UMTA-77-35
REPORT NO. UMTA-MA-06-0041-77-3

REPORT ON PHASE ONE TESTS OF FAIRCHILD AUTOMATIC VEHICLE MONITORING (AVM) SYSTEM

A. J. Pokorny
H. Briefel

Fairchild Space & Electronics Company
Germantown MD

AUGUST 1977
FINAL REPORT

Prepared for

U.S. DEPARTMENT OF TRANSPORTATION
URBAN MASS TRANSPORTATION ADMINISTRATION
Office of Technology Development and Deployment
Washington DC 20590

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.

NOTICE

The United States Government does not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
UMTA-MA-06-0041-77-3		

4. Title and Subtitle	5. Report Date
REPORT ON PHASE I TESTS OF FAIRCHILD AUTOMATIC VEHICLE MONITORING (AVM) SYSTEM	August 1977
	6. Performing Organization Code: 86360
7. Author's: A. J. Pokorny, H. Briefel	8. Performing Organization Report No.: DOT-TSC-UMTA-77-35, FR 77-372
9. Performing Organization Name and Address: Fairchild Space & Electronics Company * Germantown MD 20767	10. Work Unit No. (TRAIS): UM711/R7716
	11. Contract or Grant No.: DOT-TSC-1235
12. Sponsoring Agency Name and Address: U.S. Department of Transportation Urban Mass Transportation Administration Office of Technology Development & Deployment Washington DC 20590	13. Type of Report and Period Covered: Final Report Sept 1976 - April 1977
	14. Sponsoring Agency Code

15. Supplementary Notes

* Under Contract to: U.S. Department of Transportation, Transportation Systems Center, Kendall Square, Cambridge MA 02142

16. Abstract

The general objective of the program is to design, implement, and operate an area-wide multi-user Automatic Vehicle Monitoring System (AVM) in Los Angeles for the purpose of making a quantitative evaluation of AVM effectiveness, first, for transit and para-transit and, second, for other AVM users.

Phase I of the Program, covered by this report, was to ascertain that Fairchild's chosen technique for vehicle location satisfied the requirements as delineated in the System Performance Specifications.

A demonstration consisting of a series of operational tests was conducted in Philadelphia, Pa. A second series of engineering tests was conducted at Fairchild's facility in Germantown, Md.

The tests show the Fairchild AVM system can be operated with a high degree of accuracy and confidence.

17. Key Words	18. Distribution Statement
Location Subsystems, AVM System Accuracy, Electronic Signposts, Proximity Systems	DOCUMENT IS AVAILABLE TO THE U.S. PUBLIC THROUGH THE NATIONAL TECHNICAL INFORMATION SERVICE, SPRINGFIELD, VIRGINIA 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	192	

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

PREFACE

This report has been compiled by the Fairchild Space and Electronics Company (FSEC) of Fairchild Industries, Germantown, Maryland. It contains the results of a rigorous series of operational tests conducted in Philadelphia, Pa. These tests were designed to prove the feasibility of the Fairchild Automatic Vehicle Monitoring System. The tests were conducted during February 1977, with a separate series of engineering tests being conducted at our facility in Germantown, Maryland. As the report will disclose, the complete exercise served a two-fold purpose; 1) it proved the reliability of AVM systems and, 2) it performed as an invaluable learning tool from which all parties will profit.

FSEC wishes to acknowledge the effort of the DOT/TSC team who engineered the Test Specification; particularly Messrs. B. Blood and B. Kliem, under whose supervision it was proposed.

Also to be commended is Mr. R. Ow, the DOT/TSC Monitor assigned to FSEC, for his technical knowledge, and his ability to be compatible with the FSEC test team despite long days and nights of confinement within the test vehicle.

Last, but not least, FSEC would like to acknowledge the efforts of the many Fairchild personnel who contributed to the program's success; with special thanks to the Test Team, who, with Mr. Ow, were confined in the test vehicle for long periods, yet accomplished their tasks with dedication and good cheer.

NOTE

During the winter of 1976-77, four different techniques for automatically locating land vehicles were tested in both the low- and high-rise regions in Philadelphia PA. The tests were carried out by four different companies under separate contracts to the U.S. Department of Transportation, Transportation Systems Center. The tests were designed to evaluate the techniques for their applicability as location subsystems for automatic vehicle monitoring systems. This document represents one of the contractors' final report. A summary report on all systems tested is available as report No. UMTA-MA-06-0041-77-2.

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F

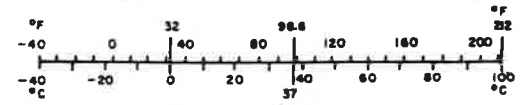


TABLE OF CONTENTS

TABLE OF CONTENTS (Cont.)

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (Cont.)

LIST OF ILLUSTRATIONS (Cont.)

LIST OF TABLES

1. INTRODUCTION

This is the final report covering Phase I of the DOT/TSC Multi-User Automatic Vehicle Monitoring Program, performed by Fairchild Space and Electronics Company under Contract No. DOT-TSC-1235.

Phase I consisted of instrumenting a section of downtown Philadelphia with approximately 140 signposts. Part of the allocated section was to be used for conducting tests applicable to fixed-route users (transit companies), and part was used for random-route applications (police cars, taxis, other fleet vehicles).

In addition to the primary tests described above, a series of special tests was conducted, which, together with the primary tests, provide a comprehensive view of the capabilities of the system.

Upon conclusion of the Philadelphia tests, the vehicle was returned to the FSEC facility in Germantown, Maryland, and a series of engineering tests performed under more controlled conditions then would have been possible in Philadelphia.

The report consists of eight (8) sections and appendices.

Section 2, Executive Summary, provides an overview of the Phase I Program with a "quick-look" summary of the test results.

Section 3, System Description, provides a functional description of the Fairchild AVM system for readers not familiar with it.

Section 4, Fixed Route Tests, gives a detailed description of the test methods, the tests themselves, and summary results in histographic form. More detailed data is found in the appendices and is appropriately referenced in the section.

Section 5, Random Route Tests, contains the same type of information as Section 4, except as pertaining to the Random Route Tests. Here, too, detailed data is also contained in the Appendices.

Section 6, Special Case Tests, provides a complete description of the special case tests conducted in Philadelphia.

Section 7, Engineering Laboratory Tests, describes the tests conducted at FSEC subsequent to the Philadelphia tests.

Section 8, Phase II Considerations, describes the lessons learned in Philadelphia and how they will be applied to Phase II (Los Angeles). In addition, Section 8 provides an overview of advances in the Fairchild AVM technology subsequent to the submittal of the original proposal, and how they will affect Phase II in a positive fashion.

2. EXECUTIVE SUMMARY

The Fairchild Space and Electronics Company of Fairchild Industries is pleased to submit this final report, thus successfully completing the first phase of a two-phase program.

It is the intention of this Executive Summary to provide the reader with an overview of the program and the results achieved.

The Phase I objectives of the two phase program were to demonstrate and test the Fairchild Location Subsystem technique. This final report presents the test results obtained during field testing in Philadelphia and engineering testing performed at the Fairchild Plant in Germantown, Md.

The Fairchild Location Subsystem uses semi-passive signposts deployed at known locations throughout the area of coverage. The electronic equipment on board each vehicle interrogates each uniquely coded signpost as it is passed, and transmits this code via radio link back to the control center. This signpost code, when first interrogated, establishes the vehicle's location at this fixed reference. To maintain accurate vehicle location during the intervals between signposts, the on-board electronics establishes the vehicle's current position relative to the last detected signpost. This travel distance is then transmitted along with the last detected signpost code, to establish a vehicle location at each control center polling request. The control center computer, using the polled vehicle location information, then establishes the vehicle position relative to a street map of the coverage area. For fixed route vehicles, the computer also verifies vehicle progress relative to the stored route schedule.

The Location Subsystem functions described in the preceding paragraph, with the exception of the radio link, were those implemented for the Phase I tests. The actual hardware and software as implemented and tested were identical in configuration

to that originally proposed. Field modifications of the equipment were minimal, as evidenced by the relatively short period during which field testing was performed, and were largely limited to software adjustments in the central processing programs.

The performance of the Location Subsystem was determined in terms of vehicle position accuracy, as measured by three different methods of processing the accumulated location data. The first accuracy measurement resulted from a comparison of the location subsystem-determined vehicle coordinates, to the reference coordinates of specific fixed locations along the routes known as checkpoints. This measurement is called location subsystem accuracy. The second measurement was derived from the errors developed at each data sample point (2 per second) averaged over 0.1 mile increments. This measurement is called System Coverage. The third measurement was derived from the errors developed at simulated polling intervals (every 25 seconds). This measurement is called System Accuracy. The basis of comparison for the last two accuracy measurements was a coordinate set derived from calibrated 5th wheel distances. All the above accuracies are expressed in terms of radial error in feet for the mean, 95th percentile and 99.5th percentile of the composite error distributions. In addition, timing accuracy was measured for the fixed route runs at 14 fixed time-points along the route.

The accuracies of the Fairchild Location Subsystem as tested in Philadelphia are summarized in Table 2-1. Three columns of data are presented. Column one lists the performance requirements as specified by DOT/TSC. The second column presents the Fairchild achieved results including all the recorded data. A review of these results indicates that all the 95th percentile requirements of 300 feet were easily achieved. In addition, the mean error value was less than 80 feet for each of the listed categories. The 99.5th percentile requirements were achieved for only 3 of the 5 categories. This is a direct result of an acquisition error which occurred during 20 of the 2994 signpost interrogations. While this resulted in relatively few affected data points, the number was sufficient to move the 99.5th percentile beyond the 450 foot requirement. Inasmuch as this error is easily correctable at both the interrogation and central control system level, those data points affected by these 20 signpost errors have been removed and a third corrected results column formed. This column represents the true performance of the Fairchild Location Subsystem technique.

TABLE 2-1

FSEC LOCATION SUBSYSTEM PERFORMANCE SUMMARY

	Specifications Requirements (Feet)	Uncorrected FSEC (Feet)	Corrected* FSEC (Feet)
AVM SYSTEM ACCURACY			
FIXED ROUTE			
95th percentile	300	82	81
99.5th percentile	450	148	125
Mean	-	44	30
TIME POINT			
95th percentile	15 (sec)	0.5 (sec)	0.5(sec)
99.5th percentile	60 (sec)	1.5 (sec)	1.5(sec)
Mean		0.159 (sec)	0.159 (sec)
RANDOM ROUTE			
95th percentile	300	230	220
99.5th percentile	450	440	430
Mean	-	60	58
SYSTEM COVERAGE (0.1 mile)			
FIXED ROUTE			
95th percentile		79	74
99.5th percentile		1154	120
Mean	-	47	30
Maximum	-	6677	756
RANDOM ROUTE			
95th percentile		230	230
99.5th percentile		440	430
Mean	-	68	64
Maximum	-	2380	623
LOCATION SUBSYSTEM ACCURACY			
FIXED ROUTE			
95th percentile	300	57	54
99.5th percentile	450	1151	70
Mean	-	47	24
RANDOM ROUTE			
95th percentile	300	250	230
99.5th percentile	450	440	440
Mean	-	76	69

*Represents effect of "reasonableness algorithm" incorporation.

Two relatively minor problem areas were uncovered during the Phase I tests, both relating to signpost acquisition by the vehicle mounted interrogator. The first concerned acquisition of signposts that were not along the route of travel. Two signposts, one on the fixed route, and one in the random route area, were mounted within six feet of an intersection. As the vehicle passed through these intersections on four of the 44 test runs, the signposts were acquired. The Fairchild deployment pattern normally specifies installation of signposts in a mid-block area rather than at intersections; adherence to this policy will then eliminate the off-route acquisitions. The second concerned incorrect signpost code acquisition. During 20 interrogations it was observed that the signpost code was first correctly decoded, then changed to an incorrect number. This has been diagnosed as a signal processing deficiency occurring as the return signal strength decreases through the established threshold level. Several simple and straightforward solutions exist to remedy this deficiency and are discussed in Section 4.4.6.1.

As a result of the excellent performance accuracies achieved during the field testing, and the technological and production improvements being developed as a result of FSEC's intensive IR and D program, substantial cost reductions in the capital investment necessary to implement a Fairchild Location System will result. These cost reductions and how they will affect future large-lot AVM procurements are shown in Table 8-1.

3. SYSTEM DESCRIPTION

3.1 OVERALL SYSTEM

3.1.1 DETAILED SYSTEM FUNCTIONS

The functions to be provided by the AVM System are directed toward the Southern California Rapid Transit District (SCRTD) type transit application of a scheduled, fixed route bus system with random route service vehicles. However, most of the functions have application in a multi-user environment where considerably more importance is placed upon random route vehicles and the protection of data between users.

The functions described herein are divided into the following categories:

a. Operational - those functions required for the real-time monitoring and control of the bus and support vehicle fleet.

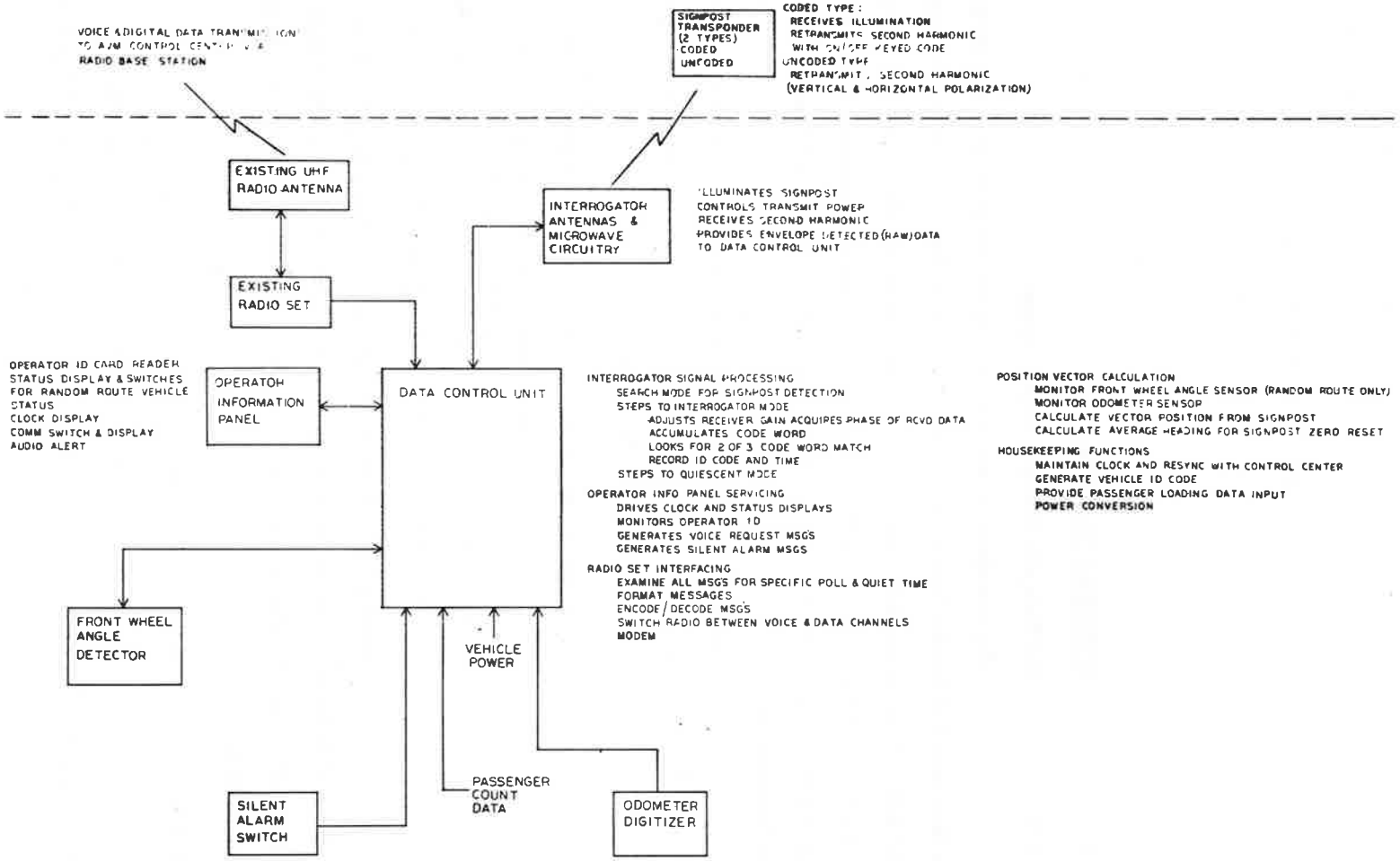
b. Output - those functions available as a result of the continuing data accrual performed automatically during system operation.

c. Ancillary - those additional functions available as side benefits made possible by having an operational AVM System.

Diagrams of Vehicle and Signpost Functions (Figure 3-1) and Control Center and Related Functions (Figure 3-2) are used to visualize functions in a physically related way since the above described breakdown cuts across physical and equipment relationships.

3.1.1.1 Operational Functions

The main purpose of the AVM System is to track the movement of vehicles throughout the area of coverage. It is divided into two related areas, a


VOICE & DIGITAL DATA TRANSMISSION TO AVM CONTROL CENTER VIA RADIO BASE STATION
SIGNPOST TRANSPONDER (2 TYPES) CODED UNCODED
CODED TYPE: RECEIVES ILLUMINATION RETRANSMITS SECOND HARMONIC WITH ON/OFF KEYED CODE
UNCODED TYPE RETRANSMIT, SECOND HARMONIC (VERTICAL & HORIZONTAL POLARIZATION)
EXISTING UHF RADIO ANTENNA
INTERROGATOR ANTENNAS & MICROWAVE CIRCUITRY
ILLUMINATES SIGNPOST
CONTROLS TRANSMIT POWER
RECEIVES SECOND HARMONIC
PROVIDES ENVELOPE DETECTED (RAW) DATA TO DATA CONTROL UNIT
EXISTING RADIO SET
OPERATOR ID CARD READER
STATUS DISPLAY & SWITCHES FOR RANDOM ROUTE VEHICLE STATUS
CLOCK DISPLAY
COMM SWITCH & DISPLAY
AUDIO ALERT
OPERATOR INFORMATION PANEL
DATA CONTROL UNIT
INTERROGATOR SIGNAL PROCESSING
SEARCH MODE FOR SIGNPOST DETECTION
STEPS TO INTERROGATOR MODE
ADJUSTS RECEIVER GAIN ACQUIRES PHASE OF RCVD DATA
ACCUMULATES CODE WORD
LOOKS FOR 2 OF 3 CODE WORD MATCH
RECORD ID CODE AND TIME
STEPS TO QUIESCENT MODE
OPERATOR INFO PANEL SERVICING
DRIVES CLOCK AND STATUS DISPLAYS
MONITORS OPERATOR ID
GENERATES VOICE REQUEST MSGS
GENERATES SILENT ALARM MSGS
RADIO SET INTERFACING
EXAMINE ALL MSGS FOR SPECIFIC POLL & QUIET TIME
FORMAT MESSAGES
ENCODE/DECODE MSGS
SWITCH RADIO BETWEEN VOICE & DATA CHANNELS
MODEM
POSITION VECTOR CALCULATION
MONITOR FRONT WHEEL ANGLE SENSOR (RANDOM ROUTE ONLY)
MONITOR ODOMETER SENSOR
CALCULATE VECTOR POSITION FROM SIGNPOST
CALCULATE AVERAGE HEADING FOR SIGNPOST ZERO RESET
HOUSEKEEPING FUNCTIONS
MAINTAIN CLOCK AND RESYNC WITH CONTROL CENTER
GENERATE VEHICLE ID CODE
PROVIDE PASSENGER LOADING DATA INPUT
POWER CONVERSION
FRONT WHEEL ANGLE DETECTOR
VEHICLE POWER
PASSENGER COUNT DATA
SILENT ALARM SWITCH
ODOMETER DIGITIZER

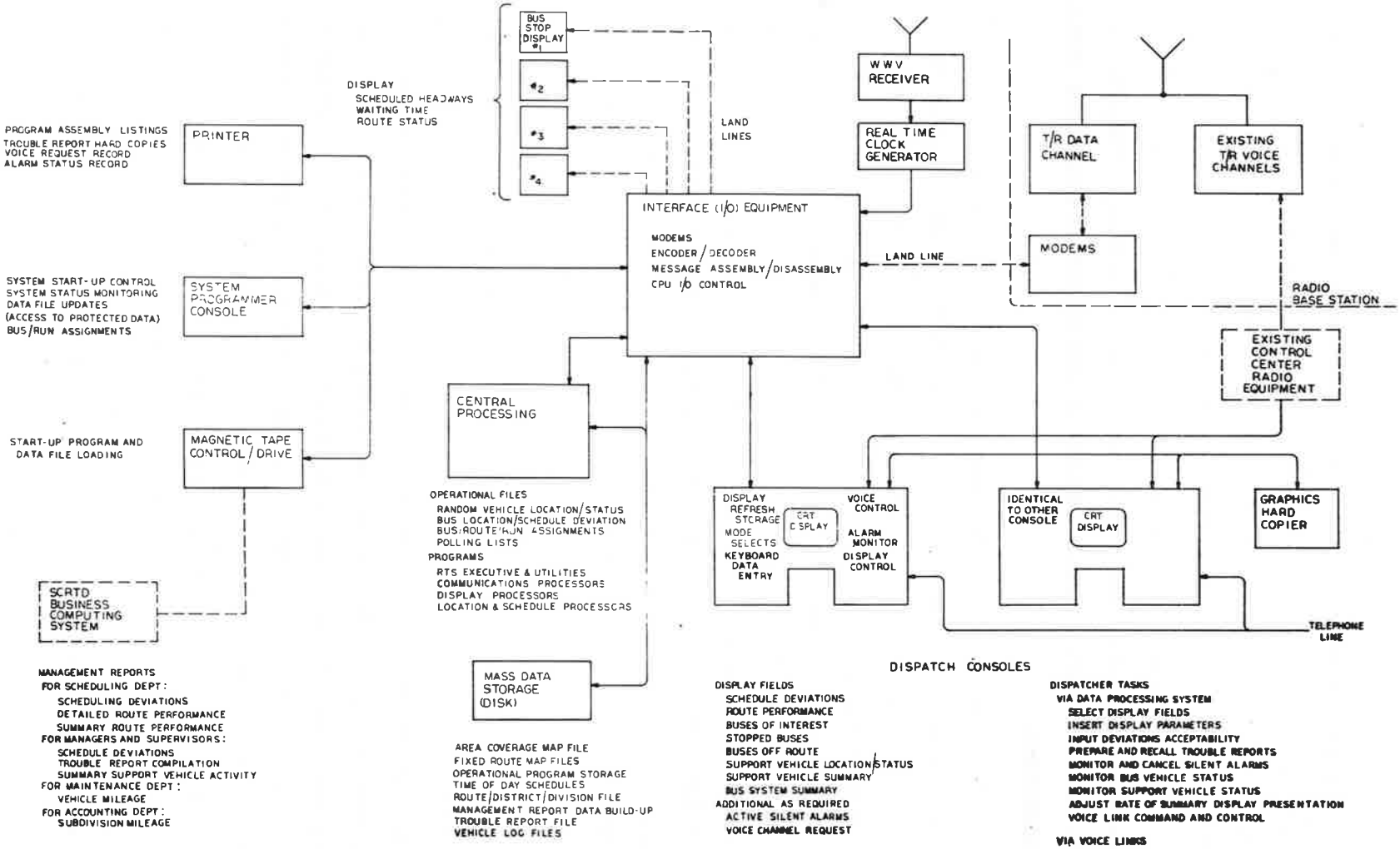


FIGURE 3 - 2
CONTROL CENTER
AND
RELATED FUNCTIONS

radial tracking function for the random route vehicles, and a primarily linear tracking function for fixed route vehicles. The linear requirement at first appears simpler. However, since the fixed route vehicles are scheduled and must be location- and time-tracked, the difficulty of the two requirements equalizes.

Random Route vehicles can be police patrol cars, taxis, fire fighting equipment, trucking fleets, etc. For the initial AVM implementation in Los Angeles, the SCRTD fleet of support vehicles has been selected to demonstrate random route capabilities.

The Fairchild AVM System uses semi-passive transponders (Signposts) located in a regular, but not necessarily rigid, pattern throughout the area of coverage. Interrogators are vehicle mounted and detect those Signposts when the vehicle is in close proximity. The location accuracy required of the AVM System can be readily achieved by siting Signposts at sufficiently small intervals. However, a location accuracy of $\pm$ 300 ft. would require a large number of Signposts. To relieve this condition and to account for instances when a Signpost may not be detected because of an interfering object, a simple Inter-Signpost Interpolator function has been added to the vehicle. The Signposts are located at approximately 1/4 mile intervals, and the Interpolator is therefore not required to maintain accuracy over long distances. (It should be noted that the linear position, i.e., travel distance, can be measured fairly accurately, but the radial position is much more demanding of equipment performance.) The detection of a Signpost provides position and direction information, and a vehicle's subsequent distance and direction relative to a Signpost is calculated by the on-board Interpolator. The location information is transmitted via the vehicle radio on demand (a poll) to the Control Center computer. The positions are stored in the computer, which converts the vehicle location information to city coordinates and locates the vehicle on a specific street. The polling rate can adapt to vehicle speed, the objective being to better track fast moving vehicles, however, every vehicle is polled within 40 second intervals regardless of speed. While a speed adaptive polling system may seem to require frequent polls and inefficient use of the radio bandwidth, an analysis of typical speed distributions for the SCRTD fleet indicates that this technique is at least equivalent to a poll of every vehicle once every 25 seconds.

Although adaptive polling is not vital to maintaining System Specification accuracies, it will increase resolution on high speed vehicles and minimize ambiguities which could arise in the Central Computer tracking algorithm.

3.1.1.1.1 In Vehicle Functions

The functions required on board the vehicle are illustrated in Figure 3-1, Vehicle and Signpost Functions. Whenever a vehicle is approaching a Signpost, the Interrogator is continually radiating in a search mode. As the illumination beam passes the Signpost, it is detected by receipt of the second harmonic of the transmitted signal, and the Interrogator signal processing equipment located in the Data Control Unit switches to the interrogate mode. The Signpost keys the second harmonic on and off sequentially producing a code word. This code word is repeatedly accumulated by the signal processing circuitry, which looks for a two out of three code word match. When a match occurs, the Signpost is successfully "read" and the ID code is stored along with the time. The system then steps to a quiescent mode and interrogation is inhibited until a new Signpost is approached.

The Data Control Unit now uses odometer and wheel steering angle data to continuously calculate a distance and direction indicating vehicle position relative to the Signpost. In a sense this process is underway before the Signpost is detected, since an average vehicle heading is continuously calculated and is used to "zero" the vector when Signpost detection occurs. This allows the instantaneous vehicle heading to be skewed when the Signpost is detected without introducing error to the vector reset.

A poll (data request) from the Control Center can occur at any time, and the Data Control Unit responds with the latest location information, namely the ID of the last Signpost detected and the vector (if any) from it. Should a Signpost be missed, due to interference, defective Signpost, etc., then the vector calculation continues until a Signpost is successfully read. The location accuracy stays within $\pm$ 300 feet even when a vehicle passes a Signpost and fails to detect its presence.

All vehicles in the fleet are sequentially polled, and each Data Control Unit examines each request, searching for its own vehicle number. When

polled, it formats the message and applies error correcting coding before sending the data to the radio for transmission to the Control Center.

Location functions for fixed route vehicles differ in two primary ways. Since the problem is linear for fixed route, steering angle detection is not necessary. Only the Signpost ID and "mileage" from the Signpost is accumulated and transmitted. The route is computer stored and the vehicle is tracked along it. Off-route vehicles are detected when the computer receives a Signpost ID that is not on the route. Since Signposts are located at every other intersection, the point where the route was left can be deduced, and the vehicle can still be tracked from Signpost to Signpost, provided the vehicle remains within the area of coverage. For a full city-wide implementation, Signposts would be located throughout the city; however, for the Los Angeles SCRTD implementation, Signposts will be located only within the required area of coverage which includes considerable portions of the fixed routes that extend outside the area of random route coverage. These fixed routes will have coded Signposts located along the routes, and to provide for off-route detection uncoded Signposts will be located at each cross street. This is the second type of Signpost indicated on Figure 3-1. When this type of Signpost is detected, the mileage from the last coded Signpost will be recorded. The point where the vehicle went off route can then be deduced.

The second difference between random route and fixed route functions is the schedule checking. A range of Signpost ID codes is reserved for fixed route timepoints. When a timepoint ID code is detected by the Data Control Unit the time is recorded and stored. When the computer requires the time point data, it interrogates the vehicle and the vehicle response will include both the location data and the time of detection of the timepoint. This approach avoids the need to extrapolate checkpoint passage times when they occur between polls. The problem of defining both time of departure (specification requirement $\pm$ 15 secs. for 95%) and time of arrival (design goal) is of course meaningful only if the vehicle stops at the checkpoint. The time data is determined by the location of the Signpost relative to the stop. For the basic requirement, the timepoint Signposts will be positioned such that they are detected as the vehicle leaves the stop. The use of a second

Signpost or vehicle time/position extrapolation in the computer for determining time of arrival will be addressed in detail during the design study phase of the contract.

3.1.1.1.1.1 Operator Interface - In addition to the above discussion other operational functions occur in the on-vehicle equipment. Within each polling message from the Control Center to a fixed route vehicle there is schedule status information. This is displayed to the operator as EARLY/ON TIME/LATE with dispatcher acceptability indicated as OK for either the early or late status. Additionally, 15 seconds before scheduled departure from a layover point, a START RUN status will be illuminated. This will be extinguished automatically with vehicle movement.

The Operator's Information Panel also contains a COMM pushbutton indicator. To request use of the radio voice channel, the operator depresses this button. In the response message to the next poll, the Data Control Unit inserts a status code requesting permission to use the voice channel. When the dispatcher OKs the request, or when the voice transmission request has been initiated by the dispatcher, the COMM light is illuminated. The radio channel switch is automatically enabled for selecting the voice channel when the handset is taken off hook.

3.1.1.1.1.2 Silent Alarm - Provided on the floor of the bus under the seat is a guarded, foot operated Silent Alarm Switch. When depressed, the Data Control Unit generates an Alarm Status Message, for transmission to the Control Center. At intervals of 2.5 seconds, the Control Center computer inserts a one message quiet time in the poll sequence (using a uniquely coded message to all vehicles) at which time an alarm status message may be transmitted. If successfully received, it is immediately acknowledged by the computer with a request for an updated location status. If not acknowledged, the vehicle continues to transmit the alarm status code at each quiet time. To cover those instances where two silent alarms are initiated during the same 2.5 second interval, and quiet times are being contested for by two or more vehicle transmissions, the alarm status is also inserted in the next poll response message if acknowledgement has not been received by that time.

3.1.1.1.2 Control Center Operational Functions

In addition to the computerized functions inplied in the above discussion, two basic operational functions are provided at the Control Center. These

involve the Dispatchers on-line situation monitoring and controlling or "commenting" on the fleet operation, and the scheduling department acting in an off-line yet closed loop situation. The Dispatch Console contains a CRT display and through a variety of itemized and summary display formats (illustrated on Figure 3-2) presents the following information:

Fixed Route Vehicles:

- Present Location
- Schedule Status
- Off Route, or Stopped Indication
- Active Alarms
- Voice Requests.

Random Route Vehicles:

- Present Location
- Call Status
- Operator in Vehicle
- Vehicle Operational Status
- Voice Requests.

Based upon this data, the dispatcher must act to resolve bus service problems, using his three lines of communication: the AVM System and its digital data link to vehicles, the voice radio, and the telephone. The dispatcher must also prepare a Trouble Report describing the problem and its resolution, and in this function the Data Processing equipment provides assistance. A blank Trouble Report Form is displayed upon request, which the dispatcher may fill in using his keyboard and cursor control. Should he designate a specific vehicle on a display format before requesting the Trouble Report Form, the heading data (e.g., vehicle #, location, time-of-day, operator #, etc.) will be filled in automatically, leaving only the remarks to be entered. After the form is completed, a hardcopy may be requested, and is immediately printed. Additionally, the report data is maintained in the computer and may be recalled later for reference or update.

The second operational function involves the scheduling department. To allow a thorough analysis of fixed route schedule performance, data is stored on magnetic tape. Data reduction is then performed using programs provided for the SCRTD Business Computing System to produce these reports:

- Schedule Deviations
- Selected Line Analyses
- Summary Performance Reports.

The control loop will be closed when the Scheduling Department adjusts bus schedules after analysis of this data.

3.1.1.2 System Output Functions

System Output Functions fall into three categories: the data displayed at the Dispatch Console, Management Information Reports, and AVM Maintenance Data. Since any of the dispatcher's display formats can be reproduced on hardcopy, "snap-shots" of vehicle fleet performance may be taken at any time for use by transit personnel.

As in the case of information for the scheduling department, magnetic tape-accrued data may be reduced off-line to produce data for other departments. For Managers and Supervisors the following reports are available:

Schedule Deviations
Trouble Report Compilation
Summary Support Vehicle Activity.

For the Maintenance Department, a log of vehicle mileage is produced and for the Accounting Department, a breakdown of vehicle mileage by subdivision.

Maintenance Data pertinent to the AVM equipment is available as an on-line function through the System Programmer's Console. This system performance monitoring data is available in real-time to allow immediate corrective action. Typical data available includes:

Areas of poor data link coverage
Vehicles whose data link is inoperative
Signposts with a low or zero percentage of good reads.

3.1.1.3 Ancillary Functions

The existence of an operational AVM System provides a number of ancillary functions. These are:

a. Bus Stop Display - To provide passengers with real-time information, Bus Stop Displays are distributed around the system. They provide Scheduled

Headways, Waiting Time and general status for each of the routes passing the display location. Data is transferred to a Bus Stop display via a dedicated land line (See Figure 3 -2) and updated at one minute intervals.

b. Passenger Counters - An interface into the Data Control Unit (Figure 3-1) is provided to accept passenger count data when that system is implemented on AVM equipped buses. In addition, the vehicle to Control Center message format has been designed to allow the transmission of this information.

c. Vehicle Information Panels - Additional functions on the Information Panel. By inserting an Operator's ID card into the slot provided, his number is automatically entered into the data transfers between vehicle and Control Center. Operator ID numbers are contained in certain of the dispatcher display formats and are used to accumulate driver performance data for the Management Reports.

A clock display is also provided for the vehicle operator. The Data Control Unit contains a crystal controlled clock which is periodically synchronized to Control Center time by a clock synchronizing message sent to all vehicles. Consequently all personnel directly involved with the AVM System have synchronized time.

3.2 FIELD TEST CONFIGURATION

The fundamental purpose of the field test program was to demonstrate the viability of the Fairchild Location Subsystem and enable a quantified evaluation of its performance. The configuration implemented for the Philadelphia testing is shown in Figure 3-3 in block diagram form. This configuration contained those Location Subsystem elements necessary to make quantitative accuracy and operational performance evaluations but did not include those functions which were only informational transmissions such as the silent alarm and the driver's status display panel.

The additional instrumentation incorporated into the test vehicle beyond the Location Subsystem, provided the means by which sufficient performance data was gathered and reference coordinates derived to permit measurement of the Location Subsystem accuracy.

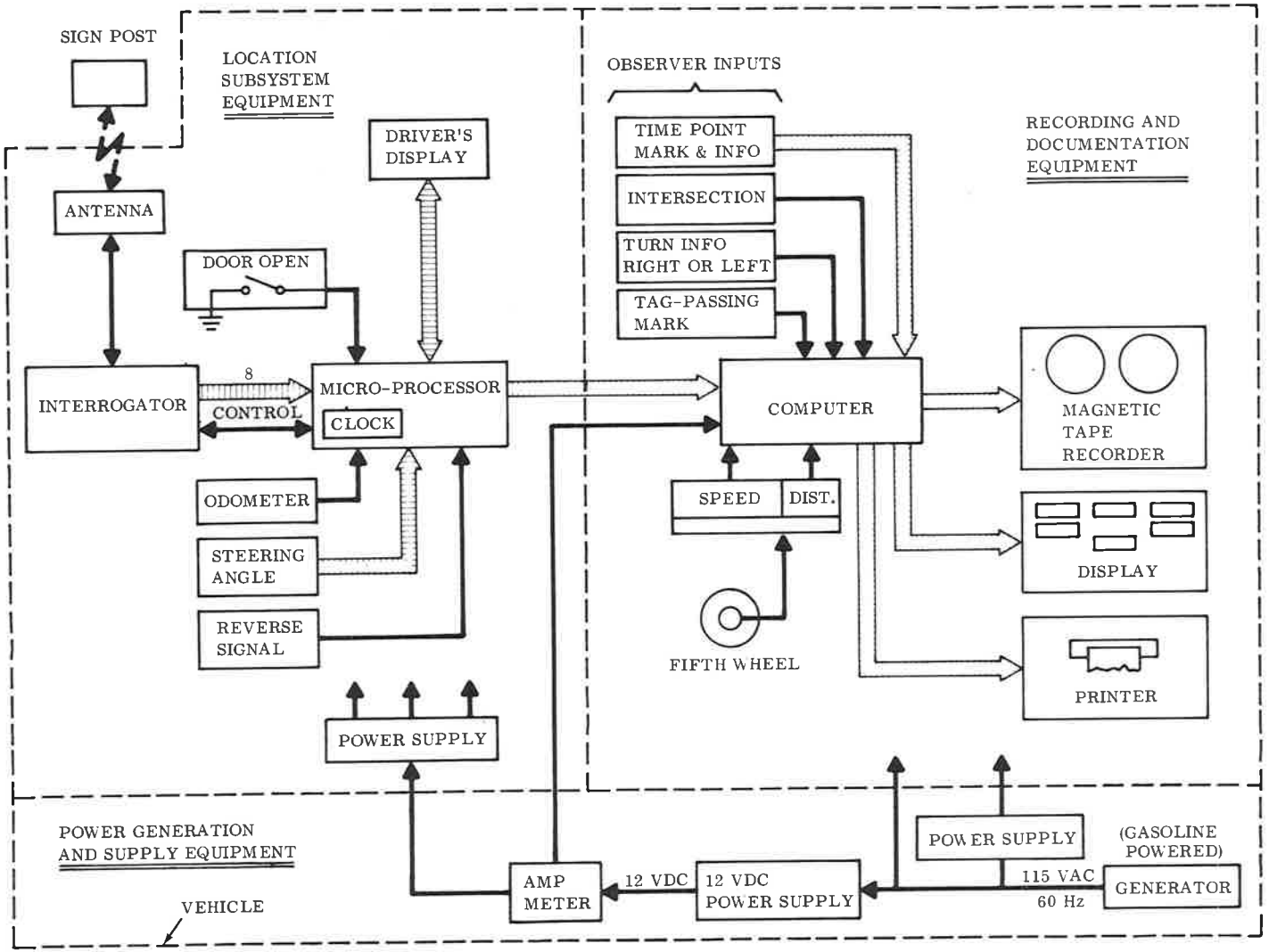


FIGURE 3-3 PHILADELPHIA VEHICLE INSTRUMENTATION

4. FIXED ROUTE TESTS

4.1 TEST CONFIGURATION

The location subsystem field test program was designed to simulate actual operational vehicle deployment in an urban environment. The first segment of the field test program was designed specifically to simulate mass transit vehicle movement over a fixed predesignated route. The route assigned to FSEC, as shown in Figure 4-1, starts and finishes at the City Hall in downtown Philadelphia and is approximately 11.4 miles in length.

This fixed route was instrumented with 67 signposts distributed as shown in Figure 4-1. Average inter-signpost distance was therefore about 900 feet, and the maximum distance about 2450 feet. Test vehicle/signpost horizontal passage distance varied from about 6 feet for the narrow one-way streets, to over 100 feet at the Logan Circle exit to the Ben Franklin Parkway. All signposts were mounted from 20 to 25 feet above the road surface mostly on metal lamp posts, and located such that they would be interrogated by the test vehicle antenna oriented to radiate to the right, perpendicular to the vehicle direction of travel.

The vehicle selected and instrumented for the field tests was a 1976 GMC Vandura truck model 7G21305. Instrumentation consisted of the Fairchild Location Subsystem (described in Section 3) and the necessary data acquisition equipment to verify the Location Subsystem (L.S.) performance. Figure 4-2 shows the double equipment rack mounted within the test vehicle and contains from top to bottom left to right the following equipments:

a) Data tape recorder 01

b) Data tape recorder 02

c) Data General NOVA 1200 data acquisition computer

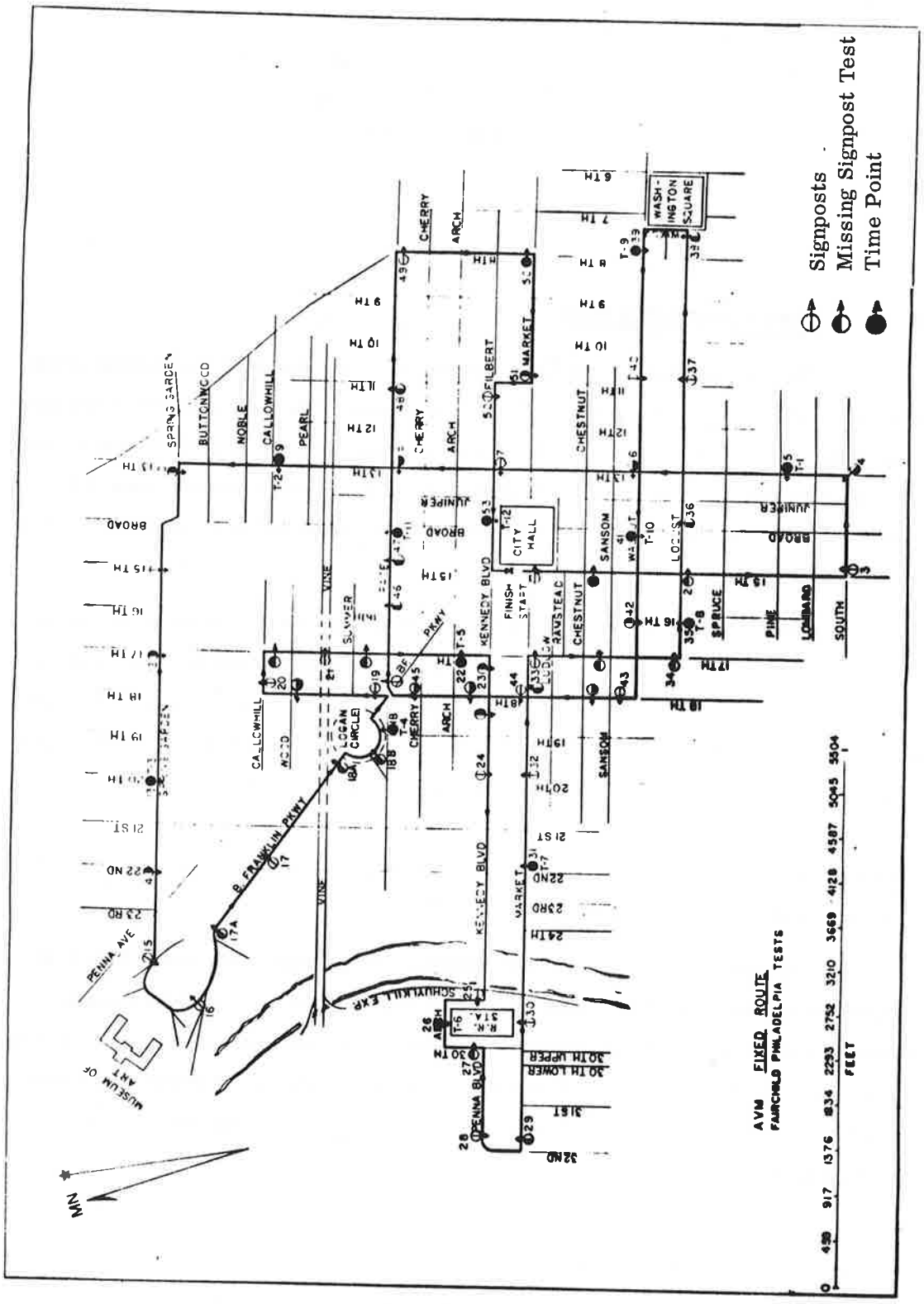


FIGURE 4-1 FSEC FIXED ROUTE

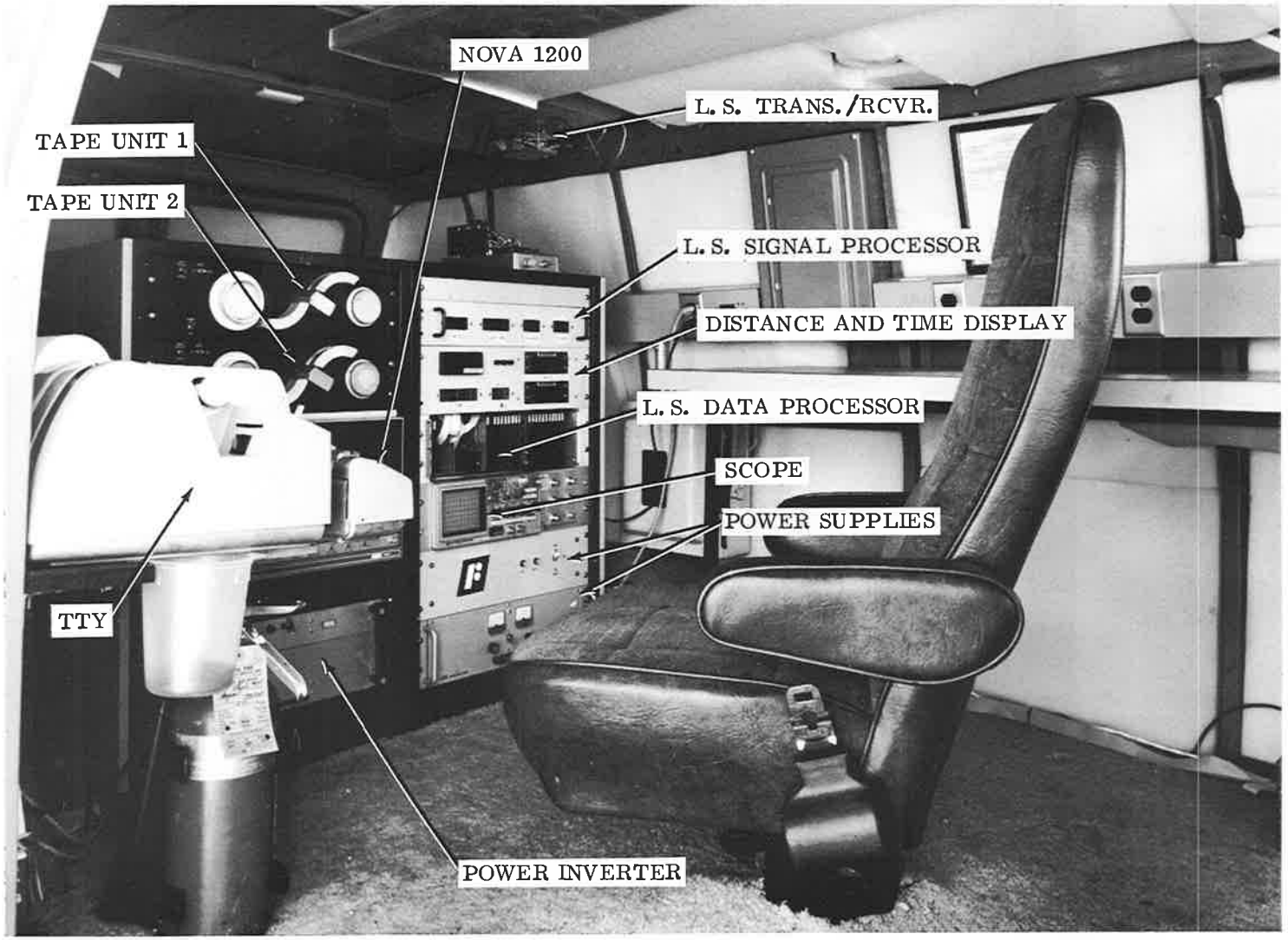


FIGURE 4-2 TEST VEHICLE INTERNAL TEST EQUIPMENT AND LOCATION SUBSYSTEM

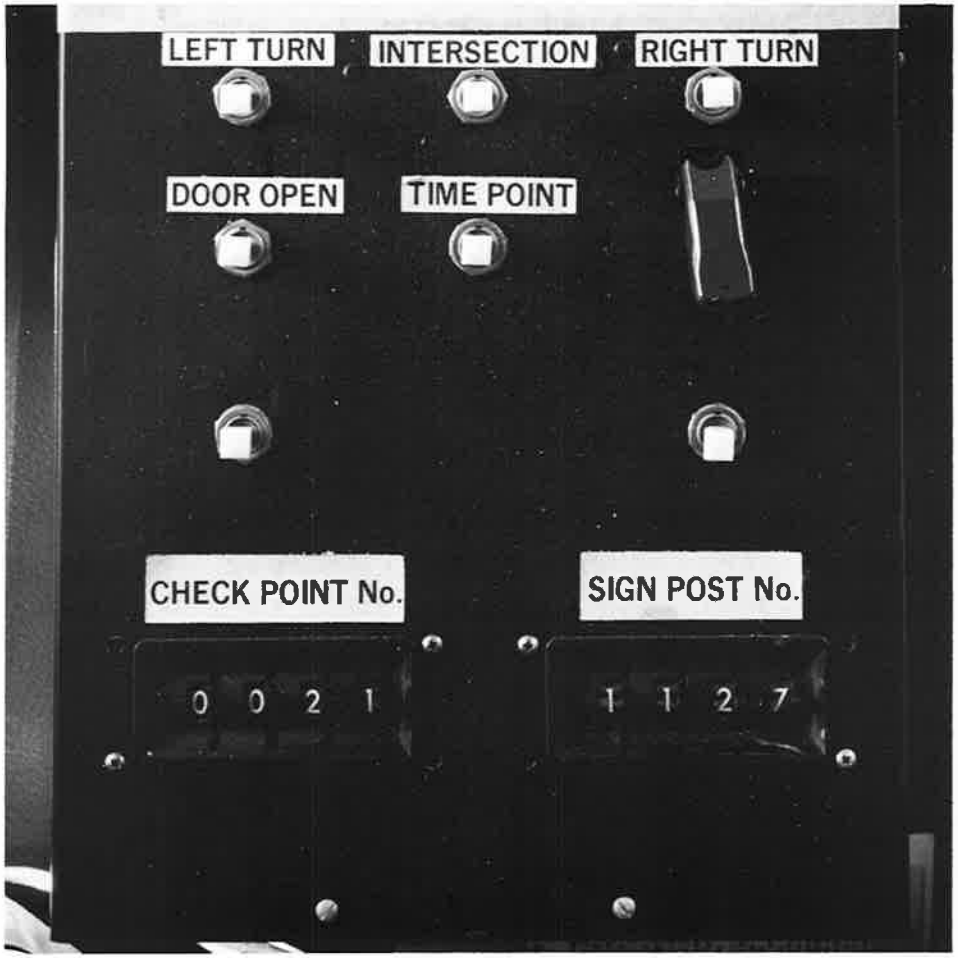


FIGURE 4-3 TEST VEHICLE TEST CONDUCTOR CONSOLE

FIGURE 4-4 TEST VEHICLE EXTERNAL TEST EQUIPMENT

d) Power inverter for test equipment

e) L.S. signal processor and display

f) Distance (5th wheel) and time display

g) L.S. Data processor

h) Test Oscilloscope

i) Data processor power supply

j) L.S. signal processor power supply.

Also visible in Figure 4-2 is an ASR33 Teletype and the roof mounted L.S. transmitter/receiver enclosure. Figure 4-3 shows the test conductor manual data entry console. This panel provides the means by which the test conductor indicates the passage or occurrence of specific events used either to simulate actual transit vehicle operation, passage of time points and checkpoints for L.S. accuracy evaluation, or turn indications to assist in assimilating the base station smoothing routine data base during preliminary runs. Figure 4-4 is an exterior view of the test vehicle showing the roof mounted L.S. antenna, the 5th wheel, and the gas-driven generator used to power all the on-board equipment. Not shown is the odometer encoder, which provides approximately one pulse per every four feet of vehicle travel; and the steering angle indicator, attached to the steering linkage, which provides an encoded signal of front wheel angle. The steering angle indicator is not used on fixed route runs.

4.2 PROCEDURE

4.2.1 FINAL ROUTE SETUP

Before starting the actual fixed route testing, preliminary test runs were made along the route to establish, with DOT/TSC observer's guidance, suitable locations for those checkpoints which were defined as being before or after but not at specified intersections. The locations of these checkpoints were then referenced to the intersection to permit a determination by DOT of their true location in state plane coordinates. After completion of the final checkpoint layout and measurement, four calibration runs were made, recording only the locations of turns, intersections, and signposts in fifth wheel distance. These measured distances then became the data base of the route description used in the base station central processor. Checkpoint locations were not entered during these calibration runs. With the fixed route thus described, actual data runs commenced.

4.2.2 RUN INITIALIZATION

At the start of each data run, each piece of equipment was verified to be operational and an appropriate header entered onto the data tape specifying the date, time, run type, and data tape number. At a fixed location just before the formal start of the run, the Location Subsystem and 5th wheel distance were reset and the data recorder enabled. The test run then formally began with the acquisition of signpost 602 on the route.

To establish the accuracy of the L.S. and demonstrate its ability to meet the contract specifications, two types of data points were utilized on the fixed route runs. These were Time Points and Checkpoints.

4.2.3 TIME POINTS

For test purposes time point accuracy is defined as the interval between automatic detection of arrival at a Time Point and manual depression of a switch by the operator of the test vehicle as he comes opposite the Time Point signpost.

In an operational system it is also important to know how long the bus remains at a stop loading and unloading passengers. To similate this situation, a DOOR OPEN and DOOR CLOSED switch on the operations console was used, and that time interval was recorded to demonstrate the system's ability to accept such data.

4.2.4 CHECKPOINTS

Checkpoints were assigned by DOT/TSC on the entire length of the test route and were correlated by actual measurement to the state plane coordinate system. As each checkpoint was passed, the test conductor indicated same by depressing a checkpoint switch on the console. Associated with this data entry switch is a thumb-wheel switch used to set the identity of each checkpoint indicated. The off-line data processor at each new checkpoint entry compared the Location System indicated vehicle location to the known checkpoint location to determine a radial error.

4.2.5 LOG BOOK

The test conductor maintained a log book in which was specified any and all observations of route conditions, manual entry errors, and noted system anomalies.

At the conclusion of each run the appropriate log book sheets were then certified by the TSC observer.

4.2.6 RUN COMPLETION

At the conclusion of each run the total 5th wheel distance was noted to determine run consistency. A cue code was entered on the data tape to signify completion of the run and the final logbook entries completed. The data tapes were then removed from the recorder and transported back to FSEC for duplication and processing.

4.3 DATA ANALYSIS

4.3.1 SAMPLE SIZE

Based on considerations set forth in the document entitled "Recommended Approach" issued by DOT/TSC, and the sample size analysis presented as Appendix E, the number of points selected by FSEC for each distance accuracy test was 450 and for the timing accuracy was 300. Summarizing the data taken during the Philadelphia tests and comparing them with the data in Table III of the referenced document, the following observations may be made. (Table III is reproduced as Table A-11 of Appendix A.)

TABLE 4-1. SAMPLE SIZE

Fixed Route	Sample Size	Error Rate (%) (Over 300')	Error Rate for 95% Confidence (Table A-11)
Time Points	328	0	4.2
Check Points	2192	0.77	4.7
0.1 MILE Int.	4176	1.1	4.7
25 Second Int.	7186	0.39	4.7
Random Route			
Check Points	560	3.7	4.2
0.1 MILE Int.	658	2.6	4.2
25 Second Int.	1138	3.3	4.7

It is seen that the error rate in all cases is considerably below that given by the table. The conclusion that the data confirms the sample size selection results in a confidence level exceeding the 95% required.

4.3.2 DATA REDUCTION

4.3.2.1 Location Subsystem Accuracy

The performance accuracy of the Location Subsystem was determined by radial errors as measured at the 60 fixed checkpoints along the Fixed Route run.

As the test vehicle progressed through the fixed route, the Location Subsystem determined from the odometer encoder the distance traversed by the vehicle. This distance was accumulated linearly regardless of the actual direction taken by the vehicle. Whenever a signpost was encountered, the accumulation register was cleared. Thus two registers of information were generated by the on-board L.S.: (1) The identification of the last signpost encountered and (2) the linear distance traversed since the present signpost was acquired. This data, as recorded on the data tape, was then processed off-line to formulate a set of X and Y state plane coordinates for comparison with the checkpoint known locations whenever a checkpoint location was indicated by the manual console entry.

To perform this conversion, the off-line processor data base consists of the following:

Route Table
Signpost File
Intersection File.

The Route Table contains the route descriptors (signposts or intersections) as encountered by the vehicle in traversing the fixed route and the distance in feet from the previous signpost. The Signpost File contains each signpost identification within the system and its true X and Y coordinates. The Intersection File contains an identification for each system intersection and its true X and Y coordinates. Location of the test vehicle, therefore, consists of (1) determining where within the Route Table the vehicle is and (2) interpolating between the coordinates which describe the bounds of the present Route Table location using the distance traversed from the last signpost.

The radial error is then determined as the square root of the sum of the squares of the X and Y coordinate errors between the Location Subsystem determined position and the reference checkpoint location.

4.3.2.2 System Accuracy

The AVM System accuracy was determined by the calculated radial errors from each data sample in a simulated vehicle polling situation. Polling frequency for this simulation was taken at 25-second intervals based on the system design goal of polling a 250 vehicle dispatch unit every 25 seconds. Since checkpoints did not necessarily coincide with the 25-second intervals along the route, the test vehicle 5th wheel was used as the basis of comparison. A separate table of 5th wheel distance vs. true X, Y coordinates was generated during the pre-test runs to define the fixed route. An interpolation was then made between these fixed locations. For curved streets such as Logan Circle, the curve was broken into chords by defining intersections at convenient locations.

The Location Subsystem coordinates for each polling point was determined identically as described in Section 4.3.2.1.

4.3.2.3 Time Point Accuracy

The time of passage of each of the 14 designated fixed route time points was recorded by the test conductor by activating a Time Point switch on the console. This caused a flag to be set in the recorded data indicating passage of a time point. The Location Subsystem Signpost file contains two auxiliary tables, one containing a list of time point signposts, the other containing a list of signposts located just before time points. At each signpost acquisition the L.S. searched these files for a match. If achieved, the L.S. then set a flag bit indicating a Time Point if the match occured in the Time Point file. If the match occured in the signposts before Time Points file, an associated distance had to be traversed before the flag was set.

The recorded data record contains a time of day reading with each data sample. A comparison must therefore be made between the manually set flag and the L.S. set flag to determine the accuracy of measurement of Time Point Passage.

4.3.2.4 System Coverage

System coverage is defined as the average positional error for each tenth mile increment along the vehicle route. This 0.1 mile increment determination is made simply as the average obtained for all 0.5 second data samples over each 0.1 mile

increment. The basis for comparison is the coordinate set determined from the 5th wheel distance using linear interpolation in the 5th wheel X Y coordinate table.

4.3.2.5 Time Point Coverage

Time point coverage is defined as the percentage of times the Location Subsystem does not make a time point measurement. This is determined by observation of the L.S. time point flag bit in the data printout.

4.3.2.6 Error Distribution Description

The error distribution descriptor parameters are discussed in Section 5.3.2.4.

4.4 FIXED ROUTE RESULTS

The data summaries supporting the final accuracy determination presented in the following sections describing fixed route performance are included in Appendix A, and are tabulated below for reference:

Table A-1	Signpost Acquisition Errors, Fixed Route
Table A-2	Checkpoint Radial Errors, Fixed Route
Table A-3	System Coverage Radial Errors, Fixed Route
Table A-4	Errors in Excess of 300 Feet, Fixed Route
Table A-5	Test Conductor Note Summary
Table A-6	System Level Radial Error Summary, Fixed Route
Table A-7	Time Point Passage Time and Accuracy
Table A-8	Time Point Arrival and Departure Times
Table A-9	System Level Large Radial Error Correction Table
Table A-10	System Coverage Data Point Correction

4.4.1 SUMMARY OF RESULTS

TABLE 4-2. FIXED ROUTE PERFORMANCE SUMMARY

	Specifications Requirements	Uncorrected FSEC	Corrected FSEC*
System Accuracy			
95th Percentile	300	82	81
99.5th Percentile	450	148	125
Mean	-	44	30
Sample Size	-	7186	7160

TABLE 4-2 (Cont.)

	Specifications Requirements	Uncorrected FSEC	Corrected FSEC
Time Point Accuracy			
95th Percentile	15 (sec)	0.5 (sec)	0.5 (sec)
99.5th Percentile	60 (sec)	1.5 (sec)	1.5 (sec)
Sample Size	-	448	-
System Coverage (0.1 mile)			
95th Percentile	-	79	74
99.5th Percentile	-	1154	120
Mean	-	47	30
Sample Size	-	4176	4134
Maximum	-	6677	756
Location Subsystem Accuracy			
95th Percentile	300	57	54
99.5th Percentile	450	1151	70
Mean	-	47	24
Sample Size	-	2192	2175
Signposts Missed	-	0.6%	0%
Signposts Misread	-	0.8%	0.04%

*See Section 4.4.6.1, removal of errors resulting from specific incorrect signpost acquisitions which are easily corrected at the system level.

4.4.2 LOCATION SUBSYSTEM ACCURACY

The performance accuracy of the Location Subsystem as determined by comparison with 60 checkpoint locations along the fixed route run was measured to be 57 feet for 95th percentile, 1151 feet for 99.5th percentile and 47 feet mean value. All data from 38 runs were included, encompassing some 2192 checkpoints. Four checkpoints were eliminated on the basis of log book-documented operator errors (see Appendix A-2), and two due to tape processing errors in run 130 (See A-10). A composite frequency distribution and cumulative error distribution is shown in Figures 4-5 and 4-6.

Although the 57 feet achieved for the 95th percentile far exceeded the required 300 feet, the 99.5th percentile did not. Examination of the data output, however, soon highlighted the reason for this very large error. During 17 acquisitions over the 38 fixed route runs, signposts along the route were correctly acquired, only to have the registered identification number change shortly thereafter. The System Processor interpretation resulted in one of the two following actions occurring: (a) The changed number matched another signpost within the test vehicle assigned route description with the result that the vehicle was placed at the other signpost. (b) The

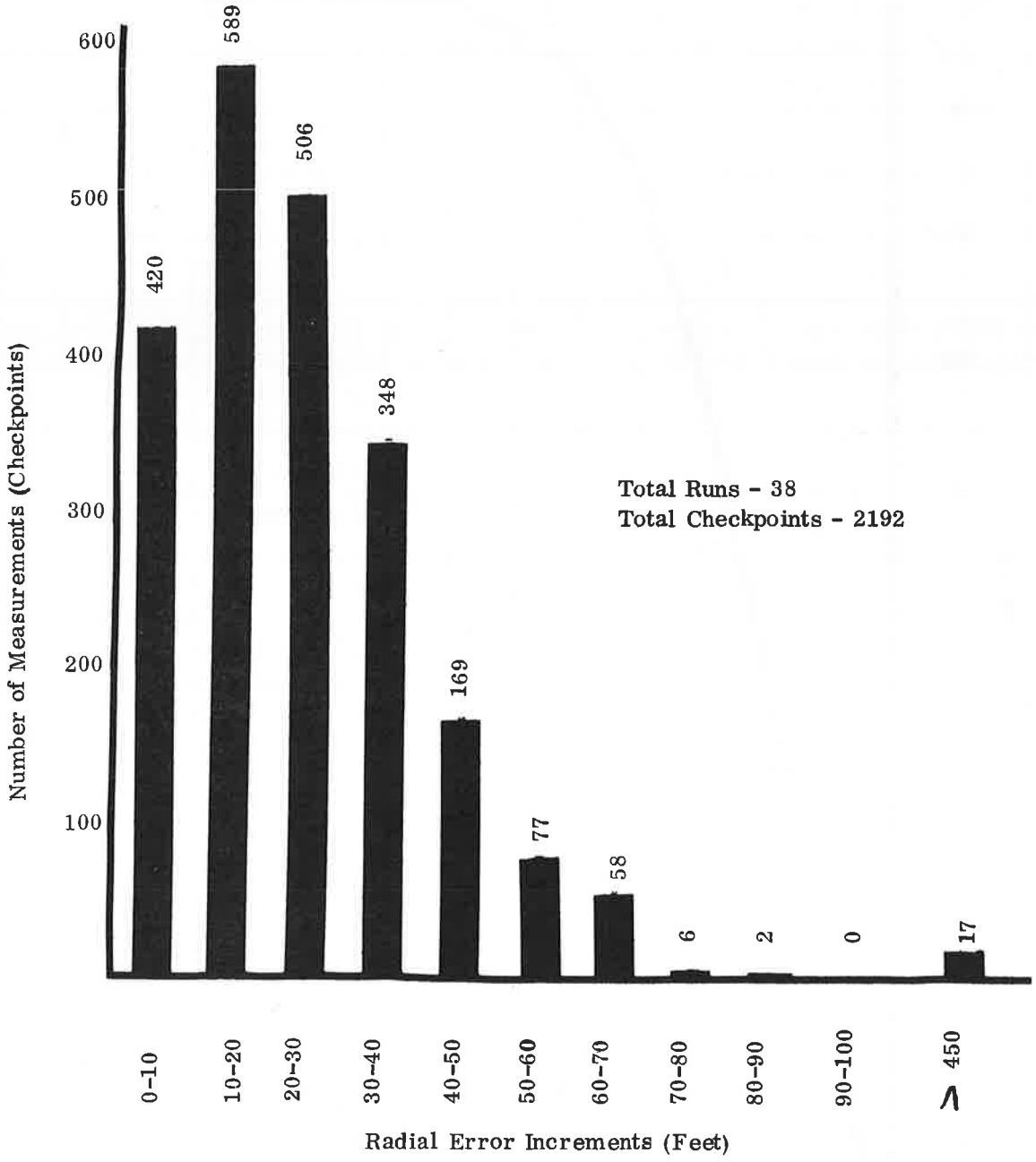


FIGURE 4-5 LOCATION SUBSYSTEM FIXED ROUTE RUNS
CHECKPOINT ACCURACY--NUMBER

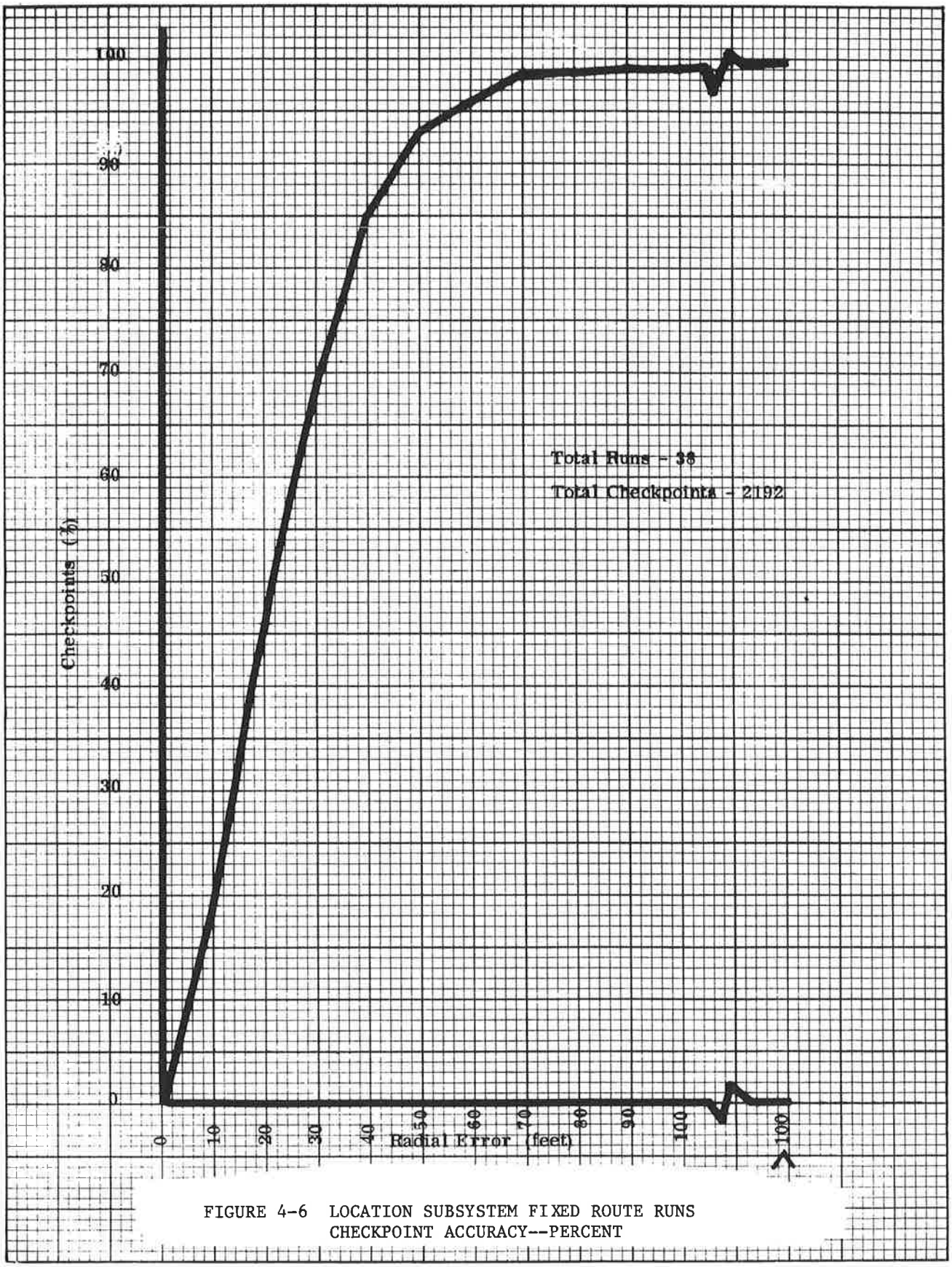


FIGURE 4-6 LOCATION SUBSYSTEM FIXED ROUTE RUNS
CHECKPOINT ACCURACY--PERCENT

changed number did not match any signpost identification. The System Processor therefore assumed the next signpost in the route description file had been acquired and placed the vehicle at this location prematurely. For either case, large errors were indicated at all succeeding checkpoints until the test vehicle correctly acquired the next signpost along the route. The development of these identification errors, as discussed in Section 4.4.6.1, indicates that these are systematic failures occurring with consistent and well-defined parameters, and therefore can be easily eliminated from the final system design. Since these are not random fluctuations in achieved checkpoint accuracy, they have been removed from the Corrected Data Column in the Results Summary to emphasize the true accuracy of the Fairchild system. Removing these 17 data points improves the 95th percentile from 57 to 54.4 feet. Much more significantly, the 99.5th percentile improves from 1151 to 69.5 feet, and the mean value from 47 to 24 feet.

A second consideration in the checkpoint accuracy evaluation can be developed from an examination of the consistency at a specific checkpoint taken across all the fixed route runs. For example, the histogram plot in Figure 4-7 indicates the dispersion in radial error for checkpoint 28. This plot indicates a tight grouping about a mean of 63.3 feet where no data point deviated by more than 10.7 feet from this mean. This type of fixed offset could be caused either by the basic accuracy of the state plane coordinate measurements, or by an offset in the vehicle route description file. In either case, this offset could be eliminated by additional calibration yielding an ultimate accuracy at checkpoint 28 of 11 feet instead of the tabulated 63 feet. While no attempt was made to retabulate the data removing any bias or offsets, this discussion does serve to highlight the direction of improvement if such corrections were incorporated into the system.

4.4.3 SYSTEM COVERAGE (0.1 MILE INCREMENTS)

System coverage accuracy is derived from a comparison of the L.S.-determined location at each 0.5 second sample point, with a location derived from the 5th wheel accumulated distance. The determined radial error at each sample is then averaged over 0.1 mile increments to determine the system coverage. This resulted in about 113 increments for each of the 38 fixed runs.

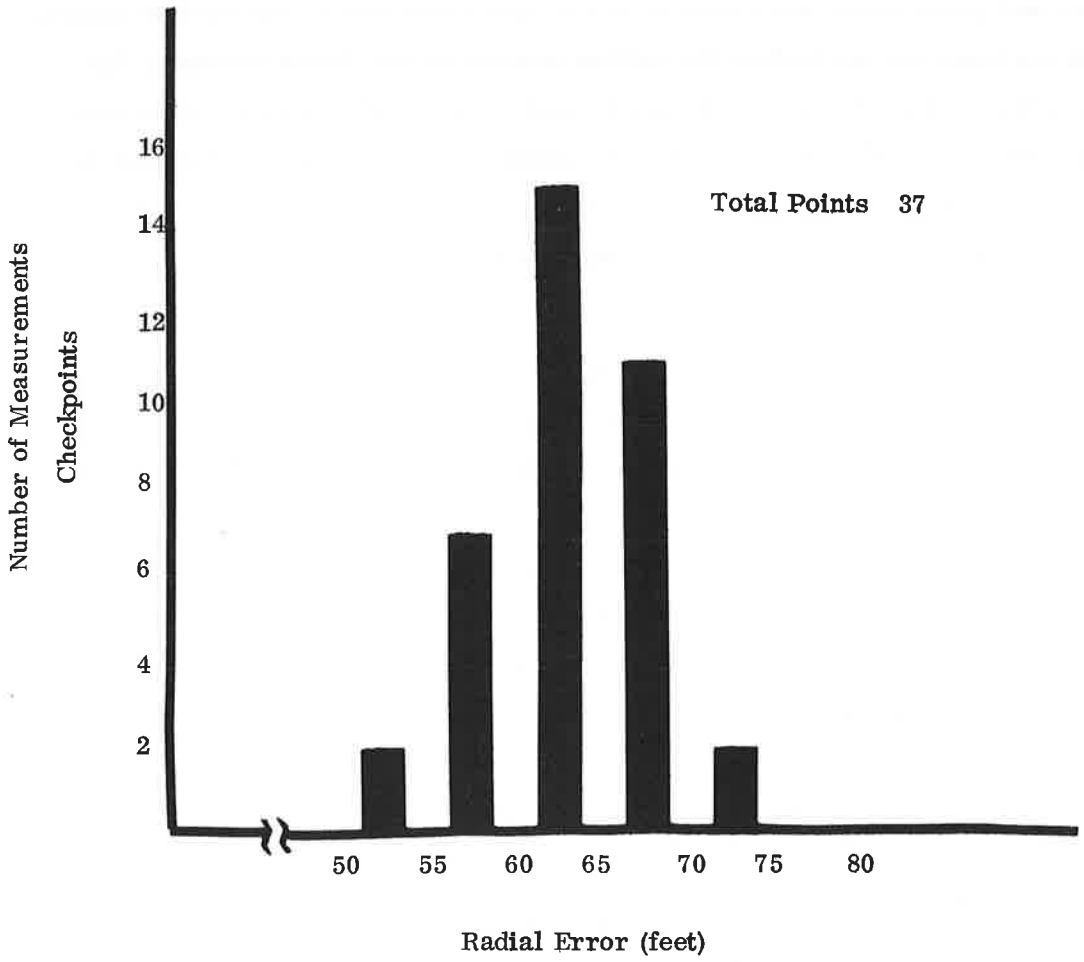


FIGURE 4-7 CHECKPOINT 28 RADIAL ERROR DISPERSAL

A review of the fixed route data printout for the System Coverage errors (0.1 mile increments) indicated several irregularities by the system 360 computer processor. These irregularities are detailed in Appendix Table A-10 and arise from the following conditions:

a) The data tape was started at 15th Street and J.F. Kennedy Blvd. about 300 feet prior to the start of the fixed route. A very large residual error was therefore averaged into the first tenth-mile increment for each run. Inasmuch as this error was accumulated before the official start of the run, each 0.0 mile increment has therefore been eliminated from the system coverage data base.

b) Run 127 contained an extra segment of data at the beginning where the fifth wheel distance started at zero then erratically jumped to 4213 feet and increased to 4480 before again indicating zero where the actual run began. This caused the first 8 tenth-mile increments to be erroneously computed as the average of the actual data and the spurious data. To rectify this error the first 8 tenth-mile increments were recalculated manually and the corrected value substituted in the data base.

c) Run 129 contained an erroneous value for the second tenth mile increment due to a tape error. The actual value was manually calculated and the corrected value substituted in the data base.

d) Run 130 contained a data tape error which caused the 5th wheel distance to jump from 2131 to 5514 generating a spurious value for two tenth-mile increments. Since no data was available for a recalculation, these two values were deleted from the data base.

In addition to the above, two runs (103 and 119) were terminated early because of road blockages. (See Table A-5). This resulted in a total population size of 4176 data points.

The tabulated results indicate a 95th percentile error of 78.7 feet, 99.5th percentile error of 1154 feet and a mean value of 47 feet. The composite frequency distribution and cumulative error curves are shown in Figures 4-8 and 4-9.

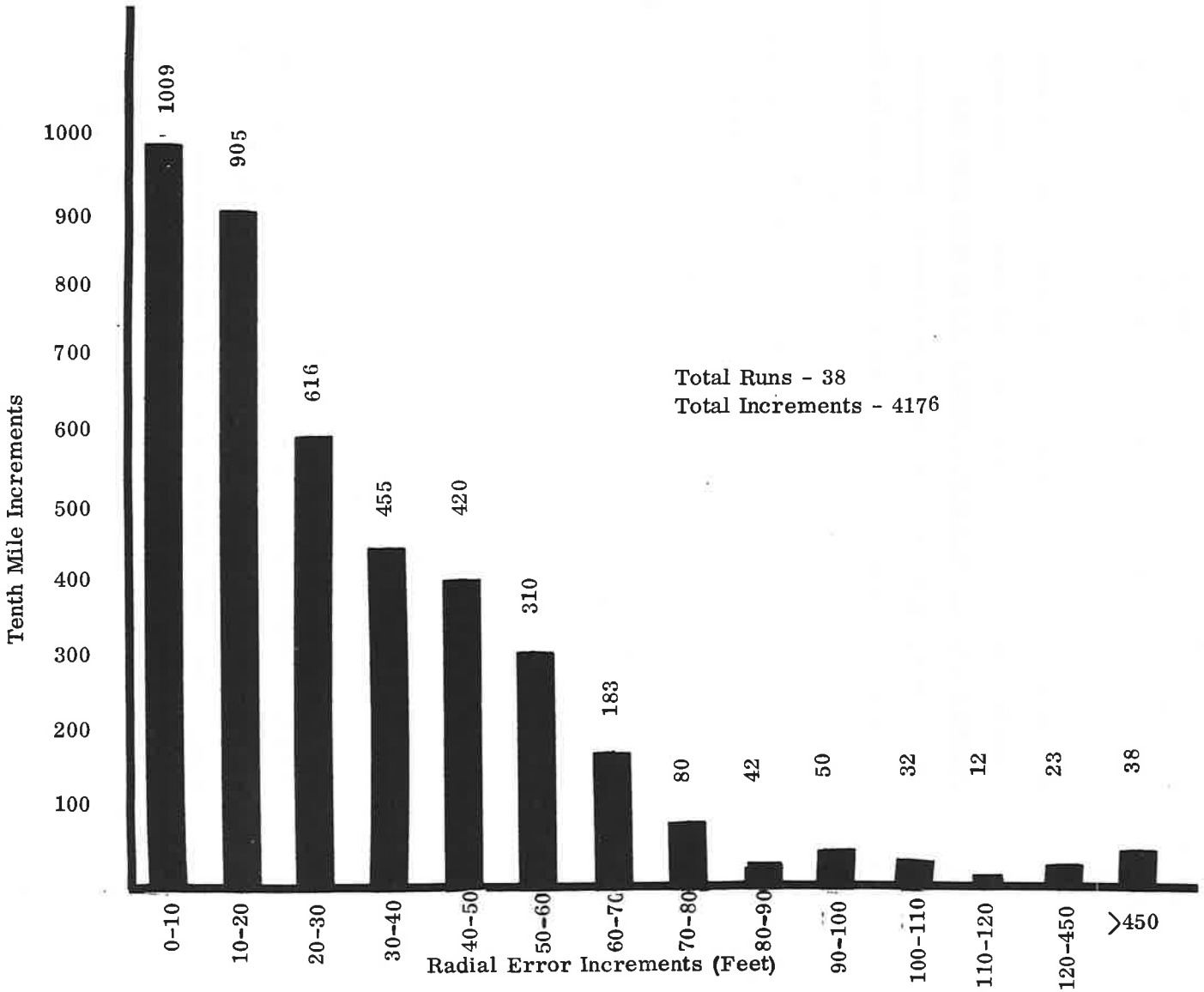


FIGURE 4-8 SYSTEM COVERAGE 0.1 MILE INCREMENTS

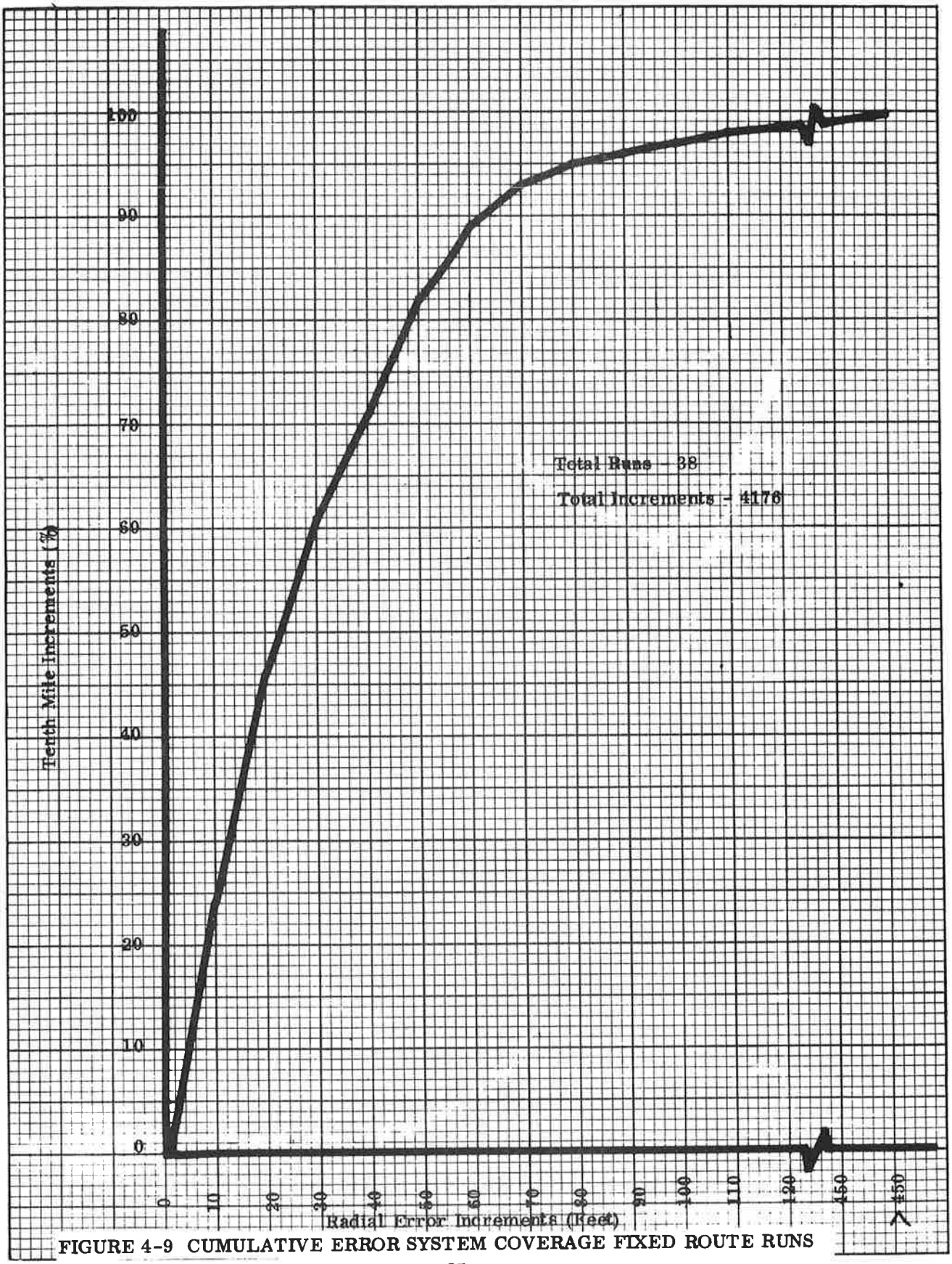


FIGURE 4-9 CUMULATIVE ERROR SYSTEM COVERAGE FIXED ROUTE RUNS

These results, like the checkpoint accuracy, were affected by the acquired signpost identification number changing during 17 acquisitions. If the errors due only to this systematic change are eliminated from the data base (42 total points), the system coverage accuracy improves to 73.7 feet for the 95th percentile, 120 feet for the 99.5th percentile, and 29.5 feet for the mean value. FSEC feels these results are more indicative of true system performance potential.

In the assimilation of this data a comparison was made of the run-to-run variations in 5th wheel readings at several well-defined locations along the fixed route. Table 4-3 indicates the expansion of this error as the route is traversed. The largest contributing factors to the variation are the Logan Circle and Art Museum segments of the route. Since the Fairchild Test Program did not reset the 5th wheel at any reference points along the route, this variation was then a significant contributor to all accuracy determinations for which the 5th wheel was used as the standard.

TABLE 4-3. 5th WHEEL VARIATIONS

Reference	Location	Variation
Signpost 520	13th & Pine	5 feet
Signpost 597	Museum of Art	32 feet
Signpost 535	17th & Arch	79 feet
Checkpoint 26	19th & Kennedy	95 feet
Checkpoint 57	8th & Arch	113 feet

Examination of the data (Table A-3) indicates that the radial error does increase as the route is traversed; a trend that is not observable for the checkpoint errors. It may, therefore, be concluded that this variation is the direct result of the variations in the 5th wheel readings, since the Location Subsystem has no known characteristics which would tend to improve accuracy at the beginning of a run. This reference inaccuracy is therefore largely suspected as the primary reason why the system coverage accuracies (corrected) are not quite as good as the Location Subsystem accuracy base on fixed checkpoints. For this reason the latter must be considered as the more accurate determinate of system performance.

4.4.4 SYSTEM ACCURACY

System Accuracy is determined by the calculated radial errors from each 25-second polling sample, simulating a multi-vehicle central processor. Like the system coverage, this radial error calculation uses the 5th wheel distance as the reference standard and therefore is subject to the same previously discussed limitations.

During an examination of the System Level data printout an astounding discovery was made. The system level printout, supposedly nothing more than 25 second polling of the subsystem level printout (basically every 50th data point), did not always agree with the subsystem level calculated errors. A manual comparison was therefore made, and wherever the two outputs disagreed, the subsystem level error was substituted. The reasonableness of this approach can be determined by an examination of the data itself. Table A-9 in Appendix A details the differences encountered. For example, see A-9, the first point corrected is Run 101, Entry Number 71. In the system printout the error is listed as 412.9 feet corresponding to a sample time of 19:45:5.1. If the same data sample is examined for the subsystem level printout (time 19:45:5.1) an error value of 24.6 feet is noted. Since the subsystem level error is consistant with the previous and succeeding sample errors, but the system level error is not; and the data recorded on the tape is identical for both computer routines, it must be logically concluded that the system level processed output is in error. On this basis then, Table A-9 was generated correcting the discrepancies in the system level output.

Using the above corrected data, a sample population of 7186 points was obtained from the 38 fixed route runs. Table A-6 lists the radial error summaries. The numerically determined statistical parameters for this distribution are 82.3 feet for the 95th percentile, 148 feet for the 99.5th percentile, and 44 feet for the mean error value. The frequency distribution and cumulative error curves are shown in Figures 4-10 and 4-11. As with the previous accuracy determinations, the signpost acquisition changes influenced the error distribution. Therefore, to show the true performance potential, they have been eliminated from the corrected data distribution.

The performance parameters for this corrected distribution are 80.8 feet for the 95th percentile, 125 feet for the 99.5th percentile, and 30 feet for the mean error value with a sample population of 7160 points.

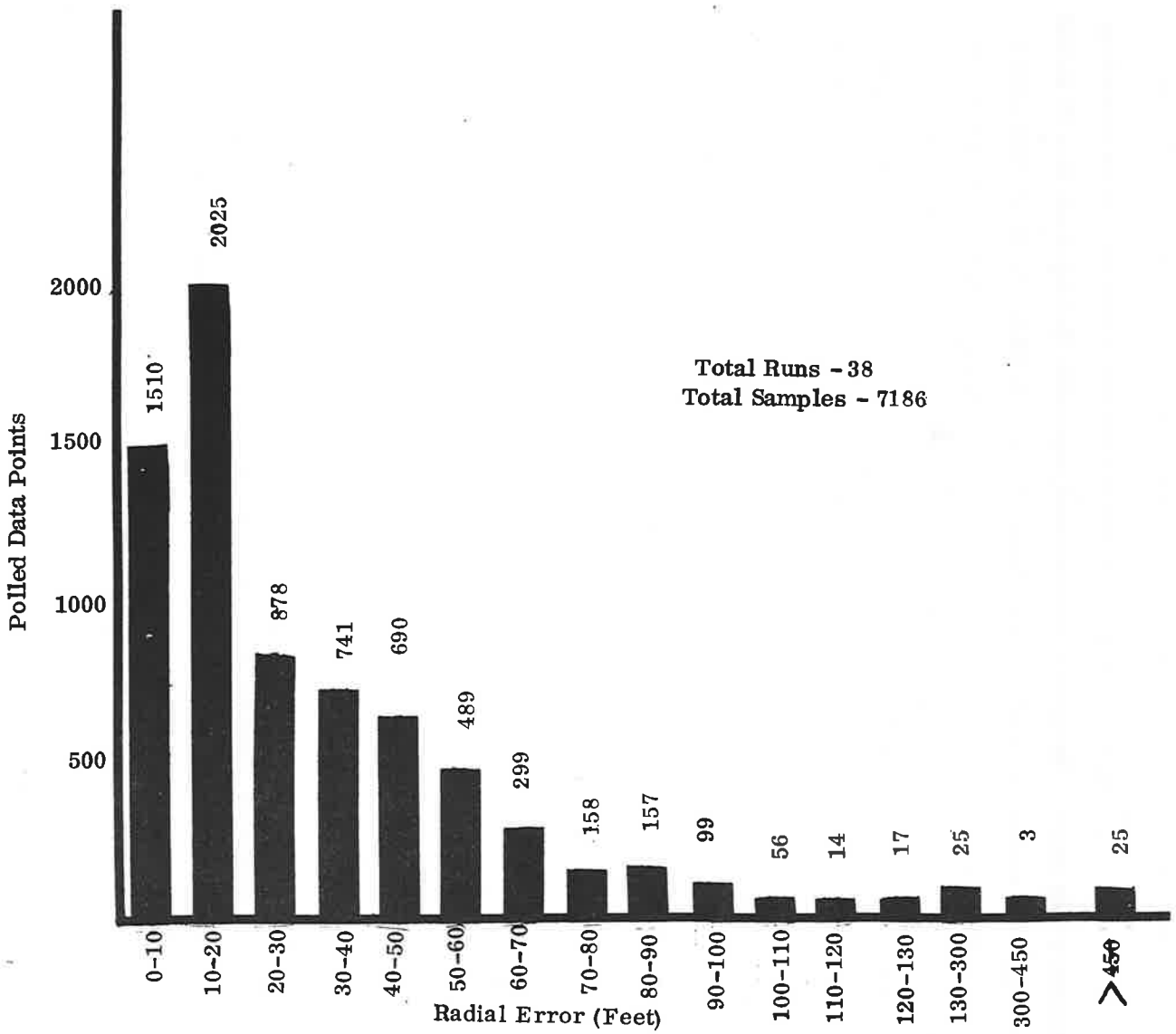


FIGURE 4-10 SYSTEM ACCURACY FIXED ROUTE RUNS

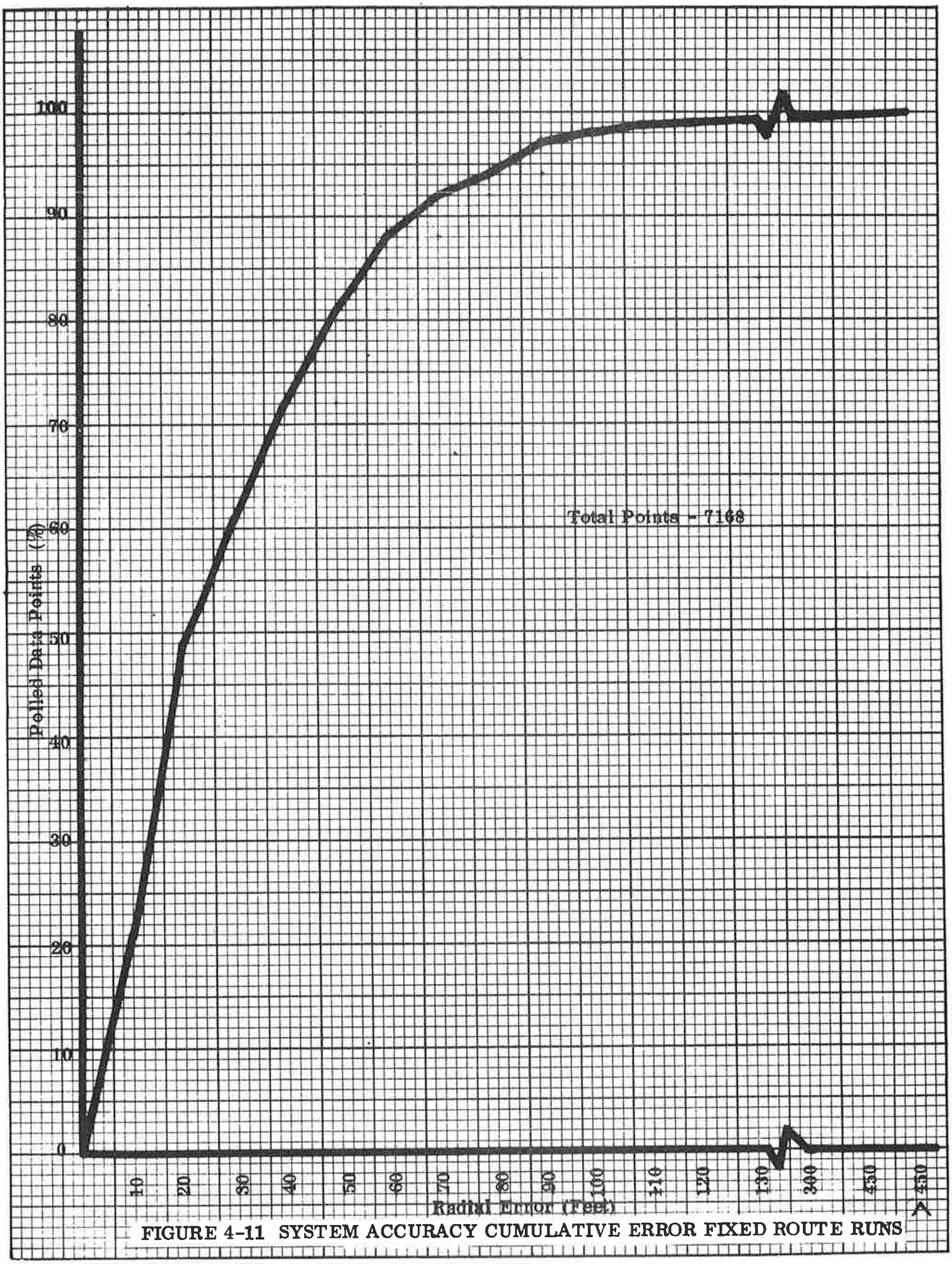


FIGURE 4-11 SYSTEM ACCURACY CUMULATIVE ERROR FIXED ROUTE RUNS

4.4.5 TIME POINT ACCURACY

Time point passage accuracy for each of the 14 fixed route Timepoints was measured as the difference in seconds between the observer's manually input indication and the Location Subsystem's automatic indication as each time point was passed. All time points are instrumented with signposts. These measurements were all made while the vehicle was in motion. As the vehicle passes each signpost, two data files are searched. The first file contains all the timepoint signposts. When a match occurs, the timepoint indicator flag is immediately set to indicate the time of passage and the time stored in the L. S. for transmittal at the next poll. If no match occurs, the flag is cleared. A timepoint flag therefore is set when a timepoint signpost is passed, and cleared at the next following signpost. The second data file contains a listing of the signposts before timepoints and an associated travel distance. If no match is achieved in the first file, the second file is searched to determine if a signpost just before a timepoint has been acquired. If a match is found, the vehicle travel distance is then monitored until the distance associated with the signpost in this second file has been traversed. The timepoint flag is then set and the time stored for transmittal at the next poll. If during this process the timepoint signpost is detected, the second file routine is terminated. This second file, then, creates an estimated passage time, in the event the actual timepoint signpost is not interrogated. This estimated passage time is discernable from the actual passage time since at each vehicle poll, the identification of the last successfully interrogated signpost is transmitted along with travel distances and the timepoint passage time. If a timepoint estimate is indicated, due to vehicle route distance variations, before the actual timepoint has been passed, and the timepoint signpost is then successfully interrogated; two times will then be sequentially transmitted to the central dispatch processor; first the estimated time, second the actual passage time. This assumes a poll is made between the time the estimated passage flag is raised. If this poll is not present then only the actual passage time will be transmitted to the central processor.

After completing five fixed route runs an operational fault in the timepoint flag was observed in that the flag was being set at each signpost before timepoint instead of waiting for the associated travel distance. The software was corrected and the fixed route runs resumed (100 series). Thus, 33 of the total 38 runs contain usable timepoint data. Of the maximum possible 462 data points, runs 103 and 119 terminated early (7 data points) and one data point (run 130) was lost due to tape parity errors. Therefore a net 454 data points were available. These data points are further subdivided into the following groups:

a. No timepoint indicator (No T) - Neither the passage nor estimated timepoint flag was raised; No data reduction possible; 4 points total.

b. No manual timepoint indicator (No S) - Test conductor failed to enter manual passage indicator; since these entries always coincide with a signpost I.D. manual entry the signpost entry was available to reduce 18 data points; 20 points total.

c. Timepoint flag reset failure (Continuous T) - Timepoint flag failed to reset between timepoints due to software anomaly, data reduced using time at which signpost automatically acquired; 122 points total.

d. Timepoint estimate flag received (T early) - Timepoint flag indicates estimated passage time, which is updated when timepoint signpost is successfully interrogated, estimate time included for information only, data reduced using successful timepoint interrogation; 38 points total.

e. Timepoint passage flag received (coincident T) - Timepoint flag set due to timepoint signpost successful interrogation, data reduced using the S and T flag indicators; 270 points total.

There were, therefore, only 6 timepoints for which data could not be reduced, 4 auto detection failures, and 2 manual entry failures or a total of 448 timepoint passage points. The histogram is shown in Figure 4-12, and has a 95th percentile error of 0.5 seconds, 99.5th percentile error of 1.5 seconds and a mean of 0.159 seconds. The raw data extracted from the 33 fixed route runs are tabulated in Table A-7 of Appendix A.

In a normal transit vehicle environment, time of arrival and departure as defined by door opening and closing are used to indicate scheduled status of the vehicle. To simulate this operation during the Philadelphia field testing, the door operation was simulated and recorded as part of the data output. Table A-8, in Appendix A, is a listing of all test vehicle stops made along the fixed route runs and indicates the arrival time, departure time, passage time at nearest time point, and the time difference between the passage and departure time. A total of 179 stops were made.

4.4.6 SIGNIFICANT OBSERVATIONS

4.4.6.1 Signposts Missed or Misread

At the completion of the 38 fixed route runs 2503 signposts were interrogated by the test vehicle. There were 16 signposts cataloged as missed and 22 as misread, representing 0.6% and 0.8% respectively.

Signpost 534 accounted for all the signposts cataloged as missed. This signpost was mounted at the exit of Logan Circle to Ben Franklin Parkway. At this location B. F. P is a split road with two groups of southeast lanes separated by a grass median. Due to a Fairchild

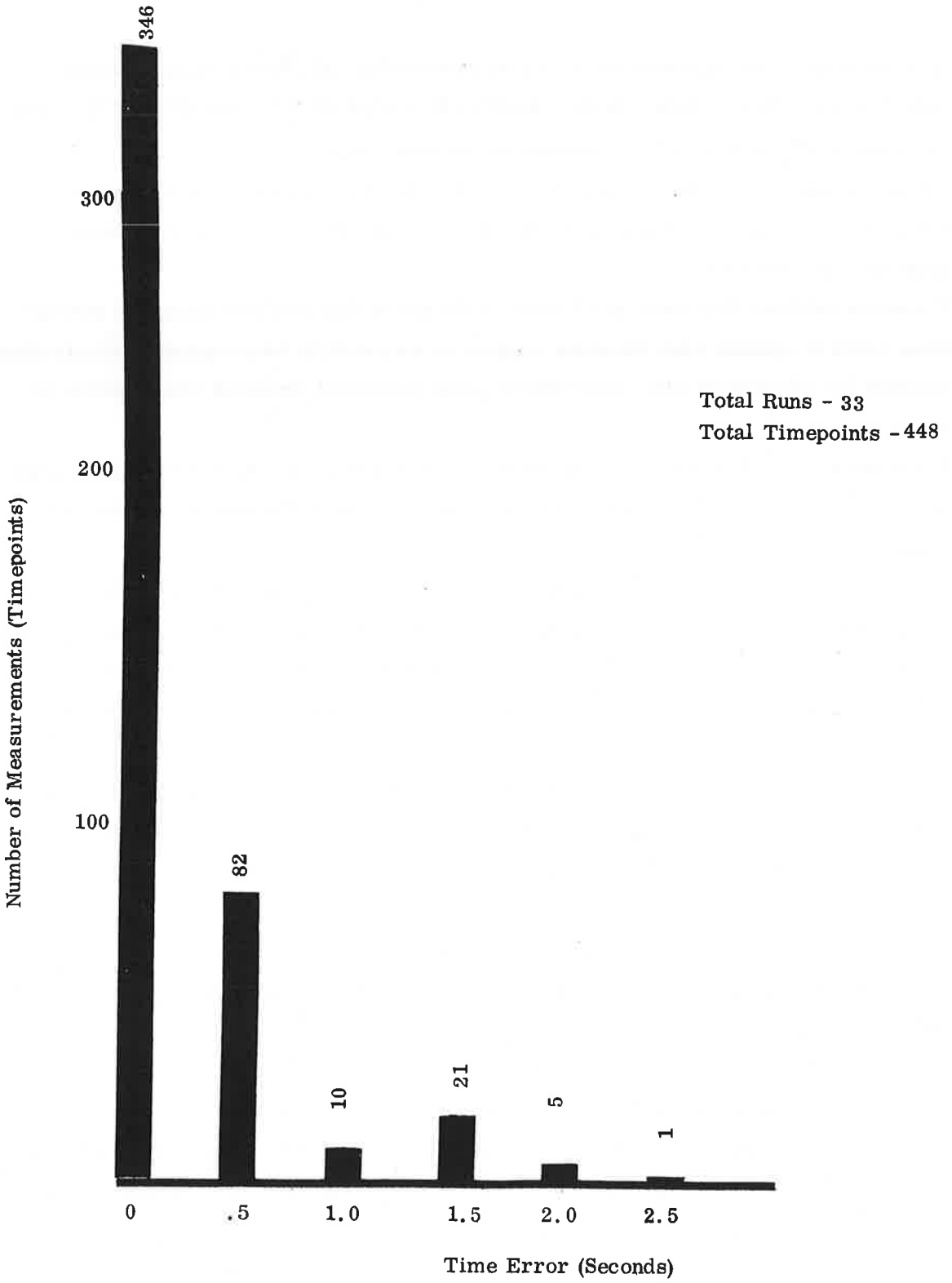


FIGURE 4-12 TIME POINT PASSAGE ACCURACY FIXED ROUTE RUNS

misunderstanding as to the exact path of the fixed route, the signpost was mounted and optimized to cover the righ hand group of lanes, while the actual route travelled down the center group of lanes. This error resulted in a relatively long distance (100') and a poor installation angle (45^{o}) for the interrogator to receive the signpost return signal. The significance of not reading a signpost along the route is minimal as shown by the missing signpost special tests.

Incorrectly read signposts can be divided into two categories:

a) Off-route signposts read

b) Signpost identification changed after being correctly acquired.

During fixed route run 106, signpost 587 was acquired from 13th street while the test vehicle was progressing down Race Street , since the signpost was located too close to the intersection. On subsequent runs the problem was not encountered and signpost 587 was correctly acquired. Since this particular signpost is located on a different segment of the fixed route, this incorrect acquisition placed the vehicle on the wrong route segment thereby generating significantly large error until the following correct route signpost was acquired. Category (a) accounted for one of the 22 misread signposts.

The second category accounting for the 21 remaining misread signposts included all signposts which were correctly acquired but whose identification subsequently changed to an incorrect number before the following route signpost was acquired. For 20 of the 21, this change occurred within 35 feet of the correct acquisition, indicating an interrogator signal processing deficiency in the return signal beam edge: While this processing deficiency will obviously be corrected for operational system use, there are several safeguards which will be additionally employed:

a) Parity check bits will be added to the signpost identification word to provide expanded error detection capability - the codes used in the Philadelphia test contained only one parity bit which proved inadequate.

b) Each new acquisition will be examined by a base station processor reasonableness algorithm to determine if it was physically possible for the vehicle to acquire (non-existant, beyond vehicle speed, not on route, etc) - no such algorithm was employed in Philadelphia.

It is interesting to note that if either of these safeguards had been employed for the Philadelphia tests, none of the incorrectly read signposts would have been accepted by the system processor.

The last misread signpost occurred during run 123 approximately 200 feet past the point at which the signpost was located. The data printout contained a full data block (16 entries) of signpost identification which is too large to fit into the alloted print field. The number then changes to an incorrect value for all subsequent data blocks. There is no obvious explanation for this output other than the overflow was most likely a tape parity error. The signpost identification, however, should have returned to the correct value for the subsequent data blocks.

A complete cataloging of all signpost acquisition errors is included in Appendix A, Table A-1.

Based on the preceeding discussion, if signposts 534 and 587 were properly located and the deficient signal processor within the interrogator corrected, the percentages of missed and misread signposts would then be 0% and .04% respectively.

4.4.6.2 Errors Exceeding 300 Feet

Table A-4 in Appendix A catalogs each incident for each fixed route run where the radial error (as computed for each 0.5 second data sample) exceeds 300 feet. Where the contributing factor causes the error to remain over 300 feet for more than one sample, only the first sample at which the value exceeded 300 feet was included. In reviewing this table there appear to be 4 repetitive contributors to these large errors.

The first contributor is the residual error accumulated by the system before the first signpost is acquired at the beginning of the run. The beginning of the run occurs when signpost 602 is acquired on 15th Street at Market. However, the 5th wheel was zeroed and the data acquisition system started at 15th and Kennedy where a convenient stopping place existed. This point is mentioned only because it exists on the data printouts but was eliminated from the data summaries and statistics.

The second contributor is the Art Museum exit curve. The system processor simulates a curve by successive line segments in effect chording the curvature. Examination of the Fixed Route Description file indicates that two such

intersections were apparently defined between signposts 650 and 534; intersections 17 and 36. However, further examination shows that the X and Y coordinate set for intersection 36 does not fit between intersection 17 and signpost 534, but instead lies along Ben Franklin Parkway close to signpost 539. Intersection 36 was misplaced in the route description file. Although all the fixed route runs were processed with this misplaced intersection, FSEC considers any statistical improvement from a reprocess minimal and therefore, only one rerun was made to verify the exact source of the large error.

The third contributor concerned the incorrect signpost identification, discussed in detail in Section 4.4.6.1. Whenever the signpost identification changed, the system processor immediately placed the vehicle either at the next signpost or at a new location on the route instantaneously creating large radial errors.

The last repetitive contributor created errors only for one data sample. When the location subsystem acquires a new signpost, it first transfers the new identification to the output storage buffer, then clears the distance register. If a data sample is taken between these two operations, the data recorded will be the new tag ID and the distance traveled from the previous signpost instead of from the present signpost. The system processor will then erroneously place the vehicle considerable further ahead on the route than its actual location. This error occurred 21 times. However, since the large error is present for only one data sample it does not cause an appreciable error in the accuracy statistics.

4.4.6.3 Field Test Weather Conditions

Weather conditions must be separated into those experienced by the installed route signposts and those encountered by the test vehicle during test runs.

The signposts were installed during November 1976 and tested to insure they were properly operating. They remained in place until completion of the testing on February 28, 1977. During the time from November to February they endured the most severe winter ever recorded in the Philadelphia area. Not one signpost failed to operate properly during the test program.

The test vehicle operated during a period of much less severe weather with temperatures ranging from 20^{o} to 65^{o} F. For the early fixed route runs there was snow accumulation on the ground but no actual snow conditions. The last three fixed route runs were conducted during a rainstorm which ranged from light showers to periods of extremely heavy downpour accompanied by distant lightning. There were no noticeable differences in performance during these last three runs.

4.4.6.4 Unscheduled Tests

With most field test programs, unusual situations usually arise which cause the equipment to be tested in some unexpected yet meaningful way. Several such situations presented themselves during the AVM testing in Philadelphia.

After signpost installation but before the fixed route runs were made a vehicular accident knocked over a lamp post on which one tag was mounted. This tag was recovered from the Philadelphia Lighting Department with no obvious external damage and functionally tested. The tag exhibited no evidence of damage.

During removal of signposts in preparation for the missing signpost test, one unit was dropped from a height of 20 feet onto the sidewalk. One corner was dented and the unit rattled. The tag was tested and found to be inoperative. The unit was then opened for examination and the battery found to be loose. After replacing the battery into its holder, the unit was again functionally tested and found to be fully operational.

Near the center of the fixed route, a small corner store was apparently being renovated. The workmen, needing electrical service not available on their side of the street, had rigged an overhead power cable which they conveniently anchored to the Fairchild signpost. Thus encumbered the tag was successfully interrogated during the five missing signpost test runs.

5. RANDOM ROUTE TESTS

5.1 TEST CONFIGURATION

The Location Subsystem Field Test Program was designed to simulate actual operational vehicle deployment in an urban environment. The second segment of the field test program was designed specifically to simulate fleet or emergency vehicle random movement within a limited predesignated area. The area assigned to FSEC is shown in Figure 5-1 and encompasses the area in downtown Philadelphia bounded by 20th and Broad Streets on the West and East, and Callowhill and Walnut Streets on the North and South.

This area was instrumented with 99 signposts to permit random vehicle movement within the area. These signposts were mounted 20 to 25 feet above the road surface on existing lamp posts or power poles angled 20 to 45 degrees to the vertical depending on the street width. All signposts were located for interrogation from the right side of the test vehicle.

The vehicle and test equipment configuration used for the random route testing was identical to the fixed route configuration and is discussed in Section 4.1.

5.2 PROCEDURE

5.2.1 FINAL ROUTE SET-UP

The day before scheduled running of the random route tests, the actual route to be driven through the area was assigned by the DOT/TSC test observer. Locations for those checkpoints not at intersections were selected, and the locations referenced by 5th wheel measured distance to the nearest known intersections. These reference distances were then transmitted to DOT for determination of each checkpoint's true state plane coordinates. Once determined, these coordinates were then entered

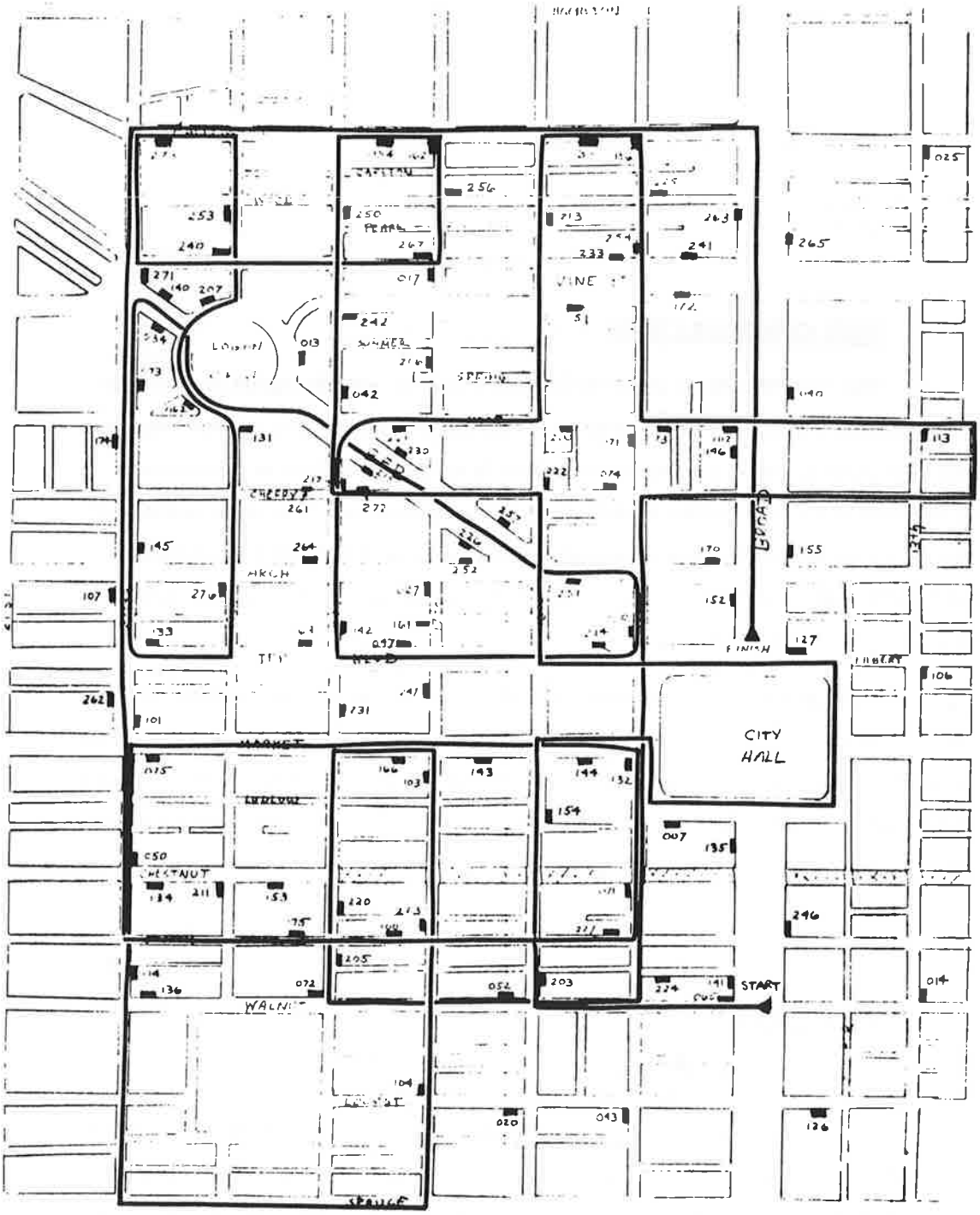


FIGURE 5-1
RANDOM ROUTE AREA
and
RANDOM ROUTE RUN

into the System Processing data base in a checkpoint location file for radial error determination.

5.2.2 RUN INITIALIZATION

At the start of each data run, the test equipment was verified to be operational and an appropriate header was entered onto the data tape by use of the on board Teletype, specifying the date, time, run-type and data tape number. At a fixed location just before the formal start of the run, the Location Subsystem and 5th wheel distance were reset and the data recorder enabled. The test run then formally began with the acquisition of signpost 565 on Walnut at Broad street.

5.2.3 CHECKPOINTS

To establish the accuracy of the Location Subsystem and demonstrate its capability to meet the control requirements, 84 checkpoints were employed along the length of the route. As each checkpoint was passed, the test conductor indicated this passage by depressing a checkpoint switch on the console. Associated with this data entry switch is a thumbwheel switch used to set the identity of each checkpoint indicated. The off-line data processor, with each new checkpoint entry, compares the Location Subsystem indicated vehicle location to the known checkpoint location to determine radial error.

5.2.4 LOG BOOK

The test conductor maintained a log book in which was specified any and all observations of route conditions, manual entry errors and noted system anomalies. At the conclusion of each run the appropriate log book sheets were then certified by the TSC observer. Table B-4 of Appendix B summarizes the significant entries from the logbook for each random run.

5.2.5 RUN COMPLETION

At the conclusion of each run the total 5th wheel distance was noted to determine run consistency. A cue code was entered on the data tape to signify completion of the run and the final logbook entries completed. The data tapes were then removed from the recorder and returned to FSEC for conversion to IBM 360 compatible format.

Each tape was then duplicated and one copy supplied to DOT/TSC for separate processing.

5.3 DATA ANALYSIS

5.3.1 SAMPLE SIZE

The sample size requirements for the random route field testing were the same as those for the fixed route testing and are described in Section 4.3.1.

5.3.2 DATA REDUCTION

5.3.2.1 Location Subsystem Accuracy

The performance accuracy of the Location Subsystem is determined by radial errors as measured at 84 fixed and known locations along the Random Route known as checkpoints.

As the test vehicle progresses through the random route, the Location Subsystem determines from the odometer encoder and the steering angle sensor the distance, in vehicle-referenced X and Y coordinates, traversed by the vehicle; X being defined as the vehicle direction of travel at the last acquired signpost. When a new signpost is encountered, the accumulation registers (X and Y) are cleared. Thus, three registers of information are generated by the on-board Location Subsystem:

(1) The identification of the last signpost encountered, (2) The distance in feet travelled in the vehicle X coordinate direction, and (3) The distance travelled in the vehicle Y coordinate direction.

The off-line central processor contains two files describing the Random Route area: (1) A signpost file containing each signpost true X and Y coordinate set (State plane) and street angle indicator and, (2) An intersection file listing each intersection X and Y coordinate set (state plane) and a connectivity list to other possible intersections.

Through use of these two files the vehicle-referenced coordinates at each data sample are translated into state plane coordinates defining the vehicle position at the sample time.

When the manually input checkpoint flag is detected by the system processor, the radial error is then determined, as the square root of the sum of the squares of X and Y

errors between the Location Subsystem translated position and the known checkpoint location. These errors are listed at the end of each data processing run.

5.3.2.2 System Accuracy

The AVM system accuracy is determined by the calculated radial error from each data sample in a simulated vehicle polling situation. Polling for this simulation was taken at 25 second intervals. The processing algorithm associated with the system accuracy determination is as follows:

a) Calculate the raw X_v, Y_v coordinate position of the vehicle.

b) Vector from the last known reference point, either Signpost or Intersection, to the raw vehicle location.

c) Choose the vehicle heading. If the last reference point was a signpost, the vehicle heading is found by searching the bounding intersections of the signpost. If the last reference point was an intersection, the candidates for the vehicle heading are found by searching the Connectivity File. This procedure assumes that the vehicle is most likely to be along the path from the last reference point in the "best-fit" direction. The "best-fit" is determined by matching the vehicle's vector angle and the associated heading angles of the streets in the local topology.

d) The next reference point becomes the last reference point when the length of the vehicle vector is greater than the actual distance to the next reference point. When this occurs, the vehicle location algorithm continues with the same sample point from Step b).

e) Correct the vehicle location according to the "best-fit" route.

The vehicle location in smoothed true X-Y coordinates as determined above is then compared to a reference set of coordinates derived from the 5th wheel distance. Several calibration runs were made previous to the official test runs to establish a 5th wheel reading at each intersection along the Random Route run. A simple linear interpolation is then performed to establish the reference coordinate position based on the 5th wheel distance reading for each sample point.

5.3.2.3 System Coverage

System coverage is defined as the average positional error for each tenth mile increment along the vehicle route.

The method of arriving at this error is identical to that discussed under system accuracy except the error generated at each 0.5 second interval sample is used as the base to generate an average error for each 0.1 mile increment. The basis for comparison is again the 5th wheel derived coordinate set.

5.3.2.4 Error Distribution Descriptors

The performance of the Fairchild Location System has been determined by error measurements taken at the system, system coverage, and subsystem levels. At each level a separate set of radial errors has been calculated and a composite error distribution for each level generated by combining the errors over six Random Route runs. Each distribution is then described by three significant statistical parameters; the mean or average value, the error value below which 95% of the tabulated errors exist, and the error value below which 99.5% of the tabulated errors exist. These three parameters have been determined by tabulation of the numerical radial error values from the composite distribution for each level of measurement. This composite distribution has been formed by binning the errors, using a bin size of 10 feet. Each bin is described by the upper bound (i.e. bin 20 contains all errors from 10.01 to 20.00 feet, etc.)

To determine the 95th percentile error value, the total number of samples in the distribution was first tallied. The number of data points comprising 95% of the population was then determined. To determine the actual radial error value at this 95th percentile one of two methods was used. If the 95th percentile fell into a binned increment for which there were not many data points, the actual values were listed and the specific value representing the 95th percent number selected from the listing. (For example, if 10 of the 25 numbers within the 130 to 140 foot bin increment fall within the 95th percentile the tenth smallest number within this increment was then selected as the error value). If the 95th percentile fell into a binned increment for which there were many data points, then a ratio of the required number of points to the total number within the bin was generated to determine the error value (for example, if 33 numbers within

the 130 to 140 foot bin increment fall within the 95th percentile and the bin contains 110 numbers, then 33/110 or 0.3 times the bin span of 10 feet was added to the bin lower edge of 130 feet to arrive at 133 feet as the error value). The assumption here is that if sufficient data points exist within the bin they are uniformly distributed.

The 99.5th percentile error value was determined using the same technique, except here the bin populations were always small so actual data values were always used.

The mean value of the distribution was determined again by numerical analysis. For those binned increments which contained a large number of data points, all points were assumed to be located at the bin center value (i.e. the 10 to 20 foot binned values were considered to all have a value of 15 feet). For those binned increments with only a few data points the actual values were used. Since the bin resolution used for the frequency distribution was small (10 feet) any error introduced by this technique is also small and estimated to be less than 0.5 feet.

5.4 RANDOM ROUTE RESULTS

The data summaries supporting the final accuracy determinations presented in the following sections describing random route performance are included in Appendix B and are tabulated below for reference:

Table B-1 Signpost Acquisition Errors

B-2 Checkpoint Radial Errors, Random Route

B-3 System Coverage Radial Error 0.1 Mile Increments, Random Route

B-4 Test Conductor Notes Summary

B-5 System Level Radial Error Summary (Smoothed), Random Route.

5.4.1 SUMMARY OF RESULTS

TABLE 5-1. RANDOM ROUTE PERFORMANCE SUMMARY

System Accuracy	Specifications Required	Uncorrected FSEC	Corrected FSEC
95th percentile	300	260	220
99.5th percentile	450	440	430
Mean	--	60	58
Sample Size		1138	1136
System Coverage (0.1 mile)			
95th percentile		230	230
99.5th percentile		440	430
Mean	--	68	64
Sample Size		658	657
Maximum		2380	623
Location Subsystem Accuracy			
95th percentile		250	230
99.5th percentile	300	440	440
Mean	450	76	69
Sample Size	--	560	599
Signposts Misread		1.1%	0%
Signposts Missed	--	0%	0%
	--		

5.4.2 LOCATION SUBSYSTEM ACCURACY

The performance accuracy of the Location Subsystem as determined by comparison to 84 checkpoints along the random route run was measured as 250 feet for the 95th percentile, and 440 feet for the 99.5th percentile and 76 feet for the mean value. The data base for this distribution included seven random route runs in which two points were removed due to operator error, three checkpoints were not entered during the runs, (See Table B-4) and three checkpoints were removed due to tape parity errors (See Table B-6). Also random route 04 processing terminated prematurely due to the large number of tape errors and included only 65 checkpoints.

During one of the Random Route runs (RR05) there were two signpost identification errors. The nature of these errors has been discussed in Sections 4.4.2 and 4.4.6.1, including the rationale for the formulation of a corrected set of performance parameters. Following this rationale, one checkpoint in Run 05 (Checkpoint 69) has

been removed from the compiled data base to formulate the corrected performance parameters. With this correction, the 95th percentile error is 230 feet, the 99.5th percentile error is 440 feet, and the mean is 69 feet.

The histogram of Figure 5-2 is the error frequency distribution plotted in 10 foot increments for the uncorrected data accumulated during the six Random Route runs.

An examination of the checkpoint errors listed in Table B-2 reveals a consistently large error for all the runs on Checkpoints 42, 43, 44 and 55. These checkpoints were encountered by the test vehicle upon re-entry into the instrumented Random Route area after having previously exited, and before encountering a reference signpost. The major reason for discussing this point is to indicate that these errors are derived from the longest route section between reference signposts and amount to a positional error of approximately 10% of the distance travelled.

5.4.3 SYSTEM COVERAGE

System coverage accuracy is derived from a comparison of the Location Subsystem measured location at each 0.5 second sample point, with a location derived from the 5th wheel-derived coordinate set. The determined radial error at each sample is then averaged over 0.1 mile increments to determine system coverage.

The statistical parameters from the radial error distribution are 230 feet at the 95th percentile, 2380 feet maximum, and 67.7 feet mean error. The composite frequency distribution and cumulative error curves are shown in Figures 5-4 and 5-5.

The errors used to compile the above statistical parameters were processed by the normal map matching algorithm, and are shown in the output listing titled Tenth Mile Errors. This listing is reproduced in the Appendix Table B-3. The first entry for each run (increment 0.0) has been deleted from the data base to remove the residual error contribution tabulated before the first signpost was encountered at the beginning of the run. Additionally 13 increments in run 04 were removed due to tape parity errors shown in table B-6. The resultant population amounted to 657 data points.

Correcting the data base to remove those errors tabulated as a result of the signpost acquisition error discussed in Section 4.4.6.1 results in the removal of one

(Text continued on p. 62.)

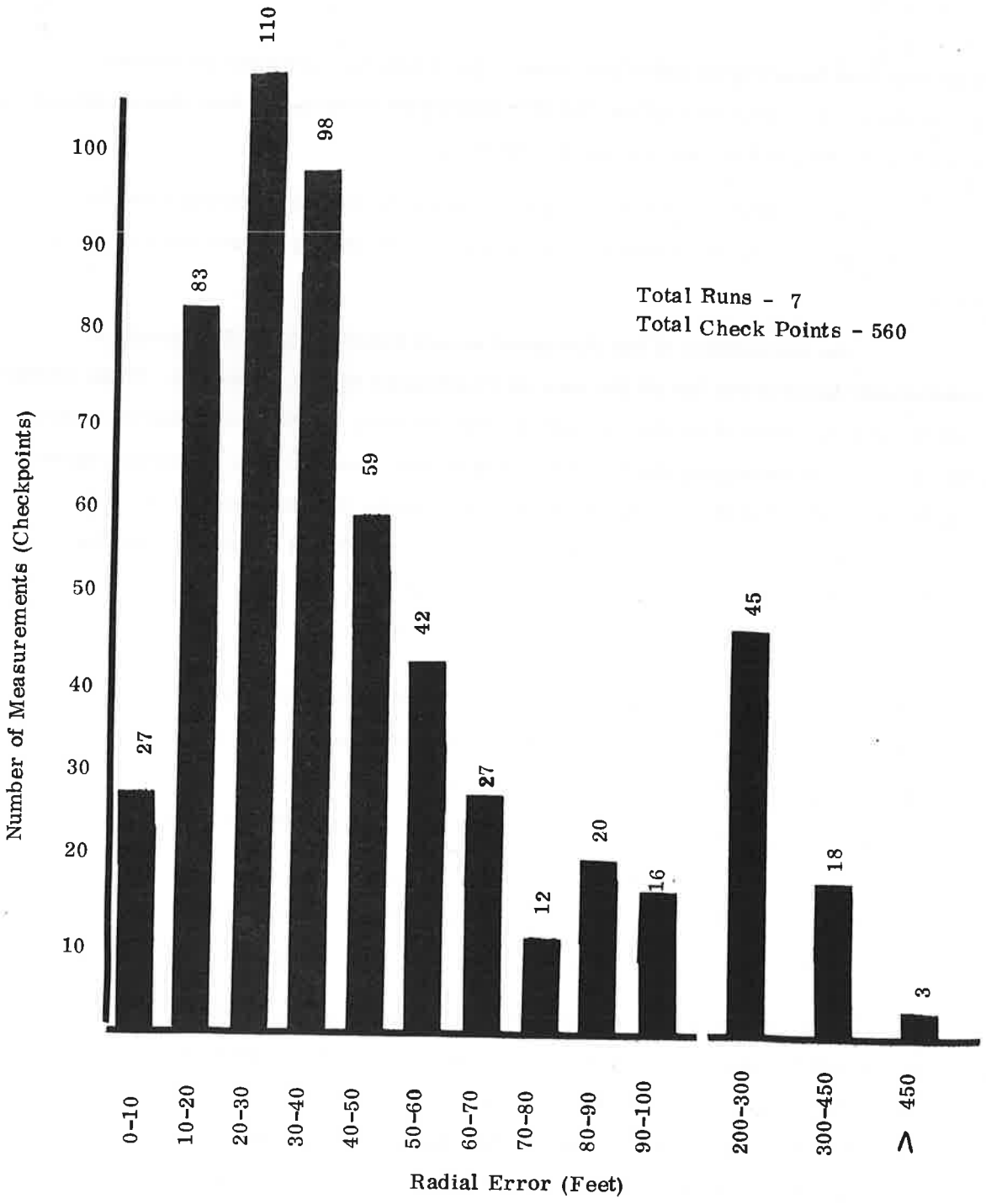


FIGURE 5-2 CHECKPOINT ERROR FREQUENCY DISTRIBUTION RANDOM RUN

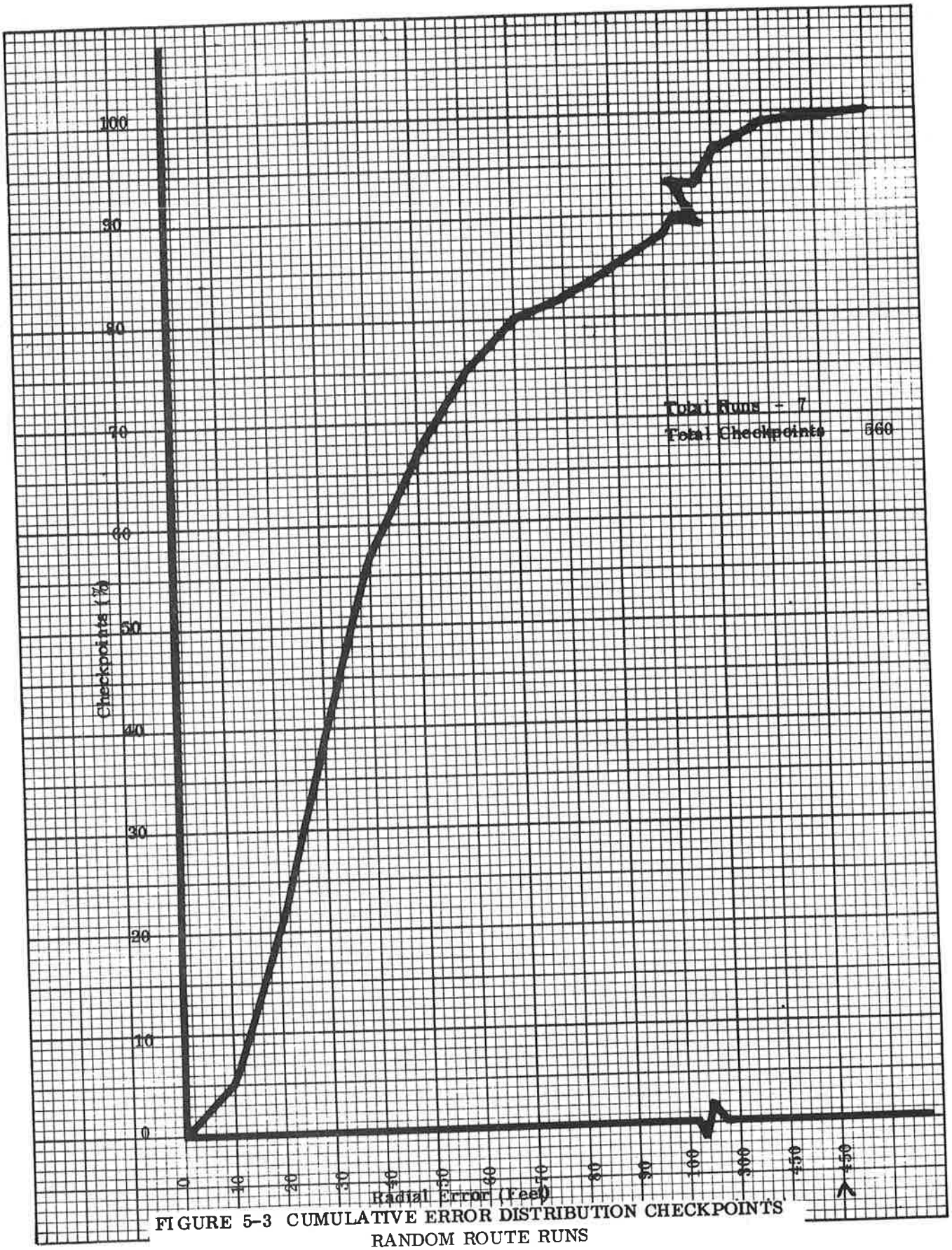


FIGURE 5-3 CUMULATIVE ERROR DISTRIBUTION CHECKPOINTS
RANDOM ROUTE RUNS

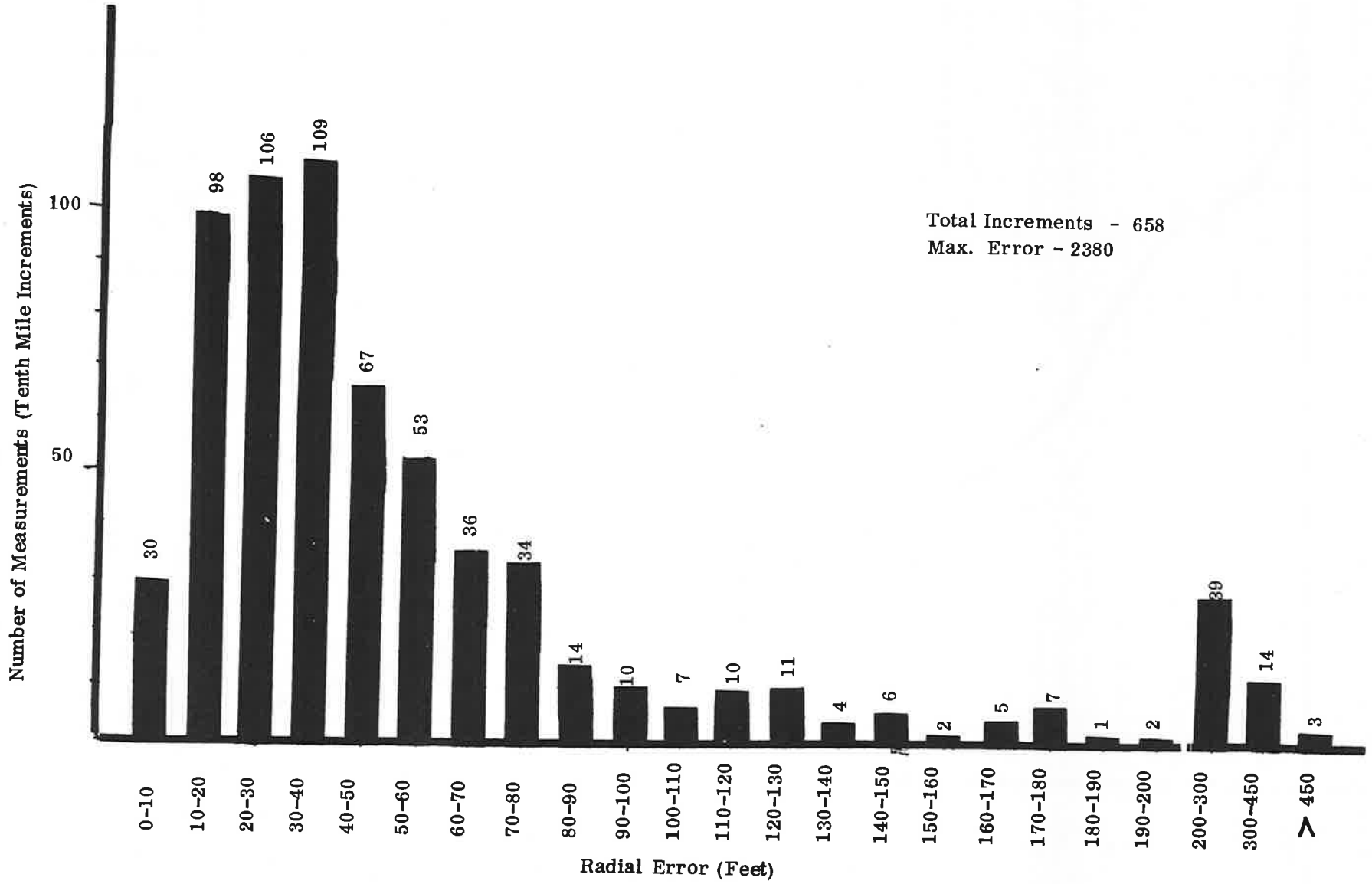


FIGURE 5-4 SYSTEM COVERAGE TENTH MILE ERROR FREQUENCY DISTRIBUTION
RANDOM ROUTE

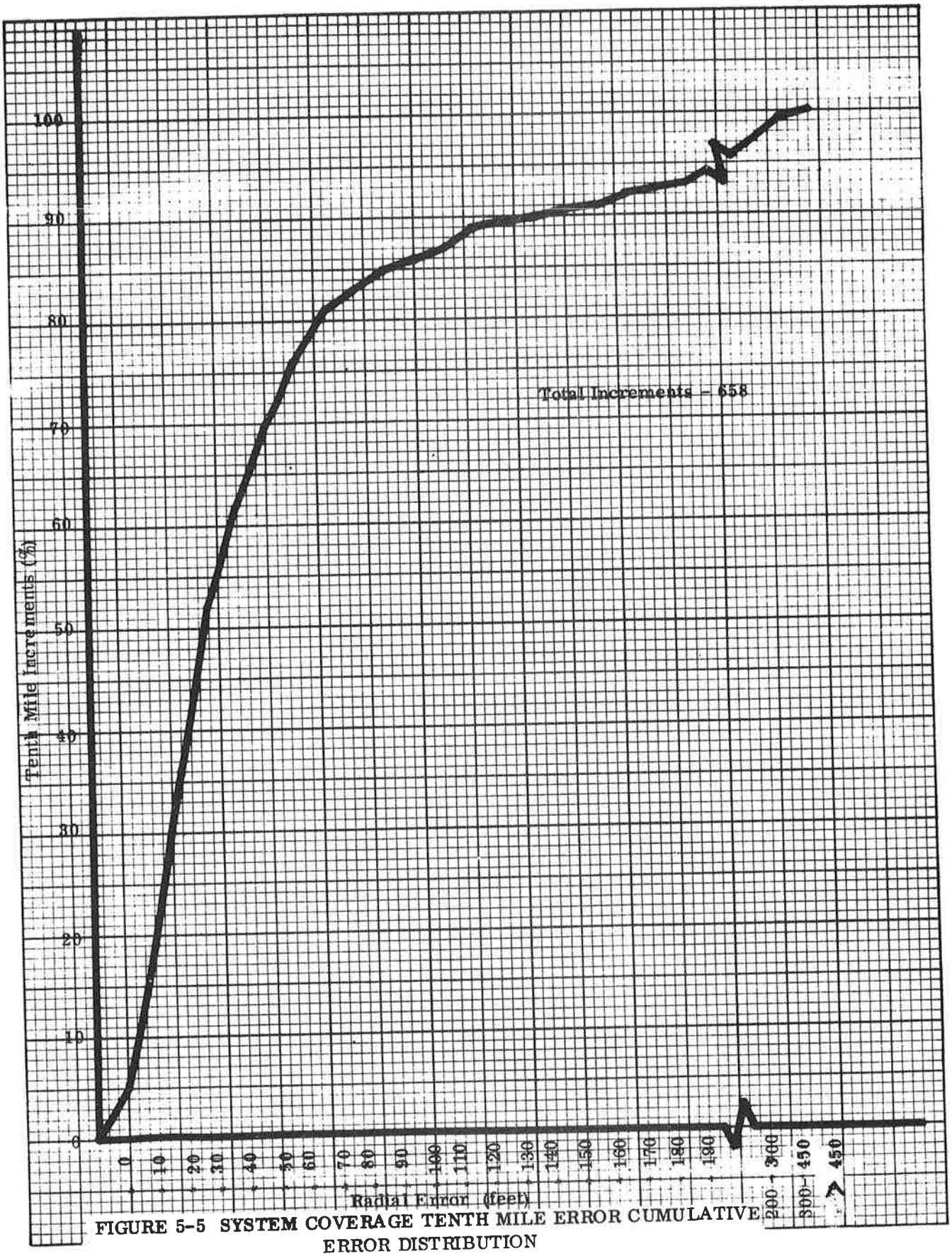


FIGURE 5-5 SYSTEM COVERAGE TENTH MILE ERROR CUMULATIVE ERROR DISTRIBUTION

data point (2380 feet run 05) and a small improvement of the parameters; 95th percentile 230 feet, maximum error 623 feet, mean value 63.8 feet.

5.4.4 SYSTEM ACCURACY

System Accuracy is determined by the calculated radial errors resulting from each 25-second polling sample, simulating a multi-vehicle central processor. Seven Random Route runs were made to accumulate sufficient data points for the accuracy determination; however, due to data tape parity errors run 04 did not run to completion. These runs provided 1138 polled data points for the system accuracy determination which is more than twice the number required to provide a 95% confidence level in the 95th percentile error size.

The composite radial error distribution was formulated using the map matched radial errors from the system level output. The parameters from the resulting distribution were numerically determined to be 230 feet at the 95th percentile, 440 feet at the 99.5th percentile and 60.2 feet mean value. Figures 5-6 and 5-7 show the frequency distribution and cumulative error curves. The individual Route Run data summaries are tabulated in Appendix Table B-5.

Correcting the data base to remove the errors tabulated as a result of the signpost acquisition error discussed in Section 4.4.6.1 results in the removal of two data points (634 and 2239 run 05). The corrected data base parameters are then 220 feet for the 95th percentile, 430 feet for the 99.5th percentile and 57.7 feet mean value.

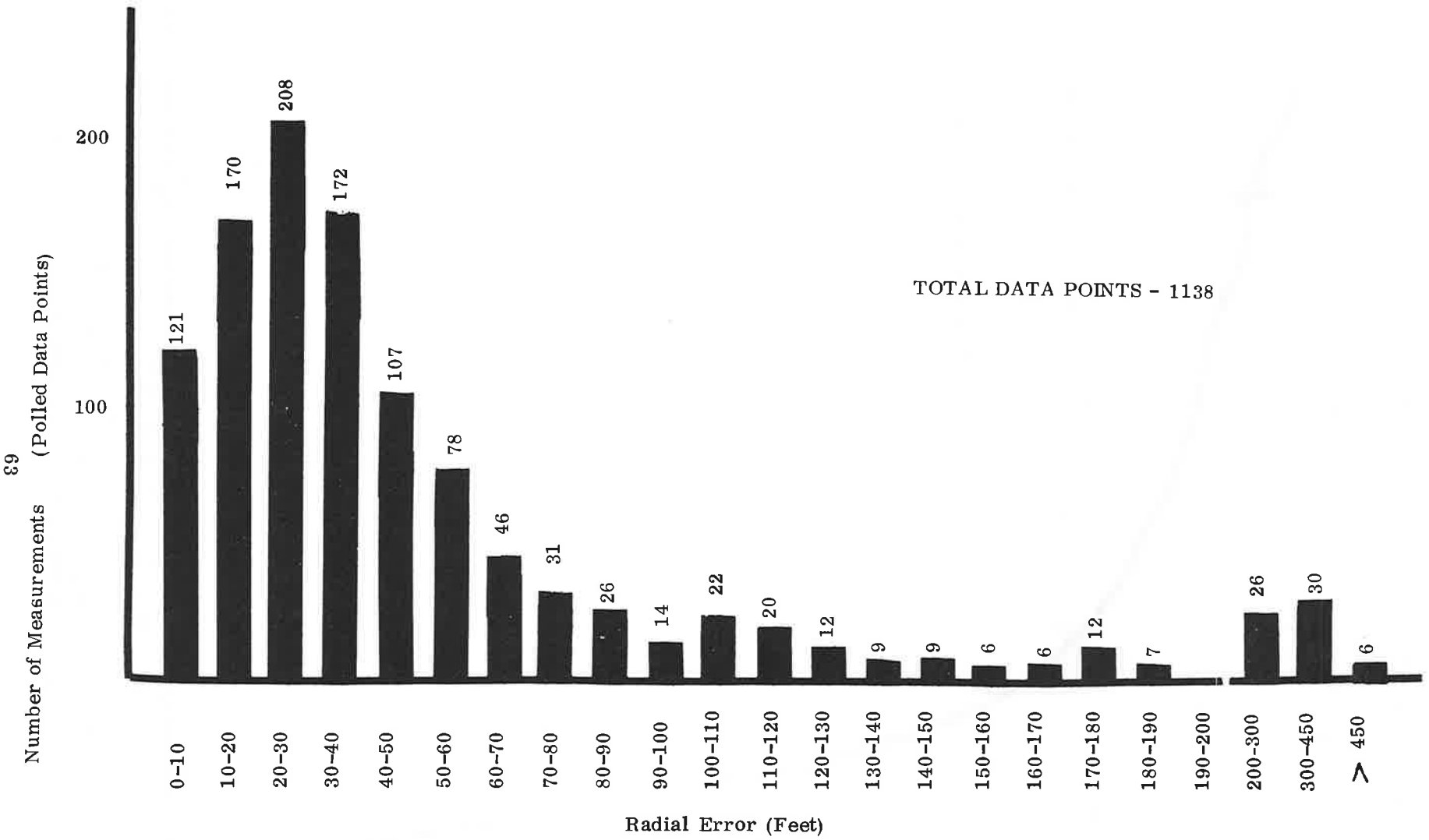


FIGURE 5-6 SYSTEM ACCURACY FREQUENCY DISTRIBUTION RANDOM ROUTE

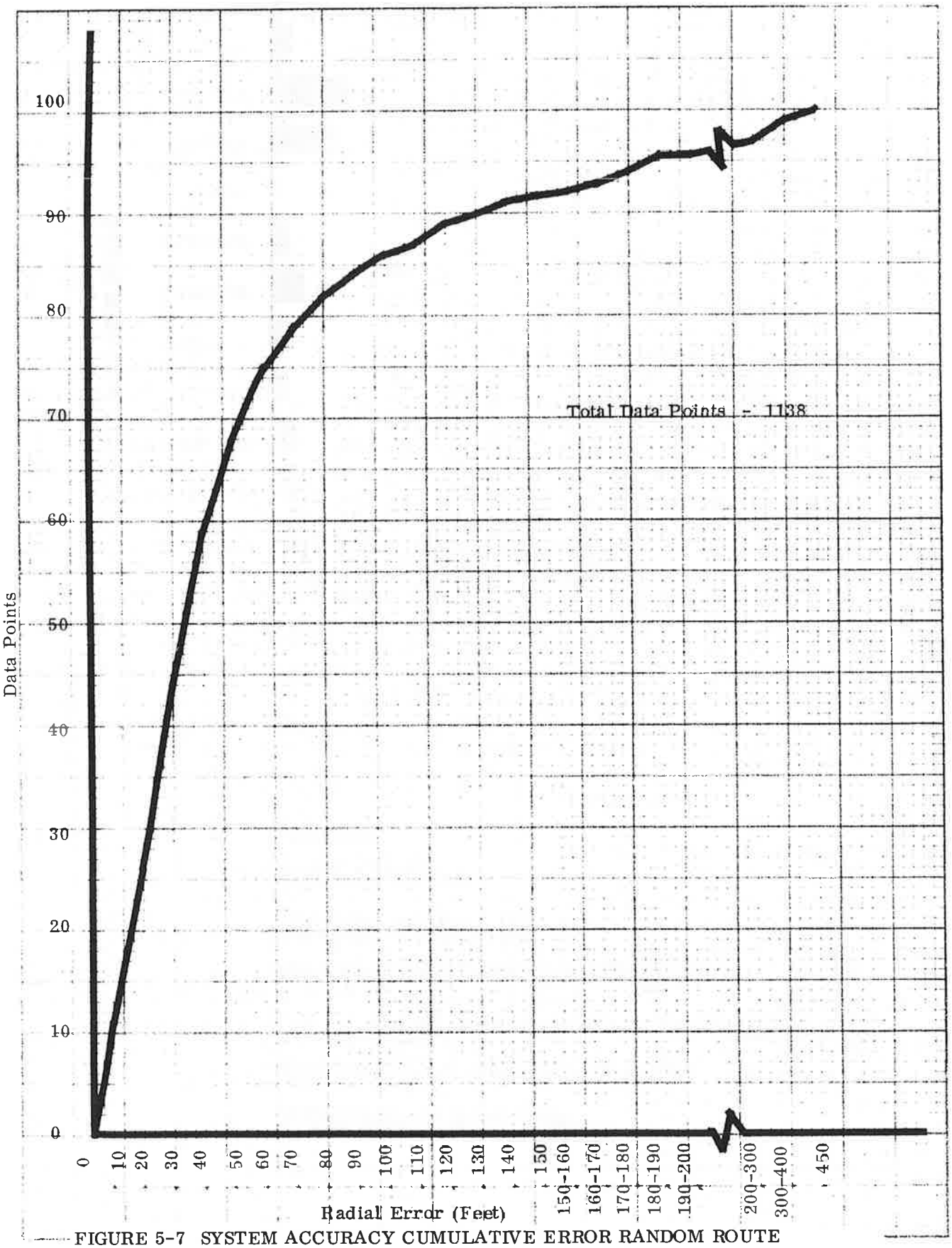


FIGURE 5-7 SYSTEM ACCURACY CUMULATIVE ERROR RANDOM ROUTE

5.4.5 SIGNIFICANT OBSERVATIONS

5.4.6.1 Signposts Missed or Misread

At the completion of the Random Route tests some 432 signposts were interrogated during the six runs. Of these none was cataloged as missed, and 10 were cataloged as incorrect.

The signposts listed as incorrect or misread can be separated into three groups:

a) Signposts which were labeled as incorrect before the start of the run at signpost 565. - 5 counts.

b) Offroute signposts which were acquired - 3 counts.

c) Signposts which were initially acquired correctly but whose I.D. changed - 2 counts.

Signpost 633 located south of Race on 15th street caused all three of the group (b) incorrect acquisitions. The Random Route travelled south on 15th to Race then east on Race and did not pass the tag 633 location. However, in making the turn from 15th onto Race the interrogator beam swept the post on which tag 633 was mounted. This tag apparently was angled to look up 15th street just enough that the test vehicle passed through the fringe of the signpost window. Thus, the tag was acquired on three of the six runs. Correct placement of the signpost (such as the middle of the block) would eliminate the root cause.

The two misreads in group (c) were due to beam fringe reading deficiencies, discussed in Section 4.4.6.1.

Of the total 10 signposts listed as incorrectly read then, none may be considered a random misread since each has a single and straightforward contributing factor which is easily rectified in an operational system deployment.

6. SPECIAL CASE TESTS

Four special case tests were performed as a part of the Philadelphia Field testing program. These tests demonstrated the Fairchild Location Subsystem response, if any, either to specific potential interference-producing areas which could not be included as part of the regular route runs; or to specific failures or deviations which could occur during a normal run.

The special tests conducted included:

Tank Farm Area Test

Airport Area Test

Missing Signpost Test

Route Deviation Test.

6.1 TANK FARM TEST

The Location Subsystem was operated in close proximity to an oil tank farm along Essington Avenue to determine the effect, if any, from a large localized metallic mass. Figure 6-1 shows the tank farm special test route and the relative location of the tank farm.

Five signposts were deployed along the route such that the interrogator faced directly toward the oil tanks. Nine checkpoints were established along the 1.1 mile route and the checkpoint and signpost relative locations measured with the 5th wheel to establish the route description file and checkpoint locations. Five runs were then made using the fixed route mode of the Location Subsystem. Since the purpose of the test had no geographic significance, no attempt was made to associate the checkpoints with actual state plane coordinates. The route then in effect was linearized in that the Y coordinate was held constant and the route considered to be

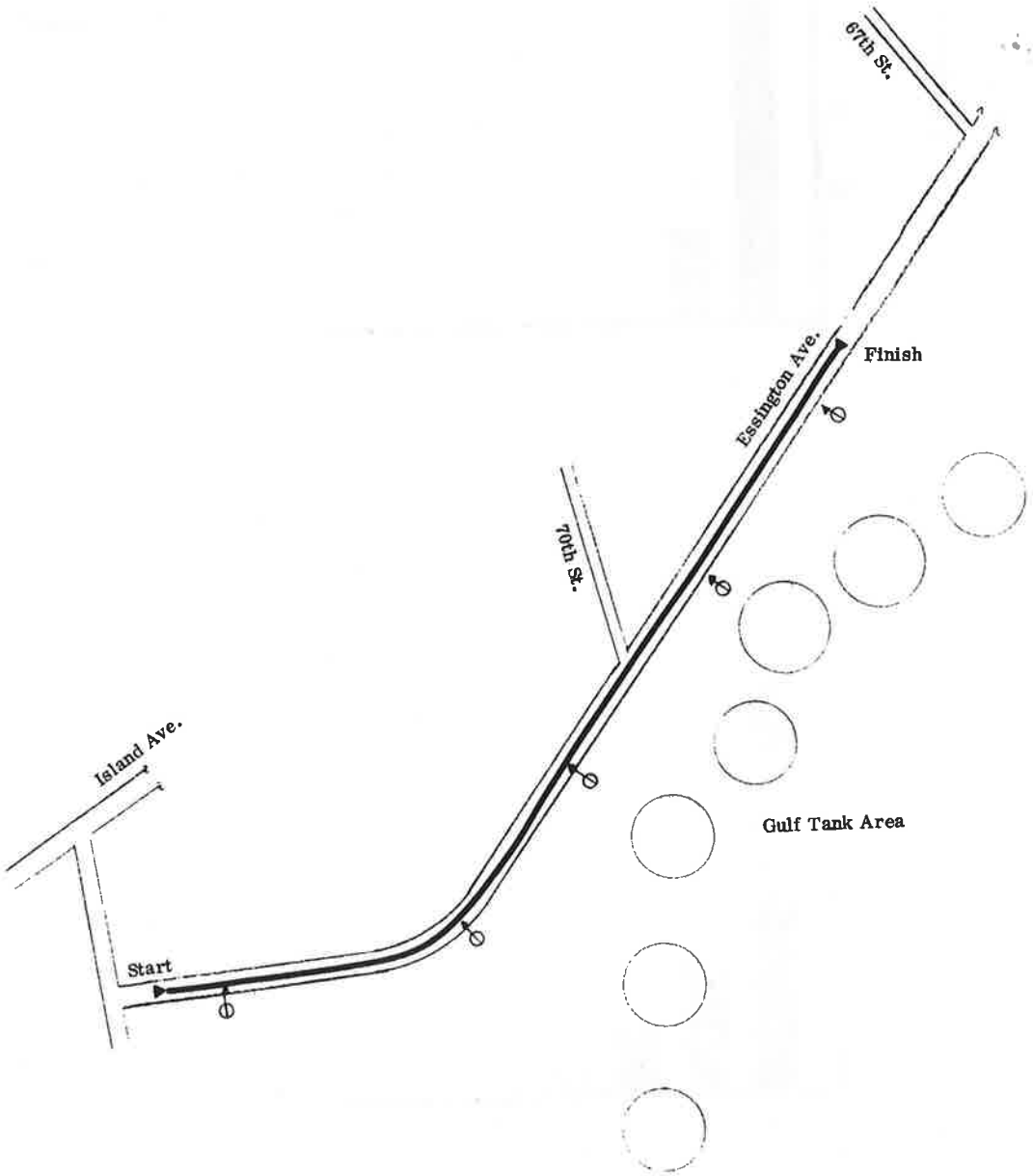


Figure 6-1 SPECIAL CASE TEST TANK FARM AREA

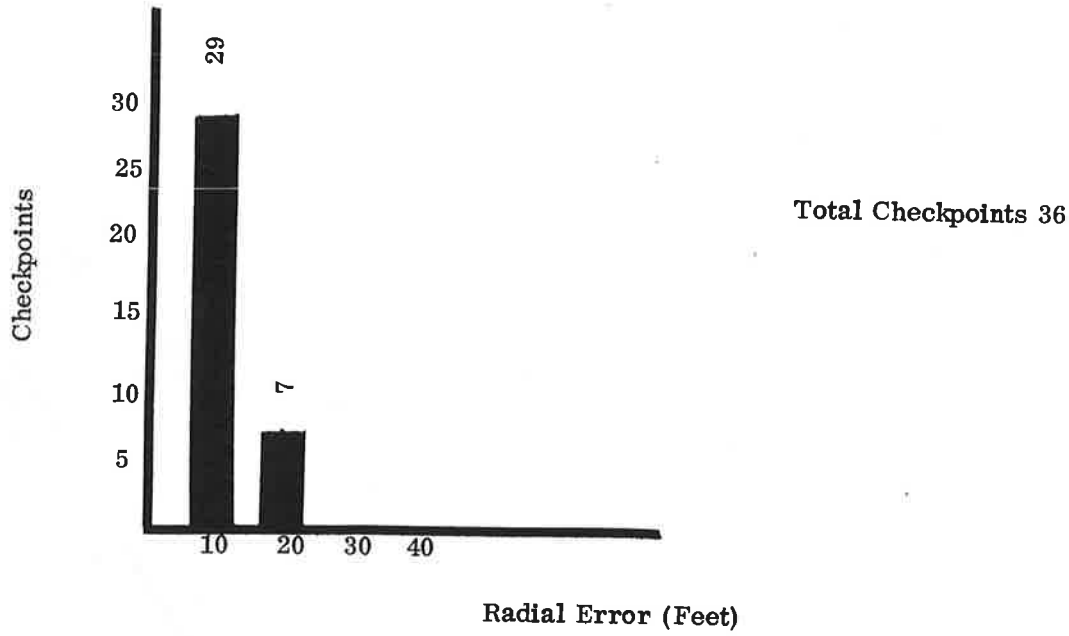


FIGURE 6-2 SPECIAL CASE TEST TANK FARM AREA CHECKPOINT ACCURACY

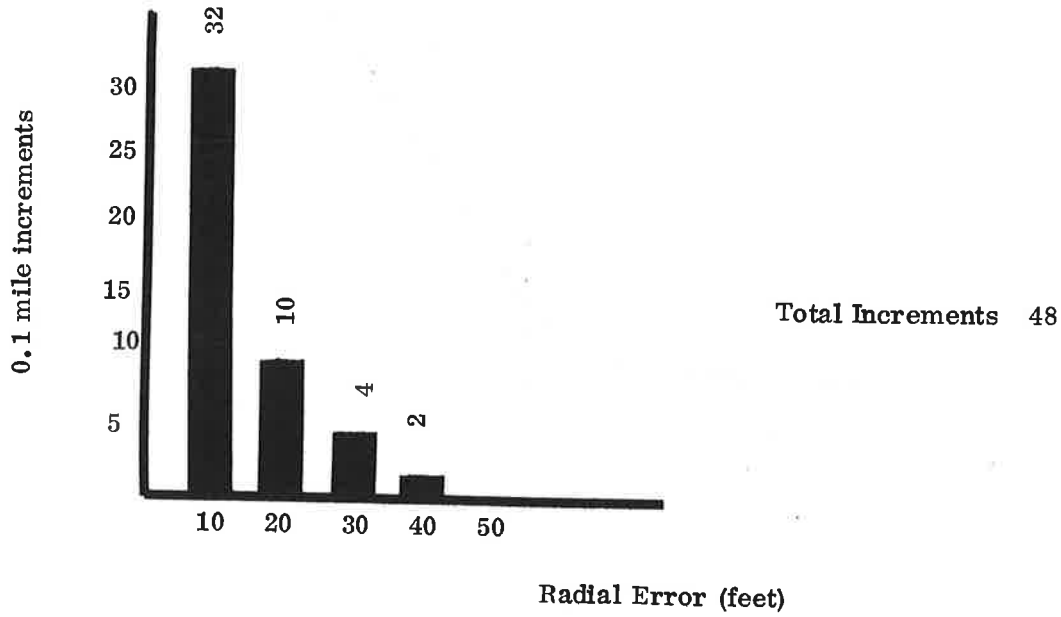


FIGURE 6-3 SPECIAL CASE TEST TANK FARM AREA SYSTEM COVERAGE

straight. Figure 6-1 shows the actual Tank Farm test route.

Run number 5 was not processed satisfactorily since it included a large residual error at the beginning of the run and several tape errors (See Appendix C-8). The 0.1 mile increments as processed indicated a route length of 2.8 miles for the 1.1 mile route. For this reason, it has been eliminated from the presented data summaries. Figure 6-2 shows the checkpoint accuracy and Figure 6-3 shows the system coverage accuracy for the remaining four runs.

There was no observed degradation in Location Subsystem performance and no observed unique effects in system performance as a result of the tank farm proximity.

6.2 AIRPORT AREA

The Location Subsystem was operated in close proximity to the Philadelphia Airport to determine the affect, if any, of interference from local radar transmissions. The Cargo Area was selected, with the concurrence of the DOT/TSC observer, as the best location permitting closest approach to the observed radar antenna adjacent to the main runway. Figure 6-4 shows the selected route location and signpost deployment.

The route was selected such that the interrogator faced directly toward the radar set for a large section of the 1.5 mile run. Nine checkpoints were established along the route and located by use of the 5th wheel before commencing the five data runs. The route was structured identically to the Tank Farm test in that no attempt was made to reference to actual state plane coordinates and the Location Subsystem Fixed Route mode was used.

The processed output for Airport run 3 produced no data output, either for checkpoints or system coverage (See Appendix C-8). Its data have therefore not been included in the summaries presented herein. All data from the remaining four runs have been included, and are plotted in the frequency distribution curves of Figures 6-5 and 6-6.

All radial errors calculated were less then 60 feet and no interference effects were noted due to the radar proximity.

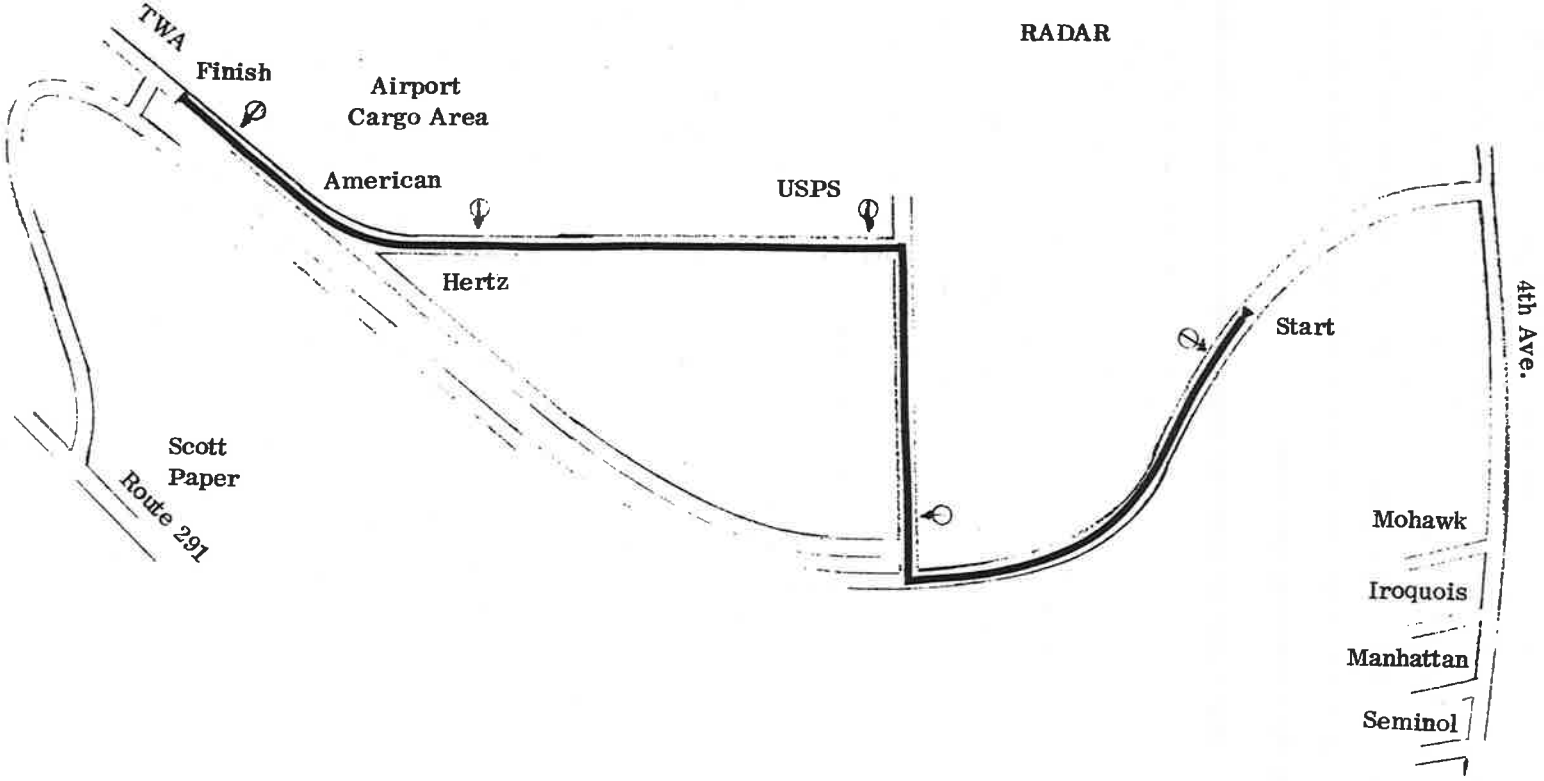


FIGURE 6-4 SPECIAL CASE TEST AIRPORT AREA

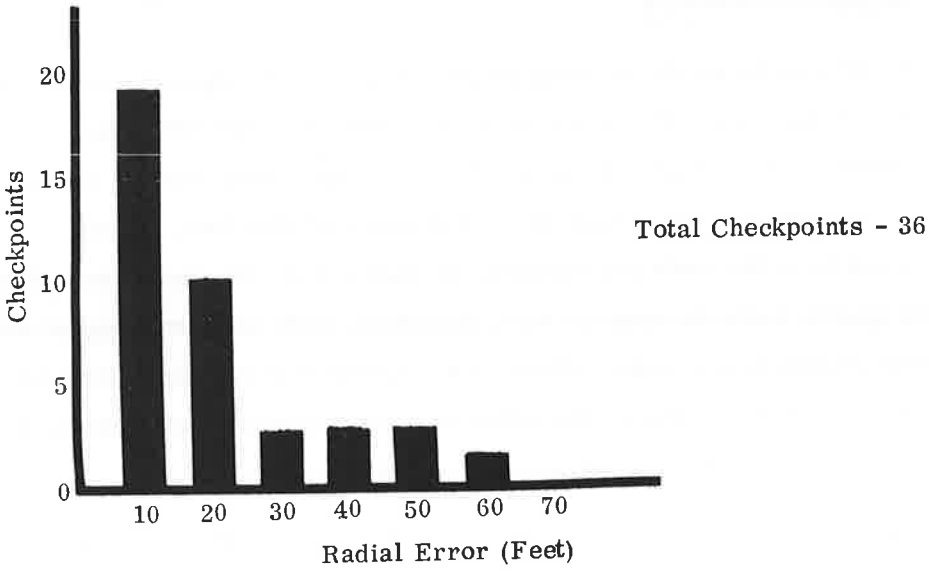


FIGURE 6-5 SPECIAL CASE TEST AIRPORT AREA CHECKPOINT ACCURACY

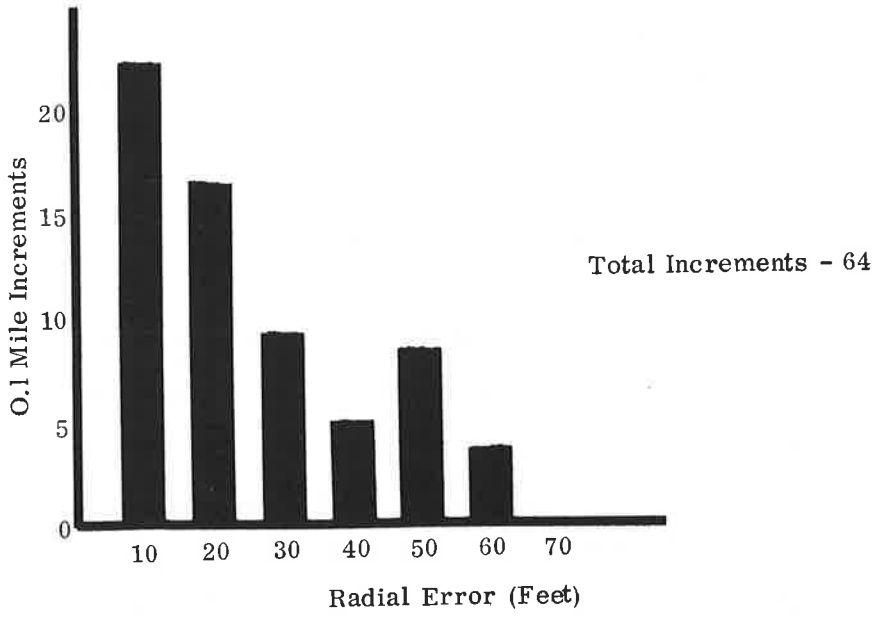


FIGURE 6-6 SPECIAL CASE TEST AIRPORT AREA SYSTEM COVERAGE

6.3 MISSING SIGNPOSTS

At the conclusion of the Fixed Route runs, some 30 signposts were removed from the fixed route and four additional runs made to determine the effect on accuracy of a larger inter-signpost distance. The 11.3 mile route was now instrumented with 37 signposts for an average interval distance of 1600 feet. Those signposts removed from the route are indicated on Figure 4-1. No change was made to the Location System route description File; therefore, each removed signpost was missed in terms of system processing effect. This special test therefore provided two insights into system performance; the effect on accuracy with greater signpost spacing, and the effect on system processing of missed signposts.

Figure 6-7 is the composite histogram of checkpoint radial errors from these four runs. As can be seen by comparison with Figure 4-5, except for the errors caused by the signpost identification number changing, no checkpoint errors exceeded 100 feet for either the Missing Signpost Test or the Fixed Route Runs. In fact, a comparison of the 95th percentile points yields 57 feet for the Fixed Route and 60 feet for the Missing Signpost Test. This result demonstrates that the system is capable of performing well within the accuracy requirement with a dramatically reduced number of signposts.

This test also demonstrates that the processing technique employed within the base station software is not dependent upon the Location Subsystem acquiring any specific number of signposts. In fact, to demonstrate this point further, a final run was made in which all signposts except the 14 time points and the beginning route signpost were eliminated. This special run was catalogued as Time Points only.

Since time did not permit the physical removal of the additional signposts, the Location Subsystem transmitter was turned off except when approaching one of the time point signposts. As each signpost was passed along the route, a visual verification was made by the Fairchild Test Conductor and the TSC observer to insure that only the time point signposts were acquired. Using this technique, an additional 22 signposts were removed from the run reducing the total number to 15

from the original 67 and providing an average 4000 feet between signposts. The results of this test are presented in Figure 6-8. While no statistical claims can be made from only one run, it is indeed encouraging to note that again not one single checkpoint has a radial error over 100 feet.

6.4 ROUTE DEVIATION

A route deviation test was conducted along a segment of the fixed route run to demonstrate the ability of the location subsystem to determine when and where a vehicle has departed from its assigned fixed route.

The test was conducted along the 18th Street segment of the fixed route beginning at 16th and Walnut. Six runs were conducted, each deviating from and returning to the 18th Street segment at different locations. These runs then were processed using the identical data base and processing routine established for the regular fixed route. The 5th wheel distances and tabulated radial errors in the printout were therefore meaningless. The importance of the test was the ability of the system to detect a signpost after having deviated from the route.

In a functional system deployment, these off-route tags would conceivably be single bit (unmodulated) tags which are easily recognized though not distinguishable from each other. They provide a uniform signal for implementing the off-route function without consuming any assignable numbers for on-route tags. Since the purpose of the test was to demonstrate the detection of a tag, any tag is useable; consequently the tags already installed for the random route area tests were used.

Table 6-1 lists the six runs and the distance in feet between the actual route deviation or resumption and the first signpost which indicated the deviation or resumption. Where the route deviation occurred as a result of a turn, the 5th wheel distance from the indicated turn to the next signpost was the measured off-route distance required to detect. If the deviation occurred by continuing at an intersection, then either another run or an indication of the vehicle stopping at the intersection was used for the computation. Table C-7 of Appendix C contains exerpted output listings showing the locations and signposts detected for each deviation and resumption of the route.

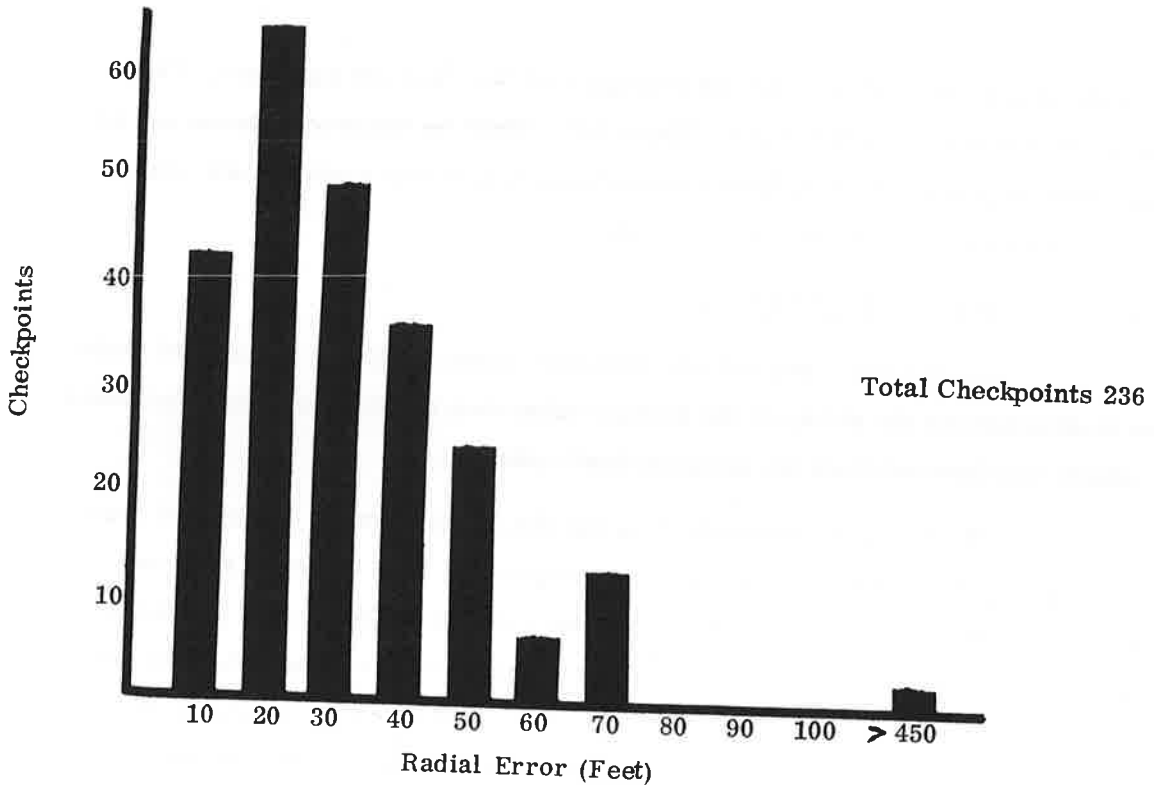


FIGURE 6-7 MISSING SIGNPOSTS CHECKPOINTS

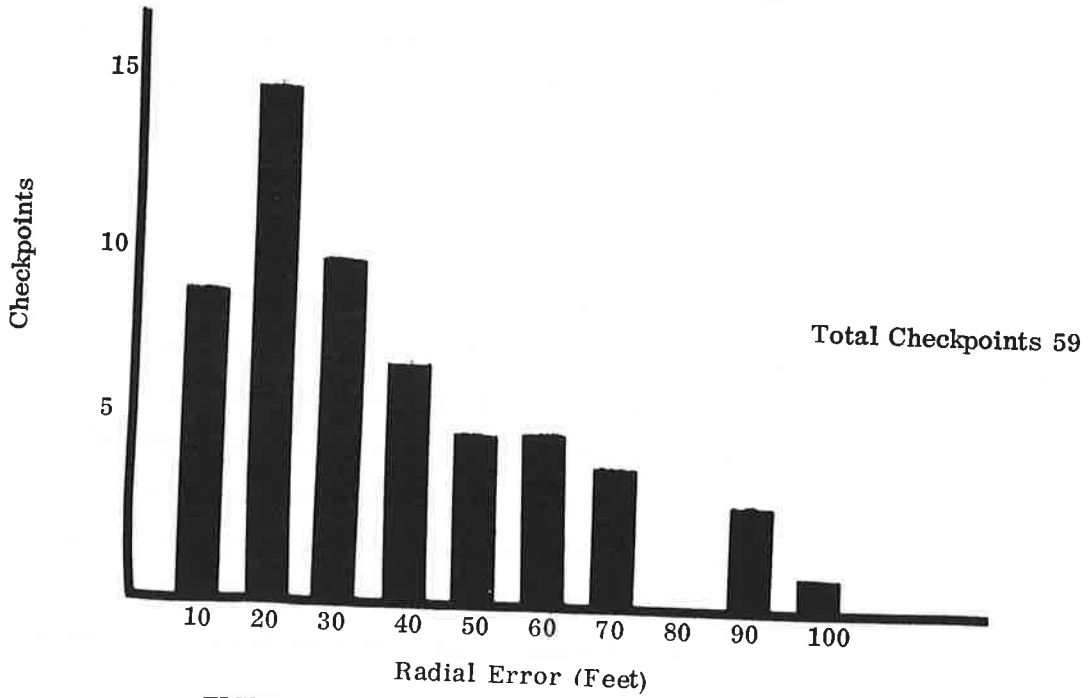


FIGURE 6-8 TIMEPOINTS ONLY CHECKPOINTS

TABLE 6-1

ROUTE DEVIATION MEASUREMENTS

	Signpost Code		Distance On/Off Route Before Detection
	Octal	Decimal	
RUN 01			
START	1052	554	-
OFF ROUTE	1175	637	143
RETURN	1231	665	709
RUN 02			
START	1052	554	-
OFF ROUTE	1215	653	191
RETURN	1217	655	361
RUN 03			
START	1052	554	-
OFF ROUTE	1166	630	338
RETURN	1220	656	115
RUN 04			
START	1052	554	-
OFF ROUTE	1163	627	161
RETURN	1231	665	703
RUN 05			
START	1052	554	-
OFF ROUTE	1072	570	36
RETURN	1231	665	708
RUN 06			
START	1052	554	-
OFF ROUTE	1042	546	386
RETURN	1221	657	487

7. ENGINEERING TESTS

The tests described in this section were conducted at the Fairchild facility in Germantown, Maryland during the period 7-9 March 1977. All tests were witnessed by the TSC monitor.

7.1 SIGNPOST BATTERY DRAIN

The signposts used for the Philadelphia field tests were of the semi-passive type. The internal modulation control electronics are continuously powered by an internal battery. To determine anticipated battery lifetime a battery current drain test was conducted.

Four signposts were selected at random and the current drain measured both before and during interrogation. The average current drain measured 35.46 microamperes. Appendix D, Table D-1 lists the individual signpost battery drain as measured.

Based on the 5.0 Ampere-hour capacity rating, extrapolating an expected battery service life:

$$L = \frac{5.0}{35 \times 10^{-6} \times 24 \times 365} = 16.0 \text{ years}$$

The manufacturer specifies a battery shelf life of 5.0 years; therefore conservatively estimated, the battery should last for approximately its average shelf life at which time it will be about 30% discharged.

7.2 OPERATIONAL VOLTAGE TEST

7.2.1 SIGNPOST

The semi-passive signposts utilizes an internal battery to operate the internal modulation logic. To determine the state of battery discharge at which the signpost

will continue to function suitably for successful interrogator acquisition, one signpost was instrumented with an adjustable voltage source.

This voltage was then decreased until the test vehicle interrogator failed to acquire the correct identification and increased until a stable display was obtained. The nominal operating voltage is 6.0 volts and the minimum voltage measured was 2.77 volts. It should be pointed out that the signpost battery voltage does not affect the signpost return R.F. power level. This measured minimum operating voltage is significantly less than the extrapolated end-of-life battery voltage.

7.2.2 INTERROGATOR

The interrogator system used to instrument the test vehicle operates from two separate power sources. A 12-volt system operates the transmitter/receiver and signal processor and a 5-volt system operates the microprocessor section. Since the microprocessor was not designed in its final form and contained many additional interface and special purpose functions useful only for the Philadelphia field testing, only the 12-volt source was adjusted for purposes of the voltage sensitivity.

The 12-volt source was reduced until the interrogator failed to acquire the signpost. The voltage was then increased until proper acquisition was made. The minimum voltage for successful operation was measured at 8.5 volts, a reduction of 29%.

7.3 HIGH SPEED SIGNPOST ACQUISITION

The purpose of the test was to determine the ability of the interrogator to read signposts successfully at speeds up to 100mph. Because it was unsafe to drive a vehicle at 100mph, a second vehicle was instrumented as a target vehicle by placing a randomly selected signpost on a 10-foot mast and attaching the mast to the vehicle. A series of runs were made at 20, 40, 60, 80, and 100 mph. At the lower speeds (20, 40) the target vehicle was stationary and the test vehicle was driven by it. At the other speeds both vehicles were driven past each other at approximately one-half the desired test speed. Minimum vehicle pass distance of approximately 5 feet was used to ensure worst case conditions (minimum acquisition time).

During each run two signals were recorded; the detected receiver AGC, and the signpost word interrupt signal. The detected AGC signal is used within the signal processor to enable the decoding logic when the signal strength is sufficient to ensure reliable bit decoding. The interrupt signal flags the microprocessor that a decoded identification word has been received. Since the frequency of this signal was beyond the capability of the recorder, a signal representing every 16th interrupt was used. Figure D-3 in Appendix D indicates the results achieved for the five test runs. Note that the number of successful decodes exceeded 8 even for the 100 mph test. Only two are necessary for the microprocessor to accept the input as valid. The first two tests were conducted with the target vehicle parked at the roadside, this additional 5 feet of pass distance can be observed as additional AGC suppression time. At each pass,the Location Subsystem output display was observed to indicate correct acquisition of the signpost.

7.4 SINGLE BIT SIGNPOST ACQUISITION

The single bit signpost test was conducted immediately following the High Speed test using the same test configuration and recording the same two signals. Table D-4 in Appendix D indicates the results of the four test runs. In each case the AGC was depressed sufficiently to be detected but no decoded interrupts were generated.

A single bit signpost is simply a unit which contains no battery or modulation electronics. The return signal therefore is received but since it is not modulated no decoded output results. This effect was observed during the test.

7.5 SIGNPOST WINDOW

A signpost window is defined as the region in which signal intensity is high enough to cause successful interrogation of that signpost. The shape that this window takes was measured for three signpost elevations by monitoring the detected AGC signal along a series of parallel lines spaced 10, 25, 40, 50, 60, and 70 feet from the base of the signpost mount. Figure 7-1 shows the window or area within which successful interrogation is possible.

This area was smaller than anticipated and subsequent investigations revealed that the receiver preamplifier had malfunctioned and was providing significantly less

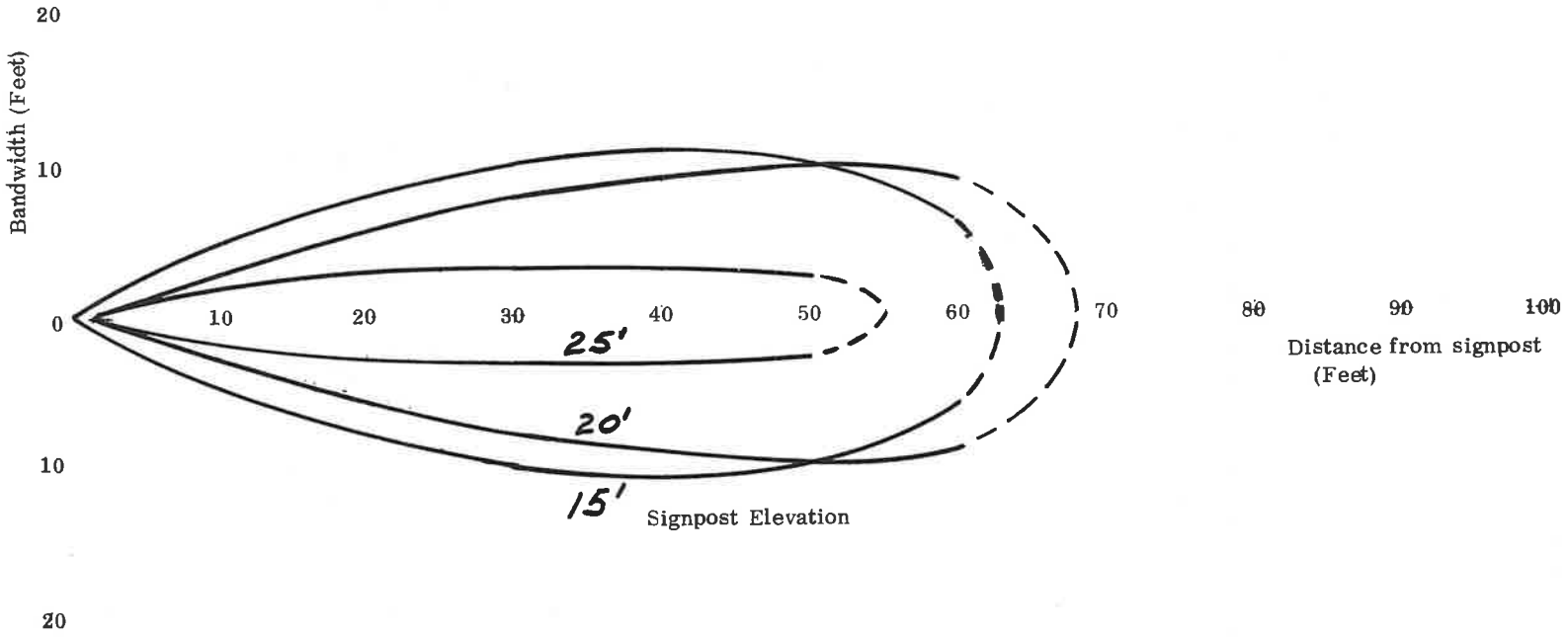


FIGURE 7-1 SIGNPOST WINDOW

gain than the design value. This failure apparently occurred after completion of the field testing, since signposts acquired along the fixed route were at greater distances than the maximum sensitivity measured during this test.

7.6 ENVIRONMENT TEST

The interrogator and signpost were subjected to one thermal cycle to determine temperature affects on system operation. The signpost was cycled from 110^{o}F to -20^{o}F and the interrogator from 0^{o}F to 90^{o}F. The test was performed in eight steps using separate chambers for the signpost and interrogator. Correct signpost acquisition was verified at each step before proceeding to the next. After completion of the final step at the cold temperature the chamber was raised to 20^{o}F above room ambient for fifteen minutes to remove accumulated moisture before removal from the chamber. No affects due to temperature were observed during this test.

7.7 ADJACENT CHANNEL INTERFERENCE

All radio receivers are subject to interference from sources external to the system. To determine the Location Subsystem susceptibility an adjacent channel interference test was conducted for both the transmit and receive frequencies.

A continuous wave frequency was injected at 100 KHz interval offsets on each side of the system center frequency. Ten intervals were injected on each side. For each injection the interference level was increased until the system failed to acquire, then decreased until correct operation was again observed. The ratio of injection signal level to system signal level in db is listed in Table D-5 of Appendix D.

Figure 7-2 is a block diagram of the test configuration. The test translator employed was an actual hardwired signpost. Conversion efficiency was measured at -20 db. Both the transmit and receive connections contained attenuators to simulate the space loss for a normally installed signpost at a distance of 50 feet.

7.8 SITE RF SURVEY

A site survey was conducted along the Fixed Route and within the Random Route areas to determine ambient noise levels. Tests were conducted both during the day and at night.

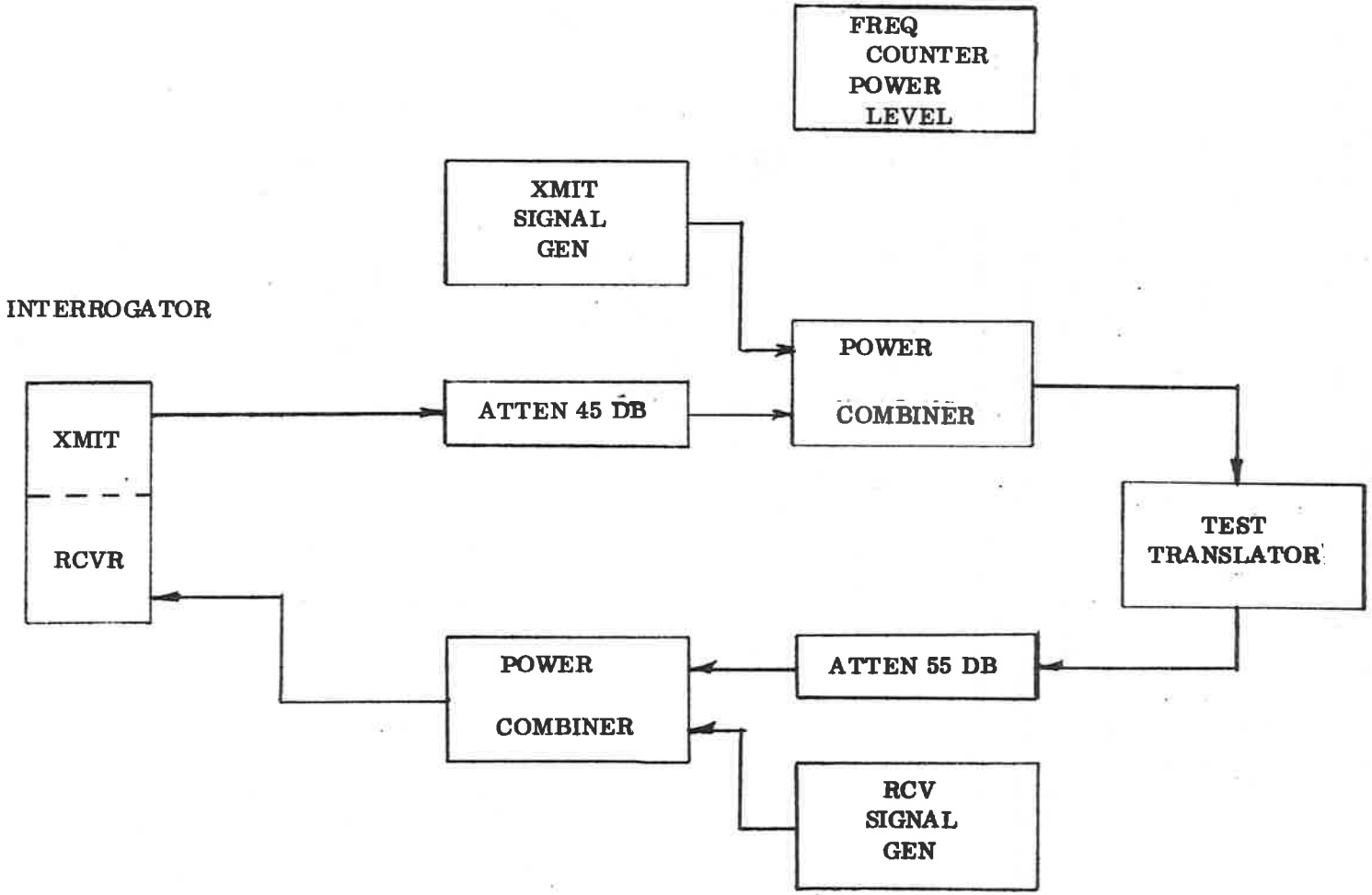


FIGURE 7-2 ADJACENT CHANNEL INTERFERENCE TEST DIAGRAM

The test equipment configuration is shown in Figure 7-3. The Fairchild interrogator mounted within the test vehicle was interconnected to provide monitoring at first the 2.48 GHz, then the 4.96 GHz frequencies, corresponding to the normal transmit and receive frequencies respectively. This was accomplished by switching between the two antennas, and changing the Phase Detector reference frequency as shown on Figure 7-3. A recorder was connected to monitor two signal locations in the receiver: the AGC amplifier output, and a signal within the AGC circuitry called threshold amplifier input. These signals have a bandwidth of about 10 KHz. Figure 7-4 indicates the relationship between the recorded signal levels and the receiver input signal level for the 4.96 GHz tests. The level for the 2.48 GHz measurement which did not use a R.F. preamplifier is 24 dB less sensitive.

A typical strip chart record is shown in Figure 7-5 where the signal level obtained for typical signpost interrogations can be compared to the ambient background noise at 4.96 GHz. Figure 7-6 shows typical ambient noise at 2.48 GHz.

During the survey there were only a few isolated points where the noise signal level exceeded the receiver front end noise. For those cases observed, the level was insufficient to have any impact on the relatively strong transponder signals received during a normal interrogation.

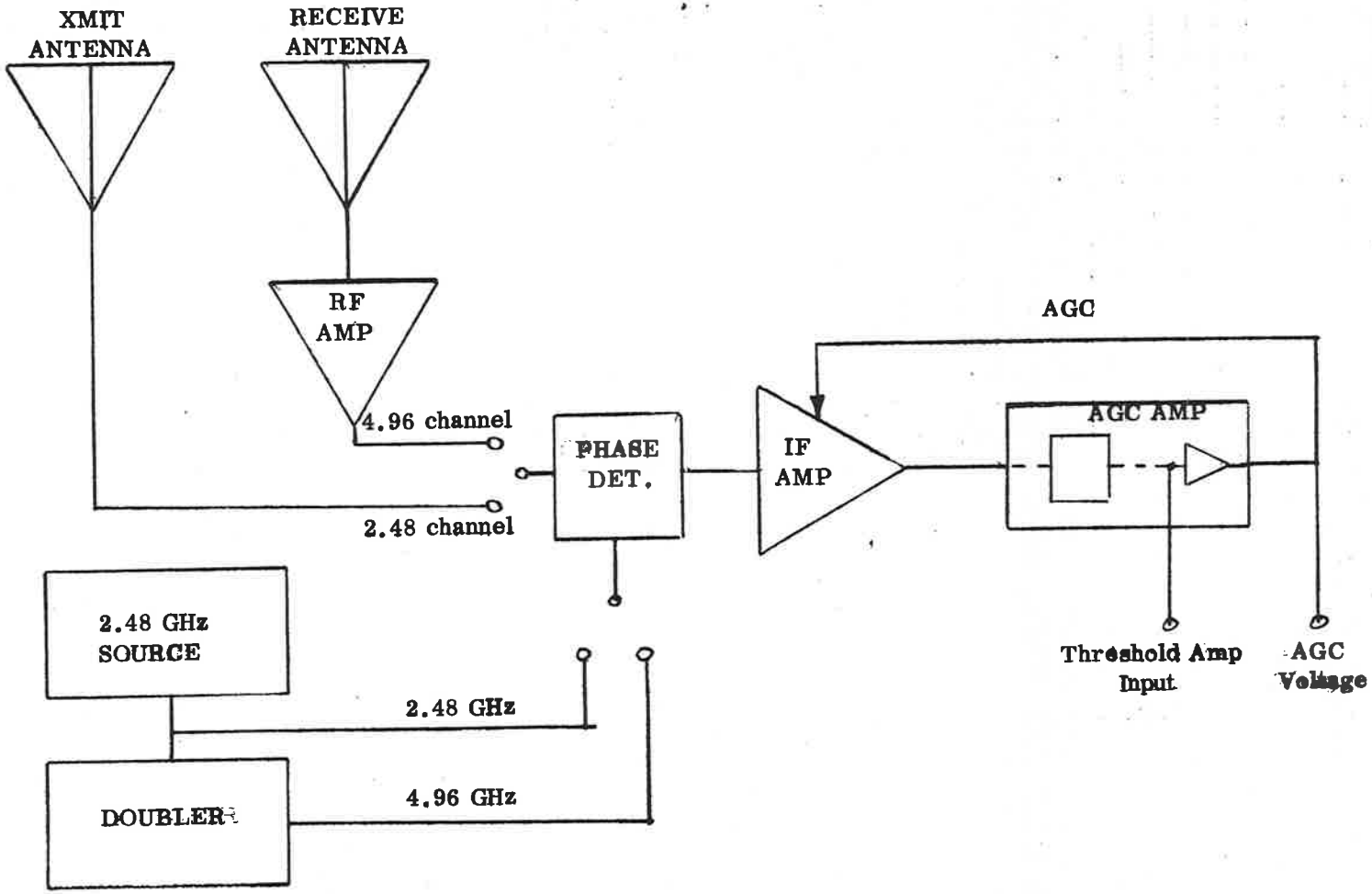


FIGURE 7-3 TEST EQUIPMENT CONFIGURATION SITE RF SURVEY

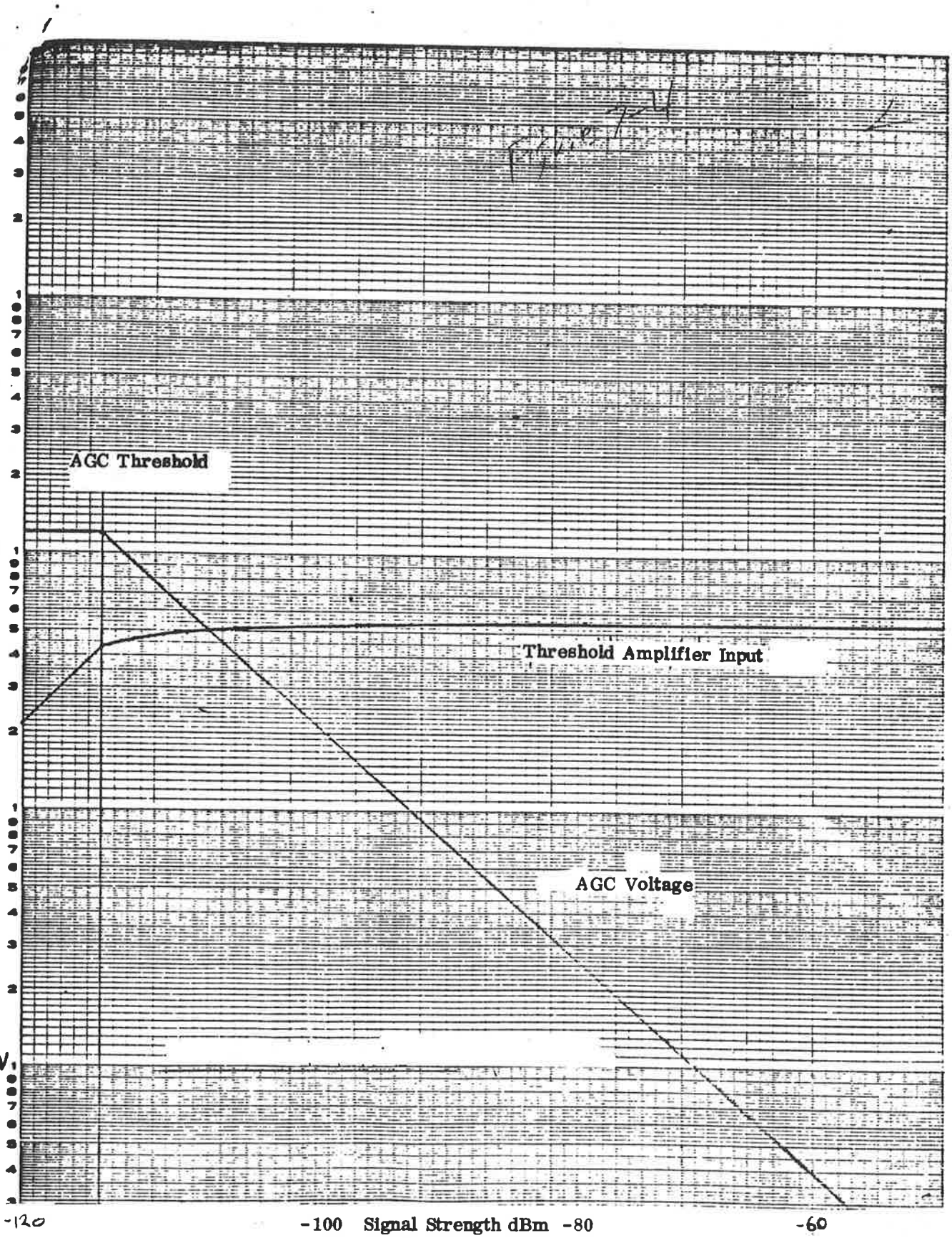


FIGURE 7-4 THRESHOLD AMPLIFIER INPUT AGC VOLTAGE CALIBRATION FIGURES

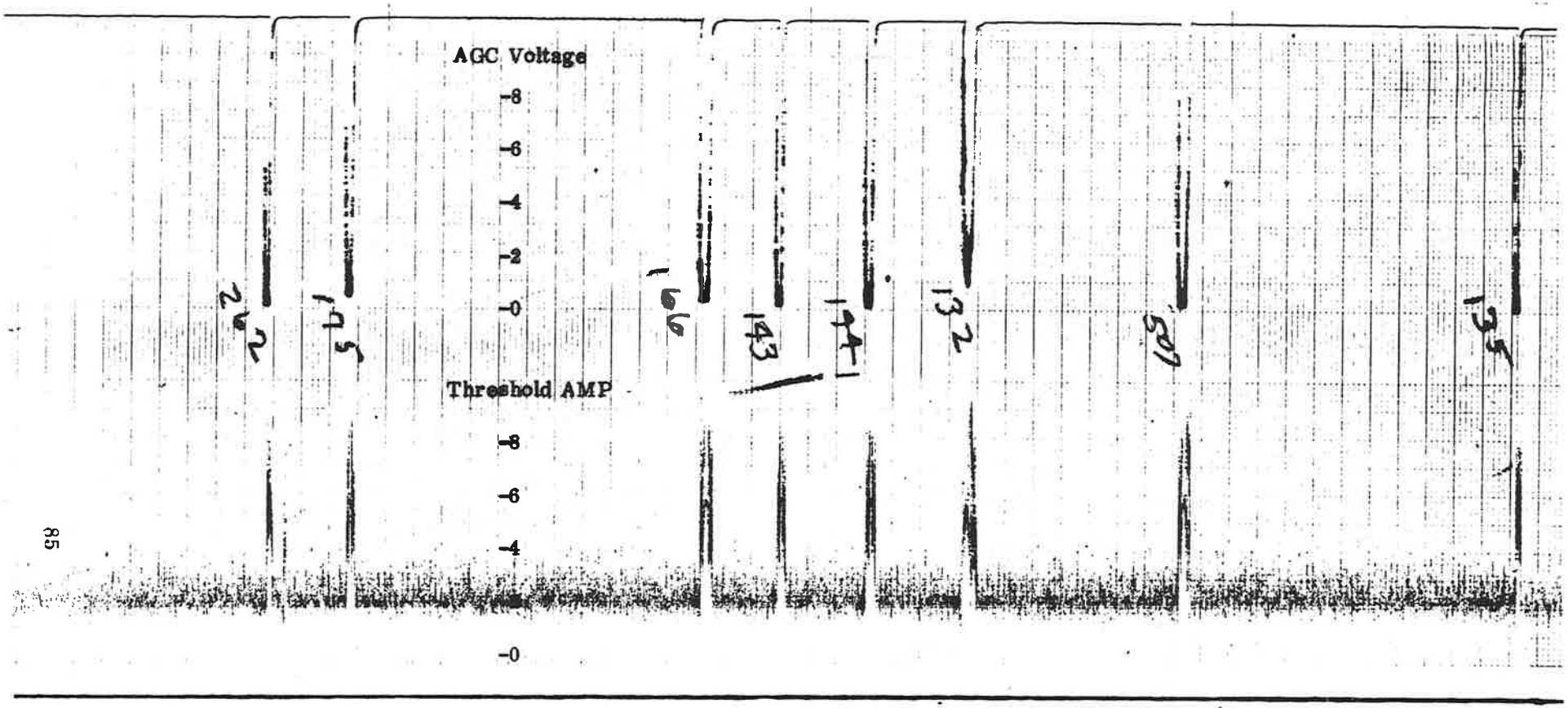


FIGURE 7-5 RF SITE SURVEY TYPICAL 4.96 GHz BACKGROUND NOISE AND SIGNPOST SIGNAL LEVELS

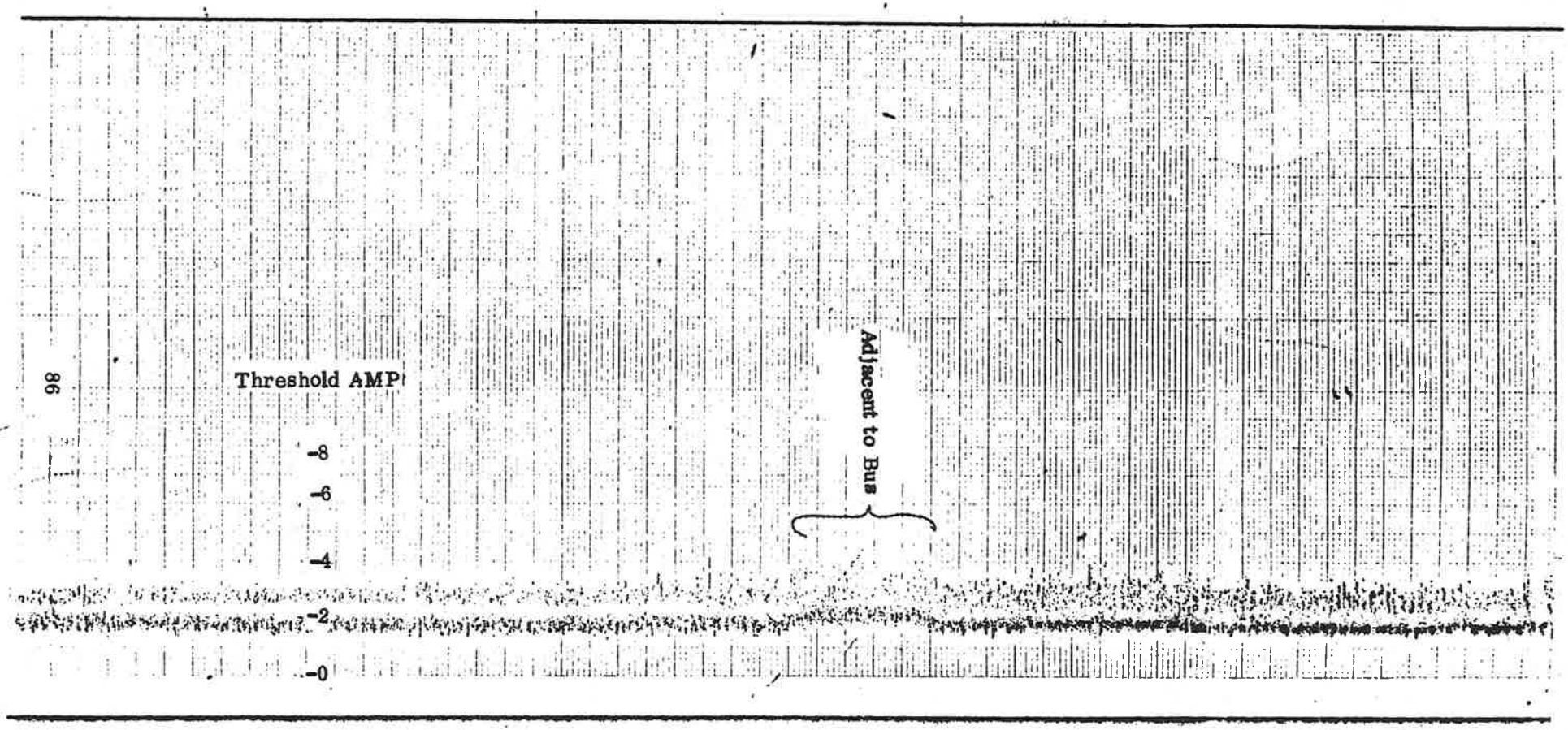


FIGURE 7-6 RF SITE SURVEY TYPICAL NOISE BACKGROUND AT 2.48 GHz

8. IMPROVEMENTS RESULTING FROM PHASE I

8.1 DESIGN IMPROVEMENTS

This section describes the nature and extent of Location Subsystem design improvements necessary to meet the Los Angeles and multi-vehicle system requirements. It is noteworthy that the on-board concept, as tested in Philadelphia, is exactly as originally proposed and that no extensive changes were required during the field test and none will be required for the Phase II program in Los Angeles.

As discussed throughout the preceding sections of this report, two easily correctable situations occurred during the field testing which affected the achieved accuracy. Once these situations are corrected, however, the test results provide a high level of confidence that the system is capable of easily achieving the requirements of multi-vehicle users. The cause and elimination of the two problems are discussed in detail in the preceding sections and are summarized below.

8.1.1 SIGNPOST PLACEMENT

Two signposts, one on the fixed and one on the random route, were mounted too close to an intersection. As a result they were interrogated by the test vehicle as it passed along the adjacent side street. Thus, a large radial error was placed in the system which remained until the next signpost was encountered. While this situation occurred only four times (1-Fixed, 3-Random), it has served to alert us; care will be taken to avoid a recurrence in Los Angeles by installing signposts further in from intersections.

8.1.2 SIGNPOSTS INTERROGATIONS

The second situation which occurred was that a successful interrogation subsequently changed to an incorrect code identification. Of the 2935 signposts interrogated this occurred 23 times, 22 of which were within 50 feet following the correctly decoded identification. While this processing deficiency will obviously be corrected for operational system use in Los Angeles, there are several safeguards which will be employed to eliminate any impact from an incorrectly decoded interrogation.

a) Parity checks bits will be added to the signpost identification word to provide expanded error detection capability - the codes used in the Philadelphia test contained only one parity bit which proved inadequate.

b) Each new acquisition will be examined by a base station processor reasonableness algorithm to determine if it was physically possible for the vehicle to acquire (non-existent, beyond vehicle speed, not on route, etc.) - no such algorithm was employed in Philadelphia.

If either of these safeguards had been employed in the Philadelphia data processor, none of the incorrectly read signposts would have been accepted by the system processor, and none of the large radial errors would have occurred.

No patentable hardware or software developments have resulted from the Phase I program effort, including both the initial design effort and all field improvements.

8.2 IN-HOUSE RESEARCH AND DEVELOPMENT (IR & D)

8.2.1 SIGNPOSTS

Since the later part of 1975, FSEC has been conducting extensive in-house and subcontracted development programs primarily aimed at preparing Automatic Vehicle Identification (AVI) products for mass production. Since the AVM and AVI programs utilize the same

technology and very similar hardware, the cross fertilization in hardware improvements is obvious. Such has already been demonstrated in the AVM program as related to the equipment used in Philadelphia. The slot line antenna arrays formed by elements and their dividing or combining networks were used in the Philadelphia signposts. The vehicle interrogator transmit and receive antenna arrays were also the product of the in-house development program. All previous programs utilized expensive and large horn antennas. Since that time FSEC undertook through a subcontractor the development of an I^2L chip for AVI transponder use. Such a chip in one package replaces the entire transponder logic board and all its discrete components. It not only contains the clock and processor circuits but also a programmable memory for identity code encoding. The development of the chip has progressed through design, preparation of masks and fabrication of chips for evaluation purposes. Such have been received by FSEC and tested not only functionally but also environmentally. The results are extremely good. The chip will be packaged in a ceramic or epoxy transfer molded package. This effort will result in a universal transponder chip and will reduce very significantly all transponder costs in production. During 1976 Fairchild undertook the task of developing a replacement material for RF boards. In the past all RF boards (including AVM signposts) were made from "Rexolite" laminates which are very expensive. The development work has identified one prime and two back-up materials which have the desired dielectric constant and power loss factor required by RF circuit boards. These materials are a fraction of the cost and are injection moldable.

Circuits have been built and tested to verify the performance of the prime material selected. The circuits were built from sheet material. FSEC has designed the substrate injection molding cavity which is now in fabrication. In approximately two weeks such substrates will be molded and again tested.

The significance of this step is not only the reduction of material costs but also the elimination of labor. The diode recesses which are now hogged-out and the coordination as well as mode suppression holes which are drilled in "Rexolite" as well as routing of periphery will be obtained automatically as a by product of molding.

FSEC has also fabricated an injection molding cavity to put a plastic "jacket" around the transponder insert to eliminate containers. Jacketing tests have been conducted for AVI transponders. While this may not be applicable to the AVM identity coded signpost due to the size (the large volume required by batteries), the single bit signpost is definitely applicable. This would automatically provide not only a hermetic seal but also mounting provisions, thus deleting the present container, bracket and front cover.

Another task scheduled for later part of this year is the development of an RF switch which would turn on a transponder battery only when the transponder is being interrogated. This may be a function of the second harmonic-generated frequency. The objective of such a switch is to reduce the size of the battery (capacity). This in turn would reduce battery cost without affecting the operating life. The battery capacity would simply be sized as a function of duty cycle, letting the shelf life predominate as is being done now.

8.2.2 VEHICLE EQUIPMENT

We are now conducting development in the following areas:

1) Solid state RF source (amplifier) up to 50 watts for road vehicle and rail car use (AVI)
2) Stripline receiver circuit development to eliminate discrete microwave components, thus permitting the circuits to be etched.
3) Stripline transmitter circuit development to eliminate discrete microwave components, thus permitting the circuits to be etched.
4) Deletion of signal processing circuits previously built from discrete components and development of programs to accomplish functions in microprocessor chips. This includes:
    a) code read/match functions
    b) power control functions
    c) code check functions, etc.

All above efforts are aimed at mass producibility and low manufacturing cost. Almost all of the above have or will soon produce significant benefits to the AVM program.

8.3 COST REDUCTIONS

FSEC presents in this section, as summarized in Table 8-1, the Full Deployment Cost Projections estimated on the basis of the following:

a) Test results achieved in Philadelphia

b) Benefits derived from product improvements as a result of the IR & D program

c) Mass production improvement resulting from the IR & D program and expanded in-house production capability

d) Separation of the Communications Subsystems cost as part of the AVM baseline.

8.3.1 SIGNPOST DEPLOYMENT

As a direct result of the Philadelphia field testing, specifically the missing signposts tests, FSEC feels conclusively that the original estimate of signpost deployment at the rate of 6 per route mile was unnecessarily conservative. The missing signpost tests, and most especially the timepoints only test, demonstrate that the Location Subsystem is capable of meeting the requirements with a deployment of no greater than one signpost per route mile.

8.3.2 VOLUME PRODUCTIONS

At the time FSEC submitted its proposal to DOT the IR & D program described above had not even been contemplated. In fact the FSEC proposal projections stated in technical volume Figure 1. 8-1 were unfortunately derived by assuming that only 100 or 1000 location subsystems would be produced by the methods of assembly of discrete

components. No assumption was made that beyond a single customer needing the above quantities there may be others. One must make the assumption that if an AVM system is developed by DOT and FSEC that there should be many other customers wanting the same product and that the supplier would look to mass produce the total requirement.

8.3.3 COMMUNICATION SYSTEM

The Communications Subsystem Capital costs were included in the FSEC full deployment cost analysis for the original proposal submission. However, in reviewing the RFP, section 10, page 8 specifies that a separate listing may be used for determination of communication costs. It is assumed that the AVM purchasers such as transit companies, police fleets and taxi fleets which are either equipped or are presently equipping themselves with communication links will have total communication links established. The FSEC System will thus simply interface with the link at both ends. The proposed equipment is designed to establish such interface for digital data transmission.

Removal of the communications equipment from the FSEC baseline also reduces the maintenance cost estimate by that amount previously included for the on-board and base station communications equipment.

8.3.4 FULL DEPLOYMENT COST ANALYSIS

The table of Full Deployment Cost Analysis which appeared as Table 1.8-1 in the original proposal is presented as Table 8-1 with a revised cost analysis based on the above considerations. The original cost elements have been included for ready comparison with the updated projections.

The signpost unit cost has been reduced from $40 to $20 reflecting the technology improvements and mass production improvements previously described. In addition the density of signposts per route mile has been reduced for fixed route vehicles as a direct result of the field test program.

The vehicle equipment costs have in particular been drastically reduced due to the production and technology techniques presently being developed in the FSEC IR & D program. For fixed route vehicles the large volume costs are estimated at $1100 per unit, and the random route vehicles at $1300 per unit.

TABLE 8-1

FULL DEPLOYMENT COST ANALYSIS (000)

		RANDOM-ROUTE VEHICLE AREA COVERAGE				FIXED-ROUTE TRANSIT ROUTE COVERAGE			
		50 Sqmi.		100 Sqmi.		100 Mi.		1000 Mi	
		Original	Update	Original	Update	Original	Update	Original	Update
Location Subsystem Capital Costs	0 Vehicles	458.8	148	592	296	34	2	240	20
	100 Vehicles	350	240	350	240	300	210	300	210
	1000 Vehicles	2400	1300	2400	1300	2100	1100	2100	1100
Data Processing Subsystem Capital Costs	100 Vehicles	250	250	250	250	250	250	250	250
	1000 Vehicles	435	435	435	435	435	435	435	435
Total System Capital Costs	100 Vehicles	1058.8	638	1192	786	584	462	790	480
	1000 Vehicles	3293.8	1883	3427	2031	2569	1537	2775	1555
Total System: Annual Maintenance Costs	100 Vehicles	171.5	100	198.5	115	85.5	60	126.5	84
	1000 Vehicles	517.5	310.5	544.5	328.5	431.5	238	472.5	252

APPENDIX A. FIXED ROUTE DATA SUMMARIES

Table A-1
Fixed Route

Signpost Acquisition Errors

Summary Listing		Actual			Description
Miss	Incor.	Miss	Incor.	Notes	
1	1	0	0		Run 101
				1	616 incorr. } before start of run
				1	569 missed }
0	1	0	1		Run 102
				2	535 changed to 278 after 20' then back to 535 while sitting at beam edge
5	1	1	0		Run 103
				1	616 incorr. } before start of run
				1	569 missed }
				3	534 missed
				4	601 listed as missed 28' before acquired
				4	585 listed as missed 9' before acquired
1	1	0	0		Run 104
				1	616 incorr. } before start of run
				1	569 missed }
5	1	1	0		Run 105
				1	519 incorr. } before start of run
				1	569 missed }
				1	547 missed }
				3	534 missed
				4	601 listed as missed 29' before acquired
				4	564 listed as missed 7' before acquired

Table A-1 (cont'd)

Signpost Acquisition Errors

Summary Listing		Actual			
Miss	Incor.	Miss	Incor.	Notes	Description
1	0	0	1		Run 106
				4	601 listed as missed 25' before acquired
				5	587 acquired from side street
3	1	0	0		Run 107
				1	616 incorr. } before start of run
				1	569 missed }
				4	627 listed as missed 432' before acquired
				4	558 listed as missed 13' before acquired
5	2	0	1		Run 108
				1	616 incorr. } before start of run
				1	569 missed }
				4	559 listed as missed 16' before acquired
				4	564 listed as missed 14' before acquired
				2	541 changed to 529 after 26'
				6	602 } listed as missed due to 541 tag change
				6	569 }
3	1	1	0		Run 109
				1	616 incorr. } before start of run
				1	569 missed }
				3	534 missed
				4	601 listed as missing 19' before acquired
2	1	0	1		Run 110
				4	601 listed as missing 33' before acquired
				2	601 changed to 600 after 17'
				4	579 listed as missing 29' before acquired
3	1	1	2		Run 111
				3	534 missed
				4	564 listed as missing 12' before acquired
				2	580 changed to 582 after 2' then back to 580 while standing still at beam edge
				2	522 changed to 525 after 13'
				6	584 listed as missing due to 522 tag change
2	1	0	0		Run 112
				1	569 missed } before start of run
				1	616 incorr. }
				4	558 listed as missed 15' before acquired

Table A-1 (cont'd)

Signpost Acquisition Errors

Summary Listing		Actual			Description
Miss	Incor.	Miss	Incor.	Notes	
3	2	0	1		Run 113
				1	519 incorr. } before start of run
				1	569 missed }
				1	547 missed }
				2	650 changed to 697 after 23'
				4	601 listed as missed 31' before acquired
0	0	0	0		Run 114
					Clean
1	0	0	0		Run 115
				4	579 listed as missed 10' before acquired
5	0	1	1		Run 116
				2	547 changed to 546 after 27'
					680 } listed as missed due to 547 tag change
					556 }
					626 }
				3	534 missed
				4	601 listed as missed 20' before acquired
6	2	0	1		Run 117
				1	616 incorr. } before start of run
				1	569 missed }
				2	603 changed to 600 after 26'
				6	585 } listed as missed due to 603 tag change
				6	559 }
				6	553 }
				4	559 listed as missed 16' before acquired
				4	579 listed as missed 40' before acquired
2	1	0	1		Run 118
				1	616 incorr. } before start of run
				1	569 missed }
				2	627 changed to 626 after 27'
				4	558 listed as missed 11' before acquired
2	1	0	1		Run 119
				1	616 incorr. } before start of run
				1	569 missed }
				2	533 changed to 534 after 30'
				6	539 listed as missed due to 533 tag change

Table A-1 (cont'd)

Signpost Acquisition Errors

Summary Listing		Actual			
Miss	Incor.	Miss	Incor.	Notes	Description
4	1	1	0		Run 120
				1	616 incorr. } before start of run
				1	569 missed }
				4	548 listed as missed 10' before acquired
				3	534 missed
				4	558 listed as missed 50' before acquired
2	1	0	0		Run 121
				1	616 incorr. } before start of run
				1	569 missed }
				4	564 listed as missed 13' before acquired
3	2	1	0		Run 122
				1	616 incorr. } before start of run
				1	569 missed }
				3	534 missed
				4	558 listed as missed 14' before acquired
4	4	1	2		Run 123
				1	616 incorr. } before start of run
				1	569 missed }
				2	650 changed to 2603 then back to 650 vehicle not moving, at beam edge.
				3	534 missed
				4	601 listed as missed 34' before acquired
				7	535 changed to *** then to 625 after 219'
				4	558 listed as missed 16' before acquired
2	1	1	1		Run 124
				1	616 incorr. } before start of run
				1	569 missed }
				3	534 missed
				2	562 changed to 561 after 27'
3	2	0	1		Run 125
				1	616 incorr. } before start of run
				1	569 missed }
				4	601 listed as missed 24' before acquired
				2	599 changed to 591 after 14'
				1	569 listed as missed after completion of run
3	1	1	0		Run 126
				1	616 incorr. } before start of run
				1	569 missed }
				3	534 missed
				4	564 listed as missed 13' before acquired

Table A-1 (cont'd)

Signpost Acquisition Errors

Summary Listing		Actual			Description
Miss	Incor.	Miss	Incor.	Notes	
2	3	1	1		Run 127
				1	*** } incorrect before start of run
				1	616 }
				2	547 changed to 549 after 23'
				6	561 listed as missed due to 547 tag change
				3	534 missed
1	1	0	0		Run 128
				1	616 incorr. } before start of run
				1	569 missed }
4	4	1	1		Run 129
				1	*** } incorrect before start of run
				1	616 }
				2	587 changed to 970
				6	595 listed as missed due to 587 tag change
				3	534 missed
				4	585 listed as missed 19' before acquired
				4	558 listed as missed 16' before acquired
2	4	0	0		Run 130
				1	616 incorr. } before start of run
				1	569 missed }
				7	*** }
				7	*** } listed as incorrect due to tape error
				7	761 }
4	2	0	2		Run 131
				1	616 incorr. } before start of run
				1	569 missed }
				2	562 changed to 561 after 65'
				4	564 listed as missed 20' before acquired
				2	665 changed to 661 after 23'
				4	558 listed as missed 15' before acquired
				4	627 listed as missed 7' before acquired
6	2	1	1		Run 132
				1	616 incorr. } before start of run
				1	569 missed }
				3	534 missed
				4	601 listed as missed 28' before acquired
				4	564 listed as missed 10' before acquired
				2	532 changed to 531 after 22'
					557 listed as missed due to 532 tag change

Table A-1 (cont'd)

Signpost Acquisition Errors

Summary Listing		Actual			
Miss	Incor.	Miss	Incor.	Notes	Description
3	1	1	0		Run 133
				1	616 incorr. } before start of run
				1	569 missed }
				3	534 missed
				4	585 listed as missed 9' before acquired
					Run 001
4	1	1	0	1	616 incorr. } before start of run
				1	569 missing }
				3	534 missed
				4	564 listed as missed 9' before acquired
				4	528 listed as missed 2' before acquired
					Run 002
5	1	0	0	1	616 incorr. } before start of run
				1	569 missing }
				4	556 listed as missed 14' before acquired
				4	585 listed as missed 32' before acquired
				4	564 listed as missed 10' before acquired
				4	579 listed as missed 10' before acquired
					Run 003
7	2	0	1	1	616 incorr. } before start of run
				1	569 missing }
				4	562 listed as missed 16' before acquired
				4	601 listed as missed 31' before acquired
				4	585 listed as missed 9' before acquired
				4	564 listed as missed 11' before acquired
				4	558 listed as missed 12' before acquired
				2	584 changed to 296 after 30'
				6	541 listed as missed due to 584 tag change
					Run 004
5	1	1	0	1	616 incorr. } before start of run
				1	569 missed }
				3	534 missed
				4	564 listed as missed 11' before acquired
				4	528 listed as missed 11' before acquired
				4	558 listed as missed 11' before acquired

Table A-1 (cont'd)

Signpost Acquisition Errors

Summary Listing		Actual			Description
Miss	Incor	Miss	Incor.	Notes	
					Run 005
3	3	0	1	1	616 incorr. } before start of run
				1	569 missed }
				4	562 listed missed 12' before acquired
				2	562 changed to 946 after 23'
				1	556 missed } after run terminated.
				1	683 incorr. }
		16	22		Total
					Total Signposts to 2503

Table A-1 (cont'd)

Notes:

1) These signposts were listed as incorrect or missed before the start or after completion of the actual fixed route run.

2) These signposts were acquired correctly as the test vehicle passed the signpost location, but the stored value subsequently changed to an incorrect identification. This occurred at the edge of the signpost window and accounted for 17 of the 20 tabulated incorrect readings.

3) Signpost 534 accounted for all 14 tabulated missed signposts. Normal vehicle pass distance is estimated at 80 feet, signpost mounting angle is 45^{o}.

4) The Fixed Route Vehicle Route Table contained in the Location System route description file; defines the linear distance between signposts. When the Location Subsystem distance from the last acquired signpost exceeds the table distance to the next route signpost; that signpost is assumed to have been missed, even if acquired a short distance further down the route.

5) Signpost 587 was installed on 13th Street almost at the intersection with RACE Street. This signpost was erroneously acquired only during run 106.

6) Misidentified support caused System Processor to mislocate vehicle on route causing subsequent erroneous missing signpost indicators.

7) Most probable tape error.

Table A-2

Checkpoint Radial Errors, Fixed Route

Checkpoint ID	101	102	103	104	105	106	107	108	109	110	111	112	113	114
1	14	17	6	2	6	1	14	6	14	6	21	32	14	6
2	3	2	13	17	9	13	9	2	13	13	1	13	17	17
3	40	20	20	16	16	18	14	33	20	16	20	18	14	18
4	22	22	24	22	28	24	23	30	24	26	26	24	24	24
5	9	14	21	21	14	17	17	17	21	5	14	17	17	17
6	7	11	13	7	11	13	7	7	16	20	11	7	13	11
7	12	15	4	15	23	4	8	8	15	15	12	8	19	15
8	44	44	35	48	48	28	35	28	32	44	44	44	39	35
9	33	22	30	41	26	30	26	22	37	26	67	41	33	33
10	18	22	11	7	11	15	15	18	7	1	7	15	11	15
11	10	10	6	2	2	21	6	5	5	10	10	2	2	2
12	22	29	22	22	22	22	22	26	22	396*	22	29	33	22
13	45	65	23	30	30	30	26	19	30		19	19	26	23
14	23	23	31	20	23	20	23	12	31	20	31	31	27	27
15	9	12	5	12	5	5	5	5	5	5	9	5	5	5
16	9	6	6	1	3	3	1	3	28	3	13	6	17	6
17	16	10	29	20	23	16	10	10	10	14	23	14	16	23
18	29	26	29	31	26	21	29	73	31	23	29	44	26	31
19	20	20	31	20	61	13	24	20	20	16	20	28	16	24
20	31	23	1	31	14	8	8	8	5	31	1	20	20	8
21	34	42	42	46	42	49	57	18	49	49	34	34	53	42
22	13	2	5	2	13	13	13	13	9	5	2	17	9	13
23	12	17	12	8	24	24	33	12	24	20	17	17	24	17
24	8	8	10	8	31	6	8	8	10	44	14	8	24	14
25	36	33	39	25	28	36	33	36	36	39	45	25	36	39
26	25	25	29	23	18	33	33	11	23	25	36	33	25	23
27	9	53	6	12	15	7	12	7	8	38	12	42	38	6
28	63	61	74	64	63	64	55	67	64	69	69	69	54	56
29	23	14	28	19	19	9	9	9	9	19	23	28	9	23
30	13	16	14	13	14	13	14	13	16	14	14	13	13	16
31	14	18	14	14	25	18	72	10	32	18	10	10	28	25
32	16	16	16	16	16	15	23	16	16	15	19	21	21	21
33	16	16	15	20	16	17	16	32	16	16	32	20	18	22
34	14	14	5	5	14	14	19	14	14	14	14	19	5	9
35	59	52	36	56	63	59	59	56	56	41	52	56	59	52
36	34	32	30	33	30	33	33	32	33	29	30	32	30	33
37	7	29	21	5	21	29	21	25	10	21	14	29	18	29
38	39	43	43	43	43	50	14	54	43	50	47	50		54
39	39	41	31	20	35	31	27	39	17	39	35	35	41	45
40	27	17	34	20	23	20	23	23	23	17	14	20	23	30
41	63	67	67	69	59	59	67	69	56	84	59	59	69	25
42	7	5	3	12	35	3	12	23	12	7	7	7	7	7
43	24	14	27	31	27	19	14	17	24	27	24	24	17	31
44	39	35	28	39	35	12	39	28	28	39	35	35	39	21
45	42	45	36	36	45	30	39	39	29	42	42	30	45	45
46	3	3	4	4	8	8	2	4	4	26	3	4	2	4
47	29	33	29	33	29	29	33	33	33	29	29	29	29	21
48	33	33	33	37	44	40	33	37	29	26	33	52	26	22
49	39	43	39	46	43	49	46	43	37	43	39	46	46	46
50	12	16	16	19	9	19	12	22	9	16	8	26	12	16
51	8	13	7	8	10	10	23	8	10	10	8	13	8	13
52	23	14	13	26	21	30	34	13	26	36	26	30	21	26
53	22	11	22	19	19	329	11		11	11	41	11	15	52
54	22	48	29	22	52	762	14	7	14	7	18	22	37	26
55	49	52		64		31	28	37	28	31	1151	37	35	41
56		44		86	55	55	51	44	59	44	1407	40	36	40
57	15	18		22	15	23	15	26	15	18	22	26	22	12
58	16	27		23	23	4	88	31	5	27	8	23	35	35
59	6	2		11	2	11	2	7	22	18	11	14	2	2
60	36	40		29	25	29	18	1105	18	18	36	25	18	25

Table A-2
Checkpoint Radial Errors, Fixed Route

Checkpoint ID	115	116	117	118	119	120	121	122	123	124	125	126	127	128
1	6	6	14	6	17	21	14	21	6	6	6	9	17	17
2	9	6	6	13	2	6	9	9	9	6	9	35	9	1
3	16	4259	14	20	16	16	16	24	20	16	14	16	5740	18
4	26	5300	27	26	27	25	28	23	35	24	26	30	6331	24
5	28	5784	24	9	17	14	3	9	21	3	21	9	6893	13
6	11	16	13	11	16	16	13	11	7	11	5	11	16	13
7	4	12	15	23	12	8	19	19	8	15	12	23	30	8
8	48	32	44	32	28	32	32	35	48	48	44	35	9	44
9	26	44	26	26	30	33	37	33	33	30	44	26	7	48
10	3	3	18	3	15	11	7	11	11	11	3	7	7	3
11	10	6	6	10	2	6	6	5	2	2	5	6	6	2
12	18	37	14	29	26	33	26	22	22	52	37	37	22	23
13	49	30	19	23	19	23	23	23	37	26	37	19	26	23
14	16	20	60	27	20	5	16	23	38	20	35	27	31	20
15	5	10	5	9	4372	5	5	5	9	12	6	12	5	5
16	6	3	6	17	6	1	1	6	1	1	3	3	6	6
17	14	10	14	11	14	43	25	20	23	23	23	25	23	23
18	34	29	31	34	23	31	34	23	29	40	38	21	31	31
19	20	16	20	16	720*	20	24	13	24	16	54	20	20	28
20	5	16	16	20	8	6	23	8	35	3	16	12	8	27
21	27	24	34	31	38	21	42	46	38	46	24	27	46	27
22		17	13	9	5	24	13	13	5	9	3	20	2	13
23	8	12	20	29	17	20	17	29	20	17	12	29	20	20
24	6	14	10	10	44	8	8	10	10	8	6	16	6	8
25	31	39	36	39	39	43	33	39	43	33	45	43	39	36
26	29	29	25	2266	29	25	18	15	29	25	33	25	23	23
27	8	11	2367	7	12	6	15	6	7	30	15		19	7
28	63	63	67	63	71	56	64	56	59	67	56	63	63	61
29	14	28	14	23	23	33	34	16	28	28	9	14	23	20
30	16	13	14	18	14	18	13	16	13	18	18	18	14	14
31	25	14	14	21	54	28	14	14	25	10	28	18	21	18
32	21	16	16	21	15	17	16	17	21	15	17	21	16	21
33	15	16	16	16	15	29	16	16	20	22	20	16	15	20
34	5	9	19	9	5	9	9	5		5	5	19	14	9
35	59	66	56	63	52	63	59	52	59	66	50	52	56	66
36	33	32	32	30	30	30	30	30	30	35	30	30	35	32
37	18	33	33	36	25	29	29	29	36	29	7	25	29	
38	21	36	47	58	47	43	39	50	39	36	47	47	39	47
39	39	39	45	41	41	41	41	41	35	41	35	35	27	35
40	30	27	20	23	23	23	23	20	30	30	20	17	20	14
41	29	63	69	67	63	59	59	48	20	73	42	67	63	59
42	12	7	7	3		44	7	12	12	16	16	40	16	7
43	27	20	27	31		24	24	24	31	20	17	17	17	20
44	25	39	28	28		35	35	14	35	28	31	25	28	19
45	42	39	42	42		42	42	39	39	42	42	18	42	42
46	4	19	8	8		4	12	26	2	3	2	4	3	12
47	5	37	29	29		33	25	45	37	37	25	29	29	33
48	33	40	37	44		44	29	37	40	37	26	12	40	48
49	43	46	37	43		39	39	43	46	39	43	37	46	33
50	22	22	19	19		16	9	26	19	12	19	16	26	39
51	8	7	8	8		8	8	10	8	17	8	7	8	34
52	26	36	34	26		30	26	30	23	26	21	34	21	15
53	11	8	15	917*		11	19	11		15	26	11	26	30
54	11	4	26	26		26	18	22	14	14	11	22	33	22
55	35	41	35	35		60	35	37	28	41	35	41	64	37
56	36	40	44	36		40	40	33	44	48	36	55	29	51
57	28	18	22	26		26	18	18	26	26	22	12	8	22
58	38	23	23	31		35	27	38	31	31	31	27	27	23
59	11	11	14	11		11	2	14	14	11	26	14	14	18
60	25	21	21	25		21	33	50	29	21	25	21.	21	29

Table A-2
Checkpoint Radial Errors, Fixed Route

Checkpoint ID	129	130	131	132	133	01	02	03	04	05
1	14	14	2	2	6	17	14	10	14	17
2	6	6	2	2	6	3	9	17	6	2
3	18	31478	18	16	16	20	18	18	18	18
4	22		26	28	23	24	23	25		23
5	3		14	9	7	14	21	14	17	9
6	7	1292	7	16	13	7	16	7	13	7
7	19	8	23	12	15	12	8	8	8	8
8	35	44	74	39	39	35	55	44	44	44
9	26	30	30	80	22	48	37	26	30	37
10	7	7	7	3	11	26	11	11	11	7
11	10	2	2	2	2	17	10	6	10	6
12	37	14	33	29	29	172*	33	29	26	22
13	19	45	23	34	26	60	52	30	30	49
14	1225	16	23	23	27	35	20	35	20	23
15	5	12	6	5	6	9	12	5	12	9
16	3	9	3	1	9	6	9	1	9	6
17	11	20	11	4	20	16	20	14	14	23
18	31	38	31	23	34	31	29	26	38	23
19	28	24	24	16	20	28	20		24	13
20	8	16	5	44	8	1	16	20	27	23
21	31	49	49	46	31	42	38	34	46	42
22	9	5	3	13	9	9	5	3	2	5
23	17		20	20	29	12	29	20	33	
24	10	8	8	10	10	14	41	10	8	
25	45	39	36	33	36	33	39	31	25	
26	11	23	25	33	20	15	29	25	18	
27	12	14	6	6	9	9	12	6	15	
28	58	61	67	69	63	58	67	67	69	
29	4	19		19	23	6	19	14	19	
30	14	14	36	16	14	24	13	13	16	
31	32	21	21	10	28	14	25	14	14	
32	34	19	19	17	17		21	17	21	
33	17	15	15	15	18	18	18	16	20	
34	9	14	14		14	14	14	9	9	
35	56	63	59	59	59	52	63	47	52	
36	31	30	32	30	33	30	30	32	32	
37	18	21	3	21	25	18	21	21	25	
38	54	39	36	6	32	36	39	43	36	
39	41	45	41	14	39	31	41	31	35	
40	17	14	27	17	14	23	17	27	23	
41	63	48	67	674	63	67	59	63	56	
42	12	12	12	19	7	16	5	5	16	
43	31	7	8	24	8	31	24	31	17	
44	12	35	35	31	43	31	13	28	31	
45	49	39	39	39	32	20	45	18	32	
46	8	4	22	2	12	7	4	4	2	
47	41	29	37	21	37	25	25	29	10	
48	44	22	29	14	33	26	37	29	33	
49	49	37	39	37	46	39	43	39	39	
60	19	16	9	16	8	8	8	18	19	
51	7	8	8	8	10	17	8	27	8	
52	30	30	26	26	23	34	30	18	26	
53	15	4	48	8	22	11	19	26	11	
54	22	14	11	22	11	22	18	26	11	
55	37	31	37	37	41	45	49	41	41	
56	48	40	59	48	36	40	44	51	55	
57	15	26	15	15		22	15	12	18	
58	35	42	23	31	27	38	31	1093	31	
59	18	14	6	11	2	22	2	2	2	
60	33	25	29	25	25	29	25	29	25	

*Operator entry errors, checkpoints not included in data summaries

Table A-3

System Coverage Radial Errors, Fixed Route

Tenth Mile	101	102	103	104	105	106	107	108	109	110	111	112	113	114
0.1	9.8	7.3	9.2	5.5	8.9	16.5	8.8	9.1	8.1	9.3	7.8	9.2	13.6	9.2
0.2	20.0	24.2	20.4	20.4	21.1	24.5	19.8	25.2	20.1	24.6	20.6	20.5	24.7	22.3
0.3	11.5	12.2	12.4	16.7	17.6	16.0	16.5	14.1	14.1	12.5	13.5	13.0	25.0	17.8
0.4	17.2	19.8	19.9	22.8	24.1	21.9	23.4	21.9	21.1	19.9	20.5	19.3	33.6	25.8
0.5	23.5	25.2	26.0	28.2	32.3	29.1	31.2	26.8	27.7	24.3	25.1	24.9	39.5	31.4
0.6	17.1	13.1	20.1	17.8	13.5	18.4	18.4	22.3	19.7	13.8	14.2	19.7	22.2	14.3
0.7	5.0	4.8	4.6	4.7	5.1	6.3	4.8	4.5	4.3	4.2	8.1	5.7	5.3	3.8
0.8	5.9	12.0	10.5	7.7	7.8	8.2	9.8	12.5	10.5	11.6	6.5	7.4	15.9	9.6
0.9	8.5	11.4	13.6	9.9	9.6	8.3	10.7	10.3	11.8	15.5	10.4	12.4	2.1	2.7
1.0	11.6	11.1	19.4	13.8	11.6	10.7	13.9	9.3	16.3	15.4	15.1	16.6	4.5	7.9
1.1	11.1	11.5	18.3	13.4	10.5	9.6	13.4	8.1	15.5	15.2	13.3	15.0	3.7	6.8
1.2	16.2	15.6	19.9	15.6	12.9	12.5	18.3	14.8	18.5	17.3	13.1	16.8	5.0	13.4
1.3	11.6	10.6	13.0	9.4	5.0	9.3	13.2	9.5	12.5	12.2	11.7	11.2	1.6	11.1
1.4	2.8	2.8	3.1	2.2	4.0	2.4	4.7	3.0	3.1	4.7	3.7	2.6	9.5	2.2
1.5	8.4	7.7	11.7	7.9	6.3	4.6	9.0	6.8	11.2	6.3	8.7	7.1	3.2	5.9
1.6	7.6	5.9	11.1	7.6	3.6	4.8	9.2	6.2	10.7	6.4	7.6	6.8	2.4	4.6
1.7	11.0	12.4	15.7	7.4	3.3	6.0	13.8	10.4	12.7	8.6	9.3	12.3	7.5	10.3
1.8	4.1	4.4	8.7	3.4	3.6	1.6	5.7	3.6	3.1	3.5	2.3	5.5	4.7	1.9
1.9	9.7	8.0	10.4	7.6	14.5	10.6	8.4	11.9	10.4	10.2	9.9	10.2	15.5	9.4
2.0	4.2	2.5	6.0	3.3	4.9	4.4	3.1	3.4	3.5	3.6	2.9	4.5	6.7	2.7
2.1	4.7	4.0	7.5	7.8	6.2	6.7	6.5	5.4	6.2	3.7	3.0	3.0	10.0	6.0
2.2	2.5	1.5	4.8	2.6	7.8	7.0	1.5	4.5	1.9	1.3	5.5	6.1	12.9	2.2
2.3	7.4	6.6	13.1	5.1	4.7	4.3	5.9	6.8	10.2	4.9	4.5	5.3	7.5	5.0
2.4	2.9	4.9	6.5	6.8	5.3	8.1	2.0	3.7	6.3	5.8	7.7	3.3	12.7	7.1
2.5	5.2	5.2	7.9	4.8	9.5	7.7	11.3	9.2	7.5	5.5	6.0	7.0	13.2	7.4
2.6	1.7	1.7	6.2	1.4	3.9	4.1	6.2	5.4	5.1	2.7	2.1	1.1	7.4	2.6
2.7	2.7	11.3	7.8	3.7	4.3	5.3	8.0	15.8	5.1	3.9	3.3	1.3	7.9	3.4
2.8	19.7	22.6	26.8	16.0	11.5	12.4	22.7	25.0	25.2	20.2	20.3	19.9	12.3	17.3
2.9	17.4	24.0	25.7	17.7	13.5	14.2	22.3	25.0	24.0	18.4	19.5	17.7	13.5	16.4
3.0	6.7	7.7	11.7	5.0	7.1	5.3	12.4	9.9	12.6	7.2	7.2	8.3	11.4	8.1
3.1	41.4	66.0	71.3	65.5	47.0	63.5	41.3	25.0	27.0	68.2	39.5	34.7	50.8	38.6
3.2	93.1	92.3	94.2	95.1	95.8	95.7	93.6	96.2	97.5	98.6	97.0	97.7	97.8	95.2
3.3	7.3	8.5	22.1	16.7	33.8	49.7	39.6	26.7	45.1	45.6	37.5	40.1	724.2	41.6
3.4	84.6	98.5	102.	66.7	118.6	146.5	85.0	111.3	144.8	89.5	122.8	119.9	623.5	100.2
3.5	29.5	28.4	24.0	34.4	33.1	62.5	51.0	39.1	41.8	87.7	35.0	50.4	41.5	43.5
3.6	11.9	12.2	12.2	25.4	26.5	64.2	51.8	28.8	41.8	85.1	45.8	48.2	33.5	44.2
3.7	8.0	11.2	18.1	23.9	30.3	60.9	51.5	26.0	50.0	81.9	48.8	46.7	32.4	51.9
3.8	96	10.1	15.0	19.6	22.6	51.4	42.3	23.2	40.4	71.7	39.4	39.0	25.0	40.5
3.9	19.8	16.7	13.7	18.8	9.5	31.1	43.0	28.8	12.6	337.6	39.1	39.3	12.6	42.0
4.0	14.5	9.0	36.7	31.3	18.1	10.8	57.6	34.9	8.0	544.8	52.2	52.4	20.1	56.3
4.1	10.3	4.8	46.1	24.4	22.4	7.4	49.6	31.3	12.8	33.6	46.7	41.2	15.3	45.0
4.2	5.4	4.0	49.8	16.5	28.9	3.9	45.6	26.2	11.4	28.2	46.1	41.9	21.5	48.1
4.3	13.2	12.0	45.0	23.6	22.7	13.5	49.0	25.2	16.0	24.4	36.0	40.2	20.8	40.5
4.4	25.8	12.4	31.7	33.1	17.5	15.4	65.6	47.8	15.5	43.4	60.6	62.0	5.9	61.6
4.5	10.6	6.0	44.5	22.4	22.0	6.0	51.0	31.5	9.8	32.0	46.9	45.3	15.9	46.6
4.6	15.8	9.2	42.7	26.9	20.1	4.6	57.2	37.1	9.9	37.5	53.9	51.2	10.4	51.0
4.7	31.5	20.4	24.5	40.8	8.7	22.1	72.1	57.0	13.1	56.8	66.3	71.5	9.2	63.7
4.8	23.1	16.8	43.0	9.0	33.7	25.6	34.0	16.4	23.2	18.1	28.4	30.8	34.8	26.1
4.9	8.6	11.1	62.4	8.2	38.9	14.2	27.8	19.7	21.3	17.5	32.2	33.2	38.0	36.3
5.0	9.1	6.2	51.6	15.1	26.3	6.5	38.1	31.5	13.6	25.7	44.0	46.2	28.8	46.9
5.1	12.2	5.0	46.2	19.8	21.3	5.4	39.9	35.9	8.9	26.3	49.0	51.7	23.3	51.7
5.2	11.2	3.5	44.5	19.5	22.1	4.1	37.9	35.1	9.1	26.1	48.0	49.9	25.2	49.4
5.3	9.8	2.0	46.3	17.2	25.6	2.2	35.4	31.9	11.4	24.8	47.0	47.9	28.0	46.1
5.4	6.4	7.8	53.1	12.2	33.7	5.5	31.5	25.2	19.1	18.8	40.4	41.2	36.0	40.9
5.5	23.4	25.1	30.2	35.5	13.8	20.2	55.0	54.5	19.5	53.9	58.7	57.1	12.7	64.7
5.6	19.4	8.8	33.8	28.6	13.9	11.9	46.6	41.9	12.5	47.8	37.8	35.4	7.3	56.0
5.7	19.3	13.6	57.7	23.4	32.3	11.9	46.8	38.2	12.6	44.1	39.2	40.3	17.0	58.9
5.8	7.0	4.8	62.8	9.3	40.4	20.5	32.8	24.7	7.6	32.0	25.9	27.4	25.7	46.3
5.9	7.5	8.9	76.9	7.4	47.1	29.2	36.9	26.1	20.5	43.8	40.3	19.1	41.9	48.4

Table A-3

System Coverage Radial Errors, Fixed Route

Tenth Mile	101	102	103	104	105	106	107	108	109	110	111	112	113	114
6.0	25.2	18.4	52.8	25.7	24.3	8.8	55.1	43.0	7.4	49.6	48.0	38.7	22.1	56.7
6.1	7.7	5.7	65.7	5.8	47.8	23.8	34.3	16.0	14.0	20.1	25.9	17.0	40.0	36.9
6.2	6.0	14.8	80.4	6.4	58.4	34.4	26.1	9.4	24.6	14.6	14.5	6.9	51.0	25.0
6.3	7.7	15.3	76.6	6.9	56.7	34.5	25.2	14.3	22.0	13.6	15.7	4.2	46.8	25.2
6.4	20.2	26.6	87.0	20.0	71.2	47.2	12.5	3.8	33.7	3.3	3.9	12.6	62.3	11.9
6.5	22.2	31.6	96.8	21.5	78.2	47.3	9.1	10.5	41.5	10.9	9.3	17.9	68.0	11.4
6.6.	14.1	19.2	84.3	11.1	63.2	46.9	15.9	6.2	31.2	7.0	10.6	3.0	58.5	17.6
6.7	20.4	26.7	91.8	17.0	72.6	54.2	9.1	2.7	38.0	4.1	4.8	4.4	66.0	10.8
6.8	14.8	23.0	87.6	11.9	65.0	49.9	17.3	1.6	30.9	6.6	9.9	1.8	58.7	16.7
6.9	14.3	23.0	87.1	11.5	68.2	51.4	16.9	1.7	30.5	9.8	9.4	8.0	61.2	17.8
7.0	16.8	18.5	75.4	14.0	39.0	29.2	19.8	18.6	22.8	22.5	30.2	18.8	57.3	28.5
7.1	17.3	21.5	91.6	10.8	70.4	50.2	17.5	6.1	38.7	8.7	13.1	7.6	63.8	20.6
7.2	17.1	13.3	64.7	20.0	46.7	22.1	52.2	27.3	10.5	46.0	43.5	27.8	32.4	55.3
7.3	11.6	7.7	56.8	19.0	37.8	15.3	42.9	22.2	14.4	33.7	30.5	16.3	34.0	54.9
7.4	3.2	4.5	65.7	7.1	45.7	29.8	37.2	14.7	17.5	29.4	23.8	10.7	38.5	40.4
7.5	4.2	9.3	73.5	2.9	53.5	36.0	31.4	9.5	26.0	22.3	17.6	3.2	47.6	33.0
7.6	2.0	4.1	71.5	7.5	50.8	34.2	40.6	16.8	16.8	28.9	23.8	11.9	46.0	39.2
7.7	2.3	3.8	72.3	8.3	51.8	34.2	38.2	15.9	15.9	30.2	22.7	13.0	48.3	37.9
7.8	5.4	4.8	66.9	11.0	50.7	30.8	45.7	19.9	12.4	32.3	25.4	15.6	41.2	41.0
7.9	3.0	7.9	69.6	5.5	53.1	35.9	36.3	9.2	18.1	23.1	19.8	9.5	40.9	29.8
8.0	19.5	23.8	83.4	11.4	73.4	54.2	20.8	5.1	36.5	6.7	5.4	11.4	59.3	17.0
8.1	18.7	20.5	78.9	25.9	46.8	23.5	47.9	27.6	16.3	38.8	32.2	20.3	42.7	49.7
8.2	13.4	13.5	69.9	22.1	49.2	25.2	48.1	14.4	18.6	28.1	30.4	13.9	40.1	40.7
8.3	7.9	6.8	67.3	2.8	62.5	25.6	40.6	15.6	14.6	27.8	21.4	8.2	39.7	42.9
8.4	10.2	8.3	69.4	1.6	66.7	27.7	36.1	13.0	16.7	24.5	19.0	6.7	42.9	40.5
8.5	19.0	20.8	67.8	3.7	65.5	27.5	37.7	15.3	15.6	29.1	19.6	14.0	40.6	43.9
8.6	14.4	12.8	73.7	3.4	66.0	31.3	33.1	7.1	22.8	21.2	18.1	3.6	45.4	35.7
8.7	24.1	25.1	86.8	12.2	75.4	47.6	29.8	3.4	36.4	13.6	5.2	4.2	59.1	23.4
8.8	17.1	22.5	87.3	6.3	71.3	43.2	28.8	7.2	29.9	20.5	15.0	6.6	60.6	33.5
8.9	12.1	9.8	76.1	3.4	67.0	34.3	32.5	7.6	24.4	24.2	21.1	5.1	47.3	38.7
9.0	5.8	4.4	71.0	7.3	57.9	30.7	39.9	11.9	20.5	31.5	30.3	15.9	37.5	46.3
9.1	9.8	11.4	53.0	23.6	42.7	12.0	46.2	26.4	9.5	39.1	42.4	28.3	22.0	56.6
9.2	13.7	20.6	83.4	12.0	77.8	39.7	34.9	14.3	23.3	27.9	15.5	11.9	41.5	35.8
9.3	7.2	9.0	69.8	5.0	70.8	28.8	39.4	17.0	13.1	31.7	25.8	6.8	33.9	46.8
9.4	11.2	9.1	74.3	4.2	71.5	42.1	39.8	13.3	15.7	26.2	22.0	7.5	40.1	43.8
9.5	17.0	15.2	79.3	7.8	76.0	47.7	32.4	8.6	25.1	23.5	16.2	5.7	46.5	37.5
9.6	8.0	9.9	59.5	11.7	61.7	796.2	51.1	25.4	10.2	45.4	37.0	28.4	22.4	59.0
9.7	5.7	4.9	73.4	2.1	64.0	33.3	39.3	16.3	12.6	31.7	27.8	9.9	38.6	51.4
9.8	4.9	4.9	72.7	1.7	62.7	31.5	42.5	17.4	9.3	35.4	30.6	12.4	36.2	58.8
9.9	10.5	6.4	55.8	13.8	57.2	26.1	50.1	30.7	7.1	47.5	42.3	29.0	29.1	57.7
10.0	4.8	6.6	61.4	9.5	58.3	28.0	48.1	18.5	8.2	40.0	32.7	18.8	29.8	60.8
10.1	9.4	9.9	63.4	12.1	59.8	343.0	45.0	20.2	10.8	40.6	34.8	19.4	32.2	58.4
10.2	13.8	14.0	66.3	18.2	58.7	426.2	46.9	29.8	14.6	42.8	784.1	23.6	33.5	63.8
10.3	11.4	13.2		20.1	51.0	25.3	48.2	32.3	9.6	45.7	1190.6	26.3	26.6	65.8
10.4	10.3	12.0		22.6	48.7	19.8	50.7	35.2	5.0	48.7	1260.4	28.5	23.0	67.8
10.5	9.4	10.3		27.1	48.8	17.2	52.4	46.2	2.3	47.1	760.4	28.6	29.5	66.9
10.6	4.4	5.8		4.8	64.4	33.2	44.5	18.2	8.0	35.9	35.0	15.6	32.5	20.2
10.7	15.2	18.7		15.7	77.0	48.1	30.9	6.9	22.8	24.2	22.2	6.5	46.0	45.2
10.8	18.6	17.5		16.6	71.9	46.6	5.7	6.6	22.8	21.3	16.2	4.5	46.8	42.7
10.9	29.1	26.2		25.9	88.8	57.1	4.9	4.6	35.6	11.3	9.2	6.0	58.0	32.6
11.0	30.6	26.5		24.2	89.3	58.8	20.6	12.9	34.6	15.1	13.0	15.7	54.1	35.0
11.1	8.4	9.1		12.6	61.4	39.4	45.7	1154.4	6.8	41.4	39.0	18.4	33.6	66.9
11.2	6.6	6.8		14.8	60.2	43.7	40.1	1189.2	8.9	38.0	37.1	14.7	36.0	63.0
11.3	6.0	4.3		17.5	63.4	38.6	36.7	676.0	8.1	42.4	35.9	16.9	29.8	65.4

Table A-3

System Coverage Radial Errors, Fixed Route

Tenth Mile	115	116	117	118	119	120	121	122	123	124	125
0.1	8.8	11.0	9.7	7.6	8.5	8.8	9.4	9.2	9.9	8.8	8.0
0.2	23.3	19.6	17.9	23.2	24.3	18.7	19.7	22.8	20.0	18.7	26.5
0.3	18.0	3783.0	11.0	17.8	9.2	12.7	16.6	13.5	12.0	14.7	19.4
0.4	27.1	4968.1	17.1	24.4	13.9	19.5	23.7	19.8	18.4	21.7	27.4
0.5	24.3	5612.3	24.8	30.4	20.9	24.7	29.5	25.1	24.0	28.0	32.3
0.6	18.6	1735.8	17.1	17.4	19.7	15.3	15.7	18.1	18.3	17.1	24.2
0.7	3.1	4.6	4.6	5.0	3.8	4.6	5.5	4.1	6.5	2.9	6.1
0.8	10.4	6.1	9.8	7.8	9.2	21.2	10.6	10.6	6.8	8.9	13.6
0.9	8.1	5.3	11.8	4.6	10.8	7.1	8.6	9.2	7.0	6.0	2.0
1.0	11.7	13.9	18.0	10.4	10.6	9.8	10.6	9.8	7.8	10.5	5.1
1.1	10.9	13.2	16.5	9.8	10.0	9.4	10.2	10.2	6.7	10.5	4.3
1.2	13.5	12.4	16.6	10.4	13.0	10.2	12.2	12.2	9.0	12.0	5.7
1.3	6.7	13.3	14.0	5.8	11.9	7.2	5.9	5.1	4.7	5.4	2.7
1.4	3.3	3.8	4.8	4.2	4.0	2.7	4.0	4.6	5.9	4.0	11.9
1.5	6.1	12.7	9.3	2.2	5.7	2.0	2.1	2.3	2.1	1.7	4.8
1.6	5.7	12.3	8.6	1.7	5.1	2.3	1.7	1.8	3.6	2.1	5.5
1.7	7.3	11.0	15.4	3.0	5.5	8.0	4.2	3.8	6.1	4.5	4.6
1.8	4.0	3.0	9.4	3.8	3.7	1.7	7.9	4.6	3.3	8.1	9.2
1.9	15.0	12.7	10.2	11.1	2436.1	11.4	15.8	11.6	12.8	16.8	15.3
2.0	3.8	5.2	7.5	4.4	4523.3	2.5	3.6	3.2	5.7	2.7	9.0
2.1	4.8	3.0	7.2	5.3	3964.9	3.5	7.5	6.7	10.5	4.9	12.0
2.2	1.4	4.2	6.0	7.5	3.1	5.2	3.1	9.8	12.9	7.9	13.1
2.3	8.7	6.3	13.6	4.6	5.4	3.3	6.4	4.7	8.1	3.7	6.8
2.4	3.1	6.0	7.5	9.5	5.5	12.0	6.7	14.2	11.1	12.5	17.7
2.5	9.2	6.7	8.8	12.3	5.5	8.5	7.0	12.7	8.6	10.1	18.6
2.6	4.9	3.2	8.3	9.2	3.6	3.1	3.7	10.2	8.0	7.9	11.5
2.7	6.8	13.2	8.6	10.9	3.7	3.9	4.4	13.9	5.9	9.7	11.2
2.8	20.4	22.4	28.6	5.1	14.1	13.4	13.7	7.8	2.1	9.5	5.1
2.9	18.8	22.0	28.1	6.9	15.9	11.6	12.9	10.2	5.2	9.1	5.3
3.0	11.6	9.4	15.5	8.9	5.7	5.7	5.7	5.8	11.5	6.2	11.1
3.1	67.8	61.7	64.8	46.4	39.3	44.9	62.1	68.1	52.0	58.8	47.6
3.2	94.9	96.8	95.7	98.0	102.1	98.5	97.8	97.5	97.9	93.2	92.4
3.3	43.1	38.8	34.6	31.0	56.1	54.6	38.1	29.9	100.2	28.6	30.8
3.4	134.6	123.3	80.0	62.9	133.5	133.0	72.4	87.7	106.7	124.0	118.5
3.5	50.0	39.7	63.6	65.6	70.9	58.3	51.5	28.5	18.5	30.6	37.5
3.6	47.2	42.8	64.1	59.7	70.3	63.1	42.8	25.1	48.8	24.4	30.8
3.7	51.7	46.4	61.8	54.8	68.3	63.4	41.7	32.9	59.3	32.1	30.5
3.8	44.0	39.8	53.1	46.7	58.2	55.8	34.2	26.6	46.6	25.9	24.1
3.9	48.7	19.6	53.6	48.0	56.3	57.1	39.8	30.9	32.4	504.8	12.2
4.0	59.9	5.0	66.6	59.8	68.7	72.3	52.2	41.8	12.8	17.8	23.4
4.1	53.7	7.1	57.7	44.3	69.5	64.0	42.8	31.3	8.5	16.0	26.3
4.2	50.4	4.6	57.6	41.2	63.4	63.0	41.3	32.8	5.7	20.9	26.1
4.3	43.8	14.7	45.2	36.9	53.3	61.2	31.3	27.4	13.0	22.5	34.8
4.4	80.6	15.3	71.8	60.0	79.9	95.4	59.4	52.6	17.9	5.7	11.0
4.5	58.1	5.1	59.7	46.4	59.9	67.6	42.9	35.7	7.3	11.9	25.0
4.6	65.0	8.6	66.5	52.8	67.4	77.4	50.7	42.4	10.4	6.0	25.2
4.7	81.9	27.9	77.1	70.9	84.7	90.6	62.4	53.9	103.7	8.2	8.3
4.8	42.0	13.5	48.7	25.7	42.5	46.2	27.5	22.6	198.9	24.2	38.0
4.9	49.1	6.5	47.4	1784.7	48.5	54.2	30.6	24.0	6.1	24.1	41.4
5.0	57.2	7.1	2103.0	763.2	57.2	61.6	42.4	33.4	9.5	14.4	28.3
5.1	59.2	8.6	2246.2	44.8	60.7	66.4	47.2	35.0	13.8	10.0	23.3
5.2	58.1	6.8	1891.9	44.5	60.9	66.6	47.1	34.2	12.6	11.1	23.6
5.3	56.6	4.0	1670.6	42.3	60.3	67.0	45.7	33.0	11.4	12.4	24.8
5.4	53.8	3.7	1484.2	39.3	58.7	64.1	40.9	28.1	6.7	18.6	32.1
5.5	76.7	28.9	75.9	61.0	75.0	74.3	62.1	49.6	26.0	15.0	11.4
5.6	60.9	12.6	60.8	37.9	53.6	59.3	44.1	29.7	15.3	6.8	13.4
5.7	60.9	17.8	61.4	47.1	60.0	59.7	40.2	31.7	11.2	15.0	15.2
5.8	46.5	6.3	47.8	35.1	47.2	46.2	28.8	19.5	6.8	25.6	19.4
5.9	61.6	7.0	42.4	40.2	62.4	61.0	43.6	13.7	19.5	30.8	38.3

Table A-3

System Coverage Radial Errors, Fixed Route

Tenth Mile	115	116	117	118	119	120	121	122	123	124	125
6.0	66.7	20.8	57.8	54.8	69.6	68.1	46.4	36.3	4.5	8.2	16.3
6.1	40.7	6.3	30.9	31.8	47.5	47.9	17.5	11.0	13.7	27.3	29.9
6.2	34.9	11.5	26.7	23.0	39.4	39.5	10.6	6.8	29.4	36.1	45.5
6.3	33.1	11.1	28.9	19.9	36.0	38.9	9.9	8.6	29.8	36.5	44.1
6.4	17.4	23.3	14.2	3.8	25.2	23.7	3.9	6.7	43.6	51.3	57.7
6.5	15.8	36.9	18.3	5.5	15.4	24.0	7.8	7.9	43.4	55.8	65.1
6.6	24.9	17.1	21.3	13.8	27.6	23.5	1.9	10.3	42.5	47.5	56.6
6.7	17.9	23.4	15.0	7.2	22.1	16.0	5.9	16.3	49.8	53.6	63.6
6.8	21.6	19.6	17.0	11.4	26.8	19.8	5.0	15.0	43.8	42.9	56.6
6.9	26.5	19.0	19,3	13.0	30.8	22.8	3.8	14.4	44.9	43.2	57.4
7.0	40.4	12.7	26.2	24.6	52.0	24.5	10.2	15.7	33.1	33.1	46.5
7.1	27.8	18.4	20.3	13.4	33.2	24.2	7.7	14.5	49.1	47.5	57.7
7.2	58.1	18.5	47.8	48.2	58.8	57.8	34.3	18.3	20.6	26.1	30.1
7.3	54.7	15.0	45.7	38.8	50.6	48.2	25.7	10.1	14.8	18.2	30.9
7.4	44.1	2.5	32.6	26.0	41.4	37.9	17.6	5.0	25.4	24.9	36.1
7.5	38.5	2.3	25.0	20.0	36.5	31.3	11.9	3.9	31.4	31.7	44.7
7.6	43.6	2.6	34.9	29.3	43.9	35.9	14.9	1.9	26.3	26.1	39.0
7.7	42.8	4.0	35.5	29.2	42.9	36.2	14.0	2.5	26.4	26.4	39.5
7.8	48.8	8.5	40.8	35.6	47.1	40.5	17.6	6.9	23.5	25.0	34.3
7.9	36.0	4.5	33.0	28.4	37.0	29.2	10.0	4.4	29.4	34.5	37.4
8.0	17.2	14.5	18.7	14.9		17.3	5.5	17.7	49.6	50.7	55.4
8.1	53.3	22.8	52.6	43.0		45.5	24.3	20.7	30.9	24.0	38.5
8.2	41.5	8.7	54.2	35.5		36.9	12.2	12.0	31.8	28.3	28.1
8.3	31.9	5.9	43.2	34.0		38.8	12.7	3.5	35.3	28.0	42.3
8.4	28.8	4.4	40.1	32.4		36.4	10.8	5.8	37.9	30.9	46.5
8.5	32.8	3.8	48.0	37.0		37.7	12.6	5.3	36.4	39.8	42.9
8.6	25.9	6.0	40.3	30.1		26.7	5.8	7.9	39.1	38.5	46.9
8.7	13.0	13.0	34.2	17.1		20.1	8.9	21.5	45.9	42.4	59.6
8.8	16.9	15.2	32.9	22.4		30.4	5.6	18.0	47.7	42.8	50.9
8.9	23.8	9.8	41.3	31.1		34.3	2.2	11.4	42.1	30.0	44.8
9.0	34.2	7.8	49.9	38.5		40.8	9.0	6.0	34.8	24.1	40.8
9.1	43.2	19.8	56.0	43.5		53.3	23.7	12.2	22.3	11.4	26.6
9.2	32.1	13.8	44.5	32.6		34.7	14.9	13.6	50.0	30.7	50.9
9.3	41.3	2.1	52.3	35.2		41.0	10.7	2.5	37.6	21.3	39.9
9.4	25.3	6.0	49.2	34.9		38.2	9.0	5.9	39.5	28.4	43.3
9.5	32.2	6.2	40.6	1072.3		29.9	5.6	12.3	48.5	35.8	53.8
9.6	56.7	21.9	58.3	46.3		46.1	10.9	12.5	25.1	10.6	23.6
9.7	43.0	6.8	47.0	34.2		42.7	10.1	2.8	31.9	23.0	39.1
9.8	47.1	9.5	50.4	36.9		46.1	11.4	4.0	29.2	21.9	36.4
9.9	58.3	20.7	66.9	44.5		47.7	12.4	12.1	21.2	13.5	24.5
10.0	45.2	12.5	56.8	44.7		53.1	13.5	8.0	23.2	15.9	31.1
10.1	45.7	13.6	56.8	44.2		52.1	14.5	10.2	27.4	19.7	34.3
10.2	51.7	20.5	58.8	43.0		51.8	18.8	15.2	28.3	23.0	37.6
10.3	55.2	24.4	62.4	44.8		52.6	21.7	14.6	24.3	17.1	32.5
10.4	57.8	28.2	64.4	48.6		55.1	23.1	13.3	18.4	12.6	29.9
10.5	68.1	27.2	62.0	45.8		49.3	22.7	13.0	18.4	12.0	28.5
10.6	45.0	12.5	51.6	33.6		34.5	11.6	2.8	33.0	12.9	36.2
10.7	32.2	4.6	38.9	21.4		23.6	4.5	14.5	47.2	36.5	51.8
10.8	32.8	2.8	35.6	17.1		23.6	3.8	15.8	43.8	38.3	50.7
10.9	23.1	11.9	23.1	8.7		14.2	13.6	27.6	61.4	49.4	62.7
11.0	24.7	14.8	26.2	12.5		15.5	17.0	26.0	56.4	51.0	59.5
11.1	50.7	14.8	57.6	31.3		41.0	11.6	7.1	30.7	21.7	33.0
11.2	48.6	11.6	55.3	30.3		36.9	9.0	2.8	30.4	22.8	33.5
11.3	50.9	15.6	57.8	32.8		39.4	8.7	6.2	31.2	20.4	58.1
11.4								41.0			

Table A-3

System Coverage Radial Errors, Fixed Route

Tenth Mile	126	127	128	129	130	131	132	133
0.1	21.3	141573.4	11.0	167235.5	8.5	8.8	8.8	9.2
0.2	40.4	1778.2	18.1	91.0	20.6	21.7	20.2	20.3
0.3	21.6	1774.3	12.5	92.6	16.5	17.3	15.6	14.8
0.4	25.7	1770.5	17.7	212.3	19.0	25.3	21.8	20.4
0.5	31.3	1767.4	22.7	26.3	275982.6	29.1	28.7	41.9
0.6	21.7	1764.4	12.0	15.8	10346.8	19.8	18.5	42.2
0.7	5.3	1761.6	11.7	6.0	11.0	4.9	6.6	29.8
0.8	13.2	1457.9	9.2	9.7	11.0	8.6	8.4	35.6
0.9	4.8	10.0	3.0	6.5	11.0	6.7	10.8	24.1
1.0	7.7	26.7	4.8	4.3	13.0	6.2	13.3	23.1
1.1	6.2	27.3	5.0	3.3	13.1	4.1	10.8	23.8
1.2	8.9	22.3	3.2	10.6	14.5	4.5	10.5	25.1
1.3	4.0	4.1	3.1	6.4	9.6	1.1	4.2	26.9
1.4	5.6	13.0	11.8	3.1	2.6	9.7	8.5	36.7
1.5	3.3	13.9	4.9	2.8	4.4	10.4	6.0	40.0
1.6	2.8	10.4	4.2	1.9	4.5	4.6	2.3	33.7
1.7	5.1	4.9	4.7	1104.1	4.0	2.3	4.5	34.5
1.8	4.6	11.5	8.7	1221.9	3.8	3.8	7.0	39.0
1.9	14.1	19.8	11.6	756.4	10.7	15.4	16.1	44.7
2.0	5.2	16.1	13.8	4.1	5.0	13.3	18.5	50.6
2.1	9.4	18.4	16.1	7.3	7.2	13.5	15.6	47.4
2.2	8.7	19.2	18.5	11.7	9.3	12.5	10.1	42.6
2.3	4.8	17.1	8.9	5.0	6.5	8.8	7.3	38.5
2.4	16.5	26.0	19.7	10.3	6.3	11.7	17.5	51.4
2.5	10.7	25.6	19.6	12.3	5.4	15.5	16.9	54.6
2.6	9.4	22.0	18.8	3.5	1.0	12.5	13.8	49.3
2.7	9.9	23.0	19.3	2.6	2.4	12.5	13.5	49.0
2.8	8.5	1.6	1.8	11.5	15.2	1.1	7.3	32.8
2.9	11.0	3.0	4.7	9.5	15.1	4.2	8.4	32.1
3.0	6.0	18.9	17.4	5.9	4.6	15.1	6.3	54.8
3.1	47.4	52.4	80.8	41.9	57.7	69.2	54.8	91.4
3.2	96.0	98.0	97.1	101.7	95.9	100.0	104.6	109.6
3.3	29.5	15.3	27.2	54.3	60.4	43.7	47.4	21.9
3.4	124.3	104.8	82.4	143.6	100.1	131.7	86.4	85.7
3.5	30.1	24.6	27.8	43.2	67.1	47.5	49.0	36.1
3.6	22.9	11.8	9.9	58.6	69.0	50.4	49.3	25.8
3.7	35.3	21.5	15.2	64.1	70.8	54.3	49.8	15.3
3.8	28.9	16.7	25.3	54.5	56.7	44.6	38.2	12.3
3.9	30.0	6.9	23.2	52.8	63.0	567.8	23.3	18.5
4.0	36.2	15.9	5.7	63.3	87.0	64.2	3.4	25.2
4.1	25.1	23.8	20.9	56.3	72.6	41.9	8.0	15.3
4.2	25.7	23.4	21.2	50.2	69.0	36.7	5.8	10.6
4.3	23.7	33.3	30.6	40.2	66.0	35.2	13.1	9.3
4.4	48.2	21.8	5.1	65.8	84.8	53.3	20.1	26.8
4.5	34.9	26.2	21.3	48.9	67.9	39.6	3.8	8.5
4.6	40.5	20.8	15.1	56.0	75.0	43.1	6.0	9.4
4.7	59.1	10.2	4.4	72.7	81.0	61.3	25.0	27.9
4.8	20.1	35.9	33.0	26.8	44.0	20.1	18.7	12.7
4.9	22.2	37.8	35.8	29.3	49.5	20.6	13.6	8.7
5.0	32.1	27.7	26.7	37.4	58.5	31.4	9.2	7.0
5.1	34.5	25.8	22.1	46.6	61.3	35.8	4.8	9.3
5.2	32.9	27.1	23.4	45.3	61.8	34.8	3.3	9.8
5.3	31.4	29.0	25.3	43.9	62.4	32.9	4.3	8.0
5.4	25.7	33.9	32.8	38.3	59.7	26.9	8.2	3.6
5.5	54.3	14.4	12.2	58.1	74.0	50.5	15.5	21.0
5.6	40.2	15.3	8.0	37.9	61.2	32.6	6.8	4.8
5.7	35.2	31.3	24.0	33.6	62.1	27.2	18.6	16.0
5.8	21.2	37.8	29.8	22.3	50.2	14.1	24.0	22.9
5.9	19.3	54.5	42.8	17.1	54.0	13.6	32.0	31.7

Table A-3

System Coverage Radial Errors, Fixed Route

Tenth Mile	126	127	128	129	130	131	132	133
6.0	35.0	34.5	20.2	37.9	71.1	21.7	6.1	9.5
6.1	7.3	42.6	34.9	16.2	47.9	3.3	21.4	29.6
6.2	3.2	59.5	49.6	6.2	39.3	10.3	35.8	36.5
6.3	3.4	59.4	46.4	3.7	35.8	12.2	40.1	37.6
6.4	17.2	71.6	57.5	10.4	24.9	26.4	53.7	50.0
6.5	21.8	80.5	70.7	17.7	13.2	36.2	75.1	58.6
6.6	12.0	63.7	75.2	2.4	33.1	40.2	88.6	48.0
6.7	18.9	71.7	83.6	6.6	27.0	50.6	101.9	55.9
6.8	15.0	70.1	64.3	9.9	29.4	35.9	104.6	47.0
6.9	13.6	71.3	66.2	11.1	32.8	34.8	103.1	46.6
7.0	13.6	53.8	62.0	19.2	38.5	27.0	77.7	47.0
7.1	8.1	67.4	68.5	7.5	29.7	28.4	114.0	53.1
7.2	17.6	49.7	43.2	21.5	70.1	11.6	96.6	31.0
7.3	18.5	34.5	37.0	21.5	60.8	10.0	72.9	31.6
7.4	6.7	47.7	46.6	13.0	53.1	14.4	89.2	36.7
7.5	2.0	55.3	53.6	5.4	47.1	19.4	94.0	43.2
7.6	6.0	49.0	50.7	12.2	49.2	15.1	99.8	42.9
7.7	3.9	51.7	51.5	10.9	50.9	15.9	99.4	45.0
7.8	9.6	48.3	47.4	16.5	56.8	13.4	238.3	45.2
7.9	5.7	51.5	51.8	11.2	47.9	21.3	1150.1	49.7
8.0	13.3	68.6	70.9	8.4	29.9	35.2	572.5	63.6
8.1	23.8	48.8	45.0	27.2	61.9	17.0	276.5	62.5
8.2	17.8	47.4	42.7	15.9	52.1	16.9	84.4	49.1
8.3	2.8	60.5	46.4	9.7	50.8	18.5	103.3	52.7
8.4	3.7	64.9	48.3	8.5	48.0	20.7	103.7	55.5
8.5	9.1	60.7	47.7	12.7	50.6	20.5	101.1	54.7
8.6	3.7	56.4	55.2	6.5	43.1	28.2	103.7	61.6
8.7	13.5	67.9	67.3	8.2	30.9	36.2	114.1	74.7
8.8	7.0	69.6	66.4	8.5	37.2	41.6	118.4	77.4
8.9	2.9	61.7	57.9	2.5	43.0	29.8	105.1	65.7
9.0	4.8	53.8	53.9	11.1	59.9	25.6	101.8	58.5
9.1	15.1	32.9	38.3	23.0	55.1	13.6	71.0	33.6
9.2	16.1	65.1	62.1	10.0	54.7	35.0	114.6	72.6
9.3	11.3	53.0	51.0	6.5	57.3	22.6	101.6	57.2
9.4	6.3	56.9	58.1	7.4	46.4	252.4	111.4	62.6
9.5	6.8	67.0	63.9	5.7	41.4	38.8	116.5	71.8
9.6	23.1	44.0	40.9	22.6	56.4	16.1	87.4	330.1
9.7	4.5	53.3	50.4	12.6	48.5	35.8	105.6	58.0
9.8	7.6	50.8	49.7	16.2	55.8	35.2	104.1	58.1
9.9	22.6	43.6	42.7	20.1	61.1	29.6	93.1	50.8
10.0	14.8	41.4	49.4	21.3	49.3	32.5	99.8	54.2
10.1	15.7	44.0	52.5	20.4	49.0	32.2	100.5	56.8
10.2	18.9	46.5	50.6	24.7	54.2	33.3	102.3	58.1
10.3	21.1	41.8	43.2	26.8	59.3	26.0	99.1	53.8
10.4	20.9	37.9	37.1	29.4	62.2	22.1	91.8	50.2
10.5	34.3	37.5	34.5	28.1	58.8	20.4	82.0	47.2
10.6	7.7	52.0	50.0	13.1	51.0	38.4	101.9	52.4
10.7	8.6	66.7	64.2	4.2	38.2	51.6	114.6	65.6
10.8	7.3	63.9	65.8	3.5	34.4	54.0	114.5	69.9
10.9	19.6	72.5	76.5	13.3	25.9	65.6	135.1	81.5
11.0	20.3	54.0	72.2	16.0	31.1	65.3	135.6	72.2
11.1	6.9	46.0	46.6	11.8	61.9	33.3	110.2	56.5
11.2	3.5	45.9	44.4	10.9	59.7	29.2	107.7	58.7
11.3	8.1	46.6	52.0	9.8	60.3	34.2	113.7	59.2
11.4							109.4	

Table A-3

System Coverage Radial Errors, Fixed Route

Tenth Mile	01	02	03	04	05
0.1	11.1	9.7	7.2	9.3	4.6
0.2	17.6	25.3	20.0	24.9	24.1
0.3	14.1	16.0	9.6	18.8	14.3
0.4	19.5	21.4	15.0	24.7	23.2
0.5	24.9	27.9	20.5	29.9	27.3
0.6	14.4	18.3	19.3	19.3	14.2
0.7	4.2	4.6	9.9	4.6	4.9
0.8	8.0	9.9	9.5	7.4	9.3
0.9	6.9	14.0	17.5	3.8	12.3
1.0	8.0	16.0	18.5	6.8	12.8
1.1	7.9	15.6	19.3	6.6	12.5
1.2	10.8	17.9	21.2	9.7	14.5
1.3	14.3	12.2	15.4	4.9	10.6
1.4	7.3	3.9	5.9	5.7	3.6
1.5	5.5	5.3	11.8	2.1	6.1
1.6	6.8	6.2	12.6	2.2	6.2
1.7	4.1	12.4	19.4	3.6	7.4
1.8	5.9	4.3	10.4	5.4	2.7
1.9	111.1	9.7	10.2	12.5	8.0
2.0	2.6	5.2	7.3	10.2	4.1
2.1	6.2	3.2	6.4	12.9	5.8
2.2	2.5	3.1	3.5	12.4	9.0
2.3	5.4	7.5	11.4	4.0	4.9
2.4	3.0	5.0	4.9	13.6	3.7
2.5	5.6	6.6	10.7	14.5	7.8
2.6	1.8	4.8	10.6	9.6	4.2
2.7	2.8	13.3	12.2	9.3	3.5
2.8	19.3	18.9	27.2	4.2	2.1
2.9	20.8	18.4	26.4	6.7	3.3
3.0	6.5	6.1	10.8	7.7	6.6
3.1	37.3	55.8	59.3	48.6	63.4
3.2	93.3	95.8	97.3	96.3	93.6
3.3	7.0	10.0	26.9	12.4	6.5
3.4	85.2	103.5	72.7	91.9	94.5
3.5	26.9	28.1	65.7	24.1	27.0
3.6	11.6	8.7	59.1	28.5	8.6
3.7	7.6	8.6	54.8	28.8	10.2
3.8	9.0	8.3	47.1	24.1	4.7
3.9	23.0	15.6	18.7	25.9	73.5
4.0	5.5	9.6	26.8	29.7	62.4
4.1	6.3	5.9	24.8	25.8	68.2
4.2	11.3	4.3	31.2	21.6	
4.3	14.0	14.7	30.8	23.2	
4.4	13.4	13.6	25.7	32.8	
4.5	6.0	5.5	28.0	17.5	
4.6	3.5	4.0	25.8	24.5	
4.7	13.8	22.7	8.7	43.2	
4.8	21.0	19.8	29.3	5.3	
4.9	22.1	17.7	45.2	8.0	
5.0	12.5	9.3	32.7	14.0	
5.1	8.2	5.6	25.5	14.3	
5.2	6.3	4.4	24.5	13.2	
5.3	6.5	2.1	25.1	12.9	
5.4	10.6	8.5	31.3	9.2	
5.5	18.1	17.9	10.8	38.4	
5.6	9.9	18.5	18.0	27.9	
5.7	9.5	17.9	37.9	18.3	
5.8	12.1	20.8	44.9	5.3	
5.9	18.6	29.1	55.2	8.0	

Table A-3

System Coverage Radial Errors, Fixed Route

Tenth Mile	01	02	03	04
6.0	3.3	7.6	31.6	24.5
6.1	17.4	27.0	49.7	6.1
6.2	28.9	39.0	65.3	13.0
6.3	24.9	37.1	65.2	17.4
6.4	36.5	49.2	75.6	28.0
6.5	38.1	54.9	83.7	38.1
6.6	36.4	49.8	73.2	23.7
6.7	43.4	57.3	81.0	29.5
6.8	37.9	50.8	75.7	22.4
6.9	36.2	49.3	75.1	21.7
7.0	28.9	40.0	63.0	13.3
7.1	42.0	56.2	78.8	21.2
7.2	12.1	29.2	51.7	10.1
7.3	13.2	26.2	43.0	5.8
7.4	23.6	33.4	51.9	15.9
7.5	29.9	39.9	59.0	20.1
7.6	23.2	33.5	56.1	12.8
7.7	22.4	33.1	55.6	13.5
7.8	20.1	29.4	50.4	11.0
7.9	29.1	35.3	54.1	19.5
8.0	43.2	50.1	67.4	35.0
8.1	19.7	32.0	60.0	13.5
8.2	20.3	33.6	53.6	10.6
8.3	25.7	37.7	54.5	16.3
8.4	27.6	39.0	56.3	16.9
8.5	24.5	36.9	53.8	11.8
8.6	30.6	41.6	58.5	20.5
8.7	40.3	55.9	71.1	31.2
8.8	38.2	55.2	72.4	32.0
8.9	31.8	44.0	63.4	22.0
9.0	27.6	41.4	56.7	15.9
9.1	6.1	23.2	39.9	4.6
9.2	33.9	47.0	63.4	30.1
9.3	21.4	35.4	54.6	16.6
9.4	28.5	39.0	58.6	23.8
9.5	447.8	43.2	68.2	28.9
9.6	12.3	20.9	40.2	13.2
9.7	25.9	35.4	57.4	21.9
9.8	22.5	32.2	55.2	19.2
9.9	10.2	26.3	45.8	6.7
10.0	16.9	25.9	47.3	19.9
10.1	19.2	27.9	49.7	19.8
10.2	21.7	29.2	50.5	18.7
10.3	17.1	22.4	43.9	11.9
10.4	11.1	17.2	39.6	5.2
10.5	8.5	17.5	37.7	5.3
10.6	22.9	28.0	52.8	19.0
10.7	31.8	40.1	66.4	28.1
10.8	42.2	45.9	981.8	32.5
10.9	53.2	55.1	1011.9	40.6
11.0	51.1	51.7	745.3	40.5
11.1	16.8	31.0	54.8	14.0
11.2	17.2	32.8	56.7	12.4
11.3	15.2	31.1	55.8	14.6
11.4			87.1	

Table A-4

Errors in Excess of 300 Feet

Fixed Route

Entry Number	Wheel Distance	Error	Note	Discussion
				Run 101
1	0	579	1	Before start of run
2047	18320	357	2	Art museum
2685	25516	514	3	Signpost just acquired
4942	45099	506	3	Signpost just acquired
				Run 102
1	0	579	1	Before start of run
2103	18325	415	2	Art museum
2749	25053	362	4	Signpost 535 changed to 278
4657	45100	505	3	Signpost just acquired
				Run 103
1	0	575	1	Before start of run
1769	18303	338	2	Art museum
				Run 104
1	0	575	1	Before start of run
2526	18339	338	2	Art Museum
				Run 105
1	0	2172	1	Before start of run
2287	18305	436	2	Art museum
				Run 106
1	0	379	1	Before start of run
2394	18261	307	2	Art museum
3233	25525	505	3	Signpost just acquired
7554	53614	307	5	Signpost 587 acquired from side street at 15th and Race
				Run 107
1	0	575	1	Before start of run
2018	18325	713	2	Art museum
2798	25518	513		Signpost 627 erroneously listed as acquired in System Processor only corrected after one sample

Table A-4 (cont'd)

Errors in Excess of 300 Feet

Entry Number	Wheel Distance	Error	Note	Discussion
				Run 108
1	0	575	1	Before start of run
2185	18292	313	2	Art museum
6515	55702	552	3	Signpost just acquired
6914	58783	1382	4	Signpost 541 changed to 529
				Run 109
1	0	575	1	Before start of run
1891	18286	455	2	Art museum
2467	23679	504	3	Signpost just acquired
				Run 110
1	0	365	1	Before start of run
2104	18295	482	2	Art museum
2294	21035	484	4	Signpost 601 changed to 600
				Run 111
1	0	377	1	Before start of run
2499	18275	330	2	Art museum
4748	38515	2751	4	Signpost 580 changed to 582 for one sample then corrected back to 582
5405	43729	537	3	Signpost just acquired
6824	54120	1493	4	Signpost 522 changed to 525
				Run 112
1	0	575	1	Before start of run
2125	18283	687	2	Art museum
				Run 113
1	0		1	Before start of run
2181	17553	831	4	Signpost 650 changed to 697
6461	55754	499	3	Signpost just acquired
				Run 114
1	0	377	1	Before start of run
2205	18315	624	2	Art museum
				Run 115
1	0	371	1	Before start of run
2292	18312	664	2	Art museum
2739	23616	569	3	Signpost just acquired

Table A-4 (cont'd)

Errors in Excess of 300 Feet

Entry Number	Wheel Distance	Error	Note	Discussion
				Run 116
1	0	373	1	Before start of run
186	1681	3510	4	Signpost 547 changed to 546
2080	18282	359	2	Art museum
				Run 117
1	0	571	1	Before start of run
2012	18301	519	2	Art museum
2774	25467	564	3	Signpost just acquired
2868	26573	2452	4	Signpost 603 changed to 600
				Run 118
1	0	575	1	Before start of run
2343	18313	309	2	Art museum
3178	25975	2380	4	Signpost 627 changed to 626
5604	50626	***		Tape error, overflow
				Run 119
1	0	579	1	Before start of run
1227	10294	4955	4	Signpost 533 changed to 534
2685	18259	345	2	Art museum
3259	23612	573	3	Signpost just acquired
				Run 120
1	0	579	1	Before start of run
477	4395	980	3	Signpost just acquired
2000	18271	469	2	Art museum
2582	23607	578	3	Signpost just acquired
				Run 121
1	0	575	1	Before start of run
1542	18318	622	2	Art museum
				Run 122
1	0	575	1	Before start of run
1829	18320	555	2	Art museum
				Run 123
1	0	575	1	Before start of run
2240	17535	846	4	Signpost 650 changed to 2603 then back to 650
2317	18315	425	2	Art museum
3184	25251	617	4	Signpost 535 changed to overflow then 625
				Run 124
1	0	579	1	Before start of run
1716	18310	494	2	Art museum
1891	20879	2350	4	Signpost 562 changed to 561
4032	45116	489	3	Signpost just acquired

Table A-4 (cont'd)

Errors in Excess of 300 Feet

Entry Number	Wheel Distance	Error	Note	Discussion
				Run 125
1	0	571	1	Before start of run
2003	18306	434	2	Art museum
2784	25550	480	3	Signpost just acquired
5740	60153	675	4	Signpost 599 changed to 591
				Run 126
1	0	575	1	Before start of run
1977	18298	378	2	Art museum
4979	55711	543	3	Signpost just acquired
				Run 127
1	0	***	1	Before start of run
388	1687	5347	4	Signpost 547 changed to 549
2679	18318	423	2	Art museum
3298	23697	486	3	Signpost just acquired
5591	45147	459	3	Signpost just acquired
				Run 128
1	0	575	1	Before start of run
1959	18346	395	2	Art museum
				Run 129
1	0	***	1	Before start of run
1440	9051	1237	4	Signpost 587 changed to 970
2104	18275	395	2	Art museum
				Run 130
1	0	579	1	Before start of run
310				Tape error
1596	18256	348	2	Art museum
				Run 131
1	0	579	1	Before start of run
2520	18289	451	2	Art museum
2704	20883	2342	4	Signpost 562 changed to 561
6584	49755	333	4	Signpost 665 changed to 661
				Run 132
1	0	579	1	Before start of run
2656	18268	336	2	Art museum
3229	23671	513	3	Signpost just acquired
6859	41589	1332	4	Signpost 532 changed to 531

Table A-4 (cont'd)

Errors in Excess of 300 Feet

Entry Number	Wheel Distance	Error	Note	Discussion
				Run 133
1	0	579	1	Before start of run
1960	18363	513	2	Art museum
5192	56720	***	3	Signpost just acquired
				Run 001
1	0	579	1	Before start of run
2296	18337	467	2	Art museum
6176	50685	***	3	Signpost just acquired
				Run 002
1	0	575	1	Before start of run
2171	18316	361	2	Art museum
				Run 003
1	0	579	1	Before start of run
1945	18301	376	2	Art museum
5833	57060	1287	4	Signpost 584 changed to 296
				Run 004
1	0	571	1	Before start of run
2520	18334	406	2	Art museum
				Run 005
1	0	575	1	Before start of run
2730	18320	357	2	Art museum
3663	22538	309		Run terminated 5th wheel lifted

Notes:

1) Residual error before the first signpost on run is encountered.

2) Large systematic error that occurs each pass just after the Art Museum. Errors increase by as much as 1000 feet while vehicle moves only 100 feet. Large error indication does not exceed 125 feet of total travel.

3) Large radial error occurring when a new signpost identification has been acquired. Never exceeds one data sample.

4) Large radial error occurring when a correctly decoded signpost changes to an incorrect identification causing the System Processor to misplace the vehicle on route.

5) Signpost 587 acquired from side street due to poorly selected location. System Processor mislocated while on route.

TABLE A-5

Test Conductor Notes Summary
Fixed Route Runs

Run	Comments
101	No problems
102	No problems
103	This run was prematurely terminated at 12:18 am at the intersection of Race at 10th St. Due to a police barracade blocking Race St. (Chinese New Year Celebration)
104	No problems
105	(1) At the true location of check point #55, Tag ID # 1056 was manually entered on the observer's panel by mistake. Check point #55 was never entered. (2) Tag ID #1166 may have been manually entered to the observer's panel instead of Tag ID # 1164.
106	(1) Tag ID # 1043 was manually entered before passing the Tag at 15th and Walnut St. instead of at 15th and Locust St. where the Tag is actually located. This does not affect L. S. accuracy. (2) Tag ID # 1116 was manually loaded at the true location of check point #43. Check point #43 was loaded late (past the true location by approximately 50 feet) (3) Tag #1113 was read on a cross street at 13th and Race St. while traveling on the inner (parking) lane on Race St.
107	No problems
108	(1) Tag ID #1043 was manually loaded at 15th and Walnut St. before passing the Tag at 15th and Locust St. No problem for L. S. accuracy. (2) Check point #53 was not entered to the observer's panel.
109	No problems

TABLE A-5 (cont'd)

Run	Comments
110	The true location of Check Point #12 was missed. Check point #12 was inadvertantly loaded at the true location of check point #13.
111	(1) Prior to passing the intersection of 13th and Race St. the van stopped and the mounting of Tag #1113 was observed. No action was taken.
	(2) The 5th wheel was "tapped" by a car from behind near the intersection of 17th and Walnut St. No apparent damage.
112	No problems
113	Check point #38 was never entered.
114	No problems.
115	(1) Check point #22 may not have been entered.
	(2) Due to heavy traffic conditions, no stop was made at time point #8.
116	(1) After passing Tag #1043 the on-board display read 1042.
	(2) Heavy traffic on Locust and Walnut Streets. Slow moving.
117	After passing Tag #1133 the on board display read 1130.
118	(1) 5th wheel was "tapped" again at 13th and Walnut St. No apparent damage.
	(2) After passing tag #1163 display read 1162.
	(3) Check point #53 was manually entered at the wrong time. (At the door open before time point #11).
119	(1) After passing tag #1025 the display read 1026.
	(2) Check point #19 was entered at wrong time (prior to passing time point #3.
	(3) Run was prematurely terminated at Locust and 8th St. Police barricade blocking Locust St. Large crane in place near St. James and Washington Square completely blocking road. Will be removed by 4 PM this day.

TABLE A-5 (cont'd)

Run	Comments
120	Check point #13 may have been missed or entered as Check Point #12.
121	No problems.
122	(1) Due to heavy traffic, no stop was made at Time point #13. (2) Check point #29 was never entered. The tape for this run was labeled Fixed 123.
123	No problems.
124	No problems.
125	No problems.
126	Check point #27 was not entered.
127	(1) After passing tag #1043, the on-board display read 1045. (2) Check point #9 was not entered. (3) Due to heavy traffic conditions, no stop was made at time point #10.
128	No problems.
129	No problems.
130	No problems.
131	Tag ID 31064 was manually loaded at the true location of check point #29. Check point #29 was never entered.
132	Due to heavy traffic conditions, no stops were made at time points #13, #5 or #11.
133	Time point #13 (Tag ID 1071) was never manually entered.

Table A-5 (cont'd)

Comments

Run 01

1) Checkpoint #12 entered prematurely
2) Timepoint switch not depressed at time point 7
3) Checkpoint #32 not entered

Run 02

None.

Run 03

1) Checkpoint #19 not entered

Run 04

1) Tag number not entered at time point #13
2) Checkpoint #4 not entered

Run 05

1) Run aborted after checkpoint 22.

TABLE A-6

SYSTEM LEVEL RADIAL ERROR SUMMARY

FIXED ROUTE

RUN	10	20	30	40	50	60	70	80	90	100	110	120	130	300	450	>450
101	72	42	23	6	0	0				1	1	1	1		2	
102	62	47	21	6	1				1	1				1	1	2
103	16	16	11	7	9	7	16	23	87	54	9	0	1		4	3
104	77	54	36	5	4	0	0	1						4		2
105	33	23	15	7	10	27	35	13	2	6	1			2		4
106	52	28	33	31	16	22	3	2	1	1		1		1	3	3
107	20	35	10	39	22	15	2	3	2	0			1	1	1	2
108	59	47	18	21	4	3	2		2	1					1	3
109	37	44	20	10	6	1			1				2	3	2	4
110	24	36	34	19	112	22	3	1	2	2	1	1	0	1	3	1
111	44	32	36	37	17	5	3	0	1					1	2	3
112	53	48	17	18	9	3	1	3	0	1	0	1	1	2	1	1
113	29	22	21	36	27	11	9	0	2	0	0	0		1	0	2
114	30	22	16	15	22	22	21	6	0	1	0	0	1	2	1	2
115	26	22	20	23	20	23	11	2	1	0	1	0	1	4	0	1
116	76	64	23	5	3	1							1	3	1	8
117	18	26	18	26	37	66	41	21	8	0	1			1	0	3
118	41	21	24	25	22	8	8	2						3	2	1
119	31	16	11	5	16	8	12	8	3	2	2			0	1	8
120	26	21	22	20	21	17	11	6	2	2	1	0	1	2	1	5
121	47	35	18	6	13	8	3				1	1		1	0	1
122	51	38	20	10	3	1	1				1			2	2	3
123	39	31	28	29	16	11	5	1						1	3	3
124	25	30	25	13	10	6	2	2		1			1	4	3	3
125	22	16	27	21	10	5	1							1	1	8
126	67	26	66	73	4	1	1			1				4	0	5
127	16	30	23	16	24	23	26	7	5			1		4	0	12
128	28	24	14	11	21	19	9	9	5	1		1		2	1	3
129	51	26	21	10	8	7	5	1	1	3				4	1	4
130	19	13	7	11	16	23	17	9	2	4				5	1	2
131	34	46	26	41	11	10	6	3	1	1				3	1	2
132	42	31	13	8	10	7	6	7	11	15	32	6	4	2		3
133	12	17	18	16	29	26	12	7	2	0	1			2		3
01	14	27	15	22	82	49	12	10	6	0	2	1		5		4
02	43	28	29	22	14	12	4	1	1					4		1
03	51	35	34	21	9	3	1			1	1			3	3	3
04	55	59	37	18	6	2	0	1	0	0	1			2	2	2
05	44	14	6	1	0	2	1	3	7					1	2	2
		1992		710		476		152		99		14		82		122
TOTAL	1486		841		664		290		156		56		15		46	

TOTAL SAMPLES - 7200

99.5% ERRORS < 2718'

95% ERRORS < 97.37'

Run No. 101 Table A7 - Time Point Passage Time

Time Point Number	L. S. Recorded Sign Post	Manual Sign Post	Auto T. P. Flag	Man. T. P. Flag	Error (Seconds)
1	19:21:59.3	19:22:01.3	19:21:59.3	—	2.0
2	19:24:01.1	19:27:01.6	19:26:29.2 E	19:27:01.6	.5
3	19:31:25.3	19:31:25.8	Set	19:31:25.3	.5
4	19:36:33.6	19:36:33.6	19:36:33.6	19:36:33.6	0
5	19:40:03.5	19:40:05.0	19:40:03.5	19:40:03.5	0
6	19:43:48.2	19:43:48.2	Set	19:43:47.7	0
7	19:47:58.6	19:47:58.6	19:47:58.6	19:44:58.1	.5
8	19:53:07.8	19:53:07.8	19:53:07.8	—	0
9	20:01:11.3	20:01:11.3	Set	20:01:11.3	
10	20:04:08.0	20:04:08.0	Set	20:04:08.0	0
11	20:10:17.1	20:10:17.6	20:10:17.1	20:10:17.1	0
12	20:18:03.8	20:18:03.8	20:18:03.8	20:18:03.8	0
13	20:14:00.8	20:14:00.8	Set	20:14:00.8	0
14	19:16:10.2	19:16:10.7	19:16:10.2	19:16:10.2	0

Run No. 102

Time Point Number	L. S. Recorded Sign Post	Manual Sign Post	Auto T. P. Flag	Man. T. P. Flag	Error (Seconds)
1	22:24:57.3	22:24:57.8	22:24:57.3	22:24:57.3	0
2	22:30:14.2	22:30:14.2	Set	22:30:13.7	.5
3	22:34:41.3	22:34:41.3	22:34:41.3	22:34:41.3	0
4	22:39:39.9	22:39:40.4	22:39:39.9	22:34:39.9	0
5	22:43:44.6	22:43:45.1	22:43:44.5	22:43:44.6	0
6	22:48:01.2	22:48:01.2	22:48:01.2	22:48:01.2	0
7	22:51:18.1	22:51:18.6	22:51:18.1	22:51:18.1	0
8	22:55:21.7	22:55:22.2	22:55:21.7	22:55:21.7	0
9	23:01:08.4	23:01:08.4	23:01:08.4	23:01:08.4	0
10	23:03:53.4	23:03:53.4	Set	23:03:53.4	0
11	23:10:13.5	23:10:14.0	23:10:13.5	23:10:13.5	0
12	23:17:50.2	23:14:52.3	23:17:50.2	23:17:50.7	.5
13	23:13:53.5	23:13:54.0	Set	23:13:535	.0
14	22:19:00.7	22:19:01.3	Set	22:19:00.3	.5

Run No. 103

Time Point Number	L. S. Recorded Sign Post	Manual Sign Post	Auto T. P. Flag	Man. T. P. Flag	Error (Seconds)
1	23:31:54.3	23:31:54.8	23:31:54.3	23:31:54.3	0
2	23:36:10.7	23:36:10.7	23:36:09.7 E	23:36:10.4	0
3	23:40:30.3	23:40:30.3	23:40:30.3	23:40:29.8	.5
4	23:45:06.1	23:45:06.6	23:44:57.2 E	23:45:06.1	.0
5	23:50:54.6	23:50:54.6	Set	23:50:54.6	0
6	23:54:32.2	23:54:32.2	Set	23:54:31.7	.5
7	23:59:02.9	23:59:02.9	Set	23:59:02.9	0
8	00:03:02.3	00!03:02.8	00:03:02.3	00:03:02.3	0
9	00:08:06.5	00:08:06.5	00:08:06.5	00:08:06.5	0
10	00:09:49.6	00:09:49.6	Set	00:09:49.6	
11	00:15:17.0	00:15:17.0	Set	00:15:17.0	0
12	—	—	—	—	—
13	—	—	—	—	—
14	23:27:03.3	23:24:03.8	Set	23:24:03.3	0

Table A7(Cont'd)

Run No. 104

Time Point Number	L. S. Recorded Sign Post	Manual Sign Post	Auto T. P. Flag	Man. T. P. Flag	Error (Seconds)
1	10:59:03.2	10:59:03.7	10:54:03.2	10:59:03.2	0
2	11:07:19.6	11:07:20.1	11:07:01.2 E	11:07:20.1	.5
3	11:11:30.0	11:11:30.0	11:11:30.0	11:11:30.0	0
4	11:17:10.7	11:17:10.7	11:17:10.7	11:17:10.7	9
5	11:21:44.7	11:21:44.7	11:21:44.7	11:21:44.7	0
6	11:25:49.8	11:25:50.3	11:25:40.8	11:25:49.8	0
7	11:30:12.8	11:13:14.4	Set	11:30:12.8	0
8	11:35:06.8	11:35:07.3	11:35:06.8	11:25:06.8	0
9	11:42:26.7	11:42:26.7	11:42:26.7	11:42:26.7	0
10	11:46:02.1	11:46:02.6	Set	11:46:02.1	0
11	11:57:18.4	11:57:18.4	Set	11:57:18.4	0
12	12:08:01.0	12:08:02.6	12:08:01.0	12:08:02.6	1.5
13	12:03:54.8	12:03:54.8	Set	12:03:54.3	.5
14	12:53:03.2	10:53:03.2	10:53:03.2	10:53:03.2	0

Run No. 105

Time Point Number	L. S. Recorded Sign Post	Manual Sign Post	Auto T. P. Flag	Man. T. P. Flag	Error (Seconds)
1	12:25:56.6	12:25:56.6	12:25:56.6	12:25:56.6	0
2	12:32:57.1	12:32:57.6	Set	12:32:57.1	0
3	12:37:25.0	12:37:25.0	12:37:25.0	12:37:24.5	.5
4	12:42:20.8	12:42:20.8	12:42:20.3	12:42:20.3	0
5	12:47:44.9	12:47:45.4	Set	12:47:45.4	.5
6	12:51:09.9	12:51:10.4	12:51:09.9	12:51:09.9	0
7	12:55:08.2	12:55:08.7	12:55:08.2	12:55:08.2	0
8	13:01:05.1	13:01:05.1	13:01:05.1	13:01:05.1	0
9	13:07:11.5	13:07:11.5	13:07:11.5	13:07:11.0	.5
10	12:11:10.3	13:11:10.8	Set	13:11:10.3	0
11	13:24:10.2	13:24:10.7	13:24:10.2	13:24:10.2	0
12	13:33:52.3	13:33:52.8	Set	13:33:52.3	0
13	13:28:55.2	13:28:55.7	Set	—	.5
14	12:20:05.5	12:20:06.0	12:20:05.5	12:20:05.5	0

Run No. 106

Time Point Number	L. S. Recorded Sign Post	Manual Sign Post	Auto T. P. Flag	Man. T. P. Flag	Error (Seconds)
1	16:23:53.3	16L23:53.8	16:23:53.3	16:23:53.3	0
2	16:30:54.6	16:30:55.1	16:30:27.2 E	16:30:54.6	0
3	16:35:38.9	16:35:38.9	Set	16:35:38.9	0
4	16:41:08.9	16:41:08.9	16:40:56.4	16:41:08.4	.5
5	16:45:53.4	16:45:53.9	16:45:53.4	16:45:53.4	0
6	16:50:54.6	16:50:55.1	16:50:54.6	16:50:54.6	0
7	16:55:04.2	16:55:04.2	16:55:09.2	16:55:07.7	1.5
8	17:08:05.0	17:08:06.5	Set	17:08:05.0	0
9	17:13:59.8	17:13:59.8	17:13:59.8	17:13:59.8	0
10	17:17:07.8	17:17:07.8	Set	17:17:07.8	0
11	17:27:06.6	17:27:07.1	17:27:06.6	17:27:06.6	0
12	17:38:55.5	17:38:56.5	17:38:55.5	17:38:56.0	.5
13	17:33:47.9	17:33:48.4	Set	17:33:48.4	.5
14	16:17:07.8	16:17:07.8	Set	16:17:07.8	0

Table A7 (Cont'd)

Run No. 107

Time Point Number	L. S. Recorded Sign Post	Manual Sign Post	Auto T. P. Flag	Man. T. P. Flag	Error (Seconds)
1	18:07:47.6	18:07:47.6	18:07:47.6	—	0
2	18:13:06.1	18:13:06.6	18:13:05.6	18:13:06.1	.5
3	18:16:17.8	18:16:18.3	18:16:17.8	18:16:17.8	0
4	18:21:26.0	18:21:26.5	Set	18:21:26.5	.5
5	18:26:35.5	18:26:36.0	18:26:36.0	18:26:35.5	.5
6	18:29:25.8	18:29:25.8	18:29:25.8	18:29:25.8	0
7	18:32:51.3	18:32:51.3	18:32:51.3	18:32:51.3	0
8	18:37:59.2	18:37:59.2	18:37:59.2	18:37:58.7	.5
9	18:42:23.3	18:42:23.8	Set	18:42:23.3	0
10	18:50:03.1	18:50:03.1	Set	18:50:03.1	0
11	18:56:11.3	18:56:11.8	18:56:11.3	18:56:11.3	0
12	19:05:21.3	19:05:21.3	19:05:21.3	19:05:20.8	.5
13	19:00:49.1	19:00:49.6	Set	19:00:49.1	0
14	18:01:58.8	18:01:58.8	18:01:58.8	18:01:58.8	0

Run No. 108

Time Point Number	L. S. Recorded Sign Post	Manual Sign Post	Auto T. P. Flag	Man. T. P. Flag	Error (Seconds)
1	19:19:46.9	19:19:47.4	—	19:19:46.9	0
2	19:24:09.3	19:24:09.8	19:24:08.8	19:24:09.3	.5
3	19:28:19.0	19:28:19.0	19:28:19.0	19:28:19.0	0
4	19:34:56.4	19:34:56.9	19:34:56.4	19:34:56.9	.5
5	19:39:38.5	19:39:39.0	Set	19:39:38.5	0
6	19:43:40.5	19:43:40.5	19:43:40.5	19:43:40.5	0
7	19:47:09.7	19:47:09.7	19:47:09.7	19:47:08.2	1.5
8	19:52:59.3	19:52:59.3	19:52:59.3	19:52:58.8	1.5
9	20:00:01.0	20:00:01.1	20:00:01.0	20:00:01.0	0
10	20:02:58.5	20:02:58.5	Set	20:02:55.5	0
11	20:10:23.5	20:10:23.5	20:10:23.5	20:10:23.5	0
12	20:19:43.2	20:19:43.7	20:19:43.2	20:19:43.2	0
13	20:15:48.2	20:15:48.7	Set	20:15:48.2	0
14	19:14:02.6	19:14:03.1	19:14:02.6	19:14:02.6	0

Run No. 109

Time Point Number	L. S. Recorded Sign Post	Manual Sign Post	Auto T. P. Flag	Man. T. P. Flag	Error (Seconds)
1	20:48:46.3	20:46:46.8	20:46:46.3	20:46:46.3	0
2	20:51:56.6	20:51:56.6	Set	20:51:56.1	.5
3	20:55:21.1	20:55:21.1	20:51:21.1	20:51:21.1	0
4	21:00:01.7	21:00:01.7	21:00:00.7	21:00:01.7	1
5	21:04:44.6	21:04:44.6	21:04:44.6	21:04:44.6	0
6	21:07:36.7	21:07:36.7	21:07:36.7	21:07:36.7	0
7	21:10:56.9	21:10:56.9	21:10:56.9	—	0
8	21:14:58.8	21:14:58.8	21:14:58.8	—	0
9	21:20:00.4	21:20:00.8	Set	21:20:00.8	0
10	21:21:53.2	21:21:53.2	Set	21:21:53.2	0
11	21:27:23.3	21:27:27.8	21:27:23.3	21:27:23.3	0
12	21:34:45.1	21:34:45.1	21:34:45.1	21:34:45.1	0
13	21:30:49.4	21:30:49.4	Set	—	0
14	20:41:52.4	20:41:52.9	20:41:52.4	20:41:52.9	.5

Table A7 (Cont'd)

Run No. 110

Time Point Number	L. S. Recorded Sign Post	Manual Sign Post	Auto T. P. Flag	Man. T. P. Flag	Error (Seconds)
1	23:09:45.0	23:09:45.5	23:09:45.0	23:09:45.0	0
2	23:15:53.1	23:15:53.1	Set	23:15:52.6	.5
3	23:15:24.2	23:15:24.2	Set	23:19:23.7	.5
4	23:23:34.8	23:23:35.3	23:23:34.3	23:23:34.8	.5
5	23:28:36.3	23:28:36.8	23:28:36.3	23:28:36.3	.5
6	23:31:56.0	23:31:57.5	23:31:56.0	23:31:56.0	.5
7	23:36:11.4	23:36:11.9	23:36:11.4	23:36:11.4	.5
8	23:39:58.1	23:39:58.6	Set	23:37:58.1	0
9	23:45:59.4	23:45:59.4	23:45:59.4	23:45:59.4	.5
10	23:50:57.9	23:50:58.4	Set	23:50:57.9	0
11	23:57:8.3	23:57:8.8	Set	23:57:8.3	0
12	00:05:44.9	00:05:45.4	Set	00:05:44.9	0
13	00:01:48.1	00:01:48.6	00:01:14.8 E	00:01:48.1	
14	23:03:00.8	23:03:00.8	23:03:00.8	23:03:00.8	0

Run No. 111

Time Point Number	L. S. Recorded Sign Post	Manual Sign Post	Auto T. P. Flag	Man. T. P. Flag	Error (Seconds)
1	10:38:50.4	10:38:50.4	10:38:50.4	10:38:50.4	0
2	10:46:56.5	10:46:56.5	10:46:55.0 E	10:46:56.5	0
3	10:50:27.7	10:50:27.7	10:50:27.7	10:50:27.7	0
4	10:55:29.3	10:55:29.8	10:55:29.3	10:55:29.8	.5
5	11:00:32.9	11:00:33.4	11:00:32.9	11:00:32.9	0
6	11:03:12.6	11:03:13.1	11:03:12.6	11:03:12.6	0
7	11:07:05.8	11:07:06.3	11:07:05.8	11:07:05.8	0
8	11: 15:59.9	11:15:59.9	11:15:59.9	11:15:59.4	.5
9	11:21:06.6	11:21:06.6	11:21:06.6	11:21:06.6	0
10	11:24:50.8	11:24:51.3	Set	11:24:50.8	0
11	11:33:17.1	11:33:17.6	Set	11:33:17.1	0
12	11:45:47.8	11:45:47.8	Set	11:45:47.8	0
13	11:39:48.3	11:34:48.8	Set	11:39:48.3	0
14	10:31:02.4	10:31:02.9	Set	10:31:02.9	.5

Run No. 112

Time Point Number	L. S. Recorded Sign Post	Manual Sign Post	Auto T. P. Flag	Man. T. P. Flag	Error (Seconds)
1	13:38:51.1	13:38:51.6	13:38:51.1	13:38:51.1	0
2	13:44:51.8	13:44:51.8	13:44:14.5 E	13:44:51.8	0
3	13:47:20.4	13:49:20.4	13:49:20.4	13:49:20.4	0
4	13:55:01.6	13:55:01.6	Set	—	0
5	13:59:45.5	13:59:45.5	13:59:45.9	13:59:45.9	0
6	14:03:10.9	14:03:11.4	14:03:10.9	14:03:10.9	0
7	14:07:02.3	14:07:02.8	14:07:02.3	14:07:02.3	0
8	14:12:02.5	14:12:02.5	14:12:02.5	—	0
9	14:18:58.1	14:18:58.1	14:18:58.1	14:78:58.1	0
10	14:22:02.3	14:22:02.3	Set	14:22:02.3	0
11	14:29:21.8	14:29:22.3	14:29:21.8	14:29:21.8	0
12	14:39:50.5	14:39:51.5	14:39:50.5	14:39:51.0	.5
13	14:34:48.7	14:34:51.3	Set	14:34:51.3	2.5
14	13: 33:48.9	13:33:48.9	13:33:48.9	13:33:48.9	0

Table A7 (Cont'd)

Run No. 113

Time Point Number	L. S. Recorded Sign Post	Manual Sign Post	Auto T. P. Flag	Man. T. P. Flag	Error (Seconds)
1	15:32:43.6	15:32:45.1	15:32:43.6	15:32:43.6	0
2	15:37:49.0	15:37:49.0	15:37:24.5E	15:37:49.0	0
3	15:41:13.2	15:41:13.2	15:41:13.2	15:41:13.2	0
4	15:46:57.2	15:46:57.2	Set	15:46:56.7	.5
5	15:51:31.4	15:51:31.4	15:51:31.4	15:51:31.4	0
6	15:54:20.7	15:54:20.7	15:54:20.7	15:54:20.7	0
7	15:57:59.2	15:57:59.2	Set	15:57:59.2	0
8	16:01:54.5	16:01:55.0	16:01:54.5	16:01:54.5	0
9	16:08:08.5	16:08:08.5	16:08:08.5	16:08:08.5	0
10	16:11:44.1	16:11:44.1	Set	16:11:44.1	0
11	16:22:03.3	16:22:04.9	16:22:03.3	—	1.5
12	16:30:43.4	16:30:43.9	16:30:43.4	16:30:43.4	0
13	16:26:42.8	16:26:43.3	16:26:10.1 E	—	.5
14	15:25:55.8	15:25:55.8	—	15:25:55.3	.5

Run No. 114

Time Point Number	L. S. Recorded Sign Post	Manual Sign Post	Auto T. P. Flag	Man. T. P. Flag	Error (Seconds)
1	18:59:48.6	18:59:48.6	18:59:48.6	18:39:48.6	0
2	19:04:57.9	19:04:57.9	19:04:56.9	19:04:57.9	1
3	19:08:16.8	19:08:17.3	19:08:16.8	19:08:16.8	0
4	19:13:25.4	19:13:25.9	19:13:25.4	19:13:25.4	0
5	19:18:25.8	19:18:25.8	19:18:25.8	19:18:25.8	0
6	19:20:55.9	19:20:55.9	19:20:55.9	19:20:55.9	0
7	19:24:46.1	19:24:46.1	Set	19:24:46.1	0
8	19:30:08.3	19:30:08.3	19:30:08.3	—	0
9	19:35:58.1	19:35:58.1	19:35:58.1	19:35:57.6	.5
10	19:34:43.7	19:39:43.7	Set	—	0
11	19:46:58.2	19:46:58.7	19:46:58.2	19:46:58.2	0
12	19:57:35.9	19:57:36.4	19:57:36.9	19:57:35.9	0
13	19:52:42.7	19:52:42.7	19:52:10.4 E	14:52:42.7	0
14	18:52:50.6	18:52:50.6	Set	18:52:50.8	0

Run No. 115

Time Point Number	L. S. Recorded Sign Post	Manual Sign Post	Auto T. P. Flag	Man. T. P. Flag	Error (Seconds)
1	20:28:39.8	20:28:39.8	20:28:39.8	20:28:29.8	0
2	20:32:50.8	20:32:50.8	20:32:19.3 E	20:32:50.8	0
3	20:37:10.2	20:37:10.7	20:37 10.2	20:37:10.2	0
4	20:42:00.8	20:42:01.3	20:41:54.3 E	20:42:01.3	.5
5	20:45:42.6	20:45:42.6	20:45:42.6	20:45:42.6	0
6	20:49:42.1	20:49:42.1	Set	20:49:42.1	0
7	20:53:56.8	20:53:57.3	Set	20:53:56.8	0
8	20:59:04.6	20:59:04.6	20:59:04.6	20:59:04.6	0
9	21:04:55.0	21:04:55.0	21:04:55.0	21:04:55.0	0
10	21:07:38.6	21:07:38.6	Set	21:07:38.6	0
11	21:14:13.7	21:14:14.2	Set	21:14:13.7	0
12	21:33:38.8	21:33:38.8	Set	21:33:38.8	0
13	21:19:39.8	21:19:39.8	Set	21:19:39.8	0
14	20:20:50.7	20:20:50.7	Set	20:20:50.7	0

Table A-7 (contd)
Time Point Passage Times

Run 116

Time Point Number	L. S. Recorded Sign Post	Manual Sign Post	Auto T. P. Flag	Man. T. P. Flag	Error (Seconds)
1	21:59:41.1	21:59:41.1	21:59:41.1		0
2	22:04:45.3	22:04:45.8	22:04:43.4 Est	22:04:45.3	0
3	22:08:16.9	22:08:16.9	22:08:16.9	22:08:16.4	.5
4	22:14:24.7	22:14:25.2	22:14:24.7	22:14:24.7	4
5	22:20:26.5	22:20:26.5	22:20:26.5	22:20:26.5	0
6	22:24:52.1	22:24:52.1	22:24:52.1	22:24:52.1	0
7	22:28:44.3	22:28:44.3	SET	22:28:44.3	0
8	22:35:03.9	22:35:05.4	SET	22:35:05.4	1.5
9	22:45:54.5	22:45:55.0	22:45:54.5	22:45:55.0	.5
10	22:52:51.2	22:52:51.2	SET	-	0
11	22:02:01.7	22:02:01.7	22:02:01.7	-	0
12	23:10:39.0	23:10:39.0	23:10:39.0	23:10:39.0	0
13	26:06:43.9	23:06:43.9	23:06:07.4 Est	23:06:43.9	0
14	21:53:47.6	21:53:48.1	SET	21:53:47.6	0

Run 117

Time Point Number	L. S. Recorded Sign Post	Manual Sign Post	Auto T. P. Flag	Man. T. P. Flag	Error (Seconds)
1	23:44:44.6	23:44:44.6	23:44:44.6	-	0
2	23:50:51.5	23:50:52.0	23:50:50.5 Est	23:50:52.0	.5
3	23:55:08.3	23:55:08.3	23:55:08.3	23:55:08.3	0
4	23:59:16.4	23:59:16.9	23:59:16.4	23:59:16.9	.5
5	00:04:23.2	00:04:23.2	00:04:23.2	00:04:23.2	0
6	00:07:32.8	00:07:32.8	00:07:32.8	00:07:32.8	0
7	00:10:51.4	00:10:56.9	00:10:57.4	00:10:56.9	.5
8	00:15:57.0	00:15:57.0	SET	00:15:57.0	0
9	00:21:17.0	00:21:17.0	00:21:17.0	00:21:15.5	1.5
10	00:25:39.1	00:25:39.1	00:25:39.1	00:25:39.1	0
11	00:31:13:6	00:31:14.1	SET	00:31:13.6	0
12	00:38:35.1	00:38:35.1	00:38:35.1	00:38:35.1	0
13	00:34:39.4	00:34:39.4	00:34:15.8 Est	00:34:39.4	0
14	23:39:46.4	23:39:46.9	23:39:46.4	23:39:46.9	.5

Run 118

Time Point Number	L. S. Recorded Sign Post	Manual Sign Post	Auto T. P. Flag	Man. T. P. Flag	Error (Seconds)
1	01:18:40.7	01:18:40.7	-	01:18:40.7	0
2	01:27:48.0	01:27:48.0	01:27:41.5 Est	01:27:48.0	0
3	01:31:14.7	01:31:14.7	SET	01:31:14.7	0
4	01:36:13.0	01:36:13.5	01:36:13.0	01:36:13.5	.5
5	01:40:50.6	01:40:51.1	01:40:50.6	01:40:50.6	0
6	01:44:08.9	01:44:08.9	SET	01:44:08.9	0
7	01:48:53.5	01:48:53.5	01:48:53.5	01:48:53.5	0
8	01:52:48.8	01:52:48.8	SET	01:52:48.8	0
9	01:58:54.4	01:58:54.9	SET	01:58:54.4	0
10	02:01:39.4	02:01:39.4	SET	02:01:39.4	0
11	02:08:57.2	02:08:57.2	02:08:57.2	02:08:57.2	0
12	02:18:37.2	02:18:38.2	02:18:37.2	02:18:38.2	1.
13	02:14:39.0	02:14:39.0	02:14:11.8 Est	02:14:39.0	0
14	01:12:56.9	01:12:56.9	01:12:56.9	01:12:56.9	0

Table A-7 (contd)
Time Point Passage Times

Run 119

Time Point Number	L. S. Recorded Sign Post	Manual Sign Post	Auto T. P. Flag	Man. T. P. Flag	Error (Seconds)
1	12:31:57.4	12:31:57.4	12:31:57.4	12:31:57.4	0
2	12:37:03.3	12:37:03.3	12:37:03.3	12:37:03.3	0
3	12:46:47.9	12:46:47.9	SET	12:46:47.9	0
4	12:52:32.0	12:52:32.5	12:52:32.0	12:52:32.0	0
5	12:58:47.1	12:58:47.6	12:58:47.1	12:58:47.6	.5
6	13:02:41.1	13:02:41.6	13:02:41.1	13:02:41.1	0
7	13:07:56.3	13:07:56.3	13:07:56.3	13:07:56.3	0
8	13:13:02.0	13:13:02.5	13:13:02.5	13:13:02.5	0
9					
10					
11					
12					
13					
14	12:26:14:5	12:26:14.5	12:26:14.5	12:26:14.5	0

Run 120

Time Point Number	L. S. Recorded Sign Post	Manual Sign Post	Auto T. P. Flag	Man. T. P. Flag	Error (Seconds)
1	16:45:54.7	16:45:54.7	16:45:54.7	16:45:54.7	0
2	16:51:56.4	16:51:56.4	16:51:20.1 Est	16:51:20.1 Est	0
3	16:55:30.2	16:55:30.2	16:55:30.2	16:55:30.2	0
4	17:01:53.8	17:01:53.6	SET	17:01:53.6	.5
5	17:06:34.9	17:06:34.9	17:06:34.9	17:06:34.4	.5
6	17:09:56.5	17:09:56.5	17:09:56.5	17:09:56.5	0
7	17:14:04.8	17:14:04.8	17:14:04.8	17:14:04.8	0
8	17:20:03.4	17:20:03.4	SET	17:20:03.4	0
9	17:26:04.7	17:26:04.7	17:26:04.7	17:26:04.2	.5
10	17:28:50.7	17:28:50.7	SET	17:28:50.7	0
11	17:38:07.4	17:38:07.4	17:38:07.4	17:38:07.4	0
12	17:46:48.5	17:46:49.0	17:46:48.5	17:46:48.5	0
13	17:42:49.8	17:42:49.8	17:42:15.0 Est	17:42:49.3	.5
14	16:41:06.4	16:41:06.9	16:41:06.4	16:41:06.4	0

Run 121

Time Point Number	L. S. Recorded Sign Post	Manual Sign Post	Auto T. P. Flag	Man. T. P. Flag	Error (Seconds)
1	18:11:52.1	18:11:52.1	18:11:52.1	18:11:52.1	0
2	18:15:58.0	18:15:58.0	18:15:36.5 Est	18:15:58.0	0
3	18:19:23.2	18:19:23.2	18:19:23.2	18:19:23.2	0
4	18:22:40.5	18:22:41.0	18:22:40.5	18:22:41.0	.5
5	18:27:39.1	18:27:39.1	18:27:39.1	18:27:39.1	0
6	18:30:44.1	18:30:44.1	SET	18:30:44.1	0
7	18:35:18.5	18:35:18.5	18:35:18.5	18:35:18.5	0
8	18:41:01.5	18:41:01.5	18:41:01.5	18:41:01.5	0
9	18:46:04.7	18:46:04.7	18:46:04.7	18:46:04.7	0
10	18:48:07:2	18:48:07.2	SET	18:48:07.2	0
11	18:54:08.6	18:54:08.6	18:54:08.6	18:54:08.6	0
12	19:01:49.6	19:01:51.2	19:01:49.6	19:01:51.2	1.5
13	18:57:52.6	18:57:52.6	18:57:14.9 Est	18:57:52.6	0
14	18:06:59.6	18:06:59.6	18:06:59.6	18:06:59.6	0

Table A-7 (contd)
Time Point Passage Times

Run 122

Time Point Number	L. S. Recorded Sign Post	Manual Sign Post	Auto T. P. Flag	Man. T. P. Flag	Error (Seconds)
1	19:46:53.2	19:46:53.2	19:46:53.2	19:46:53.2	0
2	19:51:00.5	19:51:00.5	19:50:59.0 Est	-	0
3	19:54:45.0	19:54:45.0	19:54:45.0	19:54:45.0	0
4	19:59:24.1	19:59:24.6	19:59:24.1	19:59:24.1	0
5	20:04:36.6	20:04:36.6	20:04:36.6	20:04:36.6	0
6	20:07:15.0	20:07:15.0	20:07:15.0	20:07:15.0	0
7	20:11:07.7	20:11:07.7	20:11:07.7	20:11:07.2	.5
8	20:16:05.5	20:16:05.5	20:16:05.5	20:16:05.5	0
9	20:20:05.7	20:20:05.7	SET	20:20:05.2	.5
10	20:21:50:4	20:21:50.4	SET	20:21:49.9	.5
11	20:28:09.5	20:28:09.5	20:28:09.5	20:28:09.5	0
12	20:35:48.3	20:35:48.3	20:35:48.3	20:35:48.3	0
13	20:31:52.3	20:31:52.3	20:31:15.4 Est	20:31:52:3	0
14	19:41:15.8	19:41:16.3	19:41:15.8	19:41:16.3	.5

Run 123

Time Point Number	L. S. Recorded Sign Post	Manual Sign Post	Auto T. P. Flag	Man. T. P. Flag	Error (Seconds)
1	11:17:56.9	11:17:56.9	11:17:56.9	11:17:56.9	0
2	11:24:52.5	11:24:53.0	11:24:19.2 Est	11:24:52.5	0
3	11:29:19.5	11:29:19.5	SET	11:29:19.5	0
4	11:35:30.8	11:35:20.8	11:35:20.3	11:35:20.3	0
5	11:40:40.7	11:40:41.2	11:40:40.7	11:40:41.2	.5
6	11:44:03.5	11:44:05.0	11:44:03.5	11:44:03.5	0
7	11:47:09.3	11:47:09.3	11:47:09.3	11:47:08.8	.5
8	11:52:02.9	11:52:02.9	11:52:02.9	11:52:02.9	0
9	11:58:00.6	11:58:00.6	11:58:00.6	11:58:00.6	0
10	12:03:03.6	12:03:03.6	SET	12:03:03.1	.5
11	12:10:08.2	12:10:08.2	12:10:08.2	12:10:08.2	0
12	12:21:41.5	12:21:42.0	12:21:41.5	12:21:41.5	0
13	12:16:56.0	12:16:51.5	SET	12:16:51.5	.5
14	11:12:06.0	11:12:06.0	11:12:06.0	11:12:06.0	0

Run 124

Time Point Number	L. S. Recorded Sign Post	Manual Sign Post	Auto T. P. Flag	Man. T. P. Flag	Error (Seconds)
1	22:52:53.0	22:52:53.0	22:52:53.0	22:52:53.0	0
2	22:56:56.7	22:56:57.2	22:56:44.3 Est	22:56:56.7	0
3	22:59:24.7	22:59:25.2	SET	22:59:24.7	0
4	23:03:47.3	23:03:47.8	23:03:47.3	23:03:47.3	0
5	23:07:36.7	23:07:37.2	23:07:36.7	23:07:36.7	0
6	23:10:03.6	23:10:03.6	23:09:48.2 Est	23:10:03.6	0
7	23:14:09.3	23:14:09.3	23:14:09.3	23:14:09.3	0
8	23:18:04.9	23:18:05.4	23:18:04.9	23:18:04.9	0
9	23:23:05.4	23:23:05.4	23:23:05.4	23:23:05.4	0
10	23:24:48.0	23:24:48.0	SET	23:24:48.0	0
11	23:30:08.7	23:30:09.2	23:30:08.7	23:30:08.7	0
12	23:37:44.4	23:37:45.7	23:37:44.4	23:37:45.7	.5
13	23:33:51.4	23:33:51.4	23:33:15.3 Est	23:33:51.4	0
14	22:46:56.5	22:46:56.5	22:46:56.5	22:46:56.5	0

Table A7 (contd)
Time Point Passage Times

Run 125

Time Point Number	L. S. Recorded Sign Post	Manual Sign Post	Auto T. P. Flag	Man. T. P. Flag	Error (Seconds)
1	01:05:52.6	01:05:52.1	01:05:52.1	01:05:52.6	.5
2	01:09:59.4	01:09:59.4	01:09:48.0 Est	01:09:59.4	0
3	01:13:19.7	01:13:19.7	01:13:19.7	01:13:19.2	.5
4	01:19:10.5	01:19:10.5	01:19:10.0	01:19:10.5	.5
5	01:23:47.1	01:23:47.1	01:23:47.1	01:23:47.1	0
6	01:28:23.0	01:38:23.5	01:28:23.0	01:28:23.0	0
7	01:31:07.5	01:31:07.5	01:31:07.5	01:31:07.5	0
8	01:34:02.2	01:34:02.7	01:34:02.2	01:34:02.7	.5
9	01:37:23.9	01:37:23.9	01:37:23.9	01:37:23.9	0
10	01:39:00.8	01:39:00.8	SET	01:38:59.8	1.
11	01:45:15.2	01:45:15.2	SET	01:45:15.2	0
12	01:51:45.3	01:51:45.3	SET	01:51:45.3	0
13	01:47:52.8	01:47:52.8	SET	01:47:52.3	.5
14	00:59:54.1	00:59:54.1	00:59:54.1	00:59:54.1	0

Run 126

Time Point Number	L. S. Recorded Sign Post	Manual Sign Post	Auto T. P. Flag	Man. T. P. Flag	Error (Seconds)
1	00:01:52.0	00:01:52.0	SET	00:01:52.0	0
2	00:07:55.9	00:07:55.9	00:07:35.0 Est	00:07:55.9	0
3	00:10:25.9	00:10:25.4	SET	00:10:25.4	5
4	00:16:04.5	00:16:05.0	00:16:04.5	00:16:05.0	0
5	00:19:40.7	00:19:41.2	00:19:40.7	00:19:40.7	0
6	00:22:08.0	00:22:08.0	00:22:08.0	00:22:08.0	0
7	00:26:00.8	00:26:00.8	00:26:00.8	00:26:00.8	0
8	00:30:04.8	00:30:04.8	00:30:04.8	00:30:04.8	0
9	00:33:27.0	00:33:27.5	SET	00:33:27.0	0
10	00:35:05.1	00:35:05.6	SET	00:35:05-1	0
11	00:41:09.2	00:41:09.2	SET	00:41:09.2	0
12	00:47:47.3	00:47:47.8	00:47:47.3	00:47:47.3	0
13	00:43:50.3	00:43:50.3	SET	00:43:49.8	.5
14	23:56:56.0	23:56:56.5	23:56:56.0	23:56:56.0	0

Run 127

Time Point Number	L. S. Recorded Sign Post	Manual Sign Post	Auto T. P. Flag	Man. T. P. Flag	Error (Seconds)
1	13:38:03.2	13:38:03.2	13:38:03.2	13:38:03.2	0
2	13:44:50.9	13:44:51.4	13:44:17.4 Est	13:44:51.4	.5
3	13:48:58.9	13:48:58.9	SET	13:48:58.9	0
4	13:54:55.7	13:54:55.7	13:54:55.7	13:54:55.7	0
5	14:01:34.8	14:01:35.3	SET	14:01:34.8	0
6	14:03:57.2	14:03:57.2	14:03:57.2	14:03:57.2	0
7	14:06:54.3	14:06:54.3	14:06:54.3	14:06:54.3	0
8	14:12:02.6	14:12:03.1	14:12:02.6	14:12:02.6	0
9	14:17:58.0	-	14:17:58.0	-	-
10	14:25:39.8	14:25:39.8	SET	14:25:38.2	1.5
11	14:34:01.1	14:34:01.6	SET	14:34:01.1	0
12	14:44:39.4	14:44:39.9	14:44:39.4	14:44:39.4	0
13	14:38:45:4	14:38:45.9	SET	14:38:45.9	.5
14	13:39:55.7	13:29:57.1	13:29:55.7	13:29:57.1	1.5

Table A7 (Contd)
Time Point Passage Times

Run 128

Time Point Number	L. S. Recorded Sign Post	Manual Sign Post	Auto T. P. Flag	Man. T. P. Flag	Error (Seconds)
1	16:01:43.0	16:01:43.5	16:01:43.0	16:01:43.5	.5
2	16:07:56.1	16:07:56.1	16:07:54.1 Est	16:07:56.1	0
3	16:11:26.3	16:11:26.8	SET	16:11:26.3	0
4	16:16:03.4	16:16:03.4	16:16:03.4	16:16:03.4	0
5	16:21:44.8	16:21:44.8	16:21:44.8	16:21:44.8	0
6	16:25:02.6	16:25:02.6	16:25:02.6	16:25:02.6	0
7	16:28:47.6	16:28:47.6	16:28:47.6	16:28:47.6	0
8	16:33:56.0	16:33:56.5	16:33:56.0	16:33:56.0	0
9	16:37:55.9	16:37:55.9	16:37:55.9	16:37:55.9	0
10	16:39:58.7	16:39:59.2	SET	16:39:58.7	0
11	16:47:59.3	16:47:59.3	16:47:59.3	16:47:59.3	0
12	16:58:15.2	16:58:15.7	SET	16:58:15.2	0
13	16:52:44.1	16:52:43.6	SET	16:52:43.6	0
14	15:56:56.9	15:56:56.9	-	15:56:56.9	0

Run 129

Time Point Number	L. S. Recorded Sign Post	Manual Sign Post	Auto T. P. Flag	Man. T. P. Flag	Error (Seconds)
1	17:18:46.4	17:18:46.4	17:18:46.4	17:18:46.4	0
2	17:23:54.5	17:23:54.5	17:23:54.5	17:23:54.5	0
3	17:29:09.7	17:27:09.7	17:27:09.7	17:27:09.7	0
4	17:30:55.0	17:30:55.5	17:30:55.0	17:30:55.0	0
5	17:35:34.0	17:35:34.5	17:35:34.0	17:35:34.0	0
6	17:39:46.8	17:39:46.8	17:39:46.8	17:39:46.8	0
7	17:42:58.7	17:42:58.7	17:42:58.7	17:42:58.7	0
8	17:46:54.3	17:46:54.3	17:46:54.3	17:46:54.3	0
9	17:50:58.7	17:50:59.2	17:50:58.7	17:50:58.7	0
10	17:52:45.7	17:52:46.2	SET	17:52:45.7	0
11	17:59:00.7	17:59:00.7	17:59:00.7	17:59:00.7	0
12	18:07:39.6	18:07:41.2	18:07:39.6	18:07:41.2	1.5
13	18:03:42.0	18:03:42.5	SET	18:03:42.0	0
14	17:12:00.6	17:12:01.1	17:12:00.6	17:12:00.6	0

Run 130

Time Point Number	L. S. Recorded Sign Post	Manual Sign Post	Auto T. P. Flag	Man. T. P. Flag	Error (Seconds)
1	Tape Error				
2	19:36:51.3	19:36:51.8	19:36:38.9 Est	19:36:15.3	0
3	19:40:15.0	19:40:15.0	19:40:15.0	19:40:15.0	0
4	19:45:02.8	19:45:03.3	19:45:02.8	19:45:02.8	0
5	19:49:39.5	19:49:40.0	19:49:39.5	19:49:39.5	0
6	19:53:18.0	19:53:18.0	19:53:18.0	19:53:18.0	0
7	19:56:46.6	19:56:47.1	19:56:46.6	19:56:46.6	0
8	20:00.59.9	20:00:59.9	20:00:59.9	20:00:59.9	0
9	20:05:58.7	20:05:59.2	SET	20:05:58.7	0
10	20:07:59.1	20:07:59.1	SET	20:07:59.1	0
11	20:13:18.9	20:13:18.9	20:13:18.9	20:13:18.9	0
12	20:21:54.7	20:21:54.7	SET	20:21:54.7	0
13	20:17:44.7	20:17:46.7	SET	20:17:45:2	.5
14	19:24:59.8	19:24:59.8	19:24:59.8	19:24:59.3	.5

Table A7 (Contd)
Time Point Passage Times

Run 131

Time Point Number	L. S. Recorded Sign Post	Manual Sign Post	Auto T. P. Flag	Man. T. P. Flag	Error (Seconds)
1	15:01:18.3	15:01:18.3	15:01:18.3	15:01:18.3	0
2	15:10:25.0	15:10:25.5	15:09:30.7 EST	15:10:25.0	0
3	15:15:45.2	15:15:45.7	15:15:45.2	15:15:45.2	0
4	15:19:26.7	15:19:27.2	15:19:26.7	15:19:27.2	.5
5	15:24:18.3	15:24:19.8	15:24:18.3	15:24:19.8	1.5
6	15:28:13.8	15:28:13.8	15:28:13.8	15:28:13.8	0
7	15:34:44.1	15:34:41.1	15:34:41.1	15:34:41.1	0
8	15:41:29.2	15:41:29.2	15:41:29.2	15:41:29.2	0
9	15:48:29.9	15:48:30.4	SET	15:48:30.4	.5
10	15:51:56.0	15:51:56.0	SET	15:51:56.0	0
11	16:00:35.6	16:00:35.6	SET	16:00:35.6	0
12	16:11:25.6	16:11:25.6	16:11:25.6	16:11:25.6	0
13	16:07:17.9	16:07:15.4	SET	16:07:18.4	.5
14	14:54:36.2	14:54:36.2	14:54:36.2	14:54:36.2	0

Run 132

Time Point Number	L. S. Recorded Sign Post	Manual Sign Post	Auto T. P. Flag	Man. T. P. Flag	Error (Seconds)
1	16:34:37.5	16:34:37.5	16:34:37.5	16:34:37.5	0
2	16:41:22.3	16:41:21.3	16:40:46.9 EST	16:41:22.3	0
3	16:48:10.1	16:48:10.6	16:48:10.1	16:48:10.1	0
4	16:54:10.5	16:54:10.5	SET	16:45:10.5	0
5	17:01:20.0	17:01:20.5	17:01:20.0	17:01:20.0	0
6	17:06:38.4	17:36:38.9	17:36:38.4	17:36:38.4	0
7	17:20:33.2	17:20:33.7	17:20:33.2	17:20:33.2	0
8	17:30:27.8	17:30:28.3	17:30:27.8	17:30:27.8	0
9	17:35:36.5	17:35:36.5	SET	17:35:36.0	.5
10	17:39:16.0	17:39:16.0	SET	17:39:16.0	0
11	17:48:51.4	17:48:51.4	17:48:51.4	17:48:51.4	0
12	17:59:27.3	17:59:27.8	17:59:27.3	17:59:27.8	.5
13	17:55:31.8	17:55:31.8	17:54:44.1 EST	17:55:31.3	.5
14	16:28:42.7	16:28:43.2	16:28:42.7	16:28:43.2	.5

Run 133

Time Point Number	L. S. Recorded Sign Post	Manual Sign Post	Auto T. P. Flag	Man. T. P. Flag	Error (Seconds)
1	18:20:22.4	18:20:22.4	18:20:22.4	18:20:22.4	0
2	18:26:32.5	18:26:32.5	18:26:31.5 EST	18:26:32.5	0
3	18:30:31.0	18:30:31.0	SET	18:30:30.5	.5
4	18:34:27.3	18:34:27.8	18:34:27.3	18:34:27.3	0
5	18:39:08.8	18:39:08.8	18:39:08.8	18:39:08.8	0
6	18:43:34.0	18:43:34.0	SET	18:43:34.0	0
7	18:47:31.6	18:47:31.6	18:47:31.6	18:47:31.6	0
8	18:52:26.3	18:52:26.3	SET	18:52:26.3	0
9	18:57:28.9	18:57:28.9	18:57:28.9	18:57:28.9	0
10	18:59:19.7	18:59:19.7	SET	18:59:19.7	0
11	19:07:35.5	19:07:35.5	19:07:35.5	19:07:35.5	0
12	19:15:11.5	19:15:13.1	19:15:11.5	19:15:13.1	1.5
13	19:11:16.1	19:11:17.7	19:10:54.5 EST	19:11:16.1	0
14	18:15:25.2	-	18:15:25.2	-	-

Table A-7

Timepoint Flag Reset Error Example

The automatic timepoint flag (column L) failed to reset after the previous timepoint and was, therefore, erroneously indicating at the presently detected timepoint signpost (tag 557 column LS). The manually indicated timepoint flag is present as indicated by the S in column S. The timepoint flag failed to reset 121 times for the 33 fixed route runs.

				FIFTH WHEEL DATA				LOC. SUBSYSTEM		RADIAL	TURNS			SIGNPOST ID				STR	HD					
ENTRY	HR	MIN	SEC	DIST	X(D)	Y(D)	SPEED	X(LS)	Y(LS)	ERROR	MR	LS	ERR	MR	LS	MISSED	INCOPR	ANG	ANG	PW	CK	D	I	S	T	L
5769	15	48	25.9	43763	2727651	234603	0.0	2727678	234598	27.5			0	538	538	0	0	-2.3	0.	23	42				T	
5770	15	48	26.4	43763	2727651	234603	0.0	2727678	234598	27.5			0	538	538	0	0	-2.3	0.	23	42				T	
5771	15	48	26.9	43763	2727651	234603	0.0	2727678	234598	27.5			0	538	538	0	0	-2.3	0.	23	42				T	
5772	15	48	27.4	43763	2727651	234603	0.0	2727678	234598	27.5			0	538	538	0	0	-2.3	0.	23	42				T	
5773	15	48	27.9	43763	2727651	234603	0.0	2727678	234598	27.5			0	538	538	0	0	-2.3	0.	23	42				T	
5774	15	48	28.4	43763	2727651	234603	0.2	2727678	234598	27.5			0	538	538	0	0	-1.8	0.	23	42				T	
5775	15	48	28.9	43763	2727651	234603	0.7	2727674	234598	23.5			0	538	538	0	0	-1.8	0.	23	42				T	
5776	15	48	29.4	43765	2727649	234604	3.7	2727674	234598	25.5			0	538	557	0	0	-1.8	0.	23	42			S	T	
5777	15	48	29.9	43770	2727644	234604	6.0	2727665	234600	21.5			0	557	557	0	0	0.3	0.	23	42				T	
5778	15	48	30.4	43776	2727638	234605	9.0	2727658	234600	20.5			0	557	557	0	0	0.0	0.	23	42				T	
5779	15	48	31.9	43804	2727610	234608	14.8	2727627	234604	17.5			0	557	557	0	0	-0.3	0.	23	42				T	
5780	15	48	32.4	43816	2727599	234610	16.5	2727616	234606	17.6			0	557	557	0	0	-0.5	0.	22	42				T	
5781	15	48	32.9	43829	2727586	234612	18.7	2727601	234607	15.6			0	557	557	0	0	-0.3	0.	23	42				T	
5782	15	48	33.4	43844	2727571	234613	19.8	2727590	234609	19.5			0	557	557	0	0	0.0	0.	23	42				T	
5783	15	48	33.9	43859	2727556	234615	21.2	2727572	234611	16.5			0	557	557	0	0	0.0	0.	23	42				T	
5784	15	48	34.4	43875	2727540	234617	21.6	2727557	234613	17.5			0	557	557	0	0	0.0	0.	23	42				T	
5785	15	48	34.9	43891	2727524	234619	21.9	2727542	234615	18.5			0	557	557	0	0	0.0	0.	23	42				T	
5786	15	48	35.4	43907	2727508	234621	22.8	2727527	234617	19.5			0	557	557	0	0	0.0	0.	23	42				T	

Table A-8. Time Point Arrival & Departure

Stop Number	Time Point Passage	Arrival Time	Departure Time	Time Difference Passage to Departure
				Minutes:Seconds
RUN 101				
1	19:47:58.6	19:48:1.6	19:48:37.6	00:41.0
2	19:53:7.8	19:52:49.8	19:53:3.8	00:4.0
3	20:04:8.0	20:04:10.5	20:04:30.6	00:22.6
RUN 102				
1	22:30:14.2	22:29:42.9	22:30:3.7	00:10.5
2	22:34:41.3	22:34:43.7	22:34:55.7	00:14.4
3	22:43:45.1	22:43:47.1	22:44:14.5	00:29.4
4	22:48:1.7	22:48:1.2	22:47:55.7	00:16.0
5	22:55:22.2	22:54:56.7	22:55:18.2	00:4.0
6	23:01:8.4	23:00:42.9	23:01:0.9	00:7.5
RUN 103				
1	23:45:6.6	23:45:9.6	23:46:15.9	01:9.3
2	23:54:31.7	23:54:35.2	23:55:5.6	00:34.1
RUN 104				
1	11:07:20.1	11:07:3.7	11:07:16.6	00:3.5
2	11:11:30	11:11:32.5	11:11:54.4	00:24.4
3	11:35:7.3	11:34:54.3	11:35:1.8	00:5.5
4	10:53:3.2	10:53:6.2	10:53:7.1	00:3.9
RUN 105				
1	12:32:57.6	12:32:13.4	12:32:41.7	00:15.9
2	12:37:25	12:37:28.5	12:37:49.9	00:24
3	12:42:20.8	12:42:23.8	12:43:6.6	00:45.8
4	12:47:45.4	12:47:48.4	12:47:59.4	00:14
5	13:11:10.8	13:11:12.3	13:11:21.3	00:10.5
6	13:24:10.7	13:23:23.9	13:24:4.1	00:6.6
7	13:33:52.8	13:33:53.8	13:34:16	00:13.2
RUN 106				
1	16:23:53.8	16:23:33.4	16:23:46.4	00:7.4
2	16:41:8.9	16:41:11.4	16:41:22.9	00:14
3	16:55:9.2	16:55:11.2	16:55:34.8	00:25.6
4	17:27:7.1	17:26:37.3	17:27:7.2	00:01
5	17:38:56.5	17:38:58.5	17:39:13.3	00:16.8
6	17:33:48.4	17:33:25.2	17:33:42.9	00:6.5
RUN 107				
1	18:32:51.3	18:32:53.8	18:33:5.3	00:14.0
2	18:50:3.1	18:50:6.6	18:50:18.2	00:15.1
3	18:56:11.8	18:55:55.7	18:56:3.8	00:8.0
RUN 108				
1	19:19:47.4	19:19:22.0	19:19:41.9	00:5.5
2	19:28:19	19:28:21	19:28:45.9	00:2.0
3	19:39:39	19:39:41	19:46:13.4	06:3.4
4	19:47:19.7	19:47:10.7	19:47:21.7	00:2.0
5	19:52:59.3	19:52:12.2	19:52:55.3	00:4.0
6	20:15:48.7	20:15:24.6	20:15:44.2	00:4.5

Stop #	Time Point Passage	Arrival Time	Departure Time	Time Difference Passage Departure
RUN 109				Minutes:Seconds
1	20:46:46.8	20:46:24.9	20:46:41.8	00:5.0
2	21:00:1.7	21:00:4.7	21:01:6.1	01:4.4
3	21:14:58.8	21:14:37.8	21:14:56.8	00:2.0
4	21:21:53.2	21:21:56.3	21:22:53.3	01:0.1
5	21:30:49.4	21:30:38.3	21:30:44.9	00:4.5
RUN 110				
1	23:15:53.1	23:15:14.2	23:15:26.2	00:26.9
2	23:23:35.3	23:23:37.3	23:23:58.8	00:23.5
3	23:23:36.8	23:28:39.3	23:28:55.8	05:19.0
4	23:39:58.6	23:39:30.0	23:39:52.6	00:6.0
5	00:05:45.9	00:05:48.4	00:06:12.1	00:26.2
RUN 111				
1	10:38:50.4	10:38:26.1	10:38:44.4	00:6.0
2	11:03:13.1	11:03:16.6	11:03:47.5	00:34.1
3	11:15:59.9	11:15:34.8	11:15:55.9	00:4.0
4	11:45:47.8	11:45:48.8	11:46:13.6	00:25.8
5	10:31:2.9	10:31:6.8	10:31:16.7	00:13.8
RUN 112				
1	13:38:51.6	13:38:29.2	13:38:43.6	00:8.0
2	13:44:51.8	13:44:23.0	13:44:47.8	00:4.0
3	14:03:11.4	14:03:13.4	14:03:45.3	00:33.9
4	14:12:2.5	14:11:32.5	14:11:54.0	00:8.5
5	14:18:58.1	14:18:26.0	14:18:52.6	00:5.5
6	14:22:2.3	14:22:2.8	14:22:9.3	00:7.0
7	14:34:51.3	14:34:21.0	14:34:40.2	00:11.1
RUN 113				
1	15:41:13.2	15:41:15.7	15:41:26.2	00:13
2	15:46:57.2	15:47:0.7	15:47:14.2	00:17
3	16:22:5.4	16:21:31.6	16:21:55.8	00:9.6
4	15:25:55.8	15:25:58.8	15:26:10.3	00:14.5
5	16:26:43.3	16:26:21.7	16:26:38.4	00:4.9
RUN 114				
1	19:24:46.1	19:24:49.6	19:25:11.1	00:25
2	19:35:58.1	19:35:28.4	19:35:48.5	00:9.6
3	19:35:43.7	19:39:46.2	19:39:52.7	04:09
4	19:46:58.7	19:46:36.5	19:46:49.1	00:9.6
5	18:52:50.6	18:52:54.1	18:53:10.5	00:19.6
6	19:52:42.7	19:52:24.6	19:52:38.2	00:4.5
RUN 115				
1	21:04:55.0	21:04:31.9	21:04:48.4	00:6.6
2	21:23:38.8	21:23:41.3	21:23:54.0	00:15.2
3	21:19:39.8	-------	-------	00:00

Stop #	Time Point Passage	Arrival Time	Departure Time	Time Difference Passage Departure
RUN 116				Minutes:Seconds
1	22:08:16.9	22:08:18.9	22:08:40.9	00:24
2	22:14:25.2	22:14:27.2	22:14:48.3	00:23.1
3	22:20:26.5	22:20:29.5	22:20:40.5	00:14
4	22:24:52.1	22:24:15.0	22:24:47.6	00:4.5
5	22:45:55.0	22:45:41.5	22:45:50	00:05
6	23:02:1.7	23:01:33.9	23:01:46.5	00:25.2
7	23:06:43.9	23:06:19.5	23:06:36.7	00:7.2
RUN 117				
1	00:10:56.9	00:11:3.4	00:11:24.4	00:9.5
2	00:25:39.1	00:25:28.0	00:25:31.0	00:8.1
RUN 118				
1	01:18:40.7	01:18:16.3	01:18:29.3	00:11.4
2	01:40:51.1	01:40:53.6	01:41:15.1	00:24
3	1:44:8.9	01:44:11.4	01:44:31.4	00:22.5
4	01:58:54.9	01:58:32.8	01:58:50.4	00:4.5
5	02:08:57.2	02:08:37.1	02:08:54.2	00:03
6	02:18:38.2	02:18:39.2	02:18:51.4	00:13.2
7	01:12:56.9	01:13:09	01:13:20.3	00:23.4
8	02:14:39.0	02:14:27.4	02:14:36.5	00:3.5
RUN 119				
1	12:58:47.6	12:58:51.5	12:59:2.1	00:14.5
2	13:13:2.5	13:12:35.4	13:12:46.9	00:15.6
RUN 120				
1	17:14:5.3	17:14:7.8	17:14:28.3	00:23
2	17:20:3.4	17:19:41.9	17:19:56.4	00:07
3	17:46:49.0	17:46:50.5	17:47:2.7	00:13.7
4	17:42:49.8	17:42:28.0	17:42:42.2	00:7.6
RUN 121				
1	18:35:18.5	18:35:20	18:35:36.6	00:18.1
2	18:46:4.7	18:45:37.6	18:45:57.6	00:7.1
3	18:48:7.2	18:48:10.7	18:48:22.3	00:15.1
4	18:54:8.6	18:53:34.8	18:53:50.9	00:17.5
5	19:01:51.2	19:01:52.2	19:02:9.4	00:18.2
RUN 122				
1	19:46:53.2	19:46:27.2	19:46:46.7	00:6.5
2	20:07:15.0	20:07:17.5	20:07:38.6	00:23.6
3	20:11:7.7	20:11:8.7	20:11:35.3	00:27.6
4	20:20:5.7	20:19:32.6	20:19:44.1	00:21.6
5	20:35:48.3	20:35:49.8	20:36:10.1	00:11.8
RUN 123				
1	11:24:53.0	11:24:20.6	11:24:33.1	00:19.9
2	11:35:20.8	11:35:23.3	11:35:45.2	00:24.4
3	11:40:41.2	11:40:42.7	11:40:59.7	00:18.5
4	11:47:9.3	11:47:10.8	11:47:36.8	00:27.5
5	11:52:2.9	11:51:48.3	11:51:55.9	00:07
6	11:58:0.6	11:57:20.0	11:57:31.5	00:29.1
7	12:10:8.2	12:09:55.6	12:10:3.7	00:4.5
8	12:16:51.5	12:16:26.7	12:16:41.4	00:10.1

Stop #	Time Point Passage	Arrival Time	Depature Time	Time Difference Passage Departure
RUN 124				Minutes:Seconds
1	23:03:47.8	23:03:49.8	23:03:59.7	00:11.9
2	23:10:3.6	23:10:6.1	23:10:22.6	00:09
3	23:23:5.4	23:22:34.9	23:22:58.9	00:6.5
4	23:33:51.4	23:33:25.3	23:33:38.8	00:12.6
RUN 125				
1	01:05:52.6	01:05:24.7	01:05:36.2	00:16.4
2	01:19:10.5	01:19:13.0	01:19:36.4	00:25.9
3	01:23:47.1	01:23:49.1	01:24:5.6	00:18.5
4	01:28:23.5	01:27:42.3	01:28:17.1	00:6.4
5	01:34:2.7	01:33:39.1	01:33:59.8	00:2.9
6	01:39:0.8	01:39:3.2	01:39:24.9	00:24.1
7	00:59:54.1	00:59:56.6	01:00:8.5	00:14.4
RUN 126				
1	00:01:52.0	00:01:24.6	00:01:37.6	00:14.4
2	00:10:25.4	00:10:26.9	00:10:42.8	00:17.4
3	00:30:4.8	00:29:36.3	00:29:58.8	00:06.0
4	00:47:47.8	00:47:49.3	00:47:59.9	00:12.1

Stop #	Time Point Passage	Arrival Time	Departure Time	Time Difference Passage to Departure
				Minutes:Seconds
RUN 127				
1	13:29:57.1	13:30:0.6	13:30:12.1	00:15
2	13:44:51.4	13:44:18.4	13:44:31.9	00:19.5
3	13:48:59.4	13:48:38.4	13:48:54.4	00:05
4	13:54:55.7	13:54:58.2	13:55:20.2	00:24.5
5	14:34:1.6	14:33:28.2	14:33:43.4	00:18.2
RUN 128				
1	16:11:26.8	16:11:28.2	16:11:39.7	00:12.9
2	16:28:47.6	16:28:49.1	16:29:7.1	00:19.5
3	16:39:59.2	16:40:1.2	16:40:5.3	00:6.1
4	16:52:43.6	16:52:17.4	16:52:28.0	00:15.6
5	16:58:15.7	16:57:45.0	16:58:3.1	00:12.6
RUN 129				
1	17:18:46.4	17:18:18.5	17:18:31.4	00:15
2	17:35:34.5	17:35:38.0	17:35:48.6	00:14.1
3	18:03:42.5	18:03:4.3	18:03:27.4	00:15.1
4	18:07:41.5	18:07:41.7	18:07:52.3	00:10.8
RUN 130				
1	19:24:59.8	19:25:3.8	19:25:19.6	00:19.8
2	19:49:40.0	19:49:42.0	19:49:55.0	00:15
3	20:05:59.2	10:05:40.1	10:05:56.2	00:03
4	20:07:59.1	10:08:0.6	10:08:10.6	00:11.5
5	20:17:46.7	20:17:22.1	20:17:41.2	00:5.5
RUN 131				
1	15:10:25.5	15:09:30.7	15:09:52.6	00:32.9
2	15:34:41.1	15:34:43.1	15:34:55.6	00:14.5
3	15:41:29.2	15:41:2.1	15:41:18.1	00:11.1
4	15:48:30.4	15:48:9.8	15:48:24.4	00:06
6	16:00:35.6	15:59:55.3	16:00:17.4	00:18.2
RUN 132				
1	16:54:10.5	16:54:13.0	16:54:25.5	00:15
RUN 133				
1	18:30:31.0	18:30:3.6	18:30:23.0	00:08
2	18:39:8.8	18:39:10.8	18:39:23.2	00:14.4
3	18:43:34.0	18:43:7.0	18:43:39.0	00:05
4	18:57:28.9	18:57:15.9	18:57:27.4	00:1.5
5	19:15:13.1	19:15:13.6	19:15:26.1	00:13

Stop #	Time Point Passage	Arrival Time	Departure Time	Time Difference Passage to Departure
RUN 01				Minutes:Seconds
1	20:41:24.9	20:41:25.9	20:42:12.4	00:12.5
2	20:48:19.9	20:47:58.4	20:48:16.4	00:3.5
3	20:57:13.1	20:57:13.6	20:57:39.7	00:26.6
RUN 02				
1	21:53:10.9	21:53:0.9	21:53:7.4	00:3.5
2	21:56:51.7	21:56:52.2	21:57:26.1	00:34.4
3	22:07:59.7	22:08:2.7	22:08:14.7	00:15
4	22:12:46.7	22:12:48.7	22:13:32.1	00:45.4
5	22:23:33.0	22:23:33.5	22:24:7.1	00:34.1
6	22:29:16.6	22:28:53.1	22:29:11.6	00:05
RUN 03				
1	23:28:16.2	23:28:18.2	23:28:52.1	00:35.9
2	23:37:13.0	23:36:40.6	23:27:8.5	00:4.5
3	00:03:1.1	00:01:41.8	00:02:34.0	00:27.1
RUN 04				
1	10:22:21.3	10:22:24.3	10:22:52.6	00:31.3
2	10:35:11.5	10:34:46.7	10:35:2.5	00:09
3	10:40:43.7	10:40:45.2	10:41:7.0	00:13.3
4	11:06:10.9	11:05:10.4	11:05:41.4	00:29.5
RUN 05				
1	12:33:7.8	12:32:42.4	12:33:3.8	00:04
2	12:37:42.3	12:37:43.3	12:38:1.8	00:19.5
3	12:43:38.1	12:43:40.6	12:44:10.6	00:32.5

TABLE A - 9

FIXED ROUTE SYSTEM LEVEL

DATA PROCESSING ERRORS

RUN NUMBER	TIME	RADIAL ERROR	
		SYSTEM	SUB-SYSTEM
101 - 71	19:45:5.1	412.9	24.6
- 89	:52:38.8	373.2	17.0
102 - 73	22:48:33.1	206.5	13.2
- 83	:52:47.9	147.4	9.0
- 134	23:14:13.5	473.4	17.3
- 138	:15:54.8	590.6	16.6
103 - 41	23:43:29.0	5318.9	14.1
- 42	:43:54.4	29709	1.0
- 67	:54:28.2	478.4	28.0
- 70	:55:43.6	401.4	53.8
- 228	0:02:31.3	437.7	55.6
- 239	:07:8.4	343.7	50.9
- 240	:07:34.5	406.3	79.9
104 - 82	11:25:41.8	203.8	28.3
- 83	:26:6.9	280.6	21.5
- 84	:26:31.9	1062.5	9.1
- 85	:26:57.0	300.3	18.6
- 173	12:04:10.6	286.0	14.2
- 177	:05:52.8	591.5	19.8
105 - 77	12:51:21.9	166.1	26.0
- 78	:51:47.0	1058.6	44.7
- 79	:52:13.0	455.0	27.8
- 99	13:00:38.1	666.4	43.6
- 167	:29:18.9	632.7	79.8
- 171	:31:0.7	263.6	78.1
106 - 86	16:52:9.7	402.7	13.6
- 170	17:27:40.6	159.6	159.6
- 171	:28:5.9	379.7	397.7
- 172	:28:32.2	642.8	642.8
- 173	:28:57.4	741.7	741.7
- 185	:34:3.1	306.5	48.5
- 190	:36:10.8	582.5	47.6
107 - 2	18:01:5.1	574.9	574.9 *
- 69	:29:24.3	497.7	27.7
- 72	:30:39.3	490.6	39.7
- 99	:42:1.9	315.9	64.5
- 144	19:01:1.7	244.5	6.0
108 - 2	19:13:0.5	572.0	572.0 *
- 76	:44:17.0	905.0	26.4
- 77	:44:42.4	427.4	50.5
- 94	:51:49.7	518.6	26.1

TABLE A-9 (Cont.)

109 - 44	20:58:38.8	6123.4	32.1	
- 66	21:07:52.7	315.7	20.1	
- 67	:08:17.7	1252.4	12.2	
- 68	:08:42.8	531.0	4.3	
- 121	:31:3.5	452.5	27.4	
- 125	:32:45.2	328.4	22.8	
110 - 2	23:02:23.6	187.9	187.9	*
- 72	:31:53.5	422.6	30.6	
- 75	:33:9.6	403.0	52.2	
- 258	0:02:7.3	421.3	21.1	
- 262	:03:49.2	500.4	26.0	
111 - 57	10:53:47.7	3345.8	46.0	
- 79	11:03:4.6	320.1	43.5	
- 84	:05:10.4	389.6	47.4	
- 167	:40:8.4	261.7	18.1	
- 174	:43:5.9	515.8	23.6	
		24952	28.8	
112 - 46	13:52:21.2	141.0	141.0	
- 53	:55:19.1	169.6	46.7	
- 75	14:04:34.3	1331.5	21.3	
- 76	:04:59.3	406	38.8	
113 - 2	15:24:19.1	2162.5	2146.8	
- 73	:54:14.7	275.0	2.1	
- 90	16:01:24.9	555.0	36.5	
114 - 2	18:51:23.6	152.7	152.7	*
- 48	19:10:51.0	148.0	148.0	
- 72	:20:55.4	550.8	34.7	
- 148	:52:58.8	355.2	43.2	
- 152	:54:40.7	601.1	48.7	
115 - 2	20:19:8.1	164.8	164.8	*
- 76	:50:18.2	616.4	56.9	
- 95	:58:18.9	140.2	68.5	
- 146	21:19:53.4	254.1	33.2	
- 150	:21:35.4	275.8	44.7	
116 - 6	21:55:8.8	3946.9	3946.1	+
- 7	:55:34.2	4222.9	4222.9	+
- 8	:55:59.5	4223.8	4223.8	+
- 9	:56:24.9	4981.6	4981.6	+
- 10	:56:50.3	5480.9	5480.9	+
- 11	:57:16.2	5948.2	5812.4	+
- 48	22:12:50.3	3463.7	43.1	
- 75	:24:11.0	489.1	10.9	
- 78	:25:27.2	400.4	16.2	
- 176	23:06:56.0	190.6	2.0	
- 180	:08:38.4	237.4	5.8	

TABLE A-9 (Cont.)

117 - 2	23:38:59.7	572.8	572.8	*
- 190	0:07:34.3	146.3	50.6	
- 255	:34:58.0	533.7	33.1	
- 259	:36:39.8	508.9	41.9	
118 - 51	1:33:26.1	148.0	148.0	
- 76	:43:55.9	178.9	51.4	
- 79	:45:12.0	277.0	52.8	
- 81	:46:2.1	392.6	51.4	
- 96	:52:21.2	336.9	45.3	
- 154	2:16:52.8	614.9	13.1	
119 - 29	12:37:21.2	4539.8	4539.8	+
- 30	:37:46.6	4362.8	4362.8	+
- 31	:38:11.9	4358.0	4358.0	+
- 32	:38:37.3	4358.0	4358.0	+
- 33	:39:2.6	4358.0	4358.0	+
- 34	:39:28.0	4358.0	4358.0	+
- 35	:39:53.3	4358.0	4358.0	+
- 36	:40:18.7	4358.0	4358.0	+
- 37	:40:44.1	4356.8	4356.8	+
- 92	13:03:57.1	273.1	63.2	
120 - 43	16:58:9.9	148.0	148.0	
- 46	:59:26.1	4113.1	59.2	
- 74	17:11:14.4	355.5	70.4	
- 94	:19:37.4	580.7	47.2	
- 107	:25:6.0	170.2	67.2	
- 108	:25:31.1	278.6	29.1	
- 150	:43:15.5	662.2	20.0	
- 154	:44:56.2	520.6	25.6	
121 - 52	18:27:58.6	136.2	30.1	
- 60	:31:20.2	540.4	37.6	
122 - 40	19:56:47.5	144.3	144.3	
- 43	:58:2.6	5688.5	16.1	
- 47	:59:43.7	182.1	35.4	
- 67	20:08:8.6	134.9	34.6	
- 93	:19:6.4	363.5	23.1	
- 94	:19:36.2	364.8	13.5	
- 124	:32:14.0	717.9	22.5	
- 128	:33:54.8	605.1	29.7	
123 - 53	11:33:29.9	3948.8	26.2	
- 54	:33:54.9	****	6.7	
- 72	:41:27.7	188.2	188.2	+
- 78	:43:59.0	321.1	15.4	
- 81	:45:15.1	439.4	3.1	
- 96	:51:33.8	391.3	9.3	
- 163	12:19:52.3	549.2	51.0	

TABLE A-9 (Cont.)

124 - 2	22:46:19.9	578.9	578.9	*
- 37	23:01:5.7	149.1	149.1	
- 40	:02:21.8	5897.5	15.4	
- 48	:05:44.7	173.0	9.5	
- 58	:09:58.7	365.6	4.2	
- 71	:15:28.7	129.2	26.1	
- 76	:17:34.5	474.6	14.4	
- 87	:22:10.9	361.8	3.4	
- 88	:22:35.9	371.1	38.6	
- 115	:33:58.4	181.5	34.3	
125 - 2	0:58:58.1	572.9	572.9	*
- 3	:59:23.4	570.8	570.8	*
- 70	1:27:41.8	514.1	15.2	
- 73	:28:57.1	592.8	10.1	
- 74	:29:22.2	304.0	35.9	
- 84	:33:34.3	616.2	33.5	
- 93	:37:19.9	219.6	36.4	
- 119	:48:13.9	696.6	57.7	
- 123	:49:54.5	574.3	54.6	
- 129	:52:25.7	696.1	696.1	+
126 - 2	23:56:10.2	572.8	572.8	*
- 183	0:14:24.7	1895.8	49.0	
- 184	:14:50.7	****	14.7	
- 191	:17:46.9	157.7	34.3	
- 201	:21:58.5	172.3	43.3	
- 202	:22:23.9	175.9	41.6	
- 203	:22:48.9	954.3	23.3	
- 204	:23:13.9	275.2	28.8	
- 219	:29:31.8	598.9	18.0	
- 254	:44:16.0	868.8	16.5	
- 258	:45:56.4	620.7	5.1	
127 - 3	13:23:4.8	1778.3	1778.3	*
- 4	:28:5.3	1774.4	1774.4	*
- 5	:28:30.6	2058.5	2058.5	*
- 13	:31:53.6	5475.4	5475.4	+
- 14	:32:19.0	5846.2	5846.2	+
- 15	:32:44.4	6259.8	6259.8	+
- 16	:33:9.7	6769.2	6769.2	+
- 17	:33:35.1	7170.6	7170.6	+
- 64	:53:25.7	2718.4	37.0	
- 65	:53:50.7	****	1.3	
- 89	14:03:56.7	568.2	19.1	
- 90	:04:21.7	172.4	24.3	
- 107	:11:31.5	207.8	25.3	
- 172	:39:3.2	147.3	62.5	
- 179	:42:2.4	234.9	56.2	

TABLE A-9 (Cont.)

128 - 53	16:18:25.6	204.4	13.4	
- 70	:25:32.6	832.5	27.4	
- 71	:25:57.6	397.1	27.9	
- 82	:30:35.7	126.1	40.0	
- 89	:33:31.9	718.5	44.7	
- 142	:55:54.0	557.3	70.8	
129 - 7	17:10:37.6	2062.1	2062.1	*
- 50	:28:47.6	173.9	147.3	
- 52	:29:37.6	6132.3	40.9	
- 76	:39:42.3	357.4	39.5	
- 92	:46:26.2	524.6	20.0	
- 101	:50:14.0	260.6	39.5	
- 102	:50:39.1	281.8	8.0	
- 116	:56:33.9	195.4	20.2	
- 138	18:05:52.4	619.4	3.0	
130 - 10	19:31:14.9	1404.1	1404.1	+
- 62	:53:9.4	206.9	61.4	
- 63	:53:34.5	209.4	65.7	
- 64	:54:1.0	1090.9	49.7	
- 65	:54:26.0	289.9	63.5	
- 79	20:00:18.9	226.5	72.5	
- 121	:18:0.8	277.9	34.2	
- 125	:19:42.4	401.9	49.5	
131 - 56	15:17:10.5	176.5	148.0	
- 82	:28:5.8	229.9	37.4	
- 83	:28:31.8	347.5	19.4	
- 84	:28:56.8	1301.0	7.1	
- 85	:29:21.8	290.9	16.4	
- 180	16:09:29.3	570.2	48.9	
132 - 61	16:53:14.5	5023.7	44.1	
- 94	17:07:8.0	494.4	14.2	
- 149	:30:23.2	710.7	88.0	
- 157	:33:46.3	135.2	553.9	+
- 158	:34:12.6	142.2	480.4	+
- 209	:55:56.1	739.2	130.2	
- 210	:56:17.4	135.3	135.3	
- 211	:56:42.8	141.5	141.5	
- 212	17:57:7.9	141.6	141.6	
- 213	:57:33.1	318.3	130.4	
- 219	18:00:9.4	180.5	180.5	
133 - 42	18:32:9.7	155.0	155.0	
- 45	:33:26.5	3589.5	33.6	
- 68	:43:6.5	538.2	3.8	
- 89	:51:55.8	521.8	29.5	
- 101	:56:59.4	135.0	43.4	

TABLE A-9 (Cont.)

03 - 2	23:08:24.1	580.9	580.9	*
- 42	:25:17.4	146.7	146.7	
- 72	:37:56.4	488.8	35.5	
- 88	:44:38.0	189.8	33.3	
- 99	:49:15.5	183.4	34.0	
- 100	:49:41.0	167.1	49.5	
- 244	0:03:22.7	639.9	1014.3	+
- 248	:05:3.2	536.6	62.4	
02 - 47	22:00:8.8	146.7	146.7	
- 82	:14:54.6	138.9	32.9	
- 114	:28:21.5	294.2	16.2	
- 115	:28:46.6	251.4	34.5	
- 154	:45:14.3	223.6	36.8	
04 - 57	10:45:16.5	5301.0	13.4	
- 83	:56:16.9	514.6	17.8	
- 86	:57:32.3	390.4	23.8	
- 103	11:04:41.4	313.0	12.0	
- 176	:35:26.9	265.8	28.3	
05 - 2	12:15:19.9	575.9	575.9	*
- 3	:15:45.2	574.7	574.7	*
- 83	:49:29.5	341.2	328.6	
- 84	:49:54.6	386.7	386.7	
01 - 2	20:05:23.4	579.0	579.0	*
- 53	:26:56.1	5988.4	9.6	
- 75	:36:12.0	165.6	4.1	
- 77	:37:2.5	384.8	0.9	
- 101	:47:6.8	468.6	8.3	
- 116	:53:25.7	302.6	0.4	
- 117	:53:51.8	204.4	22.3	
- 156	21:10:19.3	430.3	43.5	
- 160	:12:1.1	255.5	33.1	

* - Errors generated before start of run

+ - Errors generated from tag misreads

Table A-9

System Processing Error Example

ENTRY	HR	MIN	SEC	FIFTH WHEEL DATA DIST	X(D)	Y(D)	SPEED	LOC. SUBSYSTEM X(LS)	Y(LS)	RADIAL ERROR	TURNS MR	LS	EFR	SIGNPOST ID MR	LS	MISSED	INCORR	STR ANG	HD ANG	PM	CK	D	I	S	T
System Level Output																									
68	19	43	49.7	29705	2719664	237597	21.6	2719696	237601	14.7	0	585	585	0	0	-0.3	0.	23	27						
69	19	44	14.7	30394	2719402	237177	16.6	2719438	237084	99.7	0	559	559	0	0	-0.3	0.	22	27						
70	19	44	39.7	31205	2718606	237318	23.1	2718613	237317	7.1	0	559	559	0	0	0.0	0.	23	28						
71	19	45	5.1	31693	2718337	237029	0.0	2718152	237398	412.9	0	553	553	0	0	0.3	0.	23	29						
72	19	45	30.1	31693	2718337	237029	0.0	2718332	237004	24.6	0	553	553	0	0	0.3	0.	23	29						
73	19	45	55.6	32163	2718734	236893	21.2	2718753	236889	19.5	0	564	564	0	0	0.3	0.	23	29						
74	19	46	20.6	32964	2719507	236791	21.6	2719495	236792	12.0	0	564	564	0	0	0.5	0.	23	30						
Subsystem Output Corresponding to System Entry 70																									
3094	19	44	38.2	31153	2718657	237309	24.6	2718663	237308	6.1	0	559	559	0	0	0.3	0.	23	28						
3095	19	44	38.7	31170	2718640	237312	24.5	2718645	237311	5.1	0	559	559	0	0	0.3	0.	23	28						
3096	19	44	39.2	31188	2718623	237315	23.8	2718627	237314	4.1	0	559	559	0	0	0.3	0.	23	28						
3097	19	44	39.7	31205	2718606	237318	23.1	2718613	237317	7.1	0	559	559	0	0	0.0	0.	23	28						
3098	19	44	40.2	31222	2718589	237321	22.6	2718596	237320	7.1	0	559	559	0	0	0.0	0.	23	28						
3099	19	44	40.7	31238	2718573	237323	22.0	2718581	237322	8.1	0	559	559	0	0	0.3	0.	23	28						
Subsystem Output Corresponding to System Entry 71.																									
3139	19	45	4.1	31693	2718337	237029	0.0	2718332	237004	24.6	0	553	553	0	0	0.3	0.	23	29						
3140	19	45	4.6	31693	2718337	237029	0.0	2718332	237004	24.6	0	553	553	0	0	0.3	0.	23	29						
3141	19	45	5.1	31693	2718337	237029	0.0	2718332	237004	24.6	0	553	553	0	0	0.3	0.	23	29						
3142	19	45	5.6	31693	2718337	237029	0.0	2718332	237004	24.6	0	553	553	0	0	0.3	0.	23	29						
3143	19	45	6.1	31693	2718337	237029	0.0	2718332	237004	24.6	0	553	553	0	0	0.3	0.	23	29						
3144	19	45	6.6	31693	2718337	237029	0.0	2718332	237004	24.6	0	553	553	0	0	0.3	0.	1	29						
3145	19	45	7.1	31693	2718337	237029	0.0	2718332	237004	24.6	0	553	553	0	0	0.3	0.	23	29						
Subsystem Output Corresponding to System Entry 72.																									
3183	19	45	29.1	31693	2718337	237029	0.0	2718332	237004	24.6	0	553	553	0	0	0.3	0.	23	29						
3184	19	45	29.6	31693	2718337	237029	0.0	2718332	237004	24.6	0	553	553	0	0	0.3	0.	23	29						
3185	19	45	30.1	31693	2718337	237029	0.0	2718332	237004	24.6	0	553	553	0	0	0.3	0.	23	29						
3186	19	45	30.6	31693	2718337	237029	0.0	2718332	237004	24.6	0	553	553	0	0	0.3	0.	23	29						
3187	19	45	31.1	31693	2718337	237029	0.0	2718332	237004	24.6	0	553	553	0	0	0.3	0.	23	29						
3188	19	45	31.6	31693	2718337	237029	0.0	2718332	237004	24.6	0	553	553	0	0	0.3	0.	23	29						

TABLE A-10 SYSTEM COVERAGE DATA POINTS ELIMINATED OR RECALCULATED

5th Wheel Distance	Printout Error	Revised Error	Comments
			RUN 127
522 to 1056	141573	10.03	
1060 to 1585	1778	22.5	
1586 to 2116	1774	3890	tag error
2128 to 2626	1770	6180	" "
2662 to 3164	1767	6677	" "
3175 to 3695	1764	1527	" "
3704 to 4224	1761	17.5	
4225 to 4755	1457	22.6	
			} New valve used tape summation error
528 to 1056	167235	8.49	RUN 129 New valve used tape summation error
2131 to 5514	275982	-	RUN 130 Tape error both values deleted
	10346	-	
0 to 522	=	=	RUN 101 - 133, 01 - 05 All first increments deleted due to residual error before start of run

Table A-10

System Coverage Data Points Eliminated or Recalculated

The 5th wheel distance jumped from 0 to 4213, increased to 4480 then was reset to 0 at the reference marker. The run officially started when signpost 602 was acquired at entry #58. The extraneous 5th wheel distance was averaged with the correct data accumulated later in the run.

				FIFTH WHEEL DATA				LOC. SUBSYSTEM			TURNS			SIGNPOST ID									
ENTRY	HR	MIN	SEC	DIST	X(D)	Y(D)	SPEED	X(LS)	Y(LS)	RADIAL ERROR	MR	LS	ERR	MR	LS	MISSED	INCORR	STR ANG	HD ANG	PN	CK	D	T
1	46	49	58.4	0	2724457	236222	0.0	2722744	223711	******			0	0	****	0	****	0.0	220.	0	0		
2	0	33	33.2	*****	2701036	95867	35.3	2724361	235506	******	R		1	1574	****	0	****	13.8	197.	32	49	0	S
3	13	23	4.8	4213	2724918	232806	14.9	2724217	234442	1778.3			1	0	616	0	616	0.3	0.	22	0		
4	13	28	5.3	4224	2724929	232836	15.1	2724216	234431	1774.4			1	0	616	0	0	0.5	0.	23	0		
5	13	28	5.8	4235	2724941	232805	15.4	2724214	234419	1770.5			1	0	616	0	0	0.5	0.	23	0		
6	13	28	6.3	4247	2724953	232803	16.1	2724213	234409	1767.5			1	0	616	0	0	0.5	0.	23	0		
7	13	28	6.8	4258	2724964	232802	15.4	2724211	234398	1764.4			1	0	616	0	0	0.3	0.	23	0		
8	13	28	7.3	4270	2724976	232800	15.2	2724210	234387	1761.6			1	0	616	0	0	0.3	0.	23	0		
9	13	28	7.8	4281	2724987	232799	15.2	2724208	234376	1758.9			1	0	616	0	0	0.3	0.	23	0		
10	13	28	8.3	4292	2724998	232797	14.5	2724207	234365	1755.8			1	0	616	0	0	0.0	0.	23	0		
35	13	28	22.7	4478	2725113	232868	3.7	2724182	234181	1609.5			1	0	616	0	0	0.5	0.	23	0		
36	13	28	23.2	4480	2725114	232870	1.9	2724182	234181	1608.5			1	0	616	0	0	0.5	0.	23	0		
37	13	28	23.7	4480	2725114	232870	0.7	2724182	234181	1608.5			1	0	616	0	0	0.5	0.	23	0		
38	13	28	24.2	0	2724457	236222	0.1	2724182	234181	2058.8			1	0	616	0	0	0.5	0.	23	0		
39	13	28	24.7	0	2724457	236222	0.0	2724182	234181	2058.8			1	0	616	0	0	0.5	0.	23	0		
40	13	28	25.2	0	2724457	236222	0.0	2724182	234181	2058.8			1	0	616	0	0	0.5	0.	23	0		
41	13	28	25.7	1	2724456	236221	0.3	2724182	234181	2057.7			1	0	616	0	0	0.5	0.	23	0		
42	13	28	26.2	1	2724456	236221	1.4	2724181	234177	2061.7			1	0	616	0	0	0.5	0.	23	0		
43	13	28	27.6	12	2724455	236210	7.4	2724180	234166	2061.7			1	0	616	0	0	0.5	0.	1	0		
55	13	28	33.6	136	2724438	236086	16.9	2724163	234045	2060.1			1	0	616	0	0	0.3	0.	23	0		
56	13	28	34.1	149	2724436	236073	16.9	2724161	234034	2058.0			1	0	616	0	0	0.3	0.	23	0		
57	13	28	34.6	161	2724435	236061	16.6	2724159	236019	2061.0			1	0	616	0	0	0.0	0.	23	0		
58	13	28	35.1	173	2724433	236050	16.1	2724433	236049	0.8			1	602	602	0	0	0.0	0.	23	0		
59	13	28	36.6	206	2724429	236017	15.1	2724429	236016	0.4			1	602	602	0	0	0.5	0.	1	0		
60	13	28	37.1	217	2724427	236006	14.4	2724428	236009	2.9			1	602	602	0	0	0.5	0.	23	0		
61	13	28	37.6	227	2724426	235996	14.2	2724426	235998	1.9			1	602	602	0	0	0.5	0.	23	0		
62	13	28	38.1	238	2724424	235985	13.9	2724425	235987	2.2			1	602	602	0	0	0.3	0.	23	0		
63	13	28	38.6	248	2724423	235975	13.8	2724423	235976	1.1			1	602	602	0	0	0.3	0.	23	0		

Table A-10

System Coverage Data Points Eleminated or Recalculated

The 5th wheel distance jumped from 0 to 1785, increased to 2151, then was reset to 0 at the reference marker. The run officially started at signpost 602 which is entry #144. The extraneous 5th wheel data was incorrectly averaged with the correct data accumulated later in the run.

				FIFTH WHEEL DATA				LOC. SUBSYSTEM		RADIAL	TURNS		SIGNPOST ID			STR ANG	HD ANG	PW	CK	D I S T
ENTRY	HR	MIN	SEC	DIST	X(D)	Y(D)	SPEED	X(LS)	Y(LS)	ERROR	HR	LS ERR	HR	LS MISSED	INCORR					
1	46	49	58.4	0	2724457	236222	0.0	2722744	223711	******		0	0	****	0	****	0.0	226.	0	0		
2	0	33	34.2	*****	2696814	70555	34.3	2724361	235506	******	R	1	1574	****	0	****	13.6	197.	30	49	0	S
3	16	59	21.5	1785	2724216	234447	11.9	2724231	234337	91.1		1	599	616	0	616	0.5	0.	22	0		
4	17	9	66.0	1796	2724215	234440	9.2	2724230	234330	91.1		1	599	616	0	0	0.5	0.	23	0		
5	17	9	22.5	1796	2724214	234434	7.0	2724229	234526	93.1		1	599	616	0	0	0.5	0.	23	0		
6	17	9	23.0	1801	2724214	234431	4.2	2724229	234523	93.1		1	599	616	0	0	0.5	0.	23	0		
⌇																						
91	17	10	11.6	2143	2724166	234091	6.4	2724182	234184	93.8		1	599	616	0	0	0.5	0.	1	0		
92	17	10	12.1	2147	2724167	234087	4.3	2724182	234181	94.9		1	599	616	0	0	0.5	0.	23	0		
93	17	10	12.6	2149	2724167	234085	3.0	2724182	234181	96.9		1	599	616	0	0	0.5	0.	1	0		
94	17	10	13.1	2150	2724167	234084	1.1	2724181	234177	93.8		1	599	616	0	0	0.5	0.	23	0		
95	17	10	13.6	2151	2724167	234083	0.2	2724181	234177	94.8		1	599	616	0	0	0.5	0.	23	0		
96	17	10	14.1	0	2724457	236222	0.1	2724181	234177	2062.9		1	599	616	0	0	0.5	0.	23	0		
97	17	10	14.6	0	2724457	236222	0.0	2724181	234177	2062.9		1	599	616	0	0	0.5	0.	23	0		
98	17	10	15.1	0	2724457	236222	0.2	2724181	234177	2062.9		1	599	616	0	0	0.5	0.	23	0		
99	17	10	15.6	0	2724457	236222	0.5	2724181	234177	2062.9		1	599	616	0	0	0.5	0.	23	0		
100	17	10	16.1	2	2724456	236223	2.6	2724181	234177	2060.7												
⌇																						
139	17	10	38.6	156	2724436	236066	0.1	2724160	234023	2062.1		1	599	616	0	0	0.5	0.	23	0		
140	17	10	39.1	157	2724435	236065	0.3	2724160	234023	2060.9		1	599	616	0	0	0.5	0.	23	0		
141	17	10	39.6	157	2724435	236065	0.4	2724160	234023	2060.9		1	599	616	0	0	0.5	0.	23	0		
142	17	10	40.1	158	2724435	236064	1.1	2724160	234023	2059.9		1	599	616	0	0	0.5	0.	23	0		
143	17	10	40.6	159	2724435	236063	2.1	2724160	234023	2058.9		1	599	616	0	0	0.5	0.	23	0		
144	17	10	41.1	161	2724435	236061	2.6	2724435	236060	1.9		1	602	602	0	0	0.5	0.	23	0		
145	17	10	41.6	163	2724435	236059	2.9	2724434	236057	3.1		1	602	602	0	0	0.5	0.	23	0		

Table A-10

System Coverage Data Points Eleminated or Recalculated

A tape parity error at entries 310 through 313 caused large erroneous errors to be tabulated for the system coverage and checkpoints 3 and 6 (checkpoints 4 and 5 were not computed).

				Fifth wheel data				Loc. subsystem			Turns			Signpost ID												
Entry	Hr	Min	Sec	Dist	X(D)	Y(D)	Speed	X(LS)	Y(LS)	Radial error	Hr	LS	Err	Hr	LS	Missed	Incorr	Str ang	Hd ang	Pn	Ck	B	I	S	T
301	19	27	10.4	2052	2724180	234182	3.2	2724184	234199	17.5			0	547	547	0	0	0.3	0.	1	2				
302	19	27	10.9	2056	2724179	234178	5.7	2724184	234196	18.7			0	547	547	0	0	0.3	0.	23	2				
303	19	27	11.4	2061	2724179	234173	7.8	2724183	234192	19.5			0	547	547	0	0	-0.3	0.	23	2				
304	19	27	12.9	2063	2724176	234151	11.3	2724180	234170	19.6			0	547	547	0	0	0.5	0.	23	2				
305	19	27	13.4	2094	2724174	234142	11.9	2724179	234158	17.0			0	547	547	0	0	0.5	0.	23	3				
306	19	27	13.9	2101	2724173	234133	12.6	2724178	234151	19.0			0	547	547	0	0	0.3	0.	23	3				
307	19	27	14.4	2110	2724172	234124	12.8	2724178	234141	16.9			0	547	547	0	0	0.3	0.	23	3				
308	19	27	14.9	2120	2724171	234114	13.9	2724175	234133	18.9			0	547	547	0	0	0.3	0.	23	3				
309	19	27	15.4	2131	2724169	234103	14.9	2724174	234122	19.2			0	547	547	0	0	0.0	0.	23	3				
310	23	51	23.7	******	2678481	-39306	35.7	2723212	233027	******	U		1	1409	****	0	****	-0.3	-0.	58	49	0	I	S	
311	53	51	54.5	028774	2720200	237090	16.0	2729614	265173	******			1	705	****	0	****	-0.5	512.	58	3	0		S	
312	19	25	17.4	2178	2724163	234057	16.5	2724167	234074	18.2			1	547	547	0	0	-0.3	0.	23	3				
313	19	31	14.5	2194	2724161	234041	17.1	2724353	232819	1434.1			1	571	761	0	761	15.8	11.	21	3	0		S	
314	19	31	16.0	5514	2725258	233907	0.0	2725259	233918	11.0			1	520	520	0	0	0.5	0.	22	6				T
315	19	31	16.5	5514	2725256	233907	0.0	2725259	233918	11.0			1	520	520	0	0	0.5	0.	22	6				T
316	19	31	17.0	5514	2725258	233907	0.0	2725259	233918	11.0			1	520	520	0	0	0.5	0.	22	6				T

TABLE A-11 - SAMPLE SIZES & ERROR RATES FOR $p \leq 0.06$
(95 % CONFIDENCE)

SAMPLE SIZE	NUMBER OF UNSUCCESSFUL DATA POINTS	SAMPLE ERROR RATE (%)
100	2	2.0
150	4	2 7
200	6	3.0
240	8	3.3
300	11	3.7
400	16	4.0
500	21	4.2
600	26	4.3
700	31	4.4
800	37	4.6
900	42	4.7
1000	47	4.7

APPENDIX B: RANDOM ROUTE DATA SUMMARIES

Table B-1

Signpost Acquisition Errors

Random Route Runs

Entry II	Incorrect Signpost	Notes	Discussion
Run 01			
3689	633	1	Acquired from side street
Run 02			
25	609	2	Listed as incorrect before start of run
Run 03			
20	520	2	Listed as incorrect before start of run
3225	633	1	Acquired from side street
Run 04			
140	609	1	Listed as incorrect before start of run
38665			Listed as incorrect due to tape write error
Run 05			
22	53	2	Listed as incorrect before start of run
5951	558	3	552 Changed to 558 at acquisition.
6743	619	3	618 Changed to 619 after 12'
Run 06			
21	595	2	Listed as incorrect before start of run
2876	633	1	Acquired from side street
Run 07			
19	609	2	Listed as incorrect before start of run

Total Listed Misreads - 10
Total Actual Misreads - 2 (0.4%)
Total Signposts - 491

Notes: 1) Signpost 633 was located on 15th street South of Race. The route traveled South on 15th, then East onto Race, not directly passing the tag but causing the interrogator beam to sweep past the tag 633 location. Acquisition occured for only 3 of the six runs due to the resulting poor geometry.

2) Tags listed as incorrect due to L. S. being mislocated before start of run.

3) Signposts that were correctly acquired, then had the identification number change in the signpost return beam edge.

TABLE B-2

Checkpoint Radial Errors
Random Route

Checkpoint	Run						
	01	02	03	04	05	06	07
1	106	99	95	94	99	93	98
2	320	101	101	103	108	99	102
3	17	27	301	21	26	24	33
4	130	23	41	35	30	32	38
5	24	42	37	37	42	28	37
6		25	44	59	42	42	44
7	13	21	16	15	16	16	16
8	75	83	80	81	92	78	87
9	195	214	169	211	153	169	151
10	29	22	19	-	24	20	27
11	10	13	13	10	10	13	44
12	12	5	6	4	22	9	30
13	24	24	8	29	28	508	7
14	14	10	12	32	19	12	7
15	23	29	16	18	13	11	23
16	43	61	38	58	43	39	48
17	61	5	86	18	224	27	23
18	66	48	53	59	164	43	36
19	22	31	33	27	33	31	32
20	41	46	27	41	38	31	38
21	29	21	30	26	17	40	22
22	165	182	175	180	174	180	169
23	36	37	92	40	41	71	43
24	57	49	51	52	51	51	53
25	13	20	13	16	23	30	16
26	44	37	33	37	54	33	40
27	23	28	35	2	31	23	24
28	78	84	82	75	95	82	52
29	63	23	30	30	30	30	42
30	40	42	40	42	40	33	45
31	69	57	66	59	69	73	67
32	19	32	33	17	59	21	113
33	261	118	53	39	33	39	39
34	48	45	42	38	45	42	38
35	21	22	330	32	21	16	22
36	110	121	378	93	73	191	99
37	27	32	29	41	36	39	41
38	31	19	83	4623	31	27	31
39	62	52	56	57	48	63	70
40	58	23	24	52	25	21	65
41	18	19	18	19	23	21	20
42	358	213	376	269	380	286	300
43	384	197	419	-	410	289	317
44	403	203	443	257	414	295	322
45	38	35	28	-	35	24	13
46	81	99	90	84	81	86	89
47	25	29	25	30	26	26	25
48		61	56	54	51	68	40
49	25	13	25	29	21	18	9
50	41	44	54	24	34	41	36
51	10	17	4	04	13	5	7
52	58	59	80	66	68	38	61
53	101	88	86	99	97	86	84
54	11	7	7	20	7	9	9
55	262	239	341	232	415	301	212
56	34	49	27	30	34	39	27
57	28	33	28	-	32	27	27
58	42	21	27	39	25	27	25
59	42	2	26	41	30	23	30
60	8	14	8	8	6	41	62
61	34	42	38	49	64	27	42
62	45	58	58	57	60	50	51
63	143	53	69	62	166	86	96
64	122	12	14	13	14	13	68
65	398	37	42	68	40	42	84
66	18	21	22	-	19	22	21
67	51	29	25	-	25	25	21
68	30	35	27	-	32	30	30
69	34	19	17	-	3594	19	18
70	21	6	13	-	17	13	9
71	20	38	23	-	16	25	38
72	40	33	37	-	33	37	33
73	28	21	21	-	34	28	42
74	29	38	43	-	45	56	54
75	12	19	19	-	19	18	19
76	19	30	30	-	30	30	30
77	26	12	14	-	13	13	12
78	35	49	45	-	38	33	32
79	20	25	18	-	19	18	18
80	51	42	45	-	65	46	37
81	78	56	77	-	58	66	65
82	66		55	-	62	43	54
83	16	18	24	-	16	24	21
84	30	24	23	-	39	32	32

TABLE B-3

SYSTEM COVERAGE

RADIAL ERROR (0.1 MILE INCREMENTS)

RANDOM ROUTE

Tenth Mile	01	02	03	04	05	06	07
0.1	253	49	45	53	39	45	50
0.2	38	21	27	26	19	20	20
0.3	22	14	13	10	13	13	14
0.4	40	33	25	21	27	28	166
0.5	55	47	63	53	49	51	45
0.6	42	45	125	33	26	51	30
0.7	45	40	175	42	31	45	37
0.8	89	75	72	72	79	91	85
0.9	67	38	39	37	56	71	62
1.0	107	145	146	155	57	92	120
1.1	172	207	190	238	138	228	138
1.2	76	69	75	88	45	66	42
1.3	37	15	37	46	23	47	29
1.4	58	36	47	53	42	54	39
1.5	52	23	31	30	35	39	23
1.6	34	12	31	39	6	75	7
1.7	54	11	11	26	18	33	23
1.8	52	9	16	28	7	33	15
1.9	55	8	17	25	24	36	18
2.0	20	15	101	35	202	18	16
2.1	52	22	55	48	70	31	23
2.2	27	58	71	78	53	30	35
2.3	25	89	98	110	78	52	62
2.4	121	130	124	124	117	122	127
2.5	142	143	102	257	122	122	120
2.6	51	28	67	78	11	37	44
2.7	24	8	54	51	24	24	7
2.8	38	164	42	35	13	39	19
2.9	32	20	38	43	17	34	22
3.0	37	43	59	57	57	59	34
3.1	83	84	77	87	100	92	65
3.2	65	62	106	95	40	56	65
3.3	60	42	59	49	29	60	37
3.4	44	18	40	32	11	36	13
3.5	28	17	48	40	22	30	17
3.6	27	9	48	34	22	24	9
3.7	27	10	49	35	25	25	17
3.8	30	27	44	25	18	28	48
3.9	75	51	13	19	24	78	37
4.0	29	47	27	32	21	50	13
4.1	31	9	175	29	18	26	8
4.2	89	76	291	64	64	84	76
4.3	55	34	115	31	28	206	181
4.4	27	10	51	205	20	23	9
4.5	46	17	61	62	33	21	38
4.6	79	67	96	96	83	71	90
4.7	27	9	54	39	26	23	24
4.8	39	22	34	23	10	34	8
4.9	39	42	70	113	39	35	32
5.0	215	214	245	251	252	193	230
5.1	268	222	303	264	321	240	263
5.2	299	175	354	266	355	245	277
5.3	371	165	441	330	411	322	343
5.4	241	131	290	162	323	175	166
5.5	44	39	40	36	33	42	31

TABLE B-3 (cont'd)

SYSTEM COVERAGE

RADIAL ERROR (0.1 MILE INCREMENTS)

RANDOM ROUTE

Tenth Mile	01	02	03	04	05	06	07
5.6	63	55	39	38	39	77	47
5.7	19	10	60	49	37	11	25
5.8	11	13	66	65	54	14	27
5.9	19	4	58	45	34	8	14
6.0	37	41	70	65	70	38	53
6.1	32	10	48	37	18	19	9
6.2	40	21	62	50	37	29	22
6.3	16	18	68	56	52	13	15
6.4	8	16	70	43	49	401	16
6.5	15	12	62	37	44	142	10
6.6	15	11	56	38	65	436	12
6.7	10	28	67	47	99	510	26
6.8	31	45	99	58	125	412	35
6.9	111	86	143	57	171	227	61
7.0	156	110	112	71	44	395	74
7.1	69	47	25	35	72	236	59
7.2	28	12	43	15	24	26	14
7.3	10	11	62	18	38	8	7
7.4	9	10	62	-	37	11	8
7.5	18	24	71	-	49	24	80
7.6	24	23	49	-	34	24	21
7.7	46	20	30	-	39	47	24
7.8	18	21	51	-	52	34	44
7.9	56	23	62	-	40	5	34
8.0	623	19	58	26	36	7	29
8.1	14	21	114	-	27	15	17
8.2	34	18	38	-	14	34	16
8.3	14	44	76	-	192	175	33
8.4	13	33	65	-	2380	117	32
8.5	14	8	47	-	22	14	12
8.6	23	7	38	-	16	23	8
8.7	22	23	63	-	32	23	25
8.8	35	29	42	-	40	20	31
8.9	30	22	35	-	19	29	21
9.0	7	13	51	-	27	11	16
9.1	18	10	44	-	20	19	12
9.2	30	17	33	-	13	31	13
9.3	33	17	28	-	9	35	12
9.4	37	24	26	-	20	39	22
9.5	46	70	104	-	79	42	68
9.6	55	75	107	-	86	52	85
9.7	27	16	48	-	113	28	32

Table B-4

Test Conductor Notes Summary

Random Route Runs

RUN	COMMENTS
01	1) Checkpoint 06 never entered 2) Checkpoint 48 entered at wrong intersection (15th and Walnut)
02	1) Checkpoint 82 never entered.
03	1) Checkpoint 3 entered at wrong location.
04	1) Checkpoint 43 never entered. 2) Checkpoint 81 loaded about 20 feet passed correct location. 3) Teletype error bell rang after tag 1052, tag 1166, Tag 1075. 4) This test monitored by DOT/TSC personnel B. Blood and B. Kliem
05	1) After passing tag 1050, display read 1056. 2) After passing tag 1152, display read 1053.
06	No Comments
07	No Comments

TABLE B-5

SYSTEM LEVEL RADIAL SUMMARY

RANDOM ROUTE

BINNED RADIAL ERROR (FEET)

		10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	300	450	>450
RUN	01	24	30	67	70	17	19	9	2	5	4	4	10	4	1	1	3	1	3	2	0	2	7	2
	02	33	22	32	8	12	1	5	4	0	1	6	4	1	1	0	0	3	1	0	0	1	4	1
	03	3	16	12	22	25	24	16	9	3	1	4	4	0	1	1	1	0	3	1	0	5	4	1
	04	2	7	22	16	23	12	7	6	4	1	3	0	1	1	0	1	1	1	1	1	7	2	0
	05	21	19	27	22	13	14	2	2	4	3	1	1	2	4	4	0	1	1	3	0	0	5	2
	06	13	17	17	23	13	2	4	2	7	1	2	1	3	0	1	1	0	1	0	0	8	5	0
	07	25	39	31	11	4	6	3	6	3	3	2	0	1	1	2	0	0	2	0	0	3	3	0
TOTAL		121	170	208	172	107	78	46	31	26	14	22	20	12	9	9	6	6	12	7	1	26	30	6

TOTAL SAMPLE SIZE 1020

Table B-6

Random Route 04 Processing Errors

a) Tape write error caused checkpoint to jump from 57 to 10 and back, causing large errors for both checkpoints and system coverage.

4747	13	54	32.5	38629	2722280	236446	15.5	2722297	236466	26.3							0	552	552	0	0	-1.3	285.	22	57					
								2722297	236443	17.2																				
4748	13	54	33.0	38641	2722292	236444	16.2	2722307	236466	26.4							0	552	552	0	0	-1.0	284.	22	57					
								2722306	236442	14.3																				
4749	13	54	33.4	38653	2722304	236443	16.7	2722322	236467	30.6							0	552	552	0	0	-0.8	284.	22	57					
								2722321	236439	17.3																				
4750	13	54	33.9	38665	2722316	236441	17.0	2722333	236427	22.3							0	552	573	0	0	-1.3	359.	22	57					
								2722348	236437	32.3																				

	FIFTH WHEEL DATA							LOC. SUBSYSTEM		RADIAL	TURNS			SIGNPOST ID				STR	HD					
ENTRY	HR	MIN	SEC	DIST	X(D)	Y(D)	SPEED	X(LS)	Y(LS)	ERROR	MR	LS	ERR	MR	LS	MISSED	INCORR	ANG	ANG	PW	CK	D	I	S	T
4751	13	54	34.4	98101	2718831	191057	7.2	2726224	258368	******	R		1	&1004	573	0	0	-2.0	359.	18	10	0	I		T
								2744730	233335	******															
**** PASSED 162 HEADING TOWARDS 163 ****																									
4752	55	55	13.5	&97760	2718876	191395	7.0	2712535	255577	******	R		2	&1004	&****	0	573	-10.0	1.	31	10	0	I		T
								2727353	257869	******															
**** PASSED 163 HEADING TOWARDS 143 ****																									
4753	55	55	13.5	97761	2718876	191394	7.2	2695158	280141	******	R		3	& 980	&****	0	****	-10.0	1.	43	10	0	I		T
								2730322	287889	******															
**** PASSED 143 HEADING TOWARDS 1022 ****																									
4754	55	55	13.5	97763	2718876	191392	7.2	2698127	310161	******	R		4	& 972	&****	0	****	-7.0	1.	56	10	0	I		T
								2733886	313589	******															
**** PASSED 1022 HEADING TOWARDS 122 ****																									
4755	55	55	13.5	&89763	2719951	199321	7.2	2701691	335861	******	R		5	& 964	&****	0	****	9.5	1.	68	10	0	I		T
								2731092	337873	******															
**** PASSED 122 HEADING TOWARDS 106 ****																									
4756	55	55	13.5	&89762	2719951	199322	7.2	2698897	360145	******	R		6	& 940	&****	0	****	8.5	1.	80	10	0	I		T
								2747822	360100	******															
**** PASSED 106 HEADING TOWARDS 87 ****																									
4757	13	54	39.3	&38794	2722446	236424	15.1	2722331	236415	115.4			6	573	573	0	****	0.3	1.	0	57				
								2722359	236435	87.7															
**** PASSED 573 HEADING TOWARDS 162 ****																									
4758	13	54	39.8	38805	2722457	236423	15.0	2722478	236389	39.9			6	573	573	0	0	0.5	1.	22	57				
								2722484	236417	27.5															
4759	13	54	40.3	38816	2722468	236421	15.0	2722490	236387	41.0			6	573	573	0	0	0.8	1.	0	57				
								2722496	236416	28.6															
4760	13	54	40.8	38827	2722479	236420	14.8	2722501	236385	41.3			6	573	573	0	0	0.3	1.	22	57				
								2722507	236414	28.6															

b) Tape error caused erroneous jump in checkpoint ID with resulting large error for both checkpoint 45 and system coverage.

								2723525	235500	25.8																				
5172	13	58	36.3	42349	2723570	235395	13.7	2723562	235465	70.3							6	663	663	0	0	0.3	0.	22	64					
								2723547	235431	23.8																				
5173	13	58	36.8	42359	2723560	235396	13.8	2723552	235467	70.8							6	663	663	0	0	0.3	0.	22	65					
								2723537	235402	23.7																				
5174	13	58	37.3	42369	2723550	235397	13.7	2723541	235468	71.6							6	663	663	0	0	0.3	0.	22	65					
								2723526	235403	24.7																				
5175	13	58	37.8	42379	2723540	235399	13.6	2723533	235470	71.5							6	663	663	0	0	0.3	0.	22	65					
								2723518	235404	22.7																				
5176	23	51	26.5	46954	2722527	238753	0.0	2724658	234970	4362.7							6	565	565	0	0	0.3	0.	23	45					T
								2724658	234970	4362.7																				
**** PASSED 565 HEADING TOWARDS 235 ****																														
5177	23	51	27.0	46954	2722527	238753	0.0	2724357	234970	4203.2							6	565	565	0	0	0.3	0.	1	45					T
								2724360	235012	4166.5																				
5178	23	51	27.5	46954	2722527	238753	0.0	2724357	234970	4203.2							6	565	565	0	0	0.3	0.	23	45					T
								2724360	235012	4166.5																				

APPENDIX C: SPECIAL CASE TESTS DATA SUMMARIES

Table C-1

Tank Farm Special Test

Checkpoint Radial Error (Feet)

	Run			
Checkpoint	01	02	03	04
1	3	12	1	12
2	5	1	5	2
3	7	8	7	11
4	2	2	2	2
5	4	7	4	7
6	8	7	4	4
7	7	1	7	7
8	9	13	16	9
9	18	1	1	10

Table C-2
Tank Farm Special Test
System Coverages (0.1 mile increments)

Tenth Mile Increments	Run			
	01	02	03	04
0.0	2.0	3.5	1.8	1.6
0.1	4.2	3.2	4.7	5.9
0.2	3.5	2.0	4.8	7.9
0.3	2.4	2.0	2.5	3.3
0.4	6.2	7.0	5.8	6.6
0.5	1.8	4.0	3.5	2.7
0.6	4.7	11.0	10.5	10.1
0.7	6.6	10.1	10.9	10.6
0.8	1.8	1.5	6.1	4.3
0.9	5.9	7.1	13.0	11.8
1.0	12.8	14.3	22.3	21.2
1.1	23.0	23.3	31.0	32.4

Table C-3
Airport Special Test
Checkpoint Radial Error (feet)

Check Point	Run				
	01	02	03	04	05
1	8	12		49	8
2	3	7		7	8
3	19	52		45	34
4	15	8		19	12
5	5	10		14	18
6	18	26		26	15
7	3	1		5	9
8	4	0		4	4
9	38	1		5	1

Table C-4
Airport Special Test
System Coverage (0.1 mile increments)

Tenth Mile Increments	Run				
	01	02	03	04	05
0.0	3.4	3.0		6.0	3.2
0.1	3.0	4.1		2.5	4.1
0.2	10.6	12.3		11.3	12.0
0.3	18.9	22.3		23.5	20.9
0.4	27.7	31.6		34.8	30.7
0.5	36.7	41.1		44.8	40.1
0.6	45.7	52.0		54.9	50.9
0.7	42.8	48.0		49.3	41.1
0.8	3.3	2.8		3.4	2.5
0.9	12.1	6.2		13.3	10.4
1.0	7.7	3.2		20.7	20.3
1.1	1.8	7.7		10.1	12.7
1.2	8.1	19.8		1.9	4.8
1.3	15.5	28.5		10.1	3.6
1.4	20.7	33.3		20.3	10.8
1.5	11.3	13.6		2.5	4.7

Table C-5
Missing Signpost Special Test
Checkpoint Radial Error Summary

Feet											
Run	10	20	30	40	50	60	70	80	90	100	>450
01	9	19	11	13	4	0	3				
02	8	16	13	9	6	3	3				2
03	13	14	13	8	6	2	4				
04	13	16	12	7	8	1	2				
Total	43	65	49	37	24	6	12				
Time Pts.	9	15	10	7	5	5	4	0	3	1	

TABLE C - 6

SYSTEM COVERAGE SUMMARY

MISSING SIGNPOST TEST

RUN	INCREMENTS (FEET)												
	10	20	30	40	50	60	70	80	90	100	300	450	>450
01	43	36	14	12	5	0	1	0	0	2			
02	24	42	25	10	4	1	1	0	0	1	2	0	3
03	39	39	18	8	6	0	0	1	0	1	1		
04	18	19	14	24	15	16	3	2	0	1	1		
TOTAL	124	136	71	54	30	17	5	3	0	5	4	0	3
Time points only	27	33	19	18	7	2	2	1	2	0	2		

Table C-7

Route Deviation Printout Summary

FIFTH WHEEL DATA			LOC. SUBSYSTEM				TURNS			SIGNPOST ID	
DIST	X(D)	Y(D)	SPEED	X(LS)	Y(LS)	RADIAL ERROR	MK	LS	ERR	MK	LS
906	2724334	235321	3.7	2723000	235404	1336.6			2	645	645
909	2724334	235318	3.8	2723000	235404	1336.8			2	645	645
912	2724334	235315	4.1	2723001	235409	1336.3		L	3	645	645
915	2724335	235312	4.3	2723001	235414	1335.9			3	645	645
1038	2724317	235190	11.3	2723019	235555	1348.4			3	645	645
1046	2724316	235182	11.3	2723020	235564	1351.0			3	645	645
1055	2724314	235173	11.4	2723140	236453	1736.6			3	637	637
1063	2724313	235165	11.2	2723141	236461	1747.1			3	637	637
2919	2724065	233320	5.7	2724705	237550	4278.8			5	619	619
2924	2724062	233315	5.9	2724708	237550	4283.9			5	619	619
2928	2724062	233311	6.5	2724712	237550	4288.0		L	6	619	619
2933	2724061	233306	6.8	2724720	237549	4293.4			6	619	619
3613	2724311	232887	15.5	2725368	237467	4700.1			6	619	619
3625	2724323	232886	15.7	2725379	237465	4700.0			6	619	619
3637	2724335	232884	15.8	2723140	236450	3760.5			6	665	665
3648	2724347	232883	15.7	2723142	236464	3778.4			6	665	665
3071	2724042	233169	7.0	2723304	237649	4539.9			0	655	655
3087	2724040	233155	7.5	2723306	237666	4572.1		R	1	655	655
3092	2724040	233148	7.6	2723306	237669	4580.5			1	655	655
3098	2724039	233142	7.4	2723308	237679	4595.1			1	655	655
3267	2724016	232974	14.9	2723429	237703	4764.7			1	655	655
3278	2724015	232965	14.5	2723618	237679	4732.6			1	653	653
3288	2724013	232953	14.3	2723620	237678	4740.6			1	653	653
4836	2725163	233227	5.3	2725491	237451	4236.4			2	682	682
4840	2725164	233231	5.0	2725495	237450	4232.1		R	3	682	682
4844	2725165	233235	4.8	2725496	237450	4227.9		R	4	682	682
4847	2725165	233238	5.1	2725502	237449	4224.7			4	682	682
[illegible]		[illegible]	[illegible]	2725650	237404	3869.8			4	682	682
5201	2725215	233593	7.5	2725275	237428	4297.7			4	655	655
5208	2725215	233586	6.8	2723276	237433	4296.9			4	655	655
1719	2724225	234513	10.7	2723113	236254	2064.2			0	656	656
1727	2724224	234505	11.1	2723114	236259	2075.9		R	1	656	656
1734	2724223	234498	10.8	2723115	236267	2087.6		R	2	656	656
1742	2724222	234490	10.6	2723116	236274	2099.3			2	656	656
2052	2724180	234182	18.5	2723161	236587	2611.7			2	656	656
2065	2724178	234169	17.7	2723435	236272	2230.4			2	656	630
2076	2724176	234156	16.6	2723450	236270	2235.2			2	630	630
2089	2724175	234145	15.2	2723467	236268	2237.8			2	630	630
3392	2724087	232916	5.7	2723636	234672	1812.4			4	576	576
3396	2724091	232916	6.1	2723640	234671	1812.6		R	5	576	576
3401	2724097	232915	6.2	2723644	234671	1813.2		R	6	576	576
3501	2724198	232902	14.4	2723737	234659	1816.7			6	576	576
3511	2724208	232901	14.6	2723820	235567	2918.7			6	656	656
3522	2724219	232899	14.6	2723822	235578	2935.9			6	656	656

Table C-7

Route Deviation Printout Summary

Route Dev 01	Deviation at Left Turn
	Detected at Tag 637
	Return to Route at Left Turn
	Detected at Tag 665
Route Dev 02	Deviation at Right Turn
	Detected at Tag 653
	Return to Route at Right Turn
	Detected at Tag 655
Route Dev 03	Deviation at Tag Right Turn
	Detected at Tag 630
	Return to Route at Right Turn
	Detected at Tag 656

Table C-7 (cont'd)

Route Deviation Printout Summary

FIFTH WHEEL DATA				LCC. SUBSYSTEM		RADIAL	TURNS			SIGNPOST ID	
DIST	X(D)	Y(D)	SPEED	X(LS)	Y(LS)	ERROR	MR	LS	ERR	MK	LS
2117	2724171	234117	6.4	2723171	236651	2724.0			0	665	665
2123	2724170	234111	6.4	2723173	236659	2736.0		L	1	665	665
2129	2724169	234105	6.8	2723174	236666	2747.4			1	665	665
2276	2724150	233963	17.6	2723196	236809	3001.8			1	665	665
2284	2724149	233951	18.7	2723330	236710	2976.6			1	665	627
2297	2724147	233938	18.5	2723316	236711	2993.7			1	665	627
3681	2724582	232852	2.5	2719910	237574	6642.8			5	619	619
3683	2724584	232851	2.6	2719906	237574	6646.0		L	6	619	619
3685	2724586	232851	2.7	2719908	237574	6647.6			6	619	619
4574	2725127	232964	18.7	2719477	237521	7258.5			6	619	619
4586	2725128	232976	18.7	2723140	236453	4004.4			6	619	665
4598	2725130	232989	17.4	2723142	236464	4003.5			6	665	665
641	2724370	235584	16.0	2722983	235184	1445.6			0	554	554
653	2724369	235572	15.9	2722970	235187	1451.1	R		0	554	554
665	2724367	235561	16.1	2722971	235195	1443.1			0	554	554
677	2724365	235549	16.4	2722972	235203	1435.3			0	554	554
689	2724364	235537	16.7	2722989	235311	1393.5			0	570	570
701	2724362	235525	16.6	2722990	235323	1386.7			0	570	570
2922	2724063	233317	6.4	2723872	237649	4335.7			3	619	619
2936	2724060	233301	6.3	2723887	237647	4349.1		L	4	619	619
2944	2724060	233295	9.1	2723894	237646	4353.9			4	619	619
3634	2724332	232884	16.7	2724588	237564	4686.4			4	619	619
3646	2724344	232883	16.7	2723141	236461	3774.6			4	665	665
3658	2724357	232881	16.5	2723143	236472	3790.1			4	665	665
3015	2724050	233225	0.0	2723295	237584	4423.7			0	655	655
3015	2724050	233225	0.0	2723295	237584	4423.7	I		0	655	655
3016	2724050	233224	1.4	2723295	237584	4424.7			0	655	655
3390	2724085	232917	15.7	2723536	237669	4604.2			0	655	655
3401	2724097	232915	15.0	2723342	237943	5083.8			0	655	546
3412	2724108	232914	15.1	2723343	237954	5097.5			0	546	546
5395	2725242	233786	0.0	2723374	238166	4760.4			2	601	600
5395	2725242	233788	0.0	2723374	238166	4760.4	I		2	601	600
5395	2725242	233788	0.0	2723374	238166	4760.4			2	601	600
5881	2725306	234281	20.0	2723440	238032	4754.0			2	601	600
5882	2725310	234276	20.1	2723615	237680	3802.4			2	601	657
5897	2725312	234291	20.2	2723629	237678	3782.1			2	657	657

Table C-7 (cont'd)

Route Deviation Printout Summary

Route Dev 04	Deviation at Left Turn
	Detected at Tag 627
	Return to Route at Left Turn
	Detected at Tag 665
Route Dev 05	Deviation at Right Turn
	Detected at Tag 570
	Return to Route at Left Turn
	Detected at Tag 665
Route Dev 05	
	Deviation at Intersection
	Detected at Tag 546
	Return to Route at Intersection
	Detected at Tag 657

Table C-8. Data Processing Errors

a) Airport test run 3 produced only the data output shown below which was completely discarded.

				FIFTH WHEEL DATA			LOC. SUBSYSTEM		RADIAL	TURNS			SIGNPOST ID				STR HD						
ENTRY	HR	MIN	SEC	DIST	X(D)	Y(D)	SPEED	X(LS)	Y(LS)	ERROR	AR	LS	LRR	AR	LS	MISSED	INCORR	ANG	ABS	PW	CR	D	I	S	T
1	41	45	52.5	0	27422981	2300000	0.0	2744117	2300000	******				0	****	0	****	0.0	143.	0	0				
2	0	23	32.2	*****	29259831	2300000	37.3	2726559	2300000	******	R		L	1574	****	0	****	13.W	221.	32	49	0		S	

AVERAGE RADIAL ERROR PER TENTH MILE

TENTH MILE	AVERAGE ERROR
0.0	21536.00

NUMBER OF MISSED SIGNPOSTS = 0
NUMBER OF INCORRECT SIGNPOSTS = 2

MAXIMUM RADIAL ERROR = 179132.00
MEAN OF RADIAL ERROR = 100334.00
VARIANCE OF RADIAL ERROR = **********
STANDARD DEVIATION OF RADIAL ERROR = 78798.00

Table C-8. Data Processing Errors

b) Output summary listing for the Tank Farm Special Case Test. The listing on the left is typical and shows the Run 4 results. The listing on the right was the output from Run 5. The 5th wheel distance as recorded by the data tape jumped to 14, 196 and reset to zero after 185 data samples generating the large erroneous listing.

AVERAGE RADIAL ERROR PER TENTH MILE

TENTH MILE	AVERAGE ERROR
0.0	1.62
0.1	5.92
0.2	7.92
0.3	3.28
0.4	7.65
0.5	2.67
0.6	10.17
0.7	10.62
0.8	4.30
0.9	11.84
1.0	21.16
1.1	32.40

NUMBER OF MISSED SIGNPOSTS = 0
NUMBER OF INCORRECT SIGNPOSTS = 0

MAXIMUM RADIAL ERROR = 42.00
MEAN OF RADIAL ERROR = 10.21
VARIANCE OF RADIAL ERROR = 108.45
STANDARD DEVIATION OF RADIAL ERROR = 10.41

AVERAGE RADIAL ERROR PER TENTH MILE

TENTH MILE	AVERAGE ERROR
0.0	16721.00
0.1	171596.00
0.2	162.00
0.3	12204.00
0.4	4171.00
0.5	4171.00
0.6	4171.00
0.7	4171.00
0.8	4171.00
0.9	4171.00
1.0	1645.00
1.1	8180.00
1.2	8180.00
1.3	8180.00
1.4	8180.00
1.5	8180.00
1.6	8180.00
1.7	8180.00
1.8	8180.00
1.9	8180.00
2.0	8180.00
2.1	8180.00
2.2	8180.00
2.3	8180.00
2.4	8180.00
2.5	8180.00
2.6	8179.91
2.7	8736.91
2.8	12202.51

NUMBER OF MISSED SIGNPOSTS = 15
NUMBER OF INCORRECT SIGNPOSTS = 3

MAXIMUM RADIAL ERROR = 171596.00
MEAN OF RADIAL ERROR = 3825.61
VARIANCE OF RADIAL ERROR = **********
STANDARD DEVIATION OF RADIAL ERROR = 6814.69

APPENDIX D: ENGINEERING TESTS DATA SUMMARIES

Table D-1

Signpost Battery Drain

Signpost	Static (μ a)	Interrogated (μ a)
1123	36.5	36.5
1217	32.9	32.9
1206	31.7	31.7
1052	40.7	40.8
AVG	35.45	35.47

Table D-2

Operational Voltage Test

	Nominal	Minimum	
Interrogator (less microprocessor) -	12.0	8.5	Volts
Signpost (signpost 1123) -	6.0	2.77	Volts

Table D-3

High Speed Signpost Acquisition

Test Speed	Thresholded Seconds	AGC Feet	Number of Decoded Interrogations
20	0.467	13.7	80 - 88
40	0.247	14.5	40 - 48
60	0.058	5.14	16 - 24
80	0.044	5.14	8 - 16
100	0.035	5.14	8 - 16

Table D-4

Single Bit Signpost Acquisition

Run	Thresholded Seconds	AGC Feet	Number of Decoded Interrogations
1	0.243	10.71	0
2	0.253	11.14	0
3	0.233	10.28	0
4	0.233	10.28	0

Table D-5

Adjacent Channel Interference

	Frequency Offset MC	Transmit Interference Ratio (dB)	Receive Interference Ratio (dB)
Above Center	1.0	>8	+46
	0.9	>8	+43
	0.8	>8	+40
	0.7	>8	+36
	0.6	>8	+30
	0.5	>8	+28
	0.4	>8	+30
	0.3	+3	+33
	0.2	+1	+30
	0.1	0	+29
-	00	-2.5	+38
Below Center	0.1	0	+23
	0.2	+1	+31
	0.3	+4	+36
	0.4	+6	+34
	0.5	+7	+38
	0.6	>8	+36
	0.7	>8	+40
	0.8	>8	+45
	0.9	>8	+46
	1.0	>8	+48

Transmit level +27 dbm
Simulated transmit path loss 45 db
Signpost conversion efficiency -20db
Simulated receive path loss 55 db
Interference Ratio - The level of interference signal necessary to prohibit system acquisition of signpost identification.

Table D-6

Environmental Test

Sequence No.	Time	Signpost Temperature	Interrogator Temperature	Operational
1	1:15	90°F	80°F	Yes
2	1:30	100	90	Yes
3	1:45	70	70	Yes
4	2:00	50	50	Yes
5	2:10	30	30	Yes
6	2:25	10	20	Yes
7	2:35	-10	10	Yes
8	2:45	-20	0	Yes

Chamber transition rate 8°/min

APPENDIX E: SAMPLE SIZE ANALYSIS

SAMPLE SIZE

The estimation of the required number of measurements that need be made to assure the 95% confidence level cannot categorically be determined, since the probability distribution is unknown and there is no prior information to establish a "good guess." We are to determine the position of the vehicle within 450 feet at least 95% of the times a position measurement is made, and within 300 feet 99.5% of the time. We require then that the probability of a distant error less than 450 feet be greater than or equal to 0.95.

Employing the approach suggested by non-parametric statistics enables such an estimate to be made without having to specify the type of error distribution. The approach is as follows:

Assume that the 450 foot error occurs at the 95% point of a cumulative error distribution. A sample selected from this distribution will then have a probability of 0.95 of being at most 450 feet or a probability of 0.05 of exceeding 450 feet.

The null hypothesis, that the 450 foot error will correspond to the 95% mark will be tested as follows: Samples selected from the distribution will be independent and the resulting distribution of the random variable representing the number of values less than or equal to 450 feet will be binomial. The binomial distribution has the form:

$$P_n(k,p) = \frac{n!}{k!\,(n-k)!}\, p^k (1-p)^{n-k}.$$

In order to facilitate this computation using available programmable hand calculations, it is generally seen that they are restricted to values of $n < 70$.
A fair approximation to p can be found in Parzen, "Modern Probability and its Application" (John Wiley & Sons, Inc., New York: 1960), p. 242.

N is the total sample size, k = probability of value being less than or equal to 450. Pn (k_1 p) is the probability of k values being less than 450 feet.

If we assume an alternative hypothesis, that the probability of the total error being less than or equal to 450 is 0.90, we can test the null hypothesis against this alternative in the following way:

Plots of the cumulative distribution function for the binomial distribution are made for various values of n for p = 0.90 and 0.95. Selecting a level of significance which represents the probability that the test will reject a true null hypothesis, the number of samples required which would reject the null hypothesis can be found, using the value of 0.05 for α. The probability that the alternative hypothesis would be incorrectly accepted (β) can be found for this number from the value intercepted in the alternate (0.90) curve. Data are plotted for values of n = 100, 150, 200, 210, 300 for p = 0.90 or 0.95 (0.995 are plotted and will be discussed below).

The following results can be abstracted from these curves:

N	k (.95)	β	k_r
100	90	0.50	10
150	138	0.22	12
200	184	0.12	16
250	232	0.08	18
300	278	0.05	92

The value k_r is the number of samples of the n which will cause rejection i. e., if 10 or more are greater than 450 feet in a sample of 100, the null hypothesis would be rejected. This rejection criterion table can be extended by finding those values of k for which α = 0.05 for n's.

P = 0.95	n	k_r
	250	18
	300	22
	350	24
	400	26.

The value of β selected is somewhat arbitrary, but for consistency we set $\beta = \alpha = 0.05$ and see that the sample size should be at least 300

Looking at the curves for p = 0.995 and 0.95 it is seen that the $\alpha = \beta = 0.05$ criteria are not met for nearly all values of n>150. The rejection criterion results in smaller values for k_r.

P = 0.995	n	k_r
	300	7
	350	7
	400	8.

While, on the basis on this analysis, it would appear that 300 data points would be sufficient, a larger number of samples would reduce problems arising from the approximation assumed for p (r) and unforseen other effects. There is no clear criterion for selection but an adhoc argument might be made for planning the number of data points in one bin of the histogram to be at least equal to k_r. On this basis, say about 22 data points (n = 300 p = 0.95) in each line with bin width 30' would yield 20 bins in 600' (assume maximum error in distribution). To be absolutely confident that, regardless of distribution, statistically adequate data is obtained at the 95th percentile, the number of a data points will be increased to 450.

APPENDIX F

REPORT OF INVENTIONS

After a diligent review of the work performed under this contract, no innovation, discovery or invention was found to have been made. However, possible system design improvements were noted but not implemented during Phase I, and are herein described:

1. Signpost Deployment

   As a direct result of the Philadelphia field testing, specifically the missing signposts tests, it is concluded that the original estimate of signpost deployment at the rate of 6 per route mile was unnecessarily conservative. The missing signpost tests, and most especially the time points only test, demonstrate that the Location Subsystem is capable of meeting the requirements with a deployment of no greater than one signpost per route mile.

2. Signpost Installation

   The Philadelphia test proved that installation of the signposts can be performed much more quickly than anticipated since no critical alignment is necessary.

3. Reasonableness Algorithm

   A reasonableness algorithm will be added to the Phase II software to mitigate against misread signposts after having originally read them correctly.

☆U.S. GOVERNMENT PRINTING OFFICE: 1977—701-661/177

125 Copies