FAA-74-4.I

REPORT NO. FAA-RD-74-195.I

ASDE-2 RELIABILITY IMPROVEMENT STUDY
Volume I: Operational Data and Modification Recommendations

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NOVEMBER 1974

FINAL REPORT

Prepared for
U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
Systems Research and Development Service
Washington DC 20591

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FAA-RD-74-195.I		

4. Title and Subtitle	5. Report Date
ASDE-2 RELIABILITY IMPROVEMENT STUDY Volume I: Operational Data and Modification Recommendations	November 1974
	6. Performing Organization Code
7. Author(s) David N. Grover, C. Norman Butler	8. Performing Organization Report No. DOT-TSC-FAA-74-4.I
9. Performing Organization Name and Address Texas Instruments, Inc.* Dallas TX	10. Work Unit No. (TRAIS) FA-421/R4113
	11. Contract or Grant No. DOT-TSC-445-1
12. Sponsoring Agency Name and Address U.S. Department of Transportation Federal Aviation Administration Systems Research and Development Service Washington DC 20591	13. Type of Report and Period Covered Final Report July 1972 - March 1973
	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

Eight airport sites and the FAA Oklahoma Depot were visited and surveys conducted to obtain reliability, maintainability and performance data on the ASDE-2 Radar System. The data was analyzed and recommendations for modification to the equipment made based on cost/benefit trade-offs. Three electronic modifications were recommended: modulator, local oscillator, and solid state duplexer modifications. (These modifications have since been accomplished.) To increase the operational utility of the ASDE-2 Radar, a bright display is recommended and, where space permits in the control tower, multiple displays.

The report contains detailed information on ASDE-2 reliability/maintainability. operational status, performance, and future ASDE system considerations as of March 1973.

The report is in two Volumes: Vol. I: Operational Data and Modification Recommendations and Vol. II: Modulator, Receiver and Indicator Interface Recommendations.

17. Key Words	18. Distribution Statement
Airport Surface Detection Equipment (ASDE); Airport Surface Traffic Control; Radar (ASDE); ASDE-2 Reliability/Maintainability/Performance	DOCUMENT IS AVAILABLE TO THE 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	204	

Form DOT F 1700.7 (8-72)

Reproduction of completed page authorized

PREFACE

The ASDE-2 Reliability Improvement Study report was prepared by Texas Instruments Incorporated of Dallas, Texas under contract DOT-TSC-445, dated 20 June 1972, (completed 3/73) and is contained in two volumes as follows:

Volume I: Operational Data and Modification Recommendation;

Volume II: Modulator, Receiver and Indicator Interface Recommendations.

The principal objective of the study effort was to obtain reliability, maintainability, and performance data from ASDE-2 site visits, and based on an analysis of the site data, to recommend cost effective modifications to the equipment.

A secondary objective was to obtain information on the present and future desired control tower operational usage of the ASDE radar at each site.

The following sites were visited during the period from 7/72 to 9/72

New York (JFK)
Newark
Dulles
Andrews
Chicago (O'Hare)
Los Angeles
Seattle
San Francisco
Oklahoma City Depot

Two-day visits were made to each site during which maintenance logs/records were recorded, maintenance and air traffic personnel interviewed and electronic and field (performance) test data taken.

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1. INTRODUCTION

This report (Volume -1) is submitted in accordance with the terms of Contract DOT-TSC-445 and covers the requirements of tasks defined in items 1, 2, and 3 of the Statement of Work. The requirements of tasks defined in Items 4, 5 and 6 of the contract Statement of Work will be reported in subsequent reports.

1.1 The work reported in this volume consists of the following:

1. Operational site survey

   The eight ASDE-2 sites were visted and surveys were conducted to obtain maintenance data and operational status.

2. Operational Problem Analysis

   Maintenance and Operational Data were analyzed to localize failed parts and adjustment failures by reference designators and geographical location, to categorize failure incidents by functional areas, to determine operational procedures that exist at ASDE-2 sites and to identify areas where improved operational procedures can improve ASDE operation.

3. Operational and Modification Recommendations.

   A summary of operational interviews and maintenance data have been prepared and are included together with recommended corrective actions. A tabulation of personnel interviewed at each site is presented in Appendix A. Also included is a summary of the performance status of each ASDE-2.

1.2 The Operational Problem Analysis has resulted in the following conclusions:

RELIABILITY[1]

1. The ASDE-2 average single channel MTBF for high voltage operation is 24 hours.
2. High incidence of distributed random failures prevents cost effective reliability improvement to MTBF's greater than 79 hours, under present usage conditions.
3. Significant cost effective reliability improvements can only be made to the modulator (FA-6618) and to the receiver (FA-6613).
4. Availability is high due to frequent maintenance and general low usage.
5. Maintenance costs are more directly related to filament operate hours than to high voltage operate hours.

OPERATIONAL PROCEDURES

1. Accessibility of the display to controllers determines the operational use. Accessibility is defined as a function of the number of displays, location of display(s) and brightness.
2. Poor performance results in limited usage; and limited usage, in turn, results in still poorer performance, creating a cyclic degradation.

PERFORMANCE

1. The ASDE-2 will not penetrate moderate to heavy precipitation.

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[1] See definitions of MTBF and MTBM on page 41.

2. Range resolution averages 2.2 times specification and azimuth resolution averages 1.36 times specification.

1.3 Recommendations are as follows:

RELIABILITY:

1. Incorporate TSC determined modulator modifications
2. Incorporate solid state duplexers
3. Incorporate solid state local oscillator on the merit of reliability improvement and relatively low cost.

OPERATIONAL

Increase display accessibility by use of ASDE-2 BRITE modifications. Multiple displays are recommended where space permits.

PERFORMANCE

Increase bandwidth of receivers and video amplifiers for better range resolution.

1.4 Report Organization

The balance of this report is divided into the following sections:

2. Summary Reliability
3. Reliability

4. Operational
5. Performance
6. Future System Considerations

An overview of reliability, operational and performance status and recommended improvements can be quickly obtained by reading sections 2 and 6. Detailed supporting data, analyses, interviewee response summaries and performance test results are presented in sections 3, 4, and 5.

2. SUMMARY

The purpose of the summary is to describe the ASDE-2 equipment and to provide an overview of the discoveries, conclusions and recommendations that are based on the operational site survey and the operational problem analysis. We discuss the topics of reliability, operational procedures and performance status separately throughout the report for clarity. Pertinent information and analysis are added as it applies to each subject.

2.1 ASDE-2 DESCRIPTION

A brief general description of the ASDE-2 radar, its intended use, and performance expected from the equipment is provided in this section. A more detailed description of the system including official nomenclature and reference designators is provided in Appendix B.

2.1.1 Type

The ASDE-2 radar, FA-6600, is a high resolution, ground surveillance, dual-channel, pulse radar comprised of approximately 3600 electrical and electro-mechanical piece parts per channel. Of the 3600 parts, 224 are electron tubes.

2.1.2 Intended Use

The ASDE-2 is intended to provide radar observation of airport Operational areas, including all runways, taxiways and apron areas, during darkness and other conditions of poor visibility, except during moderate to heavy rain and snow. The system is a traffic control aid for detecting position and heading of aircraft and other vehicles within the airport boundary.

2.1.3 Expected Performance

ASDE-2 has a specified range resolution of 20 feet and azimuth resolution of 27 feet at a distance of 4000 feet (.383°), peak power of 36 to 50 KW, and a frequency of 24 GHz.

2.2 RELIABILITY/MAINTAINABILITY

Analysis of maintenance data has shown the following:

1. Current ASDE-2 status is defined as;
   a. Average $MTBF_{HV/SC}$ = 24 hours
   b. Average $MTBM_{HV/SC}$ = 19 hours
   c. Availability is greater than 95%. Note that this is due to close attention to performance requirements by maintenance personnel and to the limited use.

2. Maintenance costs are more directly related to filament operating hours than to high voltage hours.

3. Cost effective corrective actions are limited to two major areas primarily because the modulator and receiver are the only areas of concentrated failures.

2.2.1 Assessments

Assessments revealed that, as presently used, the ASDE-2's

$MTBF_{HV/SC}$[1] of 24 hours and $MTBM_{HV/SC}$[1] of 19 hours results in unscheduled maintenance at each site an average of once every four days. The maintenance data used was gathered during visits to the eight operational ASDE-2 sites. A summary of current ASDE-2 $MTBF_{HV/SC}$ and $MTBM_{HV/SC}$ by site is shown in Figure 2-1. The wide variance in $MTBF_{HV/SC}$ and $MTBM_{HV/SC}$ from site to site is primarily due to the difference in ratios of high voltage hours to filament operating hours and the dependence of failure rates of tube-type equipment on filament operation. For example, Seattles's High Voltage operate hours are 3.6 times the average of the other seven sites, and their MTBF is 4.3 times the average of the other sites. Maintenance procedures are essentially the same at all sites. Although single-channel MTBFs in Figure 2-1 are very low maintenance personnel are able, through close attention to ASDE operational status, to make at least one channel available for use greater than 95% of the time the system is requested by air traffic personnel.

Cost assessments performed considering only direct labor and parts costs indicated the following:

1. Average yearly maintenance costs of approximately $15,000 per ASDE installation.
2. Little difference in ASDE maintenance costs from site to site in spite of large differences in hours of high voltage operation accumulated.

2.2.2 Corrective Action

Review of data to identify high failure rate assemblies revealed Receiver Assembly FA-6613 and Modulator Assembly FA-6618 as the

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1 Defined in section 3.2.1.

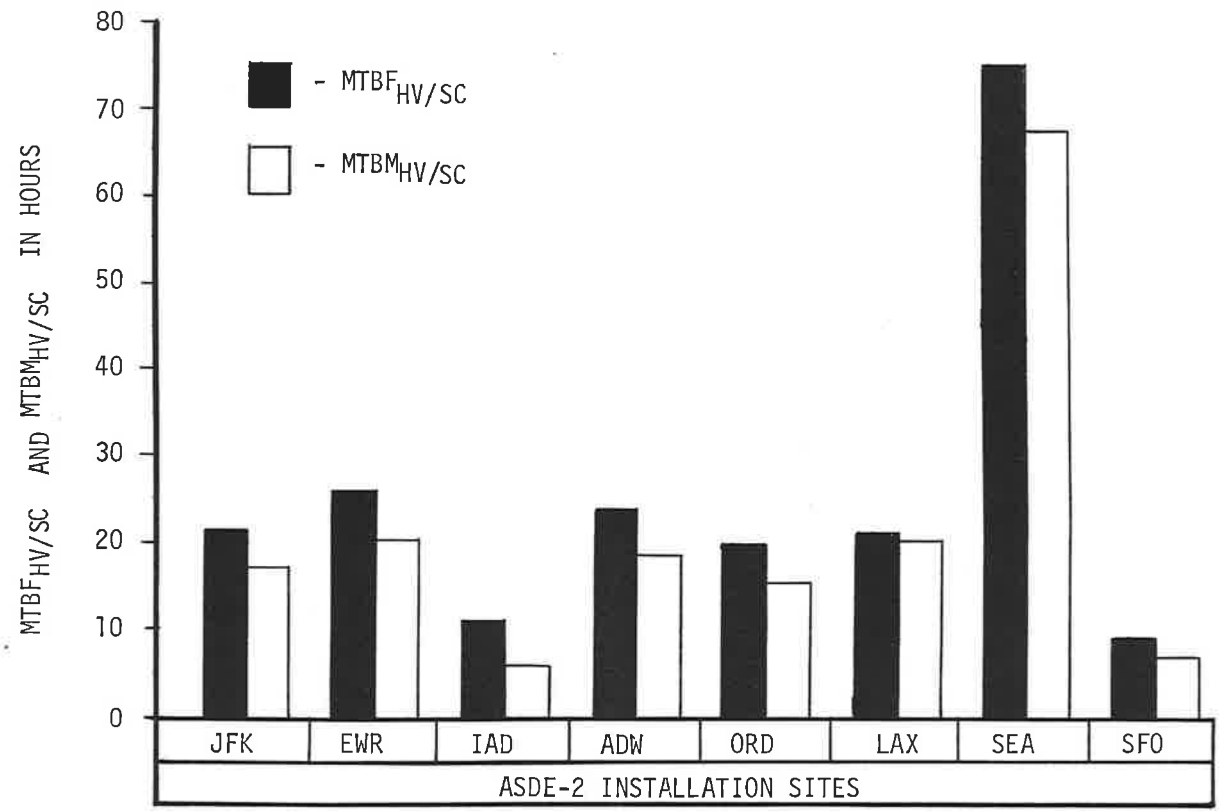

FIGURE 2-1. $MTBF_{HV/SC}$ / $MTBM_{HV/SC}$ SUMMARY BY SITE

only assemblies in which significant cost effective reliability improvements can be achieved. It is projected that improvements in local oscillator, duplexer, modulator driver and power amplifier circuitry in these assemblies should eliminate approximately 70% of all single-channel failures and 60% of all system maintenance actions; incorporating these improvements an $MTBF_{HV/SC}$ of only 79 hours and an $MTBM_{HV/SC}$ of only 51 hours can be expected, assuming present usage conditions.

Distribution of single-channel failures by percent contribution of individual assemblies is shown in Figure 2-2 and distribution of maintenance actions is shown in the same manner in Figure 2-3. Figures 2-2 and 2-3 are based on data for all sites combined.

Failures and maintenance actions for assemblies other than the receiver and modulator are distributed in such a manner that if individual assemblies were corrected in order of failure rate contribution the maximum realizable improvement in $MTBF_{HV/SC}$ and $MTBM_{HV/SC}$, respectively would be 11 to 16 and 4 to 10 hours with each of the first eight assemblies successively corrected subsequent to incorporation of receiver and modulator corrective actions. Potential $MTBF_{HV/SC}$ and $MTBM_{HV/SC}$ improvements addressed above are graphed in Figure 2-4. Projections in Figure 2-4 assume the same ratio of high voltage hours to filament hours as is presently being accumulated.

Estimates of cost impact for incorporating receiver and modulator corrective actions indicates that duplexer and modulator recommendations would result in significant savings and solid state local oscillator recommendations would result in comparatively low net cost. It is estimated that overall savings from improvements in these areas would be approximately $151,000 over a five year period.

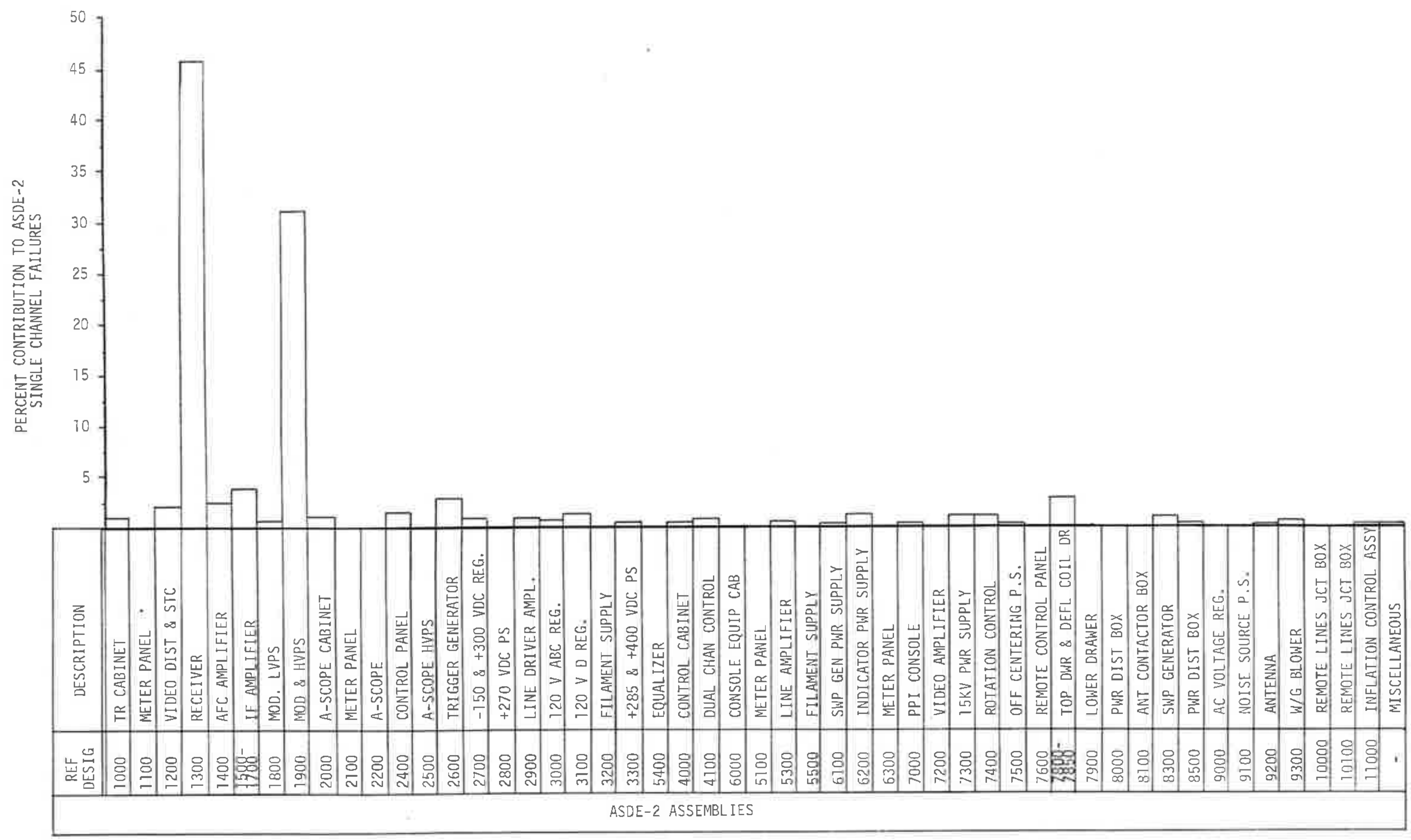

FIGURE 2-2. ASDE-2 SINGLE-CHANNEL FAILURE DISTRIBUTION

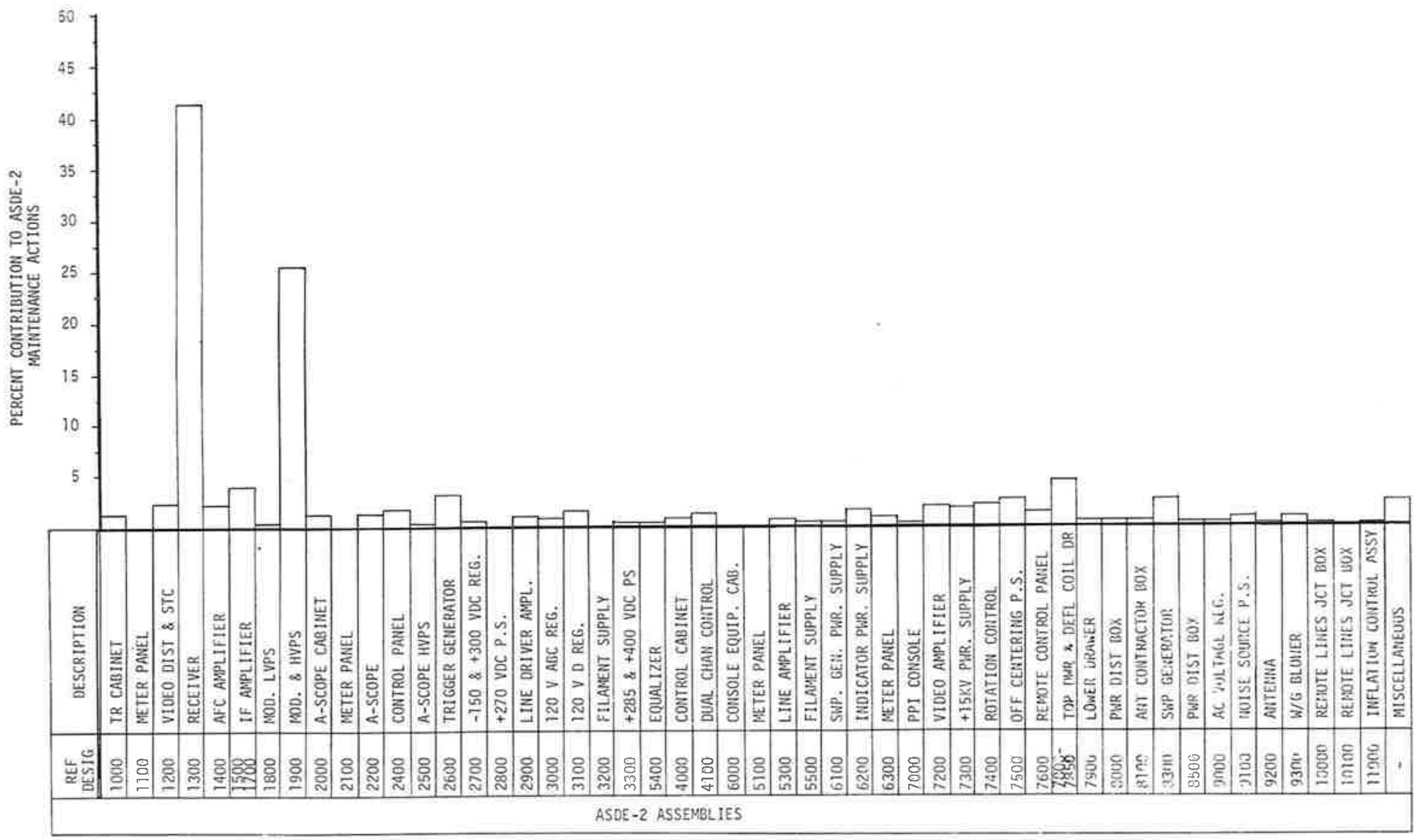

FIGURE 2-3. DISTRIBUTION OF ASDE-2 MAINTENANCE ACTIONS

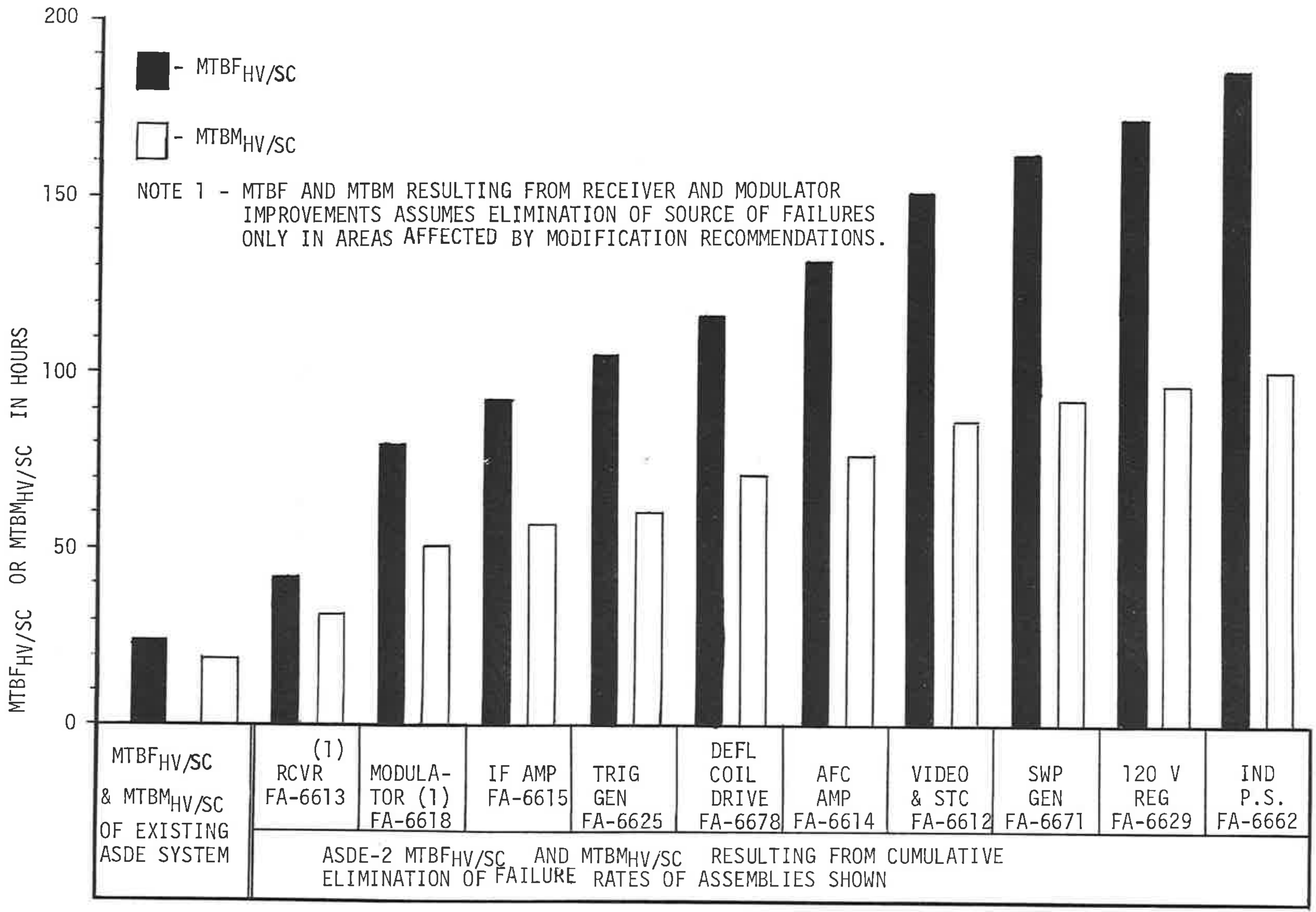

FIGURE 2-4. POTENTIAL FOR ASDE-2 RELIABILITY IMPROVEMENT

Contributions from the solid state duplexer, the solid state local oscillator and modulator modifications would be approximately $34,000, $-8,000, and $125,000 respectively. Combined cost impact of implementing all three recommendations is illustrated in Figure 2-5.

2.3 OPERATIONAL PROCEDURES

The purpose of the operational interviews was to determine present procedures for the use of the ASDE-2 and to determine what unique and standard procedures have evolved to optimize its utilization. It was further intended that areas would be identified where improved operational procedures could enhance the ASDE-2 operation.

Present procedures for operational usage of the ASDE-2 were determined by interviews. Data summaries were tabulated and indicate the following principle facts:

1. There are no set standards for air traffic personnel to verify that the ASDE-2 is performing satisfactorily for operational use.

2. Display accessibility determines ASDE-2 operational use. Increased functional usage occurs where the display is more accessible to controllers either because of the use of multiple or high brightness indicators. The low brightness PPI display significantly limits display accessibility.

3. Two airports use the ASDE-2 primarily for ground control, three airports use it primarily for local control and three use it both for local and for ground control.

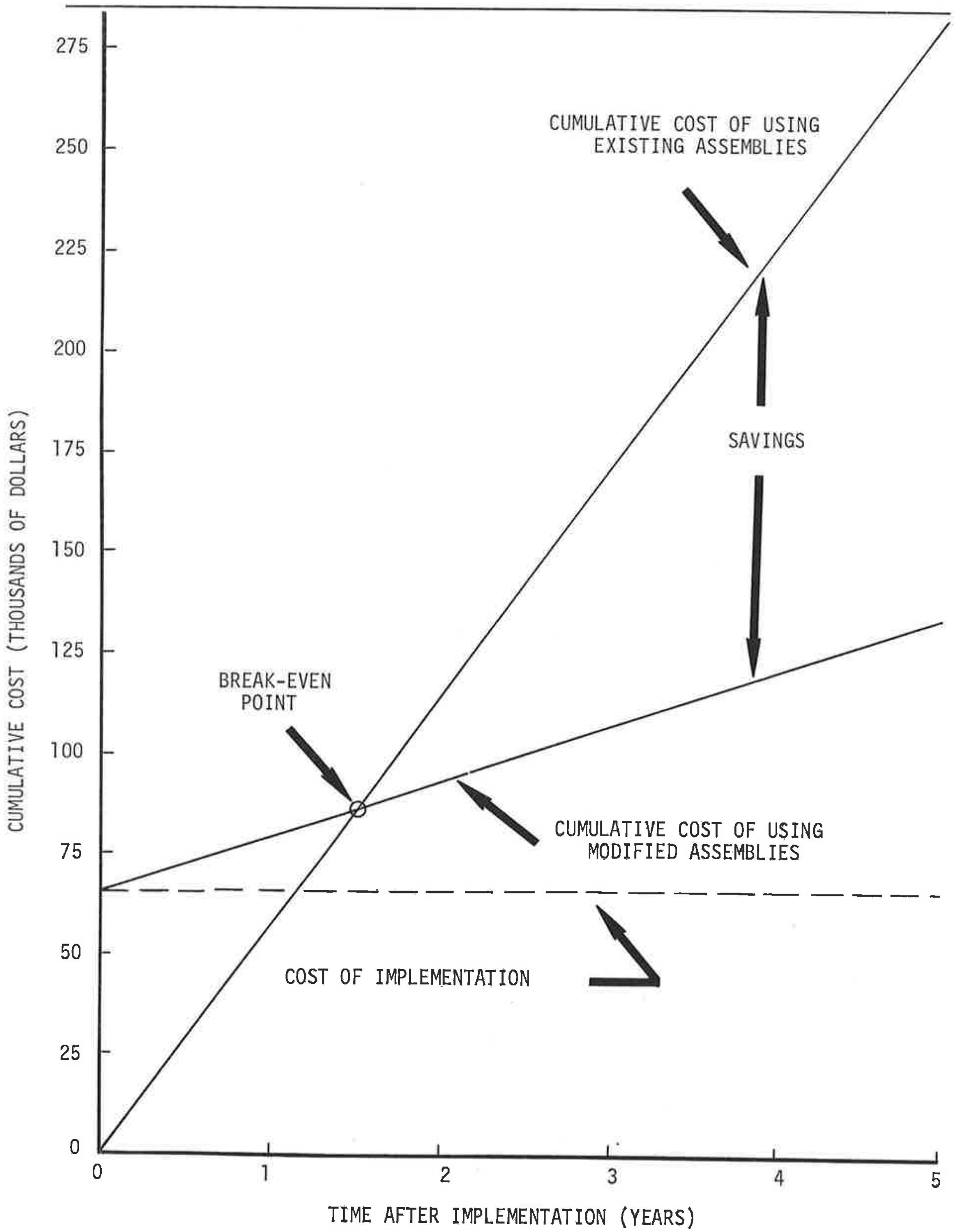

FIGURE 2-5. COMBINED COST IMPACT OF RECOMMENDED MODULATOR AND RECEIVER IMPROVEMENTS

4. The safety impact of the ASDE-2 is significant since its use has resulted in several "saves" when conflicts have existed.

5. The low amount of usage of the ASDE-2 is apparently caused by poor performance. It also appears that the limited use of the ASDE-2 permits gradual degradation of performance which in turn results in less use in a cyclic fashion. The result of this cyclic degradation is to reach a point where the radar is only used when visibility is so poor that there are no alternatives. It appears that this point has been reached.

6. The ASDE-2 cannot be used in moderate to heavy rain or snow because of display "white-out". This is apparently due to the under-illumination of the csc^2 antenna pattern, the poor circular polarization being achieved and the increased backscatter at the 24 GHz frequency.

7. A problem was reported with the use of the ASDE-2/BRITE conversion both at Kennedy and O'Hare that moving targets have poor signal strength and are hard to detect.

2.4 PERFORMANCE MEASUREMENTS

The primary objective of performance measurements was to determine overall resolution of each ASDE-2. The second objective of the tests was to qualitatively determine if the ellipticity of polarization of the antenna is a problem.

Present performance status of the ASDE-2's is represented by the following:

1. The average azimuth resolution was 0.53 degrees which is 1.39 times the system resolution specification of .38 degrees.

2. The average range resolution was 44.3 feet which is 2.2 times the ASDE-2 specification of 20 feet.

3. Antenna ellipticity measurements, performed on the three west coast ASDE-2's, indicated cancellation ratios from four to nine db.

The following action is recommended to effect performance improvements.

Improve the bandwidth of the receiver and video amplifiers to achieve specified range resolution. Further analysis of the ASDE-2 circuits are necessary to determine specific improvements in tuning and alignment or in modifications.

3. RELIABILITY/MAINTAINABILITY

Maintenance data consisting of copies of Facilities Maintenance Logs (FAA Form 406C), information from Technical Performance Records (FAA Form 418), tube replacement logs and interviews with maintenance personnel were used as the basis for the reliability/maintainability analysis. In addition the installations were visited to provide familiarization with features which might impact reliability or maintainability.

Resulting information is provided in the following categories.

1. Maintenance Data
2. Assessments
3. Conclusions
4. Recommendations

3.1 MAINTENANCE DATA

Maintenance data provided in this section is the primary basis for assessments, conclusions and recommendations presented in sections 3.2, 3.3, and 3.4. Information relative to maintenance actions and failures is addressed in 3.1.1 and corresponding hours of equipment operation are addressed in 3.1.2.

3.1.1 Maintenance Actions and Failures

Maintenance action and failure data was extracted from Facility Maintenance Logs, FAA Form 406C for periods of 22 to 30 months from 1 January 1970 through 30 June 1972 for the various sites. Periods assessed are shown in Figure 3-1 and were dependent on availability for detailed review of log books which were still actively in use at

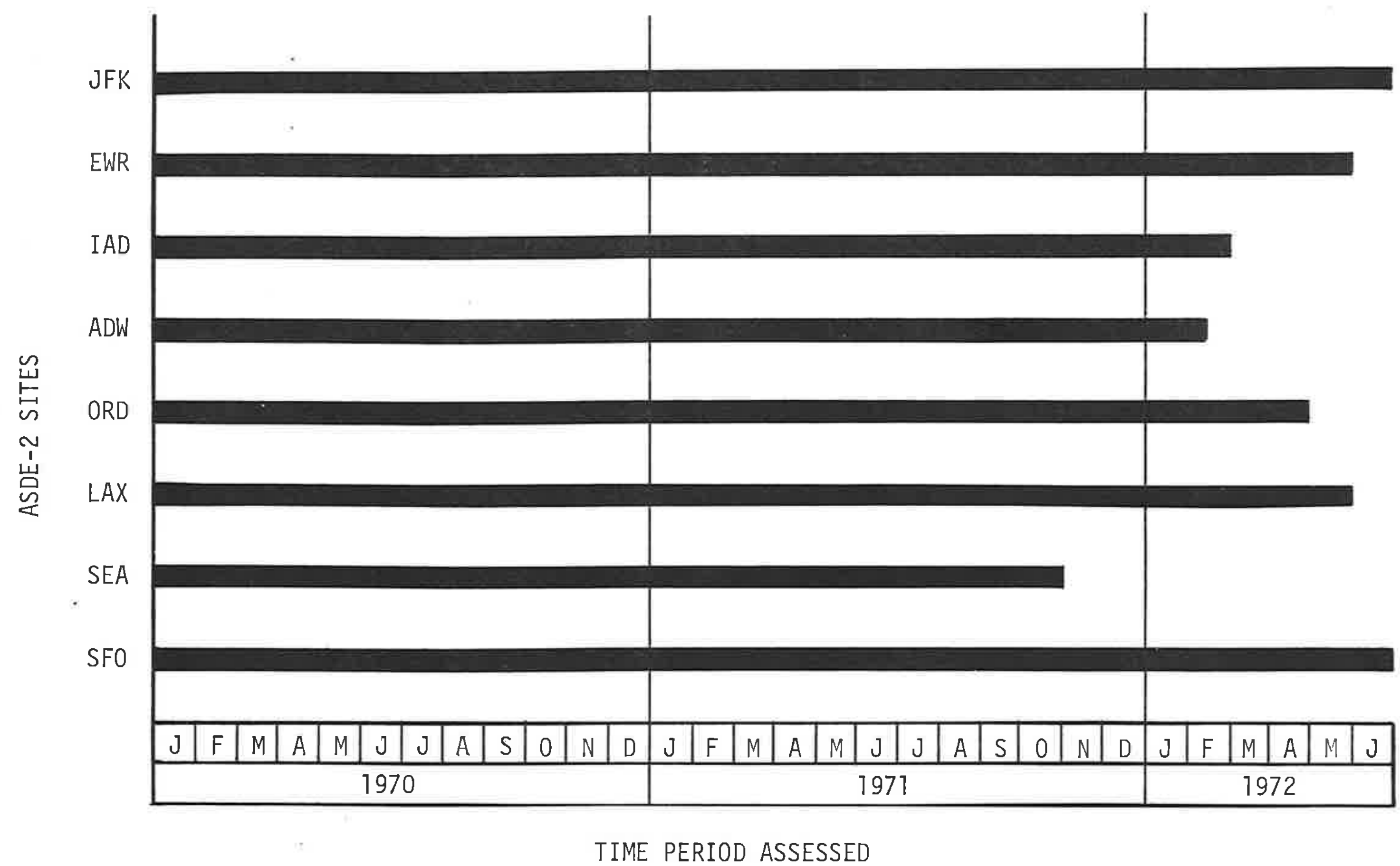

FIGURE 3-1. TIME PERIOD FOR WHICH ASDE-2 STATUS WAS ASSESSED AT EACH SITE

individual sites. Maintenance actions and failure data for these periods are summarized in the following tables:

1. Table 3-1. Unscheduled Maintenance Actions
2. Table 3-2. Percent Contribution of Assemblies to Maintenance Actions
3. Table 3-3. Single-Channel Failures (1)
4. Table 3-4. Percent Contribution of Assemblies to Single-Channel Failures
5. Table 3-5. Fifteen Most Frequently Replaced Components
6. Table 3-6. Unscheduled Adjustments

3.1.1.1 Unscheduled Maintenance Actions and Associated Assemblies

Table 3-1 reflects actual quantities of unscheduled maintenance actions associated with each aasembly at each ASDE site. These quantities are used in section 3.2 to calculate MTBM. Distribution of maintenance actions by assembly and month is shown in Appendix C for each site.

Table 3-2 is a summary of the percent of total maintenance actions associated with each assembly by site as well as percent of single-channel piece part complexity contained in each assembly. This table normalizes data presented in Table 3-1 to allow a more meaningful comparison of the effect individual assemblies have on maintenance required at different sites. It also indicates which assemblies require a disproportionate amount of maintainance compared to their piece part complexity.

3.1.1.2 Single-channel Failures and Associated Assemblies

Table 3-3 reflects actual quantities of single-channel failures

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(1) Single-channel failure is defined in paragraph 3.2.

TABLE 3-1. UNSCHEDULED MAINTENANCE ACTIONS

REF DESIG	ASSEMBLY DESCRIPTION	QUANTITY OF UNSCHEDULED MAINTENANCE ACTIONS DURING PERIODS ASSESSED								
		JFK	EWR	IAD	ADW	ORD	LAX	SEA	SFO	TOTAL
1000	TR CABINET	6	0	2	2	1	1	0	0	12
1100	METER PANEL	0	0	0	0	0	0	0	0	0
1200	VIDEO DIST & STC	6	0	7	5	7	4	3	4	36
1300	RECEIVER	141	55	144	80	119	66	62	35	702
1400	AFC AMPLIFIER	11	2	5	3	9	0	3	1	34
1500-1700	IF AMPLIFIER	19	1	7	5	13	11	1	13	70
1800	MOD LVPS	2	1	0	0	0	0	1	1	5
1900	MOD & HVPS	108	64	45	49	51	39	50	26	432
2000	A-SCOPE CABINET	4	3	1	3	1	0	2	0	14
2100	METER PANEL	0	0	0	0	0	0	0	0	0
2200	A-SCOPE	4	2	0	1	5	0	0	0	12
2400	CONTROL PANEL	4	2	2	0	3	2	2	4	19
2500	A-SCOPE HVPS	1	0	0	3	1	0	0	0	5
2600	TRIGGER GEN	10	1	6	4	9	3	8	6	47
2700	-150 + 300 VDC REG	2	0	1	0	0	1	0	1	5

TABLE 3-1. UNSCHEDULED MAINTENANCE ACTIONS (CONTINUED)

REF DESIG	ASSEMBLY DESCRIPTION	QUANTITY OF UNSCHEDULED MAINTENANCE ACTIONS DURING PERIODS ASSESSED								
		JFK	EWR	IAD	ADW	ORD	LAX	SEA	SFO	TOTAL
2800	+270 VDC P.S.	0	0	0	0	0	0	0	0	0
2900	LINE DRIVER AMP	1	0	1	1	2	1	1	1	8
3000	120 V ABC REG	0	0	0	0	2	0	0	3	5
3100	120V D REG	2	2	1	2	1	2	1	2	13
3200	FILAMENT SUPPLY	0	0	0	0	0	0	0	0	0
3300	+285 & +400 VDC PS	0	0	1	0	0	0	0	0	1
5400	EQUALIZER	0	0	0	0	0	2	0	0	2
4000	CONTROL CABINET	0	0	2	1	1	0	0	0	4
4100	DUAL-CHAN CONTROL	0	1	6	0	1	0	0	0	8
6000	CONSOLE EQUIP CAB	0	0	0	0	0	0	0	0	0
5100	METER PANEL	0	0	0	0	0	0	0	0	0
5300	LINE AMPLIFIER	1	0	2	0	0	0	0	0	3
5500	FILAMENT SUPPLY	0	0	0	0	0	0	0	0	0
6100	SWP GEN PWR SUPPLY	0	1	0	1	0	0	0	0	2
6200	INDICATOR PWR SUPPLY	3	2	3	4	3	0	0	4	19

TABLE 3-2. PERCENT CONTRIBUTION OF ASSEMBLIES TO MAINTENANCE ACTIONS

REF DESIG	ASSEMBLY DESCRIPTION	% SINGLE CHANNEL COMPLEXITY	PERCENT OF SITE MAINTENANCE ACTIONS RELATED TO ASSEMBLY								
			JFK	EWR	IAD	ADW	ORD	LAX	SEA	SFO	ALL SITES
1000	TR CABINET	.4	1.7	0	.7	1.0	.4	.7	0	0	.7
1100	METER PANEL	.3	0	0	0	0	0	0	0	0	0
1200	VIDEO DIST & STC	5.3	1.7	0	2.3	2.6	2.7	2.8	2.2	3.8	2.1
1300	RECEIVER	2.8	39.0	27.9	47.8	41.0	45.2	45.4	44.6	33.4	41.2
1400	AFC AMPLIFIER	3.6	3.1	1.1	1.7	1.5	3.4	0	2.2	1.0	2.0
1500-1700	IF AMPLIFIER	22.6	5.4	.5	2.3	2.6	4.9	7.6	.7	12.4	4.1
1800	MOD LVPS	2.0	.6	.5	0	0	0	0	.7	1.0	.3
1900	MOD & HVPS	4.1	30.1	33.7	14.9	25.2	19.4	21.9	35.9	24.8	25.6
2000	A-SCOPE CABINET	.5	1.1	1.6	.3	1.5	.4	0	1.4	0	.8
2100	METER PANEL	.5	0	0	0	0	0	0	0	0	0
2200	A-SCOPE	8.6	1.1	1.1	0	.5	1.9	0	0	0	.7
2400	CONTROL PANEL	1.5	1.1	1.1	.7	0	1.1	1.4	1.4	3.8	1.1
2500	A-SCOPE HVPS	.4	.3	0	0	1.5	.4	0	0	0	.3
2600	TRIGGER GENERATOR	3.3	2.8	.5	2.0	2.1	3.4	2.1	5.8	5.7	2.8

TABLE 3-2. PERCENT CONTRIBUTION OF ASSEMBLIES TO MAINTENANCE ACTIONS (CONTINUED)

REF DESIG	ASSEMBLY DESCRIPTION	% SINGLE CHANNEL COMPLEXITY	PERCENT OF SITE MAINTENANCE ACTIONS RELATED TO ASSEMBLY								
			JFK	EWR	IAD	ADW	ORD	LAX	SEA	SFO	ALL SITES
2700	-150, +300 VDC REG	2.1	.6	0	.3	0	0	.7	0	1.0	.3
2800	+270 VDC PS	.3	0	0	0	0	0	0	0	0	0
2900	LINE DRIVER AMP	3.4	.3	0	.3	.5	.8	.7	.7	1.0	.5
3000	120V ABC REG	4.3	0	0	0	0	.8	0	0	2.9	.3
3100	120V D REG	1.6	.6	1.1	.3	1.0	.4	1.4	.7	1.9	.8
3200	FILAMENT SUPPLY	.1	0	0	0	0	0	0	0	0	0
3300	+285, +400 VDC PS	.6	0	0	.3	0	0	0	0	0	.1
5400	EQUALIZER	1.8	0	0	0	0	0	1.4	0	0	.1
4000	CONTROL CABINET	.3	0	0	.7	.5	.4	0	0	0	.2
4100	DUAL-CHAN CONT	.6	0	.5	2.0	0	.4	0	0	0	.5
6000	CONSOLE EQUIP CAB	.4	0	0	0	0	0	0	0	0	0
5100	METER PANEL	.3	0	0	0	0	0	0	0	0	0
5300	LINE AMPLIFIER	4.1	.3	0	.7	0	0	0	0	0	.2
5500	FILAMENT SUPPLY	< .1	0	0	0	0	0	0	0	0	0

TABLE 3-2. PERCENT CONTRIBUTION OF ASSEMBLIES TO MAINTENANCE ACTIONS (CONTINUED)

REF DESIG	ASSEMBLY DESCRIPTION	% SINGLE CHANNEL COMPLEXITY	PERCENT OF SITE MAINTENANCE ACTIONS RELATED TO ASSEMBLY								
			JFK	EWR	IAD	ADW	ORD	LAX	SEA	SFO	ALL SITES
6100	SWP GEN PWR SUPPLY	1.0	0	.5	0	.5	0	0	0	0	.1
6200	INDICATOR PWR SUPPLY	1.5	.9	1.1	1.0	2.1	1.1	0	0	1.9	1.0
6300	METER PANEL	.5	0	0	0	0	0	.7	0	0	.1
7000	PPI CONSOLE	.1	.3	2.1	0	.5	0	0	0	0	.4
7200	VIDEO AMPLIFIER	1.5	.3	.5	.7	0	.4	0	.7	0	.4
7300	15KV PWR SUPPLY	1.3	1.1	5.3	2.3	1.5	.4	2.1	.7	1.0	1.8
7400	ROTATION CONTROL	1.7	.6	1.1	.7	.5	1.1	0	0	0	.6
7500	OFF-CENTERING PS	2.5	.3	.5	0	0	.4	0	0	0	.2
7600	REMOTE CONTROL PANEL	1.1	0	0	1.7	0	.4	0	0	0	.4
7800-7850	TOP DWR & DEFL COIL DRIVE	2.2	2.3	10.5	7.0	3.6	3.8	4.8	0	0	4.3
7900	LOWER DRAWER	.2	0	.5	0	0	0	0	0	0	.1
8000	PWR DIST BOX	.5	.3	0	0	0	0	0	0	0	.1
8100	ANT CONTRACTOR BOX	.7	.3	0	0	0	0	0	0	0	.1
8300	SWP GENERATOR	7.2	.6	3.2	3.7	4.1	3.8	1.4	0	0	2.4
8500	PWR DIST BOX	.3	.3	0	.3	0	0	0	0	0	.1
9000	AC VOLTAGE REG	< .1	0	.5	0	0	0	0	0	0	.1

TABLE 3-2. PERCENT CONTRIBUTION OF ASSEMBLIES TO MAINTENANCE ACTIONS (CONTINUED)

REF DESIG	ASSEMBLY DESCRIPTION	% SINGLE CHANNEL COMPLEXITY	PERCENT OF SITE MAINTENANCE ACTIONS RELATED TO ASSEMBLY								
			JFK	EWR	IAD	ADW	ORD	LAX	SEA	SFO	ALL SITES
9100	NOISE SOURCE PS	.8	0	1.1	.3	.5	.4	0	0	0	.3
9200	ANTENNA	.1	0	.5	0	0	0	0	.7	0	.1
9300	W/G BLOWER	1.0	0	1.1	1.3	1.5	0	0	0	1.0	.5
10000	REMOTE LINES JCT BOX	.1	0	1.1	0	0	.4	0	0	0	.1
10100	REMOTE LINES JCT BOX	0	0	0	0	0	0	0	0	0	0
11000	INFLATION CONTROL	.1	.6	0	0	0	0	0	0	1.0	.1
-	MISCELLANEOUS	0	2.0	2.7	3.0	3.5	2.0	0	1.4	3.0	2.5

TABLE 3-3. SINGLE-CHANNEL FAILURES

REF DESIG	ASSEMBLY DESCRIPTION	QUANTITY OF SINGLE-CHANNEL FAILURES DURING PERIODS ASSESSED								
		JFK	EWR	IAD	ADW	ORD	LAX	SEA	SFO	TOTAL
1000	TR CABINET	2	0	0	3	0	1	0	0	6
1100	METER PANEL	0	0	0	0	0	0	0	0	0
1200	VIDEO DIST & STC	0	0	6	5	7	4	3	4	29
1300	RECEIVER	120	51	116	70	112	66	58	36	629
1400	AFC AMPLIFIER	11	2	5	3	9	0	3	1	34
1500-1700	IF AMPLIFIER	15	1	2	4	11	11	1	9	54
1800	MOD LVPS	1	1	0	0	0	0	1	0	3
1900	MOD & HVPS	107	62	47	48	50	38	50	24	426
2000	A-SCOPE CABINET	3	1	0	0	1	0	2	0	7
2100	METER PANEL	0	0	0	0	0	0	0	0	0
2200	A-SCOPE	0	0	0	0	0	0	0	0	0
2400	CONTROL PANEL	3	2	2	0	0	1	0	2	10
2500	A-SCOPE HVPS	0	0	0	0	0	0	0	0	0
2600	TRIGGER GEN	8	1	7	2	6	2	7	6	39
2700	-150 +300 VDC REG	2	0	1	0	0	1	0	1	5

TABLE 3-3. SINGLE-CHANNEL FAILURES (CONTINUED)

REF DESIG	ASSEMBLY DESCRIPTION	QUANTITY OF SINGLE-CHANNEL FAILURES DURING PERIODS ASSESSED								
		JFK	EWR	IAD	ADW	ORD	LAX	SEA	SFO	TOTAL
2800	+270 VDC P.S.	0	0	0	0	0	0	0	0	0
2900	LINE DRIVER AMP	0	0	0	1	2	1	0	1	5
3000	120V ABC REG	0	0	0	0	1	0	0	3	4
3100	120V D REG	2	2	1	2	1	2	1	2	13
3200	FILAMENT SUPPLY	0	0	0	0	0	0	0	0	0
3300	+285 & +400 VDC PS	0	0	1	0	0	0	0	0	1
5400	EQUALIZER	0	0	0	0	0	0	0	0	0
4000	CONTROL CABINET	0	0	1	0	1	0	0	0	2
4100	DUAL-CHAN CONTROL	0	0	5	0	1	0	0	0	6
6000	CONSOLE EQUIP CAB.	0	0	0	0	0	0	0	0	0
5100	METER PANEL	0	0	0	0	0	0	0	0	0
5300	LINE AMPLIFIER	1	0	1	0	0	0	0	0	2
5500	FILAMENT SUPPLY	0	0	0	0	0	0	0	0	0
6100	SWP GEN PWR SUPPLY	0	1	0	1	0	0	0	0	2
6200	INDICATOR PWR SUPPLY	3	2	3	2	1	0	0	2	13

TABLE 3-3. SINGLE-CHANNEL FAILURES (CONTINUED)

REF DESIG	ASSEMBLY DESCRIPTION	QUANTITY OF SINGLE-CHANNEL FAILURES DURING PERIODS ASSESSED								
		JFK	EWR	IAD	ADW	ORD	LAX	SEA	SFO	TOTAL
6300	METER PANEL	0	0	0	0	0	0	0	0	0
7000	PPI CONSOLE	0	1	0	0	0	0	0	0	1
7200	VIDEO AMPLIFIER	0	0	0	0	0	0	0	0	0
7300	15KV PWR SUPPLY	1	2	3	1	0	3	1[(1)]	0	11[(1)]
7400	ROTATION CONTROL	1	2	4	1	1	0	1[(1)]	0	10[(1)]
7500	OFF-CENTERING P.S.	0	1	0	0	1	0	0	0	2
7600	REMOTE CONTROL PANEL	0	0	0	0	0	0	0	0	0
7800-7850	TOP DWR & DEFL. COIL DR.	3	10	8	2	2	6	4[(1)]	0	35[(1)]
7900	LOWER DRAWER	0	0	0	0	0	0	0	0	0
8000	PWR DIST BOX	0	0	0	0	0	0	0	0	0
8100	ANT CONTACTOR BOX	0	0	0	0	0	0	0	0	0
8300	SWEEP GEN	0	2	6	3	2	1	0	1	15
8500	PWR DIST BOX	1	0	1	0	0	0	0	1	3
9000	AC VOLTAGE REG.	0	0	0	0	0	0	0	0	0
9100	NOISE SOURCE P.S.	0	0	0	0	0	0	0	0	0

TABLE 3-3. SINGLE-CHANNEL FAILURES (CONTINUED)

REF DESIG	ASSEMBLY DESCRIPTION	QUANTITY OF SINGLE-CHANNEL FAILURES DURING PERIODS ASSESSED								
		JFK	EWR	IAD	ADW	ORD	LAX	SEA	SFO	TOTAL
9200	ANTENNA	0	1	0	1	0	0	0	0	2
9300	W/G BLOWER	0	1	2	2	0	0	0	1	6
10000	REMOTE LINES JCT BOX	0	0	0	0	0	0	0	0	0
10100	REMOTE LINES JCT BOX	0	0	0	0	0	0	0	0	0
11000	INFLATION CONT ASSY	1	0	0	0	0	0	0	0	1
-	MISCELLANEOUS	0	0	0	0	0	0	1	0	1
-	TOTAL	285	146	222	151	209	138	133[1]	94	1383[1]

(1) ESTIMATED. (ACTUAL DATA FOR SEA TOWER CAB PPI NOT OBTAINED.)

associated with each assembly at each ASDE site. These quantities are used in section 3.2 to calculate MTBF. Distribution of single-channel failures by month is very similar to that of maintenance actions shown in Appendix C.

Table 3-4 is a summary of percent of single-channel failures associated with each assembly by site as well as percent piece part complexity. This table allows the same comparisons of assembly contributions to single-channel failures that Table 3-2 did for maintenance actions.

3.1.1.3 Component Replacements

A summary of parts replaced during unscheduled maintenance actions is provided in Table 3-5 by reference designator, part number and site for the 15 most frequently replaced parts. The large number of 6AK5's replaced is due to tube quality, the number used (78 per channel) and the practice of "tube checking" in lieu of circuit tuning. More detailed component replacement data is contained in Appendix D. This data reflects total number of parts replaced during unscheduled maintenance actions by reference designator, part number, year and site.

3.1.1.4 Adjustments

Table 3-6 provides a summary of quantities of unscheduled adjustments by site and type of adjustment. It can be seen that AFC alignment was the only chronic adjustment problem indicated by facility maintenance logs.

3.1.1.5 Operator/Maintenance Induced Failure Incidents

There is little indication in ASDE logs of failure incidents caused by improper operator or maintenance actions other than the following:

TABLE 3-4. PERCENT CONTRIBUTION OF ASSEMBLIES TO SINGLE-CHANNEL FAILURES

REF DESIG	ASSEMBLY DESCRIPTION	% SINGLE CHANNEL COMPLEXITY	PERCENT OF SITE SINGLE-CHANNEL FAILURES RELATED TO ASSEMBLY								
			JFK	EWR	IAD	ADW	ORD	LAX	SEA	SFO	ALL SITES
1000	TR CABINET	.4	.7	0	0	2.0	0	.7	0	0	.4
1100	METER PANEL	.3	0	0	0	0	0	0	0	0	0
1200	VIDEO DIST & STC	5.3	0	0	2.7	3.3	3.3	2.9	2.3	4.3	2.1
1300	RECEIVER	2.8	42.1	34.9	52.3	46.3	53.6	47.8	43.6	38.3	45.6
1400	AFC AMPLIFIER	3.6	3.9	1.4	2.3	2.0	4.3	0	2.3	1.1	2.5
1500-1700	IF AMPLIFIER	22.6	5.3	.7	.9	2.6	5.3	8.0	.8	9.6	3.9
1800	MOD LVPS	2.0	<.1	.7	0	0	0	0	.8	0	.2
1900	MOD & HVPS	4.1	37.6	42.4	21.2	31.8	23.9	27.5	37.6	25.5	30.8
2000	A-SCOPE CABINET	.5	1.1	.7	0	0	.5	0	1.5	0	.5
2100	METER PANEL	.5	0	0	0	0	0	0	0	0	0
2200	A-SCOPE	8.6	0	0	0	0	0	0	0	0	0
2400	CONTROL PANEL	1.5	1.1	1.4	.9	0	0	.7	0	2.1	.7
2500	A-SCOPE HVPS	.4	0	0	0	0	0	0	0	0	0
2600	TRIGGER GENERATOR	3.3	2.8	.7	3.2	1.3	2.9	1.4	5.3	6.4	2.8

TABLE 3-4. PERCENT CONTRIBUTION OF ASSEMBLIES TO SINGLE-CHANNEL FAILURES (CONTINUED)

REF DESIG	ASSEMBLY DESCRIPTION	% SINGLE CHANNEL COMPLEXITY	PERCENT OF SITE SINGLE-CHANNEL FAILURES RELATED TO ASSEMBLY								
			JFK	EWR	IAD	ADW	ORD	LAX	SEA	SFO	ALL SITES
2700	-150, +300 VDC REG	2.1	.7	0	.5	0	0	.7	0	1.1	.4
2800	+270 VDC PS	.3	0	0	0	0	0	0	0	0	0
2900	LINE DRIVER AMP	3.4	0	0	0	.7	1.0	.7	0	1.1	.4
3000	120V ABC REG	4.3	0	0	0	0	.5	0	0	3.2	.3
3100	120V D REG	1.6	.7	1.4	.5	1.3	.5	1.4	.8	2.1	.9
3200	FILAMENT SUPPLY	.1	0	0	0	0	0	0	0	0	0
3300	+285, +400 VDC PS	.6	0	0	.5	0	0	0	0	0	.1
5400	EQUALIZER	1.8	0	0	0	0	0	0	0	0	0
4000	CONTROL CABINET	.3	0	0	.5	0	.5	0	0	0	.1
4100	DUAL-CHAN CONT	.6	0	0	2.3	0	.5	0	0	0	.4
6000	CONSOLE EQUIP CAB	.4	0	0	0	0	0	0	0	0	0
5100	METER PANEL	.3	0	0	0	0	0	0	0	0	0
5300	LINE AMPLIFIER	4.1	<.1	0	.5	0	0	0	0	0	.1
5500	FILAMENT SUPPLY	<.1	0	0	0	0	0	0	0	0	0

TABLE 3-4. PERCENT CONTRIBUTION OF ASSEMBLIES TO SINGLE-CHANNEL FAILURES (CONTINUED)

REF DESIG	ASSEMBLY DESCRIPTION	% SINGLE CHANNEL COMPLEXITY	PERCENT OF SITE SINGLE-CHANNEL FAILURES RELATED TO ASSEMBLY								
			JFK	EWR	IAD	ADW	ORD	LAX	SEA	SFO	ALL SITES
6100	SWP GEN PWR SUPPLY	1.0	0	.7	0	.7	0	0	0	0	.1
6200	INDICATOR PWR SUPPLY	1.5	1.1	1.4	1.4	1.3	.5	0	0	2.1	.9
6300	METER PANEL	.5	0	0	0	0	0	0	0	0	0
7000	PPI CONSOLE	.1	0	.7	0	0	0	0	0	0	.1
7200	VIDEO AMPLIFIER	1.5	0	0	0	0	0	0	0	0	0
7300	15KV PWR SUPPLY	1.3	<.1	1.4	1.4	.7	0	2.2	.8	0	.7
7400	ROTATION CONTROL	1.7	<.1	1.4	1.8	.7	.5	0	.8	0	.7
7500	OFF-CENTERING P.S.	2.5	0	.7	0	0	.5	0	0	0	.1
7600	REMOTE CONTROL PANEL	1.1	0	0	0	0	0	0	0	0	0
7800-7850	TOP DWR & DEFL COIL DRIVE	2.2	1.1	6.9	3.6	1.3	1.0	4.3	3.0	0	2.6
7900	LOWER DRAWER	.2	0	0	0	0	0	0	0	0	0
8000	PWR DIST BOX	.5	0	0	0	0	0	0	0	0	0
8100	ANT CONTACTOR BOX	.7	0	0	0	0	0	0	0	0	0
8300	SWP GENERATOR	7.2	0	1.4	2.7	2.0	1.0	.7	0	1.1	1.1

TABLE 3-4. PERCENT CONTRIBUTION OF ASSEMBLIES TO SINGLE-CHANNEL FAILURES (CONTINUED)

REF DESIG	ASSEMBLY DESCRIPTION	% SINGLE CHANNEL COMPLEXITY	PERCENT OF SITE SINGLE-CHANNEL FAILURES RELATED TO ASSEMBLY								
			JFK	EWR	IAD	ADW	ORD	LAX	SEA	SFO	ALL SITES
8500	PWR DIST BOX	.3	<.1	0	.5	0	0	0	0	1.1	.2
9000	AC VOLTAGE REG	<.1	0	0	0	0	0	0	0	0	0
9100	NOISE SOURCE PS	.8	0	0	0	0	0	0	0	0	0
9200	ANTENNA	.1	0	.7	0	.7	0	0	0	0	.1
9300	W/G BLOWER	1.0	0	.7	.9	1.3	0	0	0	1.1	.4
10000	REMOTE LINES JCT BOX	.1	0	0	0	0	0	0	0	0	0
10100	REMOTE LINES JCT BOX	0	0	0	0	0	0	0	0	0	0
11000	INFLATION CONTROL	.1	<.1	0	0	0	0	0	0	0	.1
-	MISCELLANEOUS	0	0	0	0	0	0	0	.8	0	.1

TABLE 3-5. FIFTEEN MOST FREQUENTLY REPLACED COMPONENTS

COMPONENTS REPLACED		QUANTITY OF COMPONENTS REPLACED								
REFERENCE DESIGNATOR	PART NUMBER	JFK	EWR	IAD	ADW	ORD	LAX	SEA	SFO	TOTAL
Note (1)	6AK5	131	13	187	121	134	72	15	97	770
CR1303,4	IN26AMR	59	21	64	26	117	55	38	7	387
V1902	3C45/6130	86	25	27	30	37	23	43	18	289
V1903,4,5	4PR60	53	59	22	21	33	18	10	1	217
V1301	2K50	38	13	17	20	27	25	17	13	170
CR1301,2	IN26,IN26R	21	4	25	12	33	13	4	1	113
V1303	BL-T-036	18	19	9	15	7	15	6	2	91
V1906	BL-M006	8	11	12	7	11	12	0	7	68
V1302	416B/6280	10	5	4	6	13	10	3	1	52
V1901	6AQ5A	13	3	7	7	4	8	3	0	45
7850	-	1	19	11	3	6	2	0 (2)	0	42
V2605	12ATTWA	4	0	3	4	4	1	4	4	24
V1405	12AX7	9	1	5	1	6	0	2	0	24
V2603	5687WA	4	1	1	0	3	1	1	1	12
V7302	1X2A	5	1	1	1	1	1	1	1	12

NOTE: (1) Amplifier tubes in IF strips
(2) Does not include tower cab indicator

TABLE 3-6. UNSCHEDULED ADJUSTMENTS

ADJUSTMENT PERFORMED	QUANTITY DURING PERIODS ASSESSED								
	JFK	EWR	IAD	ADW	ORD	LAX	SEA	SFO	TOTAL
AFC	39	6	75	19	15	3	15	13	185
STC	6		1	4					11
Rotation Control	1	2	3	4					10
Deflection Coil Drive	1	2	2	2	1	1			9
Equalizer				1		2			3
Trigger Generator			1	2					3
IF Amplifier						3			3
Modulator High Voltage			2						2
Crystal Current			1	1					2
120V Power Supply			1	1					2
Mag. Filament Voltage				1		1			2
Sweep Generator				2					2
Mag. Airflow Switch	1								1
15KV Power Supply			1						1
Vertical Centering				1					1

1. A few scattered incidents of operators inadvertently turning filament voltages off.

2. An instance of tower cab PPI console failure due to overheating caused by articles placed on top of the console covering the vent at the back.

3.1.1.6 Scheduled Maintenance Actions

Scheduled Maintenance is performed as required by Chapter 6 of FAA Handbook SMP 6330.1. Electron tubes found to be bad during system tube checks are essentially the only components replaced during this preventive maintenance activity. Other preventive maintenance actions consist primarily of performance checks, visual inspections, adjustments, cleaning and lubrication tasks.

3.1.2 Hours of Equipment Operation

Hours of equipment operation corresponding to maintenance actions and failures addressed in section 3.1.1 were obtained from elapsed time meter readings in Technical Performance Records, FAA Form 418, for most sites. However, hours of operation were determined from tube replacement records at sites which use revised 418 logs not containing elapsed time meter readings. Total hours of single-channel high voltage and filament voltage operation as well as average daily high voltage hours accumulated during the periods assessed are shown in Table 3-7.

3.1.2.1 High Voltage Operation

Average number of hours of high voltage operation accumulated varied greatly from site to site. The ASDE at San Francisco is commissioned only six months of each year during which time it is operated an average of approximately 1.6 hours per day. Seattle equipment is operated an

TABLE 3-7. HOURS OF SINGLE-CHANNEL OPERATION

SITE	PERIOD ASSESSED	TOTAL FILAMENT OPERATE HOURS	TOTAL HIGH VOLTAGE OPERATE HOURS	AVG. HIGH VOLTAGE OPERATE HOURS/DAY
JFK	1 JAN '70 - 30 JUN '72 (30 MONTHS)	43776	6095	6.7
EWR	1 JAN '70 - 31 MAY '72 (29 MONTHS)	42336	3746	4.3
IAD	1 JAN '70 - 29 FEB '72 (26 MONTHS)	37920	1811	2.3
ADW	1 JAN '70 - 9 FEB '72 (25 MONTHS)	36000	3483	4.5
ORD	1 JAN '70 - 30 APR '72 (28 MONTHS)	40848	4010	4.7
LAX	1 JAN '70 - 31 MAY '72 (29 MONTHS)	42336	2900	3.3
SEA	1 JAN '70 - 31 OCT '71 (22 MONTHS)	31296	9760	14.6
SFO	1 JAN '70 - 30 JUN '72 (30 MONTHS)	21888	750	1.6
ALL SITES	-	296400	32555	5.4

average of 14.6 hours per day throughout the year.

3.1.2.2 Filament Voltage Operation

The number of hours during which filament voltage is applied to each channel is essentially the same as calendar time for periods assessed at all sites except San Francisco. Filament voltages at San Francisco are only "ON" from 1 October to 1 April each year.

3.2 ASSESSMENTS

3.2.1 Definitions

Assessment of mean-time-between-failure (MTBF) and mean-time-between-maintenance (MTBM) were performed on the basis of single-channel operation; values were computed as follows:

1. $MTBF_{HV/SC}$ = (high voltage operating hours accumulated on each ASDE channel)/(corresponding quantity of single-channel failures [1])

2. $MTBM_{HV/SC}$ = (high voltage operating hours accumulated on each ASDE channel)/(corresponding quantity of unscheduled maintenance actions)

3. $MTBF_{LV/SC}$ = (hours of filament voltage operation accumulated on each ASDE channel)/ (corresponding quantity of single-channel failures)

4. $MTBM_{LV/SC}$ = (hours of filament voltage operation accumulated on each ASDE channel)/(corresponding quantity of unscheduled maintenance actions)

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(1) Single-channel failure is defined as failure of either ASDE channel, excluding the maintenance indicator, to operate in accordance with standards and tolerances specified in Chapter 4 of FAA Handbook SMP 6330.1.

Maintenance actions which were included in MTBM calculations but not in MTBF calculations are those associated with failures of non-essential functions such as meters and indicator lamps, self test circuitry, maintenance indicators, and adjustments or other maintenance performed to improve parameters which appeared to have already been within specified limits.

3.2.2 Results

Assessment of data for all sites combined revealed the following values of MTBF and MTBM.

1. $MTBF_{HV/SC}$ = 24 hours
2. $MTBM_{HV/SC}$ = 19 hours
3. $MTBF_{LV/SC}$ = 214 hours
4. $MTBM_{LV/SC}$ = 174 hours

Table 3-8 reflects MTBF and MTBM and the average number of days between unscheduled maintenance for each site. With little exception systems which had a higher ratio of high voltage operate hours to hours of filament operation reflected higher $MTBF_{HV/SC}$ and $MTBM_{HV/SC}$. Distribution of $MTBF_{LV/SC}$ and $MTBM_{LV/SC}$ by site tended to be more random. This is to be expected of electron tube-type equipment due to the greater dependence of tube failure rates on filament voltages than on high voltage operation.

3.3 CONCLUSIONS

Analysis of maintenance data and assessments from sections 3.1 and 3.2 resulted in the following significant conclusions:

1. Wide distribution of ASDE-2 failures severely limits the possibility for cost effective reliability improvements beyond those in the following paragraph 2.

TABLE 3-8. ASDE-2 RELIABILITY/MAINTAINABILITY ASSESSMENT SUMMARY

SITE	TIME PERIOD ASSESSED	HV OPERATE HOURS/YEAR (AVERAGE)	MTBF HV/S-C	MTBM HV/S-C	MTBF LV/S-C	MTBM LV/S-C	AVG. NO. OF DAYS BETWEEN UNSCHEDULED MAINTENANCE
JFK	1 JAN '70 - 30 JUN '72 (30 MONTHS)	2,440	21	17	154	123	2.6
EWR	1 JAN '70 - 31 MAY '72 (29 MONTHS)	1,500	26	20	290	220	4.6
IAD	1 JAN '70 - 29 FEB '72 (26 MONTHS)	840	11	6	171	126	2.6
ADW	1 JAN '70 - 9 FEB '72 (25 MONTHS)	1,530	23	18	238	185	3.9
ORD	1 JAN '70 - 30 APR '72 (28 MONTHS)	1,720	19	15	196	155	3.2
LAX	1 JAN '70 - 21 MAY '72 (29 MONTHS)	1,160	21	20	306	292	6.1
SEA	1 JAN '70 - 31 OCT '71 (22 MONTHS)	5,320	73	66	246	226	4.5
SFO	1 JAN '70 - 30 JUN '72 (30 MONTHS)	300	8	7	233	203	4.2
ALL SITES	-	14,810	24	19	214	174	4.0

2. Major problem areas are associated with the following system functions:

    a. Modulator
    b. Duplexer
    c. Local Oscillator

3. There are many component and application problem areas for which apparent solutions would not be cost effective.

4. The problem of cathode depletion due to barium evaporation is aggravated by continuous filament operation and limited high voltage operation. This largely accounts for the disproportionate quantity of tubes replaced at sites with less high voltage operation.

5. Maintenance procedures are essentially the same at all ASDE-2 sites.

6. ASDE-2 maintenance costs are a more direct function of filament operation than of high voltage operation.

Information relative to the above conclusions is addressed in paragraphs 3.3.1, 3.3.2, 3.3.3, 3.3.4, 3.3.5, and 3.3.6, respectively.

3.3.1 Distribution of Failures

Receiver Assembly, FA-6613 and Modulator Assembly, FA-6618 combined, comprise less than 7% of total ASDE-2 piece part complexity, yet are responsible for 67% of all unscheduled maintenance actions and 77% of all single-channel failures. Distribution of failures within the receiver and modulator is shown in Table 3 - 9.

Failure rates of other ASDE-2 assemblies are so randomly distributed that corrective actions to significantly improve their reliability would not be cost effective. Failure rates of all assemblies which individually contribute greater than 1% to the total ASDE single-channel failure rate are shown in Table 3 - 10.

TABLE 3-9. RECEIVER AND MODULATOR FAILURE CATEGORIES

ASSEMBLY	TYPE OF FAILURE		PERCENT CONTRIBUTION TO:	
	DESCRIPTION	REF DESIG	SINGLE-CHANNEL FAILURE RATE	ASSEMBLY FAILURE RATE
RECEIVER FA-6613	AFC CRYSTALS	CR1301, 2	3%	6%
	IF CRYSTALS	CR1303, 4	13	29
	L.O. TUBES	V1301	11	24
	L.O. ADJUSTMENTS	-	10	21
	TR TUBES	V1303	6	12
	PREAMP TUBES	V1302	2	5
	OTHER	-	1	3
	TOTAL	-	46	100
MODULATOR FA-6618	MOD. DRIVER TUBES	V1902	17%	56%
	POWER AMP. TUBES	V1903, 4, 5	7	21
	MAGNETRONS	V1906	4	14
	MAGNETRON BLOWER	B1901, S1903	1	3
	OTHER	-	2	6
	TOTAL	-	31	100

TABLE 3-10. HIGH[1] FAILURE RATE ASSEMBLIES

SYSTEM/ASSEMBLY/COMPONENT	ASSESSED FAILURE RATE (FAILURES/HOUR)
SINGLE-CHANNEL SYSTEM, FA-6600	.0423
RECEIVER ASSEMBLY, FA-6613	.0193
AFC CRYSTALS, CR1301, 2	.0010
IF CRYSTALS, CR1303, 4	.0058
L.O. TUBES, V1301	.0046
L.O. ADJUSTMENTS	.0041
TR TUBES, V1303	.0024
PREAMP TUBES, V1302	.0010
OTHER	.0004
MODULATOR ASSEMBLY, FA-6618	.0131
MOD. DRIVER TUBES, V1902	.0074
POWER AMP TUBES, V1903, 4, 5	.0027
MAGNETRONS, V1906	.0018
MAGNETRON BLOWER, B1901, S1903	.0004
OTHER	.0008
IF AMPLIFIER ASSEMBLY, FA-6615	.0017
PARTS	.0016
ADJUSTMENTS	.0001
TRIGGER GENERATOR ASSEMBLY, FA-6625	.0012
DEFL. COIL DRIVE ASSEMBLY, FA-6678	.0011
AFC AMPLIFIER ASSEMBLY, FA-6614	.0010
VIDEO DIST. & STC ASSEMBLY, FA-6612	.0009
SWP. GENERATOR ASSEMBLY, FA-6671	.0005

(1) ASSEMBLY FAILURE RATE >1% OF SYSTEM FAILURE RATE

Corrective action to make failure rates of crystals, local oscillator circuitry, TR tubes, modulator drivers, power amplifiers and magnetrons negligible in comparison with remaining system failure rate would result in an $MTBF_{HV/SC}$ of 79 hours and an $MTBM_{HV/SC}$ of 51 hours.

The lack of potential for significant cost effective reliability imrpovement outside of Receiver Assembly FA-6613 and Modulator Assembly FA-6618 is further emphasized by considering cost impact and reliability improvement associated with corrective action for IF Amplifier Assembly FA-6615. While the IF Amplifier is the highest contributor to single-channel failures exclusive of receiver and modulator assemblies it accounts for only 3.9% of such failures. Replacement with a solid state IF amplifier would result in an additional 13 hour improvement in system $MTBF_{HV/SC}$ and a 6 hour improvement in $MTBM_{HV/SC}$ at an estimated implementation cost of $26,000 and an estimated net combined cost of $10,000 for all ASDE sites after a five year period. This estimate is based on cost comparison of parts and direct labor for existing and solid state assemblies. Totally effective corrective action for other assemblies in order of failure rate contribution would result in minor improvements of approximately the same magnitude with each assembly corrected as shown in Figure 3-2.

3.3.2 Major Problem Areas

The primary contributors to ASDE-2 unreliability are:

1. Receiver Assembly, FA-6613
    a. Duplexer
    b. Local Oscillator
2. Modulator Assembly, FA-6618

This is supported by Tables 2-2 and 2-3 and data presented in preceding sections.

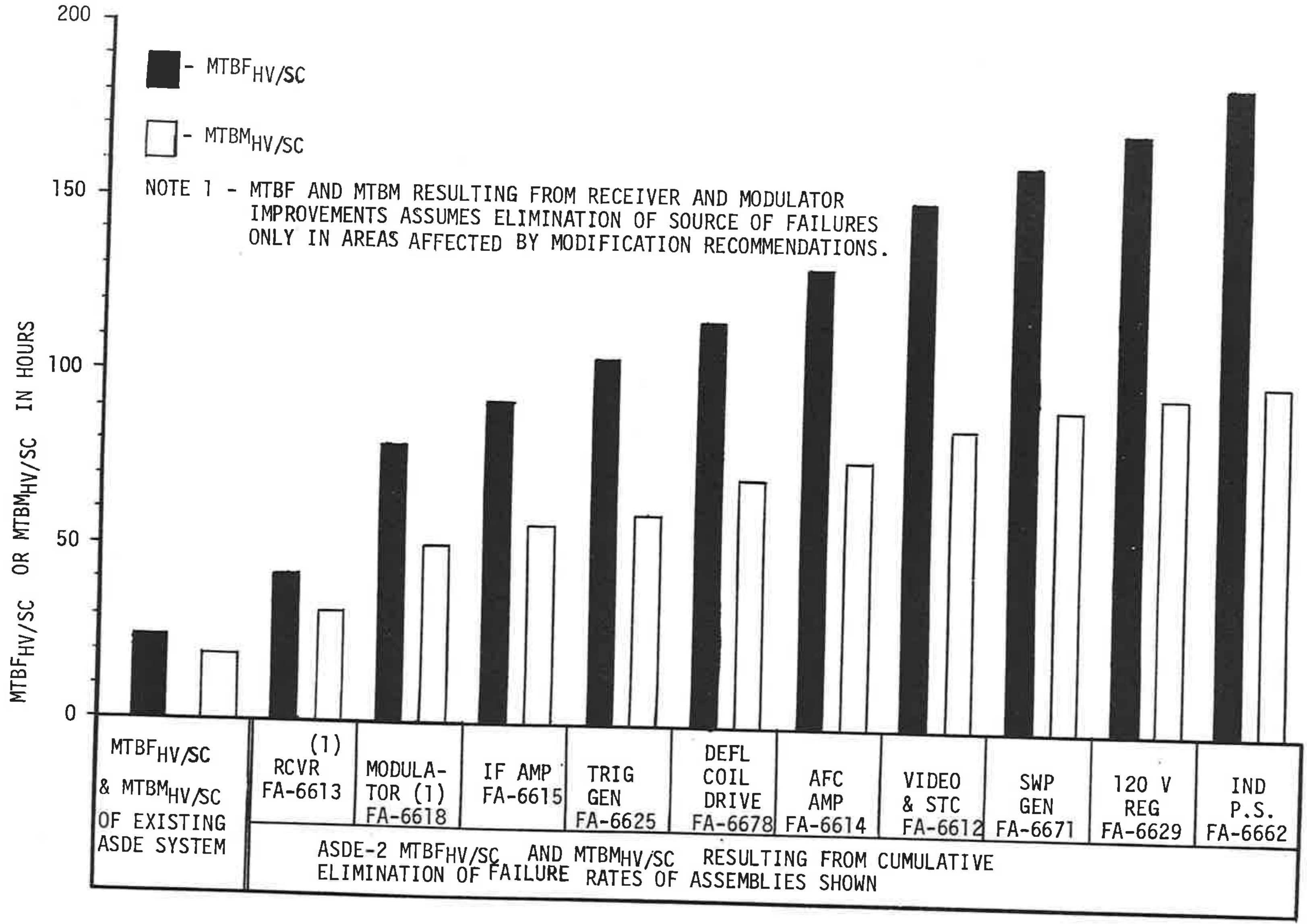


FIGURE 3-2. POTENTIAL FOR ASDE-2 RELIABILITY IMPROVEMENT

3.3.2.1 Duplexer

Maintenance data indicates a definite need for an improved duplexer to extend TR tube and IF crystal life. Only approximately 360 hours of high voltage operation are being accumulated between replacement of TR tubes and 200 hours between replacement of crystal pairs at sites with old configuration duplexers.

This is a previously identified problem area. As reported in FAA Report No. RD-65-122, dated October 1965, two prototype solid state duplexers were manufactured by Microwave Associated for evaluation in ASDE-2. The duplexers had a specified life of 5000 hours. No failures of crystals or TR tubes were reported during 2500 hours of evaluation testing in the NAFEC ASDE-2.

The two Microwave Associates duplexers were subsequently installed in ASDE-2 at O'Hare. One is still in service in channel A. The other was replaced in August 1971 with an old configuration ASDE-2 duplexer due to failure and unavailability of a solid state replacement. Figure 3-3 reflects replacement rates of crystal pairs, as a function of calendar time, in both Microwave Associates duplexers and the old configuration duplexer for the period from 1 January 1970 through 30 April 1972. Even where crystal failure rate appears constant for channel A only approximately 250 hours were accumulated between replacement of crystal pairs. Over the entire period assessed crystal pairs were replaced in channel A approximately every 90 high voltage operate hours.

The FAA Center in Oklahoma City has recently procured thirty-two production model solid state duplexers from Varian. The Varian duplexers were manufactured to essentially the same specifications as the Microwave Associates duplexers addressed above. Experience with the Varian duplexers is expected to be more consistent with the NAFEC experience reported in RD-65-122 than with O'Hare experience addressed above.

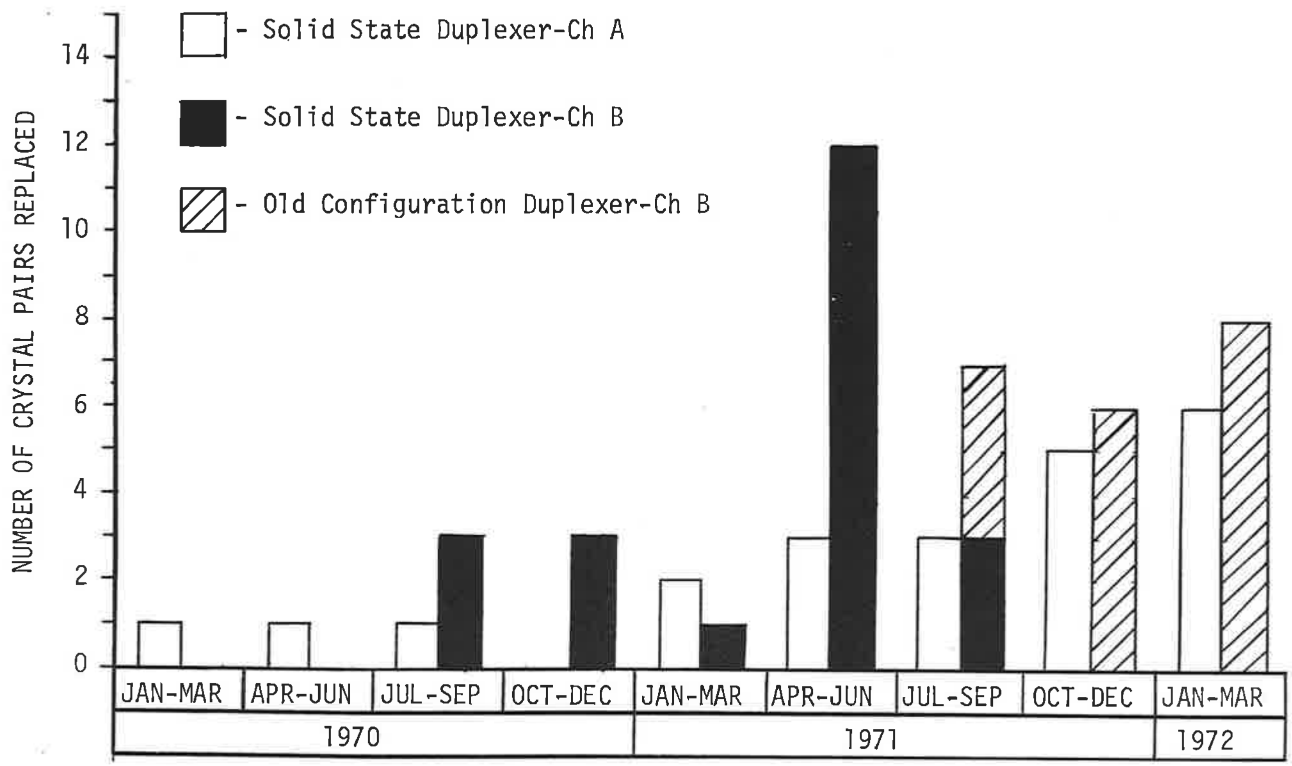


FIGURE 3-3. REPLACEMENT RATE OF IF CRYSTAL PAIRS AT O'HARE

The Microwave Associates duplexers had been operated far in excess of their specified limited life prior to the period assessed for the O'Hare ASDE-2.

3.3.2.2 Local Oscillator

The reflex klystron type local oscillator currently employed in the ASDE-2 does not provide acceptable service. Replacement of local oscillator tubes (2K50) is accomplished at the rate of one tube every 190 high voltage operate hours. This fact combined with the necessity for AFC adjustments, independent of component replacements, once every 175 hours indicates a need for modifications in the local oscillator area. In addition to correcting tube replacement and adjustment problems local oscillator improvements could also be expected to increase AFC crystal life. It is felt that variable attenuators are being tuned to provide greater than specified signal levels to AFC crystals to compensate for improper AFC performance. It is also suspected that AFC crystals are frequently replaced unnecessarily to correct symptoms for which they are not responsible.

3.3.2.3 Modulator

High replacement rates of tubes in Modulator Assembly, FA-6618, severely impair ASDE-2 reliability. For all sites combined, modulator driver tubes (3C45's and 6130's) are replaced an average of once every 110 high voltage operate hours. Power amplifier tubes (4PR60's) are replaced at the rate of one every 150 hours and magnetrons once every 480 hours. The modulator has been recognized by TSC as a deficient area and design changes have been identified and incorporated in one channel of the Logan ASDE-2 and one channel of the Kennedy ASDE-2 for evaluation. Experience to date indicates that the TSC modifications will be adequate to correct the high failure rates experienced on modulator driver, power amplifier and magnetron tubes.

3.3.3 Problem Areas With No Apparent Cost Effective Solutions

Identified problem areas which should be noted but for which corrective action would not be cost effective are addressed below.

3.3.3.1 Quality of Components

Component replacement rates reflected by maintenance data indicates a significant variance in electron tube quality for different time periods. For example, magnetron failure rates in 1970 were approximately twice as high as in 1971 while failure rates of 4PR60 power amplifier tubes were approximately three times as high in 1971 as in 1970. Interviews and data also indicated significant quality differences in 6AK5 tubes. While such changes in tube quality impact reliability and maintainability of ASDE systems they are recognized as a function of established depot procurement practices based on cost tradeoffs, current ASDE data does not provide sufficient basis for recommendations that these policies be revised.

3.3.3.2 Electron Tube Application Problems

Primary part application or design problems are associated with receiver and modulator assemblies. However, review of component failure data indicates the presence of part application problems associated with several tubes in the following assemblies as well.

1. Video Distribution and STC, FA-6612
2. AFC Amplifier, FA-6614
3. Trigger Generator, FA-6625
4. Indicator Power Supply, FA-6662

While high failure rate tubes associated with the above assemblies are used in several locations they seem to fail much more often in some locations than others. For example, 12AT7WA tubes are used in 15 locations throughout each ASDE channel. This tube was replaced 24 times in one location (V2605), from 1 to 3 times in each of nine locations, and not at all in any of the five remaining locations. This as well as other areas of part application problems are indicated in Table 3 - 11.

However, due to the quantity of total failures and the cost of the components involved, hardware changes would not be cost effective for the additional three to five year period during which ASDE-2 is expected to be in service. The electron tube with the worst history of those addressed above is only replaced an average of once per year per system during unscheduled maintenance and has a unit cost of 81¢. Even where problem locations are associated with circuitry common to other problem parts hardware changes would not be cost effective.

3.3.3.3. Miscellaneous Problem Areas

Following are additional problem areas which impair ASDE reliability but for which corrective actions would not be cost effective.

1. Deflection Coil Drive, FA-6678 (rotating yoke assembly) - responsible for approximately 3% of single-channel failures and 4% of maintenance actions. Due primarily to gear wear and misalignment.

2. Magnetron Blower Motor and Air Flow Switch - responsible for approximately 1% of failures and maintenance actions. Primarily due to switch failures and reduced airflow resulting from motor bearing failure and build up of lint in squirrel cage blower.

3. Tuning Capacitors in IF Amplifier - concentric rings of capacitors tend to short while being tuned. Rate of occurrence is low because IF strips are seldom tuned. Most IF strip maintenance is accomplished through tube replacement.

TABLE 3-11. PART APPLICATION PROBLEMS

PART NUMBER	QUANTITY USED PER CHANNEL	PROBLEM LOCATIONS	QUANTITY REPLACED IN PROBLEM LOCATIONS	AVG. QUANTITY REPLACED IN OTHER LOCATIONS
12AT7WA	15	V2605	24	1.2
12AX7	7	V1405	24	1.7
5687WA	9	V2603	12	1.2
		V1209	10	
		V2604	8	
12AU7	6	V1407	11	1.7
		V1406	7	
		V1210	7	
6AH6	9	V6201	6	.9

3.3.4 Cathode Depletion Due To Barium Evaporation

Component replacement data indicates a tendency toward higher magnetron replacement rates at sites with fewer high voltage operate hours. This trend is believed to be the result of cathode depletion due to barium evaporation. When only filament voltages are applied for extended periods the thin layer of barium evaporates from the sufrace of the cathode and results in a tendency for tubes to arc when high voltage is applied. More frequent application of high voltage works to restore barium to the surface of the cathode before it has evaporated in sufficient quantity to cause arcing. This mechanism is characteristic of other electron tubes as well as magnetrons.

3.3.5 Maintenance Procedures

Maintenance procedures are essentially the same at all sites and are in accordance with FAA Handbook SMP 6330.1. Procedures appear to be adequate except with respect to bandwidth measurements and adjustments as addressed in section 5.0 of this report.

3.3.6 Maintenance Costs

Average yearly costs for parts and direct labor associated with ASDE-2 maintenance actions have been calculated at approximately $15,000 per site. Costs for unscheduled and scheduled maintenance are provided in sections 3.3.6.1 and 3.3.6.2 respectively for individual sites.

3.3.6.1 Unscheduled Maintenance

Approximate yearly costs of unscheduled maintenance for each site for periods assessed were as follows:

1. JFK - $11,000
2. EWR - 13,000
3. IAD - 13,000
4. ADW - 11,000
5. ORD - 10,000
6. LAX - 10,000
7. SEA - 8,000
8. SFO - 5,000

These costs are based only on cost of parts replaced and documented in maintenance logs and cost of direct labor. Direct labor is estimated at one hour per maintenance action for each site. Parts costs comprise greater than 90% of the above unscheduled maintenance costs. Lower unscheduled maintenance costs at SFO are due to the fact that the equipment is operated only six months out of each year. Unscheduled maintenance costs are primarily dependent on hours of filament voltage operation due to the failure mechanism of electron tubes and due to the fact that electro-mechanical components such as blower motors are operated independent of high voltage operation. Major factors that contribute to the lower cost of unscheduled maintenance at SEA are less frequent replacement of TR tubes and magnetrons. Longer use of TR tubes results from the poorer recovery time that can be tolerated at SEA due to the location of the free standing tower with respect to terminal and traffic areas. Also, the system is modified to keep voltage off of TR tubes until high voltage is applied to the system. Greater magnetron life experienced at Seattle is believed to be due primarily to the higher ratio of high voltage hours to filament hours which helps prevent cathode depletion caused by barium evaporation.

3.3.6.2 Scheduled Maintenance

Approximate yearly costs of scheduled maintenance (direct labor and parts) for each site are as follows:

1. JFK - $5,500
2. EWR - 5,500
3. IAD - 5,500
4. ADW - 5,500
5. ORD - 5,500
6. LAX - 3,000
7. SEA - 4,500
8. SFO - 2,000

Differences in costs of scheduled maintenance are due to differences in frequency of daily checks and parameters tested. LAX, SEA, and SFO daily check only parameters provided for on FAA Form 418-25 and FAA 418-26 while all other sites record parameters provided for on FAA Form 418-24. LAX "daily" checks are performed approximately every 3-4 days and SFO "daily" checks are performed approximately once every week during the six months the equipment is in use each year.

3.4 RECOMMENDATIONS

Modifications to the existing ASDE-2's are recommended as follows:

1. Receiver Assembly, FA-6613
    a. Duplexer
    b. Local Oscillator (L.O.)
2. Modulator Assembly, FA-6618

These recommendations are based on data, assessments and conclusions discussed in paragraphs 3.1, 3.2, and 3.3. Support for recommendations is provided in the form of estimates of resulting reliability improvement and cost impact in 3.4.3 and 3.4.4.

3.4.1 Receiver Recommendations

Maintenance data indicates a need for corrective action in duplexer and local oscillator areas of the receiver due to high component replacement rates in both areas and frequent adjustments required by local oscillators.

3.4.1.1 Solid State Duplexer

Need for incorporation of adequate solid state duplexers to improve TR tube and IF crystal failure rates is indicated by ASDE-2 experience addressed in section 3.3.5. To this end, it is recommended:

1. That the new Varian solid state duplexers, already procured by the FAA Center in Oklahoma City, be deployed as soon as possible and closely evaluated in the field to determine their affect on crystal and TR tube life.
2. That the similar solid state Microwave Associates duplexers at Chicago be tested and failure analyzed, if necessary, to determine the exact cause of short crystal life recently experienced at ORD.

3.4.1.2 Solid State Local Oscillator

Incorporation of solid state local oscillators is recommended to correct problems of frequent AFC adjustment and high failure rate of 2K50 klystron tubes.

3.4.1.3 AFC Crystals

In view of the high rate of replacement of AFC crystals it is recommended:

1. That signal levels to AFC crystals be closely monitored at all ASDE sites and adjustment of variable attenuators be maintained to assure that AFC crystals are not subjected to greater than specified signal levels.
2. That AFC crystals replaced due to failure in the future be failure analyzed to determine their status and the exact cause of failure.

3.4.2 Modulator Recommendations

It is recommended that modulator modifications designed by TSC and currently undergoing additional testing at JFK be implemented to correct the high rate of replacement of modulator driver, power amplifier and magnetron tubes. Modulator improvements will be addressed further in Volume II of this report.

3.4.3 Projected Reliability Improvement

If implemented, receiver and modulator corrective actions in areas addressed in section 3.4.1 above can be expected to provide an ASDE-2 $MTBF_{HV/SC}$ of 79 hours or a resulting improvement of 230% over existing ASDE $MTBF_{HV/SC}$. Corresponding resultant $MTBM_{HV/SC}$ should be 51 hours. Projected $MTBF_{HV/SC}$ and $MTBM_{HV/SC}$ are shown in Figure 3-4 for all combinations of receiver and modulator modifications. Projections in Figure 3-4 assume that the cause of short AFC crystal life can be corrected with incorporation of an SSLO.

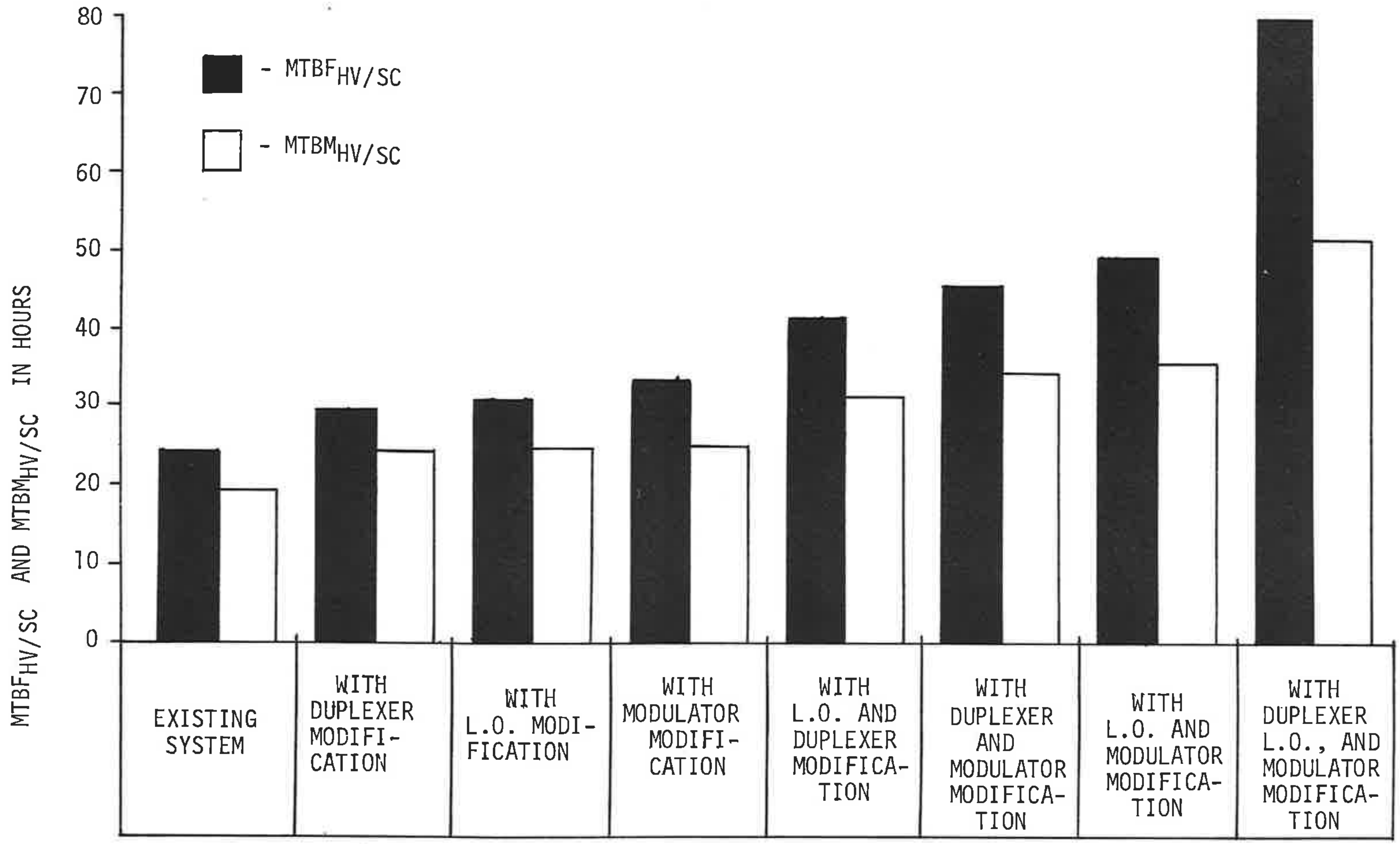


FIGURE 3-4. MTBF$_{HV/SC}$ AND MTBM$_{HV/SC}$ PROJECTED FOR RECEIVER AND MODULATOR MODIFICATIONS

3.4.4 Estimated Cost Impact

Estimated cost impact of recommended corrective actions is shown individually in Figure 3-5, 3-6, and 3-7 for duplexer,local oscillator, and modulator improvements, respectively. Basis on which the graphs were plotted is shown in Tables 3-12, 3-13, and 3-14, respectively. Impact for implementing all three improvements simultaneously is shown in Figure 3-8.

Cost impacts projected in this report are only estimates of direct labor and parts costs. No attempt has been made to include overhead costs.

Savings from duplexer improvements are projected at $34,000 over a five year period. Solid state local oscillator recommendations are not expected to be cost effective during the interim period prior to deployment of a new ASD system. However, they are recommended on the merit of projected reliability improvement and low net cost (approximately $8,000 over a five year period) when compared to savings associated with duplexer and modulator recommendations. Savings from modulator improvements are projected at $125,000 over a five year period. Simultaneous implementation of all three modifications should result in approximate savings of $151,000 over a five year period.

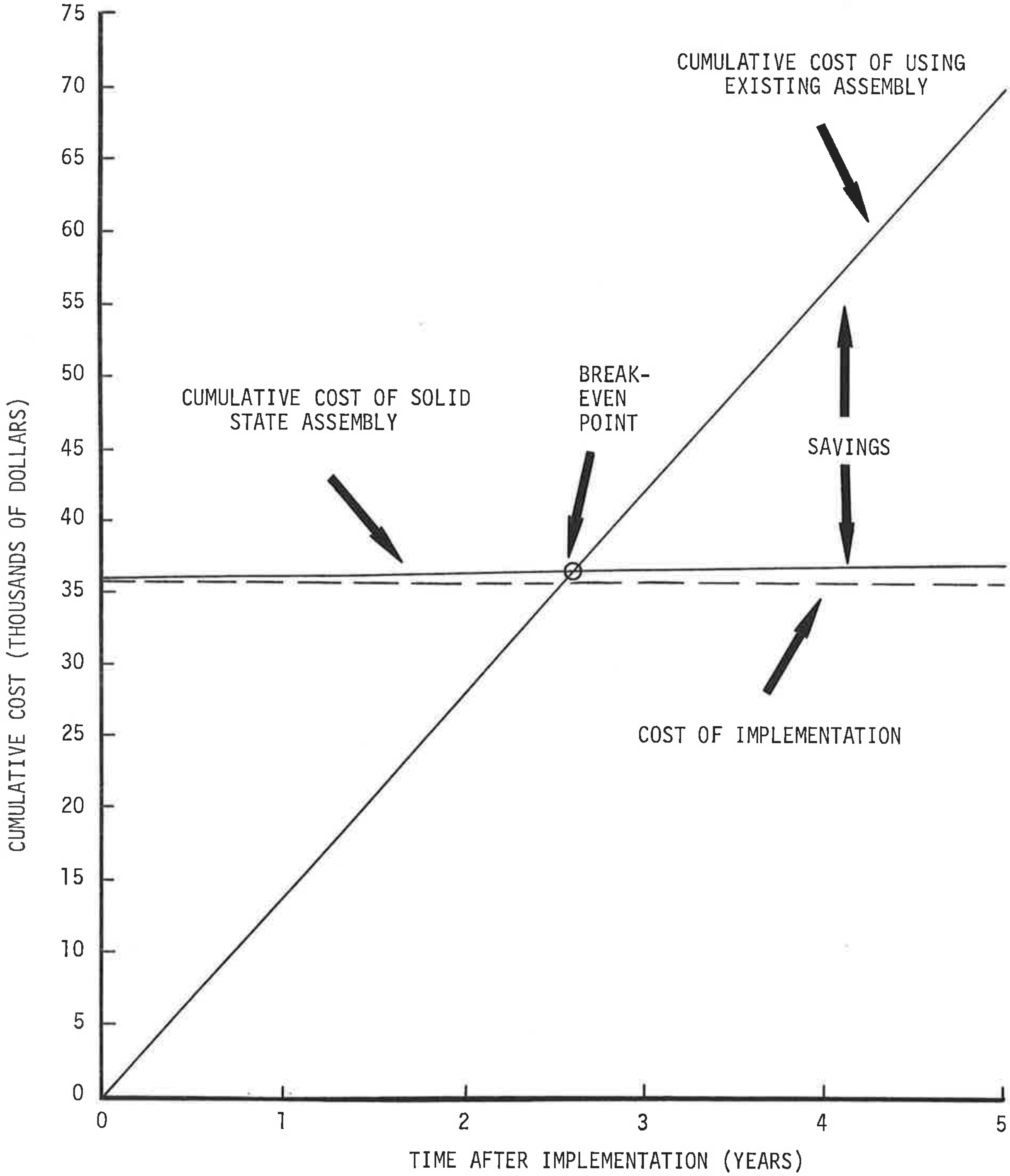


FIGURE 3-5. ESTIMATED COST IMPACT FOR SOLID STATE DUPLEXER IMPROVEMENT

TABLE 3-12. DUPLEXER IMPROVEMENT - COST IMPACT

I. COST OF USING EXISTING DUPLEXER ≃ $14,000/YEAR

- A. CRYSTALS → $876
  1. PARTS - 146/YEAR @ $5.00 = $730/YEAR
  2. LABOR - (14.6 HRS) X (8.50) = $146/YEAR
- B. TR TUBES → $12,970
  1. PARTS -40/YEAR @ $320 = $12,800
  2. LABOR - (.5 HRS) X (40) X (8.50) = $170

II. COST OF USING SOLID STATE DUPLEXER ≃ $35,500 + $150/YEAR

- A. IMPLEMENTATION COST → $35,490
  1. PARTS - (28 X $1000) + (4 X $1600) = $34,400
  2. LABOR - (8 HRS/CHANNEL) X (16 CHNLS) X (8.50) = $1090
- B. YEARLY MAINTENANCE COST → $150/YEAR
  1. PARTS - NEGLIGIBLE SINCE SPARES HAVE ALREADY BEEN PROCURED AS PART OF IMPLEMENTATION COST.
  2. LABOR - ASSUMING WORST CASE REPLACEMENT OF TWO DUPLEXERS PER YEAR WOULD RESULT IN LABOR COSTS OF $150/YEAR

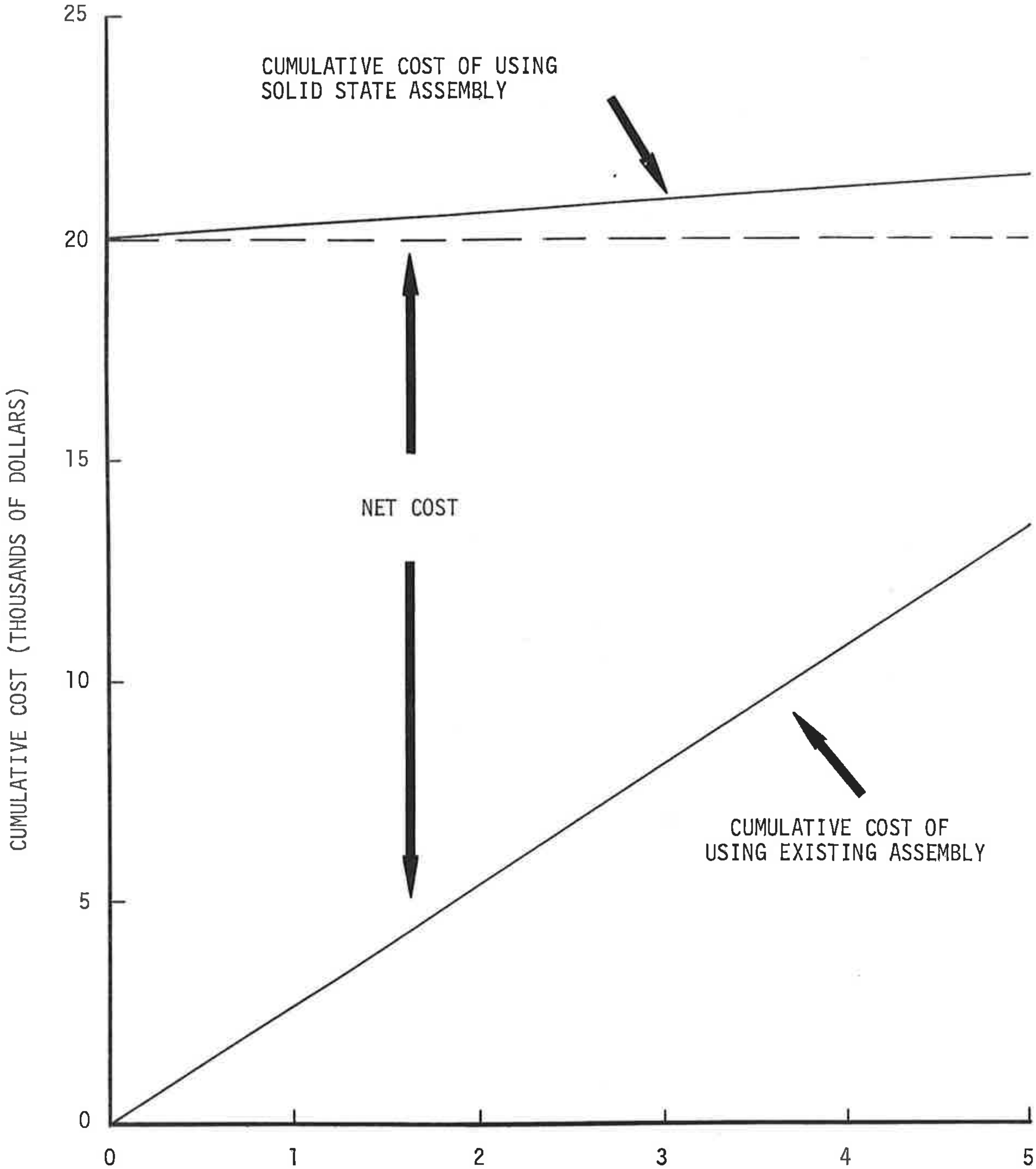


FIGURE 3-6. ESTIMATED COST IMPACT FOR SOLID STATE LOCAL OSCILLATOR IMPROVEMENT

TABLE 3-13. LOCAL OSCILLATOR IMPROVEMENT - COST IMPACT

I. COST OF USING EXISTING LOCAL OSCILLATOR ≃ $2700/YEAR

   A. KLYSTRON TUBES → $2,267

      1. PARTS - 67/YEAR @ $27 = $1839/YEAR

      2. LABOR - (.75 HRS) X (67) X (8.50) = $428/YEAR

   B. L.O. ADJUSTMENTS → $400

      1. LABOR - (188) X (.5 HRS) X (8.50) = $400/YEAR

II. COST OF USING SOLID STATE LOCAL OSCILLATORS ≃ $20,000 + $300/YEAR

   A. IMPLEMENTATION COST → $20,000

      1. ENGINEERING - $5,000

      2. PARTS - $12,800

         a. SSLO - 16 @ $600 = $9,600

         b. INTERFACE CIRCUITRY - 16 @ $200 = $3,200

      3. LABOR - (16 HRS) X (16 CHANNELS) X (8.50) = $2,170

   B. YEARLY MAINTENANCE COST → $300/YEAR

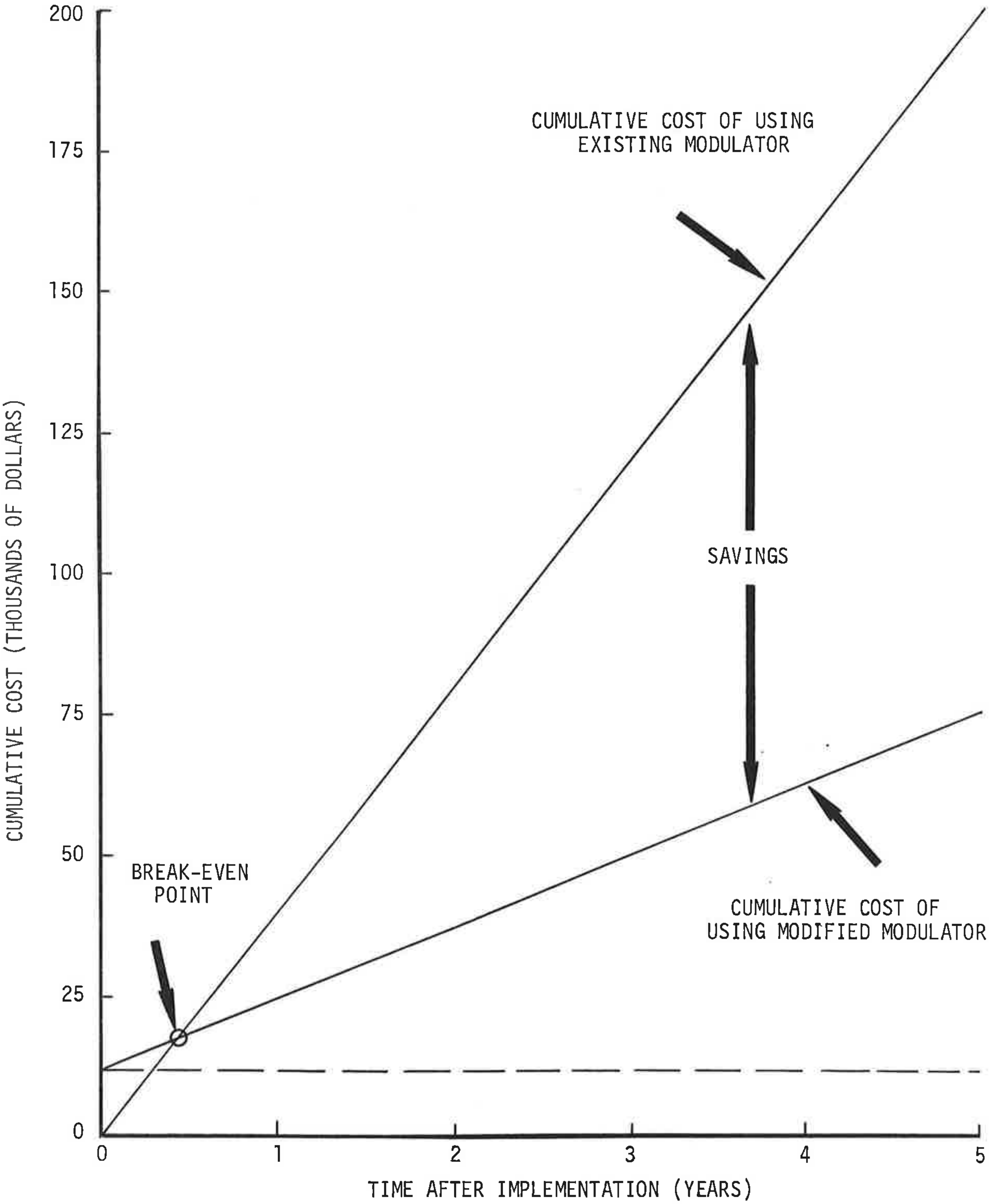


FIGURE 3-7. ESTIMATED COST IMPACT FOR MODULATOR IMPROVEMENT

TABLE 3-14. MODULATOR IMPROVEMENT - COST IMPACT

I. COST OF USING EXISTING ASSEMBLY ≃ $40,000/YEAR

A. REPLACEMENT OF V1902 ⟶ $2725/YEAR
  1. PARTS - 128/YEAR @ $17 = $2180/YEAR
  2. LABOR - (.5 HRS) X (128/YR) X ($8.50/HR) = $545/YEAR

B. REPLACEMENT OF V1903, 4, 5 ⟶ $7330/YEAR
  1. PARTS - 89/YEAR @ $78 = $6950/YEAR
  2. LABOR - (.5 HRS) X (89/YEAR) X ($8.50) = $380/YEAR

C. REPLACEMENT OF V1906 ⟶ $29,838/YEAR
  1. PARTS - 28/YEAR @ $1055 = $29,600/YEAR
  2. LABOR - (1 HR) X (28/YEAR) X ($8.50/HR) = $238/YEAR

II. COST OF USING MODIFIED ASSEMBLY ≃ $10,000 + $13,000/YEAR

A. IMPLEMENTATION COST ⟶ $10,180
  1. PARTS - ($500/CHANNEL) X (16 CHANNELS) = $8,000
  2. LABOR - (16 HRS/CHNL) X ($8.50/HR) X (16 CHNLS) = $2,180

B. REPLACEMENT OF V1902 ⟶ $3043/YEAR
  1. PARTS - 10/YEAR @ $300 = $3000/YEAR
  2. LABOR - (.5 HRS) X (10/YEAR) X ($8.50/HR) = $43/YEAR

C. REPLACEMENT OF V1903, 4, 5 ⟶ $1234/YEAR
  1. PARTS - 15/YEAR @ $78 = $1170/YEAR
  2. LABOR - (.5 HRS) X (15/YEAR) X ($8.50/HR) = $64/YEAR

D. REPLACEMENT OF V1906 ⟶ $7445/YEAR
  1. PARTS - 7/YEAR @ $1055 = $7385/YEAR
  2. LABOR - (1 HR) X (7/YEAR) X ($8.50) = $60/YEAR

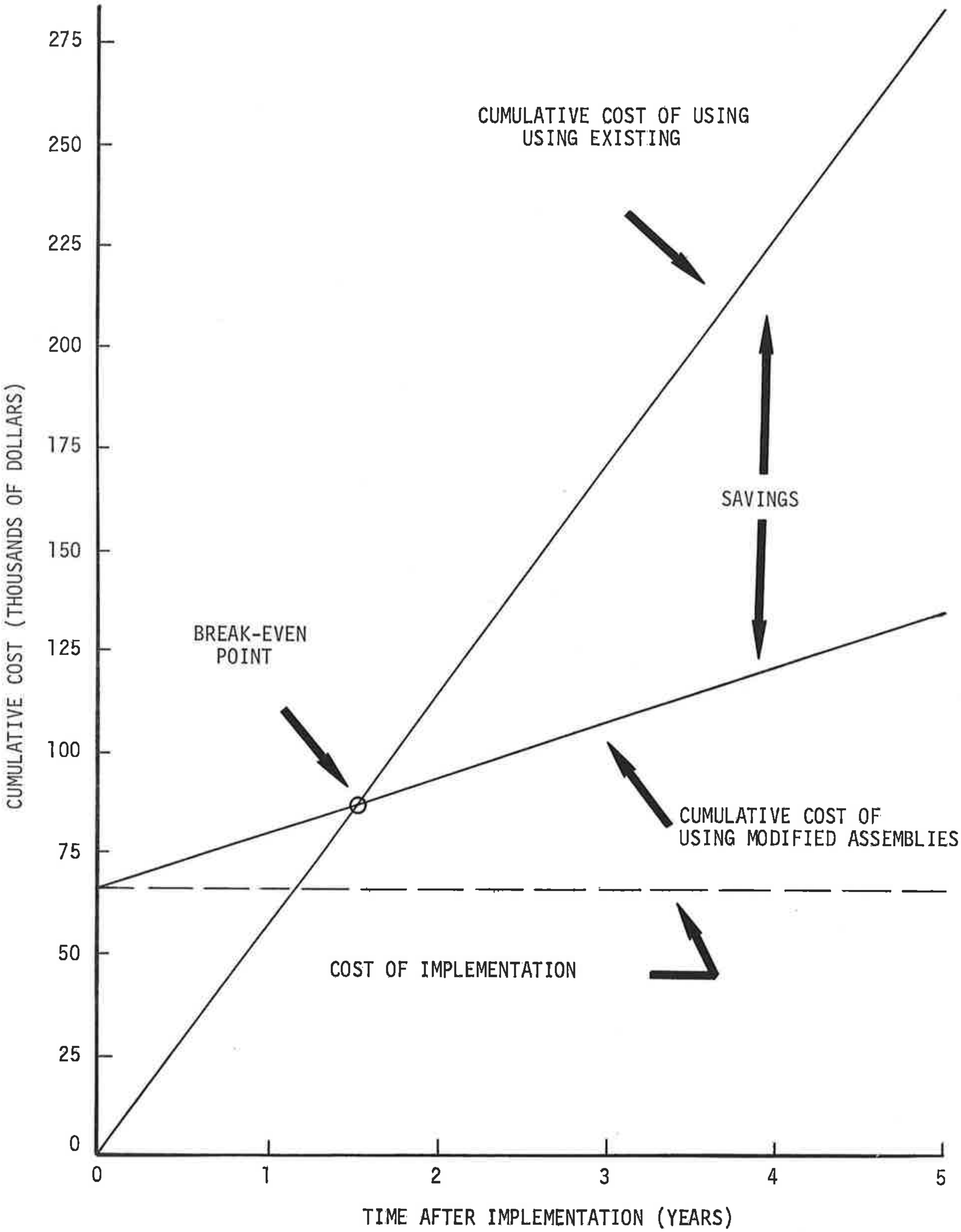


FIGURE 3-8. COMBINED COST IMPACT OF RECOMMENDED MODULATOR AND RECEIVER IMPROVEMENTS

4. OPERATIONAL STATUS

Air traffic personnel were interviewed at the eight sites surveyed to determine existing operational procedures that govern the use of the ASDE-2. The data is tabulated in the following categories:

1. Operational Verification
2. Operational Usage
3. Airport Operation Rate, Safety and Availability
4. Problem Areas

The tabulated entries are keyed to indicate responses as follows:

Y - Affirmative Answer

N - Negative Answer

Other letters refer to comments that are listed following each table. Blanks indicate that interviewee did not volunteer an answer or that answers were inconclusive.

4.1 OPERATIONAL VERIFICATION

Questions were asked to determine what criteria is used by air traffic personnel to verify that the ASDE-2 is performing satisfactorily for operational use. In essence the questions asked were; are the factors in table 4-1 used by 'air traffic' to verify the operational readiness of the ASDE-2?

4.1.1 Operational Verification Conclusions

There are no fixed standards used to determine the operational usefulness of the ASDE-2. Controllers and supervisors generally determine the usefulness of the ASDE-2 by the clarity or definitions of map

TABLE 4-1

OPERATIONAL VERIFICATION

FACTORS	JFK	EWR	IAD	ADW	ORD	LAX	SEA	SFO
AIRCRAFT SIZE OR SHAPE	Y Y	N A	N N	N N	N N	N H	N N	N N
TARGET STRENGTH/DEFINITION	Y Y	B N	Y Y	D F	Y Y	Y Y	Y Y	Y Y
DEFINITION OF RUNWAYS	Y Y	Y Y	Y Y	E Y	Y Y	Y Y	Y Y	Y Y
DEFINITION OF TAXIWAYS	Y N	Y Y	N Y	E Y	Y Y	Y Y	Y Y	Y Y
RETURNS IN WEAK SIGNAL AREAS	Y Y	B Y	C Y	N Y	Y Y	Y	N N	Y Y
RETURNS FROM OTHER FIXED TARGETS	N N	N N	N N	N Y		Y Y	N N	Y Y
DETECTION OF RUNWAY LIGHTS	Y Y	Y Y	N N	Y N				
RETURNS FROM MOVING TARGETS	Y N	N N	N N	N N	N G			

COMMENTS ON OPERATIONAL VERIFICATION (Table 4-1)

A. Did at one time - can't now.

B. Ground targets near main bang - when radar is poor it's darker near main bang.

C. "No we can't - it would be nice".

D. Presentation is terrible.

E. Now it's very poor - little contrast. ("Now" refers to the last few years.) Still used. (Experienced Controller)

F. Presentation is adequate.

G. Fast moving aircraft can't be seen - especially in landing.

H. No - but 747's paint wings.

quality (runways and taxiways) and not by definition, relative size or shape of aircraft. The lack of detailed or specific requirements for verification is apparently a result of the poor resolution being achieved by the ASDE-2; it is also evident that the degradation has occurred slowly over the past several years.

4.2 OPERATIONAL USAGE

Air traffic personnel were interviewed to determine the present operational usage of the ASDE-2. The tabulated data shown in Table 4-2 are divided into three sections that indicate the usage in terms of operational data, use situation and control and control function. Questions were asked to determine if the ASDE-2 was used to obtain the indicated operational data and if it was used in the various use situations listed in the table.

The control function section of the table shows the primary control usage and the number and type of displays in the tower cab.

TABLE 4-2

OPERATIONAL USAGE

OPERATIONAL DATA	JFK	EWR	IAD	ADW	ORD	LAX	SEA	SFO
RUNWAY CLEARANCE	Y Y	Y E	J J	L Y	Y Y	Y Y	Y T	V Y
TAXIWAY TRACKING	N Y	N N	Y N	Y Y	Y Y	Y Y	Y Y	Y Y
AIRCRAFT STEERING (BY COMM.)	Y B	N N	N N	M N	Y Y	Y Y	Y Y	X X
CONFLICT RESOLUTION (SEPARATION)	N N	Y N	I Y	N M	Y Y	Y Y	Y Y	Y Y
AIRCRAFT LOCATION	Y Y	N N	J N	M M	N N	N N	Y Y	N N
AIRCRAFT TYPE (SIZE AND SHAPE)	N N	N N	G N	N N	N N	N N	N Y	U N
AIRCRAFT HEADING (WITHOUT TRAIL)	Y N	N N	N N	N N	N N	R N	N Y	N N
AIRCRAFT IDENTIFICATION	N N	N N	N N	N	N N	N N	N N	N N
QUICK LOOK/PART TIME	A N	Y Y	N Y	N Y	N P	S N	N Y	N N
VEHICLE DETECTION	Y N	N N	H Y	N N	Y Y	Q	Y Y	N N
USE SITUATION	JFK	EWR	IAD	ADW	ORD	LAX	SEA	SFO
NIGHT	Y C	Y Y	N N	O O	N N	N N	Y Y	N N
FOG	Y Y	F Y	Y Y	F F	Y Y	Y Y	Y Y	W Y
RAIN	N D	N N	K K	N N	N N	N N	N N	N N
SNOW	N N	N N	K K	N N	N N			
CONTROL FUNCTION	JFK	EWR	IAD	ADW	ORD	LAX	SEA	SFO
LOCAL (PRIMARILY		Y		Y				
GROUND (PRIMARILY)			Y				Y	Y
BOTH	Y				Y	Y		
DISPLAYS (NUMBER & TYPE)*	1B	1P	1P	1P	2B	2P	1P	1P

COMMENTS ON OPERATIONAL USAGE (Table 4-2)

A. For an experienced operator

B. Did with the PPI - cannot with the BRITE

C. Would use it more at night if it had better resolution

D. Medium to heavy rain causes a white out - localized rain cells cause area to blank out

E. Primary usage; ground controller doesn't have access to the display

F. Used mostly for fog

G. No, aircraft shape changes for smaller (DC-9) aircraft

H. Service vehicles won't show in rain. (Fog or haze, it's good)

I. Separation between mobile lounges and a/c.

J. Not used by local controller - sometimes asks ground controller about runway clearance

K. Weather is biggest problem - display whites out in rain and snow - unusable

L. ASDE doesn't work in moderate rain - The old ASDE at National was much better. Use should be to see if runway is clear.

M. Ground controller can't see it - therefore, no.

N. No (negative answer)

O. It's on at night but very seldom used. If presentation was good, it would be used.

P. Use is difficult - have to study it.

Q. Not all vehicles are detectable (198 data shows holes in coverage prior to the blockage by larger hangers)

R. Yes - for 747's

S. At night ground controller can - local can't.

T. Not primarily - used by ground control

U. No, shape and size for 727's and 747's are the same (. . . and they were)

V. Local can't use the ASDE - ground controller relays information to local for intersections

W. Only used in super dense fog

X. Don't used ASDE for control - it's a cross check; (it's operational procedure)

Y. Yes - affirmative answer.

* The number and type of displays in the tower cab are indicated respectively by the numeral and the letter: B for BRITE DISPLAY, P for PPI Display.

4.2.1 Operational Usage Conclusions

Display accessibility is the principal factor that determines operational usage of the ASDE-2. Accessibility is improved by high brightness displays and also by multiple displays.

The ASDE-2 is being used operationally in three distinct ways:

1. Primarily for local control at Newark and Andrews;
2. Primarily for ground control at Dulles, Seattle, and San Francisco;
3. Both for local and for ground control at Kennedy, O'Hare, and Los Angeles.

It is apparent that these procedures have evolved because of the accessibility of the display, ease of use and the need for the radar information. Where only one PPI display is available, the primary use has been limited to one of the two control functions. For example, the ASDE-2 will be used first where it is most easily accessible, however at airports where the radar information is more important, controllers find ways to use what they have.

The following relates information concerning the various airports to their operational usage of the ASDE-2:

1. Newark's use of the ASDE-2 primarily for local control is most likely related to the need to expedite operations on the principal runway. Also, the simplicity of the airport most likely reduces ground conflict opportunities.
2. Andrews' primary use of the ASDE-2 for local control is also most likely related to the relative simplicity of the airport and the need to assure clear runways for the smaller military aircraft.

This may also have been influenced by the reduced usefulness of the ASDE-2 to detect taxiing military aircraft with smaller radar cross sections.

3. Dulles' operational use of the ASDE-2 primarily for ground control is explained by the increased threat of conflict due to mobile lounge traffic.

4. Seattle's use of the ASDE-2 primarily for ground control is most likely related to the more complex taxiing required for the parallel runways. Also the ground control position is closer to the local controller and communication between ground and local controllers may be easier.

5. San Francisco's use of the ASDE-2 primarily for ground control is influenced by two predominant factors:

   a. The single local controller's workload is high due to the crossing runways. The high workload wouldn't permit direct usage of the ASDE.

   b. Tower space is small and the display has been located behind the control positions where it is not easily accessible to the controller. The new BRITE conversion being installed (August 72) should improve accessibility.

6. New York's Kennedy, Chicago's O'Hare and the Los Angeles International's use of the ASDE-2 for both local and ground control is attributed to display accessibility. Chicago has two console BRITE and Los Angeles has two console PPI displays. The Los Angeles operation requires the use of an "ASDE-man" to relay information to the local controllers, but information is made accessible in this way.

4.3 OPERATIONS, SAFETY AND AVAILABILITY

Questions were asked to determine if the use of the ASDE-2 in conditions of reduced visibility would influence the number of possible operations per hour or the safety of handling traffic. A question was also asked to determine the apparent operational availability of the ASDE-2. Results of these questions are shown in Table 4-3.

4.3.1 Operations, Safety and Availability Conclusions

Questions asked to determine if airport capacity would be increased during reduced visibility conditions revealed that operational procedures at several airports prohibit the use of the ASDE-2 in this way. Comments were made that the ASDE-2 isn't that good. The 'fifty-fifty' answers are not considered significant.

Safety is thought to be improved by the ASDE-2. Five of the sites interviewed recalled "saves" that were made because the ASDE-2 was in use. A "save" is an incident when one aircraft would end up in the path of another aircraft. For example, New York reported 20 incidents in the last two years where taxiing aircraft didn't stop for runway 4R/22L causing serious conflicts with departing aircraft using the runway. Other "saves" include recognition of aircraft taxiing on a runway rather than on an assigned taxiway, aircraft turning the wrong way on a runway for take off and aircraft reporting that they are "holding short" of a runway when they are actually on an active runway.

Availability of the ASDE-2 was generally estimated in the 95 to 100% range in spite of the low MTBF. Evidentally, the low number of hours of actual use and the dual channel configuration permit at least one channel to be available when needed. There were some comments that it wasn't always "to our standards". Another fact that may contribute to 'high availability' is the paperwork difficulty of reporting an equipment outage.

TABLE 4-3

OPERATIONS, SAFETY AND AVAILABILITY

NUMBER OF OPERATIONS	JFK	EWR	IAD	ADW	ORD	LAX	SEA	SFO
INCREASED	Y Y	Y Y				Y Y	Y Y	
SAME			Y Y	E Y	Y Y			Y
SAFETY IMPACT	JFK	EWR	IAD	ADW	ORD	LAX	SEA	SFO
IMPROVED	Y A	Y Y	Y Y	F	Y Y	H Y	Y Y	Y
NONE								I
"SAVES"	B B		Y Y		Y Y		Y Y	Y
AVAILABILITY	JFK	EWR	IAD	ADW	ORD	LAX	SEA	SFO
95 TO 100%	C			Y	G Y	Y Y	Y Y	Y Y
90 TO 95%			Y Y	Y				
80 TO 90%		Y Y						
LESS		D						

COMMENTS ON OPERATIONS, SAFETY AND AVAILABILITY. (Table 4-3)

A. Use it less at night because BRITE definition is not good.

B. Several saves: 20 incidents in last two years where aircraft doesn't stop for 4R/22L (4 in one week).

C. Paper work to document outages - usually out for short times.

D. Prior availability was near 50% - now, it's run on mid every night. Maintenance is a terrific problem.

E. Couldn't use it that way - presentation isn't good enough.

F. Safety improved but when wx is bad, there's little traffic at a military base.

G. It's always available (working) but may not be to our standards.

H. Ground control would be impossible without ASDE.

I. No safety increases for present use - have to step over people to use it with the hood.

4.4 PROBLEM AREAS

Questions were asked to determine what specific problems are being encountered with the operational use of the ASDE-2. The entries listed in Table 4-4 can each be considered as answers to the question, "Is the listed function or operation a problem?" In actual interviews, the majority of the reported problem areas were volunteered; however, in some interviews the direct questions were asked. It was also standard practice to ask if there were other problems that were not covered or if we should have asked a question that we didn't.

TABLE 4-4

PROBLEM AREAS

FUNCTION OR OPERATION	JFK	EWR	IAD	ADW	ORD	LAX	SEA	SFO
DISPLAY								
BRIGHTNESS		Y Y	Y Y	Y Y		Y Y	Y Y	Y Y
NUMBER OF DISPLAYS		C	Y Y	Y H			Y Y	Y Y
SIZE OF PRESENTATION		F F						
MAP								
RESOLUTION	Y Y		G G	Y I	Y Y	Y Y		Y
WEAK TARGETS	D D	E E	Y Y	Y Y				
MOVING TARGETS	A				K K			
BLOCKAGE BY AIRCRAFT	N N	N N	N N	N N	N N	Y Y	Y Y	Y
BLOCKAGE BY STRUCTURES	Y Y	N N	N N	N N	Y Y	Y Y	N N	N N
WEATHER								
RAIN	Y Y	Y Y	Y Y	Y Y	Y Y	Y Y	Y Y	Y Y
FOG					L L			
SNOW	Y Y	Y Y			Y Y			
OTHER				J	M	P O		

COMMENTS ON PROBLEM AREAS (Table 4-4)

A. Moving targets have poor signal strength - are hard to see - lose some detection of landing aircraft on BRITE. Direct view PPI was better for moving targets.

B. Middle 3-inches of display goes black if radar is poor.

C. Display needed for ground controller (only have one hooded display on wheels.)

D. Targets on edges of airport are sometimes very weak.

E. Weak targets near main bang when radar is poor.

F. Presently use ASDE-2 display offset on expanded range to increase size.

G. Very little shape for aircraft.

H. Display has to be moved into position - not very mobile.

I. Fair.

J. Antenna makes noise.

K. Fast moving targets are weak - hard to detect.

L. Not always good in fog (either).

M. Adaptation to display from outside is not difficult.

N. Negative answer.

O. Long warmup time.

P. Location of indicators in corners is difficult for local to use - need "ASDE-man".

Q. Blockage by larger hangers.

4.4.1 Problem Area Conclusions

Major operational problems and difficulties reported by the air traffic personnel interviewed are summarized as follows:

1. Rain and Snow

Moderate to heavy rain causes the radar to be unusable. It was consistently reported that the reason for being unusable was that the display would "white-out". Three northern sites (Kennedy, Newark, and O'Hare) commented that the same effect occurred for moderate to heavy snow.

It is interesting to note that the ASDE-2 is <u>not expected</u> to perform normally in moderate to heavy rain. We refer to the FAA Handbook for maintenance of the ASDE-2 (SM P 6330.1 dated 12/7/64) page 20 paragraph 59 reproduced below.

59. RADOME WATER REPELLENT TEST.

a. Object. To test the effectiveness of the radome water repellent coating.

b. Discussion. The radome is treated with a water repellent so that water will not penetrate the radome fabric. Water penetrating the radome fabric or beading on the surface will attenuate the transmitted and received energy. During a rain storm, water running down the sides of the radome will cause an appreciable deterioration of the picture presented on the ASDE indicators. When rain ceases to fall on the radome, the system should recover in approximately one minute. Deterioration of the water repellent coating will cause the recovery time of the system to be noticeably longer. Severe soaking of the fabric may result in a halo effect in the center of the PPI presentation similar to echo box ring time effects.

c. Equipment Required. None.

d. Procedure.

(1) Prior to a period of moderate to heavy rain insure that system performance is within operational tolerances.

(2) Adjust the PPI presentation to compare with FAA Form 198 photographs.

(3) During the rain observe display on PPI indicator and note system performance.

(4) When the rain ends note the time required for system performance to return to normal.

(5) Normal system performance should occur within one minute to provide adequate operation during conditions of light mist and fog.

(6) If the system does not recover in approximately one minute, the radome water repellent coating should be replaced as set forth in paragraph 62.

Specific acknowledgment is made to the effect that rain on the random "will cause an appreciable deterioration of the picture of the ASDE indicators." It further states that "Normal system performance should occur within one minute (after the rain ends) to provide adequate operation in light mist and fog.

From the above mentioned reports and acknowledgments, it is evident that the "white-out" is a manifestation of a backscatter problem and the signal attenuation caused by rain on the radome is a lesser problem. If the attenuation were the most significant problem then moderate to heavy rain would have caused the PPI presentation to "black-out". If the radome became an excellent reflector because of the rain, it would have caused a halo effect in the center with the rest of the display being blacked out. Since the latter conditions were not reported, it is concluded that the primary rain penetration difficulty is due to backscatter. Crude measurements were made to determine the ellipticity of the ASDE-2 antenna polarization. These measurements indicate ellipticities of 3.5 to 7.7 dB for the situations measured. These ellipticities are used to calculate concellation ratios respectively of 9 to 4 dB. Since it is considered that a minimum ICR of approximately 17 dB is required for satisfactory rain performance, it is apparent that backscatter may be a problem.

2. Display Parameters

The low brightness of the ASDE-2 PPI display is a major problem. It prevents effective operational utilization of the ASDE-2 because of the need for a viewing hood. The net effect of low brightness and the need for a viewing hood is to decrease the accessibility of the radar information.

It was shown in paragraph 4.2 that the number of displays also has a definite effect on accessibility of radar information to controllers and the use of a single PPI display imposes significant limitations on the operational usage of the ASDE-2. It may be significant to note that the single BRITE display at Kennedy was apparently able to overcome the accessibility limitations. This may be influenced by the smaller size of the Kennedy tower and the closer proximity of the controllers to the display.

3. Resolution

Generally, the overall resolution of the ASDE-2's was found to be poor. Measurements (discussed in Section 5) of the overall resolution showed the ASDE-2's average range resolution to be 2.2 times worse than the system specification and the average azimuth resolution to be 1.39 times worse than the system specification and 2.1 times worse than the antenna azimuth beamwidth specification.

Air traffic personnel interviewed didn't complain about the poor resolution and one, when questioned said that shape and size weren't necessary - all they wanted was a good solid return from the aircraft. Half of the personnel interviewed did indicate that they considered the poor resolution a problem. While any conclusion here must be speculative there are several factors to consider:

a. Controllers are much more familiar with lower resolution ASR-type radar on BRITE displays.

b. In general, the controllers haven't used a higher resolution radar. It may be that they wouldn't criticize the ASDE-2 because they haven't seen better.

c. In response to photographs of higher resolution radars they were almost unanimous in comments to the effect that it would be great.

d. Operational procedures at some airports prohibit the use of the ASDE-2 to determine aircraft heading. (This is in contradiction to the intended use of the ASDE-2 as stated in SM P 6330.1 - probably influenced by the poor resolution being achieved operationally.)

4. Weak Targets

There seems to be a problem at Kennedy with weak targets at the extremities of the airport - most likely due to the longer range. Dulles and Andrews have similiar problems.

The problems at Newark of weak targets in the center of the display (close in ranges) is most likely due to antenna tilt or STC - or a combination of both. It should be looked into - more data is needed before a reasonable conclusion can be made.

5. Blockage

Buildings and structures tend to block some taxiways at the larger airports. Los Angeles is the only airport that has blockage of runways by buildings. It seems to be a rule that the lower antenna heights of the remote structures do cause larger shadows. The shadows of buildings and aircraft can obscure other targets.

6. Moving Targets

It was reported at Kennedy and O'Hare that the ASDE bright display presents faster moving targets at such a low intensity that the targets are difficult to detect. This effect is mainly due to the characteristics of the vidicon camera and the PPI CRT. The vidicon camera provides storage of the rho-theta PPI images between successive antenna scans to present a complete PPI scan in raster format to the bright TV display. The trade-off between storage to maintain the image of a complete scan and to present fast moving targets at an acceptable intensity level is critical. An added complexity in this trade-off is site preference for display presentation. Some sites prefer long trails on moving targets and are not interested in target shape, while other sites prefer good target images with a minimum moving target trail.

Proper selection of the vidicon and the PPI CRT should result in an acceptable bright display.

5. PERFORMANCE MEASUREMENTS

Standardized tests were conducted to determine the performance capabilities of each ASDE-2.

The primary objective of these tests was to measure the overall resolution of the ASDE-2. Measurements of transmitter pulse shape, receiver and indicator bandwidths were taken to support the overall resolution measurement and to help identify areas which may cause degraded performance.

A secondary objective of the tests was to investigate the ellipticity of the antenna polarization. Since it is difficult to make accurate measurements of ellipticity in field installations - because of reflections and interference and because we can only made point measurements - we could only expect to make a qualitative determination. Results may be considered significant, nevertheless, if the measurements indicate either large ellipticities or small variances.

The field measurements may be used to indicate if an ellipticity problem exists but should not be used to establish quantitative values. Quantitative antenna data can only be reliably established under the controlled conditions of an antenna range.

It should be noted that refinements were made in the course of testing. For example, the measurement of receiver bandwidth using a swept signal generator was abandoned in favor of pulse bandwidth measurements. This change was made because the IF bandwidths which were measured with signal generators showed response variations on the pass band up to twenty-four (24) dB. Another reason for the change was that some sites did not have signal generators. A third reason for the change was that the pulse bandwidth measurement is actually more meaningful for pulse amplifiers. A second change that was made in the measurement of overall resolution was the use of bigger corner reflectors. The original Five-square-meter reflectors were not large enough for consistent detection. Larger reflectors - still point targets - with effective cross sections of forty (40) to eighty (80) square-meters were used to assure detection.

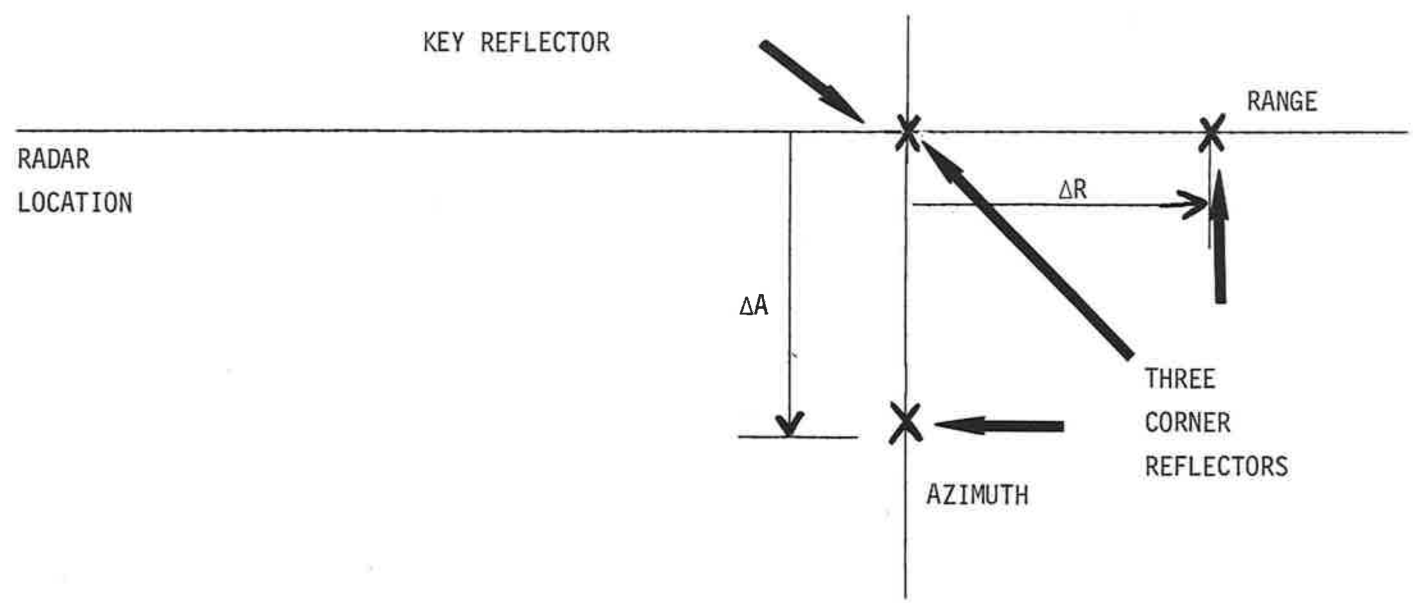
In general test equipment that was available at the site was used.

5.1 TEST DESCRIPTIONS

The following tests and measurements were performed:

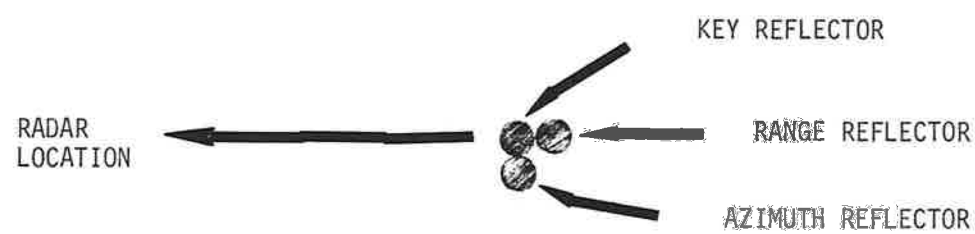
1. Overall resolution measurements were performed by arranging three (3) corner reflectors in a "L" pattern on a low contrast area of the airports at a range of 4000 to 6000 feet. Figure 5-1 shows the "L" pattern arrangement consisting of reflectors designated as "Key", "Azimuth" and "Range". The azimuth and range reflectors were moved using two way radio communication until the display indication shown in figure 5-2 was obtained. The range to the reflector pattern was determined from airport maps. The range resolution is the distance between the key and the range reflectors. The azimuth resolution is determined by computing the quantity $\Delta A/R$ where ΔA is the range between the key and the azimuth reflectors and R is the range from the radar antenna to the corner reflector pattern, and then entering the graph of figure 5-3 to determine the overall azimuth resolution.

2. Measurements were performed on receivers and video amplifiers to determine pulse bandwidths. Since pulse generators were not generally available at the sites these measurements were made with the radar pulse itself.



OVERALL RESOLUTION MEASUREMENT
USING CORNER REFLECTORS

FIGURE 5-1



OVERALL RESOLUTION MEASUREMENT
DISPLAY INDICATION

FIGURE 5-2

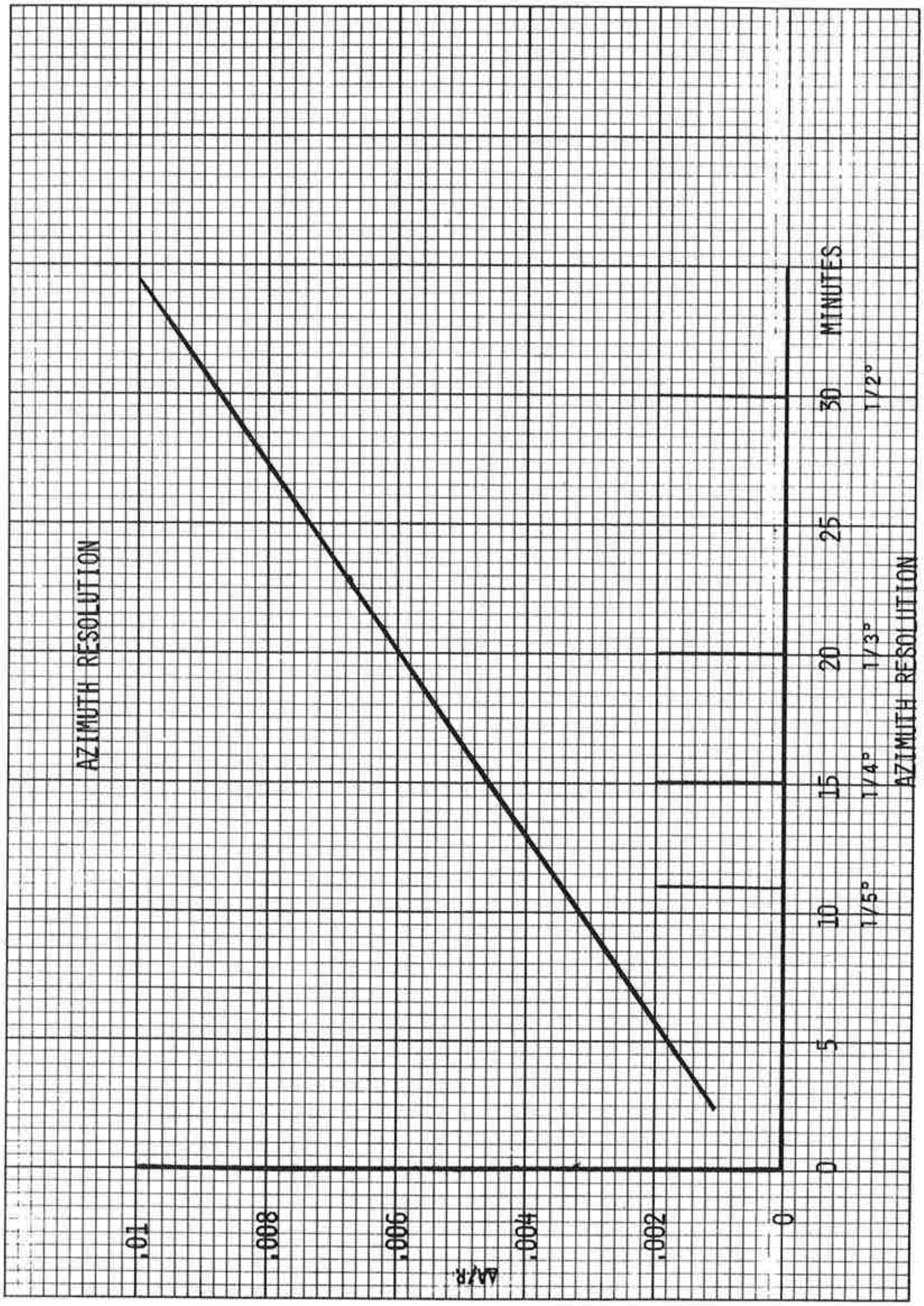

AZIMUTH RESOLUTION
ΔA/R.
.01
.008
.006
.004
.002
0
0
5
10
15
20
25
30
MINUTES
1/5°
1/4°
1/3°
1/2°
AZIMUTH RESOLUTION

FIGURE 5-3

The pulse bandwidth (B) of a circuit is derived in the literature [1] and defined here as

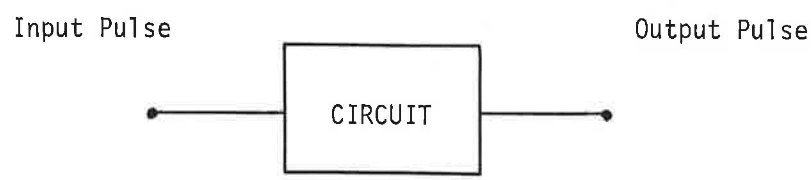
$$B = \frac{.35}{t_{rc}}$$

where t_{rc} is the risetime of the circuit.

It can be shown that the defined pulse bandwidth (B) is the same as the 3 dB bandwidth of a single pole filter by considering the response to both a sinusoidal and a step excitation. It can further be shown using Fourier transforms that the error in determination of bandwidth of an ideal filter will be less than ten percent. Therefore this technique is versatile and relatively insensitive to filter rolloff.

Since the risetime of the circuit cannot be measured directly it must be determined by measurement of input and output rise times. The pulse bandwidth technique is insensitive to the bandwidth of the oscilloscope used to measure these rise times, as long as the value of the risetime can be read with sufficient accuracy.

The following brief analysis shows that the rise time (or bandwidth) of the oscilloscope does not affect the calculation of circuit rise time. Consider the following circuit:



(1) Millman and Taub, Pulse, Digital and Switching Waveforms, Section 2, McGraw Hill, New York, 1965.

Where:

t_1 = input rise time

t_2 = output rise time

t_{10} = input rise time observed on oscilloscope

t_{20} = output rise time observed on oscilloscope

t_s = oscilloscope rise time

It has also been shown(1) that the input, output and circuit rise-times are related by the following approximate equation;

$$t_2^2 \doteq t_{rc}^2 + t_1^2$$

The approximation is within 3 percent for the cases considered.

Then:

$$t_{10}^2 = t_1^2 + t_s^2 \quad \text{and} \quad t_{20}^2 = t_2^2 + t_s^2$$

Since

$$t_{rc} = (t_2^2 - t_1^2)^{1/2} \quad \text{(the desired circuit rise time)}$$

We can compute

$$t_{rc} = (t_{20}^2 - t_{10}^2)^{1/2} = (t_2^2 - t_1^2)^{1/2}$$

directly from the oscilloscope measurements.

---

(1) ibid

3. Ellipticity measurements were performed at the three west coast sites to qualitatively determine if a polarization problem exists. (These tests were relatively crude).

Tests were performed using a linearly polarized horn antenna and a calibrated peak reading signal strength meter. The ASDE-2 antennas were stopped for the measurements. The signal strength meter was first used to locate the azimuth peak of the ASDE-2 antenna, then it was peaked for pointing angle of the linear antenna in azimuth and in elevation. Then a rotational reference angle (about the pointing axis) was established for the linear antenna. The signal strength meter was then set to read zero dB for the maximum signal at the optimum point axis. The rotational angle of the linear antenna was changed and the variation in signal strength recorded.

These values of signal strength are a direct measure of the ellipticity of the ASDE-2 antenna polarization. The relationship between ellipticity and ICR (Integrated Cancellation Ratio is shown by Jasik[(1)] to be:

$$ICR = \frac{\Sigma \text{ total power received}}{\Sigma \text{ total power returned}}$$

Where:

Total power returned = $(P_{max} + P_{min})^2$

Total power received = $(P_{max} - P_{min})^2$

is the elevation angle

P_{max} is the maximum one-way response in decibels obtained from a rotated linearly polarized antenna

(1) Jasik, Antenna Engineering Handbook, McGraw Hill, New York, 1961

P_{min} is the minimum response.

Therefore the ICR can be calculated as follows:

$$ICR = \frac{\Sigma\ (P_{max} - P_{min})^2}{\Sigma\ (P_{max} + P_{min})^2}$$

Further, the cancellation ratio is graphed as a function of the ellipticity in figure 5-4.

5.2 DATA SUMMARY

Test and measurement data are summarized in graphs and tables to show the overall resolution of the ASDE-2 radar at each site. Supporting bandwidth measurements are tabulated as they were available. The ellipticity data for the west coast sites is also tabulated.

The overall ASDE-2 resolution is summarized by graphs in figure 5-5. The azimuth resolution averages 0.53 degrees or 1.39 times the system specification and 2.14 times the antenna beamwidth specification. It is interesting to note that the measurement on the Andrews azimuth resolution is the largest - and occurred with the use of the larger corner reflectors. We might have attributed this to display or receiver smearing due to larger signals but the range resolution improved and azimuth resolution degraded for the larger corner reflectors. (Measurements were made at Andrews with 5-inch and with 18-inch corner reflectors.) It may well be that the weaker targets were at the limit of detectability and not being displayed simultaneously. The measurements of azimuth resolution, with the exception of the Andrews, are very consistent for different areas at the same site; the measurement can therefore be considered reasonably accurate.

The range resolution measurements are also generally consistent for

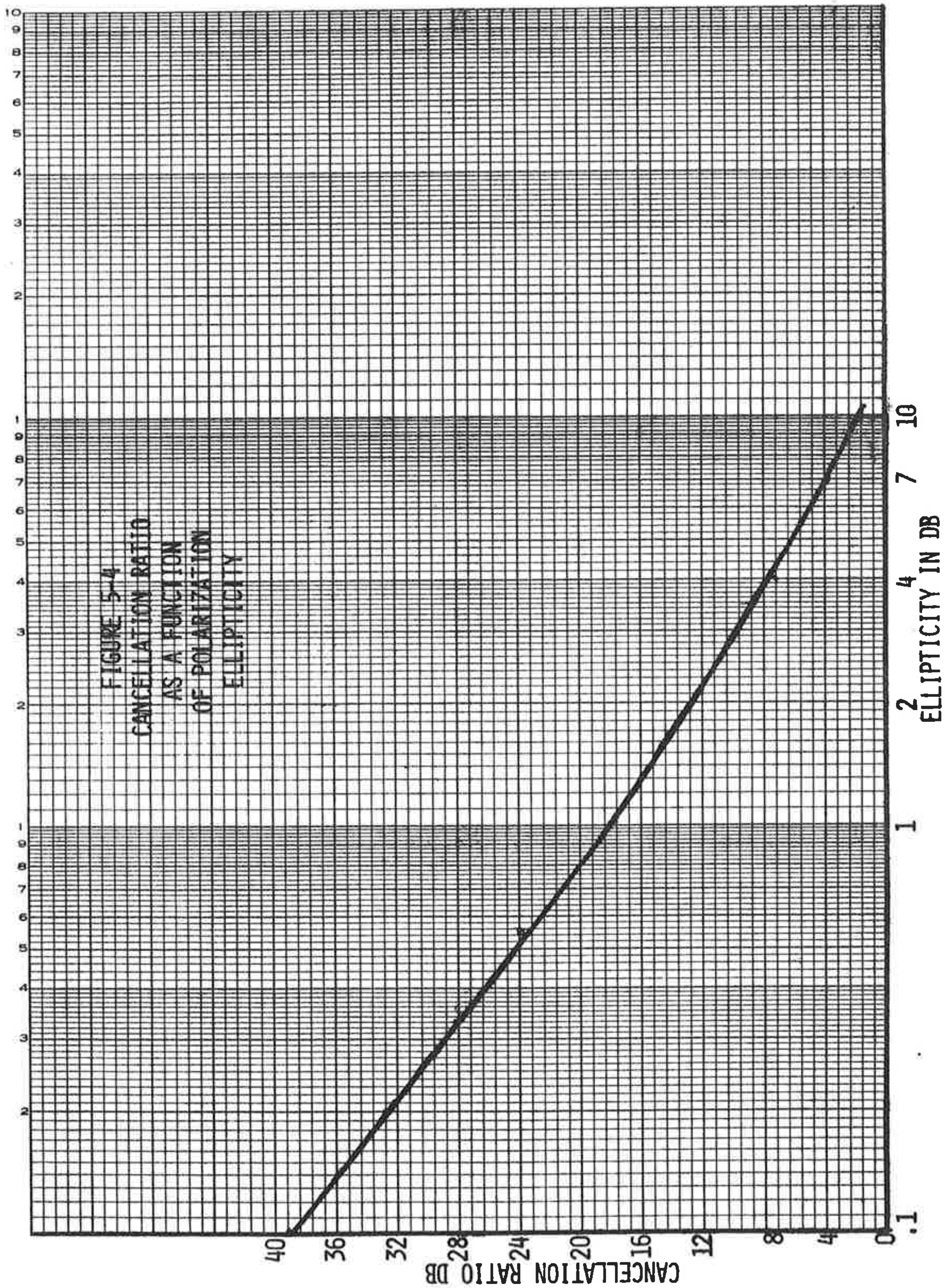
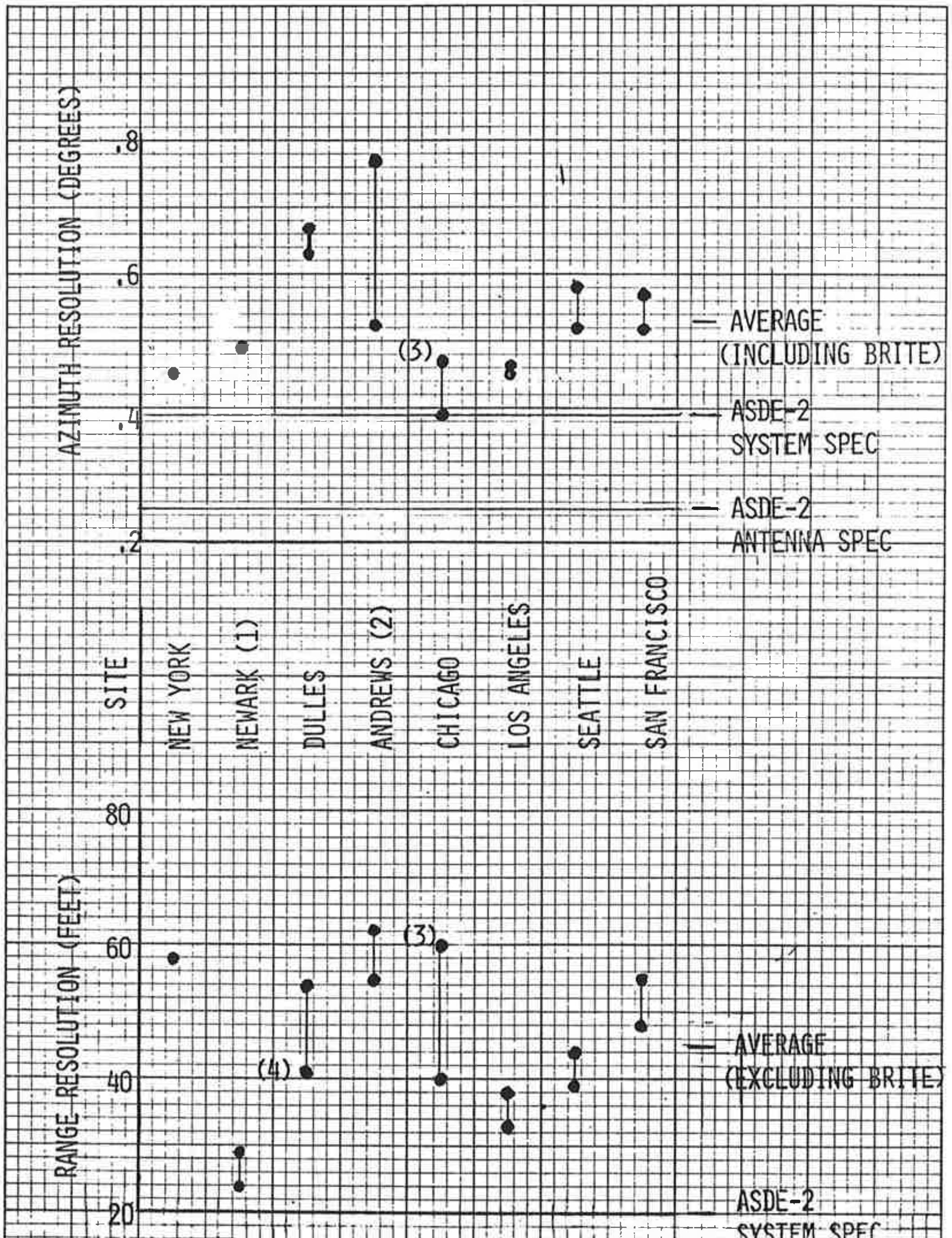


FIGURE 5-4
CANCELLATION RATIO
AS A FUNCTION
OF POLARIZATION
ELLIPTICITY



ASDE-2 OVERALL RESOLUTION
FIGURE 5-5

(1) TWO MEASUREMENTS (2) SAME LOCATION - DIFFERENT REFLECTORS
(3) BRITE (4) VERY POOR CONTRAST

different areas at the same airports. The average value of range resolution for the eight ASDE-2's is 44.3 feet. This is 2.2 times the ASDE-2 system specification. The measurement of range resolution of 60 feet of the BRITE at Chicago's O'Hare was not included in the averaging; the range resolution reported pertains to the original system configuration.

Bandwidth of the receiver, indicator video-amplifier and the overall system were determined by pulse techniques as described in paragraph 5.1. Most measurements were made with test equipment available at the ASDE-2 sites. Pulse generators were not generally available and measurements were therefore made with ASDE-2 transmitter and receiver pulses. Oscilloscopes such as Tektronix 545's and HP AN/USM 281's were used for measurements. The ability to accurately read risetimes on the "545's" is degraded somewhat due to the slower horizontal sweep rates.

Measurements were also made on video amplifiers at Andrews with much better pulse generators ($tr \doteq 5$ ns) and oscilloscopes (Tektronix 454). These measurements indicated a bandwidth of 24.3 MHz for the indicator video amplifier previously computed (table 5-1) as 14.5 MHz. While the later measurement is inherently more accurate - because of the use of better test equipment - we do not expect such large differences in measurements.

To verify this last statement several tests were performed in the laboratory on single and two pole low pass filters. Results of these tests showed that the pulse bandwidth measurement as described above is accurate within ten percent for input risetimes that varied from one-fifth to five times the value of t_{rc} In addition, the 3 dB bandwidth measured with a swept C.W. signal was within ten percent of the pulse bandwidth.

Additional tests were run in the laboratory on an ASDE-2 video amplifier. The swept C.W. bandwidth and the pulse bandwidth were again within a few percent for input pulse risetimes of up to ten nanoseconds. Some degradation was observed for poorer risetimes however it did not cause the measured pulse bandwidth to be reduced to less than sixty percent of the true bandwidth. This phenomenon is not explained but will be considered further in a following report. In any case - the bandwidths of the video amplifiers (or the apparent bandwidths) even if corrected, are not performing to specification.

Table 5-1 is a summary of bandwidth measurements and overall system resolution data. We note that the video amplifier bandwidths (for a 25 volt peak pulse) are in the approximate range from 4 to 27 MHz which is in itself very poor. It is thought that while the Dulles video amplifier meausred only 3.95 MHz, it was most likely being used in a "small-signal" mode of operation for the resolution measurements. This is supported by the fact that indicator detail presentation was noted as being of "very poor contrast" making targets very difficult to detect. Very probably the targets did not separate when the video amplifier was driven harder.

Polarization ellipticity measurements are summarized in table 5-2. Notice that the maximum cancellation ratio is 9 dB. Again it must be emphasized that the values can only be taken as indications and are not to be considered quantitatively. It is significant that the cancellation ratio is as poor as it was measured, however, more tests would have to be made on an antenna range before definite recommendations can be made to improve the ICR.

5.3 CONCLUSIONS AND RECOMMENDATIONS

The standardized tests showed that the ASDE-2's performance is

TABLE 5-1

BANDWIDTH & RESOLUTION DATA SUMMARY

SITE	RECEIVER BANDWIDTH	INDICATOR BANDWIDTH (25 V PEAK PULSE)	SYSTEM BANDWIDTH	OVERALL RESOLUTION	
				RANGE (FEET)	AZIMUTH
JFK *	MEASUREMENT NOT MEANINGFUL	14.8 MHZ (MAINT)		58 PPI	.45° @ 4900'
NEWARK	NO MEASUREMENT EQUIPMENT			29 24	.49° @ 3750' .49° @ 4950' EQUIP.
DULLES	25.5 MHZ	3.95 MHZ	3.9 MHZ	54 41 (VERY POOR CONTRAST)	.63° @ 6000' .67° @ 4000'
ANDREWS	20.5 MHZ	14.5 MHZ	12.4 MHZ	62.5 55	.525° @ 3600' .77° @ 3600'
O'HARE *	33.3 MHZ	19.5 MHZ	16.8 MHZ	40 PPI 60 BR	.39° (PPI) @ 6600' .47° (BR) @ 6600'
LOS ANGELES	A 39 MHZ B 50 MHZ	TOWER: (1) 26.5 MHZ SITE: 15.3 MHZ	19.1 MHZ 14.8 MHZ	33 38	.45° @ 4350' .46° @ 4350'
SEATTLE	A 42 MHZ B 42 MHZ	TOWER: 13.5 MHZ SITE: 10.5 MHZ	12.1 MHZ 9.6 MHZ	39 44	.58° @ 4870' .52° @ 4870'
SAN FRANCISCO	A B 38.9 MHZ	TOWER: DECOMM. SITE: 16.4 MHZ	16 MHZ	55 48	.52° @ 4950' .57° @ 4300'

(1) BOTH TOWER UNITS MEASURED THE SAME

* BRITE CONVERSION INSTALLED

TABLE 5-2: POLARIZATION ELLIPTICITY

SITE	ELLIPTICITY IN dB	CANCELLATION RATIO
Los Angeles	4.0 dB	8 dB
Seattle	5.2 @ Loc 1	6 dB
	7.7 @ Loc 2	4 dB
San Francisco	3.5	9 dB

NOTE: The above are results based on crude measurements that indicate the probability of a problem in the antenna area. Specifications for ASDE-2 production antennas required an ellipticity of 0.2 dB or less at the peak of the beam, which assures an ICR of better than 20 dB. At the time of manufacture all antennas and feeds were tested and found to meet this requirement. This parameter is sensitive to changes in the feed horn window, and these windows after years of usage and service may be a problem. Additional tests and analysis are recommended to determine the cause of the ASDE-2 degraded performance in rain and snow.

approximately a factor of two poorer than the specification.

Bandwidth measurements indicate that a major percentage of the degraded resolution is possibly due to the video amplifier in the indicator.

Receiver bandwidths are also poor in general, however wider video amplifier bandwidths will, in all cases, improve the overall bandwidths (and overall resolution).

Modulator performance appears to be uniformly good in regard to pulse shape and power. The problems with the modulator are solely related to reliability.

Polarization measurements indicate that the ellipticity of the polarization may be significantly degrading the performance in precipitation.

The following actions are recommended, based on performance deficiencies, to improve the ASDE-2's performance:

1. Increase the video amplifier bandwidth. This item is treated in detail in a later, separate report. More testing is indicated to determine if mismatched delay lines in the video amplifier are responsible for poor bandwidth measurements.

2. Increase the receiver bandwidth. This item will be treated in a following report. Poor bandwidth and/or mismatched distributed amplifier sections are suspect.

3. Provide measurement procedures and equipment to test performance indicating parameters such as pulse bandwidth and overall resolution. Present maintenance procedures do not require the attainment of minimum levels of performance of these parameters.

4. Analyze the ASDE-2 antenna parameters. An analysis of the antenna with or without the radome can be performed to determine if the ASDE-2 antenna can be significantly improved to permit operation in rain and snow. The effect of sidelobes or beamwidth on azimuth resolution also needs to be studied.

6. FUTURE AGTC RADAR AND SYSTEM CONSIDERATIONS

Air traffic personnel were interviewed to determine their opinions regarding the implementation of future AGTC systems. This data is tabulated and reported in the following categories:

1. Desired Coverage
2. Operational Usage
3. Desired Display Parameters

Some responses do tend to show the influence of that sites' operational usage of the ASDE-2. For example, controllers at airports that use the ASDE-2 primarily for ground control did not generally indicate that it would be useful for local control.

6.1 DESIRED COVERAGE

Questions were asked to determine what coverage was desired for future radars or AGTC systems. Table 6-1 shows the responses.

6.1.1 Desired Coverage Conclusions

All interviewed agreed that coverage of the movement areas (runways, taxiways, ramps and satellite areas) exclusive of the background areas (all other areas) was desirable. Two of the controllers said they wanted the background areas also - on another question. Nine of the people interviewed felt that the background was objectional while seven didn't object to the background.

TABLE 6-1
DESIRED COVERAGE

COVERAGE	JFK	EWR	IAD	ADW	ORD	LAX	SEA	SFO
MOVEMENT AREAS ONLY	Y Y	Y Y	Y Y	Y Y	Y Y	Y G	Y Y	Y Y
BACKGROUND AREAS	N N	N N	N N	N Y	N N	N N	Y N	N N
RUNWAY APPROACHES	B N	A B	C N	D E	Y F	H I	J N	K N
BACKGROUND OBJECTIONAL	Y Y	Y Y	N N	N N	Y Y	N Y	N N	Y Y

COMMENTS ON DESIRED COVERAGE (Table 6-1)

A. Would like to have 2000' for anticipation of landing aircraft.

B. Would like to have aircraft over the approach lights.

C. Approach coverage to 50' above ground for 2000' distance would be helpful - but not needed.

D. Would like 3 miles out.

E. The further you can see the better.

F. Would be nice to have a quarter of a mile - even a PAR type.

G. Include satellite areas.

H. It would help - not necessary.

I. To show aircraft under 50' on approach - to show what aircraft are committed to landing.

J. Only to airport boundary.

K. 2000' may be beneficial but it's generally offset and wouldn't be used. May be helpful but not necessary.

On the question of runway approach coverage the following summarizes responses:

6 - don't want it

2 - beneficial but not needed

3 - would like to see aircraft under 50' over approach lights

3 - would like coverage to 2000 feet out

2 - want coverage to three miles out

6.2 DESIRED OPERATIONAL USAGE

Questions were asked to determine the desired operational capabilities of future AGTC Radars and systems. Table 6-2 summarizes the responses.

TABLE 6-2
DESIRED OPERATIONAL USAGE

DESIRED OPERATIONAL USAGE	JFK	EWR	IAD	ADW	ORD	LAX	SEA	SFO
RUNWAY CLEARANCE	1 1	1 1	2 2	1 1	1 1	1 1	K K	1 1
TAXIWAY TRACKING	2			2 2	2 3	2 3	1 1	2 2
STEERING			3				2 2	2 2
CONFLICT RESOLUTION	3 A	2 3	1 1	Y Y	3 2	3 2	2 2	2 2
AIRCRAFT LOCATION	2 3	3 2	4 4		4 4	2 4	2 2	2 2
TYPE	N 5	N N	N	N N	N N	N 5	N N	N 3
HEADING	4 4	4 N	5 3	N N	Y Y	N N	N N	N N
IDENTIFICATION	N N	N N	N	N N	N N	N N	N N	N 3
QUICK LOOK AND PART TIME	Y N	Y Y	Y Y	Y Y	Y Y	Y Y	Y Y	N Y
VEHICLE DETECTION	Y N	F N	G Y	Y 3	Y Y	Y Y	Y Y	N N
USE SITUATION	JFK	EWR	IAD	ADW	ORD	LAX	SEA	SFO
NIGHT	Y Y	Y Y	Y Y	Y Y	Y Y	Y Y	Y Y	Y Y
FOG	Y Y	Y Y	Y Y	Y Y	Y Y	Y Y	Y Y	Y Y
RAIN	Y Y	Y Y	Y Y	Y Y	Y Y	Y Y	Y Y	Y Y
SNOW	Y Y	Y Y	Y Y	Y Y	Y Y			
SPECIAL FEATURES	JFK	EWR	IAD	ADW	ORD	LAX	SEA	SFO
BACKGROUND SUPPRESSION	Y Y	N Y	Y N	Y N	Y Y	Y Y	Y Y	Y Y
MOVEMENT AREA OUTLINE	Y Y	Y Y	Y Y	Y N	Y Y	Y Y	Y Y	Y Y
SYNTHETIC AIRCRAFT SYMBOLS	Y N	Y N	Y Y			Y Y	Y N	N Y
INDEPENDENT DISPLAYS	Y Y	Y Y	Y Y	Y Y	Y I	J Y	Y Y	Y Y
RUNWAY APPROACH	B N	D E	Y N	Y Y	Y Y	Y Y		Y N
ALPHANUMERIC IDENTIFICATION	Y Y	Y Y	Y Y	Y Y	N N	Y Y	Y Y	N Y
TARGET SHAPE	N Y	Y C	N H	N N	N N	N Y	Y N	N Y

COMMENTS ON DESIRED OPERATIONAL USAGE (Table 6-2)

A. Conflicts are not possible - controller doesn't permit intersection conflicts to arise

B. Want 100' over approach lights

C. We would know type of aircraft without shape

D. 2000' out for local to anticipate arrivals

E. Want coverage over approach lights

F. When it's working good - about 50% of the time

G. Particularly for mobile lounges

H. Would like size and shape if Dulles becomes a busier airport

I. Even bigger displays would be desirable

J. Four positions would be good

K. Definitely a secondary usage item in SEA - it's all done with communication

6.2.1 Desired Operational Usage Conclusions

Interviewees were asked to indicate the relative importance of various operational uses. Responses indicated in Table 6-2 show highest ratings for runway clearance, taxiways tracking, steering, conflict resolution and aircraft location.

There was complete agreement that an all weather capability was needed. It was generally stressed that it would be used for all conditions of limited visibility - including night, fog, rain, and snow.

In regard to special features, responses are summarized as follows:

SPECIAL FEATURE	YES	NO	COMMENT
Background Suppression	13	3	
Movement Area Outline	15	1	
Synthetic Aircraft Symbols	8	4	
Independent Displays	16	0	
Runway Approach	11	3	
Alphanumeric Identification	13	3	
Target Shape (Desired)	6	9	1 - don't need it

6.3 DESIRED DISPLAY PARAMETERS AND FEATURES

Questions were asked to determine if special features or parameters were desired for future displays. Responses are shown in Table 6-3.

6.3.1 Desired Display Conclusions

Consistent responses indicate preferences for background suppression, background outline, alphanumeric display offsets both fixed and manual and the need for good high brightness indicators.

TABLE 6-3

DESIRED DISPLAY FEATURES

DISPLAY FEATURES	NUMBER FOR FEATURE	JFK	EWR	IAD	ADW	ORD	LAX	SEA	SFO
CONSOLE	14		B Y	Y Y	Y Y	Y Y	Y Y	Y K	Y Y
OVERHEAD	3	A	C N	N N	N N	N N	N N	N K	N N
COLOR	3					Y	N Y	Y N	N N
SYNTHETIC A/C	9	Y Y	Y N	Y Y			Y Y	Y N	N Y
BACKGROUND OUTLINE	15	Y Y	Y Y	Y Y	Y N	Y Y	Y Y	Y Y	Y Y
ALPHANUMERICS	14	Y Y	Y Y	Y Y	Y Y	N N	Y Y	Y Y	Y Y
OFFSET						H			O
FIXED	16	Y Y	Y Y	Y Y	Y Y	Y Y	Y Y	Y Y	Y Y
MANUAL	16	Y Y	Y Y	Y Y	Y Y	Y Y	Y Y	Y Y	Y Y
HIGH BRIGHTNESS	15	Y Y	Y Y	Y Y	Y Y	Y Y	Y I	Y J	L Y
SPECIFIC ORIENTATION	6	N N	N N	N N	N N	N N	Y Y	Y Y	Y Y
OTHER					D E	F G			M P

COMMENTS ON DESIRED DISPLAY FEATURES (Table 6-3)

A. Hanging is better for the BRITE
B. For ground controller
C. For local controller
D. Better presentation: Convertible display for ASDE or ASR
E. Display size - the bigger the better - definitely not 7 inch.
F. Instantaneous turn on
G. Quick look capability
H. Variable Range Control
I. Bright Displays would eliminate the ASDE man
J. If the BRITE for SEA is the same as the BRITE for JFK, we don't want it; we saw JFK's
K. Console for ground - hanging for local
L. Bright display is mandatory
M. Quick look monitor desired - convertible display between ASDE and ASR is best. Also prefer gray tv type screen.
N. Negative reply.
O. Want expanded offset for ground control
P. Want better target definition and shape

APPENDIX A

PERSONNEL INTERVIEWED

AND

SITE DATA

APPENDIX A

PERSONNEL INTERVIEWED

AIRPORT	MAINTENANCE	OPERATIONAL
JFK	Ben Cliffe	Mike Sarli Causby White
EWR	Arty Sacks Ronald Jackson	George Powell Jim Miller
IAD	Bill Weber	Max Boyer Richard Wade
ADW	Bob Walsh	Bill Sargent Bill Schuster
ORD	Al Qualiardi Ken Krauter	Chester Anderson Emil Hensler
LAX	Sidney Bowen	Jim Blair Jim Lundie
SEA	Fred Frost Jim Wickert	Jim Hommel Ray Schiller
SFO	Jack Mathews Tony Marvan	D. E. Bennet H. Barbachano
AERO CENTER	Merle Freeman	George Lagaly

APPENDIX A

ASDE-2 SITE DATA

AIRPORT	ATC TOWER HEIGHT (AGL)	ASDE-2 ANTENNA		
		HEIGHT (AGL)	LOCATION	RADOME
JFK	145'	165'	ATC TOWER	INFLATABLE
EWR	130'	150'	ATC TOWER	INFLATABLE
IAD	165'	185'	ATC TOWER	INFLATABLE
ADW	122'	142'	ATC TOWER	RIGID
ORD	190'	210'	ATC TOWER	SPACE FRAME
LAX		136'	REMOTE	INFLATABLE
SEA	85'	96'	REMOTE	INFLATABLE
SFO	136'	56'	REMOTE	INFLATABLE

APPENDIX B

ASDE-2 EQUIPMENT DESCRIPTION

1. EQUIPMENT DESCRIPTION

This appendix is intended to provide a description of major components and assemblies of the ASDE-2 system. Official nomenclature, reference designators and a brief functional description are provided to aid in interpreting information presented in the body of the report.

1.1 MAJOR COMPONENTS

A typical ASDE-2 system consists of the major components listed below by official nomenclature and reference designator.

1. TR Group
   a. TR Cabinets, FA-6610, 1000 (2 each)
   b. A-Scope Cabinets, FA-6620, 2000 (2 each)
   c. Control Cabinet, FA-6640, 4000 (1 each)
   d. AC Voltage Regulators, FA-6683, 9000 (3 each)
   e. AC Pwr. Dist. Box, FA-6680, 8000 (1 each)
   f. Antenna Contactor Box, FA-6681, 8100 (1 each)
   g. Remote Lines Jct. Box, FA-6686, 10000 (1 each)
   h. Waveguide Switch, FA-6695, 9300 (2 each)

2. Antenna Group
   a. Antenna Assembly, FA-6690, 9200 (1 each)

3. Indicator Group
   a. Console Cabinet, FA-6670, 7000 (2-3 each)
   b. Console Equip. and Remoting Cabinet, FA-6660, 6000 (1 each)
   c. AC Pwr. Dist. Box, FA-6682, 8500 (1 each)
   d. Remote Control Box, FA-6676, 7600 (1 each)
   e. AC Voltage Regulator, FA-6683, 9000 (1 each)
   f. Power Supplies in FA-6640, 4000 (1 each)

1.2 ASSEMBLIES

TR Cabinets contain the following assemblies:

1. Meter Panel, FA-6611, 1100
2. Video Dist. and STC, FA-6612, 1200
3. Receiver, FA-6613, 1300
4. AFC Amplifier, FA-6614, 1400
5. IF Amplifier, FA-6615, 1500-1700
6. Modulator LV Power Supply, FA-6616, 1800
7. Modulator Transformer, FA-6618, 1900
8. Modulator and HV Power Supply, FA-6617, 1900

A-Scope Cabinets contain the following assemblies:

1. Meter Panel, FA-6621, 2100
2. A-Scope, FA-6622, 2200
3. Video Amplifier, FA-6672, 7200
4. TR Control Panel, FA-6623, 2400
5. A-Scope HV Power Supply, FA-6624, 2500
6. Trigger Generator, FA-6625, 2600
7. -150 and +300 V Regulator, FA-6626, 2700
8. +270 V Power Supply, FA-6627, 2800
9. Line Driver, FA-6628, 2900
10. +120 V ABC Regulator, FA-6629, 3000
11. +120 V D Regulator, FA-6630, 3100
12. Filament Supply, FA-6631, 3200
13. +285 and +400V Power Supply, FA-6632, 3300
14. Equalizer, FA-6653, 5400

Control Cabinet, FA-6640 contains the following assemblies.

1. Meter Panel, FA-6663, 6300
2. Dual-Channel Control, FA-6641, 4100

3. Sweep Amplifier Power Supply, FA-6661, 6100
4. Indicator Power Supply, FA-6662, 6200

Console Cabinet, FA-6670 contains the following assemblies.

1. Console Top Drawer, FA-6677, 7800
2. Console Lower Drawer, FA-6679, 7900
3. Sweep Amplifier, FA-6671, 8300
4. HV Power Supply, FA-6673, 7300
5. Video Amplifier, FA-6672, 7200
6. Servo Amplifier, FA-6674, 7400
7. Off-Centering Power Supply, FA-6675, 7500
8. Deflection Coil Drive, FA-6678, 7850

Console Equipment and Remoting Cabinet, FA-6660 contains the following assemblies.

1. Meter Panel, FA-6651, 5100
2. Line Amplifier, FA-6652, 5300
3. +270V Power Supply, FA-6627, 2800
4. +120V D Regulator, FA-6630, 3100
5. Filament Supply, FA-6654, 5500
6. Meter Panel, FA-6663, 6300
7. Sweep Amplifier Power Supply, FA-6661, 6100
8. Indicator Power Supply, FA-6662, 6200

Antenna Assembly, FA-6690 consists of the following assemblies.

1. Antenna Reflector and A-Frame, FA-6691, 9200
2. Antenna Feed and Polarizer, FA-6692, 9200
3. Antenna Pedestal, FA-6693, 9200
4. Antenna Drive Motor, FA-6694, 9200
5. Radome Assembly, FA-6601
6. Inflation Control Assembly, FA-6602

7. Inflation Blower, FA-6603
8. Airlock, FA-6604

1.3 FUNCTIONAL DESCRIPTION

This section is intended to provide a general functional description of ASDE-2 using block diagrams from Section 3, Volume I of the ASDE-2 Instruction Book.

1.3.1 Trigger Generator, FA-6625

Trigger Generator FA-6625 synchronizes the ASDE system with three timing signals which are supplied to the transmitting receiving and indicating systems. The basic timing signal is generated by cathode-coupled Hartley oscillator, V2601. The signal from V2601 is coupled to timing gate shaper V2602. The positive output of V2602 is differentiated and applied to trigger generator V2603 and delay line DL 2601. The STC trigger timing signal is taken from V2603 and DL 2601. A 4 μsec delayed signal from DL 2601 is applied to pretrigger generator V2604 and a 6 μsec delayed signal is applied to trigger shaper and blocking oscillator V2606. One output of V2606 is supplied to Modulator HV Power Supply FA-6617.

1.3.2 Modulator, FA-6617 and FA-6618

The modulator trigger from Modulator HV Power Supply FA-6617 is applied to pulse amplifier V1901 in Modulator-Transformer Assembly, FA-6618. The resulting signal is then applied to thyratron V1902 through transformer T1901. V1902 is used to develop a large positive pulse across cathode resistors R1924, R1905 and R1904 which is coupled to the grids of power amplifiers V1903, V1904 and V1905. A negative pulse is developed by the power amplifiers and coupled to magnetron V1906 which produces the RF output pulse. A block diagram of Modulator-Transformer Assembly

FA-6618 is shown in Figure B-1.

1.3.3 Waveguide System

The RF pulse from the magnetron is coupled to the duplexer. One output from the duplexer is supplied to A-Scope, FA-6622 via an RF envelope detector. Another output is fed from the duplexer to a directional coupler. The directional coupler provides one output 30 dB down from the main signal to a test point. The other output is connected through the transfer waveguide switch to the antenna where it is radiated from the reflector.

Return signals reach the duplexer along the same path traveled by the transmitted pulse. The signals are then fed to the receiver via a dual TR tube, V1303 in Receiver Assembly FA-6613.

Figure B-2 is a block diagram of the waveguide system.

1.3.4 Receiving System

Echo signals are returned via TR tube, V1303, to the IF mixer containing IF crystals CR1303 and CR1304 also located in Receiver Assembly FA-6613. Here the signal is heterodyned with the signal from local oscillator, V1301. The output from the mixer is an IF signal which is fed to IF preamplifier, V1304. AFC Amplifier, FA-6614 is used to maintain a 130 Mc separation in the frequency of the transmitted signal and that of the local oscillator. The signal from the IF preamplifier is provided to IF amplifier, FA-6615 where additional amplification is achieved and the video is removed from the IF carrier in the last stage. Detected video is then fed through an FTC circuit to Video Distribution and STC Assembly, FA-6612, where the signal is amplified by V1201, V1202, V1203, V1204, and V1205 and coupled via V1206, V1207 and V1208 to the A-Scope and PPI Consoles. STC circuitry, located in FA-6612 consists of blocking

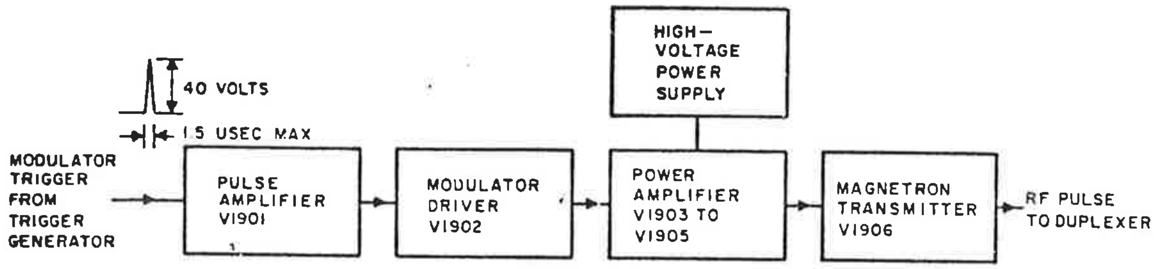


Figure B-1. Modulator-Transformer Assembly FA-6618, Block Diagram

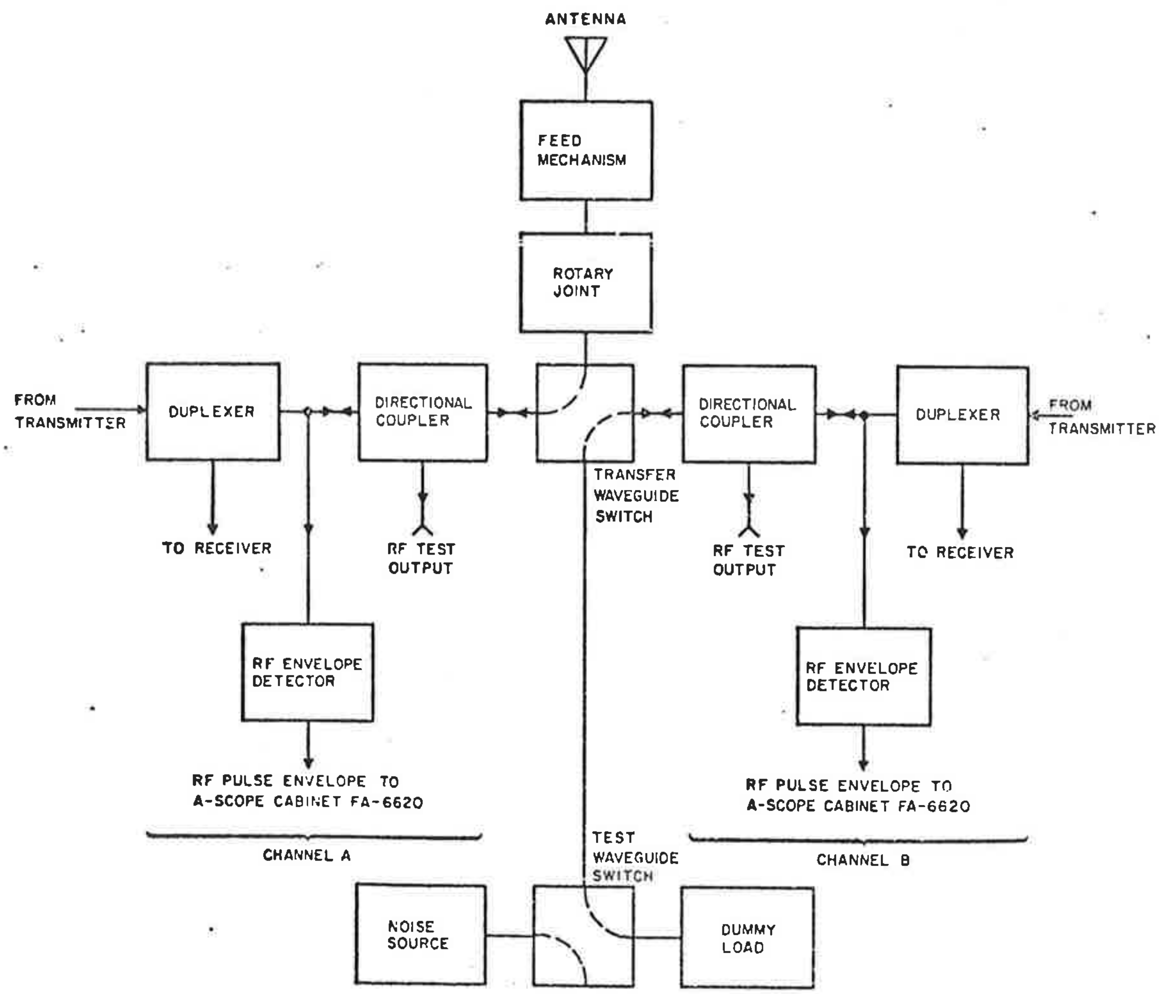


Figure B-2. Waveguide System, Block Diagram oscillator V1209, STC multivibrator V1210 and STC generator V1211.

Figure B-3 is a block diagram of the receiving system.

1.3.5 Remoting Equipment

Remoting equipment shown in Figure B-4 allows operation of PPI consoles at distances up to 6000 feet from the radar site.

1.3.6 Indicator System

The PPI trigger from FA-6625 is applied to Sweep Amplifier FA-6671 which generates the sweep for the PPI. A rotation signal from an alternator geared to the shaft of the antenna is applied to Servo Amplifier, FA-6674, which drives deflection motor B7852 in Deflection coil Drive, FA-6678. Signals from the antenna and the rotating deflection coil, L7853, are fed to correction motor, B7851 to keep the sweep line synchronized with antenna rotation.

Video signals are applied the to the cathode of CRT, V7801, via Video Amplifier, FA-6672.

Off-centering power supplies, FA-6675 in lower drawer, FA-6679 provide current to the off-centering deflection coils to prevent the display from shifting from scan to scan and to allow manual control of the position of the center of the display.

HV Power Supply, FA-6673 provides high voltages to the grid and anode of the CRT.

A block diagram of the PPI console is shown in Figure B-5.

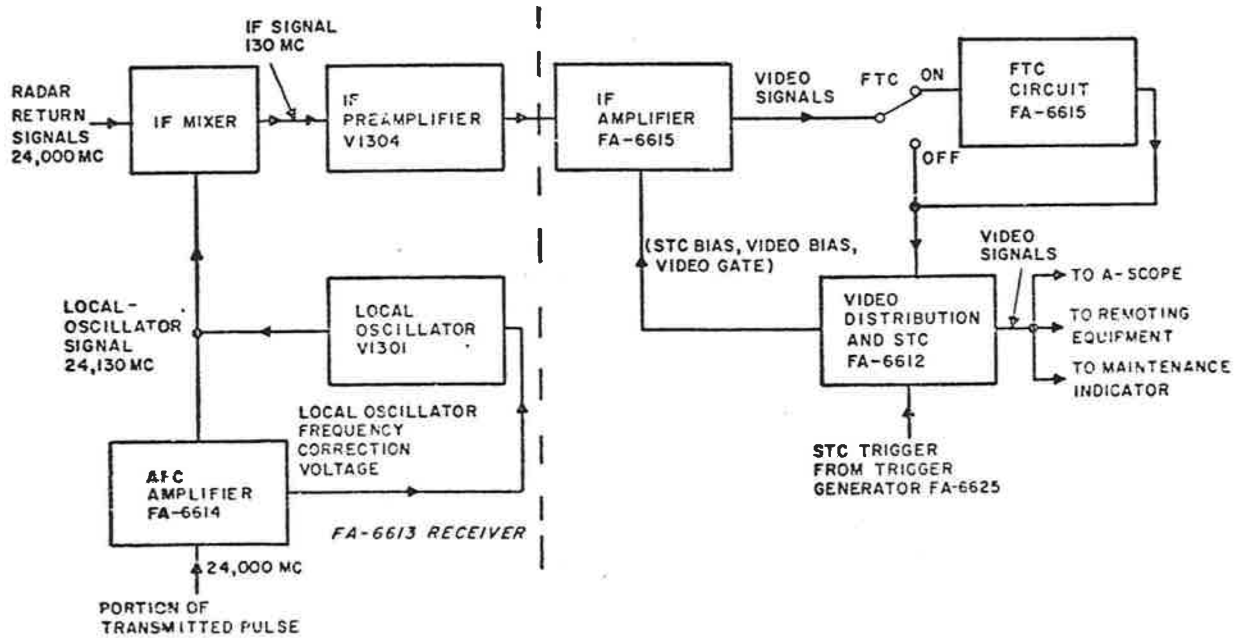


Figure B-3. Receiving System, Block Diagram

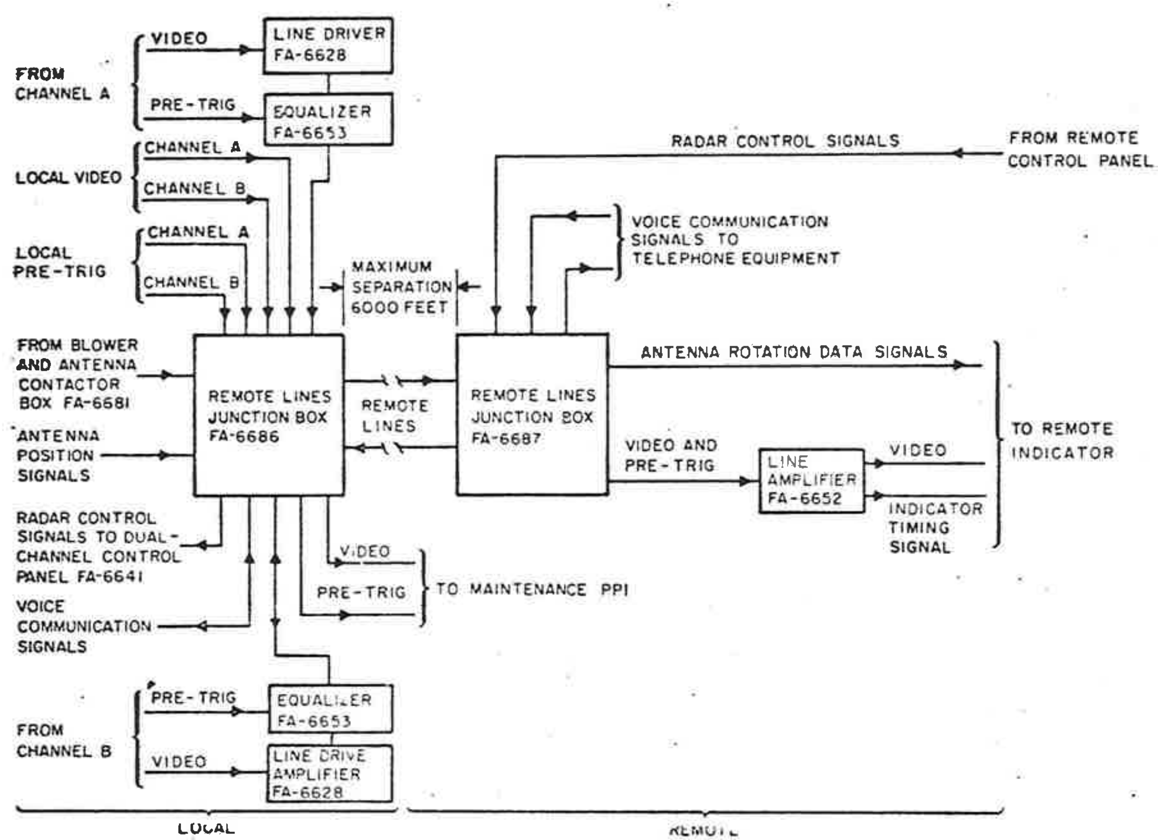


Figure B-4. Remoting Equipment, Block Diagram

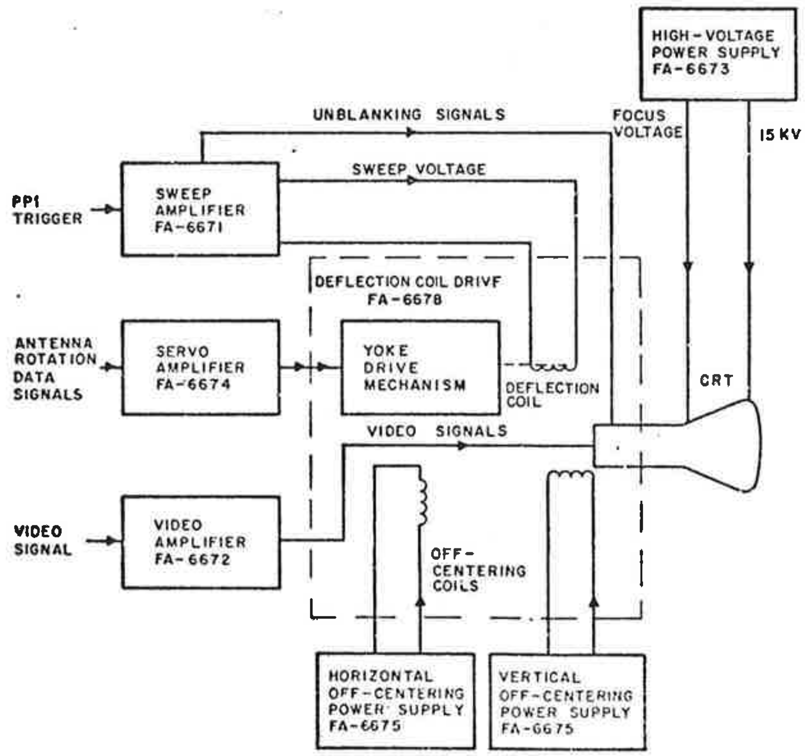


Figure B-5. PPI Console, Block Diagram

APPENDIX C

MAINTENANCE ACTION DATA

1. MAINTENANCE ACTION DATA

This appendix contains data relative to the quantity and distribution of maintenance actions for each ASDE-2 site surveyed for the time periods assessed. Quantity of maintenance actions is tabulated by site, assembly and month.

Data for individual sites is provided in Tables C-1 through C-8 as follows:

1. Kennedy - Table C-1.
2. Newark - Table C-2.
3. Dulles - Table C-3.
4. Andrews - Table C-4.
5. O'Hare - Table C-5.
6. Los Angeles - Table C-6.
7. Seattle - Table C-7.
8. San Francisco - Table C-8.

Data for all sites combined is provided in Table C-9.

TABLE C-1; QUANTITY AND ASSEMBLY ASSOCIATED WITH UNSCHEDULED MAINTENANCE ACTIONS AT JFK

REF DESIG	DESCRIPTION	QUANTITY OF UNSCHEDULED MAINTENANCE ACTIONS 1970 J	F	M	A	M	J	J	A	S	O	N	D	1971 J	F	M	A	M	J	J	A	S	O	N	D	1972 J	F	M	A	M	J	TOTAL
1000	TR Cabinet		1			1							1	1											1	1						6
1100	Meter Panel																															0
1200	Video Dist & STC															2				2	2											6
1300	Receiver	2	6	2	3	2	6	8			1	9	3	3	6	2	5	8	8	7	3	5	9		2	6	2	7	7	8	11	141
1400	AFC Amplifier		1				3	2			2	1		2																		11
1500-1700	IF Amplifier		2				1	1	2	1		1						1	1	1	2		1	2		3						19
1800	Mod. LVPS										2																					2
1900	Mod & HVPS	2	1	1	7	3	7	3	4	1		5	1	10	5	6	5	1	3	5	10	10	8			3	1			3	3	108
2000	A-Scope Cabinet				1																					1	1				1	4
2100	Meter Panel																															0
2200	A-Scope											1	2		1																	4
2400	Control Panel		1										1					1				1										4
2500	A-Scope HVPS																														1	1
2600	Trigger Generator		1			1			2		1									1			2	1			1					10
2700	-150 & +300 VDC Regulator					1																				1						2
2800	+270 VDC PS																															0
2900	Line Driver Ampl.															1																1
3000	120V ABC Reg.																															0
3100	120V D Reg.																		2													2
3200	Filament Supply																															0
3300	+285 & +400 VDC PS																															0
5400	Equalizer																															0
4000	Control Cabinet																															0
4100	Dual-Chan Control																															0
6000	Console Equip Cab																															0
5100	Meter Panel																															0
5300	Line Amplifier			1																												1
5500	Filament Supply																															0
6100	Swp. Gen. Power Supply																															0
6200	Indicator Power Supply					1																1				1						3
6300	Meter Panel																															0

TABLE C-1; QUANTITY AND ASSEMBLY ASSOCIATED WITH UNSCHEDULED MAINTENANCE ACTIONS AT JFK (continued)

REF DESIG	DESCRIPTION	QUANTITY OF UNSCHEDULED MAINTENANCE ACTIONS 1970 J	F	M	A	M	J	J	A	S	O	N	D	1971 J	F	M	A	M	J	J	A	S	O	N	D	1972 J	F	M	A	M	J	TOTAL
7000	PPI Console																						1									1
7200	Video Amplifier																			1												1
7300	15KV Pwr Supply				1	1															1										1	4
7400	Rotation Control																							1			1					2
7500	Off-Centering PS																		1													1
7600	Remote Control Panel																															0
7800 - 7850	Top Dwr. & Defl. Coil Dr.			1	1	1		2									1			1								1				8
7900	Lower Drawer																															0
8000	Pwr. Dist. Box													1																		1
8100	Ant. Contractor Box																									1						1
8300	Swp. Generator					1																		1								2
8500	Pwr. Dist. Box					1																										1
9000	AC Voltage Reg.																															0
9100	Noise Source PS																															0
9200	Antenna																															0
9300	W/G Blower																															0
10000	Remote Lines Jct. Box																															0
10100	Remote Lines Jct. Box																															0
11000	Inflation Cont. Assy	1							1																		1					3
	Miscellaneous							1		1		1			1		1												1	1		7
	TOTAL	5	13	5	13	13	17	17	9	3	6	18	8	17	13	11	12	11	15	18	18	17	21	5	3	16	8	8	8	12	17	357

TABLE C-2; QUANTITY AND ASSEMBLY ASSOCIATED WITH UNSCHEDULED MAINTENANCE ACTIONS AT EWR

REF DESIG	DESCRIPTION	QUANTITY OF UNSCHEDULED MAINTENANCE ACTIONS																														TOTAL
		1970												1971												1972						
		J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	
1000	TR Cabinet																														-	0
1100	Meter Panel																														-	0
1200	Video Dist & STC																														-	0
1300	Receiver	2		3	4	2		2	2	3	2	1	2	1	2	3	1	2	5	2	2	1	1		2	4	1	3	1	1	-	55
1400	ATC Amplifier															1	1														-	2
1500-1700	IF Amplifier							1																							-	1
1800	Mod. LVPS																						1								-	1
1900	Mod & HVPS			6	3	2				1			3		1	1		2	3	5	4	5	5	4	3	9	5	2			-	64
2000	A-Scope Cabinet	1																1		1											-	3
2100	Meter Panel																														-	0
2200	A-Scope						1									1															-	2
2400	Control Panel																									1				1	-	2
2500	A-Scope HVPS																														-	0
2600	Trigger Generator		1																												-	1
2700	-150 & +300 VDC Regulator																														-	0
2800	+270 VDC PS																														-	0
2900	Line Driver Ampl.																														-	0
3000	120V ABC Reg.																														-	0
3100	120V D Reg.					1																				1					-	2
3200	Filament Supply																														-	0
3300	+285 & +400 VDC PS																														-	0
5400	Equalizer																														-	0
4000	Control Cabinet																														-	0
4100	Dual-Chan Control																		1												-	1
6000	Console Equip Cab																														-	0
5100	Meter Panel																														-	0
5300	Line Amplifier																														-	0
5500	Filament Supply																														-	0
6100	Swp. Gen. Power Supply									1																					-	1
6200	Indicator Power Supply					1																		1							-	2
6300	Meter Panel																														-	0

TABLE C-2; QUANTITY AND ASSEMBLY ASSOCIATED WITH UNSCHEDULED MAINTENANCE ACTIONS AT EWR (continued)

REF DESIG	DESCRIPTION	QUANTITY OF UNSCHEDULED MAINTENANCE ACTIONS																													TOTAL
		1970												1971												1972					
		J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	
7000	PPI Console														1											1		1	1		-	4
7200	Video Amplifier																										1				-	1
7300	15KV Pwr Supply						1				1				2				1			2		1		1	1				-	10
7400	Rotation Control																					1				1					-	2
7500	Off-Centering PS																									1					-	1
7600	Remote Control Panel																														-	0
7800 - 7850	Top Dwr. & Defl. Coil Dr.					3	1		3		1			3		1		1			1	3						1	2		-	20
7900	Lower Drawer																								1						-	1
8000	Pwr. Dist. Box																														-	0
8100	Ant. Contractor																														-	0
8300	Swp. Generator					1	1				1			1							1	1									-	6
8500	Pwr. Dist. Box																														-	0
9000	AC Voltage Reg.																							1							-	1
9100	Noise Source PS									1																		1			-	2
9200	Antenna																	1													-	1
9300	W/G Blower																								1						-	1
10000	Remote Lines Jct. Box																														-	0
10100	Remote Lines Jct. Box																														-	0
11000	Inflation Cont. Assy																														-	0
	Miscellaneous			1			1			1														2							-	5
	TOTAL	3	1	10	7	10	5	3	5	7	5	1	5	5	6	7	2	7	10	8	8	13	7	8	8	19	8	8	4	2	-	192

TABLE C-3; QUANTITY AND ASSEMBLY ASSOCIATED WITH UNSCHEDULED MAINTENANCE ACTIONS AT IAD

REF DESIG	DESCRIPTION	QUANTITY OF UNSCHEDULED MAINTENANCE ACTIONS																														TOTAL
		1970												1971												1972						
		J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	
1000	TR Cabinet											1			1													-	-	-	-	2
1100	Meter Panel																											-	-	-	-	0
1200	Video Dist & STC	1		1		1					1			1								1		1					-	-	-	7
1300	Receiver	2	5	9	12	8	7	9	4	5	6	3	4	5	4	3	1	2	4	7	9	2	5	8	7	5	8	-	-	-	-	144
1400	AFC Amplifier				1	1										1			1				1					-	-	-	-	5
1500-1700	IF Amplifier			1		1	1				1						1							1	1			-	-	-	-	7
1800	Mod. LVPS																											-	-	-	-	0
1900	Mod & HVPS	3		2	2	3		2	1	3	2	1	5	2	2	1	1	3	2	1	2	1		1	1	3	1	-	-	-	-	45
2000	A-Scope Cabinet																							1				-	-	-	-	1
2100	Meter Panel																											-	-	-	-	0
2200	A-Scope																											-	-	-	-	0
2400	Control Panel								2																			-	-	-	-	2
2500	A-Scope HVPS																											-	-	-	-	0
2600	Trigger Generator			1										1							1	1	1			1		-	-	-	-	6
2700	-150 & +300 VDC Regulator				1																							-	-	-	-	1
2800	+270 VDC PS																											-	-	-	-	0
2900	Line Driver Ampl.																							1				-	-	-	-	1
3000	120V ABC Reg.																											-	-	-	-	0
3100	120V D Reg.						1																					-	-	-	-	1
3200	Filament Supply																											-	-	-	-	0
3300	+285 & +400 VDC PS																				1							-	-	-	-	1
5400	Equalizer																											-	-	-	-	0
4000	Control Cabinet					1			1																			-	-	-	-	2
4100	Dual-Chan Control				2		2	1		1																		-	-	-	-	6
6000	Console Equip Cab																											-	-	-	-	0
5100	Meter Panel																											-	-	-	-	0
5300	Line Amplifier	1											1															-	-	-	-	2
5500	Filament Supply																											-	-	-	-	0
6100	Swp. Gen. Power Supply																											-	-	-	-	0
6200	Indicator Power Supply				1															1						1		-	-	-	-	3
6300	Meter Panel																											-	-	-	-	0

TABLE C-3; QUANTITY AND ASSEMBLY ASSOCIATED WITH UNSCHEDULED MAINTENANCE ACTIONS AT IAD (continued)

REF DESIG	DESCRIPTION	QUANTITY OF UNSCHEDULED MAINTENANCE ACTIONS 1970 J	F	M	A	M	J	J	A	S	O	N	D	1971 J	F	M	A	M	J	J	A	S	O	N	D	1972 J	F	M	A	M	J	TOTAL
7000	PPI Console																											-	-	-	-	0
7200	Video Amplifier													2														-	-	-	-	2
7300	15KV Pwr Supply	1			1		1	1		1				1								1						-	-	-	-	7
7400	Rotation Control				1		1																					-	-	-	-	2
7500	Off-Centering PS																											-	-	-	-	0
7600	Remote Control Panel						1				2	1		1														-	-	-	-	5
7800 - 7850	Top Dwr. & Defl. Coil Dr.	4	1		1	2	4		2	1					3	1			1	1								-	-	-	-	21
7900	Lower Drawer																											-	-	-	-	0
8000	Pwr. Dist. Box																											-	-	-	-	0
8100	Ant. Contractor																											-	-	-	-	0
8300	Swp. Generator		1												1	1				1			2	1	3		1	-	-	-	-	11
8500	Pwr. Dist. Box																										1	-	-	-	-	1
9000	AC Voltage Reg.																											-	-	-	-	0
9100	Noise Source PS					1																						-	-	-	-	1
9200	Antenna																											-	-	-	-	0
9300	W/G Blower				1		1			1																	1	-	-	-	-	4
10000	Remote Lines Jct. Box																											-	-	-	-	0
10100	Remote Lines Jct. Box																											-	-	-	-	0
11000	Inflation Cont. Assy																											-	-	-	-	0
	Miscellaneous			3	1	1	1	1	2			1	1															-	-	-	-	11
	TOTAL	12	7	17	24	19	20	14	12	12	12	7	11	13	11	7	3	5	8	11	13	6	9	14	12	10	12	-	-	-	-	301

TABLE C-4; QUANTITY AND ASSEMBLY ASSOCIATED WITH UNSCHEDULED MAINTENANCE ACTIONS AT AND

REF DESIG	DESCRIPTION	QUANTITY OF UNSCHEDULED MAINTENANCE ACTIONS																														TOTAL
		1970												1971												1972						
		J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	
1000	TR Cabinet									1		1																-	-	-	-	2
1100	Meter Panel																											-	-	-	-	0
1200	Video Dist & STC	3									1			1														-	-	-	-	5
1300	Receiver		7	4	3	1	5	1	4	1	3	3	3	3	2		2	1	1	5	1	4	7	2	2	12	3	-	-	-	-	80
1400	AFC Amplifier	1																								1	1		-	-	-	3
1500-1700	IF Amplifier	1	1					1	1																	1		-	-	-	-	5
1800	Mod. LVPS																											-	-	-	-	0
1900	Mod & HVPS	4	3		2		3			1		3	1	3	1	1		1	1	4	2	3	9	5		1	1	-	-	-	-	49
2000	A-Scope Cabinet	1																				1			1			-	-	-	-	3
2100	Meter Panel																											-	-	-	-	0
2200	A-Scope																1											-	-	-	-	1
2400	Control Panel																											-	-	-	-	0
2500	A-Scope HVPS															1	1			1								-	-	-	-	3
2600	Trigger Generator	1						1			1									1								-	-	-	-	4
2700	-150 & +300 VDC Regulator																											-	-	-	-	0
2800	+270 VDC PS																											-	-	-	-	0
2900	Line Driver Ampl.													1														-	-	-	-	1
3000	120V ABC Reg.																											-	-	-	-	0
3100	120V D Reg.															1							1					-	-	-	-	2
3200	Filament Supply																											-	-	-	-	0
3300	+285 & +400 VDC PS																											-	-	-	-	0
5400	Equalizer																											-	-	-	-	0
4000	Control Cabinet																						1					-	-	-	-	1
4100	Dual-Chan Control																											-	-	-	-	0
6000	Console Equip Cab																											-	-	-	-	0
5100	Meter Panel																											-	-	-	-	0
5300	Line Amplifier																											-	-	-	-	0
5500	Filament Supply																											-	-	-	-	0
6100	Swp. Gen. Power Supply																								1			-	-	-	-	1
6200	Indicator Power Supply			1													1									2		-	-	-	-	4
6300	Meter Panel																											-	-	-	-	0

TABLE C-4; QUANTITY AND ASSEMBLY ASSOCIATED WITH UNSCHEDULED MAINTENANCE ACTIONS AT AND (continued)

REF DESIG	DESCRIPTION	QUANTITY OF UNSCHEDULED MAINTENANCE ACTIONS																														TOTAL
		1970												1971												1972						
		J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	
7000	PPI Console									1																		-	-	-	-	1
7200	Video Amplifier																											-	-	-	-	0
7300	15KV Pwr Supply					1			1					1														-	-	-	-	3
7400	Rotation Control					1																						-	-	-	-	1
7500	Off-Centering PS																											-	-	-	-	0
7600	Remote Control Panel																											-	-	-	-	0
7800 - 7850	Top Dwr. & Defl. Coil Dr.									1				2		1	1									1	1	-	-	-	-	7
7900	Lower Drawer																											-	-	-	-	0
8000	Pwr. Dist. Box																											-	-	-	-	0
8100	Ant. Contractor																											-	-	-	-	0
8300	Swp. Generator							1		1												2		2		2		-	-	-	-	8
8500	Pwr. Dist. Box																											-	-	-	-	0
9000	AC Voltage Reg.																											-	-	-	-	0
9100	Noise Source PS																	1										-	-	-	-	1
9200	Antenna																											-	-	-	-	0
9300	W/G Blower	2																					1					-	-	-	-	3
10000	Remote Lines Jct. Box																											-	-	-	-	0
10100	Remote Lines Jct. Box																											-	-	-	-	0
11000	Inflation Cont. Assy																											-	-	-	-	0
	Miscellaneous	1		1											1		3							1				-	-	-	-	7
	TOTAL	11	11	6	5	3	8	4	6	6	5	7	4	11	4	4	9	3	2	11	3	10	18	11	4	20	6	-	-	-	-	195

TABLE C-5; QUANTITY AND ASSEMBLY ASSOCIATED WITH UNSCHEDULED MAINTENANCE ACTIONS AT ORD

REF DESIG	DESCRIPTION	QUANTITY OF UNSCHEDULED MAINTENANCE ACTIONS																														TOTAL
		1970												1971												1972						
		J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	
1000	TR Cabinet																1													-	-	1
1100	Meter Panel																													-	-	0
1200	Video Dist & STC	1				1			1					2										2						-	-	7
1300	Receiver	1	2	1	3		2	3	2	3	1	6	4	3	3		4	2	14	3	7	2	4	10	7	7	6	13	6			119
1400	AFC Amplifier		1			1	1						1										1	1			2					9
1500-1700	IF Amplifier						1			1		1	1	2		1					1	1				3		1		-	-	13
1800	Mod. LVPS																													-	-	0
1900	Mod & HVPS		1	1	3		1	3	1	1	1			5	2	1	1		5	5	3	6	2	1	2		1	4	1	-	-	51
2000	A-Scope Cabinet				1																									-	-	1
2100	Meter Panel																													-	-	0
2200	A-Scope				1				1	1														1	1					-	-	5
2400	Control Panel						1		1											1										-	-	3
2500	A-Scope HVPS																										1			-	-	1
2600	Trigger Generator								1					2					2				1		1			1	1	-	-	9
2700	-150 & +300 VDC Regulator																													-	-	0
2800	+270 VDC PS																													-	-	0
2900	Line Driver Ampl.			1										1																-	-	2
3000	120V ABC Reg.												2																	-	-	2
3100	120V D Reg.										1																			-	-	1
3200	Filament Supply																													-	-	0
3300	+285 & +400 VDC PS																													-	-	0
5400	Equalizer																													-	-	0
4000	Control Cabinet	1																												-	-	1
4100	Dual-Chan Control						1																							-	-	1
6000	Console Equip Cab																													-	-	0
5100	Meter Panel																													-	-	0
5300	Line Amplifier																													-	-	0
5500	Filament Supply																													-	-	0
6100	Swp. Gen. Power Supply																													-	-	0
6200	Indicator Power Supply							1						2																-	-	3
6300	Meter Panel																													-	-	0

TABLE C-5; QUANTITY AND ASSEMBLY ASSOCIATED WITH UNSCHEDULED MAINTENANCE ACTIONS AT ORD (continued)

REF DESIG	DESCRIPTION	QUANTITY OF UNSCHEDULED MAINTENANCE ACTIONS																														TOTAL
		1970												1971												1972						
		J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	
7000	PPI Console																													-	-	0
7200	Video Amplifier												1																	-	-	1
7300	15KV Pwr Supply						1																							-	-	1
7400	Rotation Control										1						1								1					-	-	3
7500	Off-Centering PS															1														-	-	1
7600	Remote Control Panel																											1		-	-	1
7800 - 7850	Top Dwr. & Defl. Coil Dr.				1		1		1	3				1					1						1	1				-	-	10
7900	Lower Drawer																													-	-	0
8000	Pwr. Dist. Box																													-	-	0
8100	Ant. Contractor																													-	-	0
8300	Swp. Generator	1		1	1		1	1		3	1			1																-	-	10
8500	Pwr. Dist. Box																													-	-	0
9000	AC Voltage Reg.																													-	-	0
9100	Noise Source PS																					1								-	-	1
9200	Antenna																													-	-	0
9300	W/G Blower																													-	-	0
10000	Remote Lines Jct. Box																				1									-	-	1
10100	Remote Lines Jct. Box																													-	-	0
11000	Inflation Cont. Assy																													-	-	0
	Miscellaneous				1					1														1		1			1	-	-	5
	TOTAL	4	4	4	11	2	10	8	8	13	5	7	9	19	5	3	7	2	23	9	12	10	8	16	13	12	10	20	9	-	-	263

TABLE C-6; QUANTITY AND ASSEMBLY ASSOCIATED WITH UNSCHEDULED MAINTENANCE ACTIONS AT LAX

REF DESIG	DESCRIPTION	QUANTITY OF UNSCHEDULED MAINTENANCE ACTIONS																														TOTAL
		1970												1971												1972						
		J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	
1000	TR Cabinet	1																														1
1100	Meter Panel																															0
1200	Video Dist & STC									2			1			1																4
1300	Receiver	6				2	3		3	2	4	3	2	4		3	1	2	4	1	1			1	3	3	5	2	4	3	4	66
1400	AFC Amplifier																															0
1500-1700	IF Amplifier		1		1					1		1	1				1		1			1					2			1		11
1800	Mod. LVPS																															0
1900	Mod & HVPS	1	3			3	1	1		3		1	1	3	1	1	1	1		1	1	1	1	2		6	1	2	1	1	1	39
2000	A-Scope Cabinet																															0
2100	Meter Panel																															0
2200	A-Scope																															0
2400	Control Panel													2																		2
2500	A-Scope HVPS																															0
2600	Trigger Generator																									1		2				3
2700	-150 & +300 VDC Regulator																									1						1
2800	+270 VDC PS																															0
2900	Line Driver Ampl.															1																1
3000	120V ABC Reg.																															0
3100	120V D Reg.													1													1					2
3200	Filament Supply																															0
3300	+285 & +400 VDC PS																															0
5400	Equalizer															2																2
4000	Control Cabinet																															0
4100	Dual-Chan Control																															0
6000	Console Equip Cab																															0
5100	Meter Panel																															0
5300	Line Amplifier																															0
5500	Filament Supply																															0
6100	Swp. Gen. Power Supply																															0
6200	Indicator Power Supply																															0
6300	Meter Panel																		1													1

TABLE C-6; QUANTITY AND ASSEMBLY ASSOCIATED WITH UNSCHEDULED MAINTENANCE ACTIONS AT LAX (continued)

REF DESIG	DESCRIPTION	QUANTITY OF UNSCHEDULED MAINTENANCE ACTIONS 1970												1971												1972						TOTAL
		J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	
7000	PPI Console																															0
7200	Video Amplifier																															0
7300	15KV Pwr Supply					1													1									1				3
7400	Rotation Control																															0
7500	Off-Centering PS																															0
7600	Remote Control Panel																															0
7800 - 7850	Top Dwr. & Defl. Coil Dr.				1	2	1								1				1							1						7
7900	Lower Drawer																															0
8000	Pwr. Dist. Box																															0
8100	Ant. Contractor																															0
8300	Swp. Generator						1									1																2
8500	Pwr. Dist. Box																															0
9000	AC Voltage Reg.																															0
9100	Noise Source PS																															0
9200	Antenna																															0
9300	W/G Blower																															0
10000	Remote Lines Jct. Box																															0
10100	Remote Lines Jct. Box																															0
11000	Inflation Cont. Assy																															0
	Miscellaneous																															0
	TOTAL	8	4	0	2	8	6	1	3	8	4	5	5	10	2	9	3	3	8	2	2	2	1	3	3	12	9	7	5	5	5	145

TABLE C-7; QUANTITY AND ASSEMBLY ASSOCIATED WITH UNSCHEDULED MAINTENANCE ACTIONS AT SEA

REF DESIG	DESCRIPTION	QUANTITY OF UNSCHEDULED MAINTENANCE ACTIONS																														TOTAL
		1970												1971												1972						
		J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	
1000	TR Cabinet																							-	-	-	-	-	-	-	-	0
1100	Meter Panel																							-	-	-	-	-	-	-	-	0
1200	Video Dist & STC								1							1				1				-	-	-	-	-	-	-	-	3
1300	Receiver	5	2	4	1	4	2	3	3	1	1	4	5	5	2	4	8	1	2	1	2		2	-	-	-	-	-	-	-	-	62
1400	AFC Amplifier										2		1											-	-	-	-	-	-	-	-	3
1500-1700	IF Amplifier			1																				-	-	-	-	-	-	-	-	1
1800	Mod. LVPS									1														-	-	-	-	-	-	-	-	1
1900	Mod & HVPS	4	4	4	4	3	3			2	1		4	1		2	3		3	1	3	4	4	-	-	-	-	-	-	-	-	50
2000	A-Scope Cabinet	1				1																		-	-	-	-	-	-	-	-	2
2100	Meter Panel																							-	-	-	-	-	-	-	-	0
2200	A-Scope																							-	-	-	-	-	-	-	-	0
2400	Control Panel			1								1												-	-	-	-	-	-	-	-	2
2500	A-Scope HVPS																							-	-	-	-	-	-	-	-	0
2600	Trigger Generator		1				1	1	1		2				1					1				-	-	-	-	-	-	-	-	8
2700	-150 & +300 VDC Regulator																							-	-	-	-	-	-	-	-	0
2800	+270 VDC PS																							-	-	-	-	-	-	-	-	0
2900	Line Driver Ampl.											1												-	-	-	-	-	-	-	-	1
3000	120V ABC Reg.																							-	-	-	-	-	-	-	-	0
3100	120V D Reg.								1															-	-	-	-	-	-	-	-	1
3200	Filament Supply																							-	-	-	-	-	-	-	-	0
3300	+285 & +400 VDC PS																							-	-	-	-	-	-	-	-	0
5400	Equalizer																							-	-	-	-	-	-	-	-	0
4000	Control Cabinet																							-	-	-	-	-	-	-	-	0
4100	Dual-Chan Control																							-	-	-	-	-	-	-	-	0
6000	Console Equip Cab																							-	-	-	-	-	-	-	-	0
5100	Meter Panel																							-	-	-	-	-	-	-	-	0
5300	Line Amplifier																							-	-	-	-	-	-	-	-	0
5500	Filament Supply																							-	-	-	-	-	-	-	-	0
6100	Swp. Gen. Power Supply																							-	-	-	-	-	-	-	-	0
6200	Indicator Power Supply																							-	-	-	-	-	-	-	-	0
6300	Meter Panel																							-	-	-	-	-	-	-	-	0

TABLE C-7; QUANTITY AND ASSEMBLY ASSOCIATED WITH UNSCHEDULED MAINTENANCE ACTIONS AT SEA (continued)

REF DESIG	DESCRIPTION	QUANTITY OF UNSCHEDULED MAINTENANCE ACTIONS 1970 J	F	M	A	M	J	J	A	S	O	N	D	1971 J	F	M	A	M	J	J	A	S	O	N	D	1972 J	F	M	A	M	J	TOTAL
7000	PPI Console																							-	-	-	-	-	-	-	-	0
7200	Video Amplifier						1																	-	-	-	-	-	-	-	-	1
7300	15KV Pwr Supply																			1				-	-	-	-	-	-	-	-	3(1)
7400	Rotation Control																							-	-	-	-	-	-	-	-	0
7500	Off-Centering PS																							-	-	-	-	-	-	-	-	0
7600	Remote Control Panel																							-	-	-	-	-	-	-	-	0
7800 - 7850	Top Dwr. & Defl. Coil Dr.																							-	-	-	-	-	-	-	-	6(1)
7900	Lower Drawer																							-	-	-	-	-	-	-	-	0
8000	Pwr. Dist. Box																							-	-	-	-	-	-	-	-	0
8100	Ant. Contractor																							-	-	-	-	-	-	-	-	0
8300	Swp. Generator																							-	-	-	-	-	-	-	-	0
8500	Pwr. Dist. Box																							-	-	-	-	-	-	-	-	0
9000	AC Voltage Reg.																							-	-	-	-	-	-	-	-	0
9100	Noise Source PS																							-	-	-	-	-	-	-	-	0
9200	Antenna									1														-	-	-	-	-	-	-	-	1
9300	W/G Blower																							-	-	-	-	-	-	-	-	0
10000	Remote Lines Jct. Box																							-	-	-	-	-	-	-	-	0
10100	Remote Lines Jct. Box																							-	-	-	-	-	-	-	-	0
11000	Inflation Cont. Assy																							-	-	-	-	-	-	-	-	0
	Miscellaneous														1					1				-	-	-	-	-	-	-	-	2
	TOTAL	10	7	10	5	8	7	4	6	5	6	6	10	6	4	7	11	1	5	6	5	4	6	-	-	-	-	-	-	-	-	147

NOTE; (1) ESTIMATED (TOWER CAB PPI DATA NOT OBTAINED).

TABLE C-8; QUANTITY AND ASSEMBLY ASSOCIATED WITH UNSCHEDULED MAINTENANCE ACTIONS AT SFO

REF DESIG	DESCRIPTION	QUANTITY OF UNSCHEDULED MAINTENANCE ACTIONS																														TOTAL
		1970												1971												1972						
		J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	
1000	TR Cabinet																														-	0
1100	Meter Panel																														-	0
1200	Video Dist & STC										3															1					-	4
1300	Receiver	3	3	4							4	2	1	4	2			1				3	3		4			1			-	35
1400	AFC Amplifier																					1									-	1
1500-1700	IF Amplifier				3						4		2										1			2				1	-	13
1800	Mod. LVPS																								1						-	1
1900	Mod & HVPS	2	2		1						2	2	1	2		2		1				2	2		1		3	1		2	-	26
2000	A-Scope Cabinet																														-	0
2100	Meter Panel																														-	0
2200	A-Scope																														-	0
2400	Control Panel				1																	1	2								-	4
2500	A-Scope HVPS																														-	0
2600	Trigger Generator	1	2		1																				1	1					-	6
2700	-150 & +300 VDC Regulator	1																													-	1
2800	+270 VDC PS																														-	0
2900	Line Driver Ampl.																					1									-	1
3000	120V ABC Reg.												2									1									-	3
3100	120V D Reg.											1	1																		-	2
3200	Filament Supply																														-	0
3300	+285 & +400 VDC PS																														-	0
5400	Equalizer																														-	0
4000	Control Cabinet																														-	0
4100	Dual-Chan Control																														-	0
6000	Console Equip Cab																														-	0
5100	Meter Panel																														-	0
5300	Line Amplifier																														-	0
5500	Filament Supply																														-	0
6100	Swp. Gen. Power Supply																														-	0
6200	Indicator Power Supply			1													2					1									-	4
6300	Meter Panel																														-	0

TABLE C-8; QUANTITY AND ASSEMBLY ASSOCIATED WITH UNSCHEDULED MAINTENANCE ACTIONS AT SFO (continued)

REF DESIG	DESCRIPTION	QUANTITY OF UNSCHEDULED MAINTENANCE ACTIONS 1970 J	F	M	A	M	J	J	A	S	O	N	D	1971 J	F	M	A	M	J	J	A	S	O	N	D	1972 J	F	M	A	M	J	TOTAL
7000	PPI Console																														-	0
7200	Video Amplifier																														-	0
7300	15KV Pwr Supply																													1	-	1
7400	Rotation Control																														-	0
7500	Off-Centering PS																														-	0
7600	Remote Control Panel																														-	0
7800 - 7850	Top Dwr. & Defl. Coil Dr.																														-	0
7900	Lower Drawer																														-	0
8000	Pwr. Dist. Box																														-	0
8100	Ant. Contractor																														-	0
8300	Swp. Generator														1																-	1
8500	Pwr. Dist. Box																														-	0
9000	AC Voltage Reg.																														-	0
9100	Noise Source PS																														-	0
9200	Antenna																														-	0
9300	W/G Blower										1																				-	1
10000	Remote Lines Jct. Box																														-	0
10100	Remote Lines Jct. Box																														-	0
11000	Inflation Cont. Assy																					1									-	1
	Miscellaneous			1												1						1									-	3
	TOTAL	7	7	6	6	-	-	-	-	-	14	5	7	6	3	3	2	2	0	0	0	12	8	0	7	4	3	2	0	4	-	108

TABLE C-9; QUANTITY AND ASSEMBLY ASSOCIATED WITH UNSCHEDULED MAINTENANCE ACTIONS AT ALL SITES COMBINED

REF DESIG	DESCRIPTION	QUANTITY OF UNSCHEDULED MAINTENANCE ACTIONS																														TOTAL
		1970												1971												1972						
		J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	
1000	TR Cabinet	1	1			1				1		2	1	1	1		1								1		1					12
1100	Meter Panel																															0
1200	Video Dist & STC	5		1		2			2	2	5		1	4		4				3	2	1	0	3		1						36
1300	Receiver	21	25	27	26	19	25	26	18	15	22	31	24	28	21	15	22	19	38	26	25	17	31	21	27	37	25	26	18	12	15	702
1400	AFC Amplifier	1	2		1	2	4	2	1		4	1	2	2		2	1		1			1	2	1		1	3					34
1500-1700	IF Amplifier	1	4	2	4	1	3	3	3	3	5	3	4	2		1	2	1	2	1	3	2	2	3	1	9	2	1	0	2	0	70
1800	Mod. LVPS									1	2												1		1							5
1900	Mod & HVPS	16	14	14	22	14	15	9	6	12	6	12	16	26	12	15	11	9	17	22	25	32	31	13	7	22	13	9	2	6	4	432
2000	A-Scope Cabinet	3			2	1												1		1		1		1	1	1	1				1	14
2100	Meter Panel																															0
2200	A-Scope				1		1		1	1		1	2		1	1	1							1	1							12
2400	Control Panel		1	1	1		1		3			1	1	2				1		1		2	2			1				1		19
2500	A-Scope HVPS															1	1			1							1				1	5
2600	Trigger Generator	2	5	1	1	1	1	2	4		4			3	1				2	3	1	1	4	1	2	3	1	3	1			47
2700	-150 & +300 VDC Regulator	1			1	1																				2						5
2800	+270 VDC PS																															0
2900	Line Driver Ampl.			1								1		2		2						1		1								8
3000	120V ABC Reg.												4									1										5
3100	120V D Reg.					1	1		1		1	1	1	1		1			2					1		1	1					13
3200	Filament Supply																															0
3300	+285 & +400 VDC PS																				1											1
5400	Equalizer															2																2
4000	Control Cabinet	1				1			1														1									4
4100	Dual-Chan Control				2		3	1		1									1													8
6000	Console Equip Cab																															0
5100	Meter Panel																															0
5300	Line Amplifier	1		1									1																			3
5500	Filament Supply																															0
6100	Swp. Gen. Power Supply									1															1							2
6200	Indicator Power Supply			2	1	2		1						2			3			1		2			1	4						19
6300	Meter Panel																		1													1

TABLE C-9; QUANTITY AND ASSEMBLY ASSOCIATED WITH UNSCHEDULED MAINTENANCE ACTIONS AT ALL SITES COMBINED (continued)

REF DESIG	DESCRIPTION	QUANTITY OF UNSCHEDULED MAINTENANCE ACTIONS																														TOTAL
		1970												1971												1972						
		J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	
7000	PPI Console									1					1								1			1		1	1			6
7200	Video Amplifier						1						1	2						1							1					6
7300	15KV Pwr Supply	1			2	3	3	1	1	1	1			2	2				2	1	1	3		1		1	1	1		1	1	32[1]
7400	Rotation Control				1	1	1				1						1					1		1	1	1	1					10
7500	Off-Centering PS															1			1							1						3
7600	Remote Control Panel						1				2	1		1														1				6
7800 - 7850	Top Dwr. & Defl. Coil Dr.	4	1	1	4	8	7	2	6	5	1			6	4	3	2	1	3	2	1	3			1	3	1	2	2			79[1]
7900	Lower Drawer																								1							1
8000	Pwr. Dist. Box													1																		1
8100	Ant. Contractor																									1						1
8300	Swp. Generator	1	1	1	1	2	3	2		4	2			2	2	2				1	1	3	2	4	3	2	1					40
8500	Pwr. Dist. Box						1																				1					2
9000	AC Voltage Reg.																							1								1
9100	Noise Source PS					1				1								1				1						1				5
9200	Antenna									1								1														2
9300	W/G Blower	2			1		1			1	1												1		1		1					9
10000	Remote Lines Jct. Box																				1											1
10100	Remote Lines Jct. Box																															0
11000	Inflation Cont. Assy	1							1													1					1					4
	Miscellaneous	1		6	2	1	2	2	2	3		2	1		3	1	4			1		1		4		1			2	1		40
	TOTAL	63	54	58	73	63	73	51	49	54	57	56	59	87	48	51	49	34	71	65	61	74	78	57	50	93	56	45	26	23	32	1708

(1) ESTIMATED (ACTUAL DATA FOR SEA TOWER CAB PPI NOT OBTAINED).

APPENDIX D
COMPONENT REPLACEMENT DATA

1. COMPONENT REPLACEMENT DATA

This appendix contains component replacement data for each ASDE-2 site surveyed for the time periods assessed. Quantity of parts replaced during unscheduled maintenance is tabulated by site, reference designator, part number and year.

Data for individual sites is provided in Tables -1 through -8 as follows:

1. Kennedy - Table D-1.
2. Newark - Table D-2.
3. Dulles - Table D-3.
4. Andrews - Table D-4.
5. O'Hare - Table D-5.
6. Los Angeles - Table D-6.
7. Seattle - Table D-7.
8. San Francisco - Table D-8.

Data for all sites combined is provided in Table D-9.

TABLE D-1;

COMPONENTS REPLACED DURING UNSCHEDULED MAINTENANCE ACTIONS AT JFK

REF DESIG	PART NUMBER	QUANTITY OF PARTS REPLACED			
		1970	1971	1972*	TOTAL
B1001	SEE TABLE D-9 FOR PART NUMBERS	2	1	1	4
S1001		1	0	0	1
S1004		0	1	0	1
R1240		0	1	0	1
R1244		1	0	0	1
R1246		1	0	0	1
V1205		1	0	0	1
V1209		1	0	0	1
V1210		0	2	0	2
B1302		0	0	1	1
C1315		0	0	1	1
C1318		0	1	0	1
CR1301		6	2	1	9
CR1302		8	2	2	12
CR1303		8	13	8	29
CR1304		8	12	10	30
V1301		7	15	16	38
V1302		4	4	2	10
V1303		6	7	5	18
R1424		1	0	0	1
R1429		1	0	0	1
R1430		1	0	0	1
V1401		3	0	1	4
V1402		3	0	1	4
V1403		3	0	0	3
V1404		3	0	0	3
V1405		7	2	0	9
V1406		3	0	0	3

TABLE D-1;

COMPONENTS REPLACED DURING UNSCHEDULED MAINTENANCE ACTIONS AT JFK

REF DESIG	PART NUMBER	QUANTITY OF PARTS REPLACED			
		1970	1971	1972*	TOTAL
V1407		5	0	0	5
V1408		2	0	0	2
V1409		2	0	0	2
V1410		2	0	0	2
V1411		2	0	0	2
IF STRIPS	6AK5	69	45	17	131
CR1801	SEE	1	0	0	1
CR1804	TABLE D-9 FOR	0	2	0	2
CR1805	PART NUMBERS	0	2	0	2
CR1806		0	2	0	2
K1801		2	0	0	2
R1824		1	0	0	1
B1901		0	0	1	1
C1903		1	0	0	1
R1904		0	1	0	1
R1905		0	1	0	1
R1906		1	0	0	1
R1907		1	0	0	1
R1909		1	0	0	1
R1910		1	0	0	1
R1918		0	1	0	1
R1927		1	0	0	1
V1901		5	7	1	13
V1902		29	49	8	86
V1903		11	10	1	22
V1904		6	9	1	16
V1905		5	9	1	15
V1906		3	3	2	8

TABLE D-1;

COMPONENTS REPLACED DURING UNSCHEDULED MAINTENANCE ACTIONS AT JFK

REF DESIG	PART NUMBER	QUANTITY OF PARTS REPLACED			
		1970	1971	1972*	TOTAL
B2001		0	0	1	1
B2002		1	0	0	1
V2208		0	1	0	1
V2209		0	1	0	1
V2212		1	1	0	2
B2401		1	1	0	2
CR2401		0	1	0	1
K2409		1	0	0	1
M2405		1	0	0	1
R2401		1	0	0	1
R2630		1	0	0	1
R2634		1	0	0	1
V2601		1	0	0	1
V2603		1	2	1	4

REF DESIG	PART NUMBER	QUANTITY OF PARTS REPLACED			
		1970	1971	1972*	TOTAL
V2604		1	0	0	1
V2605		2	2	0	4
V2708		0	0	1	1
V2709		0	0	1	1
V2901		0	1	0	1
V2902		0	1	0	1
V2903		0	1	0	1
V2904		0	1	0	1
V2905		0	1	0	1
V3101		0	1	0	1
V3102		0	1	0	1
V3103		0	1	0	1
V5312		1	0	0	1
K6201		1	0	0	1

TABLE D-1;

COMPONENTS REPLACED DURING UNSCHEDULED MAINTENANCE ACTIONS AT JFK

REF DESIG	PART NUMBER	QUANTITY OF PARTS REPLACED			
		1970	1971	1972*	TOTAL
V6202		0	1	0	1
V6203		0	1	0	1
V6204		0	1	0	1
V6205		0	1	1	2
B7001		0	1	0	1
C7210		0	1	0	1
CR7201		0	1	0	1
CR7202		0	1	0	1
R7214		0	1	0	1
V7201		0	1	0	1
V7202		0	1	0	1
V7203		0	1	0	1
V7204		0	1	0	1
R7309		1	0	1	2
R7310		1	0	1	2
V7301		2	0	1	3
V7302		2	1	2	5
V7303		1	0	2	3
V7304		1	0	2	3
V7305		1	0	1	2
R7401		0	0	1	1
V7401		0	0	1	1
V7402		0	1	1	2
V7403		0	1	0	1
R7527		0	1	0	1
V7501		0	1	0	1
V7503		0	1	0	1
B7852		0	0	1	1

TABLE D-1;

COMPONENTS REPLACED DURING UNSCHEDULED MAINTENANCE ACTIONS AT JFK

REF DESIG	PART NUMBER	QUANTITY OF PARTS REPLACED			
		1970	1971	1972*	TOTAL
S7801	↓	1	0	0	1
V7801	↓	1	1	0	2
M8101	↓	0	0	1	1
V8301	↓	0	1	0	1
V8311	↓	0	1	0	1
V8312	↓	0	1	0	1
V8313	↓	0	1	0	1
B11001	↓	1	0	1	2

* Partial

REF DESIG	PART NUMBER	QUANTITY OF PARTS REPLACED			
		1970	1971	1972	TOTAL

TABLE D-2;

COMPONENTS REPLACED DURING UNSCHEDULED MAINTENANCE ACTIONS AT EWR

REF DESIG	PART NUMBER	QUANTITY OF PARTS REPLACED			
		1970	1971	1972*	TOTAL
B1302	SEE	0	1	0	1
CR1301	TABLE D-9 FOR	0	0	1	1
CR1302	PART NUMBERS	1	1	1	3
CR1303		3	6	3	12
CR1304		4	4	1	9
CR1305		1	0	0	1
CR1311		1	2	0	3
K1302		1	0	0	1
K1303		1	0	0	1
V1301		6	6	1	13
V1302		3	2	0	5
V1303		7	7	5	19
V1401		0	1	0	1
V1402		0	1	0	1

REF DESIG	PART NUMBER	QUANTITY OF PARTS REPLACED			
		1970	1971	1972*	TOTAL
V1403		0	1	1	2
V1404		0	1	0	1
V1405		0	1	0	1
IF STRIPS	6AK5	1	12	0	13
CR1801	SEE	0	1	0	1
CR1802	TABLE D-9 FOR	0	1	0	1
CR1803	PART NUMBERS	0	1	0	1
B1901		1	2	1	4
R1908		0	0	1	1
R1911		0	0	1	1
S1903		0	5	1	6
V1901		0	3	0	3
V1902		4	14	7	25
V1903		4	15	2	21

TABLE D-2;

COMPONENTS REPLACED DURING UNSCHEDULED MAINTENANCE ACTIONS AT EWR

REF DESIG	PART NUMBER	QUANTITY OF PARTS REPLACED			
		1970	1971	1972*	TOTAL
V1904		4	12	5	22
V1905		3	9	5	17
V1906		5	3	3	11
V1907		0	1	1	2
V1908		0	1	1	2
B2002		1	2	0	3
V2215		1	0	0	1
K2403		0	0	1	1
V2603		1	0	0	1
V3101		1	0	0	1
V3102		1	0	0	1
V3103		1	0	1	2
V3104		0	0	1	1
V3105		0	0	1	1

REF DESIG	PART NUMBER	QUANTITY OF PARTS REPLACED			
		1970	1971	1972*	TOTAL
K4102		0	1	0	1
V6204		0	1	0	1
V6205		0	1	0	1
B7001		1	0	1	2
7300		1	0	1	2
K7301		1	0	0	1
R7310		0	1	0	1
T7301		0	1	0	1
V7301		0	1	0	1
V7302		0	1	0	1
V7303		0	1	0	1
V7401		0	1	0	1
V7404		0	0	1	1
V7501		0	0	1	1

TABLE D-2;

COMPONENTS REPLACED DURING UNSCHEDULED MAINTENANCE ACTIONS AT EWR

REF DESIG	PART NUMBER	QUANTITY OF PARTS REPLACED			
		1970	1971	1972*	TOTAL
7850		4	7	0	11
B7852		3	3	2	8
MP7858		0	1	0	1
S7801		0	0	1	1
8300		1	0	0	1
K8305		0	1	0	1
R8377		0	3	0	3
V8310		0	1	0	1
V8311		0	1	0	1
V8312		0	1	0	1
9000		0	1	0	1
V9101		1	0	1	2
S9304		0	1	0	1

* Partial

TABLE D-3;

COMPONENTS REPLACED DURING UNSCHEDULED MAINTENANCE ACTIONS AT IAD

REF DESIG	PART NUMBER	QUANTITY OF PARTS REPLACED			
		1970	1971	1972*	TOTAL
B1001	SEE	0	1	0	1
B1002	TABLE D-9 FOR	1	0	0	1
S1005	PART NUMBERS	1	0	0	1
CR1211		1	0	0	1
R1236		1	0	0	1
R1240		1	0	0	1
R1244		0	1	0	1
R1245		1	0	0	1
R1246		1	1	0	2
R1247		0	1	0	1
R1257		1	1	0	2
V1201		0	1	0	1
V1209		1	0	0	1
V1210		0	1	0	1

REF DESIG	PART NUMBER	QUANTITY OF PARTS REPLACED			
		1970	1971	1972*	TOTAL
CR1301		9	5	1	15
CR1302		4	4	2	10
CR1303		22	12	2	36
CR1304		16	9	3	28
V1301		7	8	2	17
V1302		1	3	0	4
V1303		2	6	1	9
V1405		2	3	0	5
V1406		1	0	0	1
V1407		1	0	0	1
IF STRIPS	6AK5	110	77	0	187
V1901	SEE	3	4	0	7
V1902	TABLE D-9 FOR	12	14	1	27
V1903	PART NUMBERS	0	4	1	5

TABLE D-3;

COMPONENTS REPLACED DURING UNSCHEDULED MAINTENANCE ACTIONS AT IAD

REF DESIG	PART NUMBER	QUANTITY OF PARTS REPLACED			
		1970	1971	1972*	TOTAL
V1904		0	7	1	8
V1905		1	8	0	9
V1906		9	2	1	12
V1907		2	0	0	2
V1908		1	0	0	1
B2001		0	1	0	1
M2405		1	0	0	1
R2401		1	0	0	1
T2401		1	0	0	1
L2601		0	1	0	1
R2613		0	1	0	1
V2602		0	1	0	1
V2603		0	1	0	1
V2604		0	1	0	1
V2605		0	3	0	3
V2706		0	1	0	1
V2707		1	1	0	2
V2902		0	1	0	1
V2907		0	1	0	1
V2910		0	1	0	1
V2912		0	1	0	1
R3114		1	0	0	1
V3103		1	0	0	1
C3301		0	1	0	1
CR3301		0	1	0	1
CR3303		0	1	0	1
CR3304		0	1	0	1
CR3307		1	0	0	1

TABLE D-3;

COMPONENTS REPLACED DURING UNSCHEDULED MAINTENANCE ACTIONS AT IAD

REF DESIG	PART NUMBER	QUANTITY OF PARTS REPLACED			
		1970	1971	1972*	TOTAL
B4001		2	0	0	2
4100		1	0	0	1
K4101		2	0	0	2
K4102		1	0	0	1
K4103		3	0	0	3
K4104		1	0	0	1
K4105		1	0	0	1
K4106		1	0	0	1
K4107		1	0	0	1
K4108		1	0	0	1
V5311		1	0	0	1
V5313		1	0	0	1
K6201		1	1	0	2
V6203		1	0	0	1

REF DESIG	PART NUMBER	QUANTITY OF PARTS REPLACED			
		1970	1971	1972*	TOTAL
V6204		1	0	0	1
CR7201		0	2	0	2
CR7202		0	1	0	1
7300		0	1	0	1
R7308		1	0	0	1
R7310		1	0	0	1
V7302		1	0	0	1
V7305		3	1	0	4
K7401		1	0	0	1
V7401		2	0	0	2
V7403		1	0	0	1
V7404		1	0	0	1
DS7603		1	0	0	1
DS7604		2	0	0	2

TABLE D-3;

COMPONENTS REPLACED DURING UNSCHEDULED MAINTENANCE ACTIONS AT IAD

REF DESIG	PART NUMBER	QUANTITY OF PARTS REPLACED			
		1970	1971	1972*	TOTAL
DS7605		1	0	0	1
DS7606		1	0	0	1
7850		8	3	0	11
L7853		1	1	0	2
S7801		2	0	0	2
V7801		1	1	0	2
8300		0	1	0	1
CR8301		0	1	0	1
K8303		0	1	0	1
K8304		0	1	0	1
R8377		0	2	0	2
V8301		0	1	0	1
V8302		0	1	0	1
V8303		0	0	1	1
V8304		0	1	0	1
V8305		0	2	0	2
V8306		0	1	0	1
B9301		0	0	1	0
S9301		1	0	0	1
S9304		1	0	0	1

* Partial

TABLE D-4;

COMPONENTS REPLACED DURING UNSCHEDULED MAINTENANCE ACTIONS AT ADW

REF DESIG	PART NUMBER	QUANTITY OF PARTS REPLACED			
		1970	1971	1972*	TOTAL
S1004	SEE TABLE D-9 FOR PART NUMBERS	1	0	0	1
C1221		1	0	0	1
V1201		1	1	0	2
V1202		1	1	0	2
V1203		1	1	0	2
V1204		1	0	0	1
V1205		1	1	0	1
V1209		2	0	0	2
V1210		2	0	0	2
B1302		1	0	0	1
CR1301		3	4	0	7
CR1302		2	2	1	5
CR1303		8	3	1	12
CR1304		8	4	2	14

REF DESIG	PART NUMBER	QUANTITY OF PARTS REPLACED			
		1970	1971	1972*	TOTAL
CR1306		0	1	0	1
CR1307		0	1	0	1
CR1311		0	1	0	1
V1301		6	10	4	20
V1302		1	3	2	6
V1303		6	7	2	15
V1402		0	0	1	1
V1404		0	0	1	1
V1405		0	0	1	1
V1407		0	0	1	1
V1409		0	0	1	1
V1410		1	0	0	1
C1502		1	0	0	1
C1557		1	0	0	1

TABLE D-4;

COMPONENTS REPLACED DURING UNSCHEDULED MAINTENANCE ACTIONS AT ADW

REF DESIG	PART NUMBER	QUANTITY OF PARTS REPLACED			
		1970	1971	1972*	TOTAL
R1501	SEE TABLE D-9 FOR PART NUMBERS	1	0	0	1
IF STRIPS	6AK5	95	1	25	121
B1901	SEE TABLE D-9 FOR PART NUMBERS	1	1	0	2
R1918	SEE TABLE D-9 FOR PART NUMBERS	1	0	0	1
S1903	SEE TABLE D-9 FOR PART NUMBERS	1	2	0	3
V1901	SEE TABLE D-9 FOR PART NUMBERS	2	5	0	7
V1902	SEE TABLE D-9 FOR PART NUMBERS	8	19	3	30
V1903	SEE TABLE D-9 FOR PART NUMBERS	3	4	0	7
V1904	SEE TABLE D-9 FOR PART NUMBERS	3	4	0	7
V1905	SEE TABLE D-9 FOR PART NUMBERS	3	4	0	7
V1906	SEE TABLE D-9 FOR PART NUMBERS	4	3	0	7
V1907	SEE TABLE D-9 FOR PART NUMBERS	1	1	0	2
B2001	SEE TABLE D-9 FOR PART NUMBERS	1	1	0	2
B2002	SEE TABLE D-9 FOR PART NUMBERS	0	1	0	1

REF DESIG	PART NUMBER	QUANTITY OF PARTS REPLACED			
		1970	1971	1972*	TOTAL
V2201		0	1	0	1
V2204		0	1	0	1
R2502		0	2	0	2
T2501		0	3	0	3
V2605		2	2	0	4
R2901		0	1	0	1
R2902		0	1	0	1
R2924		0	1	0	1
R2925		0	1	0	1
V2914		0	1	0	1
V3101		0	1	0	1
V3103		0	1	0	1
B4001		0	1	0	1
V6201		0	0	2	2

TABLE D-4;

COMPONENTS REPLACED DURING UNSCHEDULED MAINTENANCE ACTIONS AT ADW

REF DESIG	PART NUMBER	QUANTITY OF PARTS REPLACED			
		1970	1971	1972*	TOTAL
V6202		0	0	2	2
V6203		0	0	2	2
V6204		0	0	1	1
V6205		0	0	1	1
B7001		1	0	0	1
V7302		1	0	0	1
7850		1	2	0	3
S7801		0	0	1	1
K8301		2	1	0	3
K8302		2	1	2	5
V8304		0	2	0	2
V8305		0	1	0	1
V8310		1	2	0	3
V8311		1	1	0	2

REF DESIG	PART NUMBER	QUANTITY OF PARTS REPLACED			
		1970	1971	1972*	TOTAL
V8312		0	1	0	1
V9101		0	1	0	1
B9301		1	1	0	2

* Partial

TABLE D-5;

COMPONENTS REPLACED DURING UNSCHEDULED MAINTENANCE ACTIONS AT ORD

REF DESIG	PART NUMBER	QUANTITY OF PARTS REPLACED			
		1970	1971	1972*	TOTAL
B1001	SEE TABLE D-9 FOR PART NUMBERS	0	1	0	1
R1236		0	1	0	1
R1240		0	1	0	1
R1245		0	1	0	1
R1246		0	1	0	1
V1201		1	0	0	1
V1202		1	0	0	1
V1203		1	0	0	1
V1204		1	0	0	1
V1208		1	0	0	1
V1209		1	0	0	1
B1302		1	0	0	1
CR1301		6	8	2	16
CR1302		6	8	3	17

REF DESIG	PART NUMBER	QUANTITY OF PARTS REPLACED			
		1970	1971	1972*	TOTAL
CR1303		7	34	19	60
CR1304		7	32	18	57
CR1305		0	1	0	1
K1301		0	1	0	1
R1309		0	1	0	1
R1310		0	1	0	1
R1322		0	1	0	1
V1301		10	11	6	27
V1302		4	6	3	13
V1303		0	1	6	7
C1434		0	0	1	1
R1402		0	1	0	1
R1429		1	1	0	2
R1430		1	1	0	2

TABLE D-5;

COMPONENTS REPLACED DURING UNSCHEDULED MAINTENANCE ACTIONS AT ORD

REF DESIG	PART NUMBER	QUANTITY OF PARTS REPLACED			
		1970	1971	1972*	TOTAL
V1401	↓	1	0	1	2
V1402		1	1	1	3
V1403		0	2	0	2
V1404		0	2	0	2
V1405		2	3	1	6
V1406		0	2	0	2
V1407		1	2	0	3
V1408		1	0	0	1
V1409		1	1	0	2
R1701		1	0	0	1
R1702		2	0	0	2
IF STRIPS	6AK5	13	52	69	134
B1901	SEE TABLE D-9	2	0	1	3
C1910	FOR PART NUMBERS	0	1	0	1

REF DESIG	PART NUMBER	QUANTITY OF PARTS REPLACED			
		1970	1971	1972*	TOTAL
C1913		0	3	0	3
R1908		0	1	1	2
S1903		1	1	0	2
V1901		1	3	0	4
V1902		5	29	3	37
V1903		1	9	2	12
V1904		1	8	2	11
V1905		1	8	1	10
V1906		5	3	3	11
V1907		0	1	1	2
V1908		0	1	1	2
B2001		1	0	0	1
CR2209		1	0	0	1
T2201		0	1	0	1

TABLE D-5;

COMPONENTS REPLACED DURING UNSCHEDULED MAINTENANCE ACTIONS AT ORD

REF DESIG	PART NUMBER	QUANTITY OF PARTS REPLACED			
		1970	1971	1972*	TOTAL
V2215		2	0	0	2
CR2401		0	1	0	1
M2405		2	0	0	2
T2501		0	0	1	1
V2501		0	0	1	1
V2502		0	0	1	1
C2605		0	1	0	1
V2602		0	1	0	1
V2603		1	2	0	3
V2604		0	1	0	1
V2605		0	3	1	4
V2606		1	0	0	1
R2721		0	1	0	1
R2725		0	1	0	1

REF DESIG	PART NUMBER	QUANTITY OF PARTS REPLACED			
		1970	1971	1972*	TOTAL
V2705		1	0	0	1
R2915		1	0	0	1
R2916		1	0	0	1
V2901		0	1	0	1
V2902		0	1	0	1
V2903		0	1	0	1
V2904		0	1	0	1
V2907		1	0	0	1
V2910		1	0	0	1
V3002		1	0	0	1
V3004		1	0	0	1
V3103		1	0	0	1
B4001		1	0	0	1
K4106		1	0	0	1

TABLE D-5;

COMPONENTS REPLACED DURING UNSCHEDULED MAINTENANCE ACTIONS AT ORD

REF DESIG	PART NUMBER	QUANTITY OF PARTS REPLACED			
		1970	1971	1972*	TOTAL
K6201		1	0	0	1
R6215		1	0	0	1
R6216		1	0	0	1
R6217		1	0	0	1
R6218		1	0	0	1
V6201		0	1	0	1
V6202		0	1	0	1
V6203		0	1	0	1
V6205		0	1	0	1
S7001		0	1	0	1
V7202		1	0	0	1
V7207		1	0	0	1
R7304		1	0	0	1
V7302		1	0	0	1

REF DESIG	PART NUMBER	QUANTITY OF PARTS REPLACED			
		1970	1971	1972*	TOTAL
V7303		1	0	0	1
K7402		1	0	0	1
V7401		1	0	0	1
7850		4	1	0	5
B7852		1	0	0	1
V7801		0	1	0	1
K8301		1	0	0	1
K8302		1	0	0	1
K8303		1	0	0	1
K8304		1	0	0	1
K8305		1	0	0	1
R8304		1	0	0	1
R8307		1	0	0	1
R8371		1	0	0	1

TABLE D-5;

COMPONENTS REPLACED DURING UNSCHEDULED MAINTENANCE ACTIONS AT ORD

REF DESIG	PART NUMBER	QUANTITY OF PARTS REPLACED			
		1970	1971	1972*	TOTAL
R8381		1	0	0	1
R8394		1	0	0	1
R8395		1	0	0	1
R8396		1	0	0	1
V8310		6	0	0	6
V8311		6	0	0	6
V8312		5	0	0	5
V8313		1	0	0	1
V9101		0	1	0	1

* Partial

TABLE D-6;

COMPONENTS REPLACED DURING UNSCHEDULED MAINTENANCE ACTIONS AT LAX

REF DESIG	PART NUMBER	QUANTITY OF PARTS REPLACED			
		1970	1971	1972*	TOTAL
B1001	SEE TABLE D-9 FOR PART NUMBERS	1	0	0	1
CR1209		0	1	0	1
R1227		0	1	0	1
R1240		1	0	0	1
R1245		1	0	0	1
R1246		1	0	0	1
R1254		1	0	0	1
R1255		2	0	0	2
R1257		1	0	0	1
B1302		0	3	0	3
CR1301		3	2	1	6
CR1302		3	2	2	7
CR1303		12	1	15	28
CR1304		13	1	13	27

REF DESIG	PART NUMBER	QUANTITY OF PARTS REPLACED			
		1970	1971	1972*	TOTAL
V1301		10	9	6	25
V1302		5	4	1	10
V1303		6	6	3	15
C1531		0	1	0	1
C1551		0	1	0	1
C1552		0	1	0	1
C1553		0	1	0	1
C1554		0	1	0	1
C1555		0	1	0	1
C1626		0	0	1	1
IF STRIPS	6AK5	48	12	12	72
L1801	SEE TABLE D-9 FOR PART NUMBERS	0	1	0	1
R1908		1	0	0	1
S1903		0	1	0	1

TABLE D-6;

COMPONENTS REPLACED DURING UNSCHEDULED MAINTENANCE ACTIONS AT LAX

REF DESIG	PART NUMBER	QUANTITY OF PARTS REPLACED			
		1970	1971	1972*	TOTAL
V1901		3	0	5	8
V1902		6	10	7	23
V1903		0	4	2	6
V1904		0	4	2	6
V1905		0	4	2	6
V1906		4	5	3	12
V1907		1	0	0	1
V1908		1	0	0	1
B2401		0	1	0	1
M2406		0	1	0	1
V2603		0	0	1	1
V2604		0	0	1	1
V2605		0	0	1	1
V2703		0	1	0	1
V2707		0	0	1	1
R2901		0	1	0	1
R2902		0	1	0	1
R2923		0	1	0	1
R2924		0	1	0	1
R3122		0	1	0	1
V3101		0	0	1	1
V3102		0	0	1	1
V3103		0	1	1	2
V3104		0	0	1	1
V3105		0	1	1	2
V6201		0	1	0	1
V6202		0	1	0	1
V6203		0	1	0	1

TABLE D-6;

COMPONENTS REPLACED DURING UNSCHEDULED MAINTENANCE ACTIONS AT LAX

REF DESIG	PART NUMBER	QUANTITY OF PARTS REPLACED			
		1970	1971	1972*	TOTAL
V6204	↓	0	1	0	1
V6205		0	1	0	1
R7309		0	0	1	1
V7302		0	1	0	1
V7305		0	1	0	1
B7852		0	1	1	2
R7808		0	1	0	1
V7801		5	0	0	5
8300		1	0	0	1
V8301		0	1	0	1
V9101		0	1	0	1

REF DESIG	PART NUMBER	QUANTITY OF PARTS REPLACED			
		1970	1971	1972	TOTAL

* Partial

TABLE D-7;

COMPONENTS REPLACED DURING UNSCHEDULED MAINTENANCE ACTIONS AT SEA

REF DESIG	PART NUMBER	QUANTITY OF PARTS REPLACED			
		1970	1971	1972	TOTAL
R1254	SEE	0	1		1
R1257	TABLE D-9 FOR	0	1		1
V1209	PART NUMBERS	1	3		4
V1210		1	1		2
C1315		1	0		1
CR1301		2	0		2
CR1302		2	0		2
CR1303		12	8		20
CR1304		9	9		18
R1316		1	0		1
V1301		9	8		17
V1302		2	1		3
V1303		3	3		6
R1429		1	0		1

REF DESIG	PART NUMBER	QUANTITY OF PARTS REPLACED			
		1970	1971	1972	TOTAL
V1405		2	0		2
V1407		1	0		1
IF STRIPS	6AK5	≃15	0		≃15
R1808	SEE	1	0		1
R1824	TABLE D-9 FOR	1	0		1
CR1902	PART NUMBERS	1	0		1
V1901		1	2		3
V1902		27	16		43
V1903		0	2		2
V1904		3	3		6
V1905		0	2		2
B2001		1	0		1
B2002		1	0		1
M2405		3	0		3

TABLE D-7;

COMPONENTS REPLACED DURING UNSCHEDULED MAINTENANCE ACTIONS AT SEA

REF DESIG	PART NUMBER	QUANTITY OF PARTS REPLACED			
		1970	1971	1972	TOTAL
R2601		1	0		1
R2603		1	0		1
R2613		0	1		1
V2603		1	0		1
V2604		2	0		2
V2605		3	1		4
V2606		1	1		2
V2912		1	0		1
V3102		1	0		1
K6201		1	0		1
V7201		1	0		1
V7302		0	1		1

REF DESIG	PART NUMBER	QUANTITY OF PARTS REPLACED			
		1970	1971	1972	TOTAL

TABLE D-8;

COMPONENTS REPLACED DURING UNSCHEDULED MAINTENANCE ACTIONS AT SFO

REF DESIG	PART NUMBER	QUANTITY OF PARTS REPLACED			
		1970	1971	1972*	TOTAL
V1201	SEE	0	0	1	1
V1204	TABLE D-9 FOR	1	0	0	1
V1206	PART NUMBERS	2	1	0	3
V1207		1	0	0	1
V1208		1	0	0	1
V1209		1	0	0	1
B1302		2	1	0	3
CR1301		0	1	0	1
CR1303		3	2	0	5
CR1304		1	1	0	2
V1301		4	8	1	13
V1302		1	0	0	1
V1303		2	0	0	2
C1420		0	1	0	1

REF DESIG	PART NUMBER	QUANTITY OF PARTS REPLACED			
		1970	1971	1972*	TOTAL
R1429		0	1	0	1
R1430		0	1	0	1
V1406		0	1	0	1
V1409		0	1	0	1
R1510		0	0	1	1
IF STRIPS	6AK5	62	12	23	97
V1902	SEE	4	9	5	18
V1905	TABLE D-9 FOR	0	1	0	1
V1906	PART NUMBERS	6	1	0	7
B2401		0	3	0	3
M2405		1	0	0	1
V2601		1	0	0	1
V2603		1	0	0	1
V2604		1	1	0	2

TABLE D-8;

COMPONENTS REPLACED DURING UNSCHEDULED MAINTENANCE ACTIONS AT SFO

REF DESIG	PART NUMBER	QUANTITY OF PARTS REPLACED			
		1970	1971	1972*	TOTAL
V2605		2	1	1	4
V2704		0	1	0	1
V2707		1	0	0	1
V2901		0	1	0	1
V2911		0	1	0	1
V3004		1	0	0	1
V3005		0	1	0	1
V3008		1	0	0	1
V3101		1	0	0	1
V3104		1	1	0	2
V3105		1	1	0	2
K6201		0	1	0	1
V6201		0	2	0	2
R7310		0	0	1	1
V7302		0	0	1	1
B9301		1	0	0	1

* Partial

TABLE D-9;

COMPONENTS REPLACED DURING UNSCHEDULED MAINTENANCE ACTIONS AT ALL SITES

REF DESIG	PART NUMBER	QUANTITY OF PARTS REPLACED			
		1970	1971	1972*	TOTAL
B1001	NBC-L14F2	3	3	1	7
B1002	KD-2501	1	0	0	1
S1001	1AC12	1	0	0	1
S1004	1AC12	1	1	0	2
S1005	C100EB3RD	1	0	0	1
C1221	MS90131-1	1	0	0	1
CR1209	1N277	0	1	0	1
CR1211	1N1596A	1	0	0	1
R1227	M35045-75	0	1	0	1
R1236	MS35045-86	1	1	0	2
R1240	MS35045-127	2	2	0	4
R1244	MS35044-118	1	1	0	2
R1245	MS35045-123	2	1	0	3
R1246	MS35045-123	3	2	0	5

REF DESIG	PART NUMBER	QUANTITY OF PARTS REPLACED			
		1970	1971	1972*	TOTAL
R1247	MS350043-151	0	1	0	1
R1254	MS35043-53	1	1	0	2
R1255	RV4LAYSD101-A	2	0	0	2
R1257	MS35043-77	2	2	0	4
V1201	6AN5	2	2	1	5
V1202	6AN5	2	1	0	3
V1203	6AN5	2	1	0	3
V1204	6AN5	3	0	0	3
V1205	6AN5	2	1	0	3
V1206	6CL6	2	1	0	3
V1207	6CL6	1	0	0	1
V1208	6CL6	2	0	0	2
V1209	5687WA	7	3	0	10
V1210	12AU7	3	4	0	7

TABLE D-9;

COMPONENTS REPLACED DURING UNSCHEDULED MAINTENANCE ACTIONS AT ALL SITES

REF DESIG	PART NUMBER	QUANTITY OF PARTS REPLACED			
		1970	1971	1972*	TOTAL
B1302	C1321-21	4	5	1	10
C1315	1802-0A	1	0	1	2
C1318	1802-0A	0	1	0	1
CR1301	1N26	29	22	6	57
CR1302	1N26R	26	19	11	56
CR1303	1N26AMR	75	79	48	202
CR1304	1N26AMR	66	72	47	185
CR1305	1N198	1	1	0	2
CR1306	1N198	0	1	0	1
CR1307	1N198	0	1	0	1
CR1311	1N76	1	3	0	4
K1301	105333-1	0	1	0	1
K1302	G-59288	1	0	0	1
K1303	G-59288	1	0	0	1

REF DESIG	PART NUMBER	QUANTITY OF PARTS REPLACED			
		1970	1971	1972*	TOTAL
R1316	MS35045-91	1	0	0	1
V1301	JAN2K50	59	75	36	170
V1302	416B/6280	21	23	8	52
V1303	BL-T-036	32	37	22	91
C1420	327-102	0	1	0	1
C1434	MS90129-1	0	0	1	1
R1402	MS35043-67	0	1	0	1
R1424	RN25X1603F	1	0	0	1
R1429	MS35045-118	3	2	0	5
R1430	MS35045-118	2	2	0	4
V1401	6AK5	4	1	2	7
V1402	6AK5	4	2	3	9
V1403	6AK5	3	3	1	7
V1404	6AK5	3	3	1	7

TABLE D-9;

COMPONENTS REPLACED DURING UNSCHEDULED MAINTENANCE ACTIONS AT ALL SITES

REF DESIG	PART NUMBER	QUANTITY OF PARTS REPLACED			
		1970	1971	1972*	TOTAL
V1405	12AX7	13	9	2	24
V1406	12AU7	4	3	0	7
V1407	12AU7	8	2	1	11
V1408	6AK5	3	0	0	3
V1409	6AK5	3	2	1	6
V1410	6AK5	3	0	0	3
V1411	6AK5	2	0	0	2
C1502	CB11SB102M	1	0	0	1
C1531	CB31QX102K	0	1	0	1
C1551	CB11RB471M	0	1	0	1
C1552	CB31QX101K	0	1	0	1
C1553	1961	0	1	0	1
C1554	CB21PX101K	0	1	0	1
C1555	CB21PX471K	0	1	0	1

REF DESIG	PART NUMBER	QUANTITY OF PARTS REPLACED			
		1970	1971	1972*	TOTAL
C1557	BYA6D1	1	0	0	1
R1501	MS35045-202	1	0	0	1
R1510	RC20GF241K	0	0	1	1
R1517		1	0	0	1
C1626	VC1G	0	0	1	1
R1701	MS35045-202	1	0	0	1
R1702	MS35045-202	2	0	0	2
IF STRIPS	6AK5	413	211	146	770
CR1801	TM106	1	1	0	2
CR1802	TM106	0	1	0	1
CR1803	TM106	0	1	0	1
CR1804	TM106	0	2	0	2
CR1805	TM106	0	2	0	2
CR1806	TM106	0	2	0	2

TABLE D-9;

COMPONENTS REPLACED DURING UNSCHEDULED MAINTENANCE ACTIONS AT ALL SITES

REF DESIG	PART NUMBER	QUANTITY OF PARTS REPLACED			
		1970	1971	1972*	TOTAL
K1801	107544-1	2	0	0	2
L1801	105125-1	0	1	0	1
R1808	MS35045-63	1	0	0	1
R1824	MS35045-107	2	0	0	2
B1901	C1321-19	4	3	3	10
C1903	CM60B103K	1	0	0	1
C1910	PAS-102-30M	0	1	0	1
C1913	106405-2	0	3	0	3
CR1902	MS901129-1	1	0	0	1
R1904	MS35045-73	0	1	0	1
R1905	MS35045-71	0	1	0	1
R1906	MS35045-118	1	0	0	1
R1907	MS35045-118	1	0	0	1
R1908	106267-1	1	1	2	4

REF DESIG	PART NUMBER	QUANTITY OF PARTS REPLACED			
		1970	1971	1972*	TOTAL
R1909	MS35045-118	1	0	0	1
R1910	MS35045-118	1	0	0	1
R1911	106267-2	0	0	1	1
R1918	MVZ-7	1	1	0	2
R1927	MS35044-74	1	0	0	1
S1903	2A/1600	2	9	1	12
V1901	6AQ5A	15	24	6	45
V1902	3C45/6130	95	160	34	489
V1903	4PR60A	19	48	8	75
V1904	4PR60A	17	47	11	75
V1905	4PR60A	13	45	9	67
V1906	BL-M006	36	20	12	68
V1907	8020	4	3	2	9
V1908	8020	2	2	2	6

TABLE D-9;

COMPONENTS REPLACED DURING UNSCHEDULED MAINTENANCE ACTIONS AT ALL SITES

REF DESIG	PART NUMBER	QUANTITY OF PARTS REPLACED			
		1970	1971	1972*	TOTAL
B2001	NBC-L14F2	3	2	1	6
B2002	NBC-L10-16	3	3	0	6
CR2209	1N1514A	1	0	0	1
T2201	P111-0A2	0	1	0	1
V2201	12AT7WA	0	1	0	1
V2204	12AT7WA	0	1	0	1
V2208	6AG7	0	1	0	1
V2209	6AG7	0	1	0	1
V2212	12AU7	1	1	0	2
V2215	5XP11A	3	0	0	3
B2401	B8262E600C	1	5	0	6
CR2401	4JA411AB1A02	0	2	0	2
K2403	9575H2020A	0	0	1	1
K2409	G-59288	1	0	0	1

REF DESIG	PART NUMBER	QUANTITY OF PARTS REPLACED			
		1970	1971	1972*	TOTAL
M2405	106073-1	8	0	0	8
M2406	106073-1	0	1	0	1
R2401	RV4NAXS0252A	2	0	0	2
T2401	10B1071	1	0	0	1
R2502	MV0-15	0	2	0	2
T2501	105849-1	0	3	1	4
V2501	1B3GT	0	0	1	1
V2502	1B3GT	0	0	1	1
C2605	CM20C102K	0	1	0	1
L2601	106113-1	0	1	0	1
R2601	MS35045-88	1	0	0	1
R2603	MS35045-111	1	0	0	1
R2613	MS35043-87	0	2	0	2
R2630	MS35043-87	1	0	0	1

TABLE D-9;

COMPONENTS REPLACED DURING UNSCHEDULED MAINTENANCE ACTIONS AT ALL SITES

REF DESIG	PART NUMBER	QUANTITY OF PARTS REPLACED			
		1970	1971	1972*	TOTAL
R2634	MS35043-87	1	0	0	1
V2601	12AU7	2	0	0	2
V2602	12AT7WA	0	2	0	2
V2603	5687WA	5	5	2	12
V2604	5687WA	4	3	1	8
V2605	12AT7WA	9	12	3	24
V2606	12AU7	2	1	0	3
R2721	MS35043-55	0	1	0	1
R2725	MS35043-135	0	1	0	1
V2703	6AQ5A	0	1	0	1
V2704	6AQ5A	0	1	0	1
V2705	6AQ5A	1	0	0	1
V2706	6AU6	0	1	0	1
V2707	12AX7	2	1	1	4

REF DESIG	PART NUMBER	QUANTITY OF PARTS REPLACED			
		1970	1971	1972*	TOTAL
V2708	6AS7G	0	0	1	1
V2709	6AS7G	0	0	1	1
R2901	MS35045-81	0	2	0	2
R2902	MS35045-81	0	2	0	2
R2915	MS35045-39	1	0	0	1
R2916	MS35045-39	1	0	0	1
R2923	MS35045-81	0	1	0	1
R2924	MS35045-81	0	2	0	2
R2925		0	1	0	1
V2901	MS35043-95	0	3	0	3
V2902	6CL6	0	3	0	3
V2903	6CL6	0	2	0	2
V2904	6CL6	0	2	0	2
V2905	6CL6	0	1	0	1

TABLE D-9;

COMPONENTS REPLACED DURING UNSCHEDULED MAINTENANCE ACTIONS AT ALL SITES

REF DESIG	PART NUMBER	QUANTITY OF PARTS REPLACED			
		1970	1971	1972*	TOTAL
V2907	6CL6	1	1	0	2
V2910	6CL6	1	1	0	2
V2911	6CL6	0	1	0	1
V2912	6CL6	1	1	0	2
V2914	6CL6	0	1	0	1
R3114	MS35045-63	1	0	0	1
R3122	MS35045-63	0	1	0	1
V3101	6AU6	2	2	1	5
V3102	12AX7	2	1	1	4
V3103	6AS7G	3	3	2	8
V3104	6AS7G	1	1	2	4
V3105	6AS7G	1	2	2	5
C3301	CP69B1EF104K	0	1	0	1
CR3301	TM106	0	1	0	1

REF DESIG	PART NUMBER	QUANTITY OF PARTS REPLACED			
		1970	1971	1972*	TOTAL
CR3303	TM106	0	1	0	1
CR3304	TM106	0	1	0	1
CR3307	TM106	1	0	0	1
B4001	NBC-L14F2	3	1	0	4
4100		1	0	0	1
K4101	105971-1	2	0	0	2
K4102	105969-1	1	1	0	2
K4103	105972-1	3	0	0	3
K4104	105972-1	1	0	0	1
K4105	106670-1	1	0	0	1
K4106	106670-1	2	0	0	2
K4107	G59292	1	0	0	1
K4108	G59292	1	0	0	1
V5311	417A	1	0	0	1

TABLE D-9;

COMPONENTS REPLACED DURING UNSCHEDULED MAINTENANCE ACTIONS AT SITES

REF DESIG	PART NUMBER	QUANTITY OF PARTS REPLACED			
		1970	1971	1972*	TOTAL
V5312	5687WA	1	0	0	1
V5313	5687WA	1	0	0	1
K6201	B2327	4	1	0	5
R6215	MS35045-63	1	0	0	1
R6216	MS35045-63	1	0	0	1
R6217	MS35045-63	1	0	0	1
R6218	MS35045-63	1	0	0	1
V6201	6AH6	0	4	2	6
V6202	6AS7G	0	3	2	5
V6203	6AS7G	1	3	2	6
V6204	OB2	1	3	1	5
V6205	OB2	0	4	2	6
B7001	BC2910F-X-2	2	1	1	4
S7001	MS16106-1	0	1	0	1
C7210	MS90129-1	0	1	0	1
CR7201	1N277	0	3	0	3
CR7202	1N277	0	2	0	2
R7214	MS35043-111	0	1	0	1
V7201	6AH6	1	1	0	2
V7202	6AH6	1	1	0	2
V7203	6AH6	0	1	0	1
V7204	6AH6	0	1	0	1
V7207	6AH6	1	0	0	1
7300		1	1	1	3
K7301	AD954	1	0	0	1
R7304	MS35054-97	1	0	0	1
R7308	MVC2	1	0	0	1
R7309	MVH4	1	0	2	3

TABLE D-9;

COMPONENTS REPLACED DURING UNSCHEDULED MAINTENANCE ACTIONS AT ALL SITES

REF DESIG	PART NUMBER	QUANTITY OF PARTS REPLACED			
		1970	1971	1972*	TOTAL
R7310	MVH4	2	1	2	5
T7301	CB807	0	1	0	1
V7301	6BG6GA	2	1	1	4
V7302	1X2A	5	4	3	12
V7303	5670	2	1	2	5
V7304	6AU6	1	0	2	3
V7305	M105-15	4	2	1	7
K7401	106672-1	1	0	0	1
K7402	106672-1	1	0	0	1
K7403	106672-1	1	0	0	1
R7401	RV4LAXSD103A	0	0	1	1
V7401	5687WA	3	1	1	5
V7402	12AX7	0	1	1	2
V7403	6BG6GA	1	1	0	2

REF DESIG	PART NUMBER	QUANTITY OF PARTS REPLACED			
		1970	1971	1972*	TOTAL
V7404	6BG6GA	1	0	1	2
R7527	MS35043-63	0	1	0	1
V7501	12AT7WA	0	1	1	2
V7503	12AT7WA	0	1	0	1
7850	-	17	13	0	30
B7852	C33A702	4	4	4	12
L7853	105365-1	1	1	0	2
MP7858	105354-1	0	1	0	1
R7808	RV4LAYSD503A	0	1	0	1
S7801	46502	3	0	2	5
V7801	CK132P2B	7	3	0	10
M8101	106073-1	0	0	1	1
8300	-	2	1	0	3
CR8301	1N277	0	1	0	1

APPENDIX E

REPORT OF INVENTIONS

REPORT OF INVENTIONS

A diligent review of the work performed under this contract has revealed no new innovation, discovery, improvement or invention.