Orbital Debris Environment Assessment and Mitigation for Launch Vehicles

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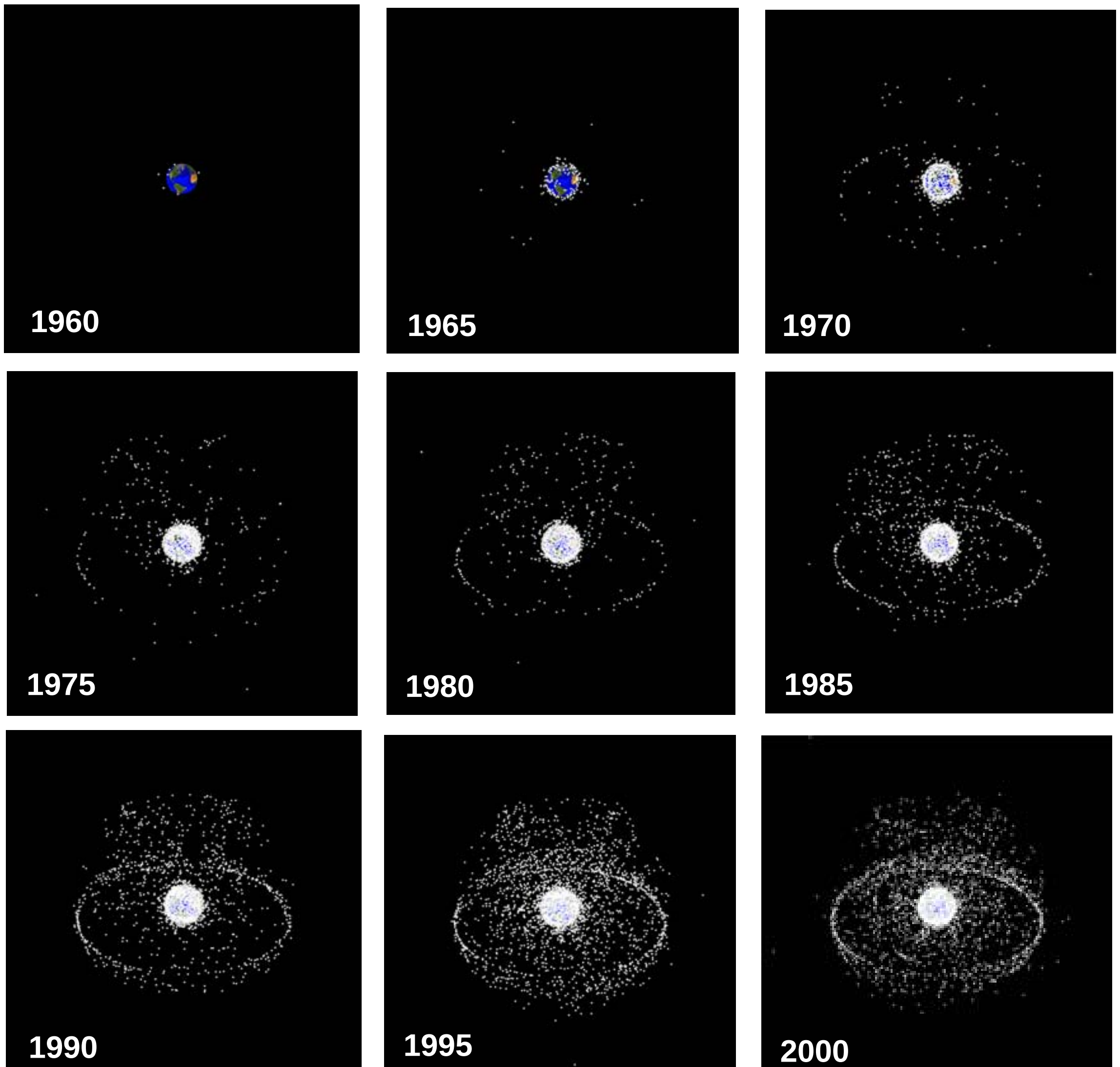
Outline

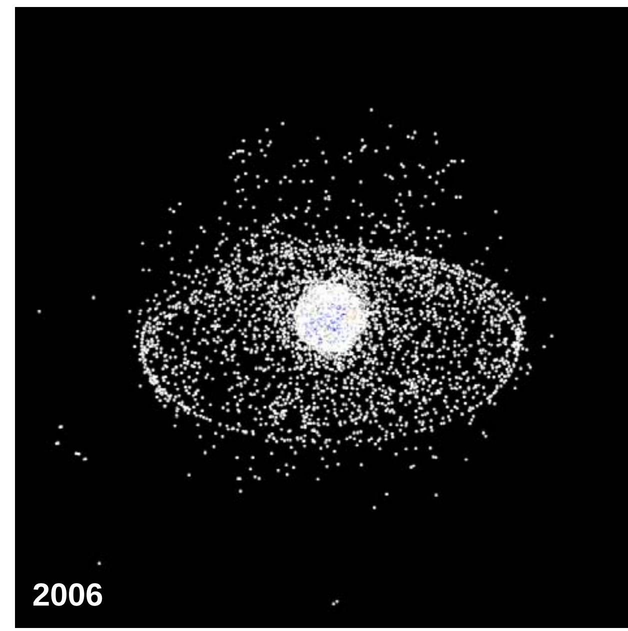
- Definition of and Concerns about orbital debris
- Characterization of Orbital Debris Environment
- Orbital Debris Policies and Mitigation Guidelines
- Principal Launch Vehicle Issues
  - End-of-mission passivation
  - Stage disposal
  - Reentry risks
- Conclusions

National Aeronautics and Space Administration

Growth of the Satellite Population



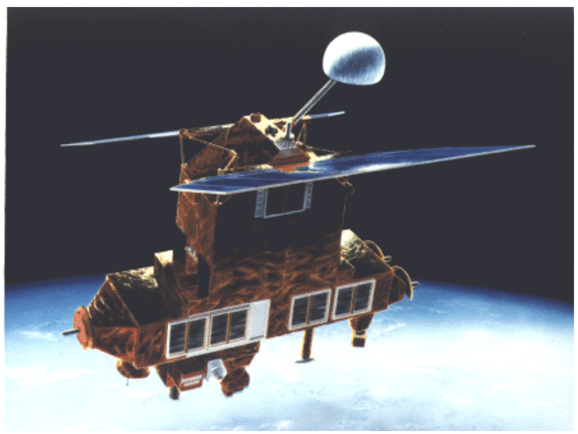
94% of Tracked Object Population are Debris



99+% of Objects Larger than 1 cm are Debris

What is Orbital Debris?

- **Orbital debris are man-made objects in orbit about the Earth.**



Non-operational Spacecraft

Derelict Launch Vehicle Stages

Fragmentation and

Mission-related Debris

Challenge of Orbital Debris

- **Failure to curtail the growth of orbital debris will eventually lead to potential loss or limitation of the practical use of portions of near-Earth space for economic, scientific, and national security purposes.**

- **As with many other global environmental issues,**

  – **Effective solutions require the cooperation of all (or nearly all) players**

  and

  – **Investments are required today for a benefit to be reaped in the distant future**

- **The challenge of orbital debris is to identify economically acceptable, but effective, mitigation practices which will be implemented by the majority of international space-faring community.**

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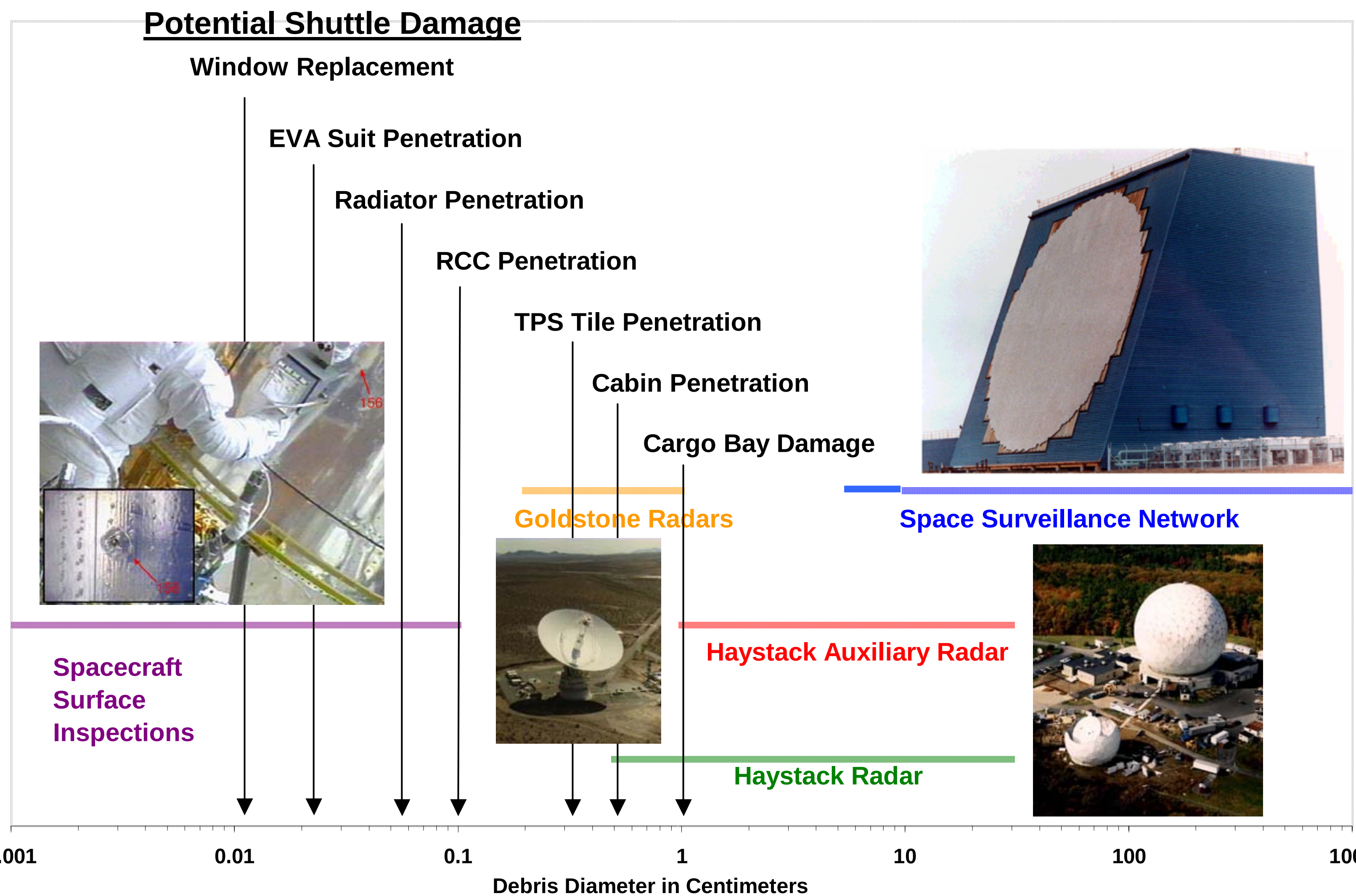
Orbital Debris Detectors and Damage Potential



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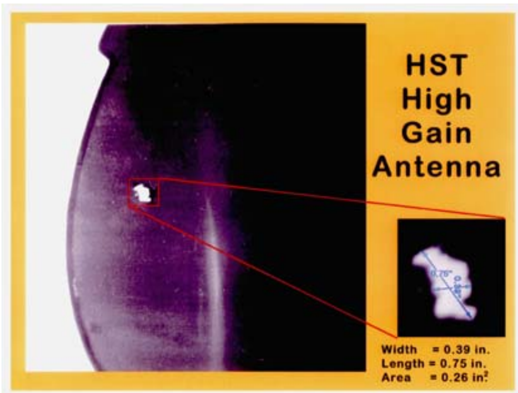
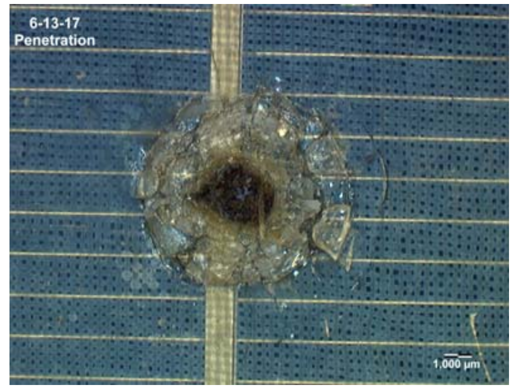
Sample Small Particle Impacts

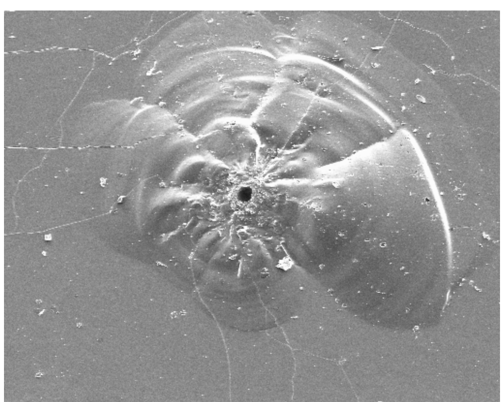


Hubble Space Telescope

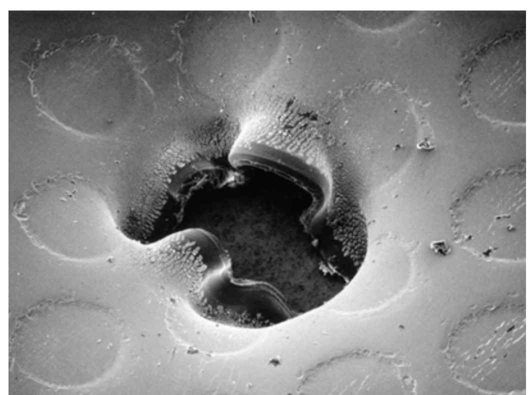


Mir Space Station

ISS Service Module



STS-92 Window

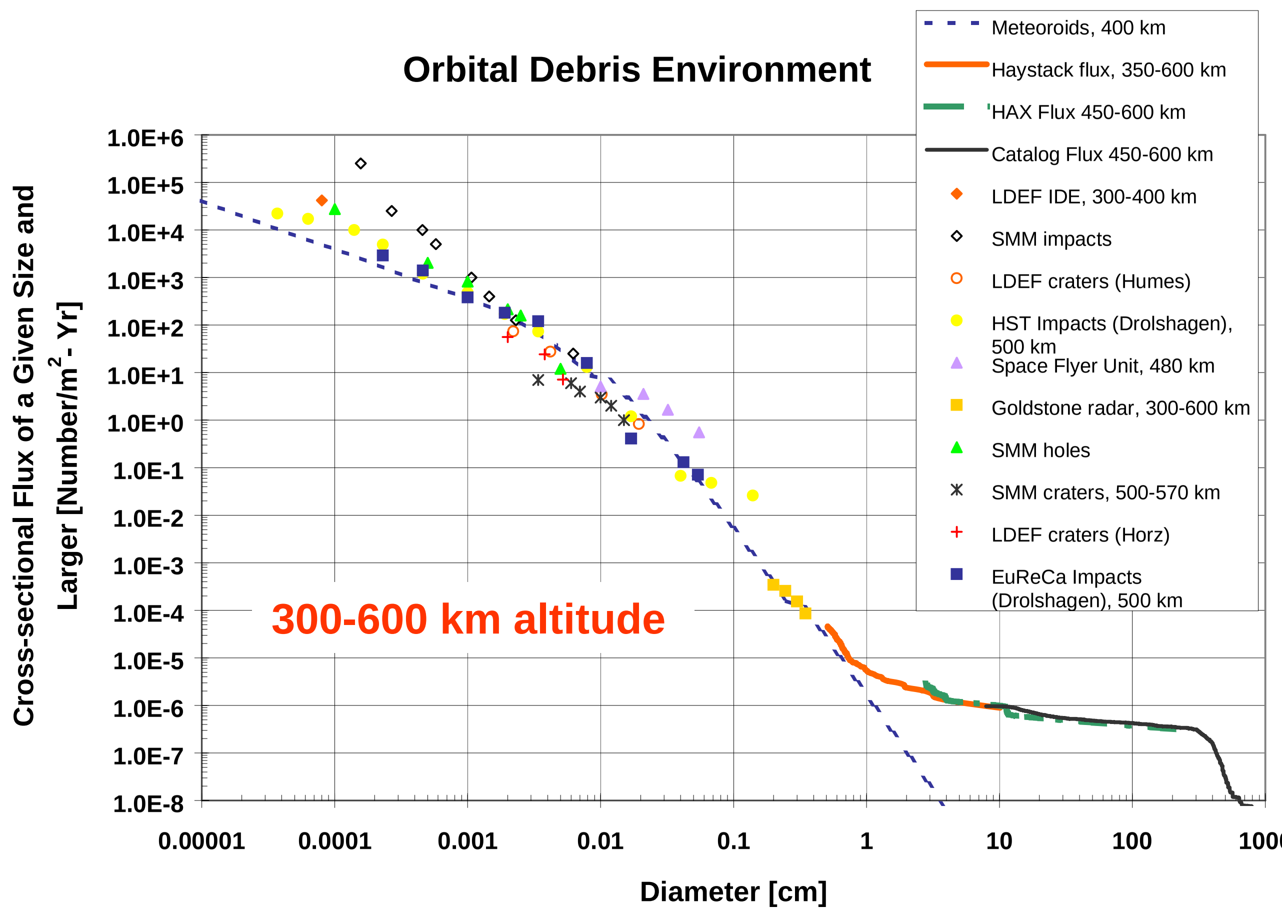


STS-90 Radiator

ISS Logistics Module

Environment Definition

A wide variety of measurements are necessary to cover the entire debris size spectrum



Orbital Debris and USA National Space Policy

- **Orbital debris has been addressed in all USA national space policies since 1988.**

- **New National Space Policy (signed 31 August 2006 by President Bush) states:**

"Orbital debris poses a risk to continued reliable use of space-based services and operations and to the safety of persons and property in space and on Earth. The United States shall seek to minimize the creation of orbital debris by government and non-government operations in space in order to preserve the space environment for future generations…."

Orbital Debris Mitigation Guidelines

- NASA issued its first set of detailed orbital debris mitigation guidelines for all space projects and programs in 1995.

- US Government Orbital Debris Mitigation Standard Practices were developed in 1997 and finalized in 2001.

- Principal international orbital debris mitigation guidelines have been issued by
  - Inter-Agency Space Debris Coordination Committee (IADC) in 2002
  - United Nations Committee on the Peaceful Uses of Outer Space in 2007

- All mitigation guidelines are very similar with varying levels of specificity

- **Major orbital debris mitigation issues for launch vehicles are**
  - **Post-mission passivation (depletion of stored energy sources)**
  - **Disposal orbits**
  - **Reentry risks**

Stage Passivation

- All aforementioned orbital debris mitigation guidelines and FAA regulations call for passivation of launch vehicle orbital stages as soon as possible after the stage has completed its mission.
  - Primary requirement: Remove all residual propellants and pressurants
- As of 1 January 2007, 73% of cataloged break-up debris was attributed to launch vehicle orbital stages.
  - 98% of cataloged LV breakup debris came from stages which had successfully completed their missions.
- 85 orbital stage post-mission breakups identified to date, including most major LV types: Ariane, Cosmos, Delta 2, Delta 4, H-2A, Long March, Pegasus, Proton, PSLV, Tsyklon, Zenit

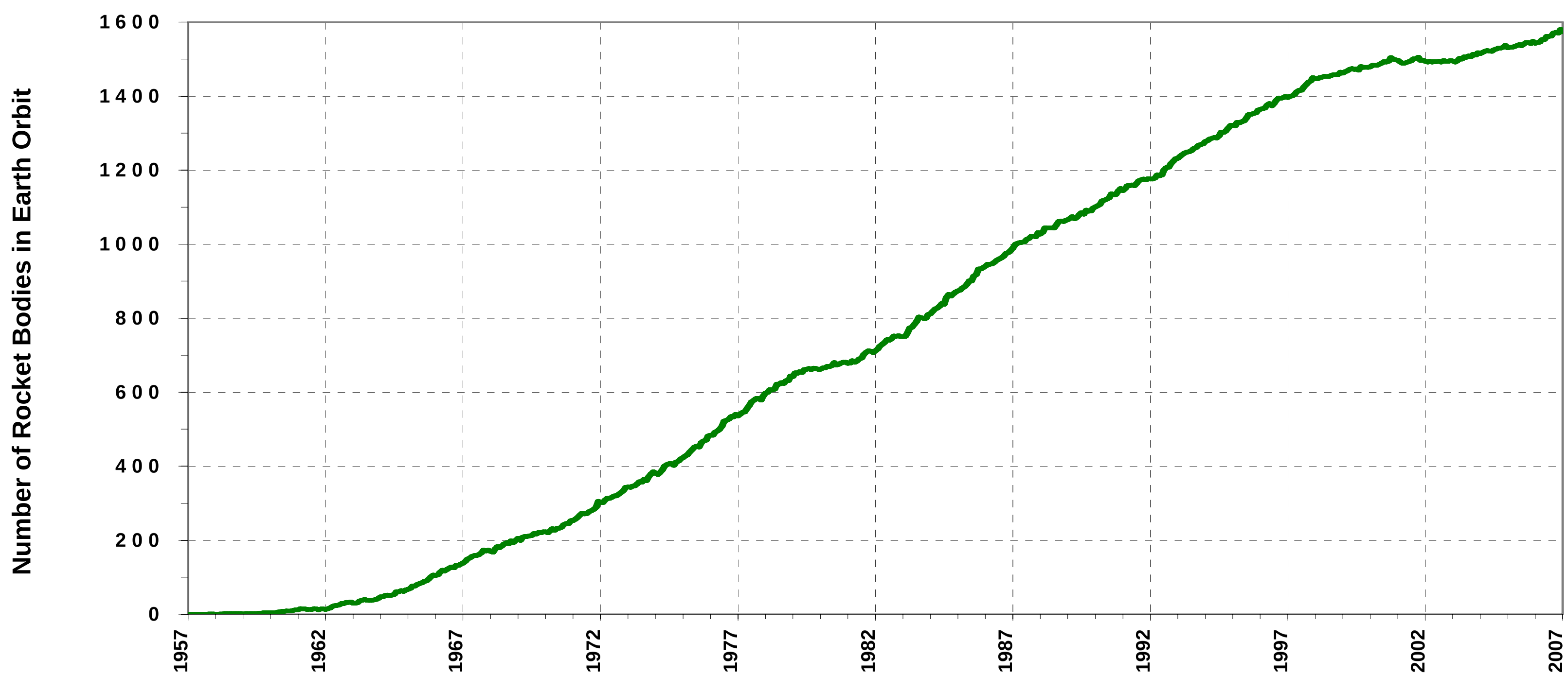
Worst LV Stage Breakups Caused by Failure to Passivate

Stage Type	Breakup Year	Time in Orbit	Debris Cataloged	Assessed Cause
Proton Briz M	2007	12 months	TBC (1000+)	Propellant induced
Pegasus HAPS	1996	24 months	713	Pressurant induced
Ariane1 3rd stage	1986	9 months	489	Propellant induced
Agena D	1970	6 months	373	Unknown; Propellant induced?
PSLV 4th stage	2001	2 months	346	Propellant induced
Long March 4 3rd stage	2000	5 months	321	Propellant induced

Passivation techniques need to be effective under both nominal and malfunction scenarios.

Stage Disposal

- **Four disposal options:**
  - **Controlled reentry**
  - **Natural decay within 25 years of launch**
  - **Storage orbit between LEO and GEO**
  - **Storage orbit above GEO**



Disposal of Launch Vehicle Stages for LEO Communications Constellations

- **Iridium**
  - **88 spacecraft launched in 25 months (1997-1999) using three different launch vehicles from three countries**
  - **26 orbital stages inserted, but only one remains in orbit due to malfunction**
    - Proton orbital stages de-orbited over Pacific Ocean
    - Delta and Long March orbital stages moved to lower disposal orbits

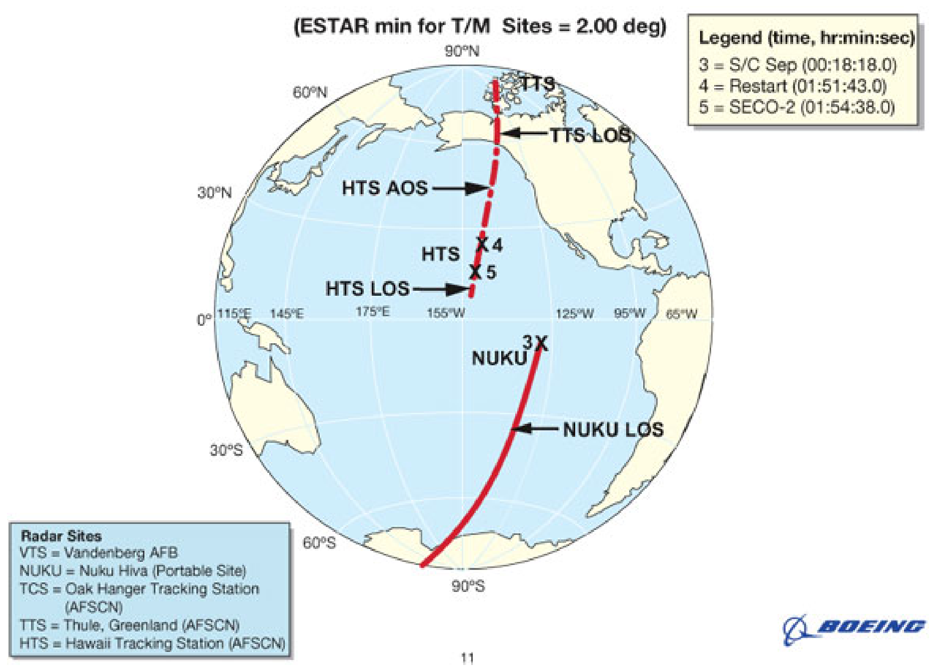
- **Globalstar**
  - **52 spacecraft launched in 24 months (1998-2000) using Delta and Soyuz launch vehicles**
  - **17 of 19 orbital stages have already decayed**
  - **Six Soyuz-IKAR stages were de-orbited into Pacific from altitude near 900 km**

- **Orbcomm**
  - **35 spacecraft launched as primary or secondary payloads**
  - **Eight orbital stages used for dedicated missions (31 spacecraft); only one orbital stage remains in orbit due to lower stage malfunction**

- **Only 4 of 53 launch stages used to orbit 175 spacecraft will fail to meet 25-year rule (two due to launch vehicle malfunctions).**

Controlled Reentry of Delta IV Second Stage

- **In 1996 the U.S. demonstrated the ability to significantly reduce the altitude of a launch vehicle stage to limit its time in low Earth orbit.**
  - **The MSX Delta II second stage was maneuvered from a payload delivery orbit of 900 km to a disposal orbit of 225 km by 870 km; reentry occurred only 9 months later.**
- **In 2006 the DMSP 5D-3 F17 Delta IV second stage was completely de-orbited from a circular orbit of 850 km.**



Launch Vehicle Stage Reentry Risks

- **29 launch vehicle orbital stages reentered in an uncontrolled manner during 2006 with a total mass of 63 metric tons.**
- **Some of these stages exceed the USG recommended human casualty risk of 1 in 10,000 per event.**
  - **New, larger stages of particular concern**

Texas, 1997

South Africa, 2000

Saudi Arabia, 2001

Guatemala, 2003

Argentina, 2004

Thailand, 2005

Conclusions

- **Adherence to national and international orbital debris mitigation guidelines is essential if the debris population is to be controlled.**
- **Launch vehicle stage passivation at end of mission is widely accomplished, but some further work needed.**
- **The disposal of launch vehicle stages requires serious consideration by both launch service provider and customer.**
  - **Solid-propellant LEO stages used above 650 km require special attention**
- **The risk of human casualties from stage reentries continues to present significant challenges.**

Frank and Ernest on Orbital Debris