ON-ORBIT SPACECRAFT RELIABILITY

PRC R-1863

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FOREWORD

This document completely updates and consolidates the results of three previous studies to compile, interpret, and analyze orbital reliability data on U.S. spacecraft. Both the earlier studies and this update were performed by Planning Research Corporation (PRC). The first study was conducted from 13 May 1966 to 3 March 1967 for the Apollo Support Department of the General Electric Company in cooperation with Headquarters, National Aeronautics and Space Administration. The second and third studies were part of a larger effort for the Navy Space Systems Activity; they reported on work conducted from 1 November 1970 to 30 November 1971, and from 1 December 1971 to 30 November 1972. This update was prepared for NASA Headquarters.

Mr. Abe Moskovitz was the Technical Monitor. This work was performed under contract number NASW-3041.

The authors wish to express their gratitude for the cooperation of the various program offices in making data available for this study. Many individuals, both in government organizations and in private industry, assisted in the development of the study data. Without their assistance and cooperation, the large data base could not have been generated.

Members of the PRC study team were V. Anderson, C. Bloomquist, D. DeMars, W. Graham, P. Henmi, and G. Stiehl. In addition, the authors wish to acknowledge the efforts of J. Amos, H. Thomas, and J. Zell for their assistance in report preparation.

ABSTRACT

This report documents four studies investigating the on-orbit reliability of spacecraft. The total effort included compiling, interpreting, and analyzing operational and historic data for 350 spacecraft from 52 U.S. space programs.

Failure rate estimates are made for on-orbit operation of spacecraft subsystems, components, and piece parts, as well as estimates of failure probability for the same elements during launch. Confidence intervals for both parameters are also given.

Based on the total data sample (this study and previous ones), the results indicate that: (1) the success of spacecraft operation is only slightly affected by most reported incidents of anomalous behavior, (2) the occurrence of the majority of anomalous incidents could have been prevented prior to launch, (3) no detrimental effect of spacecraft dormancy is evident, (4) cycled components in general are not demonstrably less reliable than uncycled components, and (5) application of product assurance elements is conducive to spacecraft success but the effect cannot be quantified on the basis of the data considered in this report.

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I. INTRODUCTION AND SUMMARY

This report is a compilation, analysis, and interpretation of orbital reliability data on U.S. spacecraft. It covers a period of nearly 20 years and is a synthesis of four individual data collection and analysis efforts. The previous study reports were published in 1967, 1971 and 1972.

A. STUDY OBJECTIVES AND SCOPE

The common objective of this study and the previous ones is to achieve better utilization of reliability information inherent in spacecraft operational data. All four studies have proceeded from the assumption that empirical on-orbit information might be applied advantageously to the planning and development of space systems.

The current study has several subsidiary objectives: (1) to compile all the relevant data into a single volume, (2) to update the results of the earlier studies by considering NASA spacecraft launched subsequent to those included in the earlier data base, (3) to prepare six experience bulletins to highlight particularly pertinent study findings, (4) to extract information from the data base relative to the dormant or standby mode of spacecraft component operation, and (5) to attempt to relate observed project success to product assurance elements.

B. GENERAL BACKGROUND

Appendix A contains the basic data on all anomalous incidents that have been collected in this study and the previous studies.

They are presented as four data sets. The first set contains data from 225 spacecraft launched prior to May 1966. The second set extends the time period to 1970 and includes data from 79 more spacecraft. The third set extends the data base another year and adds six new spacecraft. The fourth set, derived in this study, extends the time period to 1977 and adds another 40 spacecraft. The total data base covers 350 spacecraft from 52 different space programs. Appendix C provides details on this data bank coverage.

The analyses of the data in the body of the report is generally given for two samples. The first is called the pre-update sample and includes all data from the first three data sets. The second is usually referred to as "this sample" or "this update" and includes only the data collected for this study. Where the results are not obvious the data are combined for all samples.

C. DATA BASE AND LIMITATIONS OF THE STUDY

The basic approach in all four studies has been to collect and analyze as much reliability data from as many spacecraft as possible within cost and schedule constraints. The first data set includes all kinds of spacecraft. The second and third sets were generally restricted to long-term spacecraft. This data set includes only NASA spacecraft.

The basic data elements were collected and recorded for individual spacecraft. It is not the intent of these studies to explicitly compare either space programs or spacecraft within a given program. For this reason, and at the request of many program offices, program and spacecraft identification have been withheld in most analyses. The basic data recorded for each program is available at NASA Headquarters, Code DP-4.

An important underlying bias of the study analyses is one common to all large-scale reliability data studies. In the context of the subject matter of this report, the bias is that the spacecraft anomalies analyzed are "reported" anomalies rather than the desired "occurred" anomalies. The large and varied data base, however, tends to minimize the effect of this bias.

The information provided by the study analyses is extensive and covers several areas relating to the reliability of spacecraft. For the convenience of readers of varied backgrounds and specialized interests, this report has been organized so that analyses pertaining to particular interests appear in different sections. The summary below indicates these areas.

D. SUMMARY OF RESULTS AND ORGANIZATION OF THE REPORT

Details of the data base, contributing data sources, and the techniques of data analyses used are presented in Subsection II.A. For those readers who are interested only in the basic events on which all analysis was performed, the tabulation of specific events is presented in Appendix A.

In this update, a total of 708 specific events* related to on-orbit spacecraft reliability were refined from the data provided by the various program offices, cooperating agencies and individuals. In the pre-update sample there were 1,472 specific events tabulated. In the

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*The term "events" is defined here to include anomalies, unsuccessful launches, and spacecraft with no reported anomalies.

combined sample there are 2,180 such events. The classification and analysis of these events for this update and for the pre-update sample form the subject matter of the remaining subsections of Section II. Subsections II.C to II.E should be of particular interest to design engineers.

The classification of anomalous incidents reported on the successfully launched spacecraft (88 percent of all spacecraft in the combined sample) result in the following major conclusions:

1. Eighty-eight percent of the successfully launched spacecraft reported one or more incidents of anomalous behavior.

2. In this update, 90 percent of the anomalies are reported in the orbital or steady-state phase* of the spacecraft mission. In the combined sample, 77 percent are reported in the orbital phase.

3. Ninety-four percent of the reported anomalies in this update have little or no effect on accomplishment of the spacecraft mission; in the combined sample, 91 percent.

4. Two subsystems account for over one-half of the reported anomalies. The telemetry and data handling subsystem accounts for 19.3 percent of the reported anomalies in this sample; 23 percent in the combined sample. The payload subsystem accounts for 26.2 and 25.8 percent. Thirty-seven percent of the anomalous incidents are distributed essentially equally between timing and control, power supply, attitude control and stabilization and the remaining nine percent are also distributed essentially equally among the propulsion, environmental control, and structure subsystems.

*The orbital, or steady state, phase is defined here as the phase following launch, injection and acquisition.

5. Almost three-quarters of the anomalous incidents reported both in this update and in the combined sample are electrical in nature as opposed to mechanical, chemical, unknown, etc. For those incidents where it could be determined whether the anomaly was caused by a piece-part, 12 percent of the incidents in this sample and 19 percent in the combined sample were determined to be catastrophic part failures*; 20 percent in both samples were noncatastrophic part failures (degraded, intermittent, etc.); 68 percent and 61 percent, respectively, were nonpart related.

6. In this sample 36 percent of the anomalies were the result of assignable (i.e., "preventable") causes and 10 percent of the incidents had no assignable cause. In the combined sample the corresponding percentages were 35 percent and 13 percent. For the remaining incidents no conclusions could be drawn as to the assignability or nonassignability of cause of failure. For those incidents of this update having assignable causes, nearly 68 percent were attributed to various aspects of the spacecraft design, 21 percent to manufacture, and 10 percent to spacecraft operation. The corresponding percentages for the combined sample are: design, 65 percent; manufacture, 14 percent; operation, 9 percent.

Failure rate estimates for spacecraft subsystems, components, and piece parts are given in Section III. Included in that section are estimates of the probability of failure during launch for the same elements and confidence intervals for both parameters. Reliability engineers and analysts, as well as personnel responsible for program management and advance system planning, should find Section III of special

*The term "catastrophic part failure" is defined as meaning catastrophic to the part, e.g., a transistor or diode, and not necessarily to the larger component or system.

interest. The parameters presented for spacecraft subsystems and commonly used components are felt to be a significant contribution to the relatively sparse information generally available on this type of data.

Estimates of the spacecraft element reliability parameters, failure rate and probability of failure, in addition to their tabulation, result in the following general conclusions:

1. The combined sample indicates that the power and attitude control and stabilization subsystems have the highest on-orbit failure rate among the subsystems. The propulsion, environmental control, and structure subsystems have no reported catastrophic failures during orbit

2. The majority of the components considered in both samples exhibited no catastrophic failures either during launch or in orbital operation. The most failure-prone component appears, as it did in the earlier studies, to be the magnetic tape unit with 55 catastrophic failures occurring on 198 units observed. The failure rate for magnetic tape units in the combined sample is 24 failures per million hours, a significant decrease over that reported in the earlier sample (35 failures per million hours). Most other components have somehwat lower failure rates than those reported earlier.

3. In the combined sample, there are five failures attributed to piece parts during launch and 56 during orbital operations. Forty-four part types are included in the study. The on-orbit failure rates of capacitors (1.0 per billion part hours), diodes (0.97 per billion part hours), and transistors (1.5 billion part hours) reflect the large number of observed units and operating time and the relatively few observed on-orbit failures.

The analyses relative to the secondary objectives of this study are presented in Section IV.

The effect of dormancy on reliability is somewhat ambiguous. The analysis of this factor does demonstrate conclusively, on the basis of empirical data, that magnetic tape units and transmitters have a much higher operating failure rate than dormant failure rate. No failures or anomalies were identified which could be attributed to dormancy.

As reported earlier, the analysis of on/off cycling gives no clear evidence of a supposed detrimental effect on reliability of cycling spacecraft components as opposed to a steady state operation. The data do indicate, however, that for cycled components a rapid cycling rate is more adverse than a slower one.

No quantitative relationship between product assurance elements and spacecraft mission success could be demonstrated from the available data. Several particular points meriting attention by spacecraft project managers are contained in six experience bulletins.

Supporting tabulations for the entire study will be found in the appendices; text references to the appropriate appendix sections are provided.

II. CLASSIFICATION AND ANALYSIS OF ANOMALOUS INCIDENTS

The objectives of this section are to consider all reported incidents that affect the capability of a spacecraft to perform as desired, to classify these incidents in a meaningful and organized manner, to analyze the incidents in areas of interest, and to draw conclusions generally applicable to the U.S. space program.

A. BACKGROUND AND GENERAL APPROACH

The purpose of this study is to continue the examination of on-orbit spacecraft reliability reported in three earlier studies (see References 1, 7 and 9). The earlier studies collected data on 42 space programs and 310 spacecraft. This study is an "update" to the earlier reports; therefore, data have been sought for both new programs and additional spacecraft of the programs in References 1, 7, and 9. The major emphasis of the current report is on NASA spacecraft launched in a seven-year time interval starting in 1970.

The same data collection and reduction procedures are employed in each study. All of the reliability reports, including the current one, use the same format. This uniformity allows for analyses and results of the four data sets to be combined in this report into a large body of information about the reliability of spacecraft from 1958 to June 1978. For this report, the data are generally presented in two groups or samples, one representing all data collected prior to this study and the other representing this sample or update only. In some cases (such as for failure rates) results are given for the combined sample as well.

1. Data Sample

Exhibit 1 depicts the four on-orbit reliability studies, including the current one in terms of the programs and number of spacecraft considered. As shown in Exhibit 1, the 1978 update includes 45 spacecraft from 20 programs. Five of these 45 spacecraft were studied in earlier reports and have continued to operate into the period of interest to this study.

In all analyses of the combined sample (from all four studies) the data have been adjusted to reflect the non-independence of the samples. In other words, corresponding data entries in tables presented for the pre- and post-update samples will not necessarily sum to the corresponding data element for the combined sample. Thus, the data for the combined sample are based on the operational records of 350 spacecraft from 52 programs.

2. Sources of Study Data

Requests for specific data elements were made to cognizant sponsoring agencies for specific programs. Many of these agencies had previously been contacted for data utilized in the earlier studies. Contacts were made to:

NASA Project Offices (Goddard Space Flight Center, Ames Research Center, Lewis Research Center, Langley Research Center, Wallops Flight Center, Marshall Space Flight

EXHIBIT 1: CUMULATIVE STUDY DATA SAMPLE

Original Study, 1967 (Reference 1)		1971 Update (Reference 7)		1972 Update (Reference 9)		Current Study	
Program Designation	Number of Launches	Program Designation	Number of Launches	Program Designation	Number of Launches	Program Designation	Number of Launches
Agena	93	ATS	5	ESSA/TOS(1)	6	Atmospheric Explorer	2
ANNA	2	EGRS	13	IMP (1)	3	ATS (1)	3
Ariel	2	ESSA	7	NIMBUS (1)	2	GEOS	1
Courier	2	Explorer 32	1	NOAA/ITOS	3	Hawkeye	1
Early Bird	1	GEOS (1)	2	OAO (1)	1	HEAO	1
Echo	1	IMP	4	OGO (1)	5	IMP	3
Gemini	8	Mariner	3	OSO (1)	4	Landsat	2
GEOS	1	NIMBUS	4	RAE (1)	1	Mariner	3
IMP	2	OAO	2			MTS	1
Injun	3	OGO (1)	6			NIMBUS (1)	3
Lofti	2	OSO (1)	5			NOAA (ITOS)	5
NIMBUS	1	OV1	9			OSO (1)	2
Mariner	4	OV2	2			Pioneer	2
Mercury	25	OV3	6			RAE	1
OAO	1	OV4	2			SAS	3
OGO	2	OV5	3			SERT	2
Oscar	4	Pioneer (1)	5			SMS/GOES	4
OSO	4	RAE	1			Solrad (1)	1
OV-1	3	Solrad	2			SSS	1
Pioneer	2	Vela (1)	4			Viking (2)	4
Ranger	9						
Relay	1						
Secor	2						
Snapshot	1						
Solrad	1						
Syncom	3						
Telstar	2						
TIROS	8						
TRAAC	1						
TRANSIT-Oscar 04	17						
Vanguard	11						
Vela	6						
TOTAL:	32 Programs 225 Launches	TOTAL:	20 Programs 86 Launches 9 New Programs 79 New Launches	TOTAL:	8 Programs 25 Launches 1 New Program 6 New Launches	TOTAL:	20 Programs 45 Launches 10 New Programs 40 New Launches

GRAND TOTAL: 52 Programs
350 Launches

(1) Includes update(s) of spacecraft analyzed in previous data bank studies.

(2) Viking Program includes 2 Orbiters and 2 Landers.

Center, Jet Propulsion Laboratory)

NASA Headquarters

NOAA (National Environmental Satellite Service)

The open literature also provided significant amounts of all types of required data. The primary source of these data was the National Technical Information Service (NTIS, Springfield, Virginia) microfiche copies of government contract reports and symposium proceedings.

3. Methods of Data Compilation

The types of documentation sought for this study were similar to the earlier studies. The two major types of data are: (1) an engineering report of the final design of the spacecraft, and (2) a flight analysis for individual spacecraft from which operating histories and all known anomalous behaviors can be obtained. From this information Engineering Analysis Reports (EARs) are generated for each spacecraft. The EAR is tailored to provide the information content required to meet the study objectives and provides a uniform base for each spacecraft of the study. The EAR is completely described in Appendix B.

In the EARs the treatment of standby and redundant units is consistent for all data samples and emphasizes the utilization of only known values. Operational hours in the EARs were recorded as "powered" and "unpowered" where such information was known. For much of the equipment, however, the information available only indicates that at a given time the equipment was known to be operational. For this reason the unit of measure in the analyses of this section and of Section III is survival time. In those instances where standby hours are reported, it is known that the unit in question was turned off for the given number of hours and known to have been subsequently operational. These data are analyzed in Section IV.

Redundant equipment was treated in the following manner. If a spacecraft had an active redundancy composed of, say, two units, and if the descriptive material indicated that it was reasonable to assume both units operated successfully for, say, 1000 hours, then two entries are made for the two units. On the other hand, if all that could be determined was that one or the other operated for the given time, then only one entry was made.

4. Methods of Data Analysis

a. Techniques and Parameter Estimation

The authors believe that the crux of studies of this nature is the provision of a large amount of data in a readily usable form. For this reason, as well as the fact that the information from the documentation does not warrant application of highly sophisticated techniques, the methods of analysis are simple and straightforward.

Classification and summarization, using simple, readable tables, are the primary presentation techniques. In general, statistical inferences are not drawn from these efforts. At the component/equipment level and piece-part level, failure rates have been generated using techniques which are generally accepted. Conclusions have been drawn where appropriate, but the emphasis is placed on presenting data in such a form that readers may easily draw their own conclusions in areas of their special interest.

b. Assumptions and Biases

Because of the emphasis on recording only known values for the various data elements, engineering assumptions are held to a minimum in the generation of an EAR.

The major assumption underlying the estimation of failure rates is that time-to-failure is adequately expressed by the negative exponential distribution. The data generated herein preclude the use of an alternate assumption, a situation that also existed in earlier studies.

The major bias in the study continues to be that all anomalous incidents in the analyses are "reported" incidents versus the desired "occurring" incidents. The cause of the bias can be traced to several sources: (1) diversity of detail, (2) method of documentation employed by the various program offices, (3) reliance in some cases on personal interviews, and (4) state-of-the-art limitations (i.e., part operational data).

Documentation for the spacecraft in this sample was significantly more detailed and of higher quality, on the average, than in the earlier studies.

5. Definitions

Definition of terms used in this report is presented in context; terms requiring definition are generally associated with anomaly classifications. The use of acronyms has been kept to a minimum and those that are used are easily identifiable; mathematical symbols are those in general use.

B. SUMMARY OF REPORTED INCIDENTS

From the spacecraft EARs, a summary of all anomalous incidents has been compiled for each of the four study samples. The summary for this study is found in Appendix A-IVa and is in the same format as the corresponding lists for the earlier studies (see Appendices A-Ia, A-IIa, and A-IIIa). The format lists in the following order: unsuccessful launches; every anomalous incident recorded in the EARs subsequent to a successful launch; and finally, every sucessfully launched spacecraft in which no anomalous incidents were recorded.

Each line entry in the appendices referred to above includes first an index relating the entry to a specific program and spacecraft.[1] For those launches that were unsuccessful, this fact is entered to complete the entire entry. In cases where no anomalous behaviors were noted, this fact, plus the total time in orbit and whether the spacecraft is currently operable or not, completes the entry. Each anomalous incident recorded contains the following information in each entry:

[1]This relationship between the index and specific launch is not available to the reader and is a method of preserving the anonymity of programs and spacecraft.

1. Time the incident occurred. An entry of ε indicates that the incident occurred between the end of countdown and the establishment of the initial orbit. An entry of $\sim$ indicates that the anomaly cannot be pinpointed in time since it was intermittent, gradual, or unknown. All other entries are in hours.

2. Three short statements giving a description of the incident, its cause, and its effect on the mission as a whole.

3. Any known corrective action taken to prevent occurrence of the incident on future flights or to obviate its effect on the flight under consideration.

4. Other clarifying remarks required to put the incident in the proper context.

It should be made clear that this listing does not pretend to be exhaustive of all such incidents that have occurred, even on the spacecraft reported in this study, because of the wide variability in quantity and quality of data available to the study. There is no reason to believe, however, that it is not indicative of spacecraft reliability problems.

C. CLASSIFICATION OF ANOMALOUS INCIDENTS

1. Summary of Classification Codes

Because of the large number of anomalous incidents in this sample (and in the previous samples) classification and summarization is mandatory to extract readily usable information. A coding scheme, identical to that used in previous studies is used to accomplish this purpose. There are nine characteristics for which each anomalous incident is coded. Some information needed to select a particular code for a given entry occurs only in the EARs so that, in a sense, the classification carries more information than provided in the entries of Appendices A-Ia, A-IIa, A-IIIa, and A-IVa. The complete coding of each entry is given in Appendices A-Ib, A-IIb, A-IIIb, and A-IVb.

Exhibit 2 lists the names of eight of the classifications used. Definitions of the terms are given in the following paragraphs, together with the results of the classifications of the anomalies. Roman numerals following the paragraph headings refer to the Roman numerals in Exhibit 2. The ninth classification, Subsystem Function, is discussed in Subsection D.

2. Mission Subset (I)

This code simply identifies the unsuccessful launches (U) and those spacecraft for which there are no reported anomalies (S).

For this update, two of the 45 spacecraft launches were unsuccessful; there were no spacecraft that experienced zero anomalies. Five of the 43 successfully launched spacecraft were considered in the previous study as well as this one. Therefore, for the combined sample:

- Total Number of Spacecraft: 350
- Unsuccessful Launches 43

FXHIBIT 2 - ANOMALOUS INCIDENT CLASSIFICATION CODES

I. Mission Subset

- U. Unsuccessful Launch
- S. Spacecraft with No Anomalies Reported
- Spacecraft with Anomalies Reported

II. Mission Term

- L. Long Term
- S. Short Term

III. Mission Phase

- L. Launch and Acquisition
- O. Orbital (Steady-State)
- Q. Unknown

IV. Mission Effect

- 1. Negligible
- 2. Non-Negligible but Small
- 3. 1/3 to 2/3 Mission Loss
- 4. 2/3 to Nearly Total Mission Loss
- 5. Essentially Total Mission Loss
- U. Unknown

V. Spacecraft Subsystem

- a. Timing, Control and Command
- b. Telemetry and Data Handling
- c. Power Supply
- d. Attitude Control and Stabilization
- d* Propulsion
- e. Environmental Control
- f. Structure
- g. Payload (Experimental and Scientific)
- h. Unknown

VI. A. Incident Type

- E. Electrical
- M. Mechanical
- O. Other
- U. Unknown

VI. B. Incident Type

- C. Catastrophic Part Failure
- O. Other Part-Related Incident
- N. Non-Part-Related Incident
- U. Unknown

VII. Incident Cause

- A. Assignable
- N. Non-Assignable
- U. Unknown

- Total Spacecraft Reporting No Anomalies: 40
- Total Spacecraft Reporting Anomalies 267
- Total Anomalies Reported: 2,096

The breakdown, by number of spacecraft and percentage is as follows:

	Number			Percent		
	Update	Pre-Update	Total Data Base	Update	Pre Update	Total Data Base
I. Mission Subset						
U. Unsuccessful Launch	2	41	43	5.0	13.3	12.3
S. Spacecraft With No Anomalies Reported	0	40	40	0	12.9	11.4
Spacecraft With Anomalies Reported	38	229	267	95.0	73.8	76.3

3. Mission Term (II)

The code identifies long-term (L) or short-term (S) missions. If a mission is anticipated to be longer than 60 days it is classified long-term. All spacecraft except one in this data sample are long-term missions; the total sample contains 138 short-term and 212 long-term missions. In the update data, there were 705 anomalies associated with long-term missions, and one anomaly with the short-term mission. For the total data base, 79.1 percent of the anomalies are associated with long-term missions, and 20.8 percent with short-term missions.

The breakdown, by number of anomalies and percentages, is as follows:

	Number			Percentage		
	Update	Pre-Update	Total Data Base	Update	Pre-Update	Total Data Base
II. Mission Term						
L. Long Term	705	990	1,695	99.9	71.9	80.9
S. Short Term	1	400	401	0.1	28.6	19.1

For this sample, the average number of anomalies reported is 17.8 per long-term spacecraft. This is significantly greater than the pre-update figure of 7.1 anomalies per long-term spacecraft. This increase appears to be due in part to the increased detail of reporting on-orbit experience and in part to the increased complexity of spacecraft in this sample. That is, many spacecraft carried more equipment than those launched earlier and therefore were subject to more anomalies. For the combined sample, the number of anomalous entries per long-term spacecraft is 9.7.

Further analysis concerning detailed anomaly times will be found in subsection II-D-1 below.

4. Mission Phase (III)

A spacecraft mission can be thought of as consisting of two distinct phases: launch and acquisition (L) and the orbital or steady-state phase (O). An anomaly occurring during launch and acquisition is classified L; if it occurs during steady-state operation it is classified

O. A third category, Q, is provided for those instances where the dichotomy cannot be made due to insufficient information. The distinction was made on the best judgment available based on the engineering analysis reports. Generally, those incidents indicating an ε, or very few hours of elapsed time at occurrence, are classified as L, all others as O.

The breakdown of anomalies occurring in each category and the associated percentages is as follows:

	Number			Percentage		
	Update	Pre-Update	Total Data Base	Update	Pre-Update	Total Data Base
III. Mission Phase						
L. Launch and Acquisition	65	415	480	9.2	29.8	22.9
O. Orbital (Steady-State)	638	970	1,608	90.4	69.8	76.7
Q. Unknown	3	5	8	0.4	0.4	0.4

The 29.8 percent of all anomalous incidents occurring in the launch phase previous to this update, reflects, at least in part, the fact that all Ranger, Mercury, and Gemini missions were defined to consist of launch and acquisition phase only and that many other spacecraft (e.g., Agena) were relatively short-term. The 9.2 percent of all anomalies in this update occurring during the launch phase compares reasonably well with the pre-update sample when considering the spacecraft complement of the pre-update sample.

5. Mission Effect (IV)

The five groups included in this classification indicate the severity of the anomalous incident in terms of its effect on the overall mission had it occurred in isolation. The definition of each class 1, 2, 3, 4, and 5 should be self-evident from the classification names given in Exhibit 2. Thus, in column IV of the tables in Appendices A-Ib, A-IIb, A-IIIb, and A-IVb, all incidents coded 1 have essentially negligible effect on mission performance; those coded 5 are essentially catastrophic to the mission. The code U indicates there was insufficient information on which to assign a mission effect code.

The breakdown of these groups, by number and percent of anomalies, is as follows:

	Number			Percentage		
	Update	Pre-Update	Total Data Base	Update	Pre-Update	Total Data Base
IV. Mission Effect						
1. Negligible	505	825	1,330	71.5	59.4	63.4
2. Non-Negligible but Small	161	418	579	22.8	30.1	27.6
3. 1/3 to 2/3 Mission Loss	13	85	98	1.8	6.1	4.7
4. 2/3 to Nearly Total Mission Loss	0	20	20	0	1.4	0.95
5. Essentially Total Mission Loss	4	40	44	0.6	2.9	2.1
U. Unknown	23	2	25	3.3	0.1	1.2

An observation made on the pre-update sample holds both for this update and the combined sample. That is, very few spacecraft drop out of the sample as a result of a single failure (coded 5). Maximum sample time for the spacecraft is far more likely to result from the cumulative effects of several lower severity level anomalies, planned mission termination, or simply, the extent of the available data.

6. Spacecraft Subsystem (V)

Each anomalous incident is coded according to which of eight major spacecraft subsystems is most closely related to the incident. An unknown category is included for those cases where a relationship does not exist or cannot be determined from the available information. The subsystems used for this classification are meant to define broad functional operations found to one extent or another in all spacecraft. The functional definition for subsystem was chosen rather than a definition based on hardware for two reasons. First, subsystem definitions vary among organizations and among program offices of the same organization. The data analysis requires a grouping that can be applied to all spacecraft of the collective data sample. The second and more important reason for using a functional definition is that, in the predesign stages of future programs, the program management will know what functions the planned spacecraft is expected to perform with more certainty than the actual hardware configuration that will be used to perform the desired functions. The comparisons at the subsystem level as defined in this report would be useful in the predesign phase of program development. For example, one would be interested to know, based on past experience of other programs, with what certainty a spacecraft would deploy its structural elements (structure subsystem) or supply power to the other planned functions (power supply subsystem). In the later stages of development of a pro jected program, when more is known about the hardware configuration, the interest would shift to the equipment group/component level of analysis which is hardware oriented.

The following list defines the subsystems and indicates the types of equipment that are considered to be a part of each subsystem.

a. Timing, Control and Command

Command receivers, decoders, timers, programmers, sequencers, command distribution equipment

b. Telemetry and Data Handling

Encoders, D/A converters, A/D converters, tape recorders, signal conditioners, telemetry transmitters, tracking transmitters, antennas

c. Power

Batteries, solar arrays, fuel cells, converters, inverters, regulators, protective devices, charge regulators

d. Attitude Control and Stabilization

Gyros, spin control, magnetometers, sun aspect indicators, eddy current dampers, horizon scanners, star trackers, dynamic control

d* Propulsion

Coding this subsystem with a d* indicates that the propulsion subsystem considered here is more closely related to the attitude control subsystem of the spacecraft than to the launch vehicle. Included are hydrazine thrusters, tanks, valves, etc.

e. Environmental Control

Both passive and active thermal control devices, life support systems.

f. Structure

Basic structure, booms, solar paddles, separation.

g. Payload (Experimental and Scientific)

Wide-band communications (for spacecraft where this equipment was considered experimental), microwave equipment (cavities, TWTs, etc., flown for assessment purposes), university experiments, particle detectors, mass spectrometers, plasma analyzers, infrared radiometers, ultraviolet radiometers.

Although it is felt that these groupings are essentially self-explanatory, checking a few of the codes in Appendices A-Ib, A-IIb, A-IIIb, and A-IVb with their corresponding entries in Appendices A-Ia, A-IIa, A-IIIa, and A-IVa should dispel any confusi[illegible] [illegible]is procedure is applicable to most of the other classifications as well.

The breakdown, in terms of number of anomalies and their associated percentages, to each of the subsystem categories is as follows:

	Number			Percentage		
	Update	Pre-Update	Total Data Base	Update	Pre-Update	Total Data Base
V. Spacecraft Subsystem						
a. Timing, Control and Command	76	214	290	10.8	15.4	13.8
b. Telemetry and Data Handling	136	463	599	19.3	33.3	28.6
c. Power Supply	68	131	199	9.6	9.4	9.5
d. Attitude Contro and Stabilization	104	183	287	14.7	13.2	13.7
d* Propulsion	31	31	62	4.4	2.2	2.9
e. Environmental Control	7	29	36	1.0	2.1	1.7
f. Structure	28	19	47	4.0	1.4	2.2
g. Payload (Experimental and Scientific)	256	284	540	36.2	20.4	25.8
h. Unknown	0	36	36	0.0	2.6	1.7

The relatively large percentage of reported anomalies in the telemetry and data handling subsystem as indicated in the above breakdown, is to be expected. Since this subsystem is, of course, monitored more closely than other subsystems, an indication of an anomaly is more likely to be observed in this area. The large number of payload anomalies in this sample relative to the number in the pre-update sample, is felt to be due in part to the large number of payloads relative to other subsystem functions in the update. Also, payloads are often unique, push the state-of-the-art, and are constructed with fewer quality assurance provisions less stringently enforced than basic spacecraft subsystems. Finally, the payloads carried by recent spacecraft tend to be more complex than those carried by many of the spacecraft in the pre-update sample, and this may lead to more anomalous incidents per payload. Exhibits 4 and 5 provide additional information tending to confirm the increase in payload anomalies.

7. Incident Type (VI)

a. Incident Type (VI.A)

This classification places an anomaly in one of four mutually exclusive groups: electrical (E), mechanical (M), other (O), and unknown (U). Those entries in Appendices A-Ib, A-IIb, A-IIIb, and A-IVb coded with an E in the VI.A column indicate that anomalous behavior is exhibited by electrical or electronic parts, components, subsystems, or functions. Those anomalies coded M are similarly defined for mechanical parts, components, subsystems, or functions. An O indicates behavior of equipment that cannot be classified electrical or mechanical: propellant degradation, for example. A U indicates insufficient information to assign the entry to any of the other three categories.

The breakdown of anomalies and percentages in this classification group is as follows:

	Number			Percentage		
	Update	Pre-Update	Total Data Base	Update	Pre-Update	Total Data Base
VI.A. Incident Type						
E. Electrical	473	1,065	1,538	67.0	76.6	73.4
M. Mechanical	66	126	192	9.3	9.1	9.2
O. Other	60	98	158	8.5	7.0	7.5
U. Unknown	107	101	208	15.2	7.3	9.9

b. Incident Type (VI.B)

The classification of column VI.B in Appendices A-Ib, A-IIb, A-IIIb, and A-IVb attempts to divide incidents into those that are part related and those that are nonpart related. A code of C indicates those incidents arising from a catastrophic part failure*. An O indicates that the anomalous incident is related to behavior of a part (or parts) that has not failed catastrophically (degraded, intermittent, etc.). An N indicates an anomalous incident not related to any part misbehavior. A U indicates that insufficient information exists to determine whether part behavior was involved or not.

The breakdown by number and percentage of anomalies for these categories is as follows:

	Number			Percentage		
	Update	Pre-Update	Total Data Base	Update	Pre-Update	Total Data Base
VI.B. Incident Type						
C. Catastrophic Part Failure	42	183	225	5.9	13.2	10.7
O. Other Part-Related Incident	68	174	242	9.6	12.5	11.5
N. Non-Part-Related Incident	237	490	727	33.6	35.2	34.7
U. Unknown	359	543	902	50.8	39.1	43.0

* The term "catastrophic" here is defined to mean "catastrophic" to the part and not necessarily to the larger component or system. Typical types of catastrophic part failures include a transistor or diode shorting for no known reason. This definition is consistent with that used in the negative exponential distribution for modelling failure probability.

Of the 347 incidents in this update where it could be determined whether the anomaly was part or non-part caused, 110 (31.7 percent) were piece part related. Of these, 42 (12.1 percent) were catastrophic piece part failures. Of the 1,194 incidents in the total data base for which this determination could be made, 39.1 percent were piece part related, and 18.8 percent were catastrophic piece part failures.

It is important to note that, in the pre-update sample, of the 847 anomalous incidents where a relationship could be coded, over three-quarters (78.4 percent) are not catastrophic part failures, and thus not representative of the type of failures modeled by the classical reliability approach. In this update, this tendency is even more pronounced. Of the 347 anomalies where a relationship could be determined, 87.9 percent are not catastrphic part failures.

Further analysis of part types will be found in Section III, where survival hours and anomalous incidents are used as the basis for reliability calculations. Further analysis on the effects of part failures will be found in subsection II-D-4 below.

8. Incident Cause (VII)

Three broad groups are defined for incident cause in column VII of the tables in Appendices A-Ib, A-IIb, A-IIIb, and A-IVb: assignable causes (A), nonassignable causes (N), and unknown (U).

An assignable cause is attributed to an anomalous incident if the incdient could have been prevented by taking some action well within the state-of-the-art prior to launch. If the incident could not have been prevented in this manner, it is classified nonassignable (N). If insufficient information exists to make a judgment, the anomaly is classified unknown (U).

The breakdown for these categories is as follows:

	Number			Percentage		
	Update	Pre-Update	Total Data Base	Update	Pre-Update	Total Data Base
VII. Incident Cause						
A. Assignable	255	477	732	36.1	34.3	34.9
N. Non-Assignable	71	193	264	10.1	13.9	12.6
U. Unknown	380	720	1,100	53.8	51.8	52.5

The categorization of column VII is of major interest. In both this sample and the pre-update sample, the data indicate that over one-third (at least) of the incidents have assignable causes and thus form a clear basis where reliability of spacecraft might be improved. Since over half of the anomalous incidents were classified "unknown", the percentage of anomalies with assignable causes is probably much higher. Further discussion of the assignable cause category is given in Subsection II-D-3 below.

9. Subsystem Function (VIII)

This classification is a secondary breakdown of spacecraft subsystem, and is treated in detail in Subsection II-D-2 below.

10. Remarks

When the 2,096 anomalous incidents of the combined sample are categorized according to the characteristics discussed above, the results indicate that the typical reported anomaly occurs on a long-term mission in the orbital phase, has a negligible effect on the mission, occurs in a payload, and is of unknown origin and cause.

D. FURTHER OBSERVATIONS MADE FROM ANOMALOUS INCIDENT CLASSIFICATIONS

Subsection C above has served to give a large picture of the anomalous incidents reported in this study. It is the intent of this subsection to examine, in more detail, four of the characteristics used in the preceding subsection to classify anomalous incidents. The four characteristics of interest in this further analysis are: Mission Phase, Spacecraft Subsystem/Subsystem Function, Incident Cause and Catastrophic Part Failures/Mission Effect. The analysis of this subsection, then, is concerned with the time of anomaly occurrence, its location within the satellite, its assignable cause, and the effect of part failures on mission performance.

1. Mission Phase

The classification used above for this characteristic somewhat arbitrarily considers the anomaly to have occurred either during launch and acquisition or the steady-state, orbital phase of the mission. Since time is of paramount interest in reliability studies, the analysis of this section focuses on the occurrence of the incidents as a function of time.

The following analysis is based on the 211 long-term spacecraft of the combined sample.[1] For the 177 successfully launched, long-term

[1] One long-term spacecraft is not included because mission time is not available.

spacecraft, there are 1,695 associated incidents of anomalous behavior. Exhibit 3 lists the sample hours associated with each spacecraft, along with the number of anomalies that occurred on each spacecraft. The sample hours are the lengths of time for which data on anomalous behavior are available to this study. In some cases, "sample hours" represents the complete loss of the mission; in others it simply represents the extent of the available data. The Index Number is a code used to protect the identity of the spacecraft.

Note that use is made in Exhibit 3 of the symbol ε . This symbol implies that loss of mission occurred very early, generally during the launch and acquisition phase.

The rate of reported anomalous incidents as a function of time can be derived from Exhibit 3. During ε (essentially launch and acquisition) the reported anomaly rate is 0.04 anomalies per spacecraft. During the first 1,000 hours, the anomaly rate is 0.10 anomalies per spacecraft. The overall anomaly rate (subsequent to ε) is 0.37 anomalies per spacecraft per thousand hours.

For short-term systems, an analysis similar to the preceding is not particularly instructive because of the short mission times, in general less than 100 hours, and the concomitant short time to anomaly occurrence. There are 129 successfully launched short-term spacecraft included in the combined sample, and there are 401 associated anomalies. Of the 401 anomalies only 127 have a recorded occurrence time other than

EXHIBIT 3 - SAMPLE HOURS AND NUMBER OF ANOMALIES FOR LONG-TERM SPACECRAFT, COMBINED SAMPLE

Index No.	Sample Hours	Number of Anomalies	Index No.	Sample Hours	Number of Anomalies	Index No.	Sample Hours	Number of Anomalies	Index No.	Sample Hours	Number of Anomalies
1	ε	1	46	6312	7	91	14568	18	136	23000	8
2	ε	1	47	6450	2	92	14616	0	137	23424	71
3	ε	1	48	6456	4	93	14664	5	138	23472	54
4	ε	1	49	6456	3	94	14800	2	139	24120	7
5	ε	1	50	6480	2	95	14904	8	140	24144	1
6	ε	0	51	6768	0	96	14904	9	141	24875	27
7	ε	1	52	7224	8	97	15100	40	142	25116	18
8	ε	1	53	7248	1	98	15144	3	143	25560	9
9	20	1	54	7300	3	99	15288	3	144	25650	7
10	100(1)	2	55	7361	8	100	15288	2	145	25776	2
11	144	2	56	7500	7	101	15384	0	146	26700	8
12	436	1	57	7944	2	102	15456	19	147	26808	60
13	440	0	58	8030	2	103	15984	2	148	27240	8
14	456	2	59	8115	11	104	16224	1	149	27768	3
15	616	5	60	8448	10	105	16632	9	150	28872	15
16	648	2	61	8629	11	106	16800	10	151	28888	18
17	696	1	62	8736	1	107	17376	3	152	29088	1
18	864	0	63	8760	4	108	17500	6	153	29509	9
19	912	1	64	8760	2	109	17500	8	154	30096	14
20	936	0	65	8760	3	110	17500	16	155	30660	3
21	1032	7	66	8760	1	111	17500	21	156	30624	2
22	2040	2	67	9000	7	112	17592	2	157	31100	0
23	2040	1	68	9000	6	113	17830	7	158	32016	5
24	2136	2	69	9160	1	114	17928	2	159	32106	17
25	2540	3	70	9279	35	115	18336	22	160	32208	4
26	2760	1	71	9300	6	116	18980	15	161	34248	4
27	2856	9	72	9623	2	117	19156	23	162	35568	2
28	3040	8	73	10068	31	118	19370	7	163	35592	6
29	3100	6	74	10068	5	119	19518	11	164	35760	7
30	3216	2	75	10402	1	120	19728	40	165	36480	17
31	3264	2	76	10704	2	121	19728	26	166	36912	27
32	3300	8	77	11088	0	122	19944	11	167	37671	3
33	3600	1	78	11088	35	123	20184	1	168	4055[illegible]	24
34	3816	0	79	11088	8	124	20232	1	169	41112	25
35	4752	6	80	11292	14	125	20250	13	170	41[illegible]36	5
36	4848	2	81	11520	6	126	20520	29	171	41640	7
37	494[illegible]	7	82	12134	5	127	20664	31	172	42528	8
38	5360	6	83	12144	44	128	21000	1	173	43345	28
39	5448	5	84	12234	58	129	21840	11	174	45336	1
40	5500	4	85	12360	49	130	21840	4	175	45467	33
41	5760	3	86	12774	7	131	21900	1	176	52580	18
42	6028	19	87	12840	5	132	21984	5	177	54400	13
43	6040	0	88	13272	0	133	22560	8			
44	6200	10	89	13800	11	134	22630	13			
45	6240	2	90	14328	28	135	22727	16			

Note (1). Assumed, actually known to be greater than epsilon and much less than 1000 hours epsilon. These 127 incidents are distributed in time as follows:

Time of Occurrence (Hours)	Number of Anomalies
$0 < t \leq 1$	9
$1 < t \leq 2$	6
$2 < t \leq 3$	4
5	8
6	1
7	1
8	3
9	4
10	1
$10 < t \leq 20$	7
$20 < t \leq 30$	14
$30 < t \leq 40$	3
$40 < t \leq 50$	7
$50 < t \leq 60$	2
$60 < t \leq 70$	2
$70 < t \leq 80$	7
$80 < t \leq 90$	2
$90 < t \leq 100$	8
$100 < t \leq 200$	22
$200 < t \leq 300$	11
$300 < t \leq 400$	3
$t > 400$	2

2. Spacecraft Subsystem Analysis by Functional Groups

The assignment of anomalies to the subsystems (characteristic V) is helpful in narrowing down the functional aspect of spacecraft which is the most troublesome. A further step in this direction is justified to isolate more precisely the location of anomalous incidents. To do this a number of subfunctions (characteristic VIII) are defined for each previously defined spacecraft subsystem. The subfunctions for each subsystem are defined so that they are mutually exclusive and exhaustive, i.e., they do not overlap and they do cover the entire subsystem. Each anomalous incident carries, therefore, two codes relating the incident to functional location within the spacecraft. The subsystems, subfunctions, and codes used for each are tabulated in Exhibits 4 and 5. Exhibit 4 gives the total number of functions in the update sample, the total number of anomalies observed, and the anomalies per function for this update. Exhibit 5 presents the same information for the pre-update samples.

3. Incident Cause--Assignable

The interest in further examination of the anomalous incidents classified as having assignable causes (characteristic VII) stems from the observation that a major way to increase the reliability of spacecraft is to remove all causes of anomalistic behavior. Of the 706 anomalous incidents in this sample, 255 can be assigned a cause of occurrence, and of the 1,390 incidents in the pre-update sample, 477 can be assigned a cause of occurrence. These incidents are examined in this subsection to discover the contribution they could make in pointing out problem areas.

EXHIBIT 4 - DETAILED CLASSIFICATION OF ANOMALOUS INCIDENTS BY SPACECRAFT SUBSYSTEM AND FUNCTION, THIS SAMPLE

Subsystem Function	Number of Functions in Sample	Number of Reported Anomalies by Function	Anomalies per Function
a. TIMING, CONTROL, AND COMMAND	43	88	2.05
1. Receiving	43	28	0.65
2. Decoding	37	4	0.11
3. Command Distribution	20	11	0.55
4. Sequencing and Programming	21	27	1.29
5. Timing	24	11	0.46
6. Manual Control	--	--	--
7. Unknown	--	6	--
8. Unassignable	--	1	--
b. TELEMETRY AND DATA HANDLING	41	161	3.93
1. Data Point Sensing and Monitoring	10	29	2.90
2. Signal Conditioning	6	3	0.50
3. Encoding, Formatting	38	10	0.26
4. Data Storage	34	55	1.62
5. Transmission	39	59	1.51
6. Unknown	--	1	--
7. Unassignable	--	4	--
c. POWER	45	68	1.51
1. Conversion	45	16	0.36
2. Storage	41	30	0.73
3. Power Control	43	13	0.30
4. Power Distribution	38	4	0.11
5. Unknown	--	5	--
6. Unassignable	--	--	--
d. ATTITUDE CONTROL AND STABILIZATION	42	122	2.90
1. Orientation Sensing	40	58	1.45
2. Active Attitude Correction	30	57	1.90

EXHIBIT 4 - (Continued)

Subsystem Function	Number of Functions in Sample	Number of Reported Anomalies by Function	Anomalies per Function
3. Passive Stabilization	24	3	0.13
4. Unknown	--	4	--
5. Unassignable	--	--	--
d *. PROPULSION	13	31	2.38
1. Navigation	9	3	0.33
2. Propulsion	13	27	2.08
3. Unknown	--	1	--
4. Unassignable	--	--	--
e . ENVIRONMENTAL CONTROL	38	7	0.18
1. Active Thermal Control	22	7	0.32
2. Life Support	--	--	--
3. Unknown	--	--	--
4. Unassignable	--	--	--
f . STRUCTURE	45	28	0.62
1. Basic Structure	45	--	--
2. Deployable Structure	31	27	0.87
3. Separation	45	1	0.02
4. Unknown	--	--	--
5. Unassignable	--	--	--
g . PAYLOADS	292		1.01
1. Scientific	246	249	1.01
2. Technological	46	45	0.98
3. Unknown	--	--	--
4. Unassignable	--	--	--
h . UNKNOWN	--	--	--

EXHIBIT 5 - DETAILED CLASSIFICATION OF ANOMALOUS INCIDENTS BY SPACECRAFT SUBSYSTEM AND FUNCTION, PRE-UPDATE SAMPLE

Subsystem Function	Number of Functions in Sample	Number of Reported Anomalies by Function	Anomalies per Function
a. TIMING, CONTROL, AND COMMAND	222	202	0.91
1. Receiving	218	75	0.34
2. Decoding	214	19	0.09
3. Command Distribution	52	19	0.37
4. Sequencing and Programming	167	36	0.22
5. Timing	157	19	0.12
6. Manual Control	11	--	--
7. Unknown	--	23	--
8. Unassignable	--	11	--
b. TELEMETRY AND DATA HANDLING	236	440	1.86
1. Data Point Sensing and Monitoring	154	177	1.15
2. Signal Conditioning	40	--	--
3. Encoding, Formatting	226	53	0.23
4. Data Storage	92	96	1.04
5. Transmission	231	92	0.40
6. Unknown	--	14	--
7. Unassignable	--	8	--
c. POWER	237	131	0.55
1. Conversion	130	24	0.18
2. Storage	230	47	0.20
3. Power Control	204	37	0.18
4. Power Distribution	141	8	0.06
5. Unknown	--	13	--
6. Unassignable	--	2	--
d. ATTITUDE CONTROL AND STABILIZATION	202	163	0.81
1. Orientation Sensing	186	73	0.39
2. Active Attitude Correction	179	62	0.35

EXHIBIT 5 - (Continued)

Subsystem Function	Number of Functions in Sample	Number of Reported Anomalies by Function	Anomalies per Function
3. Passive Stabilization	45	8	0.18
4. Unknown	--	12	--
5. Unassignable	--	8	--
d*. PROPULSION	108	31	0.29
1. Navigation	99	8	0.08
2. Propulsion	108	10	0.09
3. Unknown	--	3	--
4. Unassignable	--	10	--
e. ENVIRONMENTAL CONTROL	42	29	0.69
1. Active Thermal Control	41	17	0.41
2. Life Support	12	5	0.42
3. Unknown	--	2	--
4. Unassignable	--	5	--
f. STRUCTURE	227	19	0.08
1. Basic Structure	222	2	0.01
2. Deployable Structure	58	6	0.10
3. Separation	211	10	0.05
4. Unknown	--	1	--
5. Unassignable	--	--	--
g. PAYLOADS	517	250	0.48
1. Scientific	465	174	0.37
2. Technological	52	75	1.44
3. Unknown	--	1	--
4. Unassignable	--	--	--
h. UNKNOWN	--	36	--

Assignable causes are attributed to those anomalies that could have been prevented by some action taken before launch, within the state-of-the-art, if those responsible for the action were prescient. Anomalies due to postlaunch errors in spacecraft command and control are also categorized as due to assignable causes. Four general areas can be identified among the entries for which assignable causes exist. Their definitions are as follows:

(1) Design: This area covers many anomalous behaviors such as RFI and sensitivity problems, unanticipated wearout or degradation as a result of time or known environmental conditions. The anomalies can be electrical, mechanical, thermal, or system-related.

(2) Manufacture: This area includes parts or materials that are faulty due to some manufacturing problem, contamination, faulty solder joints or other connections, quality control, and the like.

(3) Operation: Human error is the prime reason for anomalies classified in this group. Errors included involve those associated with the spacecraft control function, usually by commanding, programming, or calibrating the spacecraft.

(4) Other: A miscellaneous classification, grouping together several areas such as meteoroid bombardment, anticipated wearout and secondary failures.

Exhibit 6 shows the number of "assignable cause" entries in the four categories and the associated percentages for the successfully launched spacecraft in this sample. Exhibit 7 gives the same information for the pre-update sample. Of all assignable causes, 68.6 percent were attributed

EXHIBIT 6 - DETAILED BREAKDOWN OF ANOMALOUS INCIDENTS BY ASSIGNABLE CAUSE, THIS SAMPLE

	Number		Percent	
All Assignable Causes	255		100.0	
Design	175		68.6	
RFI, etc.		38		14.9
System		24		9.4
Electrical Components		54		21.2
Mechanical		24		9.4
Thermal		27		10.6
Unanticipated Wearout or Degradation		6		2.3
Launch Vibration and Shock		2		0.8
Manufacture	54		21.2	
Fabrication, Q.C., etc.		19		7.5
Contamination		15		5.9
Faulty Parts or Materials		20		7.8
Operation	26		10.2	
Other	0		0.0	

EXHIBIT 7 - DETAILED BREAKDOWN OF ANOMALOUS INCIDENTS BY ASSIGNABLE CAUSE, PRE-UPDATE SAMPLE

	Number		Percent	
All Assignable Causes	477		100.0	
Design	289		60.6	
RFI, etc.		82		17.2
System		49		10.3
Electrical Components		58		12.1
Mechanical		28		5.9
Thermal		32		6.7
Unanticipated Wearout or Degradation		27		5.7
Launch Vibration and Shock		13		2.7
Manufacture	70		14.7	
Fabrication, Q.C., etc.		34		7.1
Contamination		21		4.4
Faulty Parts or Materials		15		3.2
Operation	41		8.6	
Other	77		16.1	

to Design in this update, 60.6 percent in the pre-update sample. In this sample 21.2 percent were attributed to Manufacture compared to 14.7 percent in the pre-update sample. Of assignable causes 10.2 percent were attributable to Operation in this update, 8.6 percent in the pre-update sample. There were no assignable causes in this update that were classified in the miscellaneous "Other" category; 16.1 percent of the pre-update assignable causes were in this category.

As the exhibits indicate, two of the four categories are further subdivided. The various subcategories under "Design" are as follows: (1) the subcategory "RFI, etc." includes all anomalous incidents attributed to inadequate RFI design, noise sensitivity, and transients--14.9 percent of the assignable causes in this update belong to this category, and 17.2 percent of the pre-update assignable causes; (2) the three subcategories "System," "Mechanical," "Thermal," include incidents arising, respectively, from inadequate design (a) in the spacecraft/environment or subsystem interfaces, (b) in deployment, structural stiffness, or any moving mechanical parts, and (c) for proper spacecraft thermal balance; (3) the category "Electrical Component" refers to anomalies attributed to inadequate design of a receiver, encoder, horizon sensor, or any electrical or electronic component--there are 21.2 percent update and 12.1 percent pre-update assignable causes in this category; (4) "Unanticipated Wearout or Degradation" is attributed to anomalies where, for example, a battery simply wears out before anticipated or where other components or parts do not have the inherent capability to survive either the normal spacecraft environment or the expected life of the component or part;

(5) those anomalies classified "Launch Vibration and Shock" are attributed to designs inadequate to survive the normal stresses a spacecraft undergoes during launch. There are only 0.8 percent update and 2.7 percent pre-update assignable causes in this category.

Under "Manufacture" there are three subcategories. Included under "Fabrication, Q.C., ETC." are anomalies like cold or loose solder joints, loose conenctions and missing parts. "Contamination" covers the relatively high occurrence of clogged lines, excess moisture, foreign matter in valves and the like--5.9 percent update and 4.4 percent pre-update assignable causes fall in this category. "Faulty Parts or Materials" indicates such items as a faulty capacitor or degraded propellants caused by an improper manufacturing process. All of these subcategories are mutually exclusive.

4. Catastrophic Part Failures/Mission Effect.

As indicated earlier, there are 42 catastrophic piece part failures in the update data. These 42 anomalies are further analyzed here to provide insights into their effects on mission performance.

To achieve the proper perspective, two detailed data breakdowns are required, 1) the extent of mission loss caused by part failures, and 2) the proportions of part/non part related anomalies causing critical mission loss. In other words, the situation is examined from two directions, namely, both the extent and the role of part failures on mission loss.

The following breakdown indicates the extent, by number of anomalies and percentage, of mission loss caused by the 42 catastrophic piece part failures:

Mission Effect	Number	Percent
1. Negligible	19	45.2
2. Non-Negligible but Small	17	40.5
3. 1/3 to 2/3 Mission Loss	1	2.4
4. 2/3 to Nearly Total Mission Loss	0	0
5. Essentially Total Mission Loss	2	4.8
U. Unknown	3	7.1

From the above breakdown, it can be seen that at least 85 percent of catastrophic piece part failures do not significantly impact the mission. Some of this may be due to the provision of redundancy.

The second breakdown, provided below, indicates the role of part/non-part related anomalies in significant mission losses. The breakdown is tabulated for 1/3 or greater mission losses (mission effect categories 3, 4 and 5). In the update data, a total of 17 anomalies caused such losses, and the number and percentage of their distribution is as follows:

Incident Type	Number	Percent
C. Catastrophic Part Failure	3	17.6
O. Other Part-Related Failure	4	23.5
N. Non-Part Related Failure	4	23.5
U. Unknown	6	35.3

This breakdown indicates that of the missions incurring substantial loss, catastrophic part failures were responsible 17.6 percent of the time.

It is to be emphasized that the results of these two breakdowns are not contradictory, but rather when taken together provide a possibly useful insight into the relationship of part failures and mission loss. That is, while catastrophic part failures, per se, usually cause only minor loss, when a major loss does occur there is a signif cant probability that it will be due to a catastrophic part failure.

5. Remarks.

Note that besides the categorizations presented here and in previous sections, the reader can perform any of a large number of other classifications by using the raw data presented in Appendix A of this report. Also, more specific or detailed information is available by "querying" the data bank to obtain information from the EAR's on specific topics of interest.

E. CONCLUSIONS

The emphasis of this section, as well as the whole report, is to present the total fund of data regarding incidents of anomalous behavior reported on spacecraft. A few interesting observations from the point of view of the authors are listed below.

1. The vast majority of reported incidents have little or no effect on the accomplishment of the spacecraft mission (see subsection II.C.5). In this update, 94.3 percent of the anomalies had small or negligible effect on mission

goals, and 89.5 percent of the anomalies in the pre-update sample had small or negligible effect.

2. Of the 347 incidents in this update for which it could be determined whether the anomaly was part or non-part caused, 110 (31.7 percent) were piece part-related, and 42 (12.1 percent) were catastrohpic piece part failures. Of the 1,194 incidents in the combined sample for which this determination could be made, 39.1 percent were piece part-related, and 18.8 percent were catastrophic piece part failures.

3. Eighty-seven percent of the pre-update catastrophic part failures have small or negligible mission effect compared to 86 percent of the catastrophic part failures in this update. However, 12 percent of the major mission losses on this update were due to catastrophic part failures.

4. Of the 966 incidents in the combined sample where sufficient information exists to distinguish between assignable and nonassignable incident causes, over 73 percent fall into the assignable category. These incidents generally could have been prevented prior to launch by some action, well within the state-of-the-art (see Subsection II.C.8). The 73 percent figure is in close agreement with all earlier data samples.

5. The tabulation below indicates the five spacecraft functions with the highest anomaly rates in this update

and the pre-update sample.

This Update	Pre-Update
. Data point sensing and monitoring	. Technological experiments
. Propulsion	. Data Point sensing and monitoring
. Active attitude correction	. Data storage
. Data storage	. Life support
. Transmission	. Active thermal control

6. The five spacecraft functions with the lowest anomaly rates in this update are: Basic structure, separation, power distribution, decoding, and passive stabilization (see Exhibit 4). This list is the same for the pre-update except that passive stabilization has replaced propulsion. It is surprising to note that propulsion, which had one of the lowest rates of anomalies per function in the pre-update sample, has one of the highest rates of anomalies per function in the update sample.

7. The most common cause of spacecraft anomalies (when assignable) is design (see Exhibits 6 and 7). This agrees with the conclusion reached in all previous studies.

III. SPACECRAFT HARDWARE ELEMENT RELIABILITIES

This section discusses numerical reliability factors for three levels of hardware elements; spacecraft subsystems, components, and piece-parts. Two reliability factors of prime interest may be readily derived from available data. The first is the probability of hardware element failure during launch (q) and the second is the on-orbit hardware element failure rate (λ). The derivation of these factors is first described, then the results are presented.

A. DERIVATION OF PARAMETER ESTIMATES

If it is assumed that each identically named hardware element has an equal probability of failure during launch, irrespective of mission, then q may be readily estimated as

$$q = \frac{\ell}{N} \qquad (1)$$

where ℓ = number of hardware element failures during launch

N = number of hardware elements in the sample.

It has been shown repeatedly that, under very minimal constraints,

$$R(t) = \exp\left[-\int_0^t \lambda \, dt\right] \qquad (2)$$

where λ = hardware element failure rate

t = survival time

In this formulation λ may be any integrable function of time. The preponderance of reliability literature and practice assumes, however, that λ is constant, at least for most electronic hardware elements found in spacecraft. In this case Equation (2) assumes the more familiar form

$$R(t) = \exp(-\lambda t) \tag{3}$$

In situations where Equation (3) applies, it is also well known that the best estimate of λ for a particular hardware element type is given by

$$\lambda = \frac{f}{\sum_{i=1}^{n} t_i} \tag{4}$$

where n = number of equivalent hardware elements under observation

t_i = survival time of the ith such element

and

f = total number of failures observed.

The formulation for determining confidence intervals for q and λ are again well known and are given below for 90-percent intervals:

$$q_1 \le q \le q_2 \tag{5}$$

where q_1 is such that

$$\sum_{i=\ell}^{N} \binom{N}{i} q_1^i (1 - q_1)^{N-i} = 0.05$$

and q_2 is such that

$$\sum_{i=0}^{\ell} \binom{N}{i} q_2^i (1 - q_2)^{N-i} = 0.05$$

$$\lambda_1 < \lambda < \lambda_2 \qquad (6)$$

where

$$\lambda_1 = \frac{\chi^2_{0.05}(2f)}{2 \sum_{i=1}^{n} t_i}$$

and

$$\lambda_2 = \frac{\chi^2_{0.05}(2f + 2)}{2 \sum_{i=1}^{n} t_i}$$

If ℓ or f are zero, the above formulations give one-sided 95-percent confidence limits of the form

$$0 < q < q_2$$
$$0 < \lambda < \lambda_2 \qquad (7)$$

Thus, the primary burden of this section is to derive estimates and confidence intervals for the two parameters q and λ. This is accomplished by first discussing the input data, its derivation and limitations. Then each of the three tiers of hardware level is treated separately by deriving the pertinent estimates and evaluating the results.

B. INPUT DATA

The basic compilation of data for each spacecraft in this study was performed precisely as for the previous three studies of on-orbit reliability data from spacecraft. The procedure results in the generation of a working document called an Engineering Analysis Report (EAR). The details of the compilation process will not be repeated here.[1] A brief synopsis of the procedure, however, will clarify the origin of the basic data used in this section to derive estimates for the various parameters.

Essentially, a key step in the compiling an EAR is to determine and list components for a particular spacecraft that are of a sufficiently high level so that their operating history may be readily determined and yet are of a sufficiently low level so that it is reasonable to assume that their normal operation would be precluded by the occurrence of a piece-part failure. The spacecraft subsystems to which these components are assigned are also listed as are the piece parts within each identified component. From this data, subsystem, component, and piece part operating histories are determined and pertinent time factors are computed.

Component and piece-part failures are determined directly from the EARs. These failures are also a subset of entries contained in Appendix A and can also be determined directly therefrom. Subsystem failures are determined directly from the the entries of Appendix A, that is, those anomalies

[1]For detailed description of the EAR, the reader is referred to Appendix B.

coded as being relevant to a particular subsystem and causing severe degradation to the mission (Misssion Effect severity levels 4 or 5) are considered as being subsystem failures.

In the determination of piece-part failures for estimating λ (Equation (3)), a failure is attributed to a piece part if, and only if, it is known to have failed in a catastrophic manner for no evident cause. This definition is consistent with the definition of λ as it is utilized in Equation (2). All such piece-part failures are coded with a C in Column VIB and an N in Column VII of the classification codes of Appendix A. In this update 19 such coded anomalies have been added to the data base.

Failures are attributed to a component in the same manner, essentially by treating the entire component as if it were a big piece part.

Parameter estimates are calculated for three data sets: (1) the pre-update sample. (2) the data obtained in this sample, and (3) the combined sample. Exhibits 8, 9, and 10 tabulate the subsystems, components, and parts considered in this section of the study together with their total population, the number failing during launch, their cumulative survival hours and the number failing during orbital operation.

Two points should be noted with respect to the survival hours shown in these exhibits. First, these are the cumulative survival hours contained in the data bank for each of the various hardware elements, and are not to be confused with failure rates. Second, the survival hours vary among elements from quite high to relatively low. This occurs for several reasons. In some cases it is due to the populations of the elements under consideration being quite large or relatively small. In other cases, the elements that were used to a greater extent on short term missions did not accumu-

EXHIBIT 8 - SPACECRAFT HARDWARE ELEMENT SURVIVAL AND FAILURE STATISTICS
BASED ON PRE-UPDATE SAMPLE

	Total Number in Sample	Number Failed During Launch	Number Failed During Orbit	Total Survival Hours in Orbit
A. SUBSYSTEMS				
1. Timing, Control, and Command	227	4	4	1.83×10^6
2. Telemetry and Data Handling	243		2	1.89×10^6
3. Power	243	4	14	2.01×10^6
4. Attitude Control and Stabilization	205	4	9	1.30×10^6
5. Propulsion	111	3		one shot devices
6. Environmental Control	30			5.05×10^5
7. Structure	246	4		2.04×10^6
8. Payload	322	4	1	1.84×10^6
B. COMPONENTS				
Spacecraft				
1. Accelerometers	334			1.14×10^5
2. Accumulators	8			1.68×10^5
3. A/D, D/A Converters	96			2.50×10^6
4. Amplifiers(1)	378			6.83×10^6
5. Amplifiers, Power	23			4.23×10^5
6. Antenna Assemblies	328			6.74×10^6
7. Attitude Control Assemblies	56			8.14×10^5

	Total Number in Sample	Number Failed During Launch	Number Failed During Orbit	Total Survival Hours in Orbit
8. Battery Charge/Discharge Control Circuits	124			2.56×10^6
9. Battery Packs	358		7	3.13×10^6
10. Bolometer Assemblies	87			1.33×10^6
11. Command Decoders	235		1	2.55×10^6
12. Command Distribution Units	42		2	7.07×10^5
13. Commutators	61			8.30×10^5
14. Compressors and Pumps (Pneumatic Assembly)	48			5.1 x 103
15. Computers	12		1	4.83×10^4
16. Control Switching Assemblies	8			1.42×10^5
17. Data Handling Units	44			9.40×10^5
18. DC/AC Inverters	196			7.48×10^5
19. DC/DC Converters	194	1	3	1.45×10^6
20. Demodulators	10			1.32×10^5
21. Diplexers	15			6.79×10^5
22. Earth Sensor Assemblies	33			3.90×10^5
23. Filter Networks	9			1.44×10^5
24. Fuel Cell Modules	5		1	8.00×10^2
25. Gear Trains	95			1.34×10^5

EXHIBIT 8 - (Continued)

	Total Number in Sample	Number Failed During Launch	Number Failed During Orbit	Total Survival Hours in Orbit
26. Gyros	145		2	5.53×10^5
27. Heat Exchangers	74			7.30×10^3
28. Heaters	350	1	1	2.78×10^6
29. Horizon Sensors	121	1	4	2.22×10^5
30. Infrared Scanners	28			3.49×10^5
31. Louver Assemblies	8			3.35×10^5
32. Magnetic Tape Units	148	1	46	1.32×10^6
33. Magnetometers	22			2.42×10^5
34. Magnetic Sensing Devices	14			2.7[illegible] $\times 10^5$
35. Momentum Wheels/Reaction Wheel Assemblies	26		5	4.26×10^5
36. Motors, Electrical	445		3	2.94×10^6
37. Multiplexers	35			5.67×10^5
38. Oscillators	195		1	2.40×10^6
39. Phase Modulators	16			1.86×10^5
40. Pneumatic Assemblies	20			4.54×10^5
41. Power Distribution Units	30			4.78×10^5
42. Programmers	58	1		9.88×10^5
43. Radiometers	18		1	1.64×10^5
44. Receivers	280	2	2	2.96×10^6

	Total Number in Sample	Number Failed During Launch	Number Failed During Orbit	Total Survival Hours in Orbit
45. Regulators, Pressure	11		1	3.70×10^5
46. Regulators, Voltage	254		4	5.18×10^6
47. Sequencers	123	2		3.18×10^5
48. Signal Conditioners	60			5.55×10^5
49. Sun Sensors	97	1	1	1.42×10^6
50. Star Trackers	10			1.57×10^5
51. Subcarrier Oscillators	25			1.62×10^5
52. Telemetry Encoders	201		8	9.40×10^5
53. Timers and Clocks	218	1	10	2.13×10^6
54. Transmitters, Beacon	32			5.90×10^5
55. Transmitters, Doppler	6			6.96×10^4
56. Transmitters, FM	6			1.56×10^4
57. Transmitters, Tracking	16			6.02×10^5
58. Transmitters, S-Band	10		1	1.37×10^5
59. Transmitters, Special Purpose	20		1	3.56×10^5
60. Transmitters, Wideband	14		3	4.63×10^5
61. Transmitters, Video	20		3	3.25×10^5
62. Transmitters, Other(2)	518		13	4.27×10^6

EXHIBIT 8 - (Continued)

	Total Number in Sample	Number Failed During Launch	Number Failed During Orbit	Total Survival Hours in Orbit
63. Transponders	90	3	2	3.15×10^5
64. Undervoltage, Detectors/Control Circuits	38			6.94×10^5
65. Valves	922			1.57×10^6
66. Vidicon Cameras	58			7.95×10^5
67. Voltage Controlled Oscillators	67	1	6	9.76×10^5
Experiments				
1. Bremsstrahling Detectors	2			1.90×10^4
2. Electron Detectors	4	1		4.26×10^4
3. Experiment Packages, Miscellaneous	260	2	25	2.56×10^6
4. Impedance Probe Packages	2			3.06×10^4
5. Ion Experiments	8		1	4.01×10^4
6. Magnetic Analyzers	4			2.56×10^4
7. Monochrometers	3			3.64×10^4
8. Photometers	6		2	1.64×10^4
9. Proton Detectors	7		1	4.49×10^4
10. Spectrometers	38	1	5	3.15×10^5
11. Solar Detectors (X-ray, UV)	18		2	2.59×10^5

	Total Number in Sample	Number Failed During Launch	Number Failed During Orbit	Total Survival Hours in Orbit
C. PIECE PARTS				
Spacecraft				
1. Ball Bearings	491			1.34×10^6
2. Battery Cells	3,308		1	5.90×10^7
3. Capacitors	203,326	1	10	1.06×10^{10}
4. Circuit Breakers	515			6.47×10^4
5. Coaxial Connectors	394			2.08×10^7
6. Connectors, Noncoaxial	93,770			5.86×10^9
7. Crystals	782			1.39×10^7
8. Delay Lines	23			3.44×10^5
9. Diodes	299,235		4	3.86×10^9
10. Diode Quads	374			9.27×10^6
11. Filters	134			3.30×10^7
12. Fuses	805		3	1.28×10^7
13. Indicators	72			6.72×10^3
14. Inductors (includes coils, chokes)	22,108			3.09×10^8
15. Integrated Circuits	34,107		4	6.17×10^8
16. Lenses	75			5.29×10^5
17. Lights	526			3.23×10^4
18. Magnetic Amplifiers	151			5.45×10^6

EXHIBIT 8 - (Continued)

	Total Number in Sample	Number Failed During Launch	Number Failed During Orbit	Total Survival Hours in Orbit
19. Magnetic Cores	530,876			7.36×10^{9}
20. Magnetrons	30			1.85×10^{3}
21. Photocells	69			7.50×10^{5}
22. Potentiometers	1,301			1.45×10^{6}
23. Relays	9,114	1	1	1.18×10^{8}
24. Resistors	499,022		1	5.71×10^{9}
25. RF Networks (Diplexers, Antenna Couplers)	177			7.60×10^{5}
26. Sensitors	98			1.60×10^{6}
27. Silicon Control Rectifiers	431			1.64×10^{7}
28. Slip Rings	636			4.17×10^{5}
29. Solenoids	178		[illegible]	1.83×10^{6}
30. Switches, General	1,633		4	9.26×10^{6}
31. Thermistors	1,845		6	2.21×10^{7}
32. Thermocouples	674			5.01×10^{4}
33. Thermostats	123		1	1.50×10^{6}
34. Transducers	497	1		1.65×10^{6}
35. Transformers	14,438			1.58×10^{8}
36. Transistors	173,182	1	2	1.79×10^{9}
37. Traveling Wave Tubes	34		1	5.65×10^{5}
38. Tubes, General Purpose	563			2.66×10^{6}
39. Tubes, Special Purpose	19		1	1.66×10^{5}
40. Tuning Forks	72			7.81×10^{5}
Experiments				
1. Geiger Mueller Tubes	16		4	2.52×10^{5}
2. Photomultiplier Tubes	17		1	2.15×10^{5}

Notes: (1) These amplifiers do not include power amplifiers.

(2) These transmitters are other than: beacon transmitters, Doppler transmitters, FM transmitters, tracking transmitters, S-Band transmitters, special purpose transmitters, wideband transmitters, or video transmitters.

EXHIBIT 9 - SPACECRAFT HARDWARE ELEMENT SURVIVAL AND FAILURE STATISTICS BASED ON DATA OF THIS SAMPLE

	Total Number in Sample	Number Failed During Launch	Number Failed During Orbit	Total Survival Hours in Orbit
A. SUBSYSTEMS				
1. Timing, Control, and Command	48			1.25×10^6
2. Telemetry and Data Handling	58		1	8.79×10^5
3. Power	42		1	1.12×10^5
4. Attitude Control and Stabilization	63			1.37×10^6
5. Propulsion	22			3.64×10^5
6. Environmental Control	23			5.02×10^5
7. Structure	35			8.19×10^5
8. Payload	69		1	2.06×10^6
B. COMPONENTS				
Spacecraft				
1. Accelerometers	11		1	5.01×10^5
2. Accumulators	4			3.69×10^5
3. A/D, D/A Converters	8			1.47×10^5
4. Amplifiers, power	10			2.22×10^5
5. Amplifiers(1)	41		1	1.56×10^6
6. Antenna Assemblies	136			4.18×10^6
7. Attitude Control Assemblies	18			3.68×10^5
8. Battery Charge/ Discharge Control Circuits	55		1	2.60×10^6
9. Battery Packs	128		1	3.41×10^6
10. Command Decoders	55			1.34×10^6
11. Command Distribution Units	22			4.23×10^5
12. Commutators	15			4.95×10^5
13. Computers	23			4.09×10^5
14. Control Gas Assemblies	31		2	6.48×10^5
15. Control Swtiching Assemblies	31			6.11×10^5
16. Data Handling Units	44		1	7.63×10^5
17. DC/AC Inverters	18			5.83×10^5
18. DC/DC Converters	96			2.11×10^6
19. Demodulators	4			5.21×10^4
20. Diplexers	9			3.65×10^5
21. Earth Sensor Assemblies	5			1.05×10^5
22. Filter Networks	13			3.91×10^5
23. Gyro Assembly Units	4			3.52×10^4
24. Gyros	25		1	6.77×10^5
25. Heat Pipes	1			2.34×10^4

EXHIBIT 9 - (Continued)

	Total Number in Sample	Number Failed During Launch	Number Failed During Orbit	Total Survival Hours in Orbit
26. Heaters	40			1.51×10^6
27. Horizon Sensors	8			1.26×10^5
28. Louver Assemblies	12			3.13×10^5
29. Magnetic Sensing Devices	23		1	5.29×10^5
30. Magnetic Tape Units	52		9	9.66×10^5
31. Magnetometers	33		2	5.33×10^5
32. Memory	23			3.99×10^5
33. Momentum Wheels/ Reaction Wheel Assembly	23			6.89×10^5
34. Motors, Electrical	10			3.02×10^5
35. Multiplexers	39			7.69×10^5
36. Nutation Dampers	14			2.91×10^8
37. Oscillators	20			3.63×10^5
38. Phase Modulators	13			3.18×10^5
39. Pneumatic Assemblies	14			3.31×10^5
40. Power Distribution Units	19			5.68×10^5
41. Programmers	20			4.18×10^5
42. Radiometers	48		10	8.78×10^5
43. Receivers	86		3	3.25×10^6
44. Regulators, Pressure	25			2.11×10^6
45. Regulators, Voltage	78		1	2.41×10^6
46. Sequencers	7			1.47×10^5
47. Signal Conditioners	13		1	2.68×10^5
48. Sun Sensors	63		2	1.08×10^6
49. Star Trackers	13		2	2.45×10^5
50. Telemetry Encoders	30			1.70×10^6
51. Timers and Clocks	42			1.92×10^6
52. Transmitters, Beacon	14			2.29×10^5
53. Transmitters, Doppler	2			3.03×10^4
54. Transmitters, S-Band	31		2	5.42×10^5
55. Transmitters, Special Purpose	1			3.26×10^3
56. Transmitters, Tracking	1			3.07×10^4
57. Transmitters, Wideband	6			1.04×10^5
58. Transmitters, Other(2)	74		2	2.17×10^6
59. Transponders	20			6.02×10^5
60. Undervoltage Detectors	12			2.91×10^5
61. Valves	39			4.39×10^5
62. Vidicon Cameras	16			3.72×10^5
63. Voltage Controlled Oscillators	7			4.40×10^5

EXHIBIT 9 - (Continued)

	Total Number in Sample	Number Failed During Launch	Number Failed During Orbit	Total Survival Hours in Orbit
Experiments				
1. Electron Detectors	4			3.41×10^4
2. Experiment Packages, Miscellaneous	144		15	3.84×10^6
3. Impedance Probe Package	1			3.65×10^5
4. Ion Experiments	9		1	2.79×10^5
5. Photometers	8		1	1.21×10^5
6. Proton Detectors	6			7.73×10^4
7. Solar Detectors	10		1	2.00×10^5
8. Spectrometers	26		2	3.46×10^5
C. **PIECE-PARTS**				
1. Battery Cells	835		2	2.68×10^7
2. Bearings	186			6.06×10^6
3. Capacitors	82,910		2	1.89×10^9
4. Connectors, Coaxial	105			8.51×10^6
5. Connectors, Noncoaxial	2,361			7.13×10^7
6. Crystals	247			6.59×10^6
7. Delay Lines	2			1.94×10^5
8. Differential Amplifier	548			1.85×10^7
9. Diodes	95,825		2	3.00×10^9
10. Filters	2,650			4.37×10^7
11. Fuses	2,298		2	4.45×10^7
12. Inductors	8,701			2.45×10^8
13. Integrated Circuits	77,879		1	1.51×10^9
14. Lights	62			6.67×10^5
15. Magnetic Amplifiers	8			7.39×10^5
16. Magnetic Cores	48			3.77×10^6
17. Motors	27			6.08×10^5
18. Potentiometers	838			2.57×10^7
19. Relays	8,382			1.42×10^8
20. Resistors	209,537			5.29×10^9
21. Silicon Control Rectifiers	3			2.91×10^5
22. Slip Rings	1			8.76×10^4
23. Solenoids	5			1.63×10^5
24. Switches	115	1	1	2.51×10^6
25. Thermistors	836			2.65×10^7
26. Thermostats	38			4.12×10^5
27. Transducers	37			9.71×10^5
28. Transformers	2,852			6.47×10^7
29. Transistors	41,633		2	1.23×10^9

EXHIBIT 9 - (Continued)

	Total Number in Sample	Number Failed During Launch	Number Failed During Orbit	Total Survival Hours in Orbit
30. Traveling Wave Tubes	13			6.99×10^5
31. Tubes, General Purpose	96		3	3.01×10^6
32. Tuning Fork	3			2.72×10^5

Notes: (1) These amplifiers do not include power amplifiers.

(2) These transmitters are other than: beacon transmitters, Doppler transmitters, S-Band transmitters, special purpose transmitters, tracking transmitters, wideband transmitters, or video transmitters.

EXHIBIT 10 - SPACECRAFT ELEMENT SURVIVAL AND FAILURE STATISTICS BASED ON COMBINED SAMPLE

	Total Number in Sample	Number Failed During Launch	Number Failed During Orbit	Total Survival Hours in Orbit
A. SUBSYSTEMS				
1. Timing, Control, and Command	270	4	4	2.93×10^{6}
2. Telemetry and Data Handling	297		3	2.66×10^{6}
3. Power	282	4	15	2.03×10^{6}
4. Attitude Control and Stabilization	265	4	9	2.60×10^{6}
5. Propulsion	133	3		3.64×10^{5}
6. Environmental Control	53			1.01×10^{6}
7. Structure	278	4		2.76×10^{6}
8. Payload	370	4	2	3.30×10^{6}
B. COMPONENTS				
Spacecraft				
1. Accelerometers	341		1	6.14×10^{5}
2. Accumulators	8			4.03×10^{5}
3. A/D, D/A Converters	101			2.53×10^{6}
4. Amplifiers, power	33			6.45×10^{5}
5. Amplifiers (1)	410		1	8.13×10^{6}
6. Antenna Assemblies	453			1.06×10^{7}
7. Attitude Control Assemblies	73			1.16×10^{6}
8. Battery Charge/Discharge Control Circuits	167		1	4.42×10^{6}
9. Battery Packs	482		8	6.40×10^{6}
10. Bolometer Assemblies	87			1.33×10^{6}
11. Command Decoders	287		1	3.78×10^{6}
12. Command Distribution Units	64		2	1..3 $\times 10^{6}$
13. Commutators	76			1.32×10^{6}
14. Compressors and Pumps (Pneumatic Assembly)	48			5.10×10^{3}
15. Computers	35		1	4.37×10^{5}
16. Control Gas Assemblies	31		2	6.48×10^{5}
17. Control Switching Assemblies	39			7.53×10^{5}
18. Data Handling Units	88		1	1.70×10^{6}
19. DC/AC Inverters	214			1.33×10^{6}
20. DC/DC Converters	290	1	3	3.56×10^{6}
21. Demodulators	14			1.84×10^{5}
22. Diplexers	24			1.04×10^{6}
23. Earth Sensor Assemblies	38			4.95×10^{5}
24. Filter Network	22			5.35×10^{5}

EXHIBIT 10 - (Cont'nued)

		Total Number in Sample	Number Failed During Launch	Number Failed During Orbit	Total Survival Hours in Orbit
25.	Fuel Cell Modules	5			8.00×10^2
26.	Gear Trains	95			1.34×10^5
27.	Gyro Assembly Units	4			3.52×10^4
28.	Gyros	166		2	1.21×10^6
29.	Heat Pipes	1			2.34×10^4
30.	Heat Exchangers	74			7.30×10^3
31.	Heaters	390	1	1	4.29×10^6
32.	Horizon Sensors	161		1	3.48×10^5
33.	Infrared Scanners	28			3.49×10^5
34.	Louver Assemblies	20			6.48×10^5
35.	Magnetic Sensing Devices	23		1	5.29×10^5
36.	Magnetic Tape Units	198	1	55	2.26×10^6
37.	Magnetometers	55		2	7.75×10^5
38.	Memory	23			3.99×10^5
39.	Momentum Wheels/ Reaction Wheels Assemblies	43		5	9.49×10^5
40.	Motors, Electrical	452			3.16×10^6
41.	Multiplexers	73			1.32×10^6
42.	Nutation Dampers	14			2.91×10^8
43.	Oscillators	215		1	2.76×10^6

		Total Number in Sample	Number Failed During Launch	Number Failed During Orbit	Total Survival Hours in Orbit
44.	Phase Modulators	29			5.04×10^5
45.	Pneumatic Assemblies	33			7.69×10^5
46.	Power Distribution Units	49			1.05×10^6
47.	Programmers	78	1		1.41×10^6
48.	Radiometers	64		11	1.01×10^6
49.	Receivers	354	2	5	5.79×10^6
50.	Regulators, Pressure	36		1	2.48×10^6
51.	Regulators, Voltage	304		5	6.63×10^6
52.	Sequencers	130	2		4.65×10^5
53.	Signal Conditioners	67		1	8.23×10^5
54.	Sun Sensors	157	1	3	2.45×10^6
55.	Star Trackers	23			4.02×10^5
56.	Subcarrier Oscillators	25			1.62×10^5
57.	Telemetry Encoders	227		8	2.50×10^6
58.	Timers and Clocks	255	1	10	3.90×10^6
59.	Transmitters, Beacon	46			8.19×10^5
60.	Transmitters, Doppler	8			9.99×10^4
61.	Transmitters, FM	6			1.56×10^4
62.	Transmitters, S-Band	41		3	6.79×10^5
63.	Transmitters, Special Purpose	21		1	3.59×10^5

EXHIBIT 10 - (Continued)

	Total Number in Sample	Number Failed During Launch	Number Failed During Orbit	Total Survival Hours in Orbit
64. Transmitters, Tracking	17			6.32×10^5
65. Transmitters, Video	20		3	3.25×10^5
66. Transmitters, Wideband	20		3	5.67×10^5
67. Transmitters, Other(2)	573		15	6.44×10^6
68. Transponders	106		2	7.83×10^5
69. Undervoltage Detectors/Control Circuits	50	3		9.85×10^5
70. Valves	961			2.01×10^6
71. Vidicon Cameras	71		6	1.17×10^6
72. Voltage Controlled Oscillators	73	1		1.42×10^6
Experiments				
1. Bremsstrahling Detectors	2			1.90×10^4
2. Electron Detectors	8	1		7.67×10^4
3. Experiment Packages, Miscellaneous	389	2	40	6.40×10^6
4. Impedance Probe Packages	3			3.96×10^5
5. Ion Experiments	17		1	3.19×10^5
6. Magnetic Analyzers	4			2.56×10^4

	Total Number in Sample	Number Failed During Launch	Number Failed During Orbit	Total Survival Hours in Orbit
7. Monochrometers	3			3.64×10^4
8. Photometers	14		1	1.37×10^5
9. Proton Detectors	13			1.66×10^5
10. Solar Detectors	26		3	4.22×10^5
11. Spectrometers	61	1	7	6.19×10^5
C. PIECE PARTS				
Spacecraft				
1. Ball Bearings	677			7.40×10^6
2. Battery Cells	4,055		3	7.99×10^7
3. Capacitors	274,166	1	12	1.20×10^{10}
4. Circuit Breakers	515			6.47×10^4
5. Connectors, Coaxial	394			2.09×10^7
6. Connectors, Noncoaxial	94,998			5.91×10^9
7. Crystals	980			1.97×10^7
8. Delay Lines	23			4.69×10^5
9. Differential Amplifier	548			1.85×10^7
10. Diodes	370,416		6	6.22×10^9
11. Diode Quads	374			9.27×10^6
12. Filters	2,815			7.31×10^7

EXHIBIT 10 - (Continued)

	Total Number in Sample	Number Failed During Launch	Number Failed During Orbit	Total Survival Hours in Orbit
13. Fuses	2,995		5	5.53×10^7
14. Indicators	72			6.72×10^3
15. Inductors	29,347			5.07×10^8
16. Integrated Circuits	105,998		5	2.00×10^9
17. Lenses	75			5.29×10^5
18. Lights	588			6.99×10^5
19. Magnetic Amplifiers	151			5.92×10^6
20. Magnetic Cores	530,876			7.36×10^9
21. Magnetrons	30			1.85×10^3
22. Motors	27			6.08×10^5
23. Photocells	69			7.50×10^5
24. Potentiometers	2,137			2.71×10^7
25. Relays	12,541	1	1	1.65×10^8
26. Resistors	671,082			1.04×10^{10}
27. RF Networks	177			7.60×10^5
28. Sensistors	98			1.60×10^6
29. Silicon Control Rectifiers	431			1.66×10^7
30. Slip Rings	637			5.05×10^5
31. Solenoids	183			1.99×10^6
32. Switches	1,719	1	5	1.07×10^7

	Total Number in Sample	Number Failed During Launch	Number Failed During Orbit	Total Survival Hours in Orbit
33. Thermistors	2,451		6	4.40×10^7
34. Thermocouples	674			5.01×10^4
35. Thermostats	161			1.91×10^6
36. Transducers	522	1		2.43×10^6
37. Transformers	16,801			2.09×10^8
38. Transistors	204,669	1	4	2.75×10^9
39. Traveling Wave Tube	39			1.02×10^6
40. Tubes, General Purpose	649		3	5.47×10^6
41. Tubes, Special Purpose	19		1	2.28×10^5
42. Tuning Fork	72			9.56×10^5
Experiments				
1. Geiger Mueller Tubes	16		4	2.52×10^5
2. Photomultiplier Tubes	17		1	2.15×10^5

Notes: (1) These amplifiers do not include power amplifiers.

(2) These transmitters are other than: beacon transmitters, Doppler transmitters, S-Band transmitters, special purpose transmitters, tracking transmitters, wideband transmitters, or video transmitters.

late as many survival hours as elements used extensively on long term missions. Also, elements experiencing a large number of failures would obviously accumulate fewer survival hours than elements with a history of continued, satisfactory operation.

Exhibit 8 presents the basic data tabulation of the pre-update sample. Exhibit 9 presents a similar tabulation for the sample of this study. Exhibit 10 contains the tabulation for the combined sample.

The spacecraft samples of the previous reliability reports and this report are not independent. Five spacecraft in this sample also appeared in the earlier studies. These spacecraft were launched prior to 1970 and have continued to operate into the time period of this study. It is for this reason that the data for these five spacedraft have been updated and included in this study. Thus, corresponding entries in Exhibits 8 and 9 do not necessarily add to give the corresponding entry in Exhibit 10. Though the samples are not entirely independent, the method of presenting the data allows examination of the basic data elements by three time periods: spacecraft launched in the interval 1958 to 1970 (12 years), those launched in the interval 1970 to mid-1977 (7½ years) and the total sample, covering nearly 20 years.

The main rule in constructing Exhibits 8, 9, and 10 was to enter only known values. For example, as Exhibit 10 indicates there are 354 receivers in the combined sample for which operational histories are complete; cumulatively these components survived at least 5.8 million hours and exhibited at least two launch failures and five orbital failures. It is known that the figures are higher than those presented, but it is not known by how much. This results from incompleteness of the historical data for some of the spacecraft in the data sample[1] and does lead to difficulty in interpreting the resultant estimates of q and λ. Further discussion of the interpretation difficulty is discussed in later subsections where each hardware tier is treated in detail.

Exhibits 8, 9, and 10, then, present the basic data and form the basis of the analyses performed in the subsequent subsections. Interpretation and conclusions are, of course, influenced by the total knowledge acquired in the course of the study.

C. SUBSYSTEM ANALYSIS

For this study, the eight spacecraft subsystems are defined exactly as they were in all earlier studies. In point of fact, each program and often different vehicles in the same program use a different internal subsystem description. The expedient of relating subfunctions of each spacecraft to a set of previously defined subsystems in a mutually exclusive and exhaustive manner not only provides for ease in data compilation across variously-named subsystems but also accomplishes two other important goals. First, it allows the anomalous incidents to be assigned to one and only one functional location within the spacecraft. Second, it avoids listing recognizable subsystems, i.e., those traceable to a specific program. It is quite clear that this procedure introduces a substantial degree of heterogeneity into the eight subsystem categories thus defined. Nevertheless, for large system planning considerations,

[1] As previously noted, the completeness of historical data for the sample of this study was superior to that of earlier studies.

some indication of gross, average launch failure probabilities (q) and on-orbit failure rates for spacecraft subsystems (λ) might be useful.

Exhibit 11 presents the best estimates and confidence limits for q and λ for the earlier studies. Exhibit 12 presents the same information for the spacecraft of this study; Exhibit 13, for the combined data sample.

It should be borne in mind when using or studying the three exhibits for estimates of the subsystem parameters that a subsystem failure is defined as some anomalous incident associated with the subsystem, the result of which is to reduce mission effectiveness by at least 2/3 of its potential effectiveness. The parameters as given are felt to be reasonably indicative of failure propensities of spacecraft subsystems.

D. COMPONENT ANALYSIS

The components listed in Exhibits 8, 9, and 10 display a wide variation in both number of items in each sample and in number of survival hours. This situation reflects both variation in absolute component population as discussed earlier, and in the input data. Some of the entries may appear to be insignificant. The intent in providing the entries is to add to other data that may be available to the reader rather than to provide meaningful estimates of reliability parameters. As indicated previously, only known values are included.

The best estimates and the 90-percent confidence intervals for q (the probability of failure during launch) for components having one or more failures during the launch phase are given in Exhibits 14 and 15. Since none of the components in this update experienced a launch failure

EXHIBIT 11 - SPACECRAFT SUBSYSTEM RELIABILITY PARAMETER ESTIMATES AND 90-PERCENT CONFIDENCE INTERVALS BASED ON PRE-UPDATE SAMPLE

Spacecraft Subsystems	Probability of Failure During Launch			On-Orbit Failure Rate (Failures/Million Hours)		
	q_1	$\hat{q}$	q_2	λ_1	$\hat{\lambda}$	λ_2
Timing, Control, and Command	0.0060	0.018	0.040	0.75	2.2	5.0
Telemetry and Data Handling	0	-	0.0094	0.19	1.1	3.3
Power	0.0056	0.016	0.038	4.2	7.0	11
Attitude Control and Stabilization	0.0067	0.020	0.045	3.6	6.9	12
Propulsion	0.0074	0.027	0.070			
Environmental Control	0	-	0.074	0	-	4.6
Structure	0.0058	0.016	0.037	0	-	1.1
Payload	0.0042	0.012	0.028	0.028	0.54	2.6

Note : Upper and lower 90% confidence bounds are indicated as q_1 and q_2 for the probability of failure during launch, and by λ_1 and λ_2 for the on-orbit failure rates.

EXHIBIT 12 - SPACECRAFT SUBSYSTEM RELIABILITY PARAMETER ESTIMATES AND 90-PERCENT CONFIDENCE INTERVALS FOR THIS SAMPLE

	Probability of Failure During Launch			On-Orbit Failure Rate (Failures/Million Hours)		
Spacecraft Subsystems	q_1	$\hat{q}$	q_2	λ_1	$\hat{\lambda}$	λ_2
Timing, Control and Command	0	-	0.062	0	-	2.4
Telemetry and Data Handling	0	-	0.052	0.059	1.1	5.4
Power	0	-	0.071	0.46	8.9	42.0
Attitude Control and Stabilization	0	-	0.047	0	-	2.2
Propulsion	0	-	0.14	0	-	8.2
Environmental Control	0	-	0.13	0	-	7.0
Structure	0	-	0.086	0	-	3.7
Payload	0	-	0.043	0.025	0.49	2.3

EXHIBIT 13 - SPACECRAFT SUBSYSTEM RELIABILITY PARAMETER ESTIMATES AND 90-PERCENT CONFIDENCE INTERVALS FOR COMBINED SAMPLE

Spacecraft Subsystems	Probability of Failure During Launch			In-Orbit Failure Rate (Failures/Million Hours)		
	q_1	$\hat{q}$	q_2	λ_1	$\hat{\lambda}$	λ_2
Timing, Control and Command	0.005	0.015	0.034	0.47	1.4	3.1
Telemetry and Data Handling	0	-	0.010	0.31	1.1	2.9
Power	0.0048	0.014	0.033	4.5	7.4	12.0
Attitude Control and Stabilization	0.0051	0.015	0.035	1.8	3.5	6.0
Propulsion	0.0061	0.023	0.058	0	-	8.2
Environmental Control	0	-	0.057	0	-	3.0
Structure	0.0049	0.014	0.033	0	-	1.1
Payload	0.0037	0.011	0.025	0.11	0.61	1.9

EXHIBIT 14 - PROBABILITY OF FAILURE DURING LAUNCH AND 90-PERCENT CONFIDENCE INTERVALS FOR SELECTED SPACECRAFT COMPONENTS BASED ON PRE-UPDATE SAMPLE

	Probability of Failure During Launch		
Component	q_1	$\hat{q}$	q_2
DC/DC Converters	0.00027	0.0052	0.024
Heaters	0.00015	0.0029	0.014
Horizon Sensors	0.00043	0.0083	0.039
Programmers	0.00089	0.017	0.082
Receivers	0.0013	0.0071	0.022
Sequencers	0.0029	0.016	0.051
Sun Sensors	0.00053	0.010	0.049
Timers and Clocks	0.00024	0.0046	0.022
Voltage Controlled Oscillators	0.00077	0.015	0.071

EXHIBIT 15 - PROBABILITY OF FAILURE DURING LAUNCH AND 90-PERCENT CONFIDENCE INTERVALS FOR SELECTED SPACECRAFT COMPONENTS FOR THE COMBINED SAMPLE

	Probability of Failure During Launch		
Component	q_1	$\hat{q}$	q_2
DC/DC Converters	0.00018	0.0034	0.016
Heaters	0.00013	0.0026	0.012
Horizon Sensors	0.00032	0.0062	0.029
Programmers	0.00066	0.013	0.060
Receivers	0.00010	0.0056	0.018
Sequencers	0.0027	0.015	0.048
Sun Sensors	0.00033	0.0064	0.030
Timers and Clocks	0.00020	0.0039	0.018
Voltage Controlled Oscillators	0.00070	0.014	0.064

(see Exhibit 9), no estimates of q are provided.

Exhibits 16, 17, and 18 present the estimates of λ for the selected components of the three data samples.

Generally, there are not enough known failures to reach a reasonable degree of statistical stability. Note that in the combined sample only one component has three launch failures, two have two launch failures, and the rest have either zero or one. The width of the confidence intervals shown in Exhibit 15 are indicative of the meager failure data. The on-orbit failure rates, as shown in Exhibit 18, are slightly more stable. Ten components in the combined sample have five or more failures.

E. PIECE-PART ANALYSIS

As with the component analysis, stress was placed on using only data for piece parts that are known or can be reasonably assumed. Many more assumptions are required at the piece-part level with regard to operating hours since telemetry data simply is insufficient to describe the operational history of many specific piece parts in a given spacecraft. It will be recalled that an operating assumption of this study is that as long as a component is completely operable, so is every piece part within the component. When a component exhibits anomalous behavior, the piece parts are removed from the sample if there is any suspicion that the anomaly was caused by a piece part. The result is that the hours listed in Exhibits 8, 9, and 10, represent minimum part-hours within the limits of the input data.

EXHIBIT 16 - ON-ORBIT FAILURE RATE ESTIMATES AND 90-PERCENT CONFIDENCE INTERVALS FOR SELECTED SPACECRAFT COMPONENTS BASED ON PRE-UPDATE SAMPLE

	On-Orbit Failure Rate (Failures/Million Hours)		
	λ_1	$\hat{\lambda}$	λ_2
Batteries	1.0	2.2	4.2
Decoders	0.024	0.39	1.9
Command Distribution Units	0.50	2.8	8.9
Computers	1.1	21	98
DC/DC Converters	0.57	2.1	5.3
Heaters	0.019	0.36	1.7
Horizon Sensors	6.1	18	41
Magnetic Tape Units	27	35	45
Motors	0.28	1.0	2.6
Oscillators	0.021	0.42	2.0
Receivers	0.12	0.68	2.1
Regulators, Pressure	0.14	2.7	13
Regulators, Voltage	0.26	0.77	1.8
Telemetry Encoders	4.2	8.5	15
Timers and Clocks	2.6	4.7	8.0
Transmitters	1.8	3.0	4.8
Transponders	1.1	6.3	20
Vidicon Cameras	3.3	7.5	15

EXHIBIT 17 - ON-ORBIT FAILURE RATE ESTIMATES AND 90-PERCENT CONFIDENCE INTERVALS FOR SELECTED SPACECRAFT COMPONENTS BASED ON THIS SAMPLE

Component	On-Orbit Failure Rate (Failures/Million Hours) λ_1	$\hat{\lambda}$	λ_2
Accelerometers	0.10	2.0	9.5
Amplifiers, (1)	0.033	0.64	3.0
Battery Charge/Discharge Control Circuits	0.020	0.77	1.8
Battery Packs	0.015	0.29	1.4
Control Gas Assemblies	0.55	3.1	9.7
Data Handling Units	0.067	1.3	6.2
Gyros	0.076	1.5	7.0
Magnetic Sensing Devices	0.097	1.9	9.0
Magnetic Tape Units	4.9	9.0	16.0
Magnetometers	0.067	3.7	11.0
Radiometers	6.2	11.0	19.0
Receivers	0.025	0.92	2.4
Regulators, Voltage	0.021	0.41	2.0
Signal Conditioners	0.19	3.7	18.0
Sun Sensors	0.33	1.9	4.4
Star Trackers	1.5	8.2	19.0
Transmitters, S-Band	0.65	3.7	12.0
Transmitters, other (2)	0.13	0.92	2.9

(1) These amplifiers do not include power amplifiers.

(2) These transmitters are other than: beacon transmitters, Doppler transmitters, FM transmitters, S-Band transmitters, special purpose transmitters, tracking transmitters, wideband transmitters, or video transmitters.

EXHIBIT 18 - ON-ORBIT FAILURE RATE ESTIMATES AND 90-PERCENT CONFIDENCE INTERVALS FOR SELECTED SPACECRAFT COMPONENTS BASED ON COMBINED SAMPLE

	On-Orbit Failure Rate (Failures/Million Hours)		
Components	λ_1	$\hat{\lambda}$	λ_2
Accelerometers	0.08	1.6	7.7
Amplifiers, (1)	0.0063	0.12	0.58
Battery Charge/Discharge Control Circuits	0.012	0.23	1.1
Battery Packs	0.62	1.3	2.3
Command Decoders	0.014	0.26	1.25
Command Distribution Units	0.31	1.8	5.6
Computers	0.012	2.3	11.0
Control Gas Assemblies	0.65	3.1	9.7
Data Handling Units	0.030	0.59	2.8
DC/DC Converters	0.022	0.84	2.2
Gyros	0.29	1.7	5.2
Heaters	0.012	0.23	1.1
Magnetic Sensing Devices	0.097	1.9	9.0
Magnetic Tape Units	14.0	24.0	37.0
Magnetometers	0.29	2.6	5.2
Momentum Wheel/Reaction Wheel Assemblies	2.1	5.3	11.0
Oscillators	0.019	0.36	1.7
Radiometers	6.1	11.0	18.0
Receivers	0.34	0.86	1.8
Regulators, pressure	0.021	0.40	1.9
Regulators, voltage	0.30	0.75	1.6
Signal Conditioners	0.063	1.2	5.8

EXHIBIT 18 - (Continued)

	On-Orbit Failure Rate (Failures/Million Hours)		
	λ_1	$\hat{\lambda}$	λ_2
Sun Sensors	0.33	1.2	3.2
Star Tracker	33.0	57.0	90.0
Telemetry Encoders	1.6	3.2	5.8
Timers and Clocks	1.4	2.6	4.3
Transmitters, S-Band	1.2	4.4	11.0
Transmitters, Special Purpose	0.14	2.8	13.0
Transmitters, Wideband	1.4	5.0	14.0
Transmitters, Video	2.5	9.2	24.0
Transmitters, other (2)	1.4	2.3	3.9
Transponders	0.45	2.5	8.0
Vidicon Cameras	2.2	5.1	10.0

(1) These amplifiers do not include power amplifiers.

(2) These transmitters are other than: beacon transmitters, Doppler transmitters, FM transmitters, S-Band transmitters, special purpose transmitters, tracking transmitters, wideband transmitters, or video transmitters.

The column indicating number of failures also represents the minimum number of part failures. A failure is entered in Exhibits 8, 9, and 10 only if the part has failed catastrophically for no evident cause. The number of part failures is lower than the true value for at least the following reasons: (1) some part failures are never detected due to minimal effect, low-level redundancy, etc., (2) some detected part failures are not reported, an inevitable situation where no formal procedure exists for such reporting, (3) some anomalies strongly suspected as originating from a part failure simply cannot be isolated to the particular part, and (4) many anomalous behaviors are noted for which it is simply unknown whether or not a piece-part failure is involved.

Thus all the reliability statistics derived in this subsection are felt to be somewhat low compared to the true piece-part failure rates in space. To overcome this bias, however, it is judged that an order-of-magnitude increase in all the failure rates and failure probabilities in this subsection would be more than sufficient.

Exhibits 19, 20, and 21 present the on-orbit failure rates for piece parts exhibiting one or more failures. No table for probability of failure during launch was generated. Only five piece parts incurred failures in this phase, one for each part. These part types and their corresponding estimates of q are:

Piece Part	$\hat{q}$
Capacitor	3.7×10^{-6}
Relays	8.0×10^{5}
Switches	5.8×10^{-4}
Transducers	1.9×10^{-3}
Transistors	4.9×10^{-6}

EXHIBIT 19 - ON-ORBIT FAILURE RATE ESTIMATES AND 90-PERCENT CONFIDENCE INTERVALS FOR SELECTED PIECE-PARTS BASED ON PRE-UPDATE SAMPLE

	On-Orbit Failure Rate (Failures/Million Hours)		
	λ_1	$\hat{\lambda}$	λ_2
Battery Cells	0.00087	0.017	0.080
Capacitors	0.00051	0.00094	0.0016
Diodes	0.00035	0.0010	0.0024
Fuses	0.064	0.23	0.61
Integrated Circuits	0.0022	0.0065	0.015
Relays	0.00044	0.0085	0.040
Resistors	0.0000090	0.00018	0.00083
Solenoids	0.028	0.55	2.6
Switches	0.15	0.43	0.99
Thermistors	0.12	0.27	0.54
Transistors	0.00020	0.0011	0.0035
Traveling Wave Tubes	0.091	1.8	8.4
Tubes, Special Purpose	0.31	6.0	29
Geiger Mueller Tubes	5.4	16	36
Photomultiplier Tubes	0.24	4.7	22

EXHIBIT 20 - ON-ORBIT FAILURE RATE ESTIMATES AND 90-PERCENT CONFIDENCE INTERVALS FOR SELECTED PIECE-PARTS BASED ON THIS SAMPLE

Piece Part	On-Orbit Failure Rate (Failures/Million Hours) λ_1	$\hat{\lambda}$	λ_2
Battery Cells	0.013	0.075	0.23
Capacitors	0.00019	0.0011	0.0033
Diodes	0.00012	0.00067	0.0021
Fuses	0.0080	0.045	0.14
Integrated Circuits	0.000034	0.00066	0.0042
Switches	0.020	0.40	1.9
Transistors	0.00029	0.0016	0.0051
Tubes, General Purpose	0.27	1.0	2.6

EXHIBIT 21 - ON-ORBIT FAILURE RATE ESTIMATES AND 90-PERCENT CONFIDENCE INTERVALS FOR SELECTED PIECE-PARTS BASED ON COMBINED SAMPLE

	On-Orbit Failure Rate (Failures/Million Hours)		
Piece Parts	λ_1	$\hat{\lambda}$	λ_2
Battery Cells	0.010	0.037	0.097
Capacitors	0.00057	0.0010	0.0016
Diodes	0.00042	0.00097	0.0019
Fuses	0.036	0.090	0.19
Integrated Circuits	0.00099	0.0025	0.0053
Relays	0.00031	0.0061	0.029
Switches	0.18	0.47	0.98
Thermistors	0.053	0.12	0.24
Transistors	0.00050	0.0015	0.0033
Tubes, General Purpose	0.15	0.55	1.4
Tubes, Special Purpose	0.23	4.39	21.0
Geiger Mueller Tubes	5.4	16.0	37.0
Photomultiplier Tubes	0.24	4.6	22.0

F. MISCELLANEOUS STUDY FINDINGS

This section discusses six observations of interest that do not fit in the formalized analyses of the previous subsections. Other study findings of this nature but involving more detail are presented in the six Experience Bulletins, as described in Section IV.

It should be noted that these observations are typical of the types of specific findings that can be obtained from data bank analyses. Depending on the depth of detail desired, the analyses can be based on the raw data presented in Appendix A, or on data from the EAR's. The observations discussed below should be of general interest. Other observations or findings can, of course, be otained in response to specific queries or needs.

(1) Redundancy: As found in the three previous data bank studies, redundancy played an important role in reducing the effects of an anomaly. There are 45 instances in this update where "block" redundancy prevented a more serious effect. There are also 68 more instances where the seriousness of the anomaly was alleviated by "backup" other than block redundancy. Such backup, which was most often possible on the more complex spacecraft, consisted of either an alternate means of accomplishing the same function or "work around" procedures developed for ground control.

(2) Self-Healing: The apparent self-healing capability which has been noted in previous data bank studies was again observed. In the update sample, there were 34 instances of anomalous behavior that cleared up without any type of intervention.

(3) Aging/Wearout: As indicated in previous data bank reports, aging/wearout does not appear to be a problem. Six instances are reported in this update, with two of them involving radiometers and one each a battery, a star tracker, a tube filament, and a plasma experiment package.

(4) Ground/Operator Errors: Anomalies in this category have not been observed to any significant degree in the past data bank studies. Due in part to the more complex spacecraft included in this update, 30 instances are reported involving ground/operator error, and another five are reported involving ground software.

(5) Intermittent/Degraded Operation Prior to Failure: There have been anomalies involving intermittent or degraded operation prior to "failing solid" in all previous data bank samples, but they were not previously tabulated. In the update sample, 17 such instances are reported.

(6) Test-Related Anomalies: In the update sample, there are 30 anomalies that are known to be related in some fashion to the testing program. There are undoubtedly other anomalies of this type in the update data, but specific information is given only for the 30.

These 30 anomalies can be classified as follows:

- 11 anomalies were known to exist prior to launch
- 3 anomalies existed prior to launch but were undetected
- 8 anomalies had also been seen in test
- 6 anomalies were attributed to inadequate testing or test procedures
- 2 anomalies were attributed to damage caused by testing

IV. SPECIAL STUDIES

In each of the four data collection efforts, with the exception of the third, a special study or two was requested by the contracting agency. In this update six experience bulletins were requested to encourage higher reliability, more consistent performance, reduction in human errors, and reduced cost in NASA projects. Special studies regarding dormancy and the relationship of program success to quality assurance factors were also requested. The latter element was treated in the first collection as well. The second data collection effort briefly treated dormancy and on/off cycling. The results of these studies are presented in this section. Subsection A deals with the question of dormancy, and presents data at the spacecraft, component, and piece-part level. Subsection B presents previously derived results relating to on/off cycling.[1] Subsection C treats the relationship of reliability and quality assurance to spacecraft mission success. Subsection D briefly summarizes the most cogent findings of the six experience bulletins.

All of these special studies depend on the preceding sections of this report, the basic engineering analysis reports (EARs) for the various programs, and, to a lesser extent, the basic documentation assembled for this study. These special studies are indicative, therefore, of the information which inheres in the entire space data bank both

[1] As indicated in the introduction to this report, there have been several independent analyses of the data bank and these are reported separately (References 4, 5, 6, 10, 11, 13, and 14); only those analyses performed in conjunction with a collection effort are included in this section.

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with respect to its positive attributes and its limitations. By the very nature of the study, there tends to be some information applicable to nearly any relevant question or problem area, but for only a very few questions may large quantities of data be anticipated. Not unexpectedly, the more specific and narrowly focused the question or subject area, the scarcer the directly applicable data become.

A. DORMANCY

Reliability data on dormancy and standby operation of spacecraft components has been collected and analyzed in all four collection efforts associated with the space data bank. Until this update, however, no compilation of dormancy information at the large equipment group or spacecraft level was possible. As described in the following subsection that situation has changed and profiles of several spacecraft are available which include long periods of dormancy. The traditional component and piece-part dormancy analysis is provided in Subsection IV.A.2 below.

1. Spacecraft

Significant periods of dormancy were accumulated by nine spacecraft in this update. The spacecraft are: SERT II, OSO-5, GEOS-2, Mariner 10, SAS-B, LANDSAT 1, SMS-1 and 2, and GOES-1. The dormancy associated with these spacecraft involved the entire spacecraft in 4 cases and dormancy of major equipment groups in five cases. Except for short periods of operation and checkout twice a year, SERT-II has been essentially dormant for over six years. GEOS-2 was reactivated and checked out after a non-operational period of almost two-and-one-half years. OSO-5 and SAS-B were reactivated and checked out after about one-and-one-half years of dormancy.

It is of interest that the dormancy information available in the update data revealed no reliability problems that could be attributed to dormancy. Only one anomaly was reported to have occurred during a dormant period; the failure of a battery on SERT-II. Since this battery had operated beyond its expected life at that point, there appears to be no relationship between this failure and the effects of dormancy.

a. SERT II

SERT II was launched in February 1970 and carried two ion thrusters as its major payload. Thruster 1 failed after five-and-one-half months in orbit, and Thruster 2 after three months. In both cases, thruster operation was terminated due to a high-voltage short across the thruster grids. Since thruster restart was still possible, a series of turn-on tests were conducted in 1971 in an attempt to clear these shorts. These tests were unsuccessful and the spacecraft was placed in a storage mode.

By 1973, proposed electric propulsion missions included a need to restart thrusters many times. Therefore, the stored SERT-II spacecraft was re-activated (even though well beyond its one year design life) to demonstrate multiple restart capability and to conduct various other evaluations of thruster components.

During this 1973 reactivation, each thruster was successfully restarted 112 times. In addition, the basic subsystems provided the required support. The 1973 test program was terminated due to other priorities for the ground-support equipment.

By 1973, SERT-II's orbit had precessed such that the sun angle was oblique and inadequate spacecraft power was predicted for 1974. Therefore, at the end of the 1973 test program, maneuvers were executed to obtain a new spacecraft orientation for testing in the 1974 to 1976 period.

In August 1974, SERT-II was again reactivated. During these 1974 tests, the high-voltage short on Thruster 2 was cleared, returning it to normal operation. Multiple restart tests of both thrusters were also conducted, as well as tests of spacecraft electrical potential control via the neutralizer cathode. The spacecraft was shut down September 29, 1974.

During 1975, the spacecraft was turned on and the basic subsystems checked out in the spring and again during November and December, when the thrusters were also tested. Beginning in 1974, this has become the established pattern. That is, the spacecraft is checked out and the thrusters fired during the fall/winter period when array power is adequate for thruster firing. About midway between the annual thruster firing the spacecraft is activated and the basic subsystems checked out. A key activity occurring during the spring operation is the respinning of the spacecraft with the gas attitude adjustment system. It was discovered that SERT-II despins due to some unexplained phenomenom and must be respun every six months or so to maintain its spin-stabilization.

C-2

This data base update includes data through the reactivation in August of 1976. At that time, all major subsystems remained functional. It is also known that SERT-II was reactivated in 1978 and that all major subsystems remained functional.

Only one anomaly--failure of a battery--is reported to have occurred during any SERT-II dormancy period. This battery was a 40 ampere-hour silver oxide-zinc battery of the type that had been used on the Mariner program. The battery was reported to be capable of at least five discharge cycles.

The battery was found to be dead (failed) at the end of the first dormant period. The battery charger was turned off at this point.

The battery is reported to have operated beyond its expected life prior to the first spacecraft shut down. Therefore, it seems doubtful that dormancy conditions are in any way related to the battery failure.

The other anomalies on SERT-II occurred during operational periods. They are all of the type routinely observed in data bank evaluations of operational spacecraft, and again seem completely unrelated to dormancy.

The SERT-II gas attitude adjustment system seems of special interest in dormancy considerations. It was intended, and indeed originally called, the backup reacquisition control system (BACS). It is quite similar to the systems used in Surveyor. It has been used three times for reorientation maneuvers with the last of these maneuvers being in August of 1976. Except for these brief periods of operation (i.e., a few moments each) this system has been in a dormant state since the spacecraft was launched. There are no reported anomalies chargeable to this system.

b. OSO-5

The fifth Orbiting Solar Observatory (OSO-5) was turned off December 31, 1972 so that its transmissions would not interfere with the newer OSO-7. OSO-5 was reactivated early in July 1974 when OSO-7 reentered the earth's atmosphere. Thus, OSO-5 was dormant for about a year-and-a-half (546 days). While anomaly data are not available in the data bank for this dormant period, it is known that the basic subsystems remained capable of supporting the mission.

The following experiments were operable July 25, 1974:

- Solar X-Ray Spectroheliograph
- Zodiacal Light Monitor
- Solar Lyman Alpha Telescope

c. GEOS-2

When the GEOS-3 spacecraft became operational in April 1975, the GEOS-2 experiments were no longer needed and they were all turned off. The laser tracking reflector experiment, a passive device, continued to be used by ground stations. The basic spacecraft continued to be monitored and a telemetry readout was taken about twice a week.

In the fall of 1977 it was proposed that this minimal monitoring be stopped and the spacecraft "turned off" completely. About this same time it was reported that the laser tracking had become unusable and therefore the decision was made to deactivate GEOS-2. It was also decided to activate and check the status of as many experiments as possible prior to the spacecraft shut down. Unfortunately, the necessary ground equipment associated with several experiments had been scrapped and only the Doppler Beacons and the C-band transponders could be activated. Both experiments were found to be in good condition and operable. At that time, these experiments had been dormant for 28 months.

d. Mariner 10

The Mariner 10 ultraviolet spectrometer and infrared radiometer experiments, as well as the TV subsystem, were turned off (dormant) for major periods of time during the mission. In addition, one redundant radio frequency subsystem exciter and one redundant portion of the modulation/demodulation subsystem were turned off at any given time during the mission. There were no part failures experienced in those equipments during the time they were turned on or off.

e. SAS-B

The SAS-B gamma-ray telescope experiment failed early in the mission. Since this was the only experiment carried by SAS-B, the spacecraft was deactivated and then used as a training aid as the need arose. It was reactivated from Africa about two-and-one-half years post-launch and all basic systems were normal. It had been dormant (turned off) for about 18 months at that time.

f. LANDSAT-I

Redundant units in two equipment groups were switched into service after long periods of dormancy on LANDSAT-I. A redundant S-band receiver/transmitter was turned on after just short of two years of dormancy. Also, a redundant Rate Measuring Package was switched into service after approximately 26 months of dormancy. The data bank contains no reported anomalies on these previously dormant equipment groups.

g. SMS/GOES

The SMS/GOES program consists of long-life, geostationary weather satellites. All subsystems were designed for a satellite life time of five years and contain considerable redundancy. Many of these redundant elements on SMS-1, SMS-2, and GOES-1 have experienced periods of dormancy followed by normal operation. GOES-2 (launched June 16, 1977) has not yet accumulated any significant dormancy periods.

On SMS-1, a UHF receiver and an S-band receiver operated normally after dormancy periods of approximately seven months each. On SMS-2, a VHF transmitter operated normally after four months of dormancy, and an S-band receiver after six months. On GOES-1, a UHF receiver was dormant for seven months, then operated normally. Also, a VHF transmitter was dormant for two periods of three months each, and operated without fault after both periods.

2. Components and Piece Parts

The primary data regarding dormancy or standby operation for components and piece parts is summarized in Exhibit 22. The exhibit shows the number of items in the sample of this update, the pre-update sample, and the combined sample together with the number of orbital hours

EXHIBIT 22 - STAND-BY HOURS FOR SPACECRAFT HARDWARE

Components	Update: Standby Number in Sample	Update: Standby Survival Hours in Orbit	Pre-Update: Standby Number in Sample	Pre-Update: Standby Survival Hours in Orbit	Total Data Base: Standby Number in Sample	Total Data Base: Standby Survival Hours in Orbit
1. Accelerometers	1	3.53×10^4	18	1.80×10^2	19	3.71×10^4
2. A/D,DA Converters	1	1.30×10^4	43	2.56×10^5	44	2.69×10^5
3. Amplifiers, Power	6	1.79×10^5	1	8.30×10^3	7	1.88×10^5
4. Amplifiers, Other	2	3.83×10^4	57	2.38×10^5	59	3.21×10^5
5. Antenna Assemblies	2	4.84×10^4	8	4.56×10^4	10	9.40×10^4
6. Attitude Control Assemblies	2	6.99×10^4	31	1.58×10^5	33	2.28×10^5
7. Battery Charge/Discharge Control Circuits	1	1.18×10^4	9	6.76×10^4	10	7.94×10^4
8. Battery Packs	2	2.61×10^4	30	1.20×10^5	32	1.46×10^5
9. Bolometer Assemblies	0	-	18	6.78×10^4	18	6.78×10^4
10. Calibrator, Two Level	1	3.53×10^4	0	-	1	3.53×10^4
11. Command Decoders	7	2.20×10^5	4	3.04×10^4	11	2.50×10^5
12. Command Distribution Units	4	1.39×10^5	2	5.20×10^3	6	1.44×10^5
13. Commutators	1	1.30×10^4	0	-	1	1.30×10^4
14. Computers	0	-	6	6.00×10^2	6	6.00×10^2
15. Control Switching Assemblies	0	-	3	1.71×10^4	3	1.71×10^4
16. Converter, Regulated	2	2.60×10^4	0	-	2	2.60×10^4
17. Current Limiter	2	2.51×10^4	0	-	2	2.51×10^4
18. Data Handling Units	1	1.31×10^4	1	8.50×10^3	2	2.16×10^4
19. DC/AC Inverters	8	2.82×10^5	4	2.55×10^4	12	3.08×10^5
20. DC/AC Converter	2	2.43×10^4	35	4.10×10^5	37	4.34×10^5
21. Detector, Narrow Band	1	1.91×10^4	0	-	1	1.91×10^4
22. Detector, Wide Band	1	1.91×10^4	0	-	1	1.91×10^4
23. Diplexers	3	8.37×10^4	0	-	3	8.37×10^4
24. Earth Sensor Assemblies	0	-	1	4.90×10^3	1	4.90×10^3
25. Filter Networks	3	4.44×10^4	3	9.00×10^2	6	4.53×10^4
26. Frequency Multipliers	5	8.44×10^4	0	-	5	8.44×10^4
27. Gyros	4	1.42×10^5	15	7.64×10^4	19	2.18×10^5
28. Heaters	5	1.32×10^5	71	8.38×10^5	76	9.70×10^5
29. Horizon Sensors	1	3.53×10^4	11	1.50×10^4	12	5.03×10^4
30. Hybrids	3	8.37×10^4	0	-	3	8.37×10^4
31. Louver Assemblies	0	-	2	3.13×10^4	2	3.13×10^4
32. Low Voltage Sensor	1	1.30×10^4	0	-	1	1.30×10^4
33. Magnetic Tape Units	3	6.14×10^4	55	4.51×10^5	58	5.12×10^5
34. Magnetometers	2	2.32×10^4	1	2.30×10^2	3	2.34×10^4
35. Mixer, Telemetry	4	1.09×10^5	0	-	4	1.09×10^5
36. Modulation Selectors	1	3.53×10^4	0	-	1	3.53×10^4
37. Momentum Wheel/Reaction Wheel Assemblies	2	2.61×10^4	4	2.99×10^4	6	5.60×10^4
38. Motors, Electrical	3	3.93×10^4	75	6.38×10^5	78	6.77×10^5
39. Multicoder	1	3.53×10^4	0	-	1	3.53×10^4
40. Multiplexers	2	2.61×10^4	2	3.13×10^4	4	5.74×10^4
41. Nutation Dampers	2	3.71×10^4	0	-	2	2.61×10^4
42. Oscillators	8	2.43×10^5	30	2.07×10^5	38	4.50×10^5
43. Phase Modulators	4	7.50×10^4	2	1.64×10^4	6	9.14×10^4

EXHIBIT 22 - (Continued)

Components	Update: Standby Number in Sample	Update: Standby Survival Hours in Orbit	Pre-Update: Standby Number in Sample	Pre-Update: Standby Survival Hours in Orbit	Total Data Base: Standby Number in Sample	Total Data Base: Standby Survival Hours in Orbit
44. Pitch Angle Monitor	1	1.31×10^4	0	-	1	1.31×10^4
45. Pneumatic Assemblies	1	1.31×10^4	0	-	1	1.31×10^4
46. Power Conditioners	2	7.06×10^4	0	-	2	7.06×10^4
47. Power Supply	2	2.52×10^4	0	-	2	2.52×10^4
48. Power Switching Unit	3	1.06×10^5	0	-	3	1.06×10^5
49. Programmers	1	1.30×10^4	15	4.96×10^4	16	6.26×10^4
50. Radiometers	1	1.15×10^4	6	1.31×10^4	7	2.46×10^4
51. Receivers	4	1.74×10^4	31	3.07×10^5	35	3.24×10^5
52. Regulator, Data Storage	1	1.30×10^4	0	-	1	1.30×10^4
53. Regulator, Pressure	2	2.62×10^4	0	-	2	2.62×10^4
54. Regulator, Switching Mode	2	7.06×10^4	0	-	2	7.06×10^4
55. Regulator, Voltage	2	2.51×10^4	50	6.20×10^5	52	6.45×10^5
56. Sequencers	0	-	4	1.92×10^4	4	1.92×10^4
57. Servo Loops	3	3.93×10^4	0	-	3	3.93×10^4
58. Shunt Driver	2	2.60×10^4	0	-	2	2.60×10^4
59. Signal Conditioners	1	3.53×10^4	6	2.60×10^4	7	6.13×10^4
60. Solar Aspect Sensors	2	1.42×10^4	19	1.43×10^5	21	1.57×10^4
61. Spin Rate Control	2	2.61×10^4	0	-	2	2.61×10^4
62. Star Trackers	2	1.30×10^4	2	1.10×10^4	3	2.40×10^4
63. Subcarrier Oscillators	0	-	10	9.63×10^4	10	9.63×10^4
64. Sub Commutators	6	1.44×10^5	0	-	6	1.44×10^5
65. Sub-Sub Commutators	1	1.31×10^4	0	-	1	1.31×10^4
66. Sub Multiplexer	1	1.31×10^4	0	-	1	1.31×10^4
67. Telemetry Encoder	2	2.61×10^4	22	2.15×10^4	24	4.75×10^4
68. Timers and Clocks	2	4.84×10^4	7	1.78×10^4	9	6.62×10^4
69. Transmitters, Other	11	1.86×10^5	132	1.51×10^6	143	1.70×10^6
70. Transmitter, Beacon	0	-	14	6.54×10^4	14	6.54×10^4
71. Transmitter, Doppler	3	6.56×10^4	3	2.45×10^4	6	9.01×10^4
72. Transmitter, RF	2	2.62×10^4	0	-	2	2.62×10^4
73. Transmitter, S-Band	1	4.34×10^3	3	3.78×10^3	4	8.12×10^3
74. Transmitter, Special Purpose	0	-	14	1.48×10^5	14	1.48×10^5
75. Transmitter, Tracking	0	-	15	4.02×10^5	15	4.02×10^5
76. Transmitter, Wide Band	0	-	12	3.67×10^5	12	3.67×10^5
77. Transmitter, VHF	2	6.62×10^3	0	-	2	6.62×10^3
78. Transmitter, Video	0	-	14	2.90×10^4	14	2.90×10^4
79. Transponders	2	4.37×10^4	24	1.55×10^5	26	1.99×10^5
80. Trim Magnet, Chargeable	1	1.30×10^4	0	-	1	1.30×10^4
81. Valves	7	9.17×10^4	425	1.38×10^5	432	2.30×10^5
82. Vidicon Cameras	2	5.96×10^3	41	2.75×10^5	43	2.81×10^5
83. Voltage Controlled Oscillators	7	2.31×10^5	14	3.99×10^4	21	2.71×10^5
84. Voltage Limiter	1	1.30×10^4	0	-	1	1.30×10^4

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EXHIBIT 22 - (Continued)

Piece Parts	Update: Standby Number in Sample	Update: Standby Survival Hours in Orbit	Pre-Update: Standby Number in Sample	Pre-Update: Standby Survival Hours in Orbit	Total Data Base: Standby Number in Sample	Total Data Base: Standby Survival Hours in Orbit
1. Ball Bearings	4	5.20×10^4	46	1.26×10^4	50	6.50×10^4
2. Battery Cells	42	5.50×10^5	245	2.46×10^6	287	3.01×10^6
3. Capacitors	1,728	2.28×10^7	46,838	2.03×10^8	48,566	2.26×10^8
4. Connectors, Coaxial	38	6.46×10^5	116	1.93×10^6	154	2.58×10^6
5. Connectors, Noncoaxial	0	-	23	5.03×10^4	23	5.03×10^4
6. Crystals	5	6.41×10^4	189	1.58×10^6	194	1.64×10^6
7. Delay Lines	0	-	2	6.35×10^2	2	6.35×10^2
8. Diodes	1,004	1.15×10^7	98,314	3.80×10^8	99,318	3.92×10^8
9. Diode Quads	0	-	185	1.29×10^6	185	1.29×10^6
10. Filters	23	2.79×10^5	182	1.20×10^6	205	1.48×10^6
11. Fuses	130	1.69×10^6	83	8.92×10^4	213	1.78×10^6
12. Gas Bottles	8	1.05×10^5	0	-	8	1.05×10^5
13. Indicators	0	-	58	4.60×10^3	58	4.60×10^3
14. Inductors	245	3.70×10^6	7,635	4.91×10^7	7,880	5.28×10^7
15. Integrated Circuits	2,012	3.52×10^7	7,903	3.04×10^7	9,915	6.56×10^7
16. Lenses	0	-	40	1.15×10^5	40	1.15×10^5
17. Lights	0	-	50	9.44×10^2	50	9.44×10^2
18. Magnetic Amplifiers	4	1.41×10^5	84	4.70×10^5	88	6.11×10^5
19. Magnetic Cores	0	-	133,948	1.12×10^9	133,948	1.12×10^9
20. Magnetrons	0	-	2	3.79×10^2	2	3.79×10^2
21. Potentiometers	0	-	299	5.86×10^5	299	5.86×10^5
22. Relays	117	1.55×10^6	1,912	7.46×10^6	2,023	9.01×10^6
23. Resistors	5,982	7.35×10^7	129,081	8.40×10^8	135,063	9.14×10^8
24. RF Networks (Diplexers, Antenna Couplers, etc.)	1	1.31×10^4	15	3.60×10^5	16	4.91×10^4
25. Sensistors	0	-	14	1.15×10^4	14	1.15×10^4
26. Sensor, Solar	3	3.93×10^4	0	-	3	3.93×10^4
27. Silicon Control Rectifiers	0	-	169	1.08×10^6	169	1.08×10^6
28. Slip Rings	2	2.62×10^4	237	9.70×10^3	239	3.59×10^4
29. Solenoids	5	6.55×10^4	82	4.30×10^5	87	4.96×10^5
30. Switches, General	0	-	193	1.62×10^6	193	1.62×10^6
31. Thermistors	22	2.84×10^5	377	1.60×10^6	399	1.88×10^6
32. Thermostats	0	-	57	3.55×10^5	57	3.55×10^5
33. Transducers	1	1.31×10^4	42	8.82×10^4	43	1.01×10^5
34. Transformers	75	9.87×10^5	2,960	1.76×10^7	3,035	1.86×10^7
35. Transistors	1,363	1.67×10^6	37,099	2.32×10^8	38,462	2.49×10^8
36. Traveling Wave Tubes	1	1.21×10^4	18	2.66×10^5	19	2.78×10^5
37. Tubes, General Purpose	0	-	292	1.50×10^6	292	1.50×10^6
38. Tubes, Special Purpose	0	-	4	6.46×10^4	4	6.46×10^4
39. Tuning Forks	0	-	1	7.76×10^3	1	7.76×10^3

the items in each category were known to have survived in space in a non-operating condition. Only one item (a battery) is even suspected of failing during dormancy or standby and even for this battery there seems to be no causal relationship. An explicit calculation of failure rates is therefore inappropriate. The sheer number of hours accumulated against some items, however, indicates that a rather low rate would be appropriate.

Exhibit 23 tabulates the upper 90 percent confidence limit on the dormant failure rate for selected components and piece parts using the combined data base. For comparative purposes, the upper 90 percent confident limit on the overall on-orbit failure rate is also presented. The generally higher dormant failure rate limit simply reflects the reduced amount of data available, but for many components and piece parts the failure rate limits are quite comparable. For three hardware elements the dormant failure rate limit is actually less than the overall on-orbit limit. These three elements and their failure rate statistics are:

	Failure Rate (Failures/Million Hours)			
	Dormancy	On-Orbit		
Hardware Element	λ_2	λ_1	$\hat{\lambda}$	λ_2
Magnetic Tape Units	4.5	14.0	24.0	37.0
Transmitters, Wideband	6.3	1.4	5.0	14.0
Vidicon Cameras	8.2	2.2	5.1	10.0

For vidicon cameras and wideband transmitters, the upper failure rate confidence limits are about equal which only indicates that dormancy is probably no worse than general on-orbit experience. The Magnetic Tape Units, however, indicate a clear cut failure rate reduction from dormant

EXHIBIT 23 - COMPARISON OF UPPER 90 PERCENT CONFIDENCE LIMITS FOR DORMANT AND GENERAL ON-ORBIT FAILURE RATES

Hardware Element	Upper 90 Percent Confidence Limit on Failure Rate (Failures/Million Hours) Dormancy	On-Orbit
Components		
Amplifiers (1)	7.2	0.58
Battery Packs	16.0	2.3
Command Decoders	9.2	1.25
Command Distribution Units	16.0	5.6
Computers	3800.0	11.0
DC/DC Converters	5.3	2.2
Gyros	10.0	5.2
Heaters	2.4	1.1
Magnetic Tape Units	4.5	37.0
Oscillators	5.1	1.7
Receivers	7.1	1.8
Regulators, Voltage	3.6	1.6
Transmitters, Wideband	6.3	14.0
Transmitters, Other (2)	1.3	0.043
Transponders	11.0	8.0
Vidicon Cameras	8.2	10.0
Piece-Parts		
Battery Cells	0.76	0.097
Capacitors	0.010	0.0016
Diodes	0.0059	0.0019
Fuses	1.3	0.19
Integrated Circuits	0.035	0.0053
Relays	0.25	0.029
Switches	1.4	0.98
Thermistors	1.2	0.24
Transistors	0.0093	0.0033
Tubes, General Purpose	1.5	1.4

Notes: (1) These amplifiers do not include power amplifiers.

(2) These transmitters are other than: beacon transmitters, Doppler transmitters, FM transmitters, S-band transmitters, special purpose transmitters, tracking transmitters, wideband transmitters, or video transmitters.

operations; a reduction factor of nearly 10 to 1 is indicated. It is therefore reasonably clear, and made clear by demonstration from actual field data, that dormant failure rates are lower for some components than general in-orbit rates and hence lower than operating failure rates.[1] It is reasonable to conjecture that additional data would extend this conclusion to other components as well.

In addition to the above data, two additional reports related to dormancy and reliability came to light in the course of the data bank studies. The first[2] of these uses a two-year set of data from the spacecraft known as ESSA 2 through ESSA 9 with particular emphasis being given to the vidicon cameras and tape recorders on the AVCS satellites (ESSA 3, 5, 7, and 9). Both dormant and operating data were found on these components and were analyzed. The conclusions from this analysis are as follows:

"For the vidicon cameras and tape recorders of the TOS satellites designated ESSA 3, 5, 7, and 9, correlation analysis was done using the data available on these subsystems in an attempt to establish a relationship between pattern of use and subsystem performance and between pattern of dormancy and subsystem performance.... No distinct differences in correlation were found between "good" subsystems and "bad" ones.

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[1]This is true since the in-orbit rates are based on a combination of powered and unpowered hours in unknown ratios.

[2]Stanford Research Institute, A Study of Dormant-Mode Reliability for the TOS Satellite Systems, Robert S. Ratner and C. Bruce Clark, January 1970, (Final Report on Contract NAS 12-33 (Item 10) SRI Project 5580).

"There are four possible explanations for this lack of a positive result. The first is that the data available are not complete or extensive enough for a statistical analysis. The second is that there is no relationship between performance and operation. Thirdly, the correlations done may not be sufficiently sophisticated to reveal the relationship present. Fourthly, the components we are dealing with appear not to be samples of a larger population in a statistical sense--that is, each component is sufficiently different so as to obscure any relationships between them."

The second report is from the Aerospace Corporation[1] and concludes on the basis of a theoretical analysis that dormant and operating failure rates for electronic parts tend to equality as part quality and application conditions improve. The following tabulation of Q-factors is offered where Q-factor is the ratio of dormant failure rate to operating failure rate.

Q-FACTORS AS A FUNCTION OF PART QUALITY

Quality Level	Q-Factor	Quality Requirements
Mil-Std	0.1	Military Specification quality control with no additional screening.
Mil-Std-Aug	0.5	Military Specification quality control augmented by special requirements and some screening.
Hi-Rel	0.8	Rigorous Specifications, stringent manufacturing controls, excessive screening.

[1]The Aerospace Corporation, Report No. TOR-0172(2133), Failure Rates of Non-Homogeneous Parts Populations, A.C. Reed, 15 September 1971.

B. ON/OFF CYCLING

Related study efforts bearing on this subject area which utilize the space data bank are reported in References 4, 5, and 6. References 4 and 5 are sequential efforts devoted to the reliability effects of ground storage, space dormancy, standby operation and on/off cycling on satellite electronics. Reference 6 discusses the reliability of spaceborne switching devices. As outlined in the previous reports and confirmed in this study effort, defining the subject matter in clear and unambiguous terms is the most difficult part of the problem. This difficulty is a function of the dynamic behavior of nearly all orbiting spacecraft and particularly the more recent and complex satellites. Each major subsystem may be characterized by a number of operational modes, many components are normally subject to cyclical operation (for example, the record and playback cycle of tape recorders, battery charge and discharge cycles, etc.) and configuration changes via the ground/spacecraft link are common on nearly every pass. To compound the problem there are rarely sufficient data to quantify any of the parameters associated with the above operation (time spent in playback mode or record modes, number of playbacks, operational hours per mode, etc.)

The approach taken to surmount this difficulty is that used in all four study efforts. That is, reliance is placed on "known" values, with engineering assumptions being kept to an absolute minimum. When available program documentation provides clear and reasonably straightforward data regarding the cycling of spacecraft components, it is reported; otherwise, it is not.

Exhibits 24 and 25 summarize pertinent data with respect to on/off cycling and standby operation. Only data points which were sufficiently well documented to provide a complete line of information in these exhibits were included. By the same token, the data presented in these exhibits are all that is available from the data bank which carries all the data elements identified in the column headings. Two exhibits were constructed to separate those spacecraft components built with the later integrated circuit technology from the earlier spacecraft constructed primarily from discrete piece-parts. There are 142 entries representing the earlier technology and 49 representing integrated circuit components. The component type is quite variable ranging from a 20-piece-part power converter to an entire spacecraft consisting of some 20,000 electronic piece-parts. The names of the components are purposely kept somewhat general; however, their use in conjunction with the column indicating the number of discrete parts (or integrated circuits) contained in the component should give a reasonable idea of its general characteristics.

The survival hours represent the time that the component under consideration was known to be operable. Power-on time is the number of hours that full, nominal power was applied to the component. Survival hours minus power-on hours gives the time that the component was dormant or on inactive standby.[1] The number of cycles is essentially the number of turn-ons, i.e., switching from inactive standby to full, nominal power. It is not too unreasonable to assume that the on periods in each cycle are approximately equal.

[1]The terms "dormant" and "inactive standby" are considered to be synonymous in this report.

EXHIBIT 24 - CYCLE DATA FOR COMPONENTS COMPOSED OF DISCRETE PIECE PARTS

Index Number	Component Type	Number of Discrete Piece-Parts	Survival Time (hours)	Power-On Time (hours)	Number of Cycles	Number of Anomalies
1	Power Converter	20	20,232	100	732	
2	Power Converter	20	21,184	37	232	
3	Television Camera	20	19,518	4	61	
4	Television Camera	20	19,518	4	61	
5	Television Camera	20	19,518	4	61	
6	Television Camera	20	2,304	1	14	1
7	Transmitter	30	430	357	258	
8	Transmitter	30	430	357	258	
9	Voltage Regulator	32	9,915	9,767	1	
10	Voltage Regulator	32	9,915	148	1	
11	Voltage Regulator	32	3,183	2,887	1	
12	Voltage Regulator	32	3,183	295	1	
13	Voltage Regulator	32	207	76	1	
14	Voltage Regulator	32	207	75	1	
15	Charge Rate Controller	36	11,202	3,861	3	
16	Transmitter	50	20,232	100	732	
17	Transmitter	50	20,184	37	232	
18	Transmitter	50	8,760	3,859	388	
19	Transmitter	50	8,760	45	86	
20	Magnetic Attitude Control	51	11,202	11,162	1	
21	Magnetic Attitude Control	51	9,915	9,857	4	
22	Magnetic Attitude Control	59	19,162	7,848	88	
23	Transmitter	60	9,000	60	1,000	
24	Transmitter	60	6,200	100	1,000	
25	Transmitter	60	5,500	100	1,000	
26	Transmitter	60	430	73	258	
27	Transmitter	60	430	[illegible]	258	
28	Tape Recorder	70	23,000	475	1,700	

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EXHIBIT 24 (Continued)

Index Number	Component Type	Number of Discrete Piece-Parts	Survival Time (hours)	Power-On Time (hours)	Number of Cycles	Number of Anomalies
29	Tape Recorder	70	23,000	440	1,600	
30	Tape Recorder	70	17,500	630	2,600	2
31	Tape Recorder	70	9,300	400	1,500	
32	Tape Recorder	70	8,900	120	560	
33	Tape Recorder	70	8,900	60	300	
34	Tape Recorder	70	7,700	400	1,500	1
35	Tape Recorder	70	2,900	150	600	1
36	Tape Recorder	70	2,400	150	750	1
37	Tape Recorder	70	2,000	65	270	
38	Tape Recorder	70	1,800	130	430	
39	Tape Recorder	70	1,800	30	140	
40	Tape Recorder	70	1,760	100	380	
41	Tape Recorder	70	436	35	130	1
42	Tape Recorder	70	285	16	80	
43	Transmitter	70	23,000	400	3,000	
44	Attitude Control Subsystem	70	23,000	200	200	
45	Attitude Control Subsystem	70	17,500	100	100	
46	Power Amplifier	70	20,232	100	732	
47	Power Amplifier	70	20,184	37	232	
48	Attitude Control Subsystem	80	9,300	100	100	
49	Attitude Control Subsystem	80	9,000	100	300	1
50	Attitude Control Subsystem	80	7,700	100	100	
51	Attitude Control Subsystem	80	6,200	100	200	
52	Attitude Control Subsystem	80	5,500	100	200	
53	Doppler Beacon	100	8,628	496	2,000	
54	Charge Rate Controller	108	9,915	1	2	
55	Charge Rate Controller	108	263	3	4	
56	Transmitter	110	8,900	100	656	

EXHIBIT 24 (Continued)

Index Number	Component Type	Number of Discrete Piece-Parts	Survival Time (hours)	Power-On Time (hours)	Number of Cycles	Number of Anomalies
57	Transmitter	110	8,900	50	344	
58	Transmitter	110	6,200	110	680	
59	Transmitter	110	2,400	130	900	
60	Transmitter	110	2,000	50	330	
61	Transmitter	110	1,800	115	540	
62	Transmitter	110	1,800	28	180	
63	Transmitter	110	285	14	100	
64	Transmitter	120	23,000	360	1,900	
65	Transmitter	120	23,000	340	1,800	
66	Transmitter	120	17,500	500	3,000	
67	Transmitter	120	9,300	310	1,700	
68	Transmitter	120	7,700	300	1,650	
69	Transmitter	120	3,600	300	600	
70	Transmitter	120	1,700	72	390	
71	Transmitter	120	410	26	144	
72	Transmitter	125	17,500	17,200	600	
73	Sun Angle Detector	175	23,000	1,000	2,000	
74	Sun Angle Detector	175	17,500	700	3,000	
75	Sun Angle Detector	175	9,300	500	1,700	1
76	Sun Angle Detector	175	8,900	150	1,000	
77	Sun Angle Detector	175	7,700	450	1,600	
78	Sun Angle Detector	175	6,200	230	1,000	
79	Sun Angle Detector	175	5,500	200	1,000	
80	Sun Angle Detector	175	1,800	160	540	1
81	Transmitter	175	8,760	2,674	1,446	
82	Transmitter	175	8,760	30	161	
83	Receiver	180	430	73	258	
84	Receiver	180	430	73	258	

EXHIBIT 24 (Continued)

Index Number	Component Type	Number of Discrete Piece-Parts	Survival Time (hours)	Power-On Time (hours)	Number of Cycles	Number of Anomalies
85	Transmitter	200	15,984	2,000	30	
86	Transmitter	200	15,984	2,000	30	
87	Receiver	260	430	73	258	
88	Receiver	260	430	73	258	
89	Receiver	260	430	73	258	
90	Receiver	260	430	73	258	
91	SECOR Transponder	300	8,628	221	875	1
92	Receiver	335	8,760	2,937	329	
93	Encoder	335	8,760	2,674	1,446	
94	Encoder	335	8,760	30	161	
95	Transmitter	340	430	73	258	
96	Transmitter	340	430	73	258	
97	Transmitter	340	430	73	258	
98	Transmitter	340	430	73	258	
99	Telemetry Subsystem	350	20,232	15,174	8,500	
100	Telemetry Subsystem	350	20,184	15,000	8,000	
101	TV Camera Subsystem Electronics	360	19,518	12	61	
102	Science Experiment	400	19,518	15,438	1	1
103	Receiver	450	8,760	1,043	228	
104	TV Camera Subsystem	500	8,900	142	656	1
105	TV Camera Subsystem	500	8,900	71	344	1
106	TV Camera Subsystem	500	6,200	161	680	1
107	TV Camera Subsystem	500	2,400	180	900	2
108	TV Camera Subsystem	500	2,000	76	330	1
109	TV Camera Subsystem	500	1,800	164	540	2
110	TV Camera Subsystem	500	1,800	41	180	1
111	TV Camera Subsystem	500	285	20	100	1

EXHIBIT 24 (Continued)

Index Number	Component Type	Number of Discrete Piece-Parts	Survival Time (hours)	Power-On Time (hours)	Number of Cycles	Number of Anomalies
112	Combiner	500	430	73	258	
113	TV Camera Subsystem	550	23,000	500	1,900	1
114	TV Camera Subsystem	550	23,000	460	1,800	
115	TV Camera Subsystem	550	17,500	700	3,000	5
116	TV Camera Subsystem	550	9,300	440	1,700	1
117	TV Camera Subsystem	550	7,700	420	1,650	1
118	TV Camera Subsystem	550	3,600	300	600	2
119	TV Camera Subsystem	550	1,760	100	390	2
120	TV Camera Subsystem	550	436	36	144	2
121	Receiver	650	19,518	192	1	1
122	Entire Spacecraft	700	20,232	300	1,200	1
123	Entire Spacecraft	700	14,352	275	1,100	1
124	Radiometer	750	19,518	18,368	1	1
125	Radiometer	750	19,518	18,368	1	1
126	Radiometer	750	19,518	14,448	3	1
127	Radiometer	750	19,518	14,448	3	1
128	Range and Range Rate Transponder	850	8,628	365	1,390	1
129	Telemetry Generator	1,000	430	73	258	
130	Entire Spacecraft	1,655	31,100	450	1,800	
131	Entire Spacecraft	1,655	15,384	13	50	
132	Entire Spacecraft	1,655	6,768	13	50	
133	Entire Spacecraft	1,655	4,848	13	50	2
134	Entire Spacecraft	1,655	3,216	50	200	2
135	Telemetry Subsystem	2,161	29,088	2,320	5,032	
136	Telemetry Subsystem	2,161	5,448	870	1,870	
137	Decoder	2,500	430	73	258	
138	Entire Spacecraft	6,760	11,520	6,624	2	6

EXHIBIT 24 (Continued)

Index Number	Component Type	Number of Discrete Piece-Parts	Survival Time (hours)	Power-On Time (hours)	Number of Cycles	Number of Anomalies
139	Entire Spacecraft	20,000	54,400	26,900	12	13
140	Entire Spacecraft	20,000	39,300	30,540	12	7
141	Entire Spacecraft	20,000	22,920	20,520	2	12
142	Entire Spacecraft	20,000	20,664	5,332	6	30

EXHIBIT 25 - CYCLE DATA FOR COMPONENTS COMPOSED OF INTEGRATED CIRCUITS

Index No.	Component Type	Number of Integrated Circuits	Survival Time (hrs.)	Power-On Time (hrs.)	Number of Cycles	Number of Anomalies
1	Beacon Transmitter	7	19,756	13,122	10	2
2	Beacon Transmitter	7	19,156	13,087	55	2
3	Beacon Transmitter	7	13,880	7,198	70	
4	Beacon Transmitter	7	13,880	6,973	21	1
5	Beacon Transmitter	7	3,183	2,905	7	
6	Beacon Transmitter	7	3,183	183	1	
7	Beacon Transmitter	12	24,736	19,453	210	2
8	Beacon Transmitter	12	24,736	14,473	109	2
9	Beacon Transmitter	12	11,202	8,650	211	
10	Beacon Transmitter	12	11,202	3,860	2	1
11	Beacon Transmitter	12	9,917	4,128	7	
12	Beacon Transmitter	12	9,915	5,583	36	
13	Beacon Transmitter	12	207	101	3	
14	Beacon Transmitter	12	207	48	4	
15	Solar Aspect Indicator	22	19,156	7,012	516	
16	Solar Aspect Indicator	22	13,883	1,314	563	
17	Solar Aspect Indicator	22	11,202	4,130	326	1
18	Solar Aspect Indicator	22	9,915	9,489	446	
19	Solar Aspect Indicator	22	5,655	25	13	2
20	Solar Aspect Indicator	22	3,183	168	176	
21	Solar Aspect Indicator	22	263	43	46	
22	Transmitter	24	19,156	10,232	3,656	
23	Transmitter	24	13,880	3,961	1,326	
24	TV Camera Subsystem	90	263	164	2	
25	TV Camera Subsystem	90	263	99	3	
26	TV Camera Subsystem	290	24,737	12,858	13	
27	TV Camera Subsystem	290	24,736	23,496	13	
28	TV Camera Subsystem	290	11,202	11,155	1	1

EXHIBIT 25 (Continued)

Index No.	Component Type	Number of Integrated Circuits	Survival Time (hrs.)	Power-On Time (hrs.)	Number of Cycles	Number of Anomalies
29	TV Camera Subsystem	290	9,915	7,562	13	
30	TV Camera Subsystem	290	9,915	2,353	13	1
31	TV Camera Subsystem	350	3,182	3,008	11	1
32	TV Camera Subsystem	350	539	320	11	
33	TV Camera Subsystem	362	19,156	10,476	1	2
34	TV Camera Subsystem	362	13,880	12,328	16	
35	TV Camera Subsystem	362	13,880	2,357	17	
36	Programmer	626	24,736	22,456	175	
37	Programmer	626	24,736	13,252	157	
38	Programmer	626	11,202	10,618	17	
39	Programmer	626	11,202	3,583	26	
40	Programmer	626	9,918	6,808	34	
41	Programmer	626	9,915	3,058	41	
42	Programmer	626	263	185	8	
43	Programmer	626	263	103	8	
44	Programmer	800	19,256	11,178	110	
45	Programmer	800	19,156	15,114	54	
46	Programmer	800	13,880	9,853	55	
47	Programmer	800	7,600	4,716	29	2
48	Programmer	800	3,183	2,83[illegible]	29	
49	Programmer	800	3,183	15[illegible]	24	

The final column lists the number of anomalies. All recorded instances of anomalistic behavior recorded against the components of interest are listed here. Components failing catastrophically are as follows: discrete part components which failed catastrophically at the indicated survival hours are those represented by the index numbers: 6, 35, 36, 109, 111, 113, 116, 117, 118, 119, 120, and 133 (Exhibit 24); catastrophically failing integrated circuit components are listed as index numbers 19, 32, 33, and 47 in Exhibit 25.

The most notable feature of these data, taken as a whole, is the general lack of anomalistic behavior associated with the cycled components. Not evident from the exhibits is the fact that none of these anomalies can be attributed, unambiguously, to the cycling itself or to the dormant period of the component's operational profile.

Comparing the data of Exhibits 24 and 25 to the survival data including all kinds of operation, there is no striking or statistically significant difference. There are, for example, 51 transmitters represented in Exhibits 24 and 25 with a total of 455,779 survival hours, no catastrophic failures,[1] and 27,517 on/off cycles. In terms of survival hours this represents a 90 percent confidence interval on the failure rate of 0 to 5.1×10^{-6} failures per hour compared to the interval of 1.5 to 3.9×10^{-6} failures per hour that may be found from the data of Section III for all transmitters. These results are not unexpected given that the two populations are essentially equal in terms of failure rate. To

[1]Although there are 10 anomalies recorded against six integrated circuit transmitters, none of these resulted in the termination of transmitter operations.

deduce from this example that cycled and uncycled components, which are otherwise similar, have the same failure rates is not warranted, however, on two counts. First, it is not unlikely that all the transmitters included in the Section III analysis were cycled to some extent, those represented here being simply the transmitters for which quantitative cycled data are available. The second problem is the sparsity of failure data which tends to make all failure rate comparisons somewhat nebulous. It is rather clear, however, that cycled components in general do not have "order of magnitude" higher failure rates than their noncycled counterparts.

There may well be compensating tendencies in the cyclic mode of operation in that turning a component on and off may be detrimental to reliability whereas periods of no or reduced stress (ie., "dormancy") may be beneficial. In the analysis of Reference 5, the detrimental effect of on/off switching was found for the various scientific experiment packages of an observatory class satellite; the beneficial effects of dormancy were not found. These relationships are repeated here in Exhibit 26. The data on spacecraft components shown in Exhibits 24 and 25 were analyzed in a manner similar to that which produced the results of Exhibit 31.

First, however, the data of Exhibit 24 was further subdivided to separate ou those components which represent entire spacecraft. Three sets of data then result, two from Exhibit 24 and one from Exhibit 25. The first set consists of cycling data on components primarily constructed of discrete piece parts (Exhibit 24). The second set (Exhibit 25) is similar but the components are constructed primarily of integrated circuits. The last data set (Exhibit 24) is that representing cycling data on entire

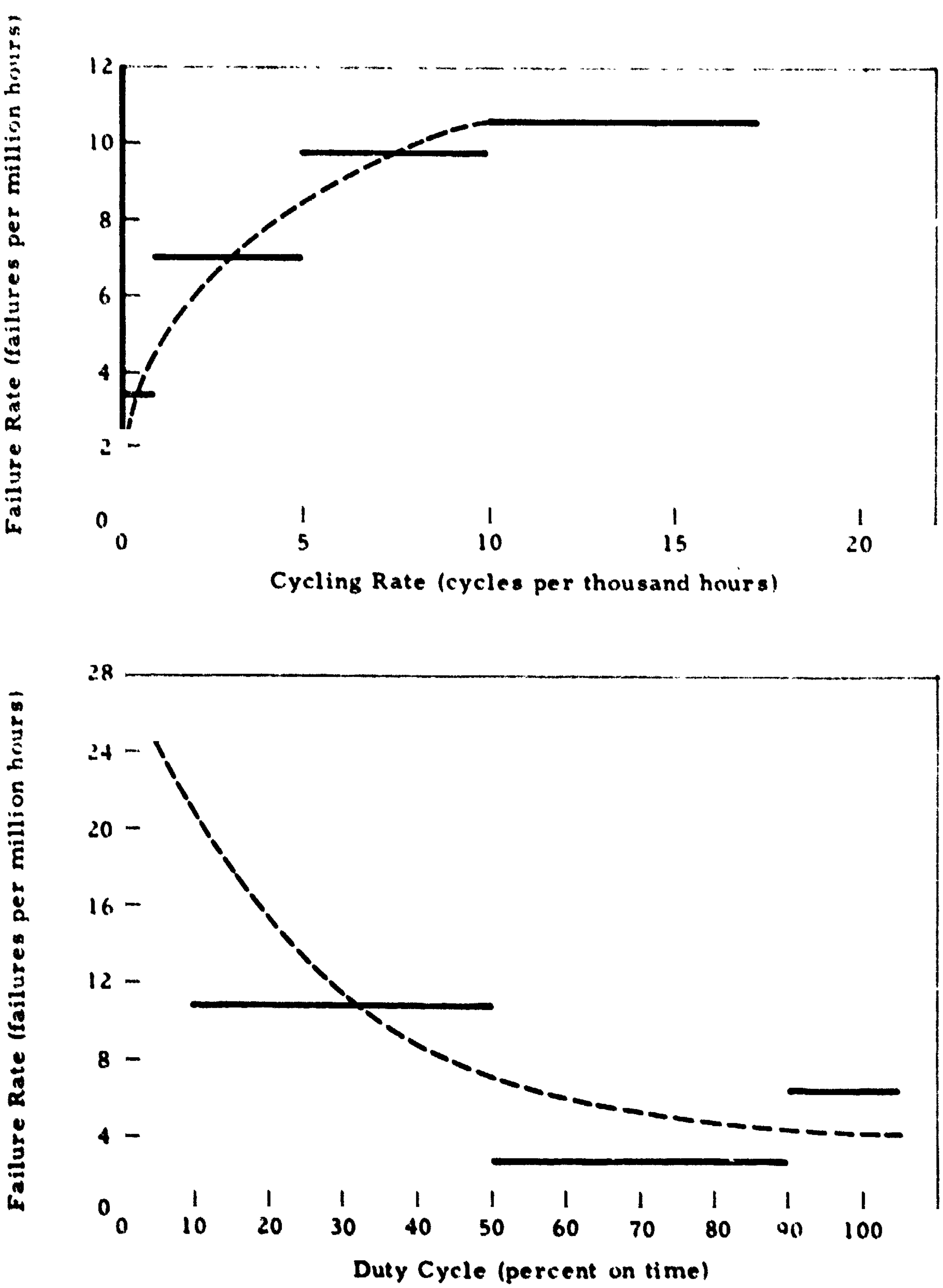

EXHIBIT 26 - FAILURE RATE VERSUS CYCLING RATE AND DUTY CYCLE FOR SPACEBORNE SCIENTIFIC EXPERIMENTS (FROM REFERENCE 2)

spacecraft all of which, coincidentally, are constructed primarily of discrete piece parts. There are 130 data points in the data set for discrete part components, 49 for integrated circuit components and 12 for entire spacecraft.

Dividing power-on time by survival time and multiplying by 100 gives the duty cycle for each component. Cycling rate is the number of cycles divided by survival time. The distribution of the number of anomalies, failures, survival hours, and numbers of components, is given for these two variables for each of the three data sets. These distributions are shown in Exhibits 27, 28, and 29. Exhibit 30 sums these distributions across component types.

An anomaly rate (or a failure rate) may be obtained for any combination of cycling rate and duty cycle given by simply dividing the number of anomalies (failures) appearing in the appropriate cell of the upper matrix by the number of survival hours appearing in the same cell of the lower matrix. For example, the anomaly rate for integrated circuit components with a cycling rate between one cycle per thousand hours and one cycle per hundred hours and a duty cycle between 50 and 90 percent is given by 9/239292 = 38 anomalies per million hours. The corresponding failure rate is 4.2 failures per million hours; both estimates are based on data from 17 components.

Since there are generally so few anomalies associated with each individual cell it is recommended that anomaly or failure rates derived as in the example be used with some care. Exhibit 31 presents these rates for the marginal and overall totals.

EXHIBIT 27 - DISTRIBUTION OF ANOMALIES, FAILURES, COMPONENT SURVIVAL HOURS AND NUMBERS OF COMPONENTS BY DUTY CYCLE AND CYCLING RATE FOR DISCRETE PART COMPONENTS

a. Distribution of Anomalies (Failures)

Cycle Rate, r (cycles per hour)	Duty Cycle, d (percent on time) 0 < d < 10	10 ≤ d < 50	50 ≤ d < 90	90 ≤ d < 100	Totals
0.00001 ≤ r < 0.0001	1(0)		1(0)	2(0)	4(0)
0.0001 ≤ r < 0.001	0(0)	0(0)	2(0)	0(0)	2(0)
0.001 ≤ r < 0.01	1(1)	0(0)			1(1)
0.01 ≤ r < 0.1	4(1)	0(0)		0(0)	4(1)
0.1 ≤ r < 1	31(9)	0(0)	0(0)		31(9)
Totals	37(11)	0(0)	3(0)	2(0)	42(11)

b. Distribution of Survival Hours (Number of Components)

Cycle Rate, r (cycles per hour)	0 < d < 10	10 ≤ d < 50	50 ≤ d < 90	90 ≤ d < 100	Totals
0.00001 ≤ r < 0.0001	19,518(1)		19,518(1)	50,238(3)	89,274(5)
0.0001 ≤ r < 0.001	23,013(3)	11,202(1)	39,036(2)	23,013(3)	96,264(9)
0.001 ≤ r < 0.01	129,636(8)	19,576(3)			149,212(11)
0.01 ≤ r < 0.1	384,171(27)	26,280(3)		17,500(1)	427,951(31)
0.1 ≤ r < 1	311,189(49)	70,146(21)	41,276(4)		422,611(74)
Totals	867,527(88)	127,204(28)	99,830(7)	90,751(7)	1,185,312(130)

EXHIBIT 26 - DISTRIBUTION OF ANOMALIES, FAILURES, COMPONENT SURVIVAL HOURS AND NUMBERS OF COMPONENTS BY LUTY CYCLE AND CYLING RATE FOR INTEGRATED CIRCUIT COMPONENTS

a. Distribution of Anomalies (Failures)

Cycling Rate, r (cycles per hour)	Duty Cycle, d (percent on time)				
	0 < d < 10	10 ≤ d < 50	50 ≤ d < 90	90 ≤ d < 100	Totals
0.00001 ≤ r < 0.0001			2(1)	1(0)	3(1)
0.0001 ≤ r < 0.001	0(0)	1(0)	2(0)	0(0)	3(0)
0.001 ≤ r < 0.01	2(1)	1(0)	9(1)	0(0)	12(2)
0.01 ≤ r < 0.1	0(0)	1(0)	1(1)	0(0)	2(1)
0.1 ≤ r < 1			0(0)		0(0)
Totals	2(1)	3(0)	14(3)	1(0)	20(4)

b. Distribution of Survival Hours (Number of Components)

Cycling Rate, r (cycles per hour)	0 < d < 10	10 ≤ d < 50	50 ≤ d < 90	90 ≤ d < 100	Totals
0.00001 < r < 0.0001			19,156(1)	11,202(1)	30,358(2)
0.0001 ≤ r < 0.001	3,183(1)	21,119(2)	44,493(2)	24,736(1)	93,531(6)
0.001 ≤ r < 0.01	8,838(2)	33,710(3)	239,292(17)	42,303(4)	324,143(26)
0.01 ≤ r < 0.1	17,066(2)	45,441(8)	12,004(3)	9,915(1)	84,426(14)
0.1 ≤ r < 1			19,156(1)		19,156(1)
Totals	29,087(5)	100,270(13)	334,101(24)	88,156(7)	551,614(49)

EXHIBIT 29 - DISTRIBUTION OF ANOMALIES, FAILURES, COMPONENT SURVIVAL HOURS AND NUMBERS OF COMPONENTS BY DUTY CYCLE AND CYCLING RATE FOR ENTIRE SPACECRAFT

a. Distribution of Anomalies (Failures)

Cycling Rate, r (cycles per hour)	Duty Cycle, d (percent on time)				
	$0 < d < 10$	$10 \le d < 50$	$50 \le d < 90$	$90 \le d < 100$	Totals
$0.00001 \le r < 0.0001$				12(0)	12(0)
$0.0001 \le r < 0.001$		43(0)	13(0)		56(0)
$0.001 \le r < 0.01$	0(0)				0(0)
$0.01 \le r < 0.1$	6(1)				6(1)
$0.1 \le r < 1$					
Totals	6(1)	43(0)	13(0)	12(0)	74(1)

b. Distribution of Survival Hours (Number of Components)

Cycling Rate, r (cycles per hour)	$0 < d < 10$	$10 \le d < 50$	$50 \le d < 90$	$90 \le d < 100$	Totals
$0.00001 \le r < 0.0001$				22,920(1)	22,920(1)
$0.0001 \le r < 0.001$		75,064(2)	50,820(2)		125,884(4)
$0.001 \le r < 0.01$	22,152(2)				22,152(2)
$0.01 \le r < 0.1$	73,748(5)				73,748(5)
$0.1 \le r < 1$					
Totals	95,900(7)	75,064(2)	50,820(2)	22,920(1)	244,704(12)

EXHIBIT 30 - COMBINED DISTRIBUTION OF ANOMALIES, FAILURES, COMPONENT SURVIVAL HOURS AND NUMBERS OF COMPONENTS BY DUTY CYCLE AND CYCLING RATE

a. Distribution of Anomalies (Failures)

Cycling Rate, r (cycles per hour)	Duty Cycle, d (percent on time) 0 < d < 10	10 ≤ d < 50	50 ≤ d < 90	90 ≤ d < 100	Totals
0.00001 ≤ r < 0.0001	1(0)		3(1)	15(0)	19(1)
0.0001 ≤ r < 0.001	0(0)	44(0)	17(0)	0(0)	61(0)
0.001 ≤ r < 0.01	3(2)	1(0)	9(1)	0(0)	13(3)
0.01 ≤ r < 0.1	10(2)	1(0)	1(1)	0(0)	12(3)
0.1 ≤ r < 1	31(9)	0(0)	0(0)		31(9)
Totals	45(13)	46(0)	30(3)	15(0)	136(16)

b. Distribution of Survival Hours (Number of Components)

Cycling Rate, r (cycles per hour)	0 < d < 10	10 ≤ d < 50	50 ≤ d < 90	90 ≤ d < 100	Totals
0.00001 ≤ r < 0.0001	19,518(1)		38,674(2)	84,360(5)	142,552(8)
0.0001 ≤ r < 0.001	26,196(4)	107,385(5)	134,349(6)	47,749(4)	315,679(19)
0.001 ≤ r < 0.01	160,626(12)	53,286(6)	239,292(17)	42,303(4)	495,507(39)
0.01 ≤ r < 0.1	474,985(34)	71,721(11)	12,004(3)	27,415(2)	536,125(50)
0.1 ≤ r < 1	311,189(49)	70,146(21)	60,432(5)		441,767(75)
Totals	992,514(100)	302,538(43)	484,751(33)	201,827(15)	1,981,630(191)

EXHIBIT 31 - ANOMALY RATES (a) AND FAILURE RATES (f) FOR VARIOUS COMPONENT TYPES AND DUTY CYCLES AND FOR VARIOUS COMPONENT TYPES AND CYCLING RATES

			ES		IC		DP		ES+IC+DP	
			a	f	a	f	a	f	a	f
Duty Cycle d, (percent on time)	0 < d < 10	a	63		69		43		46	
		f		10		34		13		13
	10 ≤ d < 50	a	570		30		0		15	
		f		0		0		0		0
	50 ≤ d < 90	a	260		42		30		62	
		f		0		9,0		0		6,2
	90 ≤ d < 100	a	520		11		22		74	
		f		0		0		0		0
Cycling Rate r, (cycles per hour)	0,00001 < r < 0,0001	a	520		99		45		130	
		f		0		33		0		7,0
	0,0001 ≤ r < 0,001	a	440		32		21		190	
		f		0		0		0		0
	0,001 ≤ r < 0,01	a	0		37		6,7		26	
		f		0		6,2		6,7		6,0
	0,01 ≤ r < 0,1	a	81		24		9,4		11	
		f		14		12		2,3		2.8
	0,1 ≤ r < 1	a			0		73		20	
		f				0		21		5,9
	Overall Average	a	230		36		35		69	
		f		3,1		7,3		9,3		8,1

Code: ES = Components which are actually entire spacecraft.
IC = Components constructed primarily of integrated circuits.
DP = Components constructed primarily of discrete piece parts.
a = Anomaly rate in anomalies per million hours.
f = Failure rate in failures per million hours.

With respect to duty cycle no clear cut trends are evident. For both integrated circuit and discrete part components the maximum anomaly (and failure) rate occurs at the minimum duty cycle. For the discrete part components there is clearly a strong correlation between low duty cycle and high cycling but this is not the case for integrated circuit components.

As regards cycling rate the data show a general decline in anomaly rate with increasing cycling rates from very low values of cycling rate up to about one cycle every 10 hours. No data beyond this point are available from entire spacecraft and no failures or anomalies were found against integrated circuit components at rates of cycling faster than once in 10 hours. For discrete part components a large increase in both anomaly rate and failure rate is noted in this region. Theories to explain this phenomenon are left to the reader as an exercise.

To determine if component size (i.e., the number of piece parts a component contains) influences the results, the tabulation of Exhibit 32 was constructed for discrete part components. Although the general pattern noted earlier carries over here (i.e., a decreasing anomaly rate with increasing cycle rate until a cycle rate of 0.1 cycles per hour is reached at which time the anomaly rate increases drastically) the only clear conclusion that can be drawn on the basis of the data is that cycling in excess of 0.1 cycles per hour is worse, from the point of view of reliability, than cycling at a lower rate. To see this more clearly consider the following two-by-two array based on anomaly rate.

EXHIBIT 32 - ANOMALY AND FAILURE RATES AS A FUNCTION OF COMPONENT SIZE AND CYCLING RATE

		0.00001≤r <0.0001	0.0001≤r <0.001	0.001≤r <0.01	0.01≤r <0.1	0.1≤r <1	Totals
Components with 150 or fewer Piece Parts	No. of Anomalies	0	0	1	1	6	8
	No. of Failures	0	0	1	0	2	3
	No. of Components	1	7	10	23	31	72
	Survival Hours	11202	57228	129694	314871	154884	667879
	Anomaly Rate*	0	0	7.7	3.2	39	12
	Failure Rate*	0	0	7.7	0	13	4.5
Components with more than 150 Piece Parts	No. of Anomalies	4	2	0	3	25	34
	No. of Failures	0	0	0	1	7	8
	No. of Components	4	2	1	8	43	58
	Survival Hours	78072	39036	19518	113080	267727	517433
	Anomaly Rate*	51	51	0	27	93	66
	Failure Rate*	0	0	0	8.8	26	15

*Anomaly and failure rates given in occurrences per million hours.

Cycling Rate, r (cycles per hour)	Component Size	
	<150 Piece Parts	>150 Piece Parts
$0.1 \le r < 1$	39	39
$r < 0.1$	2.0	36

EXHIBIT 33 - ANOMALY RATE[1] AS A FUNCTION OF COMPONENT SIZE AND CYCLING RATE

It is not clear on the basis of the foregoing whether cycling per se is detrimental to spacecraft components, compared to steady state operation; it is reasonably clear, however, that if spacecraft components are to be cycled it is desirable to reduce the cycling rate.

C. RELATIONSHIP OF PROJECT SUCCESS TO PRODUCT ASSURANCE

Product assurance elements are defined here to include the reliability, quality assurance, and related activities conducted from design and development through the final checkout of the spacecraft at the launch site. An attempt was made in this update to collect this kind of information; the results are summarized in Tables 5 and 6 of the engineering analysis reports (see Appendix B). This information is less available, more uneven in quality and considerably [illegible] quantitative than the other data elements collected during the study. Much of the information, for example, comes from contractor "in-house" documentation which is difficult to obtain once the spacecraft contract is closed. Also, many of the spacecraft in this update have evolved through long-term,

[1]Anomaly rate is given in anomalies per million hours.

on-going programs (the NOAA spacecraft, for instance, evolved from the earlier TIROS and ITOS spacecraft). In these cases, the traditional R & QA activities tend to be minimal, with evaluations of actual operating performance serving instead as a basis for corrective actions.

Of the 42 spacecraft added to the data bank on this update, varying amounts of Tables 5 and 6 data were available for 30 of them. In some cases the data can only be described as skimpy; in other cases the tables contain a fair amount of detail in some areas and little or no detail in others. In a few cases, data coverage is detailed for all pertinent areas. This is the same situation that was encountered during the first data bank study. (On the two subsequent data bank studies, R & QA information was not sought since the objectibves of those two studies did not require it.)

The previous attempt (during the first data bank study) to relate product assurance to project success was relatively unsuccessful. All spacecraft programs were rated as to their "success" by classifying them as "marginal," "successful," or "outstanding success." Then ratings of a similar type for the same programs were developed for the following product assurance elements:

- Development Testing
- Parts Selection
- Quality Control Provisions
- Off-the-Shelf Versus New Design
- Prelaunch Activities

- Spacecraft Complexity
- State-of-the-Art

Attempts were then made to find some correlation between the program success ratings and the ratings for the various product assurance elements. Correlating techniques such as regression analysis were applied, with the result that no well defined, quantitative trends could be identified. At the time, this lack of measurable correlation was attributed to lack of good data.

It was felt that this situation might have been remedied in this study, but unfortunately it was not. In fact, the approach developed earlier was determined to be inapplicable to this update for two reasons: (1) the programs represented in the update were generally quite successful, and (2) for all programs where the data are available, at least a serious R & QA program existed. The resulting situation is that there are not sufficient "gradations" in the update data to allow for a meaningful scale of comparisons.

With respect to the data on R & QA programs in this update, three basic approaches were noted: (1) on low-budget programs, use of previously space qualified hardware and designs was emphasized; (2) on the programs with fewer budgetary restraints and, concommitantly, more complex spacecraft, more testing was conducted and more stringent R & QA controls were implemented; and (3) on long-term programs where spacecraft evolved from earlier designs, the emphasis was on evaluating actual orbital performance to provide a basis for corrective actions. The success of the spacecraft represented in this update would indicate that each of these three R & QA approaches was adequate for its associated situation.

D. EXPERIENCE BULLETINS

This subsection summarizes the six Experience Bulletins prepared as part of the special studies on this effort. These bulletins are based on engineering analyses using the data bank as a resource, and highlight areas that warrant increased consideration on new projects. The six Experience Bulletins are provided in Appendix D. Their major findings are summarized below.

Experience Bulletin #1: Persistent On-Orbit Problem Areas

Analysis of the update data for spacecraft launched in the 1970s indicates that anomaly types that have been persistent in the past are still occurring. Eight categories of these persistent anomaly types encompass approximately one-half of all anomalies.

Experience Bulletin #2: Some On-Orbit Reliability Aspects of Integrated Circuits

The data bank contains information on over 100,000 integrated circuits which accumulated 2.0 x 10^9 survival hours on-orbit. These data indicate that the orbital reliability of an integrated circuit is quite similar to that of a transistor. Also, there is some evidence that integrated circuits have reduced the number of problems associated with circuit design.

Experience Bulletin #3: Areas With a History of Few On-Orbit Problems

Evaluation of the data bank indicates that most spacecraft hardware areas have incurred a number of anomalies. Six areas were identified, however, that have essentially trouble-free histories.

Experience Bulletin #4: On-Orbit Interference (RFI) From External Sources

The data bank contains at least 20 cases of problems in spacecraft RF equipment due to interference from a source external to the affected spacecraft. In some cases the external source was another spacecraft; in some cases the source was unknown. Analysis indicates that this type of incident is increasing.

Experience Bulletin #5: Some On-Orbit Reliability Aspects of On-Board Programmable, General Purpose Computers

This update is the first data bank effort in which data from on-board, programmable, general purpose computers began to become available. This limited amount of data indicates that the space environment has not introduced any unusual types of anomalies. The capability for reprogramming in-flight is recommended.

Experience Bulletin #6: Specific Orbital Anomalies Posing Potential Reliability Problems

Three specific types of anomalies were noted on this update which had not been seen to any significant extent, if at all, on previous data bank studies. These include array temperature sensor failures, leaks through thin windows, and thruster catalyst bed susceptibility to RFI. These anomaly types may either denote the beginning of a trend, or signify some basic, underlying problem.

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Appendix A

ANOMALOUS INCIDENTS LISTINGS

Appendix A

ANOMALOUS INCIDENTS LISTINGS

This appendix is divided into four sections--one for each previous data collection effort (References 1, 7, and 9) and one for this study. The sections and their respective data sets are as follows:

(I) 1967 Study (Reference 1)

(II) 1971 Update (Reference 7)

(III) 1972 Update (Reference 9)

(IV) 1978 Update (Current Study)

Each section contains two parts that include part (a), the basic data tabulations; and part (b), classification codes. Therefore, for example, Appendix A-IIIb contains the classification codes for the third data set. The contents of these parts are discussed below.

PART (a): BASIC DATA TABULATIONS

This part contains, in tabular form, the basic data referred to in Sections II, III, and IV of this report. The tables presented here will provide the reader with a means to understand the compilation procedures used in this study and facilitate any further classification or analysis of particular interest to the individual.

The first step in the data reduction procedure (using the Engineering Analysis Reports described in Appendix B) was to produce a listing that contained the following data elements associated with each spacecraft of the sample: (1) unsuccessful launch, primarily due to the launch

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vehicle; (2) successful launch with reported anomalies; and (3) successful launch with no reported anomalies.

The tabulation of this section lists first the unsuccessful launches. Reported anomalies are listed next, ordered by time of occurrence and containing these data elements:

- Time-to-occurrence of anomaly in hours. A time ϵ is associated with the launch interval, prior to injection into orbit. The symbol ~ denotes either unknown time or intermittent occurrence.
- Three short phrases indicating the description of the observed anomaly, its suspected or known cause, and the effect on the mission objective(s).
- Corrective actions, both in-orbit or for subsequent launches, if known.
- Brief remarks, if needed to place the anomalous incident in context.

The last group, successful launches with no reported anomalies, ends the basic data tabulation. Data elements for this group are (1) whether or not the spacecraft is still operational and (2) total spacecraft time included in this study.

The sequential coding, the index listed in column 1, provides a means of cross reference to the table presented in part (b) of the respective section.

PART (b): CLASSIFICATION CODES

This part is a listing of classification codes for each of the anomalies of the basic data tabulations in Part (a) of the section. For convenience, the identification of the anomaly characteristics discussed in Section II of the text and the alpha-numeric codes employed are repeated at the end of this Introduction.

NOTE: The following matrix shows the index numbers of anomalies that were updated in subsequent reports. For example, the anomaly which corresponds to index number 22 in the 1971 report (Reference 7) is updated as index number 3 in the 1972 report (Reference 9).

1971 Update	1972 Update	Current Study
# 22	# 3	
# 130	# 27	
	# 9	# 16
	# 18	# 70
	# 23	# 83
	# 33	# 121
	# 36	# 124
	# 37	# 125
	# 48	# 170
	# 108	# 408
	# 127	# 447

ANOMALOUS INCIDENT CLASSIFICATION CODES

I. Mission Subset

U. Unsuccessful Launch

S. Spacecraft with No Anomalies Reported

Spacecraft with Anomalies Reported

II. Mission Term

L. Long Term

S. Short Term

III. Mission Phase

L. Launch and Acquisition

O. Orbital (Steady-State)

Q. Unknown

IV. Mission Effect

1. Negligible
2. Non-Negligible but Small
3. 1/3 to 2/3 Mission Loss
4. 2/3 to Nearly Total Mission Loss
5. Essentially Total Mission Loss

U. Unknown

V. Spacecraft Subsystem

a. Timing, Control and Command

b. Telemetry and Data Handling

c. Power Supply

d. Attitude Control and Stabilization

d* Propulsion

e. Environmental Control

f. Structure

g. Payload (Experimental and Scientific)

h. Unknown

VI. A. Incident Type

E. Electrical

M. Mechanical

O. Other

U. Unknown

VI. B. Incident Type

C. Catastrophic Part Failure

O. Other Part-Related Incident

N. Non-Part-Related Incident

U. Unknown

VII. Incident Cause

A. Assignable

N. Non-Assignable

U. Unknown

Appendix A-I

(REFERENCE 1: 1967 STUDY)

Appendix A-Ia

BASIC DATA TABULATIONS

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
1		Unsuccessful Launch				
2		Unsuccessful Launch				
3		Unsuccessful Launch				
4		Unsuccessful Launch				
5		Unsuccessful Launch				
6		Unsuccessful Launch				
7		Unsuccessful Launch				
8		Unsuccessful Launch				
9		Unsuccessful Launch				
10		Unsuccessful Launch				
11		Unsuccessful Launch				
12		Unsuccessful Launch				
13		Unsuccessful Launch				
14		Unsuccessful Launch				
15		Unsuccessful Launch				
16		Unsuccessful Launch				
17		Unsuccessful Launch				
18		Unsuccessful Launch				
19		Unsuccessful Launch				
20		Unsuccessful Launch				
21		Unsuccessful Launch				
22		Unsuccessful Launch				
23		Unsuccessful Launch				
24		Unsuccessful Launch				

Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
25		Unsuccessful Launch				
26		Unsuccessful Launch				
27		Unsuccessful Launch				
28	c	Loss of wide-angle picture resolution	Contamination from third stage rocket exhaust	Bad but improved		
29	c	Accidental stepping of control switch in magnetic attitude control	Radio frequency interference	Minor	Design for RF interference	
30	c	Sharp 10-degree rise in battery temperature	Sudden solar cell transition from dark to sunlight	None; battery turned off for 10 minutes		
31	c	Beacon and keyer operated erratically from launch	Unknown	Serious		
32	c	Loss of control at terminal maneuver	Part failure in command subsystem	Serious		
33	c	Power subsystem failure	Unknown. Possible short circuit	Loss of electrical power	Further launches delayed to incorporate extended testing and design changes	
34	c	TV subsystem inoperative	Possible momentary turn-on during boost	Failure of only experimental payload carried		
35	c	Leak in oxygen supply system	Failure of pressure reducer	Not serious		
36	c	Yo-yo despin mechanism failed to function	At activation the satellite was already despun by other means	None		
37	c	One of a redundant pair of command receivers inoperable	Transistor failure	None, due to redundancy		

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
38	*	Gravity gradient stabilization not achieved	Motor failure	Negative results on one of four objectives		
39	*	Memory failure	Unknown	Loss of one of four objectives		
40	*	Satellite stabilized upside-down	Jet effects of solid subliming material used to release lossy spring	Significant loss		
41	*	Shroud failed to be ejected	Unknown	Catastrophic	Fiberglass shroud replaced with metal shroud on subsequent flights	
42	*	Impedence probe inoperative	Unknown	Slight		
43	*	Telemetry monitor intermittent	Unknown	Negligible		
44	*	Telemetry monitor intermittent	Unknown	Negligible		
45	*	Telemetry monitor intermittent	Unknown	Negligible		
46	*	Telemetry monitor operation erratic	Improper installation	Negligible	Redesigned transducer incorporated on subsequent flights	
47	*	Telemetry monitor calibration failure	Unknown	Negligible		
48	*	Telemetry monitor opened during ascent	Unknown	Negligible		
49	*	Telemetry monitor calibration failure	Unknown	Negligible		
50	*	Telemetry monitor failed to operate initially	Defective connection	Negligible	New process using high temperature solids used on subsequent spacecraft	
51	*	Telemetry monitor shift	Unknown	Negligible		
52	*	Telemetry monitor invalid	Unknown	Negligible		

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
53	c	Telemetry monitor failure	Faulty installation	Negligible		
54	c	Telemetry monitor invalid	Unknown	Negligible		
55	c	Telemetry monitor range failure	Unknown	Negligible		
56	c	Telemetry monitor intermittent	Unknown	Negligible		
57	c	Telemetry monitor open	Unknown	Negligible		
58	c	Telemetry monitor open	Unknown	Negligible		
59	c	Telemetry monitor shift	Unknown	Negligible		
60	c	Telemetry monitor failure	Unknown	Negligible		
61	c	Release mechanism for antennas, booms, and solar paddles failed	Unknown	None, due to good fortune		
62	c	Loss of one experiment	Detector failure	Loss of one of seven experiments		
63	c	Loss of solar patch data	Intermittent open or short in solar patch	Slight		
64	c	Failure of experiment booms to completely deploy	Insufficient hinge spring torque	Severe loss		
65	c	Spacecraft failed to separate after launch	Unknown	Anomalous orientation		
66	c	Solar array panel failed to completely deploy	Latch spring failed and excessive restraint	None. Fully deployed after spin-up		
67	c	Output of both batteries lost	Unpredicted spin mode of satellite	Restricted operation to periods of sunlight only (~ 30 percent)		
68	c	Telemetry monitor invalid	Unknown	Negligible		
69	c	Telemetry monitor invalid	Unknown	Negligible		
70	c	Telemetry monitor invalid	Unknown	Negligible		

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
71	c	Telemetry monitor open	Unknown	Negligible		
72	c	Telemetry monitor invalid	Unknown	Negligible		
73	c	Telemetry monitor invalid	Unknown	Negligible		
74	c	Telemetry monitor invalid	Unknown	Negligible		
75	c	Telemetry monitor invalid	Unknown	Negligible		
76	c	Sharp drop in both telemetry signal strength	Loss of multicoupler's pressure seal	Some loss of data	Eliminated multicoupler in subsequent flights	
77	c	Telemetry point fluctuation under varying loads	Penetration of rainwater during countdown	Apparently none	Relocation of commutator; sealing against moisture	
78	c	Random losses of one telemetry monitor output	Unknown	None	Installation of low-pass filter	
79	c	Periodic interference in telemetry monitor	Unknown	At least 80 percent of data acquired		
80	c	Telemetry monitor noisy during engine operation	Unknown	Negligible		
81	c	Telemetry monitor noisy during engine operation	Unknown	Negligible		
82	c	Telemetry monitor noisy during engine operation	Unknown	Negligible		
83	c	Telemetry monitor noisy during engine operation	Unknown	Negligible		
84	c	Telemetry monitor invalid	Unknown	Negligible		
85	c	Telemetry monitor invalid	Unknown	Negligible		
86	c	Telemetry monitor open	Unknown	Negligible		
87	c	Telemetry monitor shift	Unknown	Negligible		
88	c	Telemetry monitor open	Unknown	Negligible		
89	c	Telemetry monitor shift	Unknown	Negligible		

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
90	*	Telemetry monitor invalid	Unknown	Negligible		
91	*	Telemetry monitor inoperative	Unknown	Negligible		
92	*	Telemetry monitor failure	Transducer failure	Negligible		
93	*	Triggering of voice operated relay erroneously	Oversensitive helmet microphone	Negligible		
94	*	Spacecraft failed to separate from launch vehicle	Inadequately designed interface structure	Mission abort	A redesigned interface to increase structural stiffness for subsequent launches is presently successful	
95	*	Escape rocket motor ignited before separation	Attributed to an unknown failure in spacecraft sequential system	Mission abort		
96	*	Cabin inflow valve opened during ascent	Faulty valve detent system design	Forced use of emergency environmental control system	Tolerances of valve detent system were changed to ensure positive detention during vibration for subsequent flights	
97	*	Holes punctured in lower bulkhead on landing	Attributed to deficient design	Cabin took on water		
98	*	Heat shield lost after landing	Fatiguing by water action	Some information lost		
99	*	Early ignition of escape rocket motor	Structural deformations in spacecraft	Mission objectives not met		
100	*	Cabin pressure not maintained	A piece of wire lodged in cabin pressure valve seat	No effect on mission		
101	*	Deflection of turbine exhaust duct thrust	Expenditure of extra control gas during ascent	None		
102	*	Yaw actuator bias not performed	Nonperformance inadvertent	Slight		
103	*	Pitch gyro G-sensitive drift excessive	Defective gyro	Mission terminated early		

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
104	ϵ	Momentary losses of accelerometer carrier amplifier output voltage	Sensitivity of amplifier to shock	Negligible	Improved design of accelerator; revised test procedures	
105	ϵ	Steering transients resulted in flight path error	Possibly radar noise interference	Orbit not as predicted, but adequate for mission purposes	Re-optimized steering filter	
106	ϵ	Intermittent accelerometer malfunctions	Unknown	None		
107	ϵ	Ascent sequence timer malfunction caused failure of flight control pneumatics to switch from high to low pressure	Defective switch in timer	Slight	Inspection methods and procedures modified	
108	ϵ	Intermittent operation of accelerometer	Opening and closing of some of the amplifier circuitry	None		
109	ϵ	Telemetry monitor open	Unknown	Negligible		
110	ϵ	Telemetry monitor shift	Unknown	Negligible		
111	ϵ	Telemetry monitor malfunction	Unknown	Negligible		
112	ϵ	Telemetry monitor failure	Transducer failure	Negligible		
113	ϵ	Telemetry monitor failure	Transducer amplifier failure	Negligible		
114	ϵ	Telemetry monitor open	Unknown	Negligible		
115	ϵ	Commutator response problems	Unknown	Negligible		
116	ϵ	Failure of shroud to separate	Explosive destruction of honeycomb panels due to combination of environmental effects	None to spacecraft mission	Manufactured an all-metal shroud	
117	ϵ	Telemetry monitor opened during ascent	Unknown	Negligible	All sensors and readout units returned to vendor for adjustment and repair as required	

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Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
118	*	Telemetry monitor opened	Unknown	Negligible		
119	*	Telemetry monitor opened during ascent	Unknown	Negligible		
120	*	Telemetry monitor failed	Defective electronic component	Negligible	Vibration and temperature tests required transducer	
121	*	Telemetry monitor operation inadequate	Unknown	Negligible		
122	*	Telemetry monitor shift	Unknown	Negligible		
123	*	Telemetry monitor failure	Transducer failure	Negligible		
124	*	Telemetry monitor shift	Improper installation	Negligible	Application of standardized torque valve to pressure fitting	
125	*	Telemetry monitor shift	Unknown	Negligible		
126	*	Telemetry monitor readings irregular	Open return line	Negligible		
127	*	Tape recorder	Unknown	Loss of data		
128	*	Loss of temperature data	Gage failure	No temperature data		
129	*	Data multiplexer malfunction	Loose connection in a -24 v d.c. return	Loss of data		Failure was self-correcting during orbit
130	*	Digital command system voltage monitor intermittent	Dirty relay contacts	Negligible		
131	*	Programmer malfunction	Sheared pin used to maintain alignment of gear	Not serious		
132	*	Programmer malfunction	Noise triggering (oversensitivity)	Not serious		
133	*	Power supply turnoff capability lost	Dew point problem in a transistor of a power regulator	Incapacitated spacecraft for 336 hours		Recovered after 336 hours. Trouble recurred briefly after about 2100 hours

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
134	*	Periodic delays in command clock and possible battery o[illegible]ing	Unknown	Complete loss of mission		
135	*	Ampere-hour meter failed between liftoff and first acquisition	Unknown	None		
136	*	Ampere-hour meter gave incorrect count	Probable transient introduced at separation	None		
137	*	Short caused premature activation of oxidizer jettison valves and disabled pneumatic control system	Unknown	Orbit not attained	Redesign; instituted thorough inspection and application of flow coating to all exposed terminals	
138	*	Overload due to short	Malfunction in +28 volts cabling to telemetry transmitter	Portion of telemetry lost	Telemetry transmission shock isolated	
139	*	Overload at separation	Shock-induced short	Apparently none	Redesign of power and pyro distribution system; shock isolation	
140	*	Heavy current at separation	Short of pyro-bus voltage to structure through the retrorocket igniter	Apparently none	Redesign change	
141	*	Overload at separation on the 28-volt pyro-bus/return line	Unknown short	Serious	Redesign of power and pyro distribution system; shock isolation	
142	*	Overload after engine first cutoff	Series of shorts in or near connector for aft compartment pressure monitor; possible engine nozzle heat	None	Aft compartment pressure monitor removed	
143	*	Interference in narrow angle TV pictures	RF interference and microphonics	Significant		
144	*	Interference in wide angle TV pictures	RF interference and microphonics	Significant		

Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
145	e	TV subsystem operated during launch	Vibration induced switch closures of the command and control subsystem	No serious effect		
146	e	Loss of telemetry data	Part or connection failure in sensors	Slight		
147	e	Reduced command subsystem sensitivity	Part failure in command receivers	Not serious		Failure overcome by stronger ground transmission
148	e	Loss of IR data	Part failue in DC-DC converters	Significant		
149	e	Error in one of nine sensors in sun angle detector	Manufacturing defect	Slight		
150	e	Picture distortion from TV camera	Modulation by earth's field (a design deficiency)	Significant		
151	e	Poor solar attitude data	Failure of three sensors in solar attitude detector during or immediately after launch	Significant		
152	e	Temperature monitor failed	Unknown	Negligible	Replaced temperature monitor	
153	e	Bus current monitor operation intermittent during separation	Unknown	Negligible		
154	e	Premature disconnection of one pressure and four temperature transducers in nose fairing	Separation pyrotechnic shock	Negligible	Ensure snap-locks on connectors are in place during checkout	
155	e	Telemetry monitor invalid	Unknown	Negligible		
156	e	Telemetry monitor noisy	Unknown	Negligible		
157	e	Telemetry monitor invalid	Unknown	Negligible		
158	e	Telemetry monitor invalid	Unknown	Negligible		
159	e	Telemetry monitor invalid	Unknown	Negligible		

Appendix A-1b

CLASSIFICATION CODES

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Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
62		L	L	2	g	[illegible]	C	N	1
63		L	L	1	b	E	U	U	1
64		L	L	4	f	M	N	A	2
65		L	L	3	f	O	U	U	3
66		L	L	2	f	M	N	A	2
67		L	L	3	c	E	N	A	2
68		S	L	1	b	E	U	U	1
69		S	L	1	b	E	U	U	1
70		S	L	1	b	E	U	U	1
71		S	L	1	b	E	U	U	1
72		S	L	1	b	E	U	U	1
73		S	L	1	b	E	U	U	1
74		S	L	1	b	E	U	U	1
75		S	L	1	b	E	U	U	1
76		S	L	2	b	M	O	N	5
77		S	L	1	b	O	N	A	7
78		S	L	1	b	E	U	U	1
79		S	L	2	b	E	U	U	1
80		S	L	1	b	E	U	U	1
81		S	L	1	b	E	U	U	1
82		S	L	1	b	E	U	U	1
83		S	L	1	b	E	U	U	1
84		S	L	1	b	E	U	U	1
85		S	L	1	b	E	U	U	1
86		S	L	1	b	E	C	N	1
87		S	L	1	b	E	U	U	1
88		S	L	1	b	E	U	U	1
89		S	L	1	b	E	U	U	1
90		S	L	1	b	E	U	U	1
91		S	L	1	b	E	U	U	1
92		S	L	1	b	E	C	N	1
93		S	L	1	g	E	O	A	2

Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
94		S	L	5	f	M	N	A	3
95		S	L	5	a	E	C	N	4
96		S	L	2	e	M	O	A	2
97		S	L	2	f	M	N	A	1
98		S	L	2	f	M	N	A	3
99		S	L	4	f	M	N	A	1
100		S	L	1	e	M	O	A	2
101		S	L	1	d*	M	N	A	4
102		S	L	2	d	U	U	U	5
103		S	L	2	d*	E	O	N	1
104		S	L	1	d*	E	N	A	1
105		S	L	2	d*	E	N	A	3
106		S	L	1	d*	E	U	U	1
107		S	L	2	h	E	C	N	
108		S	L	1	d*	E	U	U	1
109		S	L	1	b	E	U	U	1
110		S	L	1	b	E	U	U	1
111		S	L	1	b	E	U	U	1
112		S	O	1	b	E	C	N	1
113		S	L	1	b	E	C	N	1
114		S	L	1	b	E	U	U	1
115		S	L	1	b	E	U	U	3
116		S	L	1	f	M	N	A	3
117		S	L	1	b	E	U	U	1

Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
118		S	L	1	b	E	U	U	1
119		S	L	1	b	E	U	U	1
120		S	L	1	b	E	C	N	1
121		S	L	1	b	E	U	U	1
122		S	L	1	b	E	U	U	1
123		S	L	1	b	E	C	N	1
124		S	L	1	b	E	N	A	1
125		S	L	1	b	E	U	U	1
126		S	L	1	b	E	U	U	1
127		S	L	2	b	E	U	U	4
128		S	L	1	g	M	C	N	2
129		S	L	2	b	E	N	A	3
130		S	L	1	a	E	O	A	3
131		S	L	2	a	M	C	N	4
132		S	L	2	a	E	N	A	4
133		L	L	2	c	E	O	A	3
134		L	L	5	a	E	U	U	5
135		S	L	1	b	E	C	N	1
136		S	L	1	b	E	N	A	1
137		S	L	5	c	E	U	U	4
138		S	L	2	c	E	N	U	4
139		S	L	1	h	E	N	A	
140		S	L	1	h	E	N	U	
141		S	L	3	c	E	U	U	4
142		S	L	1	b	E	N	A	1
143		L	L	3	g	E	N	A	1
144		L	L	3	g	E	N	A	1
145		L	L	1	a	E	O	A	2
146		L	L	1	b	E	C	N	1
147		L	L	1	a	E	C	N	1
148		L	L	3	g	E	C	N	1
149		L	L	1	d	E	O	A	1
150		L	L	2	g	E	N	A	1
151		L	L	2	d	E	C	N	1
152		S	L	1	b	E	U	U	1
153		S	L	1	b	E	U	U	1
154		S	L	1	b	E	N	A	1
155		S	L	1	b	E	U	U	1
156		S	L	1	b	E	U	U	1
157		S	L	1	b	E	U	U	1
158		S	L	1	b	E	U	U	1
159		S	L	1	b	E	U	U	1
160		S	L	1	f	O	O	A	3
161		S	L	2	d	E	C	N	1
162		S	L	1	g	E	N	A	2
163		S	L	2	d	E	C	N	1
164		S	L	2	d	M	O	A	2
165		S	L	1	d	E	C	N	1
166		S	L	1	a	E	U	U	7
167		S	L	1	e	M	O	A	2
168		S	L	5	d	E	N	A	1
169		S	L	2	d	E	N	A	1
170		S	L	1	d*	O	N	A	4
171		S	L	2	d*	E	O	A	1
172		S	L	2	d*	E	N	A	1
173		S	L	1	b	E	N	A	1
174		S	L	1	b	E	C	N	1
175		S	L	1	b	E	N	A	1
176		S	L	1	b	E	N	A	1
177		S	L	1	b	E	C	N	1
178		S	L	1	b	E	U	U	1
179		S	L	1	b	E	C	N	1
180		S	L	1	b	E	U	U	1
181		S	L	1	b	E	U	U	1

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Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
182		S	L	1	b	E	N	A	1
183		S	L	1	f	E	N	U	3
184		S	L	5	c	E	N	A	3
185		S	L	1	b	E	C	N	3
186		S	L	2	b	E	N	A	5
187		S	L	1	b	E	N	A	5
188		S	L	2	b	E	C	N	5
189		S	L	2	b	E	U	U	5
190		S	L	1	b	E	U	U	7
191		S	L	1	b	E	U	U	1
192		S	L	1	b	E	C	N	1
193		S	L	1	b	E	C	N	1
194		S	L	1	b	E	U	U	1
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196		S	L	1	b	E	U	U	1
197		S	L	1	b	E	U	U	1
198		S	L	1	b	E	U	U	1
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200		S	L	1	b	E	U	U	5
201		L	L	1	d	M	O	A	2
202		S	L	4	g	E	U	U	2
203		S	L	1	b	E	N	A	7
204		S	L	2	d*	M	N	A	4
205		S	L	2	d*	O	N	A	2
206		S	L	2	d*	O	N	A	2
207		S	L	2	d*	O	N	A	2
208		S	L	1	d*	O	U	U	4
209		S	L	2	h	M	N	A	
210		S	L	1	d*	M	N	A	4
211		S	L	1	d*	M	N	A	4
212		L	L	4	d	E	N	A	1
213		L	L	2	d	E	N	A	2

Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
214		L	L	3	g	E	U	U	1
215		L	L	2	b	E	U	U	5
216		L	L	5	d	M	U	U	2
217		L	L	2	d	M	O	A	2
218		S	L	4	a	E	N	A	8
219		S	L	3	b	E	U	U	6
220		S	L	5	a	E	U	U	4
221		S	L	1	f	M	N	A	3
222		S	L	1	d	M	N	A	2
223		S	L	1	b	E	N	A	7
224		S	L	2	a	E	U	U	4
225		S	L	2	d	U	U	U	1
226		S	L	1	d	M	N	A	2
227		S	L	2	d	M	O	A	2
228		S	L	2	c	E	O	A	3
229		S	L	2	d	E	N	A	1
230		S	L	1	b	E	U		1
231		S	L	1	b	E	U	U	1
232		S	L	1	b	E	U	U	1
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237		S	L	1	b	E	U	U	1
238		S	L	1	b	E	C	N	1
239		S	L	2	d*	M	U	U	2
240		S	L	5	d*	E	U	U	1
241		S	L	1	d*	M	O	A	3
242		S	L	1	d*	E	O	N	2
243		S	L	1	d*	E	U	U	2
244		S	L	1	d*	E	N	U	4
245		L	L	5	h	U	U	U	

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Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
246		L	L	5	h	U	U	U	
247		S	L	2	a	E	N	A	7
248		S	L	1	b	E	C	N	1
249		S	L	1	b	M	N	A	5
250		S	L	1	b	E	U	U	3
251		S	L	3	d*	U	U	U	3
252		S	L	2	d	E	U	U	4
253		S	L	4	d*	E	N	A	4
254		S	L	2	g	E	C	N	2
255		S	L	1	b	E	O	A	3
256		S	L	2	d	E	N	A	1
257		S	L	2	d	E	N	A	1
258		S	L	1	c	E	U	U	5
259		S	L	1	d	M	U	U	2
260		S	L	2	b	E	C	N	5
261		S	L	2	b	M	O	A	1
262		S	L	1	b	E	U	U	1
263		S	L	2	d	E	O	A	2
264		S	L	1	g	M	U	U	2
265		S	L	1	e	M	O	U	1
266		S	L	2	g	U	U	U	2
267		S	L	1	a	E	U	U	7
268		S	L	1	a	E	N	U	7
269		S	L	2	f	M	N	A	4
270		S	L	1	a	E	N	U	7
271		S	L	1	b	E	U	U	1
272		S	L	1	b	E	U	U	1
273		S	L	1	b	E	N	A	5
274		S	L	1	g	E	O	A	2
275		S	L	1	d	E	U	U	1
276		S	L	3	d	U	U	U	4
277		S	L	1	b	E	U	U	1

Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
278		S	L	1	b	E	O	U	5
279		S	L	1	b	E	C	N	5
280		S	L	1	a	E	N	A	1
281		S	L	1	a	E	U	U	7
282		S	L	1	b	E	U	U	4
283		S	L	2	b	M	C	N	4
284		S	L	2	d	E	U	U	1
285		S	L	1	b	E	C	N	5
286		S	L	1	b	E	O	N	5
287		S	L	1	d	E	O	U	1
288		L	L	2	g	M	U	U	1
289		S	L	2	b	M	C	N	4
290		S	L	2	b	M	C	N	4
291		L	L	5	c	E	U	U	5
292		S	O	2	b	E	N	U	5
293		S	L	1	d	E	C	N	1
294		S	L	2	b	E	N	U	3
295		S	O	1	b	E	U	U	1
296		L	L	2	a	E	C	N	3
297		S	O	1	b	E	U	U	1
298		S	O	1	b	E	U	U	1
299		S	O	1	b	E	O	N	3
300		S	L	2	b	M	O	A	4
301		S	L	1	f	E	C	N	3
302		S	L	1	h	E	C	N	
303		S	L	2	b	E	N	U	3
304		S	L	1	b	E	C	N	1
305		S	L	U	d	M	C	N	1
306		S	L	2	a	E	O	A	4
307		L	L	2	g	E	O	A	1
308		S	L	2	c	E	O	A	4
309		S	O	1	a	E	U	U	8

Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
310		S	O	3	c	E	O	A	2
311		L	L	2	a	E	N	A	5
312		S	L	2	b	E	N	U	3
313		L	O	2	g	M	C	U	1
314		S	O	1	b	E	U	U	5
315		S	O	1	a	E	N	A	8
316		S	O	1	a	E	N	A	8
317		S	L	2	b	E	N	A	5
318		L	O	1	a	E	O	N	1
319		S	L	1	d	E	U	U	1
320		S	L	2	b	O	O	U	4
321		S	O	1	b	E	U	U	3
322		S	O	1	b	E	C	N	3
323		L	O	3	b	M	O	A	4
324		S	L	2	b	E	U	U	3
325		S	O	2	c	E	C	A	3
326		S	O	1	b	E	C	N	3
327		S	L	U	d	E	U	U	1
328		S	O	2	a	E	U	U	2
329		L	L	1	c	E	C	A	2
330		S	L	1	d	M	O	A	2
331		S	L	2	d	E	U	U	2
332		S	L	2	d*	E	C	N	1
333		S	O	1	b	E	C	N	4
334		S	O	2	b	E	O	N	5
335		S	O	1	d	E	U	U	4
336		S	O	2	b	E	O	A	3
337		S	O	2	a	E	C	N	5
338		S	L	1	g	O	N	A	2
339		S	O	2	b	M	U	U	4
340		S	O	1	a	E	U	U	8
341		S	L	1	b	E	C	N	1

Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
342		S	L	2	b	E	U	U	4
343		S	L	2	d	U	U	U	2
344		S	O	1	b	E	C	N	1
345		S	O	2	c	E	C	N	3
346		S	O	1	b	E	C	N	1
347		S	O	2	d	E	N	A	2
348		S	L	2	d	E	U	U	2
349		S	O	3	h	E	N	U	
350		S	O	1	a	E	N	A	8
351		S	O	2	a	E	U	U	5
352		S	O	1	b	E	U	U	3
353		S	O	1	b	E	C	N	1
354		S	O	1	b	E	U	U	1
355		S	O	1	b	E	U	U	1
356		S	O	1	b	E	U	U	1
357		S	O	1	b	E	O	N	3
358		S	O	2	a	E	N	A	8
359		S	O	1	b	E	N	U	1
360		S	O	2	b	E	O	A	1
361		S	O	3	c	E	O	A	2
362		S	O	4	c	E	C	N	3
363		S	O	1	c	E	C	N	2
364		S	L	2	b	E	U	U	1
365		S	O	2	b	E	U	U	4
366		S	O	2	b	E	U	U	4
367		L	O	1	b	E	N	A	4
368		L	O	2	g	E	C	N	1
369		S	L	2	b	M	C	A	4
370		S	O	1	b	E	O	N	4
371		S	O	3	a	E	N	A	4
372		S	O	3	c	E	N	A	3
373		S	O	1	c	E	U	U	5

Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
374		S	O	2	b	E	U	U	4
375		L	O	2	b	E	N	A	4
376		S	O	1	b	M	C	U	3
377		L	O	2	a	E	N	A	5
378		L	O	1	g	E	C	N	1
379		S	O	1	b	E	C	N	3
380		S	O	2	c	E	O	A	2
381		S	L	1	b	U	U	U	1
382		S	L	1	d	U	O	U	4
383		L	O	2	g	E	C	N	1
384		S	O	2	h	E	U	U	
385		S	O	2	c	E	C	N	1
386		S	O	1	d	E	U	U	1
387		L	O	2	b	E	O	A	4
388		L	O	1	b	E	O	N	5
389		L	O	2	g	U	U	U	1
390		L	O	1	b	E	C	N	4
391		L	O	2	d	O	N	A	2
392		S	O	2	a	E	U	U	5
393		L	O	4	a	E	U	U	7
394		L	O	3	g	E	C	N	1
395		L	O	5	c	E	O	A	2
396		L	O	4	c	E	O	A	2
397		L	O	1	b	E	C	N	3
398		L	O	2	b	E	U	U	3
399		L	O	1	c	E	N	A	3
400		L	O	2	c	E	N	A	2
401		L	O	2	d	U	U	U	2
402		L	O	3	b	E	U	U	4
403		L	O	5	d	M	N	A	2
404		L	O	2	c	E	N	A	2
405		L	O	2	b	E	N	U	4

Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
406		L	O	1	a	E	O	A	2
407		L	O	2	c	E	N	A	2
408		L	O	2	b	E	O	N	5
409		L	O	2	b	E	C	N	4
410		L	O	3	b	E	U	U	5
411		L	O	1	d	E	O	A	1
412		L	O	1	a	E	O	A	2
413		L	O	5	c	E	C	N	3
414		L	O	1	b	E	U	U	6
415		L	O	1	a	E	O	N	3
416		L	O	2	a	E	O	N	2
417		L	O	1	c	E	N	A	2
418		L	O	2	g	E	C	N	1
419		L	O	3	c	E	O	A	2
420		L	O	4	d	E	O	A	1
421		L	O	2	g	E	O	U	1
422		L	O	1	a	E	U	U	5
423		L	O	2	c	E	N	U	5
424		L	O	2	c	E	U	U	1
425		L	O	2	g	E	C	N	1
426		L	O	3	b	E	U	U	4
427		L	O	2	a	E	U	U	7
428		L	O	2	c	E	U	U	3
429		L	O	3	g	E	C	N	1
430		L	O	1	c	E	U	U	3
431		L	O	1	c	E	N	N	3
432		L	O	2	g	E	U	U	1
433		L	O	2	b	E	N	U	5
434		L	O	3	c	E	C	N	2
435		L	O	1	b	E	O	N	3
436		L	O	2	g	E	O	A	1
437		L	O	1	b	E	U	U	5

Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
438		L	O	1	e	E	N	A	1
439		L	O	2	a	E	C	N	2
440		L	O	3	g	E	U	U	1
441		S	O	2	b	E	C	N	3
442		L	O	2	g	E	U	U	1
443		L	O	2	a	E	C	N	7
444		L	O	2	c	E	N	A	2
445		L	O	4	c	E	U	U	1
446		L	O	3	b	E	O	A	5
447		L	O	3	c	E	O	N	3
448		L	O	1	d	E	N	A	2
449		L	O	3	b	E	C	U	4
450		L	O	2	d	E	U	U	4
451		L	O	1	b	E	C	N	3
452		L	O	1	g	E	C	N	1
453		L	O	2	g	E	O	A	1
454		L	O	1	c	E	U	U	3
455		L	O	2	b	E	U	U	3
456		L	O	3	b	U	U	U	4
457		L	O	2	b	M	N	A	4
458		L	O	1	b	E	C	N	1
459		L	O	2	a	E	N	A	7
460		L	O	1	a	E	U	U	4
461		L	O	2	b	U	U	U	3
462		L	O	1	c	E	N	A	3
463		L	O	1	d	E	N	A	1
464		L	O	1	c	E	N	U	5
465		L	O	2	d	E	N	A	1
466		L	O	2	a	E	C	N	5
467		L	O	2	b	M	C	N	4
468		L	O	2	d	U	U	U	2
469		L	O	2	c	E	O	N	3

Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
470		L	O	2	a	E	C	N	7
471		L	O	1	b	E	C	N	3
472		L	O	1	c	E	C	A	3
473		L	O	2	b	E	U	U	3
474		L	O	2	g	E	U	U	1
475		L	O	1	a	E	O	A	2
476		L	O	4	d	O	N	A	2
477		L	O	2	a	E	O	A	2
478		L	O	1	b	E	N	U	5
479		L	O	1	b	E	N	U	5
480		L	O	2	c	E	C	N	2
481		L	O	2	g	E	U	U	1
482		L	O	1	a	E	N	U	7
483		L	O	2	d	M	O	N	2
484		L	O	2	b	M	C	N	4
485		L	O	3	a	O	N	A	8
486		L	O	2	g	E	U	U	1
487		L	O	2	g	E	O	N	1
488		L	O	2	c	E	N	A	1
489		L	O	3	b	E	C	N	4
490		L	O	1	b	E	N	A	5
491		L	O	1	b	E	N	U	5
492		L	O	1	d	E	N	A	1
493		L	O	1	d	E	O	A	1
494		L	O	2	g	E	C	N	1
495		L	O	1	a	E	C	N	1
496		L	O	1	a	E	U	U	7
497		L	O	1	c	E	O	A	2
498		L	O	2	c	E	C	N	2
499		L	O	1	c	E	C	A	2
500		L	O	1	g	E	O	N	2
501		L	O	4	c	E	O	A	2

Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
502		L	O	2	g	E	U	U	1
503		L	O	1	d	E	N	A	1
504		L	O	2	g	E	O	N	2
505		L	O	3	c	E	U	U	1
506		L	O	2	c	E	U	U	5
507		L	O	5	a	E	O	A	2
508		L	O	2	g	E	U	U	1
509		L	O	3	c	E	N	A	1
510		L	O	3	c	E	C	N	2
511		L	O	1	c	E	O	A	1
512		L	O	3	c	E	N	A	1
513		L	O	5	c	E	N	A	1
514		L	O	1	b	E	C	N	4
515		L	O	3	g	E	U	U	1
516		L	O	1	d	E	N	A	1
517		L	O	5	c	E	U	U	2
518		L	O	4	d	O	N	A	2
519		L	O	2	g	E	U	U	1
520		L	O	4	g	E	C	N	1
521		L	O	5	h	E	U	U	
522		L	O	2	a	E	U	U	4
523		L	O	2	g	E	U	U	1
524		L	O	1	c	E	N	A	5
525		L	O	2	d	O	O	A	2
526		L	O	1	b	E	N	A	5
527		L	O	1	a	E	U	U	5
528		L	O	1	a	E	C	N	5
529		L	O	2	g	E	O	N	2
530		L	O	3	b	E	C	N	5
531		L	O	5	h	U	U	U	
532		L	O	3	g	E	C	N	1
533		L	O	3	d	U	U	U	4

Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
534		L	O	4	h	E	U	U	
535		L	O	1	d	E	U	U	1
536		L	O	1	g	E	N	A	3
537		L	O	1	a	E	C	N	1
538		L	O	1	b	E	C	N	4
539		L	O	1	c	E	C	N	3
540		L	O	1	a	E	C	N	5
541		L	O	5	h	U	U	U	
542		L	O	2	g	E	O	N	1
543		L	O	1	c	E	C	A	3
544		L	O	5	b	E	N	A	5
545		L	O	5	c	E	O	A	2
546		L	O	3	g	E	C	N	1
547		L	O	2	g	E	U	U	1
548		L	O	5	b	E	U	U	3
549		L	O	1	a	E	C	N	5
550		L	O	1	a	E	O	A	7
551		L	O	1	a	E	N	U	7
552		L	O	2	b	E	C	N	5
553		L	O	1	c	E	U	U	3
554		S	L	3	d	E	C	N	1
555		S	L	1	d	E	N	A	1
556		S	L	2	d*	M	N	A	4
557		S	L	2	h	E	N	A	
558		S	L	1	d	M	N	A	2
559		S	L	1	h	O	N	A	
560		S	O	1	b	E	U	U	1
561		S	O	1	b	E	C	N	1
562		S	O	1	b	E	U	U	1
563		S	O	1	b	E	C	N	1
564		S	O	1	b	E	U	U	1
565		S	O	1	b	E	U	U	1

Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
566		S	O	1	b	E	U	U	1
567		S	O	1	b	E	U	U	1
568		S	O	1	b	E	U	U	1
569		S	O	1	b	E	U	U	1
570		S	O	1	c	E	N	A	2
571		S	L	1	c	M	O	A	2
572		S	O	1	b	E	C	N	5
573		S	O	1	b	E	U	U	1
574		S	O	2	b	E	U	U	1
575		S	O	1	b	E	U	U	1
576		S	O	1	b	E	U	U	1
577		S	O	1	b	E	C	N	1
578		L	O	1	a	E	U	U	3
579		L	O	1	c	E	N	U	3
580		L	O	1	b	E	N	U	6
581		L	O	1	c	E	N	U	5
582		L	O	1	b	E	N	U	6
583		S	L	1	h	M	U	U	
584		S	L	2	g	O	N	A	2
585		S	L	2	g	M	O	A	2
586		S	L	1	h	E	U	U	
587		S	L	1	h	E	O	A	
588		S	L	1	g	U	U	U	1
589		S	L	1	b	E	N	A	6
590		S	L	1	d	E	N	A	1
591		L	O	1	a	E	N	A	7
592		L	O	2	[illegible]	E	N	U	1
593		L	O	1	a	E	N	U	7
594		L	O	3	b	E	U	U	5
595		L	O	5	c	E	N	A	1
596		L	O	2	g	E	N	A	1
597		L	O	2	a	E	N	A	4

Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
598		L	O	2	g	E	N	A	1
599		L	O	2	g	O	N	A	1
600		L	O	2	d	E	O	N	1
601		L	O	2	d	E	N	A	1
602		S	L	1	b	E	U	U	5
603		L	O	2	b	M	O	A	4
604		L	O	1	a	E	O	A	7
605		L	O	2	g	E	N	A	2
606		L	O	1	a	E	N	U	5
607		S	L	2	d	E	C	N	1
608		S	L	1	b	E	N	A	6
609		L	O	1	b	E	U	U	7
610		L	O	1	a	E	N	U	7
611		L	O	1	b	E	N	A	7
612		L	O	1	a	E	U	U	1
613		S	L	1	h	E	O	U	
614		S	L	1	b	E	N	A	1
615		S	L	1	b	E	U	U	1
616		S	L	1	e	M	O	A	1
617		L	O	2	c	E	O	A	2
618		L	O	1	b	E	N	A	6
619		S	L	1	h	E	O	U	
620		S	L	2	d	U	U	U	2
621		L	O	3	b	E	C	N	4
622		L	O	1	b	U	U	U	4
623		L	O	1	g	E	C	N	1
624		L	O	1	a	E	N	U	7
625		L	O	2	b	E	N	A	6
626		L	O	2	d	O	N	A	4
627		L	O	2	b	E	N	A	6
628		S	O	1	b	E	U	U	1
629		S	L	1	b	E	N	A	1

Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
630		S	O	1	b	E	U	U	1
631		S	O	1	b	E	C	N	1
632		S	O	1	b	E	U	U	1
633		S	O	1	b	E	U	U	3
634		S	O	1	b	E	U	U	3
635		S	O	1	b	E	U	U	3
636		S	O	2	e	O	N	A	4
637		L	O	1	a	E	N	A	8
638		L	O	3	c	E	N	A	1
639		L	O	1	a	E	N	A	4
640		S	L	1	g	E	O	U	2
641		L	O	3	g	E	N	A	1
642		L	O	2	d	E	N	A	1
643		L	O	3	d	E	N	A	1
644		L	O	2	g	E	N	A	1
645		L	O	1	a	E	N	A	5
646		S	L	1	g	M	C	N	2
647		L	O	1	b	E	N	A	3
648		S	L	1	b	E	N	A	6
649		S	L	1	d	U	U	U	4
650		S	L	1	d	E	U	U	4
651		S	L	1	b	E	N	U	5
652		S	L	1	g	E	U	U	1
653		S	L	1	g	E	N	A	2
654		S	L	2	g	E	C	N	1
655		S	O	1	b	E	U	U	1
656		S	L	1	b	E	O	A	1
657		S	L	1	b	M	U	U	-
658		S	L	1	b	E	U	U	1
659		S	L	1	b	E	U	U	1
660		S	L	1	b	E	U	U	1
561		S	L	1	b	E	U	U	1

Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
662		S	O	1	b	E	U	U	1
663		S	O	1	b	E	C	N	1
664		S	L	2	d	E	U	U	1
665		S	L	2	d	E	N	A	1
666		S	L	1	d	E	U	U	1
667		S	L	1	h	U	U	U	
668		S	O	3	h	M	N	A	
669		S	L	5	d*	O	N	A	2
670		S	L	2	c	E	U	U	5
671		S	L	2	c	E	U	U	4
672		S	L	1	d	E	C	N	2
673		S	L	1	b	E	U	U	1
674		S	L	1	e	E	U	U	2
675		L	O	2	c	E	N	A	2
676		L	O	1	b	E	U	U	6
677		S	L	1	h	E	O	A	
678		L	O	2	c	E	U	U	3
679		S	L	2	g	O	N	A	1
680		S	L	3	b	E	N	A	5
681		L	O	1	c	E	U	U	5
682		L	O	1	g	O	N	A	2
683		L	O	1	d	E	N	A	1
684		L	O	2	c	E	N	A	1
685		L	O	2	a	E	N	A	7
686		L	O	2	g	E	U	U	1
687		L	O	1	d	O	N	A	4
688		L	O	2	e	O	N	A	3
689		S	O	1	c	E	N	A	1
690		S	O	1	c	E	N	A	2
691		S	L	1	d*	M	N	A	4
692	S	L							
693	S	L							

Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
694	S	L							
695	S	S							
696	S	S							
697	S	L							
698	S	S							
699	S	S							
700	S	S							
701	S	S							
702	S	S							
703	S	S							
704	S	S							
705	S	S							
706	S	L							
707	S	L							
708	S	L							
709	S	S							
710	S	S							
711	S	S							
712	S	S							
713	S	S							
714	S	S							
715	S	S							
716	S	S							
717	S	S							
718	S	S							
719	S	S							
720	S	S							
721	S	S							
722	S	S							
723	S	S							
724	S	S							
725	S	S							
726		L	O	S	h	U	U	U	

Appendix A-II

(REFERENCE 7: 1971 UPDATE)

Appendix A-IIa

BASIC DATA TABULATIONS

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INTENTIONALLY ...

Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
1		Unsuccessful Launch				
2		Unsuccessful Launch				
3		Unsuccessful Launch				
4		Unsuccessful Launch				
5		Unsuccessful Launch				
6		Unsuccessful Launch				
7		Unsuccessful Launch				
8		Unsuccessful Launch				
9		Unsuccessful Launch				
10		Unsuccessful Launch				
11		Unsuccessful Launch				
12		Unsuccessful Launch				
13		Unsuccessful Launch				
14	*	TV data on position of earth pointing boom not available	Earth albedo too bright for the cameras	Lost data not critical for spacecraft operations		
15	*	After injection in orbit the spacecraft exhibited an abnormaly high spin rate	Launch vehicle anomaly	Negligible, small delay in initial boom extension, etc.		
16	*	Linear energy spectrometer produced no useable on orbit data	Unknown	Loss of one of 12 payload experiments		
17	*	One telemetry subcommutator stepped incorrectly during initial checkout	Spacecraft noise	Negligible		

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
18	*	Loss of sun "crossings" data normally used for spin control and acquisition maneuvers	Internal electrical problems in the circuitry between the sun sensor assembly and the control electronics assembly possibly due to impedance changes as a function of normal thermal variance with sun angle	Not serious because of work around procedures		
19	*	Transponder failed during launch	Unknown	Complete inutility of the spacecraft		Related to Index Number 73
20	*	Tape recorder motor drive current changed	Hysteresis changes in sensor transformer core coincident with power transients at squib firing for separation	Negligible		
21	*	A spurious sun pulse appearing infrequently from launch produces the effect of a high spin rate	Unknown	Negligible, no problem in spacecraft operation or data interpretation		Due to limited testing the anomaly was not evident prior to launch
22	*	Inoperable filter wedge spectrometer	Ice deposit on cooled detector	Loss of data		
23	*	Excessive battery temperature	Initially undesirable satellite/sun attitude	Negligible	Attitude altered by extending gravity gradient booms and nominal temperatures resulted	
24	*	Pressure transducer output dropped to zero	Faulty part	Negligible		Transducer became erratic after about 30 hours in orbit
25	*	A leaking valve was discovered in the resistojet experiment during the post launch checkout	Unknown	Loss of less than 10 percent of total experimental payload		

Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
26	*	It is impossible to "load" one of two redundant memory units	The relay in the power switching matrix which switches between the two memory units does not make contact with one of the memories	Negligible, due to redundancy		
27	*	Thermal control heater failure	Unknown	Not serious		
28	*	Desired data from an experiment not received	Wiring error which disables experiment high voltage when 8 counts are received in two milliseconds as opposed to the correct 64 (or 128) counts	Not too serious since the low count regime is of most interest, however, entire experiment shut down in about 6 weeks		
29	*	Low gain antenna experiment step changes in drive amplitude	Discontinuity in cabling impedance or varying conditions within the TWTA.	Negligible since the last step brought the antenna drive within specification		
30	*	Rapid decay of available spacecraft power: 27 to 22 watts in the first month, 0.6 to 0.8 watts per month thereafter	Radiation damage causing general deterioration of the entire array. Abetted by the high apogee of 3,100 nautical miles	Power remained high enough enough to meet all experiment requirements		
31	*	Low level interference between two spacecraft transponders resulting in undesirable oscillations	Fundamental design problem	Negligible, since ground station power capability completely overrides the interference	Ground station interrogation procedures modified to assure continued lack of interference	
32	*	A short circuit in the status telemetry circuits or wiring	Unknown	Not serious		
33	*	Data severely degraded by RF interference	Transmitter frequency of a companion payload actually within the receiver bandwidth of this experiment	Negligible, since bandwidth adjusted to preclude the problem		

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
34	•	An electrostatic experiment yielded calibration and background output but no data and the experiment door firing command caused the spacecraft to shut down and the clock to momentarily lose count	Unknown, but launched with a known failure in the logic and a just replaced photomultiplier tube	Loss of one of six experiments		
35	•	The prima.y millimeter wave transmitter suffered a 9-db loss in output power	Mechanical discontinuity in one of the final stages	Small loss because a backup transmitter provided		
36	•	Erroneous equilibrium orientation of the damping booms relative to the spacecraft main body	Boom bending or spring biases	Difficulty in damping large satellite librations and attendant interference with experimental data		
37	•	Inadvertent triggering of a camera shutter	Voltage transient during launch	None		
38	•	Failure of binary telemetry parameters used to monitor 4th stage timers	Unknown	Negligible		
39	•	Decrease in infrared interferometer spectrometer sensitivity	Excessive bolometer and optics housing temperature as a result of earth albedo entering the optics housing	About 40 percent of experiment data lost	Additional filtering will be added to future spacecraft	
40	•	Intermittent and erratic transmitter operation from launch for about 3 weeks	Frequency instability due to high voltages	Loss of nearly half of theoretically possible experimental data		
41	•	Transponder degraded to 75 percent usefulness	Improper adjustment to data loop due to a design deficiency	Loss in payload utility of nearly 25 percent		

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
42	*	The telemetry channels associated with transponder received signal strength are inaccurate	The telemetry data are over sensitive to temperature variations	Slight, but delay determinations using these data had to be abandoned		
43	*	Abnormally high regulator pass transistor temperature throughout the missions	Failure of the transistor thermal bonding, possibly loosened during launch	No adverse effects		
44	*	"False lock" observed in spacecraft data and shifts in best lock frequency indicated about 4 to 7 times	Spurious signal generated in the spacecraft transponder, specifically the cascade circuits of the mixer amplifier	Negligible	Anomaly corrected by applying power uplink at reduced power levels	This anomaly detected in ground test and design changes implemented to remove it. However, comprehensive testing of the changes were not possible due to schedule constraints
45	*	Degradation of neon reference for the infrared interferometer spectrometer	High radiation levels early in the mission particularly over the South Atlantic	Substantial experiment degradation		
46	*	Initially inoperative experiment package	Malfunction in command subsystem	Negligible - problem circumvented within a week		
47	*	Excessive spin rate subsequent to launch	No despin mechanism provided	Precluded receipt of useful data although spacecraft interrogated 50 times in about 6 months		
48	*	Telemetry falsely indicated that the experiment antennas did not deploy	Faulty wiring of micro-switch position sensors attached to the antennas	Negligible		
49	*	False telemetry indication	Unknown	Negligible		
50	*	Failure of experimental transponder during launch	Unknown	Spacecraft completely unuseable		

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
51	*	Spacecraft boom deployment sequence was concluded prematurely	Short in one of two redundant squibs upon firing to deploy one boom group set up a sneak path that prematurely detonated one of two redundant squibs to deploy the second boom group	None		
52	*	Magnetometer booms apparently did not fully deploy since no positive indication was received	Unknown	Negligible		
53	*	The omnidirectional spectrometer experiment provided no data from one of three directional sensors and 1 of the 4 omnidirectional sensors	Detector wire broken during launch	Significant degradation in one of 12 payload experiments		
54	*	Peculiar counting sequence in one of two encoders	Two flip-flops shorted at close proximity to their leads	Slight, minor changes in programming for data reduction necessitated		During fabrication of the encoder (at all levels) shorts were common. The test procedure was such that this particular short could have existed, undetected, prior to launch
55	*	Frequency drift in the narrow band VCO	Unknown	Prohibited analysis of nearly all narrowband (status) data		
56	*	Intermittent data received from a regulator converter temperature sensor	Defective circuit in the signal conditioning unit	Not significant		
57	*	Low signal levels in two gas counters	Gas lost during launch	Loss of experimental data		

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
58	*	Malfunctioning Faraday Cup experiment; abnormal response to ground commands	Unknown	Majority of anticipated data lost from this experiment		
59	*	After apogee motor boost the spacecraft spin rate was excessively high	Unknown	Negligible; corrected after apogee injection		
60	*	Data from the X-ray photomultiplier experiment unuseable from launch	Unknown but condition may have existed prior to launch	One of about 10 experiments lost		
61	*	During the first few weeks on orbit the multicoder clock (on one of two multicoders) would not start until after 4 or 5 minutes of operation (either real time or data storage)	Marginal operation of clock drive at low temperature	Insignificant		After 3 weeks of spacecraft operation when electronic area temperatures were over 40°C the problem ceased to exist
62	*	Back-up millimeter wave experiment suffered severe power drops within minutes of being turned on	Outgassing problem in area of the multipactor	Millimeter wave experiment lost for 6 months while outgassing was completed		
63	*	Regulated bus voltage exceeded specification limits	Occurred coincident with squib firing in the separation sequence	Not serious	Future designs to draw power from the unregulated bus	Related to index numbers 20 and 73
64	*	Failure of binary telemetry performance parameter to indicate that magnetometer booms were locked in orbit	Marginal microswitch closure condition	Negligible	For future spacecraft each boom is to be monitored separately and switch tolerance improved	
65	*	Battery temperatures increasing to abnormal levels in continuous change mode	Unknown	None	Switch to cycle mode reduced temperatures to nominal levels	

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
66	,	Solar panel temperature data incorrect	Inboard and outboard temperature transducer connections were reversed upon installation	Necessitated careful interpretation of recorded data but no detrimental effect on the spacecraft		
67	,	A experiment exhibited occasional random high counts and noise bursts at turn-on with frequency increasing with time	An open circuit in the base (internal) connections to one of the two transistors which are used in the push-pull sine wave oscillator of the photomultiplier power supply. May have separated during launch	Severely degraded data from one of six experiments		Similar failure observed in ground test
68	,	Telemetry falsely indicated that the experiment antennas did not deploy	Faulty wiring of microswitch position sensors attached to the antennas	Negligible		
69	,	Retarding potential analyzer experiment suffered 80 percent data loss shortly after initial turn-on	Unknown, but may be associated with the turn-on circuit	Some data loss		Experiment returned to full operation at 4,000 hours
70	,	Power fluctuations in transmitted RF power up to 3 db before final separation	Unknown	Delayed normal beginning of ranging by a few days but performance thereafter was normal		
71	,	Several difficulties experienced in performing the first spacecraft reorientation	Reorientation programmer was commanded and initiated using improper values	Considerable pain and suffering at the ground stations and some data loss	Proper values were substituted for the improper ones after several days	
72	,	Electron detector experiment failed to operate	Probably due to arcing in the high voltage module	Loss of 5 to 10 percent of spacecraft payload data		
73	,	Clock upset during spacecraft/Agena separation	Power transients at squib firings	None, reset clock to accurate time		This anomaly was expected to occur

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
74	<	Automatic nutation controller actuated for 5.5 seconds indicating a nutation angle in excess of one degree	Telemetry data show no valid reason for the firing nor do they indicate any malfunction	Negligible		
75	<	Electron trap experiment continuously on	Relay failure in the on position	Very small but continuous power drain, no other interference		
76	<	The spacecraft programmer momentarily went into an unplanned configuration	Electrical power transients at spacecraft launch vehicle separation	None, normal configuration resumed		
77	<	Final satellite orbit too high	Small rocket motor imparted a longer impulse at separation than anticipated	Compromised original experimental objectives		
78	<	Inadequate or extra flash counts in optical beacon subsystem	Insufficient sensitivity in flash detector and oversensitive flash tube	Negligible consequence		
79	<	Solar panel temperature data incorrect	Inboard and outboard temperature transducer connections were reversed upon installation	Necessitated careful interpretation of recorded data but had no detrimental effect on the spacecraft		
80	4	The spacecraft initially locked on Vega rather than Canopus as planned	Attributed to the known warmup characteristics of the Canopus sensor	Negligible		
81	5	One of two TWT's in one of two repeaters failed	Unknown but thought to be faulty TWT power supply	Limits the power output of the associated repeaters		
82	7	The slits of an aspect sensor were found to be electrically reversed	Improper assembly and checkout	None, after corrective action	Software changes corrected the ground displays	

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
83	9	First attempt to deploy Vertistat booms was unsuccessful	An experiment had been turned on prematurely preventing deployment	Negligible		
84	10	The telemetry from the digital solar aspect indicator gradually decreased in pulse amplitude and disappeared	Unknown	Loss of important engineering data		The indicator operated sporadically for nearly a year
85	12	Minor power transients observed upon establishing initial spacecraft configuration	Slight differences in the transient timers allow one battery to switch to full charge before the other	Negligible		
86	20	Tape recorder stopped during playback	Either (1) tape pack jamming, (2) motor bearing lubricant failure, or (3) clutch failure	None, due to redundancy		
87	20	Spacecraft attitude stabilization attempt was unsuccessful; Vertistat booms were properly deployed but to no avail	Basically unknown. Considered to be the result of gravity gradient, aerodynamic pressure and solar pressure "commutated" by rhythmic motion in Veristat booms, which in turn, was caused by asymmetrical configuration, solar heating and spacecraft spin	Significant degradation of data		
88	23	The ultraviolet spectrometer experiment exhibited internal problems and was turned off	Unknown	One of ten experiments lost		
89	24	No reverse mode measurements in a zodiacal light polarimeter experiment	Unknown	Degraded experiment performance		

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
90	25	Limit cycling of roll wheel tachometer at first and subsequent occurrences of perigee	Experiment boom motion coupling into attitude control error signals. Motion largely caused by solar array drive system	Contributed, ultimately, to loss of attitude control but mainly a nuisance factor by itself		
91	30	Excessive duration of command verification tones	A combination of noise transients and command transmission procedures	Not serious	Changed command transmission procedures	The corrective action was entirely effective
92	34	Telemetry transmitter center frequency began shifting and continued to do so for the remainder of the satellite life	Instability of the frequency determining loop in the transmitter	Data loss of 5 to 10 percent in both real time and playback modes		
93	40	One experiment package exceeds its limiting temperature almost continuously	Poor thermal design	Experiment must be cycled		
94	45	Infrared detector cell temperature starting to increase	Probably a change in the characteristics of the cooling system	Radiation response somewhat degraded		
95	45	Digital solar aspect indicator readings were intermittently faulty, bearing an erroneous second bit in the readout	Unknown	This condition can cause faulty solar aspect indications but is generally surmountable		
96	47	One of two cameras indicated an inoperable shutter and a light leak	A high current transient at camera selection blew the unregulated shutter bus fuse	Loss of capability		This camera was 2-1/2 years old prior to launch and the shutter had been operated about 5,000 times. Normal shutter life is claimed by the vendor to be at least 400,000 to 1,000,000 operations

Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
97	48	The redundant system for monitoring calibration was found to be inoperative in an ultraviolet polychromator experiment	Unknown	Negligible, due to redundancy		
98	50	Regulated bus voltage exceeded specification limits	Sending a particular payload power off command in an inappropriate sequence	Not serious	Operational procedures modified to preclude recurrence of the problem	Related to Index Numbers 99 and 100
99	50	Tape recorder motor drive current changed	Hysteresis changes in sensor transformer core coincident with a particular payload power off command	Negligible	Operational procedures modified, prevented recurrence of problem	Related to Index Number 100
100	50	Clock upset	Sending a particular payload power off command apparently triggered the upset	None, reset clock to accurate time	Operational procedures modified to preclude recurrence of problem	
101	57	Damper booms did not deploy properly	Malfunction of the damper deployment stop device either by fouling of a tape on the last turn of the spool or by a mechanical failure of the stop pin to drop after tape was deployed	Significant data degradation		
102	60	Shutter (temperature controller) indicated full open position when it should not be so	The shutter position monitor failed in the open position followed by intermittent shorting	Not serious		
103	60	Temperature on one face of the spacecraft rose above expected levels	Thermal design	Necessitates cycling some experiments on and off during worst spacecraft solar orientation		

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Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
104	87	Increased satellite spin rate, sharply decreased battery temperature, and somewhat later a decrease in unregulated voltage	Failure of a tantalum capacitor in the shunt regulator caused the battery to overcharge, burst and cause the above symptoms	Complete loss of the spacecraft	In subsequent spacecraft the offending capacitor was replaced as well as a transistor and fuse in the same circuit	
105	96	Logic electronics in the upper neutral particle mass spectrometer became locked in one operating sequence	Failure of a 68 ufd tantalum capacitor	Loss of experiment data		
106	100	Oscillations in the pitch axis observed after deployment of an experiment antenna (60')	The tubular antenna was being driven by a thermal engine effect	In plane bending of the antenna and out of plane whipping due to torsional twisting with considerable disruption to normal attitude control operation	Momentum management techniques were devised and implemented from the ground to preserve gas and prolong nominal operation. On subsequent launches antenna length reduced to 30' and redesigned for increased torsional stiffness	
107	100	A minor anomaly appeared in the special purpose transmitter	Unknown	Negligible		Later observation indicated nothing wrong with this transmitter
108	120	Improperly exposed photographs	Camera iris drive motor failure	Negligible, due to drive motor redundancy		
109	120	Abrupt and erroneous change in a telemetry reading	Unknown	Negligible		
110	120	The ultraviolet spectrophotometry experiment experienced numerous wheel subcommutator slips	Caused by the azimuth indexer stopping when it viewed the sun, as it should, and when viewing the reflection of the sun in the ocean, which it should not	Slight, since in each instance synchronization was reestablished		

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
111	120	Earth albedo and radiometer telescope experiments failed	Unknown	Two of nine experiments lost		
112	120	Poor signal to noise ratio on the RF downlink and improper lock on the uplink carrier when using one of two redundant communication subsystems	Unknown but an internal receiver oscillation in the 25 MHz [illegible] section causing [illegible] receiver to lock up on itself is considered most likely	Slight due to redundancy		Although the problem was noted almost immediately after launch it was somewhat intermittent and the receiver was not switched out of service until 6,840 hours of operation
113	120	Excessive temperature in an experiment boom package	Thermal design did not account for reflection from solar arrays	Simultaneous operation of the two experiments in this package has been restricted		
114	130	A star presence and periodic null is detected by the boresight star tracker with the shutter closed	Light leakage through the shutter mechanism	Not serious		
115	135	Midcourse maneuver change in velocity was smaller than predicted	An unexpected drag force produced by excessive deflection of the jet vanes in the post injection propulsion system exhaust stream reduced the magnitude of the thrust vector	Negligible, since trajectory correction satisfactory, but some degradation of UV photometer noted		
116	158	Star tracker hang-up with fixed error in command mode	Unknown	Negligible	The problem was cleared by executing the star search program	
117	190	Logic electronics in the equatorial mass spectometer became locked in one operating sequence	Failure of a 68 μfd tantalum capacitor	Loss of experiment data		

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
118	194	No readout from a tape recorder	Blown fuse in the power distribution unit	Loss of redundancy		
119	195	Temperature indication (housekeeping) became erratic and then stopped at maximum indication	Failed thermistor	Negligible		
120	200	Two of five ultraviolet solar energy monitors degraded beyond use in opposite directions (i.e., sensor readings increased to saturation in one case and decreased below useable levels in the other)	May be due to radiation damage	Substantial degradation of this experiment		
121	216	Star track temporarily lost	The star was either occulted by an unknown dark object or the inner gimbal digital error signal behaved abnormally following an array slew	Negligible		
122	216	Spacecraft tumbling end-over-end and shortly thereafter assumed a rather smooth spin about on undetermined axis near the original spin axis	Poor mass property design	Not too serious	For future spacecraft concentrate weight more about girth band area to increase the ratio of inertia about the spin axis to a secondary axis axis	
123	220	Unlatching process to begin spacecraft scan task 50 percent longer than anticipated	Clogging of porous metal restrictor by pyrotechnics blowdown debris	Negligible		
124	220	Canopus sensor lost lock	Sun reflection from spacecraft particles loosened by pyro shock	Negligible, spacecraft reacquired Canopus in 25 minutes		

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
125	270	Additional commands actuated when desired commands were sent	Marginal conditions in the command subsystem change gate transistor control circuitry	Negligible		
126	288	The spacecraft erroneously switched from one camera to the other with power on	Unknown	No harm done but not a recommended procedure		
127	300	Spacecraft potential in sunlight shifted from the -4 to -6 volt region to a level less than -20 volts	Unknown	Severely effects 4 or 5 (of 26) experiments		This problem also noted on another spacecraft in the series
128	320	No pictures produced from one of two cameras	Unknown	Loss of flexibility and redundancy		
129	380	Nonexecution of a stored command	Stored command erased by noise	Not serious		
130	400	Occasional dropouts and low level oscillation on 3 of 12 scanning IR spectrometer channels	Unknown	Slight		
131	432	During the first of three delta velocity maneuvers one thruster heater failed to respond	Unknown	Apparently no serious effects		
132	456	One experiment (of six) began drawing excessive current and was shut off	Unknown	Loss of data from the experiment		
133	500	Unable to make up loss in spin rate	One of two series valves stuck in the nearly closed position	Apparently not too serious although the spin rate decayed from 60 to 6 rpm in about 9 months	The valve was shaken loose at 9 months using the command system and the resonant frequency of the valve	

Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
134	500	Range and range rate experiment turned on without command	Unknown	Negligible, causes no interference		Also happened subsequently
135	500	Gas leak in orientation system	Vibration at launch assumed to have compromised the integrity of the system	Slight because of the very small leak rate		
136	500	The expected 1.3 to 1 ratio between the measurement of unregulated voltage and combined solar cell voltage dropped to 1 to 1	Capacitor or transistor breakdown or a blown fuse in the voltage booster circuit	Partial loads required for approximately 7 weeks during maximum eclipse		
137	520	Star tracker hang-up with fixed error in the command mode	Unknown, but a mechanical hang-up is suspected	Negligible	The problem was cleared by executing a related command	
138	540	Invalid unregulated voltage measurements	Shorted gate in the multiplexer gating network	Some loss of experimental and housekeeping data		
,39	560	One group of 32 telemetry words not being sampled at all while another group of 32 words sampled twice each frame	Shorted timing switch, which, however, apparently self-healed at approximately 1,900 hours	Some data loss		This may be related to another anomaly in the telemetry subsystem noted less than a day earlier
140	600	S-Band transmitter power dropped approximately 3 percent	Unknown	Negligible		
141	600	Anomalous command reception commenced at the rate of about 5 or 6 per month	Unknown	Slight		
142	600	Receiver calibration oscillators failed	Failure of the sequencing relays	Calibration measurements no longer useable. Not too serious		

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
143	670	Spacecraft receiver lost phase lock with the up link carrier	Unknown, but attributed to receiver or ranging code characteristics	Minor, since phase lock was quickly restored		
144	700	All eight channels of the satellite infrared spectrometer exhibited an increased output of approximately 2 percent.	Unknown	None		
145	700	The satellite clock advanced 262,144 seconds	The flip-flop for bit 6 of word 10 (2^{18}) changed state from a zero to a one for no known reason	Negligible		
146	720	Data storage system ceased operation	Thermal problems	Loss of all stored data capability		
147	720	Power output of wide band transmitter dropped from 4.5 to 0.5 watts	Unknown	None, due to redundancy		
148	720	One channel of an auxiliary detector experiment failed	Unknown	Five percent of the data from one of six experiments lost		
149	720	High count rates on the main photoelectric detector of a celestial X-ray experiment	Unknown	Degraded experiment data		
150	740	Excessive power subsystem temperature	Contamination of the thermal control surface by the fourth stage exhaust	No immediate effect but probably contributory to later failures		
151	768	28 V DC regulator provided out of tolerance voltages when input voltage was less than 32 volts. Part failure in solid state dc to dc converter	Minimal by commanding regulator bypass circuit when required	Subsequent designs used redundant regulators rather than the regulator/bypass circuit combination		

Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
152	790	S Band transmitter failed to radiate when commanded	Ground tests indicate an open capacitor duplicates all telemetry symptoms	Nuisance; due to redundancy and intermittent operation	None	The transmitter works good if it can be turned on which it sometimes can and hence it is used as much as possible
153	800	The X-ray telescope experiment was lost	Possible failure modes: (1) rupture of a window by a meteorite which in turn depleted the gas system; (2) a high voltage power supply failure; or (3) multiple failures in the remaining electronics	Loss of 1 of 10 experiments		
154	840	Three satellite housekeeping measurements become intermittently invalid	Intermittently shorted gate or timing switch in the multicoder	Not serious		
155	860	Modulation lost for a few minutes, payload clock shifted and several payload detectors misconfigured	Unknown, but thought to be associated with payload logic	Negligible		
156	865	Ultraviolet spectrometer falsely commanded	Unknown	Negligible		
157	880	Attempted spacecraft contact was unsuccessful	Unknown	Negligible		The spacecraft was successfully contacted 345 times; these contacts occurred both before and after this anomaly
158	930	Noisy infrared spectrometer channel	Unknown	Slight		
159	940	Roll wheel case pressure telemetry suddenly indicated a full scale reading	Transducer failure in the open mode due to excess heat (80°F) from the roll wheel operating (temporarily) at maximum speed	Not serious		

Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
160	950	Tape recorder failed	Unknown	None, due to redundancy		
161	990	Frequency change and excessive drift in one of two oscillators	Unknown	Negligible, due to redundancy		
162	1000	Erratic solar array drive amplifier and improper shaft track during slew period	Unknown but possibly due to the feedback potentiometer	Slight		
163	1000	Sudden 17 percent decrease in current being supplied from the solar panels	Temperature induced open circuits on some of the solar array panels	Necessitated periodic turn-off of telemetry and doppler beacons under partial sunlight conditions		
164	1000	A cloud of bright particles observed in the Canopus sensor field of view	A pyrotechnic event	None, since spacecraft was placed in all-axes-inertial mode in anticipation of the difficulty	Future missions to establish tighter contamination control procedures	
165	1000	Satellite spin rate gradually increasing	Momentum was added to the spacecraft by gravity, aerodynamic or solar pressure forces, or all three, acting on the damper booms	Serious data degradation		
166	1030	Ultraviolet spectrometer experiment high voltage power supply failure	Unknown	Loss of one of ten experiments		
167	1080	Experiment power supply failed	Rectifier diode shorted	Loss of one of six experiments		
168	1100	Spacecraft stabilization lost	Shorted gate winding in the roll wheel magnetic amplifier which in turn caused the attitude control power inverter to fail and hence the entire subsystem	Data from some experiments lost; others degraded. Ability to slew the arrays lost with concomitant loss of power and experiment data	Magnetic amplifier redesigned recommended	

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
169	1100	No signal from the beacon transmitter	End-of-life timer activated prematurely for unknown reasons	Not serious		
170	1120	High voltage inadvertantly applied to the tape recorder 'or 8 minutes (nominal time is 1 second)	Intermittent failure of a time delay circuit or a start/run relay	No adverse affect	Operational constraints undertaken to avoid the problem	
171	1150	Interference and loss of data on a helium I and II monochromator experiment	Unknown	Degraded experimert performance		
172	1200	Significant interference caused by operation of an experiment	Unknown	Experiment turned off thus losing data from one of six experiments		
173	1250	Telemetered temperature of camera 2 electronics indicated instantaneous 20°C changes	Electrical failure of the thermistor temperature sensor	Negligible, since other indicators give no evidence of a problem		
174	1296	Continuous discharge of one of a set of two geiger tubes	Failed tube	Loss of experiment		
175	1320	Tracking transmitter (100 mw) beacon signal strength 15 dbm low	Unknown	None, due to redundancy		Three days later the transmitter was turned on and found to be satisfactory
176	1320	Decoder is erratic in accepting commands	Unknown	Negligible, due to redundancy		
177	1330	Loss of primary high thrust regulator pressure	Pneumatic line leakage	Not too serious	An operational limitation is suggested for subsequent spacecraft in the series	
178	1344	Recurring noise burst on a particular frame of a particular tape recorder	Degradation or "drop out" of the magnetic tape	Not too serious		

Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
179	1360	Playback data from tape recorder lost intermittently, became worse, lost altogether, and totally restored within a period of about 1,000 hours	The cause may have been related to spacecraft temperature and probably involved an intermittent open or shorted input to the playback VCO or a problem in the VCO input circuit itself	Some data loss		
180	1370	Modulation lost for a few minutes, payload clock shifted and several payload detectors misconfigured	Unknown, but thought to be associated with payload logic	Negligible		
181	1400	Beacon transmitter inoperative	Premature shut down by end-of-life timer for unknown reasons	Not serious		
182	1420	Large spacecraft roll/yaw perturbations in the Antarctica region after satellite night/day transition	Roll/yaw/pitch errors allowing sun in the horizon scanners; possible contributors to the error are (1) large beta angle (11°), (2) 1.5° pitch bias	Approximately 2% of total gas impulse used and useable data lost during perturbations	1.5° pitch bias removed	Anomaly has not repeated
183	1430	Shutter (temperature controller) indicated full open position when it should not be so	The shutter position monitor failed in the open position followed by intermittent shorting	Not serious		
184	1440	Drive motor failure	Loss of lubrication and ultimate seizure	Loss of experiment		
185	1440	Data from two interrelated ultra violet photometer experiments lost	A failure of the detector itself rather than the supporting electronics	Loss of two of ten experiments		
186	1440	Four second modulation dropout at approximately the same point in memory readout	Intermittent connection in the data storage unit memory	Less than 1 percent of the data storage unit capacity is lost; furthermore the data storage unit is redundant		

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
187	1440	The multi-color spin scan cloud camera suffered a red channel failure	Unknown	Loss of color pictures although black and white pictures still available	A computer program was developed to produce pseudo color photos by sampling the active blue and green channels and predicting the red channel information	
188	1450	High voltages inadvertently applied to cameras for approximately 100 seconds	Operational procedures	None were detectable	Operational constraints established to prevent inadvertent application of high voltage	
189	1460	Solar flare detection system could no longer monitor solar proton fluxes	Proton detector failed	Subsequent to the failure, a manual payload turn-on would have been required in the event of a solar flare		
190	1464	The fine channel in three of four radiometers became inoperative	Attributed to wear out of a 10 Hz relay in the thermistor bridge of each channel	Small since the data can be deduced from other channels	On subsequent spacecraft a solid state switch is to be used	
191	1470	One of eight channels of IR radiation measurements became erratically noisy	Unknown	This channel no longer used operationally		
192	1500	One channel (of 12) on scanning IR spectrometer exhibits zero output 50 to 100 percent of each orbit	Unknown	Overall performance is good		
193	1500	Short term frequency instability of the downlink signal	A faulty tantalum capacitor in the auxiliary oscillator which self healed in a short time	Not serious		
194	1610	Power fluctuations in S-Band transmitter	Unknown	No data degradation		

Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
195	1640	Premature termination of data transmission	Spurious command	Slight loss of data		
196	1700	Satellite fails to return to battery charge mode at end-of-tape during a play-back or record cycle	Failure in the shut down logic circuit of the end-of-tape sensor system due to a defective relay, a shorted diode or a shorted capacitor	Small by implementing additional ground command sequences		
197	1700	One of a series string of three nickel cadmium batteries weak	Battery life limitation	Not too serious since experiment in which batteries located remained operable		
198	1710	Loss of stored telemetry data and associated timing	Failure of tape recorder	Significant system loss although not crippling		Possible failure modes: (1) Inoperative playback amplifier, (2) Inoperative playback head, (3) broken tape, (4) relay stuck in record position, (5) broken wire, or (6) stalled playback motor
199	1720	Timing error in the memory portion of optical beacon subsystem	Flash tube generated noise interfered with the memory	Negligible, recovered in 24 hours		
200	1750	Data recovery from the tape recorder ranged from 30 to 70 percent	Jitter on the data from an unknown source	Only real time acquisition possible with attendant loss of data and operational flexibility		
201	1770	Loss of all experiment data	Stalled playback and compensation motors possibly due to broken tape	All medium resolution infrared data lost, significant, about 25% of total payload	Dual tape recorders to be used on subsequent missions	
202	1790	Erroneous shutter position telemetry indication	Unknown	Negligible		

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
203	1800	A tracking jitter was observed on the inner gimbal of a star tracker	Unknown, but the jitter was isolated to bright stars only	Not too serious		
204	1800	Ultraviolet solar monitor experiment main frame read out all "zeros"	Unknown, but apparently associated with automatic experiment turn-on	Not serious		
205	1850	The slits of an aspect sensor were found to be electrically reversed	Improper assembly and checkout	None, after corrective action	Software changes corrected the ground display	The phasing of the aspect sensor not checked on the ground due to the unavailability of a portable sun source
206	1896	Loss of sensitivity in the grating spectrometer of the X-ray spectrometer experiment	The high voltage power supply is apparently sensitive to high levels of gamma radiation	Not serious		
207	1920	Sharp decrease in solar array output	Failure of one module in the array	Drop of about 5% in current, not too severe		
208	1968	Routine status check indicated spacecraft operating out of normal configuration with respect to the power, attitude control, and payload subsystems	A bus voltage filter capacitor shorted to ground causing a large power transient which changed the spacecraft configuration and burned itself open leaving the spacecraft essentially undamaged	Negligible		
209	1970	An extra synchronization pulse appeared on the high resolution infrared transmissions	Unknown	Slight, requires manual phasing in the ground station		

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
210	2000	Two of 10 binary bits in the operations programmer were stuck	Chemical reaction between the mercury and contacts in the programmer switches causing them to stick	Prevented optimum operation of the spacecraft but did not seriously affect data gathering		
211	2000	Errors in memory preload and timing	Coincident internal data handling	Negligible, anomaly restricted to 5-hour period		
212	2000	Telemetry indicated small variations in exciter drive to the traveling wave tube	Unknown	Negligible		
213	2020	Tape recorder failure	Attributed to 90° phase shift of clock strobe in the tape recorder electronics	Loss of stored data capability		Temperature was 42°C at time of failure and specification maximum is 45°C
214	2050	Erratic solar array drive shaft accelerations and subsequent reversals	Unknown, but could be due to shading o[illegible] a solar array drive amplifier malfunction	Not serious		
215	2060	Temporary loss of payload data	Bad connector on data line	Negligible		
216	2366	Two four second modulation drop outs or holes appeared in one of two data storage units	Intermittant connections in the data storage unit memory	Less than 2 percent of data storage unit capacity is lost; furthermore, the data storage unit is redundant		
217	2110	Radiometer chopper motor would not restart after being shut off for three orbits (≈2.5 hours)	Marginal starting capability at low temperatures	Precludes radiometer operation	Bearing retainers redesigned for increased lubricant protection and efficiency	
218	2136	Ability to comm[illegible] spacecraft lost for 900 hours	Unknown	Loss of 900 hours data past nominal 90-day mission		21 attempts to contact the spacecraft during the 900-hour period were unsuccessful, no unsuccessful attempts [illegible]

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
219	2150	Verification errors observed during execution of experiment real time commands	Command memory address transfer from unknown causes but probably associated with the ground stations	Resulted in command memory blockage	Memory was commanded to an alternate location	
220	2170	Two command memory locations ORed with previously stored commands	Unknown; attempts to repeat the anomaly were unsuccessful	Command memory blockage	Spacecraft memory recommanded and operational procedures changed to ensure proper loading	
221	2180	The interframes gap of one of two tape recorders increased by 22.9% since launch and continues to slowly increase	Unknown	Not serious		
222	2230	Fading and occasional drop out of C-band data	Lobing in transponder antenna patterns and/or marginal operation of high voltage cutoff circuit in transponder	Poor quality data from this payload		
223	2290	Unexpected variations noted in the helix current of a traveling wave tube	Unknown, but associated with percentage modulation and modulation frequency	Negligible, but down link signal could be slightly degraded		
224	2300	Complete loss of video data from one of four TV cameras	Shorted transistor in the video amplifier. Short thought to be the result of migrating material within the transistor	Not critical to spacecraft operation		
225	2304	The wheel position word for a zodiacal light polarimeter experiment was missing from the telemetry transmission	Unknown	Experiment performance slightly degraded		

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Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Ac. (if known)	Remarks
226	2340	Seven inadvertent commands executed in about a 1-day period	Ground stations sending erroneous commands	Negligible		
227	2360	Four frames of video completely lost	Isolated shutter malfunction	Negligible		
228	2360	Unscheduled telemetry read outs received	Attributed to the turn-on of ground transmitters associated with related spacecraft	Not serious		
229	2460	Detector cell temperature exceeded upper limit	Flaking and/or out gassing of the cooling patch black coating	Limited to night time operation only		
230	2510	One of two video transmitters failed	Blown transmitter fuse due either to an internal short circuit or an inadequate fuse	Negligbile mission effect due to redundancy		
231	2565	Regulator turned off by a telemetry request command	Unknown	Negligible, regulator was commanded back on and everything checked out		
232	2600	Loss of stored video data and associated timing	Failure of tape recorder	Loss of video data except in real time from this experiment, < 25% of total payload		
233	2600	Central computer and sequencer command capability impaired	An integrated circuit in a source driver suffered a gold-aluminum intermetallic reaction producing internal corrosion (purple plague)	Reprogramming required to enable operation without the "lost" commands		
234	2660	Infrared (IR) system would not respond to "IR Playback" command	Tape either jumped the reel or broke	Loss of IR data		

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (of hours)	Remarks
235	2839	Power lost from one string of one solar array	String shorted	Negligible because the remaining capacity was sufficient to power all loads		Malfunction disappeared 2859 hours but returned 3459 hours, got worse 4249 hours, and cleared up 7449 hours
236	2849	Ignition interference noted on telemetry transmissions	Design	Slight		
237	2860	Tape recorder failure	Unknown	Loss of stored data		
238	2865	Subcarrier level of transmitted video data dropped during last few playback frames	Unknown	Not serious		
239	2879	Non-execution of a stored command	Stored command erased by noise	Not serious		
240	2895	Anomalous behavior of the central computer and sequencer subsystem	A clamp, included in the design to prevent loading of commands during critical maneuvers, had not been properly wired into the subsystem	Anomalous behavior was avoidable by refraining from sending certain commands during critical periods		
241	2920	Star presence missing on a star tracker at one ground contact	Sun sensor stuck perhaps due to out-of-specification shutter drop out voltage	The problem disappeared prior to the next contact		
242	2946	Unintentional switch between transmitter No. 1 and redundant transmitter No. 2	Unknown	No degradation		Transmitter No. 2 allowed to remain in operation
243	3096	Beacon transmitter ceased all operation	Premature shutdown by end-of-life timer for unknown reasons	Not serious		The timer was a spare installed immediately prior to launch
244	3096	Two temporary step functions were observed in the telemetered data	Power transients	Negligible		

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
245	3020	Data dropouts and other minor anomalies on some telemetry channels	Shorted commutator switch induced by a noisy spacecraft environment which in turn was caused by another anomaly	Minimal, due to redundancy		
246	3048	Excessive battery temperature	Dumping of excess power (generated because of solar array/sun angles) into the battery zener diode	No serious effects immediately evident	Corrective action was to operate the satellite more than nominally programmed to reduce the power dumped in the zener diode. Subsequent spacecraft utilized different means of temperature control and power dumping	
247	3050	Erroneous position indications of experiment sensors	Unknown	Negligible, offset by command		
248	3100	Spacecraft did not respond to transmitted digital command program	One of two redundant decoders was failed due to a defective flip-flop	Negligible due to redundancy		
249	3100	One of two Geiger-Mueller tubes in an experiment failed	Unknown	Minimal, due to redundancy		
250	3120	Data missing intermittently on two telemetry channels during tape recorder playback	Unknown	Slight data loss		
251	3140	Spacecraft unexpectedly dropped out of sight	The spacecraft battery (silver-zinc, 18 cells) ruptured causing numerous corona discharges and translational forces	Twenty telemetry channels were disabled and a high degree of uncertainty introduced into the entire mission		

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Mission Effect	Corrective Action (if known)	Remarks
252	[illegible]	The multiplier sensitivity of an X-ray spectrometer experiment decays after an orbit turn-on	Either ground support equipment or the ultra high vacuum	Degraded experiment performance		
253	[illegible]	Battery failure	Reversed polarity in a cell	Loss of spacecraft		
254	3220	Two of either battery packs were degraded, i.e., had discharged cells	Unknown	Some limitation in capability		
255	3300	Incorrect response to ground commands	Unknown	Not significant		
256	3320	Reduced signal strength received from spacecraft transponder system	Increased temperature in antenna electronics resulting from running all four TWT's simultaneously	Some loss in communications capability	Operating procedures changed so that no more than three TWT's operated simultaneously	Temperature condition may have been exacerbated by the approach of summer solstice
257	3320	Temporary loss in ability to command the spacecraft from the ground and to execute commands out of command memory	Two electrolytic capacitor failures in the command receiver equipment are suspected	Problem self-healed		
258	3380	Unintentional switch from manual to automatic pitch control mode	Unknown	Negligible		
259	3400	Inability to command memory mode	Strong interference of unknown origin prevented acceptance of command	Negligible, command sent and accepted later		
260	3400	One of a redundant pair of tape recorders would no longer record	Failure in the record-mode mechanics	Not serious, because of redundancy		

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
261	3440	Numerous timing and flashing anomalies in the optical beacon subsystem	Precise cause unknown, but eliminating lamp assembly No. 4 (of 4 such assemblies) virtually eliminated the problem	Some loss in capability and flexibility		
262	3530	Spacecraft clock oscillator (SCO) difficult to turn on	Apparently some unknown problem with the energization circuitry for the SCO	Small added power drain	The SCO when finally commanded on was left on	
263	3600	A Geiger-Mueller tube becomes intermittent resulting in the loss of an ion chamber in an experiment	Unknown	Loss of one of six experiments		
264	3700	Apparent offsets in calibration potentiometers	Unknown	Small, but did require "last minute corrections" to attain optimum utility of the spacecraft payload		
265	3720	Quantity of IR data received is down to 60 seconds from a nominal 75 seconds per playback and still dropping	The difficulty apparently lies within the IR tape recorder	Some loss of IR data		
266	3770	Infrared spectrometer subsystem detector failed to cool down following pyro valve firing of cool down bottles	A plugged cryostat prevented N_2 from venting	No long-wave infrared spectroscopy data were obtained		
267	3770	Analog tape recorder experienced a 46 percent reduction in gain on track 1 during the recording of near encounter pictures	Contamination on the recording head	Track 1 pictures degraded but not lost		

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
268	3776	Erroneous position indications of experiment sensors	Unknown	Negligible, offset by command		
269	3778	Television pictures of poor quality	Vidicon tube temperature too low	Unfortunate but not critical		
270	3800	Portions of data played back in a digital tape recorder were garbled	Contaminated playback head	None, since data were also received in real time		
271	3800	Excessive variance in infrared radiometer data	Noise generated by platform slew interfering with radiometer data	Not particularly severe		
272	3820	Streaking in the spin scan cloud camera pictures	Low busvoltage resulting from extended periods of excessive power demands which depletes the battery and reduces bus voltage	Reduced coverage by the spin scan cloud camera	Operational procedures changed to assure that the camera operated only when sufficient voltage was available	
273	4066	Five of eight battery packs were degraded, i.e., had discharged cells	Unknown	Severe loss in power capability		
274	4066	Abnormal temperature excursions in an experiment package	Failed heater or thermostat	Temperature within the package not detrimental to the experiment		
275	4130	Major short in the battery	Failure of internal insulation due to prolonged over heating causing silver migration	Complete loss of eclipse operation		
276	4180	At spacecraft turn-on after eclipse the voltages oscillate in a totally unregulated fashion	Design coupled with previous factors of the battery	Nothing works well until the oscillation ceases	Redesign of the solar array regulator could preclude the anomaly	

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
277	4219	One of two video transmitters failed approximately 2 seconds after turn-on	Assumed to have been caused by a blown fuse	Slight due to redundancy		The transmitter had been off, prior to this turn-on, for approximately 3800 hours
278	4230	Star tracker hang-up with fixed error in the command mode	A mechanical sticking of the inner gimbal caused by a detent around earth	Negligible	A special command exercise freed the gimbal	
279	4344	Excessive noise observed on the beacon signal recurring about once every 100 orbits (180 hours)	Unknown	Not serious but reduces resolution of the primary data somewhat		
280	4369	Anomalous command distribution	Unknown	An extra command implemented for nearly every one sent but in a predictable manner so that its effect may be countermanded		Anomaly appears to be intermittent
281	4380	One of two partially redundant tape recorders losing pressure at the rate of approximately 1/2 psia/month	Unknown	None, unless pressure loss continued for another 6 months at the same or greater rate		1: August 1969 this TR was still operating properly at 4.6 psia
282	4400	One of two partially redundant tape recorders suffered a failure in the record mode	Assumed to be a stalled "record" motor, an open solenoid or an open capacitor	Loss of substantial data		
283	4420	Loss of all experiment data	Mechanical failure of tape recorder in playback mode	All high resolution infrared data lost, significant, about 25 percent of the total payload	Redundant tape recorders to be used on subsequent missions	
284	4500	Three anomalous gyro turn-ons within 6 weeks	Unknown; determined not to be a command anomaly	Minor effect and no recurrence after exercising redundancy in the attitude control subsystem		

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Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
285	4525	Command transmission not received	Unknown	Negligible, retransmission was successful		
286	4560	Tape recorder failed	Unknown	Limited to real time data		Excessive spacecraft temperature (~110°F) existed for 2 months and may have contributed to the failure
287	4670	No real time commands could be executed	Unknown	Minor, after corrective action	Commandability reestablished by changing the clock-to-tone ratio; periodic updates are required to maintain commandability	
288	4700	Payload scan platform slewed in the wrong direction	Human error in programming the maneuver	Prevented photography of the star Alpheratz (α-Andromedae)		
289	4725	Oscillation observed on the AGC signal from the command receiver	Unknown	Apparently not serious		
290	4750	Telemetry indicated RF drive and RF output from both transmitters when only one, in fact, was operating	Coaxial switch failure which premitted the RF from one transmitter to be fed back to the output stages of the second	Negligible as the phenomenon only lasted a few orbits		
291	4750	Star tracker hang-up with fixed error in the command mode	A mechanical sticking of the inner gimbal caused by a detent around zenith	Negligible	A special command exercise freed the gimbal	
292	4760	Loss in spacecraft power	Shorted battery cell	Loss not severe		
293	4780	Star tracker hang-up with fixed error in the command mode	A mechanical sticking of the inner gimbal caused by a detent around zenith	Negligible	A special command exercise freed the gimbal	

Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
294	4800	One of two video transmitters failed	Unknown	Negligible, due to redundancy		
295	4850	Battery failure	Unknown	Loss of spacecraft		
296	4850	Ignition interference observed in the primary data	Unknown	Not serious		
297	4920	Momentary loss of earth lock following a command transmission	Failure in logic circuit of one control electronics assembly or simply noise entering the control electronics assembly from the command distribution unit	None due to redundant control electronics assemblies		
298	4975	An attempt to command off a beacon transmitter was unsuccessful	Ground antenna elevation was only 4.5 degrees	Negligible, command was successful on the next revolution		
299	5040	No valid results from a navigation experiment	Oversensitive photomultiplier tube	Loss of less than 10 percent of the experimental payload		
300	5090	Second of a redundant pair of tape recorders failed to play back	Unknown	Loss of all data storage capability		Failure began by missing a few frame counts in each playback; from first indication to total loss about 1,000 hours
301	5100	Attempt to precess spin axis by ground command was unsuccessful	Deterioration of sun sensor sensitivity	Loss of operational flexibility	Subsequent spacecraft were provided with much thicker protective glass covers on the sun sensors	
302	5300	Shift noted in the minus 3 volt performance parameter of an experiment	Unknown	Essentially resulted in the loss of one of six experiments		

Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
303	5420	An internal command to shift the Canopus cone angle was unsuccessful	Transients	Negligible, due at least in part to backup	The Canopus sensor was turned off in favor of the gyros	
304	5420	Spacecraft would not accept a sequence of five commands	Unknown	Negligible, after corrective action	The ground transmitter was turned off, returned, and then successfully contacted this spacecraft	
305	5740	Three pressure (vacuum) gauges arced over and failed	Sudden loss of spacecraft pressure from unknown cause	Some performance degradation		
306	5750	Momentary video dropout on one frame of data	Unknown	Negligible		
307	5760	Loss of gas pressure in the reaction control system	Pressure leak of unknown origin	Not too serious since an alternate hydrazine system remained operable		As a result of the leakage a series of spacecraft maneuvers were performed to derive maximum use of the remaining propellant
308	5800	Loss of sensitivity in an ultraviolet spectrometry experiment	Unknown	Experiment performance somewhat degraded		
309	6090	A level of shift in the video gradually occurred after about 6 months in orbit	Malfunction within the video switching circuitry	None, can be compensated for on the ground		
310	6300	End of battery life	Wearout	Operation limited to sunlight periods only		
311	6340	Loss of camera calibration	Failure (intermittent) of Xenon flash tube	Negligible		
312	6400	Ignition interference noted on telemetry transmissions	Design	Slight		
313	6475	Programmer malfunction of an undisclosed nature	Unknown	Apparently not serious		

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
314	6570	Mechanical drive antenna ceased operation	Regulator failure perhaps related to a heat problem within the control electronics	Switching in the redundant regulator restored operation		
315	6900	A plasma experiment partially failed	Apparently due to the extence of a long (7-1/2 hours) shadow which was beyond design requirements	Loss of part of one of six experiments		
316	6900	A photomultiplier tube was lost in the anti-coincidence count of a low energy proton and alpha detector experiment	Experiment operated in a shadow for 7-1/2 hours which was beyond design requirements	Loss of 20 percent of the data from one of six experiments		
317	7010	Spacecraft/ground communication difficulties	Atmospheric interference, noise, low elevation, etc.	Garbled data, transmitted commands not received, etc.		From the noted time onward an incident of this type occurred about once every 16 orbits (30 hours)
318	7056	Part of the memory section of one of two data storage units was lost	Unknown	Negligible, since real time data not affected and payload data used the other unit		At approximately 10,800 hours the unit was functioning although it soon became intermittant and remained so at the last contact at 15,000 hours
319	7100	Beacon transmitter data noisy for 4 minutes following primary data transmission	Unknown	Negligible		
320	7110	Spacecraft spin-up less than anticipated	Lunar interference with magnetic spin control	Not serious		
321	7130	Telemetered value of camera housing temperature dropped sharply	Either an electrical malfunction in the telemetry conditioning circuitry or mechanical degradation of the thermal bond between the sensor and the housing	Negligible, since other telemetry points indicated no problem		

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if any)	Remarks
322	7200	Satellite spin rate above nominal and complete loss of control gas	Valve left open by faulty ground command procedures	Not too serious as satellite spin rate decayed in a highly predictable way and was still useful		
323	7200	Data from an X-ray photometer experiment lost	Gas leakage through the mylar window of the experiment	Loss of one of ten experiments		Useful life was anticipated to be 1 year
324	7200	Momentary dropout of primary data signal	Unknown	No primary data lost signal quickly reenabled		
325	7220	Spacecraft reentered earth's atmosphere	Orbital mechanics	End of life		Mission had been successfully accomplished prior to reentry
326	7270	The detection efficiency of an X-ray spectroheliograph experiment decreased below specification	Unknown	Degraded experiment performance		
327	7320	Thermistor output on solar array dropped to zero	Failed thermistor	Negligible		
328	7350	X-ray spectrometer data overridden by a series of all ones	Unknown	Temporary and hence not serious		
329	7360	A proportional counter failed	Unknown	Ten percent loss of data from one of six experiments		
330	7375	AGC fading	Unknown	Apparently not serious		
331	7400	All attempts to contact spacecraft were unsuccessful	Spacecraft inadvertently left in real time mode with consequent battery failure	Catastrophic in terms of the spacecraft; however, its nominal mission duration was successfully completed		

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
332	7600	Anomalous tracking by the horizon scanner began and occurs 2 or 3 times a month	Unknown	Abnormal gas depletion and other attitude correction activity		
333	7600	Unable to load any remote programs into one, of two, programmers and the 400 pps signal is unavailable in that programmer	Unknown	None, due to redundancy		
334	7635	Transmitted command not received	Noise spike	None, second transmission successful		
335	7650	About 1 or 2 command anomalies per week began to occur at this time	Unknown	Some data lost		
336	76[illegible]	Transmitted command interpreted erroneously by the spacecraft	Unknown	Five commands were required to correct the affects of the anomaly. No lasting affect		
337	7700	Ignition interference noted on both primary and secondary telemetry transmissions	Design	Slight		
338	7700	Two late turn-ons and one early turn-off observed on a primary data telemetry transmitter	Unknown	Not serious		
339	[illegible]	Record and playback commands resulted in loss of signal	The tape recorder apparently became hung up on the end-of-tape sensor	Further satellite operations were restricted to the real time mode		
340	7820	Momentary video AGC dropouts	Unknown	Negligible		

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Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
341	7840	Loss of primary data on a few frames of telemetry	Spacecraft attitude with respect to the sun was momentarily abnormal, for unknown reason	None		
342	7900	Sharp decrease in solar array output	Probable failure of one module in the array but confirmation not possible due to telemetry constraints	Drop of about 5 percent in current, not too severe		
343	7934	Intermittent malfunction of tape recorder programmer by recycling once before shutting itself off	Unknown	Slight, requires additional ground commands		
344	7958	Intermittent crosstalk between two command switching functions	Unknown	Minor		
345	7970	Some telemetry encoder words are being obliterated	Unknown	None, due to redundancy		
346	8030	Difficulty in maintaining lock on telemetry signal	Temperature sensitive component in the multicoder	Not too serious since nominal mission is complete		
347	8050	Data from one tape recorder only 35 percent recoverable due to jitter	Unknown	Negligible due to redundancy		
348	8100	Loss of sensitivity of a single spectrometer in an X-ray spectrometer experiment	Discrepant outputs from the high voltage power supply	Some experiment performance degradation		
349	8120	Command tape out of synchronization	Synchronization problem on the ground	Loss of one stored command, not serious		

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (If Known)	Remarks
350	8248	An extra telemetry read-out received	A command conflict from a related satellite	Negligible		
351	8330	The controller used for the gyro heater in the orbital plane experiment package failed	Emitter to collector short in the transistor network of the controller related to the power supply overstresses caused by lack of useable batteries	Four experiments ultimately lost; two others would have been but for previous failures		
352	8400	Ranging channel impossible to turn off	Integrated circuit failure in the central computer and sequencer	Apparently not particularly debilitating		
353	8530	Spacecraft dropped out during tape recorder playback	Unknown	Not serious		This incident also occurred on three later occasions
354	8540	An event frame in the data storage unit was being dropped every fourth line	Unknown	Negligible due to redundancy of data storage units		
355	8560	Tape recorder failure	Unknown	Significant data loss, only real time data available		Design life of the satellite was 6 months
356	8570	A request for telemetry command was received erroneously	Unknown but an excessive amount of noise was present on all three subcarrier oscillators	Slight		
357	8680	One of two television cameras abruptly stopped functioning during a picture taking sequence	Failure in the shutter electronics system	Slight, due to redundancy		
358	8690	Four specific playback frames of TV camera data are quite noisy	Faulty tape in the tape recorder	Negligible due to work around	Five frames on the tape recorder are used as a buffer between the faulty tape sections by using the command subsystem	

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Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
359	8700	Special purpose programmable computer failed	Attributed to the existence of "purple plague" in the integrated circuits	Serious loss, especially in operational flexibility	Subsequent spacecraft will avoid gold aluminum bonding in their integrated circuits as it contributes to the formation of purple plague	
360	8710	Thermal ion experiment ceased providing data	Unknown	Loss of one of six major experiments		
361	8760	One, of two, television cameras showing four types of degradation: (1) increasing black level, (2) fading right hand fiducials, (3) a vertical moire pattern, (4) a gray scan line between the third and fourth fiducials	Unknown	Camera used very little because of inferior pictures compared to the other camera		
362	8900	Transmitter turned on (erroneously) by tape recorder playback command	Unknown	Negligible		
363	9015	Momentary fading of the beacon transmitter signal	Unknown	Negligible		
364	9030	Tracking difficulties	Unknown	Creates noisy received signals		Same phenomenon occurred on three other occasions
365	9150	The count rate of one channel of an experiment went abruptly to zero	Unknown	Twenty-five percent of the data from one of six experiments lost		
366	9240	Two bits in the telemetry format of the digital data processor were stuck	Failure of a flip-flop	Not too serious but essentially unknown		
367	9300	One of three subcarrier oscillators hung up at lower band edge	Unknown	Apparently none		

Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
368	9340	All contact lost with the spacecraft	Failure in the command subsystem	Catastrophic		
369	9460	Loss of focus in one of three cameras	A change in mechanical alignment of the optical system or a change in the optics due to thermal distortion or a mechanical shock	Slight loss of clarity in some pictures		
370	9500	All modulation of the transmitter from one of two redundant equipment groups ceased	Failure of the power converter	Loss of simultaneous real time and data storage modes of operation		
371	9600	Attempted reacquisition of dormant spacecraft unsuccessful	Unknown	Loss of considerable data although primary mission objectives were already accomplished		
372	9700	Star tracker caused glitches in the spacecraft memory and could not maintain star track for useful periods of time	Unknown but previous usage was non-nominal in that black space was looked at for long periods of time. This is felt to be contributory to the anomaly	Loss of maneuverability and flexibility		
373	9765	The interframe gap on one (of two) tape recorders increased from a nominal 2 seconds to 3.4 seconds	Investigation indicated this anomaly to be a "normal" condition	None		
374	9800	One voltage output of a power converter to the ana-analog data handling assembly of one of two equipment groups changed from -16 to -18 volts and oscillated	Unknown	This effected the data by shifting the level of the analog telemetry words in an unpredictable manner		

Index	Anomaly Time (hours)	Anomalies Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
375	9600	Output lost from gr[illegible] spectrometer of an [illegible]-ray spectrometer experiment	May be due to drop out in the high voltage power supply	Degraded performance of the experiment		
376	9940	Tape recorder failure	Unknown	Loss of stored data		Design life of the satellite was 6 months
377	10,300	Tape recorder did not respond to playback	Unknown	None, due to redundancy		About 530 hours later the "failed" tape recorder responded and operated
378	10,340	Tape recorder failed to playback data	Broken drive belt or possibly a broken magnetic tape	Quite severe because of previous degradation of redundant recorder		
379	10,350	A transmitted command was erroneously changed to an unsent command	Command was garbled and the error sensing device was off	Not serious in this case		
380	10,380	Playback telemetry had an excess of 20 telemetry points with no time code	The telemetry commutator apparently became confused because of a multiplicity of telemetry requests including one to a related spacecraft	Not serious		
381	10,400	The video subcarrier level dropped to zero in 2 quick steps and then returned to normal	Unknown	None		Total period of non-normal subcarrier level was 265 milliseconds
382	10,530	High frequency timing unit lost	Unknown	None, due to redundancy		
383	10,600	Extra telemetry received	Command conflict with a related spacecraft	Slight		

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
384	18,599	Solar Array Drive (SAD) began intermittent but significant degradation	Erratic performance may be due to (1) a noisy potentiometer, (2) a mechanical anomaly in the gear train, (3) electronic difficulty in SAD amplifier, (4) degradation of SAD motor lubricant, or (5) any combination of these	The system is not seriously degraded		
385	18,606	The spacecraft L-band receiver began malfunctioning	Unknown but associated with on/off commands	A number of "work-arounds" have been devised to prevent recurrence of the malfunction	The L-band repeater from end is left on, as is the associated driver but mode changes are permitted	
386	18,600	Charge regulator occasionally losing control of charge bus voltage	Not apparent from available data	Would be more serious except for previous failures		
387	18,600	Both spacecraft command receivers were saturated by a strong RF signal of unknown origin for 2.5 hours	Unknown	No lasting effects		
388	18,800	PCM modulation lost as well as spacecraft timing and synchronization signals	One or more failures in the telemetry or its power converter plus a failure in the high frequency timing unit. Also, 3 of 4 digital line drivers in the redundant telemetry were found to be inoperative	Not catastrophic only because of redundancy		
389	18,900	Tape recorder failure	Unknown	Loss of stored data		Design life of satellite was 3 months

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
390	11,000	Erratic operation of two thermostatically controlled heaters in two experiment packages. They do not always turn-on at the specified close temperatures although the heaters are operable	Faulty thermostats; one totally failed and confirmed	Apparently none		
391	11,500	One of three batteries exhibited a sharp increase in temperature (20 percent) and charge current (40 percent)	Unknown	Apparently not too detrimental to the mission		
392	11,500	Temperatures of some equipments (contiguously located) exceeded their design limits	Unknown, but temperature increases larger than can be explained solely by degradation of the white painted surfaces	Minor		
393	11,500	Temperatures of some equipments (contiguously located) exceeded their design limits	Unknown, but temperature increases larger than can be explained solely by degradation of the white painted surfaces	Minor		
394	11,500	Tape recorder malfunction	Unknown	Significant loss of stored data capability		
395	11,520	Tape recorder would not playback	Record motor not rotating	None, due to redundancy		
396	11,700	Unable to make up loss in spin rate	One of two series valves stuck in the closed position	Negligible, due to secondary propulsion system		After exhausting the secondary system an attempt will be made to unstick the valve
397	11,850	Spacecraft nominal spin rate exceeded	Noise burst on a related command	Negligible, since spacecraft spin down was commanded successfully		

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Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
398	11,870	Spacecraft potential in sunlight shifted from the -6 to -8 volt region to a level less than -20 volts	Unknown	Apparently not too serious		During eclipse spacecraft potential was unchanged
399	11,980	Interference on telemetered data beginning this time and recurring about 5 times per month for the remainder of the spacecraft life	Attributed to the atmosphere and/or the signal itself but essentially unknown	Loss of data and data clarity		
400	12,000	The detector gain of a proton/electron detector experiment drifted below tolerance	Unknown	Degraded experiment performance		
401	12,120	Spacecraft earth lock was lost	Erratic pointing error thought to be due to some unknown problem in the control electronics assembly	Not serious except for a few days of earth lock lost while a work around was devised	Work around consisted of raising the threshold at which attitude correction occurs and increasing the spacecraft spin rate slightly	
402	12,200	An extra telemetry readout received	Extraneous command which corresponded in time to a command transmitted to another satellite in the vicinity	Negligible		
403	12,200	Noise on the beacon transmitters first reported	Unknown	Not serious		
404	12,500	Battery temperatures increased beyond desired range	Decreasing angle between the spacecraft spin axis and satellite sun vector	Not serious		A design problem
405	12,600	A checkout of the digital solar aspect indicator provided no output	A subcarrier oscillator was operating at the lower band edge	Not serious		This same incident occurred another half dozen times in the next two months

Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
406	12,800	Interference observed upon attempting to transmit an ignition command	Unknown	Negligible		The ground station inhibited error sensing in order to complete the command
407	12,860	Tape recorder playback was only 13.25 hours when it should have been 17.25 hours	Lack of response to a transmitted command to power the tape recorders	Small data loss		
408	12,960	Tape recorder would not playback	Record motor stopped in "record" mode after recording 1/4 tape	Severe loss of data		Redundant unit failed earlier
409	13,140	Gyro noise level gradually increased from launch until at 18 months it had increased by a factor of 2	Normal wear	None, gyro continues to operate normally (at 18 months)		
410	13,140	Failure of one of two partially redundant tape recorders	Failed playback motor	Significant loss of data storage capability		
411	13,150	Half the tape (referenced to the recording directions) of one or two partially redundant tape recorders produces only noise	Unknown	Loss of data storage capability		
412	13,430	From the indicated time onward the reception of commands became increasingly problematical with multiple transmissions required in numerous instances	Atmospheric noise perhaps	Not too serious		
413	13,440	Spacecraft turned off after transmission of certain commands once or twice a month from this point until end of life	Unknown	Spacecraft always reacquired		

Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action if Known	Remarks
414	13,52?	A telemetry command error disabled the telemetry	Unknown	Telemetry reenabled		This incident occurred about once every 2 months until end of spacecraft life
415	13,[illegible]	Momentary dropouts observed on one or two frames of data on three orbits in the same month	Attributed to a particle of dirt, oxide, etc. on the tape recorder head or tape	Not too serious		
416	13,900	Mechanical drive antenna ceased operation	Regulator failure due to a heat problem within the control electronics	Loss of the antenna for about 5 months		The failure is apparently temporary and correlated with the heat problem which in turn is related to seasonal fluctuations
417	14,300	Oscillations on the power bus originating at the output of the power control unit regulators	Unknown	Drift in wideband transmitter carrier frequency and anomalistic charge regulation	Problem is alleviated by pointing solar arrays away from the sun and switching out one of the redundant regulators	
418	14,300	Temperature in an experiment package exceeded specification limits	Malfunction of proportional heater	Minimal, since temperatures returned to normal and cycling of the heaters permits full operation		
419	14,950	Extraneous "ones" observed on the output of the X-ray spectrometer	Appears to originate in the experiment/recorder interface	Experiment performance degradation		
420	15,000	A grating spectrometer and KAP scintillator of an X-ray spectrometer experiment deteriorated	Unknown but may be associated with the high voltage power supply	Experiment performance degradation		
421	15,120	Six db loss of signal in one of two burst receivers due to a one volt drop in calibration	Unknown	Negligible, due to redundancy		
422	15,400	Exhaustion of attitude control gas	Gradual leak due to wear on the valve seats	Not serious since all primary and most secondary mission objectives already achieved		

Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
423	15,430	A 5.5 percent difference in in battery voltage readings was observed between the two telemetry commutators	Unknown	Not serious		
424	15,600	An experiment lost range identification	Unknown	Twenty percent of the data from one of six experiments lost		
425	16,200	Both spacecraft command receivers were saturated by a strong RF signal of unknown origin	Unknown	Negligible		
426	16,280	No primary data transmissions for three consecutive orbits	Unknown	Negligible, a new program was transmitted and subsequent operations have been entirely normal		
427	16,300	Fine detail lost from primary experiment	Failure of a preamplifier from unknown causes	Usefulness of experiment data dropped by about 30 percent		
428	16,350	The program for primary data not loading correctly	Unknown	No primary data at attempted program loading plus four orbits		
429	16,500	Special purpose programmable computer failed	Attributed to the existence of "purple plague" in the integrated circuits	Serious loss, especially in operational flexibility	Subsequent spacecraft will avoid gold-aluminum bonding in their integrated circuits as it contributes to the formation of purple plague	
430	16,800	Spacecraft reentered earth's atmosphere	Orbital mechanics	End of life		Mission had been successfully accomplished prior to reentry
431	17,060	Temporary loss of spacecraft stabilization	Failure of one tracking head, probably failure of bolometer or sensor electronics	Negligible, only 3 of 4 tracking heads required		

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Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
432	17,500	Reflectometer experiment ceased operation	Failure of the sampling arm motor	Minimal since experimental objectives had already been achieved		
433	17,860	No cloud data on 5 of a group of 10 orbits	Unknown, but the video looks like a "capped lens" shot	Small data loss		
434	18,180	One of three subcarrier oscillators hung up at lower band edge	Unknown	The next command sequence produced errors because command confirm could not get through		
435	18,200	The proportional counter of the double spectrometer of an X-ray spectrometer experiment is degrading	Unknown	Experiment performance degradation		
436	18,650	One of approximately 10 power converters failed without warning	Unknown	Highly deleterious in terms of commands, timing, telemetry, ACS and experiment operation		
437	19,200	As an enable transmission was being received the subcarrier oscillator suddenly shifted to "0" volts	Unknown	Negligible; all subsequent transmissions of this type have been normal		
438	20,180	Spacecraft telemetry indicated that a TWT filament was on after it had been commanded off	Ineffective command transmission	Minor since a second transmission effected the desired change		
439	20,200	Anomalous command distribution	Unknown	An extra command implemented for nearly every one sent but in a predictable manner so that its effect may be countermanded		Anomaly appears to be intermittent

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Mission Effect	Corrective Action (if known)	Remarks
440	20,232	Battery degraded beyond use	Operation extended beyond designed life time	Complete loss of satellite		
441	20,250	The calibration circuit reference cell of a solar X-ray detector experiment failed	Wearout	Loss of one of nine experiments		
442	20,600	Noise observed on a subcarrier oscillator	Interference from beacon receiver	Not too serious and only temporary		
443	21,300	Wideband transmitter produced no forward power when commanded on	Unknown	Some loss of data in spite of partial redundancy		
444	21,880	Spacecraft dropout	Unknown	Negligible; spacecraft reenabled and completed the pass		
445	22,180	Restricted power availability in portions of the orbit	Solar array degradation	Loss of some data from some experiments		
446	22,200	Sun sensors unuseable	Degradation due to ultra violet radiation	Severe loss of experiment data and capabilities	Subsequent spacecraft were provided with much thicker protective glass covers on the sun sensors	
447	23,040	Intermittent dropout of wideband transmitter signal	Unknown, but the power converter current input was near zero and output voltages were very low	Negligible since problem disappeared within 48 hours		
448	23,400	Numerous and worsening frequency of glitches on pitch and roll fine error telemetry	Essentially unknown, probably involves numerous sources, tolerance buildup, etc.	Quite degrading		These observations made just prior to termination of the satellite mission
449	23,400	Battery voltages observed to be low and decreasing	Normal wear	Doubtful survival of spacecraft through satellite nights		These observations made just prior to termination of the satellite mission

Index	Anomaly Time (Hours)	Description	Anomalous Cause	Mission Effect	Corrective Action (If Any)	Remarks
450	23,900	Telemetry data lost from tape recorder playback	Unknown	Negligible, due to redundancy		
451	24,900	Sun sensor output down slightly	Degradation due to ultraviolet radiation	Negligible		Installing thicker glass covers on this spacecraft relative to those used on previous spacecraft in the series solved a serious degradation problem
452	27,200	Thermistor on one of the two solar arrays producing erroneous temperature data	Thermistor failed	Slight		
453	28,400	Decoder fails to accept commands on an intermittent basis	Unknown	Negligible, due to redundancy		
454	32,700	No commands accepted by the spacecraft for a period of approximately 25 hours	Interference of unknown origin from one of 20 payload experiments	Small loss in capability by commanding the experiment off		
455	40,560	Ten watt beacon transmitter timer operated for 30 seconds rather than specified 45 seconds	Anomalous operation of the nonredundant timer circuitry	Negligible		
456	41,500	Low average helix current in one TWT	Degradation from use	Negligible due to redundancy		Redundancy not implemented because of concern about the coaxial switch
457	41,640	Severe power degradation	Solar particle damage to solar arrays	Slight, since orbital characteristics are favorable		
458	--	Errors in the data loaded into the spacecraft memory during some ground interrogations	RFI over highly populated areas	Negligible		
459	--	Spacecraft could not be contacted, three times during the first 180 days in orbit	Look angle errors	Loss of data for a few revolutions		The satellite was contacted successfully 195 times in the same 180 day period

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Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
460	~	Noisy primary data signals about once every 17 orbits (32 hours) after about 1700 hours (900 orbits)	Unknown	Degradation in the clarity of some data		
461	~	Interference on the command receiver output telemetry channels and on the clock input telemetry channels	Operation of payload subsystems	Slight		
462	~	Jumps in the solar aspect angle measured on successive vehicle spin cycles	A failure of unknown origin in the solar aspect sensing system	Approximately 40 percent of solar angle measurements in error although vehicle attitude could be determined using other means		
463	~	Occ sional loss of earth lock	False sun conditions generated by a combination of internal spacecraft noise and spurious signals from tracking stations controlling other satellites	Minimal after institution of work around	Work around consisted of overriding a relay actuated by the noise, etc.	
464	~	Noisy primary data signals about once every 8 orbits (15 hours) from launch	Unknown	Degradation in the clarity of some data		
465	~	200-Hz interference	200-Hz ac signal riding on radiometer power bus	Negligible due to low magnitude		
466	~	Command receivers interference twice causing the blockage of the command memory program; lower levels of interference experienced on a regular basis	Unknown	Not too serious		

Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
467	~	Ten commands were executed between 20 and 1200 hours on orbit which were not specifically commanded by a ground station	Certain ground stations over deviating their carriers	Primarily a nuisance factor		
468	~	Erratic behavior of voltage controlled oscillator in command receiver	A conductor between the antenna and receiver is believed separated from the substrate	Significant loss of capability and noise generation		
469	~	Interference present on the video of one camera	Originates in the high voltage converter circuitry of the camera electronics	Negligible		Present only rarely
470	~	Approximately two spurious commands received per month	Decoder sensitivity to RFI	Not serious		
471	~	Command subsystem produces the results of many commands which were not sent from the ground	Unknown	Nuisance		
472	~	Invalid attitude control pointing error and partial loss of an associated telemetry word	Unknown	Negligible		
473	~	Approximately one spurious unencoded command execution per day; almost always one (or more) of four specific commands	Receiver susceptibility	Some reduction in operational flexibility		
474	~	The "Recorder Record" command was not accepted 8 times between 300 and 3000 hours in orbit	Intermittently sticking tone relay or drift in transmitter and/or receiver frequencies	Some data loss	This command utilized a backup tone after the last occurrence noted above	

Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
475	—	Indication of a temperature differential between solar paddles	Either unsymmetrical sensor placement or unknown	None		This behavior also noted on the preceding spacecraft in the series
476	—	The fine channel in one of four radiometers became inoperative	Attributed to the wearout of a 10 Hz relay in the thermistor bridge	Not serious		This relay only operated 1 day in 7 to prolong its life
477	—	Instability of a local oscillator in the radio frequency system used to maintain ground/spacecraft communications	Variations in contacts between a tuning screw and its grounding contacts	No effect on spacecraft performance	For future programs the contact fingers should be redesigned	
478	—	Obliteration of recorded video data during IR data transmission	Interference	Loss of some pictures (relatively few)		After about 1770 hours the problem disappeared due to a failure in the interfering subsystem. The problem was there from the beginning
479	—	Spacecraft was found in record mode when it should have been in battery charge mode on five occasions between 4200 and 5600 hours into the mission	Tape recorder hanging up before end of tape sensor reached due either to mechanical stoppage or electrical stall	Did not seriously affect data gathering capability		
480	—	Once or twice a month experiments are unintentionally disabled	Abnormal operation of the command subsystem	Not serious; in each case a ground command restored the experiment		
481	—	Loss of signal occurred five times between 130 and 4100 orbital hours when either a record or playback command was transmitted	Either an intermittently sticking tone relay on a frequency drift in the satellite receiver or ground transmitter	Not serious		
482	—	Degradation of video quality on approximately 4 percent of the pictures	Interference caused by vibration of an adjacent recorder when under power which in turn vibrates the vidicon elements	Slight overall mission effect		

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
483	~	Noisy primary data signals about once every 50 orbits (100 hours) from launch	Unknown	Degradation in the clarity of some data		
484	~	On approximately 10 occasions the second half of the tape playback was invalidated	Marginal operation of the tape recorder servo loop caused a change in bit rate at tape turnaround	Resulting loss of data was minimal		
485	~	Telemetered value of transmitter output gradually rose for the first 800 orbits (1440 hours)	Erroneous telemetry caused by antenna impedance shifts as a result of outgassing	None		No real change in transmitter power
486	~	Command transmission difficulties (erroneous commands not received, etc.) about once every 50 orbits (100 hours) for the first 2 months after launch; no recurrence noted in the second 2 months	Unknown	Not too serious		
487	~	Solar array drive amplifier intermittently saturated or high on a momentary basis	Assumed due to one or a combination of (1) shading (2) dropout of feedback pot due to wear or contamination, (3) contamination of slip rings on solar array drive shaft	Not serious		
488	~	Battery temperatures generally higher than anticipated by about 15 percent	A basic design problem, apparently	Minimal, due to work around	The work around was to change the normal charge level and to cycle the batteries on and off in response to load conditions	
489	~	Five tape recorder playback cycles were erratic in the 2850-hour spacecraft mission	Unknown	Negligible		

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
490	\~	Battery temperatures generally higher than anticipated by about 15 percent	A basic design problem, apparently	Minimal, due to work around	The work around was to change the normal charge level and to cycle the batteries on and off in response to load conditions	
491	\~	At day/night and night/day transitions, sunlight obliterates all data for approximately 2 minutes	Radiometer mirror shields designed for 500 n. mi. orbits, spacecraft at a 600-n. mi. orbit	Slight	Mirror shields to be redesigned for subsequent missions	
492	\~	Loss of signal occurred on three occasions when the record command was sent	Ground transmitter or spacecraft receiver frequency drift beyond the 0.05 percent stability level	Negligible		
493	\~	Interference present on the video of one camera	Originates from another spacecraft subsystem	Negligible		
494	\~	Spurious commands ranging from about 3 to 10 per month	Decoder sensitive to all types of RFI; most spurious commands occasioned by external source of RFI	None serious		Frequency of occurrence increased from launch until about the 15th month and then declined
495	\~	Level shifts in video data	Interference from beacon transmitter	Obscured a number of TV pictures		This interference was present from the beginning. It improved upon failure of the PLM tape recorder at about 1700 hours
496	\~	The power regulation and control unit change mode logic often fails to transfer to the shunt charge mode and to switch to the standby charge regulator upon entry to dark as required	The effect of the earth's penumbra on the automatic regulator transfer circuitry; a design fault	Not serious		

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
497	~	The satellite never reached static equilibrium but oscillated about the equilibrium direction by $\pm 15^{0}$ on the average; the dynamic equilibrium was reached only after 190 orbits (~300 hours)	Hysteresis damping rods were inadequate	A large but diminishing nuisance factor	More effective hysteresis damping recommended for future spacecraft in this series	
498	~	One of two television cameras gradually degraded	Unknown	Significant degradation of primary data		
499	~	Apparently 5000 hours after launch the spacecraft overheated and remained in this condition for 1200 hours	Period of full sunlit orbits for which the thermal design was inadequate	Minor since all components survived and incident occurred after the nominal mission time	Recommended that all experiments be designed to operate at 0^{o} centigrade rather than room temperature to improve high temperature response	
500	~	Video data sometimes present between "triplets"	Incomplete erasure of recording tape	None		Present from launch to failure of the tape recorder
501	~	The spacecraft receiver exhibited an excessively low threshold	Parasitic oscillation in the receiver module; a design problem	Not serious	The receiver subsystem was commanded to high power from low power (the only alternative) and thereafter maintained an appropriate threshold	
502	~	Abnormal rec[illegible]ion of multiple comman[illegible]gnals occur approx[illegible]tely once per month	RFI	Negligible		
503	~	Gradually degrading video quality	Microphonics attributed to mechanical degradation of the rigidity of internal vidicon elements	Slight		

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Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
504	~	Poor attitude control and unreliable attitude data throughout the mission	Unexplained high drift rates, aerodynamic efforts, damper misalignment, other anomalies, etc.	Utility of the data is seriously degraded		
505	~	Microphonics occasionally appeared on the video of 2 of 3 TV cameras	Vibration of internal elements of the vidicon	Negligible		
506	~	The contents of the "state of the charge unit" integrator registers changes on occasion	Voltage transients between regulated return and shunt common	Negligible		When the same condition was noted during ground testing the cause was attributed to a "noisy" solar array simulator
507	~	Thirty-five second period of pitch damping boom flutter at each spacecraft sunrise	Marginal design	Minimal	Recommendation made for stiffer boom material on subsequent spacecraft	
508	~	Approximately three command sequences per month (for 3 months) which were sent were not executed	Unknown	Nuisance		For some failures, satellite range and elevation were good, for others they were marginal
509	~	Commands not received by the spacecraft	Interruption or interference of the incoming command by RFI	Negligible since retransmission always assures (eventually) receipt of the command		
510	~	Amplitude variations in timing signals received on the ground from data storage accompanied by increases in flutter and wow	Recorder tape degradation	Did not affect the quality of stored data		
511	~	The spacecraft receiver exhibited an excessively low threshold	Unknown	Negligible	The receiver subsystem was commanded to high power from low power (the only alternative) and thereafter maintained at appropriate threshold	

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
512	~	Two hundred milliamps of array output lost	Unknown	Not serious		
513	~	Occasional sunlight interference	Conjunction of slight spacecraft attitude errors and satellite day/night transitions and possibly reflections from the spacecraft structure	Slight		
514	~	Occasional loss of earth lock	False sun conditions generated by a combination of internal spacecraft noise and spurious signals from tracking stations controlling other satellites	Minimal after institution of work around	Work around consisted of overriding a relay actuated by the noise, etc.	
515	~	Large sporadic attitude excursions in yaw, >180° in some orbits	Thermally induced bending and twisting of the Vertistat gravity gradient control rods	Improper attitude was detrimental to some experiments; however, sufficient operation at nominal attitude was accumulated to satisfy experimenter objectives	Subsequent spacecraft used a different rod material for the Vertistats which provided an order of magnitude improvement in rod manufactured straightness	
516	~	Orientation sensors not useable	Gradual ultraviolet degradation	Orientation corrections cannot be made		
517	~	Data handling system PCM buffer produced all "ones"	Failed PCM buffer	Degraded data handling capability		
518	~	Solar array drive amplifier occasionally rises to 2-1/2 times its nominal value as the spacecraft exits from the umbra	Unknown but possibly due to (1) feedback potentiometer, (2) slip ring contamination, or (3) (3) shading	None observable		
519	~	Difficulty experienced in commanding playback	Unknown	Data lost from approximately 1 percent of all orbits		

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Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
520	~	The time required to unload the roll fine wheel via the low thrust jets is in excess of the pitch and yaw systems	Jet plume impingement on the external surface of of the spacecraft is suspected	Negligible		
521	~	Improper command verification tones transmitted from the spacecraft	Noise entry into the clock memory resulting in a pseudo command	Only one pseudo command executed and that with no adverse effect		
522	~	Between 1,000 and 3,000 hours of the mission, an inadvertent transfer of functions occurred three times between the two programmers	Spurious commands	Negligible		
523	~	Instead of the normal 50 percent on and 50 percent off telemetry indication varied throughout a given pass to as much as 70 percent on and 30 percent off	Sun interference on a horizon crossing indicator sensor	Could result in a spin count error	The spacecraft attitude was altered to decrease the angle between the spacecraft-sun line and the spacecraft spin axis	
524	~	Shift in "beat pattern" between PCM sampling rate and and clock 1Hz and 10Hz telemetry monitors	PCM/clock phasing	Not serious		
525	~	About once every 100 orbits the spacecraft fails to accept a playback command	Receiver/decoder malfunction in which a tone relay is intermittently dropping out	Negligible due to the availability of a parallel tone relay		
526	~	Noisy primary data signals about once every 12 orbits (23 hours) from launch	Unknown	Degradation in the clarity of some data		
527	~	Spurious command execution of unencoded (audio tone) commands	Primarily an overly sensitive command receiver	Negligible		

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
528	~	A long term frequency drift of the down link signal	A small temperature change in the crystal and oscillator circuit in the auxiliary oscillator module, coupled with the frequency characteristics (250 Hz/°F drift at S-band) of the primary oscillator over the mission temperature range	Accurate prediction of down link frequency as a function of time rendered the effect negligible		
529	~	Improper clash sequences in the optical beacon subsystem	Noise in flash tubes interfering with memory unit	Negligible, occurrences relatively rare		
530	~	Command transmission difficulties (erroneous commands, commands not received, etc.) about once a month from launch	Unknown	Not too serious		
531	~	Anomalistic readout pattern of the data code and grid	Phasing of different timing elements	Negligible		Only happens occasionally and then is no real problem
532	~	Noisy operation from one of four optical flash lamps after 18,000 cycles	Unknown	Taken out of service		The other three lamps operated approximately 66,000 cycles each without failure
533	~	Gradual increase in telemetry reading for tape recorder motor drive current	Either increased tape friction or shifting of telemetry sensor calibration	Negligible		
534	~	Aperture wheel of a proton/electron detector experiment stepping incorrectly on rare occasions	Thought to be due to a faulty reed switch	Degraded experiment performance		Only four instances of this behavior were recorded at 48, 55, 122, and 500 days after launch

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Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
535	~	A long term frequency drift of the down link signal	A small temperature change in the crystal and oscillator circuit in the auxiliary oscillator module, coupled with the frequency characteristics (250Hz/°F drift at S-band) of the primary oscillator over the mission temperature range	Accurate prediction of downlink frequency as a function of time rendered the effect negligible		
536	~	Command errors twice in the first 100 orbits (~200 hours)	Unknown	Not serious		
537	~	Commands to advance Canopus tracker cone angle retarded it instead, etc.	The problem is in the Canopus cone angle update circuit with a sticking relay being the most likely source of the trouble	Not severe, since the difficulty can be corrected by ground commands		Same problem recurred at 90 and 228 days
538	~	Erroneous indications of a "hot band" in the vicinity of the South Pole during night to day transitions	Sensor shielding designed for a 500 n. mi. orbit rather than the actual 600 n. mi. orbit	Slight	Shielding redesigned for subsequent spacecraft	
539	31,100	No anomalies of any kind. Operational as of 15 January 1971				
540	15,384	No anomalies of any kind. Operational as of 15 January 1971				
541	6,770	No anomalies of any kind. Operational as of 15 January 1971				
542		No reported failures for/at decay at 39 days				

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
543		No reported anomalies in 11,040 hours of orbital operation. Spacecraft reentered atmosphere 9 March 1969				
544		No reported anomalies or orbital time other than an admission that it did get into orbit successfully. Spacecraft not operational				
545		No reported anomalies in 14,600 hours of orbital operation. Spacecraft not operational				

ORIGINAL PAGE IS
OF POOR QUALITY

Appendix A-IIb

CLASSIFICATION CODES

PRECEDING PAGE BLANK NOT FILMED (232)

Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
1	U	L							
2	U	L							
3	U	L							
4	U	L							
5	U	L							
6	U	L							
7	U	L							
8	U	L							
9	U	L							
10	U	L							
11	U	L							
12	U	L							
13	U	L							
14		L	L	1	b	O	N	A	1
15		L	L	1	d*	O	N	U	2
16		L	L	2	g	U	U	U	1
17		L	L	1	b	E	N	A	3
18		L	O	1	d	E	N	A	1
19		L	L	5	g	U	U	U	2
20		L	L	1	g	E	N	A	2
21		L	L	1	d	E	U	A	1
22		L	O	2	g	O	N	A	1
23		L	L	1	e	O	N	A	4
24		L	L	1	b	E	C	N	1
25		L	L	2	g	U	U	U	1
26		L	L	1	a	E	C	U	3
27		L	L	1	e	U	U	U	1
28		L	L	2	g	O	N	A	1
29		L	L	1	b	E	N	A	5
30		L	O	2	c	E	N	A	1
31		L	L	1	g	E	N	A	1
32		S	O	1	b	E	U	U	1
33		L	O	1	g	E	N	A	2
34		L	L	2	g	E	U	U	1
35		L	O	1	g	M	N	U	2
36		L	L	2	d	M	N	A	3
37		L	L	1	g	E	N	N	2
38		L	L	1	b	E	U	U	1
39		L	O	2	e	O	N	A	4
40		S	O	3	c	E	U	U	5
41		L	O	2	g	E	N	A	2
42		L	L	1	b	E	N	U	1
43		L	L	1	c	M	O	A	3
44		L	L	1	b	E	N	A	5
45		L	O	2	g	E	N	U	1
46		L	O	1	a	U	U	U	7
47		L	L	4	d	O	N	A	2
48		S	L	1	b	E	N	A	1
49		L	L	1	b	E	U	U	1
50		L	L	5	g	U	U	U	2
51		L	L	1	f	E	C	N	2
52		L	L	1	f	M	N	U	2
53		L	L	2	g	M	C	U	1
54		L	L	1	b	E	N	A	3
55		S	O	2	b	E	U	U	5
56		L	L	1	b	E	U	U	1
57		L	L	2	g	O	O	A	1
58		L	O	2	g	U	U	U	1
59		L	L	1	d	U	U	U	2
60		L	L	2	g	U	U	U	1
61		L	O	1	b	E	N	A	3

Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
62		L	O	2	g	E	N	A	2
63		L	L	1	c	E	N	A	3
64		L	L	1	b	M	O	A	1
65		L	L	1	c	U	U	U	2
66		L	L	1	b	O	N	A	1
67		L	L	2	g	E	C	U	1
68		S	L	1	b	E	N	A	1
69		L	L	2	g	E	U	U	1
70		L	L	1	b	E	U	U	5
71		L	O	2	d	O	N	A	2
72		L	L	2	g	E	N	A	1
73		L	L	1	a	E	N	A	5
74		L	L	1	d	U	N	U	2
75		L	L	2	g	E	C	N	1
76		L	L	1	a	E	N	U	4
77		S	L	3	d*	O	N	U	2
78		L	L	1	g	E	O	U	1
79		L	L	1	b	O	N	A	1
80		L	L	1	d	O	N	A	1
81		L	O	2	g	E	U	U	1
82		L	O	1	d	E	N	A	1
83		L	O	1	d	O	N	A	5
84		L	O	2	d	E	U	U	1
85		L	L	1	c	E	N	A	3
86		L	O	1	b	M	U	U	4
87		L	O	3	d	O	N	U	5
88		L	L	2	g	E	U	U	1
89		L	L	1	g	U	U	U	1
90		L	O	2	d	O	N	A	5
91		L	O	1	a	E	N	A	1
92		L	O	2	b	E	U	U	5
93		L	O	2	e	O	N	A	1
94		L	O	1	g	O	O	A	2
95		L	O	2	h	E	U	U	-
96		L	C	2	g	E	C	A	1
97		L	L	1	g	U	U	U	1
98		L	O	1	c	E	N	A	3
99		L	O	1	g	E	N	A	2
100		L	O	1	a	E	N	A	5
101		L	O	2	d	M	N	A	3
102		L	O	1	e	E	C	N	1
103		L	O	2	e	O	N	A	1
104		L	O	5	c	E	C	N	3
105		L	O	2	g	E	C	N	1
106		L	O	2	d	O	N	A	2
107		L	O	1	b	U	U	U	5
108		L	L	1	g	E	O	U	2
109		L	O	1	b	E	U	U	1
110		L	O	1	g	O	N	A	1
111		L	O	2	g	U	U	U	1
112		L	O	1	a	E	U	U	1
113		L	O	1	e	O	N	A	1
114		L	O	1	d	O	N	A	1
115		L	O	1	d	O	N	A	2
116		L	O	1	d	E	N	U	1
117		L	O	2	g	E	C	N	1
118		L	O	1	c	E	C	U	4
119		L	O	1	b	E	C	N	1
120		L	O	2	g	O	O	U	1
121		L	O	1	d	U	N	A	1
122		L	O	2	d	O	N	A	3
123		L	L	1	f	U	U	U	2
124		L	L	1	d	O	N	A	1
125		L	C	1	a	E	U	U	3

Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
126		L	O	1	a	E	N	U	4
127		L	O	2	c	E	U	U	4
128		L	O	2	g	U	U	U	1
129		L	O	1	a	E	N	A	1
130		L	O	1	g	E	U	U	1
131		L	O	1	d*	U	U	U	2
132		L	O	2	g	E	U	U	1
133		L	O	2	d	M	O	N	2
134		L	O	1	g	E	N	U	2
135		L	L	1	d	M	N	U	2
136		L	O	2	c	E	C	N	3
137		L	O	1	d	U	N	U	1
138		L	O	1	b	E	C	N	3
139		L	O	2	b	E	O	N	3
140		L	O	1	b	E	N	U	5
141		L	O	1	a	E	N	U	1
142		S	O	2	g	E	C	U	2
143		L	O	1	a	E	N	U	1
144		L	O	1	g	E	N	U	2
145		L	O	1	a	E	N	N	5
146		L	O	3	b	E	U	U	4
147		L	O	1	b	E	U	U	5
148		L	O	1	g	E	U	U	1
149		L	O	1	g	E	U	U	1
150		L	O	1	e	O	N	A	4
151		L	O	2	c'	E	C	N	3
152		L	O	1	b	E	C	N	5
153		L	O	2	g	U	U	U	1
154		L	O	1	b	E	O	N	3
155		L	O	1	g	E	N	U	1
156		L	O	1	a	E	N	U	3
157		L	O	1	a	E	N	U	1

Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
158		L	O	1	g	E	U	U	2
159		L	O	1	b	E	C	A	1
160		L	O	1	b	U	U	U	4
161		L	O	1	g	E	U	U	1
162		L	O	1	d	E	U	U	2
163		L	O	2	c	E	N	A	1
164		L	O	1	d	C	N	A	1
165		L	O	3	d	C	N	A	5
166		L	O	2	g	E	U	U	1
167		L	O	2	g	E	C	N	1
168		L	O	3	d	E	C	A	2
169		L	O	2	b	E	U	U	5
170		L	O	1	g	E	C	U	2
171		L	O	1	g	E	N	U	[illegible]
172		L	O	2	g	E	U	U	1
173		L	O	1	g	E	C	N	2
174		L	O	2	g	E	C	N	1
175		L	O	1	b	E	U	U	5
176		L	O	1	a	E	U	U	2
177		L	O	2	d	M	N	A	2
178		L	O	2	b	O	C	U	4
179		L	O	2	b	E	U	U	4
180		L	O	1	g	E	N	U	1
181		L	O	2	b	E	U	U	5
182		L	O	1	d	O	N	U	2
183		L	O	1	e	E	C	N	1
184		L	O	2	g	M	C	U	1
185		L	O	2	g	E	U	U	1
186		L	O	1	b	E	U	U	4
187		L	O	2	g	E	U	U	2
188		L	O	1	g	O	N	A	2

Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
189		L	O	2	g	E	U	U	1
190		L	O	1	g	M	O	A	1
191		L	O	1	g	E	U	U	2
192		L	O	1	g	E	U	U	1
193		L	O	1	b	E	O	N	5
194		L	O	1	b	E	U	U	5
195		L	O	1	g	E	N	U	2
196		L	O	1	a	E	C	N	4
197		L	O	1	g	E	O	A	1
198		L	O	3	b	U	U	U	4
199		L	O	1	g	E	N	A	1
200		L	O	2	b	U	U	U	4
201		L	O	2	g	M	U	U	2
202		L	O	1	b	E	U	U	1
203		L	O	2	d	U	U	U	1
204		L	O	1	g	E	U	U	1
205		L	O	1	d	E	N	A	1
206		L	O	1	g	E	N	A	1
207		L	O	1	c	E	U	U	1
208		L	O	1	h	E	C	N	-
209		L	O	1	g	E	U	U	2
210		L	O	2	a	E	C	A	4
211		L	O	1	g	E	N	U	1
212		L	O	1	b	E	N	U	5
213		L	O	2	b	E	U	U	4
214		L	O	1	d	E	U	U	2
215		L	O	1	g	E	O	U	1
216		L	O	1	b	E	U	U	4
217		L	O	2	g	M	O	A	2
218		L	O	2	a	U	U	U	1
219		L	O	2	a	E	N	U	1
220		L	O	2	a	U	N	U	1

Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
221		L	O	1	b	E	U	U	4
222		L	O	2	g	E	N	A	1
223		L	O	1	b	E	U	U	5
224		L	O	1	b	E	C	A	1
225		L	C	1	b	E	U	U	3
226		L	O	1	a	O	N	A	1
227		L	O	1	g	M	N	U	2
228		L	O	1	a	E	N	A	1
229		L	O	2	g	O	O	U	2
230		L	O	1	b	E	C	A	5
231		L	O	1	a	E	N	U	1
232		L	O	2	g	M	N	U	2
233		L	O	2	a	E	C	A	4
234		L	O	2	b	M	U	U	4
235		L	O	1	c	E	U	U	1
236		L	O	1	h	E	N	A	-
237		L	O	3	b	U	U	U	4
238		L	O	1	b	E	U	U	
239		L	O	1	a	E	N	A	
240		L	O	1	a	O	N	A	4
241		L	O	1	d	M	N	A	1
242		L	O	1	a	E	N	U	4
243		L	O	2	b	E	U	U	5
244		L	O	1	c	E	N	U	3
245		L	O	1	b	E	C	A	3
246		L	O	2	e	E	N	A	1
247		L	O	1	b	E	U	U	1
248		L	O	1	a	E	C	N	2
249		L	O	1	g	E	C	U	1
250		L	O	1	b	U	U	U	4
251		L	O	2	c	O	C	U	2
252		L	O	1	g	E	N	A	1

Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
253		L	O	5	c	E	C	A	2
254		L	O	2	c	E	O	N	2
255		L	O	1	a	E	U	U	8
256		L	O	2	g	E	N	A	2
257		L	O	1	a	E	C	[illegible]	1
258		L	O	1	a	E	N	U	4
259		L	O	1	a	E	N	A	1
260		L	O	2	b	U	U	U	4
261		L	O	2	g	E	O	U	1
262		L	O	2	a	E	U	U	3
263		L	O	2	g	E	O	U	[illegible]
264		L	O	1	g	E	U	U	1
265		L	O	2	b	U	U	U	4
266		L	O	2	g	M	O	U	1
267		L	O	2	b	E	N	A	4
268		L	O	1	b	E	U	U	1
269		L	O	2	g	E	N	A	1
270		L	O	1	b	E	N	A	4
271		L	O	1	g	E	N	U	1
272		L	O	2	g	E	N	A	2
273		L	O	3	c	E	O	N	2
274		L	O	1	e	E	U	U	1
275		L	O	3	c	E	O	A	2
276		L	O	3	c	E	N	A	3
277		L	O	1	b	E	C	N	5
278		L	O	1	d	M	O	A	1
279		L	O	1	b	E	N	A	5
280		L	O	1	a	E	U	U	3
281		L	O	1	b	M	U	U	4
282		L	O	2	b	U	C	U	4
283		L	O	2	g	M	U	U	2
284		L	O	1	d	E	U	U	2

Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
285		L	O	1	a	E	N	U	1
286		L	O	3	b	U	U	U	4
287		L	O	2	a	E	U	U	1
288		L	O	1	g	O	N	A	1
289		L	O	1	a	E	U	U	1
290		L	O	1	b	E	C	N	5
291		L	O	1	d	M	O	A	1
292		L	O	2	c	E	C	N	2
293		L	O	1	d	M	O	A	1
294		L	O	1	b	E	U	U	5
295		L	O	5	c	E	U	U	2
296		L	O	1	h	E	N	U	-
297		L	O	1	d	E	U	U	2
298		L	O	1	a	E	N	A	1
299		L	O	2	g	E	O	A	2
300		L	O	3	b	U	U	U	4
301		L	O	2	d	E	O	A	1
302		L	O	2	g	E	U	U	1
303		L	O	1	a	E	N	U	4
304		L	O	1	a	E	N	A	1
305		L	O	2	e	U	U	U	4
306		L	O	1	b	E	U	U	6
307		L	O	2	d	M	N	U	2
308		L	O	1	g	E	U	U	1
309		L	O	1	g	E	U	U	2
310		L	O	3	c	E	O	A	2
311		L	O	1	g	E	O	N	2
312		L	O	1	h	E	N	A	-
313		L	O	1	a	U	U	U	4
314		L	O	2	g	E	N	A	2
315		L	O	1	g	U	U	U	1
316		L	O	1	g	E	C	A	1

Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
317		L	O	2	h	E	N	A	-
318		L	O	1	b	U	U	U	4
319		L	O	1	b	E	N	U	5
320		L	O	1	d	O	N	A	2
321		L	O	1	g	U	U	U	2
322		L	O	2	d	O	N	A	2
323		L	O	2	g	M	O	A	1
324		L	O	1	b	E	N	U	5
325		L	O	5	h	O	N	A	-
326		L	O	1	g	E	U	U	1
327		L	O	1	b	E	C	N	1
328		L	O	1	b	E	U	U	3
329		L	O	1	g	E	U	U	1
330		L	O	1	b	E	U	U	5
331		L	O	5	a	E	N	A	4
332		L	O	1	d	E	U	U	1
333		L	O	1	a	E	U	U	4
334		L	O	1	a	E	N	A	1
335		L	O	1	a	E	N	U	1
336		L	O	1	a	E	N	N	2
337		L	O	1	h	E	N	A	-
338		L	O	1	a	E	U	U	4
339		L	O	3	b	U	U	U	4
340		L	O	1	b	E	U	U	5
341		L	O	1	d	U	U	U	4
342		L	O	1	c	E	U	U	1
343		L	O	1	a	E	U	U	4
344		L	O	1	a	E	N	U	2
345		L	O	1	b	E	U	U	3
346		L	O	3	b	E	O	U	3
347		L	O	1	b	E	N	U	4
348		L	O	1	g	E	U	U	1

Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
349		L	O	1	a	E	N	A	3
350		L	O	1	a	E	N	A	1
351		L	O	2	d	E	C	A	2
352		L	O	1	a	E	C	N	4
353		L	O	1	b	E	N	U	4
354		L	O	1	b	E	U	U	4
355		L	O	3	b	U	U	U	4
356		L	O	1	a	E	N	A	1
357		L	O	2	g	E	U	U	1
358		L	O	1	b	E	O	U	4
359		L	O	3	a	E	O	A	4
360		L	O	2	g	U	U	U	1
361		L	O	2	g	E	U	U	1
362		L	O	1	a	E	N	U	1
363		L	O	1	b	E	U	U	5
364		L	O	1	b	E	U	U	5
365		L	O	1	g	E	U	U	1
366		L	O	1	b	E	C	N	3
367		L	O	1	b	E	U	U	5
368		L	O	5	a	E	U	U	1
369		L	O	1	g	O	N	U	2
370		L	O	2	b	E	U	U	3
371		L	O	2	h	U	U	U	-
372		L	O	2	d	E	N	U	1
373		L	O	1	b	E	N	A	4
374		L	O	2	b	E	U	U	3
375		L	O	1	g	E	U	U	1
376		L	O	3	b	U	U	U	4
377		L	O	1	b	E	U	U	4
378		L	O	2	b	M	C	N	4
379		L	O	1	a	O	N	A	1
380		L	O	1	b	E	N	A	3

Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
381		L	O	1	b	E	U	U	5
382		L	O	1	a	E	U	U	5
383		L	O	1	a	E	N	A	1
384		L	O	2	d	U	U	U	2
385		L	O	2	g	E	U	U	2
386		L	O	2	c	E	U	U	3
387		L	O	1	a	E	N	A	1
388		L	O	3	b	E	U	U	3
389		L	O	3	b	E	U	U	4
390		L	O	1	e	E	U	U	1
391		L	O	1	c	E	U	U	5
392		L	O	1	e	U	U	U	1
393		L	O	1	e	U	U	U	1
394		L	O	2	b	U	U	U	4
395		L	O	1	b	E	C	U	4
396		L	O	1	d	M	O	N	2
397		L	O	1	a	E	N	A	1
398		L	O	1	c	E	U	U	4
399		L	O	2	b	E	N	U	5
400		L	O	1	g	E	U	U	1
401		L	O	1	d	E	U	U	2
402		L	O	1	a	E	N	A	1
403		L	O	2	b	E	N	U	5
404		L	O	1	c	O	N	U	2
405		L	O	1	b	E	U	U	5
406		L	O	1	a	E	N	U	1
407		L	O	1	b	U	U	U	4
408		L	O	3	b	E	C	U	4
409		L	O	1	d	M	O	N	2
410		L	O	2	b	U	C	U	4
411		L	O	1	b	O	O	U	4
412		L	O	1	a	E	N	U	1
413		L	O	1	a	E	N	U	1
414		L	O	1	a	U	N	U	1
415		L	O	1	b	E	C	N	4
416		L	O	2	g	E	N	A	2
417		L	O	2	c	E	U	U	3
418		L	O	1	e	E	U	U	1
419		L	O	1	b	E	U	U	3
420		L	O	1	g	E	U	U	1
421		L	O	1	g	E	U	U	1
422		L	O	1	d	M	O	A	2
423		L	O	1	b	E	U	U	6
424		L	O	1	g	E	U	U	1
425		L	O	1	a	E	N	A	1
426		L	O	1	b	U	U	U	6
427		L	O	2	g	E	U	U	1
428		L	O	1	g	U	U	U	1
429		L	O	3	a	E	O	A	4
430		L	O	5	h	O	N	A	-
431		L	O	1	d	E	U	U	1
432		L	O	2	g	E	C	N	1
433		L	O	1	g	E	U	U	1
434		L	O	1	b	E	U	U	5
435		L	O	1	g	E	U	U	1
436		L	O	3	c	E	U	U	1
437		L	O	1	b	E	N	U	5
438		L	O	2	a	E	N	U	6
439		L	O	1	a	E	U	U	3
440		L	O	5	c	E	O	A	2
441		L	O	2	g	E	O	A	1
442		L	O	1	b	E	N	A	7
443		L	O	2	b	E	U	U	5

Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
444		L	O	1	h	U	U	U	-
445		L	O	2	c	E	O	A	1
446		L	O	3	d	E	O	A	1
447		L	O	1	b	E	U	U	5
448		L	O	2	d	E	U	U	1
449		L	O	3	c	E	O	A	2
450		L	O	1	b	E	U	U	4
451		L	O	1	d	E	O	A	1
452		L	O	1	b	E	C	N	1
453		L	O	1	a	E	U	U	2
454		L	O	1	a	E	N	U	1
455		L	O	1	b	E	U	U	5
456		L	O	2	b	E	O	A	5
457		L	O	2	c	E	N	A	1
458		L	O	1	g	E	N	A	2
459		L	O	1	a	E	N	A	1
460		L	O	2	b	E	N	A	5
461		L	O	1	a	E	N	A	1
462		L	O	2	d	E	U	U	1
463		L	O	1	d	E	N	A	5
464		L	O	2	b	E	N	A	5
465		L	O	1	g	E	N	U	2
466		L	O	2	a	E	N	A	1
467		L	O	1	a	E	N	A	1
468		L	O	2	a	E	N	A	1
469		L	O	1	g	E	N	A	2
470		L	O	1	a	E	N	A	1
471		L	O	1	a	E	N	U	1
472		L	O	1	d	E	U	U	4
473		L	O	2	a	E	N	A	1
474		L	O	1	a	E	O	N	1
475		L	O	1	c	O	N	A	1

Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
476		L	O	1	g	M	O	A	1
477		L	O	1	a	M	O	A	1
478		L	O	1	g	E	N	A	2
479		L	O	1	b	U	U	U	[illegible]
480		L	O	1	a	E	N	U	1
481		L	O	1	a	E	U	U	1
482		L	O	1	g	E	N	A	2
483		L	O	2	b	E	N	A	5
484		L	O	1	b	E	U	U	4
485		L	O	1	g	E	N	N	2
486		L	O	1	a	E	N	U	1
487		L	O	1	d	U	U	U	2
488		L	O	1	c	O	N	A	6
489		L	O	1	b	E	U	U	4
490		L	O	1	c	O	N	A	6
491		L	O	1	g	O	N	A	2
492		L	O	1	a	E	N	A	1
493		L	O	1	g	E	N	A	2
494		L	O	1	a	E	N	A	1
495		L	O	1	g	E	N	A	2
496		L	O	1	c	E	N	A	3
497		L	O	2	d	O	N	A	3
498		L	O	2	g	E	U	U	1
499		L	O	2	e	O	N	A	1
500		L	O	1	g	O	N	U	2
501		L	O	1	a	E	N	U	1
502		L	O	1	a	E	N	A	1
503		L	O	1	g	E	O	N	2
504		L	O	3	d	O	N	A	5
505		L	O	1	g	E	O	N	2
506		L	O	1	c	E	N	A	3
507		L	O	1	d	O	N	A	3

Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
508		L	O	1	a	E	N	U	1
509		L	O	1	a	E	N	A	1
510		L	O	1	g	E	O	U	2
511		L	O	1	a	E	N	U	1
512		L	O	1	c	E	U	U	5
513		L	O	1	g	O	N	N	2
514		L	O	1	d	E	N	A	5
515		L	O	3	d	O	N	A	3
516		L	O	2	d	O	O	A	1
517		L	O	2	b	E	U	U	3
518		L	O	1	d	E	U	U	2
519		L	O	1	a	E	N	A	1
520		L	O	1	d	O	N	A	2
521		L	O	1	a	E	N	A	2
522		L	O	1	a	E	N	A	1
523		L	O	1	h	O	N	A	-
524		L	O	1	a	E	N	A	5
525		L	O	1	a	E	O	N	2
526		L	O	2	b	E	N	A	5
527		L	O	1	a	E	N	A	1
528		L	O	1	b	E	N	A	5
529		L	O	1	g	E	O	U	1
530		L	O	1	a	E	N	U	1
531		L	O	1	g	E	N	U	2
532		L	O	1	g	E	O	U	1
533		L	O	1	g	U	U	U	2
534		L	O	1	g	E	U	U	1
535		L	O	1	b	E	N	A	5
536		L	O	1	a	E	N	U	1
537		L	O	1	a	E	O	U	4
538		L	O	1	g	O	N	A	2

Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
539	S	L							
540	S	L							
541	S	L							
542	S	L							
543	S	L							
544	S	L							
545	S	L							

Appendix A-III

(REFERENCE 9: 1972 UPDATE)

Appendix A-IIIa

BASIC DATA TABULATION

Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
1	--	Unsuccessful Launch				Preliminary indication was that a nitrogen jet system in the second stage of the launch vehicle did not maintain attitude stability during the coast phase of the launch.
2	<	Unable to command a stellar photo experiment from channel 1 or 2 to channel 3.	Worn motor in the experiment prior to launch.	Loss of some data.		
3	<	Substantial and increasing signal degradation of filter wedge spectrometer.	Ice deposit on cooled balometer detector	Loss of data.	New cooler design required for new applications.	
4	<	Digital output from one spectrometer in stellar photo experiment is faulty.	Open circuit in a welded unit is suspected.	Experiment operation not significantly affected.		
5	<	Experiment package temperature too low.	Heater failed to cycle on until the ninth orbit due to transmitter interference.	Negligible; temperature stabilized within specification by orbit 16.		
6	<	An explosive valve in the ordnance system failed to fire.	Unknown	None, because the redundant explosive valve did work.		
7	<	The pitch sign bit of the pitch aspect sensor does not change state at the terminator.	Silicon solar cell detector had open circuited due to launch stresses.	No degradation in experiment data.		The type of bond used in this cell has been discontinued by the manufacturer.
8	<	Telemetry monitoring internal power system temperature intermittent.	Unknown--might have been launch associated.	Slight.	Telemetry channels reassigned to maintain the temperature monitor.	
9	<	Telemetry indicated y-axis attitude control boom not locked.	A telemetry failure assumed for experiment data indicates attitude control is satisfactory.	Negligible.		
10	<	One of two tape recorders provided no output in playback.	Attributed to launch shock.	Loss of experiment data and operational flexibility.		

Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
11	•	Spacecraft spin rate excessive upon orbit attainment.	Yo-yo design mechanism did not function properly for unknown reason.	Some degradation in experiment data and generally lower satellite temperatures.	Corrective maneuver instituted in a few days and completed in about 2 weeks.	
12	•	Loss of one of four channels in a stellar photo experiment below -10°C.	Unknown	Some loss of data.		
13	•	The digital solar aspect sensing system indicated a physically impossible variation of three degrees between readings.	Unknown	Negligible since this system is not generally used after lock-on in any event.		
14	•	Filter wheel on one of four channels in a stellar photo experiment skips detents.	Detent worn prior to launch.	Some loss of data.		
15	24	No telemetry received regarding momentum wheel assembly bearing noise.	Unknown	No serious mission degradation.		
16	100	Unwanted 8 KHz modulation mixed with 64 KBS data.	Unknown	Minor due to corrective action.	Redundant master oscillators and redundant high frequency timing units both switched which removed the problem.	
17	120	Subcarrier oscillator shifted to and hung up at the lower band edge for a few seconds on two different occasions.	Unknown--might be related to command and other up link difficulties.	Not serious.		
18	120	Three command errors.	Unknown.	Not serious.		
19	192	A 625 Hertz interference signal observed on the transmitted video from a television camera.	Unknown	Not serious.		This problem recurs approximately every two or three weeks.
20	198	Ultraviolet sensor diffuser did not deploy completely to the stored position.	Thermal warping of diffuser frame under South Pole conditions of illumination caused diffuser to bounce off magnetic stops.	Loss of experiment data.	Add a telemetry channel to monitor status and commands to store diffuser if not stored two frames after deploy sequence.	

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
21	216	One cell in command storage unit does not execute or verify stored commands.	Unknown	Minimal due to reprogramming.		
22	223	A discrepancy noted between the visible and infrared light levels from two scanning radiometers.	Unknown	Not serious.		
23	240	One detector failed in the main cosmic ray telescope experiment.	Unknown	Essentially one of 13 experiments failed.		
24	240	Noise spike consistently appears on telemetry read out.	Bad spot on tape due to excessive silicone lubricants in tape binder.	Tape used in follow-on units to be of a new type.	Tape used in this unit was type 617.	
25	252	The video output from the tape recorder used with a scanning radiometer was unstable.	Unknown	Negligible as it cleared up in a day.		
26	288	Hang up in the command memory.	Ground interference.	Not serious.	Design modified on later units to preclude this anomaly.	
27	336	Data dropouts and low level oscillation on three of 12 channels of the synchronous demodulator of an infrared spectrometer experiment.	Intermittent open-circuited solder joints where port leads join the printed circuit boards.	Intermittent loss of small amount of data.	New construction techniques to be used on future modules.	Identical problem was observiced on the prototype during ground testing.
28	336	The surface barrier detector of the charged particle portion of a solar x-ray monitor experiment became very noisy.	Unknown.	Loss of experiment data.		
29	360	Infrared spectrometer experiment field of view partially obstructed causing loss of 10 percent of experiment data.	Optical-mechanical design oversight causing small protrusion of beam baffle into the optical path.	Negligible effect on total mission.	Problem could be readily resolved by redesign.	Should have been detected on the ground but testing was inadequate.

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
30	410	Abnormal brush wear on two momentum wheel assembly motors.	Unknown	Some redu[illegible] tion and q[illegible] tude contro[illegible]		One brush completely gone at approximately 2,000 hours
31	504	Abnormal brush wear on the motor of one of two momentum wheel assemblies.	Unknown	No significant [illegible]		
32	552	A failed mispoint sensor of a coronagraph experiment inhibits the coronagraph sequence.	Unknown	Negligible due to manual override of the sensor.		
33	576	Spacecraft moved to southeast instead of west during an attitude correction.	Unknown	Not serious		
34	590	Extraneous switching of two power regulators.	Unknown	Negligible		
35	598	The mirror assembly of one of two redundant scanning radiometers stopped scanning.	Unknown	Negligible due to redundancy; without redundancy this would have caused an approximate 33 percent degradation in spacecraft capability.		
36	624	150 feet deployable antenna will not extend more than 80 feet	Unknown	Serious degradation in the quality of some experiment data.		
37	624	Experiment in detector current 120 ma above normal.	Unknown	Loss of experiment data.		
38	648	Data dropouts on one at 12 channels of the synchronous demodulator of an infrared spectrometer experiment.	Intermittent open-circuited solder joints where part leads join the printed circuit boards.	Intermittent loss of a small amount of data.	New construction techniques to be used on future modules.	Identical problem was observed on the prototype during ground testing.

Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
39	696	Aluminum filters in coronagraph experiment causing rapid loss in sensitivity.	Unknown	Experiment lost.		
40	750	The amplitude of the neon reference in an infrared interferometer spectometer experiment decreased about 10 percent.	The neon detector (silicon diode) is degrading due to energetic particle bombardment.	Not serious.		
41	792	Vertical interference bars appearing are television pictures.	Determined not to affect life of camera or utility of pictures.			
42	836	Sinusoidal modulation of one telemetry channel-monitoring momentum wheel motor voltage.	Unknown	Not serious by itself.		Disappeared within 3 weeks.
43	920	The scan angle of an earth viewing mirror of an IR interferometer spectrometer experiment decreased from 4.8 to 4.1 degrees (15 percent).	Most probable cause is a gradual magnetizing of the ball bearings in the torquer due to the alignment of the ball bearings in the field of the fixed magnets of the torquer.	Some degradation to this experiment.		
44	1032	Interference on data from high data rate tape recorder.	Flutter caused by vibration of unsupported tape lengths excited by planetary noise in record mode.	Not too severe.	Flutter compensation circuits (z-axis) installed in ground station.	
45	1090	One cell in command storage unit does not execute or verify stored command.	Unknown	Minimal due to redundancy and reprogramming.		
46	1135	Subcarrier oscillator did not drop out until 13 seconds after it was supposed to.	Unknown	Not serious.		

Index	Anomaly Time (hours)	Anomaly: Description	Anomaly: Cause	Anomaly: Mission Effect	Corrective Action if known	Remarks
47	1248	Camera output of 1 of 4 stellar telescopes degrading.	Aging Vidicon tube.	Loss in data quality.		
48	1296	Solar electron detector experiment cannot be commanded on.	Unknown problem with internal (to the experiment) power supply.	Loss of the experiment.		
49	1486	Recorder ran continuously not having received the requisite stop signal.	Unspecified fault in the television camera controller.	Negligible, fault was overcome by switching between cameras.		According to the source data: the fact that no further failures have been observed can only be traced to the "innate perversity of inanimate objects."
50	1615	The temperature monitor associated with the calibration mirror of a selective chopper radiometer experiment failed.	Catastrophic thermistor failure.	No detrimental effects on experiment operation.		Failure occurred coincidental with a calibration cycle.
51	1680	Several nonnominal interrogation lengths observed in the data and ranging module of an interrogation recording, and location experiment.	Unknown	Negligible		The anomaly had been observed in ground test.
52	1752	High voltage power supply internal to a stellar photo experiment failed.	Poor potting of the power supply.	Loss of filter and aperture stepping capability for the experiment.		
53	1848	Inoperative camera associated with 1 of 4 stellar telescopes.	Gassy Vidicon due to damage prior to launch and/or wearout due to improper operation.	Loss of data.		
54	2058	Optical end-of-tape switch failed to turn off recorders as required.	Basically unknown but conjectured to be an intermittently opening diode emitter, photo transistor, or other circuit component, including wire.	Negligible, since command backup instituted.		
55	2160	Attitude control momentarily lost.	Sunlight entering the horizon scanner--a design problem.	Slight		

Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
56	2160	Noise spikes on the data from one of two PCM tape recorders.	Unknown	Negligible		
57	2184	Spacecraft suffered loss of pitch lock.	Assumed due to a stalling momentum wheel which in turn might have been caused by a motor brush momentarily binding the armature/fly wheel assembly.	Negligible as lock was reacquired in less than 15 minutes.		
58	2256	Loss of a solid state detector in an unidentified experiment.	Unknown	Loss of 1 of 6 prime experiments.		
59	2264	Pitch lock control lost.	Failure in the motor of one of two momentum wheel assemblies ascribed to internal motor contamination, resultant heat, etc.	Loss in flexibility of operation although the other momentum wheel assembly can maintain pitch lock.		
60	2340	Interference lines noted in scanning radiometer infrared data.	Unknown	Not serious.		
61	2376	Clock upsets	Transient on oscillator power supply exceeded four volts peak-to-peak.	No significant degradation.		
62	2400	Yaw mode in the attitude control system changed to gyro.	Command transient.	Negligible	Yaw mode restored by command.	
63	2492	Subcarrier oscillator shifted to and hung up at the lower band edge for a few seconds on three different occasions.	Unknown	Not too serious.		
64	2496	State of charge unit shifting counts erroneously.	Design deficiency.	Not too serious.		
65	2496	Camera output of 1 of 4 stellar telescopes degrading.	Aging Uvicon tube.	Loss in data quality.		

Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
66	2647	Irregularities in the earth scanning mirror of the IR interferometer spectrometer.	Unknown, but occurs at minimum housing temperature, 6 to 8 minutes after earth day.	Not too serious.		
67	2664	Unuseable data on PCM tape recorder from one playback.	Unknown	Some loss of data.		
68	2832	Unuseable data on PCM tape recorder from one playback.	Unknown	Some loss of data.		
69	2856	Complete saturation of 1 of 12 channels of the synchronous demodulator of an infrared spectrometer experiment.	Assumed to be an opened solder point.	Loss of some experiment data.	New construction techniques to be used on future modules.	Similar problem was observed on the prototype during ground testing.
70	3048	Loss of spacecraft command capability for 8 hours.	Failure of capacitor.	No long term effects.	Design checks and task instituted for follow-on units.	May be related to or the same as a later anomaly on this spacecraft.
71	3096	Partial loss of video in picture readout.	Unknown failure in television camera electronics.	Degradation in overall mission data.		
72	3576	The minus 24.5 reference voltage began fluctuating.	Unknown malfunction in a voltage regulator.	Not too serious.		
73	3600	Transmitter shut down prematurely on two readout attempts.	Unknown	Negligible, third try and all subsequent attempts have been successful.		
74	3920	An S-band transmitter continued transmitting when the RSD tone was dropped by the ground station contrary to normal operating procedures.	Attributed to some unknown ground RF transmission with characteristics of the FSK tone.	Not serious		
75	4000	Entire spacecraft about 4°C warmer than expected.	Unknown	No nominal response of some experiments but no serious mission degradation.		

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Index	Anomaly Time (hours)	Anomalies			Corrective Action (if known)	Remarks
		Description	Cause	Mission Effect		
76	4032	Temperature of the momentum wheel assembly rose sharpely.	Attributed to contamination within the motor;	Required operating the momentum wheel assembly at reduced speeds thereby reducing data quality, etc.		
77	4036	No data received from an incremental tape recorder upon playback.	Unknown	Loss of secondary sensor data--about 10 percent of total spacecraft data return.		
78	4056	Noise level from the yaw gyro ranged from 200 to 400 volts.	Unknown	Not serious		
79	4224	Count rate of spectroheliograph experiment fluctuated, then went to zero.	Unknown	Loss of experiment.		
80	4272	Loss of spacecraft command capability for 10 hours.	Shorted capcitor	No long term effects.	Design checks and tests instituted for follow-on units.	May be related to or the same as an earlier anomaly on this spacecraft.
81	4370	Timer failed to shut off wideband transmitter when desired.	A degraded wet tentalum capacitor is suspected.	Negligible due to command override of timer.		
82	4560	Extra pulses noted on one of three subcarrier oscillators after termination of FSK tone by ground station.	Unknown	Not serious.		
83	4640	Command decoder activated between command sequences.	Extraneous signal or noise pulse of unknown origin.	In spite of the anomaly all commanding proceeded normally.		
84	4968	No response to a command.	Improper use of interpretation of data prior to command transmission.	None		
85	4968	Antenna aspect system television camera shutters remained closed.	Unknown problem with shutter drive.	No serious mission effect.		
86	5040	Coherent noise from tape recorder used to store data from a scanning radiometer.	Noise is being generated by the tape capstan assembly in the recorder.	Not too serious.	A "fix" developed on the ground which cancels out much of the noise.	

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
87	5060	Attitude control in pitch lost.	Failure in the motor of the momentum wheel assembly caused by brush debris, resultant temperatures, motor seizures, etc.	Loss of all primary data.		Redundant momentum wheel assembly had failed earlier for essentially the same cause.
88	5640	The inner gimbal in one of four startracker channels temporarily stuck.	Possibly a wear related detent on the gimbal.	Not serious.		Investigation of similar units on the ground undertaken.
89	5736	Two bit positions in second half of data storage function failed.	Transistor (2N2412) failure.	Some loss of data.		
90	6072	The outer gimbal in one of four startracker channels stuck in position.	Loss of gimbal stop pulse	Not too serious.		
91	6072	Camera output of one of four stellar telescopes degrading.	Aging Uvicon tube.	Loss in data quality.		
92	6216	Degraded performance in pitch axis.	Rate and position sensor gyro failure after nominal operational life exceeded.	All data affected somewhat.	Operational changes effected to mitigate worst effects of the anomaly.	
93	6330	An extraneous readout was received from the digital solar aspect indicator.	A transient pulse in the associated electronics.	Occurred only once and even if it were recurring no data would be lost.		
94	6504	Attempted transmitter readout was short, no phase lock and no apparent drop in RF.	Unknown	Negligible, next try a success on all counts.		
95	6570	Some degradation noted in both television cameras on this spacecraft.	Increased temperature and aging effects.	Some loss in data quality.		
96	6624	Excessive noise on high data rate tape recorder affecting all channels except time code.	A bearing on the planetary shaft believed to be the noise source.	Substantial data degradation.	Bearing inspection and acceptance procedures reviewed for possible improvement on future systems.	

Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
97	6720	The output of the high voltage power supply internal to an ultraviolet polychromator experiment increased to 5 kv and then stabilized.	Unknown	Increased stress on the experiment.		
98	7135	Incremental tape recorder provided no useable data during playback.	Slippage of the tape drive-stepping function while in the record mode.	Catastrophic tape recorder failure resulting in approximately 10 percent loss in total spacecraft capability.		
99	7390	Abrupt video dropout for 4.5 seconds.	Unknown	Not serious.		
100	7392	Startracker lost star presence during several spacecraft slews.	Possibly caused by spacecraft power variations.	Not serious.		Flutter and wow did not drop out.
101	7480	Tape recorder exhibited rapidly decreasing play back duration until no data were received at all.	Unknown	Loss of substantial quantities of data.		
102	7500	The forward and reverse bits of a zodiacal light observatory assembly coming up "1" periodically.	Unknown but associated with a particular printed circuit board.	None, performance of the is not affected.		
103	7704	Data programming system won't switch from playback to record.	Unknown	Loss of experimental data and operational flexibility.		
104	7800	Spurious RF signals twice commanded the spacecraft unintentionally.	Transmission of commands to other satellites combined with fortuitous unknown direction	Negligible		
105	7896	Startracker inner gimbal sticking in position temporarily.	Unknown	Not too serious.	Later units checked thoroughly.	
106	8112	Attitude perturbations in pitch, roll, and yaw.	Initial analysis indicated a "possible" electrical malfunction.	Significantly degrading		

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
107	8115	Video tape recorder failed during playback.	Most likely cause is a failed negator spring or drive belt of the tape transport mechanism.	Substantial loss of scientific data.		
108	8136	Low energy particles detector experiment became inoperative after having been somewhat degraded for months.	Unknown	Loss of the experiment.		
109	8140	Incorrect command executed.	Voltage transient operating on stored command suspected.	Negligible		
110	8232	Solar aspect indicator failed.	Unknown	Apparently not too serious to judge by subsequent spacecraft operation.		
111	8250	Signal outputs from two channels of selective chopper radiometer became very noisy.	Unknown	Loss of data from these channels.		
112	8568	Small but notable black level increase on one of two television cameras.	Unknown	Negligible since little change in the actual picture dynamic range can be detected when observing the average picture.		
113	8616	Photometer shutters on backscattering ultraviolet experiment did not return to normal data mode after calibration on four occasions.	High voltage indicates shutters were incorrectly positioned; otherwise unknown.	Apparently transient and not critical.		
114	8760	Attitude control in yaw lost.	Gyro malfunction in the rate measuring package.	Severe compromise of mission objectives.		
115	8880	Scanning mirror of temperature-humidity IR radiometer stopped rotating intermittently.	Unknown	Not too serious.		
116	8900	One of two PCM tape recorders suffered an increase in current beyond specification in the record motor.	Unknown	Recorder was turned off causing some loss in data and operational flexibility.		

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
117	8976	High data rate tape recorder will not play back.	Bearing failure in the planetary gear.	Significant loss of data.		
118	8976	Startracker inner gimbal sticking in position.	Unknown	Not too serious.	Later units checked thoroughly.	
119	8980	One of three subcarrier oscillators hung up at lower band edge after completing a tape recorder playback.	The end of tape switch did not activate the beacon data relay as required.	None, corrected by ground command.		
120	9336	Startracker twice failed to acquire guide star as required.	Unknown	Not serious.		
121	9500	Data dropouts and low level oscillations on six of 14 channels of the synchronous demodulator of an infrared spectrometer experiment.	Intermittent open-circuited solder joints where part leads join the printed circuit boards in cord wood construction.	Some data loss from the experiment.	New construction techniques to be used on future modules.	Power applied continuously to module to attempt to raise and stabilize its temperature and thus reduce the occurrence rate and/or effect of the anomaly.
122	9550	An unexpected telemetry readout was transmitted.	Triggered by a spurious RF tone.	Not serious.		
123	9648	A low resolution infrared radiometer experiment began experiencing high noise in the sensor data causing mistriggering and aborting of data.	Unknown fault in the radiometer electronics.	Loss of the experiment.		The experiment was turned off approximately 1200 hours later.
124	10000	The bearing temperature in a momentum wheel assembly increased significantly.	Attributed to a slight increase in dynamic loading.	Numerous attempts were made to more precisely determine the cause and/or to lower the bearing temperature resulting in data loss, etc.		
125	10200	"Black" level in one of two television cameras increased significantly.	Unknown, probably related to aging.	Substantial loss in picture quality.		
126	10500	Range rate transponder failed.	Unknown	Loss of both scientific and technical data.		
127	10632	Commands not received at orbital distances exceeding 30 percent or apogee.	Unknown	Some degradation in operational flexibility and data received.		

Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
128	10650	Attitude control in pitch became increasingly difficult until it was impossible at 12,220 hours.	Thermal effects on the motor brushes, armatures, and bearings of the two momentum wheel assemblies until both become inoperable.	Loss of pitch lock and hence of all primary sensor data.		Thermal effects were exacerbated by high operating duty cycles and adjacent components.
129	10800	Digital decoder suspected of translating improper code.	The decoder had operated beyond its design life.	None, since redundant decoder used exclusively for commands.		
130	10820	Housekeeping telemetry indication on one channel varied by a factor of 3.5.	Unreliable sensor.	Not too serious.		
131	11000	Random noise and failure of the ionization chamber in an experiment.	Unknown	Significant data loss.		
132	11496	Command counter jumped 32 counts.	Noise spike.	Minimal		
133	11500	About 18 transmits or "glitches" noted on the pitch and roll fine error channels with resulting fly wheel response.	Unknown	Quite detrimental to mission objectives.		
134	11568	Glitch occurred on address transfer.	Unknown	Not serious.		
135	11600	Tape recorder failed to play back upon command.	Stalled playback motor possibly due to failure of brake to release on command.	Negligible, since subsequent interrogations were successful.	Design changed for next spacecraft in this program.	
136	11880	Data from three channels of an x-ray ion chamber experiment failed to appear.	Unknown	Some loss of data.		
137	12678	Loss of attitude control and horizon scanner video.	Horizon scanner stopped rotating for unknown reason.	Spacecraft motion quite erratic especially during satellite night. Many data transmissions terminated.		Subsequent to failure the scanner temperature rose 13°C.

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
138	12696	Zodiacal light monitor experiment sensitivity is degrading.	Aging photomultiplier tube.	Some loss of data.		
139	12912	A sun shutter in a star tracker unit failed to open.	Unknown mechanical cause.	Apparently not serious.		
140	12936	Clock jumped by 12995 counts.	Noise spikes.	Minimal		
141	13400	End of tape switch failed to turn off transmitter as required.	Unknown	Negligible	Record command sent to perform the desired function.	
142	13680	Intermittent loss of star presence and tracking null in an optical star tracker unit.	Loss in unit sensitivity due to aging.	Not particularly serious.		
143	14000	Degraded quality of television pictures.	Increase in "white" level perhaps associated with aging.	Not too serious.		
144	14100	Intermittent PCM modulation observed on data link.	Spacecraft clock operated intermittently for unknown reason. May be due to a short in a power converter.	Intermittent loss of nearly all spacecraft data.		
145	14220	Four untransmitted commands executed in the spacecraft.	Assumed to be due to signals radiated for an entirely different purpose by other ground stations.	Not severe.		This is a recurring anomaly with very few months completely free of this kind of anomalous commands.
146	14900	Tape recorder dropouts and flutter and wow noticed on video.	Unknown	Slight data loss, problem cleared within a week.		
147	15100	Tape recorder failed to playback upon command.	Stalled playback motor possibly due to failure of brake to release on command.	Negligible, since subsequent interrogations were successful.	Design changed for next spacecraft in this program.	
148	15284	Tape recorder dropouts and occasional noise bursts	Unknown	Slight loss of data.		
149	15400	Realtime and stored video data swamped momentarily.	Unknown	Slight loss of data temporarily.		

Index	Anomaly Time (hours)	[illegible] Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
150	15432	The terminal voltage of one of two batteries dropped and its temperature increased.	Unknown	Some loss of data due to	Reconditioned the battery.	
151	15800	Degraded pictures from both of two television cameras.	Block level increases.	Degradation caused temporary shutdown of the function.		Function reactivated one week later for special hurricane coverage.
152	15969	Television pictures not distinct on one playback.	Unusual interference in a tape recorder.	Negligible		
153	16000	Pitch flywheel stopped rotation.	Unknown. Just prior to stopping the average duty cycle required to maintain speed increased from 20 to 60 percent.	Severe loss to mission objectives.		
154	16500	One of three subcarrier oscillators became noisy and output power decreased.	Unknown	Negligible, due to backup capability.		
155	16632	Substantial degradation and "permanent clouds" from one of two television cameras.	Old age deterioration.	Substantial loss of coverage.		
156	16992	A sun shutter in a star tracker unit stuck closed when in a hot condition.	Unknown mechanical cause	Apparently not serious.		
157	17376	Recycle commands in redundant command storage unit slipped in time 6 minutes during one interrogation.	Unknown	Not serious.		
158	17400	Adhydrone output lower than normal.	Overcharge operation at too high a level.	Not serious.	Operational constraints applied to subsequent operations.	
159	17496	Wideband transmitter output power dropped by 7 watts.	Unknown	Redundant transmitters presented a serious mission effect.	Confidence tests instituted for subsequent units.	
160	17760	Signal outputs from two channels of selective chopper radiometer become very noisy.	Unknown	Loss of these data channels.		

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
161	17760	Signal outputs from two channels of selective chopper radiometer became very noisy.	Due to some unknown malady of a balometer bias converter.	Loss of data from this experiment.		
162	18072	The output of a startracker unit reference amplifier dropped significantly.	Unknown but the tracker exceeded design life.	Slight		
163	18576	Adhydrene output lower than normal.	Overcharge operation at too high a level.	Not serious.	Operational constraints applied to subsequent operations.	
164	18600	Spacecraft time code abruptly upset.	Unknown	Not serious.		
165	18672	Command memory jumped upon execution of a command and then hung up.	Unknown	Apparently correctable.		
166	18960	Tape recorder continued recording between two television pictures.	Unknown	Not too serious.		
167	18982	One of three subcarrier oscillators hung up at lower band edge.	Unknown	Apparently none.		Anomaly continued until the television transmitter was turned off.
168	18984	Loss of synchronization and erratic counter advance in the data handling installation.	Unknown	Severe data degradation.		
169	18990	An extended interrogation of the experiment occurred at one pass.	Unknown	All data and commands lost for one day--negligible.		
170	19147	Tape recorder unable to reach its end-of-tape position.	Slowing tape recorder due to "old age."	Recorder still usable.		Anomaly may be related to occasional tape recorder dropouts.
171	19176	Spectral scan of an x-ray spectrometer increased by ten steps.	Unknown but associated with a microswitch.	Degraded data quality.		
172	19560	Three spurious enable tone commands received.	Unknown, but related to transmissions to another satellite in the same program.	No effect.		

Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		Anomalies				
173	19650	Some loss of contrast in the television pictures from one (of two) cameras.	Conjectured to be caused by aging of the camera.	Not serious.		
174	19699	Solar array drive motor stalled.	Unknown	Serious degradation in power availability.		
175	19728	Calibrations of IR spectrometer are attenuated on some orbits.	Looks like loss of higher order bits, otherwise, cause unknown.	Not serious.		
176	19774	Loss of three of 18 frames of television data on one pass.	Combination of "moon conflict" with temperature problems led to a temporarily bound up shutter	Not too serious.		
177	19944	Loss of unidentified experiment.	Unidentified failure in analog to digital converter.	Loss of one of six experiments.		
178	20490	Loss of five of 36 frames of television data on one pass.	Combination of "moon conflic" with temperature problems led to a temporarily bound up shutter.	Not too serious.		
179	20660	Significant decrease in television picture quality.	Orbital drift of the spacecraft, with age, toward the terminator caused poor picture illumination.	Camera (one of two) turned off resulting in a significant loss of data.		
180	21384	Severity percent of the data from one of two tape recorders not useable.	Worn tape.	Loss of experiment data and operational flexibility.		
181	21768	Tape recorder temperature 15°F colder than specification limit.	Thermostat failure.	No immediate mission effect.		
182	22000	Black level increased in television pictures.	Unknown	Camera (one of two) turned off.		
183	22400	Noisy playback data from one of two tape recorders.	Unknown	Slight loss in data quality.		
184	22560	Detector counts of an ultraviolet polychramotor experiment dropped to zero.	Unknown	Loss of experiment data.		

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
185	23448	The startracker telemetry indicates the unit is off when it is on or off.	Defective telemetry sensing for unknown reason.	Negligible.		
186	23500	Loss of video sensitivity in one of two television cameras.	Increased camera temperature caused by spacecraft orientation.	Not serious, since the other camera has a beneficial orientation.		
187	24480	Two commands executed when only one of the two was transmitted.	Unknown	Not serious.	Falsely executed command de-executed by means of another command.	
188	25080	Two commands executed when only one of the two was transmitted.	Unknown	Not serious.	Falsely executed command corrected with another command.	
189	26160	Tape recorder stopped recording.	Possible loss of lubrication in record motor bearing.	Would have been more severe but for partial redundancy.		
190	26700	Temperature of one of three batteries increased from 29°C to 50°C in about 4 hours, then decreased to a nominal value within one day.	Assumed to be a self-healing short (probably a punch-three of a plate separator which partially shorted a cell) within the battery.	After apparent self-healing the battery resumed accepting charge and delivery power as required.		
191	26712	Black level in television pictures from one camera increased.	Unknown, but degradation from age is a reasonable conjecture.	Negligible due to redundancy and the inconsequential nature of the anomaly.		
192	26808	Hangup in the command memory.	Ground interference.	Not serious.	Design modified on later units to preclude this anomaly.	
193	27240	No data received from one of two tape recorders.	Attributed to a worn belt.	Loss of data and operational flexibility.		
194	27670	Loss of a plasma probe experiment.	Unknown	Significant data loss.		
195	28848	Intermittent shift of command confirm signal.	Unspecified fault in the command receiver.	Not serious.		
196	28872	Tape recorder playback failed to stop between television pictures.	Unknown	Not too serious.		

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Index	Anomaly Time (hours)	[illegible]			Corrective Action (if known)	Remarks
		Description	Cause	Mission Effect		
197	29068	Spacecraft spin problem.	Hang up bit in command programmer register for unknown reason.	Negligible since anomaly resolved by additional commands.		
198	29980	All attitude control and stabilization functions lost.	Unknown	Half the year the spacecraft is inoperable due to concomitant power loss and at least half the experiments would provide useless data even if there were sufficient power.		Malfunction looks as though power were lost to the commandable ACS power bus.
199	30096	Every third telemetry subcommutator channel read out was zero.	Debris in slip rings.	Negligible, anomaly corrected itself.		
200	30660	After 10 months of spacecraft dormancy a special purpose telemetry transmitter failed to function upon spacecraft reactivation.	Unknown	Loss of 1/12 to 1/16 of telemetry data.		
201	30660	After 10 months of spacecraft dormancy, excessive internal resistance of both batteries was noted upon spacecraft reactivation.	Unknown	Not particularly severe.	Batteries brought up to sufficient charge utilizing commandable option in the charge control circuitry.	
202	33282	Black level in television pictures from one camera increased significantly.	Unknown but degradation of the camera with age is a reasonable conjecture.	Loss in picture quality.		
203	35500	After 6 months of spacecraft dormancy, excessive internal resistance of both batteries was noted upon spacecraft reactivation.	Unknown	Loss of some data over some time periods of interest.	Batteries brought up to sufficient charge utilizing commandable option in the charge control circuitry.	Required 2 weeks to recondition batteries but undervoltages noted sporadically for 2 months of operation.
204	42528	Battery 95°F thermal switch switch failed open.	No assignable cause.	Some protection lost but no other effect after the thermal switch was overridden by ground command. command.		Battery temperature may, in fact, have exceeded 95° F.
205	~	Dropouts occur intermittently at the midportion of playback of an incremental tape recorder.	Unknown but associated with "dirty" tape heads, etc.	Slight loss of data.		

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
206	~	Spacecraft fails about once per month to execute on the first transmission of a command even though it is confirmed.	Unknown	None, commands were retransmitted and executed.		
207	~	Noise, etc. observed on the telemetry data once every 5 or 6 orbits from launch.	Essentially unknown.	No significant reduction in data quantity or quality.		
208	~	Spacecraft nutation noticed about three times per year.	Partially due to "moon conflicts" and partially due to momentum wheel assembly response.	No significant effect on transmitted satellite data.		
209	~	Numerous command difficulties throughout spacecraft life including interference with telemetry system, spurious commands, unexecuted commands, etc.	Basic spacecraft susceptibility to interference, conflicing spacecraft in the area, etc.	Individually each anomaly is essentially negligible; cumulatively they represent a definite degradation in spacecraft capability.		
210	~	Commands destined for another spacecraft are erroneously received and cause problems in the telemetry subsystems.	Basic design problem.	Not serious but recurs during each "conflict" period.		
211	~	Spacecraft nutations noticed every week or so after about 4 months spacecraft operation.	Partially due to external causes, "moon conflicts" etc., and partially due to motor glitches within the momentum wheel assembly.	No significant degradation in mission objectives.		
212	~	Difficulties in routine spacecraft commanding.	At least partially due to noisy propagation conditions.	Not serious since retransmissions assure the desired commands.		Problems seemed worse over the South Atlantic when operational tests were being performed for an upcoming Apollo launch.

Appendix A-IIIb

CLASSIFICATION CODES

Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
1	U	L							
2		L	O	1	g	M	N	A	1
3		L	O	2	g	O	N	A	1
4		L	O	1	g	E	N	A	1
5		L	L	1	g	E	N	A	1
6		L	L	1	f	E	C	N	3
7		L	L	1	g	E	C	A	1
8		L	L	1	b	E	U	U	1
9		L	O	1	b	E	U	U	1
10		L	L	2	b	M	U	A	4
11		L	L	1	d	U	U	U	2
12		L	O	1	g	O	N	U	1
13		L	L	1	d	E	U	U	1
14		L	O	1	g	M	O	A	1
15		L	L	1	b	E	U	U	1
16		L	O	1	b	E	N	U	5
17		L	O	1	b	E	U	U	5
18		L	O	1	a	E	U	U	7
19		L	O	1	g	E	N	U	1
20		L	O	2	g	M	N	A	1
21		L	O	1	a	E	U	U	3
22		L	O	1	g	E	N	U	1
23		L	O	2	g	E	U	U	1
24		L	O	1	b	O	N	A	4
25		L	O	1	b	E	U	U	4
26		L	O	1	a	E	N	A	3
27		L	O	1	g	E	N	A	1
28		L	O	2	g	E	U	U	1
29		L	O	1	g	M	N	A	1
30		L	O	2	d	M	O	U	2

Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
31		L	O	2	d	M	O	U	2
32		L	O	1	g	E	U	U	1
33		L	O	1	d	U	U	U	2
34		L	O	1	a	E	N	U	4
35		L	O	1	g	M	U	U	1
36		L	O	2	f	U	U	U	2
37		L	O	2	g	U	U	U	1
38		L	O	1	g	E	N	A	1
39		L	O	2	g	E	U	U	1
40		L	O	1	g	E	O	A	1
41		L	O	1	g	E	U	U	1
42		L	O	1	b	E	N	U	6
43		L	O	1	g	E	N	A	1
44		L	O	1	b	E	N	A	4
45		L	O	1	a	E	U	U	3
46		L	O	1	b	E	U	U	5
47		L	O	2	g	E	O	A	1
48		L	O	2	g	E	U	U	1
49		L	O	1	b	U	U	U	4
50		L	O	1	g	E	C	N	1
51		L	O	1	g	E	U	U	1
52		L	O	2	g	E	N	A	1
53		L	O	2	g	E	O	A	1
54		L	O	1	b	E	O	U	4
55		L	O	1	d	O	N	A	1
56		L	O	1	b	E	N	U	4
57		L	O	1	d	M	N	A	2
58		L	O	2	g	E	U	U	1
59		L	O	2	d	M	O	A	2
60		L	O	1	g	E	N	U	1
61		L	O	1	a	E	N	U	3
62		L	O	1	a	E	N	U	3

Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII	Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
63		L	O	1	b	E	U	U	5	95		L	O	2	g	E	N	A	1
64		L	O	1	c	E	N	A	3	96		L	O	2	b	M	N	U	4
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66		L	O	1	g	U	U	U	1	98		L	O	2	b	M	U	U	4
67		L	O	1	b	U	N	U	4	99		L	O	1	g	E	N	U	1
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71		L	O	2	g	E	U	U	1	103		L	O	2	a	E	U	U	3
72		L	O	1	c	E	U	U	3	104		L	O	1	a	E	N	A	1
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80		L	O	1	a	E	C	N	1	112		L	O	1	g	E	N	U	1
81		L	O	1	a	E	O	N	4	113		L	O	1	g	U	U	U	1
82		L	O	1	b	E	U	U	5	114		L	O	3	d	E	U	U	2
83		L	O	1	a	E	N	U	1	115		L	O	1	g	U	U	U	1
84		L	O	1	a	O	N	A	1	116		L	O	2	b	U	U	U	4
85		L	O	1	b	U	U	U	1	117		L	O	2	b	M	C	N	4
86		L	O	1	b	M	U	U	4	118		L	O	1	d	M	N	U	2
87		L	O	4	d	M	O	A	2	119		L	O	1	b	E	O	U	5
88		L	O	1	d	M	N	A	1	120		L	O	1	d	U	U	U	2
89		L	O	1	b	E	C	N	4	121		L	O	1	g	E	N	A	1
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91		L	O	2	g	E	O	A	1	123		L	O	2	g	E	U	U	1
92		L	O	2	d	E	O	A	2	124		L	O	2	d	M	U	U	2
93		L	O	1	b	E	N	A	1	125		L	O	2	g	E	U	U	1
94		L	O	1	b	E	U	U	5	126		L	O	2	g	E	U	U	1

Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII	Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
127		L	O	2	a	E	U	U	1	159		L	O	1	b	E	U	U	5
128		L	O	4	d	O	N	A	2	160		L	O	1	g	E	U	U	1
129		L	O	1	a	E	U	U	2	161		L	O	1	g	E	U	U	1
130		L	O	1	b	E	O	U	1	162		L	O	1	d	E	U	U	1
131		L	O	2	g	E	U	U	1	163		L	O	1	c	E	N	A	2
132		L	O	1	a	E	N	A	3	164		L	O	1	a	E	U	U	5
133		L	O	2	d	E	U	U	2	165		L	O	1	a	E	U	U	3
134		L	O	1	a	E	U	U	3	166		L	O	1	b	U	U	U	4
135		L	O	1	b	E	N	U	4	167		L	O	1	b	E	U	U	5
136		L	O	1	g	E	U	U	1	168		L	O	3	b	E	U	U	3
137		L	O	3	d	U	U	U	1	169		L	O	1	g	E	U	U	1
138		L	O	1	g	E	O	A	1	170		L	O	1	b	M	N	A	4
139		L	O	1	d	M	U	U	1	171		L	O	1	g	E	U	U	1
140		L	O	1	a	E	N	A	3	172		L	O	1	a	E	N	A	1
141		L	O	1	a	U	U	U	4	173		L	O	1	g	E	N	A	1
142		L	O	1	d	E	N	A	1	174		L	O	3	d	E	U	U	2
143		L	O	1	g	E	U	U	1	175		L	O	1	g	E	U	U	1
144		L	O	3	b	E	U	U	3	176		L	O	1	g	M	N	A	1
145		L	O	1	a	E	N	A	1	177		L	O	2	g	E	U	U	1
146		L	O	1	b	E	U	U	4	178		L	O	1	g	M	N	A	1
147		L	O	1	b	E	N	U	4	179		L	O	2	g	E	N	A	1
148		L	O	1	b	E	U	U	4	180		L	O	2	b	O	O	A	4
149		L	O	1	g	E	U	U	1	181		L	O	1	b	E	C	N	4
150		L	O	2	c	E	N	U	2	182		L	O	2	g	E	U	U	1
151		L	O	3	g	E	U	U	1	183		L	O	1	b	U	U	U	4
152		L	O	1	g	E	N	U	1	184		L	O	2	g	E	U	U	1
153		L	O	3	d	U	U	U	2	185		L	O	1	b	E	U	U	1
154		L	O	1	b	E	U	U	5	186		L	O	1	g	E	N	A	1
155		L	O	2	g	E	U	A	1	187		L	O	1	a	E	N	U	3
156		L	O	1	d	M	U	U	1	188		L	O	1	a	E	N	U	3
157		L	O	1	a	E	U	U	4	189		L	O	2	b	M	N	A	4
158		L	O	1	c	E	N	A	2	190		L	O	1	c	E	U	U	2

Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
191		L	O	1	g	E	U	U	1
192		L	O	1	a	E	N	A	3
193		L	O	2	b	O	O	A	4
194		L	O	2	g	E	U	U	1
195		L	O	1	a	E	U	U	1
196		L	O	1	b	U	U	U	4
197		L	O	1	a	E	N	U	4
198		L	O	4	d	E	U	U	5
199		L	O	1	b	E	O	A	7
200		L	O	2	b	E	U	U	5
201		L	O	2	c	E	O	U	2
202		L	O	2	g	E	U	U	1
203		L	O	3	c	E	O	U	2
204		L	O	1	c	E	C	N	2
205		L	O	1	b	O	N	A	4
206		L	O	1	a	E	U	U	3
207		L	O	1	b	E	N	U	7
208		L	O	1	d	O	N	A	2
209		L	O	2	a	E	N	A	1
210		L	O	1	a	E	N	A	1
211		L	O	1	d	O	N	A	2
212		L	O	1	a	E	N	A	1

Appendix A-IV

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Appendix A-IVa

BASIC DATA TABULATIONS

Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
1	c	Launch vehicle malfunctioned.	Failure of an IC in pitch channel of autopilot.			
2	c	Launch vehicle malfunctioned. Spacecraft did not orbit.				
3	c	Cesium thruster did not operate.	Unknown.	Did not seriously impair mission since the other thruster (mercury) operated as predicted.		Mission objective was simply to verify the production of thrust by an ion thruster system and the neutralization of an ion beam in space.
4	c	Receiver Local Oscillator drive changed by approximately -0.5 db.	Due to changes in temperature & pressure.	None, change had been expected, although magnitude of change was slightly more than expected.		
5	c	TWT Helix current changed by approximately 0.2 db	Due to changes in temperature and pressure.	None, change had been expected.		
6	c	TWT Drive changed by approximately 0.2 db.	Due to changes in temperature & pressure.	None, change had been expected.		
7	c	Incorrect Computer Command Subsystem Processor B checksum at first "hours pulse" after launch.	Attributed to transient associated with the launch environment.	None-performed normally before and after launch.		
8	c	Array shunt current excessive.	Cause unknown.	Negligible, because design included adequate safety margin.		
9	c	Slow deployment of North Star Array.	Cause unknown.	Negligible, array did deploy.		
10	c	One pair of bumper wings failed to fully deploy.	Probably caused by the possible failure to reinstall a gear lock in one of the spacecraft's wing actuators.	Resulted in the spacecraft revolving about an axis which exposed its telemetry system to solar heat, causing shut-down of one telemetry system.	Communications with secondary experiments suspended to insure maximum data from primary experiment, which continued to yield good data.	

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
11	c	Thermal torques on the booms produced precession of the spacecraft spin axis.	Unknown.	A spin period of approximately 8.4 seconds was established to attain dynamic stability. Spacecraft was supposed to be spin-stabilized with a period of 16 seconds.	The spin control system was used to modify the period as required during the course of the mission.	
12	c	Low pressure in forward Attitude Control Scanner.	Due to a leak which was discovered pre-launch.	Has no effect on Attitude Control System operation.		
13	c	Two telemetry indications (Thermal Shield 5 Temperature and Magnetic Moment Compensation Board 2 Temperature) are defective.	Cause unknown.	No mission effect; temperatures can be obtained by interpolating from other temperature indications.		These two temperature sensors failed prior to launch.
14	c	Attitude Control System 350 ms pulse on system #1 indicated a pulse point shift	Unknown.	Negligible, due to redundancy.		It was never determined whether the shift was permanent. The redundant system #2 was satisfactory and was used thereafter.
15	c	Optical (Solar) Aspect Sensor anomaly.	System appears to have a bit stuck.	Unknown.		
16	c	Attitude Control system malfunction.	Due to microswitch failure.	Not serious.		
17	c	Abrupt decreases in exciter drive, local oscillator drive, and low gain antenna drive.	Attributed to differential cooling of parts of the Radio Frequency Subsystem in entering the space environment; exciter drive degradation was due to "zenering" effects on 2 transistors.	Negligible, due to redundancy.	Exciter drive #1 was used as long as downlink signal strength was adequate; it continued to degrade until it was necessary to switch to exciter drive #2 at end of primary mission. This drive also began degrading, but remained adequate for the extended mission.	
18	c	Unexpected cross-coupling between axes and abnormal sun aquisition followed by excessive limit cycles in pitch and yaw caused excessive gas consumption.	Due to design error: series resistors in Attitude Control System power supply regulator for sun sensor network are too large, causing jets to stay on longer than necessary.	Did not affect primary mission, but increased gas consumption continued throughout, causing termination of extended mission after 18 months of successful operation.		

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
19	c	TV heaters failed to cycle through positions.	Most likely cause is leakage path from heater circuit--raw DC power line to chassis, biasing off Flight Data Subsystem MOSFET's that control TV optics heater.	Negligible, due to functional redundancy.		Optics heater came on at 1,800 hours after launch when direct command DC-64 sent.
20	c	Magnetometer temperature at -54°C, 11.1°C lower than predicted.	An interpretation problem, not a thermal anomaly.	No effect on mission.	Heater function verified by manual command.	Heater function verified by manual command.
21	c	Plasma Science Experiment scan package temperature 5.5°C below specification limit.	Due to combination of supplemental heater size, test errors, lower unregulated DC supply voltage, and the fact that experiment was not on early in the mission.	No effect on mission.		
22	c	Tracker temperature below specification limit of -6.6°C.	Due to fact that tracker dissipates less power when star is acquired than in viewing dark field.	No effect on performance.		
23	c	Tracker failed to acquire Vega in brightness gate 2.	Due to desensitization of tracker by exposure to Earth.	No effect on mission, recovery completed within 24 hours and is operating satisfactorily.		
24	c	Incorrect scan clock and cone commands reversed scan platform operation program.	Was a systems problem.	None, due to corrective action.	Was corrected by software, though was not a software anomaly.	
25	c	Separation switch started sequencer 99 seconds early.	Switch was apparently activated at end of 3rd stage burn, rather than at separation.	No adverse effect because sequencer time margins were designed to be great enough to accommodate such an event.		
26	c	Radioisotope Thermoelectric Generator boom deployment incomplete.	Unknown.	None--full deployment occurred spontaneously 6 hours later before any corrective actions were attempted.		

Anomalies

Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
27	c	Power Subsystem anomaly.	Unknown--nature of anomaly is obscure.	Apparently, no mission effect.		
28	c	More thruster spin coupling than expected.	Attributed [illegible] re-flection, [illegible] error, causing an [illegible] 1.5° in one thrust [illegible].	No significant effect		Also occurred on previous spacecraft
29	c	Solar x-ray monitor data noisy.	Unknown.	No mission impact.		
30	c	UHF Receivers #1 & #2, data dropouts.	Unknown.	Apparently not significant		
31	c	Roll attitude error of approximately -5.7° due to longer than expected nutation damper time constant.	Possibly due to leakage of nutation dampers due to extensive testing on the ground.	None.	Lock-on was commanded and proper attitude established.	
32	c	Attitude Control System-pitch position bias required alternating between -0.6° and -0.2° to keep flywheel speed low.	Unknown; spacecraft designed to require -0.6° pitch bias, in-flight value found to be near -1.0°. No commandable -1.0° step available, hence, alternation between -0.6° and -2.0°.	No impact on mission.		
33	c	High-Resolution Infrared Radiation Sounder-filter chopper motor jitter	Due to gears; known to be present pre launch, but worsened post-launch.	Seriously affected data quality, leading to complete failure of experiment at 8454 hours.		
34	c	Pressure Modulated Radiometer--interference from South Atlantic anomaly (noise spikes).		Not serious.		From launch and throughout mission.
35	c	Limb Radiance Inversion Radiometer outgassing of coolants.	Unknown.	Troublesome, but not major, affected drag factor which caused problems with orbit ephemeris.		From launch and throughout mission.
36	c	Tracking and Data Relay Experiment squib firing affected spacecraft attitude.		Insignificant, errors were corrected.		Also occurred at 58 hours.

Anomalies

Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
37	6.8	Right forward sun sensor registers higher than expected temperature.	Due to location and bonding techniques used for sensor.	... ,ligible.		
38	6.8	Solar paddle temperature excursions greater than expected.	Unknown.	Probably negligible.		
39	24	Battery temperature 7.2°C higher than expected.	Attributed to lapse in testing procedure.	No effect: spacecraft put in more thermally benign attitude for several weeks.		
40	24	Thruster temperature sensor erratic.	Apparently problem in sensor.	No mission effect.		
41	24	Electrically Scanned Microwave Radiometer, FIS data shows banding through middle of picture.	Unknown.	Apparently not serious.		
42	24	Surface Compositio. Mapping Radiometer sun calibrate voltage too low.	Unknown.	Apparently not serious.		
43	24	Control Amplifier 1 in Power Supply Electronics tripping off.	Attributed to design error--time constant too short.	Apparently not significant.	Design modified for subsequent missions.	
44	24	Active Thermal Controller Temperature Sensor, Quad 2, wired in reverse.	Manufacturing error.	None.	Was corrected by entering correct coefficients into computer.	
45	24	Active Thermal Controller Temperature Sensor, Quad 2 readout was 2° C cooler than Quad 1.	Operator error--thermal gradients are normal.	None.		
46	30	Vertical Temperature Profile Radiometer #1 stopped mechanically and electrically.	Unknown.	None, trouble cleared up 3 orbits later, and subsequent tests were normal.		
47	30	Telemetry from command decoder terminated.	Unknown.	A subsequent test was normal.		
48	30	Versatile Information Processor Beacon, RF Transmitter A; Beacon signal fades and drops out.	Believed due to radiation pattern caused by Electrically Scanned Microwave Radiometer antenna.	Apparently not serious, duration of anomaly approximately two minutes.		

Anomalies

Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
49	48	Moon affects earth sensor. Due to design and configuration. Negligible.				
50	48	The 136 MHz Range and Range Rate Transmitter signal strength was 10 dbm.	Unknown.	Limited the lunar ranging, which was considered a major setback.		
51	48	Camera temperatures fell below specification limit of -15° C.	Due to TV heaters not functioning--see #19.	Apparently no effect on mission.		TV heaters came on at 1,680 hours.
52	48	Imaging Photopolarimeter calibration lamp values low by ~10%	Due to pressure change on the high voltage power supply.	Not significant.		It is not clear how many of these Imaging Photopolarimeter anomalies, 181, 403-405, 419, 420 and 507 are cause and effect.
53	59.4	High Data Rate Storage System-B recorder restricted to a 65 minute record period.	Suspect brake release problem on playback motor.	Negligible, storage system-A is available.		
54	60	Spinning sun sensor angle output failed.	Unknown.	Sun pulse not affected, so reasonable attitude data still available.		
55	64	Wide-band Video Tape Recorder #1 failed to execute rewind commands or terminated rewinds prematurely on at least four occasions.	Attributed to loose metal particles contaminating a microswitch.	After special common procedures restored normal operation, operation was restricted to the central 1,200 feet of tape.		
56	65	Orbit Adjust Subsystem firing gave 60% of computed thrust.	Unknown.	Trivial--has been fired 5 times and all longer burns produced very near computed thrust.		
57	72	Magnetometer continuously in calibrate mode.	Attributed to EMI on command lines.	Negligible--corrected from ground.		
58	72	Panoramic Aspect Sensor #2 temporarily lost one-half of its data.	Due to reflection of the sun on 180° of the window.	Negligible due to redundancy.	Panoramic Aspect sensor #1 was commanded on and proved satisfactory.	The Panoramic Aspect Sensor was in the spherical (spinning) mode at the time, and was satisfactory later in the planar (non-spinning) mode.

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
59	72	In main telescope of Solar Flare Isotope experiment, Priority 2 toggle seems to be set by Priority 3 events.	Unknown.	Effect on experiment not known		
60	72	Scanning electrostatic analyzer ion and electron counts too low.	Possible causes were: Experiment's aperture door failed to open, experiment's analyzer plates damaged during launch, or component or solder failure in analyzer's electronics.	Was a significant problem.		
61	72	Magnetometer flipper failed to complete stroke.	Due to cable temperature being too low.	Not serious due to corrective action.	Work-around procedure used to insure adquate power for flips.	Flipper continued incomplete strokes until 2,640 hours when cable warming to -26.1°C allowed complete stroke.
62	75	Propellant fuel tank temperatures toggled abnormally.	Attributed to rapid tank wall temperature changes due to propellant circulation, possibly caused by tape recorder slowing during rewind.	Apparently not serious.		
63	90	Infrared Temperature Profile Radiometer scan errors from 90 hours onward.	Apparently due to design inadequacy in encoder.	Scan mode operation restricted, but instrument still collects good data.		
64	96	C-band transmitter power drop.	Attributed to outgassing of contaminants in epoxy or multipacting.	Negligible.		
65	96	Noise in Electron/Helium/Hydrogen Isotope experiment detector when 136 MHz transmitter is turned on.		Restricts operation of transmitter.	This transmitter only commanded ON during range and range rate and special DST testing throughout rest of mission.	
66	96	Plasma Electrostatic Analyzer data noisy.	Unknown.	Apparently insignificant.		
67	96	All detectors in Electron/Helium/Hydrogen Isotope experiment on except D9, which was saturated.	Unknown.	Apparently not serious--D9 was turned back on later in the mission and operated normally.		

Anomalies

Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
68	96	Communications and Data System--degradation of data.	Unknown.	Negligible due to corrective action.	It was determined that data is degraded unless a 26-meter antenna is utilized.	
69	96	"Faraday Cup" Plasma experiment data noisy with either or both transmitters on.		Experiment only partially operable.		
70	120	Command System malfunction.	Unknown.	Command errors on three occasions.		
71	120	Very High Resolution Radiometer #1 responded improperly to command.	Unknown.	Subsequent tests were normal.		
72	120	Noise signal on data from axial cylindrical electrostatic probe.	Momentum Wheel Assembly vibration caused movement in triaxial cable, which caused the noise signal.	Not significant.	On later missions the axial probes were relocated to a more rigid mount.	
73	-144	Mission thruster pulses as indicated by telemetry.	Attributed to erratic thruster pressure switch, which is used only for assessment of firing, not for control.	No effect, doppler measurements of spacecraft response to thrusting commands indicate that the pulses were not actually missed.		
74	-192	Command failures experienced until gravity-gradient stabilization, when the spin rate was reduced to one rotation per orbit.	Due to the fact that, although two command receivers were employed, the complete command sequence must be received by one receiver before it will be executed; at an attitude having significant nulls in the antenna pattern; a spin rate of 12 RPM can "drop" a large portion of the command sequence.	The problem was cleared up when the spin rate was reduced, around 744 hours.		
75	192	Canopus Tracker tracked a particle or series of particles.	Unknown.	Not serious, owing to successful corrective action.	Reacquisition of lock on Canopus was via ground command procedures that included changing the sensitivity setting; this design provision was for just such situations.	Occurred following pressurization of the propulsion system.

Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
76	192	Occasional loss of Yaw Inertial Reference Unit Rate Bias.	Possible causes (1) relay being energized by RFI; (2) a degrading SCR; (3) a failed open capacitor.	Negligible--Polaris Sensor used for Yaw control.		
77	192	Active Thermal Control Temper. ure Sensor, Quad 2, reads negative.	Operator error--reading is normal.	None.		
78	192	Pitch Loop Motor current erratic in Attitude Control System Pitch Control.	Unknown.	Not significant.		
79	200	Solar Experiment Alignment Sensor--A, control AGC signal variations.	It was postulated, that, to some extent, this could be due to the filters over the sensor "eyes" changing their light transmitting characteristics.	Signal level increased over a long period, then decreased gradually, then increased; unit still able to perform required functions		See #239
80	216	Low energy proton/electron experiment failure.	Initial turn on caused permanent malfunction in the 64 level word #189.	Loss of experiment.		
81	216	Scanning electron spectrometer channel A has 1881 counts added to all data.	Unknown.	Negligible--problem had cleared when channel A checked at 1128 hours.		Spectrometer is sensitive to 2.4 kHz rise time and may have cleared due to slight change in rise time.
82	216	Scanning Radiometer Recorder #3 momentary speed increased cause data dropouts.	Due to design error.	Apparently not serious.		
83	240	Main Telescope #1 detector failed.	Unknown.	Not known.		
84	240	Bright particle caused loss of Canopus lock.		No effect on mission.	Roll search to Canopus inhibited by setting of roll search inhibit logic in Attitude Control electronics; corrective action is to send DC-21 to allow roll search.	

Anomalies

Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
85	252	Power transient in wide-band Video Tape Recorder #2.	Attributed to short between T2 transformer taps in tape recorder dc-dc converter.	Disabled tape recorder #2--used tape recorder #1.		
86	264	Momentum wheel assembly #1 pitch loop voltage and current dropped to zero.	Unknown.	Apparently not serious.		
87	288	Stellar reference system sending jumbled messages to earth.	Unknown.	None, alternate approaches possible.		
88	300	Spacecraft bus goes into "soft region."	Effect caused by solar array's characteristic curve entering the "knee" after dawn when the array has replenished the battery.	None--problem went away once extreme pitch angles were corrected.		This effect was known to be possible, but it was thought that there was adequate protection.
89	312	Millimeter wave 20GHz horn antenna TWTA failure.	Cause unknown.	Negligible--the second 20GHz TWTA operates properly.		
90	312	Rate Gyro Assembly #1 roll gyro null high during initial earth acquisition.	RGL #1 degraded during launch or separation.	Negligible due to redundancy.		
91	312	Camera A cathode current low at turn on.	Probably due to leaving TV's power on due to TV heaters not coming on--see #1.	Apparently no effect on mission.	Diagnostic tests run and vidicon beams turned off in Earth-Venus cruise; Television Science power off during Mercury cruise.	
92	333	Return Beam Vidicon failed to respond to "off" command.	Problem believed to be associated with relay that feeds power to the Return Beam Vidicon.	Return Beam Vidicon no longer used.	Vidicon commanded off by alternate commands; since then, mission has been performed with the Multi-Spectral Scanner.	
93	336	Electron/Proton Spectrometer experiment medium energy channel inoperative.	Cause unknown.	No serious effects.		
94	350	Slight TV raster switch.	Due to spacecraft leaving the Earth's magnetic field.	No effect.		

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Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
95	360	Selective Chopper Radiometer--moonlight causes negative shift on some data for approximately 2 days every 400 revolutions.	Attributed to design error.	Not serious.		
96	384	Outer housing temperatures high on Very High Resolution Radiometer recorders #1 and #2.	Unknown.	Apparently not serious		
97	384	Data errors from Memory Programmer 2 in Dual Programmer.	Attributed to manufacturing error--a short circuit in wiring.	Not significant.	In later missions, the welded wire pro...ss was changed.	
98	408	Attitude Control nitrogen gas usage higher than expected.	Initial estimate was based on insufficient data.	No effect.		
99	432	Flight Data Subsystem power-on-reset when gyros turned on by command 7M3, pre-roll control maneuver.	Probably due to random combination of normal 2.4 kHz bus dip at gyro turn on and converted common mode noise in Flight Data Subsystem.	No appreciable effect because functional redundancy provided "work around," otherwise would have been serious.		A power-on-reset also occurred at 8,184 hours.
100	456	Very High Resolution Radiometer recorder motor current increases from 400 mA to 680 mA.	Apparently due to design error.	None, performance considered normal.		
101	480	C-band Earth coverage horn/Prime Focus Feed receive coupling.	Isolution provided by C-band receive switch less than anticipated.	Not serious--additional isolation is provided by Prime Feed Focus polarization switch.		
102	480	TV Relay Experiment negative power spikes.	Unknown.	Negligible.		
103	480	Spacecraft magnet dipole drift test out-of-spec.	Unknown.	None.		
104	480	Solar Proton Monitor #1 failed.	Unknown	No effect on mission, not primary experiment		
105	399	Scanning Microwave Spectrometer, channel unexplainably noisy.	Unknown.	Insignificant, later cleared.		

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Anomalies

Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
106	500	Solar Experiment Alignment Sensor--A sensitive to VHF transmitter.	Thought related to wheel booms; also some evidence that stray light in an experiment's telescope was causing shifts in sensor's elevation collimator channel.	Negligible due to redundancy.		See #174.
107	504	Polarity bit on V4 sec subcom in Attitude Control System Pitch Control. Electronics is incorrect.	Unknown.	Not significant.		
108	528	Solar Array A5 temperature sensor failure (previously intermittent).	Sensors failed--open.	No impact on flight operations.		
109	528	Noisy video pictures on HET (ground problem).	Due to polarity reversal in HET ground antenna feeds.	None.		
110	528	S-band transmitter #2 failed--no output.	Unknown.	Negligible due to redundancy.		
111	528	Shunt dissipator current appears to vary; ~24 hours later variations appeared in battery #1 charge current.	Due to design error in A/D converter.	Apparently no mission effect.		
112	528	Temperature sensor readout negative, should be 40° C.	Attributed to manufacturing error--bonding or harness defects.	None.	It is noted that special care was to be taken on subsequent spacecraft.	
113	528	Wheel Horizon Scanners 1 & 2 Earth times output varied, and output is noisy.	Unknown.	Not signficant.		
114	552	Erroneous Digital Operational Controller, Polaris Sensor roll off-set command.	Unknown.	Negligible.		
115	552	L-band negative power spikes (ground problem).	Due to ground station adjustments.	Negligible.		

Anomalies

Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
116	552	No platform telemetry response to 2 of 8 CC-6 commands.	Unknown.	None.	Cone limits established--see #156.	
117	552	Filament failed in closed-source mass spectrometer ion source.	Attributed to design error; feed through pin fractured.	Not serious, but see #200.	In subsequent missions the design was changed--added sleeve over pin and welded it to pin.	
118	540	Selective Chopper Radiometer--reflected sunlight and earth albedo effect on some data in calibrate mode at high gain.	Unknown.	Not serious.		
119	540	Selective Chopper Radiometer--high radiation flux in the area of the South Atlantic affects some data channels.		Not serious.		
120	576	Use of Surface Composition Mapping Radiometer terminated due to loss of scan mirror sync pulse.	Possibly due to design error.	Problem began as intermittent, then progressed to the point that no usable data could be obtained.		
121	576	Attitude Control System anomaly--spacecraft moved to southeast instead of west.	Unknown.	Apparently none.		
122	576	Attitude Control System Pitch Control malfunction--nutation induced in spacecraft during despin.	Unknown.	Not significant.		
123	600	Miniature electrostatic accelerometer (MESA) failed.	Unknown.	Apparently negligible.		The documentation on this is not clear, and there may be more than one anomaly involved. See #207.
124	624	Electric Field Meter X antenna mechanism will not extend more than 80 feet.	Unknown.	Not clear.		

Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
125	624	Ion Composition Experiment Detector #1 current 120 ma above normal.	Unknown.	Not known.		
126	624	Scanning Radiometer recorder #3 pressure shows decrease.	Unknown.	Apparently not serious.		
127	672	Magnetometer data from z-axis slightly noisier than data from other two axes.	Cause unknown.	Not serious.		
128	672	Solar Cell radiation experiment: erratic data on one channel.	Cause unknown.	Not serious.		
129	696	The 136MHz Range and Range Rate Transmitter and the 140 MHz Transmitter signal strengths were down ~5 db.	Unknown.	Some loss in performance of the telemetry links.		The 136 MHz transmitter signal strength is higher than it was previously--see #50.
130	696	Noise cross-coupling in L-band.	Unknown.	Negligible.		
131	696	Synthesizer interferes with RFI experiment.	Unknown.	Negligible.	Problem avoided by turning synthesizer off during RFI experiment operations.	
132	696	L-band transmitter noise in absence of an up-link carrier.	Cause unknown.	No significant effect on operations.		
133	696	Very High Resolution Radiometer (VHRR) turn-on failure.	The VHRR scan start was intermittent and tended not to start at housing temperatures below 20° C.	Loss of experiment.		Condition known prior to launch.
134	720	Lyman-Alpha Flare Detector failed.	Unknown.	Loss of anticipated data.		
135	720	Unexpected roll bias.	Caused/abetted by SCM Radiometer scan mirror anomaly--see #8.	None; when scanner motor turned off, roll bias returned to within specification.		

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Anomalies

Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
136	744	The Attitude Control System, on the last despin from 0.7 rpm to 0.25 rpm, went into approximately a 30 second steady state firing; the spacecraft spun through zero and up to 6.4 rpm before it could be shut down.	Unknown.	The spacecraft acquired a nutation of 6° half angle during recovery and spin-down to correct spin direction; this did not prevent antenna deployment at 768 hours.		
137	744	Slow battery discharge when it is supposed to be floating.	Attributed to design error; see #10.	No effect since alternate modes of operation maintain battery in charged condition.		
138	768	RFI generated by antenna boom motors.		With degraded VHF antenna patterns, RFI sometimes prevented shut-off commands from being executed.	For all critical deployments/retractions, on-board timer was used successfully as a back-up to ground command for boom motor shut-off.	
139	768	Filament failed in closed-source mass spectrometer ion source.	Attributed to design error, feed through pin fractured	Electrically inoperative (loss of experiment).	In subsequent missions the design was changed--added sleeve over pin and welded it to pin.	
140	792	C-band oscillations (ground problem).	Due to faulty ground instrumentation.	Negligible.		
141	816	X-band transmittter output power drop from 96 to 90 data numbers; several such drops seen since launch, during spacecraft maneuver with transmitter case temperature of 10° C to 15.5° C.	Unknown.	None, power output is still 1.5 db above requirement (6 data numbers = 0.3 db).		
142	816	Tracker failed to acquire Canopus six times.	Marginal acquisition conditions caused by low temperature, prolonged darkness exposure in roll control maneuver and gate calibration accuracy.	Apparently not serious.	Used gate G-2 for future acquisitions after prolonged dark condition.	

Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
143	864	Visible-Infrared Spin-Scan Radiometer: photomultiplier tube #7 failed.	Unknown.	Not serious: the other 7 photomultiplier tubes remain operational and provide degraded but acceptable data.		
144	864	Grating drive in Solar Extreme Ultraviolet Spectrophotometer unable to reach fourth step.	Unknown, but see cause of #145.	Not significant.		
[illegible]	864	Aperature mask in Solar Ext-eme Ultraviolet Spectrophotometer reads "test" intermittently, should read "position 2."	Attributed to design error--incomplete damping of stepping motor. This may be the cause of #144 also.	Not significant.	Apparently the design was changed for subsequent missions: select best motor and extend pulse to 250 ms.	
146	888	Antenna Aspect Camera #2 does not always provide a shut-off pulse to the Antenna Aspect Subsystem processor.	Unknown.	Negligible due to redundancy and effective corrective action.	Although malfunction resulted in incomplete pictures, recovery and reconfiguration by ground command resulted in some good pictures from camera #2; camera #1 was used for the longest sequences.	
147	888	TWT ampl- er showed erratic drops in output power of several db, lasting for several hours.	Unknown.	Negligible due to redundancy.		
148	912	Very High Resolution Radiometer #1 recorder motor current randomly decreases to zero.	Unknown.	Apparently not seriou		
149	943	Flight Telemetry Subsystem subcommutator intermittently gave incorrect readings.	Attributed to loose particle floating about inside a deck switch field effect transistor which periodically shorted or partially shorted it.	None--data affected was not critical, and problem disappeared after 21 days.		
150	1000	Extra "off" command. ... by com- ... Syste	...e to diode short or ...ort across diode in the ...ommand System Power Switching Matrix.	Negligible due to redundancy. "Off" commands issued through the other, redundant matrix.		Without redundancy, problems could have been significant.

Anomalies

Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
151	1008	Tape Recorder failure.	A static charge built up on the tape with no way to dissipate it, and eventually it caused the tape to jam, then break.	Only real-time operation possible.		Was an endless loop recorder.
152	1008	Abnormal backlash in cone slews at 160°.	Unknown.	Apparently not serious.	Cone limits established--see #156.	
153	1032	Attitude Control System loss of control using C-band monopulse as roll/pitch sensor.	Due to procedural difficulties on several occasions; on some occasions apparently due to mechanical distortion of reflector at spacecraft dawn and dusk.	Negligible.		
154	1040	Mars Atmospheric Water Detector--PbS responsivity down 30% from pre-launch values.	Unknown.	Instrument's performance was not altered, only its operating point.		See #182.
[illegible]5	1[illegible]67	Electrically Scanned Microwave Radiometer data dr[illegible]outs for 16 to 64 seconds duration.	Attributed to unknown problem in analog multiplier integrator dump circuit.	None; operation returned to normal.		
156	1086	Scan cone slew sluggish from 150° to 179°.	Unknown.	Apparently not serious.	Cone limits established.	
15[illegible]	1080	Visible-Infrared Spin-Scan Radiometer, Photomultiplier tube #5 arcing.	Unknown.	Placed in standby; apparently no effect on data quality.		
15[illegible]	1080	TR1 and TR2 appear to be reversed in Temperature Sensor.	Attributed to an error in the calibration procedure.	None.	It is noted that calibration techniques were to be improved on subsequent missions.	
159	1104	Failed capacitor in experiment.		Caused loss of experiment, and therefore loss of mission.		Spacecraft had only one experiment, a gamma ray telescope. Spacecraft was turned on 2½ years post-launch for use as a training aid, and all basic subsystems were normal; it had been off about 18 months.

Anomalies

Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
160	1128	Radio beacon interferes with S-band and C-band return link for tracking and Data Relay (T & DR) Experiment.	Unknown.	Negligible.		
161	1128	Boom #4 was deformed in a smooth bend.	Boom may have had an interlock malfunction.	Negligible, good experiment data still being received.		Anomaly confirmed by a series of Antenna Aspect Camera pictures, deformation occurred during the deployment sequence when the spacecraft had large librations.
162	1175	Canopus tracker did a flyback and sweep on certain, specific mode steps.	Unknown.	System performance not affected.		This anomaly exhibited throughout remainder of mission in a predictable fashion.
163	1176	Erratic opening and closing of Active Thermal Controller #4 in Thermal Control Subsystem.	Unknown.	Not significant.		
164	1200	Ion Engine #2 turn-on failure.	Design deficiency.	Experiment impaired, but one engine left.		
165	1200	Time Base Unit #1 runs approximately 5 seconds slow.	Unknown.	Apparently not serious.		There is a redundant unit #2.
166	1246	High-gain antenna drive changed from 84 to 85 DN, low-gain antenna drive changed from 0 to 9 DN.	Due to fault in hybrid cavity or in S-band radiating cavities.	Resulted in drop in RF power.	As an emergency action, special equipment installed in ground stations prior to Mercury encounter to preclude loss of data; check design and fabrication cleanliness on future projects.	
167	1248	One sun sensor has double sun pulse.	Unknown, but occurs over a very limited combination of sun-angles and sun distance.	No effect on mission due to redundancy.		
168	1296	Magnetic Moment Compensation Assembly Pitch Flux density: increase in flux density on charged magnet.	Probably due to sensor drift.	No apparent effect on spacecraft performance		

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Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
169	1296	The +X Electric Field Meter antenna could not be extended beyond 12 feet.	Unknown.	No x-axis impedance measurement for Electrostatic Wave and Radio Noise Experiment.		
170	1296	Detector electronics malfunction: experiment cannot be commanded "on."	5v power supply problem.	Not known if experiment was lost.		
171	1296	Wrong command executed from spacecraft.	Operator error.	None.	Corrective instructions given to operator.	
172	~1300	Battery charger failure.	Unknown.	Redundancy prevented loss of mission, but still serious.	Redundant battery charger utilized, but new operating mode developed to keep at least 1 battery constantly charged so that it could be used to transfer Lander subsystems from Orbiter power to Lander Radioisotope Thermoelectric Generator source.	Original plan was to let all batteries discharge during cruise, but if remaining battery charge had failed, could have resulted in loss of mission.
173	1320	Broken shaft coupling in Extreme Solar Ultraviolet Monitor.	Unknown.	Loss of experiment.	Design was changed in subsequent spacecraft--changed to solid-shaft coupling.	
174	1334	Solar Experiment Alignment Sensor--A failed.	Attributed to a catastrophic short within the unit, which caused unit's fuses to blow.	Not serious due to redundancy.		Without redundant unit B, two experiments could not have been utilized.
175	1350	Limb Radiance Inversion Radiometer encoder asymmetry caused increased number of "filler" bits.	Apparently a mechanical problem.	Caused loss of approximately 25% of experiment data.		
176	1368	Temperature sensor has only 1° C variation.	Operator error-thermistor operation is normal.	None.		
177	1374	Power output of S-band Transmitter A dropped to 0.26 watts.	Unknown.	Insignificant, system performance still exceeds link margin requirements.		Power output of S-band transmitter A was 1.6 watts at launch.

Index	Anomaly Time (Hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (If known)	Remarks
178	1392	Power output of s-band transponders -2 lower than normal.	Unknown.	None.		
179	1440	Star sensor misses more star pulses than it should.	Attributed to calibration procedure error.	Not serious due to corrective action.	Problem can be overcome by using sun sensor instead of the non-redundant star sensor.	
180	1440	Automatic (non-intended) switch from star sensor to sun sensor.	Unknown.	Not serious	Problem can be overcome by using sun sensor instead of star sensor.	See #179.
181	1440	Imaging Photopolarimeter aperture anomalies in a few rolls of data; the "phosphor source" position came into place once every few hundred rolls of Mode 3 data.	Unknown.	Not significant.		See #52.
182	1440	Mars Atmospheric Water Detector - Pb S detector sensitivity down 30% from pre-launch values.	Unknown.	Instrument's performance was not altered, only its operating point.		Also occurred on next spacecraft in this series.
183	1440	Solar array A3 temperature sensor failure	Sensor failed - open.	None.		
184	1440	X-band transmitter temperatures stabilized slightly higher than predicted.	Thought due to lack of previous long term data in the space environment.	None.		See #209.
185	1440	One of two identical, independent ionization chambers sensitive to the 8 to 16 A x-ray spectrum failed.	Unknown.	None, due to redundancy		
186	1464	High Data Rate Storage System - A, data shows flutter at 107 Hz.	Attributed to noisy bearings in tape transport - similar problem occurred on previous spacecraft.	...se of HDR Storage System - A restricted to slinds.		

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Index	Anomaly Time (Hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (If known)	Remarks
187	1488	Spacecraft Propulsion Subsystem (SPS) #2 Primary Valve heaters not functioning	Due to random failure in undetermined part in actuator control electronic driver circuit		Back-up heaters were used.	
188	1488	Fine channel on Ryle-Vonberg Radiometers failed.	Unknown.	Not known, but had block and functional redundancy.		Reed relay has a life time of 10^6 cycles (2,784 hours), see #536.
189	1488	Ions and electrons experiment Ultra Low Energy Telescope (ULET) gas system depleted.	Problem cause is rupture of thin window in proportional counter.	ULET inoperative.		
190	1510	Battery telemetry in Power Supply has intermittent readout level.	Unknown.	Not significant.		
191	1512	L-band/C-band crosstalk modulation observed on C-band downlink in the absence of an uplink L-band signal.	Due to noise in the system.	Negligible		See #130
192	1512	High-gain antenna dish stopped before reaching stop position.	Due to curled antenna cabling wrapped around antenna boom.	Apparently no effect on mission.	High gain antenna dish position limits set to avoid problem, and incremental commands used near limits.	
193	1536	C-band Earth coverage horn/Prime Focus Feed receive coupling.	Isolation provided by C-band receive switch less than anticipated.	Not serious - additional isolation is provided by Prime Feed Focus polarization switch.		See #101.
194	1608	Power Subsystem went from main to standby chain.	Probably due to shorted Dickson 1 N3892 diode in the main booster/regulator.	Not serious due to redundancy, otherwise would have been catastrophic to mission.	Switched to block redundancy, modified in-flight sequence to minimize Power Subsystem stresses.	
196	1632	NET video cross talk.	Possibly due to insufficient selectivity at ground station.	None.	Crosstalk eliminated by using S1.	

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
196	1632	Data Storage Subsystem tape recorder stuck in parking window when commanded low-rate playback.	May be due to 57% to 86% relative humidity in subsystem causing excess catalyst in magnetic heads to come out, reacting with oxide coating and causing sticking.	Apparently not serious due to corrective action.	Corrected by parking on window and exiting with high torque.	
197	1632	High-rate (3.62 Hz) roll gyro oscillation and high gas use.	Probably due to excitation of seventh spacecraft structural mode.	Functional redundancy provided "worn-around," otherwise would have been catastrophic to mission.	Used solar sailing to minimize gas use.	
198	1680	Selective Chopper Radiometer electronics, Field of View Chopper drive; errors ranging from 350 to 650 per orbit.	Believed to be thermally related.	Not serious - error average returned to normal when spacecraft temperature returned to normal.		
199	1752	Visible-Infrared Spin-Scan Radiometer photomultiplier tubes #2, #3, & #4 exhibited 20% degradation.	Unknown.	Apparently no effect on data quality.		
200	~1800	Failed (short-circuited) battery cell.	Unknown, analysis shows that battery thermal history not responsible.	No effect, since battery could perform its function even with two failed cells.		The relation between this anomaly and #137 not clear.
201	1800	Command matrix-B "hot line" causes extra commands when certain other commands are transmitted.	Unknown.	None-corrected operationally.		
202	1800	Digital Solar Aspect Sensor - sensor #2, slight variation in azimuth reading.	Believed to be a function of sun incidence angle.	Not significant.		
203	1800	Tropical Wind, Energy Conservation and Reference Level Experiment/RAMS RFI.	Unknown.	Not significant.		
204	1800	Pressure Modulated Radiometer mirror calibration indicators incorrect for both channels during the day portion of the orbit.	Unknown.	Does not affect data quality.		

Anomalies

Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
205	1824	Command clock: COMSTOR execute time slipped.	Not indicated, but same problems occurred on previous spacecraft.	Apparently overcome.		
206	1870	Slight increase in yaw motor drive duty cycle.	Unknown.	Minor; lasted for several days.		
207	1880	Apparently received data from miniature electrostatic accelerometer (MESA), which indicated unexplained orbital variation whether thruster was on or off.	Unknown.	Apparently none.		See #123.
208	1896	Yaw-roll inertia cross-product out-of-spec.	Problem in dynamics alignment calibration.	Apparently not serious.		
209	1920	X-band transmitter temperatures stabilized slightly higher than predicted.	Thought due to lack of previous long term data in the space environment.	None.		Also occurred on next spacecraft in this series.
210	1968	Erroneous report of synthesizer frequency drift.	Unknown.	Negligible.		Subsequent tests showed synthesizer operation to be well within spec.
211	1968	No output from UHF transmitter #2.	Due to incorrect command sequence from ground (regulator had not been turned on.)	None.		
212	1968	C-band downlink power dropout during Interferometer test.	Attributed to procedural error: saturation of RFI transponder by interferometer c-band uplink, which suppressed the signal being monitored by ground.	None.		
213	1992	S-band subsystem transmitted 9 seconds of data; should have been 322 seconds.	Unknown.	Slight amount of data shown, apparently happened only once.		
214	1992	Spacecraft commanded to zero offset; should be 180°.	Operator error.	None.	Malfunction was discussed with operator.	

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
215	1992	Pitch control Electronics would not lock on settings.	Unknown.	Electrically inoperative.		
216	2011	High voltage short in thruster #2.	Due to fragments of eroded grid material.	Thruster no longer operable.	Both thrusters were restarted repeatedly over the next 3 months in an attempt to clear the shorts, but to no avail; so spacecraft shut down. Short was found to be cleared following spin maneuver in 1973.	Time shown is operating time; calendar time is 6,144 hours.
217	2040	Steady decrease of the calibration-wedge levels in Bands 1 & 2 of the Multi-Spectral Scanner.	Unknown.	Not significant; trend has been reversed to a slight rise.		
218	2160	Array degradation higher than expected.	Possibly due to solar flares.	Insignificant; power requirements can be met.		
219	2160	Battery temperature spread increased.	Unknown.	None; battery performance good.		Temperature spread apparently later returned to normal.
220	2160	Perturbations due to sun glint in the IR scanners.		Not disruptive enough to necessitate single scanner mode.		
221	2160	Attitude Control System gating frequency greater than expected.	Unknown (see remarks).	Insignificant; later leveled off and only 60% of impulse available at launch has been used.		Long term correlation with seasons and angle, short term correlation with payload operation.
222	2160	Star tracker failed.	Unknown.	1 of 2 star trackers; other tracker can perform function, but with reduced duty cycle.		
223	2160	Array degradation slightly more than predicted.	Cause unknown.	Not serious.		
224	2160	Solar Aspect sensor failed.	It is thought that the failure was actually a bad connection somewhere in the harness.	No effect; all required experiment data still required.		
225	2160	High-Resolution Infrared Radiation Sounder: optics contamination.	Apparently due to outgassing due to inadequate "patch cooling."	Seriously affected data quality.		

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Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
226	2184	S-band receiver-2 signal 10 to 50 DBM less than receiver-1.	Unknown; but local oscillator X9 area suspected.	Not significant.		
227	2232	Auxiliary communications oscillator intermittently had ½ cycle offset when operating in one-way mode.	Unknown.	Apparently not serious due to corrective action.	To preclude loss of data, 2-way mode was used with special ground provisions.	
228	2256	Frequency spur in R/T or P/B bands of s-band transponder #1.	Attributed to design error-thermal stress detuning x30 power amplifier.	Not significant.	Design changed for subsequent spacecraft; S-band transmitter retuned for maximum stability.	
229	2352	Magnetometer flipper does not rotate sensor automatically or by command.	Unknown.	Apparently not serious.		
230	2352	4 of 5 Geiger-Mueller tubes in the Charged Particle Counter failed.	Unknown.	Experiment partially operable.		
231	2352	Data Storage Subsystem tape recorder stuck at left end of tape; not in parking window.	Not indicated, but see #196.	Apparently not serious, the same corrective action that was used for #196 was used here.	Parked on window and exited at high torque.	
232	2376	Faulty telemetry monitor for battery discharge current.	Unknown.	Not significant.		
233	2385	Thruster #1 excessive high voltage cycling.	Due to high voltage short, caused by fragments of eroded grid material.	Insignificant; thruster turned off temporarily for 10 hours.		Time shown is operating time, not calendar time.
234	2424	Bottom solar array output saturated.	Unknown.	Not significant.		
235	2450	Canopus tracker tracked bright particles.	Particles thought to have been dislodged from spacecraft.	No effect on performance.		Occurred on three occasions.
236	2544	Visible-Infrared Spin-Scan Radiometer: pre-amps for photo multiplier tubes erratic during eclipse.	Unknown.	Apparently no impact on data quality.		
237	2592	Low level noise from Scanning Radiometer #1.	Ground station error: proper filter not used.	None; not a spacecraft anomaly.		

Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
238	2592	ARP QM Board in Dual Programmer actuated without command.	Unknown.	Not significant.		
239	2736	Solar Experiment Alignment Sensor-B; unexplainable variations in the elevation channel scale factor.	It is postulated that the filters over the sun-looking sensor "eyes" are changing their light transmitting characteristics.	Unit still able to perform required functions.		See #79.
240	2740	Roll gas jet valve leaks manifested by asymmetrical limit cycles in roll.	Attributed to mis-seating of the valve due to particles generated within the valve itself.	Not serious due to effective corrective action.	A complex "work around" procedure was used to seat the valve properly; if this procedure hadn't been successful, the resulting gas depletion would have been a major concern.	See #18.
241	2760	Power from solar array completely "shut down."	Caused by a shorted diode in the power supply electronics.	Complete loss of spacecraft.		
242	2810	UHF receiving antenna intermittently faulty with temperature.	Due to problem in harness or connector.	No mission effect.		
243	2856	Solar panel tilted to 50 degrees, temperature over specification limit of 115°C.	Not known.	Apparently no mission effect.		Peak cell temperature was 113.3°C, average was 126.1°C, flight acceptance temperature was 120°C.
244	2880	Surface Composition Mapping Radiometer scanner assembly motor; variations in motor speed compensations.	Apparently ground attempted to do something the equipment was not designed to do.	Motor designed for gross speed only, so gross speed only to be considered as a "work around" procedure.		
245	2880	Command problems-commands not executed.	Problems possibly due to either (1) clock malfunction, (2) operator error, (3) interference.	No impact on mission objectives.		
246	2904	S-band transponder #1 stayed on after uplink was down.	Attributed to frequency spur--see #228.	None.		
247	2928	Spurious signals caused Meteoroid Detector Experiment event counter to advance periodically.	Unknown.	Not serious: this was one of two redundant channels, second channel adequate for carring experiment.		

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
248	2948	Tracking and Data Relay experiment: problems in loading programmer memory for multiple tracks.	Apparently caused by interference from another spacecraft.	None.	Operational procedure established to provide work around.	
249	2950	Infrared Radiometer--anomalous channel 1 planet and thermal reference readings on at least three occasions.	Unknown.	No effect.		
250	2952	Spacecraft Command Clock drifts 3 set counts.	Operator error--drift rate is within specs.	None.		
251	3000	RFI experiment anomaly.	Open fuse in experiment's power system.	Experiment no longer usable; no consequences to mission.		
252	3000	Selective Chopper Radiometer Channel A, gain decreased and noise increased.	Detector suspected.	Negligible, worked around.		
253	3024	Battery temperatures higher than desired.	Charged to thermal control subsystem.	Apparently not serious.	Condition avoided by use at c/60 charge rate, reduction of shunt dissipation, and restriction of Millimeter wave and spacecraft pointing for 2 hrs./night during winter solstice.	
254	3024	Auroral Particles experiment scanning sensor head mechanically bound.	Unknown.	Experiment is 40% inoperative.		
255	3024	On solar panel tilt to 76°, current differential between panels increased.	Probably a partial failure, for unknown reasons, in section 1 of -x panel.	Cited as "significant problem."	Switched to block redundancy.	
256	3048	Airglow high-voltage power turned off in playback (Ultraviolet Spectrometer anomaly).	Not indicated, but similar problem occurred in subsystem test of Ultraviolet Spectrometer, though not in system tests.	No immediate impact on mission.	Commands will be sent during Mercury encounter to reset Ultraviolet Spectrometer Airglow if off at the time of state change.	
257	3070	Soft X-Ray Background Radiation experiment: vaguely defined anomaly in radiation monitor.	Unknown.	Apparently not major.		

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Index	Anomaly Time (Hours)	Description	Cause	Mission Effect	Corrective Action (If Known)	Remarks
258	3672	Soft X-Ray Background Radiation experiment methane loss rate in proportional counter higher than normal	Attributed to the formation of pin holes in the counter window	Counter could be operated only for interesting target areas, to conserve methane supply		Window is extremely thin [illegible] microns
259	3672	Engine catalyst bed resistance decrease after post-trajectory correction maneuvers. Drop after first maneuver was 16%, after second maneuver, 12%	Unknown	Negligible, resistance [illegible] after [illegible] necessary, and flight [illegible] were less than [illegible] specification		
260	3672	Spurious commands switched Scanning Radiometer modes	Unknown	Apparently no permanent effect		
261	3672	Severe noise on [illegible]-tone command to experiment	Unknown	Apparently no permanent effect		
262	3996	Scanning Radiometer #2 failed.	Unknown	Negligible, Scanning Radiometer could be off [illegible]		
263	3157	Pressure Modulated Radiometer Channel 1 scan failed.	[illegible] that an [illegible] [illegible] [illegible] of [illegible], [illegible] mechanical travel of scan mirror	Not serious, channel 2 still operable, and data from channel 1 [illegible] still obtainable.		
264	3193	Spurious command switched command receiver to prime FM demodulator	Unknown.	None, prime demod. [illegible] allowed to stay on for use		
265	3164	MET-2 driver turn-off intermittent	Driver off-relay tends to [illegible] as in "on" position	None	Problem avoided operationally by disconnecting up-converter, then turning off the MET transmitter to turn MET off	
266	3168	Unexpected changes in star sensor gain setting	Unknown, but occurrence of anomaly during spacecraft [illegible] suggests [illegible] relationship to temperature	Not serious	Apparently setting could be corrected via command	Occurred on at least 26 occasions
267	3192	High-gain antenna boom temperature exceeded specification limit of 30°C.	Unknown, attributed to thermal coatings	Apparently no mission effect		

Anomalies

Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
268	3213	Small excursion of roll drive duty cycle.	Unknown.	Minor, returned to normal after several orbits		See #206.
269	3213	Wide-band Power Amplifier #1 came on with lowered power output.	Unknown.	Negligible due to redundancy--also, power increased so that after 200 orbits was back to post-launch value.		
270	3240	High-Resolution Infrared Radiation Sounder--"bit slip."	Unknown.	Seriously affected data quality.		
271	3262	Wide-band Video Tape Recorder #2 stopped rewind prematurely.	Unknown.	Negligible--unit remains operational.		
272	3288	Spacecraft drawing 87 watts added power; TV heater off.	Suspected cause was booster regulator in the power conditioning equipment.	Not serious due to redundancy.	Switched to block redundancy, array was able to support unplanned load, thus preventing mission failure.	Other symptoms include: Data Storage Subsystem tobbles on and off, no response to DC-43447 commands, X-band spikes, +4V TV power dropped 40W, spacecraft bus temperature increase, and Radio Frequency Subsystem frequency change.
273	3288	X-band transmitter output dropped from 81 to 3 DN.	Possibly due to loss of voltage regulation in chopper transformer circuit, see #32.	None, functional redundancy provided "work-around."	Carrier can be recovered by turning X-band transmitter power off and then back on.	
274	3290	Central Computer & Sequencer loading problems.	Unknown.	Apparently no effect.		
275	3312	No response to command DC-43 (switch traveling-wave tube to low power).	Switches probably have component failure or circuit degradation; also see #32.	Negligible, functional redundancy provides "work-around."	No more DC-42's or DC-43's will be sent.	
276	3404	Ion Engine #1 turn-on failure.	Design deficiency.	Loss of experiment.		See #184.
277	3504	Solar Proton Monitor #2 failed.	Unknown.	No effect on mission, not primary experiment.		See #104.
278	3576	Scanning Radiometer #1 temperature data not tracking properly.	Unknown.	Apparently not serious.		
279	~3600	Magnetometer experiment receiving noise on the 178 MHz channel.	Suspect zero position of magnetometer flipper.	Not known.	Decision made to keep magnetometer at 90° for 90 hours, and at 0° for 6 hours.	

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Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
280	3600	Charged particle counter noise problem.	Unknown.	Data noisy and stopped from GM2A detector.		
281	3600	S-Band Transmitter #1, reduced power output.	Unknown.	Degraded but usable		Redundant unit not available--see #110.
282	3600	Earth Radiation Budget Experiment channel 15 noisy in satellite night.	Unknown.	Insignificant		
283	3600	Electrically Scanned Microwave Radiometer temperatures approximately 5° higher than expected.	Due to perhelion of the earth to the sun.	No effect		Gunn oscillator temperatures appear to be primarily affected.
284	3600	Scanning Microwave Spectrometer, channel 4 space view level degraded.	Unknown.	None, stabilized at 4050 hours.		
285	3600	Earth Radiation Budget Experiment, ± PTM excitation thermistor voltage monitors for sun and earth are out of limits.	Unknown.	Insignificant.		
286	3655	Pitch drive duty cycle increased sharply.	Unknown.	Returned to normal after 15 orbits.		See #206, #268.
287	3672	UHF Transmitter #2 failed.	Unknown.	Negligible due to redundancy.		
288	3672	UHF Receiver #1, no response at initial turn on.	Unknown.	Negligible, redundant UHF Receiver #2 available.		
289	3696	Analog engineering data from Flight Data Subsystem analog/digital converter #2 went to 127 DN.	Apparently due to isolated part failure in the Flight Data Subsystem.		Switched to block redundancy, probably would otherwise have caused l..s of extended mission.	
290	3700	Canopus tracker lost lock, downlink signal disappeared at ground station.	Unknown.	No effect due to corrective action.	Required emergency efforts on the ground: a roll search was commanded and Canopus was reacquired .ive hours later.	
291	3700	UHF Transmitter #1 restricted to low power mode only.	Apparently due to thermal design fault.	Apparently still usable		

Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
292	3720	Line-to-line jitter in video.	Due to problem in Very High Resolution Radiometer processor.	Apparently not serious.		
293	3781	Thruster #1 excessive high voltage cycling.	Due to high voltage short, caused by fragments of eroded grid material.	Negligible, due to redundancy.	Thruster #2 brought into service.	Time shown is operating time; calendar time is 4,056 hours.
294	3816	Momentum control coil telemetry channel stays "on positive."	Due to either open relay or resistor.	Little effect: affects telemetry only, momentum wheel/coil operate normally.		
295	3840	Degradation in thrust levels for all axial thrusters in the precession duty cycle mode.	Apparently due to leaks (see #7), but also pressure drops in propellant supply from such things as restricted filters.	Apparently not significant.		See #296.
296	3840	Increase in spin period (decrease in spin rate) due to thruster leaks.	Due to small leaks in despin thruster, but leaks also detected in precession pair #2 over the next several weeks.	Not sufficient to impact mission.		Occurred during Asteroid belt transit.
297	3875	Prime COMSTOR went to illegal state while redundant COMSTOR being loaded.	Due to ground problem; not a spacecraft anomaly.	None.		
298	3984	Visible-Infrared Spin-Scan Radiometer lubricant build-up.	Not indicated, but also occurred on previous spacecraft.	No impact on data gathering.	"Roll down" procedure eventually instituted to prevent hang-up.	
299	4000	Scanning Modulation Collimator experiment temperature decrease.	Believed to be caused by a heat shield film failure.	No functional problems observed.		
300	4000	Yaw gas jet leaking, produced disturbance torques.	Unknown.	Apparently no effect.	It is not clear what corrective action, if any, was taken.	Occurred on at least four occasions. Also, see #18, #240.
301	4000	Roll gyro drift rate higher than expected.	Due to gyro's being temperature sensitive.	No effect.		

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Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
302	40008	+X solar panel current increase when tilted away from sun.	Unknown - data analysis reveals all responses normal.	Because of this no counts above the expected cosmic ray background was observed.		
303	4010	Engine valve temperature exceeded allowable limit following Mars orbit insertion maneuver.	Attributed to improper predictions due to test errors.	None.		
304	4080	Radio Frequency Subsystem phase error; receiver best lock frequency had shifted approximately 10 kHz.	Probably due to charted tantalum capacitor.	Receiver tracking rate capability decreased and performance of ranging channel degraded.	Adjusted for by altering ground subcarrier frequency.	
305	4104	Erroneous report of C-band pre-amp #1 gain loss.	Due to inaccuracy in calibration curve.	Negligible.	Subsequent tests verified proper operation and provided data for improving calibration curve.	
306	4115	Tape recorder errors.	Unknown.	Not serious - "went away" after occurring over Mars orbits 9 thru 106.		
307	- 4150	16% desensitization in Canopus Tracker.	Attributed to aging of the tracker tube or electronics.	No long term effects - apparently not permanent.		
308	4176	Surface Composition Mapping Radiometer Tape Recorder +12v and -12v supply voltages unstable.	Unknown.	Require 32 seconds to reach proper level.		
309	4200	Phobos interference with Canopus tracker on at least five occasions.	Attributed to lack of knowledge concerning Phobos' characteristics during the design stage.	Caused considerable operational difficulties.		

		Anomalies				
Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
310	4200	Scan cone actuator and scan clock actuator each stepped one less step than expected on four occasions.	Due to the Central Computer and Sequencer issuing two commands too closely spaced so that the actuators "missed" the second command.	None due to corrective action.	The Central Computer and Sequencer was reprogrammed from ground.	
311	4250	Ultraviolet Spectrometer photomultiplier tube saturation.	Possibly due to slewing the field-of-view across Mars bright limb.	Effects could be seen for up to two weeks in the high gain state; could have damaged the photomultiplier tube.		Occurred several times before operational constraints established.
312	4272	Command decoder failed to execute command to switch Vertical Temperature Profile Radiometer modes.	Unknown.	Apparently no permanent effect.		
313	4296	Command decoder accepts address-verify retransmission as valid command.	Unknown.	Apparently no permanent effect.		
314	4300	Titanium window broke.	Reason unknown.	Could not determine consequences.		Window was extremely thin (0.000074 inches).
315	4370	Due to personnel error, a command could not be transmitted as required.	Ground problem, not a spacecraft anomaly.	Resulted in the scan platform being driven against its stops and the cone actuator slipping for about an hour. Fortunately, no damage was done.	Modified procedures were instituted to prevent recurrence.	
316	4392	Data Acquisition and Control Unit #1 tends to skip even words and repeat odd words when commanded to dwell on odd channels or upon turn-on after being off for an extended period.	Due to ionic contamination of address line of DACU #1 Read Only Memory, caused by improper cleaning after ammonia clearing process.	Negligible due to redundancy.	Operational procedures now restrict dwell operations to DACU #2 only.	

		Anomalies				
Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
317	4400	Power dumping shunt failed (1 of 4).	Attributed to bad parts, could not withstand the required cycling.	Other 3 shunts had to carry the load		
318	4440	Selective Chopper Radiometer analog/digital converter; -6V reference out of limits.	Unknown.	Not significant.		
319	4464	Ground erroneously assumed that RFI Transponder turn-off when certain HET commands were issued, was an anomaly. Actually, this was normal behavior under these command conditions.		None.		
320	~4560	Power supply anomaly: apparently there was a 15° temperature increase and a tripling of electrical output in the primary system.	Unknown.	Apparently none, since successful spacecraft operation continued for another 11 months.	Spacecraft was switched to its reserve (redundant) power system.	
321	4560	Extra sun pulses from sun filter.	Unknown.	No mission effect.		Occurred during Asteroid Belt transit, but any asteroids which could have triggered the sensor would have had to be in the large charted group, which was not the case.
322	4561	Wide-band Video Tape Recorder #1 record/playback head #1 failed.	Unknown.	25% of recorder data lost. Unit not used for the next 6 months, then used with the Return Beam Vidicon only.		
323	4584	Radio Frequency Subsystem TWT Amplifier #2 failed as evidenced by greater than normal power demand and degraded RF power output.	Cause narrowed down to problem in the TWT high voltage converter or in the TWT itself.	Negligible due to redundancy.	Redundant TWT & Amplifier #1 switched in via command.	
324	4584	Central Computer & Sequencer failed to issue twelve cone step commands it had been programmed to issue.	Attributed to a transient from faulty TWTA #2 (see #323) "glitching" the Central Computer & Sequencer memory.	Not serious due to corrective action.	Backup commands issued from ground, subsequent operation normal.	

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Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
		Anomalies				
325	4590	Solar Panel #3 temperature sensor failed.	Thought due to insufficient built-in strain relief for effects of temperature extremes.	Apparently negligible.		Eventually occurred in remaining three sensors.
326	4632	Magnetometer came up in abnormal configuration.	Unknown.	Negligible.	Commanded back to normal.	
327	4656	Overcurrent caused by malfunction in magnetometer.	Unknown.	Spacecraft shut off by overcurrent protection sensor.		
328	4656	Spacecraft failed to stop telemetry frame readout.	Problem in beacon transmitter or oscillator.	Apparently no permanent effect.		
329	4680	Magnetometer electrically inoperative.	Unknown.	Experiment commanded OFF for rest of mission.		See #327.
330	4680	Electrons/Hydrogen/Helium Isotopes experiment detector D7 noisy.	Unknown.	Apparently insignificant.		
331	4730	S-Band Receiver/Transmitter #1, reduced sensitivity in receive portion.	Unknown.	Not usable for visable data products; utilized redundant S-Band Receiver/Transmitter #2.		
332	4776	Power supply anomaly - when entering shadow, battery failed to pick up the load.	Unknown.	Spacecraft turned itself OFF.		
333	4992	Command error on 4th bit of command word 0600.	Unknown.	Apparently no permanent effect.		
334	~5000	Gas Chromatograph Mass Spectrometer oven heater #3 failed.	Unknown.	No effect, remaining 2 ovens sufficient for experiment.		See #335 (different spacecraft).
335	~5000	Gas Chromatograph Mass Spectrometer oven heater #3 failed.	Unknown.	No effect, remaining 2 ovens sufficient for experiment.		See #334 (different spacecraft).
336	5000	Plasma Electrostatic Analyzer erratic mode changes: experiment experienced difficulty remaining in "B" mode for periods over one hour long.	Unknown.	Apparently not serious.		

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Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
337	5064	Shunt module segment two was conducting heavily during eclipse.	Unknown.	Above normal bus current. No functional problems.	The disconnect relay for segment two was opened and bus current returned to normal.	
338	5088	EOT/BOT Sensor in Tape Recorder 1: improper indication reported.	Operator error - normal random occurrence.	Function not affected.		
339	5160	68% of the Attitude Control System Propellant onboard was lost.	Due to leakage in the valve-nozzle assemblies when the spacecraft passed through a 5-hour apogee shadow and the temperature dropped to -70° C.	None - the Attitude Control System had all but completed its required operations much earlier.	On subsequent missions, different valve seals were used for certain valves.	
340	5160	137 MHz Transmitter causing degradation of downlink modulation index as a factor of uplink power.	Unknown.	Apparently managed to work around it.	Transferred data to the 136 MHz transmitter and commanded 137 MHz transmitter OFF. At 5688 hours, 137 MHz transmitter commanded ON. Data switched from 136 MHz transmitter to 137 MHz transmitter and commanded 136 MHz transmitter OFF.	
341	5180	Earth Radiation Budget Experiment: Complete loss of digital A data in scan mode.	Believed due to short or loss of sync in Digital multiplexer.	Restricted to non-scanning mode, causing considerable degradation to experiment.		Prior to this, many problems were encountered during scan mode operations: data dropouts, gimbal error, etc., beginning at 3,146 hours.
342	5208	UHF Transmitter #1 temperature rose from 37.8°C with no uplink signal to 44°C with uplink turn-on.	Related to starting base plate temperature and was determined that 10-13° temperature rises could be expected.	Negligible due to redundancy.		
343	5256	L-band transmitter #1 intermittent power output.	Problem attributed to excessive loading on IF-2 output, resulting from an unusual configuration of the Communication subsystem to serve as a DC load.	Negligible due to redundancy.	Subsequent tests under more standard conditions revealed no problems.	
344	5280	Data dropouts during playback of Scanning Radiometer recorder #3 data.	Unknown.	Apparently no permanent effect.		
345	5304	Tape Recorder: A particle on the tape apparently broke free and floated off.	Unknown.	None.		No further details given.

Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
346	5304	Vertical Temperature Profile Radiometer #2 failed.	Unknown.	None, Radiometer #1 could be utilized.		
347	5382	Unusual Despin Bearing Assembly motor current oscillations.	Due to additional friction developing between the sail and the wheel so that the motor had to "work harder"; friction may be caused by build-up of brush debris on commutator bar.	Apparently did not impact operations.		Occurr. on several occasions.
348	5400	TV Camera-A (wide angle) orange filter wheel locked in position 5.	Unknown.	Only the 60° polarizer could now be used, but results were satisfactory.		
349	5400	Momentum control coil #1 - power remains "on."	Due to low impedance in coil-select relay.	Negligible due to redundancy.		See #294.
350	5472	Visible-Infrared Spin-Scan Radiometer: at Solstice sensitivity decreased more rapidly and further than other spacecraft; nor did it fully recover.	Unknown.	Not serious.	Grey scale adjustment made as compensation measure.	
351	5472	Bit 2 in ACS Digital Solar Aspect Indicator & Solar Gate Electronics failed to readout.	Unknown.	Not significant.		
352	5664	Central Computer & Sequencer failed to issue 216 step commands.	Due to software error.	Apparently none - presumably the Central Computer & Sequencer was re-programmed.		
353	5750	Solar Panel #2 Temperature Sensor failed.	Thought due to insufficient built-in strain relief for effects of temperature extremes.	Not indicated, but spacecraft continued to perform successfully.		Second of four sensors to fail; see #325.
354	5760	Command errors caused erroneous shutter speeds on 4 occasions.	Errors may be related to ground procedures.	Apparently no significant effect.		
355	5808	Erroneous report that Polaris Sensor assembly #2 failed to respond to acquisition command.		None.		Subsequent investigation revealed the Polaris Sensor Assembly was functioning properly for the command sequence it had received (i.e, it was supposed to "lock-out" with that sequence).

Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
356	5887	Abnormally high minor frame sync error counts in wide-band Video Tape Recorder #1 Data.	Unknown - possibly due to tape damage.	Operations continue on restricted portions of tape.		
357	6216	TWT Amplifier #1 RF power 10W.	Attributed to too much power going into ground antenna inadvertently, thus blocking receiver.	Negligible.		Ground problem.
358	6216	Plasma Science Experiment SES electron multiplier count rate decreasing.	Due to normal wearout.	Apparently no mission effect.	No corrective action except turn-off until second Mercury encounter.	
359	6222	Slow leak in forward IR scanner pressure.	Unknown.	Not expected to interfere in normal operation.		Leak rate is very slow.
360	6264	Transient drop in RF power.	Unknown.	None, did not recur.		Noted via telemetry only, too small to be seen on the RF link.
361	6410	Ground command was missed.	Unknown.	Caused under-exposure of all TV pictures for that pass.		
362	6500	Slight leak in helium pressurization system for the oxidizer and fuel tanks.	Attributed to the regulator valve.	Did not affect mission, but was time consuming - one planned burn was delayed during analysis.	A longer-than-normal burn was commanded to clear valve. Leak rate decreased but did not totally disappear. Subsequently the helium system was isolated by closing the pyro valve.	
363	6500	Mars orbit insertion burn ended 10 seconds earlier than predicted.	Unknown.	None, orbit was near nominal.		Apparently not related to 362.
364	6500	Scan platform cone position changed during propulsion maneuvers.	Attributed to engine turn on transients causing the cone actuator clutch to slip.	Could have become serious as spacecraft became lighter; but corrective action was sufficient to prevent further problems.	The scan platform was "hard-stowed," i.e. lowered securely into the cone, during all subsequent propulsion maneuvers. No further movement was observed.	See #364.
365	6500	High Gain Antenna moved during propulsion maneuvers.	Unknown.	Movement was still observed after corrective action, but the stress loads on the High Gain Antenna Actuators were minimized.	Alternative procedures derived.	See #364.
366	6550	S-Band Receiver/Transmitter #1 has spur present on TARS-1 return frequency.	EMI of spacecraft origin.	Not serious.		

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
367	6552	Wide-band Video Tape Recorder #2 stopped rewind prematurely.	Unknown.	Negligible - unit remains operational.		See #271.
368	6600	Space probe experiment failed.	Filament burned out at the end of the expected normal life.	Experiment inoperable, no impact on mission.		
369	6696	Data Storage Subsystem tape recorder appears jammed approximately 21.3 meters from right end of tape.	Probably caused by head-to-tape weld, causing tape to loop and jam.	Data Storage Subsystem had to be turned off.		
370	6696	Memory programmer #1 in Dual Programmer failed to output commands from memory.	Short circuit in wiring, attributed to manufacturing error.	Memory programmer #1 inoperative, but redundant unit available.	On subsequent spacecraft the welded wire process was changed.	
371	6700	Central Computer & Sequencer error.	Unknown.	Caused exposure error.		This is the first in a series of Central Computer Sequencer problems over approximately a 3-week period. See #373, #375, #376, and #378.
372	6750	Sudden change in uplink signal strength; AGC decreased by -1.8 db.	Unknown.	Not serious.	Ground stations used higher level uplink for "work-around."	Shift apparently "went away" at some point.
373	6792	Central Computer & Sequencer sent out-of-sequence commands to TV Camera B on 4 occasions.	Cause unknown.	No immediate consequences, but see #378.		
374	6846	Solar Panel #4 Temperature Sensor failed.	Thought due to insufficient built-in strain relief for effects of temperature extremes.	Not indicated, but spacecraft continued to perform successfully.		Third of four sensors to fail, see #325, #353.
375	6896	Central Computer & Sequencer incorrect check sum; occurred twice, 4 days apart.	Thought due to electrical transient.	No immediate consequences, but see #378.		
376	6912	Central Computer & Sequencer showed spurious reaction to ground command, and also selected unpredictable TV camera combinations.	Unknown.	No immediate consequences, but see #378.		

Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
377	6958	Scanning Microwave Radiometer. Channel c reflector movement not in sequence with the scan system.	Due to pogi-drive belt problems.	Major impact on experiment		Movement returned to a normal sequence at 7,681 hours, but was in improper position.
378	6960	Uncontrolled jump locked Central Computer & Sequencer into readout mode, also, commands were apparently received and executed, but there was no indication back to ground to verify this.	Unknown.	All instruments had to be commanded off at this point, as a safety measure while the Central Computer & Sequencer was investigated. The investigation revealed no problem, and subsequent operation was normal.		There is now no way of knowing whether anomalies 373, 374, 375, 376 were manifestations of the same problem or not.
379	7000	Circular blemish on Visual Imaging System-B camera frames.	Thought due to dust mote dislodged by MOI burn.	Not serious.		
380	7000	Command receiver #1 "locked up".	Unknown.	Consequences not clear.		
381	7000	Drifts in Infrared Thermal Mapper data.	Attributed to thermal transients after separation of bioshield & lander.	Apparently not serious.		
382	7010	Visible-Infrared Spin-Scan Radiometer, Scan hang-up at end of frame.	Due to debris.	End of frame "retreating" - apparently still provides some usable data.		
383	7086	Cathode current of both TV cameras declined slowly.	Possibly due to vidicon degradation.	Not detrimental due to ample design margin.		Apparently occurred to some extent throughout mission, but became more noticeable at this time; TV-B cathode current was lower than TV-A.
384	7080	Tracker lost Canopus lock	Due to bright particle tracking.	Apparently no mission effect.	Remain in cruise mode to minimize oscillations	
385	7104	Multi-Spectral Scanner false end-of-line codes; end-of-line codes occasionally occur in preamble or along video data.	Attributed to EMI.	Minor loss of data - creates 4 black & 4 white words in scene data, occurs over magnetic anomalies with low incidence rate.		
386	7104	Canopus tracker lost lock.	Storm of bright particles.	Apparently no mission effect.	Remain in cruise mode to minimize oscillations; see #384.	
387	7130	North-South nutation of ½ scan line periodically observed.	Unknown.	Apparently not serious.		

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Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
388	7130	Flight Command Subsystem out-of-lock during high gain antenna maneuver.	Possibly due to transient.	Loss of 3½ TV pictures; no permanent effect on spacecraft.	Caused extensive contingency analysis and planning.	
389	7225	Attitude Control System - left cosine pot in Solar Array Drive has developed signal deviation at spacecraft midnight.	Attributed to internal debris.	Degrades signal output but does not interfere with spacecraft operatons.		
390	7270	Channel P5 of the Energetic Particle Sensor failed, and subsequently recovered.	Unknown.	Unit was degraded for approximately 2 months, operation normal after recovery.		
391	7440	A430 high shunt tap voltage.	Possible cause is change in solar cell impedance during peak temperature period.	No impact on flight operations.		Evaluation indicated that no array degradation had occurred. Similar problems have occurred on A419 shunt tap.
392	-7473	Attitude Control System - right cosine pot in Solar Array Drive has developed signal deviation at spacecraft midnight.	Attributed to internal debris.	Degrades signal output but does not interfere with spacecraft operations.		See #389.
393	7473	Integrated Circuit chip in TMP failed.	Cause unknown.	Four Telemetry channels disabled; spacecraft operation not affected.		
394	7510	Visible-Infrared Spin-Sca. Radiometer Calibration function failed, then recovered about 4 months later.	Unknown.	Not indicated, but probably would not have impacted mission at this point.		
395	7680	Electrically Scanned Microwave Radiometer; fluctuation of multiplex calibration.	Apparently an antenna problem.	Not serious - worked around.		
396	-7689	Comstor B, cell 12 verified with a 256 second change in the required execute time - this problem has occurred on 23 occasions.	Unknown.	Use of cell for active commands discontinued.		On each occasion a second try verified correctly.
397	-7800	Several telemetered power system parameters varied slightly during encounter.	Unknown.	Not significant, returned to normal after periapsis.		

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Index	Anomaly Time (Hours)	Description	Cause	Mission Eff.	Corrective Action (If known)	Remarks
398	7800	Small thruster leaks detected by small changes in spacecraft spin rate.	Possibly the same leaks reported in #7, #8	Leaks were small enough that there was no detectable pressure drop.		
399	7824	Tracker lost Canopus acquisition	Due to bright particles	Apparently no mission effect	Maintain roll drift mode until third Mercury encounter.	
400	7928	Tape Recorder Playback Timer #2 returned PCM data to real time and Recorder #2 to record in 22.5 minutes vs 45 minutes.	Suspect leading bit in countdown register of timer.	Not serious, due to change in operating procedure	Almost total recovery of Tape Recorder #2 data was achieved by sending another playback command after time-out at 22.5 minutes, resulting in full 45 minutes playback.	
401	8020	High gain antenna moved 0.4° during first planetary orbit insertion burn	Due to "backlash"	No changes noted in X or S band performance		
402	8020	The 3 seismometer sensing masses failed to uncage from the stowed, flight configuration.	Due to the failure of a pinpuller.	Apparently caused the loss of this experiment		
403	8040	Sensitivity of the four Imaging Photopolarimeter channeltron detectors not well balanced	Unknown.	For mode 4 images, red signal will be twice the blue signal, precluding use of the automatic gain decrement function for maintaining optimum gain settings.		See #52, #404.
404	8040	Two Imaging Photopolarimeter channeltron outputs dropped to zero for several seconds shortly after a gain decrement command.	Unknown	Not significant, occurred only once		See #52.
405	8040	Imaging Photopolarimeter solar diffuser was 65% as bright as the calibration lamp.	Unknown	Could have some impact on measurements near a 10° sun-look angle.		See #52.
406	8064	During the offset pointing maneuver, Earth Sensor Assembly roll scan was frozen, causing complicated chain reaction, including the spacecraft Z-axis being driven off the earth, and causing the sensor sun-avoidance circuit to operate at the extreme pitch angles that existed	Caused by a combination of spacecraft attitude and sun elevation	Was a serious problem, but didn't result in mission loss.	The combination of attitude and sun elevation which can cause this are rare and predictable, so operational policies can prevent future occurrences	

Anomalies

Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
407	8070	Command receiver #1 failed to lock-in.	Unknown.	Negligible due to redundancy.		See #442.
408	8136	Low energy detectors in cosmic ray experiment inoperative/degraded for months.	Unknown.	Loss of some data.		
409	8200	0.25° change in high gain antenna pointing angle during 3rd burn to trim Mars orbit.	Due to "backlash".	0.25 db decrease on X-band downlink.		
410	8345	High data rate storage system-A failed to record, and failed completely at 8,483 hours.	Unknown.	Severely restricts aquisition of night-time data from all experiments.		See #118.
411	8400	Star advance feature at command 340 does not work.	Attributed to the micro-pulses within each star pulse; for advance feature to work, each star must have only one pulse.	Not serious due to corrective action.	Problem can be overcome by transmitting a special command sequence to acquire Canopus.	Advance feature meant to allow lock to be broken on unwanted star in order to acquire Canopus.
412	8517	Telemetry: erroneous indications of event occurrences.	Attributed to a drop-out of the least significant bit in the shift registers of the event-file circuitry.	Posed no problem, since it occurred in a predictable fashion.		Occurs more frequently at warmer temperatures.
413	8552	Scanning microwave radiometer scan mechanism jammed.	Unknown.	Complete loss of data from this experiment.		
414	8620	400 Hz inverter current to Inertial Reference Unit #1 went to zero 26 seconds after lander separation.	Analysis indicated the inverter short was probably due to a short in either 1 of 3 diodes, or - more likely - in 1 of 6 transistors; it is possible, though, that some other unknown anomaly caused it.	Caused the gyros to run down, and spacecraft went into rapid, expanding operations. This caused the Computer Command Subsystem to go into a contingency sequence, which selected Inertial Reference Unit #2, and the oscillations were thus damped out. There was a communications blackout for over an hour.	After communications were established, ground took steps to correct attitude, and modify subsequent procedures to prevent damage to the remaining Inertial Reference Unit.	
415	8660	Meteorology quad heater failed.	Unknown.	Negligible, alternate made available via software provisions.		

Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
416	~8700	S and X-band lock lost during landing sequence.	Unknown (but see #7)	None, condition soon rectified.	S-band lock was re-acquired 2 minutes later via the low-gain antenna. During this period, the spacecraft rolled off Vega reference by about 22°. Commands were then sent to continue the landing sequence.	
417	8700	Solid angle sun sensor failed.	Reason unknown.	Apparently reduced data gathering capabilities of Scorpio experiment.		
418	8709	Abnormal drops in array current over a portion of a spacecraft day.	Unknown.	None, ample power still available.		
419	~8760	Occasional uncommanded gain decrements in the Imaging Photopolarimeter.	Unknown.	Not significant; apparently a disabling command is available to by-pass this fault.		See #52.
420	~8760	Imaging Photopolarimeter channeltrons show a momentary surge in sensitivity at the instant of a gain decrement.	Unknown.	Not significant; causes elevated signal levels for ~0.5 seconds.		See #52.
421	8760	Multiple pulses from sun sensor B.	Unknown.	Negligible due to redundancy.		
422	8800	Power dumping shunt failed (2nd of 4).	Attributed to bad parts, could not withstand the required cycling.	Other two shunts had to carry the load.		See #317.
423	8800	Soil collector step switch failed.	Unknown.	Apparently not serious, software provisions somehow provided alternative.		
424	8800	Geiger-Mueller tube in low energy electrons and protons (LEPEDEA) experiment failed.		Very little effect on mission, was only a minor part of the LEPEDEA experiment.		

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Mission Effect	Corrective Action (if known)	Remarks
425	8630	When operating in the normal mode, the Infrared Thermal Mapper scan mirror stepped past the space position when it should have stopped there for 3.36 seconds.	Unknown.	5 minutes of data lost each time anomaly occurred.	Apparently instrument could be turned off, then turned back on and problem would have "gone away".	Anomaly occurred at least 14 times, intermittent.
426	8920	Gas pressure regulator relief valve venting during solar occultation.	Attributed to obstruction in vent tee which resulted in excessive pressure. Somehow related to occultation disturbance torques.	Apparently not serious.		
427	8928	Very High Resolution Radiometer #1 video jitter.	Attributed to shift in timing pulse in pulse shaper.	Cleared up, then later failed (See 461,475)		
428	8970	TWT Amplifier #1 failure (arcing).	Unknown.	Redundant TWTA #2 available, but required revising the whole General Relativity Experiment, which normally required both TWTA's, reduced ranging coverage.		First noted as degradation in the ranging SNR.
429	9000	Solar interference caused degraded communications.	Due to sun/earth/probe angle.	Apparently not serious	Special data playback procedures instituted for some data rates.	
430	9024	Electron/Hydrogen/Helium Isotope experiment detector D7 noisy.	Unknown	Not serious.	Commanded D7 OFF and left it off until 10,032 hours; when D7 was commanded ON, it operated normally.	
431	9084	Solar array current decreased.	Unknown	Not serious, contingency plans prepared.		
432	9096	Yaw position exceeds limit, switch amplifier did not fire	Exact cause not determined	Cited as "significant problem"		
433	9260	R F I from external source.	Unknown.	Disrupted transmissions for 40 minutes		See #445
434	9336	Plasma Electrostatic Analyzer came up in continuous CAL without being commanded	Unknown.	None - commanded into proper mode.		Spurious command

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
435	9408	Improper Roll Wheel operation led to instability in roll axis, subsequent to anticipated perturbations due to Moon transiting the Earth Sensor Roll Scan.	Anomaly attributed to problem in the pulse modulation lag amplifier and/or its compensation circuitry.	A serious problem, but did not result in mission loss.	Jet control was necessary to correct instability; special Digital Operational Controller programming for mixed operations with wheels and roll jets planned as corrective action.	
436	9410	Magnetometer failed, recovered 33 days later, failed 4 months after that, operating intermittently thereafter.	Unknown.	Loss of magnetic field data, not a prime mission objective.		
437	9444	Voltage decreased from right and left solar paddles.	It is suspected that a momentary short blew a fuse.	Apparently changed power source for some telemetry circuits.		
438	~ 9600	Lower boom inadvertently deployed to full 750 feet.	Unknown.	None.		May be related to #566, #649.
439	~ 9600	Large spacecraft oscillations occurred, although gravity gradient capture did occur.	Likely causes are 1) bad boom, 2) less than nominal structural rigidity, 3) out of nominal boom densities. There is also a slight possibility that the telemetry data was wrong.	Resulted in an equilibrium attitude of -6°R, -7°P, and -40°Y; predicted nominal was 0°R, 0°P, -16°Y for 600 ft. booms. However, equilibrium finally reached allowed spacecraft to pursue its primary experiment.		
440	9840	A2 South Array temperature sensor failure.	Sensors failed - open.	No serious effect, but calibration curves for temperature sensors have been changed.		See #108, #187.
441	9900	High Data Rate Storage System-A "Record Power off" command failed to execute.	Unknown problem in command clock.	Executer counter increased.		
442	10230	Command receiver #1 failed to lock in.	Unknown.	None, redundant receiver #2 utilized.		See #407.
443	10300	Computer Command Subsystem memory B - failure of 4 bits.	Thought due either to component parameter drift or to a bad wire in the plated wire memory.	No indication of consequences, but primary mission was over by this time.		

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
444	10390	UHF Receiver #1 data drop-outs.	Caused by VHF interference.	Apparently not serious.		
445	10400	RFI from external source.	Unknown.	Disrupted transmissions for 40 minutes.		
446	10416	Data Acquisition and Control Unit #1 word 0 frame sync errors occur in frames 11 and 15 permanently and frames 0, 1, 2, 3, 7, 8 and 9 intermittently.	Possibly caused by change in threshhold voltage due to ionic contamination of Read Only Memory.	Negligible due to redundancy.	Ground software changed to ignore these sync errors.	See #316.
447	10632	Communications and Data System - commands not received beyond 37,000 miles.	Unknown.	Not known.		
448	10656	Scanning Radiometer #2 failed.	Mirror stopped, probably due to mechanical failure.	Negligible due to redundancy.		
449	10656	Vertical Temperature Profile Radiometer, mechanical hangup during calibration sequence.	Unknown.	None, calibration function no longer used at this point.		
450	~10800	Degradation in star sensor gain.	Unknown.	Degenerate progression observed in the detection probability of the star Vega; Canopus detection unaffected.		
451	10848	Data Acquisition and Control Unit #1 frame sync pattern for word 2, frame 15 intermittently reads octal "000" instead of "006".	Probably due to ionic contamination of ROM.	No impact - frame 15 already masked due to previous anomaly.		See #316, #446.
452	10870	Gamma Ray Monitor totally failed.	Attributed to problem in the low voltage power supply, possibly a short in one of the output lines.	Loss of experiment.		See #657-#660.
453	11152	Wide-band Tape Recorder #1 tape unit pressure drop.	Due to defect in pressure instrumentation which causes drop in telemetry indication.	None - returned to normal.		

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
454	11184	Magnetometer Y-axis failure.	Attributed to open winding in Y-axis offset coil, possibly caused by temperature extremes during eclipse season.	Extent of impact on experiment not known.		
455	11279	Left and right solar array drives occasionally have ripple voltages on their drive mechanisms.	Attributed to wobble gear wear-in.	Insignificant - returned to normal.		
456	11484	Pitch error changed from -3.2^{o} to $+4.2^{o}$.	Unknown.	Recovered.		
457	- 11500	Plasma Electrostatic Analyzer came up in the wrong mode at various times throughout the year.	Unknown.	Negligible.	Whenever this anomaly occurred, the experiment was commanded into the proper mode.	Spurious commands, see #434.
458	11670	Wide-band Video Tape Recorder #1 had high wheel current during re-wind.	Attributed to a slip in the count-down chain delivering 2 phase power to the headwheel motor.	Restricted operation of the tape recorder.	Established policy that re-wind could be performed only when in ground station contact.	See #356.
459	11690	Tape recorder track #4 failed.	Unknown.	Negligible, remaining 3 tracks sufficient for data storage.		
460	- 11900	Stored commands blocked by real time sequences which overlap in time.	Unknown.	Not serious.		Happens occasionally.
461	11928	Very High Resolution Radiometer #1 video jitter.	Attributed to shift in timing pulse in pulse shaper.	Cleared-up, then later failed (see 475).		
462	12192	Millimeter Wave experiment 30 GHz failure - high voltage tripped off every time the HV command sent; the HV filament comes on but HV command shuts down tube.	Cause unknown.	Permanent failure of this part of experiment.		

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Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
463	12216	Simultaneous bursts of noise on both Polaris Sensor and Earth Sensor outputs, but when Polaris Sensor turned off, Earth Sensor noise cleared up; spontaneous resets of Polaris Sensor Assembly adaptive gate step also noted.	Problem indicative of arcing.	Polaris Sensor Assembly no longer used.		
464	12257	Rate Measuring Package output several times its normal value to several minutes near the spacecraft day-night transition.	Caused by unexplained energy input.	None - signal returned to normal in a few orbits.		Apparently occurred with both Rate Measuring Package #1 and #2.
465	12312	Canopus tracker found to be in a degraded state.	Unknown.	Apparently not serious.	Commands sent to step from brightness gate #1 to gate #2.	
466	12384	Vertical Temperature Profile Radiometer #2 failed.	Unknown.	Negligible; redundant unit #1 could be utilized.		
467	12900	One counter in Galactic X-ray absorption experiment ran out of gas.	Unknown.	Apparently reduced data gathering capabilities of Galactic X-ray absorption experiment.		Had been acting erratic since launch.
468	12922	Battery #6 decreased in load share and increased in charge share.	Unknown.	Battery became overcharged and battery temperature increased.	Battery was turned off for the next 391 orbits (665 hours) then returned to service.	
469	13000	Tape recorder #1 failed.	Unknown.	Negligible due to redundancy.		
470	13000	Common signal conditioning regulator failed.	Unknown.	Caused loss of data from 3 temperature sensors; no effect on mission.		
471	13124	Wide-band Video Tape Recorder #2 power supply - countdown chain occasionally slips phase, which increases motor speed and causes excessive bit errors and footage overruns.	Unknown.	Negligible, can be corrected.	Operational procedures (toggling from record to playback) correct this condition, and normal operation can then resume.	Has occurred at least 7 times.

Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
472	13200	Power dumping shunt failed (3rd of 4).	Attributed to bad parts, could not withstand the required cycling	Remaining shunt had to carry the entire load, resulting in excessive battery cycling which ruined the battery and burned out a transmitter. Overall result in spacecraft can only be used in daylight.		See #317, #422.
473	13200	Very High Resolution Radiometer #2 failed.	Unknown.	None, redundant unit #1 could be utilized.		
474	13200	Sun sensor issued a premature sun pulse.	Unknown.	Not significant.		Occurred once at considerably smaller sun aspect angle than "double pulse" anomaly.
475	13488	Very High Resolution Radiometer #1 failed due to defective timing pulse.	Attributed to aging.	Negligible due to redundancy.		
476	13649	Battery #1 increased in load share and charge share.	Unknown.	Battery #1 became overcharged & battery temperature increased.	Battery #1 was turned off for a certain number of hours, then returned to service.	Has occurred at least 4 times. Also, see #468.
477	13668	Pitch flywheel exhibited a 2-minute halt.	Unknown, possibly inadequate lubrication.	Apparently little or none	Average wheel speed was increased to obtain a better lubrication condition.	Anomaly occurred during a sun transient when wheel was changing directions.
478	13800	Attitude Control System propellant supply completely depleted.	Valve seal leakage when spacecraft passed through an apogee shadow.	Attitude correction no longer possible.		Leakage did not cause significant perturbation. See #339.
479	13800	Visible-Infrared Spin-Scan Radiometer scan mirror lubricant build up.	Not indicated, but also occurred on a subsequent spacecraft.	No impact on data gathering.	Partial disk picture made used to prevent Radiometer from "hanging up."	
480	13860	COMSTOR erratic at time of verify command.	Unknown.	Both COMSTOR's tested and are O.K.		
481	14000	Battery degraded.	Possibly due to aging, but batteries on other spacecraft in this series lasted longer than this	Would restrict night time operations.	Deep charge/discharge commanded with no significant results.	Apparently there were indications of degradation much earlier.
482	14065	Battery #6 decreased in load share and increased in charge share.	Unknown.	Battery became overcharged, and battery temperature increased.	Battery was turned off for the next 974 hours, then returned to service.	See #468.

Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
483	14088	Scanning Radiometer Recorder #3: frequent interruptions in play-back data.	Attributed to head switching transients.	Not significant.		
484	14130	Second tape recorder failed.	Unknown.	Only real time data available.		
485	14328	Parity bit error in Command Memory 1; Address but no execute.	Unknown.	Not indicated; mission objectives already met by this time.		
486	14448	Spacecraft Propulsion Subsystem #2 negative roll valve stayed open longer than designed, producing more thrust than desired	Cause unknown.	Negligible due to redundancy.	Control was switched to Spacecraft Propulsion Subsystem #1.	
487	14568	Several scientific instruments experienced increased temperatures.	Believed due to Jupiter's infrared radiation through instrument apertures.	Increases not large enough to cause damage.		
488	14568	Gradual increase in TWT helix current.	Unknown.	Not significant.		
489	14558	False count for thruster #2.	Unknown - Attitude Control was deactivated at the time, so no thruster pulse could have occurred.	No effect.		
490	14640	Wide-band Video Tape Recorder #1 has high error counts, high current indications and other signs of problems	Unknown, but see 356.	Unit not usable - turned off.		
491	14688	Very High Resolution Radiometer #2 failed.	Unknown.	None, redundant unit #1 could be utilized.		
492	14712	Star tracker lock found to have jumped from Canopus to Aldebaren.	Attributed to tracker's susceptibility to scintillation from the high energy particle radiation environment and to albedo saturation effects.	None, tracker not is use when this was detected.		

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Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
493	14952	Magnetometer Auto Range inoperative.	Unknown.	Impact not known.	Commanded to fixed 32 range at 15,000 hours.	
494	15216	Failure of unknown nature in High Resolution Ultraviolet Spectrometer Slit motor assembly.	Unknown.	Increased current (~200mA) to sail experiments; portions of UV Spectrometer no longer operated.		
495	15300	Solar Panel #1 Temperature Sensor failed.	Thought due to insufficient built-in strain relief for effects of temperature extremes.	Not indicated, but spacecraft continued to perform successfully.		Fourth of four sensors to fail; see #325, #353, #374.
496	15835	Pitch CCW motor drive duty cycle rose ~15%.	Anomaly possibly connected with lubrications.	None-returned to normal after each occurrence.		See #286, #477.
497	15864	Energetic Electrons & Protons Experiment anomaly: two parameters out of limits.	Unknown.	Not known.		
498	15912	Scanning Radiometer Recorder #3 failed.	Attributed to failure of tape or recorder motor.	Stored SR data still available from Recorders #1 and #2.		
499	16464	Altitude Control Pneumatic Subsystem on-board gas leak.	Seal leakage during shadow.	Not known.		
500	17104	Wide-band Video Tape Recorder #1 record/playback head #3 failed.	Unknown.	Recorder no longer used.		See #322.
501	17116	S-band Transmitter A power output dropped too low.	Unknown.	Negligible due to redundancy.	Operation switched to "B" unit.	Power output steadily declined to 0.14 watts with noticeable loss in coverage.
502	17210	Battery failed.	Unknown.	Not serious at the time.	Thruster start sequence had to be modified to eliminate some warm-up periods.	
503	17300	Battery #5 charge/discharge cycle and temperature abnormally high.	Unknown.	Battery had to be turned off-line for restoration.		See #468, #476, $482, #500.
504	17400	Plasma Electrostatic Analyzer sector power off.	Cause unknown.	None, commanded back on.		

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Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
505	17424	Solar Flare Isotope experiment - large telescope degraded (PH2 detector R/O noisy)	Appears to be temperature related, when package temperatures exceed 18.8°C.	Apparently not serious.		
506	17520	Plasma analyzer was turned off in attempts to isolate source of spurious commands (see #28); when commanded back on, power came on but the instrument produced no data.	Unknown.	Loss of experiment for about 2 years, at which time operation returned to normal.		
507	17520	Imaging Photopolarimeter has stepping problems at cone angles greater than 150°.	Unknown.	None, can be compensated for.		See #52.
508	18024	Vertical Temperature Profile Radiometer #1 filter wheel rotation and position code information stopped.	Attributed to aging.	Loss of Radiometer #1; no further VTP Radiometer data available, since unit #2 had already failed.		
509	18144	Roll Wheel drive failure, will operate in one direction only.	Unknown.	A nuisance, but managed to work around it.	The on-board computer routines were modified to allow one direction drive with wheel run-down to control the spacecraft; a jet assisted mode (JAM) was also developed for spacecraft control.	See #435.
510	18264	Very High Resolution Radiometer #1 failed.	Unknown.	No further VHR Radiometer data available, since unit #2 had already failed; left only one experiment still returning data.		
511	18547	Power Control Module regulators switched from Unit 1 to Unit 2 without commands.	Believed due to VHF input signal transients.	None. Switched back without commands.		
512	18648	The Millimeter Ware Transmitter associated with the 20 GH_z parabola failed to turn on.	Unknown.	Experiment no longer valid.		Only the portion of the MMW experiment associated with the 30 GHz parabola remains oper tional.

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Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
513	18913	Pitch wheel stopped for 8 hours.	Anomaly is possibly connected to lubrication.	Created emergency; large quantity of attitude control gas used to re-acquire normal attitude, solar paddles lost sun track, etc.	Pitch wheel kept close to zero speed ever since using pitch control.	See #477.
514	18980	Asteroid-meteoroid detector failure.	Due to failure of photomultiplier tube.	Instrument turned off.		
515	19137	Rate Measuring Package B began showing current variations.	Unknown.	Negligible due to redundancy.	Switched from unit B to Unit A as a precautionary measure.	
516	19300	Plasma Electrostatic Analyzer came up in wrong mode during 2 month period.	Unknown.	None.	Commanded to proper mode.	Spurious commands; see #434, #457.
517	19320	Scanning Radiometer Recorder #2 degraded gradually until it became essentially unusable.	Originally thought due to "beat" problem in 100% sun.	Can be used to a slight extent, if necessary.		
518	19630	Radial Thruster #1 failed.	Unknown.	Not clear; apparently not major, since spacecraft still collects usable data.		
519	19656	Temperature/Humidity Infrared Radiometer failed.	Unknown.	Loss of experiment.		
520	19825	136 MHz Transmitter started to have a decrease in power output.	Unknown.	Not known.		
521	20533	Battery #2 charge/discharge cycle and temperature abnormally high.	Unknown.	Battery had to be taken off-line for restoration.		See #468, $476, $482, #500, #503.
522	20724	IRLS Transmitter did not respond to D-2.	Unknown.	Not significant.		
523	20784	Spacecraft Propulsion Subsystem #1 truss valve heater (prime and backup) failed.	Unknown.	Not serious, due to redundancy.	Yaw and eastward orbit must be be controlled through Spacecraft Propulsion Subsystem #2, Pitch and roll can still be controlled through Spacecraft Propulsion #1.	

Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
524	21120	S-Band Transmitter (2075 MH_2) exhibited a reduction in RF power output of approximately 3 db.	Was accompanied by DC power reduction indicating failure of 1 of the 4 output RF transistors.	Transmitter remained operable at reduced power levels.		
525	21288	Scanning Radiometer Recorder #1; data shows 30% upward shift in frequency.	Attributed to servo loop causing maximum torque in DC torque motor.	Apparently no significant effect.		
526	21480	Burst Receiver #1 frequency select logic locked up into an unresolved angle.	Unknown.	Data from the unit essentially lost after date of occurrence.		Although most of the frequency select logic for each Burst Receiver was redundant and selectable, this problem probably occurred where redundancy is "or-ed" in redundant final stages.
527	21840	Batteries have degraded to 13 A-H.	Unknown.	Causes some restriction to experiment operations, but design goals already met at this point.		
528	22056	Command anomaly - sent Electrostatic Fields Experiment command 096 and Magnetometer flipped from 90° to 0°.	Unknown.	Apparently not serious.		
529	22100	Solar array current drops.	Unknown.	No effect on mission.		Current drops 500-600 mA early in the day, then returns to #528.
530	22104	Command anomaly - sent Electrostatic Fields Experiment command 096 and Cosmic Ray Accelerometer experiment turned off.	Unknown.	Apparently not serious.		
531	22126	Narrow Band Tape Recorder B became noisy.	Approaching wear-out of tape.	Negligible due to redundancy.	Tape recorder B was turned off.	
532	22200	Clock system, command clock: command 330 failed to execute.	Unknown.	Not significant.		
533	22374	Battery #B charge/discharge cycle and temperature abnormally high.	Unknown.	Battery had to be taken off-line for restoration.		See #521.

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
534	22610	Load sharing of battery #6 decreased and battery overcharged; subsequent current transients.	Unknown.	Use of battery #6 discontinued.		Battery was turned off for a restoration cycle; when it was again turned on high current transients resulted.
535	22632	Spacecraft Propulsion Subsystem #2 yaw thruster valve failed.	Unknown.	Apparently some spacecraft yaw control lost, but at this point the prime mission had long since been completed.		
536	22920	Lost Ryle-Vonberg Radiometer #2 "fine" channel.	Possibly due to malfunction of a solid-state "Dickey Switch"; previous spacecraft in this series lost these switches, then mechanical, early in the missions.	Resulted in a loss of data sensitivity, but not of major impact to experiment.		See #188.
537	2293.	Battery #7 charge/discharge cycle and temperature abnormally high.	Unknown.	Battery had to be taken off-line for restoration.		There were 2 occurrences. Also, see #468, #476, #482, #500, #503, and #533.
538	23448	136 MH_z transmitter current drain 320 ma vice 620 ma.	Unknown.	Not known.		See #520.
539	23500	Battery "memory" problem, limited to 30% depth of discharge.	Design problem, plus age of battery compounds problem by making load sharing trickier. Battery cannot be taken off-line to recondition via complete discharge; thus, completely unloading battery would risk shutting off command system irreversibly.	Experiment operation must be programmed for power availability.	Battery periodically commanded to "low" condition in an attempt to recondition; helps a little, but not much.	
540	24090	Despin thruster valve stuck in closed position.	Unknown.	Not indicated.		
541	24672	Plasma Electrostatic Analyzer in wrong mode.	Unknown.	None, commanded to normal mode.		

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Index	Anomaly Time (hours)	Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
542	24672	Scanning Radiometer Recorder #1 degraded gradually until it became essentially unusable.	Unknown.	Recorder #1 can be used to a slight extent, but essentially only real time data from Scanning Radiometer available.		See #517.
543	25032	Cosmic Ray Accelerometer: MED detector turned itself off.	Unknown.	None.	Commanded back to normal.	Spurious command.
544	25200	Mysterious change in axis of rotation.	Checks ruled out slight leak, interference from interstellar dust, and magnetic field distortions; later attributed to star tracker locking on wrong star.	Change causes spacecraft to point away from the earth 1/12° each day; no danger to spacecraft.		
545	25680	136 MHz transmitter current drain deteriorated to 70ma.	Unknown.	Range & Range Rate and Magnetometer affected.		See #520, #538.
546	25930	Narrow Bar Tape Recorder B failed to move tape.	Unknown.	Negligible due to redundancy.		See #531.
547	26025	Pitch wheel stopped again for 45 minutes.	Possibly connected to lubrication.	Unknown.		See #477.
548	26135	Magnetometer has faulty counts from transverse axis.	Unknown.	None, spacecraft not actively used at this point.		
549	26294	"All Battery On" command causes high current transient.	Short is postulated in Auxiliary Load controller switching relay.	Batteries turned off after the occurrence of this anomaly will have to remain off since command no longer to be used except in extreme emergency.		See #534.
550	26499	Battery #8 has high temperature problems.	Unknown.	Battery #8 had to be turned off; six batteries remain, a sufficient number to carry the load.		See #534, #549.
551	26664	Spin Scan Cloud Camera failed.	Unknown.	The mechanical portion functions but 60 db of video gain has been lost.		

Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
552	27600	D.C. Electric Fields experiment A/D Converter Subsystem voltage readings not changing.	Unknown.	Had to be commanded to proper configuration.		
553	27984	D.C. Electric Fields A/D Converter voltage readings not changing.	Unknown.	Apparently not serious.		Same as #552, anomaly continue through 30,900 hours. Around 31,600 hours the anomaly apparently cleared itself. No other problems reported after that.
554	28296	Power supply anomaly: spacecraft went into undervoltage.	Unknown.	Not known.		Occurred during a Range & Range Rate operation.
555	28752	Attitude Control System on-board gas leak.	Seal leakage during shadow.	Lost approximately one-third of the on-board gas supply.		See #499.
556	30288	Spacecraft went into undervoltage during Range and Range Rate pass.	Unknown.	Apparently not serious.		See #554.
557	30660	Unexplained velocity change during a precession maneuver.	May be due to a thruster jet sticking open.	None - subsequent maneuvers with a different set of thrusters have been normal.		
558	30700	Magnetometer failed.	Suspected cause is RF power supply problem.	Loss of experiment.		
559	31416	Plasma Electrostatic Analyzer came up in wrong mode.	Unknown.	None.	Commanded back to normal mode.	Spurious command; see #434, #457, #516.
560	32433	Rear Attitude Control System Scanner failed "solid" after experiencing intermittent problems.	Unknown.	Spacecraft switched to single scanner mode and normal operation was re-established.		
561	32544	Communications & Data System. Encoder changed from O/A mode to TM slave mode without being commanded.	Unknown.	None.	Commanded back to O/A mode.	Spurious command.
562	32688	BUV experiment high gain state malfunction.	Unknown, but this experiment had been in continuous use for over 3 years.	Night time operations degraded, does not affect day time operations		

Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (If known)	Remarks
563	32712	136 MH$_z$ Transmitter inadvertently on prior to turn on command.	Unknown.	Negligible.		Spurious command.
564	32900	Performance degradation in sun sensor.	Unknown.	Not indicated, mission completed by this point.		
565	32216	Solar Flare Isotope experiment main telescope: 60% degradation.	Component failure in the CKT Photomultiplier Tube High Voltage Module.	Apparently impaired data from this experiment.		
566	33600	Antenna Boom #2 became permanently jammed after deploying most of the required distance.	Unknown.	No effect on mission.		Occurred during the last GSFC operation, recovery from a dynamics experiment. May be related to #12, #17.
567	34704	Transponder #2, TWT #4 failed.	Unknown.	Negligible due to redundancy.		
568	35592	Transmitter failure.	Recreation of symptoms in lab indicates this was due to a bad connection, probably due to faulty workmanship.	Spacecraft no longer usable, but mission objectives had already been met.		
569	36200	136 MH$_z$ transmitter low power output.	Unknown.	Only 4 Range & Range Rate passes taken during December.		See #520, #538, #545.
570	36432	Plasma Electrostatic Analyzer by-pass ON.	Unknown.	None.	It was necessary to turn the experiment off and then reconfigure to normal.	
571	36912	Lost all remaining on-board gas from the Attitude Control System Pneumatic Subsystem.	Seal leakage during shadow.	All attitude control lost. Spin rate is now 22.241 RPM--cosmic ray telescope is unusable below 21.6 rpm. The Electrostatic Waves & Radio Noise experiment is not in one of the desired spin-rate windows		See #499, #555.
572	37008	On-board Attitude Control System gas supply completely depleted.	Excessive leakage during shadow	Attitude Control Operations no longer possible.		See #571, #339.
573	38429	Battery #5 has high temperature problems.	Unknown.	Battery #5 had to be turned off, five batteries remain operational so that battery load carrying function not significantly affected		See #534.

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
574	38710	Beam probe #1 filament failed to light.	Unknown.	Experiment probably lost, no impact on mission.		This problem may have been intermittent.
575	38710	Thruster #2 abnormal beam currents (5-10ma) and unstable discharge.	Unknown.	A change in operating set-points may be required.		
576	38976	Plasma Electrostatic Analyzer EM level changed from "1" to "2" between real time passes.	Unknown.	None - commanded back to level "1".		Spurious command.
577	39200	Intermittent failure of Tape Recorder #2 to play-back on command.	Unknown.	Not serious.		Occurred on two successive days, but play-back correctly later each day. Also, operated correctly 4 days later.
578	39916	Loss of one band (green) of the four Multi-Spectral Scanner bands.	Thought due to failure in 15 volt power supply.	Data compromised, but the Multi-Spectral Scanner has long since accomplished its mission.		
579	41112	Spacecraft command clock stopped during shadow; started at random point which advanced clock 4 days, 6 hours, 12 minutes.	Unknown.	Apparently negligible (see 580).		
580	41112	Power System failure: battery did not recharge after shadow, came up in a false level indication.	Unknown.	Loss of mission.		
581	43800	High gain antenna feed movement mechanism failed.	Movement was via a piston within a bellows; the bel-lows burst, allowing Freon 21 to escape, and impart-ing a velocity shift to spacecraft.	None, backup feed mechanism used.		Projected life of bellows was 2 years, this occurred in the fifth year.
582	44241	Battery #7 has high temp-erature problems and im-proper charge/discharge ratio.	Unknown.	Battery #7 had to be turned off; the remaining four bat-teries are sufficient for current limited payload oper-ation regime.		See #534.

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
583	44544	Transponder #1, Repeater #1 failed.	Probably cause is master oscillator failure or problem in 1st X 4 multiplier in the local Oscillator chain.	Transponder still usable with repeater #2.		
584	48600	Telemetry system sub-communicator #2 intermittent.	Unknown.	Apparently no effect on mission.		
585		Star sensor experiment problem.	Thought to have been damaged during vacuum testing.	Apparently none		
586		Nutation damper gets stuck.	Attributed to faulty workmanship.	Apparently negligible	By careful operational procedures, the damper can be "un-stuck."	The damper has a mechanical "stick" used as part of a friction stop. It somehow got "stuck" on one side.
587		"100% Sun" anomaly - less array power in full than in partial sun.	Design problem: array and battery wired in parallel, so battery tends to "clamp" array at battery voltage. Battery charge curve is temperature sensitive so that its power drops when hot (i.e. in full sun), operates O.K. when cooler (i.e. partial sun).	Experiment operation had to be programmed for power availability.		
588		Uplink AGC approximately 3 db below predictions.	Thought to be due to some poorly understood effect of vacuum.	No effect, command levels still within specs.		Occurred from launch through the following 6 months.
589		Interaction between high rate & low rate telemetry	A particular bit in the high rate channel degrades the low rate channel SNR by as much as 1 db.	Apparently no mission effect.		
590		Relay Radio Subsystem receiver VCO frequency shift.	Thought to be due to aging effects in vacuum, causing a change in the D.C. bias circuitry.	None, revised frequency curves were prepared & published.		
59[illegible]		Receiver AGC as much as 7 db below predicted value.	Unknown	Was considered a nuisance.	Revised calibration curves were issued.	

Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
592		S-Band receiver VCO rest frequencies changed from pre-launch values.	Attributed to aging effects in deep space - thought to be due to shift in phase detector output.	No effect, ground procedures revised.		
593		Unexpected increments in Computer Command Subsystem counter.	Due to modulation state changes.	Considered trivial occurred 5 times and lasted less than 5 seconds each time.		
594		Unexpected increments in Computer Command Subsystem counter.	Thought due to spurious tone on uplink.	Considered trivial.		See #593.
595		Canopus tracker straylight occurrences.		None.		At least 51 straylight tracking occurrences.
596		Inbalance between inboard and outboard solar panel currents.	Attributed to thermal gradients.	No impact on power capabilities, although this is an indication of non-optimum load sharing.		
597		Transients following same 30V converter turn-ons.	In ground tests this was was observed and was due to gravity loads on the actuators.	Apparently no effect.		
598		Changes in Infrared Thermal Mapper experiment data with scan platform position changes.	Scan platform position changes produced a difference in heat input to the Infrared Thermal Mapper, thereby changing the magnitude of the infrared data.	No effect on mission - anomaly occurred only occasionally and valid data still obtained.		
599		Mars Atmospheric Water Detector monochromator heater servo temperature anomaly.	Unknown.	Apparently not serious.		
600		Visual Imaging System pointing error.	Unknown.	None, occurred only for 1 earth picture.		
601		Visual Imaging System saturated pictures of the Earth.	Caused by overestimating required exposure due to lack of knowledge.	Not serious.		

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Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
602		Visual Imaging System - veiling glare in star field images during Earth/Star sequences.	Possibly due to sola illumination of telescope interior.	Not serious.		
603		Infrared Thermal Mapper - replacement heater & rear mount temperature measurements reversed.	Appears to be an installation error.	Apparently not serious.		
604		Mars Atmospheric Water Detector - incorrect constants used during ground calibration of gain states 0 through 3.		Resulted in 2 to 6% low readings on Mars Atmospheric Water Detector gain state telemetry; apparently not serious.		
605		Computer Command Subsystem Processor B tranferred to error mode during sun/earth occultation.	Unknown.	Not clear.		
606		Interaction between high rate & low rate telemetry.	A particular bit pattern in the high rate channel degrades the low rate channel SNR by as much as 1 db.	Apparently no mission effect.		See #589 (different spacecraft).
607		Relay Radio Subsystem receiver VCO frequency shift.	Appears to be some anomaly in the VCO itself; thought due to aging effects in vacuum.	None; revised frequency curves were prepared & published.		See #590 (different spacecraft).
608		Receiver AGC below predicted value.	Unknown.	Apparently not serious.		See #591 (different spacecraft).
609		S-band receiver VCO rest frequencies changed from pre-launch values.	Attributed to aging effects in deep space, probably in VCO per se.	No effect; ground procedures revised.		See #592 (different spacecraft).
610		Canopus tracker, straylight occurrences.		None.		At least 19 straylight tracking occurrences, including #1. Also, see #595 (different spacecraft).
611		Imbalance between inboard and outboard solar panel currents.	Attributed to thermal gradients.	No impact on power capabilities, although this is an indication of non-optimum load sharing.		See #596 (different spacecraft).

Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
612		Transients following some 30V converter turn-ons.	In ground tests this anomaly was observed, where it was due to gravity loads on the actuators.	Apparently no effect.		See #597 (different spacecraft).
613		Changes in Infrared Thermal Mapper data with scan platform position changes.	Scan platform position changes produced a difference in heat input to the Infrared Thermal Mapper, thereby changing the magnitude of the infrared data.	No effect on mission - anomaly occurred only occasionally and valid data still obtained.		See #598 (different spacecraft).
614		Infrared Thermal Mapper - replacement heater & rear mount temperature measurements reversed.	Appears to be an installation error.	Apparently not serious.		See #603 (different spacecraft).
615		Mars Atmospheric Water Detector - incorrect constants used during ground calibration of gain states 0 through 3.		Resulted in 2 to 6% low readings on Mars Atmospheric Water Detector gain state telemetry; apparently not serious.		See #604 (different spacecraft).
616		Short, abrupt "glitches" in Relay Telemetry Subsystem.	Unknown.	None, characterized as "idiosyncracy".		See #631.
617		One Relay Telemetry Subsystem data point approximately 0.5 to 1.0 db less sensitive than expected.	Unknown.	Minor operational procedure changed.		
618		Pelay Radio Subsystem - intermittent - 0.4 to 0.8 db perturbation.	Attributed to spacecraft "idiosyncracy"; the Relay Antenna Subsystem may have played some role in this.	Not serious.		
619		Canopus tracker "darker than dark" phenomenon during periods of stray light occurrences.	Unknown.	Not serious.		Manifested by telemetry indications darker than the tracker output voltage cutoff. Phenomenon had never been seen on previous missions.

Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
620		Tape recorder B: tape motion suddenly changed.	Attributed to anomalous change of state of a flip-flop; not known why.	Transient; unit functioned normally before and after anomaly.		
621		RFI on Infrared Thermal Mapper due to S-Band.		Not serious.		
622		Visual Imaging System turn-offs put Mars Atmospheric Water Detector into wave-length scan mode.	Mars Atmospheric Water Detector wiring susceptible to RFI from this source.	During the 13 minutes of this scan period, water amounts cannot be computed.	Visual Imaging System was left on if there was a possibility that water data could be disrupted.	Possibility of this was known prelaunch.
623		During playback of Visual Imaging System data, Digital Tape Recorder - B ran to synchronous speed.	Unknown.	Tape speed caused the Computer Command Subsystem to issue early track changes, resulting in playback stop 17 minutes, 21 seconds too soon.		This could be the same anomaly as #620.
624		Scan platform envelope would not permit Infrared Thermal Mapper "D" telescope to fully view the diffuser plate.	Unknown.	Not clear.		
625		Several battery cells developed a reverse voltage due to overdischarge.	3 of the 4 batteries were allowed to discharge through an isolation resistor to as low as 2.5 V dc.	No detrimental effect; rather, it proved to be an effective reconditioning method.		See #629 (different spacecraft).
626		Batteries exhibited slightly depressed voltage curve upon discharge.	Attributed to lack of battery operational activity.	None, depressed voltage was about 0.5 to 1.0 volts.		See #630 (different spacecraft).
627		TV pictures transmitted by lander revealed a blemish on the high gain antenna; damage suspected.	Possibly due to damage to antenna from landing shocks while in stowed position (antenna is susceptible to such shocks), but since subsequent operation was normal, it was thought the blemish was Martian dust thrown up on landing.	None, subsequent operation successful.		

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Index	Anomaly Time (hours)	Anomalies: Description	Anomalies: Cause	Anomalies: Mission Effect	Corrective Action (if known)	Remarks
628		Transmitter operated at 1 watt rather than 30 watts.	Unknown.	Apparently not serious due to effective corrective action.	Corrective action taken to prevent 1 watt operation (not described further).	See #625 (different spacecraft).
629		Several battery cells developed a reverse voltage due to overdischarge.	Several batteries were allowed to discharge to as low as 2.5 Vdc.	No detrimental effect; rather, it proved to be an effective reconditioning method.		
630		Batteries exhibited slightly depressed voltage curve upon discharge.	Attributed to lack of battery operational activity.	None, depressed voltage was about 0.5 to 1.0 volts.		See #616.
631		Short, abrupt "glitches" seen on Orbiter relay data.	Not known whether cause is in the Orbiter or the Lander.	None, characterized as "idiosyncracy."		
632		Polaris Sensor #2 tracks bright particles.	Possible causes: (1) sun getting into the image dissecting tube, (2) sun reflections off particles.	Negligible--Digital Operational Controller will select Yaw Inertial Reference Unit and maintain Yaw-axis control.		
633		Interferometer IF-2 operated intermittently, subsequently failed.	Cause unknown.	Negligible: F-1 channel can be used for interferometer operations.		
634		Solar array shunt tap voltage high.	Possibly due to shadowing effects, or an open or high impedance in a solar cell string.	Negligible.		
635		Aerospace omnidirectional spectrometer--channel E2 intermittent.	Cause unknown.	Not serious.		
636		Daily transient in Digital Operational Controller pitch attitude command.	Programming error.	Negligible	Was eliminated by reprogramming DOC in flight.	
637		Spacecraft Propulsion Subsystem thruster #14 catalyst bed sensitive to RF under some conditions.	Unknown.	Apparently not serious.		Occurred several times including when various telemetry transmitters/antennas were being activated.

Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
638		Error of approximately 65 seconds occur in both time code generators at the time-of-day turnover.	Unknown.	Negligible.	Software was adjusted for corrective action.	Condition was present pre-launch, and apparently not known about.
639		Quartz Crystal Microbalance experiment sensing crystal temperatures higher than expected.	Unknown.	None.		Experiment not used; not clear whether due to this anomaly or something else.
640		"Lost commands."	Due to interference from an unknown source.	Did not endanger the spacecraft, but resulted in some loss of data.		Problem was present throughout mission.
641		Anomalous pitch angle distributions.	Unknown.	Apparently negligible.	Data Processing System re-programmed over 90 times in-flight for corrections.	
642		Temporary loss of communications (ground problem).	Operations error at the control center.	No reduction in spacecraft functions.		
643		Data collection system experienced several periods of interference and one 9-day period of fewer than expected messages received.	Possibly due to external interference.	Insignificant, always returned to normal.		
644		Pitch motor driver duty cycle rose 6 times between 17, 311-19, 492 hours.	Possibly connected to lubrication.	Negligible.		Anomaly was present throughout mission.
645		Spacecraft clock consistently loses time.	Unknown.	Negligible.	Clock is periodically reset via ground command.	See #468, #482.
646		Battery #6 overcharged on at least 7 occasions.	Unknown.	Battery had to be turned on each time for restoration cycle.	Procedure established so that the other 7 of the 8 batteries could remain on-line to carry the load.	
647		Array degradation greater than expected.	Unknown.	Not a problem; sufficient power available for all requirements.		Anomaly applies throughout mission; degradation was 19.6% at the end of 33 months in orbit.

Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
648		Spacecraft clock drift rate higher than expected.	Unknown.	Negligible.	Clock is periodically reset from the ground.	There was a drift in the command clock of the previous spacecraft in this series, but the drift was in the opposite direction. This anomaly was present throughout the mission.
649		Lower V-antenna was extended only 183m during the first 16 months of operation; also, the antenna was deployed in an asymmetrical shape, nearly parallel to local vertical.	Caused by a mechanical flaw in one leg of the antenna	Not known.		May be related to #566.
650		Burst Receiver gives unreliable data when receiver temperature is above -15° C.	Caused by malfunction in control logic circuitry.	Significant (~60%) loss of observations from the dipole antenna.		See #526.
651		During occultation, noise pulses generated by weak interference from the PI-V/Burst Receivers' local oscillator when both that receiver and the burst receiver are turned to the same frequency.		Apparently not serious.		
652		Minor difficulties with the vernier offset bit in the raster offset system.	Unknown.	Use of vernier bit avoided, limiting commandable offset indexing to about 0.6 arc minutes instead of 0.3 arc minutes.		
653		SASC and SASSC hotter than predicted.	Unknown.	Not significant.		
654		Spacecraft nutates about 0.8° peak to peak at beginning of orbit day.	Due to momentum disturbances as elevation drive moves the pointed instruments' assembly into pointing position.	No effect, nutation transient decays to its residual value.		Decay time is longer than expected, possibly due to liquid viscosity deviation.

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Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
655		Scattered light from Earth enters the "control eyes" at beginning and end of orbit day.		Causes spacecraft to point towards Earth a small amount; shift not large enough to cause problems.		
656		Some imbalance in the string of battery cells during and after overcharge.	Unknown.	Apparently insignificant.		
657		Gamma Ray Monitor; severe long term detector gain change.	Attributed to a problem with a photomultiplier tube, which was a last minute replacement.	Did not significantly impact data gathering capability.		Was first noticed shortly after initial turn-on.
658		Gamma Ray Monitor; detector highly sensitive to overload caused by spacecraft's passage through radiation regions.	Unknown.	No significant impact.	Operational procedure changed during worst orbits.	See #657.
659		Gamma Ray Monitor; built in radioactive (Am^{241}) calibration scheme unsatisfactory.	Attributed to poor geometry,	Not significant--provisions were available for electronic-based calibration.		
660		Gamma Ray Monitor; greater than expected shield counting rate and central detector spectral features.	Apparently caused by local production of gamma ray radiation in the spacecraft and detector material.	Did not significantly impact data gathering capability.		
661		Soft X-Ray Background Radiation experiment; detector failed.	Unknown.	Apparently no major effect on experiment.		
662		Short time-frame bus current fluctuations during transition from charge controller voltage clamp to fully activated Bus Voltage Limiters.	Unknown.	No impact on spacecraft operations.		Occurs more frequently when the pointed instrument assembly is rastering or when the tape recorder is in playback.
663		Unexplained turn-off of Soft X-Ray Background Radiation experiment power regulator.	Apparently due to temporary overcurrent in experiment.	Negligible, regulator commanded on again.		
664		Spacecraft temperatures running warmer than expected.	Unknown.	None, temperatures still within design limits.		

Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if know)	Remarks
665		Chromosphere Fine Structure experiment, collimator-VHF susceptibility problem		Not serious.	S-band communications used whenever collimator is active.	This anomaly was also seen in systems tests.
666		Chromosphere Fine Structures experiment telescope bore-sight shifting.	Unknown.	Not indicated.		
667		Tape recorder has some "glitches" and data dropout.	Unknown.	Not serious		
668		TV electronics, both cameras: small variations in dark current.	Unknown.	Not serious.		
669		Occasional noise interference on TV readouts (wide angle).	Due to mechanical vibration of Ultraviolet Spectrometer shutter/mirror.	Not serious due to corrective action.	Image processing techniques developed to remove the noise pattern from the data.	Interference determined to have been present pre-launch.
670		Central Computer and Sequencer errors due to timing between this subsystem and the Data Automation Subsystem.	Timing was not well understood beforehand.	None, Central Computer and Sequencer was reprogrammed.		
671		Telemetry bit error rate often too high for Infrared Interferometer Spectrometer.	Not indicated, but apparently this was not unexpected.	Although adjusted for in-ground data reduction, data was still lost because occasionally the bit error characteristics were such that the ground lost sync, and several words were lost each time.		See #672.
672		Tape recorder timing and anomaly on its tachometer control track caused Infrared Interferometer Spectrometer data outages.	Unknown.	Between these outages and the data lost due to 671, over 60% of all Infrared Interferometer Spectrometer data was lost.		
673		Infrared Interferometer Spectrometer. Increasing number of phase lock loss incidents as mission progressed and communications range increased.	Most likely cause is shift in motor start position due to shift in value of electronics components.	Probable effect is loss of usable data as the communications range increased. See 671, 672 in connection with this.		

Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
674		Infrared Interferometer Spectrometer: darkening of neon bulb reference light source.	Due to metallic migration from electrodes to inner side of bulb's glass envelope.	No effect because of ample design margin.		See #671-#673.
675		Data Automation Subsystem reset pulses superimpose noise spikes in Infrared Interferometer Spectrometer.	Cause for interference not known.	No effect, ground processing removes the spikes.		See #671-#674.
676		Random noise on Ultraviolet Spectrometer data.	Due to cosmic radiation impinging on the photo-multiplier tube.	No significant effect on data gathering.		
677		Narrow angle TV camera: loss of resolution when data numbers above mid-scale.	Unknown.	Can affect the analysis of small features on some pictures.		Seen pre-flight and throughout mission.
678		Dust specks on both TV cameras.		Specks could be seen only when the data were highly enhanced.		Had been present but unnoticed prior to launch; also, see #679.
679		Both TV cameras had blemishes.	Unknown.	Blemishes could be seen easily only when the data were highly enhanced.		These blemishes were in addition to the dust specks mentioned in #678.
680		High-gain antenna pointing proved to be a major problem at X-band.	Due to limited memory storage on spacecraft so that only coarse antenna pointing increments could be contained.	Apparently no serious mission effect; X-band transmitter was experimental.		
681		Gas leak.	Unknown.	Spacecraft was turned off at 12,144 hours due to gas depletion; not clear whether the leak contributed to this see #374, #197.		
682		More thruster spin coupling than expected.	Attributed to plume reflection, a design error.	No significant mission effect.		A similar occurrence on subsequent spacecraft led to identification of cause of anomaly.

Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
683		Over 50 spurious commands were executed, beginning at 480 hours and continuing through 19,200 hours.	This situation has been intensely studied; it was postulated that the Asteroid/Meteoroid detector package might be causing the problem. The detector was turned off around 19,200 hours and apparently the spurious commands did not recur.	The spurious commands never had a serious effect on mission, since the false commands were always reversible by ground.		
684		Problems with the Visible-Infrared Spin-Scan Radiometer calibration.	Due to changing thermal gradients.	Apparently no major impact.		Could have been prevented by additional on-board temperature sensing hardware.
685		Both UHF transmitters restricted to low power mode only.	Due to thermal design fault.	Apparently did not impact mission objectives.		Occurred on previous spacecraft also.
686		Leak in Radial Thruster #2.	Unknown.	Apparently causes minor change in spacecraft spin rate.		
687		Battery overcharging problem.	Unknown.	None, work around procedures applied satisfactorily.		
688		Vertical Temperature Profile Radiometer #1 calibration function problem.	Unknown.	Did not impact acquisition of valid data.		
689		Overheating in one battery.	Unknown.	Not significant.		
690		Selective Chopper Radiometer calibration mirror hung up in space during calibrate cycle.	Believed due to execution of a normal gain command which caused a logic upset.	Not serious.		
691		Surface Composition Mapping Radiometer black body temperatures for channels 1 and 2 vary.	Unknown.	Apparently insignificant.		
692		Power notch occurs in the array current (~900ma) near end-of-day/end-of-night transition.	Unknown; may be related to #19 and #20.	Apparently not serious.		

Index	Anomaly Time (hours)	Anomalies: Description	Cause	Mission Effect	Corrective Action (if known)	Remarks
693		Missing earth pulse caused pitch, roll and yaw attitude perturbations	Unknown	Apparently not serious, occurred only once		
694		Selective Chopper Radiometer gain decreased over long period of time	Unknown	Apparently no mission effect		
695		Battery temperatures exceed 50 spread limit when Earth Radiation Budget experiment is on.	Due to design (i.e., double batteries in bays over Earth Radiation Budget experiment).	Minor problem.		
696		Pressure Modulated Radiometer, channel 1 space view and channels 1 and 2 earth view telemetry erratic	Due to light leakage	Insignificant		
697		Earth Radioation Budget experiment, channels 10 and 18 noisy.	Not indicated, but this was observed in test.	Insignificant		
698		Earth Radiation Budget experiment solar channels found to require two commands to move when in an odd (as opposed to even) position.	Due to logic design	Insignificant		
699		Earth Radiation Budget experiment, data from channels 19-22 dropped to zero.	Unknown	Not significant.		
700		Limb Radiance Inversion Radiometer, output of all 4 channels indicated view warmer than source.	Resulted from "viewing" the moon.	Not significant		
701		Earth Radiation Budget experiment temperature intermittent.	Due to Beam Blocker/Chopper motor.	Insignificant.		
702		Limb Radiation Inversion Radiometer--channel 2 source view saturated.	Due to sensitivity of detector at the warmer temperatures.	Not significant.		
703		Clock serial data error to telemetry incorrect.	Unknown.	Insignificant		

Index	Anomaly Time (hours)	Anomalies			Corrective Action (if known)	Remarks
		Description	Cause	Mission Effect		
704		Resistojet failed.	Unknown, may have been inoperable pre-launch.	Was never used, complete loss of experiment.		
705		Transponder #2 High Voltage power supply shorts out intermittently.	Unknown.	Negligible due to redundancy.		
706		Transponder #2, Repeater #2, shorts out intermittently, and can be used only for short periods.	Unknown.	Negligible due to redundancy.		
707		VHF communications experiment, 1 of the 8 transmitters and/or antenna elements was destroyed at launch.	Unknown.	Still operates satisfactorily on the remaining 7 channels.		
708		IDCS vertical scan not usable; horizontal scan operable but difficult to get logic commands in.	Unknown.	Apparently not serious.		

Appendix A-IVb

CLASSIFICATION CODES

Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
1	U	L							
2	U	L							
3		S	L	2	g	U	U	U	2
4		L	L	1	a	E	N	A	1
5		L	L	1	a	E	N	A	1
6		L	L	1	a	E	N	A	1
7		L	L	1	a	E	N	A	4
8		L	L	1	c	E	U	U	3
9		L	L	1	f	M	U	U	2
10		L	L	3	f	M	O	A	2
11		L	L	1	f	M	N	U	2
12		L	L	1	d	O	N	A	1
13		L	L	1	b	E	C	A	1
14		L	L	1	d	E	U	U	4
15		L	L	U	d	E	N	U	1
16		L	L	1	d	E	C	N	2
17		L	L	1	b	E	O	A	5
18		L	L	2	d	E	O	A	2
19		L	L	1	g	E	O	U	1
20		L	L	1	g	O	N	A	1
21		L	L	1	g	E	N	A	1
22		L	L	1	d	E	N	A	1
23		L	L	1	d	E	N	N	1
24		L	L	1	a	E	U	U	3
25		L	L	1	f	E	O	N	3
26		L	L	1	f	U	U	U	2
27		L	L	1	c	U	U	U	5
28		L	L	1	d*	O	N	A	2
29		L	L	1	g	E	U	U	1
30		L	L	1	a	E	U	U	1
31		L	L	1	d	M	N	A	3
32		L	L	1	d	O	N	A	2
33		L	L	2	g	M	O	A	1
34		L	L	1	g	E	N	A	1
35		L	L	2	g	M	U	U	1
36		L	L	1	f	M	O	A	2
37		L	L	1	d	O	N	A	1
38		L	L	1	f	U	U	U	2
39		L	L	1	c	O	N	A	2
40		L	L	1	b	E	O	A	1
41		L	L	1	g	E	U	U	1
42		L	L	1	g	E	U	U	1
43		L	L	1	c	E	N	A	3

Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
44		L	L	1	b	E	N	A	1
45		L	L	1	b	O	N	A	1
46		L	O	1	g	U	U	U	1
47		L	O	1	b	E	U	U	1
48		L	O	1	b	E	N	A	5
49		L	L	1	d	E	N	A	1
50		L	L	3	b	E	U	U	5
51		L	O	1	g	E	O	U	1
52		L	O	1	c	E	N	U	1
53		L	O	1	b	M	N	A	4
54		L	O	1	d	E	U	U	1
55		L	O	2	b	E	O	A	4
56		L	O	1	d*	U	U	U	2
57		L	L	1	g	E	N	A	1
58		L	L	1	d	E	N	A	1
59		L	O	2	g	E	O	U	1
60		L	O	2	g	E	U	U	1
61		L	O	2	g	M	N	A	1
62		L	O	1	d*	O	N	N	1
63		L	O	2	g	E	N	A	1
64		L	L	1	g	E	O	A	2
65		L	O	2	g	E	N	A	1

Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
66		L	O	1	g	E	U	U	1
67		L	O	1	g	E	U	U	1
68		L	O	1	b	E	U	U	5
69		L	O	2	g	E	N	A	1
70		L	O	2	a	E	U	U	7
71		L	O	1	g	U	U	U	1
72		L	O	1	g	E	N	A	1
73		L	L	1	b	E	O	A	1
74		L	O	2	a	E	N	A	1
75		L	O	1	d	O	N	A	1
76		L	L	1	d	E	O	U	1
77		L	O	1	b	O	N	A	1
78		L	O	1	d	E	U	U	2
79		L	O	1	d	E	N	N	1
80		L	L	2	g	E	O	N	1
81		L	O	1	g	E	U	U	1
82		L	O	1	b	M	U	A	4
83		L	O	U	g	U	U	U	1
84		L	O	1	d	E	N	N	1
85		L	O	1	b	E	N	U	4
86		L	O	1	d	E	U	U	2
87		L	O	1	d	U	U	U	1
88		L	O	2	c	E	N	A	1

Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
89		L	L	1	g	E	U	U	2
90		L	L	1	d	E	O	A	2
91		L	O	1	g	E	N	A	1
92		L	O	2	g	E	O	U	1
93		L	L	1	g	E	U	U	1
94		L	O	1	b	E	N	A	5
95		L	O	1	g	E	N	A	1
96		L	O	1	e	U	U	U	1
97		L	O	1	a	E	N	A	4
98		L	O	1	d*	O	N	A	2
99		L	O	2	b	E	N	A	3
100		L	O	1	b	E	U	A	4
101		L	O	1	f	E	N	A	2
102		L	O	1	g	E	U	U	2
103		L	O	1	d	U	U	U	2
104		L	O	2	g	U	U	U	1
105		L	O	1	g	E	U	U	1
106		L	O	1	d	E	N	U	1
107		L	O	1	d	E	U	U	2
108		L	O	1	b	E	C	N	1
109		L	O	1	g	E	N	A	2
110		L	O	1	b	U	U	U	5
111		L	O	1	b	E	N	A	2
112		L	O	1	b	E	N	A	1
113		L	O	1	d	E	U	U	1
114		L	O	1	d	E	U	U	1
115		L	O	1	g	E	N	A	2
116		L	O	1	f	E	U	U	2
117		L	O	1	g	E	C	A	1
118		L	O	1	g	E	U	U	1
119		L	O	1	g	E	N	A	1
120		L	O	2	g	E	U	A	1
121		L	O	1	d	U	U	U	2
122		L	O	1	d	U	U	U	2
123		L	O	1	g	U	U	U	2
124		L	O	2	f	M	U	U	2
125		L	O	U	g	E	[illegible]	U	1
126		L	O	1	b	U	U	U	4
127		L	O	1	g	E	U	A	1
128		L	O	1	g	E	U	U	2
129		L	O	2	b	E	U	U	5
130		L	O	1	g	E	U	A	2
131		L	O	1	g	E	U	A	2
132		L	O	1	g	E	U	A	2
133		L	O	2	g	E	U	A	1

Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
134		L	O	2	g	U	U	U	1
135		L	O	1	d	M	N	A	2
136		L	O	2	d	U	U	U	2
137		L	O	1	c	E	N	A	2
138		L	O	2	f	E	N	A	2
139		L	O	2	g	E	C	A	1
140		L	O	1	g	E	U	A	2
141		L	O	1	b	E	U	U	5
142		L	O	1	d	E	N	A	1
143		L	O	2	g	E	C	N	1
144		L	O	1	g	E	U	U	1
145		L	O	1	g	E	N	A	1
146		L	O	1	b	E	U	U	1
147		L	O	1	b	E	U	U	5
148		L	O	1	b	E	U	U	4
149		L	O	1	b	E	O	N	3
150		L	O	1	a	E	O	N	3
151		L	O	3	b	M	N	A	4
152		L	O	1	f	M	U	U	2
153		L	O	1	d	U	N	A	1
154		L	O	1	g	E	U	U	1
155		L	O	1	g	E	U	U	1

Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
156		L	O	1	f	M	U	U	2
157		L	O	1	g	E	U	U	1
158		L	O	1	b	E	N	A	1
159		S	O	5	g	E	C	N	1
160		L	O	1	g	E	N	A	2
161		L	O	1	f	M	N	N	2
162		L	O	1	d	E	U	U	1
163		L	O	1	e	E	U	U	1
164		L	O	1	g	U	U	A	2
165		L	O	1	a	E	U	U	5
166		L	O	2	h	E	N	A	5
167		L	O	1	d	E	U	U	1
168		L	O	1	d	E	O	U	1
169		L	O	2	f	M	U	U	2
170		L	O	2	g	E	U	U	1
171		L	O	1	a	O	N	A	3
172		L	L	2	c	E	U	U	4
173		L	O	2	g	M	C	U	1
174		L	O	1	d	E	C	N	1
175		L	O	2	g	M	N	U	1
176		L	O	1	b	O	N	A	1
177		L	O	1	b	E	U	U	5
178		L	O	1	b	E	U	U	5

Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
179		L	O	1	d	E	N	A	2
180		L	O	1	d	E	U	U	2
181		L	O	1	g	M	U	U	1
182		L	O	1	g	E	U	U	1
183		L	O	1	b	E	C	N	1
184		L	O	1	b	O	N	A	5
185		L	O	1	g	U	U	U	1
186		L	O	2	b	M	O	A	4
187		L	O	1	e	E	C	N	1
188		L	O	U	g	E	U	U	1
189		L	O	2	g	M	N	N	1
190		L	O	1	b	E	U	U	1
191		L	O	1	g	E	U	A	2
192		L	O	1	b	M	N	A	5
193		L	O	1	f	E	N	A	2
194		L	O	2	c	E	C	N	3
195		L	O	1	g	E	U	A	2
196		L	O	2	b	M	N	A	4
197		L	O	2	d	M	N	A	2
198		L	O	1	g	E	N	A	1
199		L	O	1	g	E	U	U	1
200		L	O	1	c	E	C	N	2

Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
201		L	O	1	a	E	N	U	3
202		L	O	1	d	E	N	A	1
203		L	O		g	E	N	A	1
204		L	O	1	g	E	U	U	1
205		L	O	1	a	E	U	A	5
206		L	O	1	d	U	U	U	2
207		L	O	1	g	U	U	U	2
208		L	O	1	d	O	N	A	2
209		L	O	1	b	O	N	A	5
210		L	O	1	g	O	N	A	2
211		L	O	1	b	E	N	A	5
212		L	O	1	f	E	N	A	2
213		L	O	2	b	E	U	U	5
214		L	O	1	a	O	N	A	3
215		L	O	1	d	E	U	U	2
216		L	O	3	g	E	N	A	2
217		L	O	1	g	E	U	U	1
218		L	O	1	c	O	O	U	1
219		L	O	1	c	U	U	U	2
220		L	O	1	d	O	N	A	1
221		L	O	1	d*	E	U	U	2
222		L	O	1	d	E	U	U	1
223		L	O	1	c	E	O	A	1

Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
224		L	O	1	d	E	N	A	1
225		L	O	2	g	O	N	A	1
226		L	O	1	a	E	U	U	1
227		L	O	1	b	E	U	U	5
228		L	O	1	b	E	N	A	5
229		L	O	2	g	U	U	U	1
230		L	O	2	g	E	C	N	1
231		L	O	2	b	M	U	U	4
232		L	O	1	b	E	U	U	1
233		L	O	1	g	E	N	A	2
234		L	O	1	c	E	U	U	1
235		L	O	1	d	E	N	N	1
236		L	O	1	g	E	U	U	1
237		L	O	1	b	E	N	A	5
238		L	O	1	a	E	U	U	4
239		L	O	1	d	E	N	N	1
240		L	O	2	d*	M	O	A	2
241		L	O	5	c	E	C	N	3
242		L	O	1	f	E	O	U	2
243		L	O	1	c	U	U	U	1
244		L	O	1	g	E	N	A	1
245		L	O	1	a	U	U	U	7
246		L	O	1	b	E	N	A	5

Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
247		L	O	1	g	E	U	U	1
248		L	O	1	a	E	N	A	4
249		L	O	1	g	U	U	U	1
250		L	O	1	a	O	N	A	5
251		L	O	1	g	E	C	N	2
252		L	O	1	g	E	U	U	1
253		L	O	1	e	U	U	U	1
254		L	O	1	g	M	O	U	2
255		L	O	2	c	E	U	U	1
256		L	O	1	g	E	U	A	1
257		L	O	1	g	E	U	U	1
258		L	O	2	g	M	N	N	1
259		L	O	1	d*	E	U	U	2
260		L	O	1	g	E	U	U	1
261		L	O	1	g	E	U	U	1
262		L	O	1	g	U	U	U	1
263		L	O	1	g	M	N	A	1
264		L	O	1	a	E	U	U	3
265		L	O	1	g	E	O	U	2
266		L	O	1	d	E	U	U	1
267		L	O	1	e	U	U	U	1
268		L	O	1	d	U	U	U	2

Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
269		L	O	1	b	E	U	U	5
270		L	O	2	g	E	U	U	1
271		L	O	1	b	U	U	U	4
272		L	O	2	c	E	U	U	3
273		L	O	1	b	E	U	U	5
274		L	O	1	a	E	U	U	4
275		L	O	1	a	E	O	U	3
276		L	O	2	g	U	U	A	2
277		L	O	2	g	U	U	U	1
278		L	O	1	b	E	U	U	1
279		L	O	U	g	E	N	A	1
280		L	O	2	g	E	U	U	1
281		L	O	2	b	U	U	U	5
282		L	O	1	g	E	U	U	1
283		L	O	1	g	O	N	A	1
284		L	O	1	g	E	U	U	1
285		L	O	1	g	E	O	U	1
286		L	O	1	d	U	U	U	2
287		L	O	1	b	U	U	U	5
288		L	O	1	a	U	U	U	1
289		L	O	1	b	E	C	N	2
290		L	O	2	d	U	U	U	1

Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
291		L	O	2	b	E	N	A	5
292		L	O	1	g	E	U	U	1
293		L	O	1	g	E	N	A	2
294		L	O	1	b	E	O	A	1
295		L	O	1	d*	M	O	U	2
296		L	O	1	d*	M	N	U	2
297		L	O	1	a	O	N	A	4
298		L	O	1	g	M	N	A	1
299		L	O	1	g	O	N	U	1
300		L	O	1	d*	U	U	U	2
301		L	O	1	d	E	N	A	2
302		L	O	2	c	E	U	U	1
303		L	O	1	d*	O	N	A	2
304		L	O	2	a	E	C	N	1
305		L	O	1	g	O	N	A	2
306		L	O	1	b	U	U	U	4
307		L	O	1	d	E	O	A	1
308		L	O	2	b	E	U	U	4
309		L	O	2	d	E	N	A	1
310		L	O	1	a	E	N	A	4
311		L	O	2	g	E	N	A	1
312		L	O	1	a	E	U	U	2

Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII	Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
313		L	O	1	a	E	U	U	2	335		L	L	1	g	E	U	A	1
314		L	O	U	g	M	N	U	1	336		L	O	2	g	E	U	U	1
315		L	O	2	a	O	N	A	8	337		L	O	1	c	E	U	U	3
316		L	O	1	b	E	O	A	3	338		L	O	1	b	O	N	A	1
317		L	O	1	c	E	C	A	3	339		L	O	2	d*	M	O	A	2
318		L	O	1	g	E	U	U	1	340		L	O	2	b	E	U	U	5
319		L	O	1	g	E	N	A	2	341		L	O	2	g	E	U	U	1
320		L	O	2	c	E	U	U	5	342		L	O	1	g	E	N	A	2
321		L	O	1	d	E	U	U	1	343		L	O	1	g	E	N	A	2
322		L	O	2	b	U	C	N	4	344		L	O	1	b	U	U	U	4
323		L	O	1	b	E	U	U	5	345		L	O	1	b	O	N	N	4
324		L	O	1	a	E	N	N	4	346		L	O	1	g	U	U	U	1
325		L	O	1	b	E	C	A	1	347		L	O	1	d	E	N	A	2
326		L	O	1	g	E	U	U	1	348		L	O	2	g	U	U	U	1
327		L	O	2	g	E	U	U	1	349		L	O	1	d	E	O	A	2
328		L	O	1	b	E	U	U	5	350		L	O	1	g	E	U	U	1
329		L	O	2	g	E	U	U	1	351		L	O	1	d	E	U	U	1
330		L	O	1	g	E	U	U	1	352		L	O	1	a	E	N	A	4
331		L	O	1	a	E	U	U	1	353		L	O	U	b	E	C	A	1
332		L	O	2	c	E	U	U	2	354		L	O	1	a	E	U	U	4
333		L	O	1	a	E	U	U	2	355		L	O	1	d	O	N	A	1
334		L	O	1	g	E	U	A	1	356		L	O	1	b	U	U	U	4

Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
357		L	O	1	g	E	N	A	2
358		L	O	1	g	E	O	N	1
359		L	O	1	d	O	N	U	1
360		L	O	1	a	E	U	U	1
361		L	O	2	a	U	U	U	7
362		L	O	2	d*	O	O	A	1
363		L	O	1	d*	U	U	U	2
364		L	O	1	f	E	N	A	2
365		L	O	1	f	E	N	A	2
366		L	O	1	a	E	N	A	1
367		L	O	1	b	U	U	U	4
368		L	O	1	g	E	C	N	2
269		L	O	2	b	M	N	A	4
370		L	O	2	a	E	N	A	4
371		L	O	2	a	U	U	U	4
372		L	O	1	a	E	U	U	1
373		L	O	2	a	U	U	U	4
374		L	O	U	b	E	C	A	1
375		L	O	2	a	E	U	U	4
376		L	O	2	a	U	U	U	4
377		L	O	2	f	M	O	A	1
378		L	O	2	[illegible]	U	U	U	4

Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
379		L	O	1	g	O	N	N	1
380		L	O	U	a	U	U	U	1
381		L	O	1	g	O	N	N	1
382		L	O	2	g	M	N	N	1
383		L	O	1	g	E	N	N	1
384		L	O	1	d	E	N	N	1
385		L	O	2	g	E	N	A	1
386		L	O	1	d	E	N	N	1
387		L	O	1	d	U	U	U	2
388		L	O	2	a	E	U	U	2
389		L	O	1	d	E	O	A	2
390		L	O	2	g	E	U	U	1
391		L	O	1	c	E	O	U	4
392		L	O	1	d	E	O	A	2
393		L	O	1	b	E	C	N	3
394		L	O	1	g	E	U	U	1
395		L	O	1	g	E	N	A	1
396		L	O	1	a	E	O	A	7
397		L	O	1	c	E	U	U	5
398		L	O	1	d*	M	N	U	2
399		L	O	1	g	E	N	N	1
400		L	O	2	b	E	N	A	4

Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII	Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
401		L	O	1	f	M	N	A	2	423		L	O	2	g	E	C	N	1
402		L	O	2	f	M	C	N	2	424		L	O	1	g	E	C	N	1
403		L	O	[illegible]	g	E	U	U	1	425		L	O	2	g	U	U	U	1
404		L	O	1	g	E	U	U	1	426		L	O	1	d*	M	O	A	1
405		L	O	2	g	E	U	U	[illegible]	427		L	O	1	g	E	N	U	1
406		L	O	2	d	E	O	A	1	428		L	O	2	b	E	U	U	5
407		L	O	1	a	E	U	A	1	429		L	O	2	b	E	N	A	5
408		L	O	2	g	E	U	U	1	430		L	O	1	g	E	U	U	1
409		L	O	2	f	M	N	A	2	431		L	O	1	c	E	U	U	1
410		L	O	3	b	U	U	U	4	432		L	O	2	d	E	U	U	2
411		L	O	1	d	E	N	A	1	433		L	O	2	b	E	N	N	5
412		L	O	1	b	E	N	N	3	434		L	O	1	g	U	U	U	1
413		L	O	2	g	M	U	U	1	435		L	O	2	d	E	U	A	2
414		L	O	2	d	E	C	N	2	436		L	O	2	g	U	U	U	1
415		L	O	1	g	E	U	U	1	437		L	O	2	c	E	C	N	1
416		L	O	2	b	E	U	U	5	438		L	O	1	f	U	U	U	2
417		L	O	2	d	E	U	U	1	439		L	O	2	d	M	N	A	2
418		L	O	1	c	E	U	U	1	440		L	O	1	b	E	C	N	1
419		L	O	1	g	E	U	U	1	441		L	O	2	a	E	U	U	5
420		L	O	1	g	E	U	U	1	442		L	O	1	a	E	U	A	1
421		L	O	1	d	E	U	U	1	443		L	O	1	a	E	O	U	4
422		L	O	1	c	E	C	A	3	444		L	O	1	a	E	N	A	1

Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII	Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
445		L	O	2	b	E	N	N	5	467		L	O	2	g	O	N	U	1
446		L	O	1	b	E	O	A	3	468		L	O	1	c	E	U	U	2
447		L	O	U	a	U	U	U	1	469		L	O	1	b	U	U	U	4
448		L	O	1	g	M	N	A	1	470		L	O	1	b	E	U	U	2
449		L	O	1	g	M	U	U	1	471		L	O	1	b	E	O	U	4
450		L	O	2	d	E	U	U	1	472		L	O	3	c	E	C	A	3
451		L	O	1	b	E	O	A	3	473		L	O	1	g	U	U	U	1
452		L	O	3	g	E	O	N	1	474		L	O	1	d	E	U	U	1
453		L	O	1	b	U	N	A	4	475		L	O	1	g	E	N	N	1
454		L	O	2	g	E	C	A	1	476		L	O	1	c	E	U	U	2
455		L	O	1	d	E	O	N	2	477		L	O	1	d	M	N	U	2
456		L	O	1	d	U	U	U	2	478		L	O	2	d*	M	O	A	2
457		L	O	1	g	U	U	U	1	479		L	O	1	g	M	N	A	1
458		L	O	2	b	E	N	U	4	480		L	O	1	a	E	U	U	4
459		L	O	1	b	U	U	U	4	481		L	O	2	c	E	N	U	2
460		L	O	1	a	E	U	U	4	482		L	O	1	c	E	U	U	2
461		L	O	1	g	E	N	U	1	483		L	O	1	b	E	U	U	4
462		L	O	2	g	E	U	U	2	484		L	O	3	b	U	U	U	4
463		L	O	2	d	E	O	U	1	485		L	O	1	a	E	U	U	4
464		L	O	1	b	E	N	U	1	486		L	O	1	d*	M	O	N	2
465		L	O	1	d	E	U	U	1	487		L	O	1	e	O	N	A	1
466		L	O	1	g	U	U	U	1	488		L	O	1	b	E	U	U	5

Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
489		L	O	1	b	E	U	U	1
490		L	O	2	b	E	U	U	4
491		L	O	1	g	U	U	U	1
492		L	O	1	d	E	N	N	1
493		L	O	U	g	E	U	U	1
494		L	O	2	g	U	[illegible]	U	1
495		L	O	U	b	E	C	A	1
496		L	O	1	d	O	N	U	2
497		L	O	U	g	E	U	U	1
498		L	O	1	b	M	N	A	4
499		L	O	U	d*	M	C	A	2
500		L	O	2	b	U	C	N	4
501		L	O	1	b	E	U	U	5
502		L	O	2	c	E	C	U	2
503		L	O	1	c	E	U	U	2
504		L	O	1	g	E	U	U	1
505		L	O	2	g	E	N	A	1
506		L	O	2	g	E	U	U	1
507		L	O	1	g	U	U	[illegible]	1
508		L	O	3	g	E	N	N	1
509		L	O	2	d	U	U	U	4
510		L	O	3	g	U	U	U	1
511		L	O	1	c	E	N	A	3
512		L	O	2	g	E	U	U	2
513		L	O	3	d	O	N	A	2
514		L	O	2	g	E	C	N	1
515		L	O	1	b	E	U	U	1
516		L	O	1	g	U	U	U	1
517		L	O	2	d	U	U	U	4
518		L	O	U	d*	U	U	U	2
519		L	O	2	g	U	U	U	1
520		L	O	U	b	E	U	U	5
521		L	O	1	c	E	U	U	2
522		L	O	1	b	E	U	U	5
523		L	O	1	d*	E	U	U	2
524		L	O	1	g	E	C	N	2
525		L	O	1	b	E	N	A	4
526		L	O	2	g	E	U	U	1
527		L	O	2	c	O	O	N	2
528		L	O	1	g	E	U	U	1
529		L	O	1	c	E	U	U	1
530		L	O	1	g	E	U	U	1
531		L	O	1	b	O	N	N	4

Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
532		L	O	1	a	E	U	U	5
533		L	O	1	c	E	U	U	2
534		L	O	2	c	E	U	U	2
535		L	O	2	d*	M	C	N	2
536		L	O	2	g	E	O	A	1
537		L	O	1	c	E	U	U	
538		L	O	U	b	E	U	U	5
539		L	O	2	c	E	N	A	2
540		L	O	U	d*	M	U	U	2
541		L	O	1	g	E	U	U	1
542		L	O	2	d	U	U	U	4
543		L	O	1	g	U	U	U	1
544		L	O	2	d	E	N	N	1
545		L	O	2	b	E	U	U	5
546		L	O	1	b	U	U	U	4
547		L	O	U	d	O	N	U	2
548		L	O	1	g	U	U	U	1
549		L	O	2	c	E	O	N	3
550		L	O	2	c	U	U	U	2
551		L	O	2	g	E	U	U	1
552		L	O	1	g	E	U	U	1
553		L	O	1	g	E	U	U	1

Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
554		L	O	U	c	E	U	U	5
555		L	O	2	d*	M	O	A	2
556		L	O	2	c	E	U	U	[illegible]
557		L	O	1	d*	M	N	U	2
558		L	O	2	g	E	U	U	1
559		L	O	1	g	U	U	U	1
560		L	O	2	d	U	U	U	1
561		L	O	1	b	E	U	U	3
562		L	O	2	g	E	U	U	1
563		L	O	1	b	E	U	U	5
564		L	O	2	d	U	U	U	1
565		L	O	2	g	E	C	N	1
566		L	O	1	f	M	U	U	2
567		L	O	1	b	E	U	U	5
568		L	O	5	b	E	N	A	5
569		L	O	2	b	E	U	U	5
570		L	O	1	g	E	U	U	1
571		L	O	3	d*	M	O	A	2
572		L	O	3	d*	M	O	A	2
573		L	O	2	c	U	U	U	2
574		L	O	1	g	E	U	U	2
575		L	O	1	g	E	U	U	2
576		L	O	1	g	E	U	U	2

Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
577		L	O	1	b	U	U	U	4
578		L	O	2	g	E	U	U	1
579		L	O	1	a	E	U	U	5
580		L	O	5	c	E	U	U	4
581		L	O	1	f	M	O	N	2
582		[illegible]	O	2	c	U	U	U	2
583		L	O	1	b	E	N	U	5
584		L	O	1	b	E	U	U	3
585		L	O	1	g	U	U	A	1
586		L	O	1	d	M	O	A	3
587		L	O	2	c	E	N	A	1
588		L	L	1	a	E	U	N	1
589		L	O	1	b	E	N	A	5
590		L	O	1	a	E	N	N	1
591		L	O	2	a	E	U	U	[illegible]
592		L	O	1	a	E	U	A	1
593		L	O	1	a	E	N	M	4
594		L	O	1	a	E	N	A	4
595		L	O	1	d	O	N	A	1
596		L	O	1	c	E	N	A	1
597		L	O	1	c	E	N	A	4
598		L	O	1	g	[illegible]	N	A	1
599		L	O	1	g	U	U	U	1

Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
600		L	O	1	g	U	U	U	1
601		L	O	1	g	O	N	A	1
602		L	O	1	g	O	N	A	1
603		L	O	1	g	E	N	A	1
604		L	O	1	g	E	N	A	1
605		L	O	U	a	E	U	U	4
606		L	O	1	b	E	N	A	5
607		L	O	1	b	E	U	U	7
608		L	O	1	a	E	U	U	1
609		L	O	1	a	E	U	A	1
610		L	O	1	d	O	N	A	1
611		L	O	1	c	E	N	A	1
612		L	O	1	c	E	N	A	4
613		L	O	1	g	O	N	A	1
614		L	O	1	g	E	N	A	1
615		L	O	1	g	E	N	A	1
616		L	O	1	b	E	U	U	5
617		L	O	1	b	E	U	U	1
618		L	O	1	b	E	N	A	7
619		L	O	1	d	E	U	U	1
620		L	O	1	b	E	O	U	4
621		L	O	1	g	E	N	A	1
622		L	O	2	g	E	N	A	1

Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
623		L	O	2	b	U	U	U	4
624		L	O	U	g	U	U	U	1
625		L	O	1	c	E	N	A	2
626		L	O	1	c	E	N	A	2
627		L	O	1	g	O	N	U	1
628		L	O	1	b	E	U	U	5
629		L	O	1	c	E	N	A	2
630		L	O	1	c	E	N	A	2
631		L	O	1	b	E	U	U	5
632		L	L	1	d	O	N	A	1
633		L	L	1	d	E	O	U	1
634		L	L	1	c	E	U	A	3
635		L	L	1	g	E	U	U	2
636		L	L	1	a	O	N	A	4
637		L	O	1	d*	O	N	N	2
638		L	O	1	a	E	U	A	5
639		L	O	1	g	U	U	U	2
640		L	O	2	a	E	N	U	7
641		L	O	1	d	U	U	U	2
642		L	O	1	b	O	N	A	7
643		L	O	1	g	E	U	U	2
644		L	O	1	d	O	N	U	2
645		L	O	1	a	U	U	U	5
646		L	O	1	c	E	U	U	2
647		L	O	1	c	E	N	U	1
648		L	O	1	a	U	U	A	5
649		L	O	U	f	M	N	A	2
650		L	O	3	g	E	O	A	1
651		L	O	1	g	E	N	A	1
652		L	O	2	d	E	U	U	2
653		L	O	1	d	U	U	U	4
654		L	O	1	d	M	N	A	3
655		L	O	1	d	E	N	A	1
656		L	O	1	c	E	U	U	2
657		L	O	1	g	E	O	A	1
658		L	O	1	g	E	U	U	1
659		L	O	1	g	E	N	A	1
660		L	O	1	g	E	N	A	1
661		L	O	1	g	E	U	U	1
662		L	O	1	c	E	U	U	3
663		L	O	1	g	E	N	U	1
664		L	O	1	e	U	U	U	1
665		L	O	1	g	E	N	A	1
666		L	O	U	f	M	U	U	1
667		L	Q	1	b	U	U	U	4
668		L	O	1	g	E	U	U	1
669		L	O	1	g	E	O	A	1

Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
670		L	Q	1	a	E	N	A	4
671		L	L	2	g	E	N	A	1
672		L	L	2	b	U	U	U	4
673		L	L	2	g	E	O	A	1
674		L	Q	1	g	E	N	N	1
675		L	O	1	b	E	U	U	3
676		L	O	1	g	E	N	N	1
677		L	O	2	g	E	U	A	1
678		L	O	1	g	O	N	A	1
679		L	O	1	g	O	N	U	1
680		L	O	2	f	O	N	A	2
681		L	O	2	d*	U	U	U	2
682		L	O	1	d*	O	N	A	3
683		L	O	2	a	E	U	U	7
684		L	O	1	g	E	N	A	1
685		L	O	2	b	E	N	A	5
686		L	O	2	d*	M	U	U	2
687		L	O	1	c	E	U	U	2
688		L	O	1	g	E	U	U	1
689		L	O	1	c	E	U	U	2
690		L	O	1	g	F	[illegible]	A	1
691		L	O	1	g	E	U	U	1
692		L	O	1	c	E	U	U	1
693		L	O	1	d	E	U	U	1

Launch Index	I	II	III	IV	V	VIA	VIB	VII	VIII
694		L	O	1	g	E	U	U	1
695		L	O	1	c	O	N	A	2
696		L	O	1	g	E	N	A	1
697		L	O	1	g	E	U	A	1
698		L	O	1	g	E	N	A	1
699		L	O	1	g	E	U	U	1
700		L	O	1	g	E	N	A	1
701		L	O	1	g	O	O	A	1
702		L	O	1	g	E	N	A	1
703		L	O	1	a	E	U	U	5
704		L	O	2	c	U	U	U	2
705		L	O	1	b	E	U	U	5
706		L	O	1	b	E	U	U	5
707		L	O	2	g	E	N	A	2
708		L	O	1	g	E	U	U	1

Appendix B

ENGINEERING ANALYSIS REPORT

Appendix B

ENGINEERING ANALYSIS REPORT

A. INTRODUCTION

This appendix describes in detail the data recorded on the working papers generated for this study. Using the available documentation for each spacecraft in the data sample, these working papers, called engineering analysis reports, were produced for each launch in the data bank. Not all the data described below were available for each spacecraft.

B. Engineering Analysis Report

1. General Data Elements

Each engineering analysis report begins with a short general description of the spacecraft and the main objectives of its parent program. This introduction also includes a short narrative of the flight experience of the spacecraft and the time interval covered by the subsequent pages of the report.

Table I lists general information needed for the analysis: (1) name of the mission; (2) the launch vehicle, with a brief description of an abortive launch if one occurred; (3) launch date; (4) orbit parameters including information relative to incorrect orbits due to launch vehicle malfunctions; (5) name of the sponsoring agency and prime contractor; (6) an overall evaluation of the in-flight performance; and (7) program objectives as given by the program office.

TABLE I - GENERAL INFORMATION

MISSION:

LAUNCH VEHICLE:

Describe abortive launch if occurred.

ORBIT PARAMETERS:

AGENCY AND PRIME CONTRACTOR:

PERFORMANCE (Were the Following Objectives Met?):

PROGRAM OBJECTIVES:

2. Reliability Data Elements

Data elements needed to perform the pertinent reliability analysis were entered in three tables of the engineering analysis report. Table II contains the hardware breakdown to two levels of indenture: (1) subsystems, i.e., power subsystem, timing, control, and command subsystem, etc.; and (2) equipment group and/or component, i.e., solar array, batteries, command receivers, beacon transmitters, etc. The list of subsystem names varies by the complexity of the spacecraft under analysis; the precise definition of the subsystems, that is, those functions assigned to a particular subsystem for purposes of this report, are found in subsection II.D.2. The equipment group or component list also is dependent on the particular spacecraft under analysis. It is important to note that the intention here is to define the second-level indenture so that the number of powered and unpowered hours (columns 2 and 3 of Table II) are applicable to all piece-parts within the given grouping. That is, the level of group or component definition is such that all constituent parts operate on the same duty cycle.

Redundancy among equipment groups and/or components was taken into consideration when entries to columns 2 and 3 were made. If the documentation was such that each unit in a redundant configuration was known to have survived, say, 1,000 hours, then 2 units are entered for 2,000 hours, However, if all that is known is that the redundant configuration survived, then the entry is 1 unit for 1,000 hours.

The purpose of columns 2 and 3 on Table II, powered and unpowered hours, is to obtain data from which "standby" reliability might be estimated. Again, it is emphasized that only known hours for the two

TABLE II - OPERATING TIME TO THE COMPONENT LEVEL

System Breakdown	Number of Powered Hours	Number of Unpowered Hours	Number of Cycles	References	Remarks and Assumptions	Anomalous Behavior Description (1)
1. Subsystem Name						
a. Equipment Group/Component Name						
b.						
c.						
. . .						
2. Subsystem Name						
a.						
b.						
c.						
. . .						
3. Subsystem Name						
a.						
b.						
c.						
. . .						

Note: (1) A brief description of anomalous behavior is recorded here, together with its time of occurrence and its index number as given in Table III.

classifications are recorded. Assumptions concerning duty cycles were limited.

Column 3 on Table II, number of cycles, was used for those hardware groups for which the relevant variable is cycles or actuations. Other columns in the exhibit are self-explanatory. The reference column was included so that the source of the data underlying the results could be easily identified. It is noted that this "traceability" is preserved on all working papers thorughout the data analysis; for example, all anomalous behavior classifications are coded so that any question concerning data classification or assumptions can be answered by searching back to the original entry in the engineering analysis report.

Table III shows another format in the engineering analysis report used to record the number of piece-part types for each higher level grouping of hardware shown in Table II. The column labeled la, for example, is the first equipment group or component in the first subsystem listed on Table II. A "total" column was provided for those spacecraft where a parts breakdown by equipment group or subsystem was not available.

The list of piece-parts varies not only by spacecraft but also by the available documentation for the spacecraft. By far the most difficult data element to obtain was the spacecraft parts list; also the level of detail given on parts lists that were obtained was very sparse. With some exceptions, subgroupings within a part type were not available. For example, the total number of resistors used in the spacecraft was generally known, but the types of resistors was not specified. The resulting analysis is necessarily limited to the generic part nomenclature.

TABLE III - PARTS BREAKDOWN

	Total Number of Parts	Number of Parts Per Subsystem and Equipment Group/Component (Coded as on Table I)											
		1a	1b	1c	...	2a	2b	2c	...	3a	3b	3c	...
Battery cells													
Bearings													
Capacitors													
Diodes, Semiconductors													

Table IV shows the format for recording spacecraft anomalous behavior. The description includes a narrative giving the consequences of the anomalous behavior: for example, (1) effect on the mission (catastrophic, negligible, modified by actions performed by ground stations, etc.), (2) effect on other hardware groupings (induced additional anomalous behavior, loss of equipment through deliberate shutdown by ground stations, etc.), and (3) implications on subsequent launches (corrective actions on hardware, changes in orbit parameters, etc.). Provision was made in the final column for any other pertinent comment relative to the overall study; of particular importance are any comments relative to assignable causes for the anomaly. Finally, the anomalous behavior event is referenced on each of the three tables. (This cross-referencing aids the anomalous behavior classifications tabulated in text Sections II, III, and IV.)

In this connection, it is emphasized that a particular anomalous behavior event is not necessarily attributable to a particular piece-part. In fact, only a few such events can be attributed to a particular part-type as suggested in Table III. In most cases, however, anomalous behavior events can be assigned to hardware at the subsystem level, and in many instances, at the equipment group and/or component level (Table II).

3. Development and Prelaunch Elements

The development and prelaunch elements were defined in the earlier study by means of five potential factors present in these two intervals of a spacecraft lifetime. These five factors are listed

TABLE IV - ANOMALOUS BEHAVIOR DESCRIPTION

Identification	Time to Failure (hours)	Consequences	Comments
(1)			
(2)			
.			
.			
.			

in Table V together with a brief description of the specific information required.

Prelaunch activity is explained on Table VI. Basically, this table discusses tests and checkouts conducted prior to launch.

4. Summary

The four tables just described and the general data elements discussed above comprise the data format used in this study in preparation for the data analysis. The first step in the analysis procedure was to generate the anomaly listing; this listing becomes the data basis for the analysis of Sections II, III, and IV of the text.

TABLE V - DEVELOPMENT ACTIVITY

A. TESTING

Narrative indicating items subjected to tests, duration of tests, testing of new items. etc.

B. PARTS SELECTION

Description of types of specifications, part screening, parameter drift screening, etc.

C. QUALITY ASSURANCE PROVISIONS

Description of quality assurance procedures imposed on or by the contractor, i.e., NPC 200-2 or 200-3; special provisions, etc.

D. OFF-THE-SHELF VERSUS NEW DESIGN

Estimation of the percentage of equipment groups in the spacecraft that can be classified as off-the-shelf versus new design. Note that at a part level almost all can be considered "off the shelf," and at a subsystem level almost all can be considered "new design."

TABLE VI - PRELAUNCH ACTIVITY

TEST AND CHECKOUT

Description of the extent of test and checkout at the launch site; description of types of tests, record of anomalies during this period; description of mating problems if any, length of time interval, etc.

Appendix C

DATA BANK COVERAGE

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Appendix C

DATA BANK COVERAGE

INTRODUCTION

The chart in this appendix lists the spacecraft in the data bank. The spacecraft are arranged in numerical order by EAR numbers.

For each spacecraft, the chart shows the launch date, spacecraft status, and the degree of completeness of the tables in the EAR[1]. For some of the spacecraft, not all the information was available and for unsuccessful launches, some of the tables were not applicable, i.e., Table II: Operating Time; Table III: Parts Breakdown; and Table IV: Anomalous Behavior Description.

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[1] See Appendix B of this update for a detailed description of the EAR.

DATA BANK COVERAGE

EAR No.	Spacecraft	Launch Date	Spacecraft Status	Data Bank Coverage: Table I General Information	Table II Operating Time/ System Breakdown	Table III Parts Breakdown	Table IV Failure Description	Table V Developmental Activities	Table VI Pre-Launch Activities
1	Courier IA	8-18-60	Unsuccessful launch	Complete	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
	Courier IB	10-4-60	Inoperable 10-22-60	Complete	Complete, in detail	Complete, in detail	Complete, good detail	Complete, good detail	Complete, good detail
2	Ariel I	4-26-62	Inoperable 11-9-64	Complete	Complete, in detail	Unavailable	Complete, poor detail	Fair detail	Launch chronology
	Ariel II	3-27-64	Last contact 3-30-66	Complete	Complete, in detail	Complete, fair detail	Complete, fair detail	Fair detail	Not given
3	Telstar I	7-10-62	Inoperable 3-18-63	Complete	Complete, in detail	Complete, in detail	Complete, fair detail	Fair detail	Very general
	Telstar II	5-7-63	Operable 8-66	Complete	Complete, in detail	Complete, in detail	Fair detail	Fair detail	No detail
4	Relay I	12-13-62	Data covers from launch to December '63	Complete	Complete, in detail	Complete, in detail	Complete, good detail	Fair detail	Unknown
5	Echo II	1-25-64	Orbital time is from 1-25-64 to 12-65	Complete	Complete, in detail	Complete, in detail	Complete, fair detail	General disc.	Unavailable
6	OAO I	4-8-66	Never operable	Complete	Not applicable	Not applicable	Not applicable	General information	Nil
	OAO II (A-2)	12-7-68	Last anomaly recorded on 12-28-71, still operating at that time	Complete	Complete, in detail	Nil	Complete, good detail	Nil	Nil
	OAO III	Unknown	Unsuccessful launch	None	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
7	Tiros I	4-1-60	Lost function 6-9-60	Complete	Complete	Complete	Complete	Fair detail	Fair detail
	Tiros II	11-23-60	Lifetime = 10 months	Complete	Complete	Complete	Complete	Nil	Fair detail
	Tiros III	7-12-61	Lifetime = 4.5 months	Complete	Complete	Complete	Complete	Nil	Fair detail
	Tiros IV	2-8-62	Lifetime = 4.5 months	Complete	Complete	Complete	Complete	Nil	Fair detail
	Tiros V	6-19-62	Lifetime = 10.5 months	Complete	Complete	Complete	Complete	Nil	Fair detail
	Tiros VI	9-18-62	Lifetime = 13 months	Complete	Complete	Complete	Complete	Nil	Fair detail
	Tiros VII	6-19-63	Lifetime = less than 36 months	Complete	Complete	Complete	Complete	Nil	Fair detail
	Tiros VIII	12-20-63	Unknown	Nil	Complete	Complete (w/VII)	Complete	Nil	Minimum detail
	Tiros IX	1-22-65	Unknown	Nil	Nil	Nil	Nil	Nil	Minimum detail
8	Nimbus I (A)	8-28-64	Failed 9-28-64	Complete	Complete	Complete, fair detail	Complete	Fair detail	Nil
	Nimbus II (C)	5-15-66	Turned off 1-17-69	Complete	Complete	Complete, in detail	Complete, in detail	Some information	Nil
	Nimbus B	5-18-68	Unsuccessful launch	Complete	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
	Nimbus III (B-2)	4-14-69	OK 7-13-69	Complete	Complete, in detail	Complete, in detail	Complete, in detail	Nil	Nil
	Nimbus IV (D)	4-8-70	Known survival hours = 3.27×10^4	Incomplete	Complete, in detail	Complete, in detail	Complete, in detail	Nil	Nil

DATA BANK COVERAGE

EAR No.	Spacecraft	Launch Date	Spacecraft Status	Table I General Information	Table II Operating Time/ System Breakdown	Table III Parts Breakdown	Table IV Failure Description	Table V Developmental Activities	Table VI Pre-Launch Activities
				Data Bank Coverage					
9	SOLRAD I	6-22-60	Turned off 4-18-61	Complete	Nil	Limited information	Limited information	Nil	Nil
	SOLRAD VI	6-15-63	Lasted only 47 days	Incomplete	Nil	Nil	Nil	Nil	Nil
	SOLRAD VII	6-64	Lost signal 11-65	Incomplete	Nil	Nil	Nil	Nil	Nil
	SOLRAD VIII	11-19-65	Stopped use 11-13-67	Complete	Ref. SOLRAD IX	Ref. SOLRAD [illegible] (+)	Limited information	Nil	Nil
	SOLRAD IX	3-5-68	Last anomaly recorded at 11,700 hours after launch	Complete	Complete	Complete	Fair detail	Nil	Nil
	SOLRAD X	7-8-71	Unknown				See EAR 52a		
10	GEOS I	11-6-65	Lost 12-1-66	Complete	Complete, in detail	Complete, in detail	Complete	Limited information	Limited information
	GEOS II	1-11-63	Experiments turned off 4-9-75	Complete	Complete, in detail	Complete, in detail	Complete	Limited information	Limited information
11	Transit 1A	9-17-59	Launch vehicle failed	Complete	Not applicable	Not applicable	Not applicable		
	Transit 1B	4-13-60	Lost 7-11-60	Complete	Complete	Complete	Complete		
	Transit 2A	6-22-60	Lost 10-26-62	Complete	Complete	Complete	Complete		
	Transit 3A	11-30-60	Launch vehicle failed	Complete	Not applicable	Not applicable	Not applicable		
	Transit 3B	2-21-61	Lost 4-1-61	Complete	Complete	Complete	Complete		
	Transit 4A	6 29-61	OK 4-66	Complete	Poor	Nil	Nil		
	Transit 4B	11-15-61	Lost 8-2-62	Complete	Poor	Nil	Nil		
	TRAAC	11-15-61	Lost 8-12-62	Complete	Poor	Nil	Nil	Limited Information summarized for the whole program	
	Transit 5A	12-18-62	Lost 12-19-62	Complete	Poor	Nil	Nil		
	Transit 5A-2	4-5-63	Unsuccessful launch	Complete	Not applicable	Not applicable	Not applicable		
	Transit 5A-3	6-15-63	OK 8-66	Complete	Poor	Nil	Nil		
	Transit 5BN-1	9-28-63	Lost 12-63	Complete	Poor	Nil	Nil		
	Transit 5BN-2	12-5-63	Partial OK 4-66	Complete	Poor	Nil	Nil		
	Transit 5BN-3	4-21-64	Unsuccessful launch	Complete	Not applicable	Not applicable	Not applicable		
	Transit 5C-1	6-3-64	Lost 8-23-65	Complete	Poor	Nil	Nil		
	Oscar 04	6-24-65	OK (limited) 8-31-66	Complete	Poor	Nil	Nil		
	Oscar 06	12-22-65	OK 4-66	Limited	Poor	Nil	Nil		
	Oscar 08	3-25-66	OK 8-31-66	Limited	Poor	Nil	Nil		
12	INJUN I	6-29-61	Lost 3-6-63	Incomplete	Very poor	Nil	Nil	Nil	Nil
	INJUN II	1-24-62	Unsuccessful launch	Nil	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
	INJUN III	12-12-62	Lost 11-3-63	Nil	Very poor	Very poor	Nil	Nil	Nil
	INJUN IV	11-21-64		Incomplete	Very poor	Nil	Nil	Nil	Nil
13	Vanguard I	3-17-58	Unknown	None	None	None	None	None	None
	Vanguard II	2-17-59	Unknown	None	None	None	None	None	None
	Vanguard III	9-18-59	Lost 12-11-59	None	None	None	None	None	None

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DATA BANK COVERAGE

EAR No.	Spacecraft	Launch Date	Spacecraft Status	Table I General Information	Table II Operating Time/ System Breakdown	Table III Parts Breakdown	Table IV Failure Description	Table V Developmental Activities	Table VI Pre-Launch Activities
				Data Bank Coverage					
14	Mariner I	7-22-62	Unsuccessful launch	Part	None	Combined, complete fair	Not applicable	Combined, limited information	Combined limited information
	Mariner II	8-22-62	Powered hours = 3,100	Part	Complete		Complete, fair		
	Mariner III	11-5-64	Unsuccessful launch	Part	None	Combined, fair	Not applicable	None	Combined information
	Mariner IV	11-28-64	OK 12-20-67	Part	Fair		Complete	None	
	Mariner V	6-14-67	Mission completed	Complete	Complete, good	Complete, good	Complete, good	General information some detail	None
	Mariner VI	2-24-69	Powered hours = 18,336	Combined, complete	Combined, complete good	Complete, good	Complete, good	None	None
	Mariner VII	3-27-69	Powered hours = 15,456					None	None
15	OGO I	9-5-64	Standby 11-25-69	Complete	Complete, good	Consolidated as one sheet	Complete, good	Nil	Nil
	OGO II	10-14-65	Off 2-68	Complete	Complete, good		Complete, good	Nil	Nil
	OGO III	6-7-66	Standby 12-1-69	Complete	Consolidated		Complete, good	Nil	Nil
	OGO IV	7-28-67	Deactivated 10-23-69	None			Complete, good	Nil	Nil
	OGO V	3-4-68	Standby 10-9-71	None			Complete, good	Nil	Nil
	OGO VI	6-5-69	Standby 9-27-71	None			Complete, good	Nil	Nil
16	ANNA 1A	5-10-62	Unsuccessful launch	Complete	Not applicable	Not applicable	Not applicable	Not applicable	Nil
	ANNA 1B	10-31-62	Powered for 30,624 hours	Complete	Fair, not much detail	Nil	Nil	Same as Transit	Same as Transit
17	EGRS I (SECOR)	1-11-64	Off 9-65	Complete (fair)	Complete, fair	Fair	Fair	Some general information	Some general information
	EGRS III	3-9-65	Not used after 7/67	Complete (fair)	Fair	Fair	Fair	Some general information	Some general information
	EGRS II	3-11-65	Unsuccessful launch	None	Not applicable	Not applicable	Not applicable	None	None
	EGRS IV	5-3-65	Transponder failed at launch	None	Not applicable	Not applicable	Not applicable	None	None
	EGRS V	8-10-65	Off 3/66	None	Poor	None	Very limited information	None	None
	GEOS A	11-6-65	Off 1/67	None	None	None	None	None	None
	EGRS VI	6-9-66	Not useful, reentered 7-6-67	None	Not applicable	Not applicable	Not applicable	None	None
	EGRS VII	8-19-66	Battery failure 1-67	None	None	None	Limited data	None	None
	EGRS VIII	10-5-66	Transponder failure at launch	None	Not applicable	Not applicable	Not applicable	None	None
	EGRS IX	6-29-67	Launch vehicle failure 8-18-68	None	None	None	None	None	None
	GEOS B	1-11-68	Off 1-70	None	None	None	None	None	None
	EGRS X	5-18-68	Unsuccessful launch	None	Not applicable	Not applicable	Not applicable	None	None
	EGRS XI	8-16-68	Unsuccessful launch	None	Not applicable	Not applicable	Not applicable	None	None
	EGRS XII	8-16-68	Unsuccessful launch	None	Not applicable	Not applicable	Not applicable	None	None
	EGRS XIII	4-14-69	OK 1-15-71	None	None	None	No failure reported	None	None
	TOPO I	4-8-70	OK 1-15-71	None	None	None	No orbital failures	None	None

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EAR No.	Spacecraft	Launch Date	Spacecraft Status	Table I General Information	Table II Operating Time/ System Breakdown	Table III Parts Breakdown	Table IV Failure Description	Table V Developmental Activities	Table VI Pre-Launch Activities
				Data Bank Coverage					
18	IMP A (Exp. 18)	11-26-63	Max. powered hours = 12,774	Complete	Complete	Complete	Complete	Unavailable	Unavailable
	IMP II (Exp. 21)	10-3-64	Lost 8-?-65	Complete	Complete	Complete	One failure reported	Limited	Limited
	A-IMP-I (Exp. 33)	7-1-66	Useful data received for over 2 years	Complete	Complete	Complete	Complete	Limited	Limited
	IMP-F (Exp. 34)	?-25-67	Lost 5-3-69	Partial	Poor	Poor	Narative	Nil	Nil
	IMP-G (Exp. 41)	?-21-69	Last anomaly recorded at 5,380 hours after launch	Part	Poor	Nil	Narative	Nil	Nil
	IMP-I (Exp. 43)	3-13-71	Last anomaly recorded at 10,632 hours after launch	See EAR 56 for update					
	A-IMP-E (Exp. 35)	7-19-67	Spacecraft survived at least 364 days	Part	Poor	Nil	Poor	Nil	Nil
19	Syncom I	2-14-63	Lost at launch	Complete	Not applicable	Not applicable	Not applicable	Limited	Limited
	Syncom II	7-26-63	Maximum powered hours known = 8,760	Complete	Complete	Complete	Only one reported	Fair	Good narrative
	Syncom III	8-19-64	OK 4-66	Complete	Complete	Complete	None	None	None
20	Oscar I	12-12-61	Maximum powered hours known = 2,540	Complete	Limited	Nil	Limited	Fair information	Limited information
	Oscar II	6-2-62	Payload reentered atmosphere in 6-21-62	Complete	Limited	Nil	Nil	Fair information	Limited information
	Oscar III	3-9-65	See Oscar I	Complete	Fair	Fair	Complete (fair)	Fair information	Limited information
	Oscar IV	12-21-65	Bad launch	Complete	Not applicable	Not applicable	Not applicable	Fair information	Limited information
21	Ranger I	8-23-61	Unsuccessful launch	Good	One table--poor; very little detail	Not applicable	Combined--fair	Nil	Nil
	Ranger II	11-18-61	Unsuccessful launch	Good		Not applicable		Nil	Nil
	Ranger III	1-26-62	Lost in flight	Good		See subsystems I-8 on Table II for Rangers VI-IX		Consolidated on one table	Nil
	Ranger IV	4-23-62	Unsuccessful mission	Good					Nil
	Ranger V	10-18-62	Unsuccessful mission	Good					Nil
	Ranger VI	1-30-64	Unsuccessful mission	Good		Combined--fair			Consolidated on one table
	Ranger VII	7-28-64	Unknown	Good					
	Ranger VIII	2-17-65	Unknown	Good					
	Ranger IX	3-21-65	Unknown	Good					
22	OSO I (A)	3-7-62	Powered hours known to be 1,600 hours	Complete	Complete	Complete	Complete	Fair information	Fair information
	OSO II (B-2)	2-3-65	Report covers from launch to 6-66	Complete	Complete	None	Complete	None	None
	OSO III (E)	3-8-67	Powered hours known to be 20,250	Good	Fair	Complete	Complete	None	None
	OSO IV (D)	10-18-67	Powered hours known to be 22,630	Good	Complete	None	Complete	None	None

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EAR No.	Spacecraft	Launch Date	Spacecraft Status	Table I General Information	Table II Operating Time/ System Breakdown	Table III Parts Breakdown	Table IV Failure Description	Table V Developmental Activities	Table VI Pre-Launch Activities
				Data Bank Coverage					
	OSO V (F)	1-22-69	Known to have operated for over 2 years	Complete	Complete	None	Complete	Fair information	Good information
	OSO VI (G)	8-9-69	Known powered hours = 3,168 hours	Complete	Complete	None	Fair	None	Good information
	OSO VII (H)	9-29-71	Last anomaly occurred at 4,224	Fair	Nil	Nil	Fair	Nil	Nil
	OSO-B1	Not given	Destroyed on pad by accidental ignition of third stage	None	Not applicable	Not applicable	Not applicable	Not applicable	None
	OSO-C	8-25-65	Unsuccessful due to launch vehicle	Complete	Not applicable	Not applicable	Not applicable	None	None
23	Pioneer VI	12-16-65	Last tracked Feb/ March, '76	Complete	Complete, in detail	Complete, in detail	Complete	Good	Good
	Pioneer VII	8-17-66	Last tracked Feb/ March, '76	Complete	Complete, in detail	Complete, in detail	Complete	Good	Good
	Pioneer VIII	12-13-67	Last tracked Feb/ March, '76	Complete	Use above	Use above	Fair	Nil	Nil
	Pioneer IX	11-8-68	Last tracked Feb/ March, '76	Complete	Use above	Use above	Fair	Nil	Nil
	Pioneer X*	8-27-69	Unsuccessful launch	Complete	Not applicable	Not applicable	Not applicable	--	--
24	Gemini I	4-3-64	Turned off	Complete	Fair	Fair	Limited		
	Gemini II	1-19-65	Mission duration sub-orbital powered time = .3 hours	Complete	Complete	Complete, in detail	Complete		
	Gemini III	3-23-65	Powered time = 5 hours	Complete	Complete	Complete, in detail	Complete		
	Gemini IV	6-3-65	Reentered	Complete	Complete	Complete, in detail	Complete		
	Gemini V	8-21-65	Reentered	Complete	Complete	Complete, in detail	Complete		
	REP	8-21-65	Ejected from Gemini V, decayed August 27	Complete					
	Gemini VI	--	Launch cancelled	Complete	Not applicable	Not applicable	Not applicable	Combined General Program Description	Nil
	G.VI target	10-25-65	Did not orbit	Complete					
	Gemini VII	12-4-65	Powered time = 331 hours	Complete	Complete	Complete, in detail	Complete		
	Gemini VIa	12-15-65	Powered time = 26 hours	Complete	Complete	Complete, in detail	Complete		
	Gemini VIII	3-16-66	Powered time = 10.7 hours	Complete	Complete	Complete, in detail	Complete		
	G.VIII target	3-16-66	Unknown	Complete	None	None	None		
	Gemini IXa	6-3-66	Unknown	Complete	None	None	None		
	TLV/ATDA	6-1-66	Unsuccessful launch	Complete	None	None	None		
	Gemini X	7-18-66	Unknown	Complete	None	None	None		
	G.X target	7-18-66	Unknown	Complete	None	None	None		

* Not to be confused with Pioneer 10.

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EAR No.	Spacecraft	Launch Date	Spacecraft Status	Data Bank Coverage: Table I General Information	Table II Operating Time/ System Breakdown	Table III Parts Breakdown	Table IV Failure Description	Table V Developmental Activities	Table VI Pre-Launch Activities
25	Mercury Project								
	LJ1	8-21-59	Unsuccessful launch	Complete	None	None	Complete		
	Big Joe	9-9-59	Ballistic flight	Complete	None	None	Complete		
	LJ-6	10-4-59	Ballistic flight	Complete	None	None	None		
	LJ-1A	11-4-59	Unsuccessful launch	Complete	None	None	Complete		
	LJ-2	12-4-59	Reentered 12-4-59	Complete	None	None	None		
	LJ-1B	1-21-60	Reentered 1-21-60	Complete	None	None	None		
	Beach Abort	5-9-60	Simulated pad abort	Complete	None	None	Complete		
	MA-1	7-29-60	Unsuccessful launch	Complete	None	None	Complete		
	LJ-5	11-8-60	Unsuccessful launch	Complete	None	None	Complete		
	MR-1	11-21-60	Unsuccessful launch	Complete	None	None	Complete		
	MR-1A	12-19-60	Suborbital flight	Complete	None	None	None		
	MR-2	1-31-61	Suborbital flight	Complete	None	None	Complete	Combined information very general	None
	MA-2	2-21-61	Ballistic flight	Complete	None	None	None		
	LJ-5A	3-18-61	Unsuccessful launch	Complete	None	None	Complete		
	MR-BD	3-24-61	Suborbital flight	Complete	None	None	None		
	MA-3	4-25-61	Unsuccessful launch	Complete	None	None	Not applicable		
	LJ-5B	4-28-61	Abort test successful	Complete	None	None	Complete		
	MR-3	5-5-61	Suborbital flight	Complete	None	None	Complete		
	MR-4	7-21-61	Suborbital flight	Complete	None	None	Complete		
	MA-4	9-13-61	One-pass orbital flight	Complete	None	None	Complete		
	MA-5	11-29-61	3-pass orbital flight	Complete	None	None	Complete		
	MA-6	2-20-62	3-pass orbital flight	Complete	Complete	Complete	Complete		
	MA-7	5-24-62	3-pass orbital flight	Complete	Complete	Complete	Complete		
	MA-8	10-3-62	6-pass orbital flight	Complete	Complete	Complete	Complete		
	MA-9	5-15-63	22-pass orbital flight	Complete	Complete	Complete	Complete		
26	Vela I	10-17-63	OK 5-15-66	Complete, combined	None	None	None		
	Vela II	7-17-64			None	None	None		
	Vela III	7-20-65			None	None	None		
	Vela IV	Not known	Not known	None	None	None	None	Table V refers one to the reference	Nil
	Vela V 6909	5-23-69	Powered hours = 14,904	Complete, combined	Complete	Combined, complete	Complete		
	Vela V 6911	5-23-69	Powered hours = 14,904		Complete		Complete		
	Vela VB 7033	4-8-70	Powered hours = 8,760	Complete, combined	Complete	Combined complete	Complete		
	Vela VB 7044	4-8-70	Powered hours = 8,760		Complete		Complete		
27	Early Bird	4-6-65	Not known	None	None	None	None	Limited	Limited
28	OVI-1	Not known	Unsuccessful launch	Combined, complete	Not applicable	Not applicable	Not applicable	None	Some detail
	OVI-2	10-5-65	Max. powered hours = 9,823		Complete	None	Complete fair	None	Some detail
	OVI-3	Not known	Unsuccessful launch		Not applicable	Not applicable	Not applicable	None	Some detail
29	Lofti	2-21-61	Launch vehicle problem poor orbit	Complete	Complete fair	Nil	No failures	Nil	Nil
30	Agena				Consolidated data for 95 Agena vehicles				
				Complete	Complete	Complete	Complete	Complete	None

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EAR No.	Spacecraft	Launch Date	Spacecraft Status	Data Bank Coverage: Table I General Information	Table II Operating Time/ System Breakdown	Table III Parts Breakdown	Table IV Failure Description	Table V Developmental Activities	Table VI Pre-Launch Activities
31	Snapshot	4-3-65	Lasted 43 day.	Complete	Complete	Not available	Complete	Limited	Limited
33	Explorer 32	5-25-66	End of life occurred 301 days after launch	Incomplete	Poor	Poor	Limited	Nil	Nil
34	RAE-A	7-4-68	RAE-A due to be phased out but was inverted via boom commands on 1^-31-72	Complete	Complete	Complete	Complete good	Test program	None
35	OV1-10	12-11-66	Known powered hours = 6,312	Complete	Complete	Complete	Complete	Nil	Nil
	OV1-12	7-27-67	Ma.. known powered hours = 736	Complete	Complete	Poor	Complete fair	Nil	Nil
	OV1-13	4-6-68 multiple launch	Max. known powered hours = 8,760	Complete	Complete	Fair	Complete fair	Nil	Nil
	OV1-14		Failed 6 days in orbit	Complete	Complete	Fair	Complete fair	Nil	Nil
	OV1-15	7-11-68 multiple launch	Known Max. powered hours = 2,856	Comp ete	Complete	Poor	Complete fair	Nil	Nil
	OV1-16		Known powered time = 39 days	Complete	Fair complete	Poor	No major anomalies	Nil	Nil
	OV1-17	3-18-69 multiple launch	Known powered hours = 8,448	Complete	Complete	None	Complete	Nil	Nil
	OV1-18		Max. known powered hours = 7,300	Complete	Complete fair	None	Complete	[illegible]	Nil
	OV1-19		Max. known powered hours = 8,030	Complete	Complete fair	None	Complete	Nil	Nil
36	OV2-1	Not known	Not known	Nil	See Table II for general program	None	None	None	None
	OV2-3	12-21-65	Failed to orbit	Poor	Not applicable	Not applicable	Not applicable	None	None
	OV2-5	Not known	Not known	Poor	Poor	None	None	None	None
37	OV3-1	4-22-66	OK 6-30-70	Complete	Complete	None	Complete	General information	
	OV3-2	10-28-66	OK 6-30-70	None	Complete	Fair	Complete		
	OV3-3	8-4-66	OK 6-30-70	Fair	Complete	None	Complete		
	OV3-4	6-10-66	OK 6-30-70	Fair	Complete	None	Complete		
	OV3-5	1-31-67	Failed to attain orbit	None	Not applicable	Not applicable	None		
	OV3-6	12-4-67	Reentered 3-9-69	Fair	Fair	Fair	Not applicable		
38	OV4-IT	11-3-66	Lasted 69 days	Fair	Complete	Complete	Complete	Combined, little detail	
	OV4 IR	11-3-66	Powered time = 63 days	Fair	Complete	Poor	Complete		

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EAR No.	Spacecraft	Launch Date	Spacecraft Status	Data Bank Coverage: Table I General Information	Table II Operating Time/ System Breakdown	Table III Parts Breakdown	Table IV Failure Description	Table V Developmental Activities	Table VI Pre-Launch Activities
39	OVS-1	4-28-67	Unknown	Complete	Fair	Fair	None	Poor, very little detail	
	OVS-6	5-23-69	Powered time = 14,616 hours	Complete	Fair	Complete	No major failures	Nil	
	OVS-9	5-23-69	Powered time = 456 hours	Complete	Fair	Complete	Complete	Little detail	
40	ATS-I	12-6-66	Still usable as of January '77	Complete	Complete, in detail	Complete, in detail	Complete, in detail	Nil	Nil
	ATS-II	4-5-67	Shut down 10-23-67	Complete	Complete, in detail	Complete, in detail	Launch failure	Nil	Nil
	ATS-III	11-5-67	Portion of equipment still operable as of January '77	Complete	Complete, in detail	Complete, in detail	Complete	Nil	Nil
	ATS-IV		No orbit	None	Complete	Complete	Not applicable	Nil	Nil
	ATS-V	8-12-69	Max. known powered hours = 12,134	Complete	Complete, in detail	Complete, in detail	Complete, in detail	Nil	Nil
41	TOS-OT 2 (ESSA 2)	2-28-66	Powered hours = 24,736	Complete	Complete, in detail	Complete, in detail	Complete, in detail	Nil	Nil
	TOS-A (ESSA 3)	10-20-66	Turned off 12-2-68	Complete	Complete, in detail	Complete, in detail	Complete, in detail	Nil	Nil
	TOS-B (ESSA 4)	1-26-67	Turned off 5-5-68	Complete	Complete, in detail	Instructed to use ESSA 2's Table II + modifications	Complete, in detail	Nil	Nil
	TOS-C (ESSA 5)	4-20-67	Deactivated 2-20-70	Complete	Complete, in detail	(See comment on ESSA 3)	Complete, in detail	Nil	Nil
	TOS-D (ESSA 6)	11-10-67	Turned off 12-3-69	Complete	Complete, in detail	(See comment on ESSA 3)	General detail	Nil	Nil
	TOS-E (ESSA 7)	8-16-68	Deactivated 3-10-70	Complete	Complete, in detail	(See comment on ESSA 3)	General detail	Nil	Nil
	TOS-F (ESSA 8)	12-15-68	Powered hours = 26[illegible]	Complete	Complete in detail	(See comment on ESSA 3)	General detail	Nil	Nil
	TOS-G (ESSA 9)	2-26-69	Put on "Stand By" 4-15-71	Complete	Not complete--just subsystems listed	(See comment on ESSA 3)	Complete in detail	Nil	Nil
42	TIROS M = (ITOS 1)	1-23-70	Deactivated 6,034 hours after launch		Complete, in detail	Complete	Complete	None	None
	ITOS A = (NOAA 1)	12-11-70	Known powered hours = 6,028		Complete, in detail	Complete	Complete	None	None
	ITOS B	10-21-71	Failed to achieve usable orbit		Nil	Nil	Nil	None	None
	ITOS C		Not known		Nil	Nil	Nil	None	None
44	SAS-A (Explorer 42)	12-12-70	Spacecraft [illegible] operable [illegible]	Complete	Complete	Partial parts count	Complete	Consolidated into one table	Complete
	SAS-B (Explorer 48)	11/15/72	[illegible] hours [illegible]	Complete	Complete	Partial parts count	Complete		Complete

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EAR No.	Spacecraft	Launch Date	Spacecraft Status	Data Bank Coverage: Table I General Information	Table II Operating Time/ System Breakdown	Table III Parts Breakdown	Table IV Failure Description	Table V Developmental Activities	Table VI Pre-Launch Activities
	SAS-C (Explorer 53)	5-7-75	Survival hours = 17,830	Complete	Complete	Partial parts count	Complete	Consolidated into one table	Complete
45	SERT I	7-20-64	50-minute ballistic flight	Complete	Lacks detail	Data not available	One anomaly	None	None
	SERT II	2-3-70	Still operable = 1-78	Complete	Complete	Data not available	Complete	Complete	Complete
46	GEOS-3	4-9-75	Survival hours = 15,144	Complete	Complete	Data not available	Complete	Complete	Complete
47	Viking Orbiter I	8-20-75	Survival hours = 11,088	Complete	Complete	Complete	Complete	Consolidated in one complete report	None
	Viking Orbiter II	9-9-75	Survival hours = 10,608	Complete	Complete	Complete	Complete		None
	Viking Lander I	7-20-76	Survival hours = 11,088	Complete	Complete	Complete	Complete		None
	Viking Lander II	9-3-76	Survival hours = 10,608	Complete	Complete	Complete	Complete		None
48	ATS-6	5-30-74	Survival hours = 28,424	Complete	Complete	None	Complete	Complete	Present, but little detail
49	Hawkeye (Explorer 52)	6-3-74	Survival hours = 30,660	Complete	Fair	Partial parts count	Complete, fair	Complete	None
50	MTS (Explorer 46)	8-13-72	Powered hours = 3,600	Complete	Not much detail	Data not available	Complete, fair	Data not available	Data not available
51	SSS (Explorer 45)	11-15-71	Survival hours = 3,264	Complete	Complete	Data not available	Fair	Data not available	Data not available
52	SOLRAD 10	7-8-71	Survival hours = 6,450	Complete	Fair	Data not available	Fair	Data not available	Data not available
53	HEAO-A	8-12-77	Survival hours = 5,760	Complete	Complete	Parts listed--no breakdowns by components	Fair	Complete	None
54	LANDSAT-I	7-23-72	Survival hours = 45,467	Complete	Complete	Complete	Complete	Combined, complete	None
	LANDSAT-II	1-22-75	Survival hours = 12,664	Complete	Complete	Complete	Complete		Complete
55	RAE-B	6-10-73	Survival hours = 36,480	Complete	Complete	Complete	Complete	Complete	Complete
56	IMP J (Explorer 50)	10-25-73	Survival hours = 36,912	Complete	Complete	Partial parts breakdown	Complete	Complete	Little detail
	IMP I (Explorer 43)	3-13-71	Reentered 10-2-74	Complete	Complete	Partial parts breakdown	Complete	Complete	Little detail
	IMP H (Explorer 47)	9-23-72	Survival hours = 41,112	Complete	Complete	Partial parts breakdown	Complete	Complete	Complete
57	OSO 8	6-21-75	Survival hours = 17,500	Complete	Complete	None	Complete	Complete	None

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EAR No.	Spacecraft	Launch Date	Spacecraft Status	Data Bank Coverage: Table I General Information	Table II Operating Time/ System Breakdown	Table III Parts Breakdown	Table IV Failure Description	Table V Developmental Activities	Table VI Pre-Launch Activities
58	Mariner 8	Not known	Bad launch	None	Not applicable	Not applicable	Not applicable	None	None
	Mariner 9	5-30-71	Spacecraft turned off 10-27-72	Complete	Complete	Fair	Complete	Complete	Complete
	Mariner 10	11-3-73	Spacecraft turned off 3-24-75	Complete	Complete	Complete	Complete	Complete	Little detail
59	Pioneer 10	3-3-72	Survival hours = 52,580	Complete	Complete	None	Complete	Combined, complete	No data available
	Pioneer 11	4-6-73	Survival hours = 43,345	Complete	Complete	None	Complete		
60	SMS-1	5-17-74	Survival hours = 32,016	Complete	Complete	None	Fair	None	None
	SMS-2	2-6-75	Survival hours = 25,650	Complete	Complete	None	Fair	None	None
	GOES-1	10-16-75	Survival hours = 19,370	Complete	Complete	None	Fair	None	None
	GO S-2	6-16-77	Survival hours = 4,750	Complete	Complete	None	Fair	None	None
61	NOAA 2 (ITOS D)	10-15-72	Placed in marginal standby mode on 3-19-74	Complete	Complete	None	Complete		None
	ITOS E	7-16-73	Bad launch--did not orbit	Complete	Not applicable	Not applicable	Not applicable		None
	NOAA 3 (ITOS F)	11-6-73	Survival hours = 2*,120	Complete	Complete	None	Fair	Combined, complete	None
	NOAA 4 (ITOS G)	11-15-74	Survival hours = 25,560	Complete	Complete	None	Complete		None
	NOAA 5 (ITOS H)	7-29-76	Survival hours = 2,840	Complete	Complete	None	Fair		None
62	Nimbus 5	12-11-72	Survival hours = 20,520	Complete	Complete	Complete	Complete	Combined, complete	None
	Nimbus 6	6-12-75	Survival hours = 9,279	Complete	Complete	Complete	Complete		None
63	Atmospheric Explorer C (Explorer 51)	12-6-73	Survival hours = 14,328	Complete	Complete	None	Complete	None	None
	Atmospheric Explorer D (Explorer 54)	10-6-75	Survival hours = 2,760	Complete	Complete	None	Complete	None	None

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Appendix D

EXPERIENCE BULLETINS

PRC R-1863

Experience Bulletin No. 1

PERSISTENT ON-ORBIT PROBLEM AREAS

August 1978

Prepared under Contract No. NASW-3041,
"Study of Reliability Data From In-Flight Spacecraft"

for

National Aeronautics & Space Administration
NASA Headquarters, Washington, D.C.

A Note on the Data Base for this Bulletin

The Space Data Bank from which the results in this bulletin were derived is presented in PRC R-1863, On-Orbit Spacecraft Reliability, September 1978. For purposes of background to this analysis, it need only be pointed out that the data bank contains orbital performance data spanning spacecraft from Vanguard to HEAO, a period of nearly 20 years. Four primary data collection efforts have been made. This experience bulletin has been written in conjunction with the most recent effort. The first three collections analyzed 1399 anomalies from 310 spacecraft launched between 1958 and 1972. The most recent collection added information on 708 anomalies from 45 spacecraft launched in the seventies. These data are referred to herein as "this update."

Experience Bulletin #1
PERSISTENT ON-ORBIT PROBLEM AREAS

Analysis of on-orbit data for spacecraft launched in the 1970s indicates that anomaly types that have been persistent in the past are still occurring. The analysis further indicates that eight categories of these anomaly types encompass approximately one half of all anomalies.

I. INTRODUCTION

In an earlier analysis of the data bank, it was found that over 80 percent of all anomalies fell into 30 categories of leading problem areas.[1] It was also noted that these categories represented "persistent" problems in that the anomalies occurring on the more recently launched spacecraft were of the same types as the anomalies on earlier spacecraft. Since a significant amount of new data were collected on this data bank update, it was deemed desirable to re-examine these persistency trends.

The findings of this re-examination, as described in more detail below, indicate that the types of problems demonstrating this persistence in the past are still occurring. In other words, even though state-of-the-art advances have occurred, they have not resulted to any noticeable extent in "new" or different types of anomalies. Nor have they resulted in significant elimination of "old" types of anomalies. It was also found that the top five persistent problem categories, i.e., those accounting for the five highest anomaly counts, have not significantly shifted to lower rankings. In seven other categories significant shifts--both up and down--were noted.

[1] Bloomquist, C.E., and Winifred C. Graham, Analysis of Spacecraft Anomalies, PRC R-1833, PRC Systems Sciences Company, March 1976.

II. ANALYSIS

The 30 leading problem areas that the data bank anomalies have been found to essentially "group themselves into" are shown in Exhibit 1. The anomalies that do not fall into one of these categories have always been found to be widely scattered. As can be seen from Exhibit 1, 16 of these categories involve specific types of hardware items. Eleven categories involve anomalies that are difficult to tie to a specific piece of hardware, but do relate directly to identifiable functions. The remaining categories consist of three particularly common and widespread types of anomalies.

The rank order of these categories, in terms of the number of anomalies each category contains, is shown in Exhibit 2. The left column in Exhibit 2 indicates the rank order prior to this update, the middle column indicates the rank order for this update, and the right column indicates the rank order for all data in the data bank.

Previous to this update, the five top ranking categories were scientific instrument packages, tape recorders, camera equipment, batteries and EMI/RFI. These remain top ranking categories for this update, except that RFI/EMI has shifted from fifth to second place thus shifting tape recorders from second to third place, and camera equipment from third to fourth place. A significant shift involves chemical propulsion[1] which jumped from fifteenth to fifth place, thus displacing batteries to sixth place.

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[1] Hydrazine systems and the like, as opposed to such hardware as solid propellant apogee engines.

EXHIBIT 1 - LEADING PROBLEM AREAS

EQUIPMENT	FUNCTIONS	OTHER
BATTERIES	COMMAND & CONTROL (TIMERS, SEQUENCERS)	RFI/EMI
CAMERA EQUIPMENT	COMMAND & CONTROL (LOGIC)	SOLAR ARRAY DEGRADATION
DEPLOYABLE STRUCTURES	COMMAND & CONTROL (REGISTERS, MEMORIES)	SPURIOUS COMMANDS
GYROSCOPES	COMMAND, RF-LOCK ON	
HORIZON SCANNERS	COMMAND, RF-OTHER	
REACTION WHEELS	POWER CONDITIONING	
SCIENTIFIC INSTRUMENTS	PROPULSION (CHEMICAL)	
SOLAR ARRAYS (EXCEPT DEGRADATION)	TELEMETRY ENCODING	
SOLAR ARRAY DRIVES	TELEMETRY, RF	
STAR TRACKERS	TELEMETRY SENSING	
SUN SENSORS	THERMAL CONTROL	
TAPE RECORDERS		
WIDE-BAND RECEIVERS		
WIDE-BAND TRANSMITTERS		
WIDE-BAND TRANSPONDERS		
WIDE-BAND, OTHER		

EXHIBIT 2 - RANK ORDER OF PROBLEM AREAS
(Note: Ranking is in descending order by number of anomalies, i.e., #1 had the most anomalies.)

PRE-UPDATE

1. Scientific Instruments
2. Tape Recorders
3. Camera Equipment
4. Batteries
5. EMI/RFI
6. Command & Control (Logic)
7. Telemetry, RF
8. Power Conditioning
9. Spurious Commands
10. Telemetry Encoding
11. Command & Control (Timers, Sequencers)
12. Command RF-Lock On
13. Command & Control (Registers, Memories)
14. (1) Star Trackers
    Sun Sensors
    Telemetry Sensing
    Wideband Transmitters
15. Reaction Wheels
    Propulsion (Chemical)
16. Command, RF-Other(2)
17. Thermal Control
18. Deployable Structures
19. Horizon Sensors
20. Wideband, Other(3)
21. Solar Arrays (Degradation)
22. Solar Array, Other
23. Gyros
24. Solar Array Drives
25. Wideband Receivers
26. Wideband Transponders

THIS UPDATE

1. Scientific Instruments
2. RFI/EMI
3. Tape Recorders
4. Camera Equipment
5. Propulsion (Chemical)
6. Batteries
   Star Trackers
7. Wideband Transmitters
8. Deployable Structures
9. Telemetry Sensing
10. Solar Array, Other
11. Telemetry, RF
    Command & Control (Timers, Sequencers)
12. Sun Sensors
13. Power Conditioning
14. Command & Control (Logic)
15. Telemetry Encoding
16. Spurious Commands
    Command & Control (Registers, Memories)
17. Wideband, Other(3)
18. Thermal Control
19. Wideband Transponders
20. Command, RF-Lock On
    Reaction Wheels
21. Wideband Receivers
22. Horizon Sensors
23. Gyros
24. Solar Array Drives
    Solar Array Degradation
25. Command, RF-Other(2)

COMBINED SAMPLE

1. Scientific Instruments
2. Tape Recorders
3. Camera Equipment
4. RFI/EMI
5. Batteries
6. Command & Control (Logic)
7. Telemetry, RF
8. Power Conditioning
9. Star Trackers
10. Spurious Commands
11. Propulsion (Chemical) (4)
12. Wideband Transmitters
13. Telemetry Encoding
14. Command & Control (Timers, Sequencers)
15. Telemetry Sensors
16. Sun Sensors
17. Command & Control (Registers, Memories)
    Command, RF-Lock On
18. Deployable Structures
19. Reaction Wheels
20. Thermal Control
21. Solar Array, Other
22. Wideband, Other(3)
23. Horizon Sensors
24. Command, RF-Other(2)
25. Wideband Transponders
26. Solar Array Degradation
    Wideband Receivers
27. Gyros
28. Solar Array Drives

Notes:
(1) Brackets indicate a "tie" for the bracketed rank.
(2) Other than command, RF-lock-on.
(3) Other than wideband receivers, transmitters, and transponders.
(4) Dashed line indicates the "median," i.e., the categories above and below the line each represent approximately half of the total anomaly count.

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Other significant shifts include star trackers shifting from fourteenth to rank with batteries for sixth place, and wideband transmitters shifting from fourteenth to seventh place. Also, deployable structures shifted from eighteenth to eighth place, and non-degradation type solar array anomalies shifted from twenty-second to tenth place. Two shifts downward that appear to be significant are the shift from sixth to fourteenth for command and control logic, and the shift from sixteenth to twenty-fifth for command RF problems other than lock-on.

The accumulated data bank information regarding anomaly types provides immediately accessible data on rank order, and shifts in rank order. The reasons behind these ranks and shifts, however, are not usually discernable without a considerable amount of further research. As an example, it can be postulated that shifts in equipment mix contribute to shifts in rank order.

For instance, more wideband equipment was carried on spacecraft in this update than in the pre-update. However, only wideband transmitters shifted upward significantly; wideband receivers and transponders did not exhibit such a significant increase in numbers of anomalies. Another example involves the upward shifts in chemical propulsion and solar array anomalies other than degradation. There has been essentially no shift in the "equipment mix" for these types of equipment between this update and the pre-update sample.

Similarly, the high rank of scientific instrument packages can be attributed, in part, to the fact that, as experiments, they are monitored closely and anomalies are thus more likely to be detected and reported. Also, many are built by universities and hence not subjected to the rigorous reliability and quality assurance provisions of basic subsystems. This does not appear to be the complete explanation, however. Scientific instrument packages were treated as basic subsystems in a number of cases (the interplanetary spacecraft, for instance) and still exhibited a high anomaly rate.

An area in which the data bank is unequivocally instructive concerns the persistence of the anomaly types. This can be seen from Exhibit 3, which depicts the occurrence of the top-ranking categories in this update by year of spacecraft launch.

These eight top ranking categories are those "above the median." That is, they account for approximately half the anomalies in all 30 categories. As can be seen from Exhibit 3, these types of anomalies have occurred fairly steadily on spacecraft launched over the 15-year period from 1960 to 1975.

IV. CONCLUSIONS

Analysis of data obtained during this data bank update indicates the following:

1. Anomaly types that have been persistent in the past are still occurring.
2. Eight categories of these anomaly types encompass approximately half of the anomalies. Five of these have not shifted significantly from pre- to post-1970 data; the eight are:

EXHIBIT 3 - ANOMALY OCCURRENCE BY YEAR OF LAUNCH

	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75
Scientific Instruments	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
EMI/RFI	●	●	●	●	●		●	●	●	●	●	●	●	●	●	●
Tape Recorders	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Camera Equipment	●	●	●	●	●		●	●	●	●	●	●	●	●	●	●
Propulsion	●		●	●		●	●	●	●	●	●	●	●	●	●	●
Batteries	●	●		●	●	●	●	●	●	●	●	●	●	●	●	●
Star Trackers					●			●	●	●	●	●	●	●	●	●
Wideband Transmitters	●					●	●	●	●	●	●	●	●	●	●	●

Note : Points not shown for spacecraft launched in 1976 and 1977 because sufficient operating history is not available in the data bank.

- Scientific Instrument
- RFI/EMI
- Tape Recorders
- Camera Equipment
- Propulsion (chemical)
- Batteries
- Star Trackers
- Wideband Transmitters

3. Upward shifts (i.e., from fewer to more anomalies) that appear significant, together with their rank order shift, include:
   - Propulsion (chemical), from fifteenth to fifth
   - Star Trackers, from fourteenth to sixth
   - Wideband Transmitters, from fourteenth to seventh
   - Deployable Structures, from eighteenth to eighth
   - Solar Array (non-degradation), from twenty-second to tenth
4. Downward shifts that appear significant include:
   - Command and Control Logic, from sixth to fourteenth
   - Command RF (other than lock-on), from sixteenth to twenty-fifth

NASA is currently developing a magnetic bubble type recorder at least partially to alleviate the persistent problems that have plagued mechanical tape recorders.[1] The results of this analysis suggest that

[1]See, for instance, "NASA Tests Magnetic Bubble Recorder," Aviation Week and Space Technology, July 24, 1978.

comparable corrective-action programs for some of the other leading problem areas would be extremely beneficial. Regardless of whether this is feasible, the leading problem areas certainly warrant increased attention during spacecraft design and development.

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Experience Bulletin No. 2

SOME ON-ORBIT RELIABILITY ASPECTS OF INTEGRATED CIRCUITS

August 1978

Prepared under Contract No. NASW-3041,
"Study of Reliability Data From In-Flight Spacecraft"

for

National Aeronautics & Space Administration
NASA Headquarters, Washington, D.C.

<u>A Note on the Data Base for this Bulletin</u>

The Space Data Bank from which the results in this bulletin were derived is presented in PRC R-1863, On-Orbit Spacecraft Reliability, September 1978. For purposes of background to this analysis, it need only be pointed out that the data bank contains orbital performance data spanning spacecraft from Vanguard to HEAO, a period of nearly 20 years. Four primary data collection efforts have been made. This experience bulletin has been written in conjunction with the most recent effort. The first three collections analyzed 1399 anomalies from 310 spacecraft launched between 1958 and 1972. The most recent collection added information on '08 anomalies from 45 spacecraft launched in the seventies. These data are referred to herein as "this update."

Experience Bulletin #2
SOME ON-ORBIT RELIABILITY ASPECTS OF INTEGRATED CIRCUITS

The data bank contains information on over 100,000 integrated circuits which accumulated 2.0×10^9 survival hours on-orbit. These data indicate that the orbital reliability of an integrated circuit is quite similar to that of a transistor. Also, there is some evidence that integrated circuits have reduced the number of problems associated with circuit design.

I. INTRODUCTION

The update under this contract marks the first of the four data bank studies in which the spacecraft analyzed made extensive use of integrated circuits. It was therefore felt appropriate to examine the available integrated circuit data for the reliability insights it might provide.

II. ANALYSIS

At least 35 of the 40 spacecraft in this update sample used integrated circuits. Some spacecraft in the pre-update sample used integrated circuits, although not to the same extent as spacecraft in this update.

Overall, the data bank contains orbital, operating information on at least 105,998 integrated circuits. During the orbital time periods of the data sample, these integrated circuits accumulated at least 2.0×10^9 survival hours. There were actually many more integrated circuits, and hence more survival hours, because some spacecraft for which parts count data were not available are known to have used integrated circuits extensively.

In both this update and the pre-update sample, only five integrated circuits are known to have incurred random, catastrophic failures (that is, the type of failure consistent with the definition of the familiar failure rate, λ). This yields an orbital, integrated circuit failure rate of 0.0025 failures per million hours with upper and lower 90 percent confidence intervals of 0.0053 and 0.00099, respectively. This failure rate does not differ significantly from the data bank orbital failure rate for transistors (0.0015 with 90 percent confidence intervals of 0.0033 and 0.00050).

There are at least three integrated circuit anomalies in the data bank that do not involve random, catastrophic failures. Two of these were due to gold-to-alumnium bonding setting up a reaction that caused corrosion. The third was due to an improper manufacturing process. The chips were cleaned with ammonia but then the ammonia residue w not adequately removed, thus later providing a mechanism for altering the chip's characteristics. The corrective actions derived to eliminate these anomalies on subsequent spacecraft are reported to have been successful.

There were undoubtedly other integrated circuit anomalies in the data sample which were not identified as such. For instance, there are anomalous incidents associated with equipment containing integrated circuits, but it is difficult, if not impossible in some cases, to determine if they were due to integrated circuits.

An observation of interest on this update that may relate to integrated circuits involves marginal circuit operation. On previous data bank studies, there have alway: been a number of anomalies due to inadequate design margins, out-of-tolerance parameters under certain conditions, etc. While there were anomalies of these types on this update, fewer were noted than on previous studies. It is not clear that this can be attributed to integrated circuits. But, in contrast with discrete part circuits, the fact that they do not require circuit analysis as part of the design procedure would seem to eliminate some chance for error.

III. CONCLUSIONS

The orbital reliability aspects of an integrated circuit appear to closely parallel those of a transistor. Their falure rates are nct significantly different, and while their tailure modes, as revealed by the data bank, are not similar, integrated circuits do not appear to have introduced any "exotic" new failure modes that are beyond present capabilities for foreseeing and correcting. In addition, there is some possibility that they have reduced problems due to errors in the design of discrete part circuits.

It is important to note that most, if not all, the integrated circuits covered by the data bank were subject to rather stringent quality assurance provisions. Thus, care should be taken in applying these conclusions to other classes of integrated circuits.

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Experience Bulletin No. 3

AREAS WITH A HISTORY OF FEW ON-ORBIT PROBLEMS

August 1978

Prepared under Contract No. NASW-3041,
"Study of Reliability Data From In-Flight Spacecraft"

for

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NASA Headquarters, Washington, D.C.

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Experience Bulletin #3
AREAS WITH A HISTORY OF FEW ON-ORBIT PROBLEMS

This experience bulletin is based on the fact that information concerning areas with few, or no, problems can be as useful as that concerning problem areas. The areas listed below are those revealed by the data bank to have such a history of few, or no, on-orbit anomalies. Any insights available from the data bank are also described. The criteria for selecting these areas was that the number of anomalies charged to each was fewer than one half of a percent of the total number of anomalies associated with long-term, unmanned spacecraft in the data bank.

- Basic Structure (excluding deployable structures): no anomalies
- Shrouds: two anomalies; shroud failed to eject in one case; corrective action (change from fiberglass to metallic shroud) was successful on subsequent spacecraft. Shroud honeycomb panels exploded due to environmental effects during launch in the other case.
- Pyrotechnics: two catastrophic failures (failure of a pin-puller and failure of an explosive valve); a few degradation anomalies (combustion debris shorted an antenna, a squib short after firing created a "sneak path," for instance); this performance record is possibly due to the extensive redundancy utilized in pyrotechnics.
- Magnetometers: Two catastrophic failures and several degradation anomalies which did not severely impact performance.

- Nutation Dampers: no catastrophic failures; three degradation anomalies. The first involved a leak in the damper that caused a significant roll error; thought to be due to extensive ground testing. The second involved a mechanical problem with a friction stop, and was attributed to faulty workmanship. The third was manifested as a slightly longer than expected nutation transient decay time, and was possibly due to some deviation in liquid viscosity.
- Heat Pipes: no anomalies, although it should be noted that only two spacecraft in the data sample carried heat pipes.

It can be seen from the above that few areas meet the criteria described above. This occurs for two reasons. First, a stringent criteria was applied to ensure that the areas meeting the criteria did indeed have an essentially trouble-free history. Second, and most important, evaluation of the data bank indicates that most spacecraft hardware areas have incurred a number of anomalies. This rules out describing these areas as trouble-free, even though a significant percentage of these anomalies did not severely degrade the mission.

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Experience Bulletin No. 4

ON-ORBIT INTERFERENCE (RFI) FROM EXTERNAL SOURCES

August 1978

Prepared under Contract No. NASW-3041,
"Study of Reliability Data From In-Flight Spacecraft"

for

National Aeronautics & Space Administration
NASA Headquarters, Washington, D.C.

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Experience Bulletin #4
ON-ORBIT INTERFERENCE (RFI) FROM EXTERNAL SOURCES

The data bank contains at least 20 cases of problems in spacecraft RF equipment due to interference from a source external to the affected spacecraft. In some cases, the external source was another spacecraft; in some cases the source was unknown. In addition, there are other cases in the data bank involving RF disruptions, but it is not known if this was due to external interference. The cases involving interference from external sources reported in this update can be summarized as follows:

Hawkeye (Explorer 52) experienced loss of data due to interference from OSO-5 and OSO-7; when the OSOs were active, Hawkeye lost about 4 percent of each orbital period's data.

Hawkeye also experienced interference from OAO and GEOS spacecraft, but this is reported as relatively insignificant.

Interference from an unknown source also caused "lost commands" on Hawkeye.

RFI from an external source disrupted transmissions from both Viking Orbiters for a period of 40 minutes.

LANDSAT-1 experienced several periods of external interference, including one nine-day period. This resulted in loss of some data.

NIMBUS-6 reception was affected by interference from ATS-6 when these two spacecraft were being utilized together for the Tracking and Data Relay Experiement. This interference was reported to be related to the ATS-6 operating mode.

- Although not an interference problem of the same type described above, radioastronomers at the Greenbank Observatory noted interference from ATS-6.

The cases involving interference from an external source reported in the data bank previous to this update can be summarized as follows:

- Both command receivers on OGO-5 were saturated for two-and-one-half hours by a strong RF signal of unknown origin.
- OGO-6 experienced anomalous command reception, but no further information is available.
- There were numerous cases of interference involving eight combinations of spacecraft on the TIROS/TOS/ESSA program. For instance, under certain conditions, ESSA-9 responded to TIROS-M commands, ESSA-4 responded to ESSA-1 commands, ESSA-5 experienced spurious commands when ESSA-2 was in the vicinity, etc. Several of these cases of interference occurred when the spacecraft were being commanded from Alaska.
- OSO-1 executed many false commands due to some unspecified type of interference over North Africa. This was attributed to an inadequate coding scheme, and the corrective action consisted of placing a special transmitter near the site of the interference. No further information is available.

It is not difficult to postulate reasons for many of the interference problems summarized above. Possibilities range from solar flares and military electronic warfare exercises to inadequate command coding schemes. The fact remains, however, that the data bank indicates external interference incidents are increasing, and that they primarily encompass RF problems (as opposed to problems relating to coding schemes). This is contrary to what would be expected since the increasing use of wideband should result in less crowded channels and more channel selection sensitivity.

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Experience Bulletin No. 5

SOME ON-ORBIT RELIABILITY ASPECTS OF ON-BOARD PROGRAMMABLE, GENERAL PURPOSE COMPUTERS

August 1978

Prepared under Contract No. NASW-3041,
"Study of Reliability Data From In-Flight Spacecraft"

for

National Aeronautics & Space Administration
NASA Headquarters, Washington, D.C.

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A Note on the Data Base for this Bulletin

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Experience Bulletin #5
SOME ON-ORBIT RELIABILITY ASPECTS OF ON-BOARD PROGRAMMABLE, GENERAL PURPOSE COMPUTERS

Six spacecraft in the update sample are known to have carried general purpose, programmable computers. While this is too limited a data sample to justify broad conclusions, the data does seem to indicate that the space environment has not introduced any unusual types of anomalies. The capability for reprogramming in-flight is recommended.

I. INTRODUCTION

The time frame covered by this data bank update roughly coincides with the early phases of the era of readily available, "off-the-shelf" general purpose, programmable computers for space applications. Spacecraft in the data bank sample prior to this update frequently used specially designed programmers, sequencers, controllers, and the like. Only the later manned spacecraft in the sample, however, carried identifiable, true, general purpose computers, and these units operated only for short durations. Hence, it was considered of interest to examine the performance record of the computers in the update sample.

II. ANALYSIS

At least six spacecraft in the update sample carried general purpose, programmable computers. Some hardware on other spacecraft called out as programmers, controllers, etc., may also have been general purpose computers, but since they were not clearly identifiable as such they were not considered in this examination.

The computers on the six spacecraft, including three cases of dual redundancy, accumulated over 80,000 hours of survival time. Eighteen anomalies are charged against the computers, with the anomalies falling into the following categories:

- 5 anomalies: "glitches"; caused no major problems
- 4 anomalies: programming errors; reprogrammed in flight
- 5 anomalies: Erroneous operation of undeterminable origin; caused major concern; "self healing"
- 1 anomaly: Program updates did not load on initial tries; subsequently loaded properly; cause unknown
- 3 anomalies: Memory problems; seriously degraded performance

Of the five above categories, the first four are felt to be self-explanatory. The fifth, memory problems, requires further explanation Of the three anomalies in this category, one involved too small a memory for computing fine pointing increments, with the result that only coarse steps were available. The second of these anomalies involved loss of access, for reasons that are not clear, to a portion of memory. The third involved failure of four memory bits, possibly due to a failed wire in the plated wire memory.

These 18 anomalies, in general, are typical of the types of problems routinely encountered with ground-based computers. That is, the space environment does not appear to have introduced any "new" types of anomalies. With regard to severity, the anomalies associated with the memory problems caused degradation. It appears that the four programming error anomalies would also have resulted in degradation had reprogramming not been possible. All other anomalies can be classified as intermittents that, after varying periods of time, did not recur. At least half of these could have posed serious problems had they continued.

With respect to the number of anomalies reported, the record can best be judged by comparison to other components. There were also 18 anomalies charged against telemetry sensors in this update, yet there are at least two orders of magnitude more telemetry sensors than computers in the sample. There are 15 anomalies charged against sun sensors in the update, which also considerably outnumber computers. This, of course, does not account for complexity. Command and control, which is more equivalent in terms of complexity, had slightly over twice as many anomalies as computers. Again, however, command and control functions greatly outnumber computers in the data sample. Based on these comparisons as well as consideration of the 80,000 hours of survival time, 18 anomalies seems a somewhat large but not excessive number.

Some of these anomalies, however, appear to be types which, as more experience is gained, may be successfully mitigated. Judging from ground computer operations, programming errors will always occur to some extent, and can be mitigated by reprogramming. Also judging from ground operations, "glitches" become less prevalent as the hardware matures and interface conditions are better understood. This suggests that, with the proper implementation, on-board computers can become extremely reliable.

III. CONCLUSIONS

Overall, the data sample is too limited to justify broad conclusions as to the on-orbit reliability of general purpose computers.

It does, however, appear to support the following conclusions based on the current state-of-the-art:

- The space environment does not seem to have introduced any types of computer anomalies that differ significantly from ground-based computer anomalies.
- On-board computers should have the capability for reprogramming in-flight.
- Properly designed and implemented computer hardware and software promises to substantially increase the reliability of control functions.

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Experience Bulletin No. 6

SPECIFIC ORBITAL ANOMALIES POSING POTENTIAL RELIABILITY PROBLEMS

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NASA Headquarters, Washington, D.C.

A Note on the Data Base for this Bulletin

The Space Data Bank from which the results in this bulletin were derived is presented in PRC R-1863, On-Orbit Spacecraft Reliability, September 1978. For purposes of background to this analysis, it need only be pointed out that the data bank contains orbital performance data spanning spacecraft from Vanguard to HEAO, a period of nearly 20 years. Four primary data collection efforts have been made. This experience bulletin has been written in conjunction with the most recent effort. The first three collections analyzed 1399 anomalies from 310 spacecraft launched between 1958 and 1972. The most recent collection added information on 708 anomalies from 45 spacecraft launched in the seventies. These data are referred to herein as "this update."

Experience Bulletin #6
SPECIFIC ORBITAL ANOMALIES POSING POTENTIAL RELIABILITY PROBLEMS

Three specific types of anomalies, which had not been seen to any significant extent, if at all, on previous data bank studies, were noted during this update. On the basis that they may either denote the beginning of a trend, or signify some basic, underlying problem, each is described below.

1. Array Temperature Sensors: Two spacecraft in this update sample had array temperature sensor problems. On one of these spacecraft, four sensors failed-open after first operating intermittently. On a second spacecraft, four array temperature sensors also failed, and this was attributed to insufficient built-in strain relief. There are a number of anomalies in the data bank involving temperature sensors in general, and several other anomalies involving array temperature sensors specifically. However, the occurrence of these eight array temperature sensor failures over a short period of time stands out as unique.

2. Leaks Through Thin Windows: In the total data bank, there are four reported incidents involving thin windows. These windows are typically 1.5 to 1.9 microns in thickness, and are used as "input ports" in experiments and detectors. Three of these incidents occurred on spacecraft in this update. The first involved a broken titanium

window, and the reason for this breakage is unknown. In the second, in another experiment, the thin window had pin holes, allowing the leakage of methane pressurant gas. The third case was a ruptured window in a charged particle experiment, which also depleted the experiment's pressurant gas. The only similar incident reported prior to this data bank update involved a punctured "membrane" in a micrometeorite detector. The reason for the failure was not determined. It is not known how much hardware covered in the data bank had "thin" windows, but presumably a number of experiments and scanners utilized such devices. The increase in the number of problems reported for them in this update seems significant.

3. Catalyst Bed Susceptibility to RFI: An anomaly was observed on this update that has never been seen on previous data bank studies. That is, it was reported that a thruster catalyst bed was sensitive to RFI under some conditions. This incident occurred several times, including periods when various telemetry transmitters and antennas were activated. It is also reported that this interaction did not have a serious impact on the mission. No further information was available. There are other incidents involving catalyst beds in the data bank. These include a decrease in catalyst bed resistance after heavy firing; this resistance decrease later stabilized. Also,

there have been several incidents involving degradation or loss of thrust due to degradation of the catalyst bed. There is no indication, however, that any of these other catalyst bed anomalies were even remotely associated with susceptibility to RFI.