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Orbital Anomalies in Goddard Spacecraft for Fiscal Year 2003

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Executive Summary

During FY 2003, Goddard Space Flight Center had 61 active satellites. Fifty-two reported at least one anomaly in the SOARS database. Two thousand ninety two (2092) anomalies were reported among these satellites: 439 were orbital and 1653 were ground systems or communication relay system anomalies.

Orbital Anomalies

HST and RXTE had the most orbital anomalies with 103 (24% of the total) and 60 (14%) anomalies, respectively. FUSE, ACE, GALEX, and EO1 each had 39, 29, 24, and 24 anomalies, respectively. One hundred sixty other anomalies occurred among 35 other spacecraft.

Of 439 orbital anomalies, 5 had a mission effect of "substantial" or greater. There were none with a "catastrophic" (criticality 5, total loss of mission) impact. Two anomalies caused "major" mission effects (criticality 4, loss of one or more major mission objectives) on Landsat 7 and ICESAT. Three anomalies caused "substantial" mission effects (criticality 3, loss of a significant mission objective) on AQUA, GOES-12, and HST. NOAA-16 and GALEX experienced anomalies that were downgraded to minor from major and substantial, respectively, after subsequent review by the projects.

The subsystem most frequently impacted by orbital anomalies was Attitude Control with 166 anomalies (38%). Instrument subsystems had 103 anomalies (24%) and Telemetry and Data Handling 73 (17%). Loss of data occurred in 73 (17%) anomalies, loss of service in 59 (14%), and subsystem or instrument degradation in 50 (11%). One hundred forty two (142, 33%) anomalies caused "no effect" and 83 (19%) "indeterminate" effects.

Anomalies categorized by *failure cause* occurred most frequently for software (71 anomalies, or 16%), environmental (69, 16%), and parts problems (68, 16%). The failure cause was unknown for 138 anomalies (32%). Anomalies classified by *type* had 118 (27%) "indeterminate," 110 (25%) random, 71 (16%) systematic (meaning it would occur in identical equipment operated under identical circumstances), and 19 (4%) wear-out failures.

Statistics for orbital anomalies occurring among all operating GSFC spacecraft during FY 2003 were:

mean time between anomaly occurrences -	**major** impact	260,100 hours
	substantial impact	173,400 hours
	minor impact	8,960 hours
	negligible impact	1,380 hours
probabilities of anomaly occurrences -	**major** impact	0.03
	substantial impact	0.05
	minor impact	0.62
	negligible impact	0.998

Ground System-Communication Relay System Anomalies

There were no catastrophic, substantial, or major anomalies among the 1653 reported for ground and communication relay systems. Nine effected "minor" mission impacts and the remainder had negligible impacts. Loss of service was effected by 615 (37%) anomalies and loss of data by 247 (15%); 375 (23%) had no (mission) effect and 243 (15%) "indeterminate" effects. The failure category was "unknown" for almost half (771 anomalies, 47%). Operations problems were cited in 371 (22%) and software problems in 240 (14%) of ground/communications anomalies. Anomaly *type* was "indeterminate" for 721 (44%), "random" for 330 (20%) and operations error for 317 (19%).

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Background

Since Goddard Space Flight Center's (GSFC) beginning, each project's management has recorded on-orbit performance data for Center-managed spacecraft. More detailed data, combining all Goddard's spacecraft, began to be collected and analyzed about twenty-five years ago. In 1983, the first detailed report containing performance data for all spacecraft was issued as a contractor report, *Analysis of Spacecraft On-Orbit Anomalies and Lifetimes,* PRC R-3579, February 10, 1983; this report covered the period from 1978 to mid-1983 and contained data for both Jet Propulsion Laboratory (JPL) and GSFC spacecraft. The next report, *Orbital Anomalies in Goddard Spacecraft 1982-1983,* included only GSFC spacecraft. From 1984 through 1995, the Office of Flight Assurance issued annual orbital-anomaly reports; these annual reports collectively document GSFC's spacecraft performance. In 1996 the Spacecraft Orbital Anomaly Reporting System (SOARS) database was expanded to include ground and communication relay systems anomalies/events. The *1996 – 1997 Orbital Anomalies in Goddard Spacecraft (OAGS) Report* included these ground system and communication anomalies for informational purposes; however, they were not included in the summary statistics. The 1996-1997 report was the last one issued until the FY 2003 report.

No data was placed into SOARS from 1998 - 2002. Available data in this period may be added to SOARS. However, no annual reports for 1998 through 2002 are planned.

Introduction

This report presents an annual performance summary for spacecraft built or managed by the Goddard Space Flight Center (GSFC). It compiles and catalogues departures from normal or "nominal" operations (i.e. anomalies) for active spacecraft for both on-orbit and ground operations for each spacecraft. Each anomaly is classified according to the subsystem in which it occurred, the time of its occurrence, its effect on the spacecraft's mission (criticality), and the failure causes and corrective actions, if known.

The GSFC Spacecraft Orbital Anomaly Reporting System (SOARS), defines an anomaly as *"any unexpected departure from normal operations, procedures, or performance. This can include unexpected events such as power problems, configuration changes, hardware or software malfunction, operational error, or departure of performance outside specified limits."*

SOARS recently has been refined and combined with the Goddard Non-Conformance Reporting (NCR) System. Contributors to SOARS include GSFC Flight Projects and Flight Operations Team members, Goddard Space Science Mission Operations (SSMO), Goddard Earth Sciences Mission Operations (ESMO), Tracking and Data Relay Satellite (TDRS) Operations, NOAA POES Satellite Operations, NOAA GOES Satellite Operations, NASA Ground Communications Network and NASA Deep Space Network.

All data derived in this report were compiled from SOARS and are current to the end of September 2003. Experience has shown anomalies may continue to be reported subsequent to their occurrences. Some data relevant to anomalies still being investigated may change. Nonetheless, the majority of anomalies have been included herein and this report represents a credible summary of annual operational performance. The data may be useful for trend analyses and for identification of reliability drivers for future spacecraft.

A brief summary of spacecraft performance in FY 2003 is included in "Anomaly Highlights by Spacecraft" [p.4]. The anomaly classification scheme is provided in "Detailed Anomaly Data" [p. 9]. This section also presents an anomaly data summary, and detailed data tables and charts for various anomaly classifications.

Historical spacecraft lifetime data are included as Appendix A - Spacecraft Lifetime Data. Goddard spacecraft mission descriptions are included in Appendix B – General Descriptions of Spacecraft Reported in OAGS 2003. Detailed data used to catalogue and compile the statistics in this report are recorded in a separate document, Appendix C - Classification and Log of FY 2003 Anomalies; these data are not included in this report. [This extensive listing is available in an electronic format to qualified persons upon written request to the GSFC Systems Safety and Reliability Office.]

Summary of Spacecraft Activity During Fiscal Year 2003

GSFC had 61 orbiting spacecraft in FY 2003, including 13 National Oceanic and Atmospheric Administration spacecraft (i.e. GOES and POES).

Five spacecraft were launched in 2003: TDRS-10, SORCE, CHIPSAT, ICESAT, and GALEX.

Although the Hubble Space Telescope (HST) was built under contract to Marshall Space Flight Center (MSFC), it is included in this report because its flight operations and servicing missions are managed by GSFC.

Of the GOES spacecraft still in orbit, GOES-3 is providing South Pole support for the National Science Foundation (NSF) and the University of Miami. GOES-6 is deactivated. GOES-7 (now renamed Peacesat) is operated under a Memorandum of Understanding (MOU) with the University of Hawaii/ National Telecommunications and Information Administration (NTIA) at 175 degrees W. GOES-8 was retired from its East mission on April 1, 2003, and is a backup for GOES-9. GOES-11 is stored on-orbit. GOES-9 (GOES-Pacific), GOES-10 (GOES-West), and GOES-12 (GOES-East) were operational during 2003.

Table 1 shows the list of active spacecraft including launch date, operating agency, and notes of interest. The table is followed by descriptions of the more notable anomalies that occurred for each spacecraft.

Table 1. List of Operational Spacecraft (FY 2003)[1]

Active Spacecraft	Launch Date (MM/DD/YY)	Operating Agency	Notes:
ACE	08/25/97	NASA	
CHIPSAT	01/13/03	NASA	Launched in FY 2003
Cluster FM 5	08/09/00	NASA/ESA	
Cluster FM 6	07/16/00	NASA/ESA	
Cluster FM 7	07/16/00	NASA/ESA	
Cluster FM 8	08/09/00	NASA/ESA	
EO-1	11/21/00	NASA	
EOS AM (Terra)	12/18/99	NASA	
EOS-AQUA	05/04/02	NASA	
ERBS	10/05/84	NASA	
FAST	08/21/96	NASA	
FUSE	06/24/99	NASA	
GALEX	04/28/03	NASA	Launched in FY 2003
GOES-3(C)	06/17/78	NOAA	Providing NSF/U of Miami South Pole support 105°W
GOES-7 (H)	02/26/87	NOAA	Univ. Hawaii/NTIA (Peacesat) 175°W
GOES-8 (I)	04/13/94	NOAA	Retired from E. mission 4/1/03. Serving as GOES-9
GOES-9 (J)	05/23/95	NOAA	Operating as GOES-Pacific
GOES-10 (K)	04/25/97	NOAA	Operating as GOES-West
GOES-11 (L)	05/03/00	NOAA	ZAP Storage 105°W
GOES-12 (M)	07/23/01	NOAA	Operating as GOES-East
HETE-2	10/09/00	NASA	
HST	04/24/90	NASA	
ICESAT	01/12/03	NASA	Launched in FY 2003
IMAGE	03/25/00	NASA	
LANDSAT-5 (D)	03/01/84	NASA/USGS	
LANDSAT-7	04/15/99	NASA/USGS	
MAP	06/30/01	NASA	

[1] CLUSTER, GOES-3, GOES-7, TDRS-4, and TDRS-5 are included in this table; they incurred no anomalies during FY 2003.

OAGS FY 2003

Active Spacecraft	Launch Date (MM/DD/YY)	Operating Agency	Notes:
NOAA-11 (-H)	09/24/88	NOAA	PM Standby
NOAA-12 (D)	05/14/91	NOAA	AM Standby
NOAA-14 (J)	12/30/94	NOAA	AM Standby
NOAA-15 (K)	05/13/98	NOAA	AM Back-up
NOAA-16 (L)	09/21/00	NOAA	PM Primary
NOAA-17 (M)	06/24/02	NOAA	AM Primary
POLAR (GGS)	02/24/96	NASA	
QUIKSCAT	06/19/99	NASA/CSA/CNES	
RHESSI	02/05/02	NASA	
SAGE III	12/10/01	NASA/RSA	
SAMPEX (SMEX-1)	07/03/92	NASA	
SEASTAR/SEAWIFS	08/01/97	NASA	
SNOE	02/26/98	NASA	
SOHO	12/02/95	NASA/ESA	
SORCE	01/25/03	NASA	Launched in FY 2003
SWAS	12/02/98	NASA	
TDRS-1 (A)	04/04/83	NASA	Provides part-time coverage of the Antarctic region in support of NSF
TDRS-3(C)	09/29/88	NASA	Operating at 275 degrees W, making it the TDRS Exclusion satellite
TDRS-4 (D)	03/13/89	NASA	Operating at 41 degrees W, serving as the TDRS East satellite
TDRS-5 (E)	08/02/91	NASA	Operating at 174 degrees W, serving as the TDRS West satellite
TDRS-6 (F)	01/13/93	NASA	Operating at 47 degrees W, serving as the TDRS Spare satellite
TDRS-7 (G)	07/13/95	NASA	Operating at 171 degrees West longitude
TDRS-8 (H)	06/30/00	NASA	Co-located with TDRS-7 at 171 degrees West
TDRS-9 (I)	03/08/02	NASA	
TDRS-10 (J)	12/05/02	NASA	Launched in FY 2003
TIMED	12/07/01	NASA	
TOMS-EP	07/02/96	NASA	
TOPEX	08/10/92	NASA/CNES	
TRACE	04/02/98	NASA	
TRMM	11/27/97	NASA	
UARS	09/15/91	NASA	Limited Operations
Wind (GGS)	11/01/94	NASA	
WIRE	03/04/99	NASA	Failure shortly after reaching orbit, aborted primary mission; providing science observation
XTE	12/30/95	NASA	

Anomaly Highlights By Spacecraft

The more significant anomalies for each spacecraft are described briefly in the following paragraphs. Details are provided for anomalies having a mission criticality greater than "negligible".

Advanced Composition Explorer (ACE)

ACE had 29 Orbital anomalies and 99 Ground-Comm anomalies, all having a negligible impact to the mission.

Cosmic Hot Interstellar Plasma Spectrometer Satellite (CHIPSat)

CHIPSat had 4 Orbital anomalies and 8 Ground-Comm anomalies. These anomalies had minor or negligible impacts. The most serious (minor) anomaly caused a loss of redundancy. The spacecraft entered a tumble after a reaction wheel caused excessive oscillation; the ACS node had difficulty commanding the wheel (# 212). On 4/04/2003 wheel 212 was taken out of the active control loop and the redundant skew wheel inserted. The spacecraft then returned to normal operations. Other anomalies involved repeated single event upsets by radiation-hardened parts not being used in the design.

Cluster II

No anomalies were reported for FY 2003.

Earth Observing-1 (EO-1)

EO-1 had 24 Orbital anomalies and 94 Ground-Comm anomalies. One anomaly caused a minor impact to the mission and the remainder were negligible.

The minor anomaly involved the Advanced Land Imager (ALI). On October 29, data from the ALI solar calibration of July 5 (Day 186) indicated a malfunction of the solar calibration sliding aperture selector: it appeared stuck in a partially open position and no further controlled movement was possible. The usual ladder pattern seen during solar calibration abruptly stopped during the down leg and the level subsequently stayed constant. The next solar calibration, on July 12, showed the same constant level. In the first 9 1/2 months, ALI had performed 40 solar calibrations flawlessly. On the 41st solar calibration, July 15, 2002, the sliding screen failed to complete its travel. Due to latency in data reception and processing, three more solar calibrations were performed with the screen appearing in a slightly different, stationary position each time. A tiger team assembled to investigate the malfunction assessed the impact and recommended remedial steps. The solar calibration script was changed, eliminating the sliding screen motor activation command. The last six solar calibrations showed the system response to be stable, indicating the sliding screen is stationary.

Earth Radiation Budget Satellite (ERBS)

ERBS had 3 Orbital anomalies and 47 Ground-Comm anomalies. All caused negligible impacts.

EOS-AM (Terra)

EOS-AM (Terra) had 8 Orbital anomalies and 80 Ground-Comm anomalies. Most of these anomalies had minor or negligible impacts on its mission. One Orbital anomaly caused a major impact (SOAR C-9231). A Solar Diffuser screen door on the MODIS instrument failed to open, likely caused by screen deformation from thermal stresses. This door now is opened permanently so certain calibration functions cannot be performed. The mission effect subsequently was downgraded to "minor."

Three additional anomalies had minor effects: SOARS C-9639, D-1050, and D-2555.

C-9639 was recorded when an Aster SSR buffer download contained 350,000 uncorrectable Engineering Data Units (EDUs). Two bad supersets of SSR memory within the ASTER buffer were discovered.

D-1050 occurred when Supersets 50, 51, 114, 115 were not properly recorded. Loss of supersets was caused by OCP trips on two different PWAs.

D-2555 involved a SFE-A HPM2 Card anomaly. During the anomaly MISR, MODIS, and VNIR2 (ASTER) science data were not recorded. The problem quickly was isolated to the HPM2 Card; it occurred in the South Atlantic Anomaly (SAA) and likely was caused by a single event upset (SEU).

EOS-AQUA

EOS-AQUA had 17 Orbital anomalies and 210 Ground-Comm anomalies. The majority of these anomalies had minor or negligible impacts on the mission. One Orbital anomaly caused a substantial mission effect (SOAR D-311). The HSB shut down and went into survival mode because of a synchronization error, caused when the scan motor current increased rapidly (stalled) and then dropped to zero. Another anomaly involved Solar Array Drive potentiometers; the conductive plastic resistance material outgassed causing a poor wiper-resistance contact and consequent intermittent noise in the circuitry. The Materials Engineering branch re-created the anomaly and performed life-cycle testing. A NASA Advisory was issued.

Fast Auroral Snapshot Explorer (FAST)

FAST had 3 Orbital anomaly and 129 Ground-Comm anomalies. All of these anomalies had minor or negligible impacts. One minor orbital anomaly affected the Mission Unique Electronics (MUE); it was caused by space radiation damage to the optocouplers in the watchdog circuitry. Another minor anomaly was caused by an EEPROM failure. This device should hold four copies of the IDPU flight software. All four copies are corrupt and the EEPROM can no longer be loaded with new software. The IPDU now gets its flight software commands from PROM that must be updated and patched from the ground.

Far Ultraviolet Spectroscopic Explorer (FUSE)

FUSE had 39 Orbital anomalies and 58 Ground-Comm anomalies. Most had minor or negligible impacts. One Orbital anomaly first was categorized as a substantial effect (SOAR C-9794); a reaction wheel failure had caused a spacecraft emergency. The failed wheel has a momentum bias applied and will continue to be observed. This anomaly was subsequently downgraded to minor by Flight Operations. Another minor anomaly was caused by to a limit violation and spacecraft event message indicating a gyro had failed. The gyro is the Z-gyro on B-side (x-axis in the body frame). Thus far, spacecraft operations have been unaffected. ACS software has switched the x-body axis to the Estimator and has proceeded nominally. This axis is NOT the same axis that had failed on the A-side gyros (the A-side failed gyro is Z-axis in the body frame).

Galaxy Evolution Explorer (GALEX)

GALEX had 24 Orbital anomalies and 22 Ground-Comm anomalies. The majority had negligible impacts. One Orbital anomaly caused a substantial mission effect (SOAR C-9477, which was deleted and replaced by D-1615, as a duplicate entry). The anomaly involved the detector subsystem, possibly related to the large current spike that had affected the NUV detector a week prior, during a Solar X-ray flare. The NUV was expected to be operational again in two days. The mission effect was downgraded to minor.

Geostationary Operational Environment Satellite (GOES)

The five GOES spacecraft had 18 Orbital anomalies and 3 Ground-Comm anomalies. Most had negligible impacts. One Orbital anomaly caused a substantial mission effect (SOAR D-769): the GOES-12 SXI Safe Trigger returned an error code 33 and went into SAFE mode repeatedly, locking the filter wheel and turning off the High Voltage Power Supply (HVPS). The SXI currently is imaging every minute. Because of operational constraints with the voltage and filter limitations, the best images are taken at a 500 V P_THIN, 3.0 second setting. The Space Environment Center at Boulder, CO, is receiving data and successfully processing it. Except that the HVPS cannot be operated higher than 500 volts and one of the pre-filters has failed, the instrument is operating nominally. Design changes are indicated for follow-on missions.

On January 1, 2003 at 0616Z, the tachometer on GOES-9 MW2 started to read 1757 instead of its true 2900 rpm reading. This caused the wheel to spin up and the spacecraft lost Earth lock and entered Safe Mode. Analysis showed the tachometer loss is similar to a tachometer loss on GOES-8 in 1997. However, on GOES-

9, the tachometer signal has reappeared for several time periods since the initial anomaly. The GOES Project classified this anomaly Minor.

High Energy Transient Explorer (HETE-2)

HETE-2 had 2 Orbital anomalies with minor mission impacts.

One anomaly was caused by a puncture of one of the four Widefield X-ray Monitor (WXM) counter windows, likely by a piece of debris.

Following recovery from a rare but previously seen anomaly affecting the attitude control system, the power system was not performing nominally. Analysis indicated a probable battery cell failure. Trending analysis indicated that this cell had been performing anomalously for at least 17 months compared to the other cells. It is unclear at this time what caused this degradation.

Hubble Space Telescope (HST)

HST had 104 Orbital anomalies and 78 Ground-Comm anomalies. Two anomalies caused minor impacts. One Orbital anomaly caused a substantial effect (SOAR D-299). A lock on MAR2 was obtained at 22:24:54 on the OMNI antenna at a 4k data rate. Spacecraft went to a "zero gyro sun-pointing mode," caused by a gyroscope failure. A spacecraft emergency was declared at 22:41:00. This anomaly was downgraded to minor, because it was a redundant gyroscope.

One minor anomaly resulted in 14 minutes 10 seconds data loss when a memory load timeout caused a return service dropout. A spacecraft emergency was declared.

A second minor anomaly due to a NICMOS Cooling System problem caused 5 days of lost science (23 visits, 48 orbits); it was believed to have been caused by power supply problems.

Ice, Cloud, and land Elevation Satellite (ICESat)

ICESat had 2 Orbital anomalies and 92 Ground-Comm anomalies. Most had negligible impacts. One orbital anomaly caused a substantial mission effect, later upgraded to major. This major anomaly resulted when the GLAS laser transmitter #1 ceased to emit laser pulses. An extensive failure review board identified the cause as indium solder used in laser diode manufacturing, which eroded and eventually the open-circuited the diode of bond wires. The anomaly was upgraded, since the redundant lasers likely will experience the same failure mode. NASA Advisory NA-GSFC-2004-01 was issued on 10/2/03.

Imager for Magnetopause-to-Aurora Global Exploration (IMAGE)

IMAGE had 1 Orbital anomaly, with a negligible impact. The IMAGE battery has insufficient capacity to operate both the payload and payload deck operational heaters during extended eclipses. A workaround to deal with this condition was planned: a) drive the payload to maximum safe temperatures before eclipse and then set heater setpoints to minimum safe temperatures and b) have other science instruments in a low power mode to conserve power. However, the combination of payload at nominal power and driving all operational heaters being driven resulted in a net negative power condition. Battery state-of-charge reached safehold limits before the desired payload deck temperatures were attained.

LANDSAT-5 (D)

LANDSAT-5 had 3 Orbital anomalies. Two anomalies had negligible impact and one a minor impact. The minor anomaly resulted from a Kalman Filter Overflow. During the Year End Transition (YET) the Kalman filter indicated excessive overflow following the spacecraft clock reset. Subsequent filter updates indicated anomalous behavior. This was the first time L5 YET was performed with the filter running because the ESA had been powered down. The Kalman filter was restarted after the ESA was powered up. The problem was traced to a flight software problem; a workaround is being tested.

LANDSAT 7

LANDSAT 7 had 3 Orbital anomalies and 42 Ground-Comm anomalies. Most had negligible impacts. One anomaly caused a major mission effect (C-9284): the ETM+ image was corrupted by a Scan Line Corrector (SLC) failure.

National Oceanic and Atmospheric Administration (NOAA)

The six NOAA satellites had 16 Orbital anomalies. The majority caused negligible impacts. NOAA-16 had a major anomaly, later downgraded to minor (SOAR C-8473). [Note- SOAR 8350 is a repeat of the same anomaly, which was entered by NOAA. SOAR 8350 is currently listed as "Major," but will be downgraded to "Minor."] The AMSU-A1 PLLO channels 9-14 count levels changed intermittently and became noisy for 5 to 6 orbits. Channels 10-14 showed "spotty" radiometric changes. Channel 9 is particularly noisy, "out-of-family" from the rest, and continues to be noisy even when channels 10-14 operate nominally.

Ocean Topography Experiment (TOPEX)

TOPEX had no reported Orbital anomalies and 32 Ground-Comm anomalies; all resulting in negligible effects.

POLAR (GGS)

POLAR had 5 Orbital anomalies and 3 Ground-Comm anomalies. All had negligible or minor impacts. One minor anomaly was caused by the Despun Platform Mechanism (DPM) shutting itself off; it occurs periodically. During each incident the trailing edge of the Earth horizon is not detected for more than one consecutive spin period, resulting in an automated despun platform safing. All events show the same symptom: four missing updates to the HSA-2 trailing edge time-tag. The time-tag is to be updated once per spin period, or approximately every six seconds. Since the telemetry updates are asynchronous to the spacecraft spin period and phase, these four missing updates equate valid time tags being out between 18 and 30 seconds.

Quick Scatterometer (QuikSCAT)

QUIKSCAT had no Orbital anomalies and 123 Ground-Comm anomalies, all having negligible effects.

Ramaty High-Energy Solar Spectroscopic Imager (RHESSI)

RHESSI had no Orbital anomalies and 24 Ground-Comm anomalies, all with negligible mission effects.

Rossi X-Ray Timing Explorer (RXTE or XTE)

XTE had 60 Orbital anomalies and 61 Ground-Comm anomalies. These anomalies all had minor or negligible impacts. Of the 60 orbital anomalies, 49 resulted from "no Kalman filter updates." Receipt of this message from only one star tracker is not considered a critical event by Mission Operations. The first of this series of anomalies was classified as Minor and the remainder (all identical) negligible.

Sea-viewing Wide Field-of-view Sensor (SeaWiFS) SEASTAR/SEAWIFS

SEAWIFS had no Orbital anomalies and 36 Ground-Comm anomalies, all having negligible impacts.

Solar Anomalous and Magnetospheric Particle Explorer (SAMPEX)

SAMPEX had 3 Orbital anomalies and 33 Ground-Comm anomalies. All anomalies had negligible effects.

Solar and Heliospheric Observatory (SOHO)

SOHO had two Orbital anomalies. Both caused negligible mission impacts.

Solar Radiation and Climate Experiment (SORCE)

SORCE had 2 Orbital anomalies and 25 Ground-Comm anomalies. All had negligible impacts. The most notable orbital anomaly was a battery pressure sensor divergence - the operations team has noticed a slight divergence in the battery pressure sensors since launch. The problem has been identified as a degrading pressure sensor and not a problem with the battery or power system. The pressure sensors are monitored for any change in behavior.

Stratospheric Aerosol and Gas Experiment III (SAGE III)

SAGE had no Orbital anomalies and 2 Ground-Comm anomalies, both having negligible effects.

Student Nitric Oxide Explorer (SNOE)

SNOE had 1 Orbital and 42 Ground-Comm anomalies. These all had negligible impacts.

Sub-millimeter Wave Astronomy Satellite (SWAS)

SWAS had 15 Orbital anomalies and 25 Ground-Comm anomalies. All had negligible impacts.

Thermosphere Ionosphere Mesosphere Energetics and Dynamics (TIMED)

TIMED had 11 Orbital anomalies and 1 Ground-Comm anomaly. Eight anomalies caused negligible impacts and four minor impacts. Three minor anomalies were caused by AST 2 intermittently being stuck in an error condition. The other minor anomaly resulted from the TIDI Instrument Telescope #2 Body Temperature readings fluctuating or being off-scale due to a temperature sensor failure.

Total Ozone Mapping Spectrometer - Earth Probe (TOMS-EP)

TOMS-EP had 3 Orbital anomalies and 34 Ground-Comm anomalies. All had negligible impacts.

Tracking and Data Relay Satellite (TDRS)

During FY 2003, the six TDRS satellites reported three Orbital anomalies and 12 Ground-Comm anomalies. These anomalies all had negligible impacts. TDRS-10 experienced a fail-safe that autonomously transferred control from the failed spacecraft control processor to an available backup unit.

Transition Region and Coronal Explorer (TRACE)

TRACE had 5 Orbital anomalies and 60 Ground-Comm anomalies, all having negligible impacts. A Sun Angle Violation caused an ACE Safehold; the Failure Detection and Handling (FDH) part of the Attitude Control System (ACS) detecting a sun angle violation. A Sun angle greater than 2 degrees was reported for at least 2 seconds by the CSS while acting as the primary sun sensor. This sent the spacecraft into the ISP ACS control mode. While in ISP, the CSS reported an angle greater than 10 degrees for at least 10 seconds, sending the spacecraft into ACE safehold.

Tropical Rainfall Measuring Mission (TRMM)

TRMM had 3 Orbital anomalies, two with minor impacts and one with a negligible impact. Seventeen Ground-Comm anomalies with negligible mission effects also were reported.

Two minor anomalies were caused by PSIB side B Chassis Current Average (WBCHSI) being above the yellow high limit; it did not return to normal during subsequent events. Further investigation revealed that the current is in nominal range during eclipse periods but ramps up past the yellow limit in sunlight, reaching values of up to 1.12 A. This behavior indicates that one solar array string has shorted to chassis. The short circuit current for one string is ~0.5 A. Since two strings are tied in parallel at the input of the diode board, two strings have effectively been shorted to chassis. Therefore, the total short circuit current is ~1 A, which is 1/68 (1.5%) of the total power. There is no immediate consequence to the power system from this short. TRMM currently is being prepared for de-orbit.

Upper Atmosphere Research Satellite (UARS)

UARS had 8 Orbital anomalies and 117 Ground-Comm anomalies. All had negligible impacts.

Wide Field Infrared Explorer (WIRE)

WIRE had 8 Orbital anomalies and 34 Ground-Comm anomalies. These anomalies all had negligible impacts.

Wilkinson Microwave Anisotropy Probe (WMAP or MAP or MIDEX 2)

WMAP had 1 Orbital anomaly. This anomaly was a single event upset in the Timing, Command, and Control Subsystem and had a negligible impact.

WIND (Global Geospace Science - GGS)

WIND had 2 Orbital anomalies and 8 Ground-Comm anomalies. All anomalies had negligible impacts.

Detailed Anomaly Data

This section provides detailed information regarding the numbers of anomalies, mission impacts, anomaly distributions among spacecraft subsystems, anomaly effects, failure categories, and anomaly types. A discussion of the classification scheme provides the definitions and coding legends for interpreting the tables and graphs in this section.

A sample SOAR report shows typical data fields included in SOARS.

Summaries of anomaly data are presented for the various classifications for orbital operations. These include frequency tables and graphs depicting anomaly occurrences by mission effects (impacts), subsystems, anomaly effects, failure categories, and anomaly types. A separate graph shows anomaly occurrences by (calendar) date. Similar tables and graphs follow for ground and communication relay system anomalies.

Classification Scheme

Anomaly data for this report were classified using the same categories as for previous reports. These also correspond to the categories and classifications for the Spacecraft Orbital Anomaly Reporting System (SOARS) database. The classification scheme assigns numerical codes to various categories to facilitate data entry, sorting, and analysis. The classification categories are:

- **Spacecraft -** The spacecraft nomenclature.
- **Date -** The anomaly date.
- **Days -** The anomaly occurrence reported as the number of days since launch.
- **Anomaly Category** – Denotes whether the anomaly occurs On-orbit or involves the Ground and Communication Relay Systems (called Ground-Comm). [Ground-Comm are NOT on-orbit spacecraft anomalies and are compiled and analyzed separately from orbital anomalies.]

    O Orbital- Occurred on an orbiting spacecraft
    G Ground System – Occurred within a ground system
    C Communication Relay System – Occurred within a communications relay system

- **Subsystem** – denotes in which spacecraft subsystem the anomaly occurred:

    100 Timing, Control & Command (TC & C)
    200 Telemetry & Data Handling (TLM & DH)
    300 Thermal
    400 Attitude Control Subsystem (ACS)
    500 Power
    600 Propulsion
    700 Instruments
    800 Structure
    900 Other
    1000 Ground System
    2000 Communication Relay System

- **Description -** A brief description of the anomaly and, if known, its probable cause. This description has been edited for this report; however, every effort has been made to preserve the content provided in the original report.

- **Effect/Action -** The anomaly's effect on the mission and corrective action, either for the involved mission or future missions, if known. Again, the original anomaly content is preserved in an edited form.

- **Reference -** The information source for the anomaly, e.g., anomaly report number, team member's name, or other document.

Each anomaly also is classified according to the following criteria:

- **Criticality** (Effect on mission objectives) **-** A number denoting the anomaly's effect on the spacecraft's mission objectives, assigned according to the following classifications:

  1 Negligible (Negligible or no impact)
  2 Minor (Non-negligible but small)
  3 Substantial (Loss of a significant mission objective)
  4 Major (Loss of one or more major mission objectives)
  5 Catastrophic (Essentially total loss)

- **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
  7 Operations Error

- **Failure Category** – (cause):

  1 Design Problem
  2 Workmanship Problem
  3 Part Problem
  4 Environmental Problem
  5 Other
  6 Unknown
  7 Software Problem
  8 Operations Problem

- **Anomaly Effect** (effect on the spacecraft):

  1 Spacecraft Failure
  2 Subsystem or Instrument Failure
  3 Component Failure
  4 Assembly Failure
  5 Part Failure
  6 Subsystem or Instrument Degradation
  7 Indeterminate
  8 Loss of Redundancy
  9 None
  10 Loss of Data
  11 Loss of Service
  12 Loss of Data (Recoverable)

Sample SOARS Report

An example of a complete SOARS report is shown in Figure 1 and Figure 2 below. The SOARS data entry system has a series of pull-down boxes and text blocks to describe an anomaly.

Current Date/Time: **01/13/2004 09:05:37**

GSFC SPACECRAFT ORBITAL ANOMALY REPORT (SOAR)

(Goto Section 2)	*Section 1. (To be completed by originator)*					
1. SOAR Number: C - 9231	1A. Project Number:		2. Spacecraft EOS AM 1(TERRA)			
3. Subsystem or Instrument ASTER	4. Anomaly Date 05/06/2003		Launch Date 12/01/1999		JDAY 126	
5. Component Name	ID Number	Serial Number	Manufacturer			
6. Assembly Name Screen door failed to open	ID Number	Serial Number	Manufacturer			
7A. Rev. No. 0	7B. Lat	7C. Long.	7D. A/D	7E. S/D	7F. Local Time	8. Days Operation (Since Launch) 1252
9. Anomaly Description Solar Diffuser screen door failed to open. AIT focused on scrren deformation from thermal stress as most likely cause. Proposal to open door permanently in planning phase ETC July 2, 2003.						
10. Additional Comments						
11. Originator: Simon Code: Phone:	12. NASA/Government Representative: Code: Phone:					

Figure 1. Section 1 of sample SOARS report

(Goto Section 1)	*Section 2. (To be completed by responsible person)*	

13A. Investigation Index: 1 - MAXIMUM RESOURCES

13. Cause of Anomaly

Screen deformation due to thermal stress as most probable cause.

14. Corrective Action

Open door on permanent basis. Action taken on 7/6/03. Door iis now open and the screen is closed. They shall remain in this configuration indefinitely. There have been no additional incidents, issues or concerns. SOAR Closeout on 7/15/03 according to Bob Kozon Flight Operatons Director, EOS Terra Mission.

15. Mission Effect: 4 - MAJOR (SEVERE MISSION DEGRADATION: LOSS OF 1+ MAJOR MISSION OBJECTIVES)

16. Anomaly Effect: 6 - SUBSYSTEM OR INSTRUMENT DEGRADATION

17. Failure Category: 3 - PART PROBLEM

18. Anomaly Type: 3 - WEAROUT (SPECIAL CASE OF SYSTEMATIC ANOMALY)

19. Action to be Taken on Follow-On S/C

Use of better material recommended to survive mission thermal stress profile.

20. Reference Document(s) ID

21. Responsible Person: **Code:** **Phone:**	**22. NASA/Government Representative:** **Code:** **Phone:**

23. FAM or SOAR System Mgr: **Code:** **Phone:**	**24. Closeout Date:** 07/15/2003	**25. Inactive?** No	**26. Type of Anomaly?** On Orbit

Attachments: *Not viewable due to ITAR contraints*

Figure 2. Section 2 of sample SOARS report

Anomaly Data Summary

During FY 2003, Goddard Space Flight Center had 61 active orbiting satellites, with 52 satellites reporting at least one anomaly. There were 2092 anomalies reported among these satellites: 439 were Orbital anomalies and 1653 Ground Systems or Communication Relay System anomalies.

Anomaly Occurrence Probabilities

Statistics were compiled to benchmark anomaly occurrence rates and probabilities among all active GSFC spacecraft operating during FY 2003. Each spacecraft was assumed to operate fully for the year or from its launch date to the year's end, to accumulate on-orbit spacecraft hours. A constant failure (anomaly) rate function (exponential distribution) was assumed to compute annual "anomaly rates"(mean time between anomaly occurrences) and annual anomaly occurrence probabilities for the four relevant mission effect categories ("criticality"). These statistics are a "snap-shot of spacecraft performance for the reporting year. As they combine all operating spacecraft ("old," "mid-life," and "newly-launched"), the resulting statistics serve only as a comparative reference. They ***do not*** represent spacecraft reliabilities, in the sense of probabilities of success (or failure).

Sixty one spacecraft accumulated 520,224 on-orbit operational hours. There were 439 Orbital anomalies: 2 "major," 3 "substantial," 58 "minor," and 376 "negligible." These generated the following anomaly occurrence statistics:

Table 2. Probability of Anomaly Occurrence for FY 2003

Criticality	**Mean time between anomaly occurrence (hours)**	**Probability of anomaly occurring**
Major	260,112	0.03
Substantial	173,408	0.05
Minor	8,959	0.62
Negligible	1,384	0.998

The probability that a "Major" anomaly occurred among all spacecraft during FY 2003 was 0.03. The probability that a "Substantial" anomaly occurred was 0.05. The likelihood that a "significant" anomaly (minor through major) occurred was 0.65; thus there was a 35% probability that a significant anomaly would not occur.

Statistics for the 1653 Ground and Communication Relay anomalies were not computed because system operating times were not available.

Orbital Anomalies

HST and RXTE contributed the most orbital anomalies: 103 (24% of all anomalies) and 60 (14%), respectively. FUSE, ACE, GALEX, and EO1 had 39, 29, 24, and 24 anomalies, respectively. The remaining anomalies occurred on 35 other spacecraft. Table 3 and Figure 3 show the numbers of orbital anomalies by spacecraft.

Table 3. FY 2003 Orbital Anomaly Distribution Among Spacecraft

Spacecraft	Number of Orbital Anomalies[2]	Spacecraft	Number of Orbital Anomalies[2]
HST	103	TRMM	3
RXTE	60	GOES-11 (L)	2
FUSE	39	GOES-8 (I)	2
ACE	29	HETE-II	2
EO1	24	ICESAT	2
GALEX	24	SOHO	2
AQUA	17	SORCE	2
SWAS	15	WIND	2
TIMED	11	IMAGE	1
TERRA	10	NOAA-14 (-J)	1
WIRE	10	SNOE	1
GOES-12 (M)	8	TDRS-3 (-C)	1
NOAA-17 (M)	8	TDRS-I	1
UARS	8	TDRS-J	1
CHIPSAT	7	WMAP	1
NOAA-16	7	NOAA-11 (-H)	0
TRACE	6	NOAA-12 (-D)	0
POLAR	5	NOAA-15 (K)	0
ERBS	3	QUIKSCAT	0
FAST	3	RHESSI	0
GOES-10 (K)	3	SAGE	0
GOES-9 (J)	3	SEASTAR/SEAWIFS	0
LANDSAT-5 (-D')	3	TDRS-1 (-A)	0
LANDSAT-7	3	TDRS-6 (-F)	0
SAMPEX	3	TDRS-7 (-G)	0
TOMS-EP	3	TOPEX	0
		Total Number of Anomalies	**439**

There is an apparent disparity in the number of anomalies among the different spacecraft. There may be some disparity due to differences in orbits, spacecraft complexity, spacecraft age, and types of data being captured. Some spacecraft designs also may be more tolerant of environmental anomalies, for example, those having more extensive shielding and radiation hardened parts. Some flight operators may have been more diligent than others reporting anomaly occurrences for certain spacecraft. These above-mentioned disparities likely are caused by a combination of these factors. They have not been researched for this study.

2 In previous reports, the number of anomalies since launch was included here. This information is not included here because of missing data from 1998 through 2002.

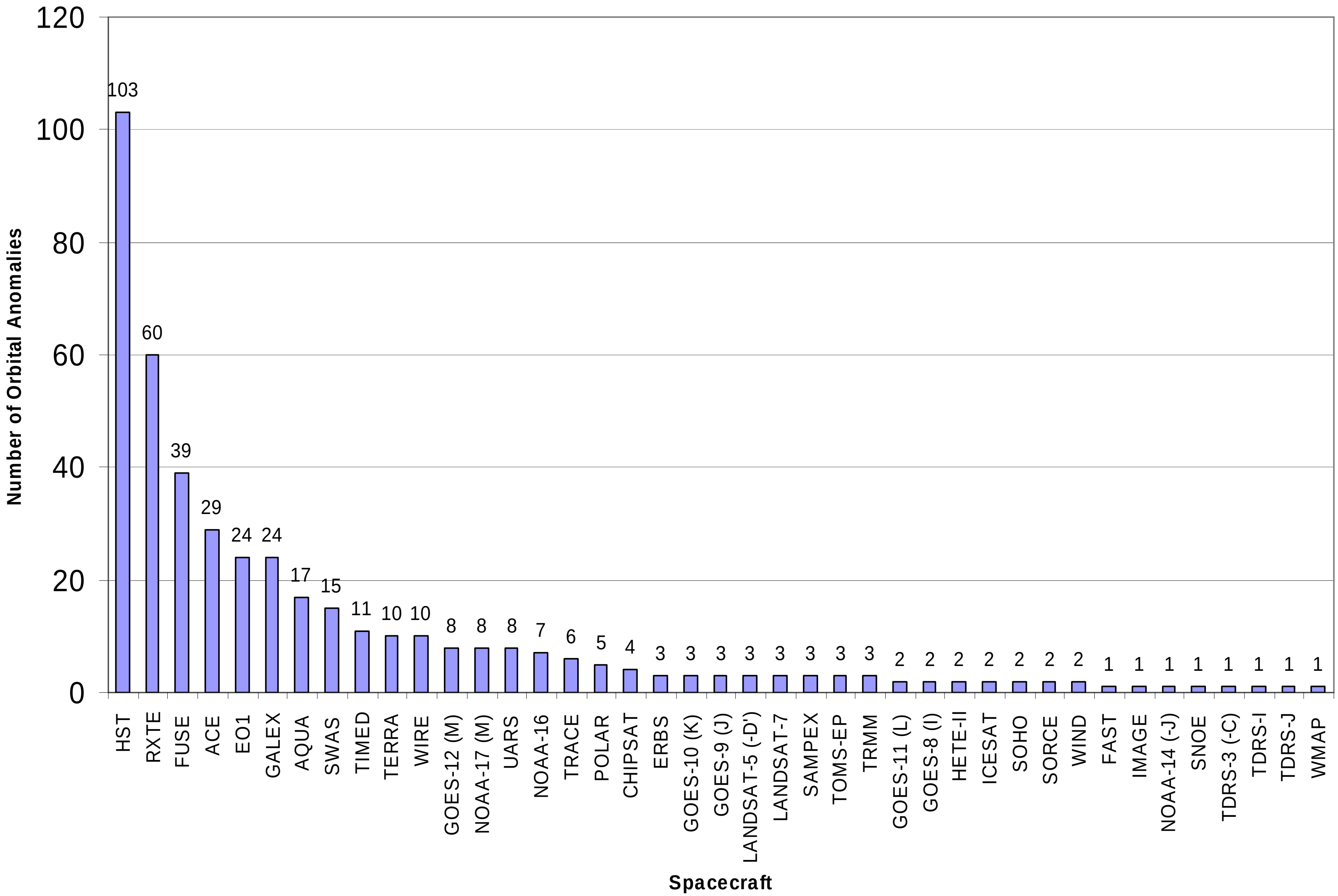


Figure 3. FY 2003 Orbital Anomalies by Spacecraft

Anomalies Classified by Mission Effect

Of 439 Orbital anomalies, 5 initially had a mission effect of substantial or greater. There were no anomalies with a catastrophic (criticality 5) mission impact. Two anomalies caused major mission effects (criticality 4) and three anomalies caused substantial mission effects (criticality 3).

Spacecraft “major” anomalies were Landsat 7 (Scan Line Corrector) and ICESAT (GLAS laser). Although the ICESAT laser failure involved only one of three redundant lasers, the two remaining lasers likely have the same failure mode, which will reduce mission operating time. The anomaly is considered to have a major impact on the mission. Science operations have already been changed to reduce laser on-times, resulting in a major impact on mission objectives.

Spacecraft with substantial anomalies included AQUA, GOES-12, and HST. The AQUA anomaly (SOAR D-311) involved the HSB shutting down and going into survival mode because of a synchronization error; this was caused by the scan motor current increasing rapidly (stalling) and then dropping to zero. The GOES-12 anomaly (SOAR D-769) involved the SXI Safe Trigger; the SXI returned an error code 33 and went to SAFE mode repeatedly, locking the filter wheel and turning off the High Voltage Power Supply (HVPS). For HST, one orbital anomaly had a substantial mission effect (SOAR D-299): the spacecraft went to a "zero gyro sun-pointing mode" caused by a gyroscope failure. This anomaly was later downgraded to minor because it was a redundant gyroscope.

Figure 4 and Table 4 provide the number of anomalies by mission effect (criticality).

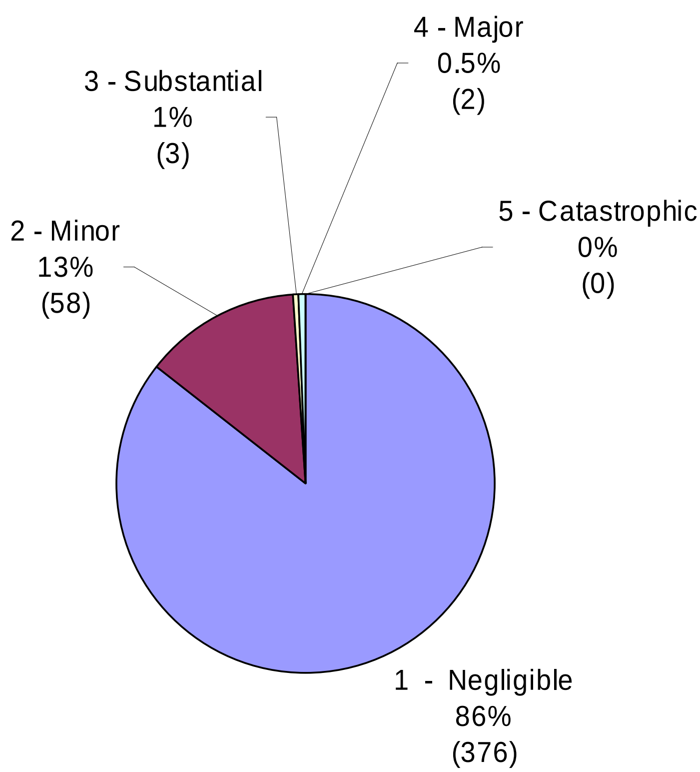


Figure 4. Mission Effect (Criticality) Percentages of FY 2003 Anomaly Data

Table 4. FY 2003 Orbital Anomaly Distribution by Mission Effect (Criticality)

Mission Effect / Spacecraft	1 Negligible	2 Minor	3 Substantial	4 Major	5 Catastrophic	Total Anomalies	% of Total Anomalies
ACE	29	0	0	0	0	29	6.6
AQUA	12	4	1	0	0	17	3.9
CHIPSAT	6	1	0	0	0	7	1.6
EO1	23	1	0	0	0	24	5.5
ERBS	3	0	0	0	0	3	0.7
FAST	1	2	0	0	0	3	0.7
FUSE	35	4	0	0	0	39	8.9
GALEX	23	1	0	0	0	24	5.5
GOES-10 (K)	2	1	0	0	0	3	0.7
GOES-11 (L)	2	0	0	0	0	2	0.5
GOES-12 (M)	5	2	1	0	0	8	1.8
GOES-8 (I)	1	1	0	0	0	2	0.5
GOES-9 (J)	2	1	0	0	0	3	0.7
HETE-II	0	2	0	0	0	2	0.5
HST	99	3	1	0	0	103	23.5
ICESAT	0	1	0	1	0	2	0.5
IMAGE	1	0	0	0	0	1	0.2
LANDSAT-5 (-D')	2	1	0	0	0	3	0.7
LANDSAT-7	2	0	0	1	0	3	0.7
NOAA-11 (-H)	0	0	0	0	0	0	0.0
NOAA-12 (-D)	0	0	0	0	0	0	0.0
NOAA-14 (-J)	1	0	0	0	0	1	0.2
NOAA-15 (K)	0	0	0	0	0	0	0.0
NOAA-16	3	4	0	0	0	7	1.6
NOAA-17 (M)	8	0	0	0	0	8	1.8
POLAR	4	1	0	0	0	5	1.1
QUIKSCAT	0	0	0	0	0	0	0.0
RHESSI	0	0	0	0	0	0	0.0
RXTE	43	17	0	0	0	60	13.7
SAGE	0	0	0	0	0	0	0.0
SAMPEX	3	0	0	0	0	3	0.7
SEASTAR/SEAWIFS	0	0	0	0	0	0	0.0
SNOE	1	0	0	0	0	1	0.2
SOHO	2	0	0	0	0	2	0.5
SORCE	2	0	0	0	0	2	0.5
SWAS	15	0	0	0	0	15	3.4
TDRS-1 (-A)	0	0	0	0	0	0	0.0
TDRS-3 (-C)	1	0	0	0	0	1	0.2
TDRS-6 (-F)	0	0	0	0	0	0	0.0
TDRS-7 (-G)	0	0	0	0	0	0	0.0
TDRS-I	1	0	0	0	0	1	0.2
TDRS-J	1	0	0	0	0	1	0.2
TERRA	5	5	0	0	0	10	2.3
TIMED	7	4	0	0	0	11	2.5
TOMS-EP	3	0	0	0	0	3	0.7
TOPEX	0	0	0	0	0	0	0.0
TRACE	6	0	0	0	0	6	1.4
TRMM	1	2	0	0	0	3	0.7
UARS	8	0	0	0	0	8	1.8
WIND	2	0	0	0	0	2	0.5
WIRE	10	0	0	0	0	10	2.3
WMAP	1	0	0	0	0	1	0.2
Total for all Spacecraft	376	58	3	2	0	439	100.0
% of Total Anomalies, all Spacecraft	85.6	13.2	0.7	0.5	0.0	100.0	

Anomalies Classified by Subsystem

The most frequent subsystem impacted by Orbital anomalies was the Attitude Control Subsystem, with 166 anomalies (37%). The Instrument Subsystems had 103 anomalies (24%). Telemetry and Data Handling had 73 anomalies (17%).

The fact that more than three-quarters of all orbital anomalies involves these subsystems is not surprising as they are the most complex subsystems.

Figure 5 and Table 5 provide details on the orbital anomaly distribution among subsystems.

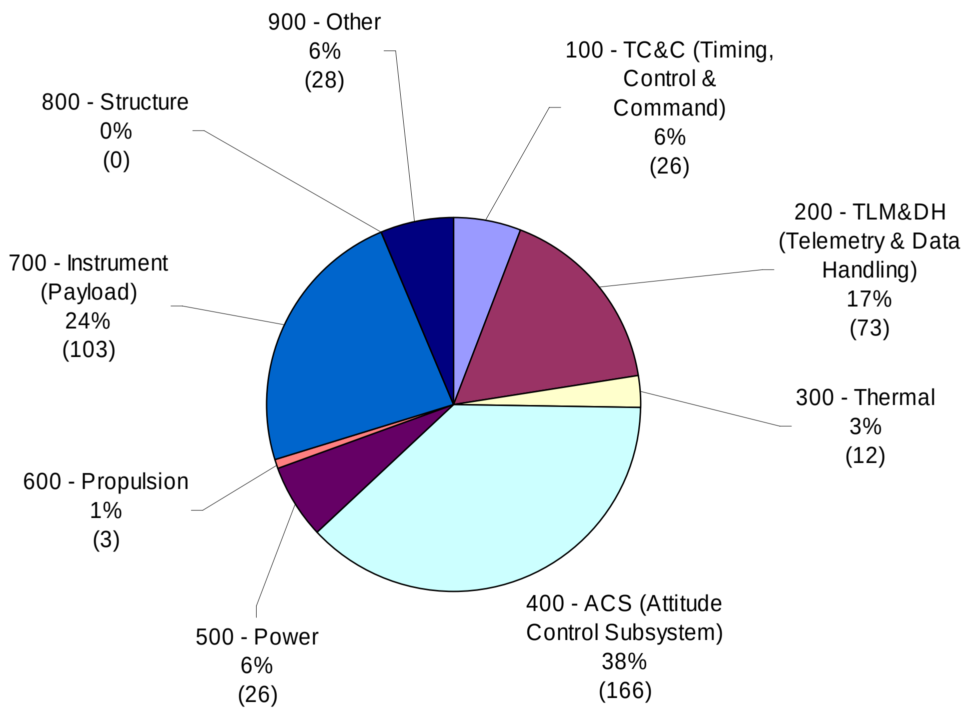


Figure 5. Subsystem Percentages of FY 2003 Orbital Anomalies

OAGS FY 2003

Table 5. FY 2003 Orbital Anomaly Distribution Among Spacecraft Subsystems

Spacecraft Subsystem / Spacecraft	100 - TC&C	200 - TLM&DH	300 - Thermal	400 - ACS	500 - Power	600 - Propulsion	700 - Instrument	800 - Structure	900 - Other	Total Anomalies	% of Total Anomalies
ACE	1	3	7	0	0	2	16	0	0	29	6.6
AQUA	3	2	0	3	3	0	6	0	0	17	3.9
CHIPSAT	0	3	0	3	1	0	0	0	0	7	1.6
EO1	0	20	0	1	0	0	2	0	1	24	5.5
ERBS	1	2	0	0	0	0	0	0	0	3	0.7
FAST	2	0	0	0	1	0	0	0	0	3	0.7
FUSE	0	1	0	21	1	0	16	0	0	39	8.9
GALEX	0	4	0	3	2	0	15	0	0	24	5.5
GOES-10 (K)	0	1	0	0	0	0	2	0	0	3	0.7
GOES-11 (L)	0	1	0	1	0	0	0	0	0	2	0.5
GOES-12 (M)	0	1	0	0	0	1	5	0	1	8	1.8
GOES-8 (I)	2	0	0	0	0	0	0	0	0	2	0.5
GOES-9 (J)	0	0	0	2	0	0	1	0	0	3	0.7
HETE-II	0	0	0	0	1	0	1	0	0	2	0.5
HST	2	7	1	46	10	0	20	0	17	103	23.5
ICESAT	0	0	0	0	0	0	2	0	0	2	0.5
IMAGE	0	0	0	0	1	0	0	0	0	1	0.2
LANDSAT-5 (-D')	0	2	0	0	0	0	1	0	0	3	0.7
LANDSAT-7	0	1	0	0	0	0	2	0	0	3	0.7
NOAA-11 (-H)	0	0	0	0	0	0	0	0	0	0	0.0
NOAA-12 (-D)	0	0	0	0	0	0	0	0	0	0	0.0
NOAA-14 (-J)	0	0	0	0	1	0	0	0	0	1	0.2
NOAA-15 (K)	0	0	0	0	0	0	0	0	0	0	0.0
NOAA-16	0	1	0	1	0	0	5	0	0	7	1.6
NOAA-17 (M)	1	3	1	0	1	0	2	0	0	8	1.8
POLAR	0	1	0	0	1	0	0	0	3	5	1.1
QUIKSCAT	0	0	0	0	0	0	0	0	0	0	0.0
RHESSI	0	0	0	0	0	0	0	0	0	0	0.0
RXTE	6	3	0	50	0	0	0	0	1	60	13.7
SAGE	0	0	0	0	0	0	0	0	0	0	0.0
SAMPEX	0	0	0	3	0	0	0	0	0	3	0.7
SEASTAR/SEAWIFS	0	0	0	0	0	0	0	0	0	0	0.0
SNOE	0	0	0	0	0	0	0	0	1	1	0.2
SOHO	1	1	0	0	0	0	0	0	0	2	0.5
SORCE	0	0	0	0	1	0	0	0	1	2	0.5
SWAS	0	0	0	13	0	0	0	0	2	15	3.4
TDRS-1 (-A)	0	0	0	0	0	0	0	0	0	0	0.0
TDRS-3 (-C)	1	0	0	0	0	0	0	0	0	1	0.2
TDRS-6 (-F)	0	0	0	0	0	0	0	0	0	0	0.0
TDRS-7 (-G)	0	0	0	0	0	0	0	0	0	0	0.0
TDRS-I	0	0	0	0	1	0	0	0	0	1	0.2
TDRS-J	0	0	0	1	0	0	0	0	0	1	0.2
TERRA	0	6	0	0	0	0	4	0	0	10	2.3
TIMED	0	2	1	7	0	0	1	0	0	11	2.5
TOMS-EP	0	0	0	3	0	0	0	0	0	3	0.7
TOPEX	0	0	0	0	0	0	0	0	0	0	0.0
TRACE	1	3	0	2	0	0	0	0	0	6	1.4
TRMM	0	0	1	0	2	0	0	0	0	3	0.7
UARS	4	2	1	0	0	0	1	0	0	8	1.8
WIND	0	0	0	0	0	0	1	0	1	2	0.5
WIRE	0	3	0	6	1	0	0	0	0	10	2.3
WMAP	1	0	0	0	0	0	0	0	0	1	0.2
Total for all Spacecraft	26	73	12	166	28	3	103	0	28	439	100.0
% of Total Anomalies, all Spacecraft	5.9	16.6	2.7	37.8	6.4	0.7	23.5	0.0	6.4	100.0	

Anomalies Classified by Anomaly Effect

One hundred forty two (142, 33%) orbital anomalies caused no anomaly effect and 83 (19%) resulted in indeterminate anomaly effects. Seventy-three (73, 17%) caused a loss of data. Fifty-nine (59, 13%) caused a loss of service, and 50 (11%) caused subsystem or instrument degradation. Only 5% (24) of orbital anomalies were caused by hardware failures.

Figure 6 and Table 6 show detailed information for anomaly effects.

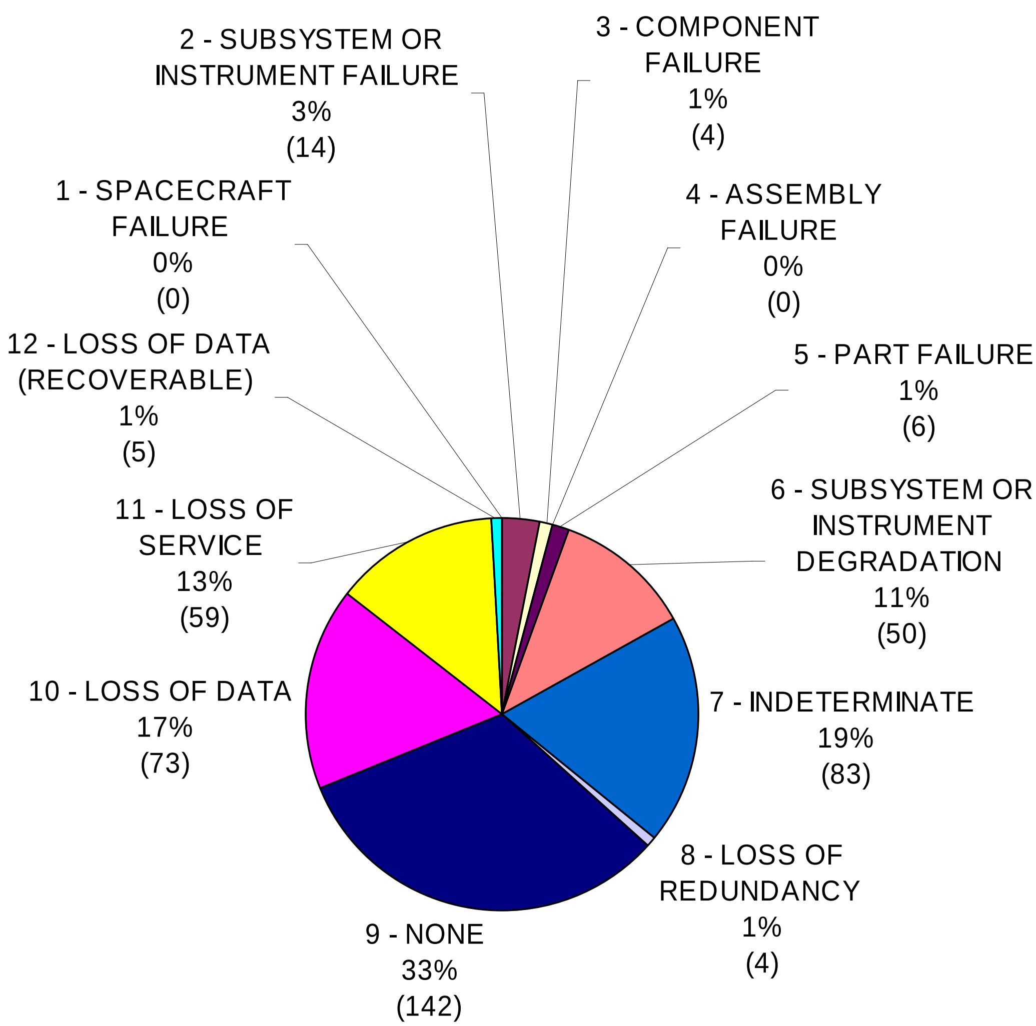


Figure 6. Anomaly Effect Percentages of FY 2003 Orbital Anomalies

Table 6. FY 2003 Orbital Anomaly Distribution by Anomaly Effect

Anomaly Effects / Spacecraft	1 – Spacecraft Failure	2 – Subsystem/ Instr. Failure	3 – Component Failure	4 – Assembly Failure	5 – Part Failure	6 – Subsystem/ Instr. Degrad.	7 - Indeterminate	8 – Loss of Redundancy	9 - None	10 – Loss of Data	11 – Loss of Service	12 – Loss of Data (Recoverable)	Total Anomalies	% of Total Anomalies
ACE	0	0	0	0	0	8	16	0	5	0	0	0	29	6.6
AQUA	0	1	0	0	2	1	6	0	4	1	0	2	17	3.9
CHIPSAT	0	0	0	0	0	0	0	1	1	3	2	0	7	1.6
EO1	0	0	0	0	0	1	2	0	8	8	4	1	24	5.5
ERBS	0	0	0	0	0	0	2	0	0	0	1	0	3	0.7
FAST	0	0	0	0	1	1	0	0	0	0	1	0	3	0.7
FUSE	0	0	0	0	1	1	1	1	4	31	0	0	39	8.9
GALEX	0	0	0	0	0	0	0	0	12	11	1	0	24	5.5
GOES-10 (K)	0	0	0	0	0	1	0	0	0	1	1	0	3	0.7
GOES-11 (L)	0	0	0	0	0	0	0	0	2	0	0	0	2	0.5
GOES-12 (M)	0	0	0	0	0	4	1	0	1	1	1	0	8	1.8
GOES-8 (I)	0	0	0	0	0	0	1	0	1	0	0	0	2	0.5
GOES-9 (J)	0	0	0	0	1	0	1	0	1	0	0	0	3	0.7
HETE-II	0	0	0	0	0	1	0	1	0	0	0	0	2	0.5
HST	0	0	1	0	0	12	29	1	25	2	33	0	103	23.5
ICESAT	0	0	1	0	0	1	0	0	0	0	0	0	2	0.5
IMAGE	0	0	0	0	0	0	0	0	0	0	1	0	1	0.2
LANDSAT-5 (-D')	0	0	0	0	0	2	0	0	0	0	1	0	3	0.7
LANDSAT-7	0	0	0	0	0	1	1	0	0	1	0	0	3	0.7
NOAA-11 (-H)	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
NOAA-12 (-D)	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
NOAA-14 (-J)	0	0	0	0	0	1	0	0	0	0	0	0	1	0.2
NOAA-15 (K)	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
NOAA-16	0	0	0	0	0	3	0	0	1	3	0	0	7	1.6
NOAA-17 (M)	0	0	0	0	0	5	2	0	0	1	0	0	8	1.8
POLAR	0	0	1	0	0	0	0	0	1	3	0	0	5	1.1
QUIKSCAT	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
RHESSI	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
RXTE	0	13	0	0	0	1	5	0	39	2	0	0	60	13.7
SAGE	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
SAMPEX	0	0	0	0	0	0	1	0	2	0	0	0	3	0.7
SEASTAR/SEAWIFS	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
SNOE	0	0	0	0	0	0	0	0	0	0	0	1	1	0.2
SOHO	0	0	0	0	0	0	0	0	0	0	2	0	2	0.5
SORCE	0	0	0	0	0	0	0	0	1	0	1	0	2	0.5
SWAS	0	0	0	0	0	0	0	0	13	1	1	0	15	3.4
TDRS-1 (-A)	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
TDRS-3 (-C)	0	0	0	0	0	0	0	0	0	0	1	0	1	0.2
TDRS-6 (-F)	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
TDRS-7 (-G)	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
TDRS-I	0	0	0	0	0	0	1	0	0	0	0	0	1	0.2
TDRS-J	0	0	0	0	0	0	0	0	1	0	0	0	1	0.2
TERRA	0	0	1	0	0	5	2	0	0	2	0	0	10	2.3
TIMED	0	0	0	0	0	0	3	0	8	0	0	0	11	2.5
TOMS-EP	0	0	0	0	0	0	0	0	1	1	1	0	3	0.7
TOPEX	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
TRACE	0	0	0	0	0	0	0	0	4	0	2	0	6	1.4
TRMM	0	0	0	0	1	1	0	0	1	0	0	0	3	0.7
UARS	0	0	0	0	0	0	5	0	1	0	2	0	8	1.8
WIND	0	0	0	0	0	0	0	0	1	1	0	0	2	0.5
WIRE	0	0	0	0	0	0	4	0	4	0	2	0	10	2.3
WMAP	0	0	0	0	0	0	0	0	0	0	1	0	1	0.2
Total for all Spacecraft	0	14	4	0	6	50	83	4	142	73	59	4	439	100.0
% of Total Anomalies, all Spacecraft	0.0	3.2	0.9	0.0	1.4	11.4	18.9	0.9	32.3	16.6	13.4	0.9	100.0	

Anomalies Classified by Failure Category

Software problems caused the most orbital anomalies: 71 (16%). Environmental problems were the second leading contributor, with 69 anomalies (16%). Part problems also were prominent, with 68 anomalies. The failure category of 138 anomalies (31%) was unknown.

Design and workmanship problems do not appear to contribute to significant numbers of orbital anomalies. Environmental problems and parts problems caused the majority of anomalies. However, both these failure modes can be affected by design or device and component (i.e., workmanship) defects, which are not identifiable because the component(s) cannot be "failure-analyzed." The most frequent contributor, software problems, often can be corrected with either uploaded patches or "work-arounds," so do not result in significant mission impacts.

Figure 7 and Table 7 show Orbital anomalies by failure category.

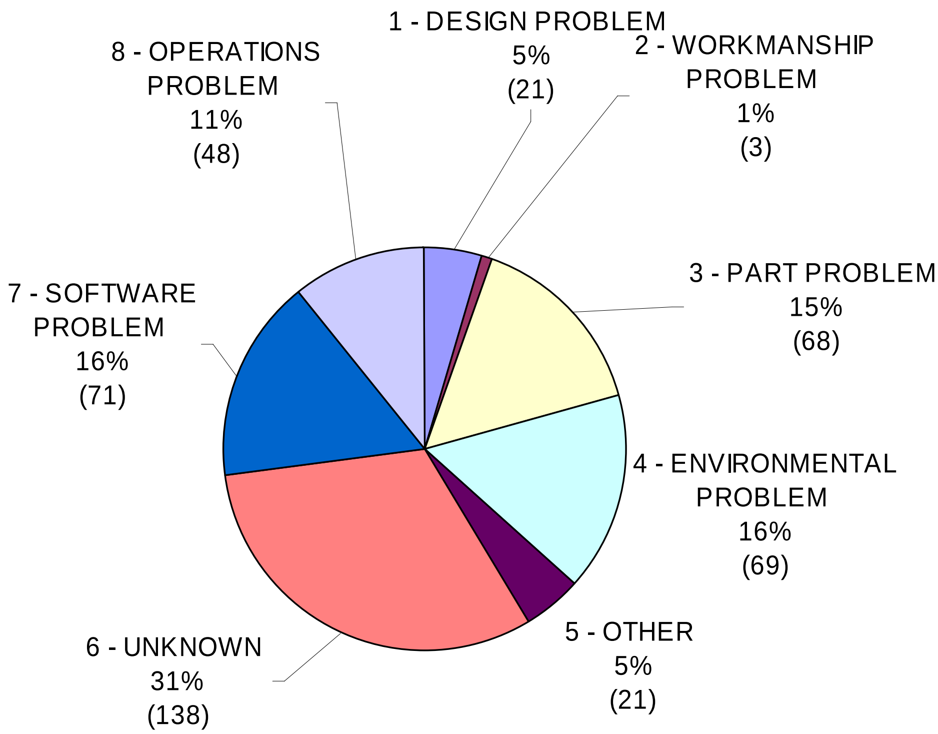


Figure 7. Failure Category Percentages of FY 2003 Orbital Anomalies

Table 7. FY 2003 Orbital Anomaly Distribution by Failure Category

Failure Category / Spacecraft	1 – Design Problem	2 – Workmanship Problem	3 – Part Problem	4 – Environmental Problem	5 - Other	6 - Unknown	7 – Software Problem	8 – Operations Problem	Total Anomalies	% of Total Anomalies
ACE	0	0	7	4	8	7	2	1	29	6.6
AQUA	2	1	2	0	0	3	9	0	17	3.9
CHIPSAT	1	0	1	4	0	0	1	0	7	1.6
EO1	0	1	0	1	0	17	4	1	24	5.5
ERBS	0	0	0	2	0	0	1	0	3	0.7
FAST	0	0	0	3	0	0	0	0	3	0.7
FUSE	2	0	5	22	5	0	4	1	39	8.9
GALEX	1	1	2	9	4	0	5	2	24	5.5
GOES-10 (K)	0	0	0	0	0	1	0	2	3	0.7
GOES-11 (L)	0	0	0	1	0	1	0	0	2	0.5
GOES-12 (M)	1	0	1	0	0	4	0	2	8	1.8
GOES-8 (I)	0	0	0	0	0	1	1	0	2	0.5
GOES-9 (J)	0	0	1	0	0	0	2	0	3	0.7
HETE-II	0	0	1	1	0	0	0	0	2	0.5
HST	9	0	11	4	0	35	27	17	103	23.5
ICESAT	1	0	1	0	0	0	0	0	2	0.5
IMAGE	0	0	0	0	0	0	0	1	1	0.2
LANDSAT-5 (-D')	1	0	1	0	0	0	1	0	3	0.7
LANDSAT-7	0	0	2	0	0	0	0	1	3	0.7
NOAA-11 (-H)	0	0	0	0	0	0	0	0	0	0.0
NOAA-12 (-D)	0	0	0	0	0	0	0	0	0	0.0
NOAA-14 (-J)	0	0	0	0	1	0	0	0	1	0.2
NOAA-15 (K)	0	0	0	0	0	0	0	0	0	0.0
NOAA-16	0	0	4	1	0	1	1	0	7	1.6
NOAA-17 (M)	1	0	3	3	0	0	1	0	8	1.8
POLAR	0	0	1	0	1	2	1	0	5	1.1
QUIKSCAT	0	0	0	0	0	0	0	0	0	0.0
RHESSI	0	0	0	0	0	0	0	0	0	0.0
RXTE	1	0	14	1	0	39	1	4	60	13.7
SAGE	0	0	0	0	0	0	0	0	0	0.0
SAMPEX	0	0	0	0	0	1	1	1	3	0.7
SEASTAR/SEAWIFS	0	0	0	0	0	0	0	0	0	0.0
SNOE	0	0	0	0	0	0	1	0	1	0.2
SOHO	0	0	0	0	0	1	0	1	2	0.5
SORCE	0	0	1	0	0	1	0	0	2	0.5
SWAS	0	0	0	0	0	2	2	11	15	3.4
TDRS-1 (-A)	0	0	0	0	0	0	0	0	0	0.0
TDRS-3 (-C)	1	0	0	0	0	0	0	0	1	0.2
TDRS-6 (-F)	0	0	0	0	0	0	0	0	0	0.0
TDRS-7 (-G)	0	0	0	0	0	0	0	0	0	0.0
TDRS-I	0	0	1	0	0	0	0	0	1	0.2
TDRS-J	0	0	0	0	0	1	0	0	1	0.2
TERRA	0	0	6	1	0	3	0	0	10	2.3
TIMED	0	0	1	5	0	5	0	0	11	2.5
TOMS-EP	0	0	0	0	0	0	3	0	3	0.7
TOPEX	0	0	0	0	0	0	0	0	0	0.0
TRACE	0	0	0	1	1	3	0	1	6	1.4
TRMM	0	0	1	1	1	0	0	0	3	0.7
UARS	0	0	1	3	0	3	1	0	8	1.8
WIND	0	0	0	0	0	1	1	0	2	0.5
WIRE	0	0	0	1	0	6	1	2	10	2.3
WMAP	0	0	0	1	0	0	0	0	1	0.2
Total for all Spacecraft	21	3	68	69	21	138	71	48	439	100.0
% of Total Anomalies, all Spacecraft	4.8	0.7	15.5	15.7	4.8	31.4	16.2	10.9	100.0	

Anomalies Classified by Anomaly Type

"Indeterminate" were the most frequently occurring on-orbit anomalies: 118 (27%) anomalies. One hundred ten (110, 25%) were assigned as "random." Another 71 (16%) were categorized as "systematic."

Figure 8 and Table 8 show detailed occurrence rates for anomalies by type.

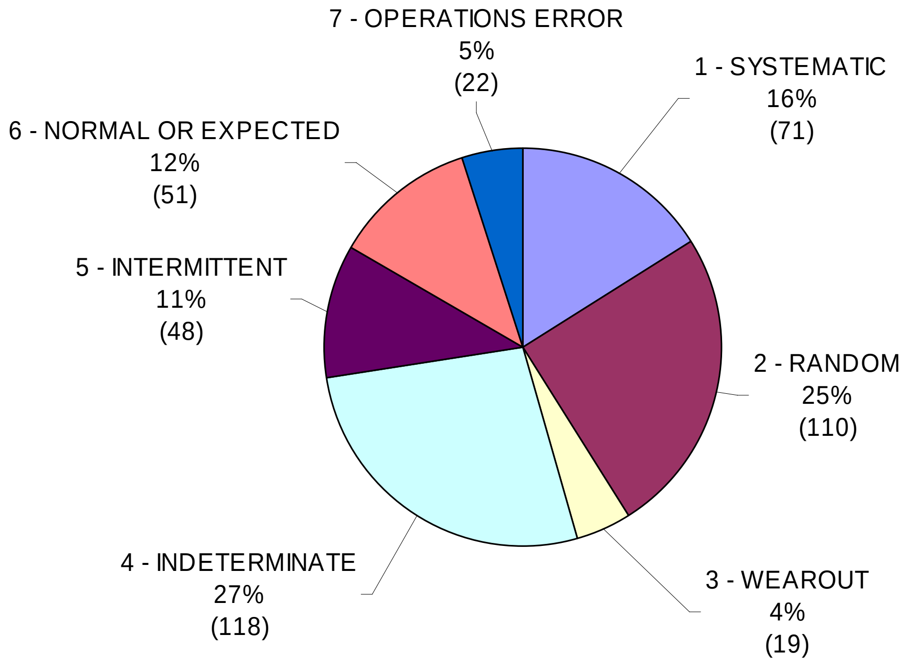


Figure 8. Anomaly Type Percentages of FY 2003 Orbital Anomalies

Table 8. FY 2003 Orbital Anomaly Distribution by Anomaly Type

Anomaly Type / Spacecraft	1 – Systematic	2 – Random	3 – Wearout	4 – Indeterminate	5 – Intermittent	6 – Normal or Expected Operation	7 – Operations Error	Total Anomalies	% of Total Anomalies
ACE	2	3	0	12	10	2	0	29	6.6
AQUA	8	2	2	5	0	0	0	17	3.9
CHIPSAT	5	1	1	0	0	0	0	7	1.6
EO1	0	8	1	10	4	0	1	24	5.5
ERBS	2	0	0	0	1	0	0	3	0.7
FAST	1	0	2	0	0	0	0	3	0.7
FUSE	1	18	5	0	8	7	0	39	8.9
GALEX	4	2	0	0	9	7	2	24	5.5
GOES-10 (K)	0	1	0	0	1	0	1	3	0.7
GOES-11 (L)	1	0	0	1	0	0	0	2	0.5
GOES-12 (M)	0	3	0	3	1	0	1	8	1.8
GOES-8 (I)	0	1	0	1	0	0	0	2	0.5
GOES-9 (J)	1	1	0	0	0	1	0	3	0.7
HETE-2	0	1	1	0	0	0	0	2	0.5
HST	22	13	3	22	7	28	8	103	23.5
ICESAT	2	0	0	0	0	0	0	2	0.5
IMAGE	0	0	0	0	0	1	0	1	0.2
LANDSAT-5 (-D')	3	0	0	0	0	0	0	3	0.7
LANDSAT-7	1	0	0	1	0	0	1	3	0.7
NOAA-11 (-H)	0	0	0	0	0	0	0	0	0.0
NOAA-12 (-D)	0	0	0	0	0	0	0	0	0.0
NOAA-14 (-J)	0	0	1	0	0	0	0	1	0.2
NOAA-15 (K)	0	0	0	0	0	0	0	0	0.0
NOAA-16	1	3	1	2	0	0	0	7	1.6
NOAA-17 (M)	1	4	1	0	0	2	0	8	1.8
POLAR	0	0	0	5	0	0	0	5	1.1
QUIKSCAT	0	0	0	0	0	0	0	0	0.0
RHESSI	0	0	0	0	0	0	0	0	0.0
RXTE	1	18	0	36	0	1	4	60	13.7
SAGE	0	0	0	0	0	0	0	0	0.0
SAMPEX	0	2	0	1	0	0	0	3	0.7
SEASTAR/SEAWIFS	0	0	0	0	0	0	0	0	0.0
SNOE	0	1	0	0	0	0	0	1	0.2
SOHO	0	0	0	0	1	0	1	2	0.5
SORCE	0	1	0	1	0	0	0	2	0.5
SWAS	4	5	0	5	0	0	1	15	3.4
TDRS-1 (-A)	0	0	0	0	0	0	0	0	0.0
TDRS-3 (-C)	1	0	0	0	0	0	0	1	0.2
TDRS-6 (-F)	0	0	0	0	0	0	0	0	0.0
TDRS-7 (-G)	0	0	0	0	0	0	0	0	0.0
TDRS-I	0	1	0	0	0	0	0	1	0.2
TDRS-J	0	0	0	0	0	1	0	1	0.2
TERRA	3	3	1	3	0	0	0	10	2.3
TIMED	0	5	0	2	4	0	0	11	2.5
TOMS-EP	3	0	0	0	0	0	0	3	0.7
TOPEX	0	0	0	0	0	0	0	0	0.0
TRACE	0	5	0	0	0	0	1	6	1.4
TRMM	1	2	0	0	0	0	0	3	0.7
UARS	2	3	0	3	0	0	0	8	1.8
WIND	0	0	0	1	1	0	0	2	0.5
WIRE	1	2	0	4	1	1	1	10	2.3
WMAP	0	1	0	0	0	0	0	1	0.2
Total for all Spacecraft	71	110	19	118	48	51	22	439	100.0
% of Total Anomalies, all Spacecraft	16.2	25.1	4.3	26.9	10.9	11.6	5.0	100.0	

Ground System-Communication Relay System Anomalies

AQUA, FAST, QUIKSCAT, and UARS contributed the most Ground-Comm anomalies, with 210 (13%), 129 (8%), 123 (7%) and 117 (7%) anomalies, respectively. The remaining anomalies occurred among 33 other spacecraft.

Table 9 and Figure 9 show the numbers of Ground-Comm anomalies by spacecraft.

Table 9. FY 2003 Ground-Comm Anomaly Distribution Among Spacecraft

Spacecraft	Number of Ground-Comm Anomalies	Spacecraft	Number of Ground-Comm Anomalies
AQUA	210	WIND	8
FAST	129	POLAR	3
QUIKSCAT	123	TDRS-J	3
UARS	117	TDRS-1 (-A)	3
ACE	99	TDRS-7 (-G)	3
EO1	94	GOES-12 (M)	2
ICESAT	93	SAGE	2
TERRA	80	TDRS-3 (-C)	2
HST	78	GOES-10 (K)	1
RXTE	61	TIMED	1
TRACE	60	TDRS-6 (-F)	1
FUSE	58	GOES-11 (L)	0
ERBS	47	GOES-8 (I)	0
LANDSAT-7	42	GOES-9 (J)	0
SNOE	42	HETE-II	0
SEASTAR/SEAWIFS	36	IMAGE	0
TOMS-EP	34	LANDSAT-5 (-D')	0
WIRE	34	NOAA-11 (-H)	0
SAMPEX	33	NOAA-12 (-D)	0
TOPEX	32	NOAA-14 (-J)	0
SORCE	25	NOAA-15 (K)	0
SWAS	25	NOAA-16 (L)	0
RHESSI	25	NOAA-17 (M)	0
GALEX	22	SOHO	0
TRMM	17	TDRS-I	0
CHIPSAT	8	WMAP	0
		Total Number of Anomalies	**1653**

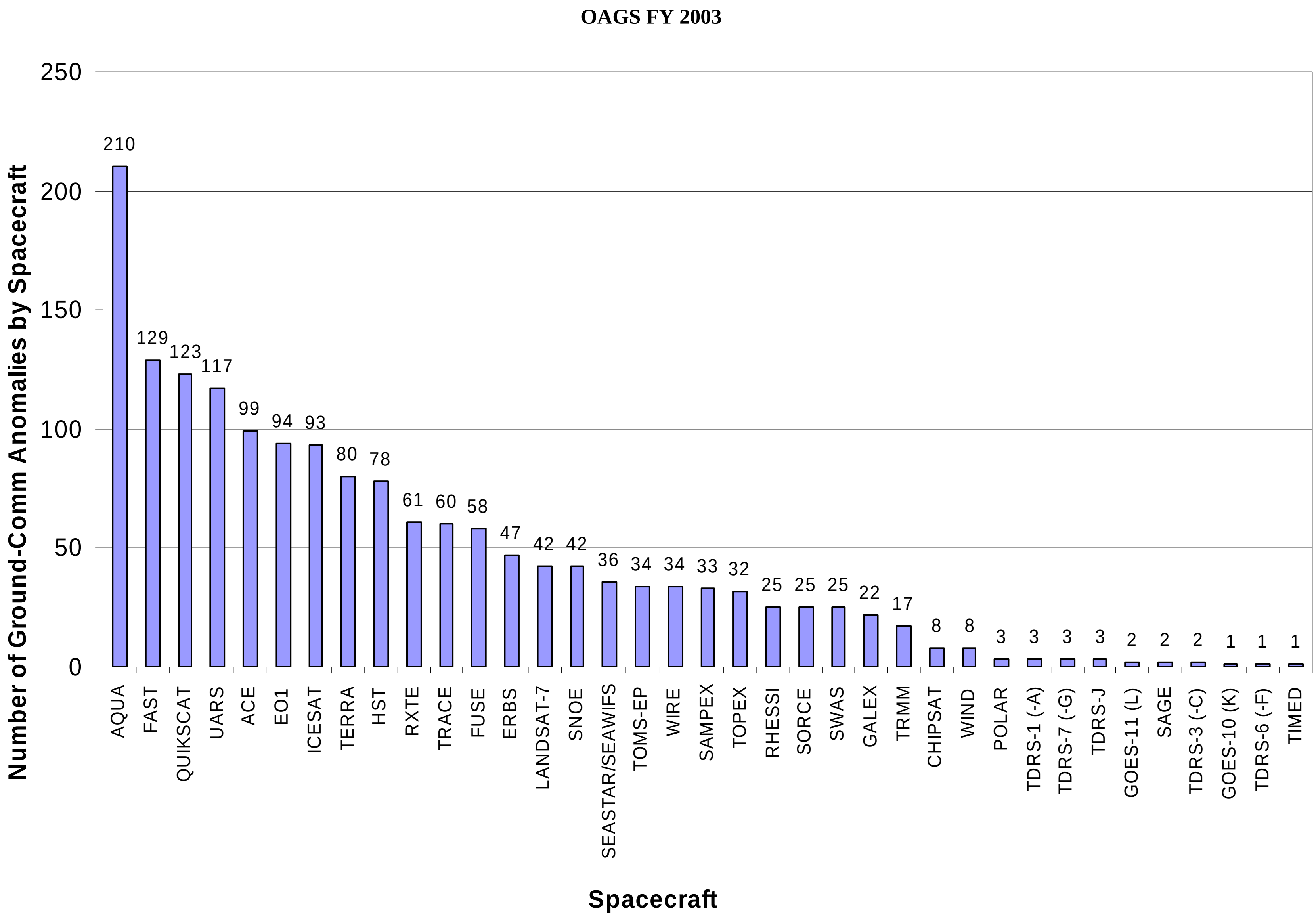


Figure 9. FY 2003 Ground-Comm Anomalies by Spacecraft

Anomalies Classified by Mission Effect

Of 1653 Ground System and Communication Relay System anomalies, none caused substantial, major, or catastrophic impacts. Nine (9) anomalies had minor mission effects (with a criticality of 3). There were 1644 anomalies with negligible mission effects (criticality of 1). Figure 10 and Table 10 provide data on Ground-Comm anomalies by mission effect (criticality).

These anomalies never cause major problems. The redundancy of multiple ground stations plus the ability to repair ground equipment contribute to the lack of significant mission effects.

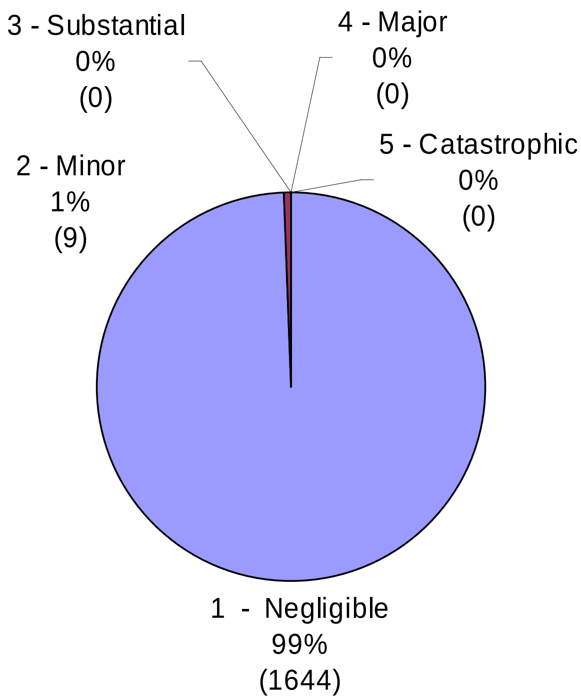


Figure 10. Mission Effect (Criticality) Percentages of FY 2003 Ground-Comm Anomalies

Table 10. FY 2003 Ground-Comm Anomaly Distribution by Mission Effect (Criticality)

Mission Effect / Spacecraft	1 Negligible	2 Minor	3 Substantial	4 Major	5 Catastrophic	Total Anomalies	% of Total Anomalies
ACE	99	0	0	0	0	99	6.0
AQUA	208	2	0	0	0	210	12.7
CHIPSAT	8	0	0	0	0	8	0.5
ERBS	80	0	0	0	0	80	4.8
EO1	47	0	0	0	0	47	2.8
FUSE	94	0	0	0	0	94	5.7
FAST	58	0	0	0	0	58	3.5
GALEX	128	1	0	0	0	129	7.8
GOES-10 (K)	21	1	0	0	0	22	1.3
GOES-12 (M)	0	1	0	0	0	1	0.1
GOES-11 (L)	2	0	0	0	0	2	0.1
GOES-8 (I)	0	0	0	0	0	0	0.0
GOES-9 (J)	0	0	0	0	0	0	0.0
HETE-II	0	0	0	0	0	0	0.0
HST	0	0	0	0	0	0	0.0
ICESAT	78	0	0	0	0	78	4.7
IMAGE	93	0	0	0	0	93	5.6
LANDSAT-5 (-D')	0	0	0	0	0	0	0.0
LANDSAT-7	0	0	0	0	0	0	0.0
NOAA-11 (-H)	42	0	0	0	0	42	2.5
NOAA-12 (-D)	0	0	0	0	0	0	0.0
NOAA-14 (-J)	0	0	0	0	0	0	0.0
NOAA-15 (K)	0	0	0	0	0	0	0.0
NOAA-16	0	0	0	0	0	0	0.0
NOAA-17 (M)	0	0	0	0	0	0	0.0
POLAR	0	0	0	0	0	0	0.0
QUIKSCAT	3	0	0	0	0	3	0.2
RHESSI	123	0	0	0	0	123	7.4
RXTE	25	0	0	0	0	25	1.5
SEASTAR/SEAWIFS	61	0	0	0	0	61	3.7
SOHO	36	0	0	0	0	36	2.2
SAMPEX	0	0	0	0	0	0	0.0
SORCE	33	0	0	0	0	33	2.0
SAGE	25	0	0	0	0	25	1.5
SNOE	2	0	0	0	0	2	0.1
SWAS	42	0	0	0	0	42	2.5
TDRS-I	25	0	0	0	0	25	1.5
TDRS-J	0	0	0	0	0	0	0.0
TERRA	3	0	0	0	0	3	0.2
TIMED	1	0	0	0	0	1	0.1
TOPEX	32	0	0	0	0	32	1.9
TOMS-EP	34	0	0	0	0	34	2.1
TDRS-1 (-A)	3	0	0	0	0	3	0.2
TDRS-3 (-C)	2	0	0	0	0	2	0.1
TDRS-6 (-F)	1	0	0	0	0	1	0.1
TDRS-7 (-G)	3	0	0	0	0	3	0.2
TRACE	58	2	0	0	0	60	3.6
TRMM	17	0	0	0	0	17	1.0
UARS	116	1	0	0	0	117	7.1
WIRE	33	1	0	0	0	34	2.1
WIND	8	0	0	0	0	8	0.5
WMAP	0	0	0	0	0	0	0.0
Total for all Spacecraft	1644	9	0	0	0	1653	100.0
% of Total Anomalies, all Spacecraft	99.5	0.5	0.0	0.0	0.0	100.0	

Anomalies Classified by Anomaly Effect

For anomaly effects, 615 (37%) of FY 2003 Ground-Comm anomalies caused a loss of service and 375 (23%) caused no effect. Two hundred forty seven (247, 15%) resulted in a loss of data and 243 (15%) resulted in an indeterminate anomaly effect. Figure 11 and Table 11 provide Ground-Comm anomaly effect summaries.

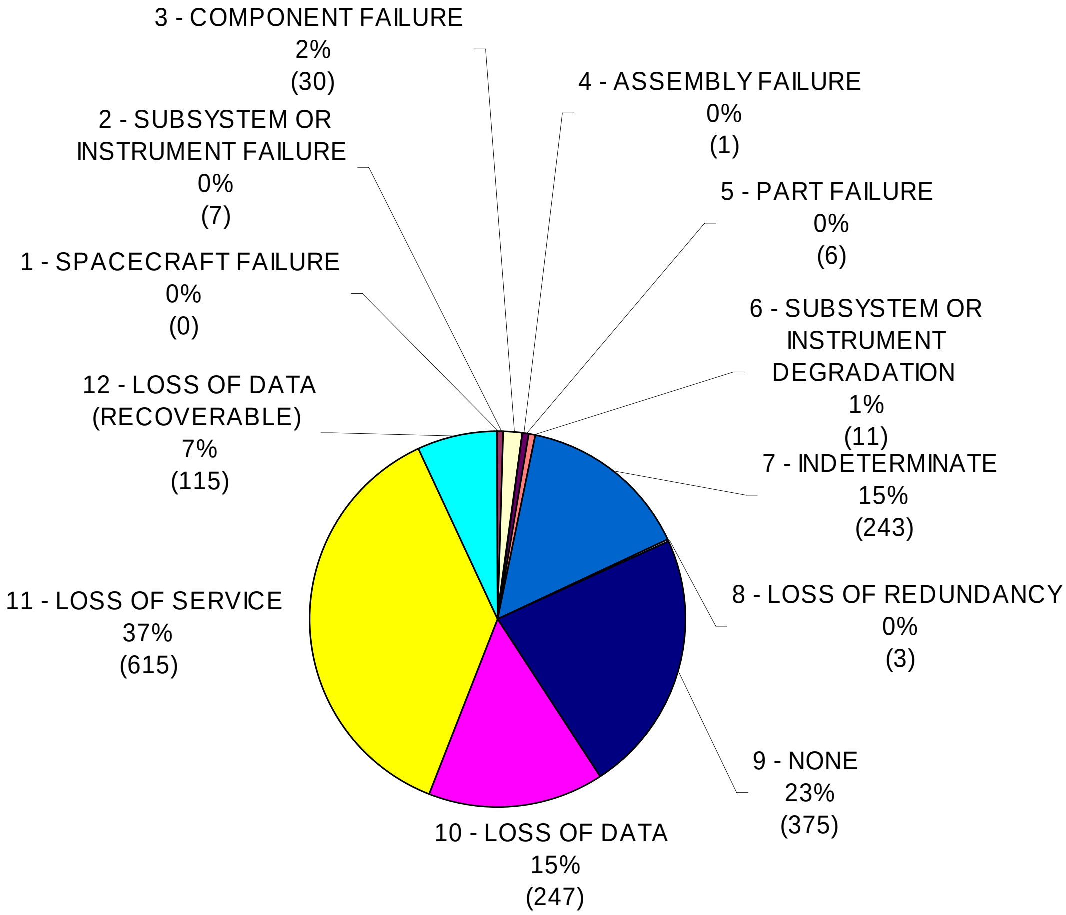


Figure 11. Anomaly Effect Percentages of FY 2003 Ground-Comm Anomalies

Table 11. FY 2003 Ground-Comm Anomaly Distribution by Anomaly Effect

Anomaly Effect / Spacecraft	1 – Spacecraft Failure	2 – Subsystem/ Instr. Failure	3 – Component Failure	4 – Assembly Failure	5 – Part Failure	6 – Subsystem/ Instr. Degrad.	7 – Indeterminate	8 – Loss of Redundancy	9 - None	10 – Loss of Data	11 – Loss of Service	12 – Loss of Data (Recov.)	Total Anomalies	% of Total Anomalies
ACE	0	5	12	1	3	5	33	1	23	4	7	5	99	6.0
AQUA	0	0	0	0	0	1	20	0	63	31	79	16	210	12.7
CHIPSAT	0	0	0	0	0	0	1	0	2	2	2	1	8	0.5
ERBS	0	0	0	0	0	0	9	0	11	17	36	7	80	4.8
EO1	0	0	0	0	0	0	5	0	15	3	19	5	47	2.8
FUSE	0	0	0	0	0	0	7	0	35	9	35	8	94	5.7
FAST	0	0	0	0	0	0	8	0	6	7	35	2	58	3.5
GALEX	0	0	0	0	0	0	12	0	31	16	56	14	129	7.8
GOES-10 (K)	0	0	0	0	0	0	2	0	4	2	14	0	22	1.3
GOES-12 (M)	0	0	0	0	0	0	0	0	0	0	1	0	1	0.1
GOES-11 (L)	0	0	0	0	0	0	1	0	1	0	0	0	2	0.1
GOES-8 (I)	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
GOES-9 (J)	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
HETE-II	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
HST	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
ICESAT	0	2	1	0	1	3	22	0	15	11	22	1	78	4.7
IMAGE	0	0	0	0	0	0	11	0	21	8	45	8	93	5.6
LANDSAT-5 (-D')	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
LANDSAT-7	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
NOAA-11 (-H)	0	0	0	0	0	0	14	0	11	6	9	2	42	2.5
NOAA-12 (-D)	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
NOAA-14 (-J)	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
NOAA-15 (K)	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
NOAA-16	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
NOAA-17 (M)	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
POLAR	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
QUIKSCAT	0	0	0	0	0	0	1	0	0	1	1	0	3	0.2
RHESSI	0	0	0	0	0	0	17	0	26	25	40	15	123	7.4
RXTE	0	0	0	0	0	0	5	0	7	9	3	1	25	1.5
SEASTAR/SEAWIFS	0	0	14	0	1	0	5	1	19	8	10	3	61	3.7
SOHO	0	0	0	0	0	0	6	0	12	8	3	7	36	2.2
SAMPEX	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
SORCE	0	0	3	0	0	2	2	0	5	9	11	1	33	2.0
SAGE	0	0	0	0	0	0	1	0	7	3	13	1	25	1.5
SNOE	0	0	0	0	0	0	0	0	0	1	1	0	2	0.1
SWAS	0	0	0	0	0	0	7	0	9	3	16	7	42	2.5
TDRS-I	0	0	0	0	0	0	3	0	4	4	11	3	25	1.5
TDRS-J	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
TERRA	0	0	0	0	0	0	1	0	1	0	1	0	3	0.2
TIMED	0	0	0	0	0	0	0	0	1	0	0	0	1	0.1
TOPEX	0	0	0	0	0	0	6	0	4	3	19	0	32	1.9
TOMS-EP	0	0	0	0	1	0	5	0	7	3	16	2	34	2.1
TDRS-1 (-A)	0	0	0	0	0	0	2	0	1	0	0	0	3	0.2
TDRS-3 (-C)	0	0	0	0	0	0	1	0	0	0	1	0	2	0.1
TDRS-6 (-F)	0	0	0	0	0	0	0	0	1	0	0	0	1	0.1
TDRS-7 (-G)	0	0	0	0	0	0	0	0	0	0	3	0	3	0.2
TRACE	0	0	0	0	0	0	15	1	11	11	19	3	60	3.6
TRMM	0	0	0	0	0	0	3	0	2	3	9	0	17	1.0
UARS	0	0	0	0	0	0	8	0	11	31	67	0	117	7.1
WIRE	0	0	0	0	0	0	6	0	6	8	11	3	34	2.1
WIND	0	0	0	0	0	0	4	0	3	1	0	0	8	0.5
WMAP	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Total for all Spacecraft	0	7	30	1	6	11	243	3	375	247	615	115	1653	100.0
% of Total Anomalies, all Spacecraft	0.0	0.4	1.8	0.1	0.4	0.7	14.7	0.2	22.7	14.9	37.2	7.0	100.0	

Anomalies Classified by Failure Category

Most ground anomalies (771 anomalies, or 47%) were classified as "unknown" failures. Operations problems were the second leading identified cause, with 371 (22%). Also significant were software problems, with 240 anomalies (15%). Figure 12 and Table 12 show Ground-Comm anomalies by failure category.

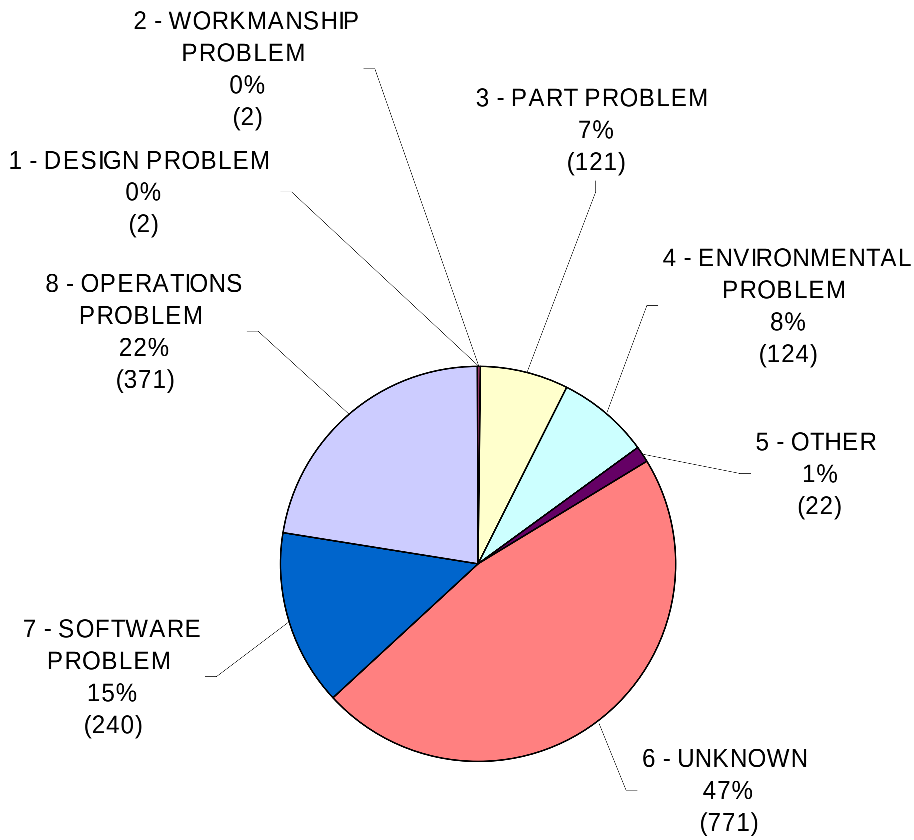


Figure 12. Failure Category Percentages of FY 2003 Ground-Comm Anomalies

Table 12. FY 2003 Ground-Comm Anomaly Distribution by Failure Category

Failure Category / Spacecraft	1 – Design Problem	2 – Workmanship Problem	3 – Part Problem	4 – Environmental Problem	5 - Other	6 - Unknown	7 – Software Problem	8 – Operations Problem	Total Anomalies	% of Total Anomalies
ACE	0	0	20	0	3	11	23	42	99	6.0
AQUA	0	1	11	35	4	97	38	24	210	12.7
CHIPSAT	0	0	0	1	0	6	0	1	8	0.5
ERBS	0	0	3	5	1	50	12	9	80	4.8
EO1	0	0	2	2	1	24	5	13	47	2.8
FUSE	1	0	3	14	4	44	11	17	94	5.7
FAST	0	0	8	1	0	39	3	7	58	3.5
GALEX	0	0	4	13	2	56	30	24	129	7.8
GOES-10 (K)	0	0	2	0	0	2	7	11	22	1.3
GOES-12 (M)	0	0	0	0	0	1	0	0	1	0.1
GOES-11 (L)	0	0	0	0	0	1	0	1	2	0.1
GOES-8 (I)	0	0	0	0	0	0	0	0	0	0.0
GOES-9 (J)	0	0	0	0	0	0	0	0	0	0.0
HETE-II	0	0	0	0	0	0	0	0	0	0.0
HST	0	0	0	0	0	0	0	0	0	0.0
ICESAT	0	0	9	5	0	38	16	10	78	4.7
IMAGE	0	0	4	7	2	44	10	26	93	5.6
LANDSAT-5 (-D')	0	0	0	0	0	0	0	0	0	0.0
LANDSAT-7	0	0	0	0	0	0	0	0	0	0.0
NOAA-11 (-H)	0	0	2	3	0	29	0	8	42	2.5
NOAA-12 (-D)	0	0	0	0	0	0	0	0	0	0.0
NOAA-14 (-J)	0	0	0	0	0	0	0	0	0	0.0
NOAA-15 (K)	0	0	0	0	0	0	0	0	0	0.0
NOAA-16	0	0	0	0	0	0	0	0	0	0.0
NOAA-17 (M)	0	0	0	0	0	0	0	0	0	0.0
POLAR	0	0	0	0	0	0	0	0	0	0.0
QUIKSCAT	0	0	0	1	0	2	0	0	3	0.2
RHESSI	0	0	15	6	1	71	14	16	123	7.4
RXTE	1	0	0	0	0	17	3	4	25	1.5
SEASTAR/SEAWIFS	0	0	17	4	1	8	5	26	61	3.7
SOHO	0	0	0	1	1	28	1	5	36	2.2
SAMPEX	0	0	0	0	0	0	0	0	0	0.0
SORCE	0	0	5	2	0	17	4	5	33	2.0
SAGE	0	0	1	4	0	7	2	11	25	1.5
SNOE	0	0	0	0	0	1	0	1	2	0.1
SWAS	0	1	0	1	1	27	4	8	42	2.5
TDRS-I	0	0	2	2	0	12	6	3	25	1.5
TDRS-J	0	0	0	0	0	0	0	0	0	0.0
TERRA	0	0	1	0	0	2	0	0	3	0.2
TIMED	0	0	0	0	0	1	0	0	1	0.1
TOPEX	0	0	2	1	0	16	9	4	32	1.9
TOMS-EP	0	0	3	3	1	17	4	6	34	2.1
TDRS-1 (-A)	0	0	0	1	0	2	0	0	3	0.2
TDRS-3 (-C)	0	0	0	2	0	0	0	0	2	0.1
TDRS-6 (-F)	0	0	1	0	0	0	0	0	1	0.1
TDRS-7 (-G)	0	0	0	1	0	1	0	1	3	0.2
TRACE	0	0	2	4	0	34	12	8	60	3.6
TRMM	0	0	2	0	0	7	6	2	17	1.0
UARS	0	0	2	4	0	33	9	69	117	7.1
WIRE	0	0	0	1	0	22	6	5	34	2.1
WIND	0	0	0	0	0	4	0	4	8	0.5
WMAP	0	0	0	0	0	0	0	0	0	0.0
Total for all Spacecraft	2	2	121	124	22	771	240	371	1653	100.0
% of Total Anomalies, all Spacecraft	0.1	0.1	7.3	7.5	1.3	46.6	14.5	22.4	100.0	

Anomalies Classified by Anomaly Type

The anomaly type for 721 (44%) Ground-Comm anomalies were indeterminate. Three hundred thirty (330, 20%) were random. Another 317 (19%) were operations errors. Figure 13 and Table 13 show data for Ground-Comm anomalies by type.

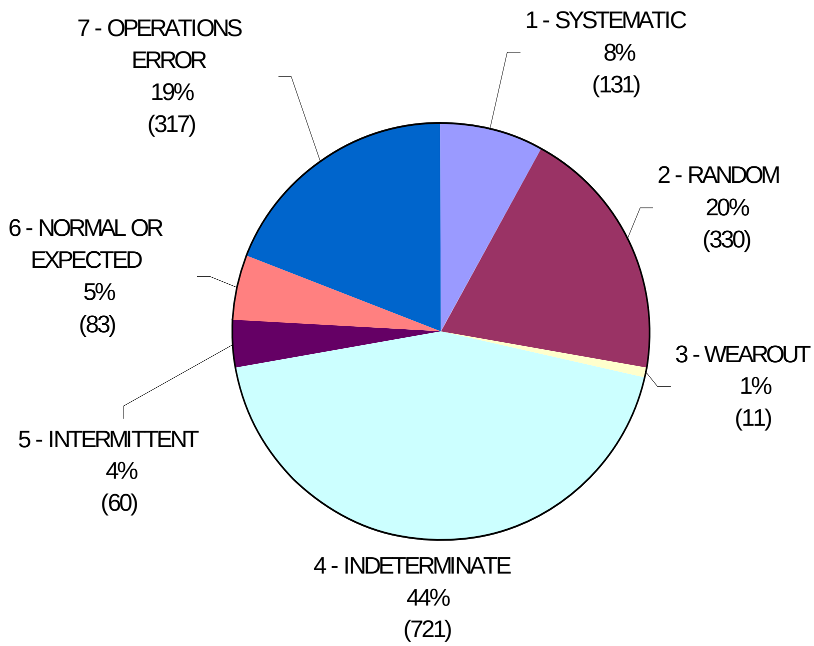


Figure 13. Anomaly Type Percentages of FY 2003 Ground-Comm Anomalies

Table 13. FY 2003 Ground-Comm Anomaly Distribution by Anomaly Type

Anomaly Type / Spacecraft	1 - Systematic	2 - Random	3 - Wearout	4 - Indeterminate	5 - Intermittent	6 – Normal/ Expected Operation	7 – Operations Error	Total Anomalies	% of Total Anomalies
ACE	45	7	3	18	6	2	18	99	6.0
AQUA	17	54	0	90	7	18	24	210	12.7
CHIPSAT	0	3	0	5	0	0	0	8	0.5
ERBS	3	16	0	47	2	2	10	80	4.8
EO1	1	7	0	24	1	1	13	47	2.8
FUSE	5	17	1	41	5	9	16	94	5.7
FAST	0	13	0	35	4	0	6	58	3.5
GALEX	7	28	0	56	3	14	21	129	7.8
GOES-10 (K)	3	4	0	2	2	0	11	22	1.3
GOES-12 (M)	0	0	0	0	0	0	1	1	0.1
GOES-11 (L)	0	0	0	1	0	0	1	2	0.1
GOES-8 (I)	0	0	0	0	0	0	0	0	0.0
GOES-9 (J)	0	0	0	0	0	0	0	0	0.0
HETE-II	0	0	0	0	0	0	0	0	0.0
HST	0	0	0	0	0	0	0	0	0.0
ICESAT	16	21	1	27	5	1	7	78	4.7
IMAGE	4	15	0	39	4	7	24	93	5.6
LANDSAT-5 (-D')	0	0	0	0	0	0	0	0	0.0
LANDSAT-7	0	0	0	0	0	0	0	0	0.0
NOAA-11 (-H)	0	2	0	30	1	2	7	42	2.5
NOAA-12 (-D)	0	0	0	0	0	0	0	0	0.0
NOAA-14 (-J)	0	0	0	0	0	0	0	0	0.0
NOAA-15 (K)	0	0	0	0	0	0	0	0	0.0
NOAA-16	0	0	0	0	0	0	0	0	0.0
NOAA-17 (M)	0	0	0	0	0	0	0	0	0.0
POLAR	0	0	0	0	0	0	0	0	0.0
QUIKSCAT	0	0	0	2	0	1	0	3	0.2
RHESSI	3	29	0	65	5	4	17	123	7.4
RXTE	0	3	1	16	1	0	4	25	1.5
SEASTAR/SEAWIFS	9	8	4	16	3	8	13	61	3.7
SOHO	1	5	0	24	1	0	5	36	2.2
SAMPEX	0	0	0	0	0	0	0	0	0.0
SORCE	1	6	0	17	1	4	4	33	2.0
SAGE	2	4	0	6	1	1	11	25	1.5
SNOE	0	1	0	0	0	1	0	2	0.1
SWAS	3	9	0	22	0	2	6	42	2.5
TDRS-I	4	6	0	13	0	0	2	25	1.5
TDRS-J	0	0	0	0	0	0	0	0	0.0
TERRA	0	2	0	1	0	0	0	3	0.2
TIMED	0	0	0	1	0	0	0	1	0.1
TOPEX	1	11	0	15	0	2	3	32	1.9
TOMS-EP	2	8	0	17	2	0	5	34	2.1
TDRS-1 (-A)	0	3	0	0	0	0	0	3	0.2
TDRS-3 (-C)	0	2	0	0	0	0	0	2	0.1
TDRS-6 (-F)	0	1	0	0	0	0	0	1	0.1
TDRS-7 (-G)	0	0	0	2	0	1	0	3	0.2
TRACE	1	16	1	29	3	2	8	60	3.6
TRMM	0	7	0	7	1	0	2	17	1.0
UARS	2	14	0	27	2	1	71	117	7.1
WIRE	1	8	0	21	0	0	4	34	2.1
WIND	0	0	0	5	0	0	3	8	0.5
WMAP	0	0	0	0	0	0	0	0	0.0
Total for all Spacecraft	131	330	11	721	60	83	317	1653	100.0
% of Total Anomalies, all Spacecraft	7.9	20.0	0.7	43.6	3.6	5.0	19.2	100.0	

GSFC Spacecraft Lifetime Data

Figures 16 through 24 illustrate the historical performance of GSFC spacecraft. The raw data is given in Appendix A - Spacecraft Lifetime Data, which contains a performance summary for all GSFC spacecraft from 1960 through September 2003. Five spacecraft were added in FY 2003: CHIPSAT, GALEX, ICESAT, SORCE, and TDRS-10.

Figure 14 and Figure 15 compare the actual years of service and the active on-orbit life (in years) with spacecraft designed lifetimes ("planned service") over five decades: 1960-1969, 1970-1979, 1980-1989, 1990-1999, and 2000-2003. For the first three decades, GSFC spacecraft average lifetimes ranged from 1.8 to 4.0 and 1.8 to 4.8 times the design life for their useful and active lives, respectively. Note that data from the 1990's and 2000's are incomplete since these spacecraft are still active and their useful and active lifetimes have not yet been established. Similarly the 1980-1989 data are incomplete, as are a few data points from the earlier decades, as some of these spacecraft still are operating.

Figure 16 and Figure 17 show the percentage of GSFC spacecraft attaining 3 years, 5 years, 7 years, and 10 years of useful life versus the year of launch. Early years showed fewer spacecraft attaining 3-year lifetimes, but these improved to 70 to 100 percent by the 1980's. Many of the early spacecraft were designed for only 0.25 to 1 year missions while modern spacecraft commonly are designed for 3 to 5 year missions.

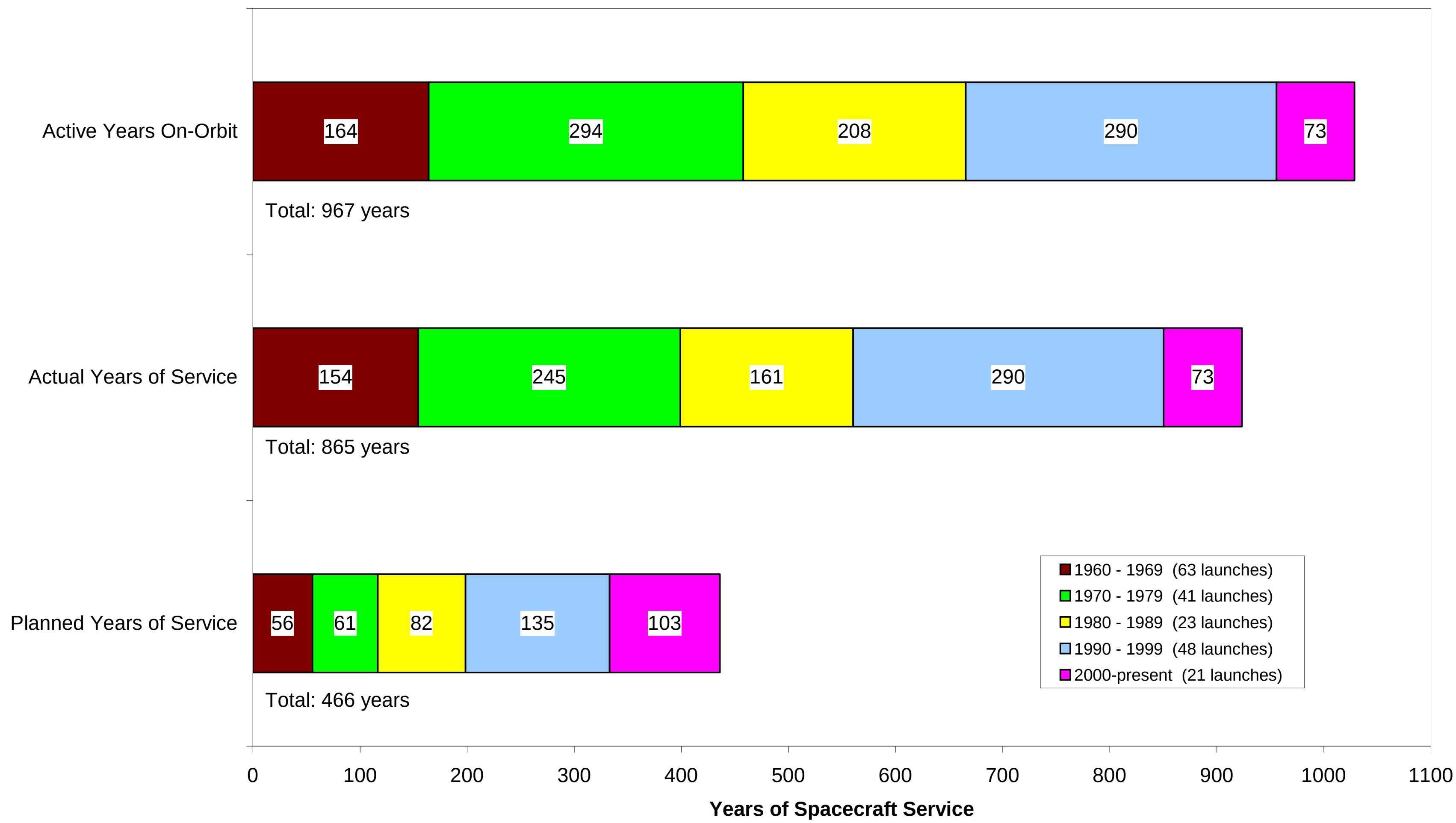


Figure 14. Goddard Spacecraft Longevity Through 2003

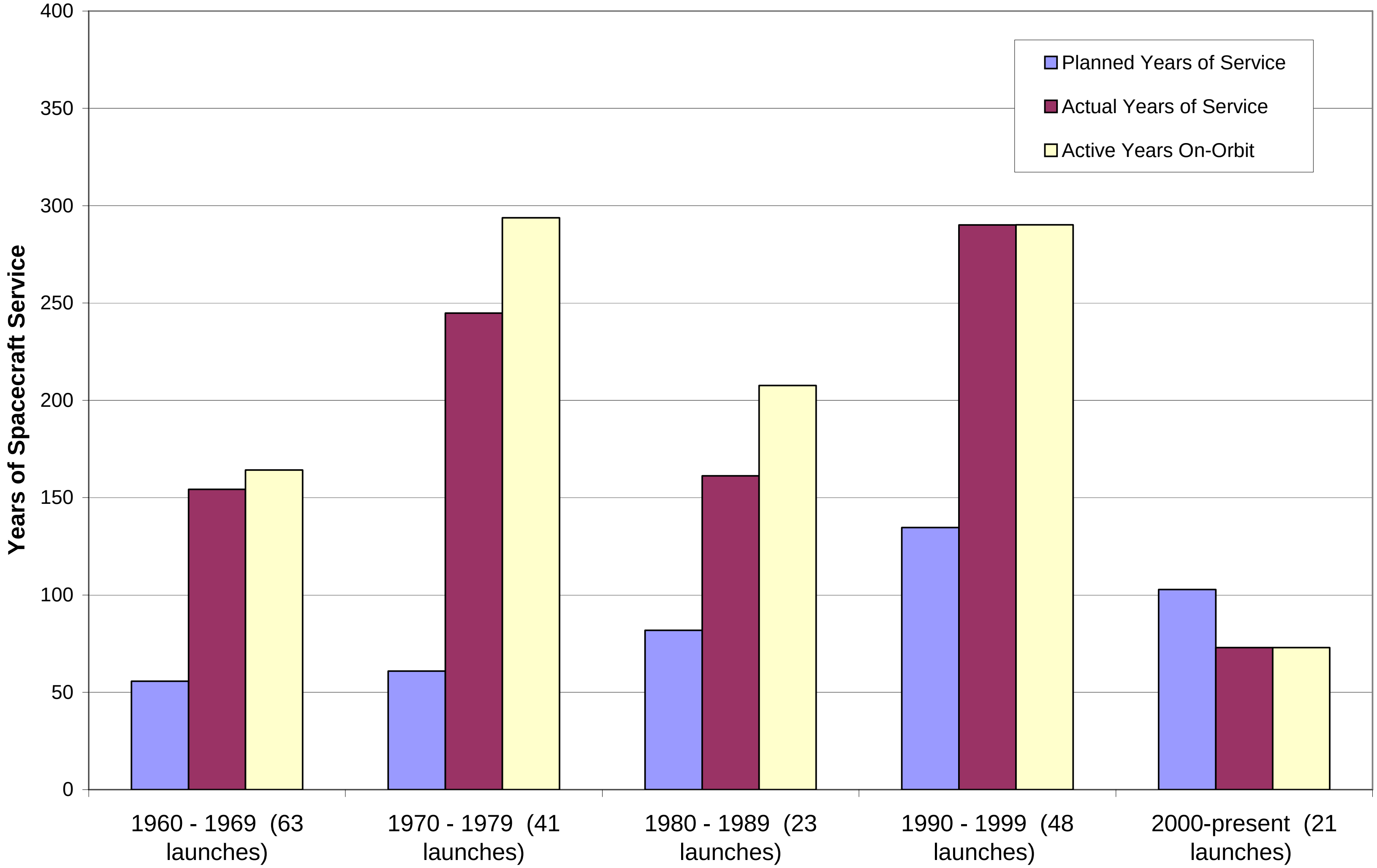


Figure 15. Goddard Spacecraft Longevity

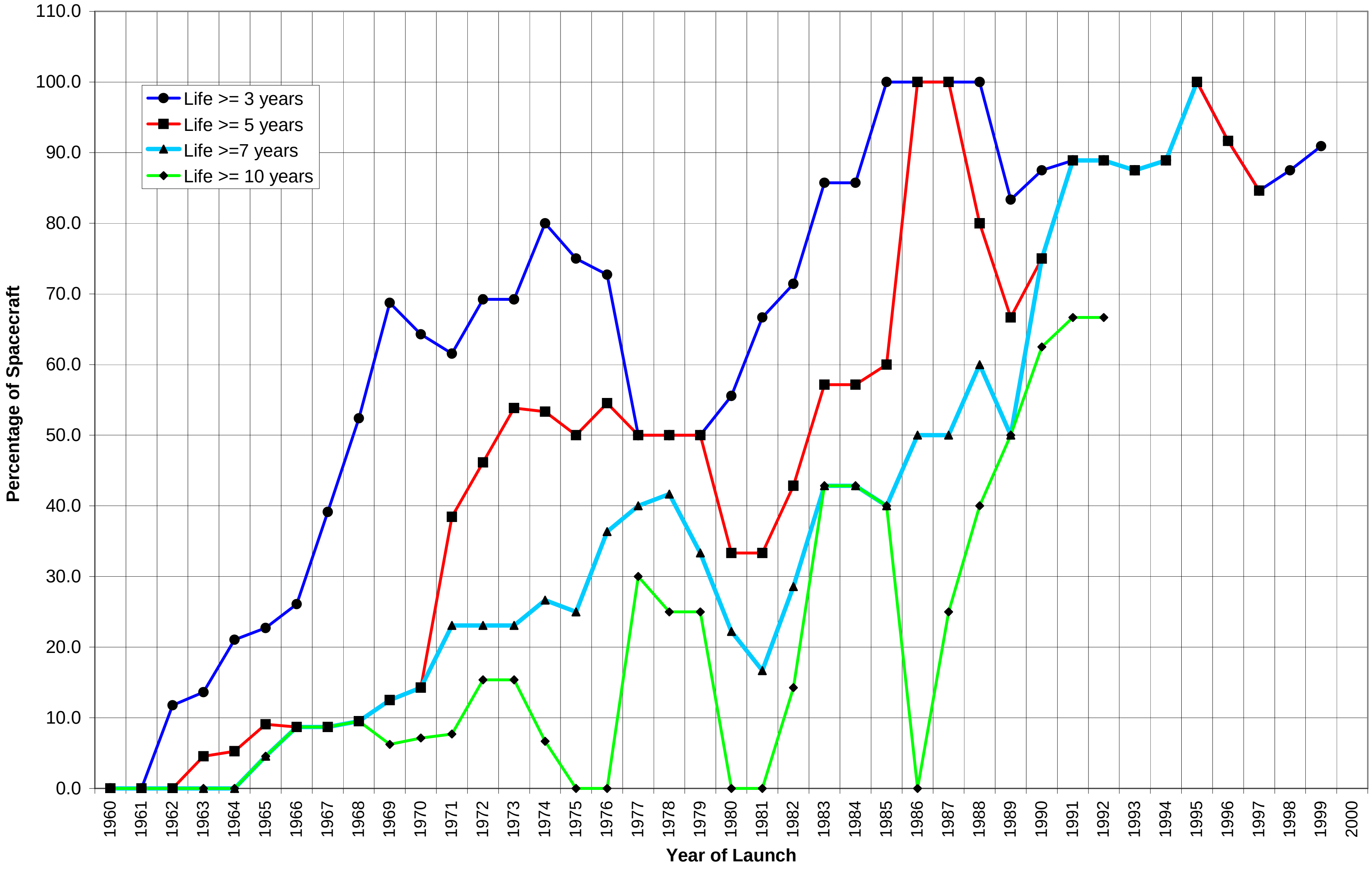


Figure 16. Success Rate for Achieving x Years of Useful Life On-orbit for GSFC Spacecraft (Three Year Moving Average) - excluding HST Servicing Missions and STS Payload Missions

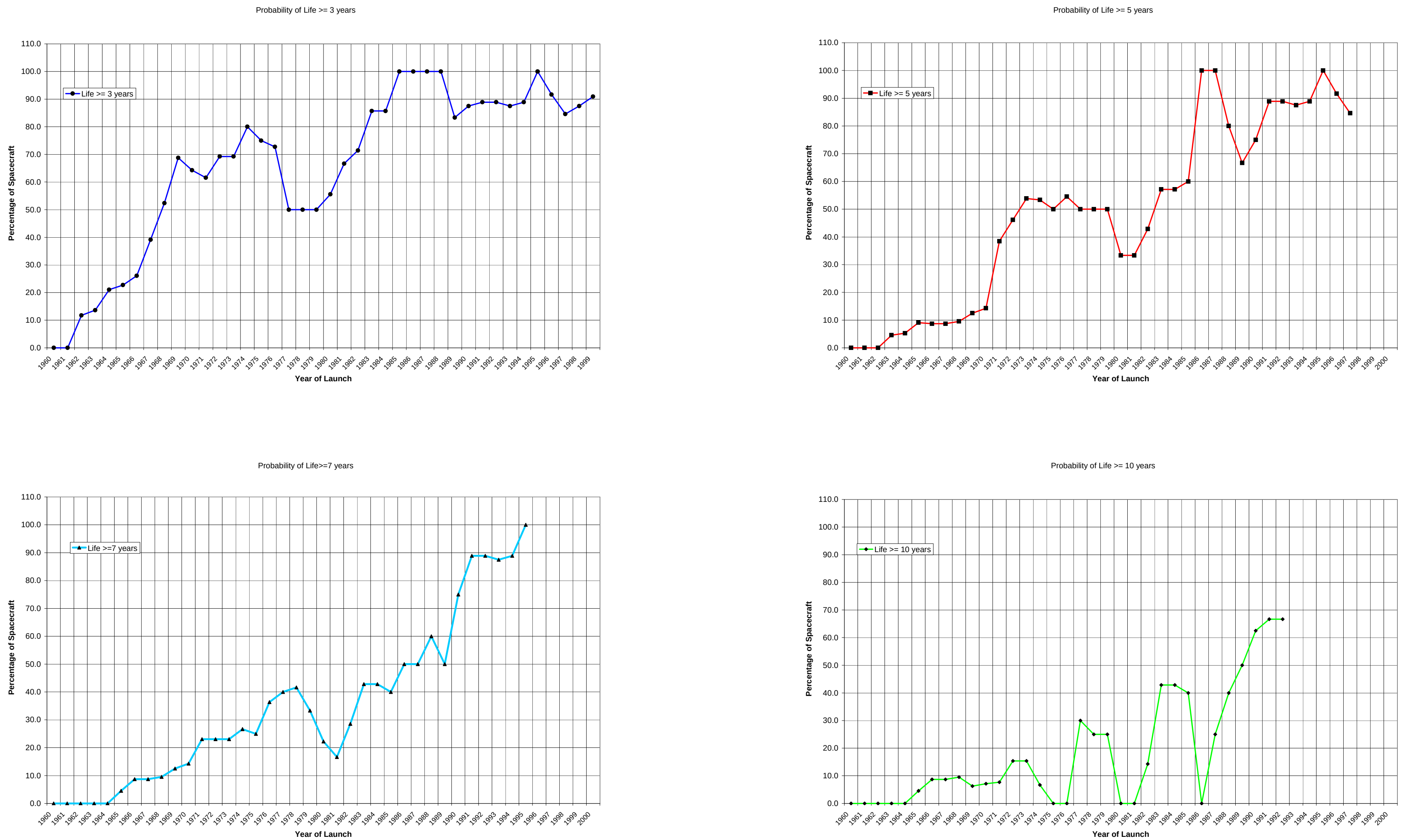


Figure 17. Success Rate for Achieving 3, 5, 7, and 10 Years of Useful Life On-orbit for GSFC Spacecraft (Three Year Moving Average) - excluding HST Servicing Missions and STS Payload Missions

Useful Life vs. Design Life

The following figures (Figure 18 through Figure 22) compare the design life and useful life of spacecraft by decade since the 1960's. These plots show active spacecraft, spacecraft no longer providing useful life, and spacecraft that failed immediately (less than 0.01 Useful Life/Design Life). Data that fall on or above the heavy dashed line (value 1 on the ordinate) indicate that the spacecraft has met or exceeded its design life. Conversely, data that fall below the value 1 on the ordinate indicate that the spacecraft has not or has not yet met its design life.

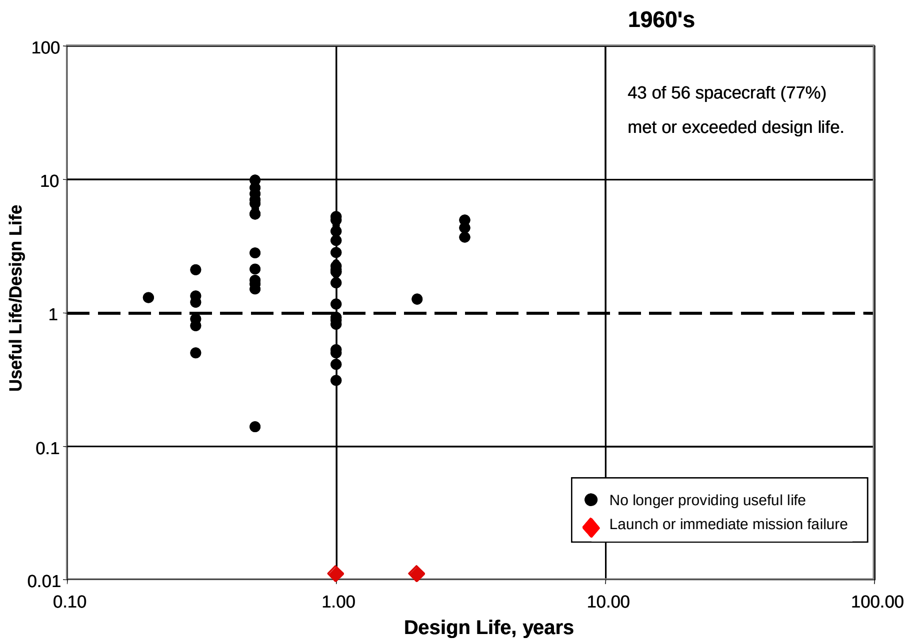


Figure 18. Useful Life/Design life for 1960's decade.

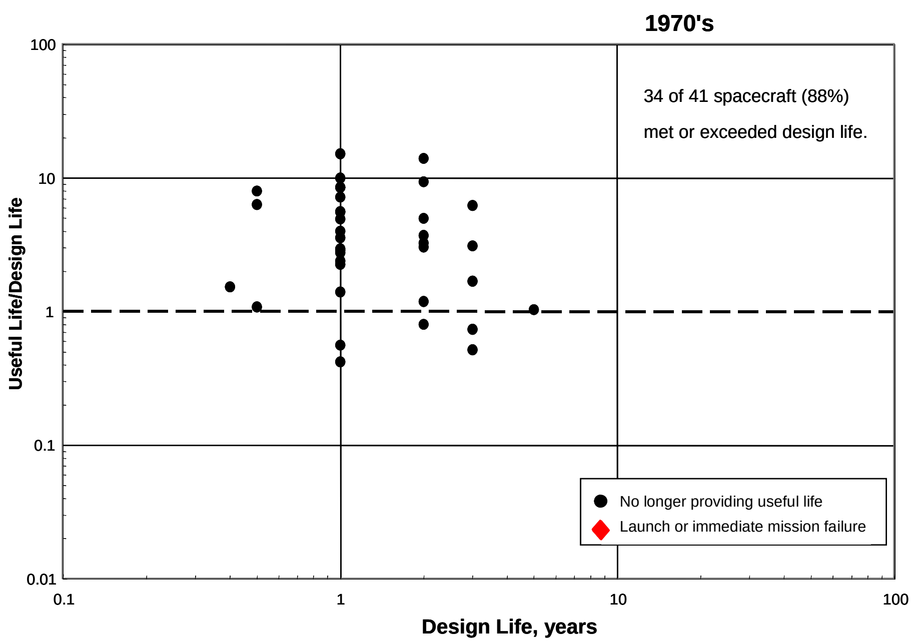


Figure 19. Useful Life/Design life for 1970's decade.

Figure 20. Useful Life/Design life for 1980's decade.

Figure 21. Useful Life/Design life for 1990's decade.

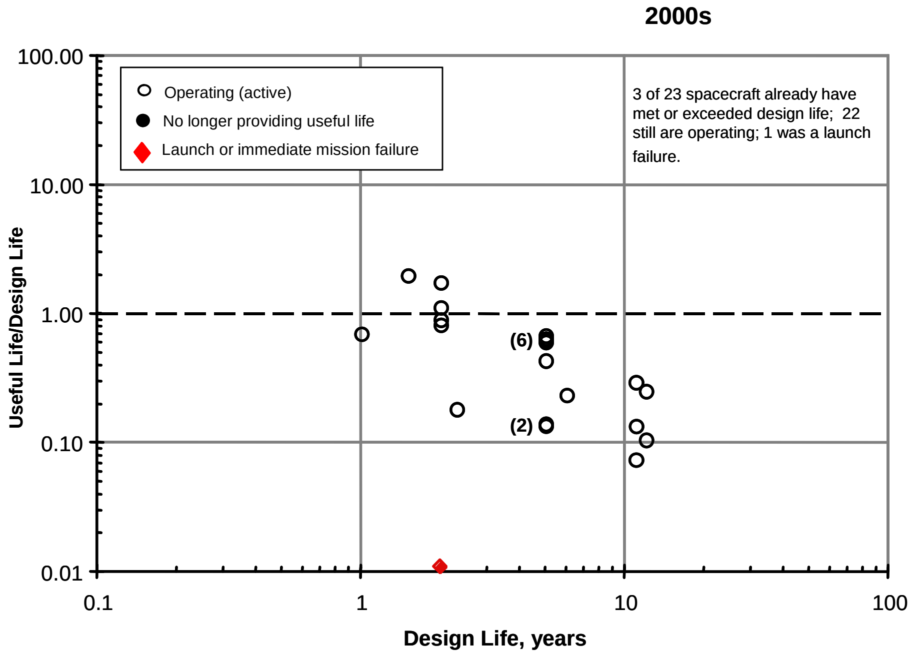
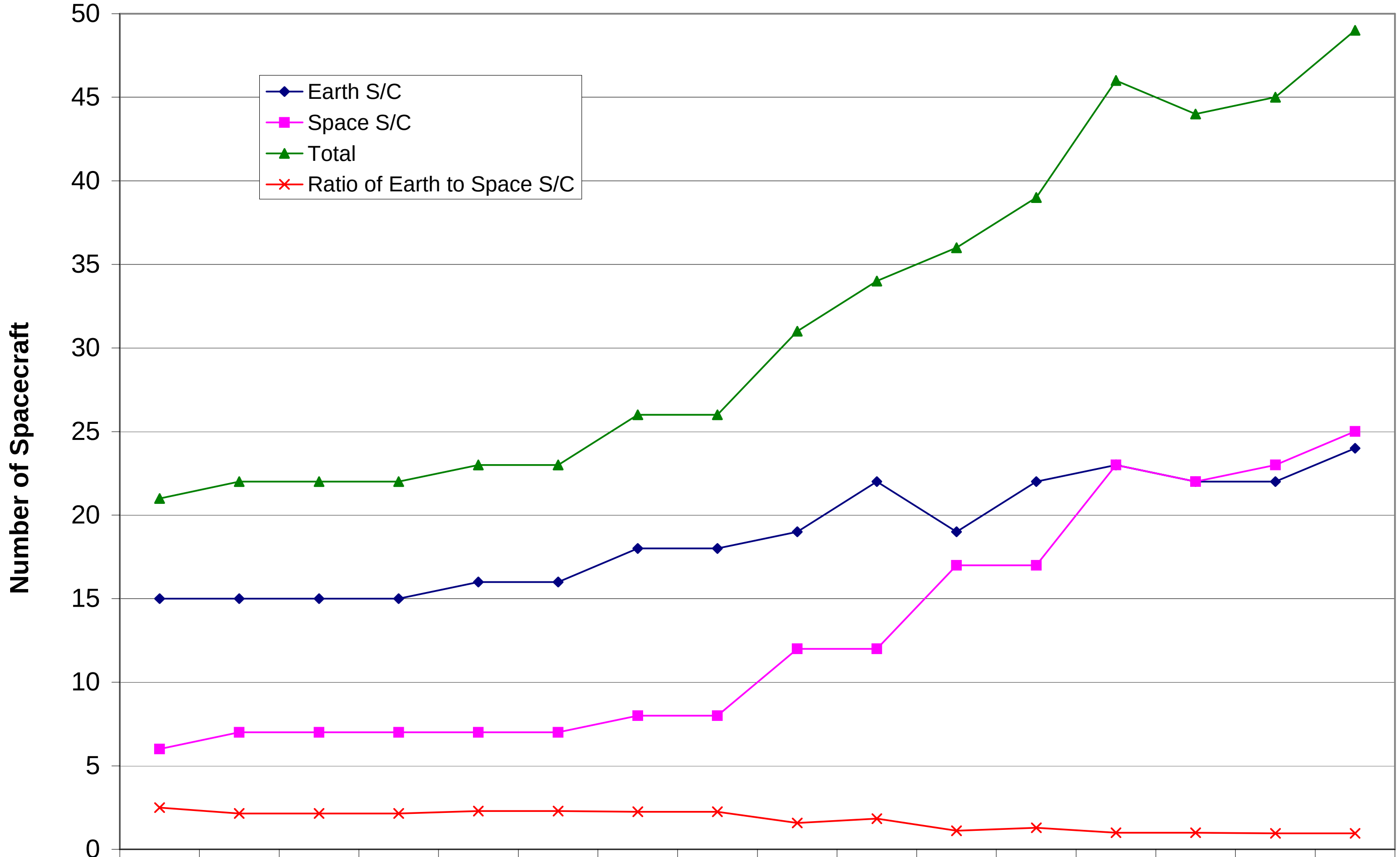


Figure 22. Useful Life/Design life for 2000's decade.

GSFC Spacecraft Data by Science Type (1988 – 1997)

This section provides a look at GSFC spacecraft performance by mission type (Earth or Space Science) over the past sixteen years. Earth Science missions study the earth, its environment and the processes affecting global change and the distribution of natural resources; that is, they look "inward" towards the Earth. Space Science missions study the solar system, the galaxy and the universe, looking "outward" from the Earth.

Figure 23 provides summaries of the total number of operating spacecraft from 1988 to 2003 by Earth and Space Science and the Earth to Space Science spacecraft ratio by year. Over the sixteen-year period, GSFC has launched about twice as many Earth Science Spacecraft as Space Science Spacecraft.



	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Earth S/C	15	15	15	15	16	16	18	18	19	22	19	22	23	22	22	24
Space S/C	6	7	7	7	7	7	8	8	12	12	17	17	23	22	23	25
Total	21	22	22	22	23	23	26	26	31	34	36	39	46	44	45	49
Ratio of Earth to Space S/C	2.5	2.1	2.1	2.1	2.3	2.3	2.3	2.3	1.6	1.8	1.1	1.3	1.0	1.0	1.0	1.0

Years

Figure 23. Number of Operating Spacecraft by Science Type and Years (1988-2003)

Acronyms and Abbreviations

ABBREVIATION	MEANING
ACE	Advanced Composition Explorer
ACS	Advanced Camera for Surveys
ACS	Attitude Control Subsystem
AIRS	Atmospheric Infrared Sounder
AMSR-E	Advanced Microwave Scanning Radiometer for EOS
AMSU-A	Advanced Microwave Sounding Unit
AR&C	Automated Rendezvous and Capture
AVHRR	Advanced Very High Resolution Radiometer
BATSE	Burst and Transient Source Experiment
CCR	Cloud Cover Radiometer
CDHF	Central Data Handling Facility
CERES	Clouds and the Earth's Radiant Energy System
CGRO	Compton Gamma-Ray Observatory
CHIPSat	Cosmic Hot Interstellar Plasma Spectrometer Satellite
CLAES	Cryogenic Limb Array Etalon Spectrometer
CNES	(French) Centre National d Etudes Spatiales
COMPTEL	Imaging Compton Telescope
COSTAR	Corrective Optics Space Telescope Axial Replacement
CPU	Central Processing Unit
DPU	Digital Processing Unit
DSN	Deep Space Network
EGRET	Energetic Gamma-Ray Experiment Telescope
EOC	Earth Observation Center
EOS	Earth Observing System
ERBE	Earth Radiation Budget Experiment
ERBS	Earth Radiation Budget Satellite
ESA	European Space Agency
ETM+	Enhanced Thematic Mapper +
EUVE	Extreme Ultraviolet Explorer
FAST	Fast Auroral Snapshot Explorer
FGS	Fine Guidance Sensor
FOC	Faint Object Camera
FOS	Faint Object Spectrograph
FOT	Flight Operations Team
FRU	frequency reference unit
FUSE	Far Ultraviolet Spectroscopic Explorer
GADACS	Global Positioning System Attitude Determination and Control Experiment
GALEX	Galaxy Evolution Explorer
GGS	Global Geospace Science
GHRS	Goddard High Resolution Spectrograph
GIR	Goes Incident Report
GLAS	Geoscience Laser Altimeter System

ABBREVIATION	MEANING
GOES	Geostationary Operational Environment Satellite
GPSDR	GPS demonstration receiver
GRB	gamma-ray burst
GSFC	Goddard Space Flight Center
GT	Geomagnetic Tail
HAO	High Altitude Observatory
HETE	High Energy Transient Explorer
HOST	HST Orbital Systems Test
HSB	Humidity Sounder for Brazil
HST	Hubble Space Telescope
IAE	Inflatable Antenna Experiment
ICE	International Cometary Explorer
ICESat	Ice, Cloud, and land Elevation Satellite
IMAGE	Imager for Magnetopause-to-Aurora Global Exploration
IMP	Interplanetary Monitoring Platform
ISAMS	Improved Stratospheric and Mesospheric Sounder
ISAS	Japanese Institute of Space and Astronautical Science
ISTP	International Solar-Terrestrial Physics
IUE	International Ultraviolet Explorer
JPL	Jet Propulsion Laboratory
LEICA	Low Energy Ion Composition Analyzer
LIS	Lightning Imaging Sensor
LRA	laser retroreflector array
MCP	Microchannel Plate
MFI	Magnetic Field Instrument
MIDEX	Medium-class Explorer
MODIS	Moderate-Resolution Imaging Spectroradiometer
MSFC	Marshall Space Flight Center
MSU	Microwave Sounding Unit
MTPE	Mission to Planet Earth
NASA	National Aeronautical and Space Administration
NASDA	National Space Development Agency of Japan
NICMOS	Near Infrared Camera and Multi-Object Spectrometer
NOAA	National Oceanic and Atmospheric Administration
NSCAT	NASA Scatterometer
NWS	National Weather Service
OAGS	Orbital Anomalies in Goddard Spacecraft
OAST	Office of Aeronautics and Space Technology
OBC	On Board Computer
OSSE	Oriented Scintillation Spectrometer Experiment
PR	Precipitation Radar
QuikSCAT	Quick Scatterometer
RCS	Reaction Control System
REFLEX	Return Flux Experiment
RHESSI	Ramaty High-Energy Solar Spectroscopic Imager

ABBREVIATION	MEANING
RPP	Recorder Packet Processor
RSA	Russian Space Agency
SADE	Solar Array Drive Electronics
SAGE III	Stratospheric Aerosol and Gas Experiment III
SAMPEX	Solar Anomalous and Magnetospheric Particle Explorer
SAO	Smithsonian Astrophysical Observatory
SBH	Steinberg Experiment
SBUV	Solar Backscatter Ultraviolet Radiometer
SeaWiFS	Sea-viewing Wide Field-of-view Sensor
SELODE	Solar Exposure to Laser Ordnance Device
SEU	Single Event Upset
SFSS	Spartan Flight Support Structure
SIM	Spectral Irradiance Monitor
SMEX	Small-Class Explorer
SMS	SWICS/MASS/STICS
SNOE	Student Nitric Oxide Explorer
SOAR	Spacecraft Orbital Anomaly Report
SOARS	Spacecraft Orbital Anomaly Reporting System
SOHO	Solar and Heliospheric Observatory
SOLSTICE	Solar Stellar Irradiance Comparison Experiment
SORCE	Solar Radiation and Climate Experiment
SSALT	solid-state radar altimeter
SSU	Stratospheric Sounding Unit
STEDI	Student Explorer Demonstration Initiative
STIS	Space Telescope Imaging Spectrograph
STP	Solar Terrestrial Probes
STSP	Solar Terrestrial Science Programme
SWAS	Submillimeter Wave Astronomy Satellite
SWE	Solar Wind Experiment
SWICS	Solar Wind Ion Composition Spectrometer
TC & C	Timing, Control & Command
TDRS	Tracking and Data Relay Satellite
TEAMS	Technology Experiments for Advancing Missions in Space
TIM	Total Irradiance Monitor
TIMED	Thermosphere Ionosphere Mesosphere Energetics and Dynamics
TIROS	Television Infrared Observing System
TLM & DH	Telemetry & Data Handling
TMI	TRMM Microwave Imager
TOMS-EP	Total Ozone Mapping Spectrometer - Earth Probe
TOPEX	Ocean Topography Experiment
TRACE	Transition Region and Coronal Explorer
TRMM	Tropical Rainfall Measuring Mission
TSI	total solar irradiance
UARS	Upper Atmosphere Research Satellite
UNEX	University-Class Explorer

ABBREVIATION	MEANING
USRA	Universities Space Research Association
UV	Ultraviolet
UVCS	Ultraviolet Coronal Spectrometer
VAM	Variable Access Memory
VGS	Video Guidance Sensor
VHF	Very High Frequency
VIRS	Visible Infrared Scanner
WFPC	Wide Field/Planetary Camera
WIRE	Wide Field Infrared Explorer
WLC	White Line Coronagraph
WMAP	Wilkinson Microwave Anisotropy Probe
XPS	XUV Photometer System
XTE	X-Ray Timing Explorer
ZAP	Z-Axis Precession

Appendix A - Spacecraft Lifetime Data

In the following table, "useful life" is the time major mission objectives were accomplished successfully. Active life is the total lifetime the satellite remained in service. Design, useful life and active lives are given in years. A blank space means information was not available. This chart is current through September 30, 2003.

Spacecraft	Launch Date	Design Life	Useful Life	Active Life	Remarks
TIROS	4/1/1960	0.3	0.24	0.24	TV system useful for 77 days.
Explorer VIII (S-30)	11/3/1960	0.3	0.15	0.15	Last transmission 12/28/60.
TIROS-II	11/23/1960	0.3	0.63	1.03	TV data useful to 07/12/61.
Explorer XI (S-15)	4/27/1961		0.61	0.61	Last transmission 12/7/61.
TIROS-III	7/12/1961	0.3	0.4	0.63	TV data useful to 12/04/61. Lost tape recorders.
Explorer XII (S-3)	8/15/1961	1.0	0.31	0.31	Transmission ceased abruptly.
TIROS-IV	2/8/1962	0.3	0.36	0.44	TV useful to 06/09/62. Lost tape recorders.
OSO-I	3/7/1962	0.5	1.4	1.4	Lost tape recorder @ 2 months. Starfish incident degraded power system.
Ariel-I (S-51)	4/26/1962	1.0	0.88	0.88	Degraded by Starfish incident of 07/09/62.
TIROS-V	6/19/1962	0.5	0.88	0.88	TV useful to 05/04/63. Camera filaments failed.
TIROS-VI	9/18/1962	0.5	1.06	1.06	TV useful to 10/11/63. Filaments and focus out.
Explorer XIV (S-3a)	10/2/1962		0.85	1.2	Last transmission 02/17/64.
Explorer XV (S-3b)	10/27/1962	0.2	0.26	0.55	Despin system failed. Last transmission 05/19/63.
Relay I	12/13/1962	2.0	2.53	2.53	
Syncom I	2/14/1963	2.0	0	0	Lost power: mission failure.
Explorer XVII (S-6)	4/3/1963	0.3	0.27	0.27	Batteries degraded: no solar array.
TIROS-VII	6/19/1963	0.5	4.33	4.96	Deactivated: camera focus out 12/65.
Syncom II	7/26/1963	2.0			Operations turned over to Department of Defense 1 Jan 1965
IMP-A	11/26/1963	1.0	0.82		Abandoned 5/10/1965
TIROS-VIII	12/21/1963	0.5	3.53	3.53	Deactivated.
Relay II	1/21/1964	1.0	1.68	3.5	
Ariel-II (S-52)	3/27/1964	1.0	0.53		Had spin rate and attitude control problems.
Syncom III	8/19/1964	3.0			Operations turned over to Department of Defense 1 Jan 1965
Explorer XX (S-48)	8/25/1964		1.6	1.6	Based on last transmission 03/30/66.
Nimbus-I	8/28/1964	0.5	0.07	0.07	Solar array drive failed.
OGO-1(A)	9/4/1964	1.0	5.23	5.23	Mission failure: 3-axis stabilization not achieved.

Spacecraft	Launch Date	Design Life	Useful Life	Active Life	Remarks
IMP-B	10/3/1964	1.0	0.5	1.25	Reentered: placed in wrong orbit.
Explorer XXVI (S-3c)	12/21/1964	1.0	2.1	2.1	Last transmission 01/21/67.
TIROS-IX	1/22/1965	0.5	2.73	3.4	Deactivated: camera contrast out 10/66.
OSO-II	2/3/1965	0.5	0.75	0.75	Used up control gas.
IMP-1(C)	5/29/1965	1.0	1.92	1.92	Reentered.
TIROS-X	7/2/1965	1.0	1.16	2	Deactivated.
OGO-2(C)	10/14/1965	1.0	3.48		Mission failure: horizon scanners did not maintain earth lock.
ESSA-I	2/3/1966	1.0	2.36	2.36	Deactivated.
ESSA-II	2/28/1966	1.0	4.64	4.64	Deactivated.
OAO-I	4/8/1966	1.0	0	0	Mission failure: lost power.
Nimbus-II	5/16/1966	0.5	2.67	2.67	ACS scanner failed.
AE-B	5/25/1966	0.5	0.82	0.82	Higher than planned orbit. Two sensors did not work.
OGO-3(B)	6/6/1966	1.0	2.04	3.5	Boom oscillation problem.
AIMP-2(D)	7/1/1966	0.5	4.92	5.22	Failed to achieve lunar orbit.
ESSA-III	10/2/1966	1.0	2.02	2.02	Deactivated: cameras failed.
ATS-I	12/6/1966	3.0	12.99	16.74	Gas expended: limited service. Used as communications satellite until 1983
ESSA-IV	1/26/1967	1.0	0.41	1.27	Deactivated: one camera failed, one degraded.
OSO-III	3/8/1967	0.5	3	3	Tape recorder failure at 18 months. ACS controlled manually.
ESSA-V	4/20/1967	1.0	2.83	2.83	Deactivated: IR failed, cameras gradually degraded.
IMP-3(F)	5/24/1967	1.0	1.95	1.95	Reentered.
AIMP-4(E)	7/19/1967		3.5	3.5	Lunar orbit. Subsequent period of intermittent operation.
OGO-4(D)	7/28/1967	1.0	2.24	2.75	Thermal bending of antenna caused stabilization control problem.
OSO-IV	10/18/1967	0.5	0.9		Tape recorder failure at 6 months.
ATS-III	11/5/1967	3.0	11.07	11.07	Instruments no longer in use.
ESSA-VI	11/10/1967	1.0	2.09	2.09	Deactivated: cameras degraded.
OGO-5(E)	3/4/1968	1.0	3.6	3.6	Deactivated: data glut.
RAE-A	7/4/1968	1.0	4.5	4.5	Deactivated: data quality had become marginal.
ESSA-VII	8/16/1968	1.0	0.92	1.56	Deactivated: early camera and tape recorder failures.
OAO-II	12/7/1968	1.0	4.2	4.2	Prime instrument (WEP) failed.
ESSA-VIII	12/15/1968	1.0	4.95	6.75	Deactivated: camera problems.

Spacecraft	Launch Date	Design Life	Useful Life	Active Life	Remarks
OSO-V	1/22/1969	0.5	3.9	3.9	
ESSA-IX	2/26/1969	1.0	4.1	4.1	Deactivated: standby after 04/71.
Nimbus-3	4/19/1969	0.5	2.76	2.76	ACS Scanner failed 01/72.
OGO-6 (F)	6/5/1969	1.0	2.06	2.25	Deactivated: data glut.
IMP-5(G)	6/21/1969		3.51	3.51	Reentered.
OSO-VI	8/9/1969	0.5	3.3	3.3	Deactivated 12/71
ATS V	8/12/1969	3.0	14.84	14.84	Mission officially unsuccessful: stabilization not achieved. Deorbited 03/20/84.
TIROS-M	1/23/1970	1.0	1.4	1.4	Momentum wheel assembly failed.
Nimbus-4	4/8/1970	1.0	10	10	Deactivated.
NOAA-1 (ITOS-A)	12/11/1970	1.0	0.56	0.75	Deactivated: momentum wheel assembly problems.
SAS-A	12/12/1970	0.5	4	4	Transmitter failure: terminated mission.
IMP-6(I)	3/13/1971	1.0	3.56	3.56	Reentered.
OSO-VII	9/29/1971	0.5	3.17	3.17	Reentered due to bad orbit.
SSS-A	11/15/1971	1.0	2.87	2.87	Deactivated: battery unusable, *as expected*, after one year.
Landsat-1 (ERTS-A)	7/23/1972	1.0	5.58	5.58	Deactivated: funding withdrawn.
OAO-C	8/21/1972	1.0	8.5	8.5	Deactivated: funding withdrawn.
IMP-7(H)	9/22/1972	2.0	6.1	6.1	Power system failed.
NOAA-2 (ITOS-D)	10/15/1972	1.0	2.25	2.4	Standby after 03/74. Some experiments failed.
SAS-B	11/16/1972	0.5	0.54	0.54	Experiment low voltage power supply failed.
Nimbus-5	12/12/1972	1.0	10.3	10.3	Second HDRSS failed 07/27/82. Deactivated 03/31/83.
RAE-B	6/10/1973	1.0	3.75	3.75	Deactivated: mission objectives achieved.
IMP-8(J)	10/25/1973	2.0	27.93	27.93	Out of service October 2001 due to fund saving.
NOAA-3 (ITOS-F)	11/6/1973	1.0	2.84	2.84	Deactivated: radiometer, VTPR, VHRR out.
AE-C	12/16/1973	1.0	5	5	Reentered.
SMS-1	5/17/1974	2.0	1.6	6.7	Standby after 01/76. Deactivated 01/31/81.
ATS-6(F)	5/30/1974	5.0	5.17	5.17	Deactivated.
NOAA-4 (ITOS-G)	11/15/1974	1.0	4	4	Deactivated: radiometer, VHRR out.
Landsat-2	1/22/1975	1.0	8.51	8.51	Yaw flywheel stopped 11/79, recovered 05/80. Deactivated 07/27/83.
SMS-2(B)	2/6/1975	2.0	6.5	7.5	Second encoder failed on 08/05/81.
SAS-C	5/7/1975	1.0	4.92	4.92	Reentered.

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Spacecraft	Launch Date	Design Life	Useful Life	Active Life	Remarks
Nimbus-6(F)	6/12/1975	1.0	7.18	8.28	Yaw flywheel failed 08/14/82.
OSO-8(I)	6/21/1975	1.0	3.4	3.4	Funding withdrawn.
AE-D	10/6/1975	1.0	0.42	0.42	Shorted diode in power supply electronics.
GOES-1(A)	10/16/1975	3.0	9.3	9.4	VISSR failed 02/85.
AE-E	11/20/1975	1.0	5.56	5.56	Reentered 06/10/81.
NOAA-5 (ITOS-H)	7/29/1976	1.0	2.96	2.96	Failed 07/79.
GOES-2 (B)	6/16/1977	3.0	1.55	17.54	VISSR failed 01/79, batteries degraded; made semi-operational as WEST DCS spacecraft 09/92. Deactivated 06/99
ISEE-1(A)	10/22/1977	2.0	9.93	9.93	Spacecraft reentered 09/26/87.
IUE	1/26/1978	3.0	18.68	18.68	Deactivated 9/30/96
Landsat-3(C)	3/5/1978	3.0	5.07	5.51	Problems with MSS instrument.
AEM-A (HCMM)	4/26/1978	1.0	2.4	2.4	Deactivated: battery degraded 09/14/80.
GOES-3(C)	6/17/1978	3.0	2.21	25.5	VISSR degraded 09/80 & failed 05/06/81. Spacecraft to standby 04/28/87. PEACESAT, only for S-band communication 04/90.
ISEE-3 (C) [ICE]	8/12/1978	2.0	18.73	18.73	Deactivated May 1997
TIROS-N	10/13/1978	2.0	2.38	2.38	ACS failed 02/27/81.
Nimbus-7(G)	10/24/1978	1.0	15.18	15.46	Ceased its science mission 12/93: spacecraft degraded. Lost spacecraft acquisition 04/94.
AEM-B (SAGE)	2/18/1979	1.0	2.75	2.75	Battery degraded: failed 11/18/81.
NOAA-6(A)	6/27/1979	2.0	7.39	7.75	Spacecraft turned off 03/31/87.
Magsat	10/30/1979	0.4	0.61	0.61	Reentered as planned 06/11/80.
SMM*	2/14/1980	2.0	0.83+5.62	9.78	Lost fine pointing control 12/12/80: repaired. Mission terminated 11/24/89; reentered 12/02/89.
GOES-4(D)	9/9/1980	7.0	2.21	6.66	VAS failed 11/25/82.
GOES-5(E)	5/22/1981	7.0	3.19	9.2	VAS failed 07/30/84. Loss of station keeping 12/89. Deactivated 07/18/90: out of fuel.
NOAA-7(C)	6/23/1981	2.0	3.62	4.92	Failed HIRS, degraded SSU, disabled power system.
DE-1(A)	8/3/1981	1.0	9.57	9.57	Mission terminated 02/28/91: can't command spacecraft.
DE-2(B)	8/3/1981	1.0	1.54	1.54	Reentered as expected 02/19/83.
OSS-1	3/22/1982				Shuttle attached payload mission.
Landsat-4(D)	7/16/1982	3.0			***No longer monitored nor reported herein. (Deactivated June 2001)***
NOAA-8(E)	3/28/1983	2.0	1.25	1.25	Failed 07/01/84. Recovered 05/85. Failed again 01/86.

* Repaired by STS 41-C crew on April 12, 1984

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Spacecraft	Launch Date	Design Life	Useful Life	Active Life	Remarks
TDRS-1(A) **	4/4/1983	10.0	***ACTIVE***	***ACTIVE***	Some loss of capability. Activated in 1993 for GRO data via Australia. Provides part time coverage of Antarctica to support NSF
GOES-6(F)	4/28/1983	7.0	5.73	25.5	VAS imager failed January 21, 1989 so direct readout images and soundings are no longer available. Still acting as the west WEFAX relay satellite, although orbit is unstable.
Landsat-5(D)	3/1/1984	3.0			***No longer monitored nor reported herein.***
SPARTAN-1	6/20/1984				STS attached payload mission.
AMPTE/CCE	8/16/1984	1.0	4.92	4.92	Some solar array degradation. Mission terminated 07/14/89.
ERBS	10/5/1984	2.0	***ACTIVE***	***ACTIVE***	All gyros except IRU-I/Z failed. ERBE-S failed 02/90. Battery #1 disconnected 08/92 (2 shorted cells). Battery #2 lost 2 cells 06/07/93. ERBE-NS is temporarily off.
NOAA-9(F)	12/12/1984	2.0	3.92	***ACTIVE***	MSU & ERBE-S failure. Into standby 11/08/88.
SPOC/HITCHHIKER	1/12/1986				STS attached payload mission.
NOAA-10(G)	9/17/1986	2.0	***ACTIVE***	***ACTIVE***	Array shunts degraded. ERBE-S & SARP failed. Roll gyro failed. AVHRR degraded 11/92: in standby ops.
GOES-7(H)	2/26/1987	7.0	***ACTIVE***	***ACTIVE***	Moved to 175 degrees W to support PEACESAT
NOAA-11 (-H)	9/24/1988	2.0	6.44	***ACTIVE***	Y-Gyro & DTR-5 A&B failed in late 1989. DTR-1B failed 02/92. placed in standby mode March 1995 and reactivated to provide sounding data after NOAA-12 sounder failure in May 1997.
TDRS-3(C) **	9/29/1988	10.0	***ACTIVE***	***ACTIVE***	Standby status 08/91.
TDRS-4(D) **	3/13/1989	10.0	***ACTIVE***	***ACTIVE***	
COBE	11/18/1989	0.8	4.1	4.1	Gyro-B failed 11/89, ESA-A failed 04/91, BX gyro failed 09/91 & gyro A&C failed 1993. Science mission ended 12/23/93. No longer monitored nor reported herein.
PEGSAT	4/5/1990	0.3	0.75	0.75	PEGASUS launched. Limited life mission.
HST	4/24/1990	15.0	***ACTIVE***	***ACTIVE***	Spherical aberration in primary mirror. Gyros 4&5 failed. Gyros 1&6 failed 10/11/92. 1st service mission 12/93.
SSBUV	10/6/1990				STS attached payload mission.
BBXRT	12/2/1990				STS attached payload mission.
CGRO	4/7/1991	2.3	9.16	9.16	Propulsion system damaged/degraded. DTR ops stopped 04/92 due to high error rate. MPS bad 07/92. Orbit reboosted to 450 km late 1993. Reentered June 2000.
NOAA-12(D)	5/14/1991	2.0	***ACTIVE***	***ACTIVE***	
TDRS-5(E) **	8/2/1991	10.0	***ACTIVE***	***ACTIVE***	
UARS	9/15/1991	3.0	***ACTIVE***	***ACTIVE***	ISAMS instrument failed 07/92. Cryogens depleted in CLAES instrument 05/93: science ended.
SSBUV	3/24/1992				STS attached payload mission.

** Complex warranty provisions call for 10 year service from TDRS system.

Spacecraft	Launch Date	Design Life	Useful Life	Active Life	Remarks
EUVE	6/7/1992	1.1	8.57	8.57	Deactivated Jan 2001.
SAMPEX (SMEX-1)	7/3/1992	3.0	***ACTIVE***	***ACTIVE***	Extended operations.
TOPEX	8/10/1992	3.0	***ACTIVE***	***ACTIVE***	
TDRS-6(F) **	1/13/1993	10.0	***ACTIVE***	***ACTIVE***	Put in on-orbit storage 06/93.
NOAA-13(I)	8/9/1993	2.0	0.03	0.03	Anomaly in power subsystem caused loss of spacecraft 08/21/93.
Landsat-6(E)	10/5/1993				***No longer monitored nor reported herein.***
HST[SM-01]	12/2/1993				HST servicing mission: WF/PC II, 2RSUs, S.A.s installed. HST entry above.
GOES-8(I)	4/13/1994	5.0	***ACTIVE***	***ACTIVE***	
SPARTAN 201-02	9/9/1994				STS attached payload mission.
Wind (GGS)	11/1/1994	3.0	***ACTIVE***	***ACTIVE***	
NOAA-14(J)	12/30/1994	2.0	***ACTIVE***	***ACTIVE***	
Spartan 204	2/4/1995				STS attached payload mission.
GOES-9 (J)	5/23/1995	7.0	***ACTIVE***	***ACTIVE***	
TDRS-7	7/13/1995	10.0	***ACTIVE***	***ACTIVE***	
Spartan 201-03	9/6/1995				STS attached payload mission.
SOHO	12/2/1995	2.0	***ACTIVE***	***ACTIVE***	
XTE	12/30/1995	2.0	***ACTIVE***	***ACTIVE***	Possible cracked solar array cells noticed shortly after launch.
SPARTAN 206	1/11/1996				STS attached payload mission (STS-72).
POLAR	2/24/1996	3.0	***ACTIVE***	***ACTIVE***	
SPARTAN 207	5/19/1996				STS attached payload mission (STS-77).
TOMS-EP	7/2/1996	2.0	***ACTIVE***	***ACTIVE***	
FAST	8/21/1996	1.0	***ACTIVE***	***ACTIVE***	
HST [SM-02]	11-Feb-97				HST servicing mission. See HST entry above.
GOES-10	4/25/1997	5.0	***ACTIVE***	***ACTIVE***	
SEASTAR/SEAWIFS	8/1/1997	3.0	***ACTIVE***	***ACTIVE***	
LEWIS	8/23/1997	1.0	0	0.1	Re-entered Atmosphere 9/28/97
ACE	8/25/1997	2.0	***ACTIVE***	***ACTIVE***	
SPARTAN 201-4	11/19/1997				STS attached payload mission (STS-87).
TRMM	11/27/1997	3.5	***ACTIVE***	***ACTIVE***	
SNOE	2/26/1998	0.2	***ACTIVE***	***ACTIVE***	

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Spacecraft	Launch Date	Design Life	Useful Life	Active Life	Remarks
TRACE	4/2/1998	1.0	***ACTIVE***	***ACTIVE***	
NOAA-15 (K)	5/13/1998	12.0	***ACTIVE***	***ACTIVE***	
Spartan 201-5	11/1/1998				STS attached payload mission (STS-??).
SWAS	12/6/1998	2.0	***ACTIVE***	***ACTIVE***	
SAC-A	14-Dec-98	0.6	0.86	0.86	
WIRE	3/5/1999	0.3	***ACTIVE***	***ACTIVE***	
LANDSAT-7	4/15/1999	5.0	***ACTIVE***	***ACTIVE***	
QUIKSCAT	6/20/1999	2.0	***ACTIVE***	***ACTIVE***	
FUSE	6/24/1999	3.0	***ACTIVE***	***ACTIVE***	
XMM	10-Dec-99	10.0	***ACTIVE***	***ACTIVE***	
EOS AM (Terra)	12/18/1999	6.0	***ACTIVE***	***ACTIVE***	
HST [SM-03A]	12/19/1999				HST servicing mission. New equipment installed, including 6 fresh gyroscopes. See HST entry above.
ASTRO-E	10-Feb-00	2.0	0	0	Problem with the first stage of the M V rocket, did not obtain orbit.
IMAGE	3/25/2000	2.0	***ACTIVE***	***ACTIVE***	
GOES-11 (L)	5/3/2000	5.0	***ACTIVE***	***ACTIVE***	
TDRSS-H (8)	6/30/2000	11.0	***ACTIVE***	***ACTIVE***	
Cluster FM 6	16-Jul-00	5.0	***ACTIVE***	***ACTIVE***	
Cluster FM 7	16-Jul-00	5.0	***ACTIVE***	***ACTIVE***	
Cluster FM 5	9-Aug-00	5.0	***ACTIVE***	***ACTIVE***	
Cluster FM 8	9-Aug-00	5.0	***ACTIVE***	***ACTIVE***	
NOAA-16	9/21/2000	12.0	***ACTIVE***	***ACTIVE***	
HETE-II	10/9/2000	1.5	***ACTIVE***	***ACTIVE***	
EO-1	10/21/2000	5.0	***ACTIVE***	***ACTIVE***	
MAP	6/30/2001	2.0	***ACTIVE***	***ACTIVE***	
GOES-12 (M)	7/23/2001	5.0	***ACTIVE***	***ACTIVE***	
TIMED	12/7/2001	2.0	***ACTIVE***	***ACTIVE***	
RHESSI	2/5/2002	2.0	***ACTIVE***	***ACTIVE***	
HST [SM-03B]	3/1/2002				HST servicing mission. Advanced Camera for Surveys (ACS) and four large flexible solar arrays (SA3) were installed. See HST entry above.
TDRS-I	3/8/2002	11.0	***ACTIVE***	***ACTIVE***	

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Spacecraft	Launch Date	Design Life	Useful Life	Active Life	Remarks
EOS-AQUA	5/4/2002	6.0	***ACTIVE***	***ACTIVE***	
NOAA-17 (M)	6/24/2002	12.0	***ACTIVE***	***ACTIVE***	
TDRS-J	12/5/2002	11.0	***ACTIVE***	***ACTIVE***	
CHIPSAT	1/13/2003	1.0	***ACTIVE***	***ACTIVE***	
ICESAT	1/13/2003	5.0	***ACTIVE***	***ACTIVE***	
SORCE	1/25/2003	5.0	***ACTIVE***	***ACTIVE***	
GALEX	4/28/2003	2.3	***ACTIVE***	***ACTIVE***	

Appendix B – General Descriptions of Spacecraft Reported in OAGS 2003

Advanced Composition Explorer (ACE)

The Advanced Composition Explorer (ACE) spacecraft launched on August 25, 1997, aboard a McDonnell-Douglas Delta II 7920 launch vehicle from the Kennedy Space Center in Florida. Its primary mission was to observe energetic particles within the solar system for a mission lifetime of two years.

The Earth is constantly bombarded with a stream of accelerated particles arriving not only from the Sun, but also from interstellar and galactic sources. Study of these energetic particles contributes to our understanding of the formation and evolution of the solar system as well as the astrophysical processes involved. The Advanced Composition Explorer (ACE) spacecraft carrying six high-resolution sensors and three monitoring instruments samples low-energy particles of solar origin and high-energy galactic particles with a collecting power 10 to 1000 times greater than past or planned experiments.

From a vantage point approximately 1/100 of the distance from the Earth to the Sun, ACE performs measurements over a wide range of energy and nuclear mass, under all solar wind flow conditions and during both large and small particle events including solar flares. ACE provides near-real-time solar wind information over short time periods. When reporting space weather, ACE provides an advance warning (about one hour) of geomagnetic storms that can overload power grids, disrupt communications on Earth, and present a hazard to astronauts.

The spacecraft is 1.6 meters across and 1 meter high, not including the four solar arrays and the magnetometer booms attached to two of the solar panels. At launch, it weighed 785 kg, which included 189 kg of hydrazine fuel for orbit insertion and maintenance. In order to get away from the effects of the Earth's magnetic field, the ACE spacecraft has traveled almost a million miles (1.5 million km) from the Earth to the Earth-sun libration point (L1). By orbiting the L1 point, ACE will stay in a relatively constant position with respect to the Earth as the Earth revolves around the sun.

Cosmic Hot Interstellar Plasma Spectrometer Satellite (CHIPSat)

CHIPSat was launched Jan. 13, 2003 on a Boeing Delta II launch vehicle from Vandenberg Air Force Base in California. CHIPSat carries the CHIPS instrument, which will examine the "empty" space between stars called the interstellar medium. The goal is to study the gas and dust in space, which are believed to be the basic building blocks of stars and planets. It will carry out all-sky spectroscopy of the diffuse background at wavelengths from 90 to 260 Å with a peak resolution of λ/150 (about 0.5 eV). CHIPS data will help scientists determine the electron temperature, ionization conditions, and cooling mechanisms of the million-degree plasma believed to fill the local interstellar bubble.

The CHIPS mission is expected to last one year. In its first six months, CHIPS mapped the entire sky to a depth of about 40,000 seconds per resolution element (resel). Each resel is 5° × 26.7°; approximately 316 resels are required to cover the entire sky. This map should provide high S/N detections of the strongest emission lines. The second six months will be spent making deep observations of regions of particular interest or mapping the emission in selected regions at higher spatial resolution.

CHIPSat is the first NASA University-Class Explorer (UNEX) mission, and also the first mission to use end-to-end satellite operations via the Internet. It weighs 131 pounds (60 kilograms) and is the size of a large suitcase. It will orbit above the Earth at about 350 miles (590 kilometers) altitude.

Cluster II

The four Cluster spacecraft (FM-5/Rumba, FM-6/Salsa, FM-7/Samba, and FM-8/Tango) were launched on 2 Russian Soyuz-Fregat launch vehicles on July 16 and August 9, 2000 into an elliptical orbit. The spacecrafts' intended apogee will be about 74,000 miles (119,000 kilometers) and its perigee about 12,000 miles (19,312 kilometers). The four spacecraft are cylindrically-shaped, weigh about 1,213 pounds (550 kilograms), with an additional 1,430 pounds (650 kilograms) of onboard fuel for orbital maneuvering. The spacecraft have a 5-year mission life.

Cluster II is part of an international collaboration to investigate the physical connection between the Sun and Earth, as part of the Solar Terrestrial Science Programme (STSP). The goals of the Cluster II mission are identical to those of the original Cluster mission lost in June 1996 and the instrument complement remains the same. Each of the spacecraft carries an identical set of 11 instruments to investigate charged particles, electrical and magnetic fields.

The mission of the four spacecraft is to explore parts of the magnetosphere and better understand the effects of the solar winds on Earth. Each spacecraft will be positioned so that each is located at one of the four points of a pyramid, allowing three-dimensional structures to be described, for the first time, in both the magnetosphere and solar wind. To study different regions and plasma structures, distances between the Cluster spacecraft will be adjusted during the mission, varying from about 400 miles to more than 10,000 miles (about 600 to 18,000 kilometers). Comparison of simultaneous measurements from the different spacecraft will be combined to produce a three-dimensional picture of plasma structures.

Earth Observing-1 (EO-1)

EO-1 is the first in a series of satellites of the New Millennium Program, which aims to explore the use of new technologies contributing to the reduction in cost and increased capabilities for future land imaging missions. One of the goals of EO-1 is to ensure the continuity of future Landsat data. Three land imaging instruments on EO-1 are collecting multispectral and hyperspectral scenes over the course of its mission in coordination with the Enhanced Thematic Mapper (ETM+) on Landsat 7, to demonstrate technologies in lightweight materials, high performance integrated detector arrays and precision spectrometers. Detailed comparisons of the EO-1 and ETM+ images have been carried out to validate these instruments for follow-on missions.

EO-1 was launched on a Delta 7320-10 from Vandenberg Air Force Base on November 21, 2000 in a 705 km circular, sun-synchronous orbit at a 98.7-degree inclination. This orbit allows EO-1 to match within one minute the Landsat 7 orbit and collect identical images for comparison.

The EO-1 mission is using several new instruments and various new spacecraft technology to lead the way for a new generation of lighter, smaller, lower power, lower cost missions. Each of the three instruments (Advanced Land Imager, Hyperion (Hyperspectral Imager), and Atmospheric Corrector) flown on EO-1 incorporate revolutionary land imaging technologies which will enable future Landsat and Earth observing missions to more accurately classify and map land utilization globally. Seven crosscutting technologies which will reduce the cost, mass and complexity of future Earth observing spacecraft have been demonstrated by EO-1 and will allow more scientific payload to fly on future missions. These include: X-Band Phased Array Antenna, Carbon-Carbon Radiator, Lightweight Flexible Solar Array, Wideband Advanced Recorder Processor, Pulsed Plasma Thruster, Enhanced Formation Flying, and LA-II Thermal Coating.

EOS-AM (Terra)

Terra is the Earth Observing System (EOS) flagship satellite, launched on December 18, 1999. Sensors aboard Terra are comprehensively measuring our world’s climate system—to observe and measure how Earth’s atmosphere, cryosphere, lands, oceans, and life all interact. Data from this mission are used in many research and commercial applications. The Terra spacecraft is roughly the size of a small school bus, carrying a payload of five state-of-the-art sensors that will study the interactions among the Earth's atmosphere, lands, oceans, life, and radiant energy (heat and light). Each sensor has unique design features that will enable EOS scientists to meet a wide range of science objectives.

Terra will circle around the Earth, very nearly from pole to pole, in an orbit that descends across the equator at 10:30 a.m. local time when cloud cover over land is minimal and its view of the surface is least obstructed. The satellite's orbit will be roughly perpendicular to the direction of Earth's spin, so that the viewing swaths from each overpass can be compiled into whole global images. Over time, these global images will enable scientists to show and tell the stories of the causes and effects of global climate change.

The sensors on Terra will not actively scan the surface (such as with laser beams or microwave pulses). Rather, the sensors work much like a digital camera. Sunlight that is reflected by Earth, and heat that is emitted from Earth, will pass through the apertures of Terra's sensors. This radiant energy will then be focused onto specially designed detectors that are sensitive to selected regions of the electromagnetic spectrum, ranging from visible light to heat. The information produced by these detectors will then be transmitted back to Earth and processed by computers into images that we can interpret.

The life expectancy of the Terra mission is 6 years. It will be followed in later years by other EOS spacecraft that take advantage of new developments in remote sensing technologies.

EOS-AQUA

Aqua was launched May 4, 2002 from the Western Test Range of Vandenberg Air Force Base, Calif., aboard a Delta II rocket into a 438-mile (705-kilometer) near-polar low-Earth orbit. The Aqua mission is a part of the NASA-centered international Earth Observing System. Aqua was formerly named EOS-PM, signifying its afternoon equatorial crossing time. Aqua has a design life of six years.

Aqua is focused on the multi-disciplinary study of Earth's interrelated processes (atmosphere, oceans, and land surface) and their relationship to changes in the Earth system. The global change research efforts emphasized with the Aqua instrument data sets include atmospheric temperature and humidity profiles, clouds, precipitation and radiative balance; terrestrial snow and sea ice; sea surface temperature and ocean productivity; soil moisture; and the improvement of numerical weather prediction. Aqua is also making critical contributions to the monitoring of terrestrial and marine ecosystem dynamics.

Aqua carries six state-of-the-art instruments in a near-polar low-Earth orbit. The six instruments are the Atmospheric Infrared Sounder (AIRS), the Advanced Microwave Sounding Unit (AMSU-A), the Humidity Sounder for Brazil (HSB), the Advanced Microwave Scanning Radiometer for EOS (AMSR-E), the Moderate-Resolution Imaging Spectroradiometer (MODIS), and Clouds and the Earth's Radiant Energy System (CERES). Each has unique characteristics and capabilities, and all six serve together to form a powerful package for Earth observations.

Earth Radiation Budget Satellite (ERBS)

Designed to study the Earth's climates, ERBS is one of the oldest GSFC operational satellites. Designed for a two-year mission life, it was deployed by the Space Shuttle on October 5, 1984, into a low Earth orbit. Its current orbit is 577 x 598 km x 57 degrees inclination.

ERBS was part of the NASA's 3 satellite Earth Radiation Budget Experiment (ERBE), designed to investigate how energy from the Sun is absorbed and re-emitted by the Earth. This process of absorption and re-radiation is one of the principal drivers of the Earth's weather patterns. Observations from ERBS were also used to determine the effects of human activities (such as burning fossil fuels and the use CFCs) and natural occurrences (such as volcanic eruptions) on the Earth's radiation balance.

Earth radiation budget measurements made by the Earth Radiation Budget Experiment (ERBE) instrument, on the ERBS spacecraft, provides a valuable continuous record for long-term studies of global climate, including cloud-radiative forcing and solar variability.

Fast Auroral Snapshot Explorer (FAST)

FAST was launched on August 21, 1996, aboard a Pegasus XL vehicle at Vandenberg Air Force Base. The spacecraft weighed 420.5 lbs, with the instruments weighing 112 lbs. FAST has a primary mission life of 1 year.

The FAST satellite is one of NASA's Small-Class Explorer (SMEX) missions. It will investigate the plasma physics of the auroral phenomena, which occur around both poles of the Earth. This will be accomplished by taking high data rate snapshots with electric and magnetic fields sensors, and plasma particle instruments, while traversing through the auroral regions. FAST will orbit in a near-polar, highly elliptical orbit.

The Orbit altitude will be approximately 350 km x 4200 km at an inclination of 83 degrees. The FAST payload consists of four experiment packages: Electric Field Experiment, Magnetic Field Experiment, Time-of-Flight Energy Angle Mass Spectrograph, and Electrostatic Analyzers.

Far Ultraviolet Spectroscopic Explorer (FUSE)

FUSE was launched into orbit aboard a Delta II rocket on June 24, 1999 for at least three years of operations. FUSE was developed and is being operated for NASA by the Johns Hopkins University, in collaboration with the space agencies of Canada and France, who shared in the observing time over the first three years. This is the first time that a mission of this scope has been developed and operated entirely by a university.

FUSE looks at light in the far ultraviolet portion of the electromagnetic spectrum (approximately 90 to 120 nanometers), which is unobservable with other telescopes. FUSE observes these wavelengths with much greater sensitivity and resolving power than previous instruments used to study light in this range.

FUSE will be used to investigate our cosmic origins, searching for deuterium in the interstellar medium near the Sun, in gas clouds in the far reaches of the Milky Way, and in distant intergalactic clouds between galaxies. By measuring the amount of deuterium relative to both hydrogen and the heavier elements produced by stars, they will be able to estimate how much deuterium has been destroyed since the Big Bang. This, in turn, will allow them to understand how galaxies evolve and to discover what the Universe was like when it was only a few minutes old.

Galaxy Evolution Explorer (GALEX)

GALEX was successfully launched on April 28, 2003 aboard a Pegasus XL Launch vehicle from Cape Canaveral Air Force Station in Florida. GALEX has a near circular orbit, altitude 694 x 700 km, and an inclination of 28.99 degrees. The spacecraft weighs 280 kg and has a mission life of 29 months.

GALEX data products will include a series of all UV sky surveys and deep sky searches in the imaging mode and partial sky surveys in the near- and far-UV spectroscopic modes. A Guest Investigator (GI) opportunity to complement the mission objectives will be announced at the CalTech site. Data releases will proceed in three steps, a "DR0" in late 2003, and "DR1" in late 2004, and a "DR2" after the end of the mission. Except for GI data, the data have no proprietary rights.

With its UV surveying capabilities, GALEX will complement the functions of the Hubble Space Telescope (HST) and the Far Ultraviolet Spectroscopic Explorer (FUSE), both currently in orbit. GALEX will also complement the Sloan Digital Sky Survey (SDSS), which will cover 1/4 of the sky.

Geo-stationary Operational Environment Satellite (GOES)

GOES are a series of geostationary weather and environmental observation satellites and are designed to operate in geosynchronous orbit 22,240 miles above the Earth, thereby appearing to remain stationary. These satellites are developed and launched by NASA for the National Oceanic and Atmospheric Administration (NOAA) and are key elements in the National Weather Service (NWS) operations and modernization program. NOAA is responsible for program funding and the in-orbit operation of the systems and determines the need for satellite replacement. Once the satellite is launched and checked out, NOAA assumes responsibility for the command and control, data receipt and product generation and distribution.

In 1983, NASA signed an agreement with the National Oceanic and Atmospheric Administration (NOAA) to design and build a new generation of weather satellites. These satellites carry instruments that operate as never before—including half hour, or near continuous, Earth observations. The new series of GOES satellites (GOES I-M) provide significant improvements over the previous GOES system in weather and sounding information. This enhanced system improves weather services, particularly the timely forecasting of life and property threatening severe storms. GOES I-M are the first ever three-axis body stabilized spacecrafts. This technology enables the satellite to "stare" at the Earth and provide more frequent images of clouds, the Earth's surface temperature, and water vapor fields. This also enables GOES to “sound” the atmosphere for its vertical thermal and vapor profiles. The new series of GOES satellites provide half hourly radiometric observations, measuring Earth emitted and reflection radiation from which atmospheric temperature, winds, moisture and cloud cover can be derived.

GOES-8, launched on April 13, 1994, was the first of a new generation of GOES I-M, to provide significant improvements. GOES-9, launched on May 23, 1995, was the second of the new series of satellites designed to provide improved imaging. It is currently serving as GOES-Pacific. GOES-10, launched April 25, 1997, was the third of the new GOES I-M series, is operating currently as GOES-West. GOES-8, GOES-9, and GOES-10 were referred to as GOES-I, GOES-J, and GOES-K, respectively, before launch (they are renamed upon reaching their orbits). GOES-11 (L), launched May 3, 2000, is currently in on-orbit storage. GOES-12 (M), launched July 23, 2001, is operating as GOES-East.

High Energy Transient Explorer (HETE-2)

HETE-2 is an international collaboration between USA, Japan, France, and Italy, headed by the Center for Space Research at MIT. It was launched on a Pegasus launcher, on October 9, 2000 from the Kwajalein missile range facility. The mission lifetime is approximately 2 years.

The High Energy Transient Explorer is a small scientific satellite, weighing 273 lbs, designed to detect and localize gamma-ray bursts. The instruments on board, including one gamma-ray and two X-ray detectors, will allow simultaneous observations of GRBs to be made in soft and medium X-ray and gamma-ray energies.

On orbit, the spacecraft will point in the anti-solar direction for optimal exposure of the solar panels to the Sun. As a result, the HETE science instruments monitor an approximately 2 steradian field centered roughly on the ecliptic. During the course of a year, HETE will survey a swatch of sky along the ecliptic that covers about 60% of the celestial sphere. HETE-2 will compute the location of the GRB and transmit the coordinates as soon as they are calculated. These coordinates will quickly be distributed to ground-based observers to allow detailed studies of the initial phases of GRBs. HETE-2 will also perform a survey of the X-ray sky.

Hubble Space Telescope (HST)

HST was launched aboard the Space Shuttle Discovery on April 24, 1990, and deployed into a low Earth orbit. The HST is 2.4 meters in diameter, with optics supporting astronomical observations in the vacuum of space: ultraviolet, visible and near-infrared (wavelengths from 1150 angstroms through several microns). It has a planned 15 year science mission, and will be periodically serviced in-orbit by Space Shuttle crews. The HST is a joint endeavor of NASA and the European Space Agency (ESA). ESA provided the Faint Object Camera and the solar arrays.

HST's two well-known post-launch problems, the aberration in its telescope mirror and a solar array jitter affecting its instruments, were resolved with the first servicing mission in December 1993. The mission installed the Corrective Optics Space Telescope Axial Replacement (COSTAR) and the Wide Field/Planetary Camera 2 (WFPC2). The other science instruments then on-board were the Faint Object Camera (FOC), the Faint Object Spectrograph (FOS), and the Goddard High Resolution Spectrograph (GHRS). The HST's Fine Guidance Sensors (FGSs) also support astrometric science. The second servicing mission in February 1997 was a nearly flawless 11-day mission to service HST, which included a record-breaking five spacewalks in which astronauts performed a number of tasks designed to improve the telescope and extend its life. During this mission, astronauts replaced the FOS and GHRS with an advanced Space Telescope Imaging Spectrograph (STIS) and the Near Infrared Camera and Multi-Object Spectrometer (NICMOS).

In October 1998, the Hubble Team conducted the HST Orbital Systems Test (HOST) on board STS-95. This Space Shuttle mission provided the opportunity to test pieces of new Hubble hardware before installation in the telescope. By flying in an orbit similar to Hubble's, the Shuttle allowed engineers to determine how the new equipment on HOST would perform on the telescope, for example, monitoring the effects of radiation on the new hardware.

After 4 of 6 gyros failed by November 1999, Hubble was placed into safe hold. On servicing mission 3A, in December 1999, new equipment was installed. Upgraded equipment included six fresh gyroscopes, six battery voltage/temperature improvement kits, a faster, more powerful, main computer, a next-generation solid-state data recorder, a new transmitter, an enhanced fine guidance sensor, and new insulation.

During servicing mission 3B, in March 2002, a new science instrument, the Advanced Camera for Surveys (ACS), was installed. In addition, four large flexible solar arrays (SA3) were installed. Although one-third smaller than the first two pairs, they will produce 30 percent more power. They are less susceptible to extreme temperatures and their smaller-sized will reduce the effects of atmospheric drag on the spacecraft. Hubble's power control unit was also replaced in SM3. Additionally, astronauts retrofitted an existing but dormant instrument called the Near Infrared Camera and Multi-Object Spectrometer (NICMOS) with a new, experimental cooling system to return it to active duty. NICMOS was placed on Hubble in 1997 but became inactive two years later, after depleting the ice it needed to cool its infrared detectors. By fitting NICMOS with the experimental cryogenic system, NASA hopes to re-cool the detectors to -334°F (-203°C or 70 K) revive its infrared vision, and extend its life by several years.

Ice, Cloud, and land Elevation Satellite (ICESat)

The ICESat spacecraft, weighing 970 kg, was launched Jan. 12, 2003 on a Boeing Delta II launch vehicle from Vandenberg Air Force Base in California. Its goal is to quantify the ice sheet mass balance and understand how changes in the Earth's atmosphere and climate affect the polar ice masses and global sea level. ICESat will also measure global distributions of clouds and aerosols for studies of their effects on atmospheric processes and global change, as well as land topography, sea ice, and vegetation cover. ICESat will enable scientists to study the Earth's climate and, ultimately, predict how ice sheets and sea level will respond to future climate change.

The Geoscience Laser Altimeter System (GLAS) on ICESat will measure ice sheet elevations, changes in elevation through time, height profiles of clouds and aerosols, land elevations and vegetation cover, and approximate sea ice thickness.

ICESat will be placed into circular orbit with a 94-degree inclination, at an initial altitude 590 km above the Earth. ICESat is designed to operate for 3 to 5 years and will be followed by successive missions to measure ice sheet elevations and other Earth phenomena over the next 15 years.

Imager for Magnetopause-to-Aurora Global Exploration (IMAGE)

Image was launched March 25, 2000 from Vandenberg AFB, California, aboard a Delta II launch vehicle. IMAGE was placed into an elliptical polar orbit with an apogee altitude of 7.2 Earth radii (45,922 km) and a perigee altitude of 1000 km. Image is NASA's first Medium-class Explorer (MIDEX) mission.

IMAGE will use neutral atom, ultraviolet, and radio imaging techniques to: identify the dominant mechanisms for injecting plasma into the magnetosphere on substorm and magnetic storm time scales; determine the directly driven response of the magnetosphere to solar wind changes; and discover how and where magnetospheric plasmas are energized, transported, and subsequently lost during substorms and magnetic storms.

The expected mission duration for Image is two years, with a possible three year extended life.

LANDSAT-5 (D)

The LANDSAT Program is the longest running enterprise for acquiring images of the Earth from space. The first LANDSAT satellite was launched in 1972.

Instruments aboard the LANDSAT satellites have recorded millions of images. These images, archived in the United States and at LANDSAT receiving stations around the world, are a unique resource for global change research and other applications. LANDSAT data also have been used extensively in agriculture and geology, global change science, education and national security.

LANDSAT 5 was launched March 1, 1984 from Vandenberg AFB in California aboard a Delta 3920 launch vehicle. Landsat 5 is in a 438-mile polar, sun-synchronous orbit with a 98.2 degree inclination. It is the fifth in a series of Earth observation platforms funded by the US Government, and continued the Thematic Mapper archive started in 1982.

LANDSAT 7

LANDSAT 7 was launched April 15, 1999 aboard a Delta II rocket from Vandenberg Air Force Base, Calif.

The LANDSAT 7 mission has the ability to collect and process up to 532 scenes per day. The earth observing instrument on LANDSAT 7, the Enhanced Thematic Mapper Plus (ETM+), replicates the capabilities of the highly successful Thematic Mapper instruments on Landsat 4 and 5*. The ETM+ also includes new features that make it a more versatile and efficient instrument for global change studies, land cover monitoring and assessment, and large area mapping than its design forebears.

The spacecraft weighs 4350 lbs (1973 kg). It is in a sun-synchronous, polar orbit at an altitude of 705 km at the Equator. LANDSAT 7 has a mission life of 5 years.

National Oceanic and Atmospheric Administration (NOAA)

Complementing the geostationary satellites are two polar-orbiting satellites, known as the advanced Television Infrared Observing System (TIROS) satellites. Constantly circling the Earth in an almost north-south orbit, passing close to both poles, the polar orbiters monitor the entire Earth. They track atmospheric variables and provide atmospheric data, and cloud images, for weather forecasting and environmental studies. They track weather patterns that affect the climate of the entire United States, providing visible and infrared radiometer data used for imaging purposes, radiation measurements, and temperature profiles.

In addition to weather and environmental data, NOAA spacecraft provide search and rescue capabilities through continuous worldwide monitoring for distress radio beacons. These services are provided through the coordinated and cooperative efforts of many nations. The NOAA satellites are constructed and launched by NASA for the National Oceanic and Atmospheric Administration (NOAA).

NOAA-11 (H) was launched September 24, 1988 and operated until the primary mission sensor, the AVHRR, failed September 13, 1994. It was placed in standby mode in March of 1995 and reactivated to provide sounding data after a NOAA-12 sounder failure in May 1997.

NOAA-12 (D) was launched May 14, 1991 as the fifth satellite in the advanced TIROS-N series. NOAA 12 operations were closed as of April 2001.

NOAA-13 (I) was launched August 9, 1993, and operated successfully for 12 days until a circuit failure resulted in a power loss aboard the craft. At this time the spacecraft is still in its polar orbit; however, no data is being received.

NOAA-14 (J) was launched December 30, 1994, and was the sixth operational satellite in the TIROS-N series. It is currently operational.

NOAA-15 (K) was launched May 13, 1998 and became the seventh operational satellite in the TIROS-N series. NOAA-15 is the first in the series to support dedicated microwave instruments for the generation of temperature, moisture and surface hydrological products in cloudy regions where visible and infrared instruments have reduced capabilities. This satellite is currently operational.

NOAA-16 (L) was launched on September 21, 2000 into a 470-mi afternoon orbit. The instrument was declared "operational" on March 20, 2001 and is functioning nominally. NOAA 16 was an afternoon equator-crossing orbit and is intended to replace the NOAA-K as the prime afternoon spacecraft.

NOAA-17 (M) was launched June 24, 2002, continuing fourth-generation of operational, polar orbiting, meteorological satellite series (NOAA K-N) operated by the National Environmental Satellite Service (NESS) of the National Oceanic and Atmospheric Administration (NOAA).

POLAR (GGS)

Polar was launched on a Delta II rocket from Vandenberg AFB in California on February 24, 1996 for the start of a planned three-year mission. The Polar spacecraft is the second mission of NASA's Global Geospace Science (GGS) program. It will perform simultaneous, coordinated measurements of the key regions of Earth's geospace, or space environment, with WIND, which was launched in November 1994 to measure the solar wind properties. A large array of ground-based scientific observatories and mission related theoretical investigations will also be involved.

The Polar spacecraft carries 11 instruments, which are designed to measure energy input to the Earth's polar regions. It will provide complete coverage of the inner magnetosphere, which is the region around the planet dominated by the Earth's magnetic field. The magnetosphere, the outermost region of geospace, begins some 360 miles above the Earth's surface. NASA is collaborating with the European Space Agency (ESA) and the Japanese Institute of Space and Astronautical Science (ISAS) in three additional solar-terrestrial missions, Geotail, SOHO and Cluster. These missions, together with GGS, make up the International Solar-Terrestrial Physics (ISTP) science initiative. The aim of ISTP is to understand the physical effects of solar activity on interplanetary space and the Earth's space environment.

Polar’s orbit around the Earth is inclined 86 degrees from the equator. The furthest point from the Earth on the orbit – the apogee - is nine Earth radii (36,000 miles or 57,000 kilometers), and the closest point to Earth - the perigee - is almost 2 Earth radii (7,100 miles or 11,000 kilometers). Polar is managed by NASA's Goddard Space Flight Center in Greenbelt, Md.

Quick Scatterometer (QuikSCAT)

QuikSCAT was launched into an elliptical orbit 800 km (500 miles) above Earth June 19, 1999 aboard a U.S. Air Force Titan II launch vehicle California's Vandenberg Air Force Base. The objectives of this mission are to acquire all-weather, high-resolution measurements of near-surface winds over global oceans; determine atmospheric forcing, ocean response, and air-sea interaction mechanisms on various spatial and temporal scales; combine wind data with measurements from scientific instruments in other disciplines to better understand the mechanisms of global climate change and weather patterns; study rain forest vegetation changes; and to study sea ice edge movement and Arctic/Antarctic ice pack changes.

The SeaWinds on QuikSCAT mission is a "quick recovery" mission to fill the gap created by the loss of data from the NASA Scatterometer (NSCAT), when the satellite it was flying on lost power in June 1997. The SeaWinds instrument on the QuikSCAT satellite is a specialized microwave radar that measures near-surface wind speed and direction under all weather and cloud conditions over Earth's oceans.

The QuikSCAT mission was the first delivery order issued under the Indefinite Delivery/Indefinite Quantity (ID/IQ) contracts for rapid delivery of satellite core-systems. The ID/IQ procurement method provides NASA a faster, better, cheaper method for the purchase of satellite systems through a "catalog," allowing for shorter turnaround time from mission conception to launch. QuikSCAT has an expected mission life of 2 years.

Ramaty High-Energy Solar Spectroscopic Imager (RHESSI)

RHESSI was launched February 5, 2002 aboard a Pegasus XL launch vehicle. It is in circular orbit at 600 km above Earth with a 38-degree inclination. The RHESSI spacecraft weighs 293 kg (645 lb).

The goal of RHESSI is to study solar flares - the solar system's mightiest explosions in the atmosphere of the Sun. During its planned two-year mission, RHESSI's unprecedented ability to make images of solar flares in X-rays and gamma rays will enable scientists for the first time to track accelerated flare particles, exploring the sudden energy release in a way never before possible.

RHESSI is the sixth Small Explorer (SMEX) mission. The principal investigator institution is the University of California, Berkeley, which has responsibility for most aspects of the mission, including instrument and spacecraft development, mission operations and data analysis.

Stratospheric Aerosol and Gas Experiment III (SAGE III)

SAGE III is an Earth Observing System (EOS) - joint mission between the U.S. National Aeronautics and Space Administration (NASA) and the Russian Space Agency (RSA). SAGE III is one of nine experiments on the Russian Meteor-3M (1) spacecraft. This mission will provide information on air quality, climate change, and improved weather models.

SAGE III was launched December 10, 2001 from the Baikonur Cosmodrome into a 1,020 km sun-synchronous orbit with 99.64-degree inclination. The spacecraft has a design life of 5 years.

Solar Anomalous and Magnetospheric Particle Explorer (SAMPEX)

Launched on July 3, 1992 via a Scout launch vehicle, SAMPEX is the first spacecraft operated under GSFC's Small Explorer Program. It is designed to study the composition of energetic particles arriving at Earth from the solar atmosphere and interstellar space. It also measures the number of relativistic electrons entering the atmosphere from outer space. Relativistic electrons contribute to ozone destruction.

Some other science goals include observing changing geomagnetic cutoff encountered by the spacecraft allowing studies of the ionization state and isotropic composition of the anomalous component of cosmic rays, observing precipitating magnetospheric electrons that interact with the middle atmosphere, investigating the isotropic composition of particles originating in energetic solar flares, and investigating the origin and transport of galactic cosmic rays.

Designed for a mission life of 3 years, SAMPEX uses several innovative technologies, including an optical fiber buss, powerful on-board computers, and large solid-state memories (instead of the usual tape recorders). Also, SAMPEX is the first NASA mission to fully implement a packet switched data network throughout the system.

Sea-viewing Wide Field-of-view Sensor (SeaWiFS) SEASTAR/SEAWIFS

Launched on August 1, 1997, from a Pegasus rocket, SeaWiFS began collecting global data operationally in mid-September and has continued to perform flawlessly for the past six years. SeaWiFS has allowed us to monitor both the short-term spatial and temporal variability in the ocean's biology, and to have the first well-calibrated, long-term data set that allows us to quantify the ocean's biological response to global change. SeaWiFS is an essential component of NASA’s Mission to Planet Earth (MTPE), an ongoing effort to study how the global environment is changing.

The SeaWiFS instrument will observe the world’s oceans from space to measure "ocean color." The color of most of the world’s oceans varies with the concentration of microscopic marine plants, called "phytoplankton," which contain chlorophyll, a green pigment. Near coastlines, the color of the ocean is affected by chlorophyll, dissolved organic material and suspended sediments from rivers and lagoons. By observing the color of different parts of the oceans, scientists can measure the amount of these materials in the water, and better understand the role of the oceans in the global carbon cycle—the process by which carbon travels through the Earth’s atmosphere, oceans, land, and living organisms. Phytoplankton removes carbon dioxide from the atmosphere for internal use, and scientists want to understand this exchange of carbon dioxide and the role it plays in the global climate.

The Sea-viewing Wide Field-of-view Sensor (SeaWiFS) represents a new way of doing business for NASA. Rather than building, launching, and controlling a satellite to study an important aspect of the Earth’s environment, NASA will purchase commercially available data from a privately built satellite and use the data for environmental research.

SeaWiFS is in 440-mile (705-kilometer) circular orbit. It has an expected lifetime of 3 years.

Student Nitric Oxide Explorer (SNOE)

SNOE is a small scientific spacecraft designed, built, and operated by the University of Colorado at Boulder, Laboratory for Atmospheric and Space Physics (LASP). Its scientific goals are to measure nitric oxide density in the terrestrial lower thermosphere (100-200 km altitude) and analyze the energy inputs to that region from the sun and magnetosphere that create it and cause its abundance to vary dramatically.

The SNOE spacecraft is a compact hexagonal structure, 36" high and 39" across its widest dimension, which weighs 254 lbs. It was launched by a Pegasus XL into a circular orbit, 580 km altitude, at 97.75 degrees inclination for sun synchronous precession, on 26 Feb. 1998. It spins at 5 rpm with the spin axis normal to the orbit plane.

It carries three instruments: an ultraviolet spectrometer to measure nitric oxide altitude profiles, a two-channel auroral photometer to measure auroral emissions beneath the spacecraft, and a five-channel solar soft X-ray photometer. SNOE is one of three satellite projects selected for the Student Explorer Demonstration Initiative program (STEDI), which is funded by NASA and managed by the Universities Space Research Association (USRA).

Students are involved in all aspects of the project. Under the supervision of LASP and industry mentors, they worked on the design study, built the spacecraft and instruments, wrote the flight software, integrated and tested the instruments and subsystems, and integrated with the launch vehicle. SNOE will be operated from the LASP Space Technology Research building by a team of students and mission operations professionals. Advanced undergraduates and graduate students will analyze the data. The student training effort was coordinated through a course offered continuously in the CU Department of Aerospace Engineering Sciences.

Solar and Heliospheric Observatory (SOHO)

SOHO, which is part of NASA’s International Solar-Terrestrial Physics program, and a joint project between NASA and the European Space Agency (ESA), was launched December 2, 1995. The spacecraft was put into orbit on an Atlas-Centaur IIAS rocket launched from Cape Canaveral Air Station, FL. The total mass at launch was 1850 kg, with the payload comprising 610 kg.

The observatory will study the physical processes taking place in the Sun's corona and changes in the Sun's interior by conducting remote sensing observations in visible, ultraviolet and extreme ultraviolet light. Goddard engineers and technicians are providing mission operations and network support for the SOHO spacecraft.

Solar Radiation and Climate Experiment (SORCE)

The Solar Radiation and Climate Experiment (SORCE) is a NASA-sponsored project that will provide Total Irradiance measurements and the full Spectral Irradiance measurements required by climate studies. The spectral measurements include ultraviolet, extreme ultraviolet, and the visible to near infrared. SORCE was launched to an altitude of 645 km, 40 degree inclination on January 25, 2003 with a Pegasus XL space launch vehicle from Kennedy Space Center. The spacecraft weighs 315 kg and has a design life of 5 years.

SORCE will examine long-term climate change, natural variability and enhanced climate prediction, and atmospheric ozone and UV-B radiation. These measurements are critical to studies of the Sun, its effect on our Earth system, and its influence on humankind. SORCE measures the Sun's output with the use of state-of-the-art radiometers, spectrometers, photodiodes, detectors, and bolometers engineered into instruments mounted on a satellite observatory. Spectral measurements identify the irradiance of the Sun by characterizing the Sun's energy and emissions in the form of color that can then be translated into quantities and elements of matter.

SORCE will continue the measurements of total solar irradiance (TSI) that began with the ERB instrument in 1979 and has continued to the present with the ACRIM series of measurements. It will also provide measurements of the solar spectral irradiance from 1 nm to 2000 nm, which make up 95% of the spectral contribution to TSI. SORCE carries four instruments including the Total Irradiance Monitor (TIM), Solar Stellar Irradiance Comparison Experiment (SOLSTICE), Spectral Irradiance Monitor (SIM), and the XUV Photometer System (XPS).

Sub-millimeter Wave Astronomy Satellite (SWAS)

SWAS was launched into low Earth orbit (in a 600 km circular orbit with a 70° inclination) on December 02, 1998 aboard a Pegasus XL launch vehicle from the Western Range/Vandenberg AFB. It is a NASA Small Explorer Project (SMEX) designed to study the chemical composition of interstellar gas clouds and establish the means by which they cool as they collapse and form planets, through observations of spectral lines emanating from dense molecular clouds. The primary objective of SWAS was to survey water, molecular oxygen, carbon, and isotopic carbon monoxide emission in a variety of galactic star forming regions.

SWAS is a three-axis-stabilized, stellar-pointed observatory with a pointing accuracy of 38 arcseconds and jitter less than 19 arcseconds. The spacecraft will typically point the science instrument at 3-5 targets per orbit. Target selection is constrained so that the solar arrays always face within ±15° of the Sun, except during eclipse.

The SWAS instrument is a submillimeter wave telescope that incorporates dual heterodyne radiometers and an acousto-optical spectrometer to investigate the composition of dense interstellar clouds. The instrument weighs 102 kg and attaches to the top of the spacecraft structure as a single module. The total observatory mass is 288 kg. SWAS had a design lifetime of 2 years.

Thermosphere Ionosphere Mesosphere Energetics and Dynamics (TIMED)

TIMED was launched December 7, 2001 aboard a Delta II rocket from Vandenberg Air Force Base, California. The TIMED mission is studying a region of our atmosphere located about 40 to 110 miles above the Earth. Known as the Mesosphere, Lower Thermosphere/Ionosphere, or MLTI, air pressure here is a thousand to a trillion times less than at sea level. During its mission, TIMED will study the basic structure of the MLTI, its chemistry and the flow of energy to and from this layer of our atmosphere. Some other goals of the TIMED mission are to understand the influence of the Sun on Earth’s atmosphere, to understand the influence of human activities on Earth’s atmosphere, to study the least-explored region of the atmosphere, and to improve the prediction of Space Weather.

The TIMED spacecraft is the initial mission in NASA’s Solar Terrestrial Probes (STP) Program, part of NASA’s initiative to lower mission costs and provide more frequent access to space to systematically study the sun-Earth system. The mission is sponsored by NASA’s Office of Space Science, Washington, D.C., and is managed by the NASA Goddard Space Flight Center’s STP Program Office, Greenbelt, Md. The Johns Hopkins University Applied Physics Laboratory (APL), in Laurel, Md., designed, built and is operating the spacecraft for NASA. APL is also leading the project’s science effort during the mission.

The TIMED spacecraft is in a 388-mile (625 km) circular orbit at 74.1 degrees from the equator. The 1294-pound (587 kg) spacecraft has a primary mission life of two years.

Total Ozone Mapping Spectrometer - Earth Probe (TOMS-EP)

TOMS aboard Nimbus-7 and Meteor-3 provided global measurements of total column ozone on a daily basis and together provided a complete data set of daily ozone from November 1978 - December 1994. After an eighteen-month period when the program had no on-orbit capability, ADEOS TOMS was launched on August 17, 1996 and provided data until June 29, 1997. TOMS-EP was launched on July 2, 1996 to provide supplemental measurements, but was boosted to a higher orbit to replace the failed ADEOS. TOMS-EP is continuing NASA's long-term daily mapping of the global distribution of the Earth's atmospheric ozone and continues to provide near real-time data. This NASA developed instrument, which measures ozone indirectly by monitoring ultraviolet light, has mapped in detail the Antarctic "ozone hole," which forms September through November of each year, and the distribution of ozone over the globe.

TOMS-EP measures total ozone by observing both incoming solar energy and backscattered ultraviolet (UV) radiation at six wavelengths. "Backscattered" radiation is solar radiation that has penetrated to the Earth's lower atmosphere. There, it is scattered by air molecules and clouds back through the stratosphere to the satellite sensors.

TOMS is part of NASA's Mission to Planet Earth (MTPE) a long term, coordinated research effort to study the Earth as a global environmental system. Using the unique perspective available from space, NASA, will observe, monitor and assess large-scale environmental processes, focusing on climate change. MTPE satellite data, complemented by aircraft and ground data, allows humans to better understand natural environmental changes and to distinguish natural changes from human induced changes. MTPE data, which NASA distributes to researchers worldwide, is essential to humans making informed decisions about their environment.

Ocean Topography Experiment (TOPEX)

The Ocean Topography Experiment (TOPEX/Poseidon) is a cooperative project between the United States and France to develop and operate an advanced satellite system to provide global sea level measurements with an unprecedented accuracy. On August 10, 1992, TOPEX/Poseidon was launched into its orbit 1336 kilometers (830 miles) above the Earth s surface. The sea level data from TOPEX/Poseidon will be used to determine global ocean circulation and to increase the knowledge of the interaction of the oceans and the atmosphere.

For this joint mission, the National Aeronautics and Space Administration (NASA) provided the satellite bus and the following instruments with their associated ground elements: a dual- frequency radar altimeter (ALT); a microwave radiometer (TMR); a laser retroreflector array (LRA); the high-precision frequency reference unit (FRU); and a GPS demonstration receiver (GPSDR). The French Centre National d Etudes Spatiales (CNES) provided a single-frequency solid-state radar altimeter (SSALT), the DORIS dual Doppler tracking system receiver, and provided the TOPEX/Poseidon launch by an Ariane rocket from the European Space Agency’s facility at Kourou, French Guiana.

TOPEX/Poseidon makes altimetric sea level measurements using either the dual-frequency NASA ALT or the CNES single frequency SSALT. Since the ALT and the SSALT share a common antenna, they cannot be operated simultaneously. The ALT, the primary mission instrument, is operated about 90% of the time, and the SSALT is operated about 10% of the time. The ALT provides a range measurement from satellite to ocean surface to a precision of 2.4 centimeters (0.95 inches) for a 1-second averaging time.

The TOPEX/POSEIDON mission is based on science and mission goals established by the TOPEX Science Working Group in 1981. NASA's Jet Propulsion Laboratory is responsible for project management, mission operation and control, and for processing, distributing, and archiving the NASA data.

Tracking and Data Relay Satellite (TDRS)

The TDRS System is a communication signal relay system that provides tracking and data acquisition services for NASA, other satellites (customers), and the Space Shuttle. The system is capable of transmitting to, and receiving data from, customer spacecraft over at least 85% of the customer's orbit.

The TDRS space segment consists of six on-orbit Tracking and Data Relay Satellites in geosynchronous orbit. Three TDRS's are available for operational support at any given time. The operational spacecraft are located at 41, 174, and 275 degrees west longitude. The other TDRS satellites in the constellation provide backup in the event of a failure of an operational spacecraft and, in some specialized cases, serve as resources for targets of opportunity activities.

TDRS-J, the third Boeing-built replenishment spacecraft for NASA's Tracking and Data Relay Satellite fleet, was successfully launched from Cape Canaveral Air Force Station, Fla. at Dec. 5, 2002.

Transition Region and Coronal Explorer (TRACE)

TRACE was launched into a 600 x 650 km Sun synchronous orbit April 2, 1998 on a Pegasus XL launch vehicle from Vandenberg Air Force Base. The spacecraft weighed 250 kg and had a 1-year required mission life.

The objective of the Transition Region and Coronal Explorer (TRACE) is to explore the three-dimensional magnetic structures that emerge through the visible surface of the Sun -- the Photosphere -- and define both the geometry and dynamics of the upper solar atmosphere - the Transition Region and Corona. The magnetic field geometry can be seen in images of solar plasma taken in wavelengths emitted or absorbed by atoms and ions formed in different temperature ranges. The transition from the 6000 degree K Photosphere, where magnetic fields and plasma are in rough equipartition (low beta), to the multi-million degree Corona, where the magnetic fields dominate (high beta), is extremely difficult to model. Many of the physical processes that occur here -- plasma confinement, reconnection, wave propagation, and plasma heating -- arise throughout space physics and astrophysics. To date, no images have ever been collected that show the required temperature range nearly simultaneously with both high spatial and temporal resolution. The TRACE data will provide quantitative observational constraints on the models and thus stimulate real advances in our understanding of the transition from low to high beta plasma. The solar atmosphere is constantly evolving because the magnetic fields that dominate the Corona are continuously being displaced by the convective motions in the outer layers of the sun just below the Photosphere. A major objective of the TRACE investigation is to explore the relation between diffusion of the surface magnetic fields and the changes in heating and structure throughout the Transition Region and Corona. The simultaneous movies of the 6000 to 10,000,000 degree K volume of the solar atmosphere will allow us to determine the rate of change of the magnetic topology and the nature of the local restructuring and reconnection processes.

Occasionally new magnetic flux emerges through the solar surface and organizes into local concentrations the largest of which are sunspots. The emergence of new flux has profound effects on the overlying atmosphere and often triggers a variety of phenomena which release significant amounts of energy and which can result in major restructuring of the Corona, the interplanetary medium, and the Earth's magnetosphere. Therefore, TRACE will observe nearly continuously for an extended period to study not only the "quiet" solar atmosphere but also the more episodic active Sun.

Tropical Rainfall Measuring Mission (TRMM)

The TRMM project is part of NASA's Mission to Planet Earth. It is a joint project between the United States and Japan. The National Space Development Agency of Japan (NASDA) provided the Precipitation Radar (PR) and an H-II rocket that launched the TRMM observatory November 27, 1997 for a 3-year mission. NASA's Goddard Space Flight Center (GSFC) in Greenbelt, Maryland, provided the observatory, four instruments, integration and test of the observatory, the science data processing system, and will operator the TRMM satellite via the Tracking and Data Relay Satellite System (TDRSS).

TRMM is the first mission dedicated to measuring tropical and subtropical rainfall through microwave and visible infrared sensors, including the first spaceborne rain radar. Through use of a low altitude orbit, 217 miles (350 kilometers) and with a complement of state of the art instruments, TRMM will provide more accurate rainfall measurements and increase knowledge of how heat energy is released to drive air circulations. TRMM's orbit is set to range between 35 degrees north and 35 degrees south latitude flying over each position on the Earth's surface at a different local time each day, allowing rain variations over the 24-hour period to be calculated. Using these instruments and special orbit, TRMM will yield a data set vastly more informative than any now available.

TRMM's science objectives are as follows: to obtain and study multi-year science data sets of tropical and subtropical rainfall measurements; to understand how interactions between the sea, air and land masses produce changes in global rainfall and climate; to improve modeling of tropical rainfall processes and the influence on global circulation in order to predict rainfall and variability at various time scale intervals; to test, evaluate and improve the performance of satellite rainfall measurement techniques .

TRMM has three instruments in its rainfall measurements package. The TRMM Microwave Imager (TMI) and the Precipitation Radar (PR) are the primary instruments for precipitation measurement. The third component of TRMM's three-instrument rain package is NASA's five channel Visible Infrared Scanner (VIRS). The Clouds and Earth's Radiant Energy System (CERES) and the Lightning Imaging Sensor (LIS) round out the instrument complement.

Upper Atmosphere Research Satellite (UARS)

UARS was launched September 15, 1991, from the Space Shuttle Discovery. It was the first satellite dedicated to studying stratospheric science, focusing on the processes that lead to ozone depletion, complementing and amplifying the measurements of total ozone made by the Total Ozone Mapping Spectrometer (TOMS) onboard NASA's Nimbus-7 and the Russian Meteor-3 satellites.

Ten UARS instruments have provided the most complete data on upper atmospheric energy inputs, winds, and chemical composition ever gathered. Together, these observations constitute a highly integrated investigation of the nature of the upper atmosphere. In its first two weeks of operation, UARS data confirmed the polar ozone-depletion theories by providing three-dimensional maps of ozone and chlorine monoxide near the South Pole during development of the 1991 ozone hole. UARS, developed and managed by GSFC, in Greenbelt, Md., provides information that nations around the world can use to guide decisions on environmental policies, according to scientists.

UARS is collecting data on the chemistry, dynamics and radiative inputs to the upper atmosphere far beyond its designed lifetime of 18 months. UARS was the first spacecraft launched as part of Mission to Planet Earth (MTPE) the NASA element of the U.S. Global Change Research Program.

WIND (Global Geospace Science - GGS)

Launched November 1, 1994 aboard a Delta II rocket from Cape Canaveral Air Station, Florida, WIND is the first of two NASA spacecraft in the Global Geospace Science initiative (GGS) and part of the ISTP Project.

The Wind spacecraft carries six U.S. instruments, one French instrument and the first Russian instrument ever to fly on an American satellite. The satellite will be put into a figure-eight orbit around the Earth with the assistance of the moon's gravitational field. The furthest point from the Earth on the orbit - the apogee - will be as far as 250 Earth radii (990,000 miles, or 1,600,000 kilometers). The closest point to Earth - the perigee - will be at least 4.5 Earth radii (18,000 miles, or 29,000 kilometers). Later, the Wind spacecraft will be inserted into a small circular orbit in the solar wind upstream from the Earth around the point where the gravity of the Earth and Sun are balanced (Approximately 990,000 miles or 1,6000,000 kilometers from the Earth).

The science objectives of the WIND mission are to provide complete plasma, energetic particle, and magnetic field input for magnetospheric and ionospheric studies; determine the magnetospheric output to interplanetary space in the up-stream region; investigate basic plasma processes occurring in the near-Earth solar wind; and provide baseline ecliptic plane observations to be used in heliospheric latitudes from ULYSSES. The spacecraft is controlled daily by the GGS Flight Operations Team at Goddard (via the Deep Space Network of antennas).

Wilkinson Microwave Anisotropy Probe (WMAP or MAP or MIDEX 2)

MAP is a NASA Explorer mission that measures the temperature of cosmic background radiation over the full sky with a high level of accuracy. MAP was launched aboard a Delta II 7425-10 launch vehicle into Lissajous orbit about the L2 Sun-Earth Lagrange Point, 1.5 million km from Earth. The goal is to measure the remnant heat from the Big Bang to determine more about the beginning and the future of the universe.

The WMAP instrument consists of a set of passively cooled microwave radiometers with 1.4 x 1.6 meter diameter primary reflectors to provide the desired angular resolution. These instruments allow measurements of temperature of the microwave sky to an accuracy of one millionth of a degree. WMAP measures small variations in the temperature of the cosmic microwave background radiation- one part of the sky has a temperature of 2.7251 Kelvin (degrees above absolute zero), while another part of the sky has a temperature of 2.7249 Kelvin.

In 1992, NASA's Cosmic Background Explorer (COBE) satellite detected these tiny temperature differences on large angular scales. WMAP measures anisotropy with much finer detail and greater sensitivity than COBE. These measurements reveal the size, matter content, age, geometry and fate of the universe. They also reveal the primordial structure that grew to form galaxies and will test ideas about the origins of these primordial structures.

The mission lifetime was 2 years, but the mission was extended for several years to collect additional high quality data. The MAP spacecraft weighs 840 kg.

Wide Field Infrared Explorer (WIRE)

WIRE was launched March 4, 1999 aboard a Pegasus XL launch vehicle from the Western Range/ Vandenberg AFB in California. WIRE is a Small Explorer Mission designed to study the evolution of starburst galaxies and search for distant ultra-luminous galaxies. The instrument consists of a cryogenically cooled, 30 cm imaging telescope, which will detect faint astronomical sources in two infrared wavelength bands.

The primary purpose of WIRE was a four-month infrared survey of the universe, focusing specifically on starburst galaxies and luminous protogalaxies. The WIRE spacecraft spun out of control when the instrument cover was prematurely ejected a half an hour after launch. It took the team a week to gain control of the spacecraft. By that time the instrument was out of cryogen and WIRE was unable to carry out its primary science mission.

Spacecraft operations have been redirected to use the onboard star tracker for long-term monitoring of bright stars in support of two separate science programs: astroseismology and planet finding. The astroseismology program is intended to measure oscillations in nearby stars to probe their structure. The planet-finding program searches for stellar occultations by large planetary bodies as they pass through WIRE's line-of-sight to its target star.

Rossi X-Ray Timing Explorer (XTE or RXTE)

The X-Ray Timing Explorer (XTE) was launched from Cape Canaveral Air Station December 30, 1995. With a planned operational lifetime of 2 years, XTE was launched on a Delta II into a low Earth orbit of 362 miles, and a 23-degree inclination.

The purpose of the XTE mission is to provide an understanding of the structure and dynamics of galactic and extragalactic compact X-ray sources. XTE gathers data about X-ray emitting objects within the Milky Way, and beyond. It performs timing studies of X-ray sources, which vary in intensity of their emissions. It also performs spectral studies, which will reveal emission processes and locations emitting X-rays. XTE has three instruments studying the variable X-ray sky: Large Area Proportional Counter Array (GSFC), All Sky Monitor (Massachusetts Institute of Technology), and High Energy X-Ray Timing Experiment (University of California at San Diego).

Appendix C - Classification and Log of FY 2003 Anomalies

Appendix C contains the detailed data used to compile and compute the statistics in this report. Due to its length, it is not included herein. It may be obtained in an electronic format to qualified persons upon written request to the GSFC Systems Safety and Reliability Office.