Preserving the Near-Earth Space Environment with Green Engineering and Operations

Nicholas L. Johnson
Chief Scientist for Orbital Debris
NASA Johnson Space Center

NASA Green Engineering Masters Forum
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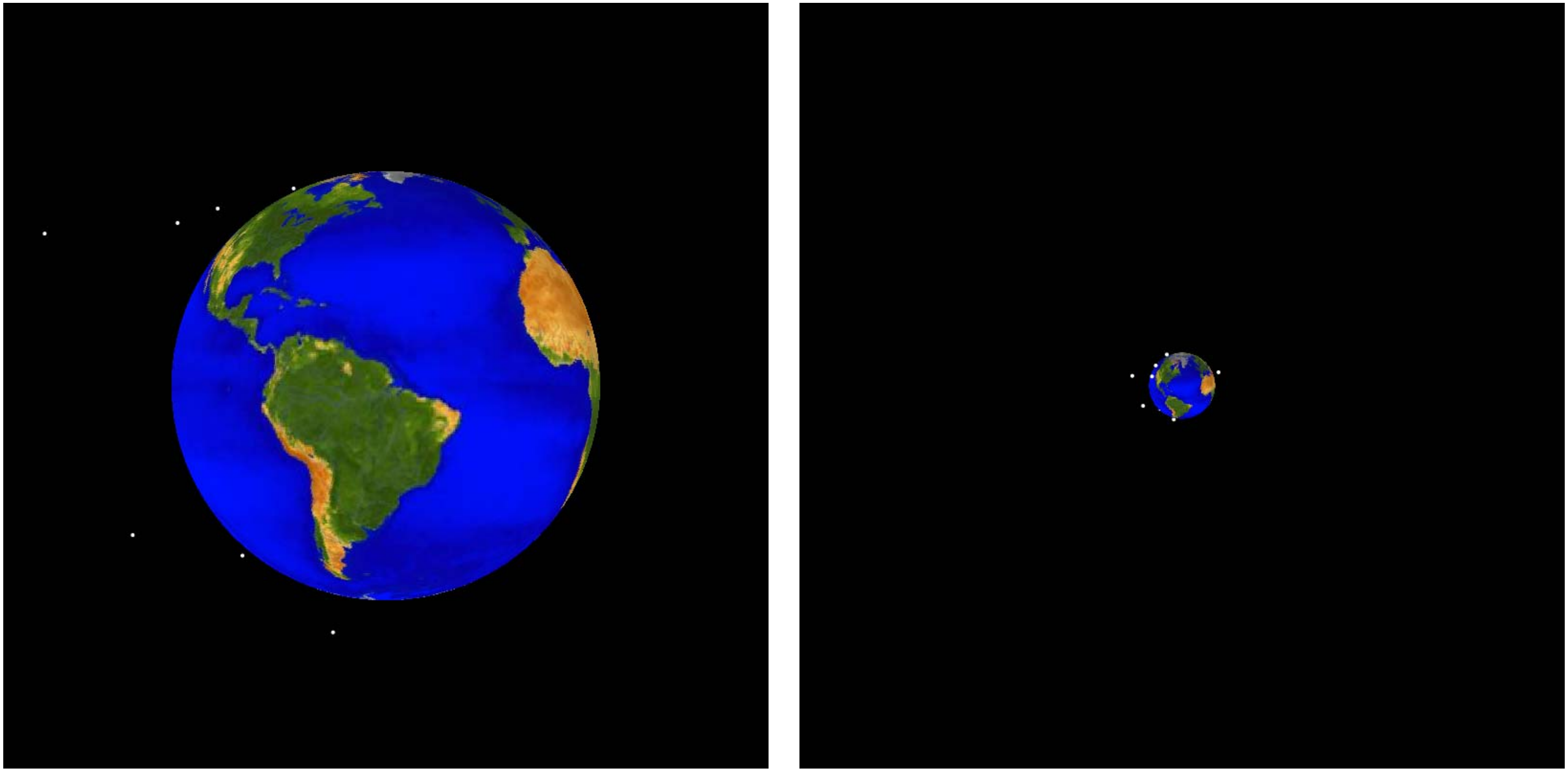
Growth of the Earth Satellite Population

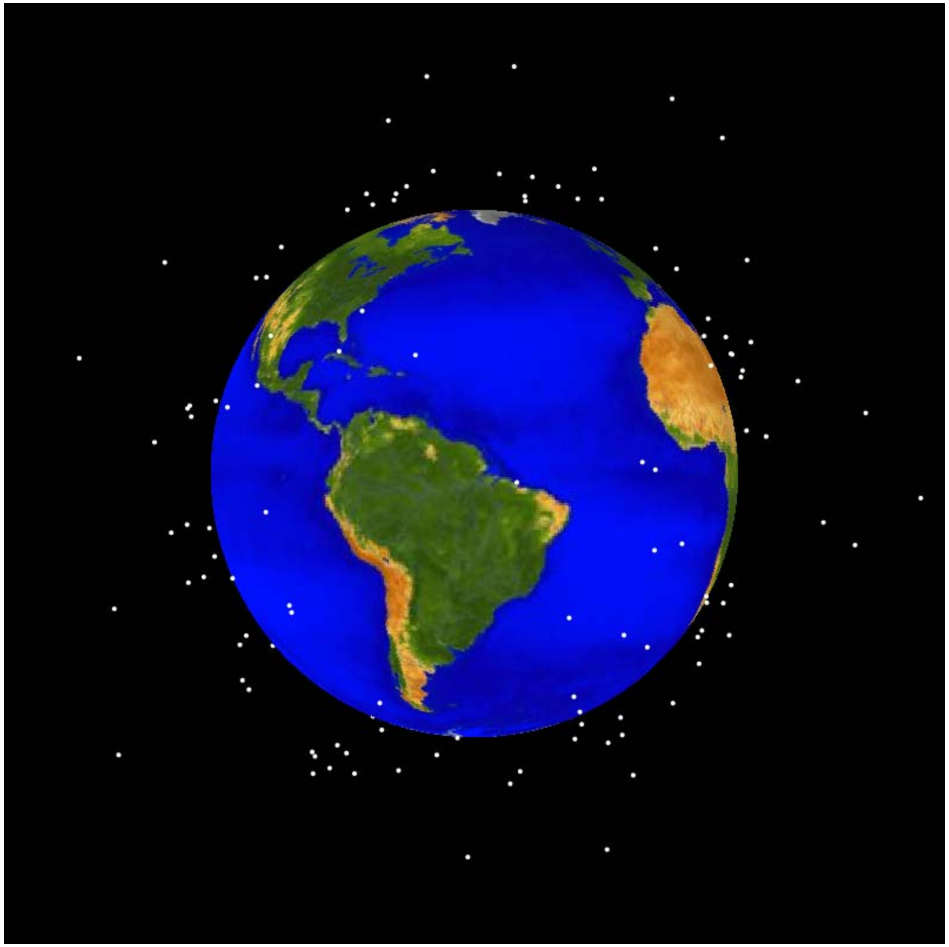
1960

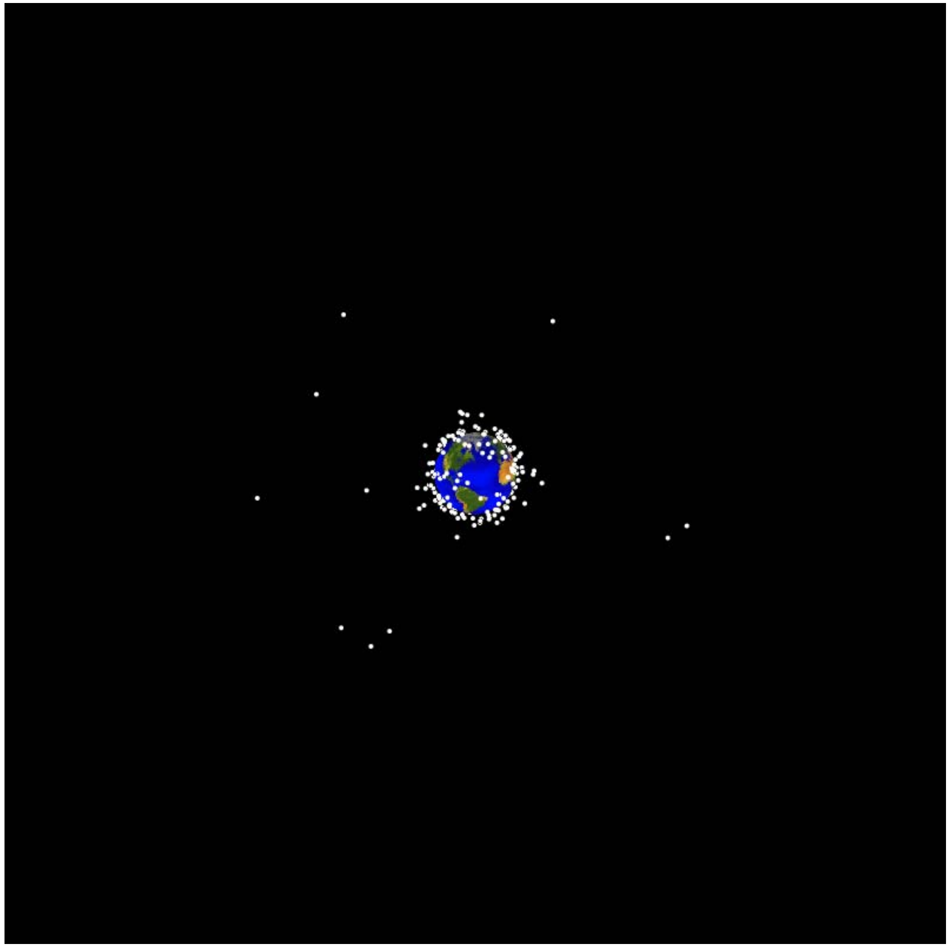


Cataloged objects >10 cm diameter

Growth of the Earth Satellite Population

1965

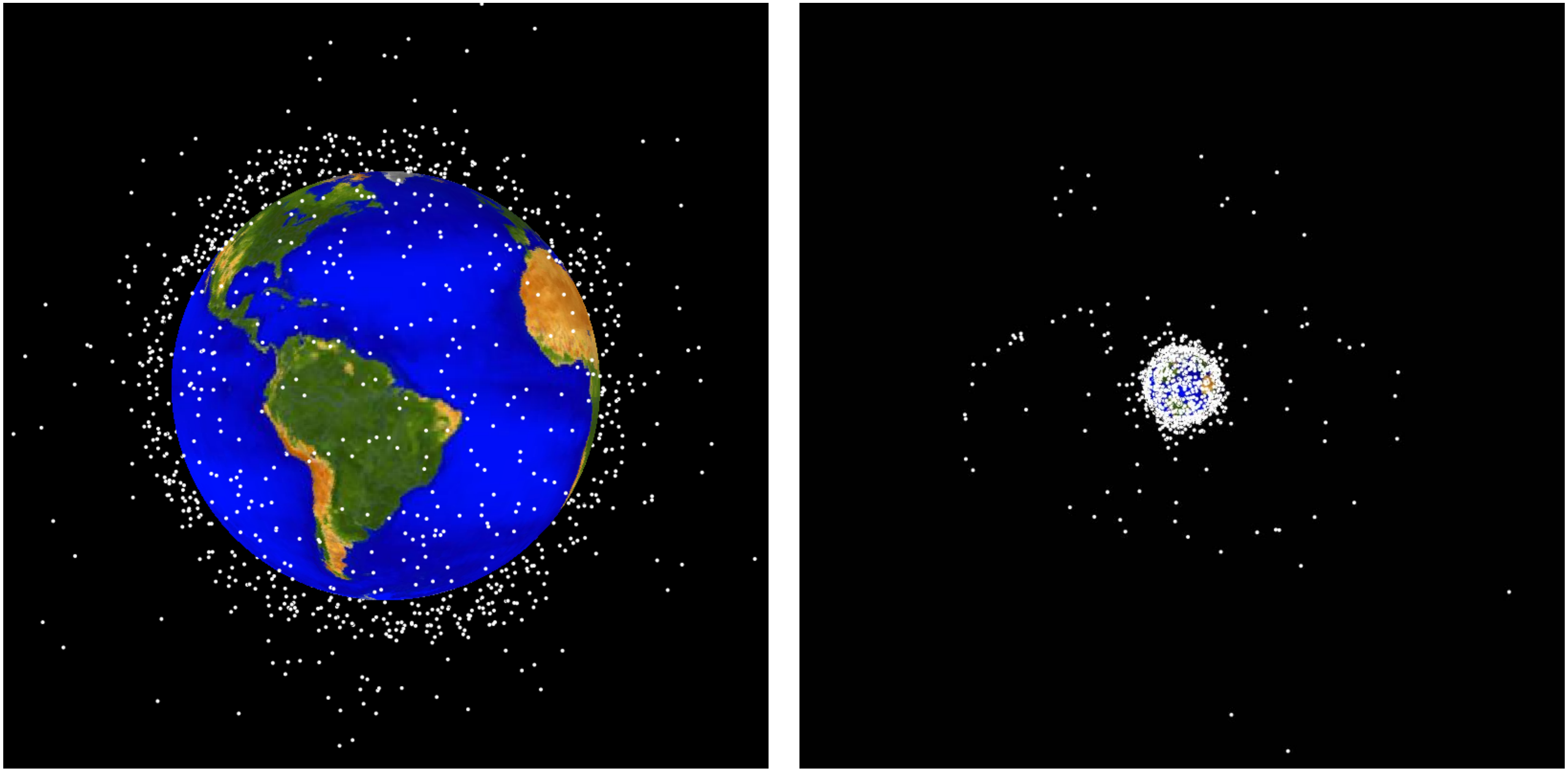




Cataloged objects >10 cm diameter

Growth of the Earth Satellite Population

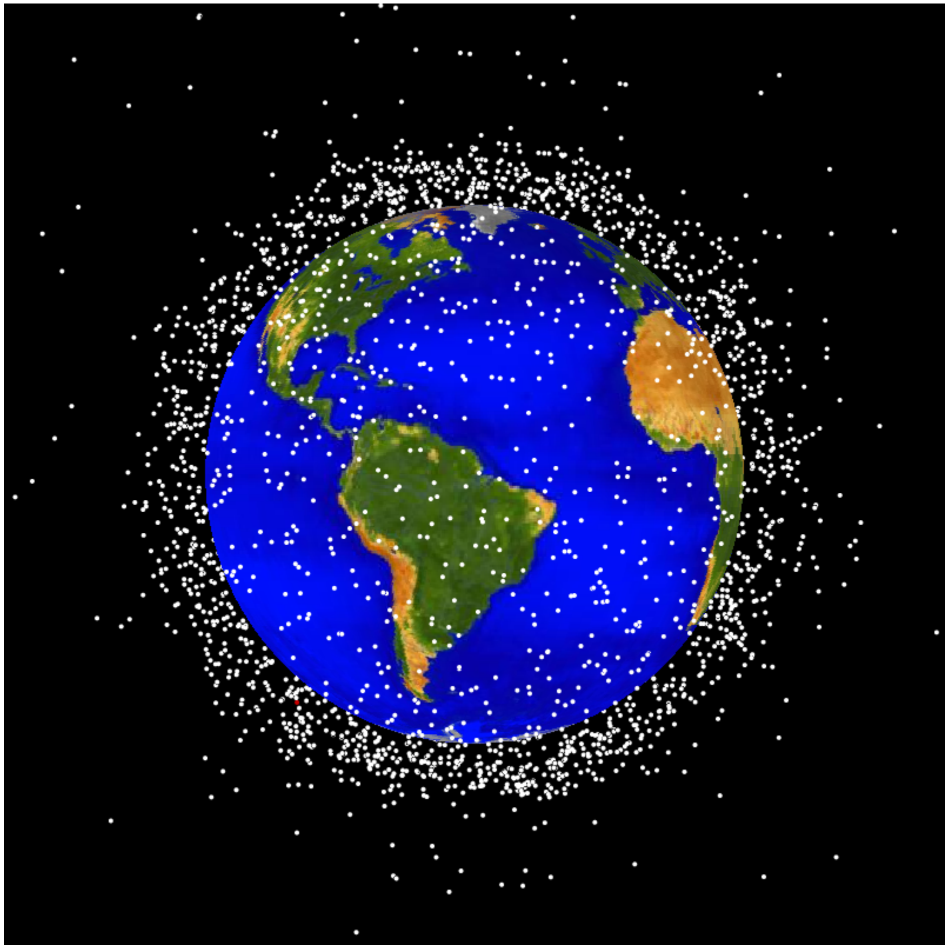
1970

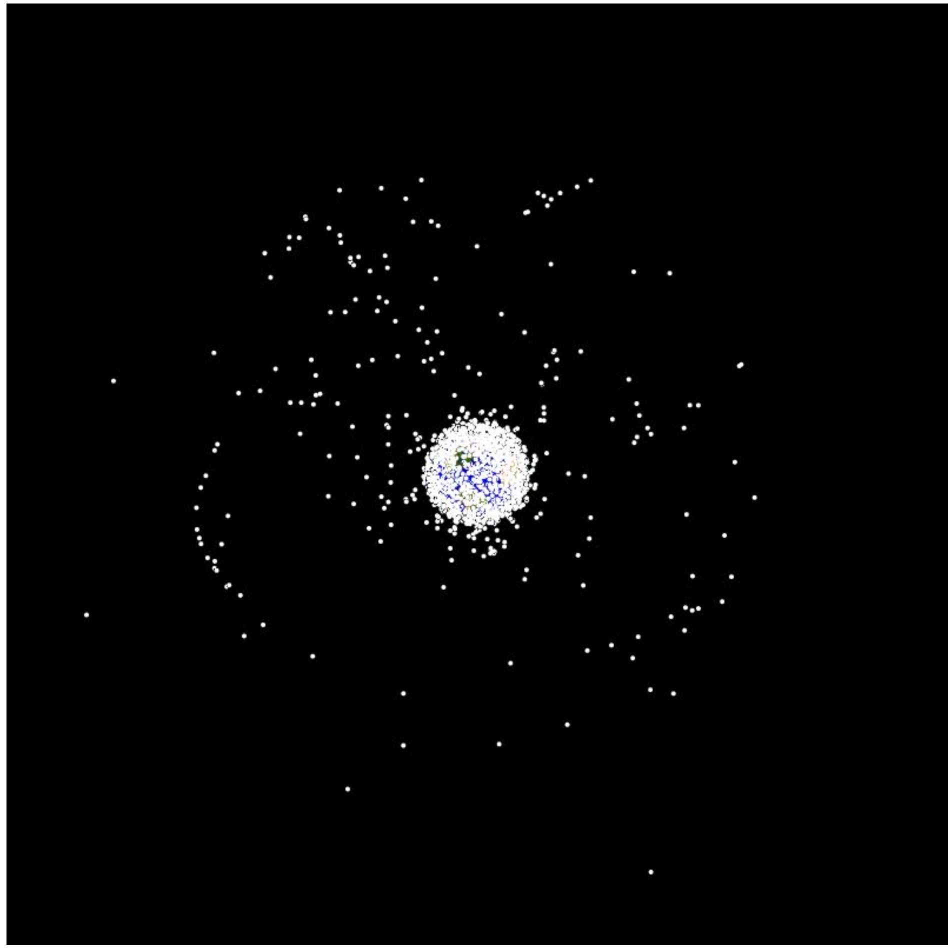


Cataloged objects >10 cm diameter

Growth of the Earth Satellite Population

1975





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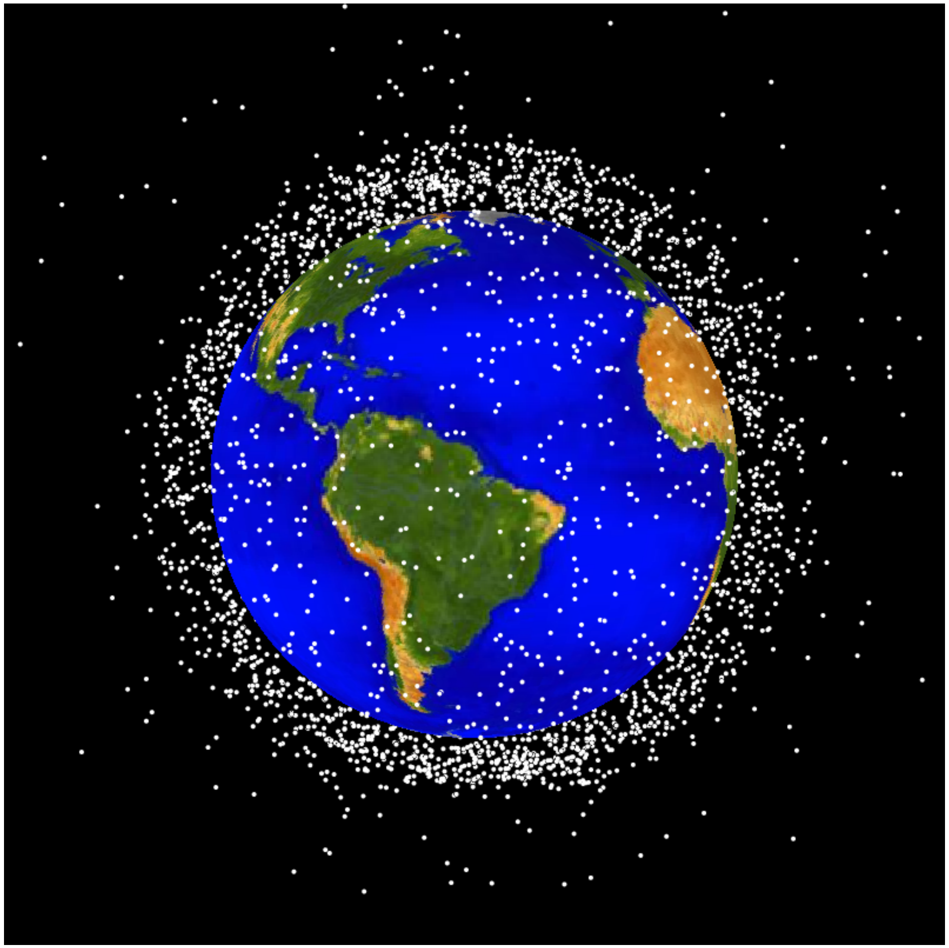
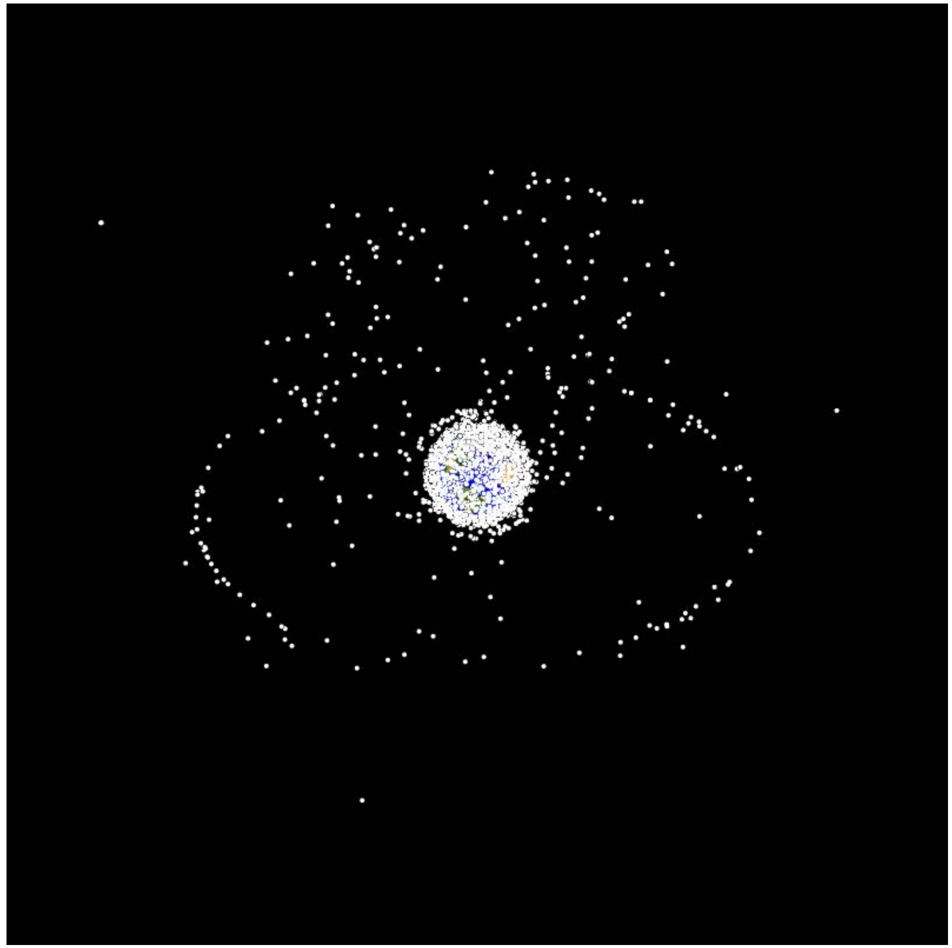
Growth of the Earth Satellite Population

1980

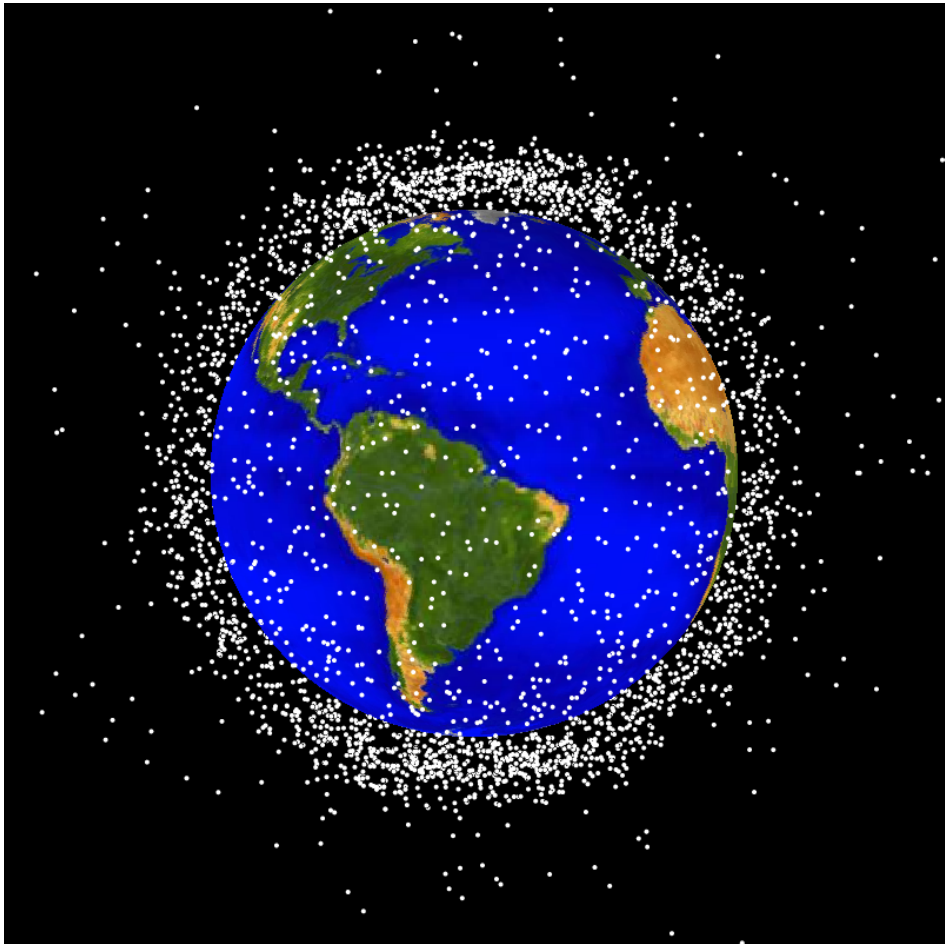


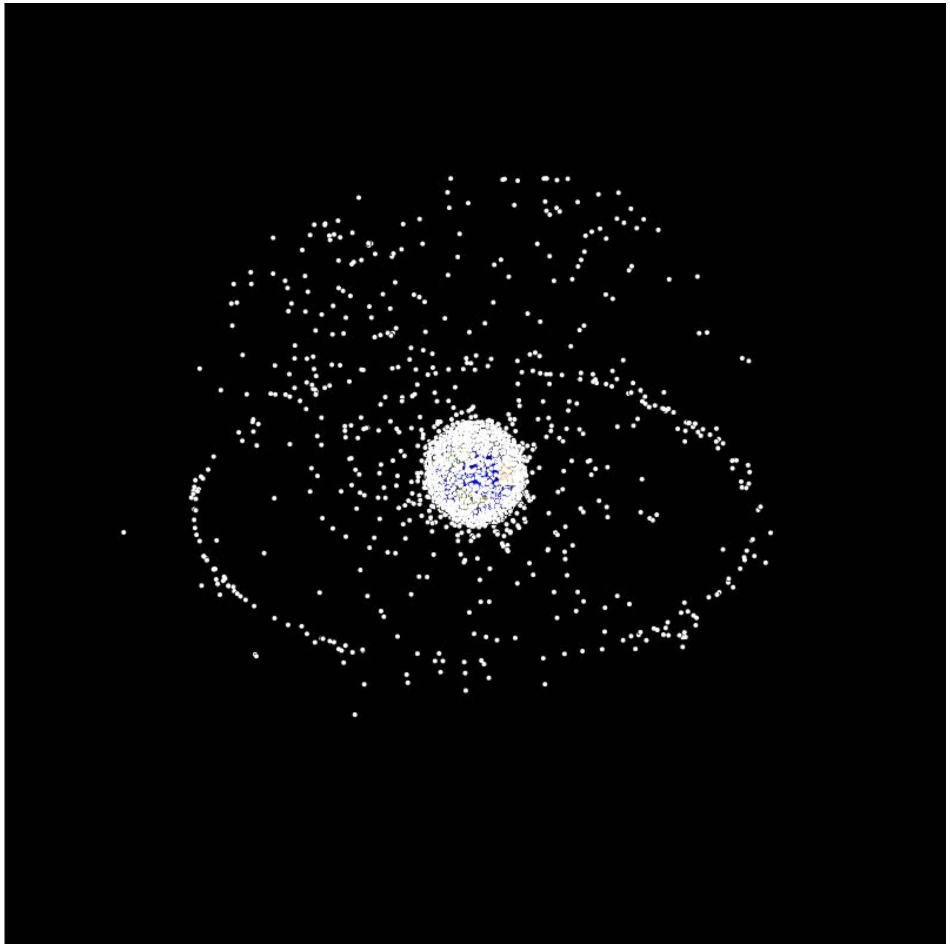


Cataloged objects >10 cm diameter

Growth of the Earth Satellite Population

1985





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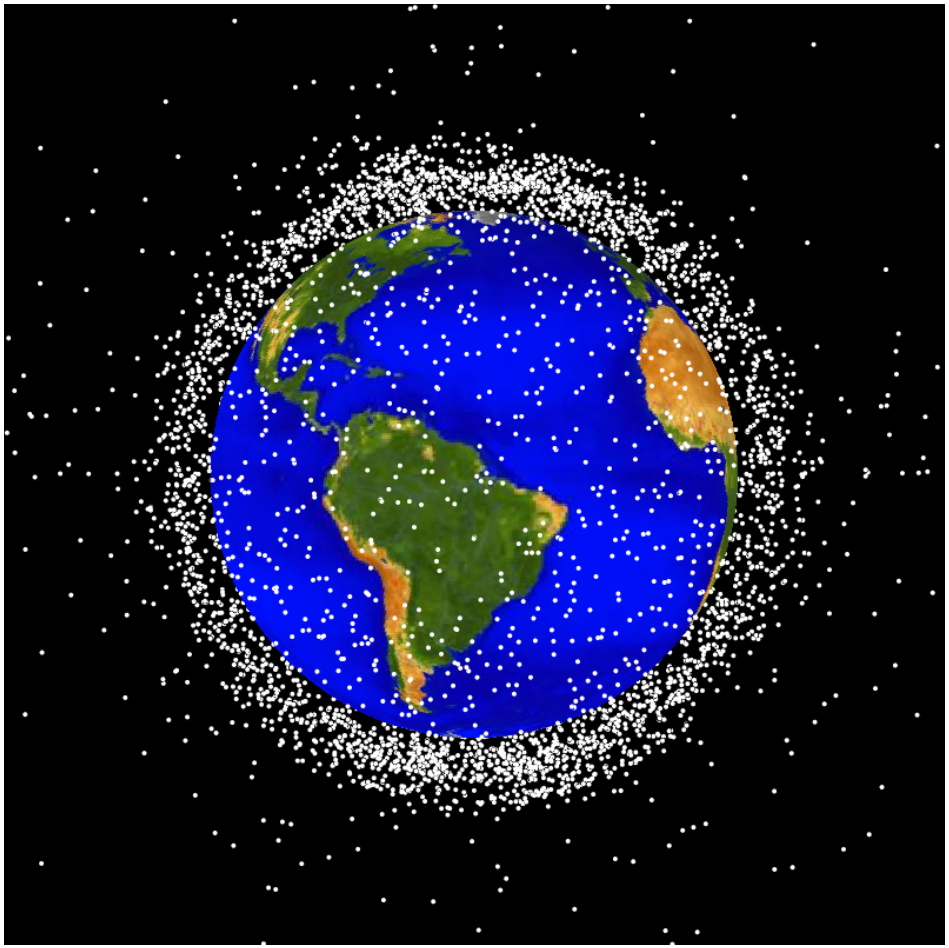
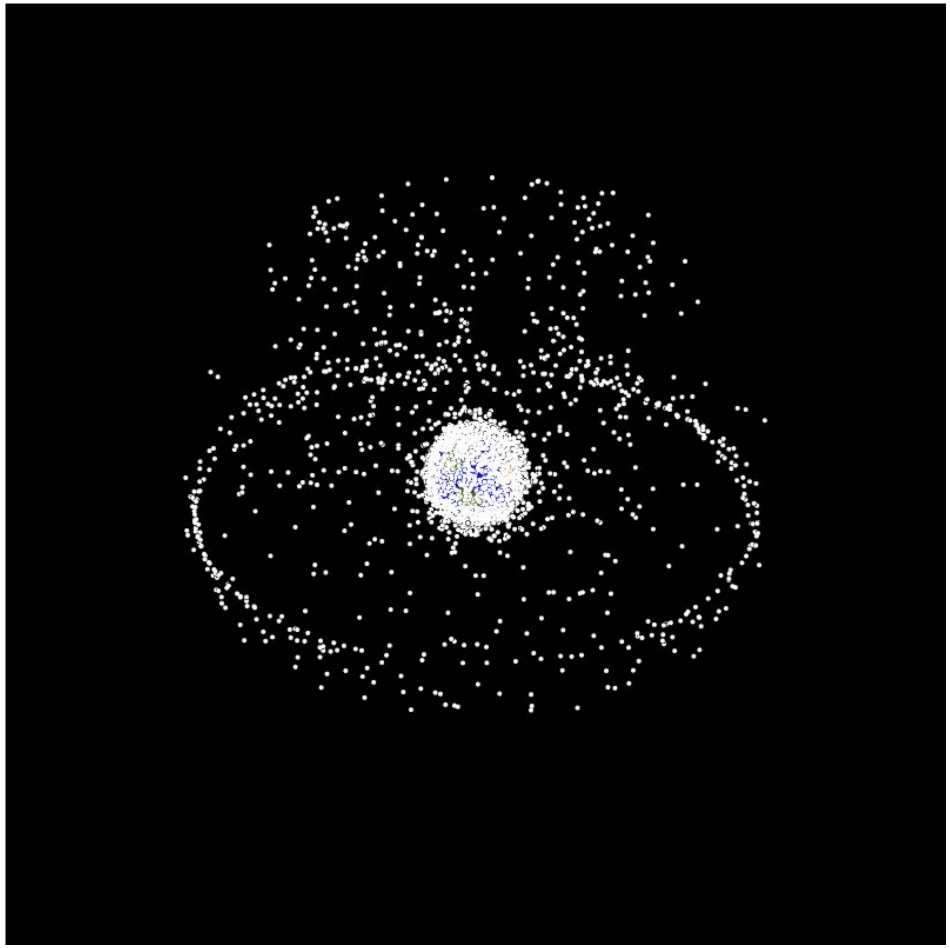
Growth of the Earth Satellite Population

1990

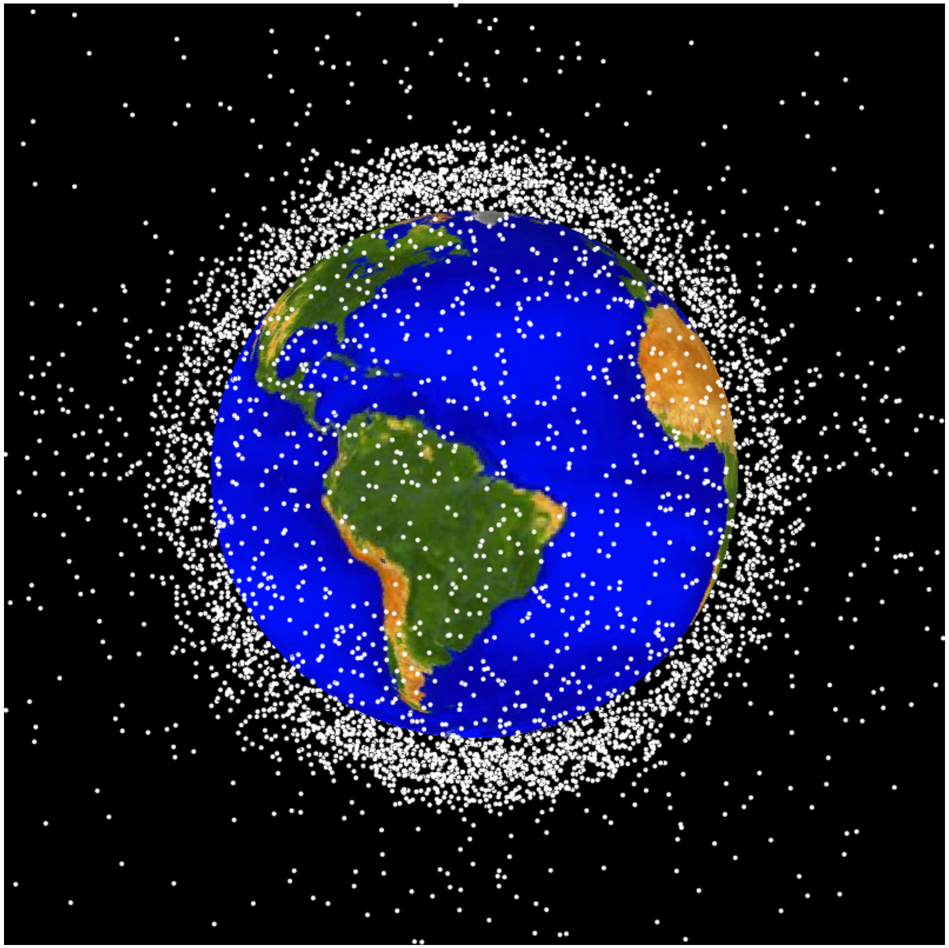


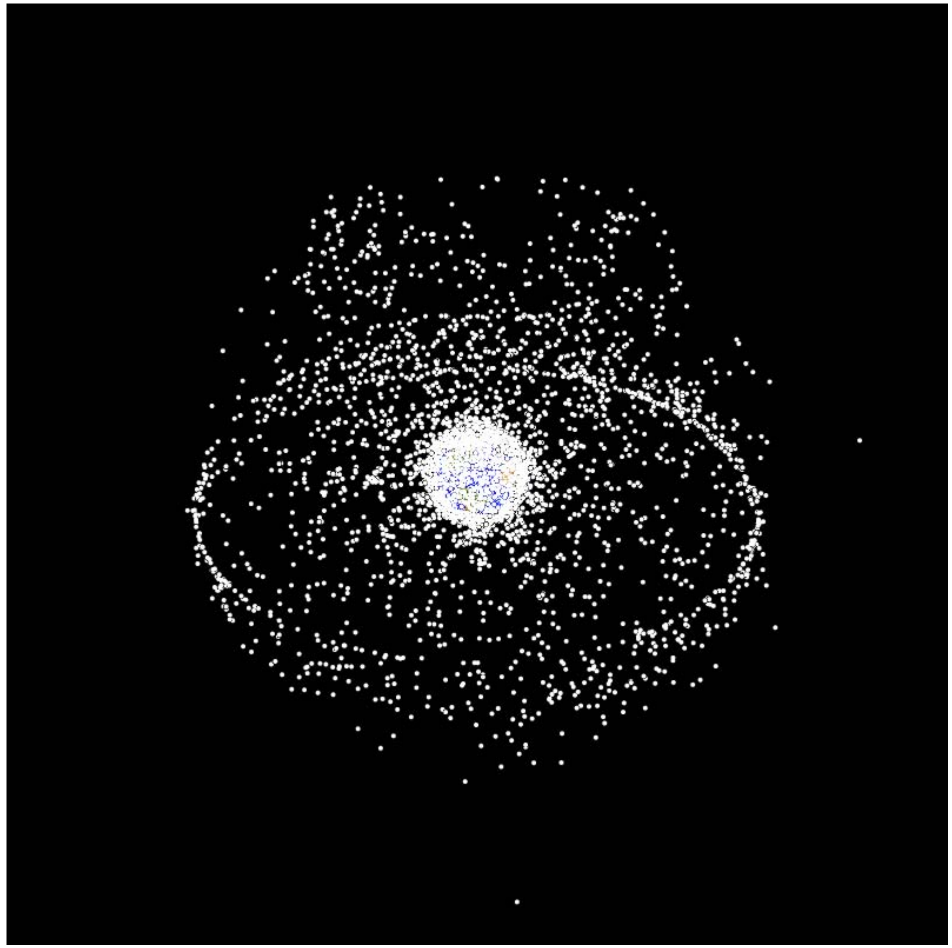


Cataloged objects >10 cm diameter

Growth of the Earth Satellite Population

1995





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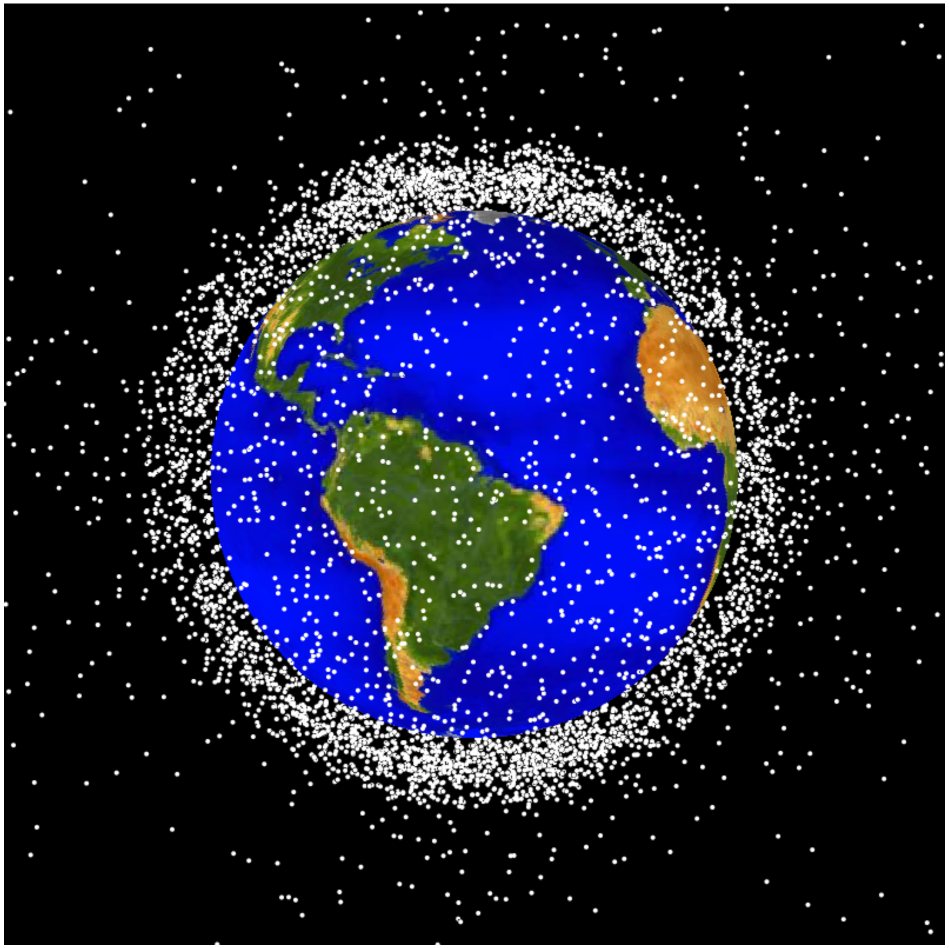
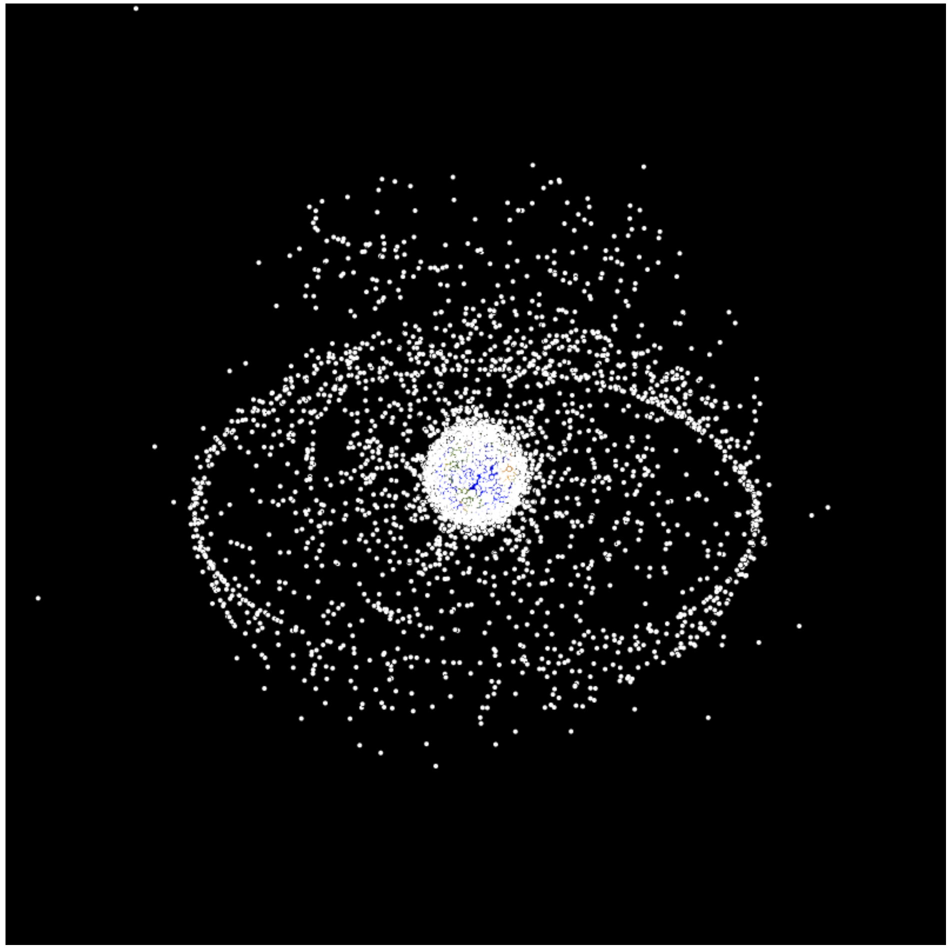
Growth of the Earth Satellite Population

2000

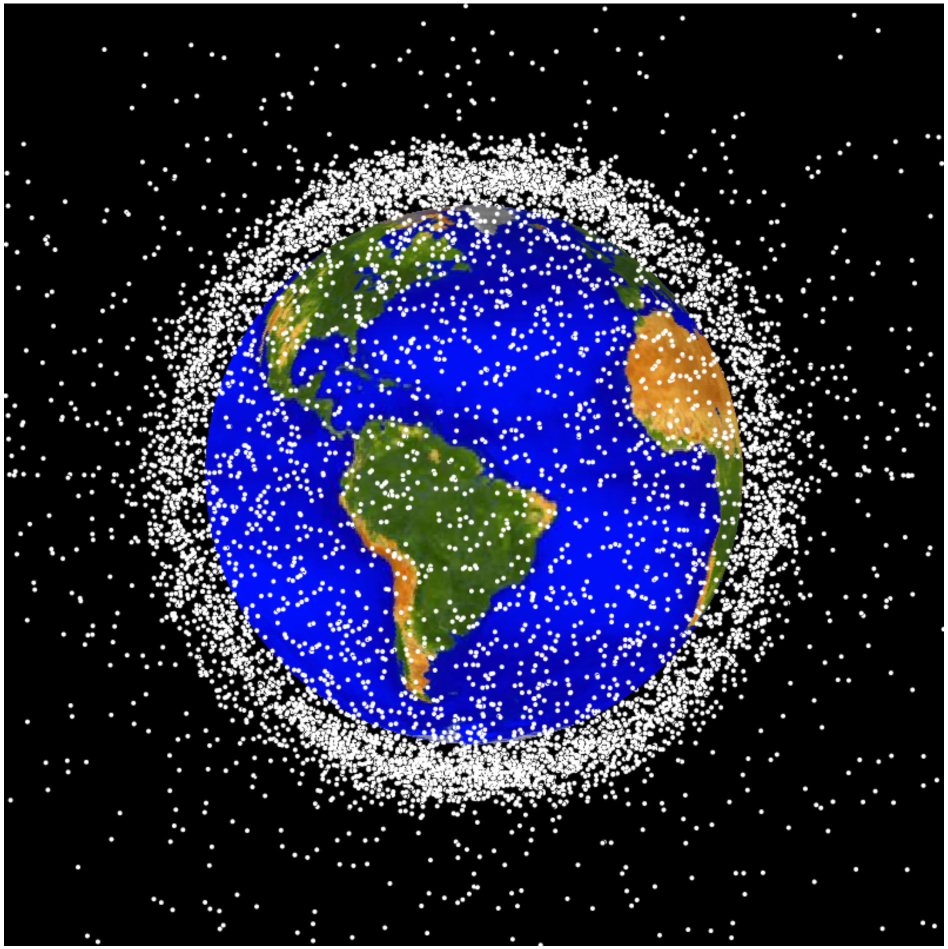


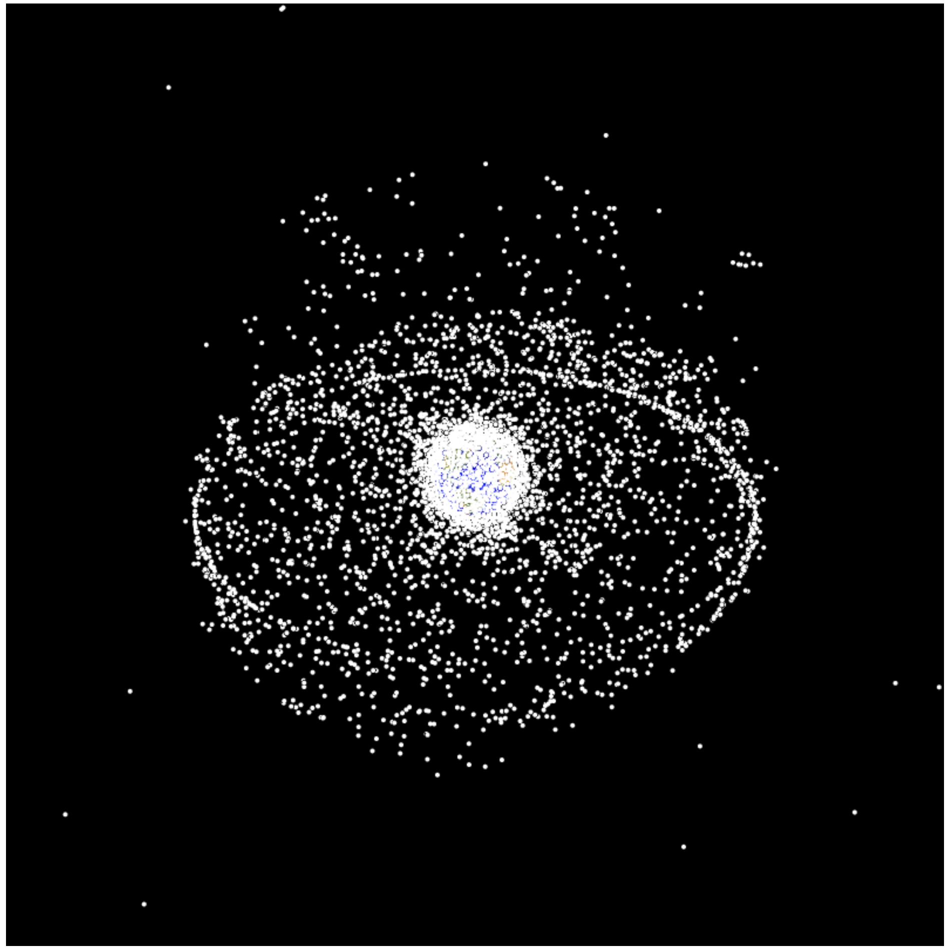


Cataloged objects >10 cm diameter

Growth of the Earth Satellite Population

2005

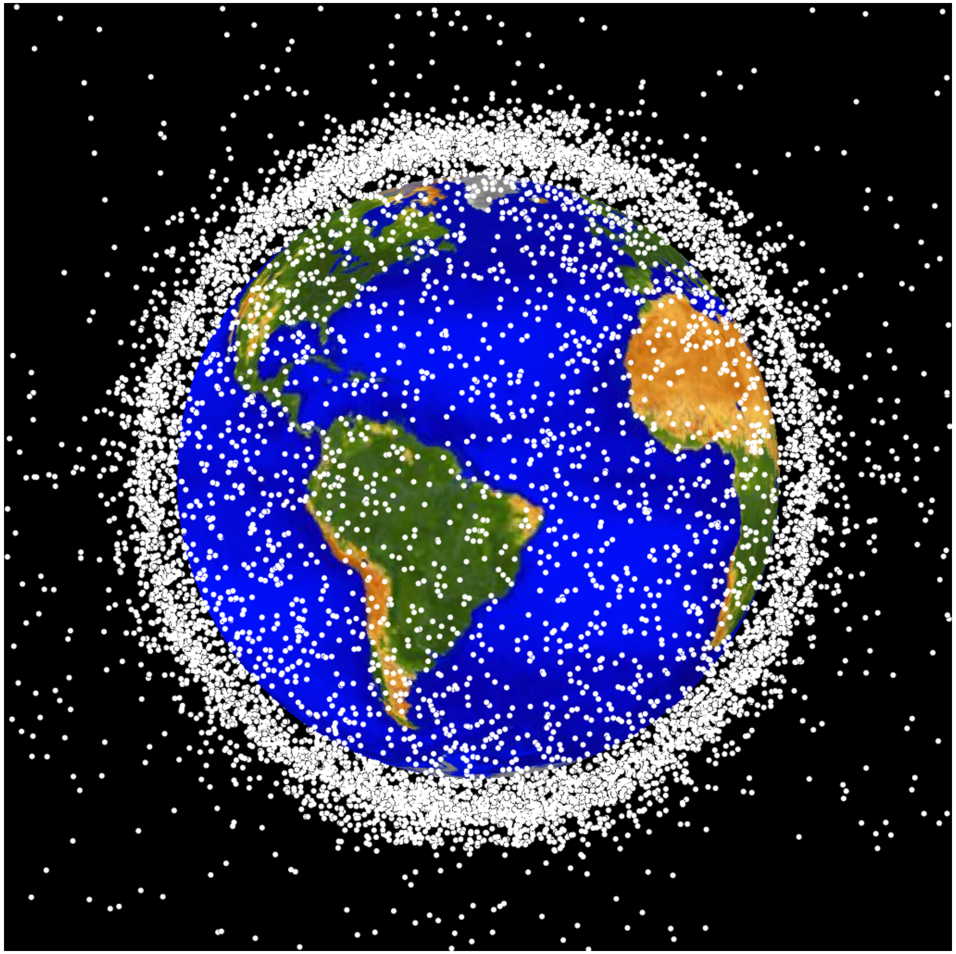


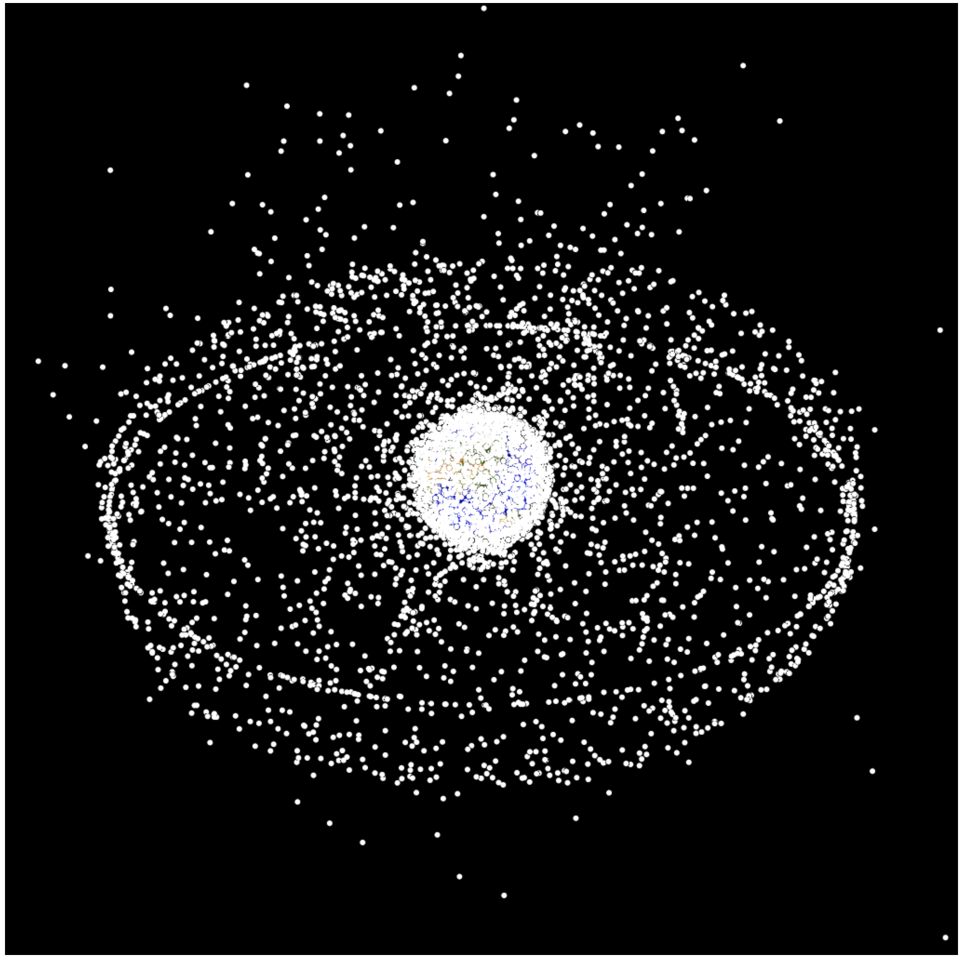


Cataloged objects >10 cm diameter

Growth of the Earth Satellite Population

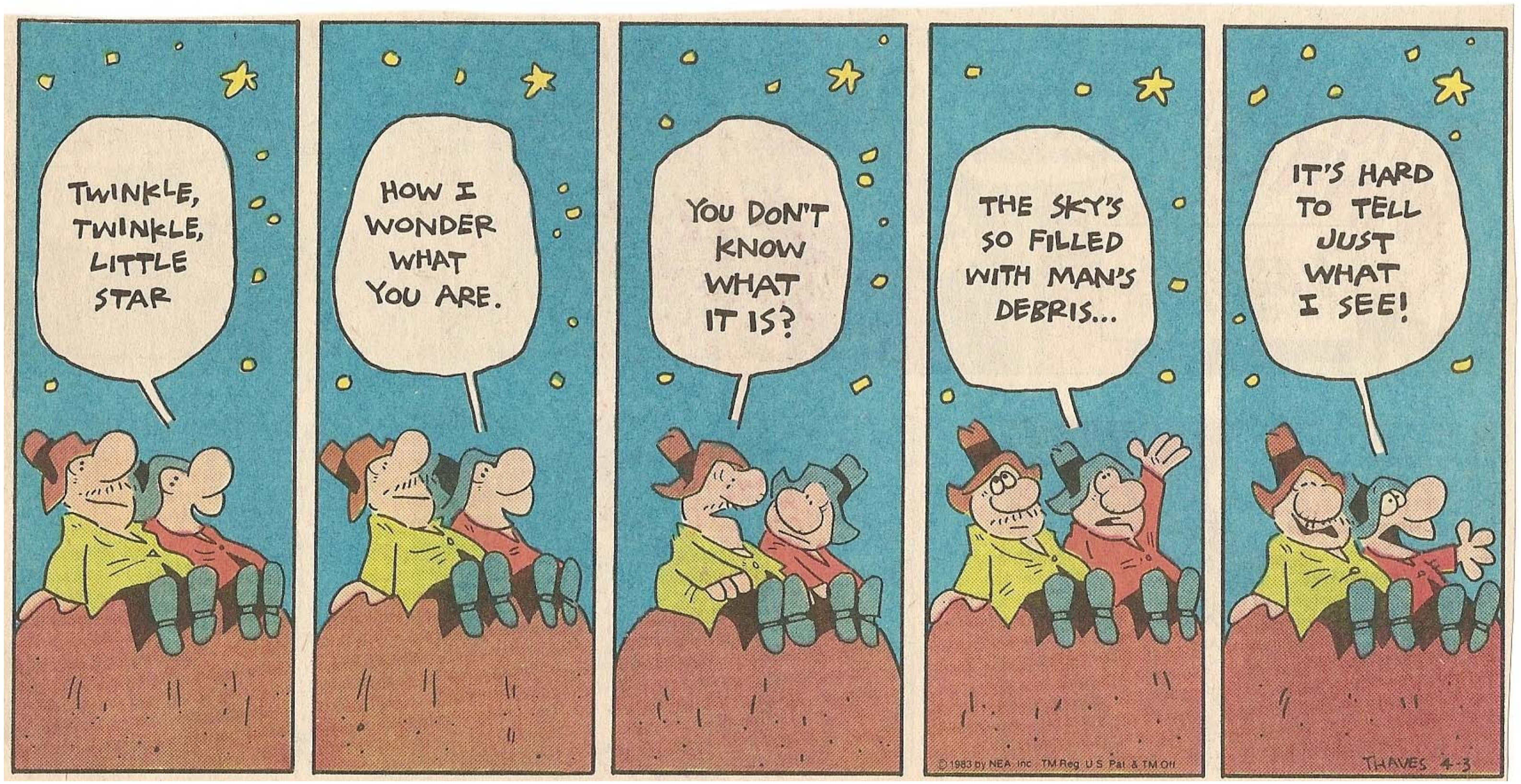
August 2009





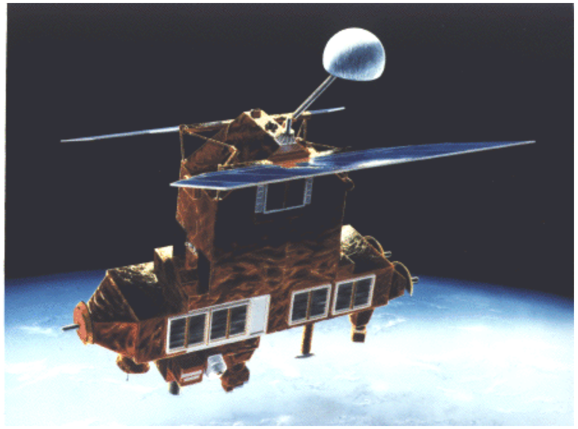
Cataloged objects >10 cm diameter

Orbital Debris: A Perspective by Frank and Ernest



What is Orbital Debris?

- **Orbital debris is any object in Earth orbit which no longer serves a useful function.**



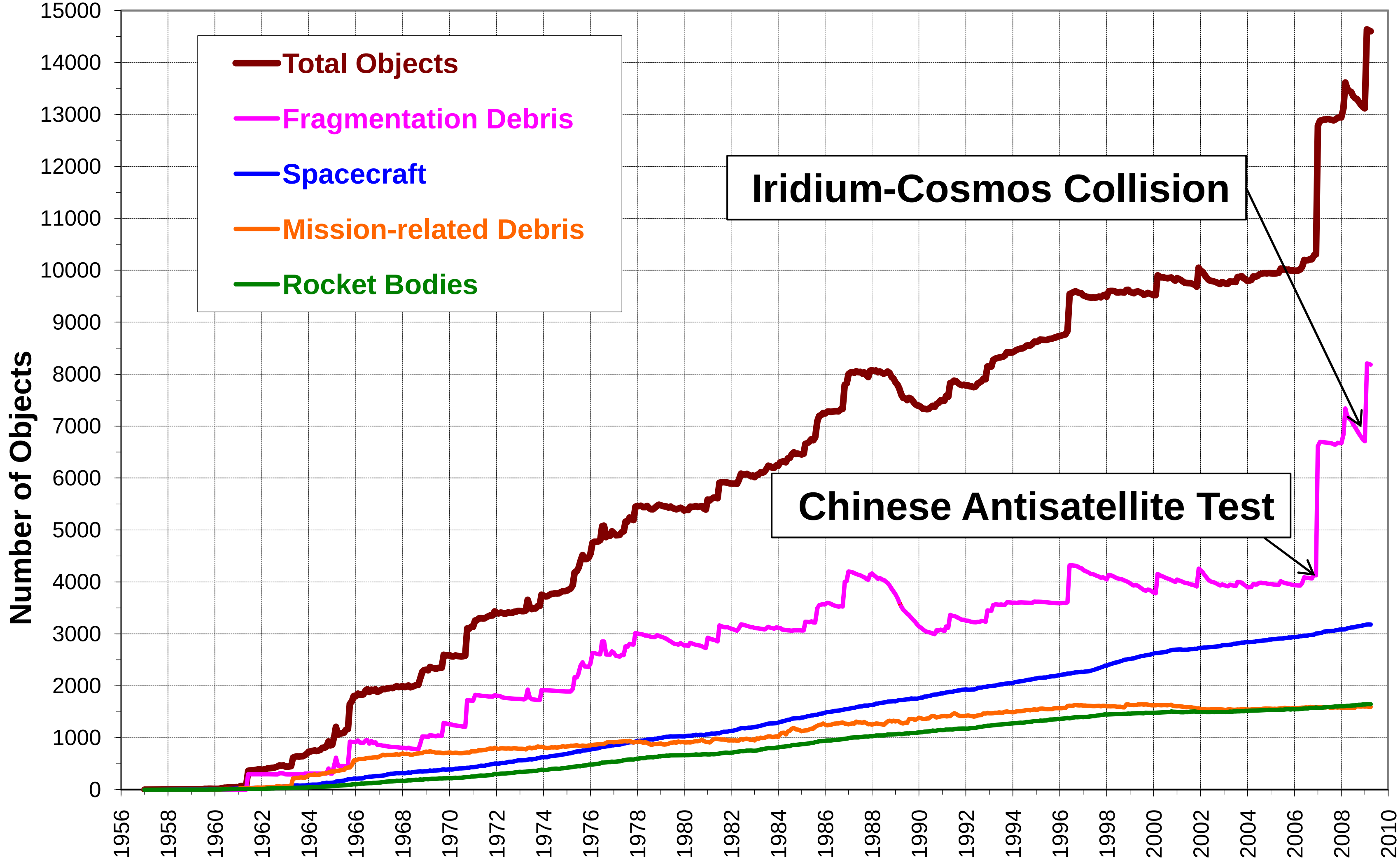
Non-operational Spacecraft

Derelict Launch Vehicle Stages

Fragmentation and

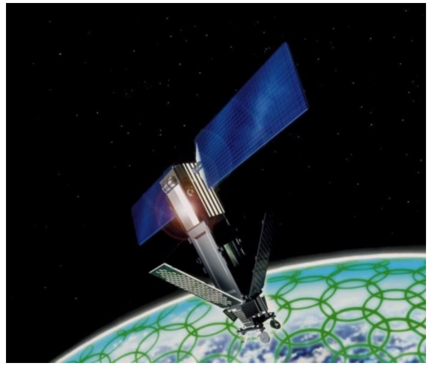
Mission-related Debris

Cataloged Objects In Earth Orbit



Collision of Iridium 33 and Cosmos 2251

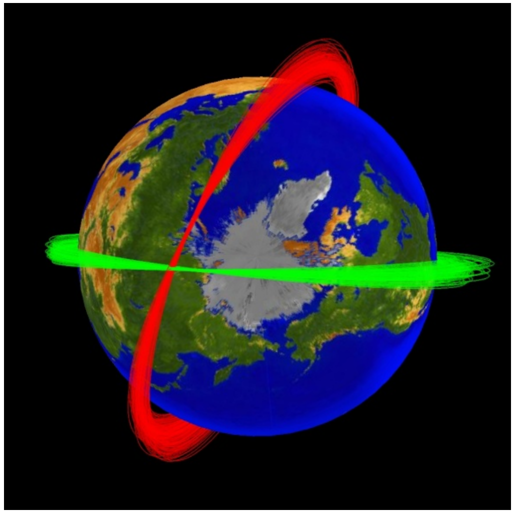
- **The first accidental hypervelocity collision of two intact satellites occurred on 10 February 2009 at an altitude of 790 km.**
  - The collision occurred in a region of high spatial density, *i.e.*, high concentration of objects.
- **Iridium 33 (1997-51C), an operational U.S. communications satellite, collided with Cosmos 2251 (1993-36A), a non-functional Russian communications satellite. The Iridium satellite ceased functioning at the time of the collision.**
- **The collision produced more than 1700 debris larger than about 10 cm, *i.e.*, trackable debris.**
  - Approximately 200,000 hazardous debris larger than 1 cm were created.



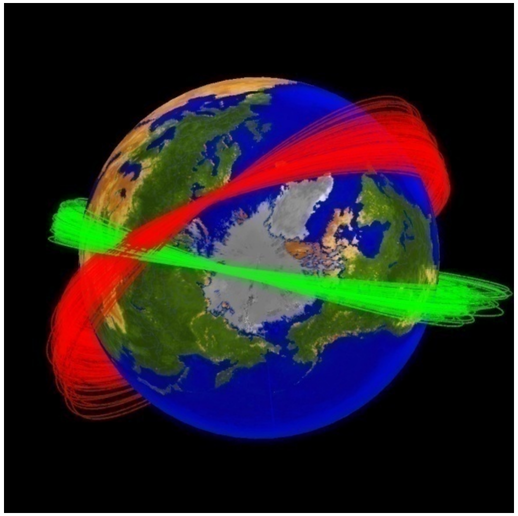
Iridium 33

Cosmos 2251

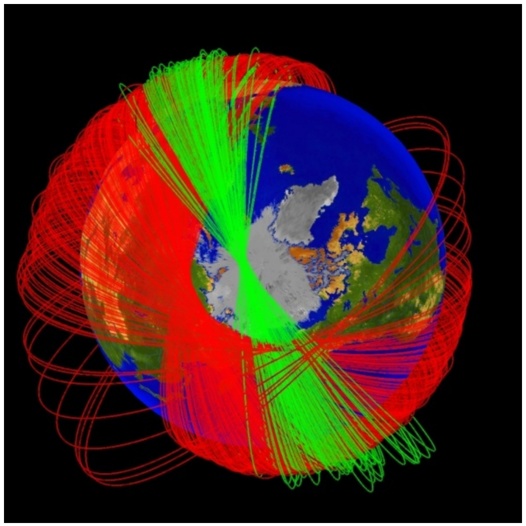
Spread of Collision Debris Orbital Planes



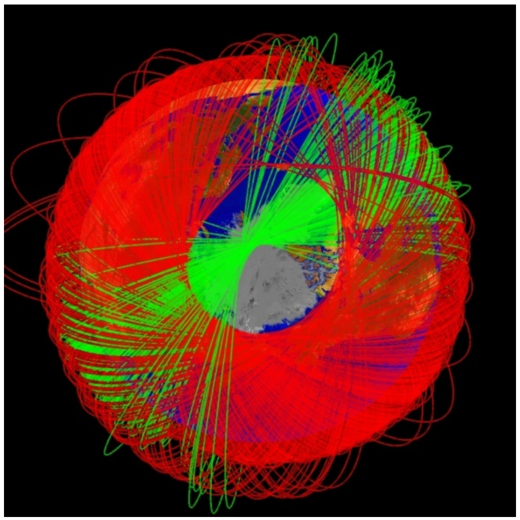
7 Days



30 Days

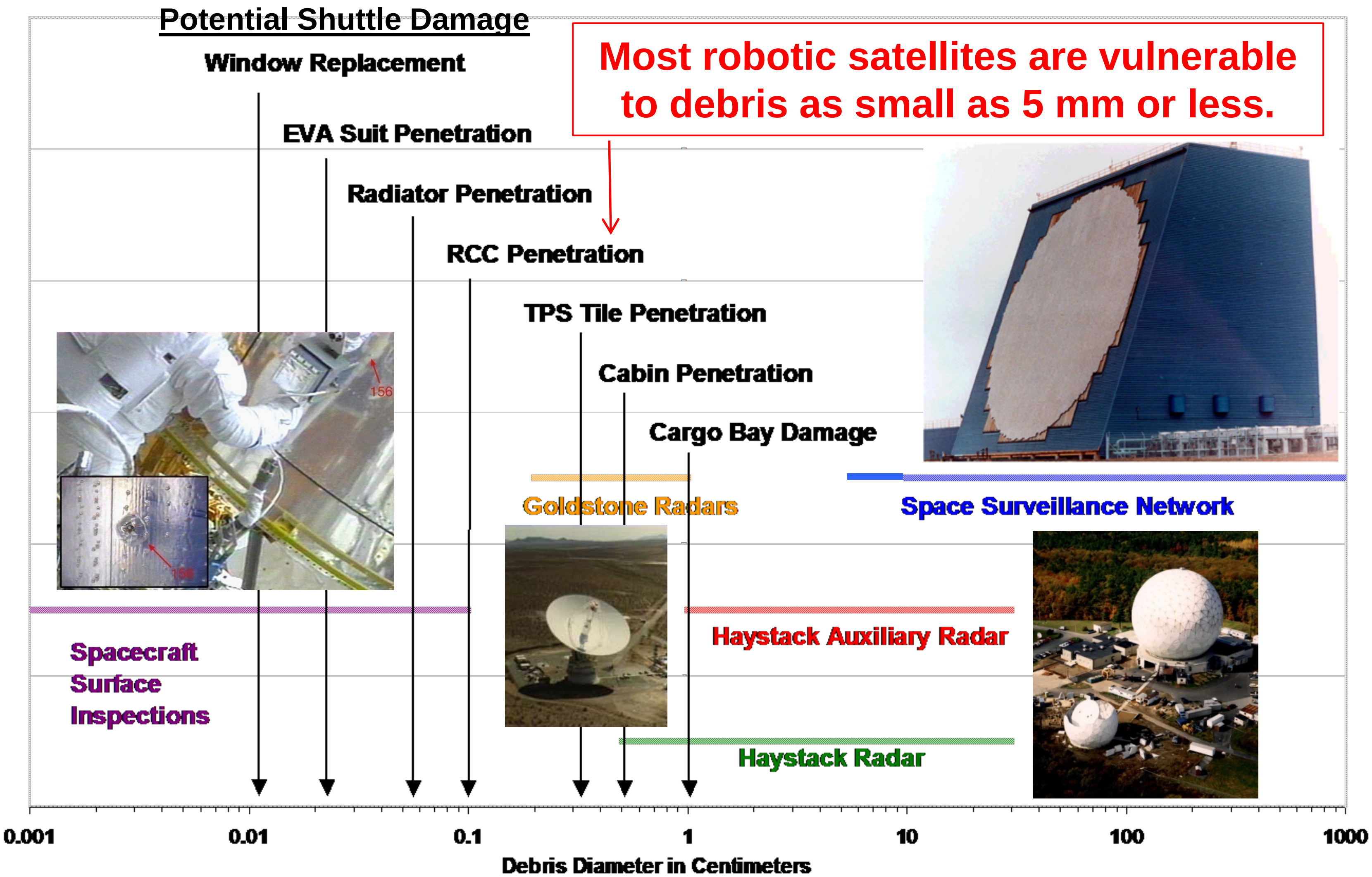


6 Months

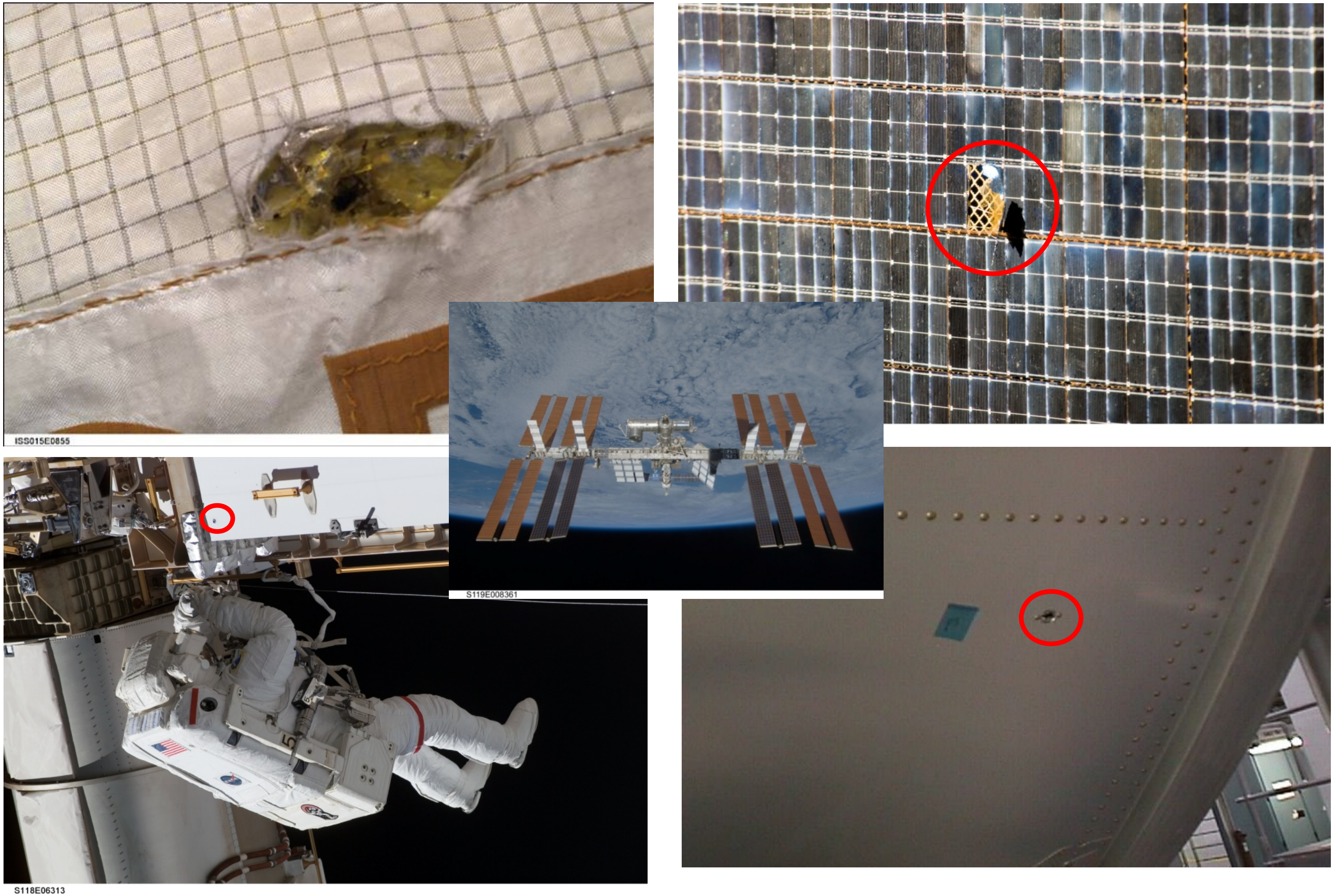


1 Year

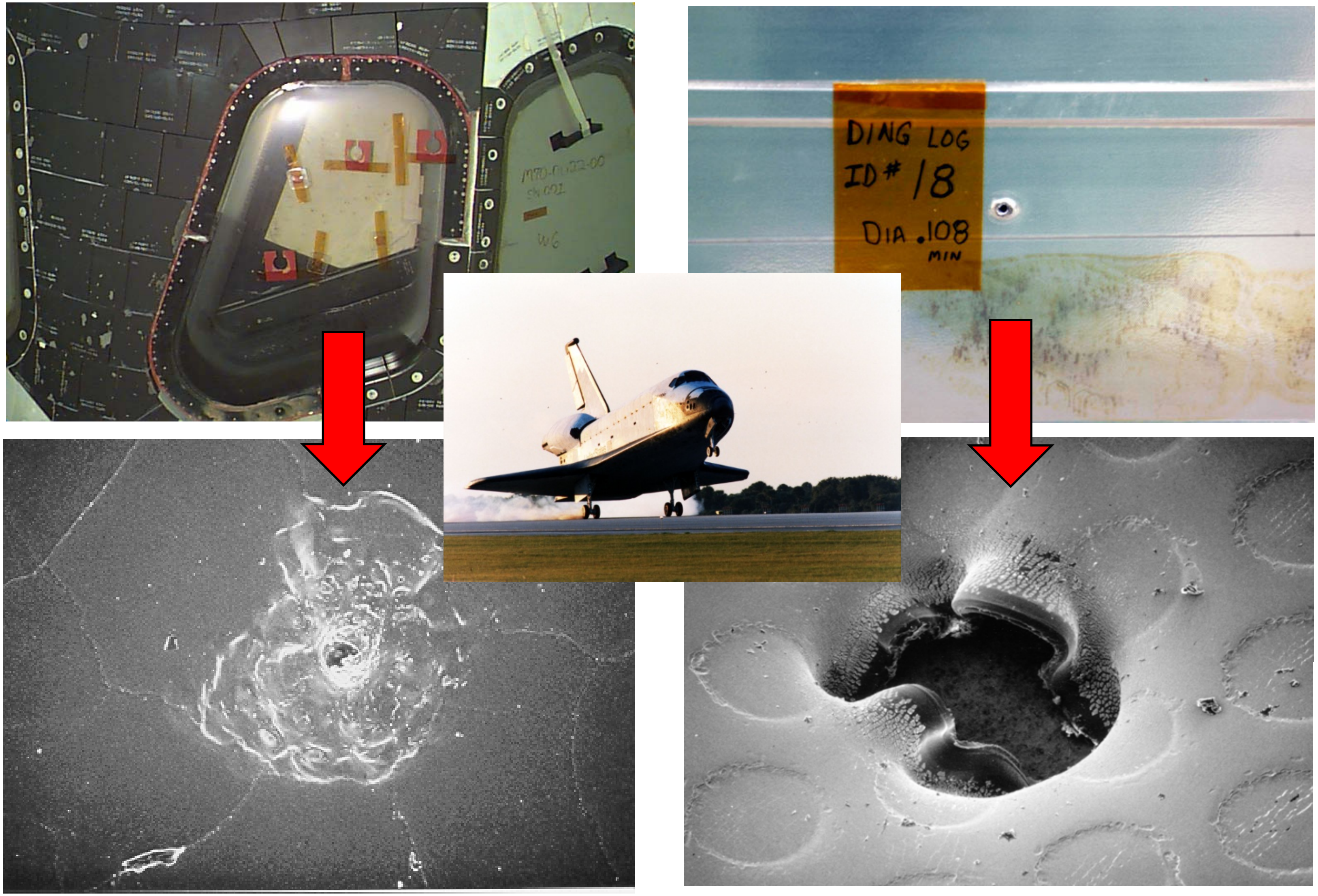
Orbital Debris Detectors and Damage Potential



Debris Impacts on the International Space Station



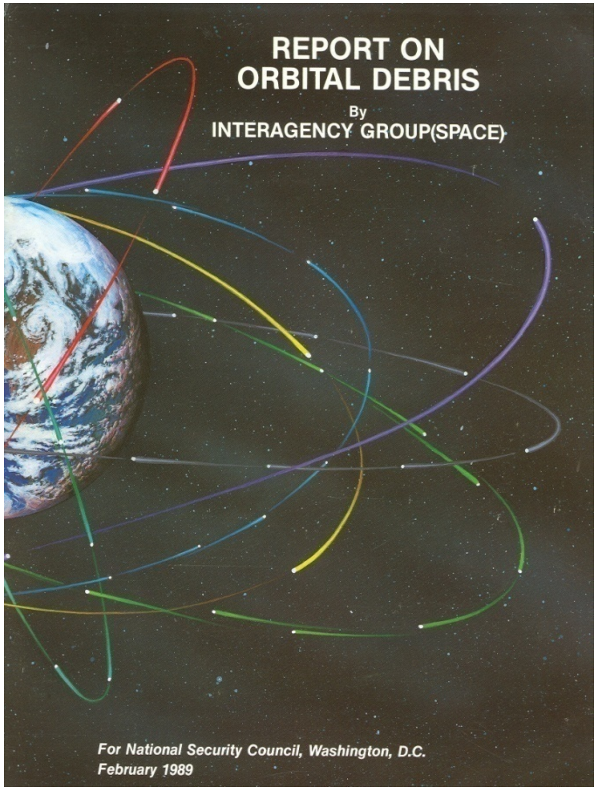
Debris Impacts on the Space Shuttle

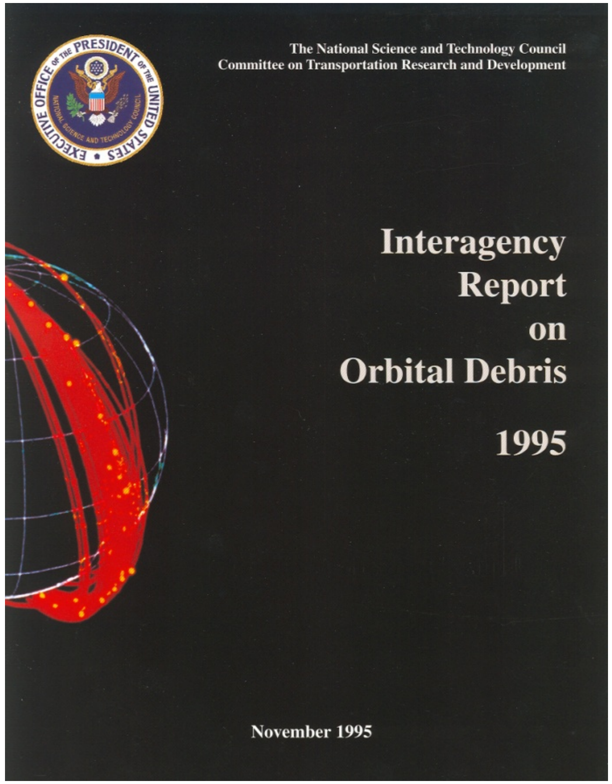


NASA Orbital Debris Mitigation Requirements

- **NASA pioneered the development of applicable orbital debris mitigation guidelines and requirements, starting in 1995.**
  - Orbital Debris Program established in 1979 to characterize the debris environment.
- **Each NASA space program/project must prepare an Orbital Debris Assessment Report in conjunction with the PDR and CDR milestones.**
  - Process seeks to minimize the generation of orbital debris during deployment and operations and post-disposal.
- **Special risk assessments are performed prior to each Shuttle mission and following on-orbit fragmentation events.**
- **ISS design has been significantly influenced by the orbital debris threat.**
  - Approximately 5% of mass of ISS at assembly complete will be debris shielding.

U.S Government Policy and Strategy





U.S. National Space Policy

August 2006

Current U.S. National Space Policy

11. Orbital Debris

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 and International Orbital Debris Mitigation Guidelines

- **The U.S. Government Orbital Debris Mitigation Standard Practices were derived in 1997 from NASA's Orbital Debris Mitigation Guidelines.**

- **Principal elements of the Standard Practices:**
  - Control debris released during normal operations
  - Minimize debris generated by accidental explosions
  - Selection of safe flight profile and operational configuration
  - Post-mission disposal of space structures

- **In 2002 the world's major space agencies adopted the IADC Space Debris Mitigation Guidelines, based on U.S. guidelines and practices.**

- **In 2007 the United Nations adopted Space Debris Mitigation Guidelines, consistent with U.S. and IADC orbital debris mitigation guidelines and practices.**

Green Engineering and Orbital Debris (1)

- **In the initial decades of the Space Age, little thought was given to the release of miscellaneous hardware in orbit, particularly during the launch and deployment phase.**
- **Typical objects released were springs, covers for sensors and motors, spin-up yo-yo's, and remnants of explosive bolts.**
- **Many missions today are debris-free by design.**
- **Instances of unexpected debris are investigated to determine the source and to implement corrective measures.**
  - U.S. Delta IV second stage
  - Japanese H-2A second stage

Green Engineering and Orbital Debris (2)

- **Spacecraft and launch vehicle orbital stages are passivated at end of mission to prevent accidental explosions.**
  - Prior to 2007 such explosions were the principal source of hazardous orbital debris; 140 vehicle accidental explosions identified to date.
  - Residual propellants and pressurants can easily be vented or burned.
  - Batteries can easily be discharged and removed from charging circuits.
- **Launch vehicle stage passivation is widely implemented internationally and has markedly curtailed the creation of new orbital debris.**

Green Engineering and Orbital Debris (3)

- **To reduce the potential for future accidental collisions (and subsequent new debris generation), spacecraft and launch vehicle stages should limit their orbital lifetimes to less than 25 years in low Earth orbit (below 2000 km) following end of mission.**
  - Guideline devised by NASA and now adopted by the U.S. Government and other foreign space agencies.
  - Often this guideline can be met with existing vehicle resources.
- **Spacecraft and launch vehicle stages in geosynchronous orbits should be maneuvered into disposal orbits which will remain at least 200 km from the geosynchronous altitude.**
  - Such maneuvers typically require less than 10 kg of propellant.

Reentry Safety

- **On average one known man-made object falls back to Earth each day.**
  - Most are small fragments and burn-up during reentry
  - Components which do survive are statistically more likely to land in the water or large, sparsely populated areas such as Siberia, the Australian Outback, or the Canadian Tundra.

- **By requiring or encouraging space system operators to limit stays in low Earth orbit to less than 25 years, the number of uncontrolled reentries of spacecraft and launch vehicle stages will increase, potentially posing elevated risks to people and property on Earth.**

- **NASA and the U.S. Government attempt to limit human casualty risks to 1 in 10,000 per reentry event.**
  - This is accomplished by directing reentries over a broad ocean area (expensive option) or by designing vehicles to demise more completely during reentry, e.g., by component redesigns and material selection.

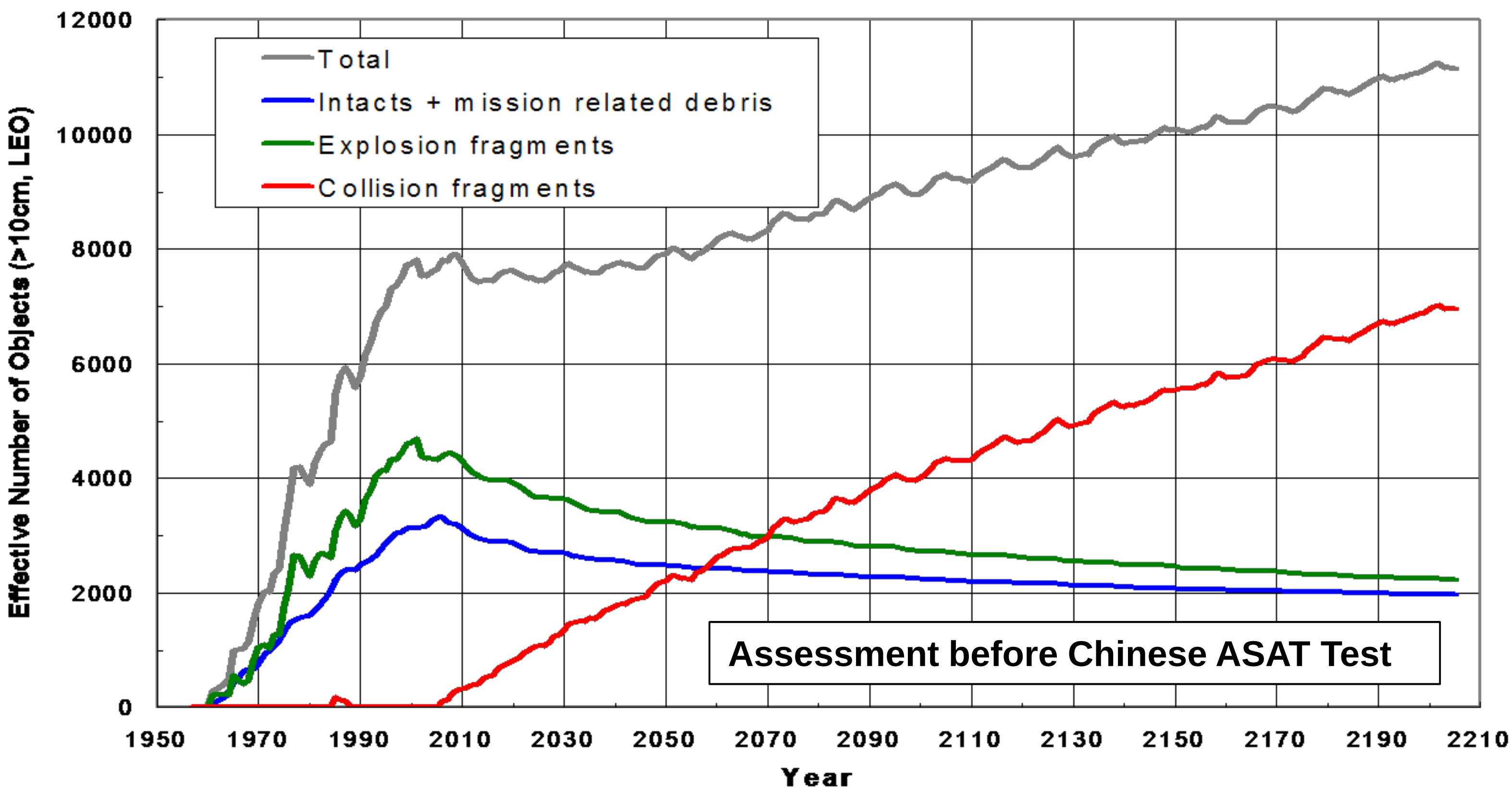
Green Engineering and Satellite Reentries

- **NASA encourages a "design-to-demise" philosophy when procuring new spacecraft.**
- **Spacecraft reentry survivability is addressed by the Preliminary Design Review (PDR) milestone. Surviving components are identified and modified, if feasible.**
- **Goddard Space Flight Center has developed new demisable propellant tanks and reaction wheel assemblies.**
- **Structural elements composed of high melting-temperature materials (e.g., titanium, beryllium, stainless steel) can sometimes be replaced with lower melting-temperature materials (e.g., aluminum).**
- **Single, dense survivable elements can sometimes be replaced with multiple, demisable elements.**

Satellite Collisions Will Continue If the Large Satellite Population Is Not Reduced

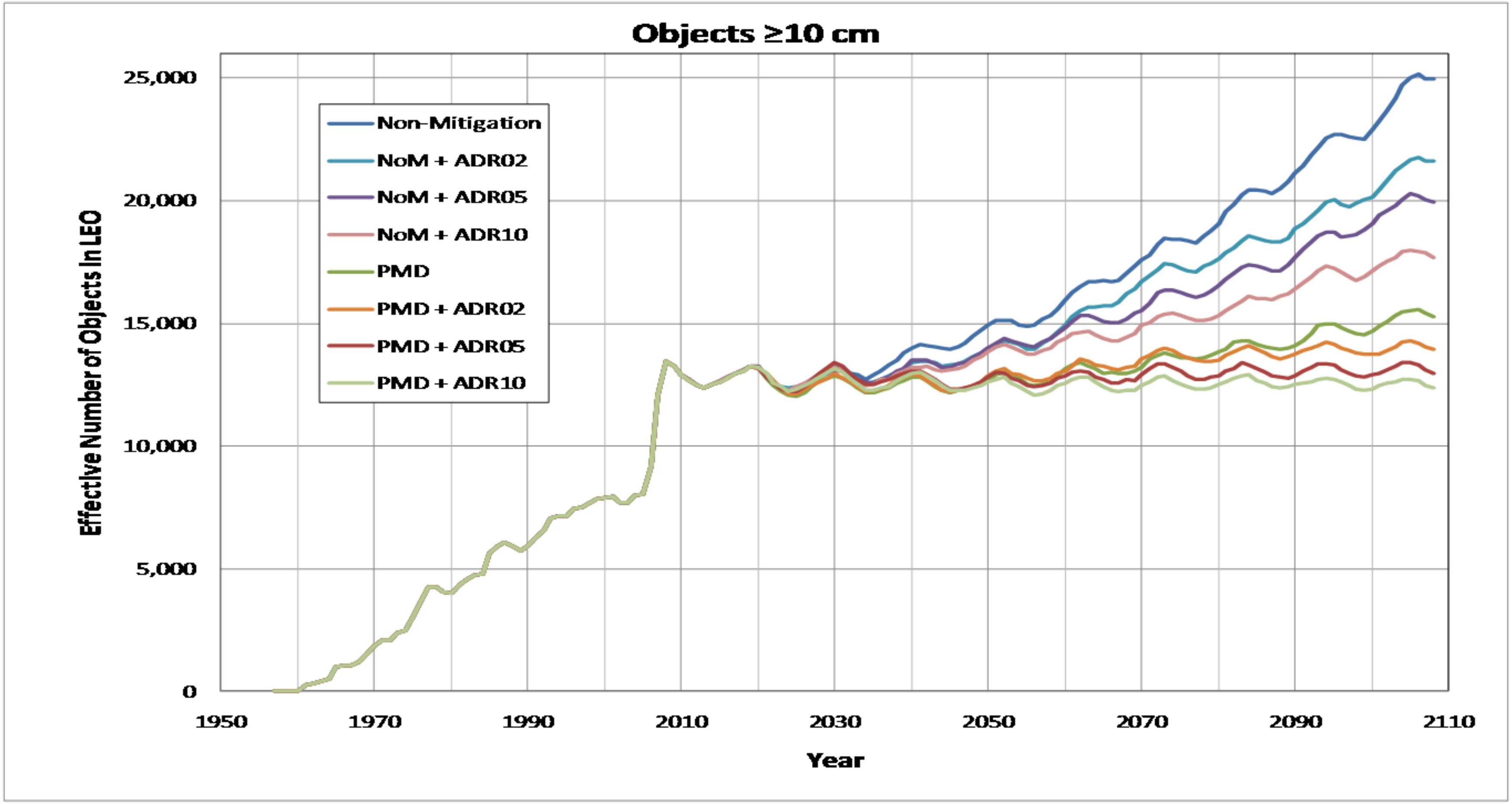
- **"The current debris population in the LEO region has reached the point where the environment is unstable and collisions will become the most dominant debris-generating mechanism in the future"**

– Liou and Johnson, ***Science***, 20 January 2006



Satellite Population Can Be Controlled with Debris Mitigation and Active Debris Removal

- **Active debris removal of 2-5 objects per year, coupled with established orbital debris mitigation measures, can stabilize the current satellite population.**



Conclusions

- **Green engineering and operations are essential to preserving the near-Earth space environment for future generations.**

- **The U.S. and the international aerospace community have been proactive in addressing the threat of the increasing orbital debris population and the risks to people and property from reentering debris.**

  – NASA has led this activity first by devoting resources to thoroughly understand the technical issues and then by developing effective and acceptable policies and guidelines.

  – NASA also worked closely with the international community to ensure that the US aerospace industry was not placed at an economic disadvantage.

- **In the long term, the removal of large orbital debris will be essential to the sustainability of space operations.**