Study of Spacecraft Deployables Failures

Alejandro Rivera
Deployables Analysis Engineer

NASA Goddard Space Flight Center

19th European Space Mechanisms and Tribology Symposium

September 24th, 2021

DISCLAIMER

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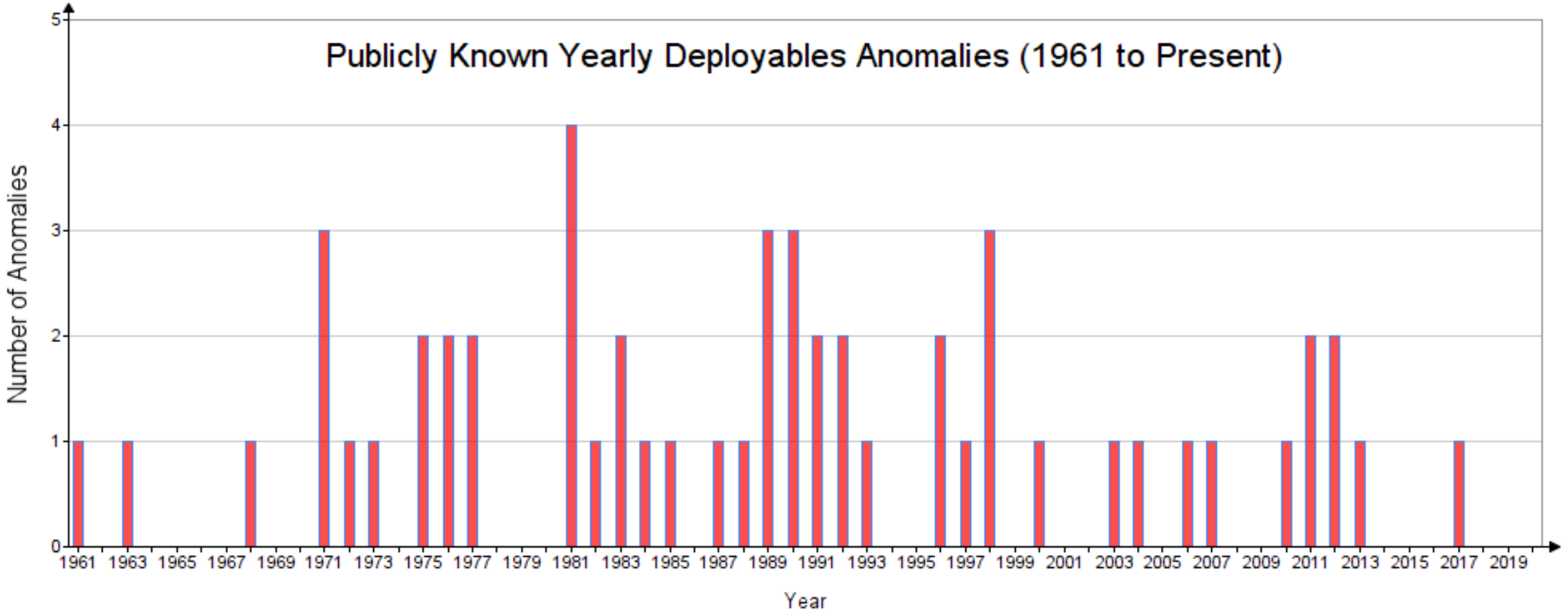
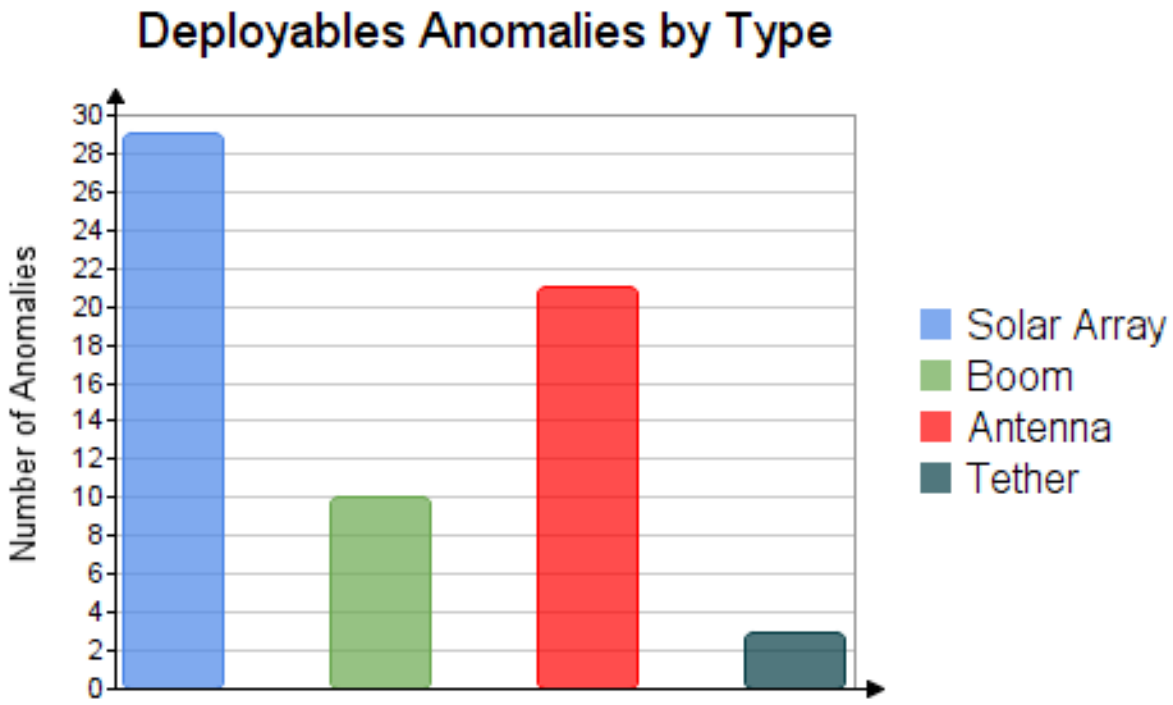
MOTIVATION

- Deployables failures still taking place at an average of 1 every two years
- Loss of mission goals and spacecraft performance
- Desire to understand what have historically been the most common modes of failure of deployables
- How can we prevent these from happening
- Share our findings with ESMATS Community

YEARLY ANOMALIES DISTRIBUTION



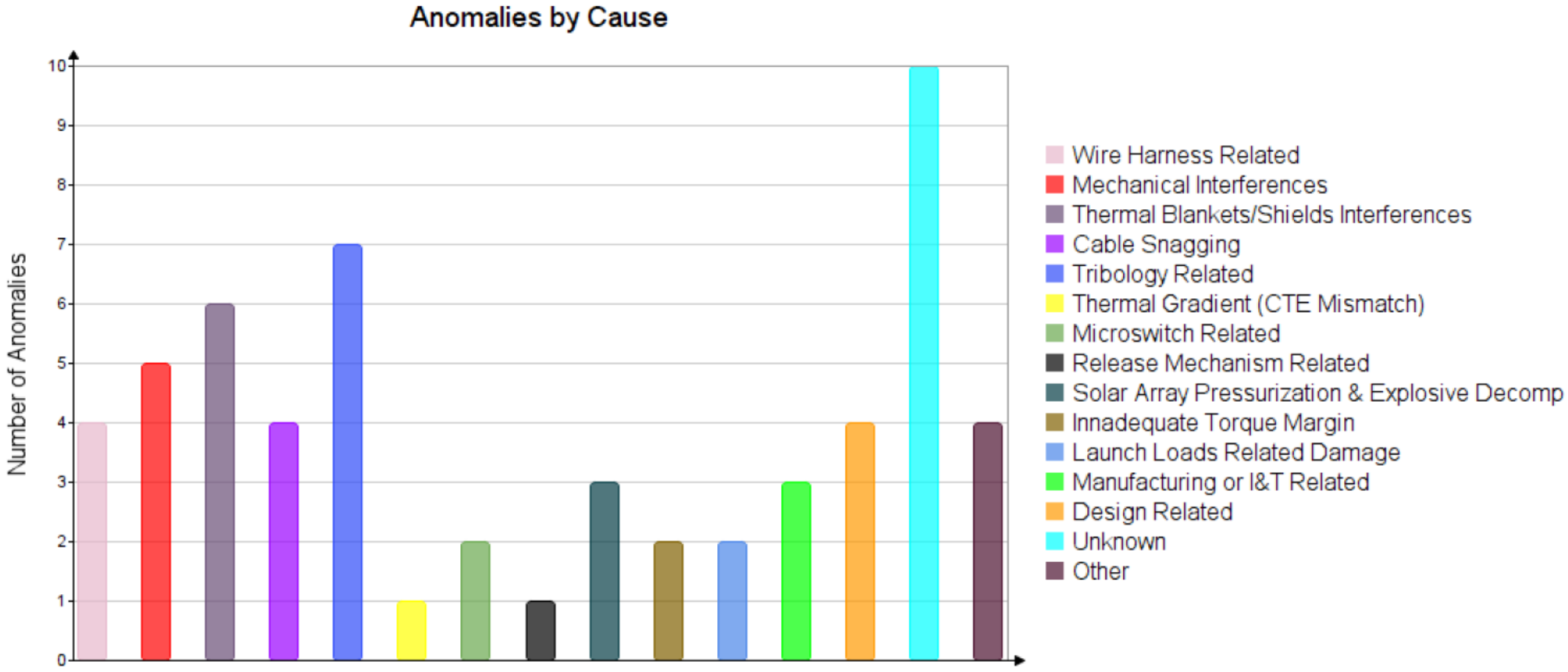
ANOMALIES BY TYPE



- Solar Array anomalies most common (54%)
- High Gain Antenna (37%)
- Booms (18%)

* Based on published information. Actuals may differ.

MAIN ANOMALIES AND FAILURES CAUSES



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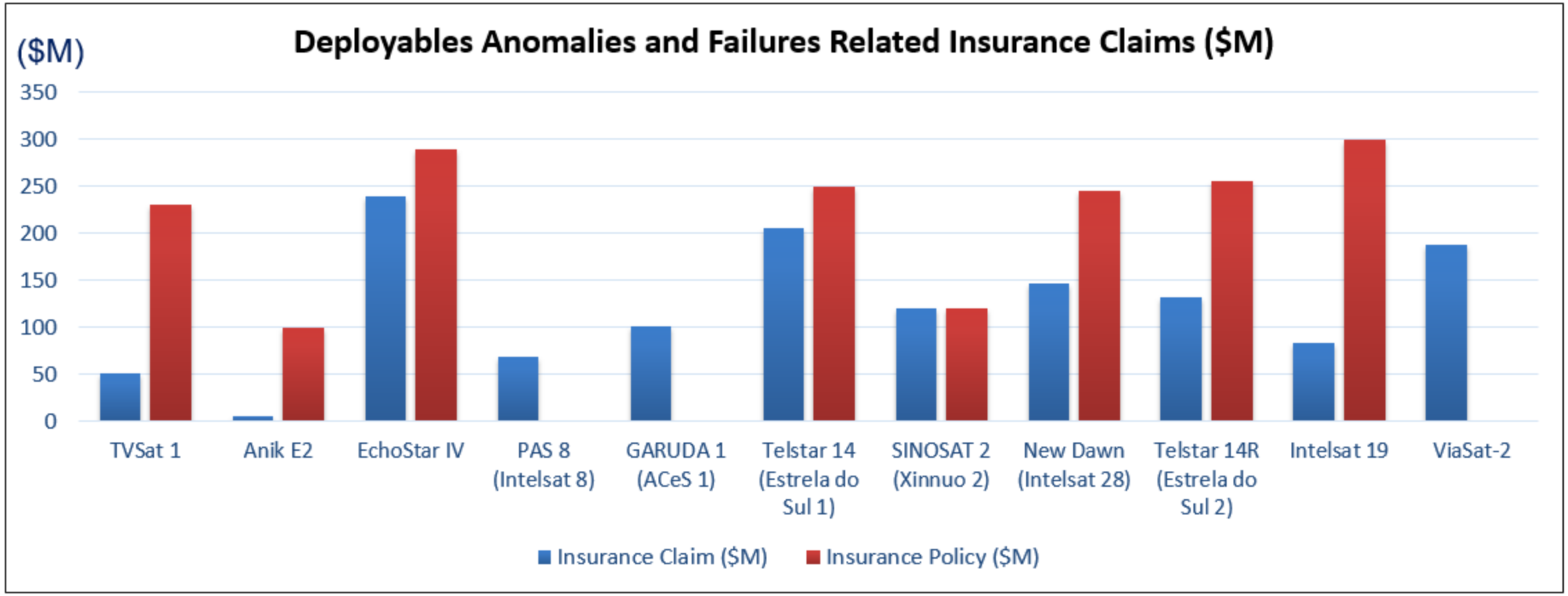
INSURANCE CLAIMS



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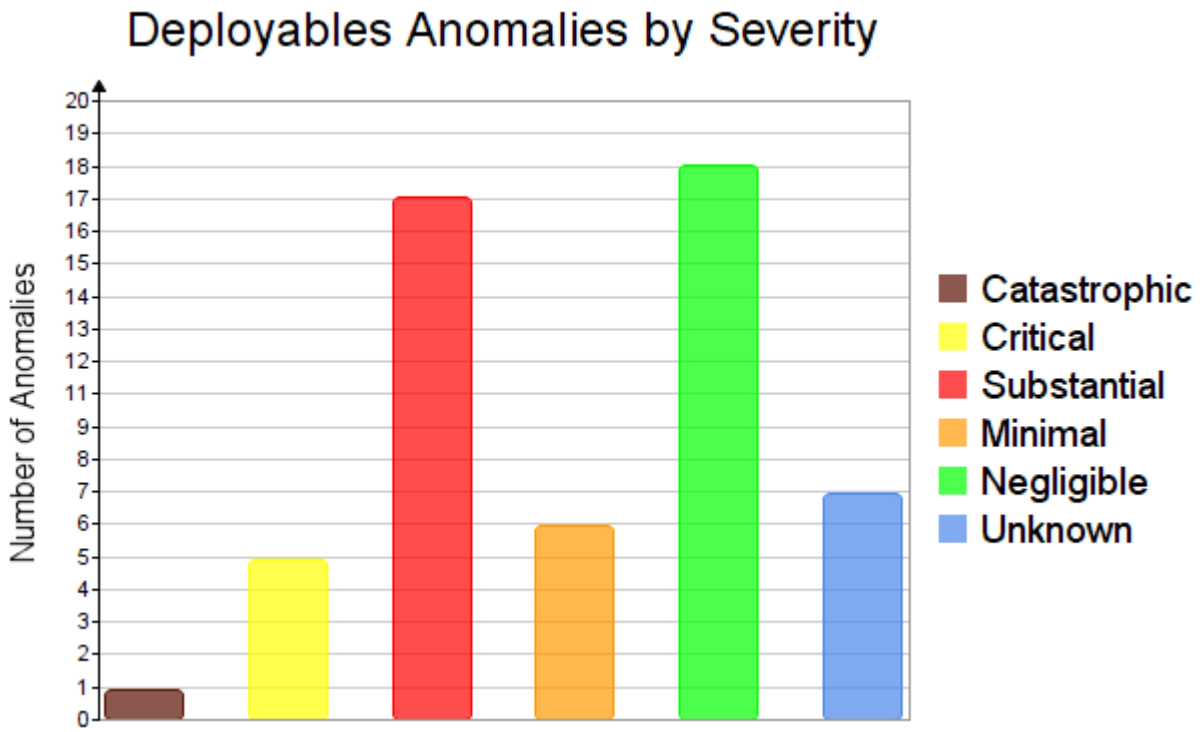
SEVERITY

- Vast majority of Spacecraft (68%) suffer some degree of mission and / or performance degradation
- 32% of anomalies results in partial loss of mission or substantial reduction of spacecraft performance



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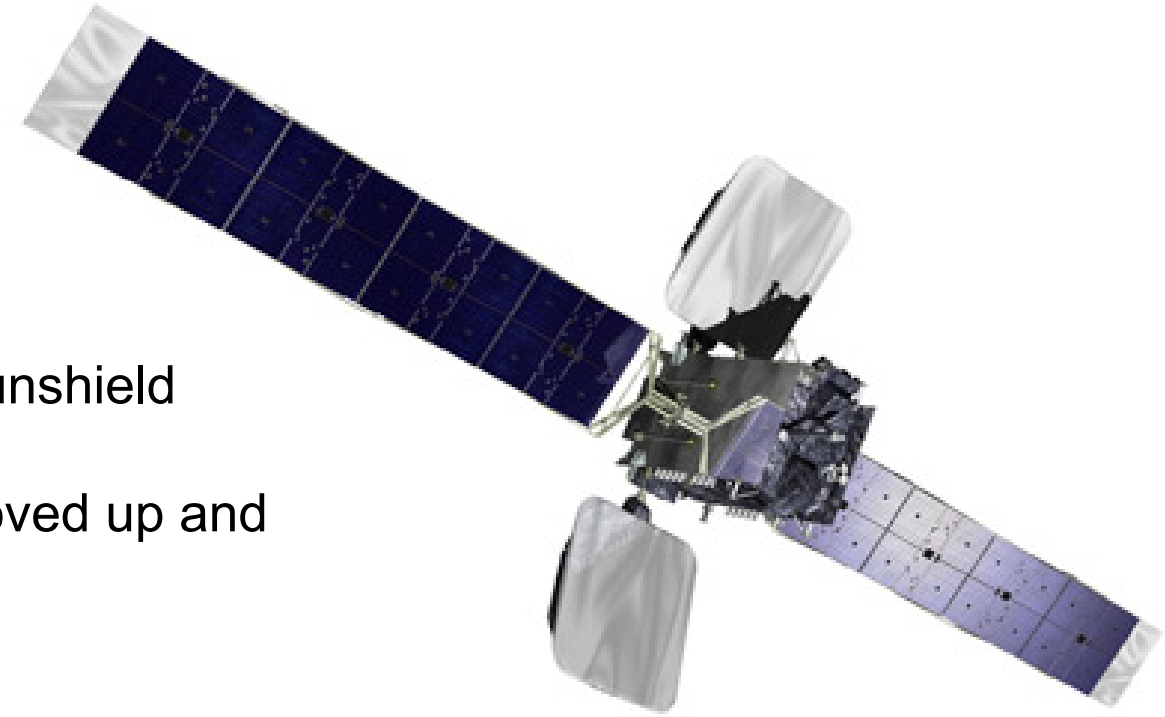
Thermal Blankets / Shields Interferences
New Dawn / Intelsat 28

Launch Date: April 22, 2011



Anomaly #1: Ku-band antenna fails to deploy

Cause: deployment mechanisms interference with sunshield

Resolution: motor-driven deployment mechanism moved up and down to free antenna from sunshield

Anomaly #2: unable to deploy its C-band reflector antenna

Cause: antenna's spring-loaded deployment mechanism got caught in the billows of its sunshield

Resolution: Shaking of the SC unsuccessful

Consequences: Mission Life reduced by 2 years

Insurance Claim: $146M

Solid Lubricant Earth Radiation Budget Satellite

Launch Date: October 10, 1984

Anomaly: One of the Solar Arrays failed to deploy

Cause: MoS_2 exposed to excessive humidity before launch resulting in excessive bearing friction in the space environment

Trouble shooting: exposure to sun until temperature above 0 °C

Ground Handling

TV-Sat 1

Launch Date: Nov 21, 1987

Anomaly: One of the Solar Arrays failed to deploy

Trouble shooting: Attempts to free it by spinning or shaking the satellite not successful.

Cause: Some of the hold down clips used to secure the SA panel during ground handling were not removed

Consequences: SC placed on a graveyard orbit. Total Mission Loss

Insurance Claim: $51M

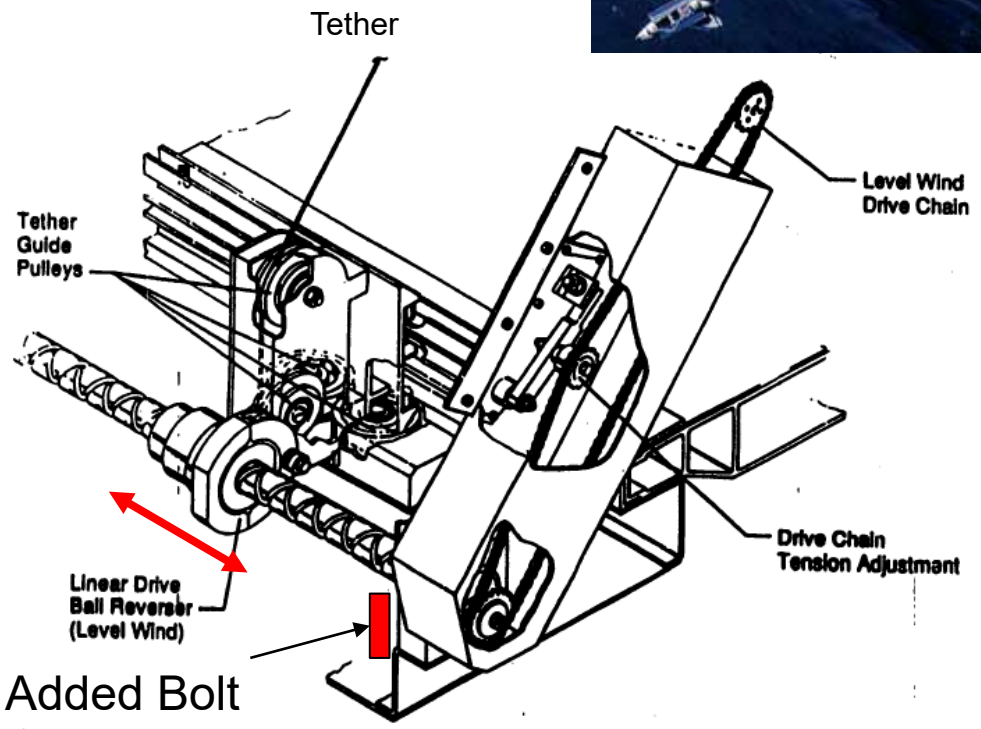
Last Minute Changes Tethered Satellite System (TSS-1)

Launch Date: Feb 25, 1996

Anomaly: Reel-out mechanism jammed. Tether only released to about 256 m out of the planned 12.5 miles (20.1 Km)

Cause: Bolt added for structural margin to address a last minute concern, interfered with a traveling ball nut and thwarted satellite deployment.

Consequences: **Total Mission Loss**



SA Explosive Decompression Telstar14, 14R, Intelsat 19

Launch Dates: 2004, 2011, 2012

Anomaly: SA partially deployed (14, 14R) or failed to deploy (IS-19)

Cause: Inadvertent solar array pressurization and explosive decompression damaged the arrays' deployment mechanism

Consequences: all of them remained in service but with serious reductions in capacity

Insurance Claims: $205M, $132.7M, $84M
($421.7M total)

Mechanisms Failure

Mars Global Surveyor

Launch Date: November 7, 1996

Anomaly: Solar Array fails to latch

Cause: input shaft of the damper sheared during SA deployment

Consequences: Aerobraking maneuvers had to be modified to put less pressure on solar panels.

New aerobraking schedule delayed reaching final polar science mapping orbit by 1 year.

Dynamic Analysis Simulations Issues

Mars Express

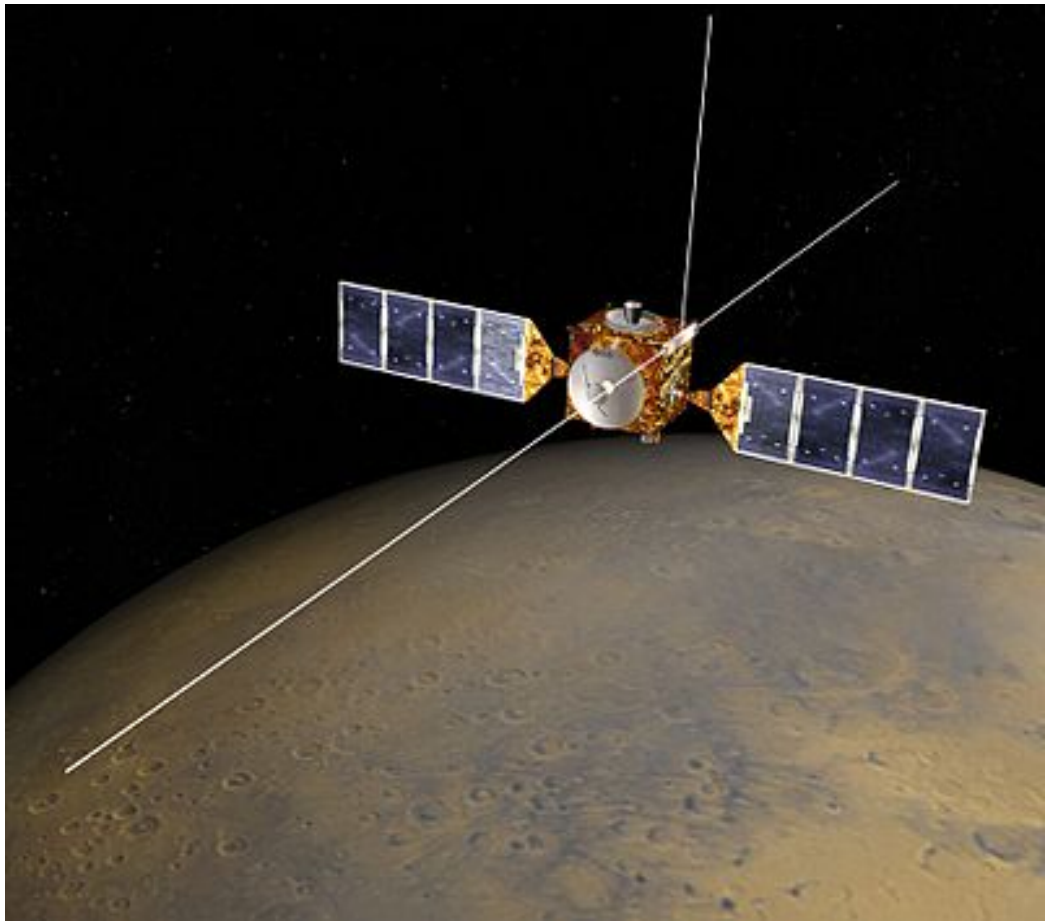
Launch Date: June 2, 2003

Anomaly: MARSIS antenna booms' deployments delayed

Cause: Simulation refinements indicated potential risk that booms could back lash and damage SC

Trouble shooting: additional contingency simulations performed to assess risks; Mitigation scenarios defined.

Resolution: 1st boom failed to deploy until after exposure to sun; 2nd and 3rd deployed successfully.



Contingency Maneuvers

Anik E2

Launch Date: April 4, 1991

Anomaly: Ku-Band Antenna deployed after 2 days
C-Band Antenna did not fully deploy

Cause: Thermal blanket interference

Trouble shooting: long list of SC contingency maneuvers supported by remarkable ground team analysis and technical ingenuity

Resolution: C-band antenna deployed and mission saved

Consequences: Rescue maneuvers used a year's worth of fuel

Insurance Claim: $208M

Prevention and Resolution Failures & Anomalies

Good Practices

- Interferences
- Tribology
- Torque Margin
- Space Environment
- Launch Loads
- Assembly & Integration
- Testing
- Modeling / analysis/ simulation
- Final Stow Inspections

Pre-Flight Contingency Ops

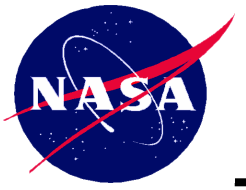
- Computer simulations of contingency and worst case scenarios

In-Space Contingency Ops

- Firing of thrusters to spin or shake the SC
- Orienting SC to sun
- Commanding motor back and forth (if motor driven)
- Inertial load maneuvers supported by dynamic simulation analysis and ground testing if deployable mockup available

FUTURE: Robotic Servicing ?

- Preliminary studies conducted at NASA GSFC



FINAL THOUGHTS

- Spacecraft Deployables anomalies are a complex problem
- Sharing of information would be very beneficial
- Collaboration between space agencies
- Public disclosures by manufacturers that have experienced anomalies