# Mission Success and Environmental Protection: Orbital Debris Considerations

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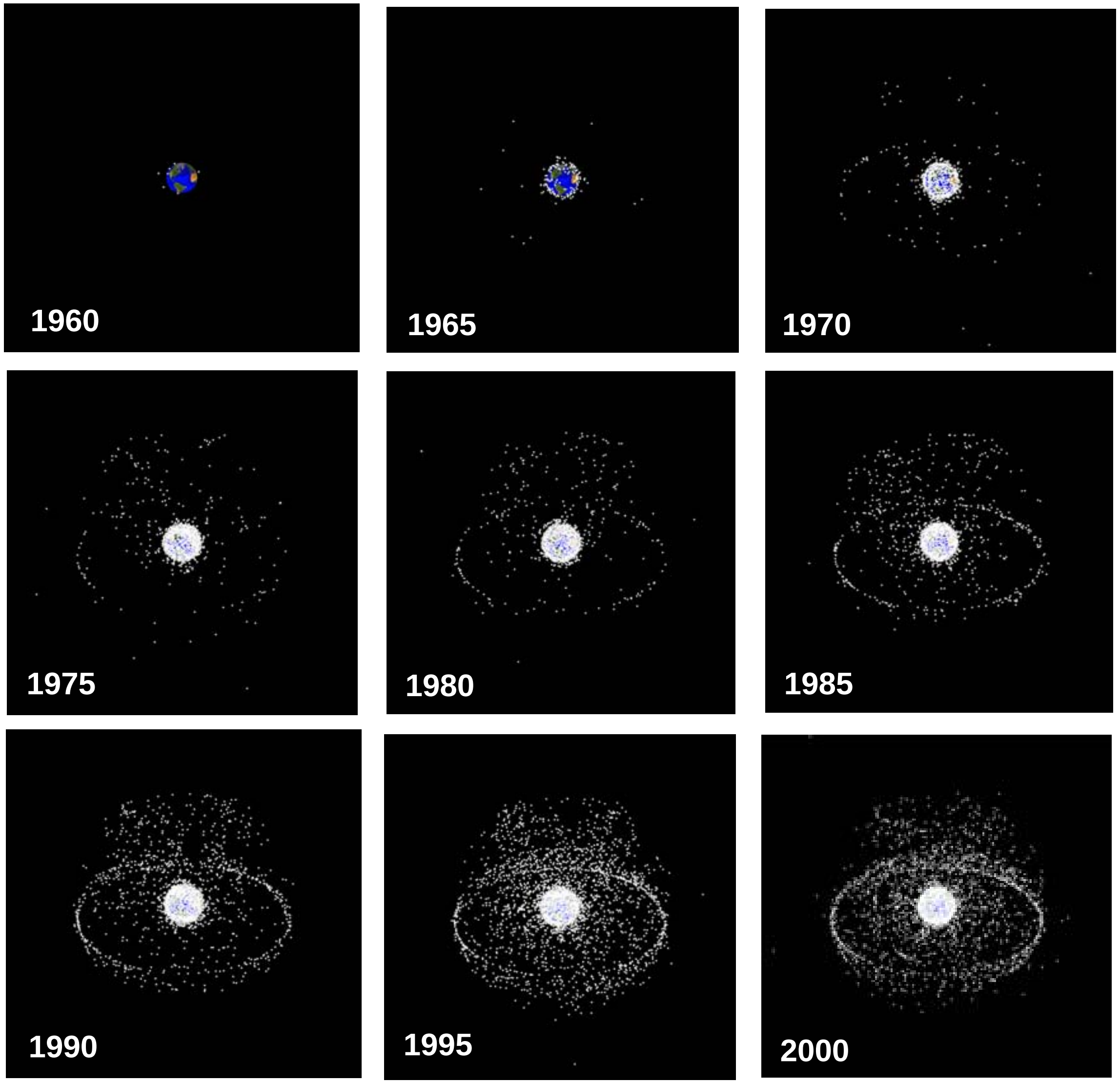
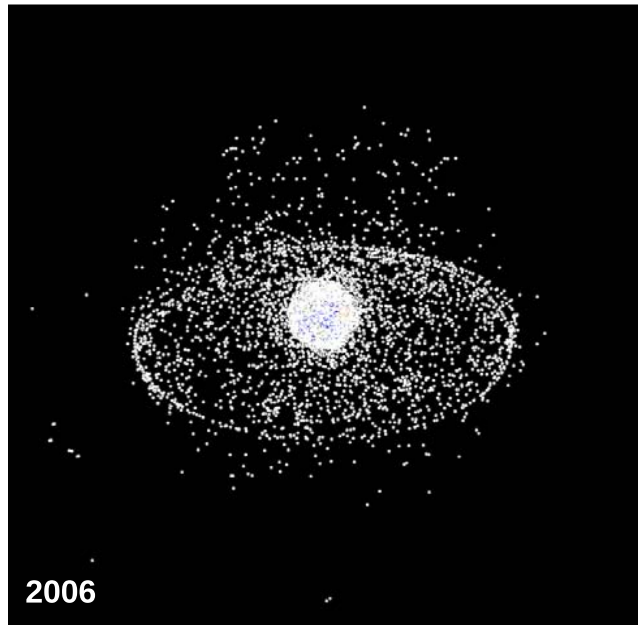
# Overview

- **Orbital Debris Background**
- **U.S. National Space Policy**
- **U.S. Government Orbital Debris Mitigation Standard Practices**
  - Background and General Application
  - Detailed Discussion
- **NASA Orbital Debris Mitigation Policy and Safety Standard**
- **Other U.S. Government departments, agencies, and organizations**

# Growth of the Satellite Population

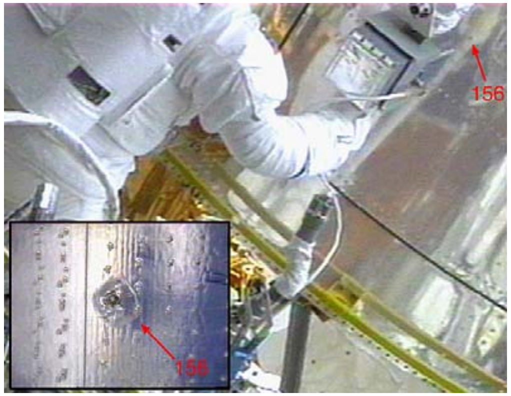


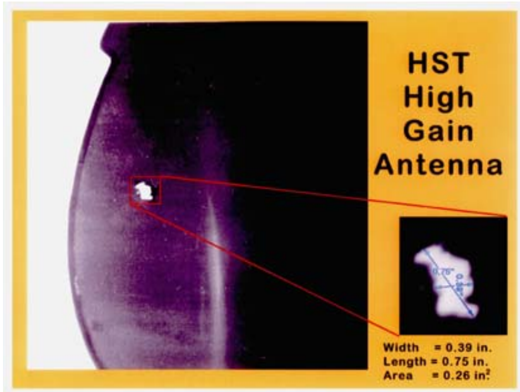

94% of Tracked Object Population are Debris



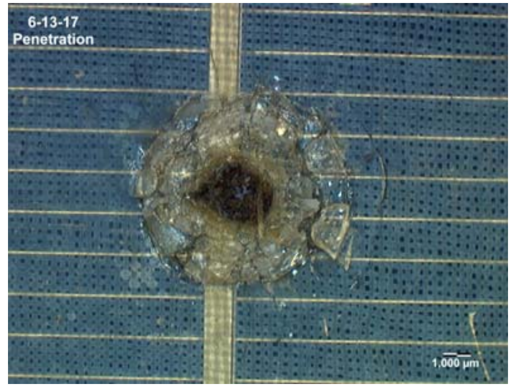

99+% of Objects Larger than 1 cm are Debris

# Sample Small Particle Impacts

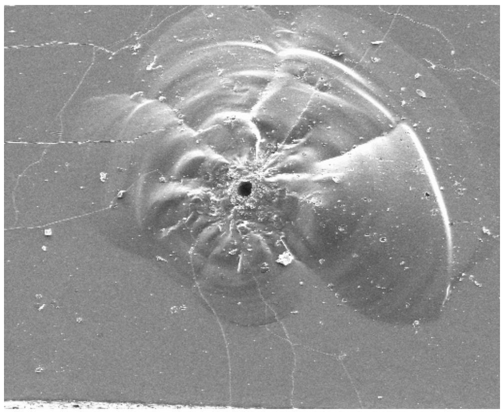


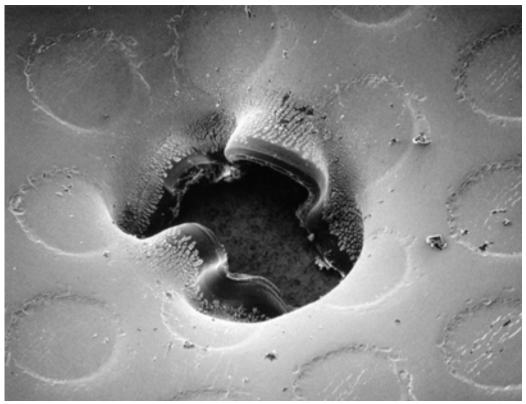

Hubble Space Telescope



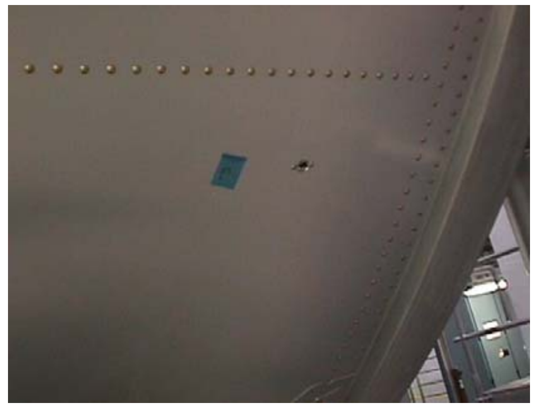

Mir Space Station



STS-92 Window



STS-90 Radiator

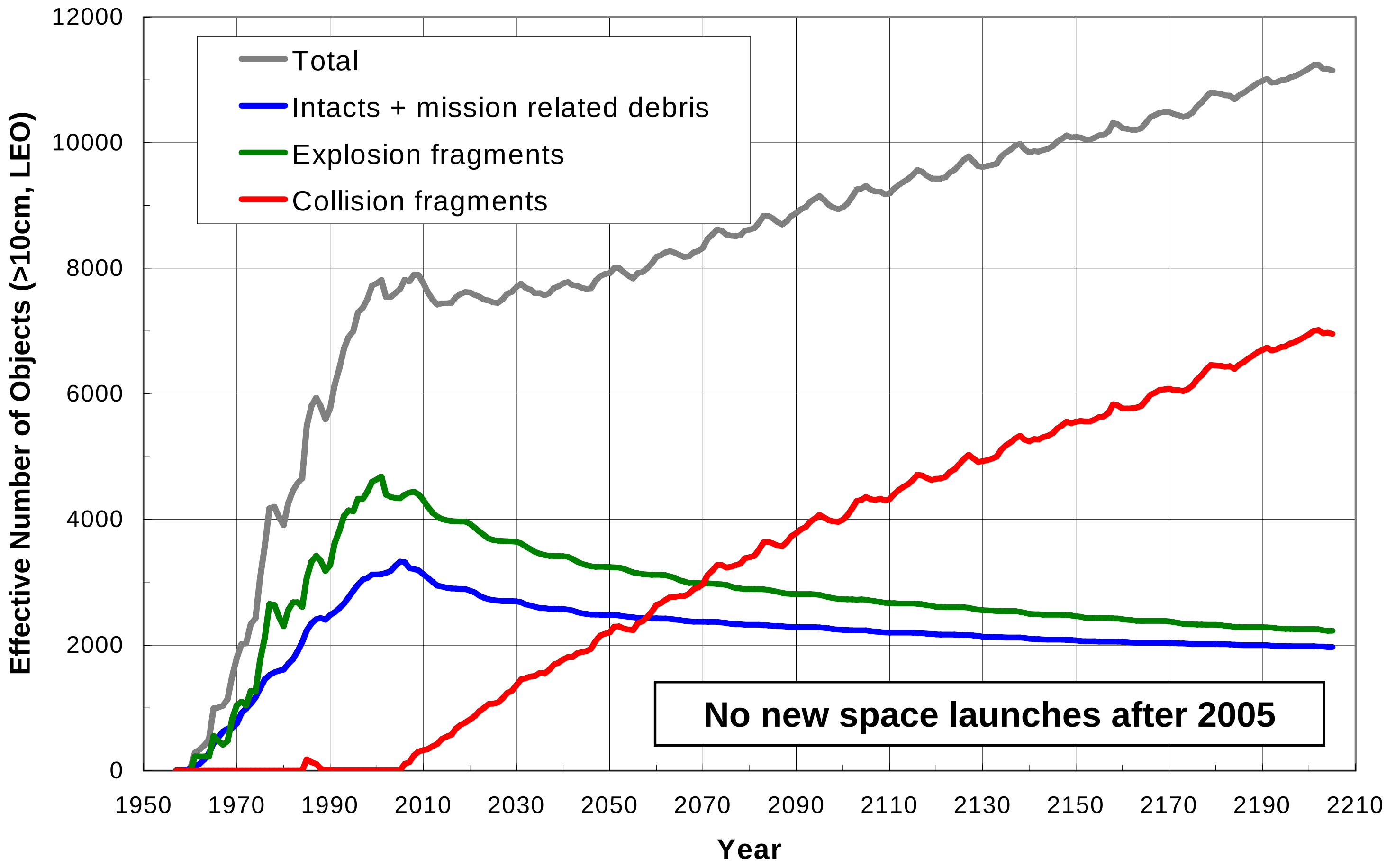


ISS Logistics Module

# Historic and Projected Growth of Debris Population

**The rate of growth of the debris environment continues to be significant.**

**Even with no new launches in the future, the debris population will increase.**



# U.S. Space Policy and Orbital Debris

- **Orbital debris has been included in all 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. Toward that end:**

- Departments and agencies shall continue to follow the United States Government Orbital Debris Mitigation Standard Practices, consistent with mission requirements and cost effectiveness, in the procurement and operation of spacecraft, launch services, and the operation of tests and experiments in space;
- The Secretaries of Commerce and Transportation, in coordination with the Chairman of the Federal Communications Commission, shall continue to address orbital debris issues through their respective licensing procedures; and
- The United States shall take a leadership role in international fora to encourage foreign nations and international organizations to adopt policies and practices aimed at debris minimization and shall cooperate in the exchange of information on debris research and the identification of improved debris mitigation practices."

# U.S. Government Orbital Debris Mitigation Standard Practices

- **In response to a 1995 Interagency report, NASA and DoD developed draft orbital debris mitigation standard practices based upon NASA Safety Standard 1740.14.**

- **The Standard Practices cover four major areas:**
  - **Control of debris released during normal operations**
  - **Minimization of debris generated by accidental explosions**
  - **Selection of safe flight profile and operational configuration**
  - **Postmission disposal of space structure**

- **The Standard Practices were briefed to Industry at a U.S. Government-sponsored workshop in Jan 1998 and were finalized in Dec 2000.**

- **The Standard Practices were approved by Feb 2001 by all relevant U.S. Government agencies, departments, and organizations and have been used as a foundation for the development of international guidelines.**
  - Each U.S. Government organization implements the Standard Practices according to established internal procedures

# Application of Standard Practices

- **Normally, only 6 of the 8 Standard Practices apply to a mission**
  - Two Standard Practices exclusively address tether systems

- **The Standard Practices apply to all spacecraft and upper stages <u>regardless of</u>**
  - **Nature of Mission (e.g., communications, Earth observations, science)**
  - **Vehicle Size**
  - **Vehicle Mass**
  - **Vehicle power source**
  - **Vehicle propulsive capability**
  - **Altitude and inclination**
  - **Mission cost or longevity**

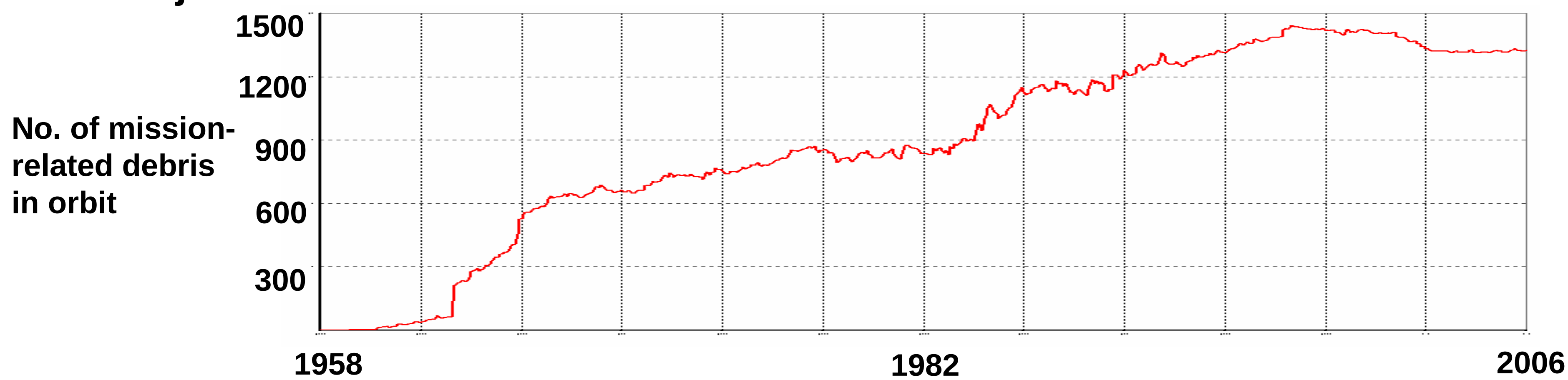
- **Compliance with Standard Practices is subject to mission requirements and cost effectiveness, <u>BUT</u> no automatic exceptions for existing hardware, including COTS.**

- **The Standard Practices address certain objectives, <u>not</u> how those objectives are to be met – this is up to the designer/operator.**

# USG OD Mitigation Standard Practice 1-1

- **“In all operational orbital regimes: Spacecraft and upper stages should be designed to <u>eliminate or minimize debris released during normal operations</u>. Each instance of planned release of debris larger than 5 mm in any dimension that remains on orbit for more than 25 years should be evaluated and justified on the basis of cost effectiveness and mission requirements.”**

- **Mission-related debris, e.g., sensor covers, springs, and clamp bands, historically have accounted for about 15% of the U.S. Satellite Catalog. In recent years significant progress has been made in eliminating such objects.**



# USG OD Mitigation Standard Practice 2-1

- **“<u>Limiting the risk to other space systems from accidental explosions during mission operations</u>: In developing the design of a spacecraft or upper stage, each program, via failure mode and effects analyses or equivalent analyses, should demonstrate either that there is no credible failure mode for accidental explosion, or, if such credible failure modes exist, design or operational procedures will limit the probability of the occurrence of such failure modes.”**

- **This element is one which is inherently addressed as a matter of mission reliability and safety.**

- **Current NASA debris mitigation guidelines set a maximum probably of 1 in 10,000 for accidental explosions.**
  - Some existing spacecraft designs and launch vehicle stages do not meet the 1 in 10,000 criterion.

# USG OD Mitigation Standard Practice 2-2

- **"<u>Limiting the risk to other space systems from accidental explosions after completion of mission operations</u>. All on-board sources of stored energy of a spacecraft or upper stage should be depleted or safed when they are no longer required for mission operations or postmission disposal. Depletion should occur as soon as such an operations does not pose an unacceptable risk to the payload. Propellant depletion burns and compressed gas releases should be designed to minimize the probability of subsequent accidental collision and to minimize the impact of a subsequent accidental explosion."**

- **This is perhaps the <u>most important</u> of all the Standard Practices for protecting the near-Earth space environment in the near-term. Principal actions:**
  - Burning or venting all residual propellants and pressurants
  - Discharging all batteries <u>and</u> removing them from charging circuits

- **At NASA some minor general exceptions do exist, e.g., heat pipes need not be depressurized.**

- **Some COTS systems are not compliant and should be modified.**

# USG OD Mitigation Standard Practice 3-1

- **"<u>Collision with large objects during orbital lifetime</u>: In developing the design and mission profile for a spacecraft or upper stage, a program will estimate and limit the probability of collision with known objects during orbital lifetime."**
  - The objective is to limit the generation of collisional debris.
- **The probability of collision between resident space objects is altitude dependent.**
- **NASA sets a maximum probability of 1 in 1,000 for compliance.**
- **This limit is generally not difficult to meet for LEO objects if disposal guidelines are satisfied (see Standard Practice 4-1).**

# USG OD Mitigation Standard Practice 3-2

- **"<u>Collision with small debris during mission operations</u>: Spacecraft will consider and, consistent with cost effectiveness, limit the probability that collisions with debris smaller than 1 cm will cause loss of control to prevent postmission disposal."**
- **For compliance, NASA sets a maximum probability of 1 in 100 for loss of ability to conduct planned disposal actions due to collisions with small debris.**
- **Most non-compliant systems can be brought into compliance with one or more sheets of multi-layer insulation.**

# USG OD Mitigation Standard Practice 4-1

- **“Disposal for final mission orbits:” (paraphrased)**
  - LEO: Spacecraft and upper stages left in LEO must reenter within 25 years of end of mission
    - Human casualty risk from reentry must not exceed 1 in 10,000
  - MEO: Spacecraft and upper stages can normally be left in stable orbits between 2000 km and 35,300 km (i.e., 500 km below GEO).
  - GEO: Spacecraft and upper stages should be left in disposal orbits at least 300 km above GEO.
- **Spacecraft and upper stage disposal can be challenging, particular for LEO missions above 800 km.**

# USG OD Mitigation Standard Practices 3-3 & 4-2

- **The Standard Practices recognize that tether systems present special issues with respect to collision potential (3-3) and disposal (4-2).**

- **Standard Practice 3-3: “Tether systems will be uniquely analyzed for both intact and severed conditions.”**

- **Standard Practice 4-2: “Tether systems will be uniquely analyzed for both intact and severed conditions when performing trade-offs between alternative disposal strategies.”**

# Example Case:  LEO Deployment Options

- **During the late 1990's three major LEO communications networks were deployed:  Iridium, Orbcomm, and Globalstar.**

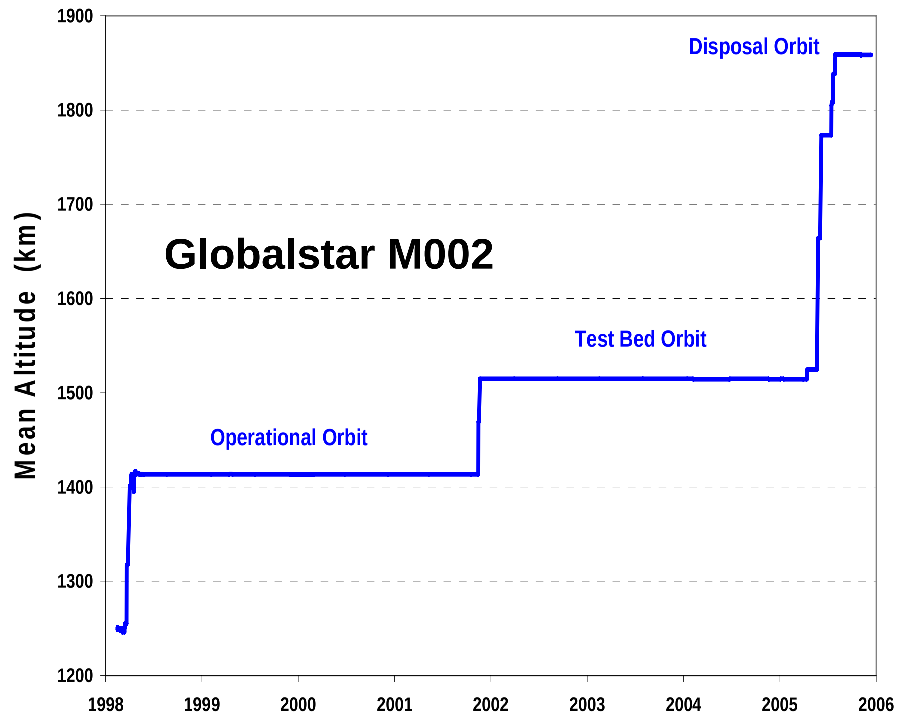
- **Iridium (780 km operational altitude)**
  - 88 spacecraft launched in 25 months (1997-1999) using three different launch vehicles from three countries
  - Spacecraft released at altitudes near 500-650 km
    - Proton orbital stages de-orbited; Delta and Long March orbital stages moved to lower orbits
  - Only 1 of 26 stages still in orbit (remaining stage malfunctioned)

- **Orbcomm (815 km operational altitude)**
  - 35 spacecraft launched as primary or secondary payloads
  - 8 orbital stages used for dedicated missions (31 spacecraft); only one orbital stage will fail to meet 25-year guideline due to lower stage malfunction

- **Globalstar (1415 km operational altitude)**
  - 52 spacecraft launched in 24 months (1998-2000)  using Delta and Soyuz launch vehicles
  - Spacecraft released at altitudes near 900 km on 7 (6 Soyuz, 1 Delta) of 13 missions
  - Only 2 of 19 stages still in orbit; Soyuz-IKAR stages were de-orbited into Pacific

# Example Case: LEO Spacecraft Disposals

- **Most spacecraft in operational orbits above 650 km will need to execute a postmission plan to leave LEO within 25 years.**
- **Heritage spacecraft are already complying by moving to lower orbits: Landsat 4 (1982) in 2001; NASA's ERBS (1984) and UARS (1991) in 2005; Iridium spacecraft since 1999**
- **Plans exist for lowering orbits of more recent spacecraft, e.g., AURA, AQUA, CALIPSO, CLOUDSAT**
  - DART executed disposal maneuver at end of its short mission in 2005
- **Globalstar spacecraft are moved into higher disposal orbits near or beyond 2000 km**



# NASA Policy for Limiting Orbital Debris Generation

- **First issued as NASA Management Instruction 1700.8 (5 Apr 1993)**

- **NASA Policy Directive 8710.3 was issued in May 1997 and updated in Jan 2003 (NPD 8710.3B) and requires NASA to:**
  - Conduct formal OD assessments in accordance with NASA Safety Standard 1740.14
  - Design for safe disposal of spacecraft and launch vehicles at end of mission
  - Provide timely notification to, and coordination with, other appropriate government entities concerning the proposed reentry of NASA spacecraft or their rocket bodies from Earth orbit
  - Promote the adoption of international policies, standards, and practices to minimize OD and its associated risks, and the exchange of information on OD research, modeling, and mitigation techniques in the international community

# NASA Safety Standard 1740.14

- **NASA Safety Standard 1740.14 (1 August 1995) serves as the implementing mechanism for NPD 8710.3B.**
- **Each mission must assess its compliance with guidelines in the following areas:**
  - Release of debris during normal mission operations
  - Accidental explosions
  - Intentional breakups
  - Collisions with small and large objects
  - Postmission disposal
  - Reentry risks
- **Orbital Debris Assessment reports are due at PDR and six weeks prior to CDR.**
  - Reports are reviewed by the offices of the Associate Administrator sponsoring the mission and of the Associate Administrator for Safety and Mission Assurance.

# Example Case: Solar Dynamics Observatory

- **NASA's 3200-kg SDO will be launched in 2008 by Atlas V for a five-year mission in GEO.**

- **Review of PDR OD assessment report submitted in March 2004 noted potential non-compliance issues:**
  - Venting of helium pressurant at end of mission
  - Disconnect of battery from charging circuit at end of mission
  - Disposal of launch vehicle upper stage, including reentry risk

- **Design and operational changes adopted by time of CDR in April 2005:**
  - Bypass valve added to permit venting of helium pressurant
  - Battery disconnect relay control added to power subsystem
  - Centaur upper stage to be left in storage orbit between LEO and GEO.

- **Cost-effective solutions were found without impacting spacecraft reliability or program schedule.**

# DOD and other USG Agencies

- **The Department of Defense has established an overall Directive on orbital debris mitigation (DoD Directive 3100.10, 1999).**
  - US Strategic Command, the former US Space Command, Air Force Space Command, and the National Reconnaissance Office have issued several policy directives and instructions to implement the DoD directive and National Space Policy.
- **The Department of Transportation/FAA has issued regulations promoting orbital debris mitigation for commercial launch vehicles.**
- **The Federal Communications Commission has issued regulations promoting orbital debris mitigation for communications spacecraft.**
- **The Department of Commerce/NOAA has issued regulations promoting orbital debris mitigation for remote sensing spacecraft.**

**All of the above are consistent with and derived from the USG Orbital Debris Mitigation Standard Practices**

# Summary

- **The current U.S. National Space Policy specifically calls on U.S. Government entities “to follow the United States Government Orbital Debris Mitigation Standard Practices, consistent with mission requirements and cost effectiveness, in the procurement and operation of spacecraft, launch services, and the operation of tests and experiments in space.”**

- **Early assessment (pre-PDR) of orbital debris mitigation compliance is essential to minimize development impacts.**
  - Engineering trade space broader, including between spacecraft and launcher
  - Costs often minimal

- **Orbital debris mitigation practices today are the most effective means to protect the near-Earth space environment for future missions.**