Miscellaneous Topics

Small Satellite Workshop 2025

Impact of Space Environments on Space Systems

Mechanism	Effect	Source
Surface Charging	• Biasing of instrument readings • Power drains • Physical damage	• *Dense, cold plasma* • *Hot plasma*
Deep Dielectric Charging	• Biasing of instrument readings • Electrical discharges causing physical damage	• *High-energy electrons*
Structure Impacts	• Structural damage • Decompression	• *Micrometeoroids* • *Orbital debris*
Drag	• Torques • Orbital decay	• *Neutral thermosphere*
Total Ionizing Dose (TID)	• Degradation of microelectronics	• *Trapped protons* • *Trapped electrons* • *Solar protons*
Displacement Damage Dose (DDD)	• Degradation of optical components and some electronics • Degradation of solar cells	• *Trapped protons & electrons* • *Solar protons* • *Neutrons*
Single-Event Effects (SEE)	• Data corruption • Noise on images • System shutdowns • Electronic component damage	• *GCR heavy ions* • *Solar protons and heavy ions* • *Trapped protons* • *Neutrons*
Surface Erosion	• Degradation of thermal, electrical, optical properties • Degradation of structural integrity	• *Particle radiation* • *Ultraviolet* • *Atomic oxygen* • *Micrometeoroids Contamination*

NASA CCMC

Space Systems Anomaly and Failures

- The next few slides give examples of the range of anomalies and failures in both spacecraft and launch vehicles that occurred in 2022 and the first months of 2023
  - Wide range of environments
  - No one is immune: government, industry, academia
  - Public sources only

Selected Spacecraft Anomalies and Failures

Date	Mission	Affiliation	Environment	Event	Cause/Notes	Ref*
5 Jan 22	ELSA-d	Astroscale	LEO	Anomalous spacecraft conditions required delay of orbital debris capture technology demo mission	Four of eight thrusters have technical difficulties and are now non-functional	1,2
3 Feb 22	Starlink	SpaceX	LEO	38 satellites lost	Loss of control, reentry due to high drag	3,4
4 Feb 22	SWIFT	NASA		Safe mode, February 2022	Failed reaction wheel, mechanical	5
31 Mar 22	Aqua	NASA	LEO	Safe mode 2022/090/17:59:08, Return to ops 2022/105/00:38	Unexpected power controller swap	6
22 Feb 22	MAVEN	NASA	Mars	Safe mode, 22 Feb – 28 May 2022	Inertial Measurement Unit anomaly during routine power cycle	7
19 May 22	Starliner OFT-2	NASA/Boeing	LEO	Two thrusters failed during orbital insertion burn	Primary and secondary units failed Tertiary backup operated successfully	8,9
25 May 22	JWST	NASA/ESA/CSA	Sun-Earth L2	Primary mirror damaged by hypervelocity impact between 23-25 May	Meteoroid impact on primary mirror	48,49
25 May 22	Vigoride-3	Momentus	LEO	Orbital transfer vehicle failure, failure to deploy 7 of 9 payloads	Solar arrays failed to deploy, reduced power and comm	10,11,52
20 Jun 22	Cygnus	NASA/NG	LEO	ISS reboost test ends early	Cygnus engine shut down 5 sec into 5 min burn	12
28 Jun 22	Geotail	JAXA/NASA	10x30 Re	Remaining data recorder failure, 28 June 2022	Shut down 28 Nov 22 after 30 years operations	14,47
5 Jul 22	CAPSTONE	NASA	Cislunar	Safe mode	Improperly formatted command	15
19 Aug 22	Galaxy 15	Intelsat	GEO	Loss of comm and control, drifting	Geomagnetic storm, broadcast payloads shut down as satellite drifts out of control	17,18, 19,55,56
24 Aug 22	JWST	NASA/ESA/CSA	Sun-Earth L2	Mid-Infrared Instrument grating wheel anomaly	Increased friction on grating wheel mechanism	20

Source: NASA SCAF 2023

Selected Spacecraft Anomalies and Failures

Date	Mission	Affiliation	Environment	Event	Cause/Notes	Ref*
8 Sep 22	CAPSTONE	NASA	Cislunar	Tumble during trajectory correction maneuver	Vehicle attitude rates growing beyond the capacity of the onboard reaction wheels to control, propulsion system valve	15,16
10 Oct 22	TESS	NASA	LEO	Safe mode 10-13 Oct 22	Unexpected flight computer reset, recovered	22
25 Nov 22	ICON	NASA	LEO	Loss of contact with spacecraft 25 Nov 22, not recovered as of 10 Feb 23	Unknown; operating in extended mission since completing 2-yr prime mission science objectives	23,24
16 Nov 22	Orion (Artemis I)	NASA/ESA	Cislunar	RAM error in star tracker system, power conditioning and distribution unit (PCDU) fault	Thruster glow impact star tracker PCDU umbilical latching current limiter opened without command	25,26
16 Nov 22	Artemis I CubeSats	NASA	Cislunar	No comm with 5 of 10 deployed cubesats	LunaHMap (thruster failure), OMOTENASHI (no stable comm), NEAScout (no comm), CuSP (comm failed), LunIR (weak comm)	27
3 Nov 22	Orion (Artemis I)	NASA	Cislunar	Loss of comm with Orion for 47 minutes		28
7 Nov 22	Cygnus	NASA/NG	LEO	1 of 2 solar arrays fail to deploy	Vehicle successfully arrived at ISS to complete cargo mission	13
11 Dec 22	Orion (Artemis I)	NASA	LEO	Unpredicted loss of thermal protection (reentry heat shield) material	Vehicle survived reentry, but heat shield lost more charred material than expected	29
14 Dec 22	Lunar Flashlight	NASA	Cislunar	Reduced thruster performance	Fuel line obstruction	30
14 Dec 22	Soyuz MS-22	RSA	LEO	Coolant leak from thermal control system while docked to ISS	0.8 mm hole, meteoroid or orbital debris impact, Geminid meteor eliminated as cause	31,32,33, 34,35
3 Jan 23	Falcon-9/ Transporter-6	SpaceX/ USSF (US)	LEO	EWS RROCI spacecraft failed to deploy from launch vehicle, 113 of 114 payloads successfully deploy	Unclear if failure to deploy is spacecraft or launch vehicle failure; 195th flight	44,45,46

Source: NASA SCAF 2023

Selected Spacecraft Anomalies and Failures

Date	Mission	Affiliation	Environment	Event	Cause/Notes	Ref*
3 Jan 23	Orbiter SN1	Launcher	LEO	Loss of power and control; failure to deploy 6 payloads, 4 hosted payloads lost	Orientation issue due to GPS antennae fault resulted in loss of power	37,38,53, 54
15 Jan 23	JWST	NASA/CSA	L2	NIRISS instrument comm delay, software timeout	GCR upset in FPGA, recovered	21
Mid Jan 23	SWOT	NASA	LEO	Ka-band Radar Interferometer (KaRIn) instrument high-power amplifier unexpectedly shut down		39,40
11 Feb 23	Progress MS-21	RSA	LEO	Coolant leak from thermal control system while docked to ISS	12 mm hole caused by "external influences"	36
16 Feb 23	MAVEN	NASA	Mars	Safe mode 16-17 Feb 22	Inertial Measurement Unit anomaly	41
18 Feb 23	IBEX	NASA	86,000 km x 260,000 km x 10.99°	Unresponsive to commands following flight computer reset	External reset successful on 2 March 23, reestablishing control of spacecraft (2 days before IBEX scheduled for autonomous power reset)	42,43
27 Feb 23	Starlink 6-1	SpaceX	LEO	Issues with new Starlink V2 design	*"…new technology in Starlink V2… experiencing some issues, as expected. Some sats will be deorbited, others will be tested thoroughly before raising altitude above Space Station."* E. Musk	50,51

2022 - 2023

Source: NASA SCAF 2023

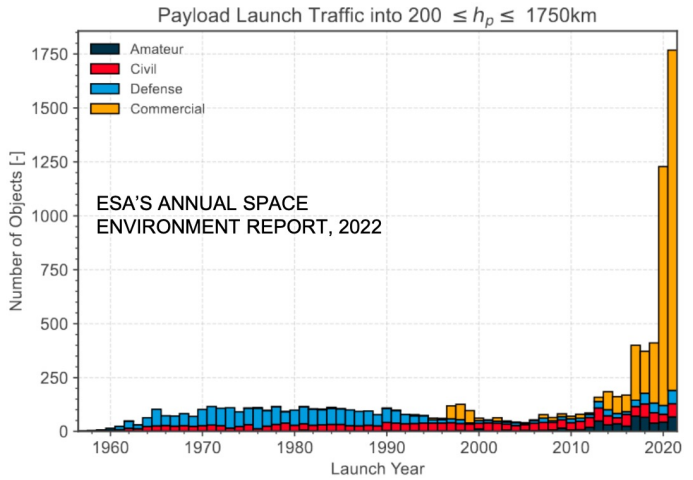
Selected Spacecraft Anomalies and Failures

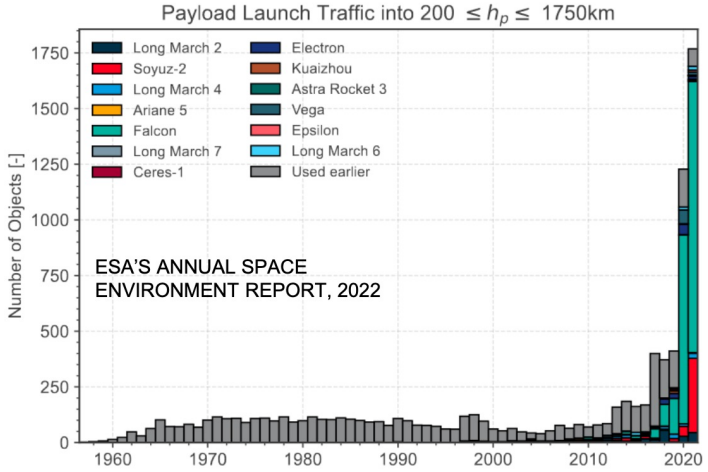
- End of mission:
  - Starlink (38), Geotail, Galaxy-15?, ICON? Artemis CubeSats (5), Soyuz MS-22, EWS RROCI, Orbiter SN1 (and 10 payloads)
- Anomalies/failure attributed to space environment (6/30 missions)

Cause	Impact
Ionizing radiation	2 (Orion, James Webb Space Telescope)
Meteoroid /Orbital Debris	2 (Soyuz, James Webb Space Telescope)
Atmospheric drag	1 (Starlink: 38 satellites)
Electronics charging	1 (Galaxy-15)

LEO Satellite Populations

- Payload launch traffic into LEO has increased dramatically in recent years with the commercial sector dominating the increase
- SpaceX is a main contributor for the number of new payloads deployed in LEO





ESA Space Environment Statistics (*22 December 2022)*

Rocket launches since 1957 (excluding failures)	~ 6,370
Objects placed into Earth orbit	~ 15,070
Objects still in space	~ 9,790
Still functioning	~ 7,200
SSN tracked and cataloged debris	~ 32,000

Debris objects estimated based on statistical models to be in orbit (MASTER-8, future population 2021)

>10 cm	36,500
>1 cm to 10 cm	1,000,000
>1mm to 1 cm	130,000,000

https://sdup.esoc.esa.int/discosweb/statistics/

https://www.sdo.esoc.esa.int/environment_report/Space_Environment_Report_latest.pdf

LEO Satellite Populations

- Payload launch traffic into LEO has increased dramatically in recent years with the commercial sector dominating the increase
- Traffic characteristics of the LEO operational environment could dramatically change in the coming years if even a fraction of the planned constellations reach their targets for planned spacecraft

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Constellation	Alt (km)	In orbit	Active	Planned
Starlink G1 (US)	540-577	3,814	3,165	4,408
Starlink G2A (US)	530-559	239	52	7,500
Starlnk G2 (US)	340-614	---	---	22,488
OneWeb, Phase 1 (UK)	1182-1221	584	426	716
OneWeb, Phase 2 (uk)	1185-1221	---	---	6,372
Kuiper (US)	590-630	---	---	3,232
Guangwan (CH)	508-1145	---	---	12,992
Galaxy Space (CH)	500	---	---	1,000
Hanwha Systems (KR)	500	---	---	2,000
Lynk Global (US)	500	---	---	2,000
Astra (US)	380-700	---	---	13,620
Boeing (US)	670-10,000	---	---	5,841
Telesat (Canada)	1015-1325	---	---	1,969
HVNET (US)	1150	---	---	1140
SpinLaunch (US)	830	---	---	1190
Globalstar3 (Germany)	485-700	---	---	3080
E-SPACE (US)	528-635	---	---	337,323
Total		4,637	3,643	427,171

Flexible Design Options

- Software
  - Software is eating the world
  - Flight Software Systems
  - Development
- FPGA-based ASIC
  - Will they be space ready?
- Structures
  - 3D printing + Polymer

What is Next?

- We plan to have
  - More workshops
  - Course module
  - A new course!

- We Want to Hear from You!
  - Your inputs are valuable

Image: IrishSat, Norte Dame University

Image: SpaceX

What is Next?

- Extend CubeSatSim v1.3.2
  - Flight software with more telecommands
  - More sensors: magnetometer, GPS, …
  - Research projects
- Weather balloon
- Real small satellite (CubeSat) mission?
- Yes, this is only the beginning

Image: IrishSat, Norte Dame University

Image: SpaceX