ORBITAL ANOMALIES IN GODDARD SPACECRAFT FOR CY 1993

June 1994

Goddard Space Flight Center (GSFC)
System Reliability and Safety Office, Code 302
Greenbelt, Maryland 20771

TABLE OF CONTENTS

	Page
Summary	1
Introduction	1
Spacecraft Activity Schedule	1
Data Sources	2
Spacecraft Performance Summary	3
Anomaly Data: Classification & Description	10
Acronym & Abbreviation List	23

Tables:

I - Classification of 1993 Anomalies	13
II - Log of 1993 Anomalies	24

Figures:

1993 Anomalies:

1	Distribution Among Spacecraft	17
2	Distribution Among Subsystems	18
3	Mission Effect (Criticality)	19
4	Anomaly Effect	20
5	Failure Category	21
6	Type of Anomaly	22

APPENDIX A - SPACECRAFT LIFETIME DATA	A-1

Summary

This report presents a summary of the in-orbit reliability performance of spacecraft that were built under the management of the Goddard Space Flight Center and that were active during calendar year 1993. It is one of a series of such reports that collectively form a continuous published record of this performance. The major feature of these reports is a log of all anomalies occurring during the report period which provides a description of the anomaly and its time of occurrence. Each anomaly is classified according to criticality, type, subsystem, and other relevant criteria. Although some statistical analyses and comparisons are given, the purpose of the report is primarily documentary, with more extensive statistical treatment to be presented elsewhere.

Introduction

Since the earliest days of the Center, attempts have been made to record the performance of Goddard-managed spacecraft. Although statistical summaries exist, it is only within the last 25 years that more detailed data were gathered and published in various forms. In 1983 a report containing very specific anomaly data was published. This was the contractor report, Analysis of Spacecraft On-Orbit Anomalies and Lifetimes, PRC R-3579, dated 10 February 1983, which covers the period from 1978 to mid-1982, and includes JPL as well as GSFC spacecraft. This was followed by Orbital Anomalies in Goddard Spacecraft 1982-1983 and yearly reports since. All these reports are published by the Office of Flight Assurance. This report updates the record through 1993.

Spacecraft Activity Schedule

On January 1, 1993, a total of 21 GSFC spacecraft were in full or partial service. This includes seven meteorological spacecraft operated by National Oceanic & Atmospheric Administration (NOAA), consisting of four of the TIROS/NOAA series and three of the GOES series.

Although the Hubble Space Telescope (HST) was not built under contract to Goddard Space Flight Center (GSFC)–it was a Marshall Space Flight Center (MSFC) program–it is included in this report because flight operations and servicing missions of the HST are assigned to GSFC.

Two new spacecraft were launched during the year. The Tracking and Data Relay Satellite-F (now TDRS-6 on orbit) was launched January 13 aboard the Shuttle (STS-54). On August 9 the NOAA-I weather satellite was launched successfully on an Atlas Expendable Launch Vehicle (ELV) and was designated NOAA-13 on orbit. Unfortunately, about two weeks later a component in the power subsystem failed; the spacecraft, which lost all power, has not been heard from since.

In December the first HST Servicing Mission (SM-01) was performed by STS-61. This mission was highly successful in that the astronauts were able to perform all the planned replacements to subsystems and components in the HST.

The complete list of satellites active during all or part of 1993 is as follows:

NASA		NOAA
COBE		NOAA-9
ERBS	**O**	NOAA-10
EUVE	**N**	NOAA-11
GRO		NOAA-12
HST		
ICE (ISEE-3)	**G**	
IUE	**O**	GOES-2
NIMBUS-7	**I**	GOES-6
SAMPEX	**N**	GOES-7
TDRS-1	**G**	
TDRS-3		
TDRS-4		
TDRS-5		
UARS		
TDRS-6	**NEW**	NOAA-13

Details are shown in the Spacecraft Lifetime Data in Appendix A, which includes virtually all GSFC launches since 1960. Those excluded are Shuttle-attached payloads and international missions in which Goddard participated but which are not considered to be Goddard's responsibility.

Overall there were 46 anomalies distributed over 14 different spacecraft during the year. No anomalies were reported in the following spacecraft: GOES-6, ICE, IUE, NOAA-9, NOAA-10, NOAA-11, NOAA-12, and SAMPEX. The distribution of these anomalies among the spacecraft is presented in Figure 1. (This compares with 71 anomalies distributed over 17 spacecraft in the previous year 1992.)

In addition, the distribution of these 46 anomalies among the spacecraft subsystems is shown graphically in Figure 2. This figure shows that most of the anomalies (14) occurred in the power subsystems, followed by attitude control subsystems and instruments with 8 anomalies each.

In the following sections, each mission and its overall performance are discussed in more detail. A complete log of anomalies appears at the end of the report in Table II.

Data Sources

The data reported herein are taken primarily from three sources. For NASA spacecraft, the main source is the Spacecraft Orbital Anomaly Reports (SOAR). For TIROS/NOAA spacecraft the TIROS Orbital Anomaly Reports (TOAR) and SOAR are used, and the GOES Anomaly Reports (GAR) cover the GOES series. These data bases are maintained by the System Reliability and Safety Office in the case of SOAR, the Meteorological Satellite (METSAT) Project in the case of TOAR, and the GOES Project in the case of GAR. The information contained in these reports originates in the corresponding spacecraft operations control centers. Supplementary information is obtained through miscellaneous written reports, attendance of the regular meetings of the Orbiting Satellites Project, and other verbal contacts. Additional backup information on many of these anomalies, which is available through the System Reliability and Safety Office, is subject to revision. This applies particularly to "open" anomalies.

Spacecraft Performance Summary

The following provides a summary of the condition and performance of the active spacecraft covered by this report. The classification of each spacecraft, according to GMI 8010.2, is listed after the spacecraft name.

Cosmic Background Explorer (COBE) CLASS B

This spacecraft continued carrying out its mission with great success during this fourth full year of operations. Science data from the two functioning instruments, Diffuse Infra-Red Microwave Radiometer (DIRBE) and the Differential Microwave Radiometer (DMR) are still good. The PB-5 Clock continues to require daily time adjustments (~ 5 ms/day) because of its continuing and increasing drift. Starting in May the spacecraft went through a three-month eclipse period with a maximum daily shadow of 17 minutes. The spacecraft survived the eclipse season with no serious problems. The two remaining transverse gyros, C and A, failed in July and October, respectively. They both had been noisy for some time preceding their demise and the cause was deemed to be old age (i.e., bearing wearout). Since these failures were expected there was only minimal impact to the spacecraft. Attitude control was switched to the X gyro after the Gyro-A failure. **On December 23rd the science mission of COBE was terminated.** The spacecraft, designed for a 1 1/2 year mission, had reached four years in orbit on November 11, 1993. Various End-of-Life engineering tests were run through January 1994.

Earth Radiation Budget Satellite (ERBS) UNCLASSIFIED

The two remaining instruments, Earth Radiation Budget Experiment-Non-Scanner (ERBE-NS) and Stratospheric Aerosol Gas Experiment (SAGE), were operating satisfactorily as the year began, with the spacecraft operating on only one battery (#2). In mid-March the Backup Command Memory had its first "hit" in over two years of operation. This was followed by a second "hit" two weeks later. Since this backup memory is not used for anything critical, the spacecraft was not adversely affected. Later in April the Flight Operations Team (FOT) performed about 45 solar calibrations of ERBE-NS for Langley Research Center to cross-calibrate it with a solar experiment on the concurrent STS mission.

In late June one cell of Battery #2 failed, followed a month later by a another cell failure. As a result, although the SAGE continues to acquire all science events, the ERBE-NS has been turned off to conserve power. Because of the conditions, battery charge is being controlled manually. In August an attempt was made to re-connect Battery #1, which had been off-line for over 10 months, to aid the power situation. The attempt was not successful: Battery #1 couldn't support the load and the battery situation was unstable.

In October the spacecraft reached nine years in orbit and at about this time there was a major failure of the spare Command Storage Memory, CSM-2. Although CSM-2 was used mainly for backup help, it did manage heater commands for the spacecraft. Because there was not enough command memory in CSM-1, all heaters were turned off. Although this caused temperatures to drop 5 degrees C, it did not cause any problems in the spacecraft. (However the loss of CSM-2 greatly increased the risk to both the battery and the spacecraft.)
In early November the SAGE successfully collected data for its yearly study of the ozone depletion over the Antarctic. At about this same time a revised procedure for performing a yaw turn was used successfully for the first time. This procedure accounted for having only one, partially failed, battery and limited command memory.

In late November there was a 10-day period of full sunlight which required that SAGE be turned off. This permitted the activation of ERBE-NS for the first time in four months. In early December the ERBS reached its 50,000th orbit since launch! This was followed by another successful yaw turn, and at the end of the year Battery #2 was still performing adequately.

Extreme Ultra-Violet Explorer (EUVE) CLASS B

In the early part of the year close monitoring and a number of adjustments of battery charging was done to improve C/D ratios. Also, from January to April, one of the three gyro channels
(-B) intermittently experienced probable bearing retainer chatter. It did not affect operations.

In early April the first target-of-opportunity measurement of the program was made: EUVE observed the Moon at the same time STS-56 was observing the Sun. At about the time of the first anniversary of the spacecraft (6/7/93), recent discoveries made by EUVE were presented at the AAS National Meeting: discovery

of elements that blanket the light from white dwarf stars, detection of ionized Helium in local interstellar gas, detection of extreme UV shadow in the local interstellar medium, and new findings on the mysteries of rare extragalactic objects.

In late July the last gap in the "All-Sky EUVE Survey" was filled and data collection activities for the map essentially ceased. At this point the spectroscopy phase of the mission started. First a 10-day Mini-In-Orbit Checkout (IOC) was conducted to ready the spacecraft for full utilization during this extended "Spectroscopy Phase". Such items as solar array articulation and high antisun angle slews were performed. This IOC revealed some interesting anomalies. First, in trying to slew solar array #2 to a 90-degree angle it was stopped by an "astronaut" hand-hold rail at the 85-degree position. No damage was done, and a software modification will prevent this in the future. Also, at high spacecraft inclination orientations to the Sun a glint from the spacecraft body causes high temperatures on parts of solar array #1. New software uplinked to the spacecraft will prevent this in future operations. In mid-August the first true Target-of-Opportunity slew was made to observe the outbursting cataclysmic variable star *SS Cygus*. Around the first of October a completely successful 2-orbit Moon observation was accomplished. Later that same month frequent small slews around a target boresight (named "dithering") to improve image quality were successfully tested. _

In early November a "clam-up" (all detector doors shut) occurred. This was probably caused by a SEU. Things were restored to normal in four hours. Later that same month another suspected SEU occurred in the Central Data Processor (CDP) which put the payload into a pre-launch mode (i.e., Ion Pumps On). Things were restored to normal the same day with no damage done. Finally, in November, UCB reported that a small area of decreased gain (a "dead spot") had developed near the center of the Deep Survey Detector. The quality of any data from this detector since 2/18/93 is suspect. At year's end, "all was well."

Geostationary Operational Environmental Satellite (GOES) CLASS A

GOES-6: This spacecraft, with all its maneuvering fuel consumed, remained in free drift (in geosynchronous orbit) throughout 1993. From January to July it drifted Eastward from 100°W to 75°W where it turned around and started drifting West. At the end of the year it was near 84°W. It was classed as semi-operational providing Space Environmental Monitor (SEM) data and simulated GOES Variable Processed Data Format (GVAR) to users all year. As of April 28 this spacecraft had been in orbit ten years. There were no reported anomalies during 1993.

GOES-7: Still designated the prime spacecraft, GOES-7 was stationed at 112 deg W during most of the year. With METEOSAT imaging providing adequate Atlantic Ocean weather data, this location provided better Pacific Ocean coverage while still being able to support most East DCS stations. GOES-7 provided Vissr Atmospheric Sounder (VAS) imaging/sounding, East WEFAX, East DCS, SEM and SAR all year. On February 26, GOES-7 reached six years in orbit.

In March three channels of the Energetic Particle Sensor (EPS) started experiencing erratic performance. When this occurred before, it was cured by turning the EPS off during the eclipse period and leaving it off for three additional hours following the eclipse period. Since this provided 21 hours of useful data each day, it was continued to the end of the eclipse season (4/11). In May, the Magnetometer Instrument in the SEM experienced a failure in the transverse data channel (H_t), and the parallel channel (H_p) data shifted, but remained usable. In early October the Battery No.1 end-of-charge voltage started to exceed the High Red limit of 41.4 volts. This is normal for aging NiCd batteries, and the battery management procedures were modified to terminate high rate charge if voltage limits were reached.

At the end of the year the orbital inclination had reached 1.2 degrees. To conserve the small quantity of fuel remaining, the North-South stationkeeping has been suspended since June 1992. The higher the inclination, the more degradation there is in the images. This inclination will continue to increase at the rate of 0.9^{o}/year.

Gamma Ray Observatory (GRO) CLASS B

At the beginning of the year the spacecraft was in good health. The batteries were working well with MPS #2 powering primary systems and MPS #1 supplying a reduced load, mainly heaters.

In mid-April, priming of the propulsion subsystem began. This is the first step in a sequence of events that will end in a re-boost of the GRO orbit from ~355 km to ~450 km altitude. The priming was successful with propellant at tank pressure available from all four tanks to the B-side Attitude Control Thrusters (ACTs). (These ACTs will be used for the orbit re-boost.) This is the first time this subsystem has been activated since the anomalous pressure surge occurred shortly after launch. In early May, engineering test burns of the four B-side ACTs were successfully conducted followed by equally successful calibration burns. (For all thruster firings the four science instruments were placed into a safe low-voltage mode.) On June 15 the first of the actual re-boost thruster firings was initiated. However, one orbit later, the firing of the thrusters drove the spacecraft attitude rates out of specified limits. This caused automatic safing sequences to be activated. The reaction wheels could not control the momentum rates, so the thrusters were fired manually to reduce the rates. The problem was caused by varying, reduced performance from thruster B2. This caused imbalance with the other three thrusters, producing excessive attitude rates. Re-boost operations were suspended, and science operations were resumed while the problem was studied. About a month later a new propulsion subsystem priming operation was begun to pressurize the B-side Orbit Adjust Thrusters (OATs). This was an alternate plan so that the B2 ACT would not have to be used by itself for the orbit adjust burns. After many tests of the OATs, (this was the first time the OATs had been fired) the actual re-boost operations started on October 4, with a nominal one-minute burn of the two B-side OATs. A series of about ten burns was conducted, without problems, over the following two weeks, culminating in the apogee being raised to ~450 km. By mid-December all the additional re-boost burns had been completed, resulting in the desired new circular orbit of 450 km.

In September a successful "shadow" test was performed which flowed real-time data from the spacecraft, through TDRS-1, through the new GRO Remote Terminal System (GRTS) in Australia, through White Sands, and to the GRO control center at Goddard. Also in September, the last Phase II observation was made and Phase III, Guest Investigators, was inaugurated.

GRO has yielded three major breakthroughs this year. Two of these enabled scientists to unmask hidden supernovae buried deep in the center of the Milky Way. The third discovery pinpoints the Orion Nebula as a source of the mysterious cosmic rays in this galaxy that have puzzled researchers for 80 years.

The TDRS-1 drift was initiated in late November to move it to its new station to support GRO real-time data flow through the new GRTS in Australia. Testing will be conducted during the drift period, which will last about two months. After a somewhat hectic year, operations for GRO were looking very good at year's end.

<u>Hubble Space Telescope (HST)</u> CLASS B
[NOTE: Built under MSFC contract.]

There were several minor anomalies in the early part of the year that did not cause too much trouble except for shutdowns of the Faint Object Camera (FOC) caused by attempting the high-voltage turn-on procedure. Use of this camera was discouraged until after the servicing mission in December 1993. In late March the Solar Array Drive Electronics No. 1 (SADE-1) became inoperable and control was switched to SADE-2. (SADE-1 was to be replaced during the Servicing Mission in December).

In early April the High Resolution Spectrograph (HRS) initiated target-of-opportunity observations of the recently discovered supernova, SN-1993J in the galaxy M81, followed by UV observations of the supernova by the Faint Object Spectrograph (FOS). In June both the Faint Object Camera and Spectrograph (FOC & FOS) were used to observe parts of the planet Jupiter and its moon, Io.

In order to protect the spacecraft from any possible damage during the annual Perseid Meteor Shower (mid-August), it was placed in an attitude that minimized the possibility of damage. The solar arrays were also adjusted to minimize their exposure to possible meteors. Apparently no meteor hits were encountered.

Because of continuing problems with the Magnetic Sensing System (MSS) hardware, the HST onboard Magnetic Field Model was enabled and was used for determining the Earth's magnetic field. Various other minor anomalies during the year are described in Table II, Log of 1993 Anomalies.

The major event of the year occurred in early December when the first (week-long) HST Servicing Mission (STS-61) by the Space Shuttle *Endeavour* took place. All the servicing mission objectives were accomplished with the following operations: insertion of new gyros and their control units, replacement of solar arrays,

replacement of Wide Field Planetary Camera (WFPC) with WFPC-II, replacement of two Magnetic Sensing Systems, replacement of High Speed Photometer with the Corrective Optics Space Telescope Axial Replacement (COSTAR), installation of a co-processor in the on-board computer, and replacement of the Solar Array Drive Electronics (SADE-1) unit. Following release of the HST by the Shuttle, the Servicing Mission Observatory Verification period began, and at year's end the new gyros and the solar arrays were operating nominally.

International Cometary Explorer (ICE) UNCLASSIFIED
[Originally ISEE-3]

Since funding of science data processing now comes from JPL's Ulysses Project, only Ulysses co-investigators received ICE data, starting 2/1. In August this spacecraft had its 15th anniversary of service in orbit. It is still providing useful data although its priority is low when competing with other spacecraft utilizing the Deep Space Network (DSN). In the middle portion of the year various instruments were turned off for periods of from four to six months at a time. This is due to limited power at increasing distances from the Sun, resulting from ICE's highly eccentric orbit.

Towards the end of the year special simultaneous data-taking opportunities occurred when the ICE and Ulysses spacecraft were aligned radially for two 10-day periods. A total of over 180 hours of valuable data were obtained. There were no reported anomalies in 1992.

International Ultraviolet Explorer (IUE) UNCLASSIFIED

In January, this spacecraft was 15 years old! (This is the longest operating spacecraft covered in this report.) During the year the spacecraft was continually plagued by the light infringement ("light streak") problem that partly covers the camera images. One to four hours of data are periodically lost due to this. Various "slewings" and rolling of the spacecraft were tried as a cure for the problem but the results were inconclusive. The cause is still not known.

In April the IUE started observing the new supernova, 1993J. (See the HST report on the previous page.) The spacecraft's orbit was such that it permitted continuous observation for a week, which gave a complete record of the supernova's changing intensity. Science-taking effectiveness for that week was 100%. In June, some observations of the planet Venus were performed, even though this put the spacecraft into a power negative condition. The battery performance was as expected, and there was no impact on the spacecraft's health.

During the year IUE went through two eclipse periods without problems. There were no new anomalies reported, and the spacecraft ended the year performing very well.

Nimbus-7 UNCLASSIFIED

In May, the chopper motor in the Total Ozone Mapping Spectrometer (TOMS) shut down, ending the acquisition of ozone data. Although two instruments, the Stratospheric Aerosol Measurement (SAM) II and the Earth Radiation Budget (ERB) were still partly operational, the sun angle on the spacecraft solar arrays was such that insufficient power was being generated to operate the spacecraft and instruments. **As a result the decision was made to terminate the NIMBUS-7 science mission, as of the 28th of December.** The spacecraft had been in orbit over 15 years. (The spacecraft is still being used as a communications relay link, serving places such as the South Pole.) NOTE: This spacecraft will no longer be included in future issues of this annual anomaly report.

National Oceanic & Atmospheric Administration (NOAA) [Satellites] CLASS B

NOAA-9

The spacecraft remained in standby status all year but it provided valuable imagery and science data from the Earth Radiation Budget Experiment-Scanner (ERBE-NS). In January a temperature sensor indicated a rise to excessive temperatures on the wide-field-of-view portion of the ERBE-NS. The ERBE was commanded into the stow position, resulting in a return to nominal temperature. After investigation it was determined that the problem was in the temperature sensor system; the high temperatures were not real. The ERBE was returned to service in April.

On August 1 all the transmitters, except the VHF Beacon Transmitter, were turned off. This was the first step of the deactivation process which would be completed pending the successful launch of NOAA-I on August 9. By September 1 all subsystems and transmitters had been turned back on due to the failure, in orbit, of NOAA-I.

During the year there were many occasions when special operations were required to properly manage the power system. This has been required since the solar array shunt failures some time ago. In December this spacecraft reached 9 years on orbit. No anomalies were submitted on the spacecraft this year.

NOAA-10 CLASS B

The NOAA-10 remained in "standby operation" status throughout the year. Several times throughout the year, high voltage on the spacecraft power bus caused a switch to the backup system. Due to power management problems resulting from earlier solar array shunt failures, this is not unexpected. (There is a similar problem on NOAA-9.) Corrective action rectifies the situation each time it occurs.

In September the spacecraft was six years old. No anomaly reports were submitted during the year.

NOAA-11 CLASS B

This satellite continued to be the operational "afternoon" polar orbit satellite throughout the year and its performance was nominal all year; no anomalies were reported.

In late September the spacecraft entered a period when it was in 100% sunlight throughout its orbit. This was the first time since launch, five years ago, that this had occurred.

NOAA-12 CLASS B

This spacecraft served as the "morning" polar orbit operational satellite throughout the year and its performance and operations were nominal. It was two years old in May.

The spacecraft experienced repetitions of the AVHRR scan motor "jitter" problem during the year. This causes high noise levels in Channel 3 and all HIRS channels. This is an old problem that has occurred before on NOAA spacecraft and is cured by letting the AVHRR's temperature increase. Another helpful procedure, used late in the year, is a 7-day outgassing period for the AVHRR. These procedures again helped alleviate the jitter/noise problems.

At year's end the performance and operations of NOAA-12 were nominal and no anomaly reports were submitted.

NOAA-13 CLASS B

On August 9 the NOAA-I spacecraft was successfully launched from Vandenberg AFB on an Atlas-E Expendable Launch Vehicle. After achieving orbit, all spacecraft systems were operating nominally; the first AVHRR pictures were received and their quality was excellent. A few minor anomalies were reported immediately following orbit insertion, but they were of no consequence. However, on August 21 the spacecraft experienced an anomaly in the power subsystem. Telemetry data, shortly afterwards, indicated the batteries were carrying the full power load and rapidly discharging even though the solar arrays were in full sunlight and indicating an output of 31 amps. It is believed that there was a short circuit in the Battery Charge Assembly

(BCX1). The last data contact with the spacecraft, before the batteries became fully discharged, was 3 hours and 21 minutes after the event. Command procedures to revive the spacecraft continued during multiple daily passes for the remainder of the year, with no success.

Solar, Anomalous, and Magnetospheric Particle Explorer (SAMPEX) CLASS C

The spacecraft started the year with nominal performance of all subsystems and instruments. The standard operational scenario is as follows: the HILT Instrument door is closed and promptly re-opened every 4-6 weeks (a 6-minute operation); the LEICA Instrument is powered off for 15 minutes each day; and the MAST/PET Instrument is powered off for 12 hours per week. (In mid-April the PI requested that the MAST "off period" be increased to 24 hours per week because of increased noise in one of its science channels.)

The spacecraft reached one year in orbit on July 3 with all operations going well. In mid-August the door of the HILT Instrument was closed for a few hours while the spacecraft was exposed to the Perseid Meteor Shower. No known meteor hits were encountered by the spacecraft. At the end of the year the SAMPEX mission was still going very well with no anomaly reports generated for the entire year.

Tracking and Data Relay Satellite (TDRS) CLASS A

TDRS-1: This spacecraft spent most of the year at 171°W. It was taken out of standby status in late March to start providing telecommunication support to the GRO Remote Terminal System (GRTS) station in Australia. About the first of December re-location maneuvers were initiated to move the spacecraft from 171°W to 85°E for GRO Spacecraft support through the GRTS. Several burns through the week would be utilized to produce a 1.5^{o}/day westerly drift. On December 6 the first GRO support event, utilizing the newly implemented GRTS (and TDRS-1), was conducted and it worked well. (TDRS-1 has been in orbit over ten years).

TDRS-3: This spacecraft, located at 62° W as TDRS-SPARE, remained in this status throughout the year. It has experienced relatively few anomalies since launch in 1988 and is in fairly good condition.

TDRS-4: This spacecraft continued to serve as TDRS-EAST throughout this year. There were some anomalies reported during the year but all were fairly minor. (However, one anomaly in August, an ACS fail-safe event, did interrupt user services for about eight hours.) Anomalies are reported in Table II.

TDRS-5: This spacecraft continued to serve as TDRS-WEST this year. TDRS-5 has experienced some minor anomalies (see Table II), but none serious.

TDRS-6: On January 13 this spacecraft was successfully launched by the Space Shuttle (STS-54). From January to May the in-orbit checkout was performed with the spacecraft getting a clean bill of health. During the last two weeks of June the spacecraft was moved to 138°W, for on-orbit storage. The spacecraft was essentially powered down until it was needed for active service. (It takes only a few days to return the spacecraft to active service.) Some minor anomalies occurring on the spacecraft through the course of the year are listed in Table II.

Upper Atmosphere Research Satellite (UARS): CLASS B

At the beginning of the year the spacecraft was operating well and producing good scientific data.
In March the UARS Science Team conducted a Meeting/Workshop. The scientific focus of the workship was high latitude processes affecting ozone in the stratosphere and mesosphere.

In mid-April there was a lubrication failure in a bearing of Earth Sensor #1 which caused an anomalous output. The spacecraft went into "earth-pointing safehold" and automatically switched to Earth Sensor #2. A software change removed Sensor #1 from the detection logic loop. Science-taking was resumed four days later. At the beginning of May the 183 GHz Radiometer failed in the Microwave Limb Sounder (MLS) Instrument. This caused only minor degradation of the instrument's total output.

In early May the Cryogenic Limb Array Etalon Spectrometer (CLAES) Instrument depleted its cryogen supply; this ended its operation. (The cryogen lasted 19 months versus a 20-month pre-launch prediction.) The other

instruments were obtaining good data and the data were becoming more available to the scientific community for geophysical studies. In August it was announced that the Microwave Limb Sounder (MLS) and the Halogen Occultation Experiment (HALOE) were seeing "greatly enhanced abundances of lower stratospheric Chlorine Monoxide (ClO) throughout the sunlit Antarctic vortex", and ozone had noticeably decreased .

The old problem of a slipping clutch on the solar array shaft during array re-positioning in connection with "yaw-around" maneuvers was still present during the year. However, at the end of September a version of the anomaly occurred with a new signature. This is a periodic-type slippage which is thought to be caused by debris on the solar array shaft. This debris acts as a lubricant between spring and shaft. During the investigation of this anomaly some instruments had to be turned off (for about three weeks duration). The conclusion was that the A-Drive can not be used for reverse rotation of the shaft for future operations. The B-Drive will be used for reverse rotation.

At the end of the year, nine of the ten instruments were still producing good data. (ISAMS Instrument failed in July 1992.)

Anomaly Data: Classification and Description

In the table of anomalies (Table II), the following information is provided:

1. Index - This is a chronological enumeration of the anomalies, beginning at launch. Numbers lower than the first number used in this report will be found in earlier reports of the series.

2. Date - This is the date of the occurrence of the anomaly, and, in parentheses, the number of days since launch is given, counting launch day as one.

3. Subsystem - For the purposes of this data base, the spacecraft is divided into nine subsystems. These are:

   1. Attitude Control Subsystem (ACS)
   2. Power
   3. Propulsion
   4. Structure
   5. Telemetry & Data Handling (TLM & DH)
   6. Thermal
   7. Timing, Control & Command (TC & C)
   8. Instrument (payload)
   9. Other (name to be entered)

4. Criticality - This describes the impact of the anomaly on the mission, according to the following schedule:

   1. Negligible (0 - 5%)
   2. Non-negligible but small (Minor) (5 - 33%)
   3. 1/3 - 2/3 Mission Loss (Substantial) (33 - 66%)
   4. 2/3 to Nearly Total Loss (Major) (66 - 95%)
   5. Essentially Total Loss (Catastrophic) (95 - 100%)

5. Description - A brief description of the anomaly and its probable cause, if known.

6. Effect/Action - The effect of the anomaly on the mission and corrective action, either for this mission or future missions, if any and if known.

7. Reference - The number on the SOAR, TOAR, or GAR (if any) covering this particular incident.

Anomalies are also classified in various ways for the purpose of statistical analysis. SOAR calls for the following classifications:

ITEM	CODE	DESCRIPTION
Anomaly Effect:		
	1	Spacecraft failure
	2	Subsystem/instrument failure
	3	Component failure
	4	Assembly failure
	5	Part failure
	6	Subsystem/instrument degradation
	7	Indeterminate
	8	Loss of redundancy
	9	None
Failure Category:		
	1	Design problem
	2	Workmanship problem
	3	Part problem
	4	Environmental problem
	5	Other (w/explanation)
	6	Unknown
Type of Anomaly:		
	1	Systematic (would occur if identical equipment were operated under identical circumstances)
	2	Random
	3	Wearout (a special case of systematic)
	4	Indeterminate
	5	Intermittent
	6	Normal/Expected Operation

These classifications for the 1993 anomalies are given in Table I.

Using the data in Table I, the 46 "1993 anomalies" can be summarized in various ways. These data are presented in various tables and graphs following Table I.

TABLE I

CLASSIFICATION OF 1993 ANOMALIES

Spacecraft	A	B	C	D	E	F
COBE	20	1	1	8	5	3
	21	1	1	8	5	3
ERBS	19	2	2	4	5	3
	20	2	2	4	5	3
	21	7	2	4	1	1
EUVE	1	2	1	9	1	1
GOES-7	21	8	2	6	6	4
	22	2	1	9	5	3
GRO	20	3	2	9	1	1 (5)*
HST	65	8	1	9	2	1
	66	8	2	6	6	4 (5)
	67	1	2	6	5	1 (5)
	68	2	1	5	3	4
	69	2	2	3	6	4
	70	9	2	9	5	6
	71	7	2	9	5	6
	72	2	2	9	5	1 (5)
	73	5	1	8	4	1
NIMBUS-7	74	8	3	2	4	4
NOAA-13	1	5	1	9	6	4 (5)
	2	2	1	9	6	4
	3	7	1	9	1	2
	4	2	5	1	1	1
TDRS-1	70	3	1	9	5	1 (5)
TDRS-3	18	3	1	9	5	1 (5)
TDRS-4	26	1	2	9	4	2 (5)
	27	1	1	9	4	4 (5)
	28	2	1	9	6	2
TDRS-5	8	5	1	9	6	2
	9	8	1	9	6	4
	10	1	1	9	4	2 (5)

*__NOTE:__ The (5) in Column F denotes anomalies that were intermittent in nature

A = Index

B = Subsystem

C = Criticality/ Mission Effect

D = Anomaly Effect

E = Failure Category

F = Type of Anomaly

TABLE I (Continued)

Spacecraft	A	B	C	D	E	F
TDRS-6	1	1	1	9	6	4 (5)
	2	3	1	9	6	4 (5)
	3	6	1	9	6	4
	4	2	1	9	5	1
	5	2	1	9	6	4
	6	8	1	9	6	4 (5)
	7	8	1	9	6	4 (5)
	8	5	1	9	4	2
	9	5	1	9	6	4 (5)
	10	7	1	9	4	4 (5)
	11	2	1	9	5	1 (5)
	12	7	1	9	5	4 (5)
UARS	8	1	2	5	3	1
	9	8	2	6	3	4
	10	2	2	6	5	1

A = Index

B = Subsystem

C = Criticality/
Mission Effect

D = Anomaly Effect

E = Failure Category

F = Type of Anomaly

1993 Anomaly Distribution Among Spacecraft

Spacecraft	No. of Anomalies
COBE	2
ERBS	3
EUVE	1
GOES-7	2
GRO	1
HST	9
NIMBUS-7	1
NOAA-13	4
TDRS-1	1
TDRS-3	1
TDRS-4	3
TDRS-5	3
TDRS-6	12
UARS	3

[See Figure 1, page 18]

1993 Anomaly Distribution Among Subsystems

Subsystem	No. of Anomalies
ACS	8
POWER	14
PROPULSION	4
STRUCTURE	0
TLM&DH	5
THERMAL	1
TC&C	5
INSTRUMENT	8
OTHER	1

[See Figure 2, page 19]

Criticality	No. of Anomalies
Negligible	29
Minor	15
Substantial (1/3 to 2/3 Mission Loss)	1
Major (2/3 to Nearly Total Loss)	0
Catastrophic (Total Loss)	1

[See Figure 3, page 20]

The anomaly listed above as "Catastrophic" was the loss of the NOAA-13 spacecraft (power failure) 12 days after launch. The anomaly listed as "Substantial" was the loss of the TOMS Instrument on Nimbus-7, ending the acquisition of ozone data.

Anomaly Effect	No. of Anomalies
1. S/C Failure	1
2. Subsys./Ins't Failure	1
3. Component Failure	1
4. Assembly Failure	3
5. Part Failure	2
6. Subsys./Ins't Degradation	5
7. Indeterminate	0
8. Loss of Redundancy	3
9. None	30

[See Figure 4, page 21]

Failure Category	No. of Anomalies
1. Design Problem	5
2. Workmanship Problem	1
3. Part Problem	3
4. Environmental Problem	7
5. Other (w/explan.)	15
6. Unknown	15

[See Figure 5, page 22]

Type of Anomaly	No. of Anomalies
1. Systematic	14
2. Random	6
3. Wearout	5
4. Indeterminate	19
5. Intermittent	18
6. Normal/Expected Operation	2

[See Figure 6, page 23]

Figure 1. 1993 Anomaly Distribution Among Spacecraft

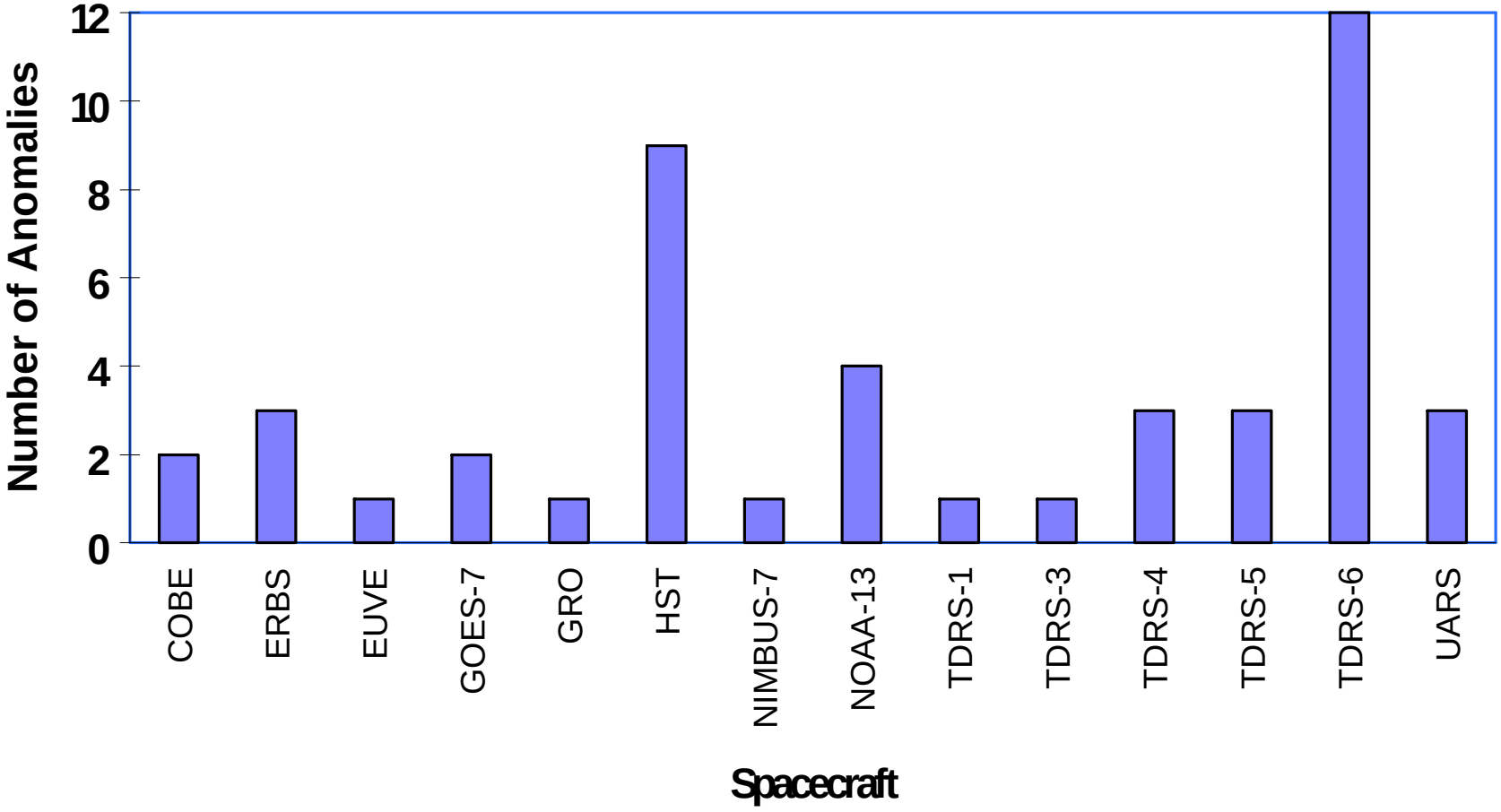


Figure 2. - 1993 Anomaly Distribution Among Subsystems

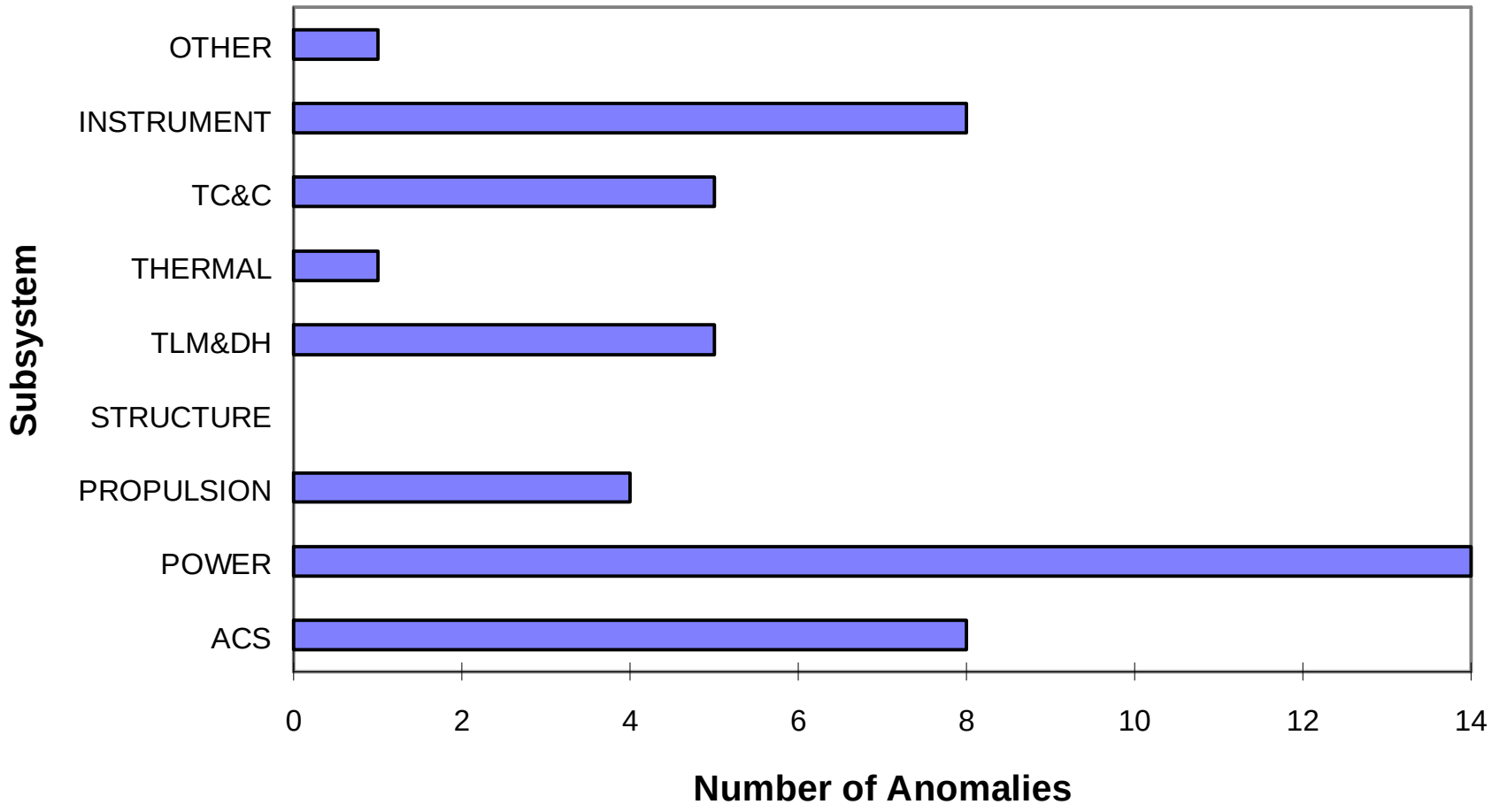


Figure 3. _ Mission Effect (Criticality)

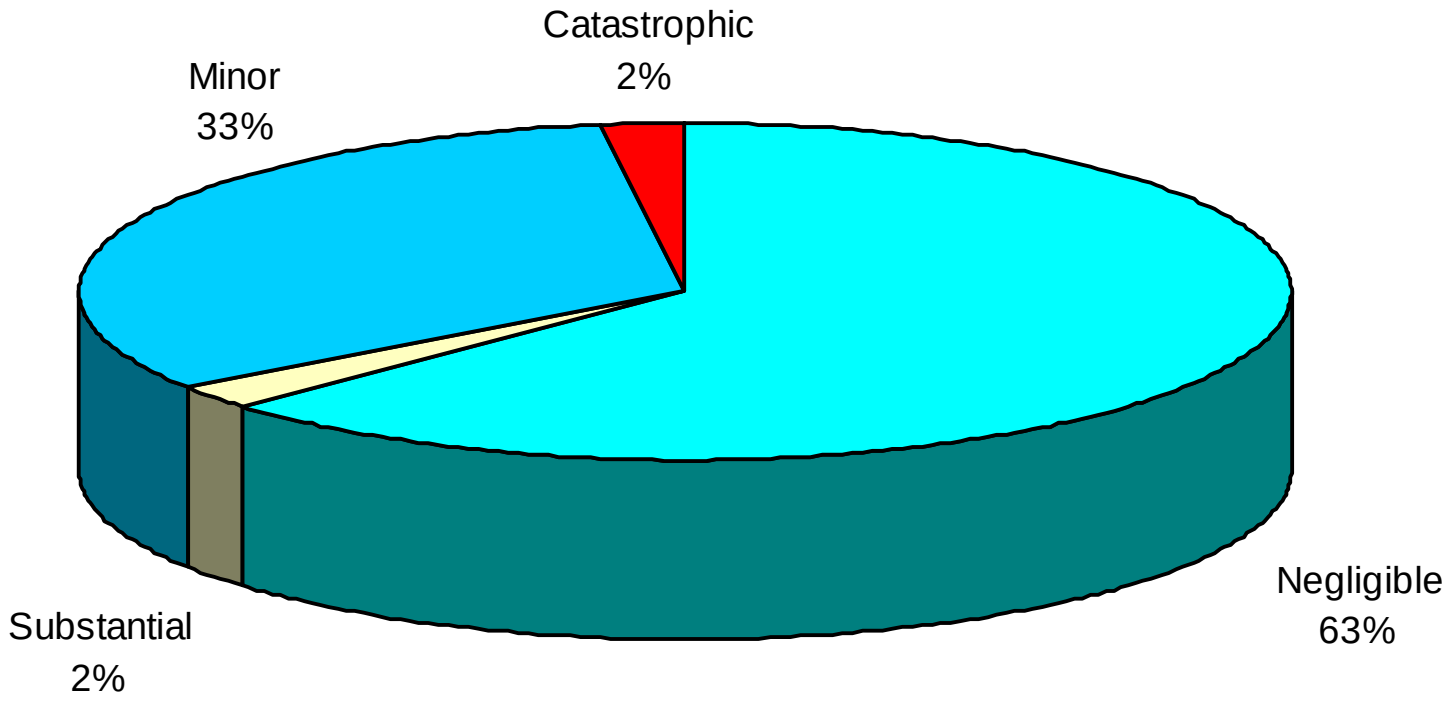


Figure 4. - Anomaly Effect

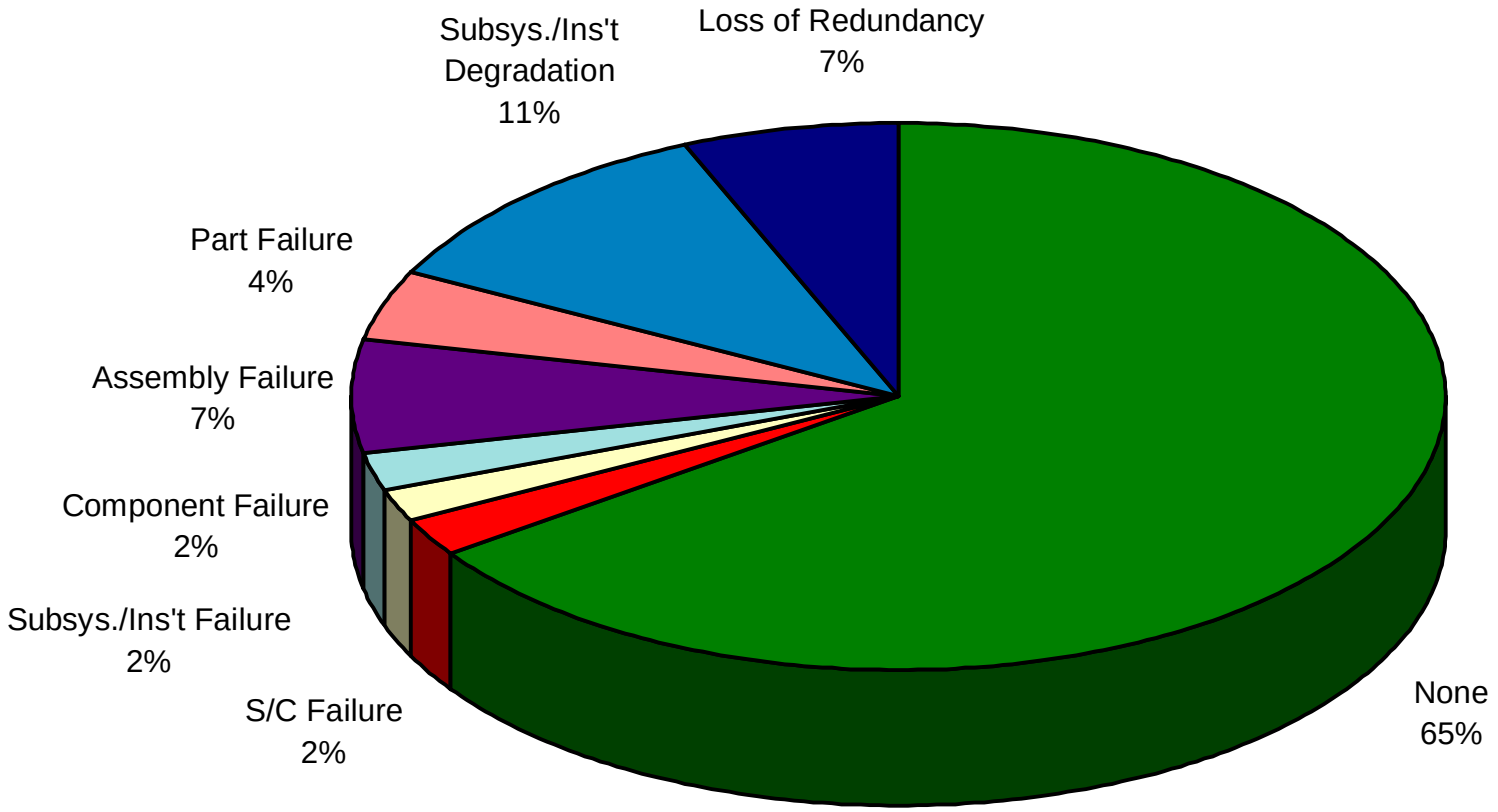


Figure 5. - Failure Category

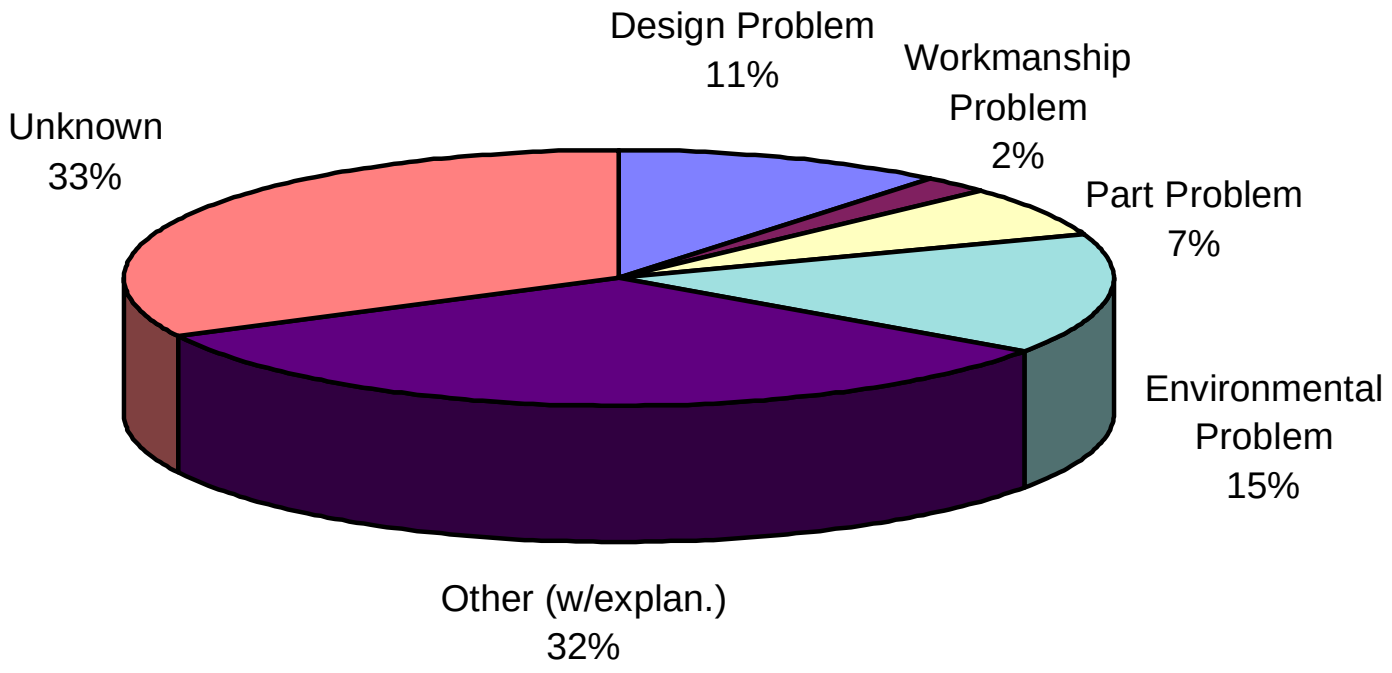
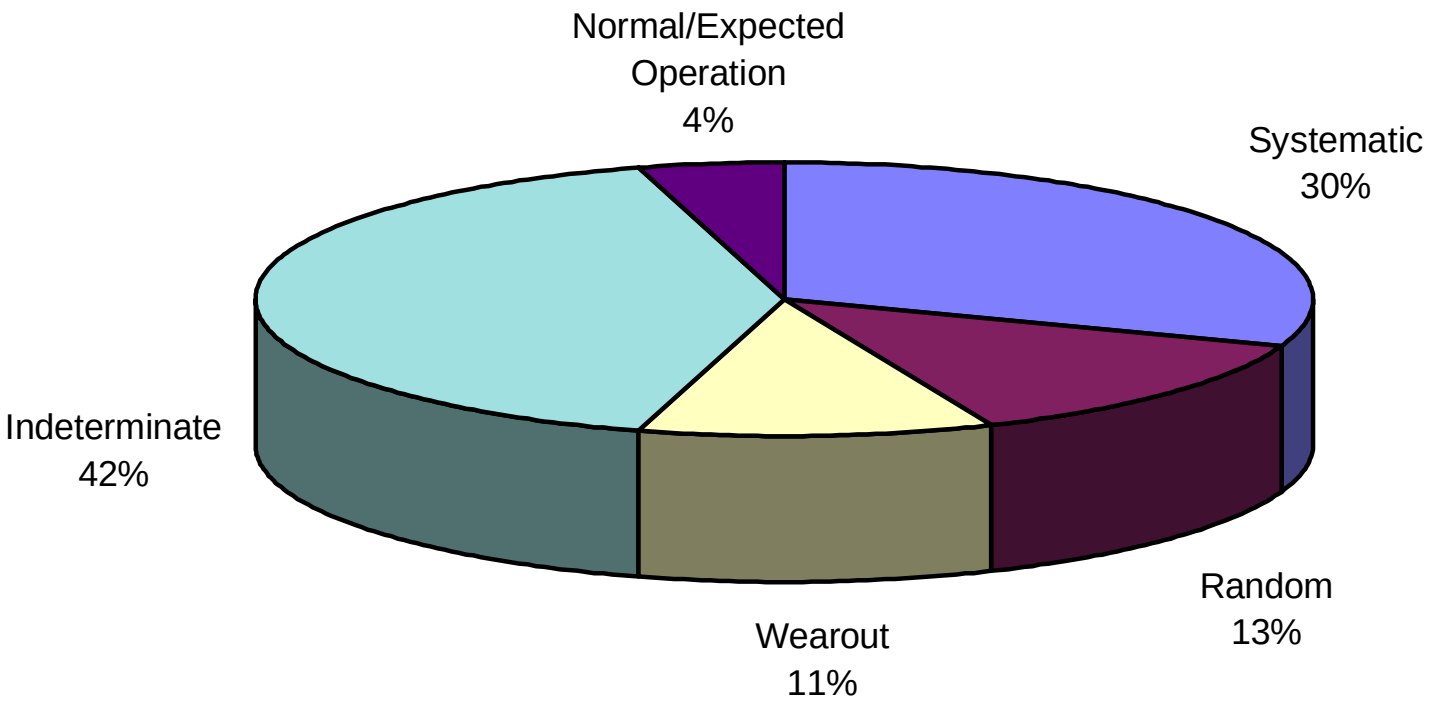


Figure 6. - Type Of Anomaly



Acronym & Abbreviation List

(Contains acronyms and abbreviations not already defined in the body of the report)

AAS	American Astronomical Society
AGS	Ascent Guidance Software
AVHRR	Advanced Very High Resolution Radiometer
C/D	Charge/Discharge
CPE	Control Processing Electronics
CSM	Command Storage Memory
CTE	Command & Telemetry Electronics
CW	Clockwise
DCS	Data Collection System
E/W	East/West
ESA	Earth Sensor Assembly
EVA	Extra-Vehicular Activity
FGS	Fine Guidance Sensor
FOC	Faint Object Camera
FOS	Faint Object Spectrograph
GHz	Giga-Hertz
HILT	Heavy Ion Large Telescope
HIRS	High-resolution Infrared Radiation Sounder
HV	High Voltage
INST	Instrument
ISAMS	Improved Stratospheric And Mesospheric Sounder
ISEE	International Sun-Earth Explorer
IUS	Inertial Upper Stage
JPL	Jet Propulsion Laboratory
LEICA	Low Energy Ion Composition Analyzer
MACS	Modular Attitude Control Subsystem
MAST/PET	Mass Spectrometer Telescope/Proton-Electron Telescope
MPS	Modular Power Subsystem
NiCd	Nickel-Cadmium
NOAA	National Oceanic & Atmospheric Administration
PASS	POCC Application Software Support
POCC	Project Operations Control Center
SA	Solar Array
SAR	Search And Rescue
SEM	Space Environment Monitor
SEU	Single Event Upset
SGL	Space-to-Ground-Link
STS	Space Transportation System
TIROS	Television/Infrared Observation Satellite
TOMS	Total Ozone Mapping Spectrometer
TWTA	Traveling Wave Tube Amplifier
UCB	University of California-Berkeley
UDA	UHF DCS Antenna [DCS = (See list above)]
UHF	Ultra High Frequency
UV	Ultraviolet
V/T	Voltage/Time
VHF	Very High Frequency
VISSR	Visible Infrared Spin-Scan Radiometer
WEFAX	Weather Facsimile

TABLE II

LOG OF 1993 ANOMALIES

INDEX	DATE/(DAYS)	SUBSYSTEM	CRITICALITY	DESCRIPTION	EFFECT/ACTION	REF.
				COBE		
20	7/10/93 (1331)	ACS	1	Gyro-C stopped running. This was preceded by a period of running with elevated temperature and current. Cause: Bearing wearout.	Minimal effect on S/C: redundancy available./ Turn off gyro.	B-0236
21	10/2/93 (1415)	ACS	1	Gyro-A stopped running. This was preceded by a period of running with elevated temperature and current. Cause: Bearing wearout.	Minimal effect on S/C: attitude not signif. affected./ Turn off gyro.	B-0237
				ERBS		
19	6/21/93 (3182)	POWER	2	Cell in Battery-2 failed. Seen as rapid increase in battery temperature & cell balance. Cause: possible overcharge & old age .	Operations more difficult (lost Batt-1 year ago)/ Reduce charge level from V/T-6 to V/T-3.	B-0238
20	7/22/93 (3213)	POWER	2	Second cell failed in Batt-2. Saw immediate cell balance increase & delayed temp. overcharge/battery condition.	Op's very difficult/ Reduce power use & reduce overch'g: current ch'g scheme.	B-0239
21	10/7/93 (3290)	TC&C	2	Anomalous changes in chips in Cmd Storage Memory-2. Cause: chips susceptible to noise/radiation.	CSM-2 unreliable & time tags changed./ Stop use of CSM-2 & use only CSM-1.	B-0240
				EUVE		
1	7/27/93 (416)	POWER	1	Solar Array-2 encountered an obstruction during slew to 180° that stopped array at 176°. Cause: Array hit EVA handrail installed on MACS Module.	Negligible effect./ Arrays will be limited to max of 170° by operational restrictions.	A-01513

INDEX	DATE/(DAYS)	SUBSYSTEM	CRITICALITY	DESCRIPTION	EFFECT/ACTION	REF.
				GOES-6		
				NO ANOMALIES REPORTED IN 1993		
				GOES-7		
21	5/2/93 (2258)	INST+SEM	2	Data channel, H_T, gains went way down & DC offset went to saturation. H_P channel data shifted 60 nano-tesla. Cause: Not known.	H_T channel has failed./ No action possible.	133
22	10/7/93 (2416)	POWER	1	Batt. No.1 voltage exceeded "High Red Limit" during hi-rate charge, before battery rollover occurred. Cause: Changing characteristics of aging battery.	Negligible/ Modified batt. charge procedure to stop high rate charge if "Red-Limit" is reached.	134
				GRO		
20	6/15/93 (801)	PROPULSION	2	Reduced & unpredictable thrust from B2 Att. Cont. Thruster (ACT) Cause: Flexing of ACT valve seal due to high delta-P across seal.	Produced excessive S/C attitude rates./ Use B-side Orbit Adjust Thrusters plus B-ACT's & inhibit B3 ACT.	B-0170
				HST		
65	1/22/93 (1005)	INST+FOS	1	Image shifts due to geomagnetic field. Cause: suspect improperly anodized shields.	Negligible effect/Soft-ware patch will compen-sate for image movement.	066
66	1/22/93 (1005)	INST+FOC	2	Several attempts to turn on high voltage using "procedure", resulted in shutdown. Cause: Not known (Possible short in HV power supply)	Can't use camera/ Use of camera is discouraged until after HST Servicing Mission in 12/93.	067

INDEX	DATE/(DAYS)	SUBSYSTEM	CRITICALITY	DESCRIPTION	EFFECT/ACTION	REF.
				HST (CONTINUED)		
67	2/10/93 (1025)	ACS	2	Numerous failed guide star acquisitions traced to Star Servo-A in FGS-2. Cause: Probable sticking (friction) in a servo bearing.	Temporary effect: operating OK later in year./ Limit use of FGS-2; use FGS-1 and FGS-3.	068
68	3/11/93 (1053)	POWER	1	Anomalous solar array section-AA current. Cause: The -AA Solar Panel Ass'y relay appears to have failed in a closed position.	Minimal effect./ Flight software changed to: Don't use this relay.	069
69	3/24/93 (1066)	POWER	2	Solar Array Drive Electronics-1 (SADE-1) output halted & solar array position angles were not following computer commands. Cause: Problem in oscillator drive circuit.	SADE-1 is not usable./ Shifted solar array control to SADE-2 until SADE-1 was re-placed in Servicing Mission.	070
70	6/14/93 (1148)	OTHER+PASS	2	S/C entered inertial hold "safemode" after failing Earth bright object protec-tion test. Cause: Ground control used erroneous V1 Axis target vector.	Minor S/C effect/ V1 Axis processing will be corrected via scheduled software change in 9/93.	071
71	7/11/93 (1175)	TC&C	2	Loss of communication resulted when a DF-224 Computer stored program command was uplinked at wrong time. Cause: Early uplink overwrote commands in progress.	This put computer in unknown state./ Restored telemetry, commanded DF-224 into a known operational state.	072
72	7/25/93 (1189)	POWER	2	S/C entered software sunpoint mode because computer detected too large a delta position of solar array during slew. Cause: probably related to day/night transition disturbance.	Minor problem/ Minimize any solar array slews near day/night transition point.	073
73	12/9/93 (1326)	TLM&DH	1	Data Interface Unit-2 (DIU-2), 'A' Side presented faulty telemetry readings for specific HST parameters. Cause: Not known (may be radiation damage.)	Negligible effect./ DIU-2 switched to redundant 'B' Side permanently & problem cleared.	074

INDEX	DATE/(DAYS)	SUBSYSTEM	CRITICALITY	DESCRIPTION	EFFECT/ACTION	REF.
				ICE		
				NO ANOMALIES REPORTED IN 1993.		
				IUE		
				NO ANOMALIES REPORTED IN 1993		
				NIMBUS-7		
74 01469	5/6/93 (5309)	INST+TOMS	3	Chopper motor current dropped to zero & indicated non-sync condition & no science data seen during scans. Cause: Not known (may be related to lower bus voltage.)	TOMS not able to take data./ None possible.	A-
				NOAA-9		
				NO ANOMALIES REPORTED IN 1993		
				NOAA-10		
				NO ANOMALIES REPORTED IN 1993		
				NOAA-11		
				NO ANOMALIES REPORTED IN 1993		
				NOAA-12		
				NO ANOMALIES REPORTED IN 1993		

INDEX	DATE/(DAYS)	SUBSYSTEM	CRITICALITY	DESCRIPTION	EFFECT/ACTION	REF.
				NOAA-13		
1	8/9/93 (1)	TLM&DH	1	Telemetry data indicated UDA antenna did not fully deploy (80° vs. 90° required). However, 27 orbits later it indicated full deploy. Cause: Not known.	No effect on mission/ None required.	331
2	8/9/93 (1)	POWER	1	Telemetry data indicated Sol. Array Hinge-1 took 175 sec. to deploy 180° (spec is 100 sec. max). Cause: Not known. Other 7 hinges were all within spec.	No effect./ None required.	332
3	8/11/93 (3)	TC&C	1	A computer error was seen during a Fairbanks pass after AGS memory was cleared. Cause: Probably a memory usage conflict between modules.	Negligible effect./ A report is being written which will give corr. action.	330
4	8/21/93 (13)	POWER	5	Although solar array indicated an output of 31 amps, all 3 batteries were discharging & indicated low voltage. Cause: Probably a short circuit in Batt. Ch'g Ass'y No. 1.	**Loss of spacecraft**/ Ground stations trying to command/revive S/C: not successful to date (6/94).	329
				SAMPEX		
				NO ANOMALIES REPORTED IN 1993		
				TDRS-1		
70	8/2/93 (3774)	PROPULSION	1	During thruster firings to unload pitch wheel, no dynamic response was seen in wheel speed sum. Cause: Probably a clogged filter or bubble in feed line.	Negligible effect./ None required. Problem cleared itself.	149-1

INDEX	DATE/(DAYS)	SUBSYSTEM	CRITICALITY	DESCRIPTION	EFFECT/ACTION	REF.
				TDRS-3		
18	12/18/93 (1907)	PROPULSION	1	During routine pitch unloading, the reaction wheel response to thruster firing was lower than normal. Cause: Probably a blockage in feed lines.	Momentum dump took longer./ None required; anomaly cleared itself.	158-3
				TDRS-4		
26	8/1/93 (1603)	ACS	2	Telemetry indicated erratic ACS data and the S/C slowly started to diverge from Earth pointing. Cause: Probably a SEU in a CPE or CTE (cont. & cmd electronics) chip.	User services out for 8 hours./ Disabled CTE & CPE, reloaded data, & re-enabled units.	148-4
27	8/26/93 (1628)	ACS	1	Earth Sensor Ass'y roll & pitch "glitch" occurred (2 sec. long) which caused ESA "Fail-Safe" to occur. Cause: Not known. May be SEU or hardware problem.	Reaction wheels ran down to zero./ Ground cmd re-enabled system. S/C recovery in 5 min.	151-4
28	11/15/93 (1709)	POWER	1	Solar Array Drive-B activated spontaneously causing -Y Solar Array to go into the slew mode. Cause: Not known; no commands were sent.	Negligible effect./ None except command sent to turn Drive Electronics off.	155-4
				TDRS-5		
8	5/5/93 (643)	TLM&DH	1	Telemetry parameter, Multiple Access Up-Converter 2B, changed state from "Off" to "On" for 65 sec. Cause: Not known: (possible faulty telemetry circuit)	Nothing affected./ None required; parameter went back to "Off" state by itself.	145-5
9	12/2/93 (854)	INST+PAYLOAD	1	K-band TWTA helix current spiked twice from "rest" value (0.32 ma) to 0.60 & 0.90 ma, then returned to 0.41 ma. Cause: Not known.	Negligible effect./ Tests were run: no change in TWTA performance.	156-5

INDEX	DATE/(DAYS)	SUBSYSTEM	CRITICALITY	DESCRIPTION	EFFECT/ACTION	REF.
				TDRS-5 (CONTINUED)		
10	12/12/93 (864)	ACS	1	Normal mode outputs from CPE went to disabled state, with numerous ACS parameters out of limits. Cause: Probably a SEU in the processor.	S/C started to lose its attitude reference./ CPE re-initialized & reloaded. (No loss of user data.)	157-5
				TDRS-6		
1	1/13/93 (1)	ACS	1	Gyro-3 output changed suddenly from 29.9 to 26.3 deg. as TDRS/IUS was being elevated on orbiter tilt table. Cause: not known.	No effect./ None; no further anomalous data were seen.	143-6
2	1/14/93 (2)	PROPULSION	1	Unexpected Tank-A pressure transducer outputs coincident with TDRS/IUS separation & during solar array deployments. Cause: Not known for sure; may be gas bubbles in thruster line.	No effect, pressure returned to normal in 96 sec./ None required.	135-6
3	1/14/93 (2)	THERMAL	1	Temperature of solar arrays +Y & -Y differed by 20°F after deployment. (Temperatures were equal before launch.) Cause: Not known; may be loose sensor.	No effect on S/C./ None possible.	138-6
4	1/14/93 (2)	POWER	1	Saw a 2.0^{o} discrepancy between telemetered solar array angle & known null positions. SA misalignment caused momentum buildup. Cause: 2° discrep. cause unknown.	Caused momentum buildup./ Brought solar arrays within 0.5^{o} of each other.	144-6
5	2/22/93 (41)	POWER	1	Battery cell C2 cautioned at 1.45 volts. (Identical anomaly has occurred in other TDRS S/C.) Cause: not known.	No impact./ None possible.	141-6
6	2/24/93 (43)	INST+PAYLOAD	1	During antenna potentiometer verif. test, 2 "space-to-ground-link" E/W nulls were missed, in both directions. Cause: not known.	No effect./ None; subsequent null searches were successful.	142-6

INDEX	DATE/(DAYS)	SUBSYSTEM	CRITICALITY	DESCRIPTION	EFFECT/ACTION	REF.
				TDRS-6 (CONTINUED)		
7	5/17/93 (125)	INST+PAYLOAD	1	C-band TWTA helix current has alarmed 4 times since launch with highest spike at 4.45 ma. Cause: not known.	None; the high values were intermittent & TWTA's were not in use./ None, except watch.	146-6
8	7/10/93 (179)	TLM&DH	1	Earth Sensor Ass'y-A Pitch Ch. output cautioned at 0.3199^{o} for one update period. Cause: prob. a SEU in CTE buffer.	No impact./ None; these events are self-healing. (Has occurred on other TDRS S/C.)	150-6
9	7/17/93 (186)	TLM&DH	1	During routine null search, no nulls were seen in TLM btwn -0.36^{o} & -5.37^{o} on SGL north/south gimbal. Cause: not known.	None; nulls were seen on later searches that day./ Monitor null telemetry.	147-6
10 152-6	9/5/93 (236)	TC&C	1	3 phantom commands were seen: *SADA-1 stopped clocking & SADA-2 began CCW rotation. * [Solar Array Drive Assembly] Cause: not known.	No effect./ Controllers re-adjusted position & rotation direction to correct within 9 minutes.	
11	9/13/93 (244)	POWER	1	Alarm message on ground console: "Mode is Slew; Direction is CW". Cause: False reading from conductive particles in V-groove of the null causing a lot of toggling.	None; array motion was normal./ None possible. Has occurred on other TDRS S/C.	153-G (153-6)
12	10/13/93 (274)	TC&C	1	Receiver-A: loop stress cautioned at 67 KHz, after ranging was started from ground. Cause: probably a bad telemetry point.	Negligible; the loop stress continued to vary for 3 days & then disappeared./ None required.	154-6

INDEX	DATE/(DAYS)	SUBSYSTEM	CRITICALITY	DESCRIPTION	EFFECT/ACTION	REF.
				UARS		
8	4/16/93 (580)	ACS	2	Earth Sensor-1(ES-1) speed became erratic. Cause: probably a bearing lubrication failure.	On-board logic put S/C into "Earth-pointing Safe-hold" & selected ES-2./ Software change removes ES-1 from detect. Logic.	93-1
9	5/1/93 (595)	INST+MLS	2	The 183 GHz Radiometer in the Microwave Limb Sounder failed. Cause: Mixer diode lost contact.	Degrades MLS Ins't Performance slightly None possible.	93-2
10	9/30/93 (747)	POWER	2	Anomalous periodic behavior started during Solar Array Drive-A tracking. Cause: Probably caused by debris on drive shaft.	Had to "park" array & turn some instruments off to study problem./ Use Drive-B for reverse-direction shaft rotation.	93-3

APPENDIX A

SPACECRAFT LIFETIME DATA

NOTE: In the following table, the term "useful life" refers to the time during which the major mission objectives were met. Active life is the total lifetime during which the satellite remained in service. A blank space means the information was not available. Data are through 1993; see text for update.

Spacecraft	Launch Date	Design Life (Years)	Useful Life (Years)	Active Life (Years)	Remarks
TIROS	1-Apr-60	0.25	0.24	0.24	TV system useful for 77 days
Explorer VIII (S-30)	3-Nov-60	0.25	0.15	0.15	Last transmission 12/28/60
TIROS II	23-Nov-60		0.63	1.03	TV data useful to 7/12/61
Explorer XI (S-15)	27-Apr-61		0.61	0.61	Last transmission 12/7/61
TIROS III	12-Jul-61	0.25	0.4	0.63	TV data useful to 12/4/61. Lost tape recorders.
Explorer XII (S-3)	15-Aug-61	1	0.31	0.31	Transmission ceased abruptly
TIROS IV	8-Feb-62	0.25	0.36	0.44	TV useful to 6/9/62. Lost tape recorders.
OSO-I	7-Mar-62	0.5	1.4	1.4	Lost tape recorder @ 2 mos. Starfish incident degraded power sys.
Ariel-I (S-51)	26-Apr-62	1	0.88	0.88	Degraded by starfish incident of 7/9/62
TIROS-V	19-Jun-62	0.5	0.88	0.88	TV useful to 5/4/63. Camera filaments failed.
TIROS-VI	18-Sep-62	0.5	1.06	1.06	TV useful to 10/11/63. Filaments and focus out.
Explorer XIV (S-3a)	2-Oct-62		0.85	1.2	Last transmission 2/17/64
Explorer XV (S-3b)	27-Oct-62	0.17	0.26	0.55	Despin system failed. Last transmission 5/19/63
Relay I	13-Dec-62	2	2.53	2.53	
Syncom I	14-Feb-63	2	0	0	Lost power. Mission failure.
Explorer XVII (S-6)	3-Apr-63	0.25	0.27	0.27	Batteries degraded. No solar array.
TIROS-VII	19-Jun-63	0.5	4.33	4.96	Deactivated. Camera focus out 12/65
Syncom-II	26-Jul-63	2			
IMP-A	26-Nov-63	1	0.82		
TIROS-VIII	21-Dec-63	0.5	3.53	3.53	Deactivated
Relay-II	21-Jan-64	1	1.68	3.5	
Ariel-II (S-52)	27-Mar-64	1	0.53		Had spin rate and attitude control problems
Syncom-III	19-Aug-64	3			
Explorer-XX (S-48)	25-Aug-64		1.6	1.6	Based on last transmission 3/30/66
Nimbus-I	28-Aug-64	0.5	0.07	0.07	Solar array drive failed
OGO-1(A)	4-Sep-64	1	5.23	5.23	Mission failure. 3 axis stabilization not achieved.
IMP-B	3-Oct-64	1	0.5	1.25	Reentered. Placed in wrong orbit.
Explorer-XXVI(S-3c)	21-Dec-64	1	2.1	2.1	Last transmission 1/21/67
TIROS-IX	22-Jan-65	0.5	2.73	3.4	Deactivated. Camera contrast out 10/66.
OSO-II	3-Feb-65	0.5	0.75	0.75	Used up control gas
IMP-1(C)	29-May-65	1	1.92	1.92	Reentered
TIROS-X	2-Jul-65	1	1.16	2	Deactivated

Spacecraft	Launch Date	Design Life (Years)	Useful Life (Years)	Active Life (Years)	Remarks
OGO-2(C)	14-Oct-65	1	3.48		Mission failure. Horizon scanners did not maintain earth lock.
ESSA-I	3-Feb-66	1	2.36	2.36	Deactivated
ESSA-II	28-Feb-66	1	4.64	4.64	Deactivated
OAO-I	8-Apr-66	1	0	0	Mission failure. Lost power.
Nimbus-II	16-May-66	0.5	2.67	2.67	ACS scanner failed
AE-B	25-May-66	0.5	0.82		Higher than planned orbit. Two sensors did not work.
OGO-3(B)	6-Jun-66	1	2.04	3.5	Boom oscillation problem
AIMP-2(D)	1-Jul-66	0.5	4.92		Failed to achieve lunar orbit
ESSA-III	2-Oct-66	1	2.02	2.02	Deactivated. Cameras failed
ATS-I	6-Dec-66	3		Active	Gas expended. Limited service.
ESSA-IV	26-Jan-67	1	0.41	1.27	Deactivated. One camera failed, one degraded.
OSO-III	8-Mar-67	0.5	3	3	Tape recorder at 18 months. ACS controlled manually.
ESSA-V	20-Apr-67	1	2.83	2.83	Deactivated. IR failed, cameras gradually degraded.
IMP-3(F)	24-May-67	1	1.95	1.95	Reentered
AIMP-4(E)	19-Jul-67		3.5	3.5	Lunar orbit. Subsequent period of intermittent operation.
OGO-4(D)	28-Jul-67	1	2.24	2.75	Thermal bending of antenna caused stabilization control problem
OSO-IV	18-Oct-67	0.5	0.9		Tape recorder failure at 6 months
ATS-III	5-Nov-67	3		Active	Instruments no longer in use
ESSA-VI	10-Nov-67	1	2.09	2.09	Deactivated. Cameras degraded.
OGO-5(E)	4-Mar-68	1	3.6	3.6	Deactivated. Data glut.
RAE-A	4-Jul-68	1	4.5	4.5	Deactivated. Data quality had become marginal.
ESSA-VII	16-Aug-68	1	0.92	1.56	Deactivated. Early camera and tape recorder failures.
OAO-II	7-Dec-68	1	4.2	4.2	Prime instrument (WEP) failed.
ESSA-VIII	15-Dec-68	1	4.95	6.75	Deactivated. Camera problems.
OSO-V	22-Jan-69	0.5	3.9	3.9	
ESSA-IX	26-Feb-69		4.1	4.1	Deactivated. Standby after 4/71.
Nimbus-3	19-Apr-69	0.5	2.67		ACS scanner failed 1/72.
OGO-6(F)	5-Jun-69	1	2.06	2.25	Deactivated. Data glut.
IMP-5(G)	21-Jun-69		3.51	3.51	Reentered.
OSO-VI	6-Aug-69	0.5	3.3	3.3	
ATS-V	12-Aug-69	3	14.84	14.84	Mission officially unsuccessful. Stabil. not achieved. Deorbit 3/20/84

TIROS-M	23-Jan-70	1	1.4	1.4	Momentum wheel assembly failed.

Spacecraft	Launch Date	Design Life (Years)	Useful Life (Years)	Active Life (Years)	Remarks
Nimbus-4	8-Apr-70	1	10	10	Deactivated
NOAA-1(ITOS-A)	11-Dec-70	1	0.56	0.75	Deactivated. Momentum wheel assembly problems.
SAS-A	12-Dec-70	0.5	4	4	Transmitter failure terminated mission.
IMP-6(I)	13-Mar-71	1	3.56	3.56	Reentered.
OSO-VII	29-Sep-71	0.5	3.17	3.17	Reentered due to bad orbit.
SSS-A	15-Nov-71	1	2.87	2.87	Deactivated. Battery unusable, as expected, after one year.
Landsat-1(ERTS-A)	23-Jul-72	1	5.58	5.58	Deactivated. Funding withdrawn.
OAO-C	21-Aug-72	1	8.5	8.5	Deactivated. Funding withdrawn.
IMP-7(H)	22-Sep-72	2	6.10	6.1	Power system failed.
NOAA-2(ITOS-D)	15-Oct-72	1	2.25	2.4	Standby after 3/74. Some experiments failed.
SAS-B	16-Nov-72	0.5	0.54	0.54	Experiment low voltage power supply failed.
Nimbus-5	12-Dec-72	1	10.3	10.3	Deactivated 3/31/83. Second HDRSS failed 7/27/82.
RAE-B	10-Jun-73	1	3.75	3.75	Deactivated. Mission objectives achieved.
IMP-8(J)	25-Oct-73	2	Active	Active	All instruments operating.
NOAA-3 (ITOS-F)	6-Nov-73	1	2.84	2.84	Deactivated. Radiometer, VTPR, VHRR out.
AE-C	16-Dec-73	1	5	5	Reentered.
SMS-1	17-May-74	2	1.6	6.70	Standby after 1/76. Deactivated 1/31/81.
AT-6(F)	30-May-74	5	5.17	5.17	Deactivated.
NOAA-4(ITOS-G)	15-Nov-74	1	4	4	Deactivated. Radiometer, VHRRs out.
Landsat-2	22-Jan-75	1	8.51	8.51	Yaw flywheel stopped 11/79, recovered 5/80. Deactivated 7/27/83.
SMS-2(B)	6-Feb-75	2	6.50	7.5	Second encoder failed 8/5/81.
SAS-C	7-May-75	1	4.92	4.92	Reentered.
Nimbus-6(F)	12-Jun-75	1	7.18	8.28	Yaw flywheel failed 8/14/82.
OSO-8(I)	21-Jun-75	1	3.4	3.4	Funding withdrawn.
AE-D	6-Oct-75	1	0.42	0.42	Shorted diode in power supply electronics.
GOES-1(A)	16-Oct-75	3	9.3	9.4	VISSR failed 2/85.
AE-E	20-Nov-75	1	5.56	5.56	Reentered 6/10/81.
NOAA-5(ITOS-H)	29-Jul-76	1	2.96	2.96	Failed 7/79.
GOES-2(B)	16-Jun-77	3	1.55	Active	VISSR failed 1/79, batts. degraded, Semi-operational as West DCS S/C.
ISEE-1(A)	22-Oct-77	2	9.93	9.93	Spacecraft reentered 9/26/87.

IUE	16-Sep-34	3	Active	Active	Fully operational. Some problems with computer "HALTS".
Landsat-3(C)	5-Mar-78	3	5.07	5.51	Problems with MSS instrument.

Spacecraft	Launch Date	Design Life (Years)	Useful Life (Years)	Active Life (Years)	Remarks
AEM-A(HCMM)	26-Apr-78	1	2.4	2.4	Deactivated. Battery degraded 9/14/80.
GOES-3(C)	16-Jun-78	3	2.21	Active	VISSR degraded 9/80, failed 5/6/81. To stdby.4/28/87. Stdby comm. only
ISEE-3(C)[ICE]	12-Aug-78	2	Active	Active	Some instrument losses. JPL funding science (10/92).
TIROS-N	13-Oct-78	2	2.38	2.38	ACS failed 2/27/81.
Nimbus-7(G)	24-Oct-78	1	15.18	Active	Ceased its science mission 12/93. Spacecraft degraded.
AEM-B(SAGE)	18-Feb-79	1	2.75	2.75	Battery degraded. Failed 11/18/81.
NOAA-6(A)	27-Jun-79	2	7.39	7.75	Spacecraft turned off 3/31/87.
Magsat	30-Oct-79	0.4	0.61	0.61	Reentered as planned 6/11/80.
SMM	14-Feb-80	2	5.62	9.78	Lost fine pt. cont. 12/12/80. Revived. Terminated 11/24/89. Reent12/89.
GOES-4(D)	9-Sep-80	7	2.21	6.66	VAS failed 11/25/82.
GOES-5(E)	22-May-81	7	3.19	9.2	VAS failed 7/30/84. Loss of station keeping 12/89. Deactivated 7/18/90.
NOAA-7(C)	23-Jun-81	2	3.62	4.92	Failed HIRS, degraded SSU, disabled power system.
DE-1(A)	3-Aug-81	1	9.57	9.57	Mission terminated (can't command S/C) 2/28/91.
DE-2(B)	3-Aug-81	1	1.54	1.54	Reentered as expected 2/19/83.
OSS-1	22-Mar-82				Shuttle attached payload mission.
Landsat-4(D)	16-Jul-82	3			No longer monitored nor reported herein.
NOAA-8(E)	28-Mar-83	2	1.25	1.25	Failed 7/1/84. Recovered 5/85. Failed again 1/86.
TDRS-1(A)	4-Apr-83	10	Active	Active	Some loss of capability. Activated in 1993 for GRO data via Australia.
GOES-6(F)	28-Apr-83	7	5.73	Active	VAS failed 1/21/89. Loss of station keeping 5/92.
Landsat-5(D)	1-Mar-84	3			No longer monitored nor reported herein.
AMPTE/CCE	16-Aug-84	1	4.92	4.92	Some solar array degradation. Mission terminated.
ERBS	5-Oct-84	2	Active	Active	All gyros except IRU-1/Z failed. ERBE-S failed 2/90. Batt. #1 deact.8/92 (2 shorted cells). Batt. #2 lost 2 cells 6/7/93, ERBE-NS temp. off.
NOAA-9(F)	12-Dec-84	2	3.92	Active	MSU & ERBE-S failure. Stdby. 11/8/88.
SPARTAN-1	20-Jun-85				STS attached payload mission.
SPOC/HITCHHIKER	12-Jan-86				STS attached payload mission.
NOAA-10(G)	17-Sep-86	2	Active	Active	Array shunts degraded. ERBE-S & SARP failed. Roll gyro failed, AVHRR degraded 11/92. In standby ops.
GOES-7(H)	26-Feb-87	7	Active	Active	

NOAA-11(H)	24-Sep-88	2	Active	Active	Y-Gyro & DTR-5 A&B failed in late 89. DTR-1B failed 2/92.
TDRS-3(C)	29-Sep-88	10	Active	Active	Standby status 8/91.
TDRS-4(D)	13-Mar-89	10	Active	Active	

Spacecraft	Launch Date	Design Life (Years)	Useful Life (Years)	Active Life (Years)	Remarks
COBE	18-Nov-89	0.83	4.1		Gyro-B failed 11/89, ESA-A failed 4/91, BX gyro failed 9/91 & gyro A&C failed 1993. Science mission ended 12/23/93.
PEGSAT	5-Apr-90	0.25	0.75	0.75	PEGASUS launched. Limited life mission.
HST	24-Apr-90	15	Active	Active	Spherical aberration in primary mirror. Gyros 4&5 failed. Gyros 1&6 failed 10/11/92. 1st service mission 12/93:WF/PC II, 2RSUs, S.A.s installed.
SSBUV	6-Oct-90				STS attached payload mission.
BBXRT	2-Dec-90				STS attached payload mission.
GRO	7-Apr-91	2.25	Active	Active	Propulsion system damaged/degraded. DTR ops stopped 4/92 due to high error rate. MPS bad 7/92.
NOAA-12(D)	14-May-91	2	Active	Active	Class B
TDRS-5(E)	2-Aug-91	10	Active	Active	Class A
UARS	15-Sep-91	3	Active	Active	ISAMS instrument failed 7/92. Cryogens depleted in CLAES instrument 5/93. Science ended. S/C Class B, Instrument class C.
SSBUV	24-Mar-92				STS attached payload mission.
EUVE	7-Jun-92	1.13	Active	Active	Class B
SAMPEX(SMEX-1)	3-Jul-92	3	Active	Active	Class C
TDRS-6(F)	13-Jan-93	10	Active	Active	Put in on-orbit storage 6/93. Class A.
NOAA-13(I)	9-Aug-93	2	0.03	0.03	Anomaly in power subsystem caused loss of spacecraft 8/21/93. Class B
HST [SM-01]	12-Dec-93				HST servicing mission. See HST entry above.