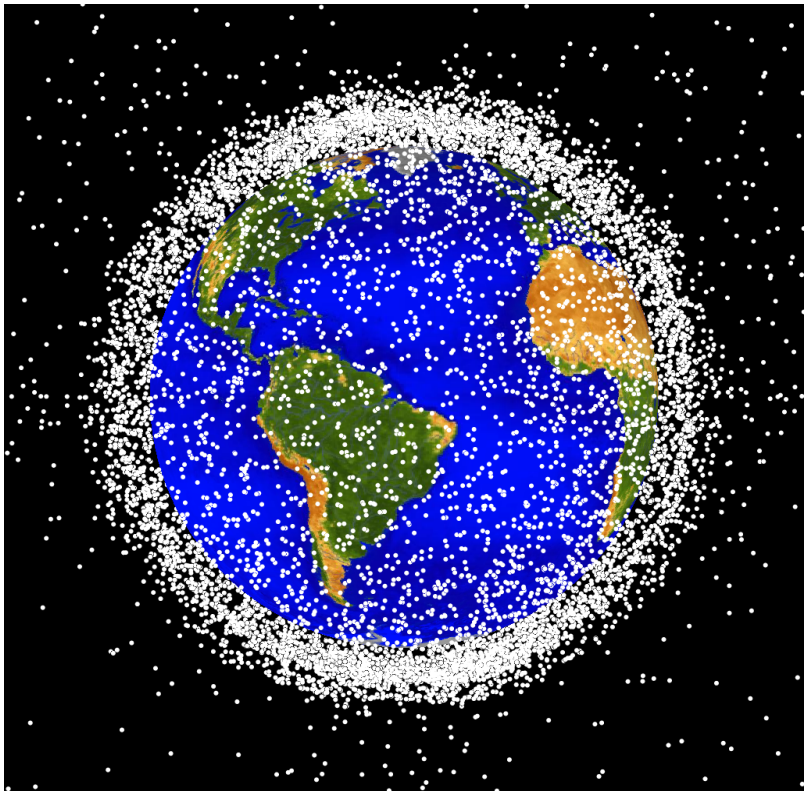
National Aeronautics and Space Administration

Orbital Debris Mitigation



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1. Jacobs, NASA Johnson Space Center, Houston, TX 77058, USA

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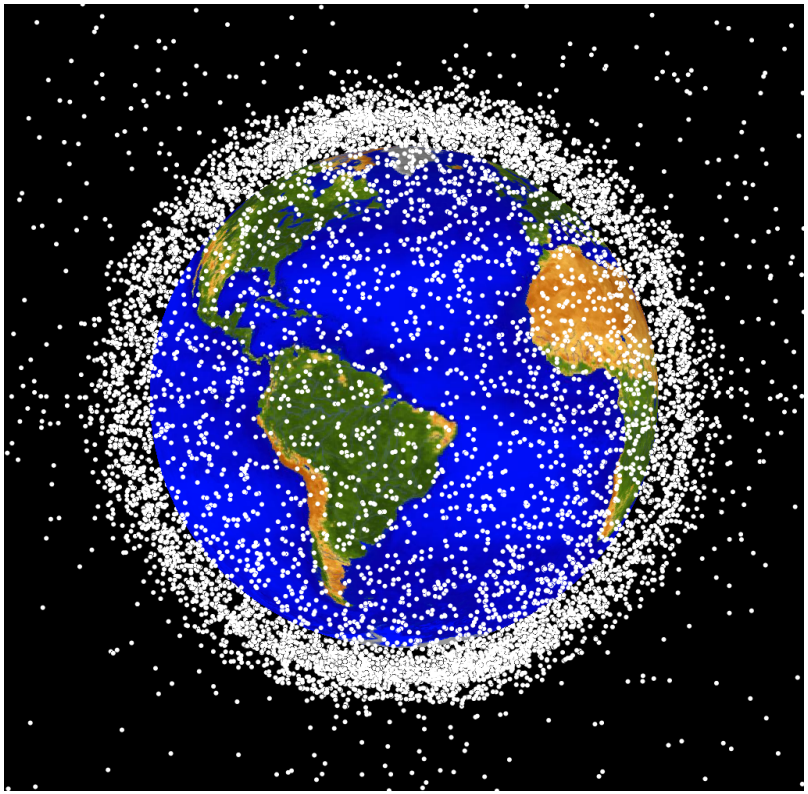
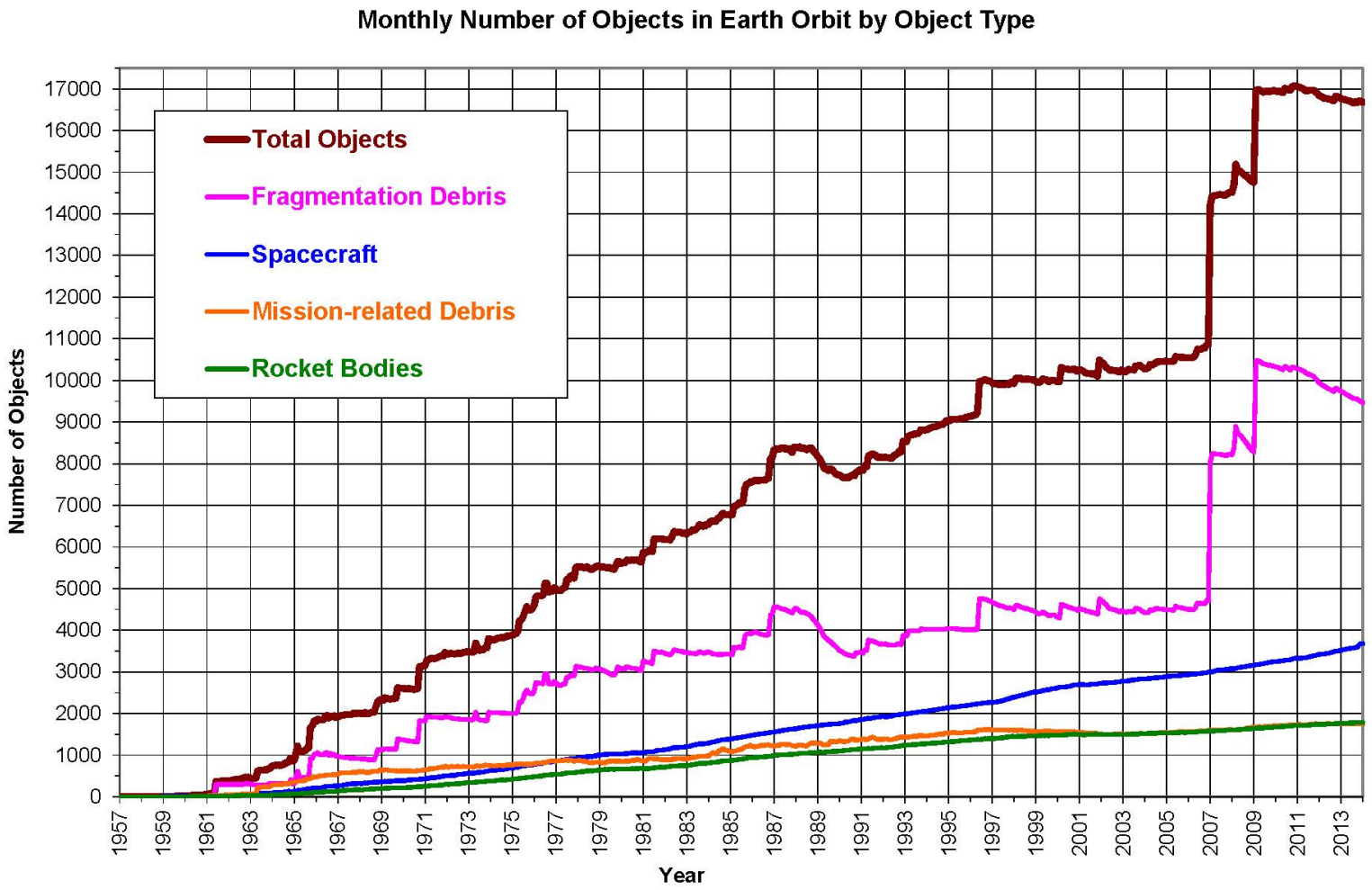
Outline

- **A Look at the Current Orbital Debris Environment**
- **U.S. National Policies and Regulations**
- **DAS**
- **Educational Value Added**

The Orbital Debris Environment

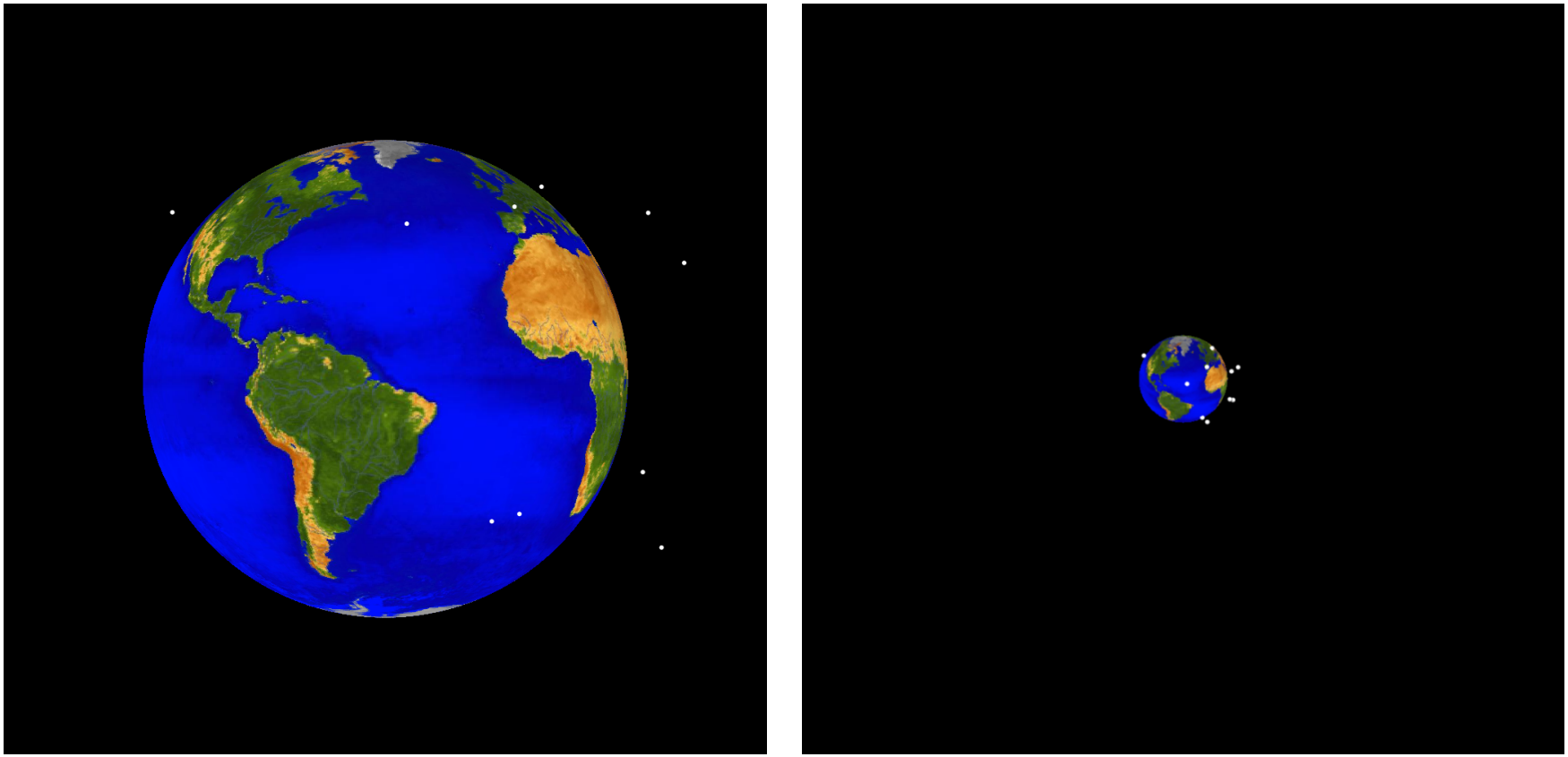


Evolution of the Cataloged Satellite Population



Growth of the Earth Satellite Population

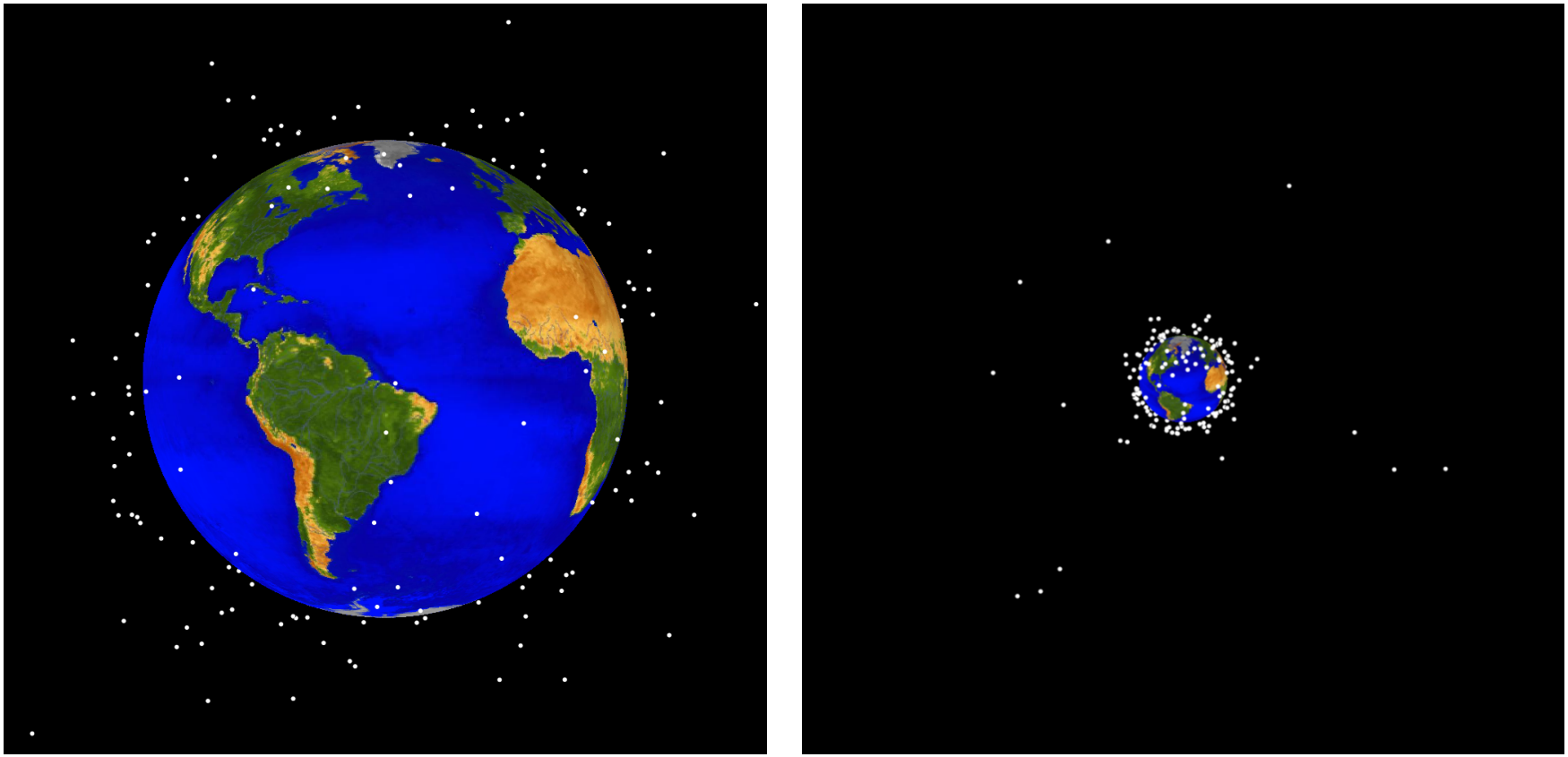
1960



Cataloged objects >10 cm diameter

Growth of the Earth Satellite Population

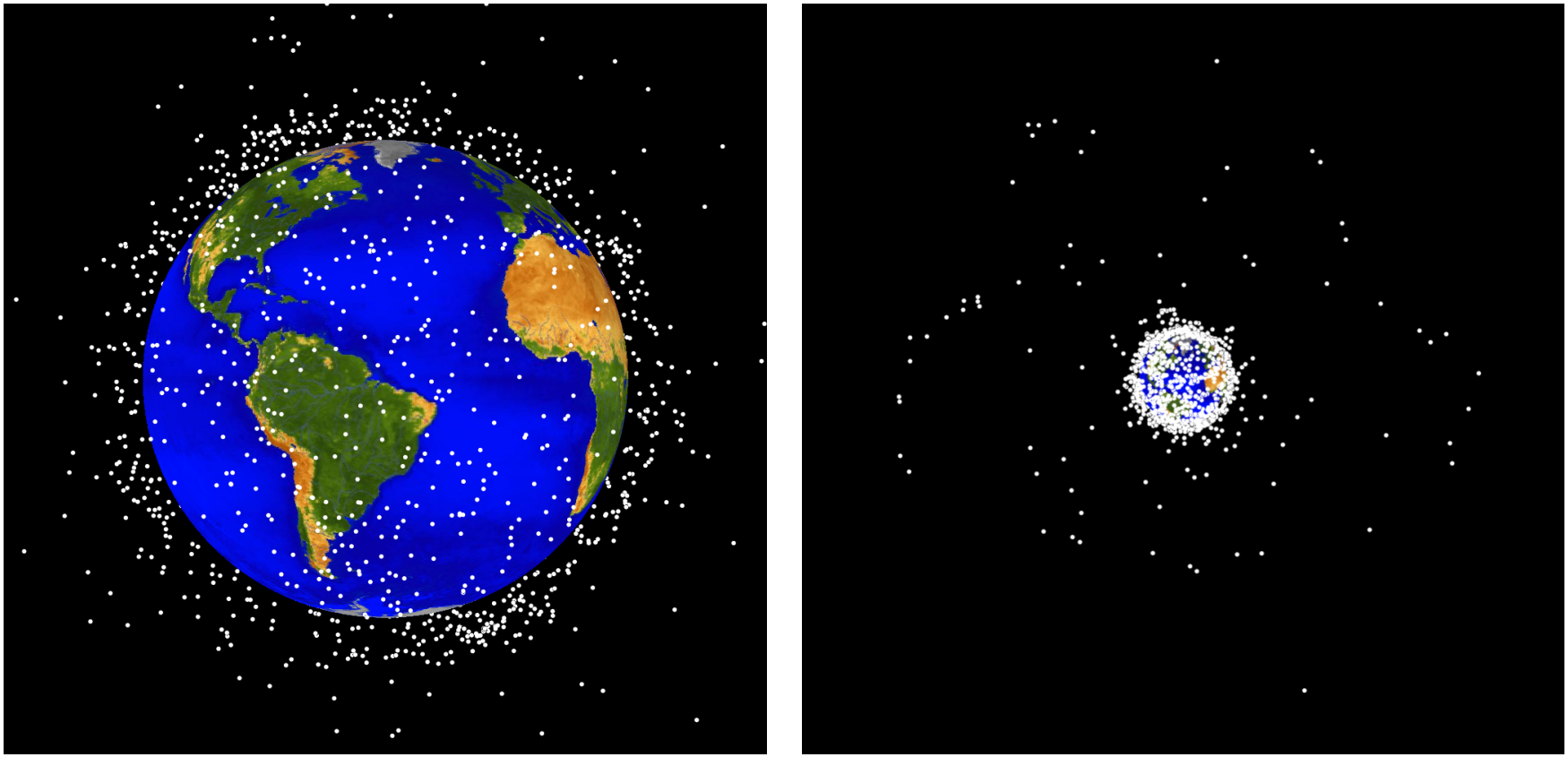
1965



Cataloged objects >10 cm diameter

Growth of the Earth Satellite Population

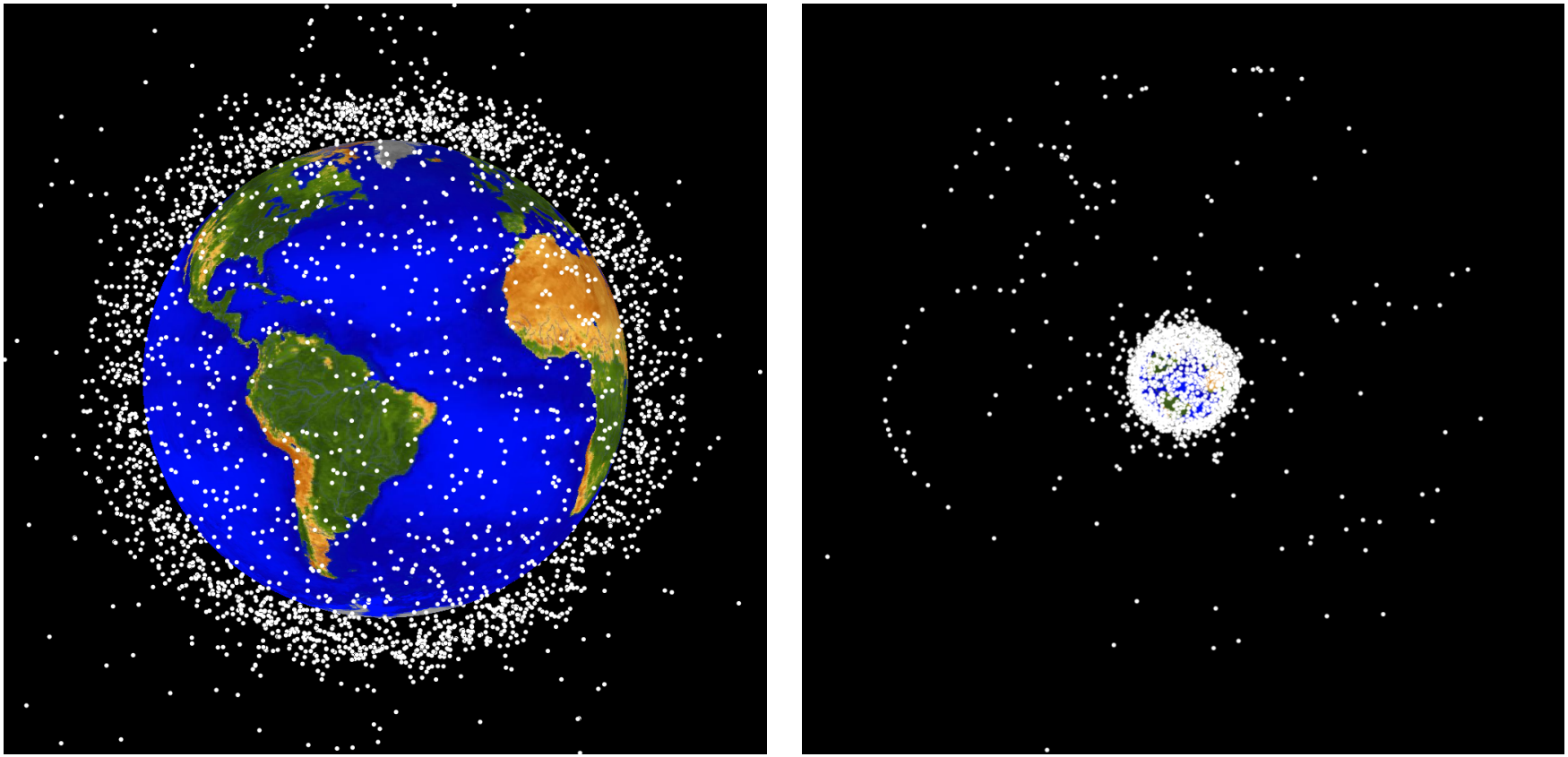
1970



Cataloged objects >10 cm diameter

Growth of the Earth Satellite Population

1975



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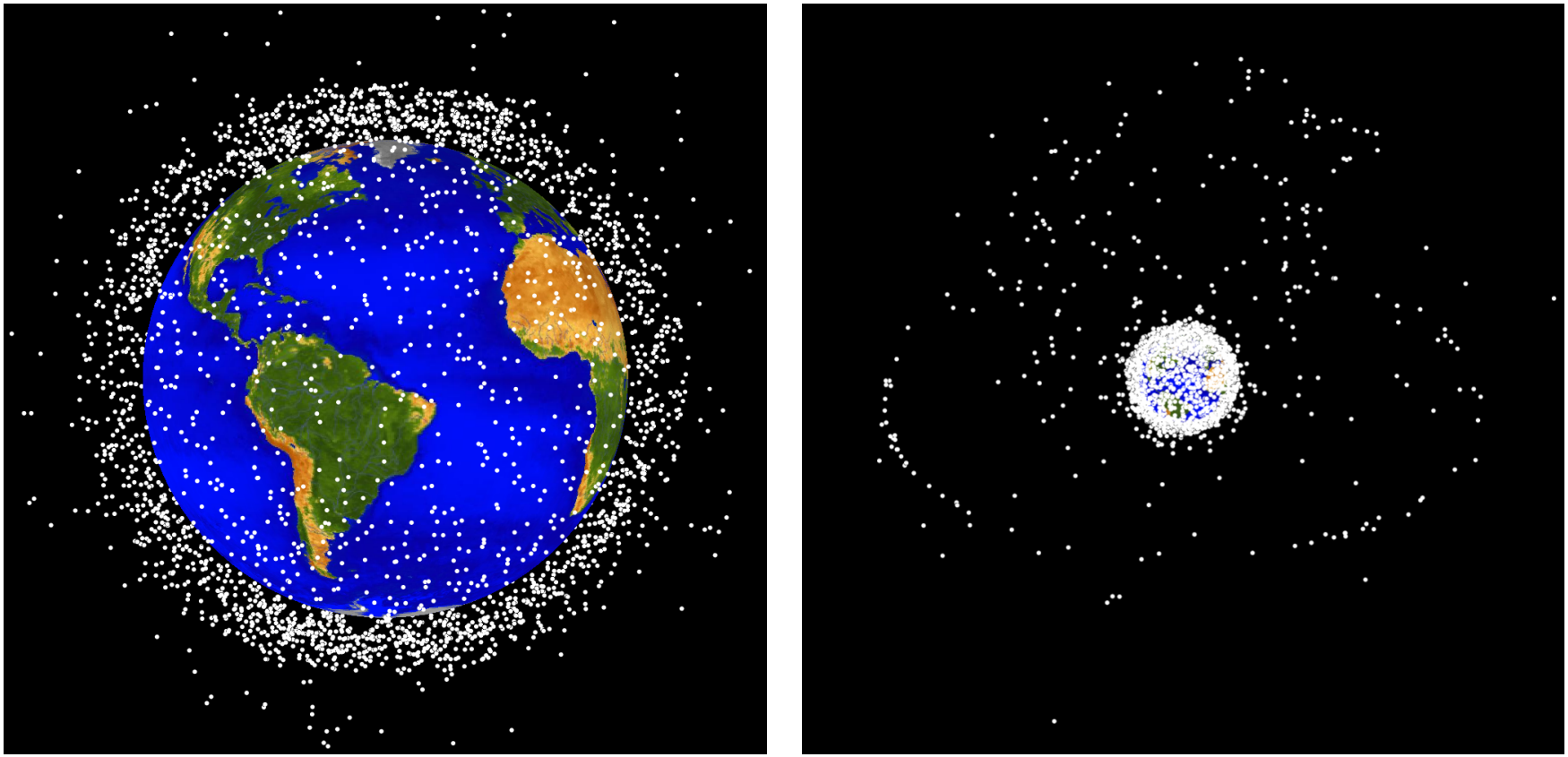
Growth of the Earth Satellite Population

1980



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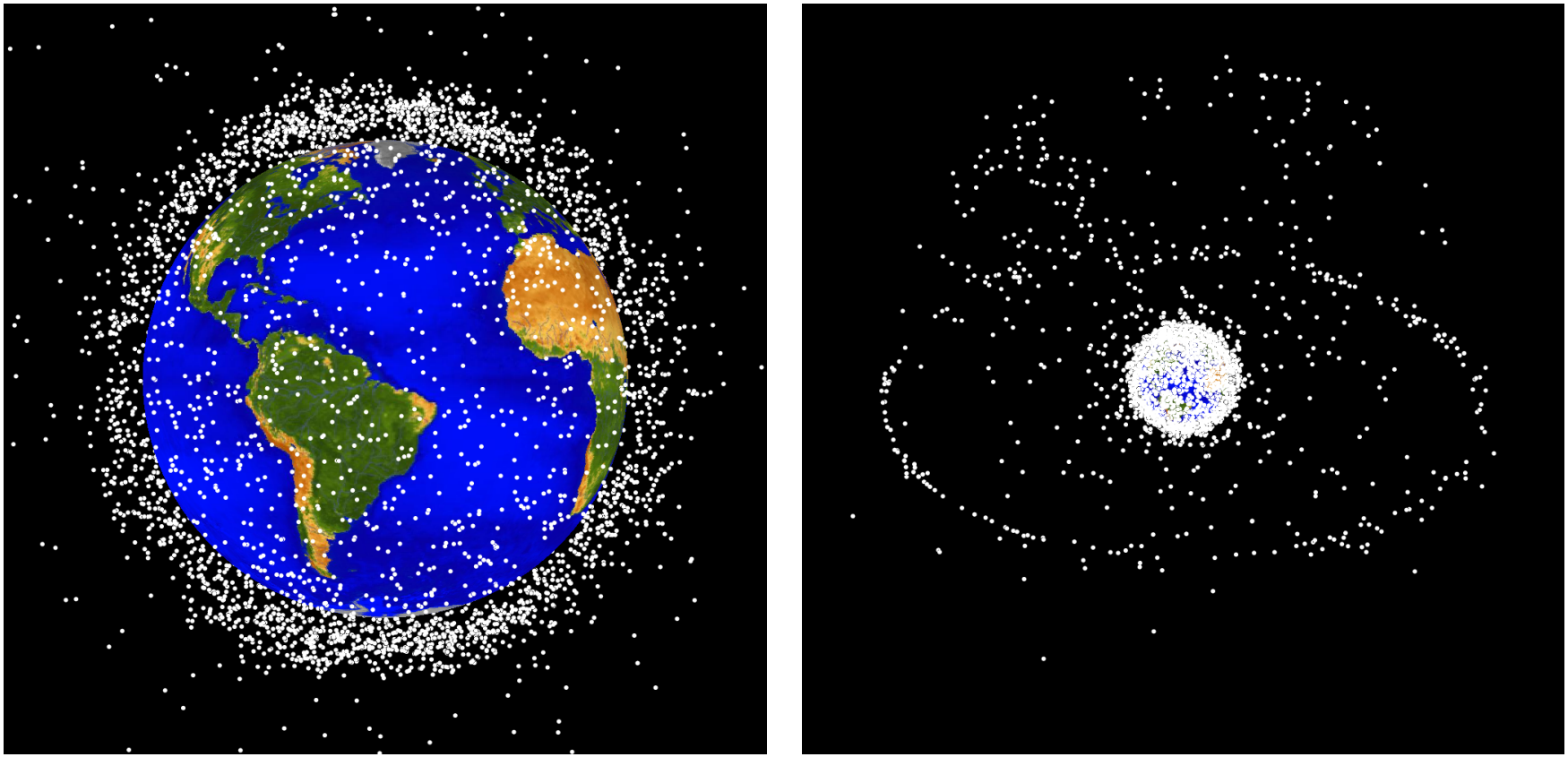
Growth of the Earth Satellite Population

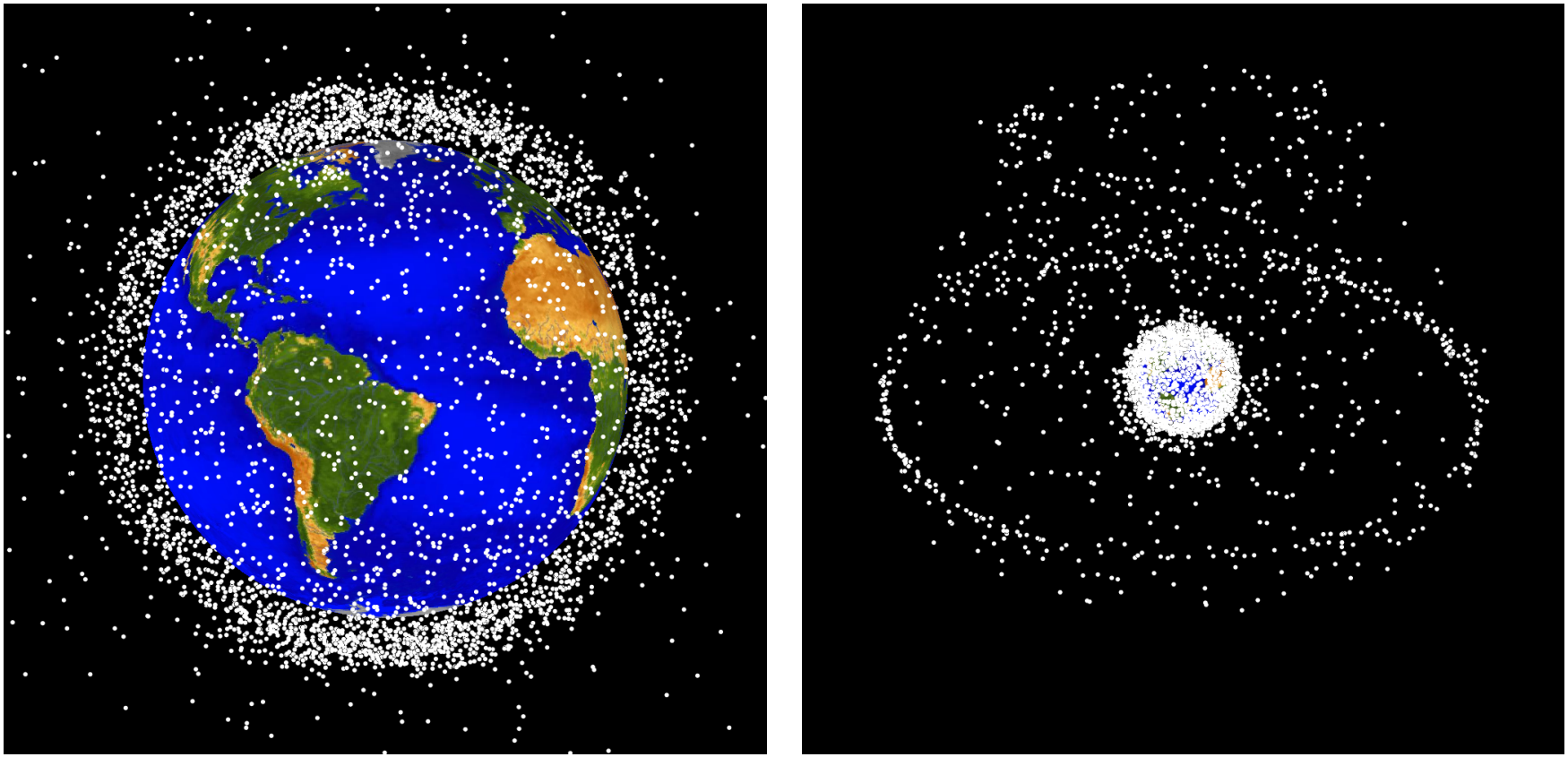
1985



Cataloged objects >10 cm diameter

Growth of the Earth Satellite Population

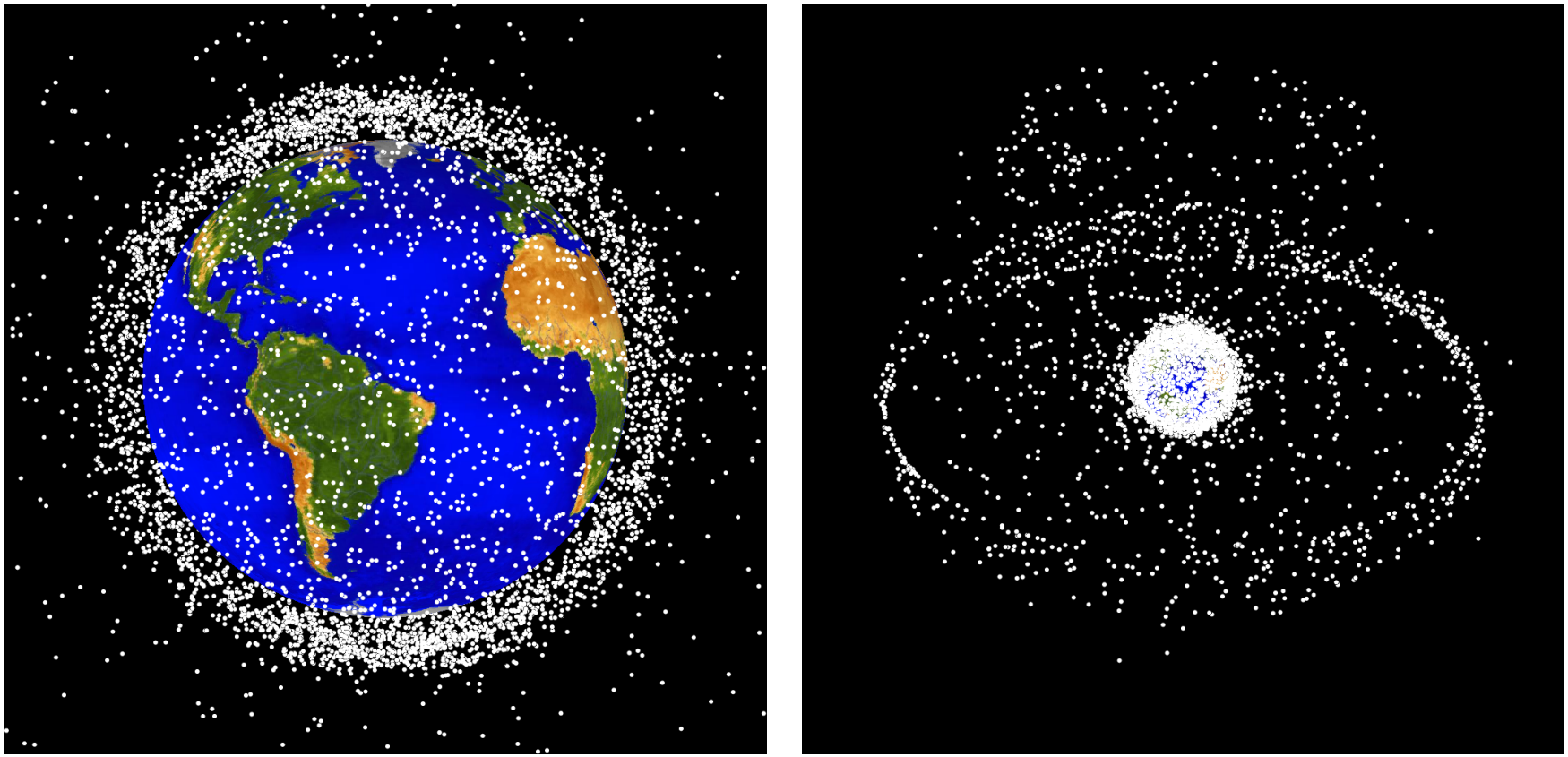
1990



Cataloged objects >10 cm diameter

Growth of the Earth Satellite Population

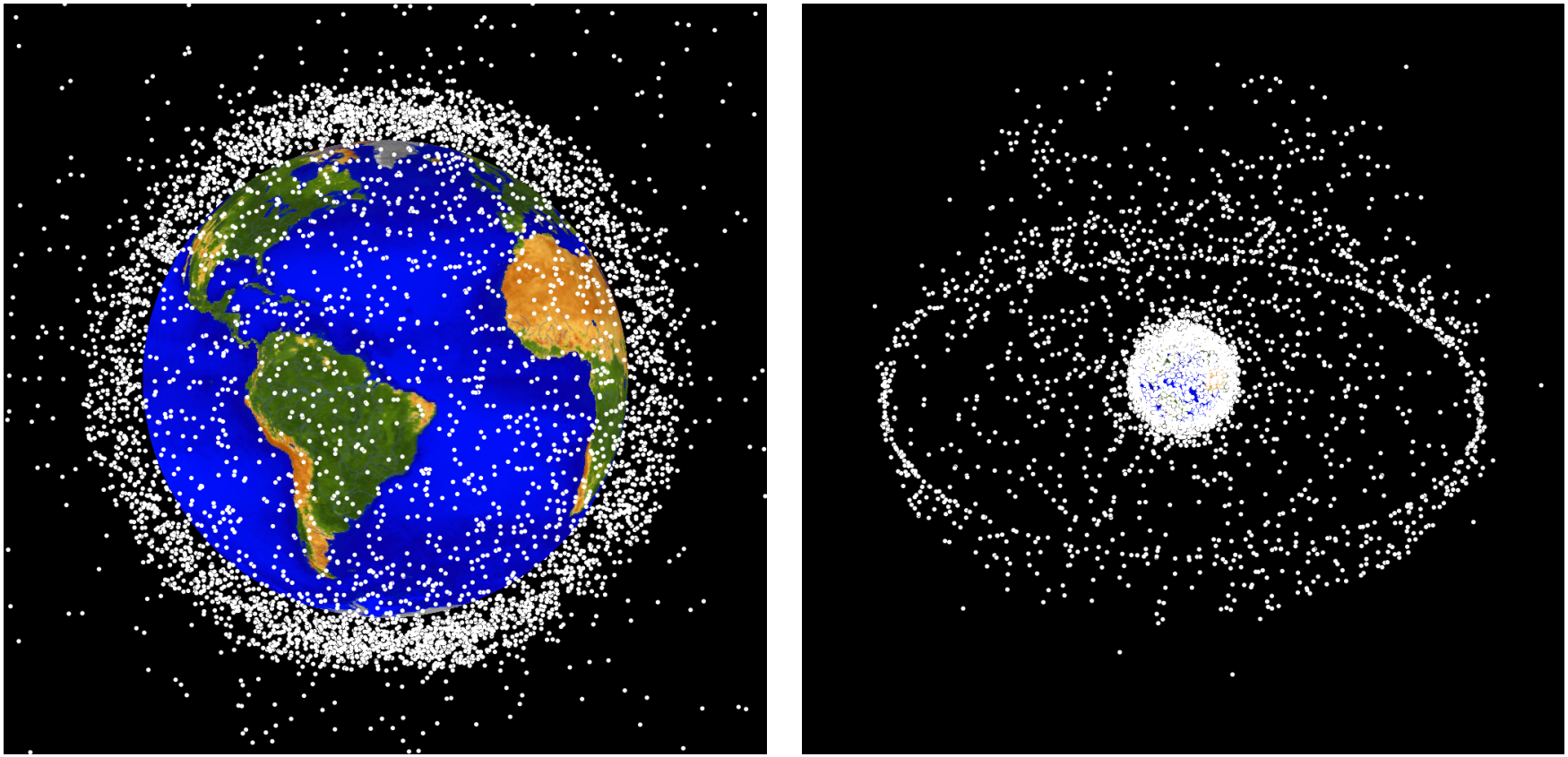
1995



Cataloged objects >10 cm diameter

Growth of the Earth Satellite Population

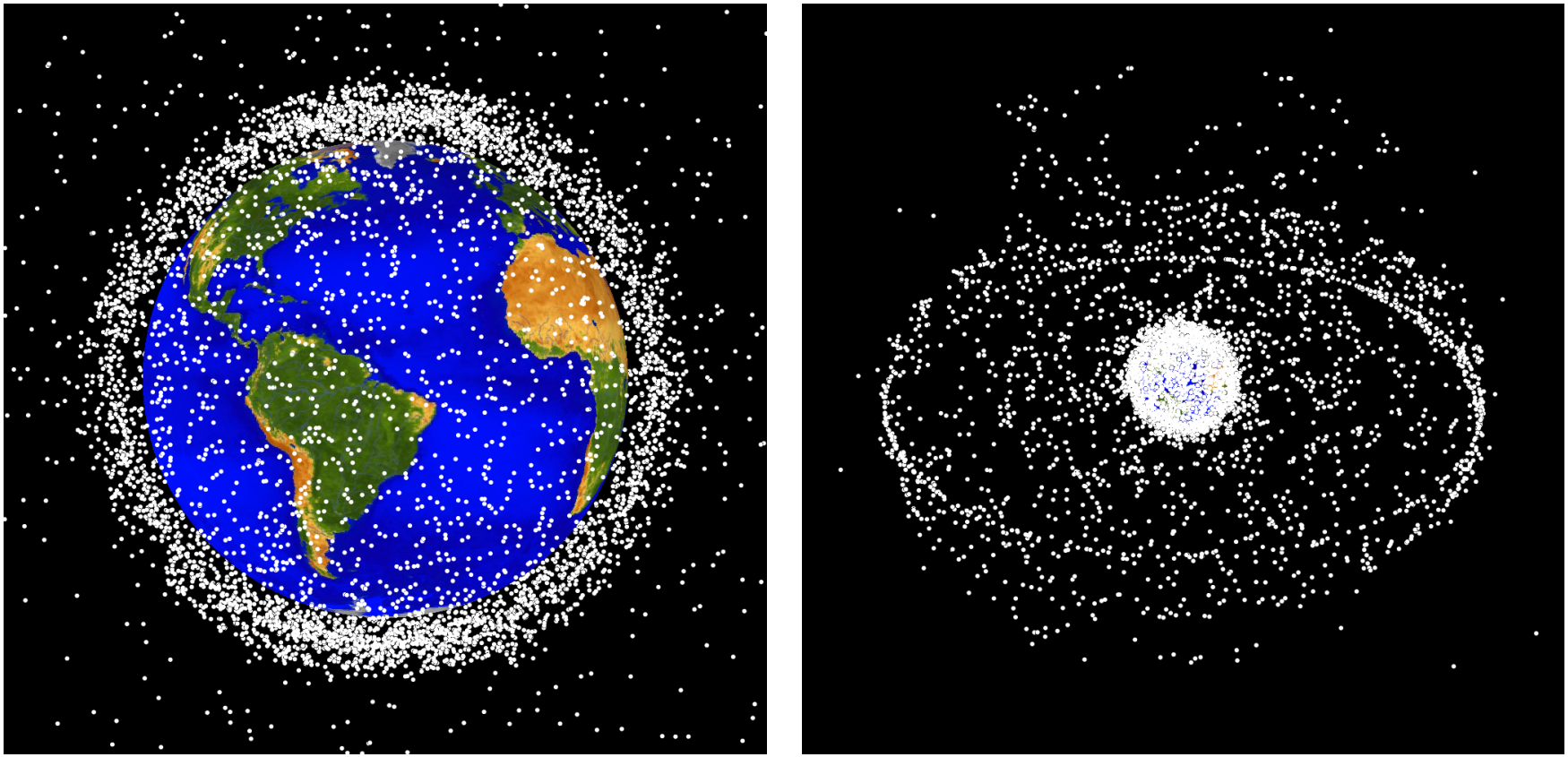
2000



Cataloged objects >10 cm diameter

Growth of the Earth Satellite Population

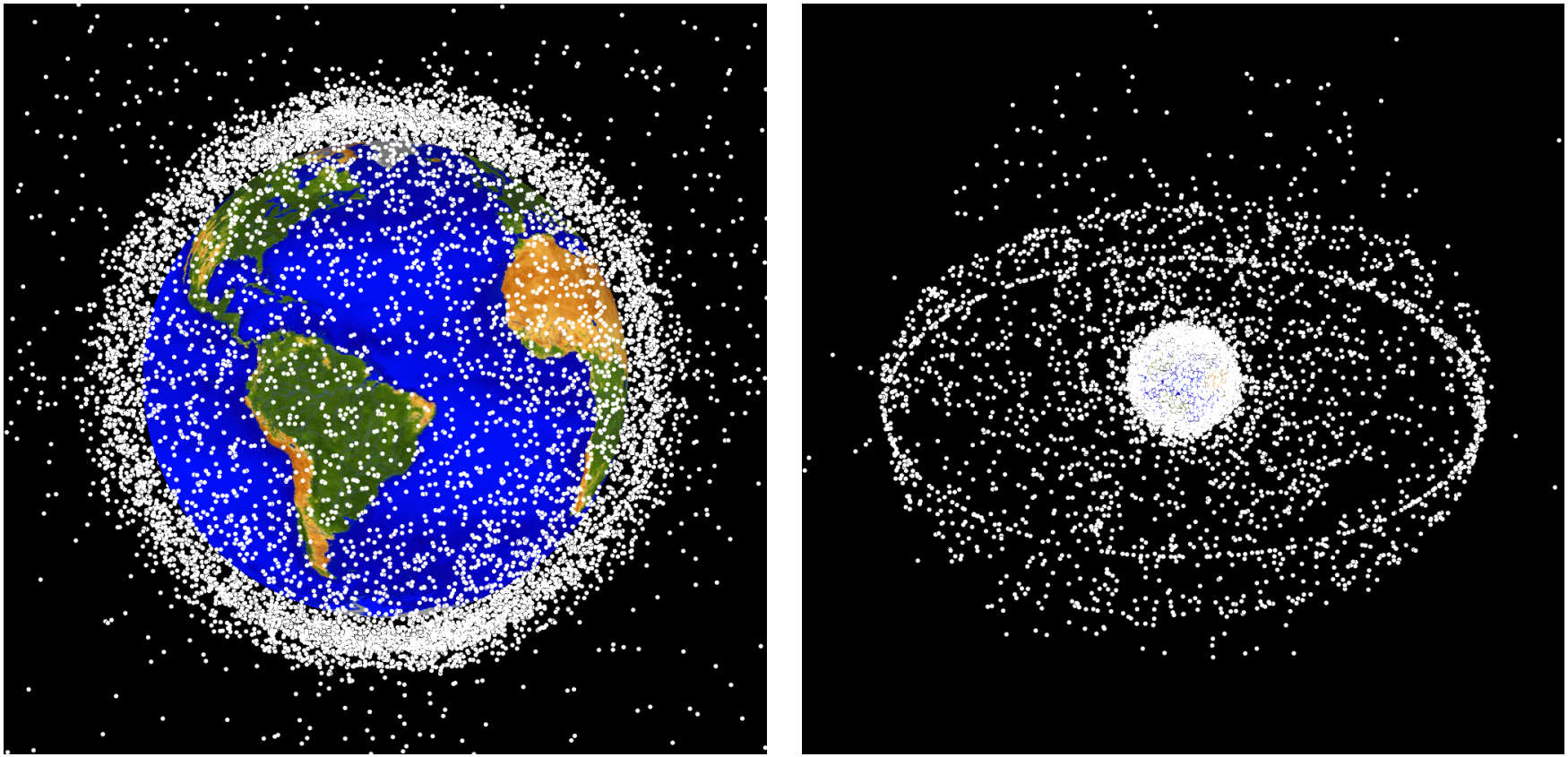
2005



Cataloged objects >10 cm diameter

Growth of the Earth Satellite Population

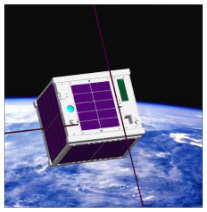
2010



Cataloged objects >10 cm diameter

Objects In Orbit

- **Spacecraft: >3700**
  - ~1000 are operational; the rest are orbital debris
- **Launch vehicle stages: ~1700**
- **Other Debris: > 10,000**
  - Mission related, e.g., sensor and engine covers, straps, springs, and yo-yo despin weights
  - Fragmentation Debris
    - Anomalous events: Typically one or a few debris released at low velocities
    - Explosions: Intentional or accidental
    - Collisions: Also can be intentional or accidental.



Cubesats: 1 kg

TDRS 1: 2 metric tons

Atlas V Centaur stage 2 metric tons

Why Orbital Debris Mitigation?

- **U.S. has endorsed the United Nations' *Orbital Debris Mitigation Guidelines***

- **President's National Space Policy directs agencies and departments to implement *U.S. Government Orbital Debris Mitigation Standard Practices***

To preserve near-Earth space for future generations

Policies for Mitigation

U.S. Government Orbital Debris Mitigation Standard Practices

- **In response to the 1995 Interagency report on orbital debris, 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

- **After coordination with the U.S. aerospace industry, the Standard Practices were approved 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**
  - Cited in 2006 and 2010 U.S. National Space Policy
  - Each U.S. Government organization implements the Standard Practices according to established internal procedures

USG Orbital Debris Mitigation Standard Practices Highlights

- **Standard Practice 1:**
  - Eliminate or minimize mission-related debris;
  - Limit orbital lifetime of LEO debris to 25 years
- **Standard Practice 2:**
  - Use design and procedures to avoid breakups during mission operations and after disposal
- **Standard Practice 3:**
  - Protect against collisions with small debris and avoid collisions with large debris
- **Standard Practice 4:**
  - LEO: Limit post-mission orbital lifetime to 25 years and limit human casualty reentry risk to 1 in 10,000
  - GEO: Maneuver to a disposal orbit ~300 km above GEO

DOD and NASA

- **The Department of Defense has established an overall directive on orbital debris mitigation (DoD Directive 3100.10, 2012)**
  - 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

- **NASA's policies on orbital debris mitigation are documented in NPR 8715.6A and NASA-STD 8719.14 Rev A**
  - NPR 8715.6 provides requirements to implement NASA's policy for limiting orbital debris
  - NASA-STD 8719.14 is a companion to the NPR and provides specific requirements as well as methods to comply with the NASA requirements for limiting orbital debris generation

Other USG Agencies

- **The Department of Transportation/FAA has issued regulations promoting orbital debris mitigation for commercial launch vehicles (14 CFR 415.39 2009)**
- **The Federal Communications Commission has issued regulations promoting orbital debris mitigation for transmitting spacecraft (47 CFR 97.207 2010)**
- **The Department of Commerce/NOAA has issued regulations promoting orbital debris mitigation for remote sensing spacecraft (415 CFR 960.1 2006)**

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

UN COPUOS STSC Space Debris Mitigation Guidelines

- **The 2007 UN COPUOS STSC Space Debris Mitigation Guidelines contains seven numbered guidelines:**
  - Guideline 1: Limit debris released during normal operations
  - Guideline 2: Minimize the potential for break-ups during operational phases
  - Guideline 3: Limit the probability of accidental collision in orbit
  - Guideline 4: Avoid intentional destruction and other harmful activities
  - Guideline 5: Minimize potential for post-mission break-ups resulting from stored energy
  - Guideline 6: Limit the long-term presence of spacecraft and launch vehicle orbital stages in the low-Earth orbit (LEO) region after the end of their mission
  - Guideline 7: Limit the long-term interference of spacecraft and launch vehicle orbital stages with geosynchronous Earth orbit (GEO) region after the end of their mission

National Orbital Debris Mitigation Guidelines

- **Since the establishment of the NASA policy and guidelines on orbital debris, an increasing number of countries have developed and adopted specific national guidelines promoting the mitigation of the growth of the orbital debris environment**
  - Japan: Space Debris Mitigation Standard (NASDA-STD-18A), March 1996
  - France: CNES Space Debris – Safety Requirements (MPM-50-00-12), April 1999; new national space law in December 2010.
  - Russia: General Requirements for Mitigation of Space Debris Population (Branch Standard), July 2000
  - China: Requirements for Space Debris Mitigation (QJ 3221 – 2005), July 2005
- **ESA issued a Space Debris Mitigation Handbook in February 1999, followed by a draft Space Debris Safety and Mitigation Standard in September 2000**
- **These guidelines are very similar in most of their recommendations with the U.S. Government Orbital Debris Mitigation Standard Practices**

European Code of Conduct for Space Debris Mitigation

- **In June 2004 a draft European Code of Conduct for Space Debris Mitigation was completed by the five leading space agencies in Europe: ESA, ASI (Italy), BNSC (UK), CNES (France), and DLR (Germany)**
  - In 2006 the final signature of the document was recorded.

- **This new European document is divided into three main categories:**
  - Management Measures
  - Design Measures
  - Operational Measures

- **Following the precedent set by IADC, a "Support to Implementation of the European Code of Conduct for Space Debris Mitigation" has also been produced**

- **The European Code of Conduct for Space Debris Mitigation does add specificity, *e.g.*, measures of effectiveness, similar to that of NASA's NSS 1740.14 and NS 8719.14**

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."**

- **A large number of U.S., foreign, and international guidelines for mitigating the creation of new orbital debris now exist**

NASA Debris Assessment Software (DAS)

Introduction

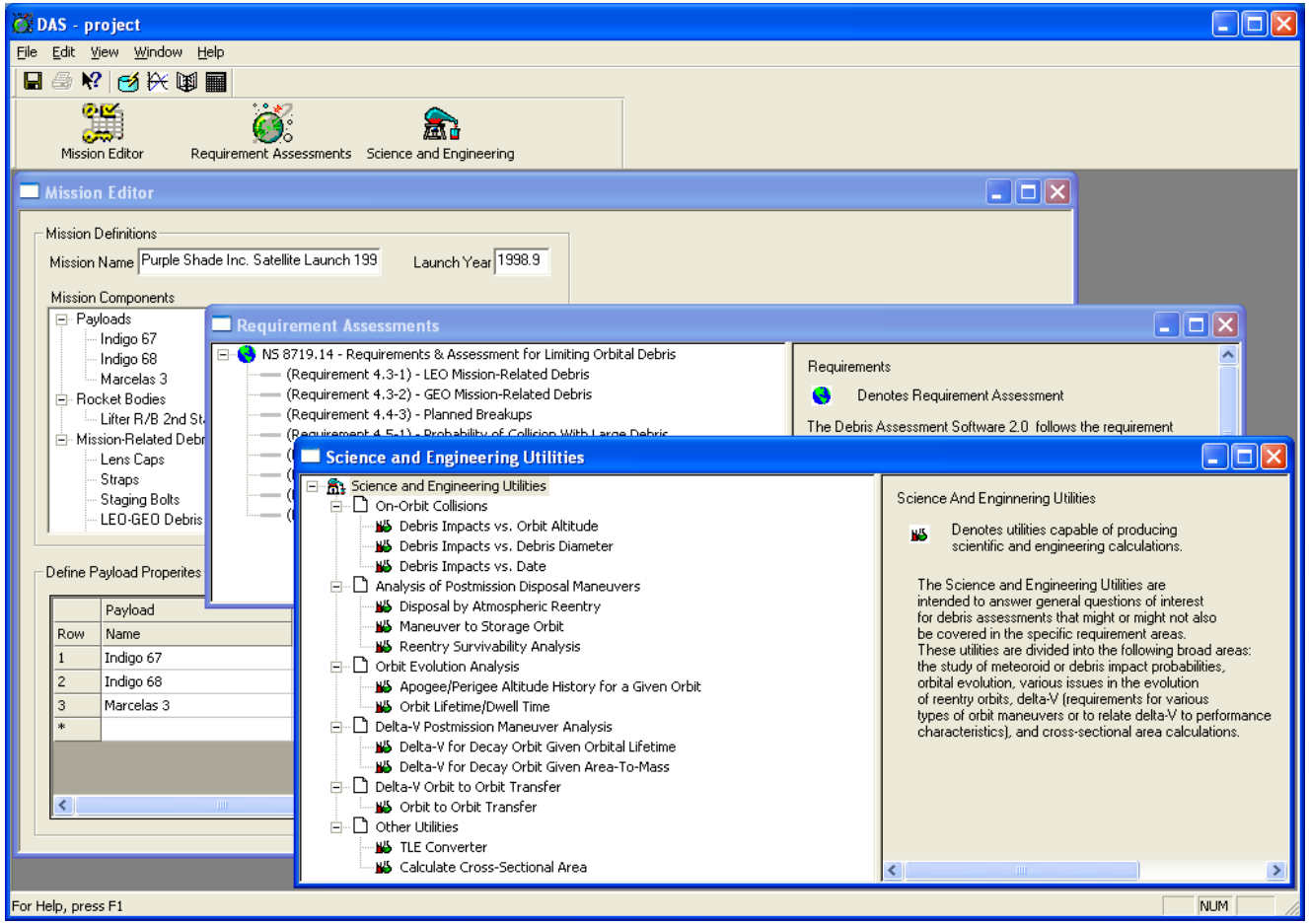
- **The NASA Debris Assessment Software (DAS) is actually a set of custom tools designed to assist space programs and projects in preparing orbital debris assessment reports.**
  - Assessment requirements are described in NASA Standard 8719.14, "Process for Limiting Orbital Debris"
  - DAS 2.0 addresses most requirements point-by-point
  - Referenced in FCC regulations as method to asses compliance
  - Widely used by satellite designers around the world as a method to asses compliance with general orbital debris mitigation guidelines

- **Download software and reference materials at:**

  http://www.orbitaldebris.jsc.nasa.gov/mitigate/das.html

DAS 2.0 User Interface

The DAS 2.0 top-level window, and three main dialog windows



GUI: Requirement Assessments

The user may assess the mission's compliance with each requirement

DAS - project_leo - [Requirement Assessments]

File Edit View Window Help

Mission Editor | Requirement Assessments | Science and Engineering

- NS 8719.14 - Requirements & Assessment for Limiting Orbital Debris
  - (Requirement 4.3-1) - LEO Mission-Related Debris
  - (Requirement 4.3-2) - GEO Mission-Related Debris
  - (Requirement 4.4-3) - Planned Breakups
  - (Requirement 4.5-1) - Probability of Collision With Large Debris
  - (Requirement 4.5-2) - Probability of Damage from Small Debris
  - (Requirements 4.6-1 to 4.6-3) - Postmission Disposal
  - (Requirement 4.7-1) - Risk from Reentry Debris
  - (Requirement 4.8-1) - Mitigate the Collision Hazards of Space Tethers

Requirements

Denotes Requirement Assessment

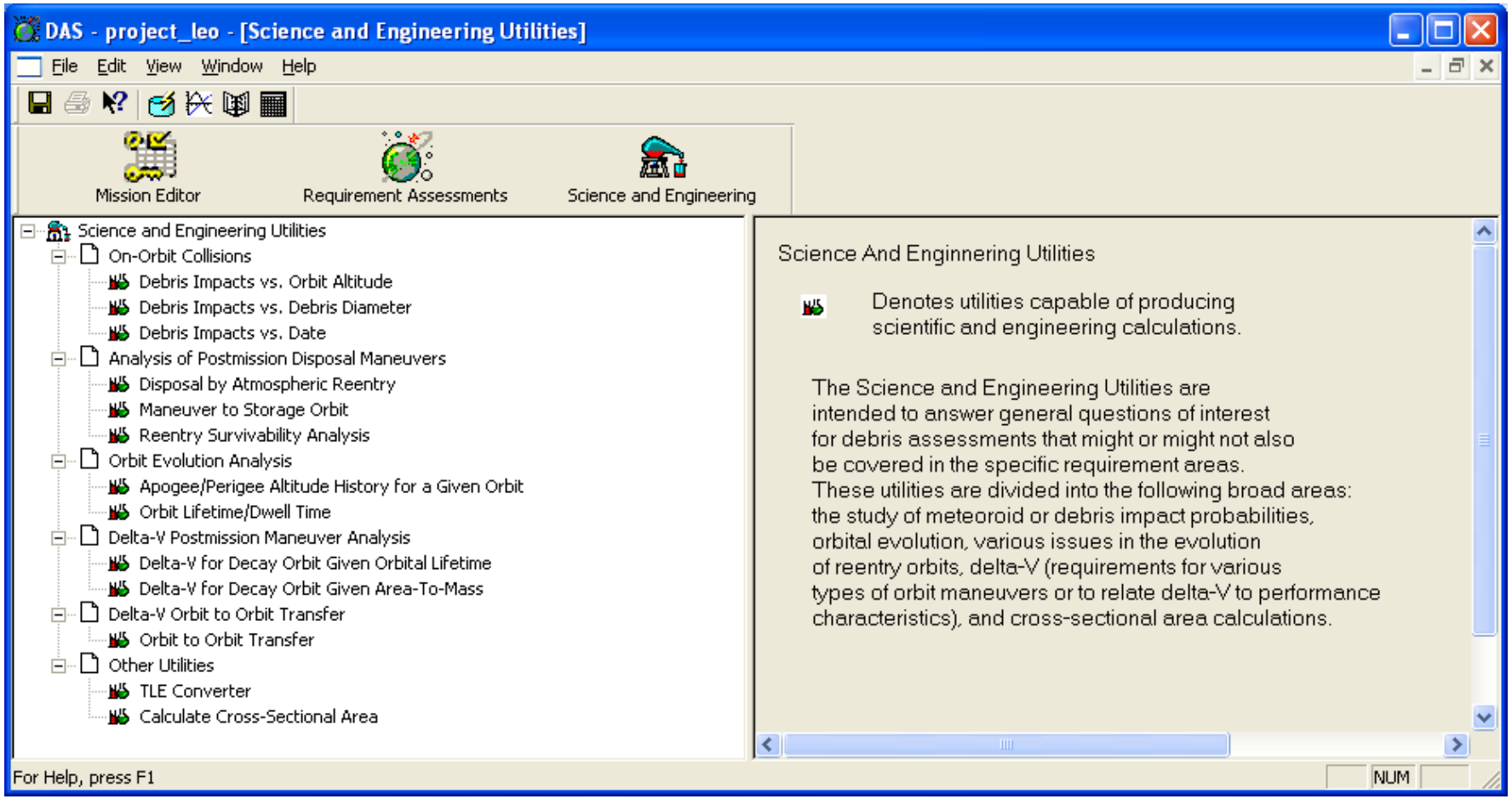
The Debris Assessment Software 2.0 follows the requirement structure of NS 8719.14.
Each program or project shall attempt to meet all pertinent requirements for its spacecraft, launch vehicle orbital stage(s), and objects released during nominal operations.
The analysis section provides calculation routines to assist in the overall process. The software generates an activity log for each user's session. The activity log is a record of all user options selected and all input and output data generated.

Reset

For Help, press F1 NUM

GUI: Science and Engineering Utilities

These utilities allow the user to explore options in mission design and to perform other supporting calculations



Summary

- **DAS is the standard method of assessing compliance with NASA's space debris mitigation requirements (NS 8719.14A).**
  - DAS provides point-by-point assessment of a mission's compliance with NASA's requirements.
  - Results from DAS may be included in reports to NASA as well as other regulating agencies
  - DAS provides additional tools for mission-planning and input conversion.
- **The modular internal structure of the software allows for easy updates (such as to the debris environment model or the human population density) in the future. Solar activity forecasts are updated quarterly.**
- **Software and documentation are available on the NASA Orbital Debris Program Office's internet site:**

http://www.orbitaldebris.jsc.nasa.gov/mitigate/das.html

Educational Value

Benefits to Student Development

- **Successfully designing, building and flying a satellite provide valuable experience that makes a resume stand out**
  - Hands-on experience gained in Systems, Mechanical, and Electrical Engineering from these projects provide career opportunities.
  - Demonstrating an ability to address requirements beyond functionality stands out more

- **In addition to addressing requirements, understanding terminology or requirements is an essential skill for job seekers**
  - Understanding the difference between “may” and “shall” can impact design decisions
  - Defining simple terms like may and shall in requirements:
    - “may” implies discretionary privilege
    - “shall” denotes mandatory action

Educational Benefits

- **When overseeing a project cost and schedule are key**
  - Overlooking operational and safety requirements during design of a satellite or component can lead to redesigns which can prove to be costly and negatively impact schedule

- **Addressing these requirements can lead to innovation**
  - The GPM mission designed new fuel tanks to meet reentry survivability goals
  - Industry responded to "Design for Demise" project by developing demiseable reaction wheels
  - Drag augmentation devices have been developed for testing on cubesats such as the NanoSail project

- **Developing a responsibility to "Keep the environment safe for future generations"**