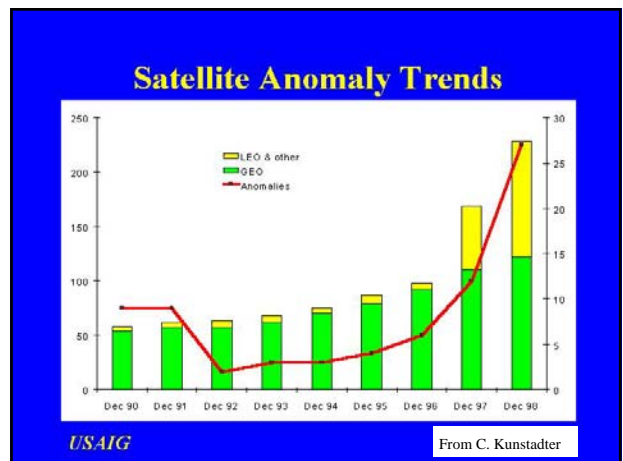
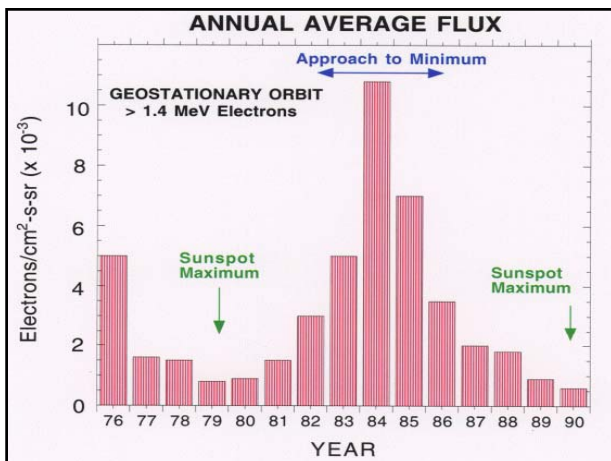
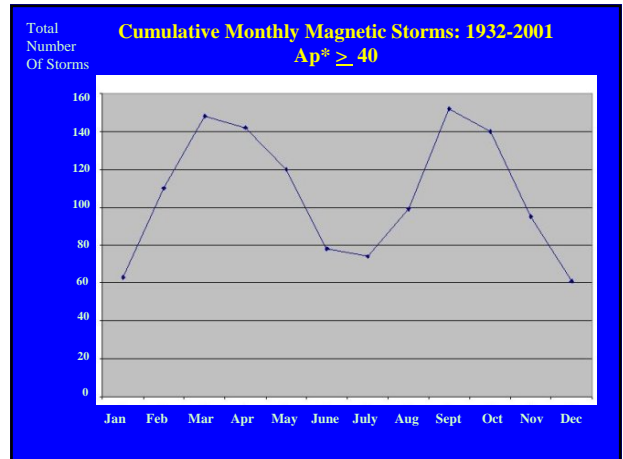
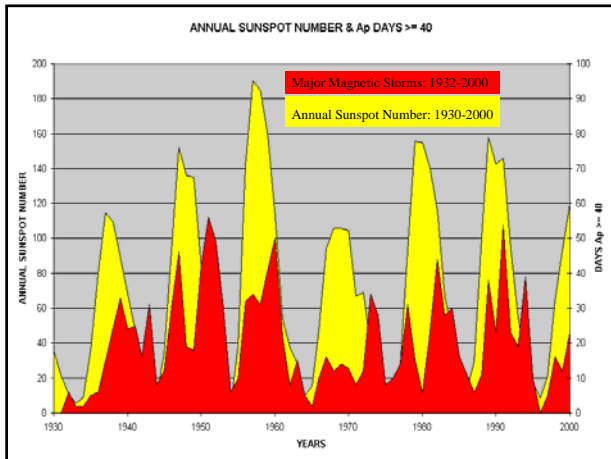
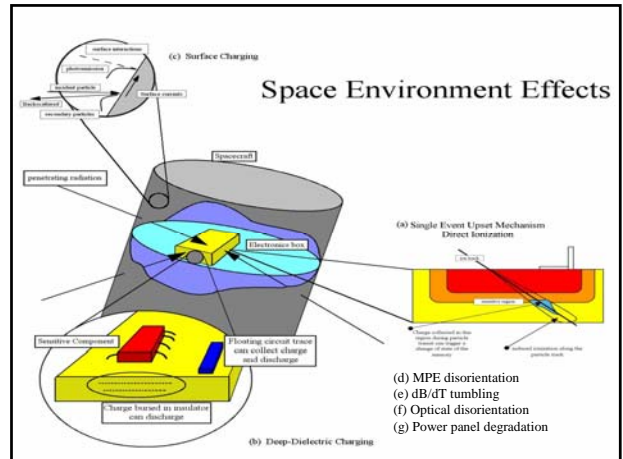


Historical and Recent Solar Activity and Geomagnetic Storms Affecting Spacecraft Operations

Joe H. Allen, SCOSTEP
 GOMAC 2002
 Session 14: Modern Space Systems Issues
 11-14 March 2002
 Monterey, California



USAIG

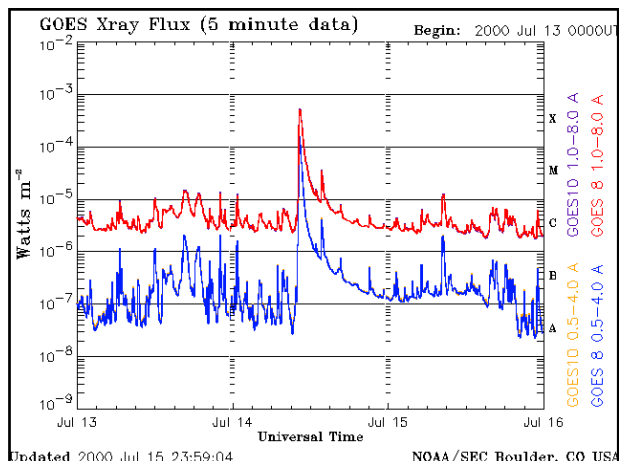
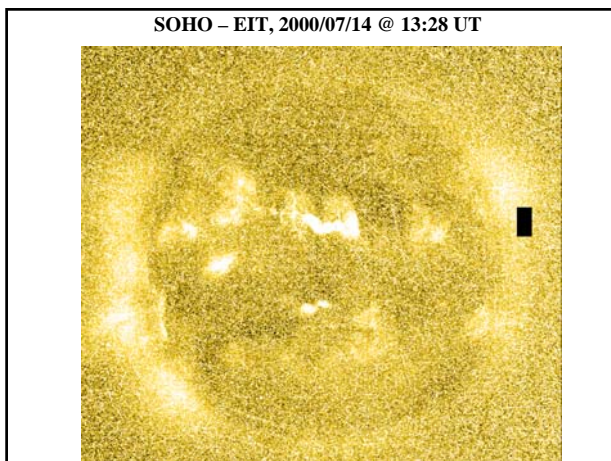
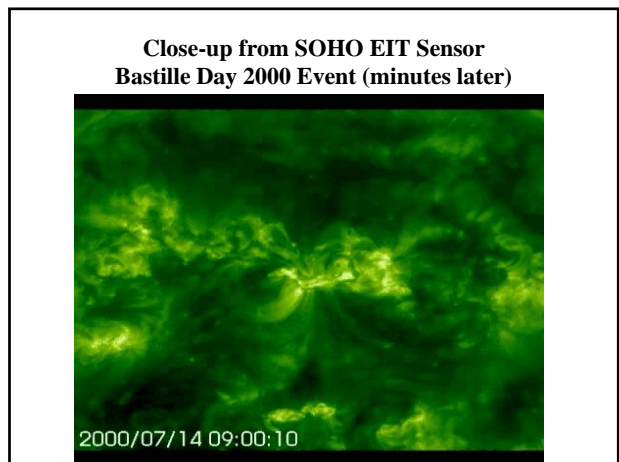
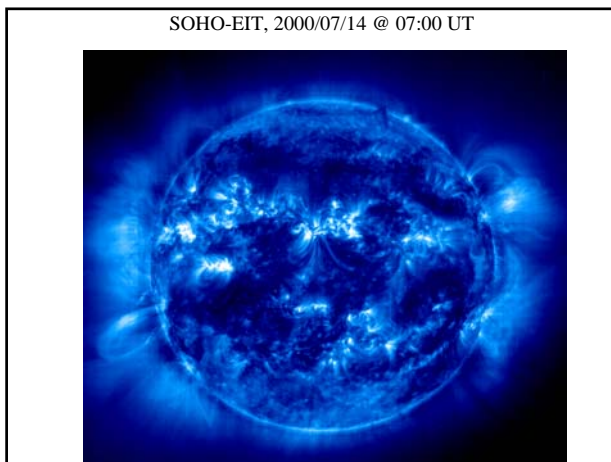
From C. Kunstadter

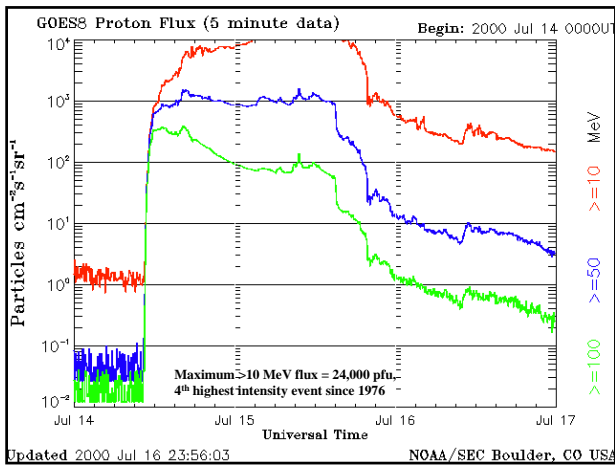
SAT-ND Timeline in-orbit failures in 2001 – P.C. Klanowski

Date	Satellite	Problem(s)
15 Dec 2001	Vishak	Safe mode during solar eclipse, unexpected spin, loss of contact
18 Dec 2001	FOXE	γ-ray neutron reflector stops working, spacecraft in safe mode
17 Dec 2001	Arctus 2A	Permanent loss of several transponders
23 Nov 2001	FOXE	ε-radiation wheel stops working
23 Oct 2001	EchoStar VI	Loss of two solar array strings (of a total of 112) announced
Sep 2001	BeppoSAX	Loss of six gyroscopes fails. Satellite now operates in gentler mode
Sep 2001	Oswin	Thermal control problem caused by faulty radiator
Sep 2001	EchoStar V	Third TWTA switched off, replaced with spares
Sep 2001	(unknown)	Exiting anomalous power degradation on 702 model solar array
6 Sep 2001	PAS-7	Sudden loss of 25 percent of power, to be declared "Constructive Total Loss"
Aug 2001	EchoStar V	Thrustor anomaly, short interruption of service
14 Aug 2001	Globular	Orbit/altitude anomalous loss of two stabilizer during 2001
11 Aug 2001	TDRS-6	Exiting anomalous performance shortfall on Multiple-Access phased array antenna
July 2001	EchoStar V	Loss of one momentum wheel, short interruption of service
11 June 2001	BeppoSAX	Loss of attitude control, undisclosed reason. Spacecraft probably lost
April 2001	OSAT	Satellite runs out of fuel after unexpected contingency
April 2001	EchoStar VI	Series of anomalous events resulting in a temporary interruption of service
22 April 2001	Tatiana 6	SCP failure
21 April 2001	Orbview 300	SCP failure
Mar 2001	Star	"Minor problems" with solar array
mid-Feb 2001	STRV 11, 14	Both spacecraft total loss caused by the same design flaw
15 Jan 2001	Blues 20	One of two transponders lost
13 Jan 2001	ERS	Loss of six gyroscopes fails

SAT-ND Timeline in-orbit failures in 2000

22 Nov 2000	Galaxy VII	Secondary SCP fails; total loss
4 Nov 2000	Insat 2B	Loss of attitude control twice for unknown reasons
31 Oct 2000	EchoStar IV	Number of lost transponders has reached 26 out of 44
26 Oct 2000	Terra	Telemetry Monitor 16 turned off Science Formatting Equipment, reason unknown
28 Sep 2000	Galaxy VIII-i	Loss of xenon ion propulsion systems. Life span reduced by 10 years
12 Sep 2000	Garuda 1	Antenna-related anomaly discovered during testing by manufacturer Lockheed Martin
27 Aug 2000	Solidaridad 1	Failure of backup SCP. Declared total loss
15 July 2000	ASCA (Astro-D)	Satellite started spinning during high solar activity. Safe mode. Declared total loss later
28 April 2000	Turksat 1C	Temporary loss of service for 55 minutes (safe mode, caused by electrostatic discharge in orbit)
31 Mar 2000	EchoStar IV	Number of lost transponders (22) has reached 50% of total (44)
21 Mar 2000	Hotbird 2	Temporary loss of service for 9 hours
3 Mar 2000	Satnux 5	84-minute outage, safehold mode triggered by faulty ground control software





Satellite Anomalies: 14-16 July 2000 Proton Event & Geomagnetic Storm, $A_p^* = 192$

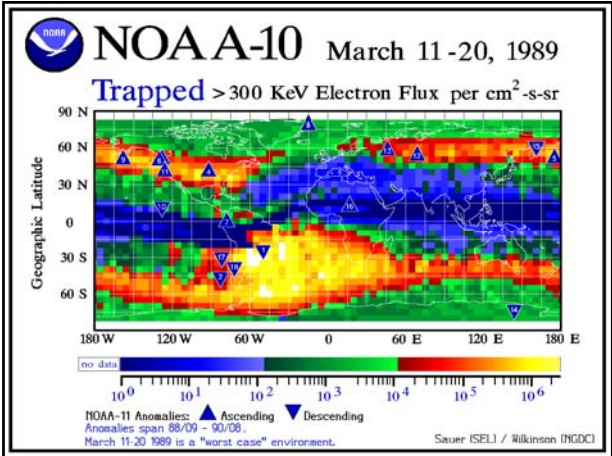
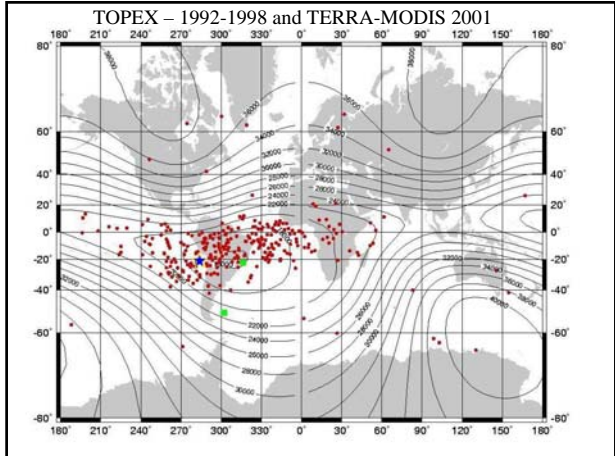
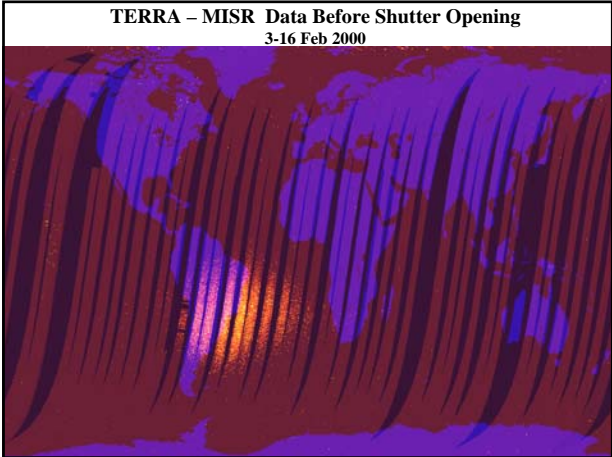
- ASCA (Advanced Satellite for Cosmology and Astrophysics) – lost attitude fix resulting in solar array misalignment and power loss, satellite probably lost (in P.C. Klanowski list).
- GOES-8 & -10 – SEM Electron sensor problems, power panels
- ACE (Advanced Composition Explorer) – Temporary SW and other sensor problems
- WIND – Permanent (25%) loss of primary transmitter power & Temporary loss of Sun and star sensors
- SOHO (also YOHKOH & TRACE) – High energy protons obscure solar imagery
- GEO and LEO Satellites – S/C orientation problems during MPE
- GEO Satellites lost -0.1 amp output from solar arrays

Satellite Anomalies at LEO

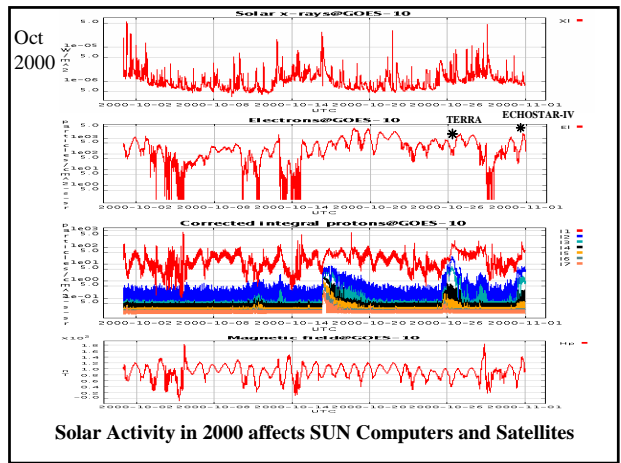
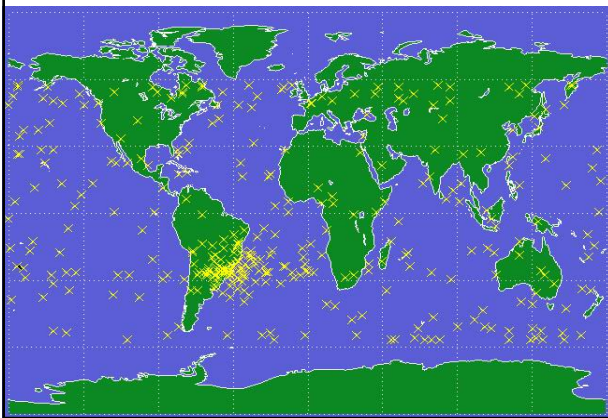
South Atlantic Anomaly (SAA) & Auroral Zone

Recent and Historical

- TERRA-MISR 3-16 Feb 2000
- TERRA-SFE off 26 Oct 2000
- TERRA-MODIS 15 June 2001, 03:56 UT
- TOPEX 1992-1998
- NOAA-11 Sept 1988 - Aug 1990
- STS-37, -39, -43, & -44 1991

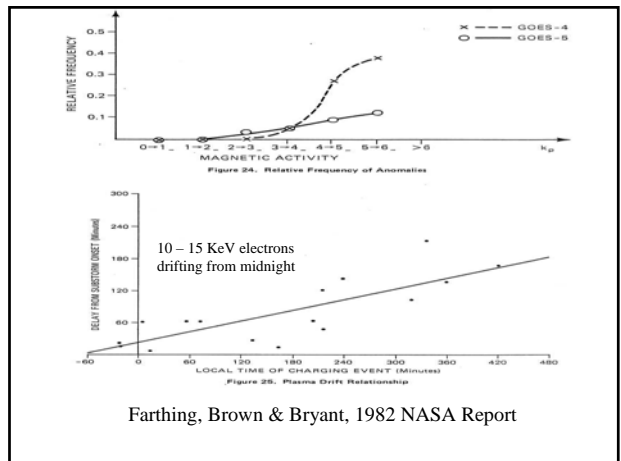
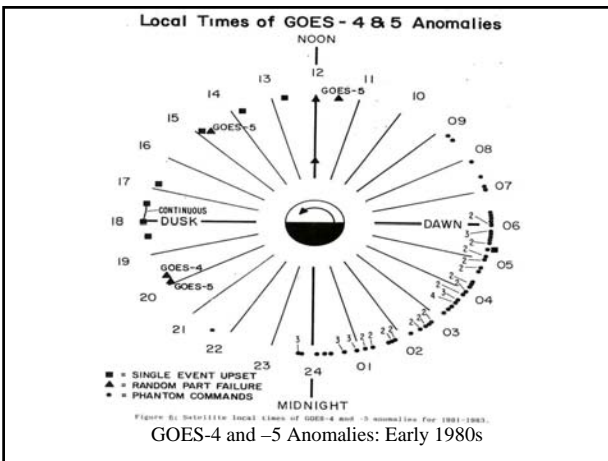
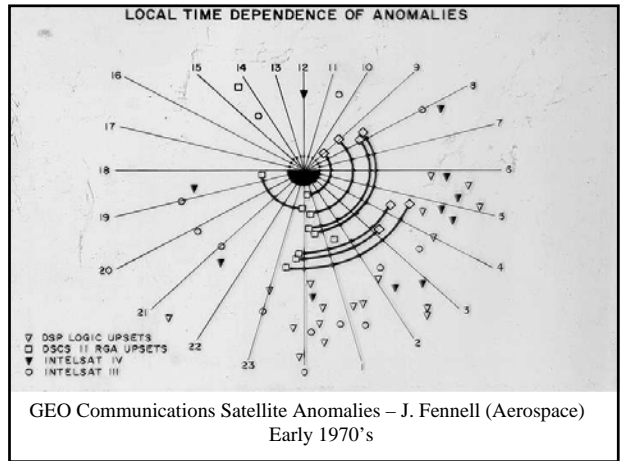


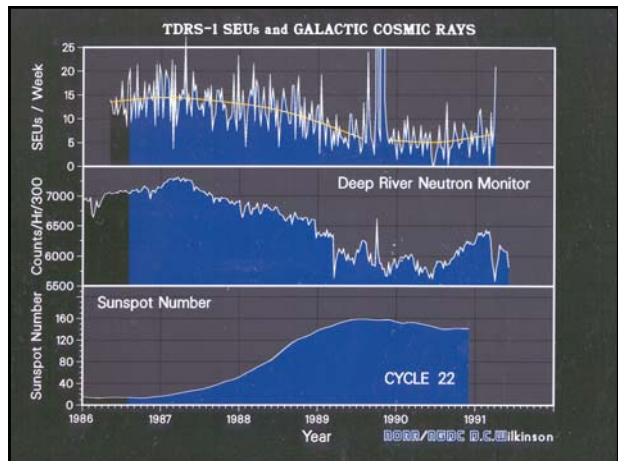
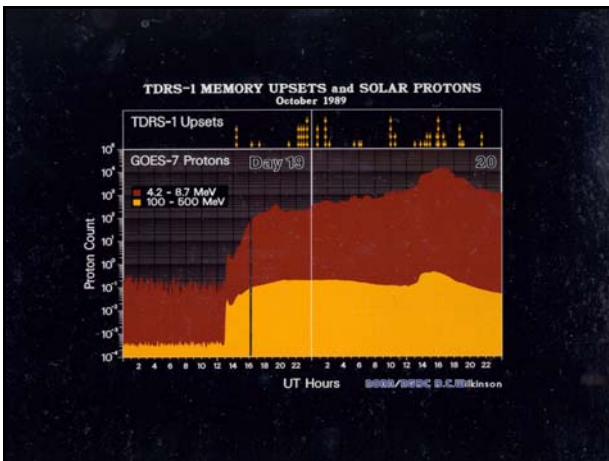
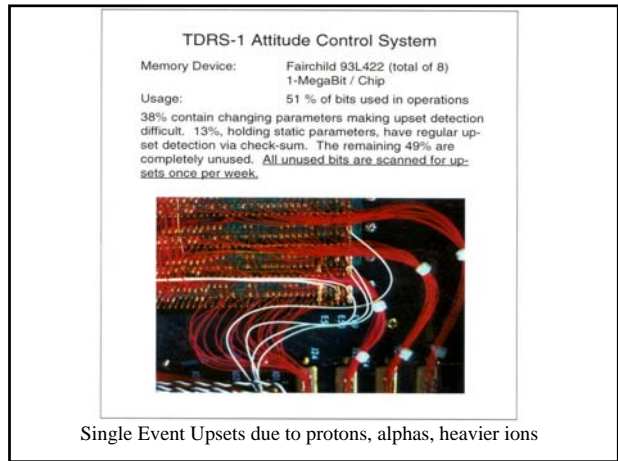
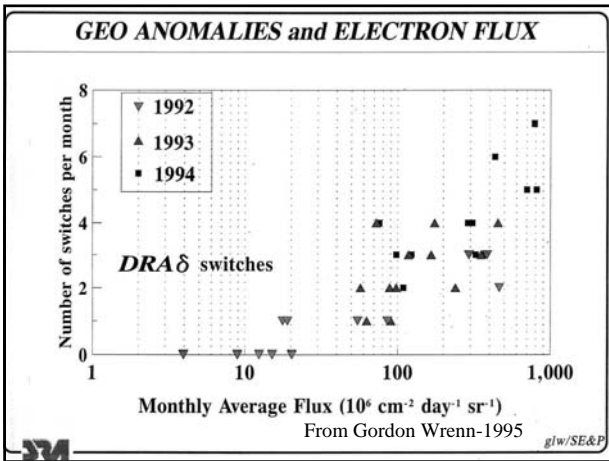
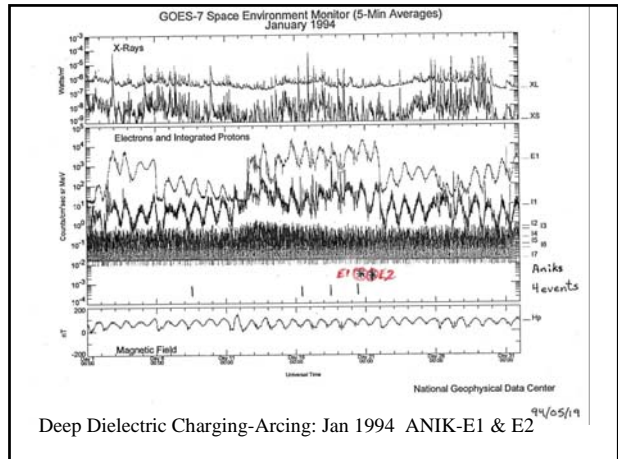
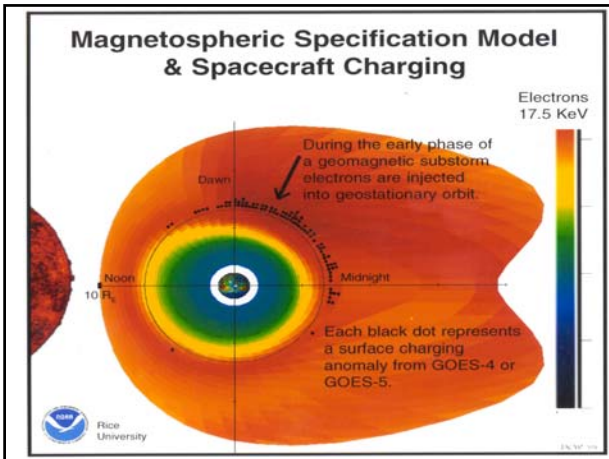
COMPUTER ANOMALIES: STS-37, -39, -43, & -44 1991 Missions



GEO ANOMALY TYPES

- PHANTOM COMMANDS – surface charging, seasonal, orbit time dependent, 10-50 KeV e-
- DEEP DIELECTRIC CHARGING – surface or interior, cycle dependent, ≥ 2 MeV e-
- SINGLE EVENT UPSET (SEU) – proton/ion event, > 10 MeV p+
- LOSS OF ORIENTATION – magnetopause crossing events, star bursts
- POWER PANEL DEGRADATION – > 10 MeV p+



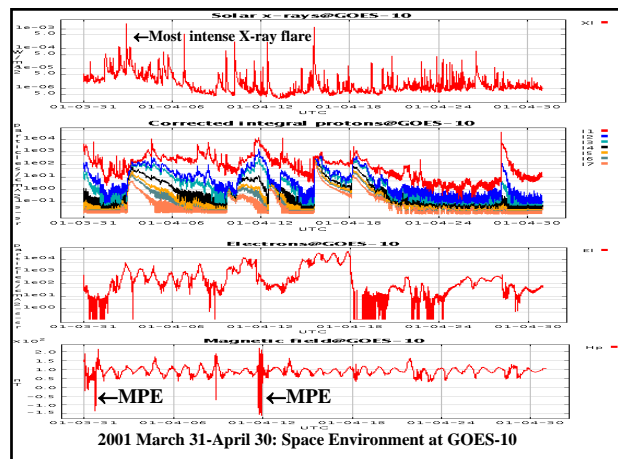
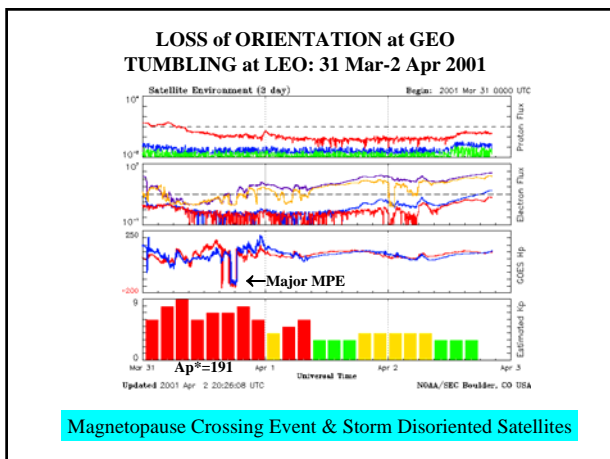
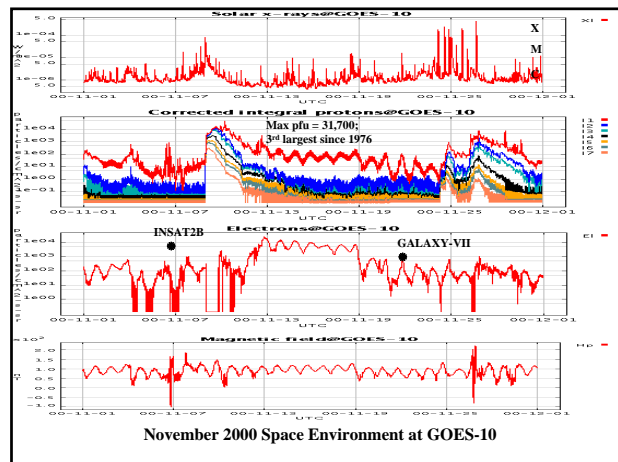
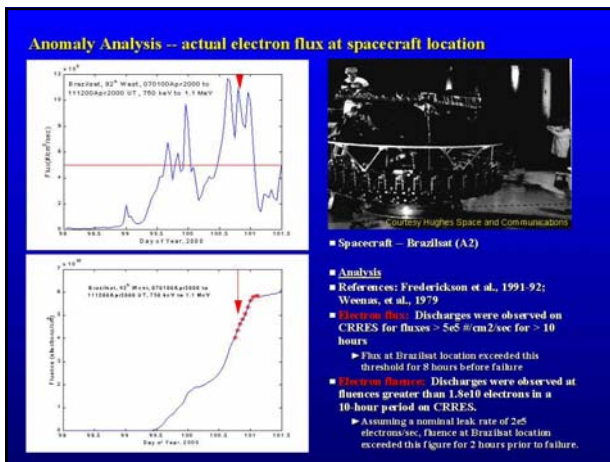


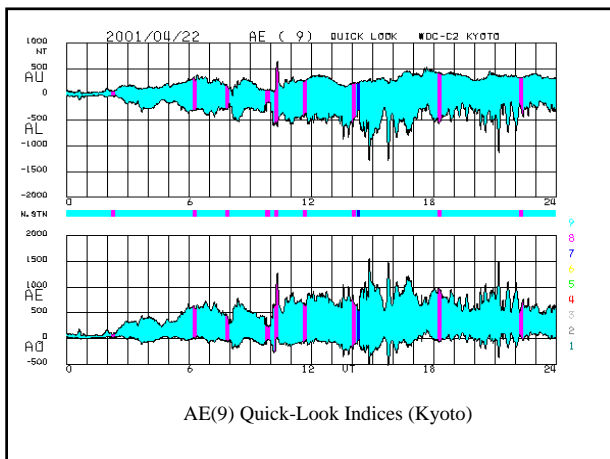
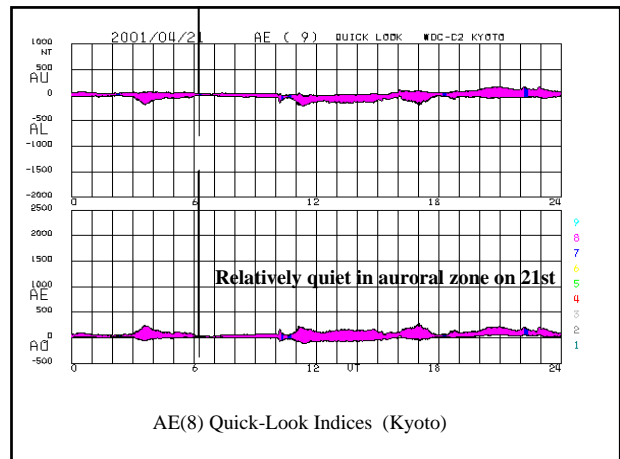
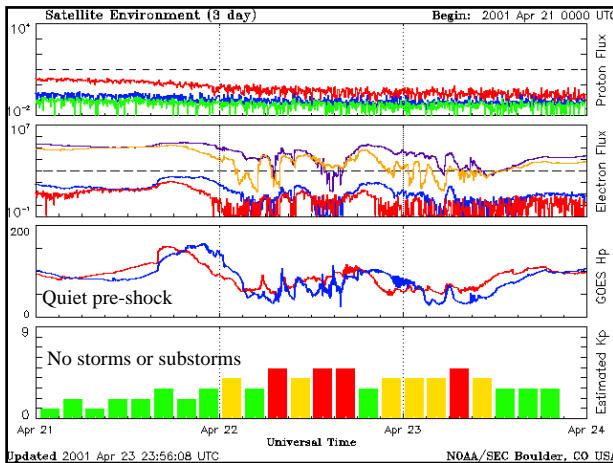
Satellite Anomalies at GEO Recent and Historical

- GALAXY-VII 13 June 1998 SCP-1
- BRAZILSAT 09 April 2000 TWTA
- SOLIDARIDAD-I 27 Aug 2000 SCP
- ECHOSTAR-IV 31 Oct 2000 Transponders lost
- INSAT-2B 4 Nov 2000 Service Outage
- GALAXY-VII* 22 Nov 2000 SCP-2
- ECHOSTAR-VI ? April 2001 service
- GALAXY-IIIR 21 April 2001 SCP
- TELSTAR-6 22 April 2001 SCP

RECENT ACTIVE TIME 2-11 April 2000

- High levels >2MeV electrons, 04/02-12 except during storms
- Proton event, 04/04-06, 55pfu
- Large geomagnetic storm, $A_p^* = 137$, 04/06-07
- Brazilsat-A2 lost TWTA on 04/09





Redesigns (Some Mission Loss)

These systems had extensive SWx problems and follow-ons required redesign

- DMSP F2 - 1977 chronic charging on one component
- METEOSAT F1 11/77 extensive charging
- GPS Blk I- clock failures
- GPS - 6/13/80 solar array tracking
- GOES-4 81/82 ungrounded radiator
- HEO signal degradations - subassembly redesigned
- TDRSS-1 4/83 attitude control system
- Telecom 1A- 8/84 ungrounded thermal shielding
- CLAS - extensive loss of data/noise
- SUPERBIRD-1 12/90 - SEU affecting attitude control led to hardened microprocessors
- MARECS-A 3/91 continuous safing
- TEMPO 4/97 New technology - increased power, use of GaAs, solar panel problems

CONCLUSIONS-1

- Sunspot cycle decline and minimum years are ideal for “killer electrons” at GEO and lower orbit altitudes.
- Sunspot cycle maximum years are ideal for energetic proton and heavier ion events that cause SEUs and sensor optics & power panel degradation.
- Major magnetic storms may happen at any time and cause spectacular effects on satellites, technology and humans.

CONCLUSIONS-2

- Every satellite (or object) in orbit is a probe of the Space Environment from which to learn.
- The history of satellites should be the basis for learning what causes operational problems.
- Combining space environment data with satellite histories is necessary.
- Solar Cycle # 23 still may be highly active. Are we any more ready today?
- What about cycle # 24? Can engineering cope?