N 70 37587

CR 112782

STUDY OF SATURN IB FACILITIES AND EQUIPMENT FOR IMPROVED LAUNCH CONTROL OF AAP MISSIONS

VOLUME II

FINAL STUDY REPORT

Prepared for
National Aeronautics and Space Administration
John F. Kennedy Space Center
Kennedy Space Center, Florida
Under Contract NAS10-6170

February 1970

Computer Applications Incorporated

F. KENNEDY SPACE
NASA LIBRARY

REFERENCE ONLY

MAY 2 1 1970

STUDY OF SATURN IB FACILITIES AND EQUIPMENT FOR IMPROVED LAUNCH CONTROL OF AAP MISSIONS

VOLUME II

FINAL STUDY REPORT

Prepared for

National Aeronautics and Space Administration
John F. Kennedy Space Center
Kennedy Space Center, Florida

Under Contract NAS10-6170

February 1970

B. L. Brown
Study Manager

COMPUTER APPLICATIONS INCORPORATED
Huntsville, Alabama

PREFACE

This report summarizes an analytical study of Saturn IB launch support operations conducted by Computer Applications Incorporated for the National Aeronautics and Space Administration, Kennedy Space Center, Florida, under Contract NAS10-6170. The work reported herein was performed during the period 1 December 1968 to 1 February 1970.

The objectives of the study were to develop a listing of support equipment exhibiting highest probability of contributing to launch delays, and provide recommendations for improving launch control. For this purpose, an analytical model was developed and a computer program was written to perform the necessary computation. Operational data concerning the countdown activities and the associated support equipment was introduced to provide a representative simulation. Application of the model resulted in an overall evaluation of launch support availability and identified the principal factors contributing to launch delays.

The final report is presented in three volumes:

VOLUME I EXECUTIVE SUMMARY

VOLUME II FINAL STUDY REPORT

VOLUME III USER'S MANUAL

Volume II documents the results of the launch support availability study and the associated analyses that were conducted. The basis of the analytical approach and the development of necessary supporting data are presented together with the significant results of the countdown evaluation. Methods for improving launch control are recommended.

Mr. Wallace H. Boggs, Design Engineering, Future Studies Office, provided technical and management guidance in serving as COR for NASA-KSC. Major contributors to the report were made by the following members of Computer Applications Incorporated: J. B. Allen, W. H. Armistead, B. L. Brown, C. H. Carlson, L. A. Carroll, D. J. Dunn, W. F. Keith, Jr., J. L. Kilkenny, M. J. Seebach and S. W. Solley.

TABLE OF CONTENTS

		Page
I	INTRODUCTION	1
	1.1 STUDY OBJECTIVES	1
	1.2 SCOPE OF STUDY	1
	1.3 SUMMARY OF RESULTS	2
II	SIGNIFICANT RESULTS	5
III	LAUNCH AVAILABILITY EVALUATION METHODOLOGY	28
IV	THE LAUNCH OPERATION MATHEMATICAL MODEL	33
	4.1 SCOPE OF THE MODEL	33
	4.2 ASSUMPTIONS	37
	4.3 MODEL DESCRIPTION	37
	4.4 FEATURES OF THE MODEL	39
V	THE COMPUTER PROGRAM	41
VI	DATA BASE	45
	6.1 PARAMETERS OF INTEREST	45
	6.2 SOURCE DOCUMENTS	46
	6.3 CONFIGURATION ANALYSIS	49
	6.4 COUNTDOWN LOGS	60
VII	OPERATIONS ANALYSIS	65
	7.1 ACTIVITY IDENTIFICATION	68
	7.2 FUNCTION CHARACTERISTICS	69
	7.3 SUMMARY OF COUNTDOWN FUNCTIONS	80
VIII	SUPPORT EQUIPMENT ANALYSIS	99
	8.1 SUPPORT EQUIPMENT DEFINITION	99
	8.2 EQUIPMENT REQUIRED TO SUPPORT FUNCTIONS	101
	8.3 RELIABILITY AND MAINTAINABILITY EVALUATIONS	119
	8.3.1 Failure Rates and Repair Time from Documentation	119
	8.3.2 UCR Analysis	120
	8.4 DATA SYNTHESIS METHODS	125
	8.4.1 Failure Rate Estimation Process	126
	8.4.2 Repair Time Estimation Process	135
	8.4.3 Spacecraft GSE Estimation Process	138
	8.5 SUPPORT EQUIPMENT R&M VALUES	141
IX	IMPLEMENTATION	156
	9.1 INPUT COMPILATION	156
	9.2 INPUT CODING	157
	9.3 MODEL APPLICATION	158

TABLE OF CONTENTS (Cont'd)

		Page
X	RECOMMENDATIONS	169
10.1	LAUNCH OPERATIONS	170
10.2	SUPPORT EQUIPMENT	173
10.3	PROCEDURAL	177
10.4	ANALYTICAL ACTIVITIES	180

LIST OF FIGURES

		Page
II-1	PROBABILITY OF LAUNCH-IN-WINDOW	7
II-2	BASELINE LISTING BY LAUNCH WINDOW	14
II-3	CONTRIBUTION TO LAUNCH DELAY BY TIMEFRAME	16
II-4	EFFECT ON LAUNCH DELAY BY FUNCTION	18
II-5	PROBABILITY OF SUCCESS VS. SCHEDULE	20
II-6	EFFECT OF ADDITIONAL SCHEDULED HOLD, LAUNCH WINDOW = ZERO HOURS	22
II-7	EFFECT OF ADDITIONAL SCHEDULED HOLD, LAUNCH WINDOW = 30 MINUTES	23
II-8	EFFECT OF ADDITIONAL SCHEDULED HOLD, LAUNCH WINDOW = ONE HOUR	24
II-9	EFFECT OF HOLD DURATION AT T-0:40:0	25
III-1	STUDY APPROACH	30
IV-1	LAUNCH OPERATIONS TIME MODEL	34
V-1	COMPUTER PROGRAM FLOW CHART	42
VI-1	LAUNCH FACILITY SUPPORT CONFIGURATION	59
VII-1	COUNTDOWN FUNCTION TIMELINESS	71
VIII-1	SUPPORT EQUIPMENT ANALYSIS	100
VIII-2	FUNCTIONAL BLOCK DIAGRAMS	102
VIII-3	PROCEDURE TO DETERMINE SYSTEM FAILURE RATES	127
VIII-4	PROCEDURE TO DETERMINE SYSTEM REPAIR TIMES (t_r)	137
VIII-5	SPACECRAFT GSE FAILURE RATES	140

LIST OF TABLES

		Page
II-1	AVAILABILITY BASELINE LISTING	9
VI-1	DOCUMENT CATALOG RELATING SYSTEMS VS. INFORMATION	50
VI-2	DATA FROM COUNTDOWN LOGS	62
VI-3	SYSTEM ANOMALIES DURING LAUNCH COUNTDOWN	63
VII-1	LIST OF HOLDPOINTS WITH TIME FUNCTIONS	67
VII-2	COUNTDOWN FUNCTION DATA	82
VIII-1	COUNTDOWN FUNCTION VS. SUPPORT EQUIPMENT	110
VIII-2	FUNCTIONAL SYSTEMS FIELD FAILURE RATES	123
VIII-3	SYSTEM FAILURE RATE ESTIMATES	132
VIII-4	FAILURE RATES OF SUBSYSTEMS COMPRISING THE H SYSTEM	136
VIII-5	SATURN IB GSE R&M VALUES	142
IX-1	NOMINAL DATA COMPUTER RUN	161
IX-2	SENSITIVITY OF EQUIPMENT 340 (COOLING TOWER)	166
IX-3	SENSITIVITY OF TWENTY EQUIPMENTS	167
IX-4	REPAIR TIME SENSITIVITY OF EQUIPMENT 341	168
X-1	RECURRING FAILURES	174

I INTRODUCTION

This report documents a study of Saturn IB launch control and its dependence on launch facilities, support equipment and associated procedures. Intended to provide planning criteria for Apollo Applications Program prelaunch mission support, the study focuses on the current capability of responding to AAP launch window constraints. Launch support availability is established on a quantitative basis and equipment systems which contribute to launch delay are identified. Possible methods of improving launch control are designated. The results and analyses of this report are submitted in accordance with the requirements of Contract NAS10-6170.

1.1 STUDY OBJECTIVES

The underlying purpose of the study is to determine the best means for preventing launch delays due to problems in ground support equipment, launch facilities or associated procedures. To this end, the general study objective is to determine the probability of a launch delay and evaluate its constituents. A listing of support equipment ranked according to their relative contribution to launch delays, and recommendations for improving launch support availability are specific objectives of the study. A subordinate objective is to develop the evaluation procedure in a manner that permits rapid assessment of availability so that it may be of use in future operations planning and design studies.

1.2 SCOPE OF STUDY

As part of this study, an analysis of all of the KSC based launch support activities during the final 14 hours and 15 minutes of the countdown is made.

Launch facility equipment and support equipment that is associated with the Saturn IB vehicle stages and the spacecraft are considered in the evaluation of launch delays. The analysis is performed at the subsystems configuration level. Mission Rules and the Countdown Procedures applicable to Apollo/Saturn 205, launched from Complex 34, are used as the baseline reference in the analysis.

This launch availability analysis is limited to ground equipment considerations. Flight vehicle systems are not a part of the analysis and are of interest only to the extent of placing requirements on facilities or support equipment. Consequently the launch probability values developed in this study are indicative of only the ground support's role in launch readiness. Weather, flight vehicle equipment and portions of the downrange system, as additional potential causes of launch delay, must also be considered if a proper complete assessment of launch probability is to be made.

1.3 SUMMARY OF RESULTS

The results of the study indicate a compliance with the basic study objectives. The principal means of accomplishing the objectives and possibly the most significant result of the study is due to the successful development of a mathematical model that is representative of the launch countdown activity and yields an assessment of launch support availability. The model translated into FORTRAN has been programmed for computer operation. The flexibility designed into this computer program permits convenient evaluation of all support equipment parameters affecting launch support. Documentation necessary for the use of the model and computer program has been developed in the form of a User's Manual and comprises Volume III of this report.

Implementation of the computer program is the basis for many of the study results. For the baseline case, the probability of supporting an on-time launch is calculated to be 0.769. The probabilities of launch support have been established as a function of launch window duration so that the probability of launch-in-window may be defined for any given window. An equipment listing, which presents each support equipment in order of its relative contribution to delay, is another result derived from the computer program. These listings are different for each launch window considered.

Special features of the availability model and computer program permit other significant conclusions to be made. For instance, the probability of being on schedule at various points in the countdown can, and has been evaluated. Groups of functions occurring during a given span of time may be compared with other groups in different timeframes. The effect on launch support availability may be readily assessed when potential modifications to equipment or procedures are considered. The baseline case is modeled to include a scheduled 6 hour hold at T-6 hours. However, if additional holds of any duration are desired at other times in the countdown, their effect on availability can be accounted. Parametric analyses relating availability with the built-in-hold characteristics of duration and countdown position have been made.

Information concerning the countdown activities and the support equipment has been acquired and documented. A thorough configuration analysis identified the systems and subsystems required for launch vehicle and spacecraft support. Failure rate and repair time estimates have been associated with each item of support equipment and a catalog of available documentation, applicable to each system, has been compiled.

Recommendations for improving launch control, either by operational or equipment modification is provided in this report. These alternatives are presented as hypothetical changes and the possible improvement in launch support availability is noted.

II SIGNIFICANT RESULTS

Two types of results are derived from the efforts of this study. One set of results is developed to satisfy the study objectives and is an end product of the study. This type of result is possibly the most interesting in that it consists of original information. Launch probability assessments, parametric relationships and the baseline listing are examples of this type result. The other set of results is basically a fallout of the study. Such results are generated to satisfy input requisites for subsequent tasks. In general, their contents supplement existing information either by applying a new format or by extending the existing data. The configuration analysis and the reliability analysis, performed as part of this study, exemplify the latter type of result. Both types of results are identified in the following listing of significant results.

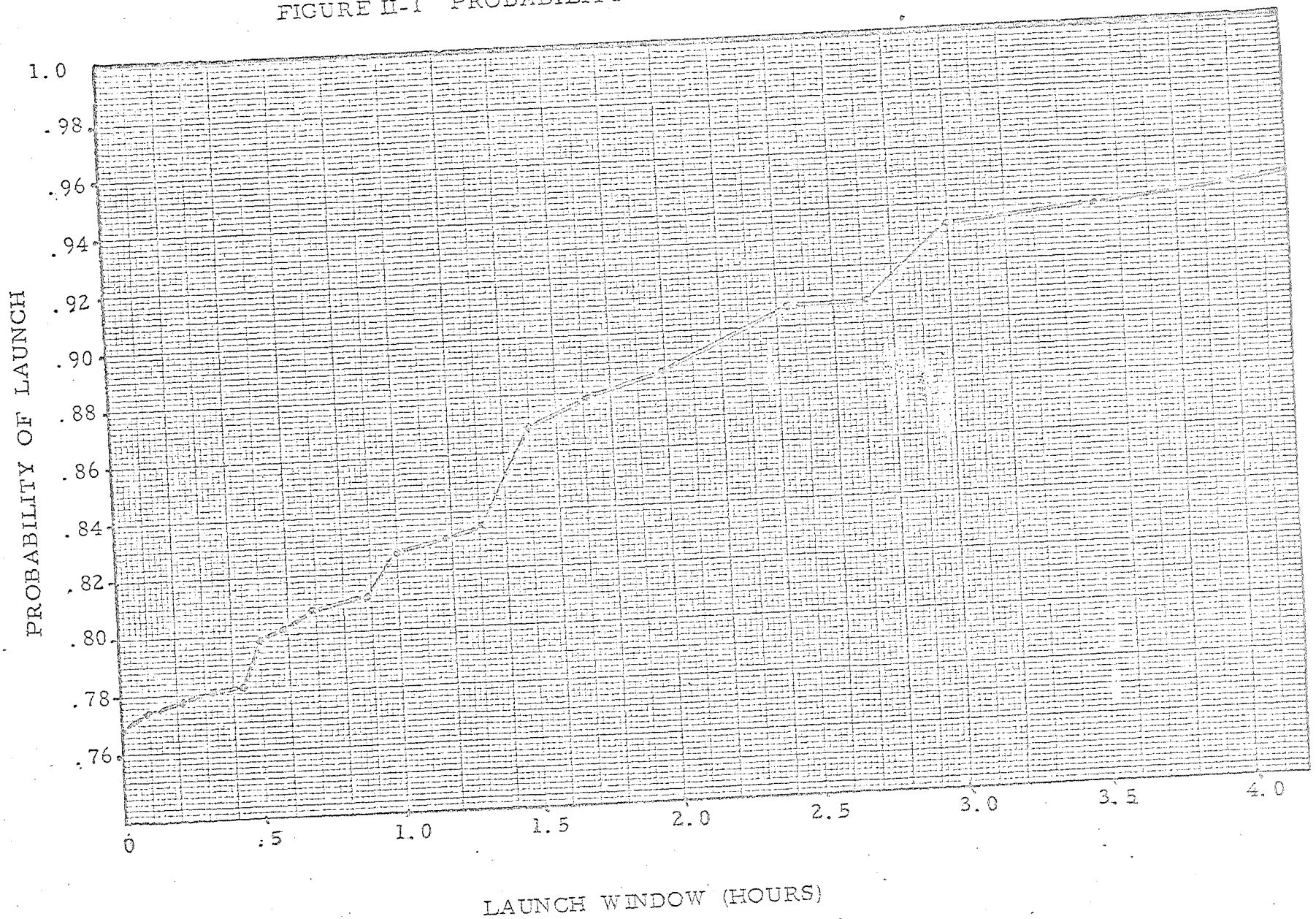
Availability Mathematical Model - A mathematical model of the operational activities of a countdown has been developed. It has been instrumental in the accomplishments of this study. The model associates, in each part of the countdown, all of the factors that may cause launch delay and properly combines them to yield statistical distributions of launch probability and delay. The probabilistic terms are derived from support equipment characteristics. Section IV of this report describes the basis of the availability model. Detailed information concerning the model may be found in Volume III.

Computer Program and User's Manual - A computer program has been developed to perform the complex calculations required in exercising the availability mathematical model. The program, written in FORTRAN IV, requires approximately 170K bytes

of storage. Special features of the program facilitate sensitivity evaluations of the nominal data set. Other study results described in the following paragraphs illustrate these features as a fallout of presenting significant countdown evaluation data. Complete information for operating the computer program has been provided by the development of a Computer Program User's Manual. This documentation contains definitions of the basic math routines, the control procedures, means of accommodating and handling inputs and definition of the FORTRAN calls. It also contains description information necessary for understanding the availability math model. Volume III and Section V of this report provide detailed information of the computer program.

Launch-In-Window Probability - The basic data derived from the computer program defines launch probability to be 0.769 for the on-time case. The complete data identifies the probability of launch within a given launch window. A plot of this data shown in FigureII-1 presents launch probability as a function of launch window duration. Probability is shown to improve with extended launch windows due to the additional time made available to affect equipment repairs; however, little improvement is exhibited for any window less than 30 minutes. The step function distribution of the data points, with principal gains in launch probability occurring in 30 minute intervals, is principally due to the equipment repair data inputs. Repair time estimates are mostly given in multiples of 30 minutes. A mathematical error of 0.0082 is associated with this data and is due to truncating those terms that are less than .000005 during the calculation process.

FIGURE II-1 PROBABILITY OF LAUNCH-IN-WINDOW



The AAP mission requirements define the launch window for the AAP CSM configuration to be 5 minutes. From Figure II-1, the probability of launch within such a window is .774, only slightly different than from the on-time case. Other results that are subsequently presented about launch-on-time are similarly close approximations to the AAP requirements.

Availability Baseline Listing - As a part of this analysis and to satisfy a principal study objective, the computer program was exercised to determine the contribution that each launch support equipment individually made to the probability of launch delay. The principal means by which the sensitivity analysis was conducted consisted of assuming an individual equipment to perform perfectly and then determine launch probability considering everything else to be normal. Then by comparing that value with the launch probability value computed in the nominal case, the difference would represent the delta probability due to the equipment in question. By repeating this procedure for each equipment, the relative delta probabilities could then be used as the criteria for ranking.

The results of this sensitivity analysis provided the data to establish an availability baseline which ranks the equipments in descending order of their contribution to launch delay. The analysis was completed for the launch-on-time case (i.e., window = 0) as well as for several other launch windows. Table II-1 presents a complete listing of the equipment criticality ranking and each equipment's contribution (ΔP) to the probability of launch delay for the zero window case. Figure II-2 shows 20 equipments that contribute most to the probability of launch delay for three different launch window durations. It is interesting to note that

TABLE II-1 AVAILABILITY BASELINE LISTING (5 sheets)

Rank	Equip. No.	Equipment Name	Δ P
1	622	Service Structure - Jacks	.01987
2	1664	110A - Computer (AGCS)	.00892
3	1660	110A - Computer (LCC)	.00883
4	1622	DEE-6 - Computer	.00850
5	341	ECS - ECU's	.00623
6	342	ECS - ECU Heaters	.00623
7	99	Batt. Rack & Cont. Pnl. (C14-268)	.00541
8	1181	60 Hz. Power - Industrial Pwr. Substa.	.00508
9	292	GN_2 - Valve Pnl. 5	.00504
10	746	PTCS - LOX PTC	.00481
11	244	LOX - Fill and Drain (S-IB Repl.)	.00475
12	245	LOX - Fill and Drain (S-IVB Repl.)	.00475
13	96	Disc. Set (A34-243)	.00474
14	627	Service Structure - Silo Gates	.00439
15	745	PTCS - RP-1 PTC	.00406
16	261	LH_2 - Fill and Drain	.00352
17	262	LH_2 - Valve Control Complex	.00352
18	747	PTCS - LH_2 PTC	.00352
19	87	Ext. Sig. Cond. Unit S/M (C14-484)	.00345
20	340	ECS - Cooling Tower	.00335
21	23	Water System	.00325
22	326	He - S-IVB Pneu. Cons. 432	.00304
23	293	GN_2 - Valve Panel 10	.00299
24	1621	DEE-6 - System Control	.00296
25	241	LOX - Fill and Drain (S-IB Ldg)	.00244
26	242	LOX - Fill and Drain (S-IVB Ldg)	.00244
27	298	GN_2 - S-IVB Pneu. Cons. (433) (432) & Heat Exch. (438)	.00239
28	37	Telemetry System	.00237
29	102	400 Hertz Power Supply	.00231
30	98	Grd. Pwr. Distr. Unit (C14-481)	.00219
31	120	Propellant Data	.00208
32	1101	Cape Power - Sub. Sta. C1 & C1A	.00200
33	83	Serv. Eq. ACE-S/C Adapter (C14 240)	.00191
34	1741	Count Clock	.00173
35	1721	S-IVB ESE	.00172
36	1723	ESE - Integ. ESE	.00171
37	1722	ESE - IU	.00162
38	12	HDA	.00155
39	1223	OTV - Processing Equipment	.00153
40	106	ECS W-G Container (S14-140)	.00152
41	1720	ESE - S-IB ESE	.00150
42	1620	DEE-6 - Remote Control	.00147
43	40	C-Band	.00143
44	61	R/S Cmd.	.00124
45	1663	110A - Data Link	.00112
46	1740	Count Clock Repeater	.00110

Rank	Equip. No.	Equipment Name	Δ P
47	82	Min. Data Interleaving (C14-232)	.00108
48	46	Cabling	.00106
49	100	Pwr. Sup. & Distr. Racks, 250 amp (GFP-C-226)	.00097
50	625	Service Structure - Traction Drive	.00093
51	942	Telemetry System - TM Equipment	.00091
52	103	Fuel Cell Htr. Pwr. Supply (A14-052)	.00090
53	1641	DDAS - Output Register Pnl.	.00084
54	1001	C-Bank - Closed Loop Equipment	.00081
55	1681	ESE Primary Power - S-IVB	.00080
56	80	Pwr. Filt. Distr. Unit ACE (C14-205)	.00080
57	91	LC antennae Coupl. Set (A14-237)	.00077
58	1682	ESE Primary Power - IU	.00076
59	260	LH_2 - Storage	.00069
60	75	ESE Aux. Power	.00068
61	86	Ext. DTCS (C14-267)	.00068
62	1680	ESE Primary Power - S-IB	.00066
63	9	LOX Mast	.00064
64	15	Sw. Arm #2	.00062
65	1640	DDAS - Memory Sys. Pnl.	.00060
66	243	LOX - Replenish Storage	.00059
67	47	Grounding	.00057
68	14	Sw. Arm #1	.00054
69	95	Elec. Load Bank (A14-074)	.00054
70	623	Service Structure - Anchor Pins	.00054
71	1662	110A - Displays	.00053
72	16	Sw. Arm #3	.00052
73	1650	DDAS - Data Control Panel	.00051
74	17	Sw. Arm #4	.00048
75	79	Press. Vessel Decay Test (C34-724)	.00043
76	81	Press. Test Assy. (S34-163)	.00043
77	94	RF Sys. C/O Set (C14-442)	.00040
78	2922	ACE - Up-link Computer	.00036
79	2926	ACE - Down-link Computer	.00036
80	802	HGDS - Mass Spectrometer	.00036
81	1280	OIS - DC Power Supply	.00035
82	32	CIF Computer	.00034
83	301	GH_2 - S-IVB Gas Ht. Exch.	.00033
84	2927	ACE - Display System	.00031
85	66	TM (Range)	.00031
86	64	Radar Tr.	.00030
87	1661	110A - Offline Perip. Equip. (LCC)	.00029
88	48	ACE Pwr.	.00028
89	748	PTCS - Distrs. & Ampl.	.00025
90	1645	Correlator Pnl.	.00024
91	299	GN_2 - Prop. Cont. Console	.00021
92	284	GN_2 - LOX Control #2	.00020

Rank	Equip. No.	Equipment Name	Δ P
93	36	C1F Data Display	.00020
94	1652	DDAS - Digital Sig. Sync.	.00019
95	33	C1F TM Ground Station	.00017
96	286	GN_2 - LH_2 Control	.00017
97	1300	Wideband Trans. Sys. - User Equip. (LC)	.00017
98	1301	Wideband Trans. Sys. - ETR	.00017
99	1302	Wideband Trans. Sys. - BRRS	.00017
100	1303	Wideband Trans. Sys. - Com. Distr. & Sw. Ctr.	.00017
101	1642	DDAS - Source Selection Pwr.	.00016
102	2622	H. V. & A. C. - Water Chillers (LCC)	.00015
103	676	Water - Valve Pit 3	.00014
104	1649	DDAS - Address Cont. Dwr.	.00013
105	1644	DDAS - Computer Interface Pwr. Pnl.	.00013
106	1380	Test & Sw. Centers - TSC (Main)	.00013
107	641	Umbilical Tower - Crane	.00013
108	1261	ALDS - CASTS	.00013
109	1266	ALDS - Communications	.00013
110	749	PTCS - Prop. Cont. Cons. (RP-1)	.00013
111	1440	R/S Checkout - Signal Generation	.00013
112	1442	R/S Checkout - Output Equipment	.00013
113	1260	ALDS - TM	.00013
114	740	PTCS - RP-1 PTCS Pnl.	.00012
115	1263	ALDS - TV	.00012
116	1262	ALDS - CASRS	.00012
117	750	PTCS - Prop. Cont. Cons. (LOX)	.00012
118	741	PTCS - LOX PTCS Pnl.	.00011
119	1400	Timing & Countdown Sys. - Timing	.00011
120	1401	Timing & Countdown Sys. - Countdown	.00011
121	2925	ACE - Analog and Event Distribution	.00010
122	324	He - S-IVB Pneu. Cons. 433	.00010
123	1321	RF Communications - SCAPE Suit	.00010
124	13	AAA	.00010
125	1643	DDAS - DRS-2A & DRS-3 Pwr. Pnl.	.00010
126	221	RP-1 - Fill and Drain	.00010
127	288	GN_2 - Deluge Purge Pnl.	.00010
128	1648	DDAS - Data Output Dwr.	.00010
129	2920	ACE - Start Modules	.00009
130	328	He - Valve Pnl. 10	.00009
131	801	HGDS - Vacuum System	.00009
132	291	GN_2 - ECS Supply	.00009
133	800	HGDS - Sampling Valve	.00009
134	2923	ACE - DTVC	.00009
135	1647	DDAS - Memory Cont. Dwr.	.00008
136	2620	H. V. & A. C. - Water Chillers (AGCS)	.00008
137	1646	DDAS - Clock Cont. Dwr.	.00008
138	751	PTCS - Prop. Cont. Cons. (LH_2)	.00008
139	1364	Paging System - Logic Pnl. & Ampl.	.00008

Rank	Equip. No.	Equipment Name	ΔP
140	1365	Paging System	.00008
141	85	Pulse Regen. Line Drives (C14-261)	.00007
142	640	Umbilical Tower - Elevators	.00006
143	78	Az. Lay. & Align.	.00006
144	753	PTCS - Calib. & Monitor Eq. (RP-1)	.00006
145	1304	Wideband Trans. Sys. - Oper. & C/O User. Equip.	.00006
146	744	PTCS - PTCS Patch Pnl.	.00006
147	743	PTCS - Readout Distrs.	.00006
148	752	PTCS - Calib. & Monitor Eq. (LOX)	.00006
149	1265	ALDS - Apollo Cmd.	.00006
150	97	Filter, S/C Grd. Pwr. (C14-316)	.00006
151	323	He - Hydrogen Line Purge Cons.	.00006
152	2921	ACE - CUE	.00005
153	1651	DDAS - Source Enable Dwr.	.00005
154	942	Telemetry Sys. - TM Equip.	.00005
155	8	Fuel Mast	.00005
156	247	GN_2 - IU Pneu. Cons.	.00005
157	283	GN_2 - LOX Control #1	.00004
158	1281	OIS - Distribution	.00004
159	1381	Test & Sw. Centers - RTSC (AGCS)	.00004
160	1382	Test & Sw. Centers - RTSC (C1F)	.00004
161	2623	H. V. & A. C. - Air Handlers (LCC)	.00004
162	2621	H. V. & A. C. - Air Handlers (AGCS)	.00004
163	63	Impact Prediction	.00004
164	65	Glotrac Tr.	.00004
165	1724	ESE - EDS	.00003
166	11	Mast #4	.00003
167	290	GN_2 - Valve Panel 9	.00003
168	1441	R/S Checkout - Patch Pnl.	.00003
169	10	Mast #2	.00003
170	1264	ALDS - ALTDS	.00003
171	761	DEE-3 - Computer	.00002
172	1100	Cape Power - Cape Pwr. Plant	.00002
173	1220	OTV - Pad Area Cameras	.00002
174	1221	OTV - LCC Cameras	.00002
175	1222	OTV - AGCS Camera	.00002
176	1224	OTV - LCC Monitors	.00002
177	1225	OTV - Operations Mgmt. Monitors	.00002
178	1363	Paging System - Remote Microphone	.00002
179	1340	Telephone - LC 34 & 37	.00002
180	1341	Telephone - XY Telephone	.00002
181	1342	Telephone - BRRB	.00002
182	1343	Telephone - CKAFS IND. Area	.00002
183	1344	Telephone - CD & SC	.00002
184	1345	Telephone - KSC IND. Area	.00002
185	327	He - Valve Panel 9	.00002

Rank	Equip. No.	Equipment Name	ΔP
186	560	Hydraulic - Supply	.00001
187	1653	DDAS - Line Drivers	.00001
188	1563	MGSE - Q-Ball Pnl.	.00001
189	320	He - Storage	.00001
190	961	ODOP C/O - Closed Loop Equip.	.00001
191	2924	ACE - DADE	.00001
192	679	Water - Torus Ring & Boattail	.00001
193	742	PTCS - LH_2 PTCS Pnl.	.00001
194	825	Fire Detection Mon. Sys. - Recorder	.00001
195	708	S/C Support Piping & APS - APS Fuel	.00001
196	709	S/C Support Piping & APS - APS Oxidizer	.00001
197	2581	TCD Seq. - S-IB Launch Seq. Pnl.	.00001
198	285	GN_2 - RP-1 Control	.00001
199	105	W-G Refrig. Unit (S14-121)	.00001
200	760	DEE-3 - Data Acquisition & Eval.	.00001

Rank	WINDOW = 0.0		WINDOW = 0.5 Hour		WINDOW = 1.0 Hour	
	EQUIPMENT		EQUIPMENT		EQUIPMENT	
	No.	Name	No.	Name	No.	Name
1	622	Service Structure: Jacks	622	Service Structure: Jacks	622	Service Structure: Jacks
2	1664	AGCS Computer (110A)	1622	DEE-6 Computer (920)	341	ECS: Control Unit
3	1660	LCC Computer (110A)	1664	AGCS Computer (110A)	342	ECS: ECU Heaters
4	1622	DEE-6: Computer (920)	1660	LCC Computer (110A)	292	GN_2: Valve Panel #5
5	341	ECS: Control Unit (ECU)	341	ECS: Control Unit (ECU)	746	PTCS: LOX
6	342	ECS: ECU Heaters	342	ECS: ECU Heaters	244	LOX: Fill & Drain
7	99	Battery Rack & Cont. Panel	292	GN_2: Valve Panel #5	245	LOX: Fill & Drain (S-IVB)
8	1181	60 Hz Pwr. Ind. Substation	746	PTCS: LOX	96	Disconnect Set
9	292	GN_2: Valve Panel #5	244	LOX Fill & Drain (S-IB)	627	Serv. Struct.: Silo Gates
10	746	PTCS: LOX	245	LOX Fill & Drain (S-IVB)	99	Battery Rack & Control Panel
11	244	LOX: Fill & Drain (S-IB)	96	Disconnect Set	745	PTCS: RP-1
12	245	LOX: Fill & Drain (S-IVB)	627	Serv. Struct.: Silo Gates	261	LH_2: Fill & Drain
13	96	Disconnect Set	99	Battery Rack & Control Pnl.	262	LH_2: Valve Control Complex
14	627	Serv. Struct.: Silo Gates	745	PTCS: RP-1	747	PTCS: LH_2
15	745	PTCS: RP-1	261	LH_2: Fill & Drain	340	ECS: Cooling Tower
16	261	LH_2: Fill & Drain	262	LH_2: Valve Control Complex	23	Water System
17	262	LH_2: Valve Control Complex	747	PTCS: LH_2	326	He: S-IVB Pneu. Console #432
18	747	PTCS: LH_2 PTC	340	ECS: Cooling Tower	293	GN_2: Valve Panel #10
19	87	Ext. Signal Cond. Unit	23	Water System	241	LOX: Fill & Drain (S-IB)
20	340	ECS: Cooling Tower	326	He: S-IVB Pneu. Con. #432	242	LOX: Fill & Drain (S-IVB)

FIGURE II-2 BASELINE LISTING BY LAUNCH WINDOW

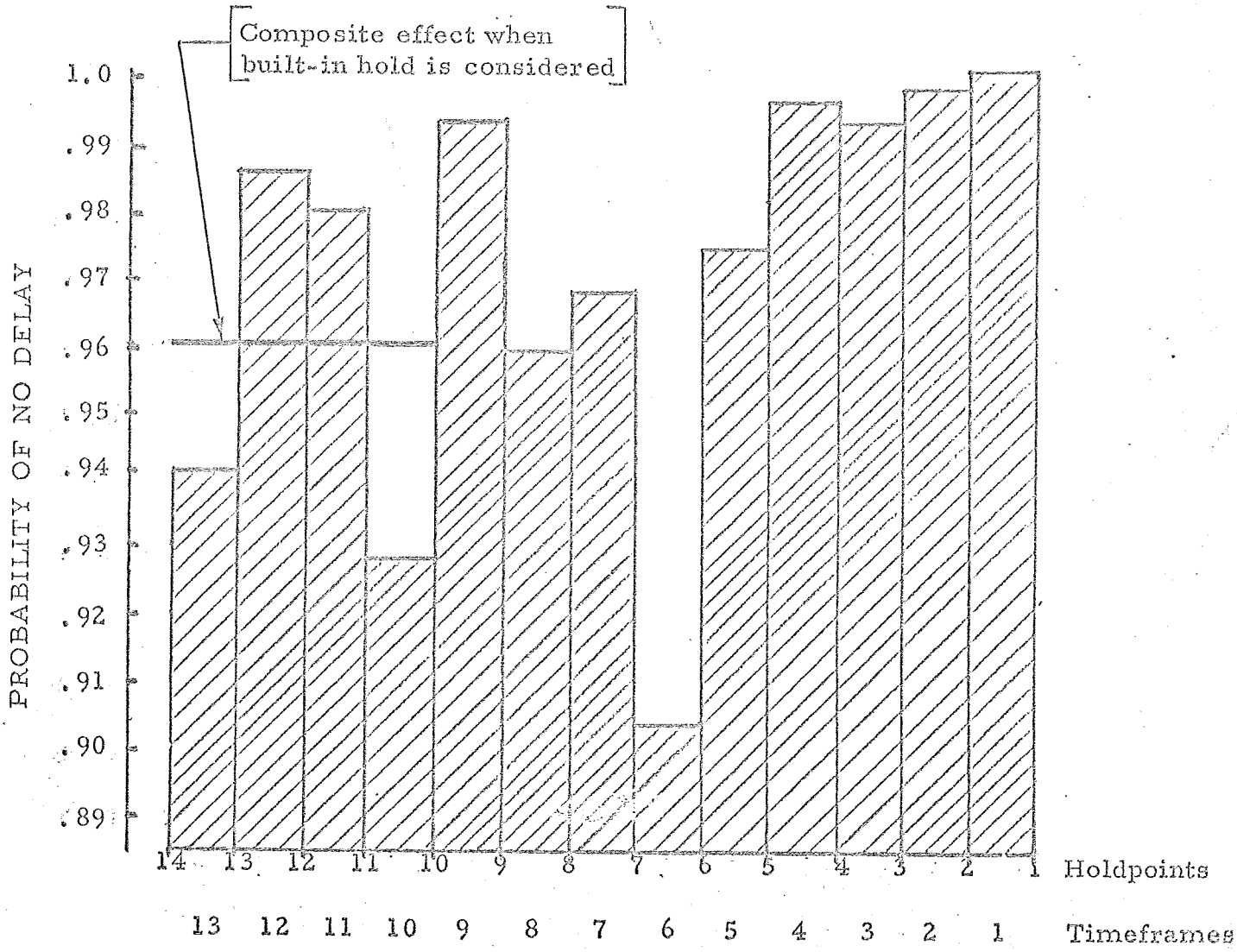
the order in which the equipments appear, change with different launch windows. Such analysis clearly demonstrates that the interaction among the parameters of launch window, failure rate, repair time and slack time must be accommodated in determining equipment availability rankings.

Contribution to Launch Delay by Timeframe - Analysis of the baseline AS205 countdown reveals 13 time periods that are distinguishable by the location of 13 "convenient" holdpoints (Refer to page 69). One may extract from the computer analysis, a probability of delay for each timeframe. Then by comparing timeframes, an evaluation can be made of which periods in the countdown functions are most troublesome. Figure II-3 presents the results of such a comparison.

Timeframe 6 is obviously the most likely to be delayed and hence cause a delay at the scheduled launch time. Timeframes 13 and 10 also appear as possible delay periods. However, timeframes 10, 11, 12 and 13 occur prior to the scheduled six hour hold and most of their delays can be absorbed by it and launch-on-time considerations are only slightly effected. Because the built-in-hold either reduces or eliminates timeframe delays for all of the operating periods that preceed it, only a composite of the preceeding timeframes can be evaluated concerning on-time launch. The probability of delay at launch, due to the combined effect of timeframes 10 through 13 is .961 when the six hour scheduled hold is accounted.

The low probability of delay exhibited in Timeframes 1, 2, 3 and 4 suggest little improvement need be made to their support systems. The minimal differences in Timeframes 5, 7 and 8 provide few indications concerning which, if any, of the three timeframes should be improved. However, this comparison does suggest

FIGURE II-3 CONTRIBUTION TO LAUNCH DELAY BY TIMEFRAME

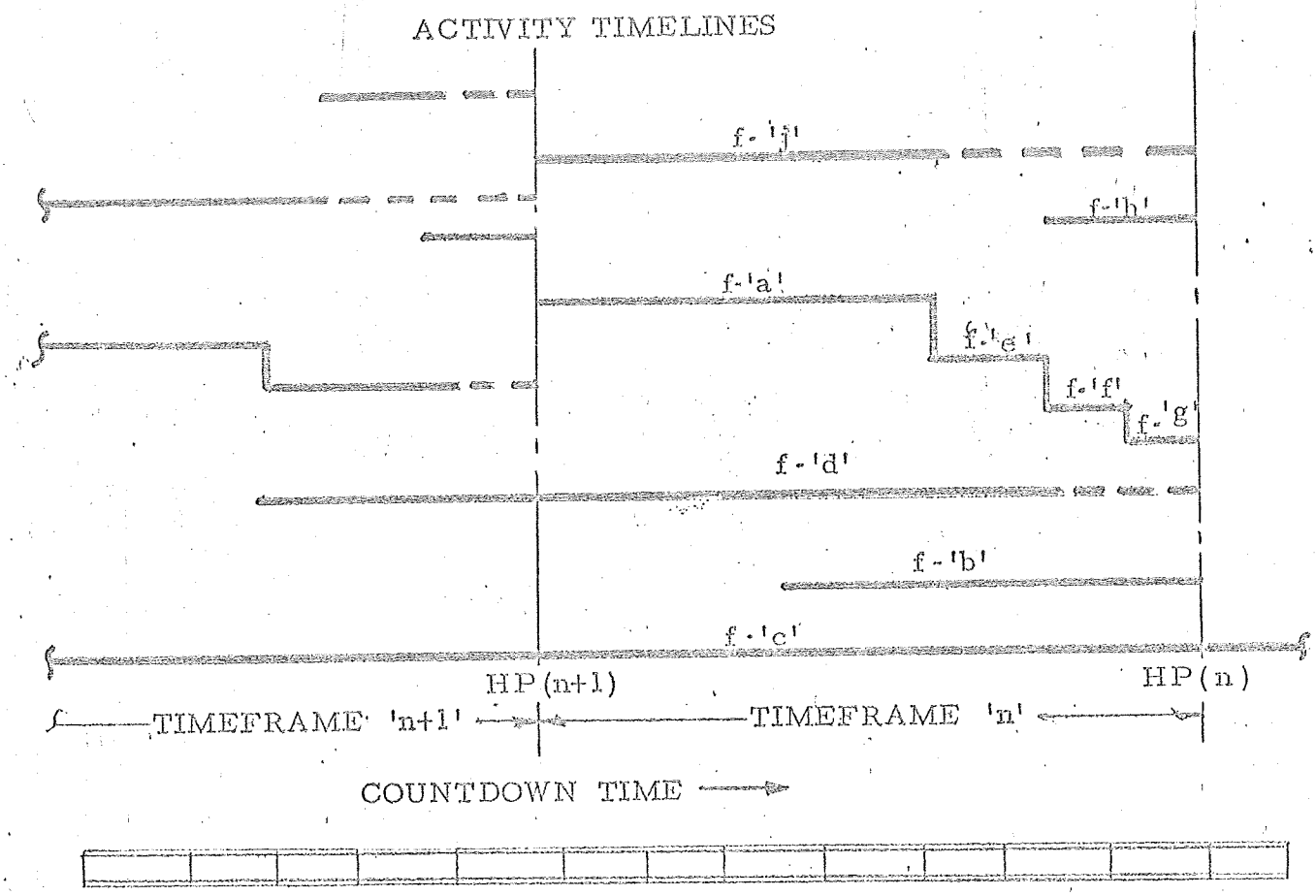


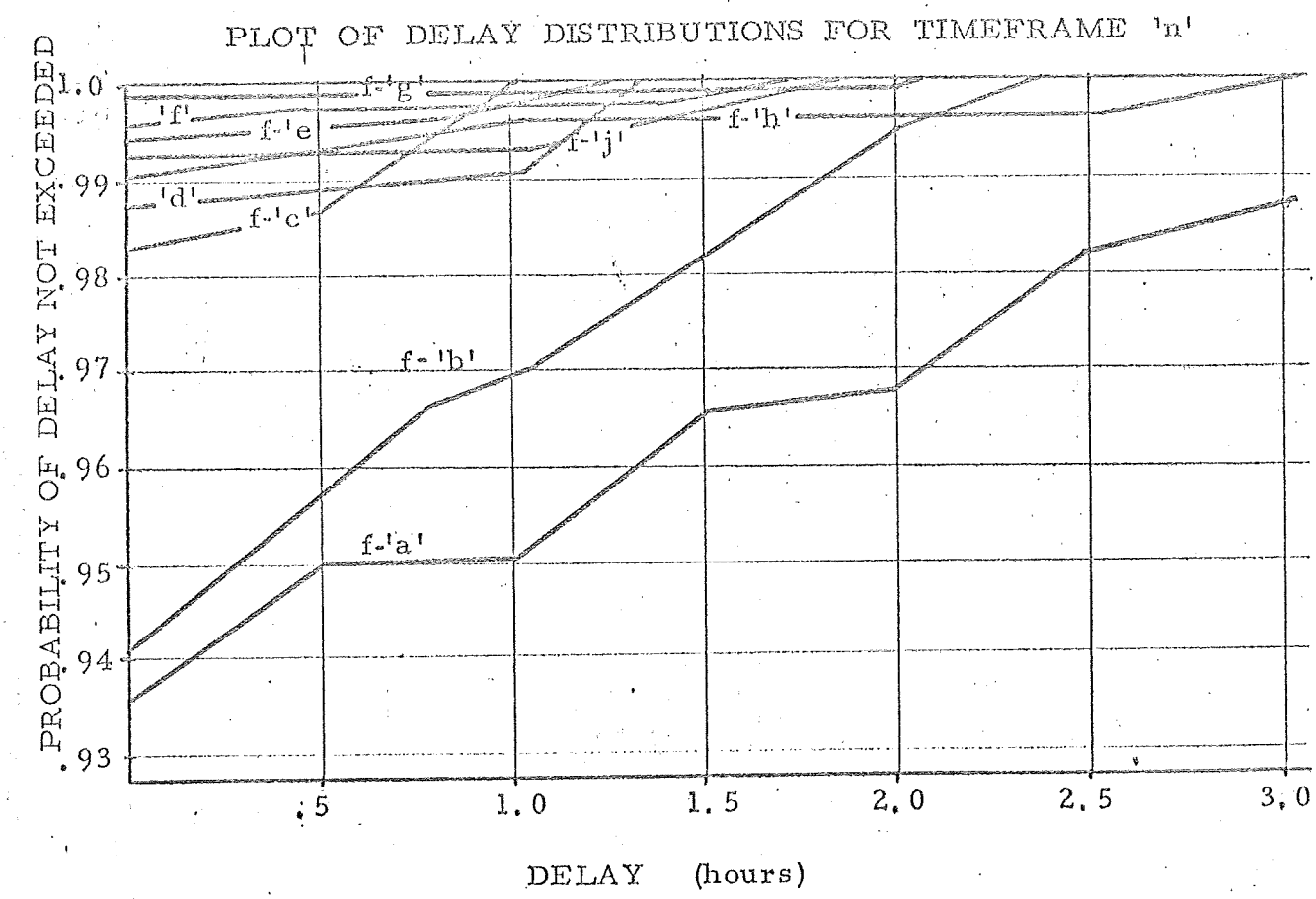
that an improvement in Timeframe 6 would be most beneficial. It should be noted that the probability values presented in this comparison are applicable to launch-on-time considerations. Different probability values as well as different relative comparisons are to be expected when the launch window is expanded significantly.

Contribution to Launch Delay by Function - Just as the countdown may be segmented into timeframes for purposes of determining troublesome operating periods, so may the timeframe be analyzed to uncover the countdown functions that are likely to cause timeframe delays. A simple modification to the computer program provides such an analysis. The analysis of Figure II-3 shows that Timeframe 6 is most likely to cause launch delays. Hence a more detailed investigation of Timeframe 6 activities wolld appear to be warranted. This analysis should consist of the examination of each individual function or activity within the timeframe to determine each activity's contribution to launch delay. With such a process, it is then possible to evaluate the effect on launch delay due to activities as well as support equipments, as previously shown. The math model and computer program are designed to nominally perform the computations that yield this kind of analysis.

For example, suppose that a timeframe is composed of a number of functions as illustrated in the upper portion of Figure II-4. After associating the necessary support equipment with each of these functions, a delay distribution is computed at Holdpoint 'n', due to each activity, given that the necessary equipment and operational parameters are available. These distributions may then be examined separately to determine their relative effect. The lower portion of Figure II-4

FIGURE II-4 EFFECT ON LAUNCH DELAY DUE TO FUNCTIONS



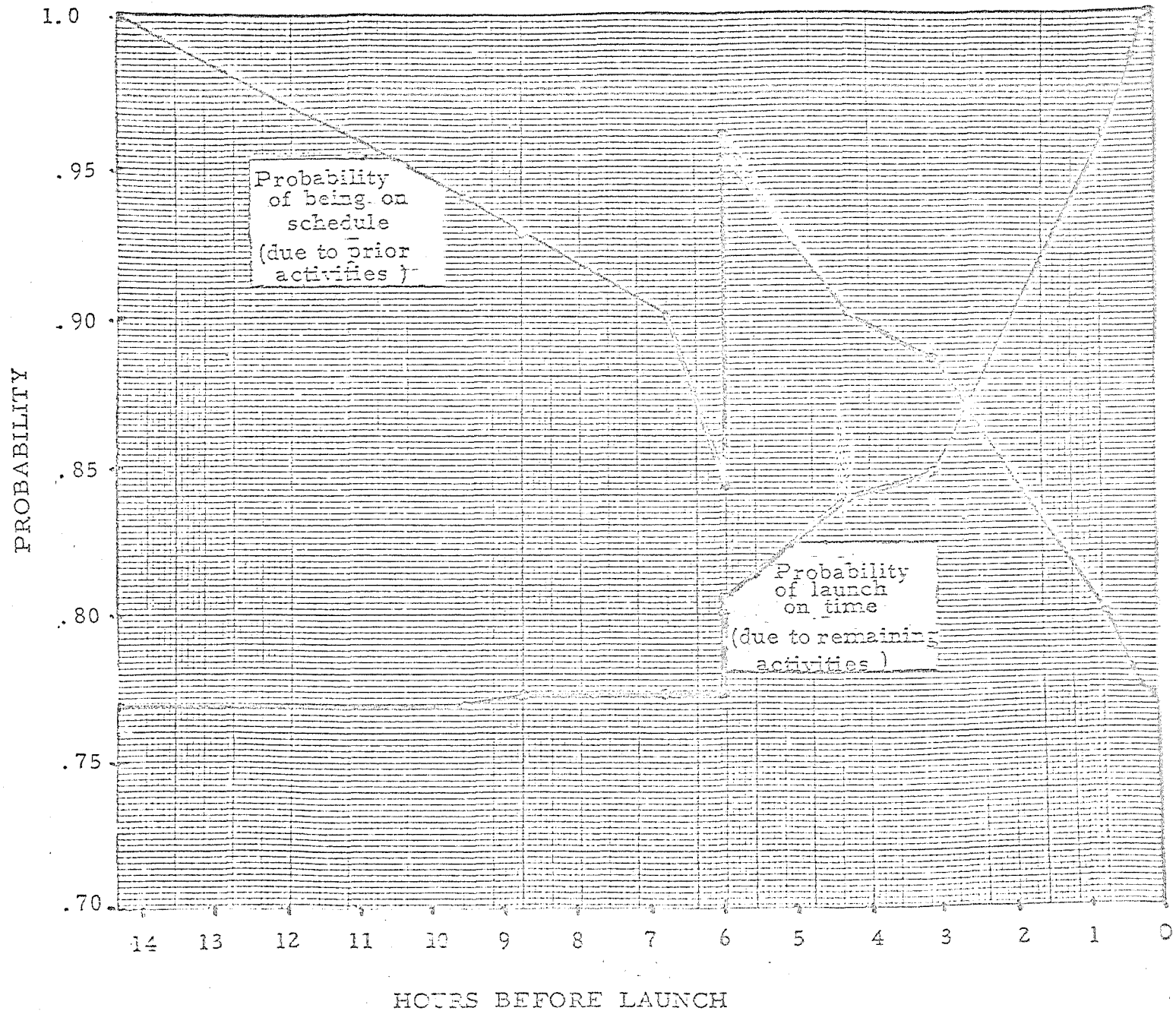


illustrates the comparisons that can be made reguarding each function. It is clearly shown that functions 'a' and 'b' are most sensitive to delays and the principal cause of probable delay to Timeframe 'n'. These two activities would therefore become prime candidates for rescheduling considerations or some other type of modification that would reduce their delay characteristics. This example suggests the possible application of this process in the evaluation of all operational or scheduling changes made to the countdown.

Probability of Being on Schedule - Another result of the countdown evaluation is presented in Figure II-5. The probability of being on schedule is indicated for various times in the countdown after T-14:15, assuming an on-time condition at that point. It is seen that the likelihood of staying on schedule steadily declines from the assumed starting point until reaching the scheduled hold at T-6 hours. The built-in-hold can be expected to absorb most of the previous delays that may have occurred. Consequently the probability of being on schedule is improved to a level of 0.961. Preparational activities required during the scheduled hold reduce this probability value to .955 at the end of the hold period. From that point, probability of being on schedule again decays until at T-0 a value of .769 is applicable.

A related consideration is also presented in Figure II-5. However, for this case, it is assumed that an on schedule condition exists at various points in the countdown and the probability of successfully performing the remaining supporting activities without causing a launch delay is evaluated. The plot of this curve also illustrates the influence of the six hour built-in-hold. Both cases shown in Figure II-5 are applicable to the launch-on-time window consideration.

FIGURE II-5 PROBABILITY OF SUCCESS VS. SCHEDULE



Parametric Analysis of Scheduled Holds - Many investigators, as well as the authors, have concluded that the judicious use of scheduled holds in the countdown is an effective means of improving launch control. The six hour built-in-hold scheduled at T-6 hours in the baseline AS205 countdown is a fine example of the effectiveness of planned holds. In this study an analysis was made to determine the advantages of providing additional scheduled holds in the countdown.

Figure II-6, II-7, and II-8, present some parametric information relating hold duration, hold location and launch probability for three different launch window sizes. The data is applicable to the baseline countdown and considers the addition of one hold. It is seen in all three cases, that holdpoint 6 (T-0:40) is an effective location for a scheduled hold. Some additional improvement is also seen when a hold is located at HP5 (T-0:14:30). However, little benefit is seen in placing a hold later in the count, independent of the impracticality of such a procedure. (It should be noted that a hold located at Holdpoint 1, (T-0), is identical to the consideration of the launch window being of that duration.) The data presented in these three figures also permits the analyst to evaluate the relative advantages of additional hold durations or compare one hold at a given point with a different hold duration at another point in the countdown.

While it is evident that the launch probability improves as a function of additional hold durations, it is recognized that practical considerations place limits on the length of a scheduled hold. Figure II- 9 presents some of the results of an investigation concerning hold duration. These results indicate that the benefits to be gained by extending the hold duration are influenced by the size of

FIGURE II-6 EFFECT OF ADDITIONAL SCHEDULED HOLD
LAUNCH WINDOW = ZERO HOURS

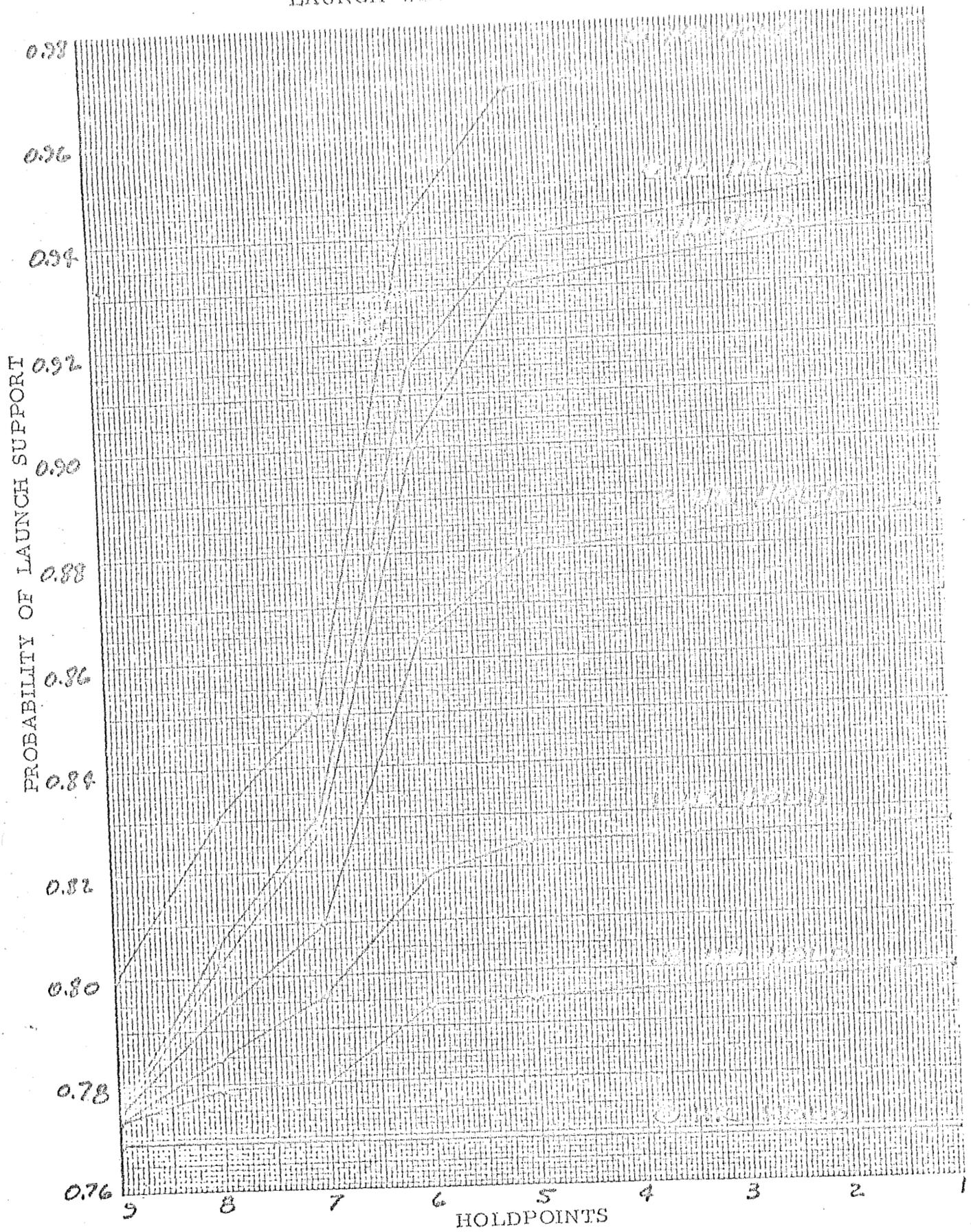


FIGURE II-7 EFFECT OF ADDITIONAL SCHEDULED HOLD
LAUNCH WINDOW = 30 MINUTES

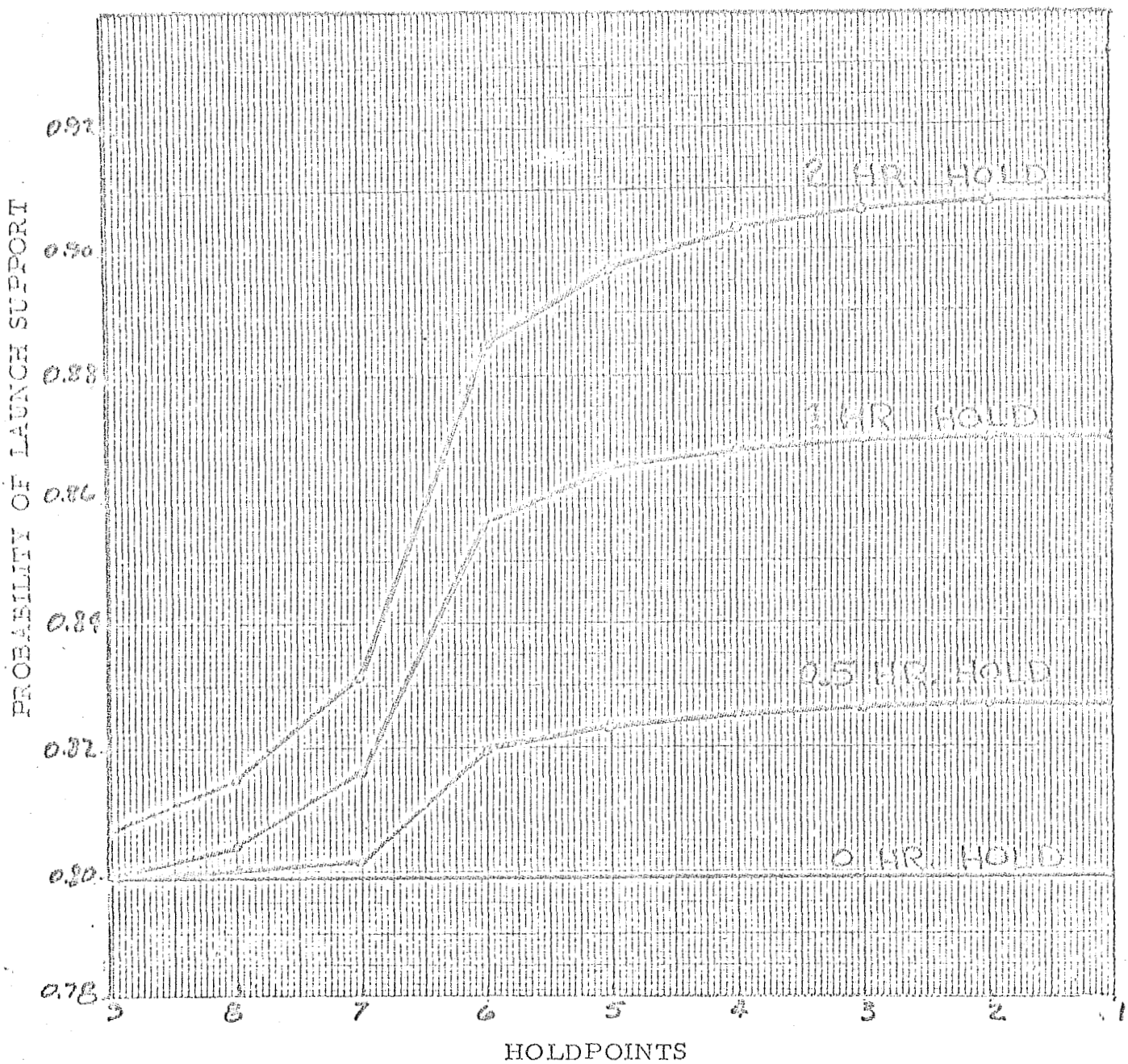


FIGURE II-8 EFFECT OF ADDITIONAL SCHEDULED HOLD
LAUNCH WINDOW = ONE HOUR

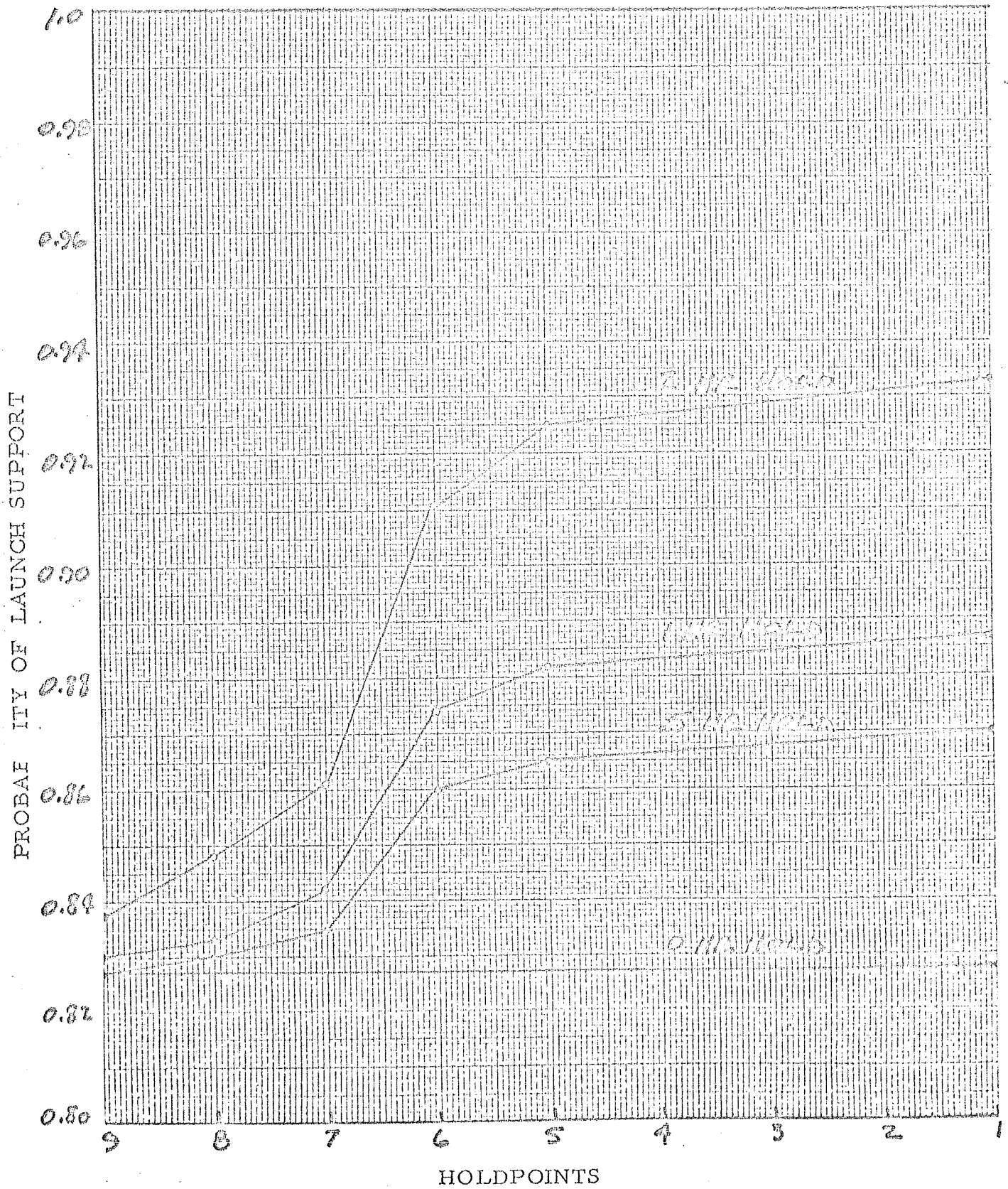
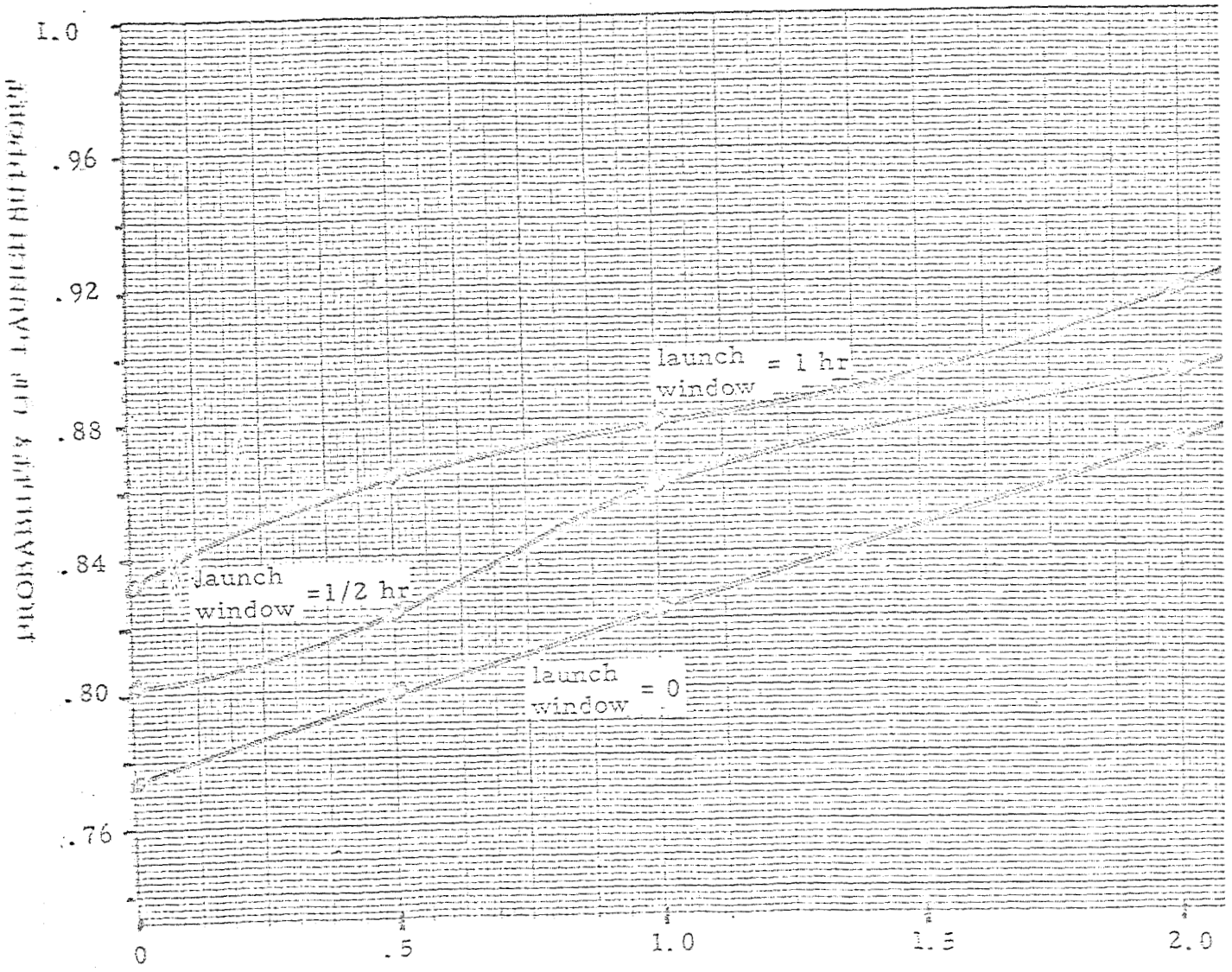


FIGURE II-9 EFFECT OF HOLD DURATION AT T-0:40:0



the launch window. For the zero window case, there appears to be an almost linear improvement in launch probability as a function of hold duration. For the 30 minute launch window, a one hour hold appears very effective. Similarly, a half hour hold for the one hour launch window case appears beneficial. These results are applicable only when considering an additional hold located at holdpoint 6 (T-0:40).

Support Equipment Characteristics - To provide the necessary input data for determining launch availability, failure rate and repair time estimates for each item of support equipment was compiled. These estimates are based on the composite data that is available in such forms as quantitative reliability analyses qualitative reliability studies and UCR analyses. This data and its basis is presented in detail in Section VIII.

Improvement Recommendations - Possible methods of improving launch control have been determined and are submitted for consideration. The recommendations concern modifications to both support equipment and certain operational procedures. Suggestions for additional analytical efforts have been developed. The specifics applicable to all of the recommendations are presented in Section X. In summary, the recommendations consider:

- Launch Operations
  - Additional one hour scheduled hold at T-0:40.
  - Model use in rescheduling considerations.
- Support Equipment
  - Repetitive component failures indicated.

- Repair improvement not effective in general.
- Use baseline listing to set priorities.

o Procedural

- Extension and Improvement of UCR System.
- Upgrade Criticality Analysis Standard.
- Document alternatives for responding to contingencies.

o Analytical Activities

- Extend availability analysis to include Flight Vehicle.
- Use model and computer program in other applications.
- Provide automatic coding
- Provide automatic coding.

III LAUNCH AVAILABILITY EVALUATION METHODOLOGY

The key to the methodology used in the performance of this study was dependent on the development of a model that would realistically reflect the rules and the nominal operations of a Saturn IB Countdown Procedure. It was concluded that study objectives could most effectively be met by designing the model in such a way as to cause it to relate launch-in-window probabilities to equipment performance characteristics. With such a plan it was possible to see that the expected results of the study would insure satisfaction of the objectives, especially in the following areas:

1. Results of the evaluation would be of a quantitative nature. Consequently an answer could be given to the question - What is the probability of launch-in-window by Saturn IB due to GSE and facility considerations?

2. The fundamental elements of the analyses would be support equipment items which is an area where it is practical to consider changes or modifications as a means of improving launch-in-window probability.

3. Sensitivity analyses of the relative contribution by each support equipment to probability of launch could be conducted. Thus, an equipment availability baseline listing could be generated.

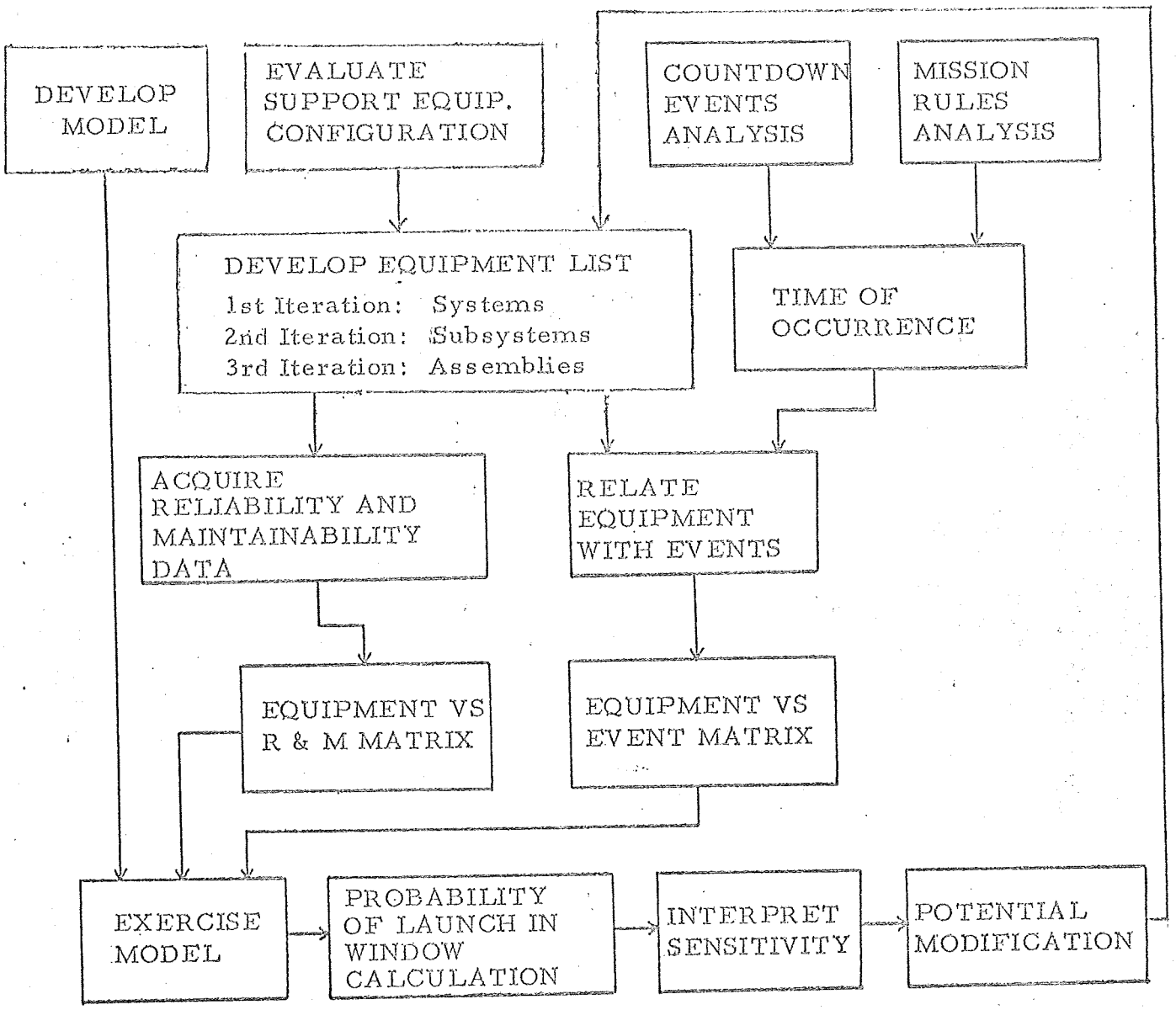
4. The scope of the study could be controlled. This control could be achieved by performing the analysis in an iterative manner, with successive iterations considering ever finer details of the system and the launch operations as the study progressed.

The basic approach followed in the performance of each iteration consists of three parallel areas of activity, followed by a period where results are obtained, conclusions are drawn and potential modifications are considered. Figure III-1 is a representation of a flow diagram describing the approach.

Two of the three parallel areas are concerned with information collection and analysis, resulting in information that is used as input to excercise the mathematical model developed as a result of the third activity. The first area of effort requires the definition of the launch support configuration, development of an equipment list and the acquisition of reliability and maintainability data characteristics about this equipment. The second area consists of evaluating countdown procedures to determine what functions must be performed, when they should occur, slack time features and functional interrelationships. This area of analysis must also insure the accommodation of the requirements set forth in the mission rules. The third area of activity, model development, is concerned with realistically defining the interrelations between support equipment and the functional characteristics of the countdown procedure in a manner that yields a quantitative assessment of launch probability. Excercising the model can then provide a measurement of launch availability and can indicate the potential contributors to launch delays, from which subsequent improvement modifications may be considered.

Performance of these previously mentioned activities represents a single iteration of analysis. Subsequent iterations, utilizing more detailed equipment definitions, i.e., subsystems instead of systems or assemblies instead of

FIGURE III-1 STUDY APPROACH



subassemblies, would extend the scope of the study and provide a more realistic representation of the real condition.

In a sense, the iteration concept is merely an extension of the process of evaluating launch availability by statistically evaluating the number of launches and the number of delay occurrences. Given that the data sample is of significant size, results from such an analysis should yield accurate predictions of availability. However, this type of analysis provides no help in suggesting improvement response. The only conclusion that can be drawn when such investigations indicate that an intolerable probability condition exists is "improve the launch complex." On the other hand, the ultimate extension of the iteration concept, i.e., relating launch probability to the lowest configuration level of support equipment which is components (transistors, solenoids, valves, etc.), requires an extensive analysis, far beyond the scope intended for this effort. The approach in this study is a compromise of these two extremes; broad enough to yield a total evaluation within the level of effort, yet detailed enough to identify areas where improvement considerations are practical.

The approach followed was also deemed to be in compliance with guidelines set forth by the Kennedy Space Center. Some of the initial important guidelines that defined the framework of the analysis included the following items:

- The baseline mission would consider AAP missions.
- Emphasis would be placed on a S-IB/CSM configuration using Launch Complex 34.

- The baseline GSE system would be that used for Apollo/Saturn 205.
- Only support equipment, i. e., not flight equipment, would be considered in the launch probability determination.
- A "systems" or top-down approach would be used.
- The launch preparation period would be treated by using a modular time concept starting at launch and working backwards in time.
- Emphasis would be placed on the terminal countdown portion of the preparation activity.
- Maximum use of previous studies and other related analyses would be made.

The study methodology described in this section was closely followed in the performance of the contract and proved to be a very workable plan.

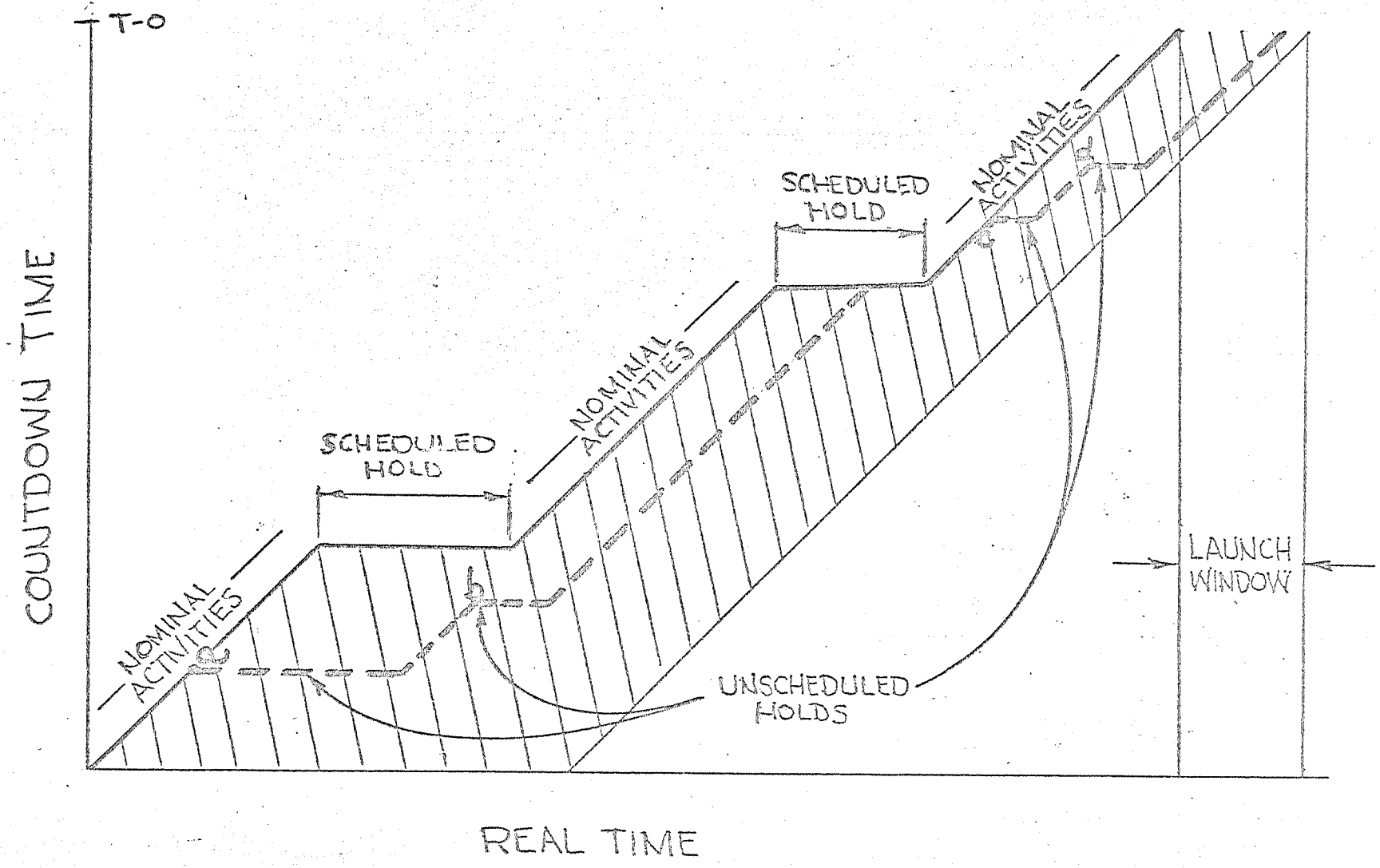
IV THE LAUNCH OPERATION MATHEMATICAL MODEL

In developing a mathematical model to simulate the launch support operations, consideration must first be given to the model's purpose, the overall scope of the problem and the elements of reality that the model must represent. Clearly, the model developed for this study must be the mechanism that leads to the accomplishment of the study objectives. The intent of the study is to evaluate launch support probability, and the means of improving it, by determining the effect due to launch support equipments. The model, then, must recognize the primacy of equipment by embedding all its statistical input in equipments only. This means that the model cannot consider human reliability except insofar as it reflects upon equipment reliability; nor can it utilize historical statistical data concerning the successful completion of launch activities; nor statistics on launch delay. The model must serve as an effective means for deriving quantitative results commensurate with available data and readily provide availability assessments concerning possible equipment modifications.

4.1 SCOPE OF THE MODEL

An examination of the fundamental characteristics of the countdown operations is conducive to establishing the basic groundrules for modeling. A conventient pictorial representation of the launch operation can be made by plotting launch countdown time vs. calendar time, (see Figure IV-1). In this representation, with a launch window of length w and scheduled holds of arbitrary lengths, h_1 and h_2, a perfect launch operation is achieved if the operation proceeds along the upper boundary of the shaded area; i. e., this path is taken when no

FIGURE IV-1 LAUNCH OPERATIONS TIME MODEL



unscheduled holds occur. However, any path that lies completly within the shaded area will also result in a successful condition, i.e., launch-in-window. For example, the dotted path in the figure is successful even though four unscheduled holds were required at points a, b, c, and d. The lower boundary of the shaded area depicts the case of an unscheduled hold at the start of the countdown, of such duration that no further unscheduled holds can be allowed if the launch is to be made within the launch window. It can be seen from Figure IV-1, that the probability of a successful launch is a function of the number and duration of unscheduled holds, the size of the launch window, the length and placement of the scheduled holds and the duration of the launch countdown.

A more detailed examination of the launch operations defines the elements that must be represented by the model. The factors of importance in the development of the availability model are defined by launch facility, operational and hardware characteristics. Operational factors are dependent on the procedures and groundrules governing the accomplishment of the countdown and include the support activities, order of events, duration of operations, mandatory functions and the number and length of scheduled holds. The hardware factors are those that define the functional and statistical information about the equipment. These factors include the physical and functional interrelationships existing among the equipments, their reliability and maintainability characteristics and their operating times.

Analysis of the launch support operations indicates that the countdown is an organized sequence of supporting activities or functions that, in most instances, are performed concurrently with other support functions. Further analysis of the countdown activities and its rules shows that during the countdown period between T-14 hours and T-0, unscheduled holds, if necessary, may be called at discrete convenient holdpoints. Equipment failures occurring during the periods between these holdpoints are to be repaired, if possible, in parallel with normal functions, but when the count reaches the holdpoint, a hold is called if certain functions are incomplete. Thirteen holdpoints are defined for the AS 205 countdown period between T-14 and T-0. Each holdpoint governs a set of functions that operate during the preceeding time periods. Consequently, functions may be considered as subsets of holdpoints and holdpoints as subsets of the countdown.

Further examination of the launch support operations indicate each countdown function is performed by a set of support equipments; a relation then between operational and hardware characteristics is evident. This relationship suggests the feasibility of modeling the support operations and forms a basis for associating launch support probability with support equipment.

Given that the probability of delay due to equipment failure and its probable delay time can be determined, a delay to a function, comprising a set of equipments, can also be determined. In turn, the probability of delay at each holdpoint can be evaluated. It then remains, only to statistically combine these delay times and probabilities, at all holdpoints to establish the probability condition at launch time.

4.2 ASSUMPTIONS

The mathematical model developed in this study is dependent on a set of basic assumptions. Each of the assumptions has been made to eliminate elements believed to be extraneous or to permit the mathematics to be manageable. Each of the simplifying assumptions are considered either to be good representations of reality or at least realistic relative to the available data and the other elements of the model. These assumptions are:

- When one equipment fails, all other equipment with the same function are in nonoperating status during its repair.
- Each equipment fails independently of other equipment.
- Equipment time-to-failure has an exponential distribution.
- One equipment can be shared by as many functions as require it.
- Repair capability is not exceeded.
- Equipment repair time is a fixed time.
- Each function has a fixed total operating time.
- An equipment can fail only when operating.

4.3 MODEL DESCRIPTION

The model does not require a standardized definition of an equipment; it can be complex or simple as long as it is reasonable to assign to it a single failure rate and repair time. Repair time is meant to include the total time between failure and return to full operating status, hence, it includes access, diagnosis, restart, etc.

The model combines equipments to form functions. These functions, for the model, are nothing but the sum of their constituent equipments, i. e., the function fails when any of its equipments fail and it is out of operation for a period of time equal to the repair time of the failed equipment. The function is the model representation of any well defined group of launch operation activities. Hence, by combining functions in their proper order and interrelations, they model launch operation activities.

The model allows the inclusion of scheduled holds and slack time, i. e., time available to repair equipment within a function, without delaying the start of other functions. The output of the model is the probability of launch-in-window for any desired window length.

This model is employed to evaluate the support equipment's influence on launch by comparing the launch-in-window probabilities of two computations, the first with the nominal failure rate of an equipment, the second with the improved failure rate; the difference between the two probabilities is the actual effect that this equipment improvement has upon launch probability. Such computations can be made for all launch operation equipment improvements so that improvements with the greatest effect upon launch probability can be determined. The model can be used in a similar manner to determine the effect of changes in repair time (maintainability) or procedural changes.

A more detailed description of the availability mathematical model is presented in Volume III of this report. Developed primarily for the potential users of the model and its computer program, Volume III details the mathematical basis, the interrelationship of elements and the features and uses for application of the model.

4.4 FEATURES OF THE MODEL

Elsewhere in this report, many of the specific design and operational features of the launch availability model and the computer program associated with it are illustrated. However, it is important to emphasize those features of the model which are of particular importance concerning economics, practicality and applicability.

- The model is a completely analytic solution to the launch availability problem. It does not, therefore, impose the economic burden upon the user that a Monte Carlo Simulation does, with its attendent long computer operating time. Consequently, with this model, it is economically feasible to make many computer runs to determine the effect upon launch availability of many different equipment or launch procedure changes.

- The model incorporates the probability of multiple failures for all support equipment in its computation.

- All parameters required by the model are actually available, since one of the important guides in its development was that the design of the model be applicable in the real world — i. e., the model is not just a theoretical model designed to assist one in understanding the launch operation, but was meant to give actual, representative, numerical results.

- The model allows for full expression of the complex interrelations among all launch activities.

- The model can determine the probability of launch within any window or set of windows.

- The model computations have been fully computerized.

- The computer program is written entirely in the FORTRAN IV language, hence, it can be run on any major computer system.

- The computer program has been designed to simplify sensitivity studies — for example, a single value on one data card will signal the computation of the sensitivity of every single equipment in the launch operation.

- All activity interrelations can be input into the program and these interrelations can be modified by the user with no reprogramming effort; consequently, these changes can be made by nonprogrammer personnel.

- The program allows not only the determination of equipment sensitivity but also facilitates the determination of the effect of: activity, rescheduling, changing the placement, length and number of scheduled holds, launch windows, and changes in slack time; moreover, all these sensitivity studies can be obtained with a single computer run.

V THE COMPUTER PROGRAM

A computer program has been written to facilitate the exercising of the launch operation model. It is coded entirely as a FORTRAN IV program, hence, it can be run on any computer for which FORTRAN IV is available. A complete documentation of the computer program is presented in Volume III of this report. Necessary information concerning input format, coding instructions, programming procedures and options is included together with program flow charts.

The computer program consists of five major parts. These parts are indicated in the program flow chart presented as Figure V-1. In part I of the program, the basic data set is input. In this data are all individual equipment failure rates and repair time, each countdown function and the complete equipment list associated with it, and a set of all slack times associated with all of the input functions. Part II computes the distribution of holdtime for each holdpoint, sequencially combining the distributions for individual holdpoints to obtain the distribution of the hold due to the combined effect for all timeframes. As scheduled holds occur in the sequence, their effect is reflected in the combined distribution of holdtime. Finally, the distribution of delay at launch is computed. Part II consists mainly of a set of calls to a group of FORTRAN subroutines developed especially for this program. Part III computes the probability of launch-in-window for each of the windows specified by the nominal case data. This computation utilizes equipment, functions, and slack data as specified by the nominal case. Part IV permits the user to modify the equipment characteristics

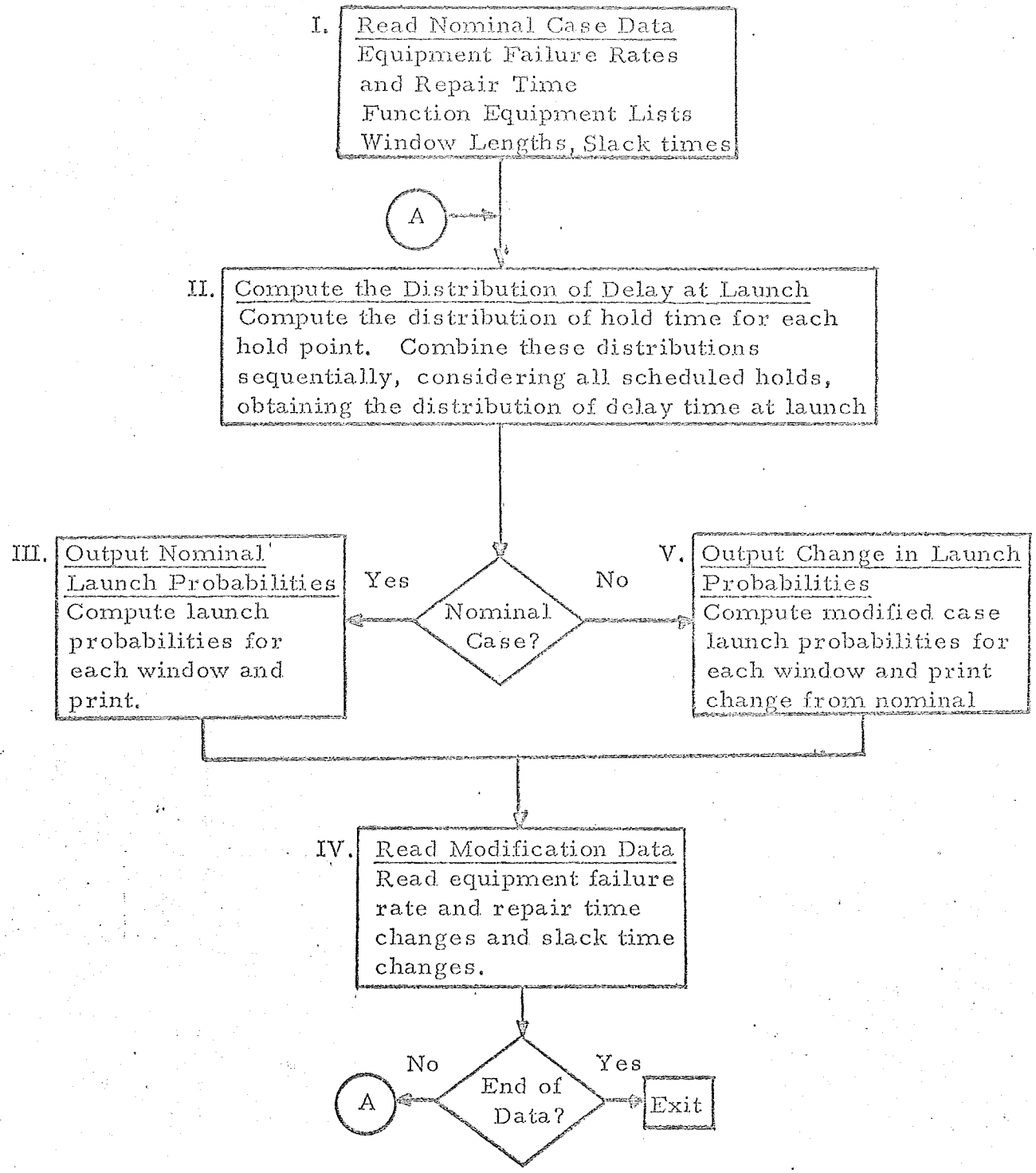


FIGURE V-1 COMPUTER PROGRAM FLOW CHART

and slack times of the nominal data set. With the modified data set, the program then returns to Part II and recomputes the distribution of delay time at launch. Upon completion of Part II with modification data, a launch-in-window probability is computed in Part V for each given window and the differences between these probabilities and those for the nominal case are output. The change in probability gives a direct measure of the effectiveness of the equipment and/or slack time changes specified in the modification data.

The program structure was designed specifically to facilitate the determination of changes in launch-in-window probabilities. This is accomplished by classifying the parametric input into a nominal data set and a modification data set. The program first computes launch-in-window probabilities for the nominal data set, then for each modification, performs the computation noting the probability changes between the two. The modification data set requires that only the changes from the nominal characteristics be given.

The data modification feature of the program permits the user to conveniently study the effects of changes in slack time, equipment reliability, or equipment repair time either as single, independent changes or as many simultaneous changes. Equipment characteristics for up to 65 equipments may be modified simultaneously if desired.

The basic input capacity of the program accommodates up to 3000 pairs of equipment parameters, i. e., failure rate and repair time values, 500 functions and 500 slack times. A maximum of 7500 entries may be used for relating equipments and functions. The program will compute, for as many as eight different windows, the probability of launch-in-window.

The nominal and modification data sets define the parametric characteristics of the model to the computer; to define the function interrelations, a special "language" was developed. This language enables one who is not familiar with FORTRAN to transcribe all interrelations permitted by the model into a form directly interpretable by the computer. Details of this language and its use are presented in the User's Manual, Volume III, together with the other details of the computer program.

This computer program was checked out and run on the IBM 360/50 computer on which it required about 170K bytes of storage and, for the final model configuration, about 4 minutes of operating time for a complete computation.

VI DATA BASE

Of critical importance in the evaluation of launch availability is the acquisition of representative information pertaining to the launch operations support equipment. Data concerning support equipment and countdown functional characteristics are required for use as input to the availability model. In addition, descriptive narrative of the nominal operations, possible alternative considerations or emergency responses form a portion of the information that contribute to insight and appreciation of launch operation problems, a necessary element in formulating an applicable model. The results of this report have been influenced to a large extent by the documentation that was available and related to this problem. One of the primary tasks and the one requiring the most expenditure of effort consisted of documentation review and analysis for the purpose of acquiring launch procedure familiarization and acquiring support equipment performance data. Reviews of related availability studies and other launch systems, especially Saturn V, were made early in the study and were undoubtably influential in the model derivation. Over 400 documents, including related study reports, Technical and Maintenance Manuals, functional descriptions, drawings and test and checkout procedures were reviewed and analyzed. Of these, approximately one fourth provided quantitative data that could be used as input in the evaluation.

6.1 PARAMETERS OF INTEREST

With the formulation of the concept of the launch availability model, it is possible to define the types of data and the parameters that are necessary

as inputs to the model. Of basic interest is the support equipment identification. Initially, it is defined by systems and subsequently by subsystems. Then for each of the equipments identified, performance characteristics are required. Such characteristics must be in terms of equipment failure rates and repair time estimates. In addition, the physical location of the equipment must be assessed in order to evaluate the possible additional repair time required during a "closed pad" period. The principal parameters of interest concerning the launch operations involves the identification of all functions required to be performed during the countdown. In turn, each of these functions must be defined by their operating times (duration) and their associated holdpoints (that point in the countdown where the incompletion of a function would result in a delay). From this evaluation it is also possible to determine the extent of functional slack time available.

Related documentation information can also be useful in evaluating two other significant parameters of interest that are requisites for the model. These factors are the interrelationship between countdown functions and the identification of the equipment required to service each function. However, related information found in the documentation, usually, only indirectly identifies these parameters and a thorough engineering analysis is required to supplement the information.

6.2 SOURCE DOCUMENTS

The principal governing document used in this study is report K-1B-02.10/5, "Apollo/Saturn IB Launch Mission Rules." In addition to it referencing the

launch vehicle and spacecraft countdown procedures that are applicable, the mission rules establish the framework to which launch procedures must conform. The four sections of the mission rules are concerned with space vehicle operations, launch vehicle operations, spacecraft operations and technical support operations, and contain information about the time period during which various launch system operations are either mandatory or highly desirable. In some cases, launch support system requirements are indicated directly. In other cases, the requirement for various specified vehicle or spacecraft measurement values imply the need for certain launch support systems. Specification by the mission rules of recommended holdpoints during the terminal countdown where unscheduled holds are best accommodated and the criteria used for calling such holds is of fundamental importance to the development of the availability model.

The principal source of information pertaining to operational requirements is supplied by the launch vehicle and spacecraft countdown procedures. These operational activities are described in Test and Checkout Procedure (TCP) I-20048, "Launch Vehicle Operations for Launch Countdown" and Report K-0033/0007A, "Spacecraft CDDT and Countdown." These documents show the events and the activities involved in preparing the flight vehicle for launch, the times at which operations are initiated and completed, the sequence of operations and descriptions of the activites. In many cases, other test and checkout procedures are referenced and these in turn provide additional information and details about a particular function to be performed. More than 130 such

TCP's are referenced during the last 14 hours of the countdown. Each of them must be reviewed and analyzed to further delineate the operating procedures.

In general, four types of source documents are of use for investigating data concerning repair time and failure rate parameters of each support equipment. Both qualitative and quantitative reliability reports can be used to assist in deriving representative failure rates. Of particular use are failure mode and effect analysis reports, single failure point identification reports, criticality analyses, and reliability predictions, estimates or assessments made as a result of various contractor investigations. Data recorded within the UCR system can also contribute to the derivation of equipment failure rates. Repair time characteristics are obtained primarily from maintainability reports; to some extent, unsatisfactory condition reports also provide this type of data. Some 50 reports containing maintainability information and/or data were used for determining average repair times for the support equipment. Approximately 30 documents containing qualitative reliability information and about 70 documents containing quantitative reliability data are applicable to the derivation of system failure rates.

Due to the many reference documents containing applicable information concerning launch operations and equipment performance characteristics, it became necessary during the course of the study to develop a document catalog system. In it, all of the available publications were indexed according to support

system, and then related to the type of information contained in the document. The types of information have been categorized according to reliability data, maintenance data, operations and procedural data or related and miscellaneous information. Table VI-1 presents the information contained in this catalog applicable to the launch facilities and GSE systems. This reference system greatly increased the efficiency of this investigation and is hoped to be of benefit to future investigators of similar support operations.

6.3 CONFIGURATION ANALYSIS

A fundamental requirement of the study is the identification of all the support equipments necessary to accomplish the Saturn IB launch. To properly identify this equipment, a launch configuration analysis was made with four major areas: Spacecraft Support and Industrial Area, Central Instrumentation Facility, Range, and Launch Complex initially being identified. Each area was further investigated to provide the breakdown of the equipment, through successive configuration levels, from the top down. Such a procedure insures that all hardware items necessary to support launch mission are accounted, and it permits the generation of equipment lists at whatever configuration level is desired.

By far, the greatest number of systems are identified with the Launch Complex Area. In fact, with the exception of the Range Systems, an accounting of all systems can be accomplished considering only the Launch Complex Area. Those systems in the other two areas, CIF and Industrial Area, which are of

TABLE VI-1 DOCUMENT CATALOG RELATING SYSTEMS vs. INFORMATION (8 sheets)

System	Miscellaneous	Operations Procedures	Maintenance	Repair	FEA's Qual. Reliability	Criticality Quant. Reliability
1. RP-1 Fuel	Chrysler BB 3.14-7-3 Chrysler SDES-64-415 G.E. 68-874-003A NASA 160-54-0005 NASA 170-44-0002 NASA 145-44-0004	NASA TM-410-D	NASA TM-379-D NASA TM-411-D	Chrysler SDES-66-447 II Chrysler SDES-66-477 II	NASA GP-551 IV G.E. 68-875-013	NASA GP-556
2. LOX	Chrysler BB 3.14-7-3 Chrysler HEC-D042 G.E. 68-874-003A NASA 160-54-0005 NASA 170-44-0002 NASA 145-44-0004	Chrysler HEC-D042 NASA TM-390-D NASA TM-406-D Boeing D2-119053-3, 2	NASA TM-377-D NASA TM-390-D	Chrysler SDES-66-477 II	NASA GP-551 II NASA SP-192-D III G.E. 68-875-013	NASA GP-556
3. LH2	Chrysler BB 3.14-7-3 G.E. 68-874-003A NASA 160-54-0005 NASA 170-44-0002 NASA 145-44-0004 Bendix 5.6.9	NASA TM-408-D Boeing D2-119053-3, 2	NASA TM-378-D NASA TM-409-D	Chrysler SDES-66-477 II	NASA GP-551 III NASA SP-192-D III G.E. 68-875-013 NASA TR-4-49-3-D	NASA GP-556 Bendix 5.6.9 NASA TR-4-49-3-D Boeing B-36
4. GN2	Chrysler BB 3.14-7-3 G.E. 68-874-003A G.E. Airframe 009 NASA 160-54-0005 NASA 170-44-0002 Bendix 5.6.7	NASA TM-416-D Boeing D2-119053-3, 2	NASA TM-380-D NASA TM-417-D	Chrysler SDES-66-447 II Chrysler SDES-66-477 II	NASA GP-551 V, VI G.E. RAU-14 NASA SP-192-D I G.E. 68-875-013 NASA TR-4-49-3-D PAA Systems Reliability Data	NASA GP-556 G.E. RAU-14 Bendix 5.4.4 Bendix 5.6.9 NASA TR-4-49-3-D Boeing B-36
5. GH2	Chrysler BB 3.14-7-3 G.E. 68-874-003A NASA 160-54-0005 NASA 170-44-0002 NASA 145-44-0004	NASA TM-416-D Boeing D2-119053-2, 3	NASA TM-380-D NASA TM-417-D	Chrysler SDES-66-447 II Chrysler SDES-66-477 II	N.A.R. 68-46 NASA GP-551 V G.E. 68-875-013 NASA TR-4-49-3-D PAA System Status Program	NASA TR-4-49-3-D Bendix 5.4.4 Boeing B-36
6. HE	Chrysler BB 3.14-7-3 G.E. 68-874-003A G.E. Airframe 009 NASA 160-54-0005 NASA 170-44-0002 Bendix 5.6.9 NASA 145-44-0004	NASA TM-416-D Boeing D2-119053-2, 3	NASA TM-380-D NASA TM-417-D	Chrysler SDES-66-447 II Chrysler SDES-66-477 II	NASA GP-551 V, VI NASA SP-192-D I G.E. 68-875-013	NASA GP-556 Bendix 5.6.9 Bendix 5.6.8 Bendix 5.4.4 Boeing B-36
7. Env. Cont. System	Chrysler BB 3.14-7-3 G.E. 68-874-003A G.E. Airframe 009 NASA 170-44-0002 NASA 145-44-0004	NASA TM-375-D Boeing D2-119053-213	NASA TM-413-D	Chrysler SDES-66-447 II Chrysler SDES-66-477 II	NASA GP-551 VII NASA SP-192-D III G.E. 68-875-013 NASA TR-4-49-3-D	NASA GP-556 NASA TR-4-49-3-D

DOCUMENT CATALOG RELATING SYSTEMS vs. INFORMATION

System	Miscellaneous	Operations Procedures	Maintenance	Repair	FEA's Qual. Reliability	Criticality Quant. Reliability
8. Fuel Mast	Chrysler BB 3.14-7-3 NASA 145-44-0004	NASA TM-390-D	KSC K-AS-02 NASA TM-390-D NASA TM-418-D		NASA GP-551 IV	Boeing D2-119053-1 NASA GP-556
9. LOX Mast	Chrysler BB 3.14-7-3 NASA TM-418-D NASA 145-44-0004	NASA TM-390-D	KSC K-AS-02 NASA TM-390-D NASA TM-418-D			Boeing D2-119053-1 NASA GP-556
10. Short Cable Mast #2	Chrysler BB 3.14-7-3 NASA TM-418-D NASA 145-44-0004 NASA 170-44-0002	NASA TM-390-D	KSC K-AS-02 NASA TM-390-D NASA TM-418-D		NASA TR-4-49-3-D NASA GP-551 I	NASA TR-4-49-3-D Boeing D2-119053-1 NASA GP-556
11. Short Cable Mast #4	Chrysler BB 3.14-7-3 NASA TM-418-D NASA 145-44-0004 NASA 170-44-0002	NASA TM-390-D	KSC K-AS-02 NASA TM-390-D NASA TM-418-D		NASA GP-551 I NASA TR-4-49-3-D	Boeing D2-119053-1 NASA TR-4-49-3-D NASA GP-556
12. Holddown Arms	Chrysler BB 3.14-7-3 NASA 170-44-0002 NASA 145-44-0004	NASA TM-398-D	KSC K-AS-02 NASA TM-398-D		NASA GP-551 I G.E. 68-875-013 NASA TR-4-49-3-D	NASA TR-4-49-3-D NASA GP-556
13. Apollo A.A.	NASA TM-418-D NASA TM-533 NASA 64-126-43 G.E. Airframe 009 TRW AAP Prelaunch Operations Analysis NASA 145-44-0004	NASA TM-394-D NASA TM-533 NASA TM-421-D	NASA TM-394-D NASA TM-421-D NASA TM-533		NASA GP-551 I	NASA GP-556
14. Swing Arm #1	Chrysler BB 3.14-7-3 NASA TM-418-D NASA 170-44-0002 TRW AAP Prelaunch Operations Analysis NASA 145-44-0004	NASA TM-390-D NASA TM-394-D NASA TM-421-D	NASA TM-390-D NASA TM-394-D NASA TM-421-D		NASA GP-551 I NASA TR-4-49-3-D	NASA GP-556 NASA TR-4-49-3-D
15. Swing Arm #2	Chrysler BB 3.14-7-3 NASA TM-418-D NASA 170-44-0002 TRW AAP Prelaunch Operations Analysis NASA 145-44-0004	NASA TM-390-D NASA TM-394-D NASA TM-421-D	NASA TM-390-D NASA TM-394-D NASA TM-421-D		NASA GP-551 I NASA TR-4-49-3-D	NASA GP-556 NASA TR-4-49-3-D
16. Swing Arm #3	Chrysler BB 3.14-7-3 NASA TM-418-D NASA 170-44-0002 TRW AAP Prelaunch Operations Analysis NASA 145-44-0004	NASA TM-390-D NASA TM-394-D NASA TM-421-D	NASA TM-390-D NASA TM-394-D NASA TM-421-D		NASA GP-551 I NASA TR-4-49-3-D	NASA TR-4-49-3-D

DOCUMENT CATALOG RELATING SYSTEMS vs. INFORMATION

System	Miscellaneous	Operations Procedures	Maintenance	Repair	FEA's Qual. Reliability	Criticality Quant. Reliability
17. Swing Arm #4	NASA TM-418-D Chrysler BB 3.14-7-3 G.E. Airframe 009 NASA 170-44-0002 TRW AAP Prelaunch Operations Analysis NASA 145-44-0004	NASA TM-390-D NASA TM-394-D NASA TM-421-D	NASA TM-390-D NASA TM-394-D NASA TM-421-D		NASA GP-551 I	NASA GP-556
18. Hydraulic System	Chrysler BB 3.14-7-3			Chrysler SDES-66-447 II	NASA GP-551 I PAA Systems Reliability Data	PAA ETV 69-64 Boeing B-36
21. Service Structure	G.E. 68-874-003A PAA TD-3040-57, -R-61, -R-66 & -R-68 G.E. Airframe 009 NASA 170-44-0002 NASA 145-44-0004				PAA Systems Reliability Data	PAA ETV 69-59, -33, -46 PAA TD-30-40-57, -R-61, -R-66
22. Umbilical Tower	MSFC-205 NASA 145-44-0004	NASA TM-532-D	NASA TM-532-D		PAA Systems Reliability Data	
23. Water Sys.	Chrysler BB 3.14-7-3 NASA TM-418-D G.E. 68-874-003A KSC Booster Pump NASA TM-418-D NASA 170-44-0002 NASA 145-44-0004	NASA TM-390-D	NASA TM-27-D NASA TM-390-D		N.A.R. AP 68-46 NASA GP-551 VI G.E. 68-876-013 G.E. 68-875-013 NASA TR-4-49-3-D PAA Systems Reliability Data	PAA ETV 69-41, -48, -6350 NASA TR-4-49-3-D PAA TD-3040-R-59, -R-64, -R-62
24. Emerg. Egress Sys.	NASA TM-543	NASA TM-543	NASA TM-543			NASA GP-556
25. S/C Support Piping & APS	NASA TM-415-D NASA 145-44-0004		NASA TM-381-D NASA TM-415-D		NASA GP-551 IV Boeing D2-119053-5	Boeing B-36
26. Q-Ball Cover & Removal System	G.E. 68-874-003A MSFC-205	NASA TM-390-D	NASA TM-390-D		NASA GP-551 VI G.E. 68-875-013	NASA GP-556
27. Propellant Tanking Computer System	G.E. 68-874-003 NASA 170-44-0002 NASA 145-44-0004	NASA TM-402-D Boeing D2-119053-2, -3			NASA SP-192-D III G.E. 68-876-013, -012 G.E. 68-875-013	
28. Digital Events Evaluator DEE-3	G.E. 68-874-003A NASA 170-44-0002 NASA 145-44-0004	Boeing D2-119053-2, -3			G.E. 68-876-013, -012 G.E. 68-875-013	Boeing B-36

DOCUMENT CATALOG RELATING SYSTEMS vs. INFORMATION

System	Miscellaneous	Operations Procedures	Maintenance	Repair	FEA's Qual. Reliability	Criticality Quant. Reliability
29. Facility Meas. & Hazards Monitoring Remote Cont. Sys.	G. E. 68-874-003A G. E. Airframe 009 NASA 170-44-0002 NASA 145-44-0004	NASA GP-540			G. E. 68-876-013, -012 G. E. 68-875-013 PAA Systems Reliability Data	
30. Haz. Gas. Detection	G. E. 68-874-003A G. E. Airframe 009 Chrysler BB 4. 1. 1-5-201 Bendix 5. 6. 9 NASA 145-44-0004	MSFC-044 NASA TM-457 NASA TM-470	MSFC-044 NASA TM-457 NASA TM-470		G. E. 68-876-013, -012 G. E. 68-875-013	Bendix 5. 6. 9 Boeing B-36
31. Fire Det. Monitoring	G. E. 68-874-003A NASA 145-44-0004	Boeing DZ-119053-2, -3			G. E. 68-876-013	
32. C1F Central Computer Complex	NASA GP-663 MSFC-205 FEC Communications & Timing NASA 170-44-0002 NASA 145-44-0004	NASA TM-552	NASA TM-552			G. E. RAU 38
33. C1F Telemetry Gd. Sta.	NASA GP-663 MSFC-205 FEC Communications & Timing NASA 170-44-0002	NASA TM-552	NASA TM-552			G. E. RAU 38
34. Launch Info. Exchg. Facility	NASA K-IB-021/2					
35. Meteor. Data Acquisition	NASA K-IB-021/2 PAA ETR-TR-65-9	PAA ETR-TR-65-9				
36. Data Display	NASA GP-663 MSFC-205 G. E. Airframe 009 NASA GP-663 NASA 170-44-0002	Philco PHO-FAM501		Chrysler SDES-66-447 III		G. E. RAU 38
37. Telemetry	NASA GP-663 G. E. 68-874-003A PAA TD-7026-12 G. E. Airframe 009 PAA ETR-TR-65-9 NASA 170-44-0002 NASA 145-44-0004 PAA Communications & Timing	PAA ETR-TR-65-9		Chrysler SDES-66-447 III	Bendix Reliability Notebook	PAA TD-7016-12

DOCUMENT CATALOG RELATING SYSTEMS vs. INFORMATION

System	Miscellaneous	Operations Procedures	Maintenance	Repair	FEA's Qual. Reliability	Criticality Quant. Reliability
38. ODOP	G. E. 68-874-003A NASA 170-44-0002 PAA Communications & Timing			Chrysler SDES-66-447 III		
39. ODOP Gd. Station	NASA GP-663 G. E. 68-874-003A PAA Communications & Timing					
40. C-Band System	G. E. 68-874-003A PAA Communications & Timing					
42. Vehicle Measuring GSE-SS	G. E. 68-874-003A NASA 170-44-0002 NASA 145-44-0004				G. E. 68-875-013	Boeing B-36
43. Vehicle Measuring GSE-LCC	NASA GP-663 G. E. 68-874-003A PAA ETR-TR-65-9 NASA 170-44-0002 NASA 145-44-0004				G. E. 68-876-013, -012	Boeing B-36
44. Abort Advisory System	G. E. 68-874-003A PAA ETR-TR-65-9 NASA 145-44-0004					
45. Cape Elect. Power & Distr. Sys.	G. E. 68-874-003A Boeing B-10 G. E. Airframe 009 PAA TD-3040-R-71 NASA 170-44-0002 NASA 145-44-0004			Chrysler SDES-66-447 III		PAA TR-3040-R-71 PAA ETV 69-83
46. KSC Elect. Distr. Sys.	G. E. 68-874-003A G. E. Airframe 009 NASA 170-44-0002				G. E. 68-876-013	
47. KSC Elect. Distr. Sys. Facilities Grounding	G. E. 68-874-003A G. E. Airframe 009					
48. KSC Elect. Distr. Sys. ACE Pwr. & Distr.	G. E. 68-874-003A G. E. Airframe 009					
49. KSC Elect. Distr. Sys. 60Hz Pwr. System	G. E. 68-874-003A NASA 145-44-0004	MSFC-240	MSFC-240	Chrysler SDES-	NASA GP-551 I, IV, VI, VII G. E. 68-876-013, -012 G. E. 68-875-013	

DOCUMENT CATALOG RELATING SYSTEMS vs. INFORMATION

System	Miscellaneous	Operations Procedures	Maintenance	Repair	FEA's Qual. Reliability	Criticality Quant. Reliability
50. KSC Elect. Distr. Sys. Special Pwr. Sys.	G. E. 68-874-003A Boeing B-10 G. E. Airframe 009	MSFC-212A	MSFC-212A		G. E. 68-876-013, -012	Boeing B-10
51. Operational Tele. Sys. (OTV)	G. E. 68-874-003A G. E. Airframe 009 USAF, AFETRM 127-1 NASA 160-54-0005 NASA 170-44-0002 NASA 145-44-0004 FEC Communications & Timing	PAA ETR-TR-65-9			G. E. 68-876-013, -012 G. E. 68-875-013 Bendix Reliability Notebook	Boeing B-36
52. Photo-Optical System	G. E. 68-874-003A USAF, AFETRM 127-1 RCA & PAA 0D4201 NASA 145-44-0004	PAA ETR-TR-65-9			G. E. 68-876-013, -012 G. E. 68-876-013	
53. Apollo Launch Data Sys.	Philco PHO-FAM-501 USAF, AFETRM 127-1 RCA & PAA 0D4201				Bendix Reliability Notebook	
54. Operational Intercommunications System	G. E. 68-874-003A G. E. Airframe 009 NASA 170-44-0002 NASA 145-44-0004 FEC Communications & Timing	NASA TM-552	NASA TM-552		G. E. 68-876-013, -012 G. E. 68-875-013 Bendix Reliability Notebook	
55. Wideband Trans. System	G. E. 68-874-003A USAF, AFETRM 127-1 NASA 145-44-0004 FEC Communications & Timing	PAA ETR-TR-65-9			G. E. 68-875-013 Bendix Reliability Notebook	
56. RF Communications System	G. E. 68-874-003A FEC Communications & Timing				G. E. 68-876-013 Bendix Reliability Notebook	
57. Tele., Data & Spec. Audio Sys.	G. E. 68-874-003A NASA 145-44-0004 FEC Communications & Timing				G. E. 68-876-013, -012 G. E. 68-875-013 Bendix Reliability Notebook	
58. Operational Paging Sys.	G. E. 68-874-003A PAA & RCA OD4201 FEC Communications & Timing				G. E. 68-875-013 Bendix Reliability Notebook	
59. Test & Switching Ctr. Sys.	G. E. 68-874-003A					
60. Timing & Countdown System	G. E. 68-874-003A PAA TD-7110-11 USAF, AFETRM 127-1 FEC Communications & Timing	PAA ETR-TR-65-9			G. E. 68-876-013, -012 G. E. 68-875-013 Bendix Reliability Notebook	PAA TD-7110-11 Boeing B-36

DOCUMENT CATALOG RELATING SYSTEMS vs. INFORMATION

System	Miscellaneous	Operations Procedures	Maintenance	Repair	FEA's Qual. Reliability	Criticality Quant. Reliability
61. Range Safety Cmd. Sys.	NASA GP-663 PAA TD-7810-7 USAF AFETRM 127-1	PAA ETR-TR-65-9				PAA TD-7810-7
62. Range Safety Sys. C/O	NASA GP-663 G. E. 68-874-003A PAA TD-7810-7 USAF AFETRM 127-1 NASA 145-44-0004	PAA ETR-TR-65-9			G. E. 68-876-013, -012 G. E. 68-875-013	PAA TD-7810-7
63. Impact Pred. Sys.	USAF AFETRM 127-1					
64. Tracking & Data Acq. Sys. -Radar	PAA TD-7810-5 USAF AFETRM 127-1	PAA ETR-TR-65-9		Chrysler SDES-66-447 III		PAA TD-7810-5
65. Tracking & Data Acq. Sys. -Glotrac		PAA ETR-TR-65-9		Chrysler SDES-66-447 III		
66. Tracking & Data Acq. Sys. -Telemetry	PAA ETR-TR-65-9 USAF AFETRM 127-1	PAA ETR-TR-65-9		Chrysler SDES-66-447 III		PAA TD-7026-12
67. Tracking & Data. Acq. Sys. -Optics	KSC K-IB-021/2 USAF AFETRM 127-1	PAA ETR-TR-65-9		Chrysler SDES-66-447 III		
68. MGSE	MSFC-205 NASA TM-393-D NASA TM-395-D NASA 160-54-0005 NASA 170-44-0002 TRW, AAP Prelaunch Operations Analysis	MSFC-021, -037	MSFC-021, -037			Boeing B-36
71. Digital Events Eval. (DEE-6)	NASA 170-44-0002		SDS 980074A SDS 980079A			Boeing B-36
72. Digital Data Acq. Sys. (DDAS)	NASA GP-497, -663 IBM 67-F-11-0007 IBM 65-232-00044 G. E. RAU-38 NASA 170-44-0002	MSFC-208, -209 NASW-410-ESE-0MM-003	MSFC-208, -209 NASW-410-ESE-0MM-003	Chrysler SDES-66-447 III	Boeing D2-119053-1 G. E. RAU-9	G. E. RAU-9-1, -38
73. S-IB, 110A Grd. Computer Equip.	RCA TP-1263, -1265, -1266 RCA Reliability Assessment Rpt. NASA 160-54-0005 NASA 170-44-0002	RCA TP-1263, -1265, -1266				Boeing D2-119053-1 G. E. RAU-38 RCA Reliability Assess. Report Boeing B-36

DOCUMENT CATALOG RELATING SYSTEMS vs. INFORMATION

System	Miscellaneous	Operations Procedures	Maintenance	Repair	FEA's Qual. Reliability	Criticality Quant. Reliability
74. Sat. IU, IVB &IB Pwr. & & Distr. ESE Prim. Pwr.	G. E. RAU-38 NASA 145-44-0004	NASA TM-422-D	NASA TM-423-D	Boeing D5-16000-563 Chrysler SDES-66-447 III	G. E. RAU-52, -7	G. E. RAU-7, -38 Boeing B-36
75. Sat. IU, IVB &IB Pwr. & Distr. ESE Aux. Pwr.	G. E. RAU-38			Boeing D5-16000-563 Chrysler SDES-66-447 III	G. E. RAU-52, -7	G. E. RAU-7, -38 Boeing B-36
76. ESE	NASA TM-392-D NASA 170-44-0002 TRW AAP Prelaunch Operations Analysis	MSFC-020, -023, -230	MSFC-020, -023, -230		G. E. RAU-14, -15, -17, -52, -8 G. E. 68-876-013	G. E. RAU-14, -15, -17, -33, -8, -38 G. E. ESE 69-0-466 Boeing B-36
77. Countdown Clock Sys.	NASA GP-66 G. E. Airframe 009 G. E. RAU-38			Chrysler SDES-66-447 III		G. E. RAU-38
78. Azimuth Laying & Alignment Equipment	IBM 67-F-11-0007 NASA 170-44-0002				G. E. RAU-14	G. E. RAU-14, -38
119. Terminal Countdown Sequencer	MSFC-205 G. E. RA-006B	MSFC-210	MSFC-210		G. E. RAU-52	Boeing B-36
120. Prop. Data Trans. Sys.						
121. Heat, Vent. & Air Cond. System	G. E. Airframe 009 NASA 145-44-0004				PAA Systems Reliability Data Complex 34	NASA GP-556 PAA ETV 69-49, -44 PAA TD-3040-R-60 PAA TD-3040-R-63
122. GOX	Bendix 5.4.6.1 TRW & AAP Prelaunch Analysis-FSR MSFC-205	NASA TM-424-D			Bendix 5.4.6 Bendix 5.4.6.1 Bendix Systems Status Program	Bendix 5.4.6 Bendix 5.4.6.1

concern in the terminal countdown, are systems that interface with Electrical Systems similarly identified within the Launch Complex Area. For purposes of this investigation such systems can be listed only once, with the understanding that its configuration includes all of the related equipment regardless of its physical location or its functional differences (i. e., electrical or instrumentation subsystems of mechanical systems are all considered as one system).

Consequently, the final configuration definition can be considered as those systems that represent the constituents of LC 34/37 and can be distinguished by the NASA Center responsible for its design, e. g., MSC, MSFC or KSC. The many KSC systems can be further categorized in terms of Mechanical Systems, Electrical Systems and Facility Systems.

The elements of the launch complex configuration have been defined in a number of alternate ways by different investigators. Whether support equipment is categorized according to functional capability, physical location responsible agency or contractor, or in most any other manner, there are some difficulties to overcome due to overlapping conditions. The basic elements, defined in this study, as representative of the support equipment configuration are shown in Figure VI-1. Additional analysis of these groupings of support equipments, by segmenting them into their constituents, ultimately results in an equipment list that represents the entire support system. A complete list of systems and their subsystems is presented in Table VIII-5 of Section VIII. Each item in the list has been arbitrarily assigned an equipment

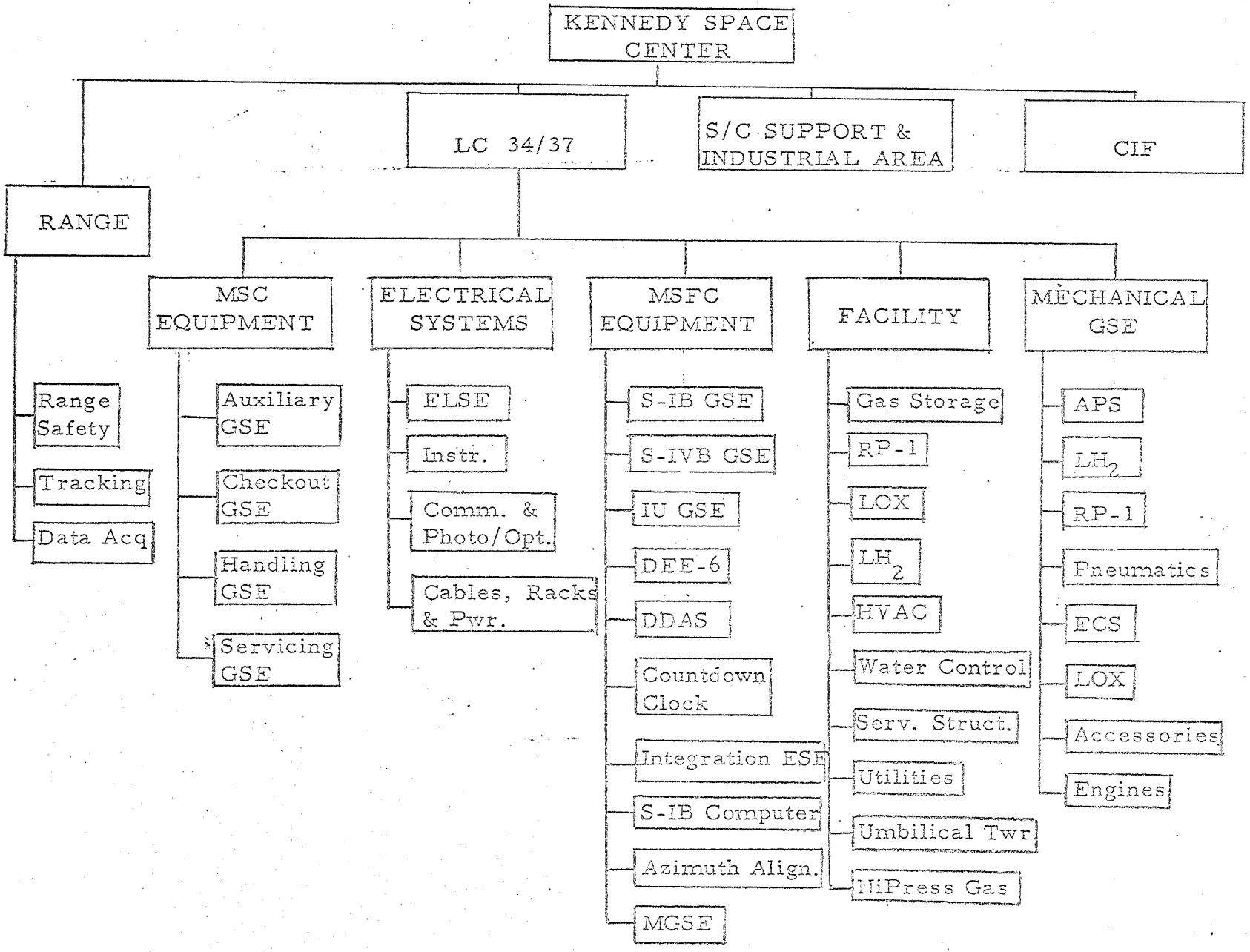


FIGURE VI-1 LAUNCH FACILITY SUPPORT CONFIGURATION

number to facilitate its use as input to the computer model. Equipment numbers less than #220 represent equipment that are classified as systems. Equipment numbers greater than #219 represent subsystems. All subsystems can be related to their system according to the relationship:

Number of the First Subsystem = 20 times System Number plus 200

Number of the Second Subsystem = 20 times System Number plus 201

Number of the Third Subsystem = 20 times System Number plus 202

Systems numbered 079 through 118 and 123 through 136 are spacecraft related systems under the responsibility of NASA-MSC. Systems 030, 031, 068, 119 and 071 through 078 are related to the launch vehicle and are MSFC responsibility. Systems that are considered a part of the Range Facilities consist of systems #061 through #067. All other systems in the equipment list are considered as facility or support equipment under the responsibility of KSC.

6.4 COUNTDOWN LOGS

Another source of information of use in this study is the countdown logs for each of the five Saturn IB/Apollo missions. The purpose of reviewing such data is to identify the systems, if any, that consistently caused delays in the countdown operation. The information in the countdown logs consists of descriptive accounts of the operations and the past anomalies that have occurred. However, in some cases, problems are indicated in general terms and insufficient details are available to determine the actual effect of the incident on the launch

operations. Analysis of the countdown logs indicates that there were 95 system associated anomalies and 5 procedural or non-system associated discrepancies reported during these 5 countdowns. Table VI-2 summarizes the results of the conclusions found from the analysis of the countdown logs. The investigation revealed that unscheduled holds resulted from only 7 system associated problems, and no single system caused more than 1 unscheduled hold. As can be seen from the data shown in Table VI-3, most of the anomalies were corrected during the course of the countdown or during scheduled hold periods and did not necessitate an unscheduled hold.

While the analysis of the countdown logs does not directly contribute to the determination of equipment performance characteristics, the information that was derived does provide a check on the other analysis and insures that potential critical systems that have already demonstrated difficulties during countdown, are not overlooked. The most valuable contribution to the study by the analysis of the countdown logs is in the provision of considerable insight into launch operation activities and an appreciation of countdown delay type problems.

TABLE VI-2 DATA FROM COUNTDOWN LOGS

	SA-201	SA-203	SA-202	AS-204 LM	AS-205
ANOMALIES	6	7	4	31	47
SYSTEM HOLDS	1	1	3	2	0
OTHER HOLDS	2	0	2	0	1
TOTAL	3	1	5	2	1
TOT. HOLD LENGTH					
SYSTEM	1.22 Hr	1.75 Hr	1.22 Hr	3.80 Hr	0
OTHER	2.32 Hr	0	1.85 Hr	0	0.03 Hr
TOTAL	3.53 Hr	1.75 Hr	3.07 Hr	3.80 Hr	0.03 Hr
TOTAL LAUNCH DELAY	3.47 Hr	1.75 Hr	0.45 Hr	3.80 Hr	0.03 Hr

TABLE VI-3. SYSTEM ANOMALIES DURING LAUNCH COUNTDOWN

FUNCTIONAL SYSTEM		TOTAL SYS. ASSOC. "FAIL."	TOTAL SYS. ASSOC. HOLDS	COUNT TIME AT HOLD T-	HOLD TIME	
NO.	NAME				HR	MIN
001	RP-1	3				
002	LIQUID OXYGEN	3				
003	LIQUID HYDROGEN	1				
004	PNEU. DISTR.: GN_2	1	1	00:00:011	01	13
006	PNEU. DISTR.: HELIUM	5				
007	ENVIRON. CONTROL	2	1	02:30:00	02	39
013	APOLLO ACCESS ARM	1				
022	UMBILICAL TOWER	2				
023	WATER	2				
027	PTCS	3				
028	DEE-3	1				
029	FACILITY MEAS.	1				
030	HAZARDOUS GAS DETECT.	5				
032	CIF: CENTRAL COMP. COMPLEX	2	1	20:00:00	00	30
033	CIF: TELEMETRY GND. STA.	1				
034	LIEF	1				
043	VEH. MEAS. GSE: LCC	7	1	00:03:00	00	04
045	CAPE ELEC. PWR. & DISTR.	1				
051	OTV	3				
054	OIS	17				
055	WIDEBAND TRANSMISSION	1				
056	RF COMMUNICATIONS	2				
061	RANGE SAFETY COMMAND	2				
065	TRACK. & DATA ACQ.: GLOTRAC	1				

TABLE VI-3 (CONT.) SYSTEM ANOMALIES DURING LAUNCH COUNTDOWN

FUNCTIONAL SYSTEM		TOTAL SYS. ASSOC. "FAIL."	TOTAL SYS. ASSOC. HOLDS	COUNT TIME AT HOLD T-	HOLD TIME	
NO.	NAME				HR	MIN
068	MECH. GSE	1				
072	DDAS	3	1	02:30:00	01	09
073	SAT. IB GND. COMPUTER	6	1	08:24:00	00	32
074	SAT. IB PWR. & DIST. ESE: PRI.	1				
075	SAT. IB PWR. & DIST. ESE: AUX.	3				
076	ESE	1				
077	COUNTDOWN CLOCK	5				
091	ACE	2				
093	TELECOMM. SUPPORT	2				
121	HEAT., VENT. & AIR CONDITION.	1				
TOTAL SYS. ANOMALIES		95				
TOTAL SYSTEM ASSOC. HOLDS			6		HRS:	MIN:
TOTAL SYS. ASSOC. LAUNCH DELAY TIME					06	15
NON-SYSTEM ASSOC. HOLDS			6			
NON-SYSTEM ASSOC. HOLD TIME					04	56
		TOTALS	12		11	11

VII OPERATIONS ANALYSIS

The operations that are performed in preparing the Saturn IB Space Vehicle for launch are composed of a number of functions intended to service, monitor, test or checkout the integrity of the vehicle. These functions may be independent, isolated activities or they may be totally interrelated with other functions such that their accomplishment is possible only after prerequisite functions have been successfully completed. Each function is nominally scheduled to begin at a specified point in the countdown and continue throughout a normal operating period. The successful completion of this function implies that information is acquired or a set of conditions is met that assists in the validation of progressive readiness states of the space vehicle.

The countdown operations can be described as a collection of supporting activities or functions that in most instances are operating concurrently with other supporting functions. The countdown is further characterized by certain periods of time, called holds, wherein no supporting functions are performed. Scheduled holds are periods of inactivity that are purposely introduced into the countdown. Unscheduled holds become a part of the countdown period when a necessary function is not completed on time (normally as a result of an equipment failure) or when its delay jeopardizes the space vehicle or the performance of another supporting function.

As specified in the Mission Rules, there are certain points in the countdown period, more convenient than others, for accommodating an unscheduled hold. In the last 14 hours and 15 minutes of the countdown, the Mission Rules identify

14 of these points. Table VII-1 lists these points, the time that they occur in the countdown and the function whose start time coincides with each holdpoint. These 14 holdpoints consequently define the start and completion times for 13 different operating periods, designated as timeframes. The final 14 hours and 15 minutes of the countdown may be considered as a collection of 13 different operating periods or timeframes, each of which consists of a collection of support functions.

The timeframe concept provides an ideal mechanism for treating the countdown period in a modular manner. All of the functions that are nominally scheduled to occur in a given timeframe can be considered as a group, and a delay in any function can be expressed in terms of a delay to its timeframe. Although each timeframe may differ according to operating duration or the number of functions it contains, there is a real similarity, given the basic consideration that all functions within any timeframe must be completed before the succeeding timeframe can be started. This conditional statement is a significant factor in the development of the overall availability model and to a certain extent simplifies the operational analysis. Consequently it is beneficial to follow this approach during the initial portion of the analysis even though it is conservative and neglects some of the alternatives that are available to reduce the probability of a delay. Subsequently, more refined analysis of the operations will be performed to account for additional slack time possibilities or functional interrelations that are influential in determining launch delays.

TABLE VII-1: HOLDPOINTS FOR AS205 COUNTDOWN

Holdpoint Number	Countdown Time	Function
1	T-0:0:0	Vehicle Launch
2	T-0:0:5	Commit
3	T-0:2:44	Begin Automatic Sequence
4	T-0:10:0	Start S-IVB Thrust Chamber Chilldown
5	T-0:14:30	Start Tank Chilldown
6	T-0:40:0	Clear Access Arm
7	T-3:0:0	Start Cabin Closeout
8	T-4:15:0	Start S-IVB LH_2 Loading
9	T-6:0:0	Start Dual LOX Loading
10	T-6:0:0	Begin Six Hour Hold
11	T-6:45:0	Service Structure Removal
12	T-8:40:0	Close Instrument Unit Door
13	T-9:30:0	Launch Vehicle Safe & Arm Connection
14	T-14:15:0	Launch Vehicle Power Application

7.1 ACTIVITY IDENTIFICATION

Given the framework within which the activity exists, the initial step in performing the operations analysis is to identify all of the individual activities necessary to validate vehicle launch readiness. The principal reference source for such information is found in the launch vehicle countdown document and the spacecraft countdown document. Each entry in the countdown documents may be initially treated as an activity. Subsequent refinement of this process, by combining related items into a more generalized activity or by analyzing and segmenting an item into subsets can then be performed. Criteria for combining or reducing the listing of the countdown documents is principally acquired as a result of engineering investigations into the purpose and the effect of each activity. Acquisition of this type of familiarization is provided to a major extent by the review and analysis of the subprocedure reports referenced in the CD documents. One additional requirement for considering if a given activity or function should be segmented into subfunctions is dependent on the ground support equipment that is necessary for its performance. A function is reduced to its simplest level only when a single set of equipments is required throughout the entire operating duration of the function.

As each individual function is identified, it can be assigned, arbitrarily, an identification number. This number simplifies the accounting of functions and is a necessary step in utilizing it as an input into the computer program. During the final 14 hours and 15 minutes of the countdown, approximately 1300 entries within the LV Countdown document and 400 entires in the S/C countdown document are applicable. These entires can be synthesized into 219 major functions, 152

are related to the launch vehicle and 67 to the spacecraft. Forty-three subfunctions have been identified as subsets of these major activities so that a total of 262 functional activities are accounted for in this analysis. A listing of these functions with a brief description of the activity and their pertinent characteristics, is presented at the end of this section.

7.2 FUNCTION CHARACTERISTICS

Definition of the functional operating parameters is a necessary part of the launch operations analysis. After an activity has been identified, its basic characteristics concerning operating duration and slack must be determined. Additional required descriptions which are related to these basic characteristics include such items as nominal start and stop times, associated timeframe and holdpoint and functional interrelations with other functions. Each of these characteristics serve either directly or indirectly as input to the availability model and must be carefully evaluated. An effective way of conducting the analysis is to initially perform the basic investigations using the timeframe concept to simplify slack time and function interrelation considerations. Subsequent detailed analysis of the operations, to identify possible alternative responses to non-nominal conditions can then refine the basic data. The following paragraphs describe the significant parameters to be established in performing the basic and the refined analysis.

BASIC ANALYSIS - One of the characteristics of primary significance and of use as input to the availability model is the function's operating duration. Establishing the time in the countdown when the activity is nominally scheduled to start and

stop is the obvious way of determining the operating period. The activity's terminal points will also necessarily establish the timeframe(s) related to the function. The start and completion times associated with each function is normally apparent from the descriptive items of the Countdown Document. Pertinent related studies, analysis of the subprocedures and data within the countdown logs will usually provide additional operating time information about certain functions not clearly defined in the CD document. Figure VII-1 presents graphically the nominal operating times for each function identified during the final countdown period. Such timelines clearly show the start and stop times of each activity and indicate the many multiple activities that must be performed concurrently.

Another functional characteristic of importance that must be carefully evaluated is functional slack. Slack is that period of time that exists between the completion time of an activity and the point in time where a delay to the countdown would be acknowledged if that function was not completed. For example, if function 'A' is nominally scheduled to be completed at T-9 hours, yet not required (e.g., as a requisite for a succeeding function) until T-8:20, then a slack time of 40 minutes would be associated with function A. In such a case, a delay in function 'A' would not be acknowledged at the nominal completion time; the 40 minutes of slack would be utilized to affect repairs and complete the function, if possible. Assuming that function 'A' was completed before T-8:20, there would be no delay in the countdown activities and an unscheduled hold would be unnecessary.

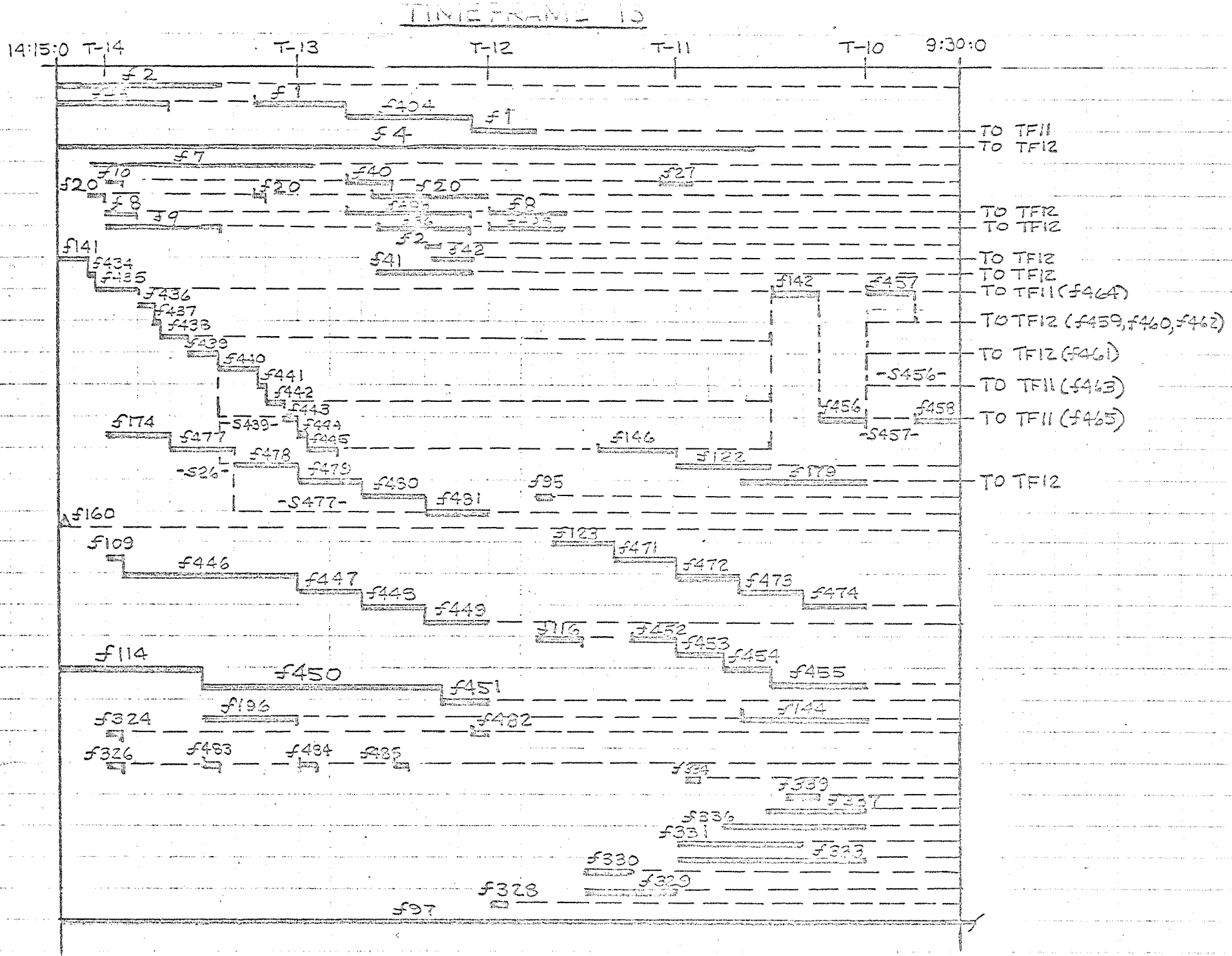
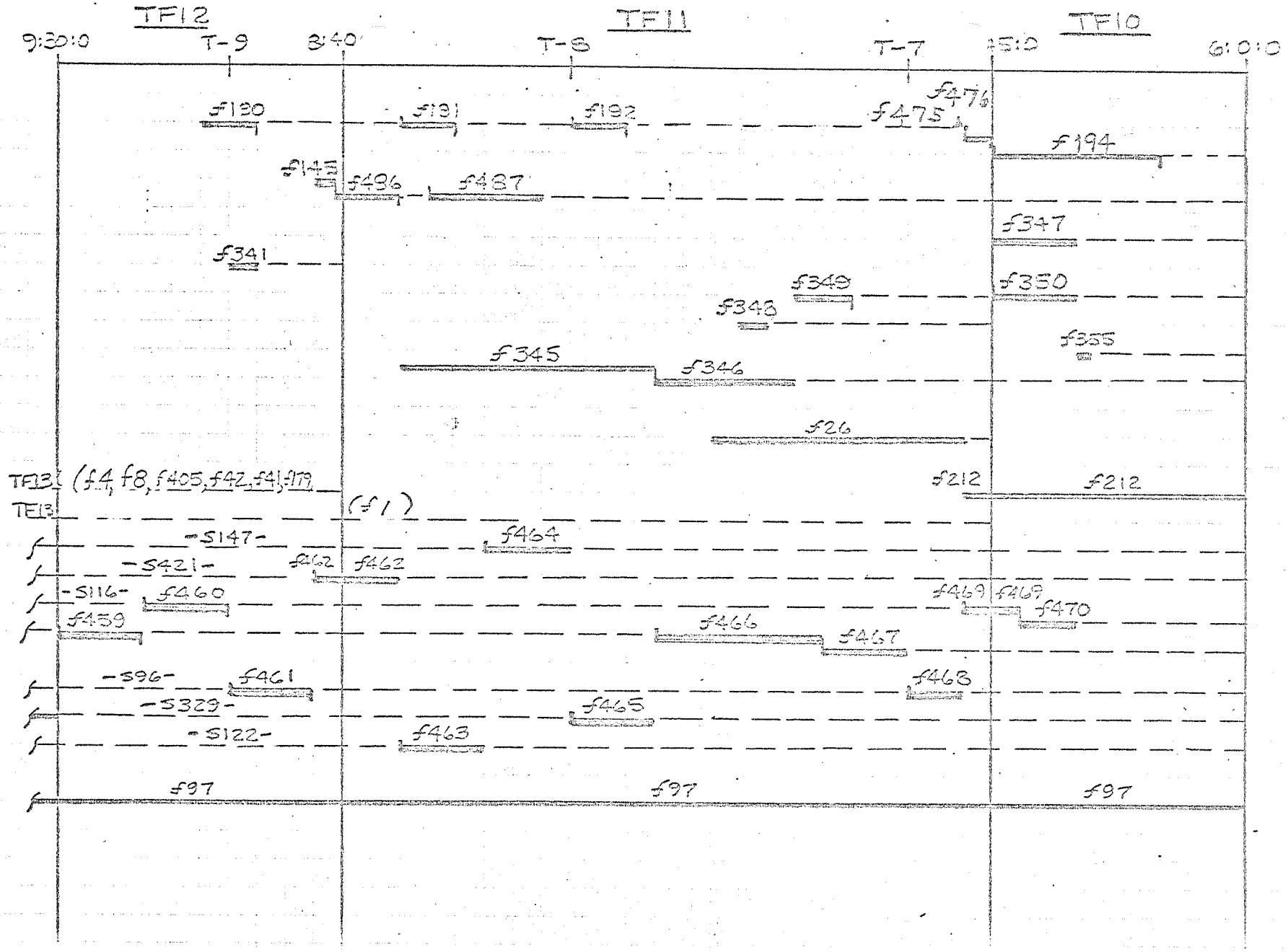
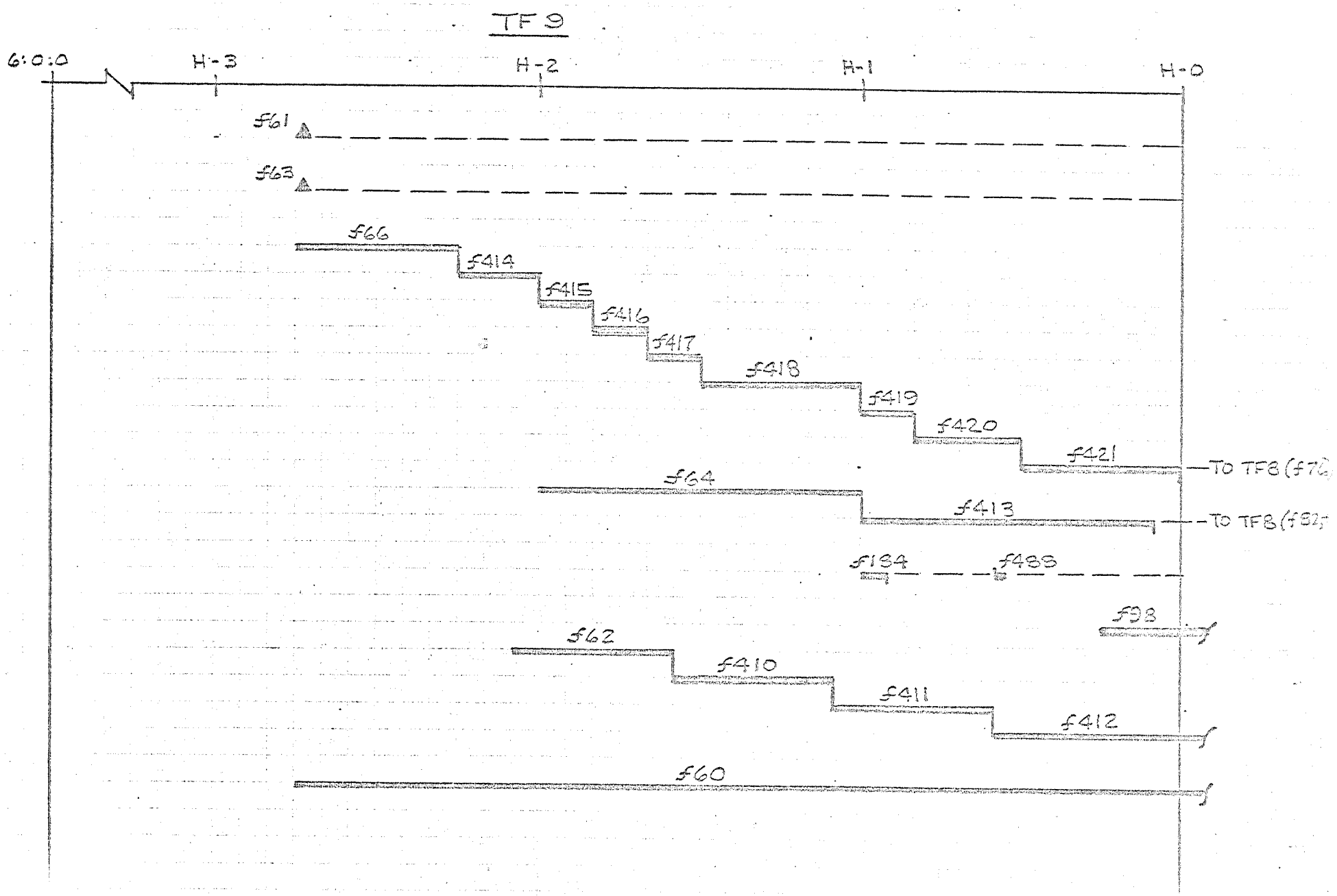


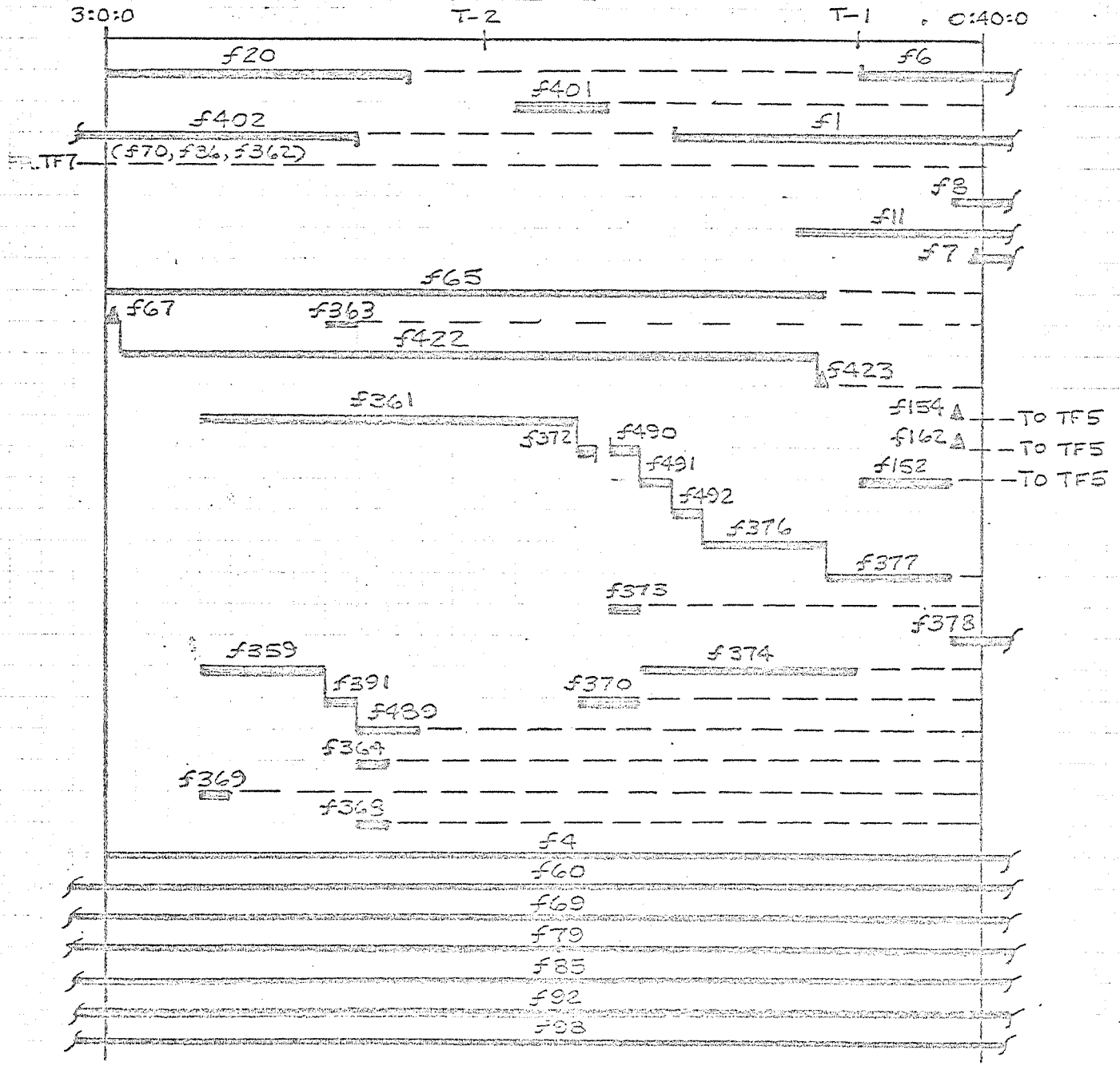
FIGURE VII - 1 COUNTDOWN FUNCTION TIMELINES (7 sheets)

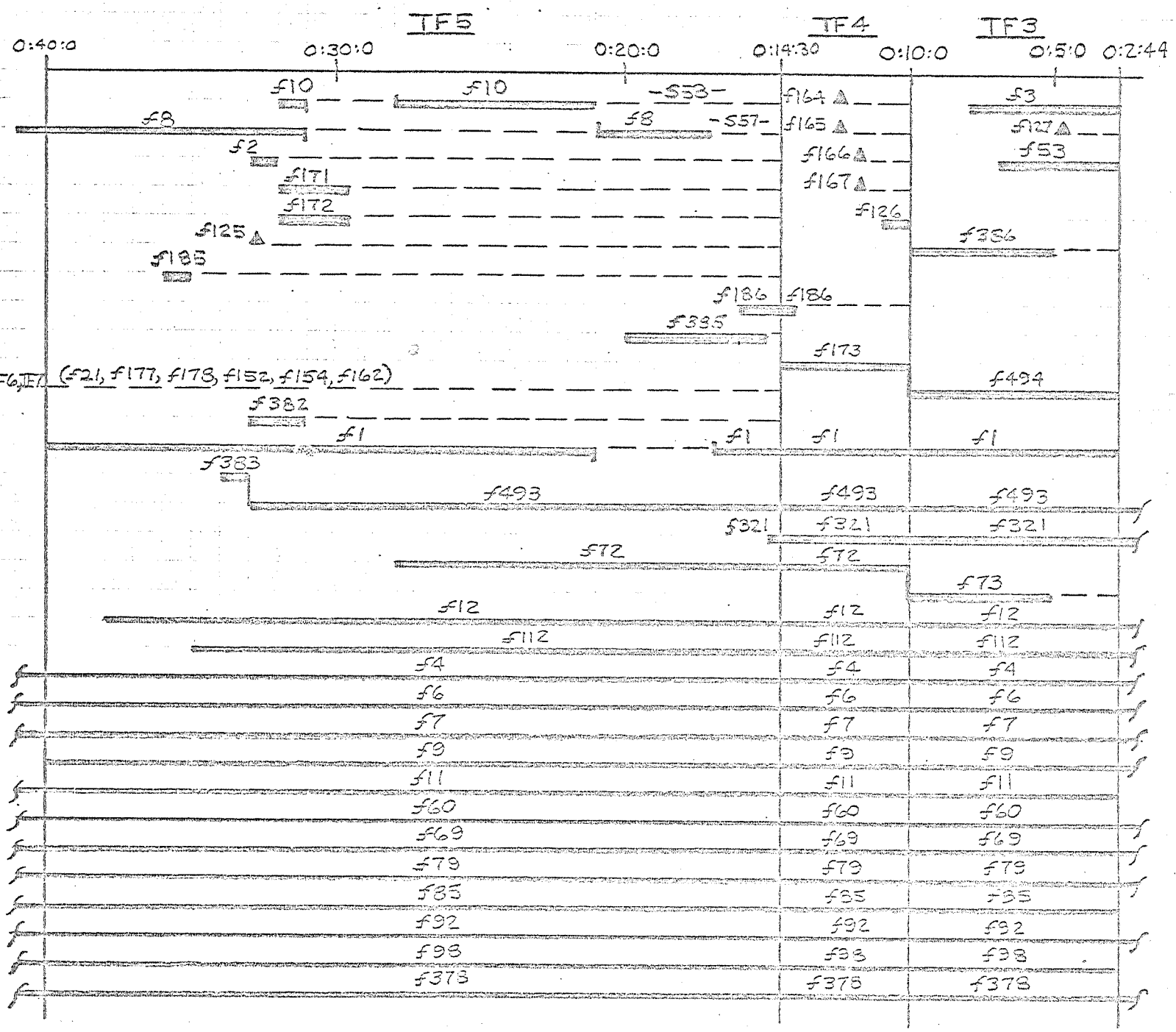

TF12
TF11
TF10
9:30:0
T-9
8:40
T-8
T-7
5:0
6:0:0
f190
f191
f192
f475
f476
f194
f145
f486
f487
f347
f341
f349
f350
f348
f355
f345
f346
f26
TF13 (f4, f8, f405, f42, f41, f179
TF13
(f1)
f212
f212
-S147-
f464
-S421-
f462
f462
-S116-
f460
f469
f469
f470
f459
f466
f467
-S96-
f461
f468
-S329-
f465
-S122-
f463
f97
f97
f97

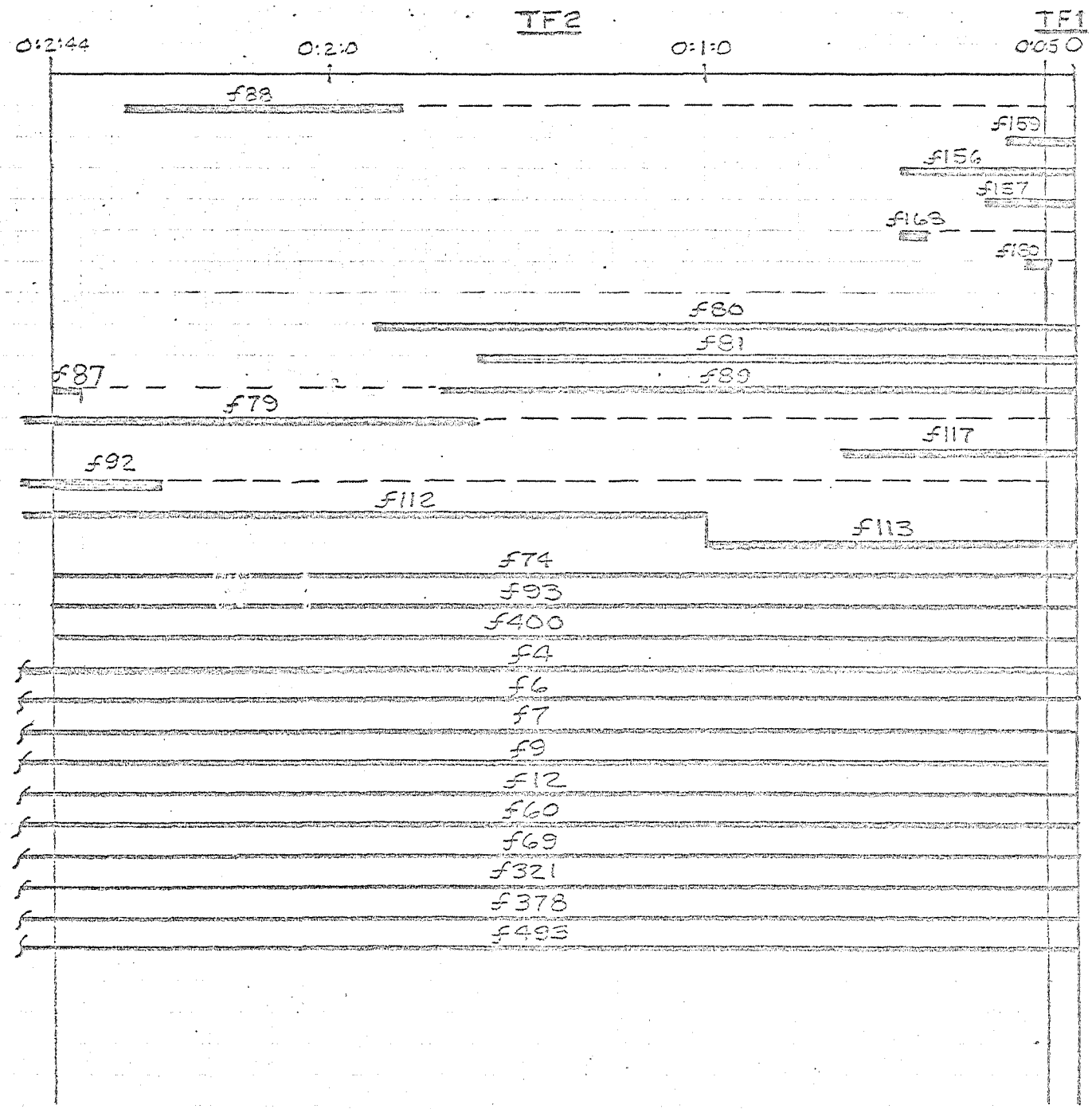

TF 9
6:0:0
H-3
H-2
H-1
H-0
f61
f63
f66
f414
f415
f416
f417
f418
f419
f420
f421
TO TF8 (f76
f64
f413
TO TF8 (f82
f184
f488
f98
f62
f410
f411
f412
f60

TF 1
TF 2
TF 3
TF 4
TF 5
TF 6
TF 7
TF 8
TF 9
TF 10
TF 11
TF 12
TF 13
TF 14
TF 15
TF 16
TF 17
TF 18
TF 19
TF 20
TF

TIMEFRAME 6


3:0:0
T-2
T-1
0:40:0
f20
f6
f401
f402
f1
TF7
(f70, f36, f362)
f8
f11
f7
f65
f67
f363
f422
f423
f361
f154
TO TF5
f162
TO TF5
f152
TO TF5
f372
f490
f491
f492
f376
f377
f373
f378
f359
f374
f391
f370
f489
f364
f369
f368
f4
f60
f69
f79
f85
f92
f98


TF5
TF4
TF3
0:40:0
0:30:0
0:20:0
0:14:30
0:10:0
0:5:0
0:2:44
f10
f10
-S53-
f164
f3
f8
f8
-S57-
f165
f127
f2
f166
f53
f171
f167
f172
f126
f125
f386
f185
f186
f186
f385
f173
TF6,TF7 (f21, f177, f178, f152, f154, f162)
f494
f382
f1
f1
f1
f1
f383
f493
f493
f493
f321
f321
f321
f72
f72
f73
f12
f12
f12
f112
f112
f112
f4
f4
f4
f6
f6
f6
f7
f7
f7
f9
f9
f9
f11
f11
f11
f60
f60
f60
f69
f69
f69
f79
f79
f79
f85
f85
f85
f92
f92
f92
f98
f98
f98
f378
f378
f378


TF2
TF1
0:2:44
0:2:0
0:1:0
0:0:50
f88
f159
f156
f157
f163
f160
f80
f81
f87
f89
f79
f117
f92
f112
f113
f74
f93
f400
f4
f6
f7
f9
f12
f60
f69
f321
f378
f495

Slack time is a built-in method of reducing the likelihood of unscheduled holds in the countdown and therefore it is important that functional slack time characteristics be evaluated carefully. This evaluation is simplified when performing the basic analysis because in that process, all functions in a timeframe are assumed to be necessary and completed at the end of that timeframe. The functional slack cannot extend beyond that timeframe's holdpoint. However, when performing a more refined analysis, this limitation is removed and the more complex, but realistic condition is assessed. The procedures of accounting for the more refined case is discussed in the following section.

Functional interrelations must also be established as a step to defining functional characteristics. Functions may be independent of all other functions within the timeframe, they may serve as a requisite or preparatory function to a subsequent function or they may be dependent on prior functions being successfully performed before they can be initiated. Those functions that are interrelated with other functions must be identified because in the availability model and the computer program, they are mathematically accounted for differently than independent functions. Determination of functional dependence can result only from a total cognizance of the countdown activities. Considerable engineering analysis is required to evaluate the intent and outcome of each function. As with slack time evaluation, the investigations into functional interrelationships is simplified during the basic analysis because only those functions within the same timeframe need to be considered.

REFINED ANALYSIS - The procedures involved in performing a more detailed analysis of the countdown functions are similar to that used in the basic analysis. All data concerning function operating time is directly applicable and the principal difference in the analyses is that due to slack time or function interrelation considerations. The purpose of this refined analysis is to reflect, wherever possible, those alternatives that are available for reducing the effect of a functional delay. Although these alternatives are not directly specified in the Mission Rules, they are implied from the directive: "proceed (with the countdown) if correction can be accomplished in parallel with normal functions; otherwise hold." An accounting of this conditional statement can be made in the availability model, only with the results of the refined analysis.

The basic analysis is dependent on the assumption that any failures occurring during a timeframe are corrected before proceeding beyond the next holdpoint, consequently, slack time is limited within such bounds. However, in the refined analysis, this assumption is not used and a more detailed view is taken of the intention of the countdown. Consideration is made for those functions that, although nominally scheduled for completion during one timeframe, are functionally essential only during a later portion of the count. In such cases, it is clear that additional time is available to facilitate repairs and therefore slack times should be adjusted accordingly.

The principal effort in this analysis is to consider each function operating during its nominally scheduled period and evaluate whether or not a hold would be called at the end of that timeframe due to the incompletion of this function. If it is

considered that a hold would be called, the situation is as treated in the basic analysis. If, however, due to functional considerations, a hold would not need to be called at that point, a similar decision would be made for the next holdpoint. This process is continued until a point is established where a hold would be called due to that function. The period of time between the nominally scheduled completion of the function and this final holdpoint is then defined as its slack time. The function is then accounted for, in terms of its probability of causing launch delay, together with those other functions that are also associated with this holdpoint. In Figure VII-1, the dashed lines after the function timeline represents slack.

Additional analysis concerning functional interrelations is similarly needed when maximum slack time considerations are made. To properly evaluate when, (i. e., at what holdpoint) an unscheduled hold is necessary due to one function's delay, all of the intervening functions must be investigated to determine if interrelated to the subject function. The essential feature of the refined function analysis is its process of ignoring nominal holdpoints and considering only functional necessity as a criteria for calling an unscheduled hold. The results of such analysis provide a better representation of the actual launch countdown condition and modeling the operations in that manner improves the accuracy of the analysis.

7.3 SUMMARY OF COUNTDOWN FUNCTIONS

More than 260 countdown functions may be identified during the final 14 hours and 15 minutes of the countdown. A listing of these functions is presented in Table VII-2, together with a summary of their operating characteristics. Included are each function's scheduled start and finish times expressed in countdown time

(i. e., time before launch). The function's operating duration is designated in hour units. Functional interrelations are summarized by identifying with each function, the subsequent function which is dependent on it. The holdpoints associated with each function are listed for both the nominally scheduled and the maximum or functionally necessary condition. When a function is scheduled to operate during multiple timeframes, each holdpoint is identified. Maximum slack time values are associated with each function and are presented in units of hours. The information contained in Table VII-2 provides a summary of the countdown operations and all of its data is used as input to the computer program for modeling launch availability.

TABLE VII-2 COUNTDOWN FUNCTION DATA (17 sheets)

Func. No.	Description	Start Time	Stop Time	Operating Time	Interrelated Functions	Nominal Holdpoint	Maximum Holdpoint	Slack Time
1	(f34) Control System Functional	13:13:0	12:45:0	.467	404	13	11	0
	(f34) Control System Functional	12:05:0	11:45:0	.333		13	11	5.000
	(f25) IU Final Flight Computer Launch Preps	6:0:0	5:40:0	.333	148	8	8	.167
	(f19) Flight Control Redundancy Checks	4:0:0	3:15:0	.750	402	7	7	.167
	Flight Computer, LVDA/LVDC Checks	1:30:0	0:21:0	1.21	1	6, 5	6, 5	.067
		0:17:0	0:2:44	.238		5 → 3	5 → 3	.000
2	Power Applications Transfer	14:15:0	13:23:0	.067		13	13	3.88
	Tests Application	12:20:0	12:15:0	.083		13	13	2.75
		0:32:0	0:31:0	.017		5	5	.27
3	EBW, Safe & Arm Tests	0:08:0	0:02:44	.133		3	3	0
4	(f32) LVDA/LVD C Checks	14:15:0	10:35:0	3.67		13	12	1.92
	ST-124M Drift & Guidance	5:40:0	5:05:0	.583		8	8	.83
	Computer Checks	4:0:0	3:30:0	.500		7	7	.50
		3:0:0	0:0:0	3.00		6 → 2	6 → 2	0
6	Intra-Complex Communications	1:0:0	0:0:0	1.00		6 → 2	6 → 2	0
7	Inter-Center Communications	14:05:0	12:55:0	1.17		13	13	3.41
		0:41:0	0:0:0	.683		5 → 2	5 → 2	0
8	(f49) RF & TM Preps.	14:0:0	13:50:0	.167	403	13	12	1.08
	(f33) LV RF & TM Checks	12:0:0	11:35:0	.420		13	13	2.92
	LV RF & TM Checks	0:45:0	0:31:0	.233	8	6, 5	5	.16
	LV RF & TM Checks	0:21:0	0:17:0	.067		5	5	.04

COUNTDOWN FUNCTION DATA

Func. No.	Description	Start Time	Stop Time	Operating Time	Interrelated Functions	Nominal Holdpoint	Maximum Holdpoint	Slack Time
9	DDAS Checks	14:0:0	13:23:0	.617	36	13	12	.867
		0:40:0	0:0:05	.667		5 → 2	5 → 2	0
10	DRSC Closed Loop Checks	14:0:0	13:55:0	.083	40	13	13	1.17
		3:10:0	3:09:0	.017		7	5	2.483
		0:32:0	0:31:0	.017	10	5	5	.05
		0:28:0	0:21:0	.117		5	5	.108
11	C-Bank Checks	1:10:0	0:02:44	1.123		6 → 3	6 → 3	0
12	ODOP Checks	0:38:0	0:0:0	.633		5 → 2	5 → 2	0
20	(f52) Intra-Complex Comm. Ck.	14:05:0	14:0:0	.083	20	13	13	.784
	(f45) Intra-Complex Comm. Ck.	13:13:0	13:10:0	.050	20	13	13	.533
	(f38) Intra-Complex Comm. Ck.	12:38:0	12:0:0	.634		13	13	2.500
	(f22) Intra-Complex Comm. Ck.	4:05:0	4:0:0	.083		7	7	1.00
	Intra-Complex Comm. Checks	3:0:0	2:12:0	.800	6	6	6	1.20
23	Commit Power Cks.	4:30:0	4:29:0	.017		8	7	1.47
26	AGCS Power Cks.	7:35:0	6:50:0	.750		11	11	.083
27	DRSCS Closed Loop Cks. #1	11:05:0	10:55:0	.167		13	13	1.42
36	DDAS Checks	12:35:0	12:05:0	.500	405	13	12	.08
40	DRSCR Open Loop Checks	12:45:0	12:30:0	.250	27	13	13	1.42
41	ODOP Open Loop Checks	12:35:0	12:05:0	.500		13	12	3.41
42	C-Band Open Loop Checks	12:18:0	12:05:0	3.410		13	12	3.41

COUNTDOWN FUNCTION DATA

Func. No.	Description	Start Time	Stop Time	Operating Time	Interrelated Functions	Nominal Holdpoint	Maximum Holdpoint	Slack Time
48	Flight Computer Power Cks.	14:15:0	13:40:0	.583	1	13	11	.450
53	EDS Ready Check	0:7:0	0:02:44	.071		3	3	0
60	Propellant System Power On	H2:45:0	0:0:0	8.75		9 → 2	9 → 2	0
61	RP-1 Sense Valve Open	H2:45:0	H2:44:0	.017		9	9	2.73
62	RP-1 System Preps.	H2:05:0	H1:35:0	.500	410	9	6	0
63	LOX Sense Valve Open	H2:45:0	H2:44:0	.017		9	9	2.73
64	LOX System Preps.	H2:0:0	H1:0:0	1.00	413	9	3	0
65	LOX Storage Tank Replenish	3:0:0	1:05:0	1.92		6	6	.41
66	LH_2 System Preps.	H2:45:0	H2:15:0	.500	414	9	7	0
67	LH_2 Storage Tank Replenish	3:0:0	2:59:0	.017	422	6	6	0
69	Monitor RP-1	5:50:0	0:0:0	5.83		8 → 2	8 → 2	0
70	Replenish RP-1	3:10:0	3:0:0	.167		7	6	2.33
72	RP-1 Level Adjust	28:0	0:10:0	.300	73	5 → 4	3	0
73	RP-1 Line Inert	10:0	0:05:0	.083		3	3	.03
74	RP-1 Pressurization	0:2:44	0:0:0	.046		2	2	0
76	LH_2 Loading Preps.	5:15:0	4:30:0	.750	77	8	8	0

COUNTDOWN FUNCTION DATA

Func. No.	Description	Start Time	Stop Time	Operating Time	Interrelated Functions	Nominal Holdpoint	Maximum Holdpoint	Slack Time
77	LH_2 Switch Verif.	4:30:0	4:28:0	.033	424	8	8	0
78	Load LH_2	4:15:0	3:10:0	1.08	79	7	7	0
79	LH_2 Replenish	3:10:0	0:01:37	3.13		7	7	0
80	LH_2 Pressurizing	0:01:53	0:0:0	.031		2	2	0
81	LH_2 Umb. Line Drain	0:01:37	0:0:0	.027		2	2	0
82	S-IVB LOX Loading Preps.	6:0:0	5:45:0	.25	83	8	8	0
83	S-IVB LOX Loading	5:45:0	4:30:0	1.25	85, 92	8	8	0
85	LOX Replenishing	4:30:0	0:02:44	4.45		8 → 3	8 → 3	0
86	LOX Bubbling Press. Test	4:0:0	3:40:0	.333		7	6	3.00
87	LOX Vent Valves Closed	0:02:44	0:02:40	.001	89	2	2	.016
88	LOX Tank Bubbling	0:02:33	0:01:47	.013		2	2	.030
89	LOX Tank Press.	0:01:43	0:0:0	.028		2	2	0
91	LOX Load Switch Pos.	6:0:0	5:58:0	.033	429	8	8	0
92	LOX Replenishing	4:30:0	0:02:27	4.46		8 → 2	8 → 2	.040
93	LOX Tank Press.	0:02:44	0:0:0	.046		2	2	0

COUNTDOWN FUNCTION DATA

Func. No.	Description	Start Time	Stop Time	Operating Time	Interrelated Functions	Nominal Holdpoint	Maximum Holdpoint	Slack Time
95	Oals Temp. Meas.	11:45:0	11:40:0	.083		13	13	2.17
96	Oals Temps Meas.	3:40:0	3:30:0	.167		7	7	.500
97	ECS Operating (Air)	14:15:0	6:0:0	8.25		13 → 10	13 → 10	0
98	ECS Operating (GN_2)	H0:15:0	0:02:44	6.18		8 → 3	8 → 3	0
109	Fire Protection System	14:0:0	13:55:0	.083	446	13	13	0
112	FDM Recorders on Slow	0:35:0	0:01:0	.567	113	5 → 2	5 → 2	0
113	FDM Recorders on Fast	0:01:0	0:0:0	.017		2	2	0
114	HGD Preps.	14:15:0	13:30:0	.750	450	13	13	0
116	Water Control System Preps.	11:45:0	11:30:0	.250	452	13	13	.250
117	Pad Flush	0:0:38	0:0:0	.011		2	2	0
122	HDA Preps	11:0:0	10:30:0	.500		13	13	1.00
123	Access/Swing Arm Preps	11:40:0	11:20:0	.333	471	13	13	0
125	Retract AAA to Park	0:28:0	0:27:56	.001		5	5	.221
126	Swing Arm Hyd, Bleed Test	0:11:0	0:10:0	.017		4	4	0
127	Retract AAA to Retract	0:05:0	0:04:56	.001		3	3	.034

COUNTDOWN FUNCTION DATA

Func. No.	Description	Start Time	Stop Time	Operating Time	Interrelated Functions	Nominal Holdpoint	Maximum Holdpoint	Slack Time
141	Pneumatic Prelaunch Preps	14:15:0	14:05:0	.167	434	13	10	0
142	Final Pneumatic Preps	10:30:0	10:15:0	.250	456, 457	13	10	0
144	Closeout IU Pneu. Console	10:40:0	10:0:0	.667		13	12	.50
145	Final GH_2 Preps.	8:45:0	8:42:0	.050	486	12	10	0
146	Pressurize Fuel Spheres	11:25:0	11:0:0	.417	142	13	10	.50
147	Press. Fuel Sphere	5:57:0	5:30:0	.45		8	8	1.25
148	Press. IU Flight Spheres	5:30:0	5:25:0	.083		8	8	1.17
149	Press. S-IB Control Spheres	5:25:0	5:20:0	.083		8	8	1.08
150	Press. Eng. Cont. Bottle	3:15:0	3:14:0	.017	151	7	7	.01
151	Press. Eng. Cont. Bottle	3:13:0	3:08:0	.083		7	7	.13
152	GG LOX Injector Purge Test	1:0:0	0:45:0	.25		6	5	.50
154	LOX Dome Purge to Auto.	0:45:0	0:44:56	.001		6	5	.50
156	Calorimeter Purge	0:0:28	0:0:0	.008		2	2	0
157	TC Fuel Injector Purge	0:0:15	0:0:0	.004		2	2	0
159	LOX Dome Purge	0:0:12	0:0:0	.003		2	2	0
160	Operate Fuel Vents to Normal	14:15:0	14:14:0	.017		13	13	4.73

COUNTDOWN FUNCTION DATA

Func. No.	Description	Start Time	Stop Time	Operating Time	Interrelated Functions	Nominal Holdpoint	Maximum Holdpoint	Slack Time
161	LH_2 Control Valve	3:10:0	3:04:56	.001		7	7	.166
162	S-IB Fuel Vent to Auto	0:45:0	0:44:56	.001		6	5	.507
164	Cycle Circuit #1 Vent	0:12:30	0:12:26	.001		4	4	.041
165	Cycle Start Tank Vent	0:12:30	0:12:26	.001		4	4	.041
166	Cycle LOX Tank Vent	0:12:0	0:11:56	.001		4	4	.032
167	Cycle LH_2 Vent	0:12:0	0:11:56	.001		4	4	.032
168	LH_2 Direction Vent to Flt. Pos.	0:0:28	0:0:24	.001		2	2	.007
169	LOX Re-Circ. Pump Check	4:30:0	4:29:30	.008		8	8	.242
170	LH_2 Re-Circ. Pump Check	3:10:0	3:09:30	.008		7	7	.159
171	LOX Re-Circ. Pump Check	0:32:0	0:29:30	.042		5	5	.250
172	LH_2 Re-Circ. Pump Check	0:32:0	0:29:30	.042		5	5	.250
173	S-IVB Chilldown	0:14:30	0:10:0	.075	494	4	3	0
174	S-IVB Propulsion Preps.	14:0:0	13:40:0	.333	477	13	13	0
176	Helium Supply On	6:0:0	5:59:0	.017	147	8	8	.033
177	Monitor Calips Manif. Press.	4:50:0	4:0:0	.834		8, 7	5	3.76
178	Top Switch Checkout	4:35:0	4:0:0	.583		8, 7	5	3.76

COUNTDOWN FUNCTION DATA

Func. No.	Description	Start Time	Stop Time	Operating Time	Interrelated Functions	Nominal Holdpoint	Maximum Holdpoint	Slack Time
179	IU GSCU Closeout	10:40:0	10:0:0	.667		13	12	1.33
180	Short Cable & Mast 2 & 4 Arm	0:0:80	0:0:04	.001		2	2	.001
184	PU System On	H1:0:0	H0:55:0	.083	488	9	9	.333
185	PU Valve Pos. Checks	0:36:0	0:35:0	.017		5	5	.342
186	Propellant Level Cks.	0:16:0	0:14:0	.033		5, 4	4	.067
190	Silo Gate 2 Opening	9:05:0	8:55:0	.167	191	12	10	.416
191	Silo Gate #1 Opening	8:30:0	8:20:0	.167	192	11	10	.333
192	Silo Gate #3 Opening	8:0:0	7:50:0	.167	475	11	10	.983
194	Move SS	6:45:0	6:15:0	.500		10	10	.250
196	Mech. Launch Preps.	13:30:0	13:0:0	.500	144	13	13	2.33
212	Lower ESP	6:50:0	6:0:0	.834		11, 10	11, 10	0
321	Fuel Cell Sharing Load (Ext. Pwr.)	0:15:0		.250		5 → 2	5 → 2	0
324	DT04	14:0:0	13:55:0	.083	482	13	13	1.83
326	Optical Sightings	14:0:0	13:55:0	.083	483	13	13	.417
328	CO_2 Can Instl.	12:0:0	11:55:0	.083		13	13	2.42
329	Suit Prepurge	11:30:0	11:0:0	.500		13	13	1.50

COUNTDOWN FUNCTION DATA

Func. No.	Description	Start Time	Stop Time	Operating Time	Interrelated Functions	Nominal Holdpoint	Maximum Holdpoint	Slack Time
330	SM Lite Ck.	11:30:0	11:15:0	.250		13	13	1.75
331	E-Mem. Verif.	11:0:0	10:20:0	.667		13	13	.833
333	Bid. Med. Ck.	11:0:0	10:0:0	1.0		13	13	.500
334	L/V DRSCS Ck.	10:58:0	10:53:0	.083		13	13	1.38
336	SCS Activation	10:45:0	10:0:0	.75		13	13	.500
337	EDS Test	10:32:0	10:0:0	.533		13	13	.500
339	Open Silo 4	10:25:0	10:15:0	.167		13	13	.750
341	Delta T	9:0:0	8:55:0	.083		12	12	.250
345	Back Up Crew Checks	8:30:0	7:45:0	.75	346	11	10	0
346	SW List	7:45:0	7:20:0	.417		11	10	1.33
347	SC RF (A/G) Voice Checks	6:45:0	6:30:0	.250		10	10	.500
348	LV/FPI	7:30:0	7:25:0	.083		11	11	.667
349	GMIL Transmitter Checks	7:20:0	7:10:0	.167	350	11	10	.417
350	GMIL Support	6:45:0	6:30:0	.250		10	10	.500
355	S-Band TM on	6:30:0	6:28:0	.033		10	10	.467
358	Delta T	4:0:0	3:55:0	.083		7	7	.917

COUNTDOWN FUNCTION DATA

Func. No.	Description	Start Time	Stop Time	Operating Time	Interrelated Functions	Nominal Holdpoint	Maximum Holdpoint	Sl Ti
361	ECS Chilldown	2:45:0	1:45:0	1.0	372	6	6	0
362	E-Memory Verify	3:45:0	3:5:0	.667		7	6	2.
363	Backup Crew Egress	2:25:0	2:20:0	.083		6	6	1.
	Pilots RR to LC 34	2:35:0		.333				
	B/U SCMP in W/R	2:30:0		0.5				
	Flight Crew Ingress	2:25:0		.417				
364	Audio Center on	2:20:0	2:15:0	.083		6	6	1.
368	DT04	2:20:0	2:15:0	.083		6	6	1.
369	Delta T	2:45:0	2:40:0	.083		6	6	2.
370	HFLT CMD Cks.	1:45:0	1:35:0	.167		6	6	.
372	Suit Cks.	1:45:0	1:43:0	.033	490	6	6	.
373	AAS Cks.	1:40:0	1:35:0	.083		6	6	.
374	EDS Test	1:35:0	1:0:0	.583		6	6	.
376	Cabin Purge	1:25:0	1:5:0	.333	377	6	6	0
377	Cabin Press. & Leak Ck.	1:5:0	0:45:0	.333		6	6	.
378	RF Readouts	0:45:0	0:0:0	.75		6 → 2	6 → 2	0
382	Pyro, Logic Busses Armed	0:33:0	0:31:0	.033		5	5	.2

COUNTDOWN FUNCTION DATA

Func. No.	Description	Start Time	Stop Time	Operating Time	Interrelated Functions	Nominal Holdpoint	Maximum Holdpoint	Slack Time
383	EDS Power On	0:34:0	0:33:0	.017	493	5	5	0
385	RCS Static Fire	0:20:0	0:15:0	.083		5	5	.008
386	A/G Voice Checks	0:10:0	0:5:0	.083		3	3	.038
391	Flight Crew to White Room	2:25:0	2:20:0	.083	489	2	2	0
400	Automatic Sequencer	0:02:44	0:0:0	.044		2	2	0
401	Azimuth Laying & Align. Cks.	1:55:0	1:40:0	.250		6	6	1.000
402	Flight Control Cks.	3:5:0	2:20:0	.750	1	7, 6	3	.833
403	RF & TM Cks.	12:45:0	12:5:0	.667	8	13	12	.083
404	Control System Functional	12:45:0	12:5:0	.667	1	13	11	0
405	DDAS Checks	12:0:0	11:35:0	.420		13	12	2.92
410	Pneu. Operated Comp. Verif.	H1:35:0	H1:5:0	.500	411	9	7	0
411	RF-1 Facility Verif. and Setup	H1:5:0	H0:35:0	.500	412	9	7	0
412	Optional Pump Verif. Oper.	H0:35:0	5:50:0	.750	70	9, 8	6	2.67
413	LOX Sys. Preps. at B/H Pnls.	H1:0:0	H0:5:0	.917	82, 91	9	13	.083
414	LH_2 Fac. Prop. Cont. Console Setup	H2:15:0	H2:0:0	.250	415	9	7	0

COUNTDOWN FUNCTION DATA

Func. No.	Description	Start Time	Stop Time	Operating Time	Interrelated Functions	Nominal Holdpoint	Maximum Holdpoint	Slack Time
415	LH_2 Cont. Valve Pnl. Setup	H2:0:0	H1:50:0	.167	416	9	7	0
416	Propellants Cont. Console Setup	H1:50:0	H1:40:0	.167	417	9	7	0
417	Helium Purge Console Setup	H1:40:0	H1:30:0	.167	418	9	7	0
418	LH_2 Purge Panel Setup	H1:30:0	H1:0:0	.500	419	9	7	0
419	GHe Stor. Tk. Vent Line Purge	H1:0:0	H0:50:0	.167	420	9	7	0
420	LH_2 Prop. Computer Cont. Setup	H0:50:0	H0:30:0	.333	421	9	7	0
421	GHe Purge of Vent Lines & O_2 Sampling	H0:30:0	H0:0:0	.500	76	9	7	.75
422	LH_2 Stor. Tanks Repl.	2:59:0	1:6:0	1.880	423	6	6	0
423	Stop LH_2 Storage Tanks Repl.	1:6:0	1:5:0	.017		6	6	.41
424	LH_2/GN_2 Cont. Pnl. Sw. Verif.	4:28:0	4:26:0	.033	425	8	7	0
425	He Cont. Pnl. Sw. Verif. for LH_2 Loading	4:26:0	4:24:0	.033	426	8	7	0
426	S-IVB LH_2 Stor. Press. Pnl. Sw. Verification	4:24:0	4:22:0	.033	427	8	7	0
427	S-IVB LH_2 Prop. Sys. Pnl. Sw. Verification	4:22:0	4:20:0	.033	428	8	7	0
428	S-IVB LH_2 ESE Pnl. Sw. Verif.	4:20:0	4:15:0	.083	78	8	7	0

COUNTDOWN FUNCTION DATA

Func. No.	Description	Start Time	Stop Time	Operating Time	Interrelated Functions	Nominal Holdpoint	Maximum Holdpoint	Slack Time
429	LOX/GN_2 Cont. Pnl. Sw. Verif	5:58:0	5:56:0	.033	430	8	8	0
430	He Cont. Pnl. Sw. Verif. for LOX Loading	5:56:0	5:54:0	.033	431	8	8	0
431	S-IVB Stage Press. Pnl. Sw. Verif.	5:54:0	5:52:0	.033	432	8	8	0
432	S-IVB LOX Prop. Sys. Pnl. Sw. Verif.	5:52:0	5:50:0	.033	433	8	8	0
433	S-IVB ESE Pnl. Sw. Verif.	5:50:0	5:45:0	.083	83	8	8	0
434	Press. VP-10 (GN_2) from PCD (1700 psig)	14:5:0	14:3:0	.033	435	13	10	0
435	Perform VP-10 (GN_2) Setups (press. 1700 psig)	14:3:0	13:50:0	.217	142	13	10	3.33
436	Perform VP-9 (GN_2 Setups)	13:50:0	13:45:0	.083	437	13	10	0
437	Press. VP-9 from PCD (1700 psig GN_2)	13:45:0	13:43:0	.033	438	13	10	0
438	Perform VP-9 (GN_2) Setups (pressurized 1700 psig)	13:43:0	13:35:0	.133	142	13	10	3.03
439	Perform PCD (He) Setups	13:35:0	13:25:0	.167	440, 443, 478	13	10	.333
440	Perform VP-10 (He) Setups (Valve Positions Verif.)	13:25:0	13:12:0	.217	441	13	10	0

COUNTDOWN FUNCTION DATA

Func. No.	Description	Start Time	Stop Time	Operating Time	Interrelated Functions	Nominal Holdpoint	Maximum Holdpoint	Slack Time
441	Press. VP-10 (1700 psig) from PCD	13:12:0	13:10:0	.033	442	13	10	0
442	Perform VP-10 (He) Setups (Pressurized 1700 psig)	13:10:0	13:5:0	.083	142	13	10	2.50
443	Perform VP-9 (He) Setups (Verification)	13:5:0	13:0:0	.083	444	13	10	0
444	Press. VP-9 from Pneu. Cont. Dist. (He)	13:0:0	12:58:0	.033	445	13	10	0
445	Perform VP-9 (He) Setups (Pressurized 1700 psig)	12:58:0	12:48:0	.167	146	13	10	1.35
446	FDM Warm Up	13:55:0	13:0:0	.917	447	13	13	0
447	Strip Chart Recorders Cks.	13:0:0	12:40:0	.333	448	13	13	0
448	DC Amplifiers Checks	12:40:0	12:20:0	.333	449	13	13	0
449	Ramp Generator Checks	12:20:0	12:0:0	.333		13	13	2.50
450	HGD Remote Control Operation	13:30:0	12:15:0	1.250	451	13	13	0
451	HGD Sys. Standby Preps.	12:15:0	12:0:0	.250		13	13	2.50
452	Water Control Pnl. Sw. Verif.	11:15:0	11:0:0	.250	453	13	13	0
453	Water Control Sys. Pwr. Up	11:0:0	10:45:0	.250	454	13	13	0

COUNTDOWN FUNCTION DATA

Func. No.	Description	Start Time	Stop Time	Operating Time	Interrelated Functions	Nominal Holdpoint	Maximum Holdpoint	Slack Time
454	Water Cont. Pnl. Valve Pos. Verif. Checks	10:45:0	10:30:0	.250	455	13	13	0
455	Main Valve Oper. Checks	10:30:0	10:0:0	.500		13	13	.500
456	Press. PCD (GN_2 Pnl) to 3100 psig	10:15:0	10:0:0	.250	458, 459, 460, 461, 462, 463	13	10	.500
457	Press. PCD (He Pnl) to 3100 psig	10:0:0	9:45:0	.250	459, 460, 462, 464	13	10	.250
458	Perform VP-5 (3100 psig GN_2) Setup	9:45:0	9:30:0	.250	465	13	10	0
459	Perform VP-10 (3100 psig) Setup	9:30:0	9:15:0	.250	466	12	10	1.50
460	Perform VP-9 (3100 psig) Setup	9:15:0	9:0:0	.250	469	12	10	2.17
461	Perform Deluge Purge Pnl. Setup	9:0:0	8:45:0	.250	468	12	10	1.75
462	Perform PCD Platform Comp. Status Check	8:45:0	8:30:0	.250		12, 11	10	2.50
463	Perform PCD (GN_2) Comp. Status Check	8:30:0	8:15:0	.250		11	10	2.25
464	Perform PCD (He) Comp. Status Check	8:15:0	8:0:0	.250		11	10	2.00
465	Perform VP-5 Comp. St. Cks.	8:0:0	7:45:0	.250		11	10	1.75

COUNTDOWN FUNCTION DATA

Func. No.	Description	Start Time	Stop Time	Operating Time	Interrelated Functions	Nominal Holdpoint	Maximum Holdpoint	Slac Tim
466	Perform VP-10 (GN_2) Comp. Status Check	7:45:0	7:15:0	.500	467	11	10	0
467	Perform VP-10 (He) Comp. Status Check	7:15:0	7:0:0	.250		11	10	1.0
468	Perform Deluge Purge Pnl. Comp. Status Check	7:0:0	6:50:0	.167		11	10	.8
469	Perform VP-9 (GN_2) Comp. Status Check	6:50:0	6:40:0	.167	470	11, 10	10	0
470	Perform VP-9 (He) Comp. Status Check	6:40:0	6:30:0	.167		10	10	.5
471	B/H AAA Pnl. Sw. Pos. Cks.	11:20:0	11:0:0	.333	472	13	13	0
472	B/H Pnl. Sw. Pos. Checks	11:0:0	10:40:0	.333	473	13	13	0
473	B/H Pnl. Light Indication Cks.	10:40:0	10:20:0	.333	474	13	13	0
474	B/H AAA Pnl. Light Ind. Cks.	10:20:0	10:0:0	.333		13	13	.5
475	Remove Anchor Pins 6:51—6:50	6:51:0	6:50:0	.017	476	11	10	0
476	Jack Service St. 6:50 — 6:45	6:50:0	6:45:0	.083	194	11	10	0
477	Pneu. Cons. & Ht. Exc. Setup	13:40:0	13:20:0	.333	481	13	13	1.0
478	Pneu. Cons. GN_2 Setup	13:20:0	13:0:0	.333	479	13	13	0

COUNTDOWN FUNCTION DATA

Func. No.	Description	Start Time	Stop Time	Operating Time	Interrelated Functions	Nominal Holdpoint	Maximum Holdpoint	Slack Time
479	Main Helium Setup	13:0:0	12:40:0	.333	480	13	13	0
480	GH_2 Regulator Verification	12:40:0	12:20:0	.333	481	13	13	0
481	Pneu. Cons. & Ht. Exch. Valve Cycling	12:20:0	12:0:0	.333		13	13	2.50
482	Final Crew Storage (Egress)	12:5:0	12:0:0	.083		13	13	2.50
483	Optical Sighting	13:30:0	13:25:0	.083	484	13	13	.417
484	Optical Sighting	13:0:0	12:55:0	.083	485	13	13	.417
485	Optical Sighting	12:30:0	12:25:0	.083		13	13	2.92
486	Final GH_2 Cont. Pnl. Preps	8:42:0	8:30:0	.200	487	12, 11	10	.083
487	(Final GH_2 Preps) S-IVB Pneu. Cons. & HEX	8:25:0	8:5:0	.333		11	10	2.08
488	PU (N63) Power Checks	H0:35:0	H0:33:0	.017		9	9	.550
489	Flight Crew Ingress (AAA)	2:20:0	2:10:0	.033		6	6	1.50
490	Suit Comp. Oper. Checks	1:40:0	1:35:0	.083	491	6	6	0
491	Suit O_2 Purge	1:35:0	1:30:0	.083	492	6	6	0
492	Suit Flow Rate Checks	1:30:0	1:25:0	.083	376	6	6	0
493	EDS Checks	0:33:0	0:0:0	.550		5 — 2	5 — 2	0
494	Thrust Chamber Chilldown	0:10:0	0:2:44	.120		3	3	0

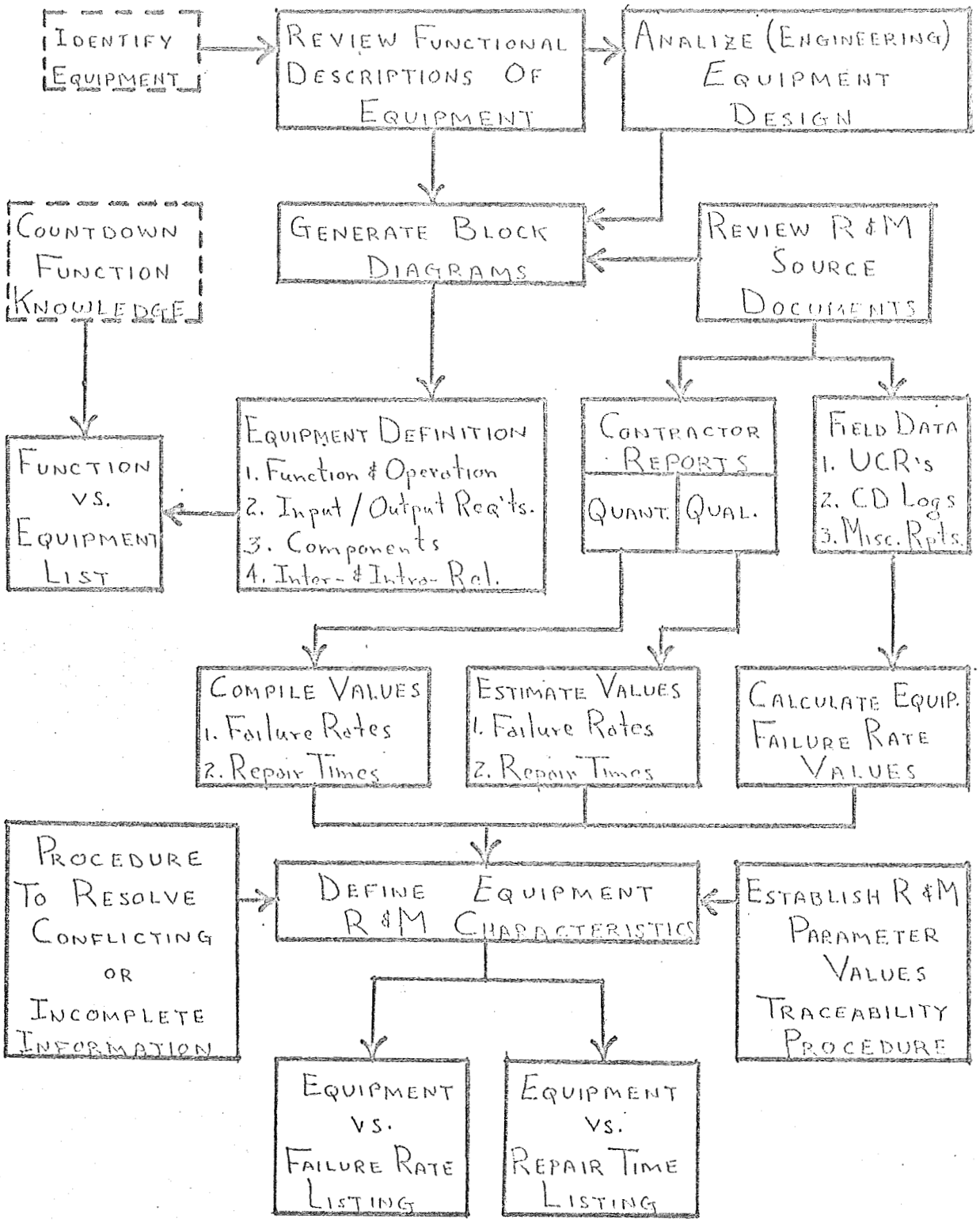
VIII SUPPORT EQUIPMENT ANALYSIS

In order to make an accurate determination of the launch probability due to support considerations, an analysis of each launch support equipment is necessary. Implementation of the launch-in-window probability model requires three outputs from this analysis: (1) the association of each equipment with applicable countdown functions, (2) the determination of a failure rate for each equipment and (3) the determination of a repair time for each equipment. The attainment of these outputs can be accomplished in the following manner: first identify the elements of the launch support system (see Section VI); second gain an understanding of the purpose, function, components and operation of each element; then associate each element with applicable countdown function (output #1); analyze available reliability and maintainability documents and field data sources to determine a failure rate and a repair time for each element (outputs #2 and #3). Figure VIII-1 is a flow diagram depicting the method used in performing the support equipment analysis.

8.1 SUPPORT EQUIPMENT DEFINITION

After the elements of the launch support system have been identified, each part is reviewed in detail in order to determine its purpose, required input and output, general operating modes, components and relation to other elements. This support equipment definition is accomplished by a detailed review and analysis of source documents which provide functional descriptions of the equipments. From these descriptions and from engineering analyses, a functional reliability

FIGURE VIII-1 SUPPORT EQUIPMENT ANALYSIS



block diagram is prepared for each launch support equipment. In Figure VIII-2 are the block diagrams determined to represent each equipment. This is done in order to clarify the inter- and intra- operating relations existing among the elements of the launch support system and among the components of each element. This portion of the analysis is performed (1) in order to determine which equipment or combination of equipments is required to perform each launch support function and (2) to aid in performing subsequent reliability and maintainability analyses. This procedure must provide an accurate representation of the launch support operations. The understanding of each element of the launch support system permits each equipment or equipment component to be associated with applicable countdown functions (NOTE: An entire system level equipment normally is not required in the performance of a support function. Often, only one or a few of its subsystems are required and the remaining subsystems are not.). For the purposes of this study, subsystems are not defined for (1) those systems which require all of its subsystems to be operable in order for it to perform every associated function, and (2) those cases where data concerning operational techniques or performance characteristics are available only at the system level.

8.2 EQUIPMENT REQUIRED TO SUPPORT FUNCTIONS

For the successful performance of each function or activity comprising the countdown operations, one or more support systems are required. The requirements for determining which equipments are actually necessary to support each and every countdown function requires a thorough understanding of the function

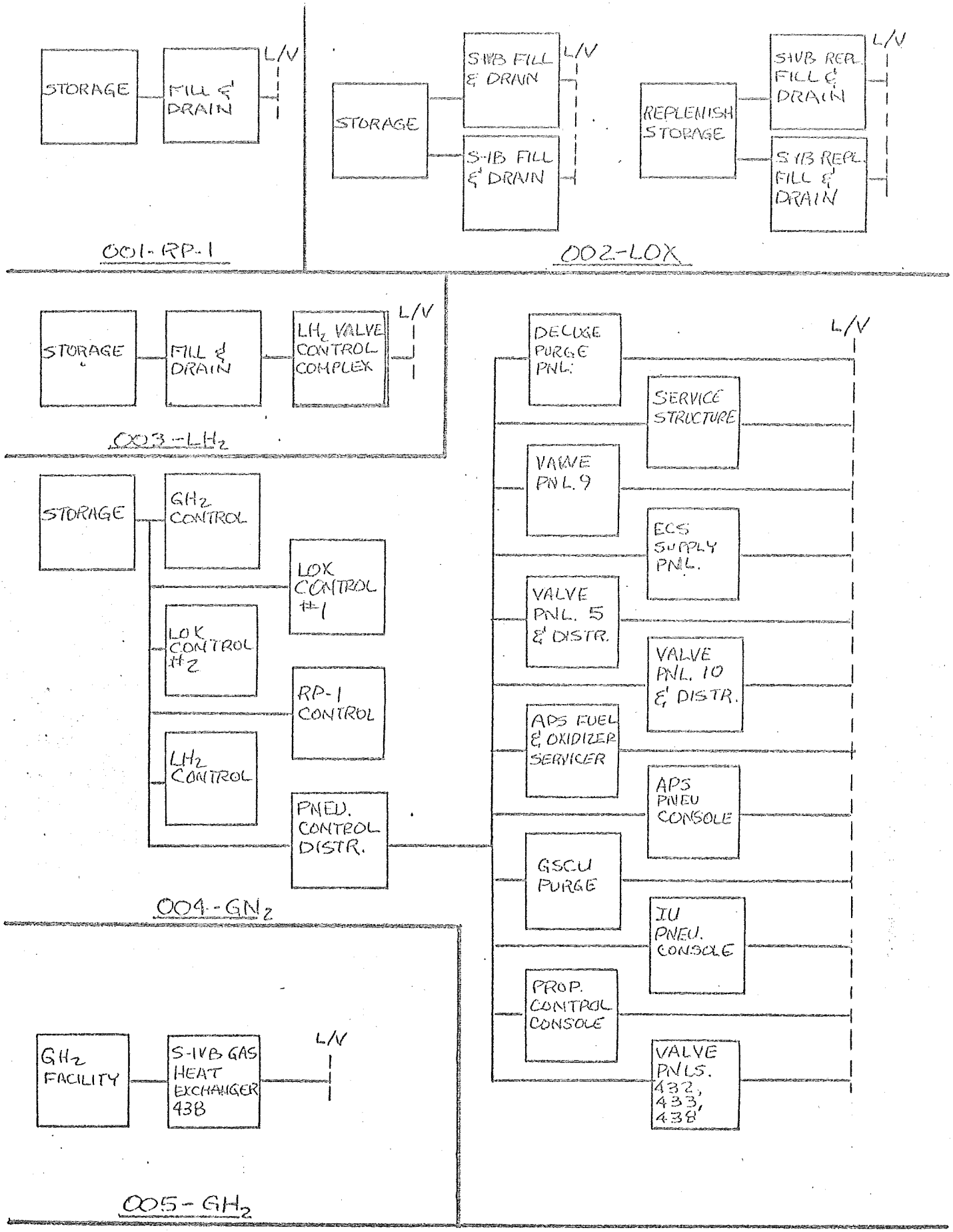
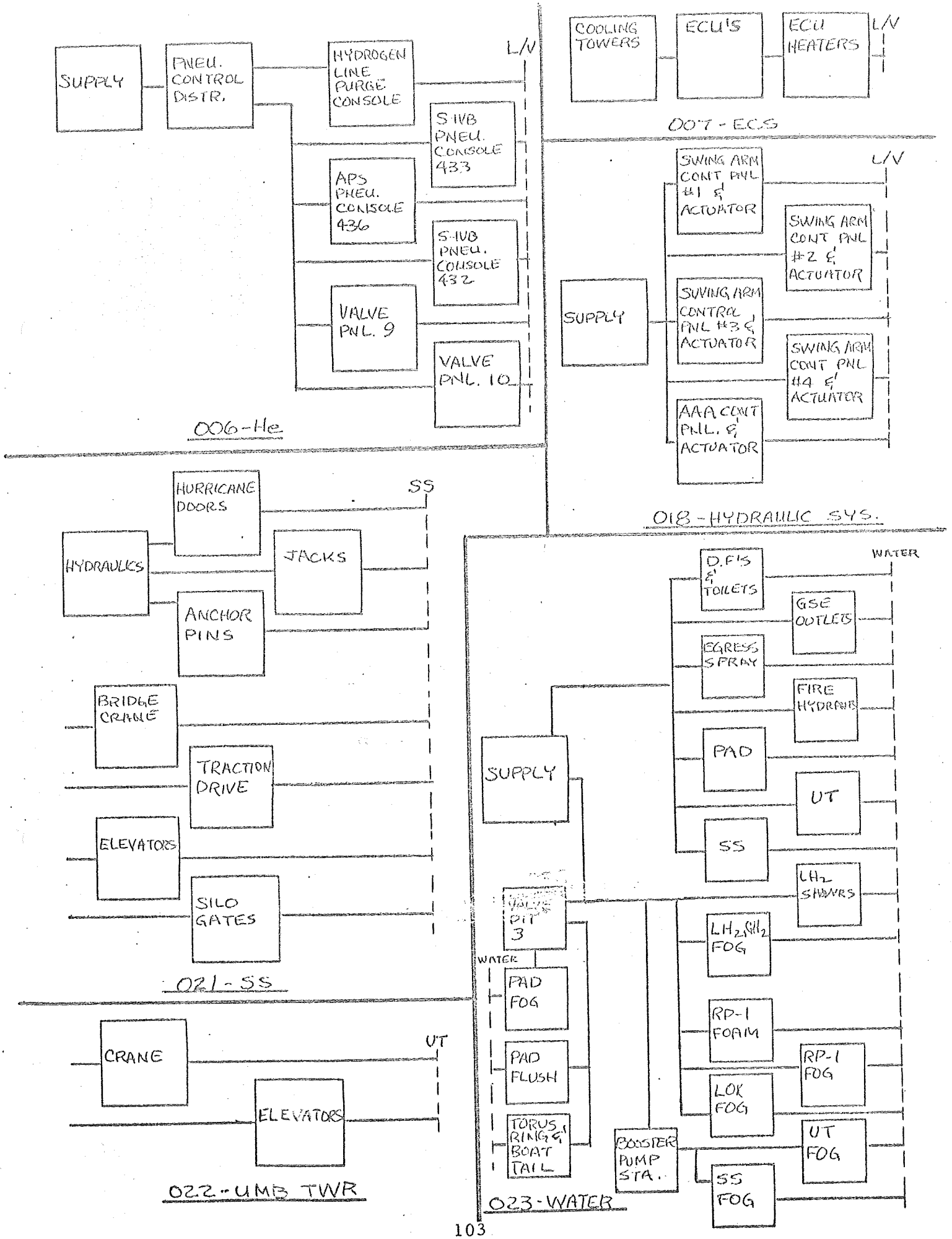
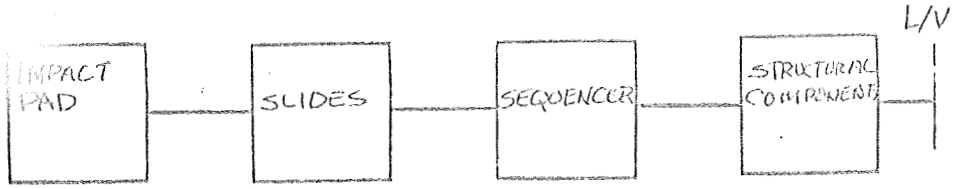
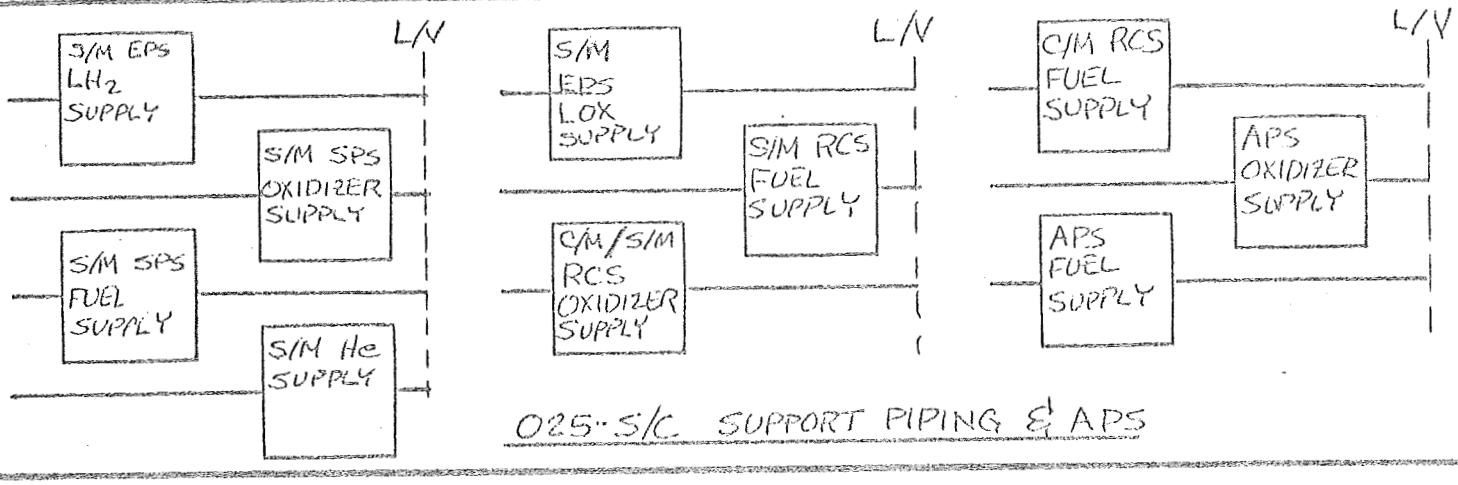


FIGURE VIII-2 FUNCTIONAL BLOCK DIAGRAMS (7 sheets)

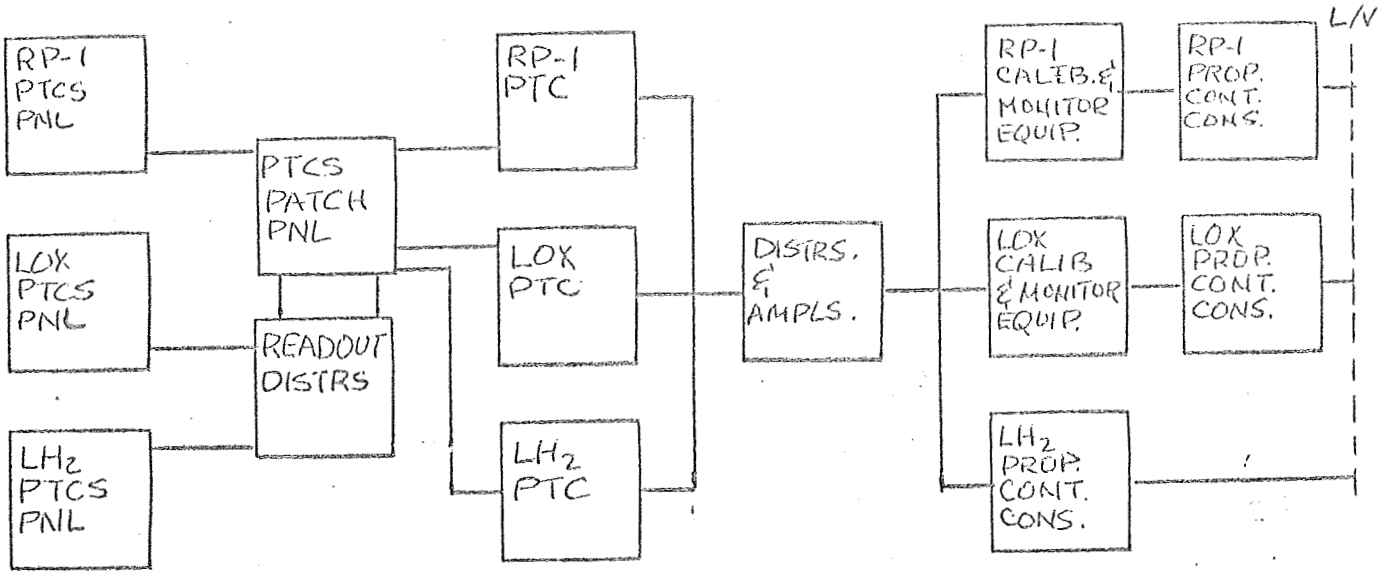

SUPPLY
PNEU. CONTROL DISTR.
HYDROGEN LINE PURGE CONSOLE
S-IVB PNEU. CONSOLE 433
APS PNEU. CONSOLE 436
S-IVB PNEU. CONSOLE 432
VALVE PNL. 9
VALVE PNL. 10
L/V
006-He
COOLING TOWERS
ECU'S
ECU HEATERS
L/V
007-ECS
SUPPLY
SWING ARM CONT PNL #1 & ACTUATOR
SWING ARM CONT PNL #2 & ACTUATOR
SWING ARM CONTROL PNL #3 & ACTUATOR
SWING ARM CONT PNL #4 & ACTUATOR
AAA CONT PNL. & ACTUATOR
L/V
018-HYDRAULIC SYS.
HURRICANE DOORS
HYDRAULICS
JACKS
ANCHOR PINS
BRIDGE CRANE
TRACTION DRIVE
ELEVATORS
SILO GATES
SS
021-SS
CRANE
ELEVATORS
UT
022-UMB TWR
SUPPLY
D.F'S & TOILETS
GSE OUTLETS
EGRESS SPRAY
FIRE HYDRANT
PAD
UT
SS
LH2 SHOWERS
LH2, SH2 FOG
RP-1 FOAM
RP-1 FOG
LOX FOG
UT FOG
SS FOG
BOOSTER PUMP STA.
VALVE PIT 3
WATER
PAD FOG
PAD FLUSH
TORUS RING & BOAT TAIL
WATER
023-WATER



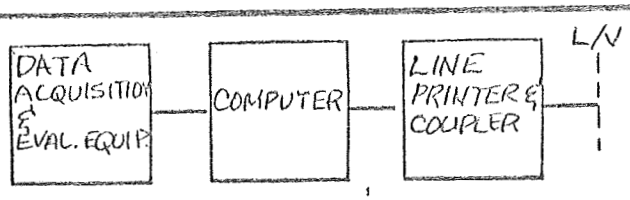
024-EMERGENCY EGRESS



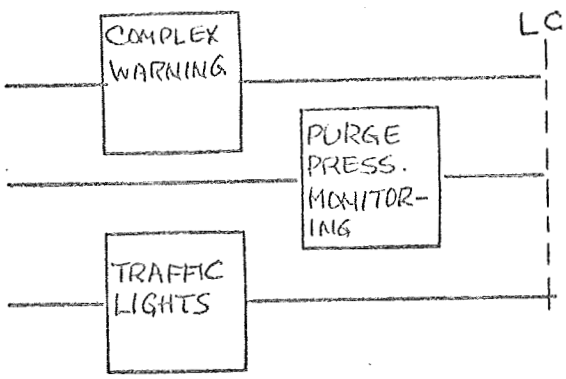
025-S/C SUPPORT PIPING & APS



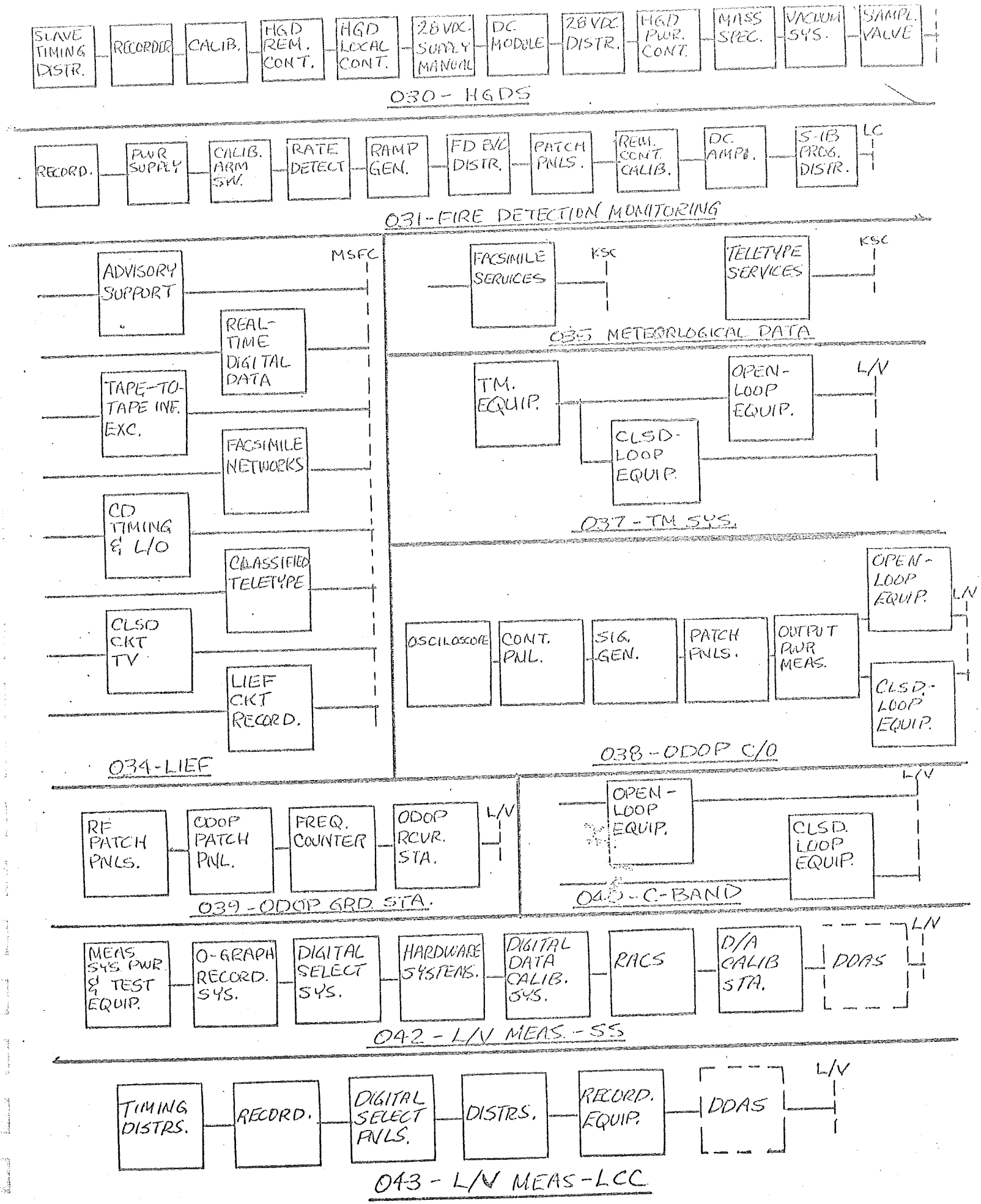
027-PTCS



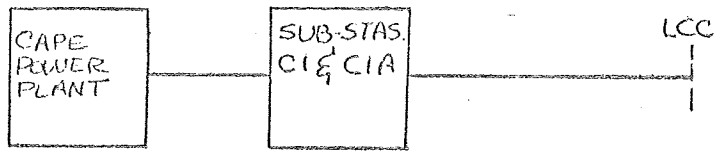
028-DEE-3



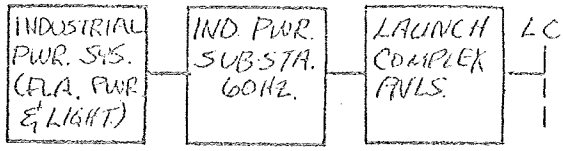
029-FACILITY MEASURING


SLAVE TIMING DISTR.
RECORDER
CALIB.
HGD REM. CONT.
HGD LOCAL CONT.
28 VDC. SUPPLY MANUAL
DC MODULE
28 VDC. DISTR.
HGD PWR. CONT.
MASS SPEC.
VACUUM SYS.
SAMPL. VALVE
030 - HGDS
RECORD.
PWR SUPPLY
CALIB. ARM SW.
RATE DETECT
RAMP GEN.
FD B/C DISTR.
PATCH PNLS.
REM. CONT. CALIB.
DC AMPS.
S-IB PROG. DISTR.
LC
031 - FIRE DETECTION MONITORING
MSFC
ADVISORY SUPPORT
REAL-TIME DIGITAL DATA
TAPE-TO-TAPE INF. EXC.
FACSIMILE NETWORKS
CD TIMING & L/O
CLASSIFIED TELETYPE
CLSD CKT TV
LIEF CKT RECORD.
034 - LIEF
FACSIMILE SERVICES
KSC
TELETYPE SERVICES
KSC
035 METEOROLOGICAL DATA
TM. EQUIP.
OPEN-LOOP EQUIP.
L/V
CLSD-LOOP EQUIP.
037 - TM SYS.
OSCILOSCOPE
CONT. PNL.
SIG. GEN.
PATCH PNLS.
OUTPUT PWR MEAS.
OPEN-LOOP EQUIP.
L/V
CLSD-LOOP EQUIP.
038 - ODOP C/O
RF PATCH PNLS.
ODOP PATCH PNL.
FREQ. COUNTER
ODOP RCVR. STA.
L/V
039 - ODOP GRD STA.
L/V
OPEN-LOOP EQUIP.
CLSD. LOOP EQUIP.
040 - C-BAND
MEAS. SYS. PWR & TEST EQUIP.
O-GRAPH RECORD. SYS.
DIGITAL SELECT SYS.
HARDWARE SYSTEMS.
DIGITAL DATA CALIB. SYS.
RACS
D/A CALIB STA.
DDAS
L/V
042 - L/V MEAS. - SS
TIMING DISTRS.
RECORD.
DIGITAL SELECT PNLS.
DISTRS.
RECORD. EQUIP.
DDAS
L/V
043 - L/V MEAS - LCC

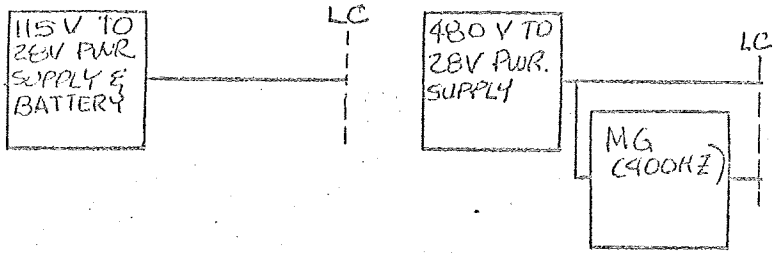
044-ABORT ADVISORY



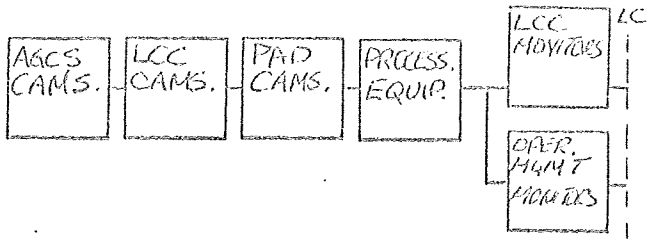
015-CAPE PWR



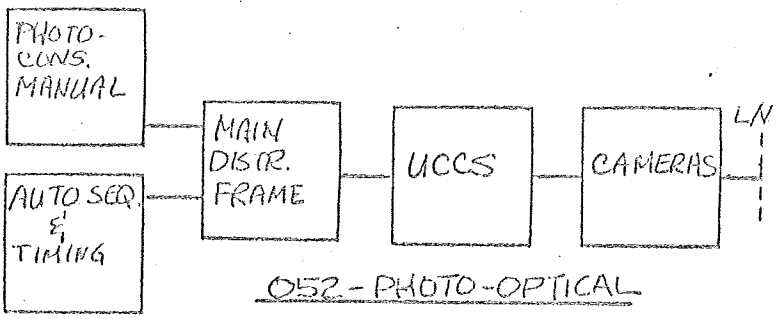
049-60 HZ.



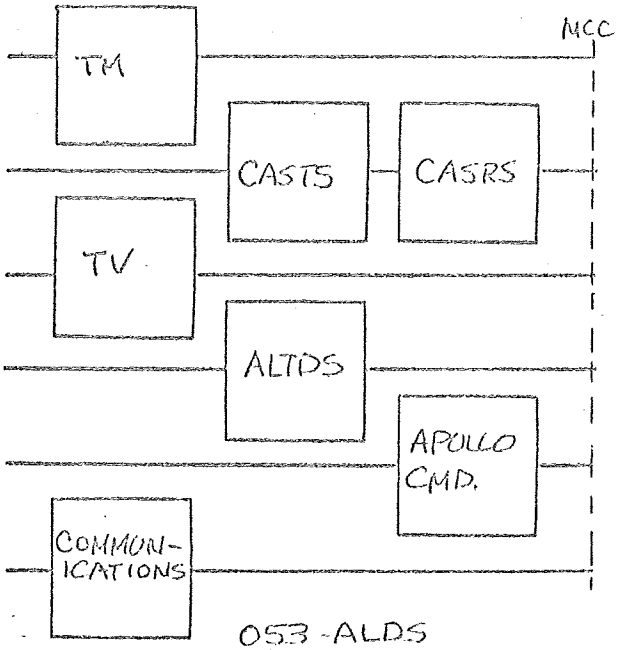
050-SPECIAL PWR



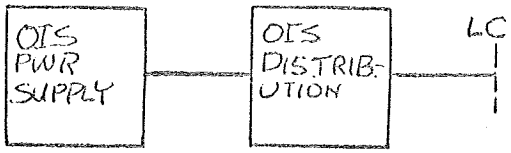
051-OPERATIONAL TV



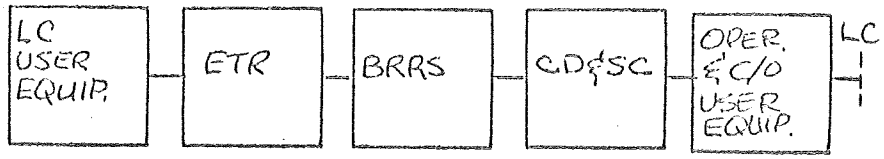
052-PHOTO-OPTICAL



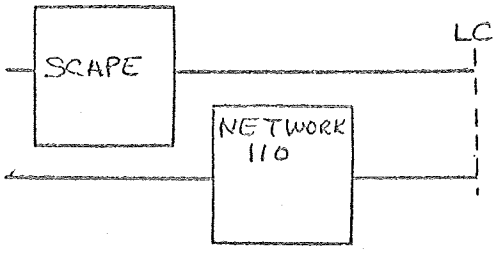
053-ALDS



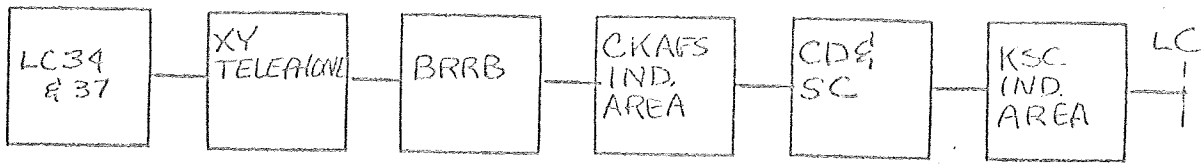
054-OTS



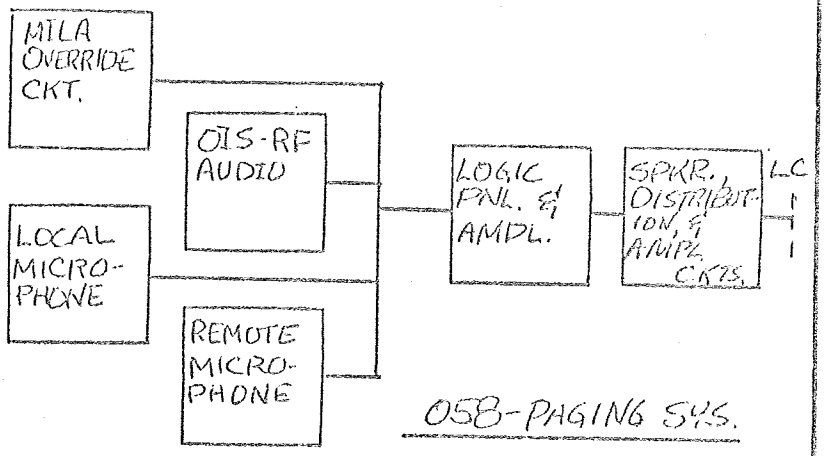
055-WIDEBAND TRANSMISSION



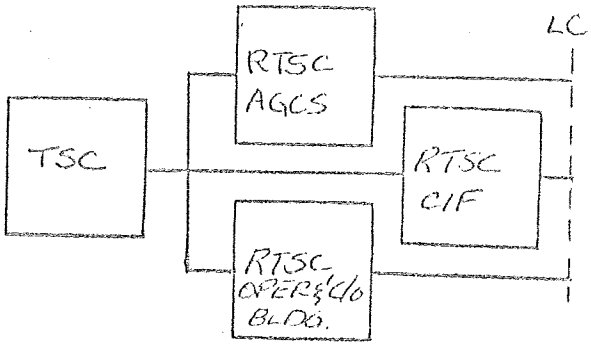
056-RF COMM.



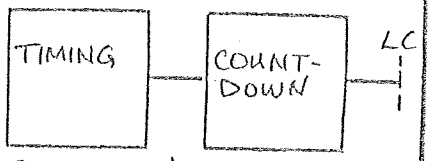
057- TELEPHONE, DATA, & SPL. AUDIO



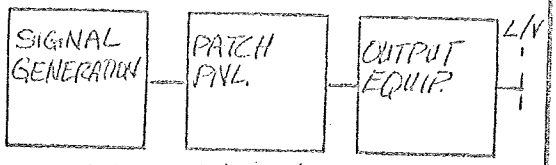
058-PAGING SYS.



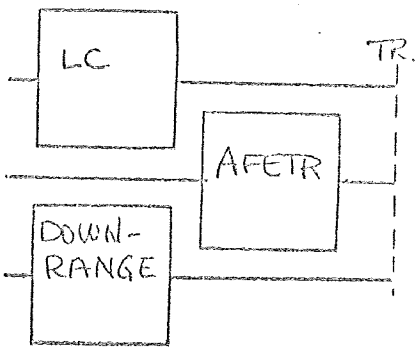
059- TEST & SWITCHING CNTRS.



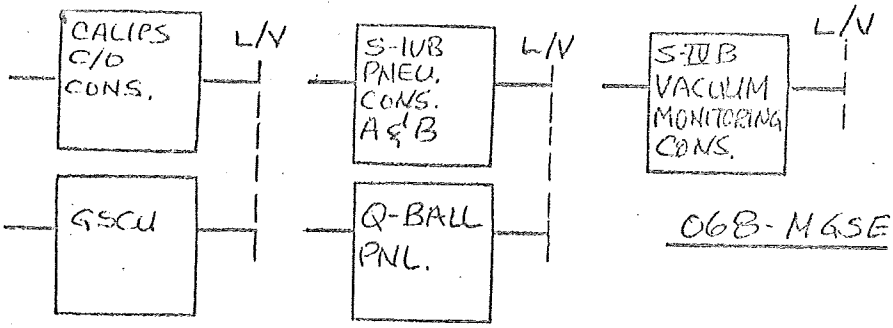
060- TIMING & COUNTDOWN



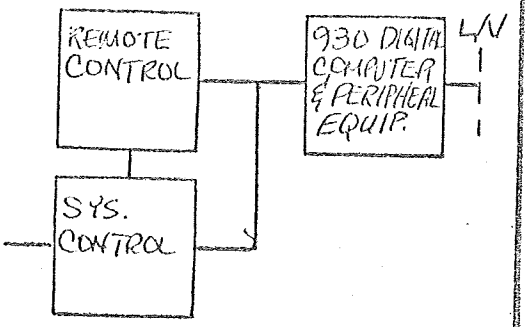
062-R/S C/O



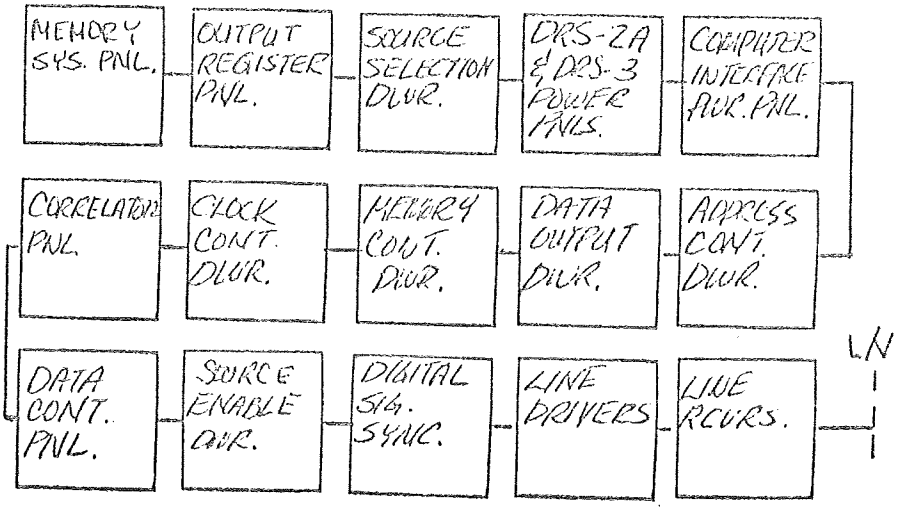
067-OPTIC TR.



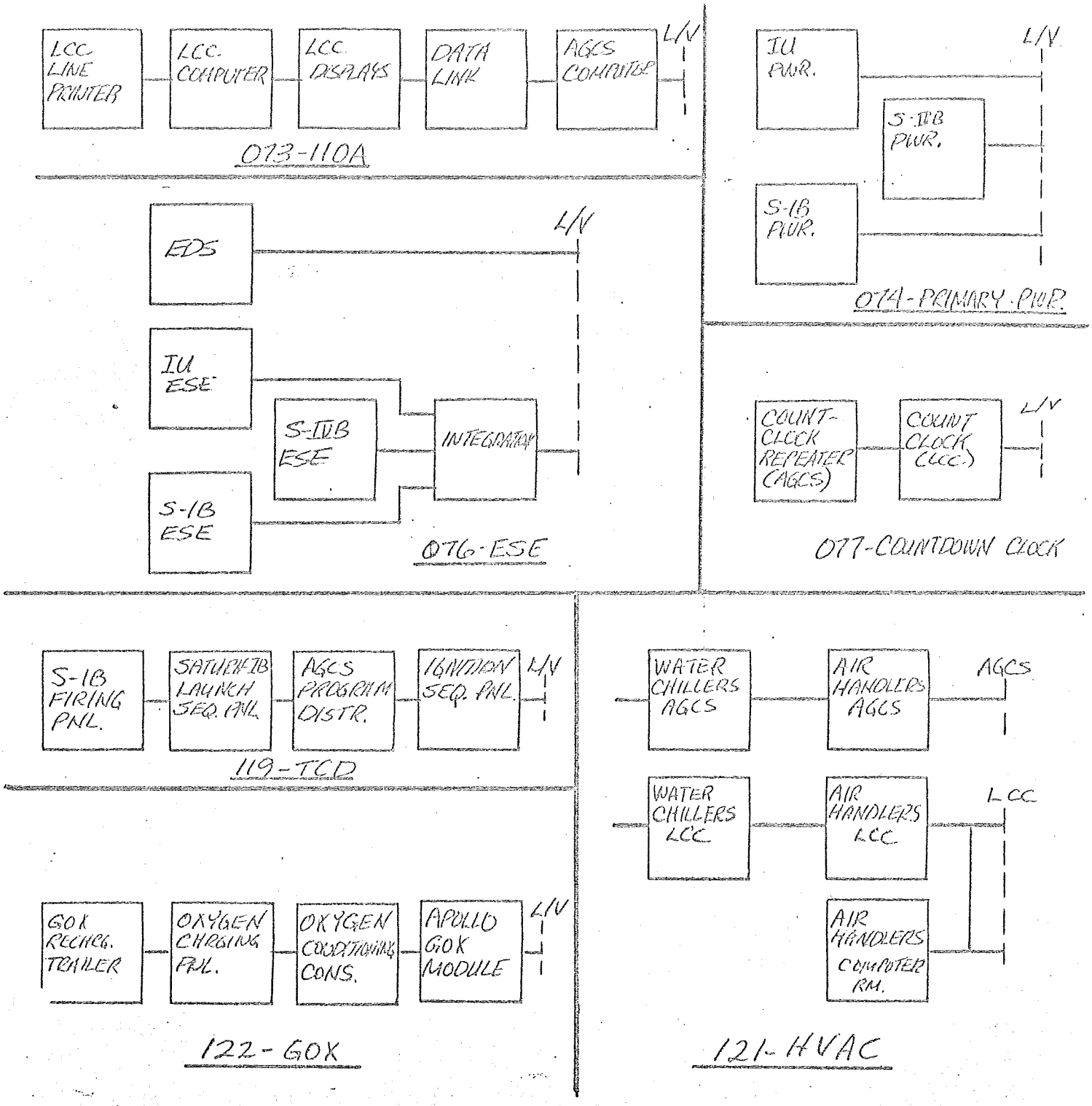
068-MGSE



071-DEE-6



072-DDAS


LCC LINE PRINTER
LCC COMPUTER
LCC DISPLAYS
DATA LINK
AGCS COMPUTER
L/V
073-110A
IU PWR.
S-IVB PWR.
S-IB PWR.
L/V
074-PRIMARY PWR.
EDS
L/V
IU ESE
S-IVB ESE
INTEGRATOR
S-IB ESE
076-ESE
COUNT-CLOCK REPEATER (AGCS)
COUNT CLOCK (LCC)
L/V
077-COUNTDOWN CLOCK
S-IB FIRING PNL.
SATURN IB LAUNCH SEQ. PNL.
AGCS PROGRAM DISTR.
IGNITION SEQ. PNL.
L/V
119-TCD
WATER CHILLERS AGCS
AIR HANDLERS AGCS
AGCS
WATER CHILLERS LCC
AIR HANDLERS LCC
LCC
AIR HANDLERS COMPUTER RM.
GOX RECHRG. TRAILER
OXYGEN CHRGING PNL.
OXYGEN CONDITIONING CONS.
APOLLO GOX MODULE
L/V
122-GOX
121-HVAC

and a total cognizance of support equipment capabilities. Familiarization with the system checkout documents as well as review and study of related documents concerning equipment and procedures can aid in acquiring such understanding. Ultimately, the application of engineering judgment must establish whether or not a function can be performed, given that an equipment is not operating.

The association of countdown functions with all of its required support equipments is a necessary input to the availability model. The process of associating functions with equipments consist simply of reviewing the total systems list (Section 6.3) and checking off, one by one, the systems that are directly and indirectly required in the performance of that function. These considerations are facilitated by the use of the system block diagrams, which indicate interdependency or independence of equipments. Even though a system may not be required in the direct support of a function, it must be associated with the function if it supports another system which is required by the function. Beyond that, even when there is no operating ties with function related equipment, an equipment must be associated with a function if its repair procedural requirements would cause the interruption of normal operations of a function-related equipment.

Table VIII-1 presents a listing of all the functions required in the last 14 hours of the countdown, together with the support equipments that they require. Table VIII-1 is a duplication of part of the input data sheet of the computer program. The functions are listed in the left column (FUN. NO.) with the associated equipments (EQP) listed as rows. Table VII-2 and Table VIII-5 should be reviewed to correlate the numbers with the functions and equipment names.

TABLE VIII-1 COUNTDOWN FUNCTION VS. SUPPORT EQUIPMENT (9 sheets)

FUN. NO.	EQP	EQP	EQP	EQP	EQP	EQP	EQP	EQP	EQP	EQP	EQP	EQP	EQP	EQP	EQP	EQP	EQP	EQP	EQP
1	32	46	47	75	941	942	1100	1101	1180	1181	1182	1260	1261	1262	1265	1266	1300	1301	1302
1	1303	1620	1621	1622	1640	1641	1642	1643	1644	1645	1646	1647	1648	1649	1650	1651	1652	1653	1654
1	1660	1663	1664	1680	1681	1682	1720	1721	1722	1723	1740	1741							
2	46	47	75	941	942	1100	1101	1180	1181	1182	1300	1301	1302	1303	1621	1622	1640	1641	1642
2	1643	1644	1645	1646	1647	1648	1649	1650	1651	1652	1653	1654	1660	1663	1664	1680	1681	1682	1720
2	1721	1722	1723	1740	1741														
3	32	46	47	61	75	1100	1101	1180	1181	1182	1260	1300	1301	1302	1303	1660	1663	1664	1680
3	1681	1682	1720	1721	1722	1723	1724	1740	1741										
4	32	46	47	75	941	942	1100	1101	1180	1181	1182	1260	1261	1262	1263	1266	1300	1301	1302
4	1303	1620	1621	1622	1640	1641	1642	1643	1644	1645	1646	1647	1648	1649	1650	1651	1652	1653	1654
4	1660	1663	1664	1680	1681	1682	1720	1721	1722	1723	1740	1741							
6	46	47	1100	1101	1180	1181	1182	1220	1221	1222	1223	1224	1225	1280	1281	1300	1301	1302	1303
6	1304	1340	1341	1342	1344	1345	1363	1364	1365	1380	1381	1382							
7	32	46	47	1100	1101	1180	1181	1182	1260	1261	1262	1263	1264	1265	1266	1300	1301	1302	1303
7	1340	1341	1342	1344	1345														
8	32	33	36	46	47	75	880	881	883	884	941	942	1100	1101	1180	1181	1182	1260	1261
8	1262	1263	1266	1300	1301	1302	1303	1304	1400	1401	1620	1621	1622	1660	1663	1664	1680	1681	1682
8	1720	1721	1722	1723	1740	1741													
9	32	33	36	46	47	75	941	942	1100	1101	1180	1181	1182	1260	1261	1262	1300	1301	1302
9	1303	1304	1400	1401	1620	1621	1622	1640	1641	1642	1643	1644	1645	1646	1647	1648	1649	1650	1651
9	1652	1653	1654	1660	1663	1664	1680	1681	1682	1720	1721	1722	1723	1740	1741				
10	32	33	36	46	47	61	63	65	75	941	942	1100	1101	1180	1181	1182	1261	1262	1266
10	1300	1301	1302	1303	1304	1440	1441	1442	1620	1621	1622	1640	1641	1642	1643	1644	1645	1646	1647
10	1648	1649	1650	1651	1652	1653	1654	1660	1663	1664	1680	1681	1682	1720	1721	1722	1723	1724	1740
10	1741																		
11	46	47	64	66	75	941	942	1001	1100	1101	1180	1181	1182	1300	1301	1302	1303	1304	1620
11	1621	1622	1640	1641	1642	1643	1644	1645	1646	1647	1648	1649	1650	1651	1652	1653	1654	1660	1663
11	1664	1682	1722	1723	1740	1741													
12	32	33	36	46	47	64	66	75	941	942	961	1100	1101	1180	1181	1182	1300	1301	1302
12	1303	1304	1400	1401	1620	1621	1622	1640	1641	1642	1643	1644	1645	1646	1647	1648	1649	1650	1651
12	1652	1653	1654	1660	1663	1664	1680	1720	1723										
20	46	47	1100	1101	1180	1181	1182	1280	1281	1300	1301	1302	1303	1304	1340	1341	1342	1344	1345
20	1380	1381	1382																
23	32	46	47	75	941	942	1100	1101	1180	1181	1182	1260	1261	1262	1265	1266	1300	1301	1302
23	1303	1304	1620	1621	1622	1640	1641	1642	1643	1644	1645	1646	1647	1648	1649	1650	1651	1652	1653
23	1654	1660	1663	1664	1680	1681	1682	1720	1721	1722	1723	1724	1740	1741					
25	46	47	75	1100	1101	1180	1181	1182	1620	1621	1622	1660	1663	1664	1680	1681	1682	1720	1721
26	1722	1723	1740	1741															
27	32	33	36	46	47	61	63	65	75	941	942	1060	1061	1062	1063	1064	1100	1101	1180
27	1181	1182	1261	1262	1266	1300	1301	1302	1303	1304	1440	1441	1442	1620	1621	1622	1640	1641	1642
27	1643	1644	1645	1646	1647	1648	1649	1650	1651	1652	1653	1654	1660	1663	1664	1680	1681	1682	1720
27	1721	1722	1723	1724	1740	1741													

36	32	33	36	46	47	75	940	942	1041	1042	1043	1044	1045	10	1047	1100	1101	1180	1181
36	1182	1260	1261	1262	1300	1301	1302	1303	1304	1400	1401	1620	1621	1622	1640	1641	1642	1643	1644
36	1645	1646	1647	1648	1649	1650	1651	1652	1653	1654	1660	1663	1664	1680	1681	1682	1720	1721	1722
36	1723	1740	1741																
40	32	33	36	46	47	61	63	65	75	940	942	1100	1101	1180	1181	1182	1261	1262	1266
40	1300	1301	1302	1303	1304	1440	1441	1442	1620	1621	1622	1640	1641	1642	1643	1644	1645	1646	1647
40	1648	1649	1650	1651	1652	1653	1654	1660	1663	1664	1680	1681	1682	1720	1721	1722	1723	1724	1740
40	1741																		
41	32	33	36	46	47	64	66	75	940	942	960	1100	1101	1180	1181	1182	1300	1301	1302
41	1303	1304	1400	1401	1620	1621	1622	1640	1641	1642	1643	1644	1645	1646	1647	1648	1649	1650	1651
41	1652	1653	1654	1660	1663	1664	1680	1720	1723										
42	46	47	64	66	75	940	942	1100	1101	1180	1181	1182	1300	1301	1302	1303	1304	1620	1621
42	1622	1640	1641	1642	1643	1644	1645	1646	1647	1648	1649	1650	1651	1652	1653	1654	1660	1663	1664
42	1682	1722	1723	1740	1741														
48	46	47	75	941	942	1100	1101	1180	1181	1182	1300	1301	1302	1303	1304	1620	1621	1622	1640
48	1641	1642	1643	1644	1645	1646	1647	1648	1649	1650	1651	1652	1653	1654	1660	1661	1663	1664	1682
48	1722	1723	1740	1741															
53	32	46	47	75	941	942	1080	1081	1082	1083	1084	1100	1101	1180	1181	1182	1260	1261	1262
53	1263	1266	1300	1301	1302	1303	1304	1620	1621	1622	1640	1641	1642	1643	1644	1645	1646	1647	1648
53	1649	1650	1651	1652	1653	1654	1660	1663	1664	1680	1681	1682	1720	1721	1722	1723	1724	1740	1741
60	1100	1101	46	1180	1181	1182													
61	221	740	744	745	748	749	753	1100	1101	46	1180	1181	1182	120					
62	748	749	753	1100	1101	46	1180	1181	1182	120	240	741	743	746	750	752			
63	240	741	743	744	746	748	750	752	1100	1101	46	1180	1181	1182	120				
64	241	242	244	245	288	290	292	298	1100	1101	46	1180	1181	1182					
65	1100	1101	46	1180	1181	1182													
66	1100	1101	46	1180	1181	1182													
67	260	1100	1101	46	1180	1181	1182												
69	14	740	741	743	744	745	746	748	749	750	752	753	1100	1101	46	1180	1181	1182	120
70	221	285	8	14	740	744	745	748	749	753	1100	1101	46	1180	1181	1182	120		
72	293	8	740	744	745	748	749	753	1100	1101	46	1180	1181	1182	120				
73	293	8	740	744	745	748	749	753	1100	1101	46	1180	1181	1182	120				
74	327	8	740	744	745	748	749	753	1100	1101	46	1180	1181	1182	120				
76	742	1100	1101	46	1180	1181	1182												
77	708	1100	1101	46	1180	1181	1182												
78	261	262	286	299	326	15	16	742	743	744	747	748	751	1100	1101	46	1180	1181	1182
78	120																		
79	261	262	286	299	326	15	16	742	743	744	747	748	751	1100	1101	46	1180	1181	1182
79	120																		
80	324	326	15	16	1100	1101	46	1180	1181	1182	2580	2581	2582	2583					
81	286	326	15	1100	1101	46	1180	1181	1182	2580	2581	2582	2583						
82	740	743	744	746	748	750	752	1100	1101	46	1180	1181	1182	120					
83	241	242	293	299	328	9	15	740	743	744	746	748	750	752	1100	1101	46	1180	1181

83	1182	120	14	16	283	4														
85	244	293	328	741	743	744	746	748	750	752	1100	1101	46	1180	1181	1182	120	9	1	
86	290	11	14	1060	1061	1062	1063	1064	1100	1101	46	1180	1181	1182	1660	1661	1662	1663	1664	
86	1680	1720	10	292	328	75	1723													
87	290	292	14	1100	1101	46	1180	1181	1182	2580	2581	2582	2583							
88	328	10	11	14	1100	1101	46	1180	1181	1182	2580	2581	2582	2583						
89	290	292	328	10	11	14	1100	1101	46	1180	1181	1182	2580	2581	2582	2583				
91	709	1100	1101	46	1180	1181	1182													
92	15	16	46	120	245	284	299	326	741	743	744	746	748	750	752	1100	1101	1180	1181	
92	1182																			
93	15	46	298	324	326	1100	1101	1180	1181	1182	2580	2581	2582	2583						
95	14	46	75	1060	1061	1062	1063	1064	1100	1101	1180	1181	1182	1660	1661	1662	1663	1664	1723	
96	14	46	75	1060	1061	1062	1063	1064	1100	1101	1180	1181	1182	1660	1661	1662	1663	1664	1723	
97	14	15	16	17	46	340	341	342	1100	1101	1180	1181	1182							
98	14	15	16	17	46	291	292	293	340	341	342	1100	1101	1180	1181	1182				
109	46	822	828	829	1100	1101	1180	1181	1182	1720										
112	46	825	1100	1101	1180	1181	1182													
113	46	825	1100	1101	1180	1181	1182													
114	46	75	800	801	802	803	805	806	807	808	809	810	811	1100	1101	1180	1181	1182	1723	
116	676																			
117	46	292	293	676	678	679	1100	1101	1180	1181	1182	2580	2581	2582	2583					
122	46	292	293	328	1100	1101	1180	1181	1182											
123	46	561	1100	1101	1180	1181	1182													
125	292	13	560	566	1100	1101	46	48	1180	1181	1182	96	97	98	99	100	111	118	123	
125	124																			
126	290	292	560	561	563	564	565	1100	1101	46	1180	1181	1182	1680	1720					
127	292	13	560	566	1100	1101	46	48	1180	1181	1182	96	97	98	99	100	111	118	123	
127	124																			
141	46	292	1100	1101	1180	1181	1182													
142	46	287	1100	1101	1180	1181	1182													
144	46	75	292	297	1100	1101	1180	1181	1182	1660	1661	1662	1663	1664	1682	1722	1723			
145	301																			
146	46	75	327	1100	1101	1180	1181	1182	1660	1661	1662	1663	1664	1680	1720	1723				
147	46	75	327	1100	1101	1180	1181	1182	1660	1661	1662	1663	1664	1680	1720	1723				
148	16	46	75	297	1100	1101	1180	1181	1182	1660	1661	1662	1663	1664	1682	1722	1723			
149	10	14	46	75	290	1100	1101	1180	1181	1182	1660	1661	1662	1663	1664	1680	1720	1723		
150	15	46	75	324	326	1100	1101	1180	1181	1182	1563	1660	1661	1662	1663	1664	1681	1721	172	

151	15	46	75	324	326	1100	1101	1180	1181	1182	1563	1660	1661	1662	1663	1664	1681	1721	1723
152	11	46	75	293	1100	1101	1180	1181	1182	1660	1661	1662	1663	1664	1680	1720	1723		
154	46	75	1100	1101	1180	1181	1182	1660	1661	1662	1663	1664	1680	1720	1723				
156	11	14	46	293	1100	1101	1180	1181	1182	2580	2581	2582	2583						
157	11	14	46	293	1100	1101	1180	1181	1182	2580	2581	2582	2583						
159	11	14	46	293	1100	1101	1180	1181	1182	2580	2581	2582	2583						
160	14	46	75	1100	1101	1180	1181	1182	1660	1661	1662	1663	1664	1680	1720	1723			
161	16	46	75	1100	1101	1180	1181	1182	1660	1661	1662	1663	1681	1721	1723	1664			
162	46	75	1100	1101	1180	1181	1182	1660	1661	1662	1663	1664	1680	1720	1723				
164	15	46	75	1100	1101	1180	1181	1182	1660	1661	1662	1663	1681	1721	1723	1664			
165	15	46	75	1100	1101	1180	1181	1182	1660	1661	1662	1663	1681	1721	1723	1664			
166	15	46	75	1100	1101	1180	1181	1182	1681	1721	1723								
167	16	46	75	1100	1101	1180	1181	1182	1681	1721	1723								
168	16	46	1100	1101	1180	1181	1182	2580	2581	2582	2583								
169	15	46	75	1100	1101	1180	1181	1182	1660	1661	1662	1663	1664	1681	1721	1723			
170	15	16	46	75	1100	1101	1180	1181	1182	1660	1661	1662	1663	1664	1681	1721	1723		
171	15	46	75	1100	1101	1180	1181	1182	1660	1661	1662	1663	1664	1681	1721	1723			
172	15	16	46	75	1100	1101	1180	1181	1182	1660	1661	1662	1663	1664	1681	1721	1723		
173	15	16	46	75	1100	1101	1180	1181	1182	1660	1661	1662	1663	1664	1681	1721	1723		
174	46	75	325	1100	1101	1180	1181	1182	1620	1621	1622	1660	1661	1662	1663	1664	1681	1721	1723
176	320	322	1100	1101	46	1180	1181	1182	1562	1681	1721								
177	14	1100	1101	46	1180	1181	1182	1560	1660	1661	1662	1663	1664	75	1723				
178	292	293	326	14	1100	1101	46	1180	1181	1182	1560	1660	1661	1662	1663	1664	1680	75	1720
178	1723																		
179	46	75	292	1100	1101	1180	1181	1182	1660	1661	1662	1663	1664	1682	1722	1723			
180	290	291	1100	1101	46	1180	1181	1182	2580	2581	2582	2583							
184	15	1100	1101	46	1180	1181	1182	1660	1661	1662	1663	1664	1681	1721					
185	15	46	1100	1101	1180	1181	1182	1660	1661	1662	1663	1664	1681	1721					
186	14	760	761	762	1100	1101	46	1180	1181	1182									
190	46	627	1100	1101	1180	1181	1182	620											
191	46	627	1100	1101	1180	1181	1182	620											
192	46	627	1100	1101	1180	1181	1182	620											
194	625	626	622																
196	46	287	1100	1101	1180	1181	1182												
212	641	1100	1101	46	1180	1181	1182												
321	1100	1101	46	48	1180	1181	1182	95	96	103	104	105	106						
324	13	640	1100	1101	46	1180	1181	1182											
325	17	1100	1101	46	48	1180	1181	1182	80	82	83	84	85	86	87	96	97	98	99
325	100	102	131	2920	2921	2922	2923	2924	2925	2926	2927	1060	1061	1062	1063	1064			
326	1100	1101	46	48	1180	1181	1182	80	82	83	84	85	86	87	96	97	98	99	100
326	102	131	2920	2921	2922	2923	2924	2925	2926	2927									
328	13	640	1100	1101	46	1180	1181	1182											

329	13	17	1100	1101	46	48	1180	1181	1182	96	97	98	99	100	111	118	123	124	2640
329	2641	2642	2643																
330	17	1100	1101	46	48	1180	1181	1182	80	82	83	84	85	86	87	96	97	98	99
330	100	131	2920	2921	2922	2923	2924	2925	2926	2927									
331	17	1100	1101	46	48	1180	1181	1182	80	82	83	84	85	86	87	96	97	98	99
331	100	131	2920	2921	2922	2923	2924	2925	2926	2927									
333	17	1100	1101	46	48	1180	1181	1182	80	82	83	84	85	86	87	96	97	98	99
333	100	131	2920	2921	2922	2923	2924	2925	2926	2927									
334	17	1080	1081	1082	1083	1084	1100	1101	46	1180	1181	1182	61	1440	1441	1442	1724		
334	96	97	98	99	100	131													
336	17	1100	1101	46	48	1180	1181	1182	80	82	83	84	85	86	87	96	97	98	99
336	100	102	131	2920	2921	2922	2923	2924	2925	2926	2927								
337	17	1100	1101	46	48	1180	1181	1182	80	82	83	84	85	86	87	96	97	98	99
337	100	102	131	1724	2920	2921	2922	2923	2924	2925	2926	2927							
339	627	1100	1101	46	1180	1181	1182												
341	17	1100	1101	46	48	1180	1181	1182	1400	1401	75	1723	1740	1741	80	82	83	84	85
341	86	87	96	97	98	99	100	102	131	2920	2921	2922	2923	2924	2925	2926	2927		
345	13	1100	1101	46	48	1180	1181	1182	96	97	98	99	100	102					
346	17	1100	1101	46	48	1180	1181	1182	80	82	83	84	86	87	96	97	98	99	100
346	102	131	2920	2921	2922	2923	2924	2925	2926	2927	85								
347	17	1100	1101	46	48	1180	1181	1182	1084	1320	1321	1361	1364	1365	96	97	98	99	100
347	102																		
348	14	16	17	1100	1101	46	48	1180	1181	1182	1660	1661	1662	1663	1664	75	1723	80	82
348	83	84	85	86	87	96	97	98	99	100	102	131	2920	2921	2922	2923	2924	2925	2926
348	2927																		
349	1100	1101	46	48	1180	1181	1182	942	96	97	98	99	100	102	82	83	87	90	91
349	94																		
350	942	1100	1101	46	48	1180	1181	1182	96	97	98	99	100	102	940				
355	940	941	942	1100	1101	46	48	1180	1181	1182	96	97	98	99	100	102			
358	17	1100	1101	46	48	1180	1181	1182	1400	1401	75	1723	1740	1741	80	82	83	84	85
358	86	87	96	97	98	99	100	102	131	2920	2921	2922	2923	2924	2925	2926	2927		
359	1100	1101	46	48	1180	1181	1182	96	97	98	99	100	102	103					
361	1100	1101	46	1180	1181	1182	96	97	98	100									
361	104	105	106																
362	17	1100	1101	46	48	1180	1181	1182	80	82	83	84	85	86	87	96	97	98	99
362	100	131	2920	2921	2922	2923	2924	2925	2926	2927									
363	13	640	1100	1101	46	1180	1181	1182											

364	940	942	1100	1101	46	48	1180	1181	1182	96	97	98	99	100	102	82	83	87	90
364	91	94																	
368	17	1100	1101	46	48	1180	1181	1182	80	82	83	84	85	86	87	96	97	98	99
368	100	102	131	2920	2921	2922	2923	2924	2925	2926	2927	1060	1061	1062	1063	1064			
369	17	1100	1101	46	48	1180	1181	1182	1400	1401	75	1723	1740	1741	80	82	83	84	85
369	86	87	96	97	98	99	100	102	131	2920	2921	2922	2923	2924	2925	2926	2927		
370	17	1100	1101	46	48	1180	1181	1182	80	82	83	84	85	86	87	96	97	98	99
370	100	102	131	2920	2921	2922	2923	2924	2925	2926	2927	90	91						
372	1100	1101	46	48	1180	1181	1182	96	97	98	99	100	102						
373	17	1100	1101	46	48	1180	1181	1182	80	82	83	84	85	86	87	96	97	98	99
373	100	102	131	1724	2920	2921	2922	2923	2924	2925	2926	2927	1080	1081	1082	1083	1084		
374	17	1100	1101	46	1180	1181	1182	96	97	98	99								
374	100	131	1724																
376	1100	1101	46	48	1180	1181	1182	90	96	97	98	99	100	102	2640	2641	2642	2643	
377	1100	1101	46	48	1180	1181	1182	79	81	90	96	97	98	99	100	102	2640	2641	2642
377	2643																		
378	1100	1101	46	48	1180	1181	1182	1321	82	83	87	90	91	94	96	97	98	99	100
378	102																		
382	1100	1101	46	48	1180	1181	1182	80	82	83	84	85	86	87	96	97	98	99	100
382	102	2920	2921	2922	2923	2924	2925	2926	2927										
383	1100	1101	46	48	1180	1181	1182	1724	80	82	83	84	85	86	87	96	97	98	99
383	100	102	2920	2921	2922	2923	2924	2925	2926	2927									
385	1100	1101	46	48	1180	1181	1182	1440	1441	1442	80	82	83	84	86	87	96	97	98
385	99	100	102	131	2920	2921	2922	2923	2924	2925	2926	2927	85						
386	1100	1101	46	48	1180	1181	1182	940	942	82	83	87	90	91	94	96	97	98	99
386	100	102																	
391	46	640	1100	1101	1180	1181	1182												
400	2580	2581	2582	2583															
401	78																		
402	32	46	47	75	941	942	1060	1061	1062	1063	1064	1100	1101	1180	1181	1182	1260	1261	1262
402	1265	1266	1300	1301	1302	1303	1620	1621	1622	1640	1641	1642	1643	1644	1645	1646	1647	1741	1648
402	1649	1650	1651	1652	1653	1654	1660	1663	1664	1680	1681	1682	1720	1721	1722	1723	1740		
403	32	33	36	46	47	75	880	881	883	884	940	942	1100	1101	1180	1181	1182	1260	1261
403	1262	1263	1266	1300	1301	1302	1303	1304	1400	1401	1620	1621	1622	1660	1663	1664	1680	1681	1682
403	1720	1721	1722	1723	1740	1741													
404	32	46	47	75	940	942	1100	1101	1180	1181	1182	1260	1261	1262	1265	1266	1300	1301	1302
404	1303	1620	1621	1622	1640	1641	1642	1643	1644	1645	1646	1647	1648	1649	1650	1651	1652	1653	1654
404	1660	1663	1664	1680	1681	1682	1720	1721	1722	1723	1740	1741							
405	32	33	36	46	47	75	941	942	1041	1042	1043	1044	1045	1046	1047	1100	1101	1180	1181
405	1182	1260	1261	1262	1300	1301	1302	1303	1304	1400	1401	1620	1621	1622	1640	1641	1642	1643	1644

405	1645	1646	1647	1648	1649	1650	1651	1652	1653	1654	1660	1663	1664	1680	1681	1682	1720	1721	1722
405	1723	1740	1741																
410	221	285	740	744	745	748	749	753	1100	1101	46	1180	1181	1182	120				
411	221	293	740	744	745	748	749	753	1100	1101	46	1180	1181	1182	120				
412	221	327	740	744	745	748	749	753	1100	1101	46	1180	1181	1182	120				
413	241	242	244	245	288	290	292	298	741	743	744	746	748	750	752	1100	1101	46	1180
413	1181	1182	120																
414	286	1100	1101	46	1180	1181	1182												
415	298	1100	1101	46	1180	1181	1182												
416	299	1100	1101	46	1180	1181	1182												
417	298	1100	1101	46	1180	1181	1182												
418	323	1100	1101	46	1180	1181	1182												
419	324	1100	1101	46	1180	1181	1182												
420	260	261	262	742	743	744	747	748	751	1100	1101	46	1180	1181	1182	120			
421	298	301	323	742	743	744	747	748	751	1100	1101	46	1180	1181	1182	120			
422	1100	1101	46	1180	1181	1182													
423	260	1100	1101	46	1180	1181	1182												
424	286	1100	1101	46	1180	1181	1182												
425	326	1100	1101	46	1180	1181	1182												
426	324	1100	1101	46	1180	1181	1182												
427	742	1100	1101	46	1180	1181	1182												
428	1721	1100	1101	46	1180	1181	1182												
429	286	1100	1101	46	1180	1181	1182												
430	326	1100	1101	46	1180	1181	1182												
431	324	1100	1101	46	1180	1181	1182												
432	741	1100	1101	46	1180	1181	1182												
433	1721	1100	1101	46	1180	1181	1182												
434	46	287	292	1100	1101	1180	1181	1182											
435	46	297	1100	1101	1180	1181	1182												
436	46	292	1100	1101	1180	1181	1182												
437	46	293	1100	1101	1180	1181	1182												
438	46	287	293	1100	1101	1180	1181	1182											
439	46	290	1100	1101	1180	1181	1182												
440	46	287	290	1100	1101	1180	1181	1182											
441	46	322	1100	1101	1180	1181	1182												
442	46	328	1100	1101	1180	1181	1182												
443	46	322	328	1100	1101	1180	1181	1182											
444	46	327	1100	1101	1180	1181	1182												
445	46	322	327	1100	1101	1180	1181	1182											

446	46	1100	1101	1180	1181	1182	1720												
447	46	820	822	823	825	827	1100	1101	1180	1181	1182	1680	1720						
448	46	820	821	822	823	827	1100	1101	1180	1181	1182	1680	1720						
449	46	820	822	823	826	828	829	1100	1101	1180	1181	1182	1680	1720					
450	800	801	802	804	805	806	807	808	809	810	811	1100	1101	46	1180	1181	1182	75	1723
451	800	801	802	803	805	806	807	808	809	810	811	1100	1101	46	1180	1181	1182	75	1723
452	46	75	1100	1101	1180	1181	1182	1723											
453	46	75	1100	1101	1180	1181	1182	1680	1720	1723									
454	46	75	676	1100	1101	1180	1181	1182	1680	1720	1723								
455	46	75	676	679	1100	1101	1180	1181	1182	1680	1720	1723							
456	46	322	1100	1101	1180	1181	1182												
457	46	292	1100	1101	1180	1181	1182												
458	46	293	1100	1101	1180	1181	1182												
459	46	322	328	1100	1101	1180	1181	1182											
460	46	292	328	1100	1101	1180	1181	1182											
461	46	288	1100	1101	1180	1181	1182												
462	46	287	288	1100	1101	1180	1181	1182											
463	46	287	322	1100	1101	1180	1181	1182											
464	46	287	1100	1101	1180	1181	1182												
465	46	322	1100	1101	1180	1181	1182												
466	46	292	1100	1101	1180	1181	1182												
467	46	293	1100	1101	1180	1181	1182												
468	46	328	1100	1101	1180	1181	1182												
469	46	290	1100	1101	1180	1181	1182												
470	46	327	1100	1101	1180	1181	1182												
471	46	563	1100	1101	1180	1181	1182												
472	46	564	1100	1101	1180	1181	1182												
473	46	565	1100	1101	1180	1181	1182												
474	46	566	1100	1101	1180	1181	1182												
475	46	623	1100	1101	1180	1181	1182	620											
476	46	622	1100	1101	1180	1181	1182	620											
477	46	75	298	1100	1101	1180	1181	1182	1660	1661	1662	1663	1664	1681	1721	1723			
478	46	75	326	1100	1101	1180	1181	1182	1660	1661	1662	1663	1664	1681	1721	1723			
479	46	75	324	1100	1101	1180	1181	1182	1660	1661	1662	1663	1664	1681	1721	1723			
480	46	75	325	1100	1101	1180	1181	1182	1660	1661	1662	1663	1664	1681	1721	1723			
481	46	75	298	324	1100	1101	1180	1181	1182	1660	1661	1662	1663	1664	1681	1721	1723		
482	13	640	1100	1101	46	1180	1181	1182											

483	1100	1101	46	48	1180	1181	1182	80	82	83	84	85	86	87	96	97	98	99	100
483	102	131	2920	2921	2922	2923	2924	2925	2926	2927									
484	1100	1101	46	48	1180	1181	1182	80	82	83	84	85	86	87	96	97	98	99	100
484	102	131	2920	2921	2922	2923	2924	2925	2926	2927									
485	1100	1101	46	48	1180	1181	1182	80	82	83	84	85	86	87	96	97	98	99	100
485	102	131	2920	2921	2922	2923	2924	2925	2926	2927									
486	282	1100	1101	46	1180	1181	1182												
487	298	301	324	1100	1101	46	1180	1181	1182										
488	15	1100	1101	46	1180	1181	1182	1660	1661	1662	1663	1664	1681	1721					
489	13	46	1100	1101	1180	1181	1182												
490	46	48	96	97	98	99	100	102	1100	1101	1180	1181	1182						
491	46	48	96	97	98	99	100	102	1100	1101	1180	1181	1182	2640	2641	2642	2643		
492	46	48	96	97	98	99	100	102	105	106	1100	1101	1180	1181	1182				
493	46	1100	1101	1180	1181	1182	1724												
494	15	16	46	75	1100	1101	1180	1181	1182	1660	1661	1662	1663	1664	1681	1721	1723		

8.3 RELIABILITY AND MAINTAINABILITY EVALUATION

Data concerning system reliability or failure rates exist in a number of forms. First of all, there are the quantitative type analyses, typified by the classical reliability prediction and assessment studies performed by the contractor responsible for that system. Secondly, there are qualitative analysis, such as the single point failure studies and the failure effects analysis that, while not directly specifying a reliability number, do provide the basis on which a quantitative measurement can be made. Finally there is the field information, documented by the UCR System than can indicate the actual number of failures that occur on each system.

There are merits and weaknesses associated with all three of these forms of reliability evaluation. Data on all launch support systems is unavailable in any one of the three forms. Consequently, to arrive at reliability measurements for use in the launch availability model, a combination of all three types of data is used. In this way, the greatest number of systems can be given substantiated reliability characteristics and the most accurate representations can be made. Repair time data that is applicable to the support systems of interest is also found in more than one form. Maintenance studies have been made on some of the systems and repair times are documented. Data concerning similar or related systems can also be considered if it is done judiciously. Field data is also of benefit in establishing repair time estimates.

8.3.1 Failure Rates and Repair Time from Documentation

Maximum use was made of previous contractor and NASA reliability studies to obtain the required equipment failure rate information. These documented

studies are a major source of the required data in addition to containing useful information related to operational descriptions, maintenance procedures, launch complex equipment definitions and other applicable engineering analyses.

Failure rate and repair time data can be extracted and compiled directly from quantitative sources such as contractor prediction and assessment reports. Evaluation of documents containing questionable reliability data is necessary determine if any portions of the data is non-applicable to this study. The qualitative information contained in FMEA and FME&CA reports, as well as qualitative reliability/maintainability analysis reports, must be analyzed further to be able to assign failure rate and repair time values to the equipments. Sources such as FARADA, MilHdbk 217, etc. provide supplemental data concerning related equipments, to enable, through the use of engineering judgment and analysis, quantitative values to be assigned.

Complete information was not found to be available for all equipments investigated. Overall, there were 55 systems found in this study that had been previously analyzed and reliability information documented in contractor and NASA reliability reports. A listing of these systems is presented in Table VIII-3.

8.3.2 UCR Analysis

A prime source of field failure data are the UCR systems existing at the NASA Centers. The discrepancy occurrences reported via these systems are analyzed and used to develop reliability information (i.e., field failure rate data) for the equipments concerned with launch support operations. The UCR's analyzed are the complete computer printouts containing all of the information

recorded about the discrepancy that has been entered in the UCR system. The accompanying narrative description of each discrepancy and the results, if any, of subsequent investigations/analyses are of assistance in evaluating the UCR.

Initially the UCR tabulations are used to determine failure rates of various launch support equipments by relating the date of occurrence of each discrepancy to its applicable launch vehicle and, therefore, to a specific launch date. In this way it is possible to determine the number of days before launch that the discrepancy was discovered.

Failure rates for each equipment have been determined based on the following assumptions:

a. Each UCR represents an actual equipment failure.

b. The date of discovery is the date of occurrence of the discrepancy.

c. Five launch vehicles are considered applicable to this analysis. These are SA-201, SA-202, SA-203, 204LM, and AS-205.

d. System operating time of interest is the period from T-30 days to T-0 for each vehicle. This thirty day period was selected as a compromise between (1) the time of most importance (i. e., the terminal portion of launch support activities) and (2) having a sufficient amount of data available for the calculation to be meaningful. Each functional system is considered to be operating continuously for each vehicle during the final thirty day period. This yields an operating time of 3600 hours for each system (i. e., 30 days per vehicle x 24 hours per day x 5 vehicles = 3600 hours).

NOTE: It is considered that the "time of most importance" is an especially pertinent concern in evaluating field data, particularly in this application, i. e., launch preparations. Of "most importance" in this study is the final 14 hours of the countdown, and obviously there is a different environment then, than at T-14 weeks. Although the environment difference is of no consequence to the equipment, it probably effects the personnel and certainly effects the judgment criteria. For example, a minor discrepancy (e. g., a wet valve) occurring at T-50 days would probably be reported and corrected before proceeding with launch operations if only to prevent it from getting worse. However, that same minor discrepancy occuring at T-5 hours or T-50 minutes might not be reported nor repaired until after launch and possibly not until necessary during another launch preparation period.

Table VIII-2 is a compilation of the failure rates calculated for each system and is based on the number of UCR's considered to be actual failures tabulated for each system during the final thirty days prior to launch. The table is a summary of the results of the UCR analysis combining the information from both KSC and MSFC UCR systems.

It is recognized that the accuracy of the failure rates derived from UCR data will be somewhat suspect due to the validity of the assumptions on which it is based. There is some question as to whether each UCR is an actual system failure,

TABLE VII-2 FUNCTIONAL SYSTEMS FIELD FAILURE RATE

COMBINED UCR DATA FROM KSC & MSFC UCR PRINTOUTS * FUNCTIONAL SYSTEMS		NUMBER OF UCR'S				[illegible]
		DAYS BEFORE LAUNCH			TOTAL (T-30 to T-00 PLUS 1)	[illegible]
No.	NOMENCLATURE	T-30 to T-20	T-20 to T-10	T-10 to T-0		
001	RP-1		2	1	4	
[illegible]	LIQUID OXYGEN		1	2	4	
003	LIQUID HYDROGEN	11	2		14	
004	PNEUMATICS DISTR.: GN_2	4	8	1	14	
005	PNEUMATICS DISTR.: GH_2	4	6	3	14	
006	PNEUMATICS DISTR.: He	1	2	3	7	
007	ENVIRONMENTAL CONTROL	11	4	7	23	
010	SHORT CABLE MAST #2			1	2	
012	HOLDDOWN ARMS	3			4	
013	APOLLO ACCESS ARM		4		5	
014	SWING ARM #1	9	1	1	12	
015	SWING ARM #2		2		3	
016	SWING ARM #3		1	1	3	
017	SWING ARM #4	1	2		4	
018	HYDRAULIC		3	2	6	
022	UMBILICAL TOWER	1		1	3	
023	WATER SYSTEM	1		2	4	
025	S/C SUPPORT PIPING	19	13	5	38	
[illegible]26	Q-BALL COVER & REMOVAL		1	1	3	

* KSC Printouts DE-7 (3 JUN 69), DE-8 (3 JUN 69), DE-9 (3 JUN 69), DE-10 (27 JUN 69) & DE-11 (27 JUN 69)
MSFC Printout XTRT (17 MAR 69)

** $\lambda = \frac{\text{Total UCRs} + 1}{3600 \text{ Hours}}$ = failures per hour

TABLE III-2 FUNCTIONAL SYSTEMS FIELD FAILURE RATES (CONT.)

COMBINED UCR DATA FROM KSC & MSFC UCR PRINTOUTS * FUNCTIONAL SYSTEMS		NUMBER OF UCR'S				FAILURE RATE (λ)**
		DAYS BEFORE LAUNCH			TOTAL (T-30 to T-0 Days) PLUS 1	FOR PERIOD T-30 DAYS TO T-0
No.	NOMENCLATURE	T-30 to T-20	T-20 to T-10	T-10 to T-0		
027	PROP. TANKING COMPUTER	1	3	1	6	0.001667
028	DIGITAL EVENT EVAL. (DEE-3)	3	1	3	8	.002222
030	HAZARDOUS GAS DETECTION	3	2	2	8	.002222
037	TELEMETRY CHECKOUT	7	5	5	18	.005000
040	C-BAND CHECKOUT		2		3	.000833
043	VEH. MEAS. GSE: LCC	12	9	6	28	.007778
049	KSC ELEC. DISTR.: 60 Hz PWR	2		3	6	.001667
051	OTV	61	53	55	170	.047222
054	OIS	44	29	17	91	.025278
058	OPERATIONAL PAGING		1		2	.000556
062	RANGE SAFETY CHECKOUT	1	4		5	.001389
068	MECHANICAL GSE	9	2	5	17	.004722
071	DIGITAL EVENT EVAL. (DEE-6)	4	11	3	19	.005278
072	DDAS	29	29	24	83	.023056
073	SAT. IB GND. COMM. EQUIP.	42	41	26	110	.030556
074	SAT. IB PWR. & DIST. ESE: PRI	28	12	7	48	.013333
075	SAT. IB PWR. & DIST. ESE: AUX	4	6	5	16	.004444
076	ELEC. SUPPORT EQUIP.	18	13	15	47	.013056
077	COUNTDOWN CLOCK	12	1	2	16	.004444
078	AZ. LAYING & ALIGN. EQUIP.	8		3	12	.003333

* KSC Printouts DE-7 (3 JUN 69), DE-8 (3 JUN 69), DE-9 (3 JUN 69), DE-10 (27 JUN 69) & DE-11 (27 JUN 69)
MSFC Printout XTRT (17 MAR 69)

** $\lambda = \frac{\text{Total UCRs} + 1}{5600 \text{ Hours}}$ = failures per hour

or if all system failures are recorded by a UCR. It is known that systems do not operate continuously throughout the launch preparation period as assumed for this analysis, but field operating time data is seldom recorded in the UCR and some estimate of operating time is necessary. (A related study performed for NASA under Contract NAS10-5852 has demonstrated the feasibility and the effectiveness of determining field failure rates using calendar time as the assumed operating time between recorded failures.) It has also been determined that various inconsistencies in the UCR data itself, causes its accuracy to be questioned. However, it is felt that the analysis of UCR's as described above, can provide reasonable estimates of the equipment failure rates. The detailed analysis of 893 UCR's from both MSFC and KSC reveals that approximately 6% (i.e., 52 UCR's) are concerned with routine maintenance and/or minor problems and, therefore, are not considered equipment failures. The analysis of the remaining 841 UCR's covering the five pertinent launch missions results in failure rate values for 39 launch support equipments. The data is summarized in Table VIII-2. These values represent only one factor in arriving at the failure rate and are later combined with the results of analyses from other sources of reliability information to arrive at the equipment failure rates used in the model.

8.4 DATA SYNTHESIS METHODS

In comparing the data input requirements of the availability model with the data that can be compiled or developed from the sources described in 8.3, it is evident that additional analysis is needed to provide supplemental data. In summarizing the existing data, it is seen that documented failure rates are

directly available for some systems and subsystems. Failure rates based on qualitative documents can be derived for another set of equipments. Finally failure rates for a third set of equipments can be derived from UCR data. The dilemma arises because in one case, all three sources of data may be available for the same system, yet contain failure rate values that are considerably different. For other systems, there may be data from only one or two of these sources. Finally, there are the support systems for which no failure rate data is available.

To resolve these conflicting or deficient conditions, a procedure must be developed that will permit the derivation of a representative failure rate and repair time estimates for equipments having either too much or too little data. The process must be logical, consistent and make maximum use of the data from previous studies and analyses. It should also be amenable to the addition of new data and conducive to traceability procedures. The subsections of Section 8.4 present the procedures that were developed and followed to derive the failure rates used in this study.

8.4.1 Failure Rate Estimation Process

The derivation of support equipment failure rate values can be accomplished by systematically following a procedure that is established to resolve the problems stated in paragraph 8.4. Figure VIII-3 indicates the overall process that should be followed. The steps in the derivation of estimated equipment failure rate values are as follows:

1. Review all available sources of reliability information and tabulate the failure rate data for each equipment. Three types of sources provide data for this purpose:

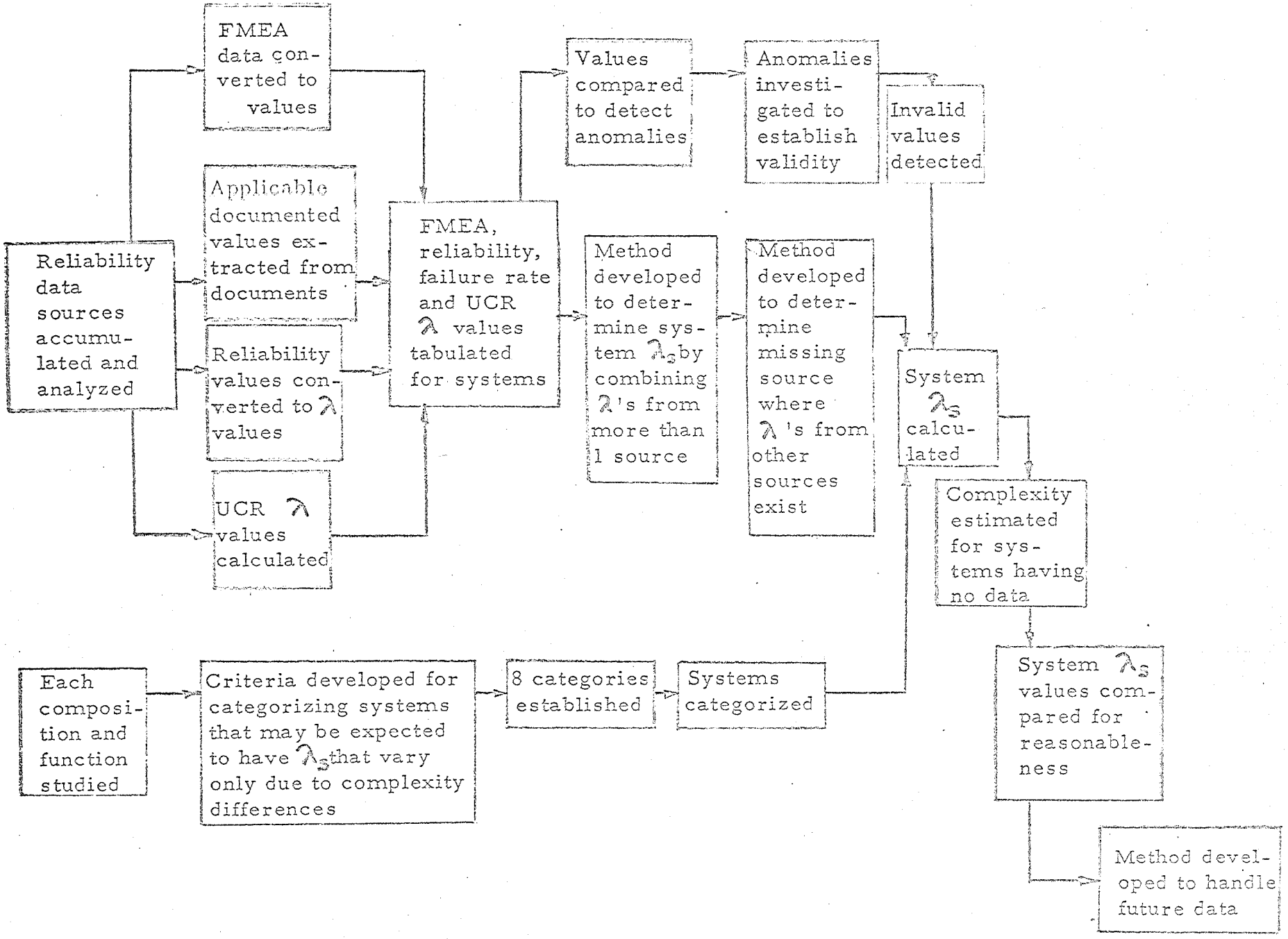


FIGURE VIII-3 PROCEDURE TO DETERMINE SYSTEM FAILURE RATES

a. Quantitative reliability reports

b. Qualitative reliability reports

c. UCR's

2. Categorize all equipments according to their type of components and function that they perform. Equipments within each category are expected to have similar failure rates. Differences in failure rates of equipments within any one category are expected to be due primarily because of differences in complexity. The categories that are established for this analysis are:

a. Structural

b. Low voltage (hard wired)

c. Power

d. Liquid (ambient temperature)

e. Liquid (low temperature and cryogenic)

f. RF

g. Computer

h. Gas (high pressure)

3. Tabulate the information derived in steps 1 and 2 in a manner that will readily indicate where redundant data exists and where no data is available.

4. Within each category, calculate hypothetical failure rate values for each equipment that has no data available. This procedure (i.e., Procedure A which is discussed later) is based on the assumption that equipment failure rate values derived from all related sources for similar systems is more representative than if derived solely from sparse or questionable equipment information.

5. Calculate the basic failure rate estimate by averaging the values now available (both documented and calculated) that are applicable to each equipment. This is referred to as Procedure B.

6. Derive the basic failure rate values for those systems for which no source data is available and, consequently, are not considered in steps 4 and 5. This is referred to as Procedure C.

The procedures for deriving estimates of equipment failure rate referenced in steps 4, 5, and 6 as well as procedures for converting qualitative and UCR information (Procedures D and E respectively) into equipment failure rate values are as follows:

1. Procedure A: Documented data may be available from one, two or three types of sources. When documented values are available from at least one of the sources and data for at least one other system in the category is available from the same source and one or two other source types, hypothetical values are calculated for those equipments having no data by solving a set of simultaneous equations describing the condition of known and unknown data entries.

2. Procedure B: The estimates of failure rate values for each equipment are derived by simply averaging the values available (both documented and hypothetical) that are applicable to each one.

3. Procedure C: This procedure consists of first ranking the equipments within each category based on their failure rate estimates. Equipments for which information is not available then are compared with the ranked equipments.

The criteria used in this comparison are complexity, volume, environment, state-of-the-art, parts count, etc. This procedure permits the "no source data" equipment to be placed in its appropriate place in the previously ranked data. Applicable failure rate values for these equipments are then derived by extrapolation methods.

4. Procedure D: Qualitative reports indicate what effect a failure of each equipment element would have on the vehicle launch operations. For elements that could cause a launch delay or mission scrub, failure rates are extracted from criticality analysis. Failure rate values for all such elements within an equipment are then summed to obtain the overall failure rate of the equipment.

5. Procedure E: The procedure used to derive failure rate values from UCR information is described in Section 8.3.2.

The estimated failure rate values that are derived, using the above methodology are then tabulated and coded for use as input data for the exercise of the probability of launch-in-window model. Any further calculations are dependent on additional or revised data becoming available. When such data is received, it is evaluated together with the previously attained basic data to derive new failure rate estimates. These new values replace the failure rates being used in the probability of launch-in-window model. To keep account of the manner in which each equipment failure rate value is derived, a log is maintained with the applicable information.

Table VIII-3 illustrates how the estimating procedure is implemented in deriving system level failure rates. It is also indicative of the amount of documented data available. For example, 29 entries (without asterisk) in the column "QUANT" represent that those systems have directly usable failure rates found in documented sources. Eighteen systems are noted in the "QUAL" column, signifying the systems where available documentation can lead to failure rate estimates. Forty-seven systems are indicated as definable by failure rates based on UCR analysis. Table VIII-3 is a composite result of performing steps 1 through 6 that have just been defined. The notes and astericks can aid in reconstructing this development.

Failure rates must also be derived for all of the subsystems required to support the launch operations. The problems of redundant or insufficient data are just as applicable to the subsystems as to the systems. On the whole, however, less data is available concerning subsystems. When documented subsystem failure rates are available, these values are normally used. If not available, values are determined by one of the three methods described below:

1. Failure rate values are assumed to be the same as the documented values given for similar components.

2. If all components comprising an equipment are shown in series on the equipment's reliability block diagram, the equipment's failure rate value is apportioned to its components in proportion to relative component complexities.

TABLE VIII-3 SYSTEM FAILURE RATE ESTIMATES

SYSTEM	λ Derived From Available Report Data			λ_s		
	QUANT.	QUAL.	UCR	BASIC	REV. A	REV. B
CATEGORY - STRUCTURAL						
008 Fuel Mast		9	69	39		
009 LOX Mast		9	69	39		
010 Mast #2		1	69	35		
011 Mast #4		1	69	35		
012 HD Arms		86*	1111	596		
013 AAA		115	1388	752		
014 S. Arm #1		111	1388	752		
015 S. Arm #2		127	1388	757		
016 S. Arm #3		107	1388	747		
017 S. Arm #4		99	1388	744		
021 SS		65*	833	449		
022 Umb. Twr.		65*	833	449		
024 Emerg. Egress		23*	278	150		
026 Q-Ball				150**		
CATEGORY - LOW VOLTAGE, HARDWIRED						
029 Fac. Meas.				409**		
030 HGDS	290		556	423		
031 Fire Det.				409**		
042 L/V Meas. SS	132*		3333	1732		
043 L/V Meas. LCC	6		4634*	2320		
044 Abort Adv.				409**		
054 OIS				822**		
057 Telephone				409**		
058 Paging	30*		556	293		
076 ESE	28		1667	848	1775	
CATEGORY - POWER						
045 Cape Power	376		1296	836		
046 KSC Cabling	37		975*	506		
047 KSC Grounding				500**		
048 KSC ACE Pwr.				600**		
049 KSC 60r Pwr.	441		1944	1192		
050 KSC Spl. Pwr.	116		1043*	580		
074 ESE Prim. Pwr.	396		5070*	2733	641	
075 ESE Aux. Pwr.	116		6944	3530		

* Value calculated from available source values, which are shown without asterisk.

** Value estimated by comparing system complexity with systems have value.

TABLE VIII-3 SYSTEM FAILURE RATE ESTIMATES

SYSTEM	λ Derived From Available Report Data			λ_s		
	QUANT.	QUAL.	UCR	BASIC	REV. A	REV. B
CATEGORY - LIQUID AT AMBIENT TEMPERATURE						
001 RP-1	326*	344	833	501		
007 ECS	2184*	10	9167	3787		
018 Hydraulic	1648	35	1111	931		
023 Water	974	95*	2500	1189		
068 MGSE	455	315*	11111	3960		
121 H., V., & A. C.	1288	75*	1389	917		
CATEGORY - RF						
033 CIF TM Gr. S.	1628*		4722	3175		
034 LIEF				2600**		
035 Met. Data				1800**		
036 Data Display	402*		1111	786		
037 TM	632*		1667	1150		
038 ODOP	325		722	524		
039 ODOP Grd. S.	625		1246*	936		
040 C-Band	1025		556	790		
051 OTV	2547		4264*	3405		
052 Photo Optical				2600**		
053 ALDS				900**		
055 Widebd. Trans.				900**		
056 RF Comm.				900**		
059 Test & Sw.				1100**		
060 Timing & CD	923*		1944	1434		
061 R/S Cmd.				400**		
062 R/S	243*		556	400		
063 Impact Pred.				2400**		
064 Radar Tr.				2400**		
065 Clotrac. Tr.				2400**		
066 Tm. Tr.	2211*		5833	4022		
067 Optic Tr.				2400**		
077 CD Clock	146		2500	1323	1084	
078 Az. Lay. Align.	805		6111	3458	324	
120 Propellant Data				700**		
CATEGORY - LOW TEMPERATURE LIQUID						
002 LOX		1702	4722	3212		
003 LH_2		943	15833	8388		

TABLE VIII-3 SYSTEM FAILURE RATE ESTIMATES

SYSTEM	λ Derived From Available Report Data			λ_s		
	QUANT.	QUAL.	UCR	BASIC	REV. A	REV. B
CATEGORY - COMPUTERS						
027 PTCS	1000		1111	1056		
028 DEE-3	64		833	449		
032 CIF Comp.	824*		1944	1384		
71 DEE-6	1728		7222	4475		
072 DDAS	11429		21389	16409	993	
073 110A	9930		31667	20798	5760	
119 TCD Seq.	100		305*	203		
CATEGORY - HIGH PRESSURE GAS						
004 GN_2	3985	1707	4167	3286		
005 GH_2	742	60	3333	1378		
006 He	2523	627	1667	1605		
025 S/C Sup. P.	800	206	1954*	986		
122 GOX				1000**		

3. A combination of methods 1 and 2 may be used. The failure rate values are scaled up or down by the ratio of the estimated system failure rate, $\hat{\lambda}$, and the documented equipment failure rate λ_1. Table VIII-4, is an example of this procedure applied to the Helium system.

It should be noted that the summation of the failure rates for all of the subsystems of a system must equal the system failure rate only if the system consists of subsystems that totally operate in series. Otherwise, the failure rate of any single subsystem may be greater than or less than that of its system. In no case, however, may the sum of subsystem failure rate values be less than its system value.

8.4.2 Repair Time Estimation Process

The procedure used to derive repair times for all functional systems required in the launch operations is presented in Figure VIII-4. This procedure can be summarized as follows:

1. All sources of data are compiled and analyzed, and documented repair time for any system or subsystem is tabulated.

2. For systems that do not have documented values but contain subsystems whose repair times are known, an estimate is made based on the constituent repairs. These values are then added to the repair time tabulation.

3. All equipment repair time values then are analyzed to detect and eliminate anomalies. Anomalies are detected by first carefully reviewing the source document to determine if the documented values are applicable to the

TABLE VIII-4 FAILURE RATES OF SUBSYSTEMS COMPRISING THE He SYSTEM

	Failure Rates (Failures per million hrs.)			
	Documented (from relia. reports) (λ_1)	FMEA (λ_2)	UCR (λ_2)	Calculated ($\hat{\lambda}$)
Helium System	2523	627	1944	1698
Subsystems:				
Supply	2484*	-	-	1672
Pneu. Cont. Distr.	75**	-	-	50***
LH_2 Line Purge Cons.	109**	-	-	32***
S-IVB Cons. 433	529*	-	-	349***
APS Cons. 436	473*	-	-	312***
S-IVB Cons. 432	1322*	-	-	873***
Valve Pnl. 9	32**	-	-	21***
Valve Pnl. 10	32**	-	-	21***

* Failure rate provided in source document.

** Failure rate of similar equipment, provided in source document.

*** Failure rate calculated by multiplying subsystem λ_1 value by Helium system $\hat{\lambda}$/Helium system λ_1.

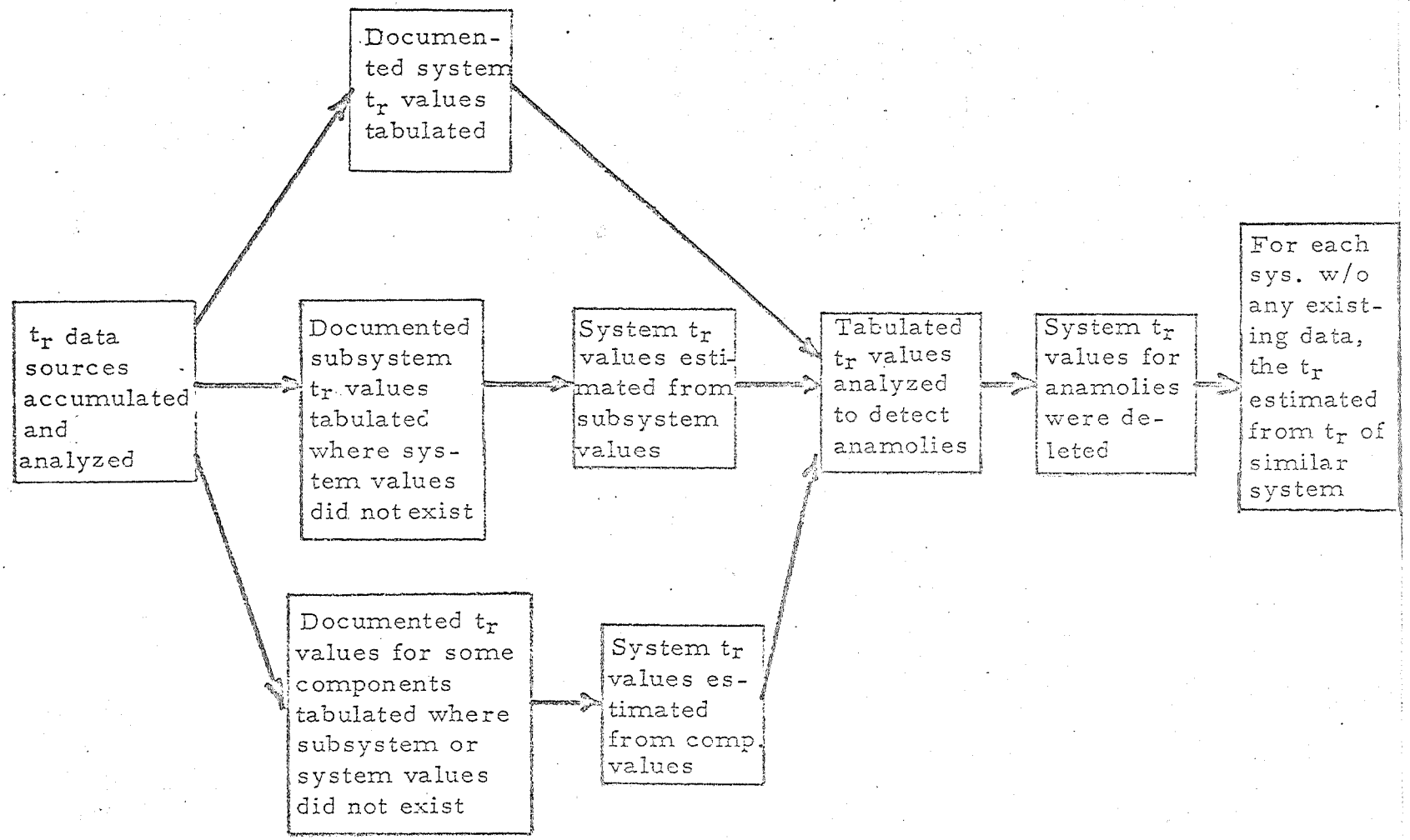


FIGURE VIII-4 PROCEDURE USED TO DETERMINE SYSTEM REPAIR TIMES (t_r)

launch support equipment as defined for this study. Second, equipment repair time values which are extreme when compared to those of other similar systems are examined from an engineering viewpoint to determine if the extreme value is warranted due to the types of components comprising the equipment, the equipment's physical location, its relation to other equipment, and its complexity.

4. For those equipment not having documented repairs from either step 1 or 2, repair time values are estimated based on the values of similar equipment in the tabulation. Equipments are considered similar if they include generally the same kinds of components performing similar functions. It should be noted that the estimates of repair time are made to include the times required for access, diagnosis, and verification as well as the repair or replacement activity itself. Repair times are in reality, estimates of the total expected down-time due to an equipment failure.

Due to the operations that are carried out during certain portions of the countdown, personnel are not permitted in the launch area. Consequently, equipment located in the closed area must be assigned greater than normal repair times to account for this extension to accessibility time during closed pad periods.

8.4.3 Spacecraft GSE Estimation Process

The derivation of failure rate and repair time estimates for spacecraft GSE is somewhat different than for the other support equipment. The principal data source documents for use in these estimates are the GSE Operational Readiness Reports and the field failure reporting system. The GSE Operational Readiness Reports provide documented estimates of cumulative operating times

times of the spacecraft equipment in addition to contractor estimates of equipment MTBF, based on their analysis of field information. The data provided in the available documents permits three estimates of failure rate values to be made. Figure VIII-5 indicates the derivation process carried out for this study.

The first set of failure rates is arrived at by taking reciprocals of the estimated MTBF's. A second set of values is determined from the number of accumulated launch impact failures and estimated cumulative operating times of each equipment provided in the GSE Operational Readiness Reports. The third set of failure rates is determined by analyzing the field failure reporting system which includes listings of all failures reported. After screening the failure listing, to remove those discrepancies reported as due to testing beyond specification limits, errors in procedures, unauthorized rework, etc., the remaining failures together with the estimated operating times from the Readiness Reports is used to estimate failure rates for each applicable system.

Judging the field failure data to be conservative and the documented MTBF's to be optimistic, the three sets of data are average to arrive at an estimated failure rate for use in the availability model. With the exception of the ACE ground station equipment, whose values were extracted directly from the contractor reliability report, all of the applicable spacecraft systems were analyzed by the above procedure. The estimated repair times for each system were directly extracted from the GSE Operational Readiness Reports.

FIGURE VIII-5 SPACECRAFT GSE FAILURE RATES

CSM - 101 LC - 34 OPERATIONAL READINESS REPORT

END ITEM NO.: A14-052	COUNTDOWN USAGE TIME T- to T- = Hrs.			Est. Cumul. Operating Time			Cumul. L.I. Failures	MTBF HRS.
				KSC	5 Units	3000 Hrs.		
				DWNY	3 Units	1500 Hrs.		
Fuel cell and cryogenic storage system heater power supply	T-40	T-0	-40	WSTF	Units	Hrs.	5	1000
END ITEM NAME:				MSC	1 Units	500 Hrs.		
				TOTAL	9 Units	5000 Hrs.		

Failure Report Number Failure Site	L.I. Crit.	L.I. Stat.	Part Number S/N	Effect	Replace Unit Avail.	Restore Time Req'd	Avail. Restore Time
				No current launch impact	0		
				failures			

$$\lambda_1 = \frac{\text{Total Field Failures}}{\text{Total Est. Cum. O.T.}}$$

$$\lambda_2 = \frac{\text{Cum. L.I. Failures}}{\text{Total Est. Cum. O.T.}}$$

$$\lambda_3 = \frac{1}{\text{MTBF}}$$

$$\lambda = \frac{\lambda_1 + \lambda_2 + \lambda_3}{3}$$

8.5 SUPPORT EQUIPMENT R&M VALUES

Reliability and maintainability characteristics for each system or subsystem needed in supporting Saturn IB launch operations have been defined in terms of failure rate and repair time estimates. The method for deriving these values was as detailed in paragraph 8.4. This data, used as a basic input requirement of the availability computer model, is presented in Table VIII-5.

TABLE VIII-5 SATURN IB GSE R&M VALUES (14 sheets)

		λ	Repair Time (Hrs)	
		10^{-6} Hrs	Nominal	Maximum
001	RP-1	693	2.5	-
220	Storage	100	2.5	-
221	Fill and Drain	500	2.5	3.0
002	LOX	1407	2.0	-
240	Storage	400	2.0	-
241	Fill and Drain (S-IB Ldg)	500	2.0	2.5
242	Fill and Drain (S-IVB Ldg)	500	2.0	-
243	Replenish Storage	400	2.0	-
244	Fill and Drain (S-IB Repl.)	500	2.0	2.5
245	Fill and Drain (S-IVB Repl.)	500	2.0	2.5
003	LH_2	2416	3.0	-
260	Storage	400	3.0	-
261	Fill and Drain	1000	3.0	3.5
262	Valve Control Complex	1000	3.0	-
004	GN_2	3194	2.5	-
280	Storage	400	3.5	-
281	None			
282	GH_2 Control Supply	45	2.5	-
283	LOX Control #1	45	2.5	-
284	LOX Control #2	45	2.5	-
285	RP-1 Control	45	2.5	3.0
286	LH_2 Control	45	2.5	-
287	Pneumatic Control Distr.	45	2.5	3.0
288	Deluge Purge Panel	65	2.5	3.0
289	SS GN_2 Supply Panel	19	2.5	3.0
290	Valve Panel 9	19	2.5	3.0
291	ECS Supply Console	19	2.5	3.0
292	Valve Panel 5	817	2.5	3.0
293	Valve Panel 10	577	2.5	3.0
294	APS Fuel and Oxidizer Ser.	88	2.5	3.0
295	APS Pneu. Cons. (436)	282	2.5	3.0
296	GSCU Purge	65	2.5	3.0
297	IU Pneu. Cons.	696	2.5	3.0
298	S-IVB Pneu. Cons. (433)(432) & Heat Exch. (438)	1571	2.5	3.0
299	Prop. Cont. Console	45	2.5	3.0

SATURN IB GSE - RELIABILITY AND MAINTAINABILITY VALUES

		λ	Repair Time (Hrs)	
		10^{-6} Hrs	Nominal	Maximum
005	GH_2	1564	2.5	-
300	GH_2 Facility	718	2.5	-
301	S-IVB Gas Ht. Exch.	846	6.0	6.5
006	He	1698	2.5	-
320	Storage	800	2.5	-
321	None			
322	Pneu. Cont. Distr.	50	2.5	3.0
323	Hydrogen Line Purge Cons.	72	2.5	3.0
324	S-IVB Pneu. Cons. 433	349	2.5	3.0
325	APS Pneu. Cons. 436	312	2.5	3.0
326	S-IVB Pneu. Cons. 432	873	2.5	3.0
327	Valve Panel 9	21	2.5	3.0
328	Valve Panel 10	21	2.5	3.0
007	ECS	3328	2.6	-
340	Cooling Tower	700	2.5	3.0
341	ECU's	1300	4.0	4.5
342	ECU Htrs.	1300	2.5	3.0
008	Fuel Mast	144	1.5	2.0
009	LOX Mast	144	1.5	2.0
010	Mast #2	278	1.5	2.0
011	Mast #4	140	1.5	2.0
012	HDA	592	1.5	2.0
013	AAA	752	5.9	6.4
014	Sw. Arm #1	111	5.9	6.4
015	Sw. Arm #2	127	5.9	6.4
016	Sw. Arm #3	107	5.9	6.4
017	Sw. Arm #4	99	5.9	6.4
018	Hydraulic	1117	5.9	-
560	Supply	945	5.9	6.4
561	Sw. Arm Cont. Pnl. #1 & Actuator	40	5.9	6.4

SATURN IB GSE - RELIABILITY AND MAINTAINABILITY VALUES

		λ	Repair Time (Hrs)	
		10^{-6} Hrs	Nominal	Maximum
018	(Continued)			
562	None			
563	Sw. Arm Cont. Pnl. #2 & Actuator	40	5.9	6.4
564	Sw. Arm Cont. Pnl. #3 & Actuator	40	5.9	6.4
565	Sw. Arm Cont. Pnl. #4 & Actuator	40	5.9	6.4
566	AAA Cont. Pnl. & Actuator	40	5.9	6.4
019	None			
020	None			
021	Service Structure	148	12.2	-
620	Hydraulics	1321	5.9	-
621	Hurricane Doors	8593	9.9	-
622	Jacks	43730	12.0	-
623	Anchor Pins	43730	12.0	-
624	None			
625	Traction Drive	2437	19.5	-
626	None			
627	Silo Gates	11382	14.4	-
628	None			
022	Umbilical Tower	444	10.1	-
640	Elevator	200	10.1	10.6
641	Crane	200	10.1	10.6
023	Water	711	4.0	-
660	Supply	300	4.0	-
661	Drinking Fount. & Toilets	57	3.5	4.0
662	Fire Hydrants	57	3.5	4.0
663	GSE Outlets	57	3.5	4.0
664	Pad	696	3.5	4.0
665	UT	811	3.5	4.0
666	SS	1721	3.5	4.0
667	Egress Spray	64	4.0	4.5
668	LH_2 Showers	52	7.1	7.6
669	LH_2 & GH_2 Fog	18	7.1	7.6
670	RP-1 Foam	840	3.5	4.0
671	RP-1 Fog	18	7.1	7.6
672	LOX Fog	18	7.1	7.6
673	Booster Pump Station	1	4.0	4.5

SATURN IB GSE - RELIABILITY AND MAINTAINABILITY VALUES

		λ	Repair Time (Hrs)	
		10^{-6} Hrs	Nominal	Maximum
023	(Continued)			
674	UT Fog	593	4.0	4.5
675	SS Fog	1358	4.0	4.5
676	Valve Pit 3	187	7.1	7.6
677	Pad Fog	18	7.1	7.6
678	Pad Flush	18	7.1	7.6
679	Torus Ring & Boattail	18	7.1	7.6
024	Emergency Egress	148	.5	-
680	Impact Pad	1	.5	-
681	Slides	16	.5	1.0
682	Sequencer	130	.5	1.0
683	Structural Components	1	.5	1.0
025	S/C Support Piping & APS	3854	2.5	-
700	S/M EPS LH_2	805	2.5	3.0
701	S/M SPS Oxidizer	231	2.5	3.0
702	S/M SPS Fuel	231	2.5	3.0
703	S/M He	566	2.5	3.0
704	S/M EPS LOX	469	2.5	3.0
705	C/M, S/M RCS Oxidizer	231	2.5	3.0
706	S/M RCS Fuel	231	2.5	3.0
707	C/M RCS Fuel	231	2.5	3.0
708	APS Fuel	231	2.5	3.0
709	APS Oxidizer	231	2.5	3.0
026	Q-Ball	444	.5	1.0
027	PTCS	1000	1.0	-
740	RP-1 PTCS Panel	20	1.0	-
741	LOX PTCS Panel	20	1.0	-
742	LH_2 PTCS Panel	20	1.0	-
743	Readout Distrs.	10	1.0	-
744	PTCS Patch Panel	10	1.0	1.5
745	RP-1 PTC	300	1.0	1.5
746	LOX PTC	300	1.0	1.5
747	LH_2 PTC	300	1.0	1.5
748	Distrs. & Ampl.	40	1.0	1.5
749	Prop. Cont. Cons. (RP-1)	20	1.0	1.5
750	Prop. Cont. Cons. (LOX)	20	1.0	1.5
751	Prop. Cont. Cons. (LH_2)	20	1.0	1.5
752	Calib. & Monitor Eq. (LOX)	10	1.0	1.5
753	Calib. & Monitor Eq. (RP-1)	10	1.0	1.5

SATURN IB GSE - RELIABILITY AND MAINTAINABILITY VALUES

		λ	Repair Time (Hrs)	
		10^{-6} Hrs	Nominal	Maximum
028	DEE-3	1143	1.0	-
760	Data Acquisition & Eval.	183	1.0	-
761	Computer	903	1.0	-
762	Line Printer & Coupler	57	1.0	-
029	Facility Meas.	146	.5	-
780	Complex Warning	50	.5	1.0
781	Purge Press. Monitoring	50	.5	1.0
782	Traffic Lights	50	.5	-
030	HGDS	1256	5.6	-
800	Sampling Valve	52	6.7	7.2
801	Vacuum System	528	6.6	7.1
802	Mass Spectrometer	208	8.8	9.3
803	HGD Local Control	65	.4	.9
804	HGD Remote Control	65	.4	-
805	Calibrator	52	5.8	-
806	Recorder	52	2.0	-
807	Slave Timing Distr.	52	2.0	-
808	28 vdc Supply Alt. Man.	52	2.0	2.5
809	DC Module	35	2.0	2.5
810	HGD Pwr. Control	52	5.6	6.1
811	28 vdc Distributor	52	2.0	2.5
031	Fire Detection Monitoring System	146	.5	-
820	S-IB Program Distr.	15	.5	1.0
821	DC Ampl.	15	.5	1.0
822	Remote Control Calibrator	15	.5	1.0
823	AGCS & LCC Patch Panels	15	.5	1.0
824	Fire Detect. Breakout Distr.	15	.5	-
825	Recorder	15	2.0	-
826	Ramp Generator	15	.5	-
827	Power Supply	15	.5	-
828	Rate Detector	15	.5	-
829	Calib. Arm Sw.	15	.5	-
032	CIF Computer	148	.15	-
033	CIF TM Ground Station	337	.25	-
034	LIEF	337	.8	-
880	Advisory Support	20	.8	-

SATURN IB GSE - RELIABILITY AND MAINTAINABILITY VALUES

		λ	Repair Time (Hrs)	
		10^{-6} Hrs	Nominal	Maximum
034	(Continued)			
881	Real-Time Digital Data	20	.8	-
882	Tape-to-Tape Inf. Exch.	20	.8	-
883	Facsimile Networks	20	.8	-
884	CD Timing & L/O	20	.8	-
885	Classified Teletype	20	.8	-
886	Closed Ckt. TV	20	.8	-
887	LIEF Ckt. Recording	20	.8	-
035	Meteorlogical Data	337	.8	-
900	Facsimile Services	168	.8	-
901	Teletype Services	168	.8	-
036	C1F Data Display	337	.5	-
037	Telemetry System	337	.5	-
940	Open Loop Equipment	15	.25	-
941	Closed Loop Equipment	15	.25	-
942	TM Equipment	307	.25	-
038	ODOP C/O	302	.7	-
960	Open Loop Equipment	50	.7	1.2
961	Closed Loop Equipment	50	.7	-
962	Output Pwr. Panels	50	.7	1.2
963	Patch Panels	50	.7	-
964	Sig. Gen.	50	.7	-
965	Control Panel	50	.7	-
966	Oscilloscope	50	.7	-
039	ODOP Ground Station	452	1.1	-
980	RF Patch Panels	50	1.1	1.6
981	ODOP Patch Panel	50	1.1	-
982	Frequency Counter	250	1.1	-
983	ODOP Receiving Station	100	1.1	-
040	C-Band	929	.5	-
1000	Open Loop Equipment	930	.5	-
1001	Closed Loop Equipment	930	.5	1.0
041	None			
042	L/V Meas. - SS	1979	.5	-
1040	None			
1041	D/A Calib. Sta.	240	.5	1.0

SATURN IB GSE - RELIABILITY AND MAINTAINABILITY VALUES

		λ	Repair Time (Hrs)	
042	(Continued)	10^{-6} Hrs	Nominal	Maximum
1042	RACS	720	.5	1.0
1043	Digital Data Calib. System	240	.5	1.0
1044	Hardware Sys.	240	.5	2.0
1045	Digital Select System	120	.5	1.0
1046	O-graph Recording System	120	.5	1.0
1047	Meas. Sys. Pwr. & Test Equip.	120	.5	1.0
043	L/V Meas. - LCC	2003	.5	-
1060	Recording Equipment	800	.5	-
1061	Distributors	300	.5	-
1062	Digital Select Panels	300	.5	-
1063	Recorders	300	.5	-
1064	Timing Distrs.	300	.5	-
044	Abort Advisory	146	.5	-
1080	Photo-Optical	25	.5	-
1081	Video	25	.5	-
1082	AAS Panels	25	.5	-
1083	Crew Safety Cons.	25	.5	-
1084	S-Band & Power Supply	45	.5	-
045	Cape Power	181	8.2	-
1100	Cape Power Plant	2	8.2	-
1101	Sub Stations C1 & C1A	179	8.2	-
046	Cabling	158	.5	1.0
047	Grounding	193	.5	1.0
048	ACE Power	193	.5	-
049	60 Hz. Power	1054	.5	-
1180	Fla. Power & Light	1	.5	-
1181	Industrial Power Substation	1052	.5	-
1182	Power Panels	1	.5	-
050	Special Power System	197	.5	-
1200	115 V to 28 V Power Supply & Batt.	100	.5	-
1201	None			
1202	480 V to 28 V Power Supply	50	.5	-
1203	MG (400 Hz)	50	.5	-

SATURN IB GSE - RELIABILITY AND MAINTAINABILITY VALUES

		λ	Repair Time (Hrs)	
		10^{-6} Hrs	Nominal	Maximum
051	OTV	2169	.5	-
1220	Pad Area Cameras	25	.5	1.0
1221	LCC Cameras	25	.5	-
1222	AGCS Camera	25	.5	1.0
1223	Processing Equipment	2000	.5	-
1224	LCC Monitors	25	.5	-
1225	Operations Mgmt. Monitors	25	.5	-
052	Photo-Optical	377	2.2	-
1240	Photo Cons. (Manual)	50	2.2	-
1241	Auto Seq. & Timing	100	2.2	-
1242	Main Distr. Fr.	50	2.2	-
1243	Cameras	100	.5	1.0
1244	UCCS	150	2.2	-
053	ALDS	337	.5	-
1260	TM	50	.5	-
1261	CASTS	50	.5	-
1262	CASRS	50	.5	-
1263	TV	50	.5	-
1264	ALTDS	50	.5	-
1265	Apollo Cmd.	50	.5	-
1266	Communications	50	.5	-
054	OIS	500	.5	-
1280	DC Power Supply	450	.5	-
1281	Distribution	50	.5	1.0
055	Wideband Transmission System	337	.5	-
1300	User Equipment (LC)	66	.5	-
1301	ETR	66	.5	-
1302	BRRS	66	.5	-
1303	Com. Distr. & Sw. Ctr.	66	.5	-
1304	Oper. & C/O User Equipment	66	.5	-
056	RF Communications	337	.5	-
1320	Network 110	170	.5	-
1321	SCAPE Suit	170	.5	-
057	Telephone	146	.5	-
1340	LC 34 & 37	24	.5	-
1341	XY Telephone	24	.5	-
1342	BRRB	24	.5	-

SATURN IB GSE - RELIABILITY AND MAINTAINABILITY VALUES

		λ	Repair Time (Hrs)	
		10^{-6} Hrs	Nominal	Maximum
057	(Continued)			
1343	CKAFS IND. Area	24	.5	-
1344	CD & SC	24	.5	-
1345	KSC IND. Area	24	.5	-
058	Paging System	291	.5	-
1360	MILA Override Ckt.	25	.5	-
1361	OIS-RF Audio	25	.5	-
1362	Local Microphone	25	.5	-
1363	Remote Microphone	25	.5	-
1364	Logic Panel & Ampl.	100	.5	-
1365	Spkr., Distr., & Ampl. Ckts	100	.5	1.0
059	Test & Sw. Centers	337	.5	-
1380	TSC (Main)	170	.5	-
1381	RTSC (AGCS)	50	.5	1.0
1382	RTSC (C1F)	50	.5	-
1383	RTSC (O & C/O)	50	.5	-
060	Timing & Countdown System	337	1.3	-
1400	Timing	168	1.3	1.8
1401	Countdown	169	1.3	1.8
061	R/S Cmd.	337	1.2	1.2
062	R/S Checkout	1682	1.2	-
1440	Signal Generation	750	1.2	-
1441	Patch Panel	182	1.0	1.5
1442	Output Equipment	750	1.2	-
063	Impact Prediction	337	.7	-
064	Radar Tr.	337	.7	-
065	Glotrac Tr.	337	.7	-
066	TM (Range)	337	.7	-
067	Optic Tr.	337	.7	-
1540	Launch Complex	110	.7	-
1541	AFETR	110	.7	-
1542	Downrange	110	.7	-

SATURN IB GSE - RELIABILITY AND MAINTAINABILITY VALUES

		λ	Repair Time (Hrs)	
		10^{-6} Hrs	Nominal	Maximum
068	MGSE	1792	1.8	-
1560	Calips C/O Console	157	1.8	-
1561	GSCU and FCVB	1193	3.0	3.5
1562	None			
1563	Q-Ball Panel	157	1.0	1.5
1564	Vacuum Monitoring Console	157	1.8	2.3
069	None			
070	None			
071	DEE-6	3503	1.0	-
1620	Remote Control	400	1.0	1.5
1621	System Control	803	1.0	1.5
1622	Computer & Perip. Equipment	2300	1.0	1.5
072	DDAS	993	1.1	-
1640	Memory System Panel	176	1.1	1.6
1641	Output Register Panel	246	.7	1.2
1642	Source Selection Dwr.	53	.7	1.2
1643	DRS-2A & DRS-3 Pwr. Panel	38	.7	1.2
1644	Computer Interface Pwr. Panel	44	.8	1.3
1645	Correlator Panel	82	.7	1.2
1646	Clock Cont. Dwr.	23	1.1	1.6
1647	Memory Cont. Dwr.	24	1.1	1.6
1648	Data Output Dwr.	28	1.1	1.6
1649	Address Cont. Dwr.	39	1.1	1.6
1650	Data Cont. Panel	149	.5	1.0
1651	Source Enable Dwr.	15	1.1	1.6
1652	Digital Sig. Sync.	64	.7	1.2
1653	Line Drivers	4	.7	1.2
1654	Line Receivers	8	.7	1.2
073	110A	5760	1.0	-
1660	Computer (LCC)	2480	1.0	-
1661	Offline Perip. Equip. (LCC)	173	1.1	-
1662	Displays	518	1.1	-
1663	Data Link	289	1.2	1.7
1664	Computer (AGCS)	2300	1.0	1.5
074	ESE Primary Power	641	.5	-
1680	S-IB	193	.5	1.0
1681	S-IVB	224	.5	1.0
1682	IU	224	.5	1.0

SATURN IB GSE - RELIABILITY AND MAINTAINABILITY VALUES

		λ	Repair Time (Hrs)	
		10^{-6} Hrs	Nominal	Maximum
075	ESE Aux. Power	197	.5	1.0
076	ESE	1775	1.2	-
1720	S-IB ESE	422	1.2	1.7
1721	S-IVB ESE	450	1.2	1.7
1722	IU ESE	450	1.2	1.7
1723	Integ. ESE	450	1.2	1.7
1724	EDS	100	.8	1.3
077	Count Clock	1084	.7	-
1740	Count Clock Repeater	333	.7	1.2
1741	Count Clock	751	.7	-
078	Az. Lay. & Align.	324	1.5	2.0
079	(C34-724) Press. Vessel Decay Test	1667	1.0	1.5
080	(C14-205) Pwr. Filt. Distr. Unit, ACE	2703	1.0	1.5
081	(S34-163) Press. Test Assy.	1667	1.0	1.5
082	(C14-232) Min. Data Interleaving	1405	1.0	1.5
083	(C14-240) Serv. Eq. ACE-S/C Adapter	2483	1.0	1.5
084	None			
085	(C14-261) Pulse Regen. Line Drives	194	1.0	1.5
086	(C14-267) Ext. DTCS	2321	1.0	1.5
087	(C14-484) Ext. Sig. Cond. Unit S/M	2443	2.0	2.5
088	None			
089	None			
090	None			
091	(A14-237) LC Antennae Coup. Set	1000	2.0	2.5
092	None			

SATURN IB GSE - RELIABILITY AND MAINTAINABILITY VALUES

		λ	Repair Time (Hrs)	
		10^{-6} Hrs	Nominal	Maximum
093	None			
094	(C14-442) RF Sys. C/O Set	622	2.0	2.5
095	(A14-074) Elec. Load Bank	2807	1.0	1.5
096	(A34-243) Disc. Set	2167	1.0	1.5
097	(C14-316) Filter, S/C Grd. Pwr.	20	2.0	2.5
098	(C14-481) Grd. Pwr. Distr. Unit	1001	1.0	1.5
099	(C14-621) Batt. Rack & Cont. Panel	2003	2.0	2.5
100	(GFP-C-226) Pwr. Sup. & Distr. Racks, 250 amp	361	2.0	2.5
101	None			
102	(A14-218) 400 Hertz Power Supply	1563	2.0	2.5
103	(A14-052) Fuel Cell Htr. Pwr. Supply	2000	2.0	2.5
104	(S14-053) E-G Fld. Trim Cont. Unit	1218	3.0	3.5
105	(S14-121) W-G Refrig. Unit	1308	2.0	2.5
106	(S14-140) ECS W-G Container	1500	1.0	1.5
107	None			
108	None			
109	None			
110	(C14-354) Pyro C/O Bridge Set	7143	1.0	-
111	(C14-620) Elect. Pwr. Distr.	83	1.0	1.5
112	None			
113	None			

		λ	Repair Time (Hrs)	
		10^{-6} Hrs	Nominal	Maximum
114	None			
115	None			
116	None			
117	None			
118	(GFP-C-126) Pwr. Supply Rack, 250 amp	361	2.0	2.5
119	TCD Seq.	189	2.2	-
2580	S-IB Firing Panel	2	1.0	-
2581	S-IB Launch Seq. Panel	147	2.2	-
2582	AGCS Program Distr.	20	2.2	2.7
2583	Ignition Seq. Panel	20	2.2	2.7
120	Propellant Data	337	.5	-
121	H.V. & A.C.	526	5.0	-
2620	Water Chillers	141	4.2	4.7
2621	Air Handlers (AGCS)	63	4.2	4.7
2622	Water Chillers (LCC)	250	5.8	-
2623	Air Handlers (LCC)	65	5.8	-
2624	Air Handlers (LCC Computer)	138	5.8	-
122	GOX	141	2.0	-
2640	GOX Recharge Trailer	35	2.0	-
2641	Oxygen Charg. Panel	35	2.0	-
2642	Oxygen Cond. Cons.	35	2.0	2.5
2643	Apollo GOX Module	35	2.0	2.5
123	(GFP-C-128) Relay & Patch Distr.	167	2.0	2.5
124	None			
125	None			
126	None			
127	None			
128	None			

SATURN IB GSE - RELIABILITY AND MAINTAINABILITY VALUES

		λ	Repair Time (Hrs)	
		10^{-6} Hrs	Nominal	Maximum
129	None			
130	(C14-346) Seq. Sys. Cont. Unit	1042	2.0	2.5
131	(C14-268) DTCS Serv. Equipment	2466	2.0	-
132	None			
133	None			
134	ACE-S/C Servicing System	5000	2.0	2.5
135	None			
136	ACE-S/C Ground Station	13745	.5	.5
2920	Start Modules	938	.5	.5
2921	CUE	538	.5	.5
2922	Up-link Computer	3608	.5	.5
2923	DTVC	880	.5	.5
2924	DADE	100	.5	.5
2925	Analog and Event Distribution	1025	.5	.5
2926	Down-link Computer	3608	.5	.5
2927	Alphanumeric Display System	3048	.5	.5

IX IMPLEMENTATION

Other sections of the report have treated, individually, the elements that are necessary to study launch support availability. The model, computer program, facility configuration, operations and equipment characteristics were discussed in Sections IV through VIII. This section is concerned with the procedures for properly assembling those elements so that a comprehensive evaluation of the launch support operations may be made. An evaluation that results in the attainment of the study objectives necessitates the implementation of the model in such ways as to utilize all of its features. Those considerations are also presented.

9.1 INPUT COMPILATION

The exercise of the launch-in-window probability model requires five types of basic, parametric data inputs. These are as follows:

1. Countdown function and support equipment interrelationship.
2. Equipment failure rate values.
3. Equipment repair time values.
4. Countdown function durations.
5. Countdown function slack times.

The computer program requires all of these inputs before representative values of launch-in-window probabilities may be obtained. The study activities and analyses described in previous sections generate this required data.

Section VIII, SUPPORT EQUIPMENT ANALYSIS, provides the first input requirement. A matrix of countdown functions vs. launch support equipment is compiled in Table VIII-1. The second and third input requirements are both developed in Section VIII also. Table VIII-5 documents failure rate and repair time values for all of the support equipment. The fourth and fifth input requirements are provided from the investigations made in Section VII, OPERATIONS ANALYSIS, and Table VII-2 summarizes the data.

9.2 INPUT CODING

For the input data to be used by the computer program, it must be converted into a computer-compatible form, consequently, such data must be compiled on load sheets and keypunched into applicable cards. Coding of this basic parametric input data is relatively simple.

There is an additional input requirement that must also be coded for computer use. This is defined as the control input and consists of the rules that represent and interrelate the events of the countdown. It is this input that describes to the computer, when a function is to occur, what other functions are interrelated with it, what holdpoint governs it and how the holdpoints are interrelated. In addition, the problems of functional interdependence due to the requirement of some launch support equipments to be simultaneously shared by two or more functions, are individually resolved in the process of developing the control input.

The coding process for providing control input employs a special language that calls a set of FORTRAN subprograms. The language is simple and there is no requirement to have an understanding of FORTRAN. The coding statements are sequenced according to the activities of the countdown, with each call performing the required computation to properly formulate the simulation. Details of the requirements and procedures for coding input information to the computer program may be found by reviewing Volume III of this report.

9.3 MODEL APPLICATION

With the data input, holdpoint codes, and holdpoint sequence code keypunched, the program is ready to be assembled and run. The procedure for assembling the deck, along with the correct job control cards, must be left to a FORTRAN programmer. The output of the computer program takes three different forms: (1) automatic output, (2) optional output, and (3) error messages.

In addition to providing a record of input data, the automatic output defines the distribution of delay at launch time. It is output as pairs of probabilities and repair times. The word "repair" is employed for each output distribution but should be interpreted in this particular instance as "delay." The probabilities are accumulated so that each is the probability that a delay less than or equal to the time printed to its right will occur. Following this distribution the probability of launch-in-window is output for each window. This probability is computed from the distribution of delay at launch by interpolating linearly. Optional output is that which is under complete control of the user. Any portion of the

program may be examined. The output at any of these selected points is of identical format to the distribution of delay at launch, i.e., pairs of probabilities and delay times.

When a modification to the nominal input data set is made, e.g., for the purpose of analyzing equipment or operational sensitivity, the distribution is computed and output in the same manner as it was for the nominal case; however, the change output also gives the difference in launch probability between the nominal case and the modification case.

Table IX-1 reproduces the computer printout of the final nominal case analyzed in this study. The results are shown in the order of the countdown, i.e., DISTRIBUTION NUMBER 13, 12, 11, 10, 9, 8, etc. and are representative of the delay causing functions associated with each of these holdpoints respectively. The intervening entires represent the combined effects from all prior distributions and establish, in a sense, a running total of the probability of delay. The last set of entires define the probability of launch for windows of 0, .1, .2, .5, 1.0, 2.5, 4.0, or 6.0 hour durations. The preceeding set of entires, under the heading DISTRIBUTION AT LAUNCH, presents the detailed distribution of delay at T-0. Both of these latter computer outputs are automatic printouts. All of the preceeding prints were optional outputs.

Several illustrations of computer runs, operating on modification data input, are presented in Table IX-2, 3, and 4. These cases were investigated during the course of the study to evaluate various parameter sensitivities.

Table IX-2 represents the case where equipment no. 340 (ECS Cooling Tower) was considered to be improved to the point of perfection, i. e., failure rate = 0. The entire computation of the countdown was performed, with this condition, and the distribution at launch given as output. The probability change, from the nominal data set is also output. This difference indicates the maximum benefit to launch support availability that is possible due to an improvement in equipment no. 340.

Table IX-3 illustrates a similar analysis wherein the combined effect on launch delay of 20 equipments was determined. Table IX-4 presents part of a sensitivity analysis concerning repair time of equipment no. 341. For this case, a repair time of 2.4 hours, 60% of the nominal value , was the only modifying data. The improvement effect on launch availability can be noted in the PROB CHANGE entries.

TABLE IX-1 NOMINAL DATA COMPUTER RUN (5 sheets)

DISTRIBUTION NUMBER 13

PROB	REPAIR	PROB	REPAIR	PROB	REPAIR	PROB	REPAIR
0.940450	0.0	0.942784	0.250	0.942834	0.300	0.961800	0.500
0.962218	0.700	0.962386	1.000	0.975918	1.500	0.976075	2.000
0.985418	2.500	0.985519	3.259	0.993551	4.037	0.993830	5.060
0.996652	6.008	0.996668	7.270	0.997566	8.180	0.997585	10.206
0.999462	13.650						

DISTRIBUTION NUMBER 12

PROB	REPAIR	PROB	REPAIR	PROB	REPAIR	PROB	REPAIR
0.986135	0.0	0.986852	0.152	0.988092	0.250	0.988181	0.450
0.992778	0.510	0.994269	0.734	0.994333	0.993	0.995477	1.750
0.996472	2.000	0.996120	2.500	0.999188	4.000	0.999553	5.900
0.999700	8.200						

DISTRIBUTION NUMBER 11

PROB	REPAIR	PROB	REPAIR	PROB	REPAIR	PROB	REPAIR
0.979816	0.0	0.979899	0.250	0.980713	0.418	0.983612	0.500
0.984408	0.617	0.990509	0.917	0.992421	1.134	0.992428	1.917
0.996220	2.500	0.996228	3.000	0.998688	4.000	0.999535	5.904
0.999872	8.200						

DISTRIBUTION NUMBER 10

PROB	REPAIR	PROB	REPAIR	PROB	REPAIR	PROB	REPAIR
0.927883	0.0	0.927888	0.043	0.928982	0.083	0.929014	0.170
0.929115	0.250	0.930426	0.418	0.934697	0.501	0.934972	0.601
0.943829	0.665	0.943840	0.750	0.949681	0.917	0.952806	1.109
0.954405	1.507	0.954421	1.961	0.954622	2.250	0.959702	2.501
0.959710	3.000	0.963248	3.994	0.964384	4.517	0.966244	5.802
0.966688	8.200	0.966842	10.100	0.997672	11.968	0.997685	16.472
0.998860	19.226	0.999321	24.159	0.999357	31.464		

DISTRIBUTION NUMBER 14

PROB	REPAIR	PROB	REPAIR	PROB	REPAIR	PROB	REPAIR
0.843160	0.0	0.843165	0.043	0.844159	0.083	0.844772	0.152
0.844801	0.170	0.848116	0.250	0.848161	0.300	0.850128	0.419
0.877439	0.502	0.877717	0.600	0.888152	0.672	0.888184	0.763
0.899283	0.921	0.904101	1.122	0.904126	1.333	0.918255	1.501
0.919262	1.749	0.920559	1.991	0.920933	2.206	0.938949	2.501
0.940203	3.180	0.940276	3.619	0.953610	4.019	0.955559	4.662
0.955628	5.086	0.961229	5.931	-0.961507	6.810	0.963331	8.210
0.963556	10.093	0.992833	11.993	0.995482	13.774	0.995900	15.949
0.997193	19.161	0.997210	21.727	0.997722	24.360	0.997755	31.464

DISTRIBUTION NUMBER 9

PROB	REPAIR	PROB	REPAIR	PROB	REPAIR	PROB	REPAIR
0.993342	0.0	0.993793	0.130	0.993878	0.250	0.993939	0.317
0.997964	0.499	0.997972	0.650	0.998374	1.200	0.999014	2.500
0.999337	4.000	0.999347	5.017	0.999458	5.900	0.999952	8.200

DISTRIBUTION NUMBER 19

0.954830	0.0	0.955263	0.130	0.955345	0.250	0.955403	0.317
0.959272	0.499	0.959280	0.650	0.959555	0.810	0.959942	1.200
0.961762	2.210	0.962377	2.500	0.962911	4.039	0.962921	5.017
0.992280	5.992	0.995411	7.841	0.995827	9.949	0.997116	13.161
0.997133	15.727	0.997642	18.360	0.997674	25.464		

DISTRIBUTION NUMBER 8

PROB	REPAIR	PROB	REPAIR	PROB	REPAIR	PROB	REPAIR
0.959943	0.0	0.963200	0.168	0.964464	0.250	0.965268	0.376
0.966248	0.434	0.969059	0.500	0.972575	0.671	0.974466	0.902
0.974479	1.250	0.975837	1.500	0.976188	1.700	0.981352	1.929
0.988319	2.417	0.994550	3.000	0.994561	3.500	0.995778	4.000
0.998009	4.502	0.998415	5.250	0.999169	6.396	0.999483	8.171

DISTRIBUTION NUMBER 28

PROB	REPAIR	PROB	REPAIR	PROB	REPAIR	PROB	REPAIR
0.916582	0.0	0.916998	0.130	0.920108	0.168	0.921393	0.250
0.921449	0.317	0.922217	0.376	0.923153	0.434	0.929551	0.499
0.932927	0.671	0.933192	0.810	0.935008	0.903	0.935406	1.201
0.936519	1.499	0.937045	1.700	0.941977	1.929	0.950992	2.383
0.950997	2.710	0.956980	2.999	0.957014	3.499	0.958689	4.012
0.960850	4.503	0.961259	5.243	0.990532	6.008	0.990622	7.122
0.994519	7.958	0.995088	10.079	0.996355	13.143	0.996404	15.389
0.996892	18.360	0.996924	25.464				

DISTRIBUTION NUMBER 7

PROB	REPAIR	PROB	REPAIR	PROB	REPAIR	PROB	REPAIR
0.967524	0.000	0.967582	0.020	0.967815	0.083	0.967827	0.120
0.967842	0.220	0.967866	0.250	0.968239	0.333	0.971095	0.506
0.972191	0.585	0.972252	0.700	0.974933	0.834	0.976668	1.013
0.976726	1.200	0.981164	1.338	0.985654	1.528	0.986227	1.700
0.987118	2.000	0.988446	2.499	0.995037	3.000	0.996264	3.500
0.997130	4.000	0.998709	4.500	0.999246	6.400	0.999462	8.200

DISTRIBUTION NUMBER 27

PROB	REPAIR	PROB	REPAIR	PROB	REPAIR	PROB	REPAIR
0.886815	0.000	0.886868	0.020	0.887082	0.083	0.887496	0.129
0.890505	0.168	0.890518	0.220	0.891784	0.250	0.892180	0.331
0.892923	0.376	0.893828	0.434	0.902636	0.502	0.903641	0.585
0.906972	0.671	0.911443	0.859	0.913067	1.013	0.913520	1.200
0.917604	1.338	0.922862	1.522	0.923896	1.700	0.929561	1.939
0.939558	2.397	0.951529	3.000	0.952692	3.514	0.955370	4.007
0.959049	4.508	0.959535	5.262	0.988591	6.017	0.989125	7.242
0.993423	8.036	0.993465	9.323	0.994118	10.144	0.995372	13.137
0.995431	15.194	0.995439	16.143	0.995912	18.360	0.995942	25.464

DISTRIBUTION NUMBER 6

PROB	REPAIR	PROB	REPAIR	PROB	REPAIR	PROB	REPAIR
0.902824	0.0	0.908673	0.090	0.908984	0.120	0.909336	0.170
0.910038	0.250	0.910375	0.418	0.916263	0.500	0.918867	0.584
0.920761	0.700	0.933457	0.994	0.937027	1.187	0.962494	1.493
0.968898	1.693	0.968940	1.917	0.970700	2.131	0.977999	2.456
0.990431	3.001	0.992660	3.500	0.994307	3.999	0.997368	4.515
0.998340	6.396	0.998735	8.168	0.998750	9.100		

DISTRIBUTION NUMBER 26

PROB	REPAIR	PROB	REPAIR	PROB	REPAIR	PROB	REPAIR
0.800638	0.000	0.800686	0.020	0.806066	0.090	0.806715	0.125
0.809744	0.169	0.809756	0.220	0.811539	0.250	0.811897	0.331
0.812575	0.375	0.813691	0.430	0.826870	0.501	0.830138	0.584
0.834870	0.682	0.834889	0.761	0.838932	0.859	0.851778	0.997
0.855457	1.188	0.859187	1.338	0.886847	1.498	0.893713	1.698
0.893751	1.917	0.901005	1.990	0.917036	2.423	0.917088	2.704
0.939732	3.001	0.943979	3.534	0.948004	4.005	0.955056	4.526
0.955805	5.304	0.983960	6.033	0.984513	6.966	0.990735	7.911
0.992103	9.643	0.992311	10.814	0.993530	13.124	0.993652	15.015
0.993668	16.138	0.994112	18.414	0.994118	21.361	0.994146	25.464

DISTRIBUTION NUMBER 9

PROB	REPAIR	PROB	REPAIR	PROB	REPAIR	PROB	REPAIR
0.974370	0.000	0.974431	0.120	0.975142	0.235	0.979091	0.498
0.979356	0.590	0.979555	0.701	0.979983	0.850	0.982273	1.007
0.982949	1.212	0.989495	1.502	0.990488	1.714	0.991032	1.997
0.991195	2.225	0.995874	2.499	0.998105	3.000	0.998519	3.500
0.998817	4.000	0.999356	4.500	0.999540	6.400	0.999614	8.200

DISTRIBUTION NUMBER 25

PROB	REPAIR	PROB	REPAIR	PROB	REPAIR	PROB	REPAIR
0.780117	0.000	0.780164	0.020	0.785406	0.090	0.786088	0.125
0.789039	0.169	0.789051	0.220	0.791358	0.246	0.791706	0.331
0.792367	0.375	0.793455	0.430	0.809457	0.500	0.812875	0.585
0.817993	0.684	0.818012	0.761	0.821974	0.859	0.836402	0.998
0.839993	1.188	0.844204	1.321	0.844220	1.357	0.876536	1.498
0.884144	1.700	0.892049	1.993	0.892180	2.225	0.911930	2.440
0.911943	2.711	0.936315	3.002	0.941187	3.532	0.945701	4.003
0.953553	4.531	0.954346	5.300	0.982412	6.034	0.983108	6.978
0.989647	7.916	0.991130	9.607	0.991400	10.771	0.992599	13.116
0.992746	15.133	0.993180	18.414	0.993185	21.361	0.993212	25.464

DISTRIBUTION NUMBER 4

PROB	REPAIR	PROB	REPAIR	PROB	REPAIR	PROB	REPAIR
0.995636	0.000	0.995647	0.353	0.995695	0.483	0.996118	0.733
0.996247	0.933	0.996616	1.232	0.996673	1.446	0.998035	1.734
0.998214	1.947	0.998265	2.233	0.999153	2.733	0.999547	3.233
0.999621	3.733	0.999670	4.233	0.999767	4.733	0.999816	6.633
0.999829	8.433						

DISTRIBUTION NUMBER 24

PROB	REPAIR	PROB	REPAIR	PROB	REPAIR	PROB	REPAIR
0.776713	0.000	0.776759	0.020	0.781978	0.090	0.782657	0.125
0.785595	0.169	0.785607	0.220	0.787904	0.246	0.788251	0.331
0.788918	0.375	0.790001	0.430	0.805971	0.500	0.809373	0.585
0.814818	0.687	0.818762	0.859	0.833228	0.998	0.836804	1.188
0.841307	1.315	0.873526	1.498	0.882183	1.704	0.890193	1.992
0.910081	2.438	0.910093	2.711	0.935111	2.994	0.940330	3.512
0.944930	3.997	0.945038	4.218	0.953009	4.535	0.953805	5.300
0.981843	6.035	0.982565	6.981	0.989154	7.919	0.990650	9.604
0.990925	10.768	0.992119	13.116	0.992265	15.133	0.992697	18.414
0.992702	21.361	0.992729	25.464				

DISTRIBUTION NUMBER 3

PROB	REPAIR	PROB	REPAIR	PROB	REPAIR	PROB	REPAIR
0.992885	0.0	0.992903	0.120	0.992980	0.250	0.993748	0.500
0.993924	0.700	0.994596	1.012	0.994757	1.253	0.996931	1.501
0.997261	1.712	0.997370	2.015	0.998797	2.500	0.999430	3.000
0.999549	3.500	0.999633	4.000	0.999788	4.500	0.999840	6.400
0.999862	8.200						

DISTRIBUTION NUMBER 23

PROB	REPAIR	PROB	REPAIR	PROB	REPAIR	PROB	REPAIR
0.771186	0.000	0.771232	0.020	0.776415	0.090	0.777103	0.125
0.780020	0.169	0.780031	0.220	0.782372	0.246	0.782716	0.331
0.783378	0.375	0.784453	0.430	0.800907	0.500	0.804285	0.585
0.809828	0.687	0.813744	0.859	0.828641	0.998	0.832192	1.188
0.836788	1.313	0.870499	1.498	0.879357	1.704	0.887501	1.993
0.908457	2.441	0.908462	2.717	0.933955	2.995	0.939326	3.511
0.944073	3.996	0.952385	4.532	0.953188	5.302	0.981187	6.035
0.981904	6.981	0.988573	7.912	0.990131	9.569	0.990413	10.756
0.991599	13.116	0.991744	15.133	0.992173	18.414	0.992178	21.361
0.992205	25.464						

DISTRIBUTION NUMBER 2

PROB	REPAIR	PROB	REPAIR	PROB	REPAIR	PROB	REPAIR
0.997720	0.0	0.997727	0.120	0.997755	0.250	0.998001	0.500
0.998064	0.700	0.998231	1.000	0.998257	1.200	0.999049	1.501
0.999155	1.714	0.999201	2.028	0.999679	2.500	0.999841	2.997
0.999858	3.473	0.999864	6.400	0.999871	8.200		

DISTRIBUTION NUMBER 22

PROB	REPAIR	PROB	REPAIR	PROB	REPAIR	PROB	REPAIR
0.769428	0.000	0.769474	0.020	0.774644	0.090	0.775336	0.125
0.778246	0.169	0.778258	0.220	0.780615	0.246	0.780958	0.331
0.781619	0.375	0.782692	0.430	0.799298	0.500	0.802668	0.585
0.808247	0.687	0.812154	0.859	0.827146	0.998	0.830689	1.188
0.835294	1.313	0.869540	1.498	0.878458	1.705	0.886641	1.994
0.907935	2.442	0.907941	2.717	0.933547	2.995	0.938939	3.511
0.943708	3.996	0.952036	4.533	0.952838	5.302	0.980798	6.035
0.981514	6.981	0.988196	7.911	0.989769	9.559	0.990050	10.756
0.991233	13.116	0.991378	15.133	0.991806	18.414	0.991811	21.361
0.991838	25.464						

DISTRIBUTION NUMBER 1

PROB	REPAIR	PROB	REPAIR	PROB	REPAIR	PROB	REPAIR
1.000000	0.0						

DISTRIBUTION AT LAUNCH

PROB	REPAIR	PROB	REPAIR	PROB	REPAIR	PROB	REPAIR
0.769428	0.000	0.769474	0.020	0.774644	0.090	0.775336	0.125
0.778246	0.169	0.778258	0.220	0.780615	0.246	0.780958	0.331
0.781619	0.375	0.782692	0.430	0.799298	0.500	0.802668	0.585
0.808247	0.687	0.812154	0.859	0.827146	0.998	0.830689	1.188
0.835294	1.313	0.869540	1.498	0.878458	1.705	0.886641	1.994
0.907935	2.442	0.907941	2.717	0.933547	2.995	0.938939	3.511
0.943708	3.996	0.952036	4.533	0.952838	5.302	0.980798	6.035
0.981514	6.981	0.988196	7.911	0.989769	9.559	0.990050	10.756
0.991233	13.116	0.991378	15.133	0.991806	18.414	0.991811	21.361
0.991838	25.464						

```
WINDOW=  0.100 LAUNCH PROB = 0.774846
WINDOW=  0.200 LAUNCH PROB = 0.778253
WINDOW=  0.500 LAUNCH PROB = 0.799241
WINDOW=  1.000 LAUNCH PROB = 0.827180
WINDOW=  2.500 LAUNCH PROB = 0.907936
WINDOW=  4.000 LAUNCH PROB = 0.943767
WINDOW=  6.000 LAUNCH PROB = 0.975468
WINDOW=  0.0   LAUNCH PROB = 0.769428
```

MODIFICATION DATA

PRINT FLAGS

9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

SLACK TIMES

0 0.0 0 0.0 0 0.0 0 0.0 0 0.0 0 0.0 0 0.0 0

THE FOLLOWING EQUIPMENT CHANGES ARE MADE TO BASIC DECK

EQUIP.NO. 340 FAILURE RATE 0.0 REPAIR TIME 0.0

DISTRIBUTION AT LAUNCH

PROB	REPAIR	PROB	REPAIR	PROB	REPAIR	PROB	REPAIR
0.709567	0.0	0.709804	0.000	0.712195	0.084	0.712896	0.124
0.722218	0.168	0.723667	0.245	0.723710	0.317	0.725499	0.349
0.736646	0.417	0.758627	0.501	0.758964	0.589	0.769070	0.683
0.773952	0.836	0.820304	0.983	0.828604	1.208	0.832673	1.484
0.839742	1.671	0.876294	1.944	0.876709	2.179	0.912247	2.447
0.923900	2.974	0.926621	3.425	0.939451	4.039	0.941102	4.884
0.972247	5.761	0.974623	6.685	0.987016	7.636	0.987594	8.545
0.989414	9.628	0.990503	11.495	0.991867	13.396	0.992006	15.522
0.992334	18.666	0.992356	21.333	0.992382	25.304		

WINDOW= 0.100	LAUNCH PROB = 0.712475	PROB CHANGE =	0.003086
WINDOW= 0.200	LAUNCH PROB = 0.722820	PROB CHANGE =	0.003131
WINDOW= 0.500	LAUNCH PROB = 0.758365	PROB CHANGE =	0.003227
WINDOW= 1.000	LAUNCH PROB = 0.820931	PROB CHANGE =	0.003558
WINDOW= 2.500	LAUNCH PROB = 0.913419	PROB CHANGE =	0.000719
WINDOW= 4.000	LAUNCH PROB = 0.938636	PROB CHANGE =	0.000332
WINDOW= 6.000	LAUNCH PROB = 0.972862	PROB CHANGE =	0.000158
WINDOW= 0.0	LAUNCH PROB = 0.709567	PROB CHANGE =	0.003074

TABLE IX-2 SENSITIVITY OF EQUIPMENT 340 (COOLING TOWER)

TABLE IX-3 SENSITIVITY OF TWENTY EQUIPMENTS

THE FOLLOWING EQUIPMENT CHANGES ARE MADE TO BASIC DECK

EQUIP.NO. 124 FAILURE RATE 0.0 REPAIR TIME 0.0

EQUIP.NO. 291 FAILURE RATE 0.0 REPAIR TIME 0.0

EQUIP.NO. 741 FAILURE RATE 0.0 REPAIR TIME 0.0

EQUIP.NO. 751 FAILURE RATE 0.0 REPAIR TIME 0.0

EQUIP.NO. 800 FAILURE RATE 0.0 REPAIR TIME 0.0

EQUIP.NO. 801 FAILURE RATE 0.0 REPAIR TIME 0.0

EQUIP.NO. 805 FAILURE RATE 0.0 REPAIR TIME 0.0

EQUIP.NO. 806 FAILURE RATE 0.0 REPAIR TIME 0.0

EQUIP.NO. 807 FAILURE RATE 0.0 REPAIR TIME 0.0

EQUIP.NO. 808 FAILURE RATE 0.0 REPAIR TIME 0.0

EQUIP.NO. 810 FAILURE RATE 0.0 REPAIR TIME 0.0

EQUIP.NO. 811 FAILURE RATE 0.0 REPAIR TIME 0.0

EQUIP.NO. 1045 FAILURE RATE 0.0 REPAIR TIME 0.0

EQUIP.NO. 1046 FAILURE RATE 0.0 REPAIR TIME 0.0

EQUIP.NO. 1047 FAILURE RATE 0.0 REPAIR TIME 0.0

EQUIP.NO. 1364 FAILURE RATE 0.0 REPAIR TIME 0.0

EQUIP.NO. 1365 FAILURE RATE 0.0 REPAIR TIME 0.0

EQUIP.NO. 1381 FAILURE RATE 0.0 REPAIR TIME 0.0

EQUIP.NO. 1382 FAILURE RATE 0.0 REPAIR TIME 0.0

EQUIP.NO. 2620 FAILURE RATE 0.0 REPAIR TIME 0.0

DISTRIBUTION AT LAUNCH

PROB	REPAIR	PROB	REPAIR	PROB	REPAIR	PROB	REPAIR
0.707001	0.0	0.707237	0.000	0.709620	0.084	0.710318	0.124
0.719607	0.168	0.721038	0.244	0.721082	0.317	0.722864	0.349
0.733970	0.417	0.755684	0.501	0.756018	0.589	0.766075	0.683
0.770939	0.836	0.816916	0.983	0.825175	1.208	0.829214	1.484
0.836253	1.671	0.872657	1.944	0.873068	2.179	0.911697	2.452
0.923472	2.975	0.926339	3.429	0.939215	4.040	0.941046	4.872
0.972144	5.761	0.974525	6.684	0.986992	7.641	0.987583	8.556
0.989429	9.644	0.990515	11.495	0.991876	13.397	0.992018	15.531
0.992346	18.666	0.992368	21.329	0.992394	25.304		

WINDOW= 0.100 LAUNCH PROB = 0.709899 PROB CHANGE = 0.000510
WINDOW= 0.200 LAUNCH PROB = 0.720210 PROB CHANGE = 0.000521
WINDOW= 0.500 LAUNCH PROB = 0.755426 PROB CHANGE = 0.000288
WINDOW= 1.000 LAUNCH PROB = 0.817540 PROB CHANGE = 0.000167
WINDOW= 2.500 LAUNCH PROB = 0.912778 PROB CHANGE = 0.000078
WINDOW= 4.000 LAUNCH PROB = 0.938372 PROB CHANGE = 0.000068
WINDOW= 6.000 LAUNCH PROB = 0.972761 PROB CHANGE = 0.000057

MODIFICATION DATA

PRINT FLAGS

9	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

SLACK TIMES

0 0.0 0 0.0 0 0.0 0 0.0 0 0.0 0 0.0 0 0.0 0

THE FOLLOWING EQUIPMENT CHANGES ARE MADE TO BASIC DECK

EQUIP.NO. 341 FAILURE RATE 0.13000E-02 REPAIR TIME 0.24000E 01

DISTRIBUTION NUMBER 6

PROB	REPAIR	PROB	REPAIR	PROB	REPAIR	PROB	REPAIR
0.858885	0.0	0.860698	0.084	0.860994	0.120	0.867988	0.167
0.868661	0.250	0.881004	0.417	0.889843	0.500	0.889895	0.590
0.899785	0.679	0.899873	0.800	0.937540	0.976	0.942323	1.200
0.942970	1.480	0.950590	1.667	0.969844	1.932	0.983152	2.477
0.989069	2.981	0.990956	4.014	0.990994	4.929	0.998502	5.900
0.998901	8.231	0.998908	11.800				

DISTRIBUTION AT LAUNCH

PROB	REPAIR	PROB	REPAIR	PROB	REPAIR	PROB	REPAIR
0.706493	0.0	0.706729	0.000	0.709110	0.084	0.709808	0.124
0.719090	0.168	0.720532	0.245	0.720576	0.317	0.722357	0.349
0.733455	0.417	0.755341	0.501	0.755676	0.589	0.765739	0.683
0.770599	0.836	0.816751	0.983	0.825011	1.208	0.829062	1.484
0.836101	1.671	0.872494	1.944	0.872908	2.179	0.917716	2.445
0.929884	2.971	0.933375	3.447	0.940172	4.097	0.941650	4.911
0.972362	5.755	0.974692	6.686	0.987273	7.652	0.987976	8.574
0.989554	9.691	0.990606	11.456	0.991975	13.399	0.992125	15.539
0.992446	18.691	0.992469	21.318	0.992495	25.304		

WINDOW= 0.100	LAUNCH PROB = 0.709389	PROB CHANGE =	0.0
WINDOW= 0.200	LAUNCH PROB = 0.719689	PROB CHANGE =	0.0
WINDOW= 0.500	LAUNCH PROB = 0.755080	PROB CHANGE =	0.0
WINDOW= 1.000	LAUNCH PROB = 0.817373	PROB CHANGE =	0.0
WINDOW= 2.500	LAUNCH PROB = 0.918988	PROB CHANGE =	0.006288
WINDOW= 4.000	LAUNCH PROB = 0.939158	PROB CHANGE =	0.006724
WINDOW= 6.000	LAUNCH PROB = 0.972975	PROB CHANGE =	0.000271
WINDOW= 0.0	LAUNCH PROB = 0.706493	PROB CHANGE =	0.0

TABLE IX-4 REPAIR TIME SENSITIVITY OF EQUIPMENT 341

X RECOMMENDATIONS

The launch probability analysis method described in other sections of this report provides a method of evaluating the effect of various suggested changes in launch operation procedures or equipment. The expected results of proposed changes may then be used as input to the decision making process for selecting which of the proposed changes should be pursued to best advantage. Ultimately, changes in launch operations, equipment, or personnel requirements are necessary to achieve improvement in launch probability.

Recommendations resulting from this study leading to launch probability improvement are of two types: (1) possible changes that directly affect launch operations, i.e., procedures and equipment, which could provide immediate improvement, and (2) other suggestions designed to indirectly improve the launch control activities by strengthening the procedural methods now employed, which may be expected to only provide long term benefits. The latter type may be presumptuous to the extent that such recommendations are biased to only reflect the interests developed through this study. Their relative worth and the overall impact on the KSC program remains to be determined by others.

The recommendations presented in this section are categorized into four areas; Launch Operations, and Support Equipment are pertinent to type (1) recommendations, Procedural and Analytical Activities are type (2).

10.1 LAUNCH OPERATIONS

Scheduled Holds - As discussed in other sections of this document, the probability of launch may be significantly affected by the placement and duration of scheduled holds in the countdown operations. In evaluating the AS 205 countdown, for this study, it was found that the 6 hour hold at T-6 absorbed almost all of the delays due to the operations preceeding it. Built-in holds located at other points in the countdown would similarly be effective in absorbing delays due to preceeding functions. But the selection of the location for a hold must include practicality considerations. Though it is obvious that a hold placed at T-0 would serve as the best delay absorber, in that it could affect all of the countdown functions, it is equally obvious that such a scheme is impractical. At other points in the countdown, a scheduled hold, though feasible, may introduce new hazards whose effect on launch delay would outweigh any benefits resulting from absorbing the delays of previous functions.

Clearly, the selection of a location for a hold should result from a trade off of delay-absorbing benefits and delay-causing detriments. Although the benefits of scheduled holds were established in this study, no effort was made to evaluate the detrimental effects of a scheduled hold. However, it is concluded that a hold scheduled after T-0:14:30, start tank chilldown is impractical due to the limitation of the GH_2 supply.

Given then that HP 5 represents the latest practical point in the countdown for locating an additional scheduled hold, it remains only to compare the effects at HP 6, 7, 8, and 9 to properly select this location. Examination of Figures II-7,

8, and 9 indicates that improvement in probability is minor until reaching HP 6 and this improvement is comparable to the improvement at HP5. A hold located at HP6 (T-0:40:0) appears as the best selection from a cursory trade off of improvement and detriment characteristics.

The selection of a scheduled hold's duration must also result from a trade off. Extended holds can absorb more delays but may also cause more problems and practical considerations will place limits on the length of holds. An additional consideration, of importance in selecting hold duration, is the size of the launch window. As shown in Figure II-10, the probability improvement for an additional increment of hold time is greatly dependent on the size of the launch window.

The recommendation of adding to the operational procedures, a scheduled hold of one hour at T-0:40:0, given a 30 minute launch window, will improve the probability of launch support success from .799 to .865.

Function Slack - Increases in the slack time for certain functions will produce an increase in launch probability. The functions that will most effectively increase launch probabilities from increased slack are those which have repair time greater than their current slack times. The higher launch probability results from providing additional time to complete the repair, thus eliminating the need for an unscheduled hold which would otherwise be required.

An analysis of the countdown procedure is recommended to maximize the slack times associated with critical functions, i.e., those functions for which equipments having high failure rates or long repair times are required to operate.

The recommended analysis must consider the many possible alternative, feasible arrangements of countdown functions to maximize the net launch probability improvement resulting from the analysis. A method similar to that described in Section II, CONTRIBUTION TO LAUNCH DELAY BY FUNCTION, would be useful in isolating the principal functions of concern.

Such an effort should enlist the experience of persons intimately associated with launch operations to assure that all acceptable alternate arrangement of functions are considered. The results of this analysis would provide the most desirable launch operations procedure possible, developed from a launch-on-time objective.

Function Scheduling - Typical curves developed by plotting launch probability against count time, using data derived from the launch probability analysis (See Figure II-5), indicates that little improvement in launch probability can be expected from improvement modifications to equipment or procedures used prior to the 6 hour hold.

An analysis of the countdown procedure and launch operations is recommended to develop a procedure which would designate completion of as many launch operations functions as possible, both launch vehicle and spacecraft functions, ahead of the final scheduled hold.

Development of the proposed procedures would require intimate knowledge of the countdown procedures and objectives of each operation function. Such scheduling would not only improve launch probability directly, but would permit operations personnel to concentrate their efforts, during the countdown,

on successful completion of the lesser number of functions during the critical period, T-6 to T-0, which would also tend to improve launch probability.

10.2 SUPPORT EQUIPMENT

UCR Analysis - Since UCR's are indicative of field failures, the analysis of UCR information may be expected to provide an indication of which components within a given system have the highest failure rates, and thus produce the largest contribution to that system's failure rate. The UCR's issued against all KSC ground support equipment in Launch Complex 34 and 37B were accumulated and analyzed. Failures were categorized according to cause and type of equipment. Systems and their components which had a significant number of failures are listed in Table X-1. Where a significant (generally less than 5) number of component's failures within a system have not occurred, the system was excluded from the list.

When improvement of the failure rate is considered for one of the systems listed, it is recommended that the components having the greatest number of failures be given priority as candidates for modifications. Elimination of failures of these components will provide maximum improvement in the system failure rates.

Digital Events Evaluator (DEE-6) - UCR printouts (i.e., Report XTRT 13, dated 17 March 1969 and XTRT 12, dated 1 December 1969) for the DEE-6 modules were reviewed in detail. It was determined that a total of 133 defects of components were reported. Of these defects, over 18% involved one component: Part No. 108236,

TABLE X-1 RECURRING FAILURES

System	Equipments Failed	Number Failures
003 LH_2	Vacuum sensing elements	39
	Bellows	17
	Vacuum jacketed lines	16
	Manual valves	11
	Relief valves	5
	Regulators	4
	Gages	4
	Subtotal	97
	Failures among 23 other equipments	36
	TOTAL	133
004 GN_2	Manual valves	56
	Solenoid valves	38
	Gages	33
	Regulators	21
	Relief valves	12
	Filters	9
	Flex hoses	9
	Pressure switches	7
	Subtotal	185
	Failures among 15 other equipments	19
	TOTAL	204
005 GH_2	Manual valves	12
	Failures among 5 other equipments	6
	TOTAL	18
006 He	Regulators	7
	Manual valves	6
	Subtotal	13
	Failures among 7 other equipments	10
	TOTAL	23
007 ECS	Temperature and pressure controller	28
	Meters	23
	Pressure switches	12
	Electrical relays	11
	Expansion valves	10
	Solenoid valves	9
	Ducts	9
007 ECS (Cont'd)	Converter	7
	Ball valves	7
	Pumps	6
	Subtotal	122
	Failures among 25 other equipments	54
	TOTAL	176

TABLE X-1 RECURRING FAILURES (Cont'd)

System	Equipments Failed	Number Failures
018 HYDRAULIC	Solenoid valves	8
	Failures among 4 other equipments	5
	TOTAL	13
023 WATER	Solenoid valves	13
	Push button	1
	TOTAL	14
025 S/C SUP. PIPING	Quick Disconnects	5
	TOTAL	5
037 TELEMETRY	Receivers	15
	Amplifiers	13
	Counters	12
	Oscillators	12
	Tuning heads	11
	Converters	10
	Tape recorders	8
	Meters	7
	Panadapters	6
	Power Supply	6
	Subtotal	99
	Failures among 18 other equipments	45
	TOTAL	144
049 60 CYL. PWR.	Circuit breakers	5
	TOTAL	5
051 OTV	Cameras	47
	Switching Amplifiers	35
	Monitors	42
	Camera Pan and Tilt	14
	Phase corrector amplifier	10
	Subtotal	148
	Failures among 13 other equipments	35
	TOTAL	183
054 OIS	Headset amplifiers	27
	Mike amplifiers	23
	Subtotal	50
	Failures among 9 other equipments	19
	TOTAL	69
058 PAGING	Frequency Sync	7
	Modern	6
	Audio amplifier	4
	Subtotal	17
	Failures among 4 other equipments	6
	TOTAL	23

Printed Circuit Module ZX 35. The DEE-6 functional elements affected by these PC module failures included the Input Chassis, Magnetic Tape Unit and Display Console #2 of the SDS 930 Computer System. The fact that this one part type contributed over 18% of all defects reported is sufficient basis for recommending that it be analyzed with the intent of modifying, redesigning or replacing it in order to increase the availability of the DEE-6 system.

Repair Time - Improvements in repair time for certain equipments will improve launch probabilities where such improvements permit repair to be completed within the available slack time instead of extending beyond this time, causing an unscheduled hold. The amount of the increase in launch probability is dependent on the number of delays eliminated by the reduced repair time.

In general, however, few instances of delay elimination should be expected by reducing equipment repair times. To expect a probability improvement from a reduction in repair time, the improved repair (R_1) would need be equal or less than the slack (S). Therefore, the change in repair (ΔR) would need to approach the original repair time, (R_o) if slack were sufficiently small, i.e.,

$$\Delta R \geq R_o - S.$$

Such an improvement in repair capability is not to be expected. The investigation of the Saturn IB characteristics indicated that most functions that do have slack times (many have none at all) are either short or have slack that are sufficiently long already. It should be noted, however, that the extension of the launch window effectively increases each function's slack by that amount. Therefore, for large launch windows, repair time improvements can be beneficial.

For AAP launches, the expected window is small and any function delay is likely to cause a launch delay. Since repair times generally cannot be expected to be reduced to the extent they are eliminated or made smaller than the anticipated AAP window size, improving launch probability through repair time improvements is unlikely for AAP missions. It would appear that efforts to improve availability should be directed toward reliability rather than maintainability.

Baseline Listing - The baseline listing provided in Section II of this report gives a ranking of support equipment, based on the contribution of the probability of launch delay. This listing is recommended for use as a means of establishing priority, concerning modification alternatives. It may also be used to establish the additional areas requiring improvement investigations. Use of the baseline listing for these purposes will provide assurance that the most serious problems are considered before those having less impact on launch support success.

10.3 PROCEDURAL

UCR Systems - The UCR System was utilized to a great extent in the conduct of this study. UCR data was useful in estimating system failure rates and was also utilized in identifying equipment and components that possibly warranted improvement considerations based on their repetitive appearance as a failure. The familiarity acquired with this system during the study has identified a number of areas where it is inadequate for such purposes.

This recommendation to improve the UCR System is not the result of a deficiency in the System. No attempt was made to review its adequacy concerning QC or failure recurrence control, which is its primary function. Rather, the self interests of this study in searching for representative data, concluded that much of what was desired could be found in UCR form, but found that everything desired was not available. This recommendation proposes the extension of an already useful system into other areas of usefulness.

Analysis of the UCR system requirements and operation is recommended to determine the feasibility of modifying the system to provide the results listed below:

1. Improve the uniformity and quality of the data recorded.
2. Provide data required to determine field failure rates.
3. Provide failure analysis results on UCR forms.
4. Provide repair time data.

To ensure that UCR's are uniformly prepared, including the requirements of the items listed above, the system should be controlled and operated by one division, such as Design Engineering, which has a specific use for the information that should be reported. It is expected that an extension of the UCR System into other areas of application, i.e., design and analytical studies, would be of reasonable cost. Such an approach would also probably fortify its present use.

Criticality Standard Analysis - KSC-STD-122, has been written to define acceptable, uniform methods for determining criticality numbers for GSE

components. This standard document was reviewed during the course of this study for its possible application to launch delay analysis. The standard was found to contain several inadequacies and errors which require correction. If this document is to be retained, a thorough analysis of its contents is recommended.

Mission Rules and Alternatives - In performing the analysis required to model the launch support operations, the Mission Rules and the Countdown Document were used as guides. These documents concisely define what and when certain events occur. However, they represent a nominal case. It is evident from the success of the Saturn programs that alternatives to the nominal procedures also exist. It is, therefore, recommended that these conditional relationships concerning the launch operations be defined and documented.

Development of the possible alternates for responding to equipment failure events would necessitate additional planning effort for each launch, however, such planning would: (1) ensure that all possible alternates are not overlooked, (2) promote the development of new alternates where few or none exist, and (3) permit these established alternates to ultimately be included in all analytical evaluations of the support operations. It is expected that such alternatives have a significant effect on the relative importance of support equipment causing launch delay.

10.4 ANALYTICAL ACTIVITIES

Probability of Launch-In-Window - The model as developed and used in this study only includes the influence of ground support equipment on launch probability. In reality, the probability of launch-in-window is dependent on the condition of the flight vehicle, the downrange facilities and the weather, in addition to launch support. To a large measure, each of these factors are interrelated and their individual effect on launch probability is dependent on the condition of the others. Given that launch probability is an important criteria for measuring the total success picture, it is necessary to investigate these other contributors to launch delay. Such an investigation is recommended.

It should be noted that this kind of analysis should result in a single model, accounting for all four areas affecting launch probability, rather than four separate models that would be unable to consider interrelationships. There is some basis for predicting the feasibility of such an effort based on the results of this study. First, the model developed for evaluating support operations has as its basis, the same launch operations that govern the flight vehicle and the range. The weather too, may be considered as a support function, required continuously during the countdown and whose failure (high winds, severe storms, low ceilings) cause an unscheduled hold. The model developed in this study appears applicable and compatible with the inclusion of the additional requirements. Secondly, sufficient input data concerning equipment and weather characteristics appears available. Given the model and the data, no apparant difficulties should be expected.

Other Model Applications - The model and computer program developed for this study, although based on Saturn IB support operations is amenable to other applications. The basic concept, which interrelates support equipment with the overall countdown operation, inherits its application uniqueness solely by input data. The model would be equally adaptable to evaluating the Centaur or Saturn V support operations as it is to Saturn IB, given that input data was available. The model and program are fully documented in User Manual form to facilitate its use. For applications other than Saturn IB, it remains only to generate the appropriate input data.

Automatic Coding of Input - The feature of the launch availability model that provides its general purpose characteristics and permits it to have a broad area of application is the same feature that requires the provision of its operational input data to be a lengthy, detailed task. Coding the basic control data as input to the computer program is a one time task but it is the type of effort that lends itself to automation.

In the present method, functions are input only in terms of operating time The analyst who inputs the operational data, must see that this function is coded in the proper countdown location and properly interrelated with other functions of its group. By defining the function with start and stop times, and establishing a set of rules for interrelating functions (the same that the analyst now uses) the total coding process could be automated. With automated coding, input effort to the availability program would be minimized and accuracy maintained. It would result in a fully automatic availability program.