The Display by Radar Mode (DXT) is of some interest since, if one display type and one radar mode when combined performed significantly poorer or better than the averages for the other two-way combinations, this should be of some interest to operational personnel. The data indicates no significant preference (either to accept or to reject) for any of the four possible combinations (D1 X T1, D1 X T2, D2 X T1, D2 X T2).

The Radar Mode by Range Block (TXQ) and Radar Mode by Altitude (TXA) are of interest in that, if a particular range block or altitude favored a radar mode, such information would be useful in system planning. Neither of these two-way interactions significantly affected any of the response variables.

The only other two-way interaction of operational importance is Range Block by Altitude (QXA). Again, no two-way combination of range block and altitude of the eight possible combinations (Q1 X A1, Q1 X A2, Q1 X A3, Q1 X A4, Q2 X A1, Q2 X A2, Q2 X A3, Q2 X A4) had a significant effect upon any of the response variables.

ANALYSIS OF RESPONSE VARIABLES

The response variables have been partially discussed from the standpoint of how they were affected by the control variables. However, it would be useful to discuss them by themselves.

(1) POSITION ERROR. The position error as presented in the tables is defined in terms of the range and azimuth errors on a radar scan by radar

scan basis, i.e., $PE = \sqrt{RE^2 + AE^2}$

$$\text{position error} = \sqrt{\text{range error}^2 + \text{azimuth error}^2}$$

As such, it is always computed as being positive in sign, regardless of the relative signs of the range and azimuth errors.

The distribution of the position errors has therefore been "folded" around zero, as if the absolute value of a normally distributed variable had been used. In order to unfold the distribution and estimate the "true" characteristics of the position error, it was necessary to use the methods of Johnson and Leone (reference 3) for estimating the ratio parameter of the underlying mean to the standard deviation.

For discussion purposes, the unfolded estimates of the mean position error and variance are:

mean position error = -0.1764 nautical miles

position error variance = 0.9784 nautical miles

This compares to the "folded" estimates of (see table II):

mean position error = 0.6835 nautical miles

position error variance = 0.1383 nautical miles

Either of these calculations is analogous to looking at the position error as though it were a circular probable error.

As seen from previous discussion concerning the range error and the azimuth error with their concomitant cross-correlation coefficients, the probability density function is not circular, but an ellipse. Therefore, the true position error is defined by the elliptical probable error distribution for the combined range error and azimuth error (figures 10 and 11 for Q1 and Q2 respectively).

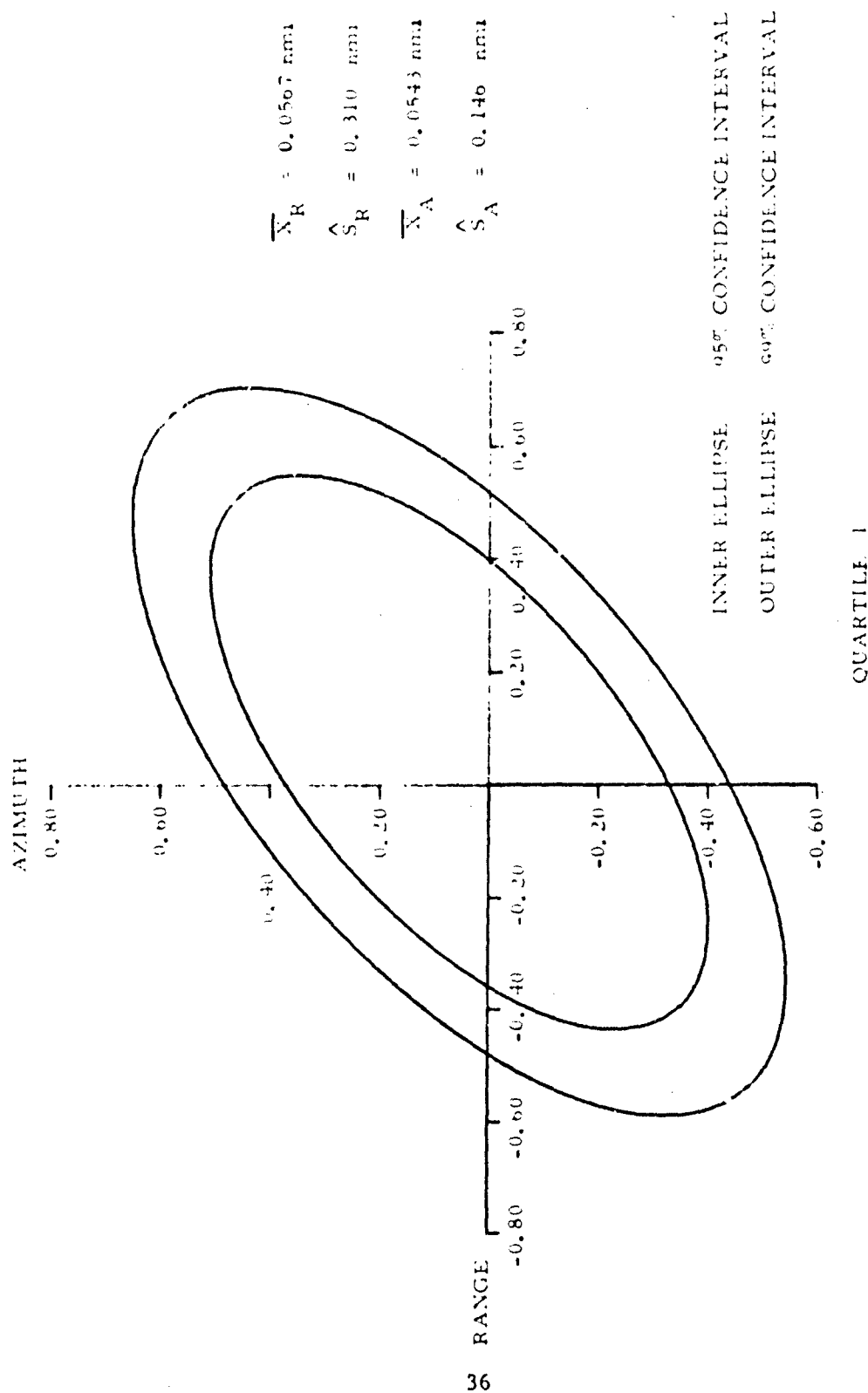
The center of the ellipses was established as the mean range error and the mean azimuth error. The contour of the ellipse is the 95-percent boundary of the mean deviation of the range and azimuth error. The tilting of the ellipse is due to the fact that the instantaneous range and azimuth values were correlated with each other.

The reader should be cautioned about extrapolating from these ellipses any inferences concerning any expected overlap of adjacent targets because at any time there is a significant positive cross-correlation between the range error and azimuth error of the two depicted targets. The question of probable overlap for adjacent targets can be addressed by examining the separation error data.

(2) SEPARATION ERROR. The mean separation error of 0.061 nautical miles, with an average standard deviation of 0.164 nautical miles (variance = 0.027 nautical miles), indicates that displayed separation, on the average, was greater than the true separation of two adjacent aircraft in close proximity to each other. The maximum deviation around the mean was -0.94 nautical miles to +0.98 nautical miles (see Part II report, under separate cover, tables V-3 and VI-3 in the addenda). This means that, for the separation range under consideration during this study, when aircraft radar targets were displayed at 3 nautical miles in separation, they were never less than 1.959 nautical miles, nor more than 3.879 nautical miles from each other (lateral or longitudinal separation). This is derived from somewhere in the neighborhood of 30 thousand observations, and for radar targets that were resolved by the ASP-4, and as measured from the center of the radar blips (targets) whether in primary mode or secondary radar mode.

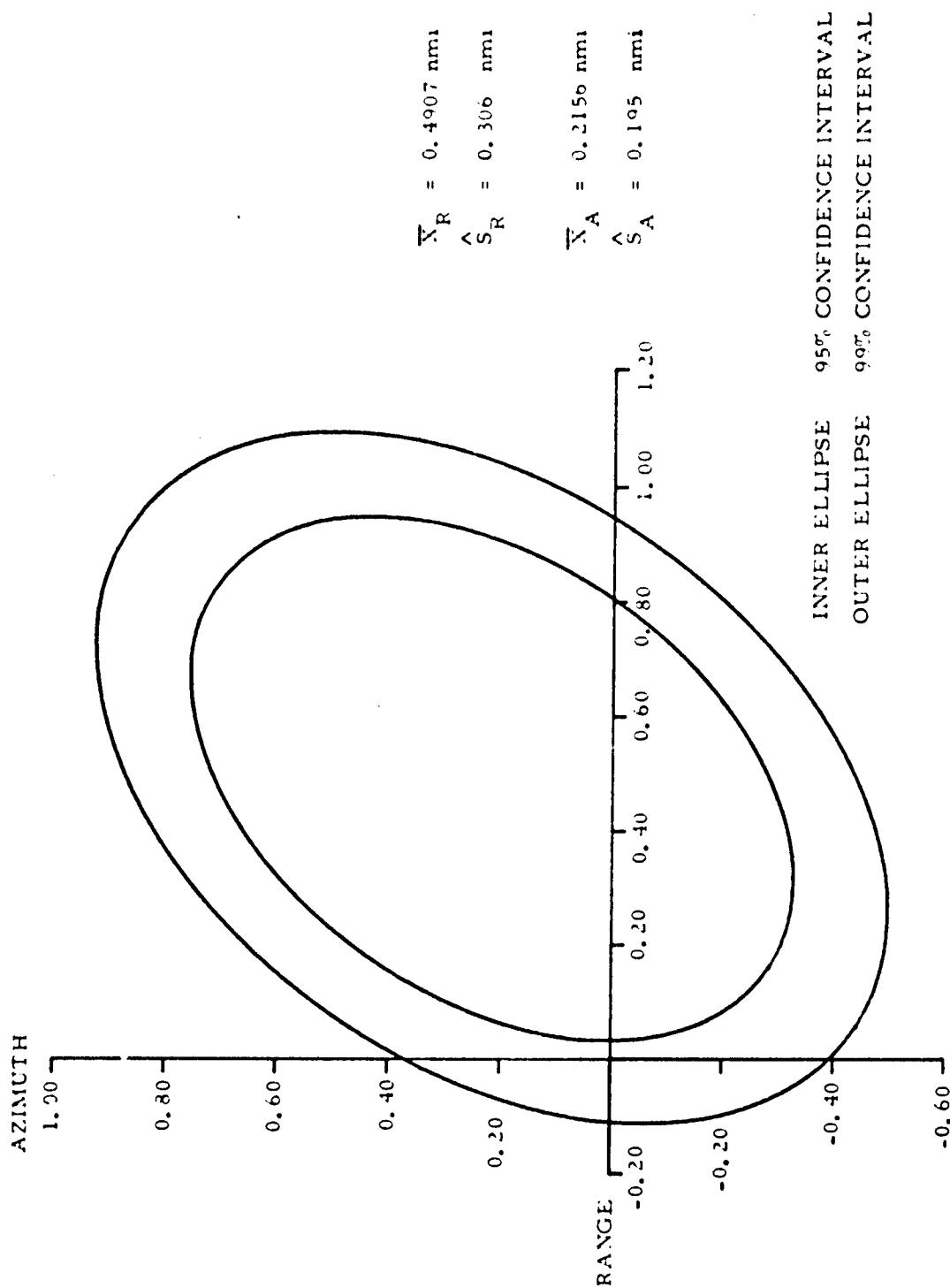
Another point to be discussed here is the cumulative probability density function of the separation error when plotted on double-exponential paper. The data evidences a straight line, demonstrating that the data is NOT normally distributed. The exponential plot (see figure 12) indicates that the data is normal for the central tendency, but that the tails of the distribution look very much like an exponential distribution. What this means is that there were many more large excursions, or data points at the extremes of the distribution, than can be accounted for by a normal distribution.

The magnitude of the separation error was clearly dependent upon the condition of the following control variables: D, R, Q, A, and F; or display type, radial, range block, altitude, and flight pattern, respectively. These have been discussed elsewhere in this report.



74-S-10

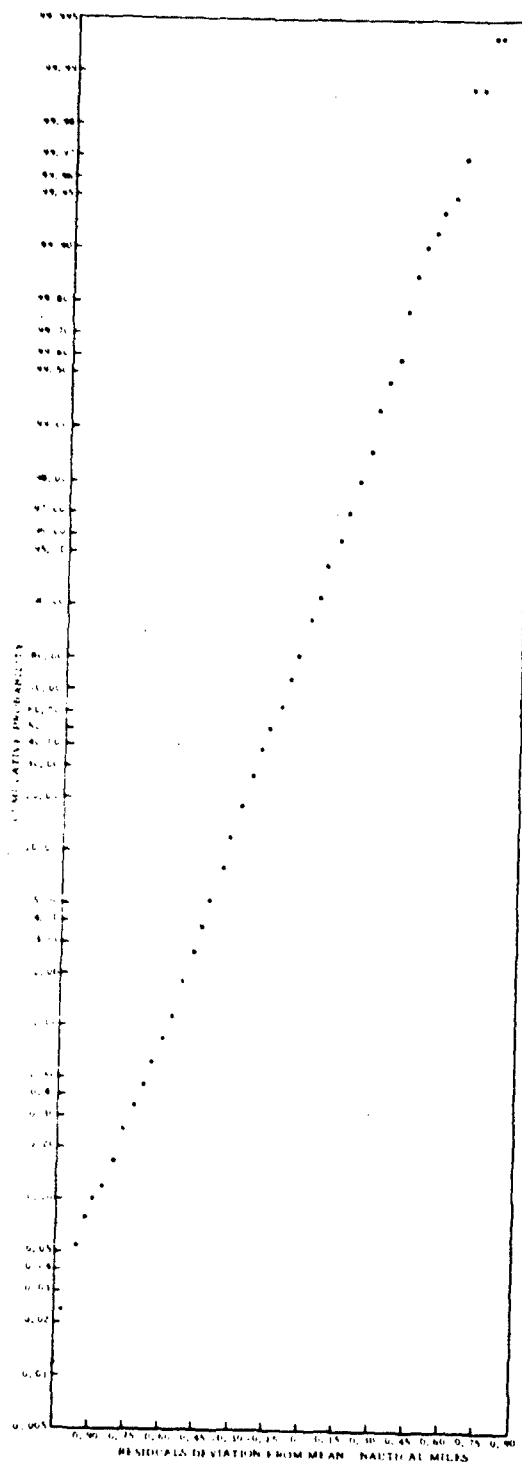
FIGURE 10. PROBABLE DISTRIBUTION OF RELATIVE POSITION ERROR - RANGE BLOCK Q1



QUARTILE 2

74-8-11

FIGURE 11. PROBABLE DISTRIBUTION OF RELATIVE POSITION ERROR - RANGE BLOCK Q2



74-8-12

FIGURE 12. SEPARATION ERROR RESIDUALS ON DOUBLE-EXPONENTIAL PAPER

A further breakdown of the data is of operational interest here: the question of what is the relative magnitude of the separation error when the aircraft are within approximately 25 nautical miles of the radar antenna and at an altitude below 10,000 feet, as compared to being at a range greater than 25 nautical miles from the radar antenna at an altitude of 10,000 feet or higher. The following data is calculated from the QXA Averages data (Range Block by Altitude), table III-14:

- | | | | |
|-----|---|--------------|-------------------------|
| (a) | Q1/A1, A2; Q2/A1, A2, A3, A4; | wt.avg.Se | = 0.0813 nautical miles |
| -- | all airspace within 50 nautical miles and above 10,000 feet; | | |
| | and | | |
| | all airspace from surface to 20,000 feet, and beyond 25 nautical miles. | wt.avg.SeVar | = 0.0324 nautical miles |
| (b) | Q1/A3, A4; | wt.avg.Se | = 0.0243 nautical miles |
| -- | airspace below 10,000 feet and within approx. 25 nautical miles. | | |
| | | wt.avg.SeVar | = 0.0165 nautical miles |

(3) RANGE ERROR. The mean range error of 0.232 nautical miles, with an average standard deviation of 0.308 nautical miles (variance = 0.0951 nautical miles) indicates that the true slant range of the aircraft tended to be significantly closer to the radar antenna than was the displayed range of the aircraft radar target.

The maximum range error observed for all data (approximately 45,000 observations) was a target displayed at 3.052 nautical miles greater than true slant range; and the minimum range error was a target displayed 2.608 nautical miles closer to the radar antenna than the true slant range.

The greatest variability between maximum and minimum within one test run (between 20 and 25 minutes flight time, outbound from the radar antenna on a radial) was 2.590 nautical miles. This was not characterized by purely random error, but had a time-dependent characteristic to it; i.e., the range error tended to get larger as the aircraft proceeded away from the antenna, or, vice versa, the range error tended to get smaller as the aircraft approached the antenna. This is expected, since slant range error increases as ground range increases.

Furthermore, the range error was highly correlated with the range blocking control variable (Q), as indicated by the VERY significant F ratio ($p < .00001$) for the Q variable (average range error Q1 = 0.057, and Q2 = 0.491).

The relative magnitude of the range error of two aircraft in proximity to each other tended to be very highly correlated. For example, the scan-by-scan cross-correlation coefficient was .763 (COR Range error: Range error). The relative magnitude of the range error was also positively correlated with the relative magnitude of the azimuth error on a scan-by-scan basis. For example, the correlation of range error to azimuth error = .486 (COR Range error: Azimuth error).

(4) AZIMUTH ERROR. The mean azimuth error of 0.119 nautical miles, with a standard deviation of 0.167 nautical miles (variance = .028 nautical miles) indicates that the true azimuth of the aircraft tended to be biased towards the radar leading edge. For purposes of this study, the term radar leading edge refers to that portion of the radar target from which the first radar returns are received, and the term radar trailing edge refers to that portion of the target from which the last radar returns (for each sweep of the antenna) are received. Since the antenna rotation is displayed as clockwise from north, the leading edge of the target has a smaller azimuth angle than the trailing edge. It should be noted that such features of the displayed target (data film) were observed and declared as perceived by a human operator, and that the Telereadex operator was instructed to declare the aircraft position to be in the geometric center of the displayed target, or the perceived point of maximum target density.

The maximum azimuth deviation towards the leading edge, for approximately 45,000 observations, was 2.821 nautical miles, and towards the target trailing edge was 2.079 nautical miles. This was characterized by a time-dependent or range-dependent error; that is, the magnitude of the azimuth error tended to increase as the aircraft range increased.

The magnitude of the azimuth error was very significantly correlated with the range of the aircraft, as indicated by the very significant F ($p < .0001$) for the Q variable (average azimuth error Q1 = 0.054 nautical miles, and Q2 = 0.216 nautical miles).

The relative magnitude of the azimuth error for two aircraft in proximity to each other was significantly correlated (COR Azimuth error: Azimuth error = .357). This is not a sufficiently large correlation to indicate a strong predictive relationship.

(5) MULTIPLE-CORRELATION COEFFICIENTS. Two multiple-correlation coefficients were calculated and analyzed. The intent here was to determine how well one could predict or determine the separation error knowing the range error and azimuth error characteristics.

The first question was to determine how well one could predict the separation error knowing the range error and azimuth error of a single aircraft.

The average multiple-correlation coefficient was .388, which means that about 15 percent ($.388^2$) of the variability of the separation error could be accounted for by knowing the range error and azimuth error of a SINGLE aircraft. This indicates that the prediction is relatively weak.

This being the case, how much better does our prediction become if we know the range error and the azimuth error of both aircraft for which the separation error estimate is desired?

To do this, we need to know the range error of each aircraft, the azimuth error of each aircraft, and the cross-correlation coefficient for each of these four responses. Given this information, the multiple-correlation coefficient was .851. This indicates that about 72 percent ($.851^2$) of the variability could now be accounted for by knowing the range error and azimuth error of both aircraft rather than for just one of the aircraft. Thus our prediction is pretty good now.

REFERENCES

1. Technical Facilities at NAFEC (Revised), National Aviation Facilities Experimental Center, Atlantic City, June 1969.
2. Busch, Allen C. and Bradbury, Paul W., Measurement and Analysis of ASR-4 System Error Part II: Analyses, Report No. FAA-RD-73-62, II, August 1973.
3. Johnson, Norman L. and Leone, Fred C., Statistics and Experimental Design In Engineering and the Physical Sciences, (2 vols.), John Wiley & Sons, Inc., New York, N.Y., 1964.

TABLE I. OVERVIEW OF SYSTEM RESPONSE MEASURES

Control Variable	Position Error		Separation Error		Range Error		Azimuth Error		COR R-A	COR R-R	COR A-A	RSQ A-R	RSQ R-R	RSQ A-A
	Mean	S ²	Mean	S ²	Mean	S ²	Mean	S ²						
D	**	**	**	ns	**	**	**	**	**	**	**	ns	ns	ns
T	ns	ns	ns	**	ns	ns	**	**	**	**	**	ns	ns	ns
R	**	**	**	**	**	ns	ns	ns	ns	**	ns	ns	ns	ns
Q	**	**	**	**	**	ns	ns	**	**	ns	**	ns	**	**
F	ns	*	**	**	ns	ns	ns	ns	ns	*	ns	*	ns	**
A	**	**	**	**	**	**	ns	ns*	*	ns	ns	ns	ns	ns
DXT	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	*	ns	ns	ns
DXR	ns	ns	ns	ns	ns	ns	ns	ns	ns	**	ns	**	ns	ns
DXQ	**	ns	*	ns	**	ns	ns	ns	ns	ns	ns	ns	ns	ns
DXF	ns	ns	**	ns	ns	ns	ns	ns	ns	ns	ns	*	ns	ns
DXA	??	ns	ns	ns	??	ns	ns	ns	??	ns	ns	ns	ns	ns
TXR	ns	ns	ns	ns	ns	ns	ns	ns	*	ns	ns	ns	ns	ns
TXQ	ns	ns	ns	ns	ns	ns	ns	*	ns	ns	ns	ns	ns	ns
TXF	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
TXA	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
RXQ	ns	*	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
RXF	**	**	ns	ns	ns	ns	ns	ns	ns	ns	ns	**	**	**
RXA	ns	*	ns	ns	ns	ns	ns	ns	ns	ns	ns	*	*	*
QXF	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
QXA	ns	*	ns	ns	ns	ns	ns	ns	*	ns	ns	ns	ns	ns
FXA	?	**	ns	??	ns	?	ns	ns	ns	ns	ns	**	**	*

ns = not significant

* = significant @ .05

** = significant @ .01

? = questionable interpretation due to gross inequality in the number of entries in the two-way table.

TABLE II-1. POSITION ERROR, MEAN

Significance Level (Probability)

	D	T	R	Q	F	A
D		.0000	.0000	.0000	.0000	.0000
T	.7985		.8056	.6344	.7704	.5612
R	.0072	.0086		.0067	.0079	.0008
Q	.0	.0000	.0		.0	.0000
F	.1773	.1728	.2022	.0876		.1630
A	.0000	.0000	.0000	.0054	.0000	
DT	.4375					
DR	.0814					
DQ	.0001					
DF	.0979					
DA	.0168					
TR	.5334					
TQ	.5690					
TF	.4075					
TA	.2297					
RQ	.5638					
RF	.0000					
RA	.1036					
QF	.0364					
QA	.0274					
FA	.0065					

TABLE II-2. POSITION ERROR, LOG VARIANCE

Significance Level (Probability)

	D	T	R	Q	F	A
D		.0000	.0000	.0000	.0000	.0001
T	.9005		.8849	.9275	.8514	.6782
R	.0005	.0005		.0002	.0001	.0003
Q	.0000	.0000	.0000		.0000	.0993
F	.0136	.0137	.0440	.0084		.0142
A	.0000	.0000	.0000	.0000	.0000	
DT	.7850					
DR	.7347					
DQ	.4115					
DF	.8228					
DA	.1805					
TR	.5857					
TQ	.3617					
TF	.2508					
TA	.2182					
RQ	.0360					
RF	.0000					
RA	.0485					
QF	.1962					
QA	.0024					
FA	.0008					

TABLE II-3. SEPARATION ERROR, MEAN
Significance Level (Probability)

	D	T	R	Q	F	A
D		.0000	.0000	.0000	.0000	.0000
T	.0796		.0827	.0348	.0883	.1277
R	.0000	.0000		.0000	.0000	.0004
Q	.0009	.0005	.0009		.0006	.2713
F	.0009	.0016	.0030	.0007		.0012
A	.0000	.0000	.0000	.0000	.0000	
DT	.4835					
DR	.7516					
DQ	.0401					
DF	.0090					
DA	.8345					
TR	.7515					
TQ	.1352					
TF	.4264					
TA	.6867					
RQ	.1955					
RF	.1143					
RA	.2838					
QF	.5122					
QA	.1211					
FA	.5873					

TABLE II-4. SEPARATION ERROR, LOG VARIANCE
Significance Level (Probability)

	D	T	R	Q	F	A
D		.4675	.5124	.2537	.4499	.5363
T	.0000		.0000	.0000	.0000	.0000
R	.0011	.0012		.0007	.0000	.0154
Q	.0000	.0000	.0000		.0000	.0000
F	.0000	.0000	.0000	.0000		.0000
A	.0000	.0000	.0000	.0000	.0000	
DT	.2133					
DR	.7589					
DQ	.1870					
DF	.3713					
DA	.8116					
TR	.7925					
TQ	.1040					
TF	.0432					
TA	.8969					
RQ	.4837					
RF	.1777					
RA	.5033					
QF	.3354					
QA	.1434					
FA	.0447					

TABLE II-5. RANGE ERROR, MEAN
Significance Level (Probability)

	D	T	R	Q	F	A
D		.0	.0	.0	.0	.0
T	.5176		.6633	.8974	.6369	.6049
R	.0000	.0000		.0000	.0000	.0000
Q	.0000	.0000	.0000		.0000	.0000
F	.0214	.0367	.1321	.0094		.0283
A	.0000	.0000	.0000	.0015	.0000	
DT	.4718					
DR	.9066					
DQ	.0000					
DF	.5300					
DA	.0010					
TR	.3123					
TQ	.2953					
TF	.1200					
TA	.5017					
RQ	.0390					
RF	.4174					
RA	.0385					
QF	.0428					
QA	.2209					
FA	.2081					

TABLE II-6. RANGE ERROR, LOG VARIANCE
Significance Level (Probability)

	D	T	R	Q	F	A
D		.0	.0	.0	.0	.0
T	.9243		.9132	.8348	.9018	.7755
R	.9266	.9042		.9328	.9436	.7451
Q	.3095	.2703	.2827		.3123	.1898
F	.0916	.1150	.1348	.1207		.1163
A	.0000	.0000	.0000	.0000	.0000	
DT	.8929					
DR	.0268					
DQ	.6047					
DF	.2351					
DA	.0693					
TR	.1731					
TQ	.6738					
TF	.9738					
TA	.5612					
RQ	.6313					
RF	.1463					
RA	.1815					
QF	.1139					
QA	.4870					
FA	.0021					

TABLE II-7. AZIMUTH ERROR, MEAN

Significance Level (Probability)

	D	T	R	Q	F	A
D		.0000	.0000	.0000	.0000	.0000
T	.0003		.0003	.0003	.0005	.0036
R	.1220	.1430		.2380	.1629	.1407
Q	.0000	.0000	.0000		.0000	.0001
F	.5060	.5670	.6032	.5028		.5951
A	.3217	.3449	.5463	.5647	.2851	
DT	.0000					
DR	.0346					
DQ	.3886					
DF	.3707					
DA	.0273					
TR	.0112					
TQ	.1253					
TF	.4163					
TA	.2486					
RQ	.3377					
RF	.2092					
RA	.0052					
QF	.4055					
QA	.7352					
FA	.2744					

TABLE II-8. AZIMUTH ERROR, LOG VARIANCE

Significance Level (Probability)

	D	T	R	Q	F	A
D		.0000	.0000	.0000	.0000	.0000
T	.0154		.0164	.0028	.0118	.0274
R	.0039	.0047		.0066	.0014	.0206
Q	.0000	.0000	.0000		.0000	.0000
F	.0000	.0000	.0000	.0000		.0000
A	.0001	.0002	.0007	.0116	.0001	
DT	.1222					
DR	.5185					
DQ	.9689					
DF	.1934					
DA	.6329					
TR	.6822					
TQ	.0390					
TF	.0384					
TA	.1340					
RQ	.7540					
RF	.0557					
RA	.0555					
QF	.0652					
QA	.3154					
FA	.0822					

TABLE II-9. CORRELATION, RANGE ERROR VERSUS AZIMUTH ERROR (COR R to A)
Significance Level (Probability)

	D	T	R	Q	F	A
D		.0001	.0001	.0002	.0001	.0001
T	.0000		.0000	.0000	.0000	.0000
R	.7775	.7558		.9300	.8681	.6810
Q	.0000	.0000	.0000		.0000	.0000
F	.8679	.8685	.9471	.9113		.5673
A	.0116	.0081	.0139	.1673	.0054	
DT	.0751					
DR	.6441					
DQ	.2145					
DF	.6055					
DA	.0193					
TR	.6995					
TQ	.3377					
TF	.0544					
TA	.3672					
RQ	.1403					
RF	.1592					
RA	.5846					
QF	.0195					
QA	.7413					
FA	.5902					

TABLE II-10. CORRELATION, RANGE ERROR VERSUS RANGE ERROR (COR R1 to R2)
Significance Level (Probability)

	D	T	R	Q	F	A
D		.000	.000	.000	.000	.000
T	.0218		.0475	.0652	.0463	.0413
R	.000	.0003		.0003	.0006	.0001
Q	.0578	.1143	.1008		.1133	.1642
F	.0041	.0099	.0112	.0141		.0371
A	.3520	.2488	.0415	.2381	.3127	
DT	.3423					
DR	.0012					
DQ	.7793					
DF	.3598					
DA	.5516					
TR	.1389					
TQ	.3599					
TF	.2722					
TA	.6471					
RQ	.8739					
RF	.0815					
TA	.3659					
QF	.6669					
QA	.9820					
FA	.0539					

TABLE II-11. CORRELATION, AZIMUTH ERROR VERSUS AZIMUTH ERROR (COR A1 to A2)

	Significance Level (Probability)					
	D	T	R	Q	F	A
D		.0017	.0018	.0041	.0015	.0015
T	.0143		.0161	.0133	.0181	.0123
R	.7441	.7650		.7399	.7862	.9503
Q	.0069	.0067	.0076		.0060	.0329
F	.1299	.1493	.2346	.1351		.0983
A	.5301	.4619	.4860	.4930	.3541	
DT	.0317					
DR	.6041					
DQ	.0942					
DF	.5931					
DA	.5306					
TR	.5611					
TQ	.9820					
TF	.0521					
TA	.9006					
RQ	.7664					
RF	.0982					
RA	.4360					
QF	.8061					
QA	.6716					
FA	.8412					

TABLE II-12. MULTIPLE CORRELATION, RANGE AND AZIMUTH ERROR ON SEPARATION ERROR (RSQ R, A, on SE)

	Significance Level (Probability)					
	D	T	R	Q	F	A
D		.3101	.2770	.4697	.3371	.3202
T	.0575		.0580	.0555	.0580	.1258
R	.6447	.6807		.9092	.4275	.7364
Q	.4772	.4552	.4850		.4922	.9862
F	.0536	.0467	.0167	.0291		.0307
A	.1046	.1136	.0882	.1316	.1188	
DT	.9321					
DR	.0006					
DQ	.1669					
DF	.0208					
DA	.5796					
TR	.8962					
TQ	.8691					
TF	.4694					
TA	.1010					
RQ	.1407					
RF	.0005					
RA	.0008					
QF	.3647					
QA	.4415					
FA	.0056					

TABLE 11-13. MULTIPLE CORRELATION, RANGE ERROR 1 AND 2 AND AZIMUTH ERROR
1 AND 2 ON SEPARATION ERROR (RSQ R₁, R₂, A₁, A₂, on SE)

Significance Level (Probability)						
	D	T	R	Q	F	A
D		.2849	.3140	.2573	.2910	.3935
T	.1738		.1937	.0990	.1347	.1777
R	.1519	.1662		.1133	.1208	.0572
Q	.0031	.0029	.0022		.0007	.0045
F	.000	.000	.000	.0000		.0000
A	.0781	.0759	.0469	.0540	.0088	
DT	.5821					
DR	.7420					
DQ	.8273					
DF	.5127					
DA	.8943					
TR	.7623					
TQ	.1088					
TF	.0784					
TA	.7656					
RQ	.1407					
RF	.000					
RA	.0008					
QF	.0723					
QA	.1862					
FA	.0231					

TABLE III-1. DXT AVERAGES*

Position Error - Mean				Position Error - Variance			
	T1	T2	Wt Avg		T1	T2	Wt Avg
D1	.5846	.6191	.6016	D1	.0984	.1195	.1088
D2	.7709	.7536	.7623	D2	.1761	.1572	.1667
Wt Avg	.6794	.6877	.6835	Wt Avg	.1379	.1387	.1383
Separation Error - Mean				Separation Error - Variance			
	T1	T2	Wt Avg		T1	T2	Wt Avg
D1	.0094	.0226	.0159	D1	.0206	.0322	.0263
D2	.0886	.1194	.1038	D2	.0186	.0370	.0277
Wt Avg	.0496	.0720	.0606	Wt Avg	.0196	.0346	.0270
Range Error - Mean				Range Error - Variance			
	T1	T2	Wt Avg		T1	T2	Wt Avg
D1	-.0924	-.1555	-.1235	D1	.0295	.0358	.0326
D2	.5733	.5766	.5749	D2	.1541	.1566	.1553
Wt Avg	.2462	.2179	.2322	Wt Avg	.0928	.0974	.0951
Azimuth Error - Mean				Azimuth Error - Variance			
	T1	T2	Wt Avg		T1	T2	Wt Avg
D1	-.0137	.0126	-.0007	D1	.0292	.0355	.0323
D2	.3592	.1091	.2354	D2	.0208	.0270	.0239
Wt Avg	.1760	.0618	.1195	Wt Avg	.0249	.0312	.0280
COR - Range Error, Azimuth Error				RSQ - Sep. Error on Range & Azimuth Error			
	T1	T2	Wt Avg		T1	T2	Wt Avg
D1	.4723	.4238	.4484	D1	.3583	.3975	.3777
D2	.5804	.4644	.5230	D2	.3835	.4119	.3976
Wt Avg	.5273	.4445	.4864	Wt Avg	.3711	.4048	.3878
COR - Azimuth Error, Azimuth Error				COR - Range Error, Range Error			
	T1	T2	Wt Avg		T1	T2	Wt Avg
D1	.2825	.2520	.2673	D1	.6676	.6163	.6420
D2	.5583	.3287	.4435	D2	.9016	.8570	.8793
Wt Avg	.4232	.2911	.3572	Wt Avg	.7870	.7391	.7631
RSQ - Sep. Error on Range Error Aircraft No. 162 and Azimuth Error Aircraft No. 162							
	T1	T2	Wt Avg				
D1	.8407	.8742	.8575				
D2	.8211	.8675	.8443				
Wt Avg	.8307	.8708	.8507				

*Weighted Average (Wt Avg) - All row and column averages are weighted averages. The final (lower right) entry for each data block was constructed on the total weighted average for the whole matrix. The weights used were determined by the number of observations in the cells of the tables.

TABLE 111-2. DXR AVERAGES*

Position Error - Mean				Position Error - Variance				Wt Avg			
R1	R2	R3	R4	R1	R2	R3	R4	D1	D2	Wt Avg	Wt Avg
.5381	.6214	.5461	.6949	.1061	.0582	.1666	.1063	.6016	.0582	.1666	.1088
.8289	.6705	.6973	.8513	.2859	.0848	.1254	.1078	.7623	.0848	.1254	.1668
.6916	.6458	.6232	.7735	.2010	.0714	.1456	.1372	.6835	.0714	.1456	.1383
Separation Error - Mean				Separation Error - Variance				Wt Avg			
R1	R2	R3	R4	R1	R2	R3	R4	D1	D2	Wt Avg	Wt Avg
.0046	.0170	-.0244	.0673	.0193	.0324	.0231	.0302	.0159	.0324	.0231	.0263
.1155	.0942	.0584	.1472	.0228	.0306	.0249	.0324	.1038	.0306	.0249	.0276
.0626	.0556	.0173	.1079	.0211	.0315	.0240	.0313	.0606	.0315	.0240	.0270
Range Error - Mean				Range Error - Variance				Wt Avg			
R1	R2	R3	R4	R1	R2	R3	R4	D1	D2	Wt Avg	Wt Avg
.0642	-.2138	-.0675	-.2649	.093	.0309	.0329	.0370	-.1235	.0309	.0329	.0326
.7677	.4909	.5678	.4677	.1877	.1127	.1905	.1291	.5749	.1127	.1905	.1553
.4356	.1368	.2565	.1052	.129	.0716	.1133	.0833	.2323	.0716	.1133	.0951
Azimuth Error - Mean				Azimuth Error - Variance				Wt Avg			
R1	R2	R3	R4	R1	R2	R3	R4	D1	D2	Wt Avg	Wt Avg
-.0976	-.0124	.0453	.0502	.0296	.0292	.0366	.0338	-.0007	.0292	.0366	.0323
.2450	.2719	.1372	.2882	.0195	.0178	.0259	.0324	.2354	.0178	.0259	.0239
.0833	.1290	.0922	.1728	.243	.0235	.0311	.0331	.1196	.0235	.0311	.0280
COR - Range Error, Azimuth Error				RSQ - Sep. Error on Range Error & Azimuth Error				Wt Avg			
R1	R2	R3	R4	R1	R2	R3	R4	D1	D2	Wt Avg	Wt Avg
.4436	.4543	.4557	.4417	.3332	.4476	.3510	.3739	.4483	.4476	.3510	.3777
.5199	.4889	.5416	.5412	.4340	.3591	.3893	.4069	.5229	.3591	.3893	.3976
.4838	.4715	.4984	.4917	.3864	.4036	.3705	.3905	.4863	.4036	.3705	.3878
COR - Azimuth Error, Azimuth Error				COR - Range Error, Range Error				Wt Avg			
R1	R2	R3	R4	R1	R2	R3	R4	D1	D2	Wt Avg	Wt Avg
.1885	.3193	.2701	.2790	.6129	.5984	.6658	.6887	.2673	.5984	.6658	.6420
.4104	.3749	.4871	.5015	.9571	.7720	.8905	.8975	.4435	.7720	.8905	.8793
.3075	.3467	.3832	.3888	.7975	.6841	.7829	.7917	.3572	.6841	.7829	.7631
RSQ - Sep. Error on Range Error Aircraft No. 162 and Azimuth Error Aircraft No. 162				Wt Avg				Wt Avg			
R1	R2	R3	R4	D1	D2	Wt Avg	Wt Avg	D1	D2	Wt Avg	Wt Avg
.8089	.8836	.8277	.8989	.8575	.8443	.8507	.8507	.8089	.8836	.8277	.8989
.8329	.7986	.8389	.9068	.8443	.8507	.8507	.8507	.8329	.7986	.8389	.9068
.8218	.8417	.8335	.9028	.8417	.8335	.9028	.9028	.8218	.8417	.8335	.9028

*Weighted Average (Wt Avg) - All row and column averages are weighted averages. The final (lower right) entry for each data block was constructed on the total weighted average for the whole matrix. The weights used were determined by the number of observations in the cells of the tables.

TABLE III-3. DXQ AVERAGES*

Position Error - Mean				Position Error - Variance			
	Q1	Q2	Wt Avg		Q1	Q2	Wt Avg
D1	.4960	.7621	.6016	D1	.0849	.1451	.1088
D2	.5537	.0604	.7623	D2	.1030	.2578	.1667
Wt Avg	.5250	.9168	.6835	Wt Avg	.0940	.2035	.1383
Separation Error - Mean				Separation Error - Variance			
	Q1	Q2	Wt Avg		Q1	Q2	Wt Avg
D1	.0095	.0259	.0158	D1	.0185	.0386	.0263
D2	.0761	.0446	.1038	D2	.0204	.0382	.0276
Wt Avg	.0429	.0876	.0606	Wt Avg	.0195	.0384	.0269
Range Error - Mean				Range Error - Variance			
	Q1	Q2	Wt Avg		Q1	Q2	Wt Avg
D1	-.0982	-.1621	-.1236	D1	.0299	.0367	.0326
D2	.2097	1.0968	.5750	D2	.1614	.1467	.1553
Wt Avg	.0567	.4907	.2322	Wt Avg	.0961	.0937	.0951
Azimuth Error - Mean				Azimuth Error - Variance			
	Q1	Q2	Wt Avg		Q1	Q2	Wt Avg
D1	-.0745	.1113	-.0007	D1	.0263	.0415	.0323
D2	.1814	.3125	.2354	D2	.0164	.0345	.0239
Wt Avg	.0543	.2156	.1195	Wt Avg	.0213	.0379	.0280
COR - Range Error, Azimuth Error				RSQ - Sep. Error on Range & Azimuth Error			
	Q1	Q2	Wt Avg		Q1	Q2	Wt Avg
D1	.4846	.3931	.4483	D1	.3620	.4014	.3776
D2	.5803	.4410	.5229	D2	.4048	.3872	.3976
Wt Avg	.5328	.4179	.4863	Wt Avg	.3835	.3940	.3878
COR - Azimuth Error, Azimuth Error				COR - Range Error, Range Error			
	Q1	Q2	Wt Avg		Q1	Q2	Wt Avg
D1	.2854	.2417	.2673	D1	.6552	.6233	.6420
D2	.5420	.3105	.4435	D2	.8768	.8826	.8793
Wt Avg	.4153	.2772	.3572	Wt Avg	.7674	.7572	.7531
RSQ - Sep. Error on Range Error Aircraft No. 1&2 and Azimuth Error Aircraft No. 1&2							
	Q1	Q2	Wt Avg				
D1	.8303	.8957	.8575				
D2	.8176	.8804	.8443				
Wt Avg	.8239	.8878	.8507				

*Weighted Average (Wt Avg) - All row and column averages are weighted averages. The final (lower right) entry for each data block was constructed on the total weighted average for the whole matrix. The weights used were determined by the number of observations in the cells of the tables.

TABLE III-4. DXF AVERAGES*

Position Error - Mean			Position Error - Variance			Wt Avg	F3	Wt Avg
F1	F2	F3	F1	F2	F3			
D1	.6030	.5941	.6082	.6016	.6005	.1348	.1005	.1088
D2	.6994	.8526	.7313	.7624	.1253	.2618	.1088	.1668
Wt Avg	.6514	.7262	.6717	.6835	.1080	.1997	.1048	.1383
Separation Error - Mean			Separation Error - Variance			Wt Avg	F3	Wt Avg
F1	F2	F3	F1	F2	F3			
D1	.0226	.0077	.0173	.0158	.0207	.0313	.0268	.0263
D2	.1629	.0807	.0683	.1038	.0182	.0394	.0251	.0276
Wt Avg	.0936	.0448	.0434	.0606	.0194	.0354	.0259	.0270
Range Error - Mean			Range Error - Variance			Wt Avg	F3	Wt Avg
F1	F2	F3	F1	F2	F3			
D1	.1872	.0933	.0877	.1235	.0315	.0368	.0292	.0326
D2	.4668	.6756	.5787	.5749	.1215	.2054	.1369	.1553
Wt Avg	.1410	.2996	.2558	.2322	.0767	.1229	.0847	.0951
Azimuth Error - Mean			Azimuth Error - Variance			Wt Avg	F3	Wt Avg
F1	F2	F3	F1	F2	F3			
D1	-.0168	.0278	-.0141	-.0007	.0206	.0410	.0356	.0323
D2	.2871	.2280	.1959	.2354	.0164	.0295	.0255	.0239
Wt Avg	.1332	.1301	.0942	.1196	.0185	.0351	.0304	.0280
COR - Range Error, Azimuth Error			RSQ - Sep. Error on Range & Azimuth Error			Wt Avg	F3	Wt Avg
F1	F2	F3	F1	F2	F3			
D1	.4599	.4325	.4528	.4483	.3725	.3638	.3981	.3777
D2	.5244	.5313	.5126	.5229	.3511	.4471	.3926	.3976
Wt Avg	.4923	.4830	.4836	.4863	.3618	.4064	.3953	.3878
COR - Azimuth Error, Azimuth Error			COK - Range Error, Range Error			Wt Avg	F3	Wt Avg
F1	F2	F3	F1	F2	F3			
D1	.3169	.2933	.1800	.2673	.5635	.6868	.6822	.6420
D2	.5171	.3974	.4178	.4435	.8595	.9143	.8611	.8793
Wt Avg	.4160	.3469	.3041	.3572	.7100	.8039	.7756	.7631
RSQ - Sep. Error on Range Error Aircraft No. 1&2 and Azimuth Error Aircraft No. 1&2			Wt Avg					
F1	F2	F3	F1	F2	F3			
D1	.9573	.7420	.8730	.8575				
D2	.9102	.7653	.8630	.8443				
Wt Avg	.9340	.7540	.8678	.8507				

*Weighted Average (Wt Avg) - All row and column averages are weighted averages. The final (lower right) entry for each data block was constructed on the total weighted average for the whole matrix. The weights used were determined by the number of observations in the cells of the tables.

TABLE III-5. DXA AVERAGES*

Position Error - Mean		Position Error - Variance		Wt Avg		Wt Avg	
A1	A2	A1	A2	A1	A2	A3	A4
D1	.5655	.6677	.6536	.4892	.6016	.1328	.0361
D2	.8586	.8329	.7907	.4714	.7623	.1545	.0452
Wt Avg	.7089	.7503	.7272	.4801	.6835	.1444	.0407
Separation Error - Mean		Separation Error - Variance		Wt Avg		Wt Avg	
A1	A2	A1	A2	A1	A2	A3	A4
D1	.0523	.0118	.0184	-.0368	.0159	.0257	.0140
D2	.1586	.0955	.0966	.0471	.1038	.0290	.0188
Wt Avg	.1051	.0540	.0595	.0056	.0606	.0274	.0063
Range Error - Mean		Range Error - Variance		Wt Avg		Wt Avg	
A1	A2	A1	A2	A1	A2	A3	A4
D1	.0786	-.1849	-.2253	-.2185	-.1235	.0371	.0222
D2	.7210	.6187	.6584	.1491	.5749	.1817	.0749
Wt Avg	.3928	.2169	.2488	-.0308	.2122	.1094	.0490
Azimuth Error - Mean		Azimuth Error - Variance		Wt Avg		Wt Avg	
A1	A2	A1	A2	A1	A2	A3	A4
D1	.0240	-.0184	.0714	-.1285	-.0007	.0369	.0226
D2	.2651	.1867	.2124	.2947	.2354	.0277	.0172
Wt Avg	.1419	.0842	.1470	.0875	.1196	.0320	.0198
COR - Range Error, Azimuth Error		RSQ - Sep. Error on Range Error & Azimuth Error		Wt Avg		Wt Avg	
A1	A2	A1	A2	A1	A2	A3	A4
D1	.4024	.4814	.4565	.4663	.4483	.3529	.3568
D2	.5003	.4539	.5443	.6138	.5229	.4066	.3816
Wt Avg	.4503	.4677	.5036	.5416	.4863	.3817	.3695
COR - Azimuth Error, Azimuth Error		COR - Range Error, Range Error		Wt Avg		Wt Avg	
A1	A2	A1	A2	A1	A2	A3	A4
D1	.2153	.2634	.3644	.2242	.2673	.7000	.6699
D2	.4210	.3880	.4563	.5555	.4435	.8525	.8432
Wt Avg	.3134	.3249	.4156	.3974	.3572	.8153	.7605
RSQ - Sep. Error on Range Error Aircraft No. 162 and Azimuth Error Aircraft No. 162		Wt Avg		Wt Avg		Wt Avg	
A1	A2	A1	A2	A1	A2	A3	A4
D1	.8841	.8227	.8249	.9225	.8575		
D2	.8890	.7536	.8448	.9213	.8443		
Wt Avg	.8864	.7886	.8360	.9219	.8507		

*Weighted Average (Wt Avg) - All row and column averages are weighted averages. The final (lower right) entry for each data block was constructed on the total weighted average for the whole matrix. The weights used were determined by the number of observations in the cells of the tables.

TABLE III-6. TXR AVERAGES*

Position Error - Mean			Position Error - Variances			Wt Avg			R4			R3			R4			Wt Avg		
R1	R2	R3	R1	R2	R3	T1	T2	Wt Avg	T1	T2	Wt Avg	T1	T2	Wt Avg	T1	T2	Wt Avg	T1	T2	Wt Avg
.6987	.6341	.5831	.8012	.6794	.5831	.2249	.0793	.1008	.2249	.0793	.1008	.2249	.0793	.1008	.2249	.0793	.1008	.2249	.0793	.1008
.6837	.6574	.6633	.7461	.6877	.6633	.1744	.0636	.1904	.1744	.0636	.1904	.1744	.0636	.1904	.1744	.0636	.1904	.1744	.0636	.1904
.6916	.6458	.6212	.7735	.6835	.6212	.2011	.0714	.1456	.2011	.0714	.1456	.2011	.0714	.1456	.2011	.0714	.1456	.2011	.0714	.1456
Separation Error - Mean			Separation Error - Variance			Wt Avg			R4			R3			R4			Wt Avg		
R1	R2	R3	R1	R2	R3	T1	T2	Wt Avg	T1	T2	Wt Avg	T1	T2	Wt Avg	T1	T2	Wt Avg	T1	T2	Wt Avg
.0579	.0501	.0058	.0852	.0496	.0058	.0145	.0274	.0151	.0145	.0274	.0151	.0145	.0274	.0151	.0145	.0274	.0151	.0145	.0274	.0151
.0680	.0610	.0290	.1305	.0720	.0290	.0286	.0356	.0330	.0286	.0356	.0330	.0286	.0356	.0330	.0286	.0356	.0330	.0286	.0356	.0330
.0626	.0556	.0173	.1079	.0606	.0173	.0211	.0315	.0240	.0211	.0315	.0240	.0211	.0315	.0240	.0211	.0315	.0240	.0211	.0315	.0240
Range Error - Mean			Range Error - Variance			Wt Avg			R4			R3			R4			Wt Avg		
R1	R2	R3	R1	R2	R3	T1	T2	Wt Avg	T1	T2	Wt Avg	T1	T2	Wt Avg	T1	T2	Wt Avg	T1	T2	Wt Avg
.4989	.1454	.1913	.1401	.2462	.1913	.1236	.0703	.0988	.1236	.0703	.0988	.1236	.0703	.0988	.1236	.0703	.0988	.1236	.0703	.0988
.3048	.1283	.3217	.0707	.2180	.3217	.1010	.0729	.1277	.1010	.0729	.1277	.1010	.0729	.1277	.1010	.0729	.1277	.1010	.0729	.1277
.4356	.1368	.2565	.1052	.2323	.2565	.1129	.0719	.1133	.1129	.0719	.1133	.1129	.0719	.1133	.1129	.0719	.1133	.1129	.0719	.1133
Azimuth Error - Mean			Azimuth Error - Variance			Wt Avg			R4			R3			R4			Wt Avg		
R1	R2	R3	R1	R2	R3	T1	T2	Wt Avg	T1	T2	Wt Avg	T1	T2	Wt Avg	T1	T2	Wt Avg	T1	T2	Wt Avg
.2247	.1538	.1384	.1853	.1760	.1384	.0230	.0206	.0298	.0230	.0206	.0298	.0230	.0206	.0298	.0230	.0206	.0298	.0230	.0206	.0298
-.0749	.1046	.0459	.1604	.0619	.0459	.0257	.0264	.0324	.0257	.0264	.0324	.0257	.0264	.0324	.0257	.0264	.0324	.0257	.0264	.0324
.0833	.1291	.0922	.1728	.1196	.0922	.0243	.0235	.0311	.0243	.0235	.0311	.0243	.0235	.0311	.0243	.0235	.0311	.0243	.0235	.0311
COR - Range Error, Azimuth Error			COR - Sep. Error on Range and Azimuth Error			Wt Avg			R4			R3			R4			Wt Avg		
R1	R2	R3	R1	R2	R3	T1	T2	Wt Avg	T1	T2	Wt Avg	T1	T2	Wt Avg	T1	T2	Wt Avg	T1	T2	Wt Avg
.4403	.4800	.5271	.5034	.4872	.5271	.3712	.3884	.3477	.3712	.3884	.3477	.3712	.3884	.3477	.3712	.3884	.3477	.3712	.3884	.3477
.4522	.4551	.5157	.5383	.4909	.5157	.4034	.4185	.3933	.4034	.4185	.3933	.4034	.4185	.3933	.4034	.4185	.3933	.4034	.4185	.3933
.4459	.4675	.5214	.5209	.4891	.5214	.3864	.4035	.3705	.3864	.4035	.3705	.3864	.4035	.3705	.3864	.4035	.3705	.3864	.4035	.3705
COR - Azimuth Error, Azimuth Error			COR - Range Error, Range Error			Wt Avg			R4			R3			R4			Wt Avg		
R1	R2	R3	R1	R2	R3	T1	T2	Wt Avg	T1	T2	Wt Avg	T1	T2	Wt Avg	T1	T2	Wt Avg	T1	T2	Wt Avg
.3780	.4121	.3875	.5122	.4232	.3875	.8440	.7381	.7189	.8440	.7381	.7189	.8440	.7381	.7189	.8440	.7381	.7189	.8440	.7381	.7189
.2306	.2831	.3790	.2685	.2911	.3790	.7467	.6314	.8451	.7467	.6314	.8451	.7467	.6314	.8451	.7467	.6314	.8451	.7467	.6314	.8451
.3075	.3467	.3832	.3888	.3572	.3832	.7975	.6841	.7829	.7975	.6841	.7829	.7975	.6841	.7829	.7975	.6841	.7829	.7975	.6841	.7829
RSQ - Sep. Error on Range Error Aircraft No. 1&2 and Azimuth Error Aircraft No. 1&2			RSQ - Sep. Error on Range Error Aircraft No. 1&2 and Azimuth Error Aircraft No. 1&2			Wt Avg			R4			R3			R4			Wt Avg		
R1	R2	R3	R1	R2	R3	T1	T2	Wt Avg	T1	T2	Wt Avg	T1	T2	Wt Avg	T1	T2	Wt Avg	T1	T2	Wt Avg
.7964	.8300	.8068	.8874	.8307	.8068	.8494	.8530	.8708	.8494	.8530	.8708	.8494	.8530	.8708	.8494	.8530	.8708	.8494	.8530	.8708
.8218	.8417	.8335	.9028	.8507	.8335															

*Weighted Average (Wt Avg) - All row and column averages are weighted averages. The final (lower right) entry for each data block was constructed on the total weighted average for the whole matrix. The weights used were determined by the number of observations in the cells of the tables.

TABLE III-7. TXQ AVERAGES*

Position Error - Mean				Position Error - Variance			
	Q1	Q2	Wt Avg		Q1	Q2	Wt Avg
T1	.5083	.9182	.6793	T1	.0842	.2130	.1379
T2	.5414	.9152	.6877	T2	.1036	.1933	.1387
Wt Avg	.5250	.9168	.6835	Wt Avg	.0940	.2036	.1383
Separation Error - Mean				Separation Error - Variance			
	Q1	Q2	Wt Avg		Q1	Q2	Wt Avg
T1	.0387	.0651	.0496	T1	.0156	.0252	.0196
T2	.0470	.1130	.0720	T2	.0233	.0533	.0347
Wt Avg	.0429	.0876	.0606	Wt Avg	.0195	.0384	.0270
Range Error - Mean				Range Error - Variance			
	Q1	Q2	Wt Avg		Q1	Q2	Wt Avg
T1	.0871	.4684	.2464	T1	.0886	.0988	.0929
T2	.0270	.5149	.2180	T2	.1033	.0882	.0974
Wt Avg	.0567	.4906	.2322	Wt Avg	.0960	.0937	.0951
Azimuth Error - Mean				Azimuth Error - Variance			
	Q1	Q2	Wt Avg		Q1	Q2	Wt Avg
T1	.0895	.2967	.1760	T1	.0206	.0311	.0250
T2	.0198	.1272	.0618	T2	.0220	.0452	.0311
Wt Avg	.0543	.2156	.1195	Wt Avg	.0213	.0378	.0280
COR - Range Error, Azimuth Error				RSQ - Sep. Error on Range & Azimuth Error			
	Q1	Q2	Wt Avg		Q1	Q2	Wt Avg
T1	.5684	.4697	.5272	T1	.3678	.3758	.3711
T2	.4978	.3615	.4445	T2	.3989	.4140	.4048
Wt Avg	.5321	.4179	.4863	Wt Avg	.3835	.3941	.3878
COR - Azimuth Error, Azimuth Error				COR - Range Error, Range Error			
	Q1	Q2	Wt Avg		Q1	Q2	Wt Avg
T1	.4722	.3577	.4232	T1	.8144	.7503	.7870
T2	.3597	.1941	.2911	T2	.7214	.7643	.7391
Wt Avg	.4153	.2772	.3572	Wt Avg	.7674	.7572	.7631
RSQ - Sep. Error on Range Error Aircraft No. 1&2 and Azimuth Error Aircraft No. 1&2							
	Q1	Q2	Wt Avg				
T1	.8090	.8598	.8307				
T2	.8384	.9167	.8708				
Wt Avg	.8239	.8878	.8507				

*Weighted Average (Wt Avg) - All row and column averages are weighted averages. The final (lower right) entry for each data block was constructed on the total weighted average for the whole matrix. The weights used were determined by the number of observations in the cells of the tables.

TABLE III-8. TXF AVERAGES*

Position Error - Mean			Position Error - Variance			Wt Avg
F1	F2	F3	F1	F2	F3	
T1	.6452	.7490	T1	.0982	.2113	.1379
T2	.6576	.7023	T2	.1179	.1875	.1387
Wt Avg	.6514	.7262	Wt Avg	.1080	.1997	.1383
Separation Error - Mean			Separation Error - Variance			Wt Avg
F1	F2	F3	F1	F2	F3	
T1	.0712	.0369	T1	.0171	.0226	.0196
T2	.1165	.0531	T2	.0219	.0490	.0346
Wt Avg	.0936	.0448	Wt Avg	.0195	.0354	.0270
Range Error - Mean			Range Error - Variance			Wt Avg
F1	F2	F3	F1	F2	F3	
T1	.1821	.3573	T1	.0784	.1330	.0646
T2	.0996	.2393	T2	.0741	.1125	.0974
Wt Avg	.1410	.2996	Wt Avg	.0766	.1229	.0951
Azimuth Error - Mean			Azimuth Error - Variance			Wt Avg
F1	F2	F3	F1	F2	F3	
T1	.1663	.2131	T1	.0182	.0324	.0249
T2	.0999	.0434	T2	.0187	.0379	.0311
Wt Avg	.1332	.1301	Wt Avg	.0184	.0351	.0280
COR - Range Error, Azimuth Error			RSQ - Sep. Error on Range & Azimuth Error			Wt Avg
F1	F2	F3	F1	F2	F3	
T1	.5245	.5539	T1	.3493	.3801	.3842
T2	.4598	.4089	T2	.3743	.4337	.4065
Wt Avg	.4923	.4830	Wt Avg	.3617	.4063	.3953
COR - Azimuth Error, Azimuth Error			COR - Range Error, Range Error			Wt Avg
F1	F2	F3	F1	F2	F3	
T1	.4683	.4928	T1	.6893	.8514	.8204
T2	.3646	.1980	T2	.7302	.7555	.7309
Wt Avg	.4160	.3469	Wt Avg	.7100	.8039	.7756
RSQ - Sep. Error on Range Error Aircraft No. 1&2 and Azimuth Error Aircraft No. 1&2						Wt Avg
F1	F2	F3	F1	F2	F3	
T1	.9310	.7046	T1	.8645	.8307	.8307
T2	.9370	.8044	T2	.8711	.8708	.8708
Wt Avg	.9340	.7540	Wt Avg	.8678	.8507	.8507

*Weighted Average (Wt Avg) - All row and column averages are weighted averages. The final (lower right) entry for each data block was constructed on the total weighted average for the whole matrix. The weights used were determined by the number of observations in the cells of the tables.

TABLE III-9. TXA AVERAGES*

Position Error - Mean			Position Error - Variance			Wt Avg			Wt Avg		
A1	A2	A3	A1	A2	A3	T1	T2	Wt Avg	A1	A2	A3
.7503	.7430	.7147	.4201	.6793	.1674	.1498	.1379	.1383	.0304	.0511	.0407
.6678	.7579	.7401	.5430	.6877	.1695	.1388	.1387	.1383	.0304	.0511	.0407
.7089	.7503	.7271	.4801	.6815	.1685	.1671	.1444	.1383	.0304	.0511	.0407
Separation Error - Mean			Separation Error - Variance			Wt Avg			Wt Avg		
A1	A2	A3	A1	A2	A3	T1	T2	Wt Avg	A1	A2	A3
.0935	.0515	.0384	.0018	.0496	.0263	.0169	.0196	.0346	.0101	.0230	.0165
.1169	.0566	.0818	.0093	.0720	.0463	.0312	.0338	.0270	.0230	.0338	.0270
.1051	.0539	.0595	.0055	.0606	.0462	.0239	.0274	.0165	.0230	.0338	.0270
Range Error - Mean			Range Error - Variance			Wt Avg			Wt Avg		
A1	A2	A3	A1	A2	A3	T1	T2	Wt Avg	A1	A2	A3
.4578	.1749	.2556	.0054	.2462	.1014	.1034	.0929	.0345	.0345	.1034	.0929
.3283	.2606	.2417	.0566	.2179	.0945	.1157	.0974	.0640	.0640	.1157	.0974
.3928	.2169	.2488	.0308	.2322	.0979	.1094	.0951	.0491	.0491	.1094	.0951
Azimuth Error - Mean			Azimuth Error - Variance			Wt Avg			Wt Avg		
A1	A2	A3	A1	A2	A3	T1	T2	Wt Avg	A1	A2	A3
.2457	.1251	.1663	.1519	.1760	.0199	.0309	.0250	.0177	.0309	.0250	.0177
.0391	.0415	.1267	.0223	.0619	.0403	.0224	.0348	.0220	.0348	.0220	.0348
.1419	.0842	.1470	.0876	.1196	.0301	.0267	.0319	.0198	.0319	.0267	.0198
COR - Range Error, Azimuth Error			COR - Sep. Error on Range & Azimuth Error			Wt Avg			Wt Avg		
A1	A2	A3	A1	A2	A3	T1	T2	Wt Avg	A1	A2	A3
.5137	.5134	.5242	.5730	.5273	.3969	.3324	.3738	.3796	.3324	.3738	.3796
.3873	.4200	.4821	.5097	.4445	.4427	.4110	.3900	.3591	.4110	.3900	.3591
.4502	.4677	.5036	.5416	.4863	.4199	.3709	.3817	.3694	.3709	.3817	.3694
COR - Azimuth Error, Azimuth Error			COR - Range Error, Range Error			Wt Avg			Wt Avg		
A1	A2	A3	A1	A2	A3	T1	T2	Wt Avg	A1	A2	A3
.4047	.3737	.4637	.4774	.4232	.7729	.7739	.7907	.8319	.7729	.7739	.7907
.2262	.2750	.3662	.3173	.2911	.7124	.6972	.8405	.6891	.7124	.6972	.8405
.3134	.3249	.4156	.3974	.3572	.7419	.7360	.8153	.7605	.7419	.7360	.8153
RSQ - Sep. Error on Range Error Aircraft No. 162 and Azimuth Error Aircraft No. 162			Wt Avg			Wt Avg			Wt Avg		
A1	A2	A3	A1	A2	A3	T1	T2	Wt Avg	A1	A2	A3
.8756	.7567	.8242	.8947	.8307	.8947	.8307	.8708	.8507	.8947	.8307	.8708
.8968	.8212	.8482	.9791	.8708	.9791	.8708	.8507	.8507	.9791	.8708	.8507
.8964	.7886	.8360	.9219	.8507	.9219	.8507	.8507	.8507	.9219	.8507	.8507

*Weighted Average (Wt Avg) - All row and column averages are weighted averages. The final (lower right) entry for each data block was constructed on the total weighted average for the whole matrix. The weights used were determined by the number of observations in the cells of the tables.

TABLE III-10. RXQ AVERAGES*

Position Error - Mean				Position Error - Variance			
	Q1	Q2	Wt Avg		Q1	Q2	Wt Avg
R1	.5088	.9647	.6916	R1	.0911	.3653	.2011
R2	.5097	.8427	.6459	R2	.0489	.1040	.0714
R3	.4662	.8688	.6232	R3	.1604	.1223	.1455
R4	.6184	.9895	.7735	R4	.0740	.2253	.1372
Wt Avg	.5250	.9168	.6835	Wt Avg	.0940	.2036	.1383
Separation Error - Mean				Separation Error - Variance			
	Q1	Q2	Wt Avg		Q1	Q2	Wt Avg
R1	.0334	.1098	.0626	R1	.0163	.0289	.0211
R2	.0483	.0662	.0556	R2	.0242	.0421	.0315
R3	.0124	.0254	.0173	R3	.0177	.0343	.0240
R4	.0805	.1468	.1079	R4	.0199	.0476	.0313
Wt Avg	.0429	.0876	.0606	Wt Avg	.0195	.0384	.0270
Range Error - Mean				Range Error - Variance			
	Q1	Q2	Wt Avg		Q1	Q2	Wt Avg
R1	.1616	.8448	.4356	R1	.1111	.1157	.1129
R2	-.0040	.3404	.1368	R2	.0706	.0729	.0715
R3	.0943	.5102	.2565	R3	.1272	.0915	.1133
R4	-.0260	.2880	.1052	R4	.0744	.0956	.0833
Wt Avg	.0567	.4907	.2322	Wt Avg	.0960	.0937	.0951
Azimuth Error - Mean				Azimuth Error - Variance			
	Q1	Q2	Wt Avg		Q1	Q2	Wt Avg
R1	-.0047	.2146	.0832	R1	.0196	.0312	.0243
R2	.0401	.2578	.1291	R2	.0198	.0289	.0235
R3	.0606	.1415	.0922	R3	.0198	.0488	.0311
R4	.1218	.2438	.1728	R4	.0262	.0427	.0331
Wt Avg	.0543	.2156	.1196	Wt Avg	.0213	.0378	.0280
COR - Range Error, Azimuth Error				RSQ - Sep. Error on Range & Azimuth Error			
	Q1	Q2	Wt Avg		Q1	Q2	Wt Avg
R1	.5322	.4119	.4840	R1	.3734	.4058	.3864
R2	.4881	.4476	.4715	R2	.4205	.3790	.4035
R3	.5497	.4181	.4984	R3	.3449	.4106	.3705
R4	.16	.3942	.4916	R4	.3961	.3827	.3905
Wt Avg	.5328	.4180	.4863	Wt Avg	.3835	.3941	.3878
COR - Azimuth Error, Azimuth Error				COR - Range Error, Range Error			
	Q1	Q2	Wt Avg		Q1	Q2	Wt Avg
R1	.3898	.2005	.3075	R1	.8117	.7790	.7975
R2	.3985	.2732	.3467	R2	.6844	.6836	.6841
R3	.4673	.2614	.3832	R3	.7839	.7815	.7829
R4	.4046	.3674	.3888	R4	.7959	.7860	.7917
Wt Avg	.4153	.2772	.3572	Wt Avg	.7674	.7572	.7631

TABLE III-10. RXQ AVERAGES* (continued)

RSQ - Sep. Error on Range Error Aircraft No. 1&2
and Azimuth Error Aircraft No. 1&2

	Q1	Q2	Wt Avg
R1	.8004	.8495	.8218
R2	.8576	.8190	.8417
R3	.7682	.9281	.8335
R4	.8650	.9536	.9028
Wt Avg	.8239	.8878	.8507

*Weighted Average (Wt Avg) - All row and column averages are weighted averages. The final (lower right) entry for each data block was constructed on the total weighted average for the whole matrix. The weights used were determined by the number of observations in the cells of the tables.

TABLE III-II. RXF AVERAGES*

Position Error - Mean				Position Error - Variance				Wt Avg			
F1	F2	F3	F4	F1	F2	F3	F4	F1	F2	F3	F4
R1	.7102	.8410	.4414	.1334	.3543	.0343	.2010	.1334	.3543	.0343	.2010
R2	.5557	.5443	.7943	.0513	.0364	.1122	.0714	.0513	.0364	.1122	.0714
R3	.4363	.5963	.8392	.1165	.1173	.2079	.1456	.1165	.1173	.2079	.1456
R4	.8800	.8629	.5472	.1383	.2156	.0523	.1372	.1383	.2156	.0523	.1372
Wt Avg	.6513	.7262	.6716	.1080	.1997	.1048	.1383	.1080	.1997	.1048	.1383
Separation Error - Mean				Separation Error - Variance				Wt Avg			
F1	F2	F3	F4	F1	F2	F3	F4	F1	F2	F3	F4
R1	.1273	.0222	.0590	.018	.0270	.0214	.0211	.018	.0270	.0214	.0211
R2	.0664	.0721	.0358	.0258	.0512	.0251	.0315	.0258	.0512	.0251	.0315
R3	.0708	-.0023	-.0102	.0168	.0317	.0218	.0240	.0168	.0317	.0218	.0240
R4	.1131	.1173	.0931	.0214	.0401	.0347	.0314	.0214	.0401	.0347	.0314
Wt Avg	.0936	.0648	.0434	.0195	.0354	.0259	.0270	.0195	.0354	.0259	.0270
Range Error - Mean				Range Error - Variance				Wt Avg			
F1	F2	F3	F4	F1	F2	F3	F4	F1	F2	F3	F4
R1	.3489	.5042	.4193	.0815	.1498	.0886	.1130	.0815	.1498	.0886	.1130
R2	.0647	.0420	.2639	.0715	.0769	.0684	.0716	.0715	.0769	.0684	.0716
R3	.0995	.3803	.2636	.0674	.1550	.1088	.1133	.0674	.1550	.1088	.1133
R4	.0935	.1330	.0900	.0859	.0856	.0776	.0833	.0859	.0856	.0776	.0833
Wt Avg	.1410	.2996	.2558	.0767	.1230	.0847	.0951	.0767	.1230	.0847	.0951
Azimuth Error - Mean				Azimuth Error - Variance				Wt Avg			
F1	F2	F3	F4	F1	F2	F3	F4	F1	F2	F3	F4
R1	-.0073	.1658	.0496	.0224	.0258	.0238	.0243	.0224	.0258	.0238	.0243
R2	.1354	.0903	.1471	.0163	.0284	.0273	.0235	.0163	.0284	.0273	.0235
R3	.1306	.1072	.0365	.0143	.0519	.0228	.0311	.0143	.0519	.0228	.0311
R4	.2400	.1396	.1253	.0211	.0330	.0480	.0331	.0211	.0330	.0480	.0331
Wt Avg	.1332	.1301	.0942	.0185	.0351	.0303	.0280	.0185	.0351	.0303	.0280
COR - Range Error, Azimuth Error				RSQ - Sep. Error on Range & Azimuth Error				Wt Avg			
F1	F2	F3	F4	F1	F2	F3	F4	F1	F2	F3	F4
R1	.4739	.4740	.5096	.3756	.3484	.4563	.3864	.3756	.3484	.4563	.3864
R2	.5127	.4985	.4157	.3434	.5216	.3874	.4035	.3434	.5216	.3874	.4035
R3	.4850	.5125	.4946	.4007	.3545	.3599	.3705	.4007	.3545	.3599	.3705
R4	.4919	.4490	.5367	.3374	.4551	.3869	.3905	.3374	.4551	.3869	.3905
Wt Avg	.4923	.4830	.4836	.3618	.4064	.3953	.3878	.3618	.4064	.3953	.3878
COR - Azimuth Error, Azimuth Error				COR - Range Error, Range Error				Wt Avg			
F1	F2	F3	F4	F1	F2	F3	F4	F1	F2	F3	F4
R1	.3810	.3005	.2441	.7808	.8066	.8008	.7975	.7808	.8066	.8008	.7975
R2	.5573	.3281	.1488	.7016	.7437	.6260	.6841	.7016	.7437	.6260	.6841
R3	.2853	.4078	.4566	.5976	.8540	.8925	.7829	.5976	.8540	.8925	.7829
R4	.4069	.3512	.4140	.7601	.7951	.8313	.7917	.7601	.7951	.8313	.7917
Wt Avg	.4160	.3469	.3041	.7100	.8039	.7756	.7631	.7100	.8039	.7756	.7631
RSQ - Sep. Error on Range Error Aircraft No. 14				RSQ - Sep. Error on Range Error Aircraft No. 162				Wt Avg			
F1	F2	F3	F4	F1	F2	F3	F4	F1	F2	F3	F4
R1	.9598	.6531	.9282	.8218	.8218	.8218	.8218	.8218	.8218	.8218	.8218
R2	.8511	.7842	.8713	.8417	.8417	.8417	.8417	.8417	.8417	.8417	.8417
R3	.9983	.7394	.7725	.8335	.8335	.8335	.8335	.8335	.8335	.8335	.8335
R4	.9457	.8550	.9072	.9028	.9028	.9028	.9028	.9028	.9028	.9028	.9028
Wt Avg	.9340	.7540	.8678	.8507	.8507	.8507	.8507	.8507	.8507	.8507	.8507

*Weighted Average (Wt Avg) - All row and column averages are weighted averages. The final (lower right) entry for each data block was constructed on the total weighted average for the whole matrix. The weights used were determined by the number of observations in the cells of the tables.

TABLE III-12. RXA AVERAGES*

Position Error - Mean		Position Error - Variance		Wt Avg		Wt Avg		Wt Avg	
A1	A2	A1	A2	R1	R2	R3	R4	A3	A4
.6770	.896	.2232	.3137	.6916	.6364	.5882	.5420	.2102	.0330
.6845	.5917	.1134	.0564	.6432	.5882	.5420	.4801	.0531	.0715
.6865	.6449	.2166	.0939	.7735	.7906	.7906	.7906	.1933	.0386
.7690	1.0163	.1532	.1839	.7735	.7906	.7906	.7906	.1439	.0558
.7088	.7503	.1685	.1671	.6835	.7271	.7271	.7271	.1372	.1363
Separation Error - Mean		Separation Error - Variance		Wt Avg		Wt Avg		Wt Avg	
A1	A2	A1	A2	R1	R2	R3	R4	A3	A4
.1407	.1025	.0272	.0184	.0626	.0209	.0133	.0055	.0234	.0168
.0763	.0342	.0138	.0258	.0556	.0133	.0055	.0055	.0189	.0115
.0414	.0095	.0173	.0218	.0173	.0022	.0055	.0055	.0166	.0240
.1515	.0835	.0380	.0250	.1079	.0380	.0380	.0380	.0337	.0313
.1051	.0540	.0362	.0239	.0606	.0055	.0055	.0055	.0165	.0270
Range Error - Mean		Range Error - Variance		Wt Avg		Wt Avg		Wt Avg	
A1	A2	A1	A2	R1	R2	R3	R4	A3	A4
.4934	.5038	.1155	.1189	.4156	.1063	.0967	.0814	.1584	.0169
.3921	.0233	.0798	.0628	.1368	.1194	.1177	.1052	.0493	.0716
.2656	.2835	.1036	.1366	.2565	.0177	.0366	.0558	.1167	.1133
.3995	.2054	.1002	.0581	.1052	.0814	.0558	.0558	.0853	.0523
.3928	.2169	.0979	.1094	.2322	.0308	.2448	.2448	.1085	.0491
Azimuth Error - Mean		Azimuth Error - Variance		Wt Avg		Wt Avg		Wt Avg	
A1	A2	A1	A2	R1	R2	R3	R4	A3	A4
.1452	.0409	.0229	.0263	.0832	.0667	.0933	.0933	.0287	.0191
.0659	.0112	.0211	.0162	.1290	.0630	.3154	.3154	.0235	.0235
.2102	.0684	.0442	.0332	.0922	.0803	.0318	.0318	.0204	.0211
.1684	.3151	.1727	.0344	.1397	.1397	.1253	.1253	.0436	.0173
.1419	.1842	.1195	.0268	.1195	.0835	.1476	.1476	.0320	.0198
COR - Range Error, Azimuth Error		RSQ - Sep. Error on Range & Azimuth Error		Wt Avg		Wt Avg		Wt Avg	
A1	A2	A1	A2	R1	R2	R3	R4	A3	A4
.4097	.4901	.3893	.4252	.4839	.5623	.4676	.5036	.3771	.3425
.4337	.4278	.4715	.4715	.4715	.5382	.5068	.4896	.4604	.4476
.5147	.4663	.4984	.4984	.4984	.5668	.5386	.5386	.3237	.3122
.4496	.4785	.4917	.4917	.4917	.4922	.5386	.5386	.3615	.3781
.4502	.4676	.4863	.4863	.4863	.4863	.5036	.5036	.3817	.3694
COR - Azimuth Error, Azimuth Error		COR - Range Error, Range Error		Wt Avg		Wt Avg		Wt Avg	
A1	A2	A1	A2	R1	R2	R3	R4	A3	A4
.1847	.2430	.4343	.4343	.3075	.4624	.3547	.3547	.9160	.8416
.2610	.3585	.3547	.3547	.3467	.3398	.3547	.3547	.7467	.5821
.4704	.3302	.3206	.3206	.3832	.4741	.3832	.3832	.7418	.7829
.3412	.3680	.5471	.5471	.3888	.1645	.5471	.5471	.8998	.7917
.3134	.3242	.4156	.4156	.3572	.3974	.4156	.4156	.7605	.7631
RSQ - Sep. Error on Range Error Aircraft No. 162 and Azimuth Error Aircraft No. 162		Wt Avg		Wt Avg		Wt Avg		Wt Avg	
A1	A2	A1	A2	R1	R2	R3	R4	A3	A4
.7727	.8560	.7190	.9067	.8218	.8218	.8218	.8218	.8218	.8218
.9717	.6092	.8646	.9801	.8417	.8417	.8417	.8417	.8417	.8417
.8289	.8344	.8464	.8104	.8335	.8335	.8335	.8335	.8335	.8335
.9500	.8542	.8525	.9776	.9028	.9028	.9028	.9028	.9028	.9028
.8864	.7886	.8360	.9219	.8507	.8507	.8507	.8507	.8507	.8507

*Weighted Average (Wt Avg) - All row and column averages are weighted averages. The final (lower right) entry for each data block was constructed on the total weighted average for the whole matrix. The weights used were determined by the number of observations in the cells of the tables.

TABLE III-13. QXF AVERAGES*

Position Error - Mean			Position Error - Variance			Wt Avg		
F1	F2	F3	F1	F2	F3	Q1	Q2	Wt Avg
.5377	.5495	.4871	.0818	.1153	.0848	.5250	.0940	.0940
.8183	.9740	.9585	.1465	.3181	.1359	.9168	.2036	.2036
.6514	.7261	.6716	.1080	.1997	.1048	.6835	.1383	.1383
Separation Error - Mean			Separation Error - Variance			Wt Avg		
F1	F2	F3	F1	F2	F3	Q1	Q2	Wt Avg
.0677	.0296	.0310	.0165	.0238	.0181	.0429	.0195	.0195
.1344	.0671	.0626	.0242	.0524	.0379	.0876	.0384	.0384
.0936	.0448	.0434	.0195	.0354	.0259	.0606	.0270	.0270
Range Error - Mean			Range Error - Variance			Wt Avg		
F1	F2	F3	F1	F2	F3	Q1	Q2	Wt Avg
.0296	.0570	.0838	.0768	.1141	.0973	.0567	.0961	.0961
.3042	.6400	.5233	.0765	.1354	.0652	.4907	.0937	.0937
.1410	.2996	.2559	.0767	.1230	.0847	.2322	.0951	.0951
Azimuth Error - Mean			Azimuth Error - Variance			Wt Avg		
F1	F2	F3	F1	F2	F3	Q1	Q2	Wt Avg
.0737	.0392	.0499	.0176	.0229	.0235	.0543	.0213	.0213
.2206	.2577	.1629	.0197	.0523	.0410	.2557	.0378	.0378
.1332	.1301	.0941	.0185	.0351	.0304	.1196	.0280	.0280
COR - Range Error, Azimuth Error			RSQ - Sep. Error on Range & Azimuth Error			Wt Avg		
F1	F2	F3	F1	F2	F3	Q1	Q2	Wt Avg
.5634	.5018	.5331	.3708	.3905	.3894	.5328	.3835	.3835
.3879	.4566	.4067	.3484	.4286	.4045	.4179	.3941	.3941
.4923	.4830	.4837	.3617	.4064	.3953	.4863	.3878	.3878
COR - Azimuth Error, Azimuth Error			COR - Range Error, Range Error			Wt Avg		
F1	F2	F3	F1	F2	F3	Q1	Q2	Wt Avg
.4745	.3882	.3830	.7109	.8071	.7837	.4153	.7674	.7674
.3397	.2933	.1802	.7088	.7999	.7629	.2772	.7572	.7572
.4160	.3469	.3041	.7100	.8039	.7756	.3572	.7631	.7631
RSQ - Sep. Error on Range Error Aircraft No. 1&2 and Azimuth Error Aircraft No. 1&2			Wt Avg			Wt Avg		
F1	F2	F3	Q1	Q2	Wt Avg	Q1	Q2	Wt Avg
.9451	.6955	.8334	.8239	.8878	.8507	.9451	.6955	.8334
.9196	.8297	.9217	.8878	.8507	.8507	.9196	.8297	.9217
.9340	.7540	.8678	.8678	.8507	.8507	.9340	.7540	.8678

*Weighted Average (Wt Avg) - All row and column averages are weighted averages. The final (lower right) entry for each data block was constructed on the total weighted average for the whole matrix. The weights used were determined by the number of observations in the cells of the tables.

TABLE III-14. QXA AVERAGES*

Position Error - Mean			Position Error - Variance			Wt Avg			Wt Avg		
A1	A2	A3	A1	A2	A3	A4	Q1	Q2	Wt Avg	A3	A4
.5581	.5591	.5294	.4600	.5250	.5250	.4600	.1292	.1061	.1032	.0420	.0940
.8691	1.0052	.9371	.6396	.9168	.9168	.6396	.2102	.2484	.1881	.0309	.2035
.7088	.7503	.7271	.4801	.6835	.6835	.4801	.1685	.1671	.1444	.0408	.1383
Separation Error - Mean			Separation Error - Variance			Wt Avg			Wt Avg		
A1	A2	A3	A1	A2	A3	A4	Q1	Q2	Wt Avg	A3	A4
.0980	.0290	.0372	.0121	.0429	.0429	.0121	.0269	.0186	.0177	.0154	.0195
.1127	.0902	.0837	.0421	.0876	.0876	.0421	.0482	.0315	.0379	.0242	.0384
.1051	.0540	.0595	.0055	.0606	.0606	.0055	.0362	.0239	.0274	.0165	.0370
Range Error - Mean			Range Error - Variance			Wt Avg			Wt Avg		
A1	A2	A3	A1	A2	A3	A4	Q1	Q2	Wt Avg	A3	A4
.1625	.0923	.0266	.0445	.0567	.0567	.0445	.0895	.1261	.1216	.0515	.0961
.6376	.3830	.4848	.0783	.4907	.4907	.0783	.1069	.0871	.0947	.0300	.0937
.3928	.2169	.2488	.0308	.2323	.2323	.0308	.0979	.1094	.1086	.0491	.0951
Azimuth Error - Mean			Azimuth Error - Variance			Wt Avg			Wt Avg		
A1	A2	A3	A1	A2	A3	A4	Q1	Q2	Wt Avg	A3	A4
.0715	.0325	.0420	.0691	.0543	.0543	.0691	.0199	.0195	.0269	.0190	.0213
.2168	.1530	.2586	.2335	.2157	.2157	.2335	.0411	.0364	.0373	.0265	.0378
.1419	.0841	.1470	.0875	.1196	.1196	.0875	.0302	.0267	.0319	.0198	.0280
COR - Range Error, Azimuth Error			COR - Sep. Error on Range & Azimuth Error			Wt Avg			Wt Avg		
A1	A2	A3	A1	A2	A3	A4	Q1	Q2	Wt Avg	A3	A4
.5130	.5034	.5521	.5587	.5328	.5328	.5587	.4339	.3573	.3726	.3703	.3836
.3835	.4199	.4522	.4054	.4180	.4180	.4054	.4051	.3892	.3914	.3627	.3941
.4502	.4676	.5037	.5416	.4863	.4863	.5416	.4199	.3710	.3817	.3694	.3878
COR - Azimuth Error, Azimuth Error			COR - Range Error, Range Error			Wt Avg			Wt Avg		
A1	A2	A3	A1	A2	A3	A4	Q1	Q2	Wt Avg	A3	A4
.4004	.3292	.5285	.4130	.4153	.4153	.4130	.7723	.7298	.8129	.7577	.7674
.2222	.3199	.2997	.2413	.2772	.2772	.2413	.7102	.7434	.8777	.7886	.7872
.3134	.3245	.4156	.3974	.3572	.3572	.3974	.7419	.7360	.8153	.7605	.7631
RSQ - Sep. Error on Range Error Aircraft No. 162 and Azimuth Error Aircraft No. 162			RSQ - Sep. Error on Range Error Aircraft No. 162 and Azimuth Error Aircraft No. 162			Wt Avg			Wt Avg		
A1	A2	A3	A1	A2	A3	A4	Q1	Q2	Wt Avg	A3	A4
.8817	.7444	.7565	.9149	.8239	.8239	.9149	.7565	.9149	.8239	.7565	.9149
.8913	.8411	.9175	.9913	.8878	.8878	.9913	.8411	.8878	.8878	.8411	.8878
.8864	.7886	.8360	.9219	.8507	.8507	.9219	.7886	.8360	.8507	.7886	.8360

*Weighted Average (Wt Avg) - All row and column averages are weighted averages. The final (lower right) entry for each data block was constructed on the total weighted average for the whole matrix. The weights used were determined by the number of observations in the cells of the tables.

TABLE III-15. FXA AVERAGES*

Position Error - Mean				Position Error - Variance				Wt Avg			
A1	A2	A3	A4	A1	A2	A3	A4	F1	F2	F3	Wt Avg
.7038	.7662	.5687	.5105	.6513	.1460	.1103	.0982	.0495	.1080	.1097	.1080
.6762	.7962	.9001	.4777	.7261	.1772	.3085	.2291	.0502	.1997	.1048	.1048
.7593	.6757	.7359	.4595	.6716	.1839	.0691	.1189	.0252	.1048	.1048	.1048
.7088	.7503	.7271	.4801	.6835	.1684	.1671	.1444	.0407	.1383	.1383	.1383
Separation Error - Mean				Separation Error - Variance				Wt Avg			
A1	A2	A3	A4	A1	A2	A3	A4	F1	F2	F3	Wt Avg
.1380	.0958	.0719	.0610	.0936	.0239	.0177	.0191	.0154	.0195	.0154	.0195
.0770	.0243	.0675	-.0108	.0448	.0413	.0291	.0457	.0209	.0354	.0209	.0354
.1073	.0401	.0417	-.0217	.0434	.0432	.0249	.0225	.0129	.0259	.0129	.0259
.1051	.0540	.0596	.0055	.0606	.0362	.0239	.0274	.0164	.0270	.0164	.0270
Range Error - Mean				Range Error - Variance				Wt Avg			
A1	A2	A3	A4	A1	A2	A3	A4	F1	F2	F3	Wt Avg
.3774	.0945	.0588	-.0711	.1410	.0971	.0995	.0442	.0615	.0767	.0615	.0767
.3315	.3209	.4599	.0215	.2996	.1026	.1571	.1620	.0581	.1230	.0581	.1230
.4949	.2453	.2728	-.0482	.2559	.0926	.1094	.1085	.0492	.0951	.0492	.0951
.3928	.2169	.2488	-.0308	.2323	.0979	.1094	.1085	.0492	.0951	.0492	.0951
Azimuth Error - Mean				Azimuth Error - Variance				Wt Avg			
A1	A2	A3	A4	A1	A2	A3	A4	F1	F2	F3	Wt Avg
.1118	.0885	.2131	.0974	.1332	.0196	.0157	.0199	.0186	.0186	.0186	.0186
.1175	.1503	.1486	.0794	.1301	.0374	.0400	.0367	.0224	.0224	.0224	.0224
.0926	.0648	.1259	.0314	.0847	.2117	-.0002	.0828	.0716	.0716	.0716	.0716
.1419	.0841	.1470	.0875	.1185	.0302	.0267	.0320	.0198	.0280	.0198	.0280
COR - Range Error, Azimuth Error				RSQ - Sep. Error on Range & Azimuth Error				Wt Avg			
A1	A2	A3	A4	A1	A2	A3	A4	F1	F2	F3	Wt Avg
.4478	.4859	.4903	.5945	.4923	.4425	.3402	.3244	.3105	.3607	.3105	.3607
.4635	.4763	.5043	.4966	.4830	.4148	.3687	.4776	.3447	.4064	.3447	.4064
.4352	.4344	.5157	.5462	.4836	.3995	.4071	.3573	.4373	.3953	.4373	.3953
.4502	.4676	.5036	.5416	.4863	.4200	.3695	.3817	.3695	.3815	.3695	.3815
COR - Azimuth Error, Azimuth Error				COR - Range Error, Range Error				Wt Avg			
A1	A2	A3	A4	A1	A2	A3	A4	F1	F2	F3	Wt Avg
.3515	.4073	.4704	.5013	.4160	.7159	.7263	.6507	.7757	.7100	.7757	.7100
.3061	.3437	.4377	.2649	.3669	.7620	.7881	.8953	.7466	.8039	.7466	.8039
.2717	.1851	.3439	.4409	.3041	.7516	.6861	.8785	.7620	.7756	.7620	.7756
.3134	.3249	.4156	.3974	.3572	.7419	.7360	.8153	.7605	.7631	.7605	.7631
RSQ - Sep. Error on Range Error Aircraft No. 182 and Azimuth Error Aircraft 182				Wt Avg				Wt Avg			
A1	A2	A3	A4	F1	F2	F3	Wt Avg	F1	F2	F3	Wt Avg
.9837	.8411	.9703	.9690	.9340	.7540	.8678	.8507	.9340	.7540	.8678	.8507
.7356	.7315	.7563	.8286	.7540	.7540	.7540	.7540	.7540	.7540	.7540	.7540
.9453	.7873	.7994	.9710	.8678	.8678	.8678	.8678	.8678	.8678	.8678	.8678
.8864	.7886	.8360	.9219	.8507	.8507	.8507	.8507	.8507	.8507	.8507	.8507

*Weighted Average (Wt Avg) - All row and column averages are weighted averages. The final (lower right) entry for each data block was constructed on the total weighted average for the whole matrix. The weights used were determined by the number of observations in the cells of the tables.

END

11