National Aeronautics and Space Administration

MONITORING THE HEAVENS, TODAY AND TOMORROW

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

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Outline

- **Growth of the Cataloged Earth Satellite Population**
- **Current and Future NASA and DoD Space Surveillance Capabilities**
  - **Low Earth Orbits**
  - **High Earth Orbits**
- **Potential Future Environments**
- **Summary**

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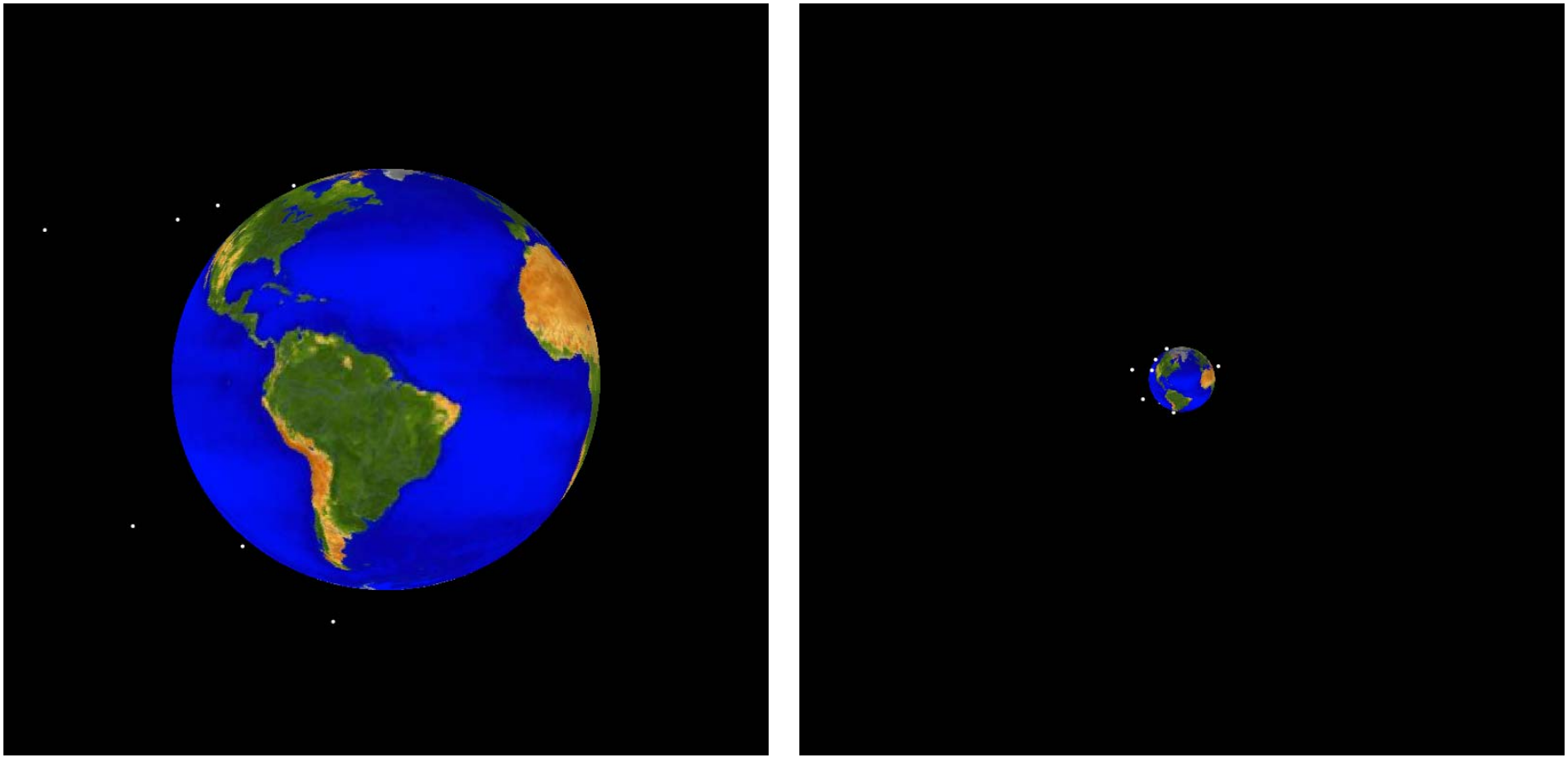
Growth of the Earth Satellite Population

1960



Cataloged objects >10 cm diameter

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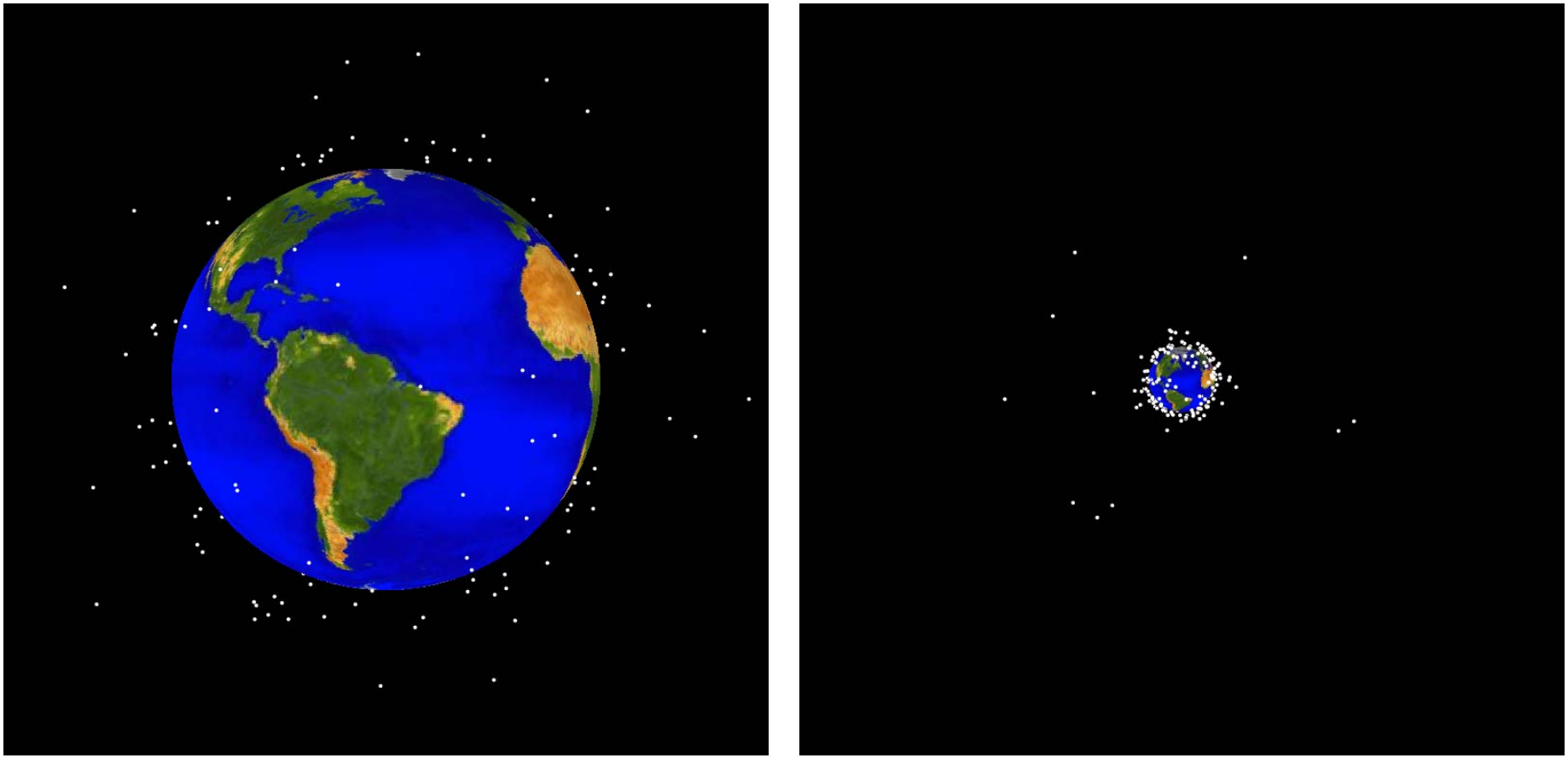
Growth of the Earth Satellite Population

1965



Cataloged objects >10 cm diameter

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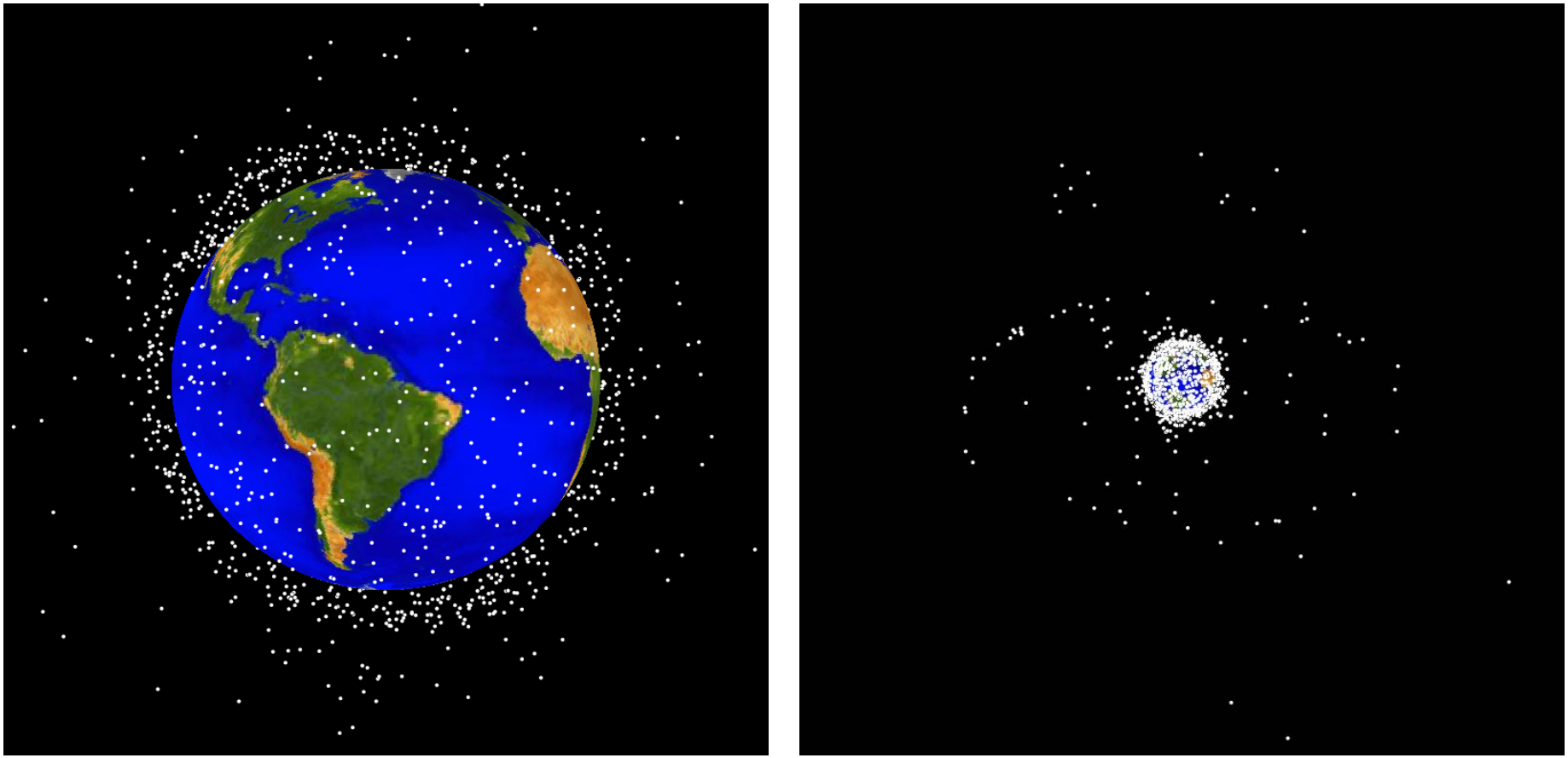
Growth of the Earth Satellite Population

1970



Cataloged objects >10 cm diameter

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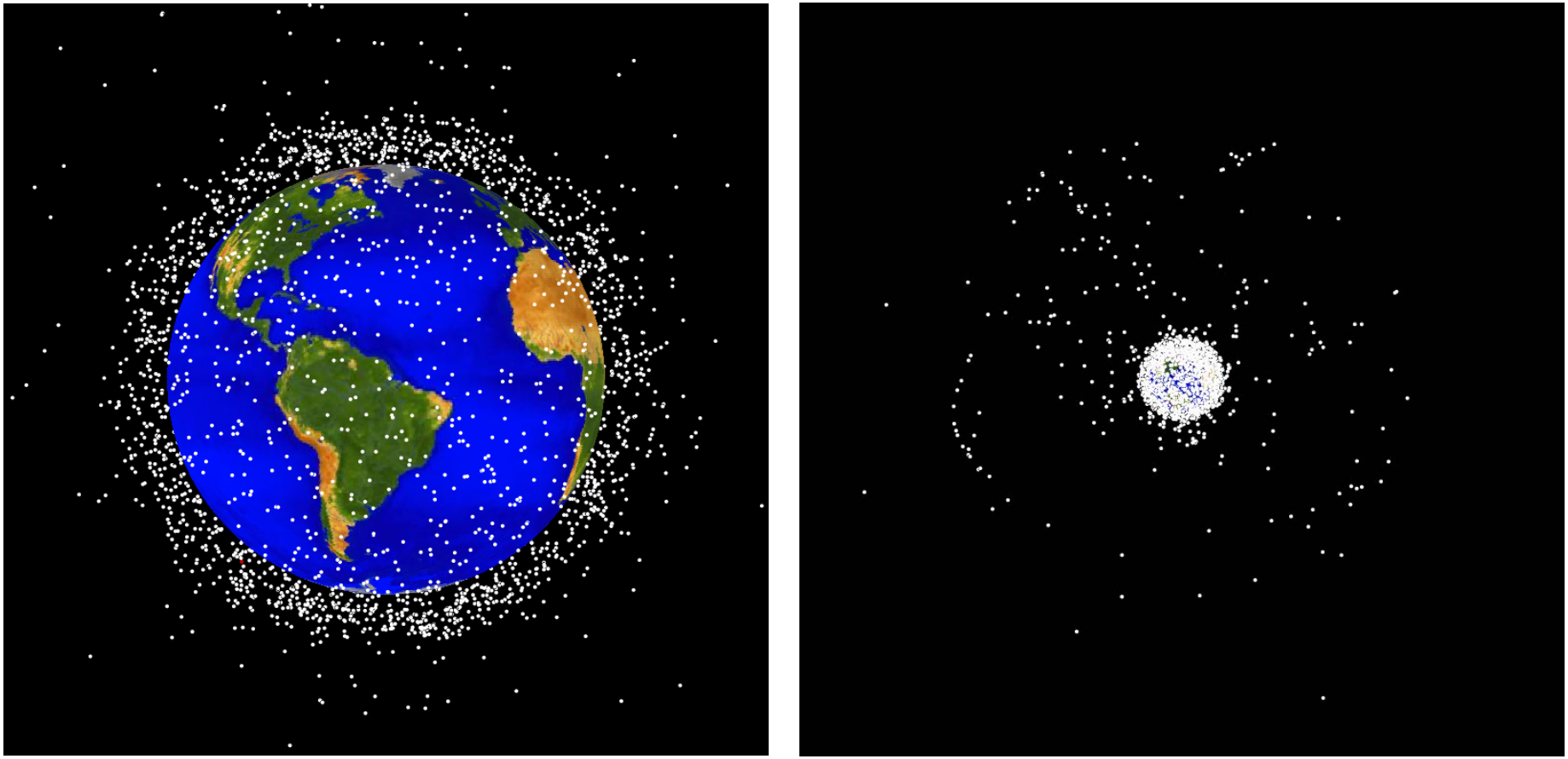
Growth of the Earth Satellite Population

1975



Cataloged objects >10 cm diameter

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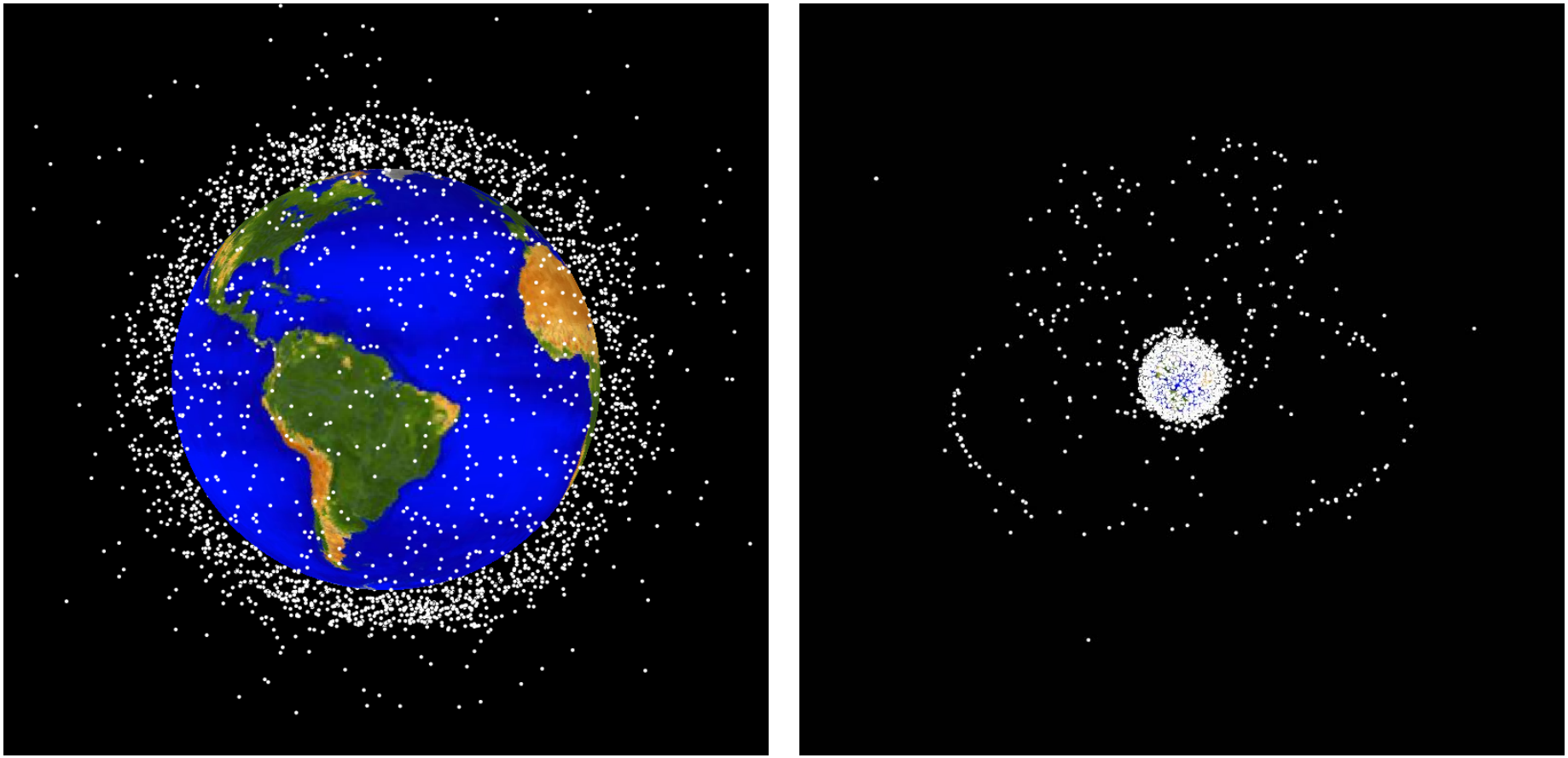
Growth of the Earth Satellite Population

1980



Cataloged objects >10 cm diameter

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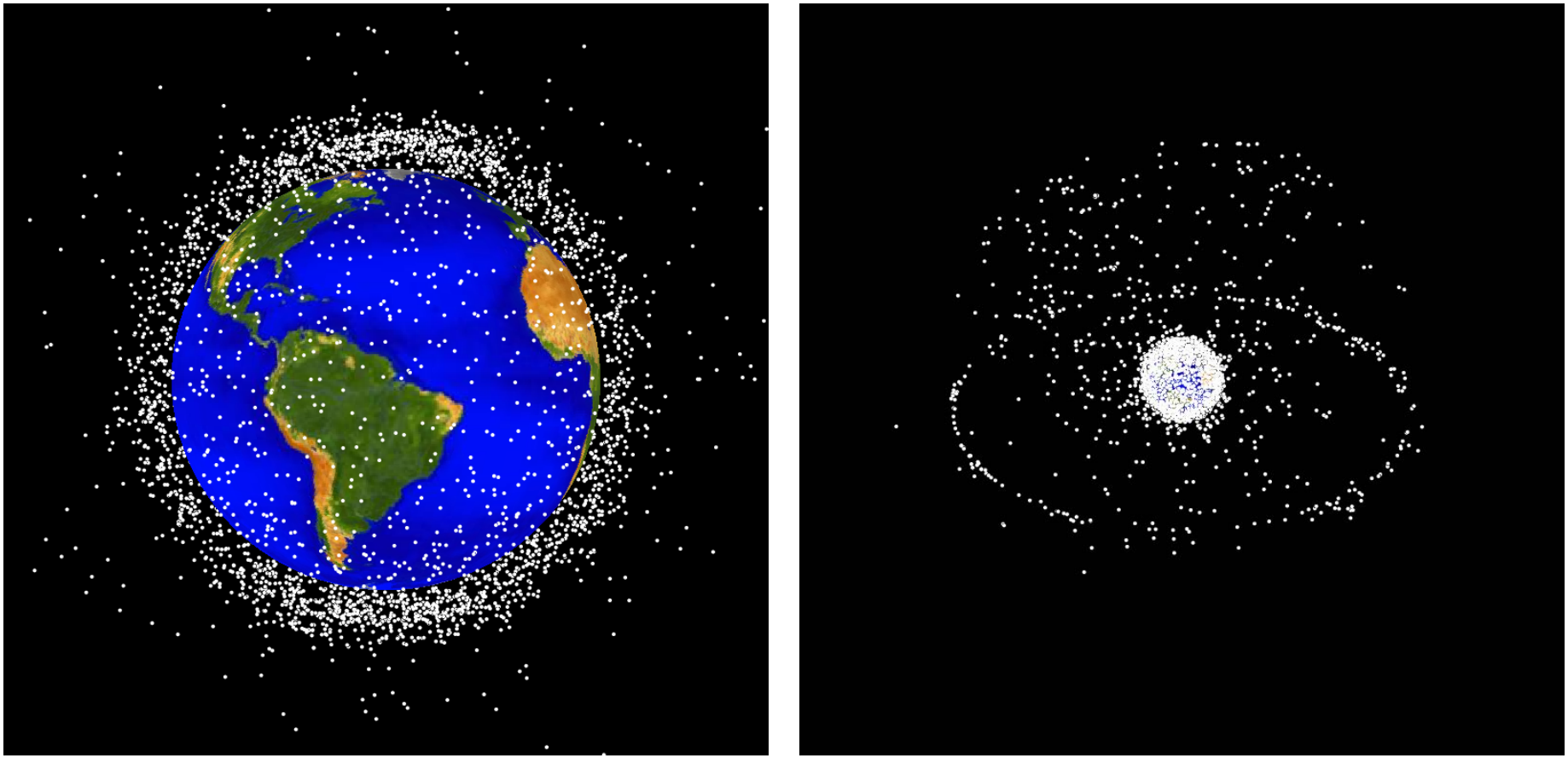
Growth of the Earth Satellite Population

1985



Cataloged objects >10 cm diameter

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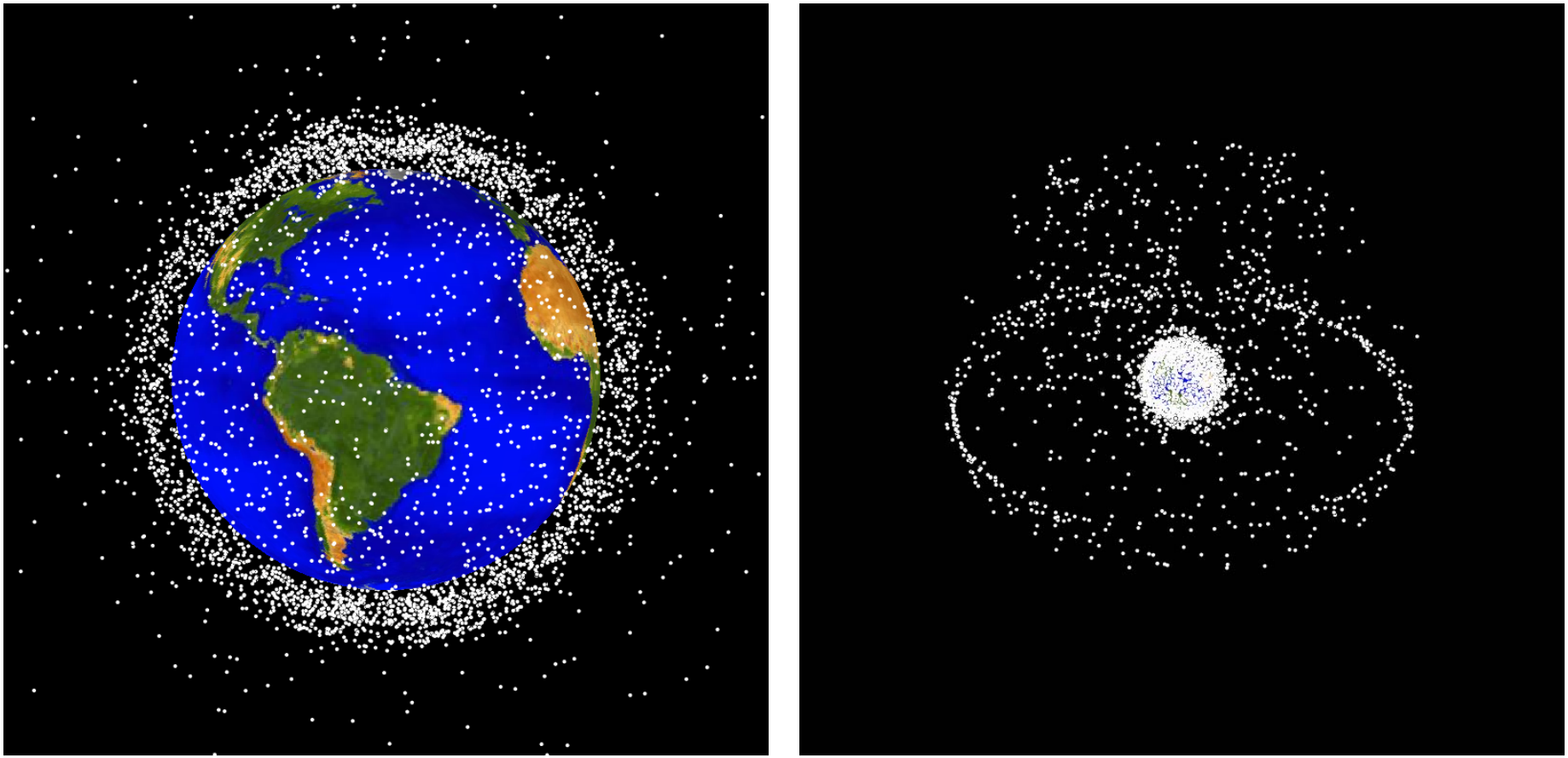
Growth of the Earth Satellite Population

1990



Cataloged objects >10 cm diameter

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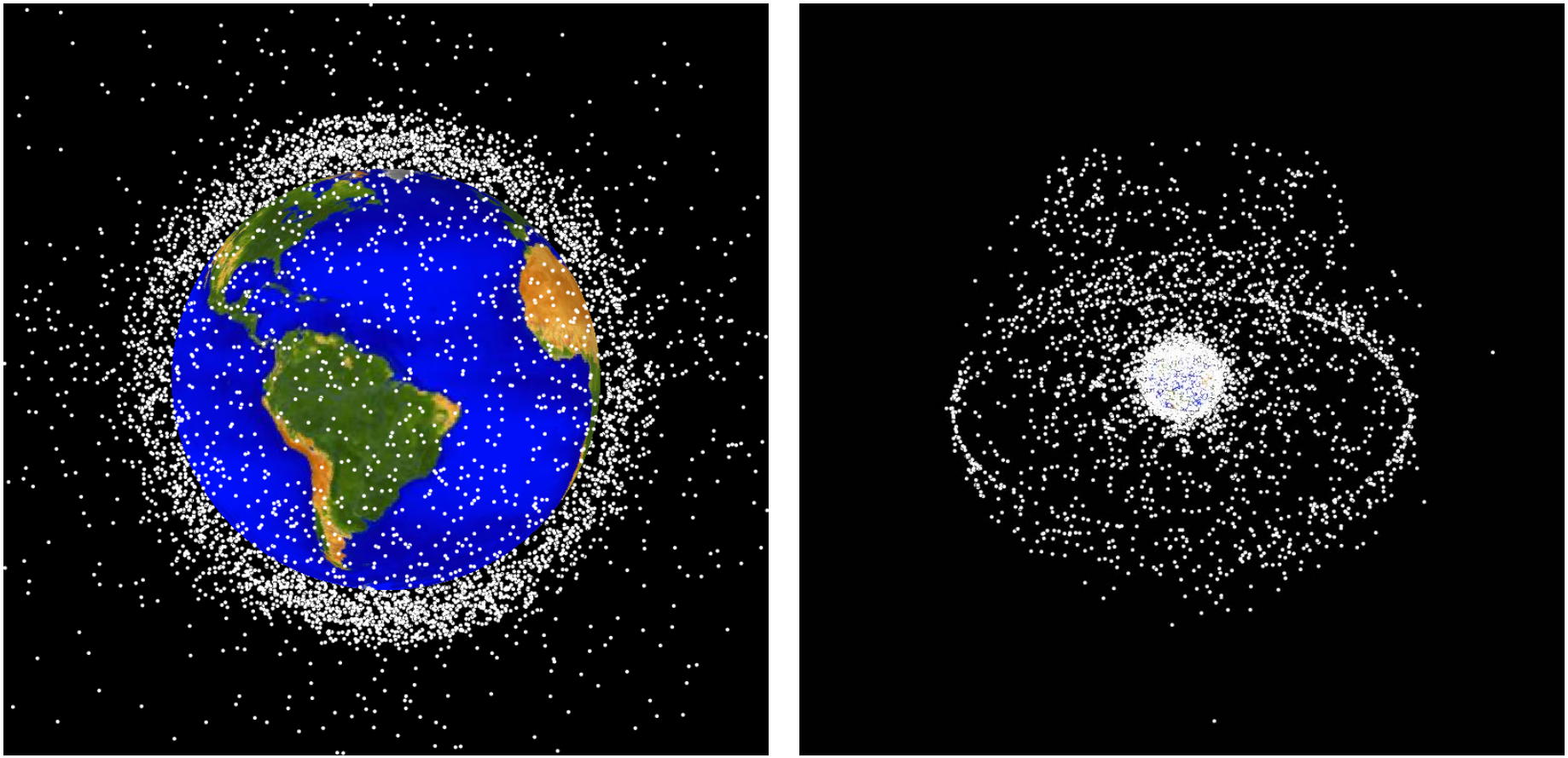
Growth of the Earth Satellite Population

1995



Cataloged objects >10 cm diameter

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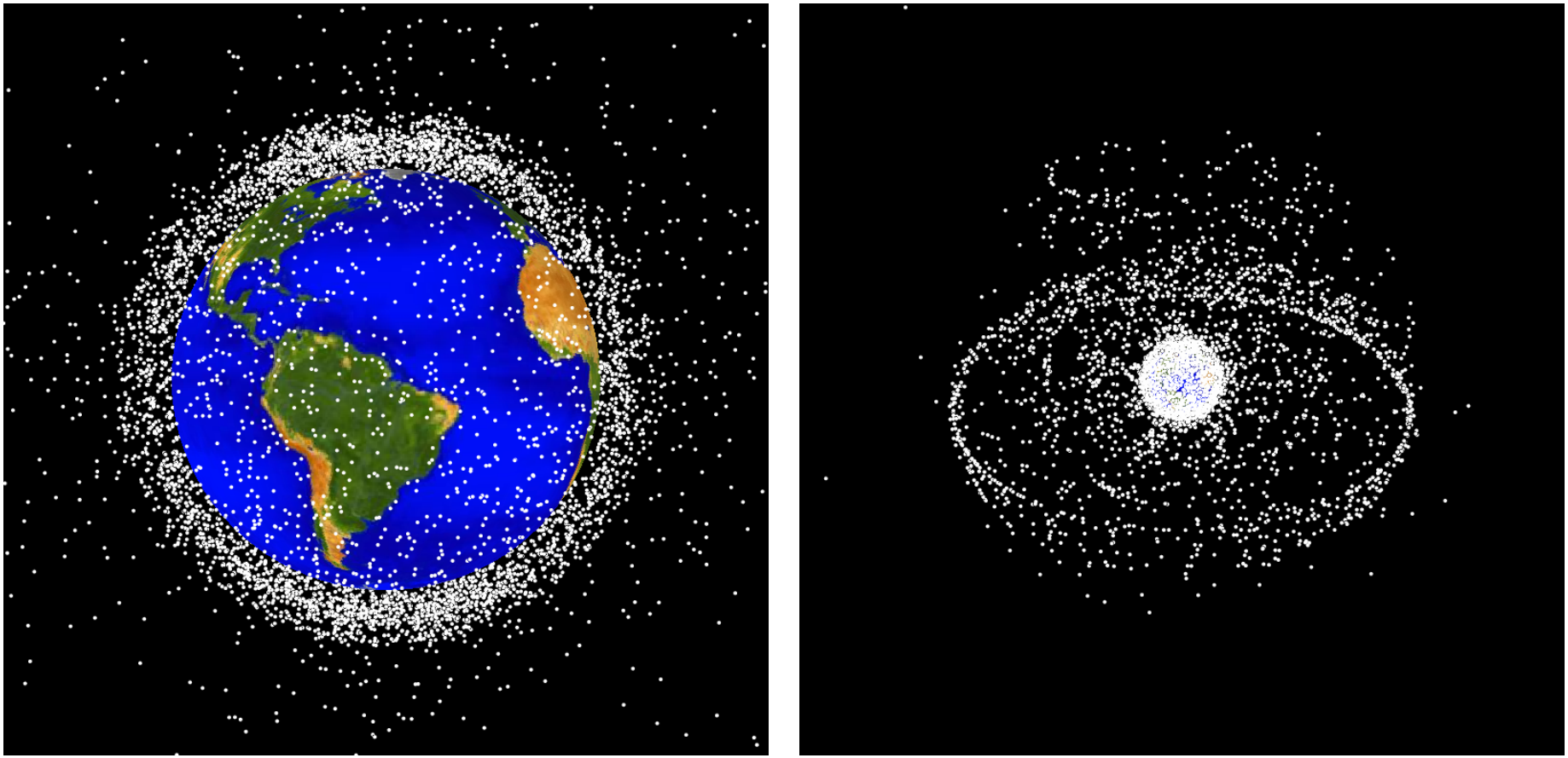
Growth of the Earth Satellite Population

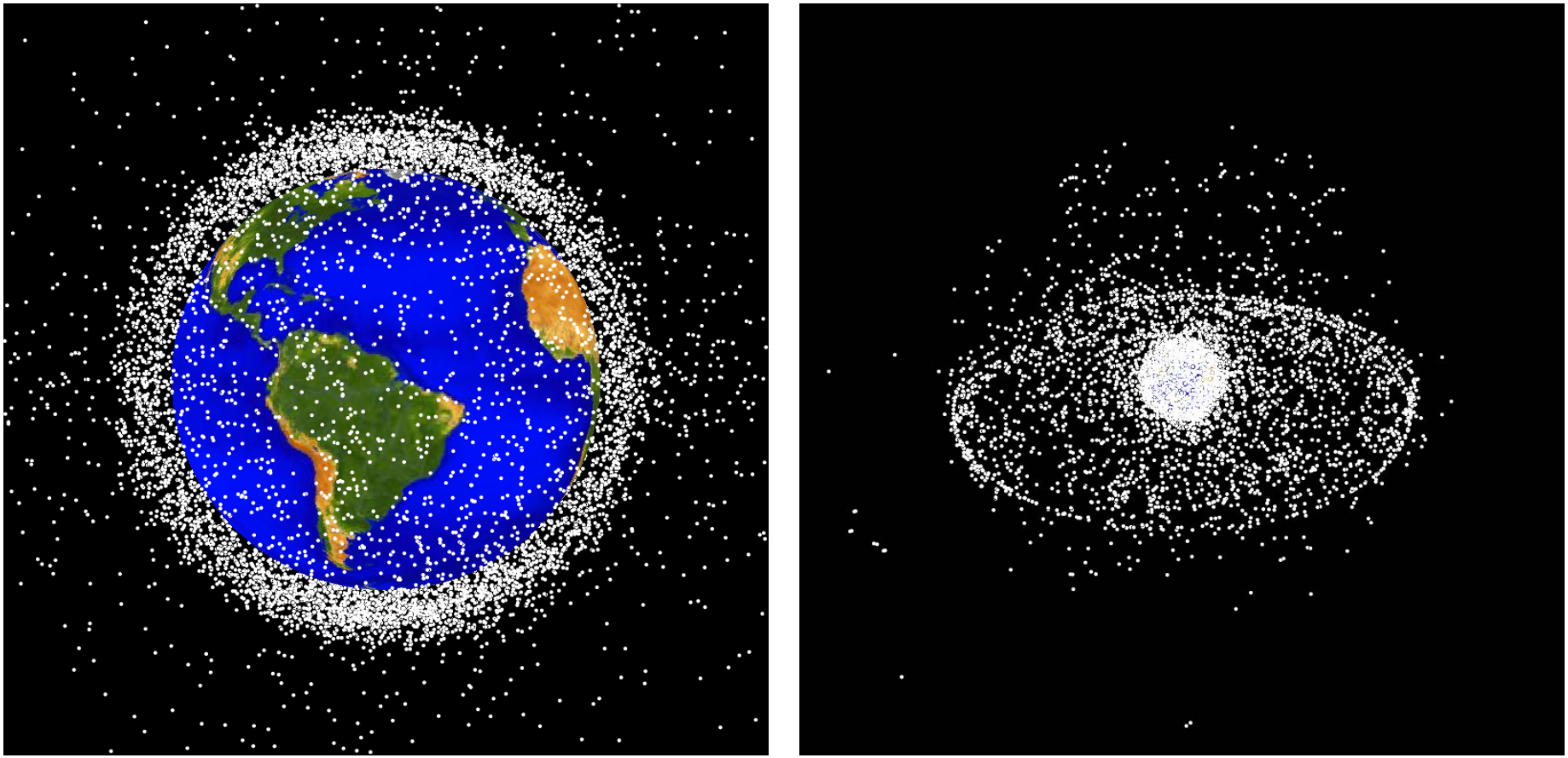
2000



Cataloged objects >10 cm diameter

Growth of the Earth Satellite Population

April 2006



Cataloged objects >10 cm diameter

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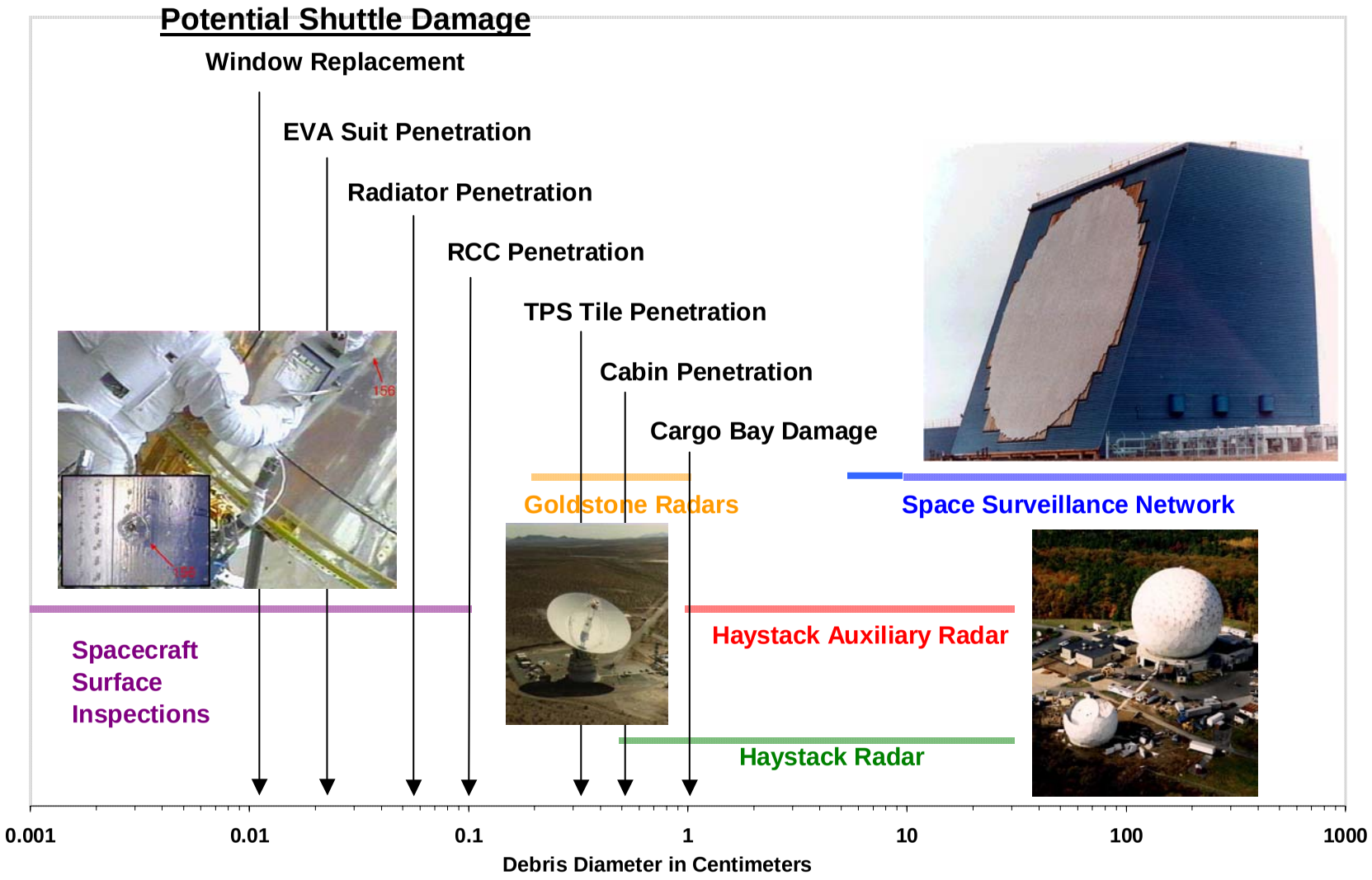
Principal Data Sources on Objects in Earth Orbit



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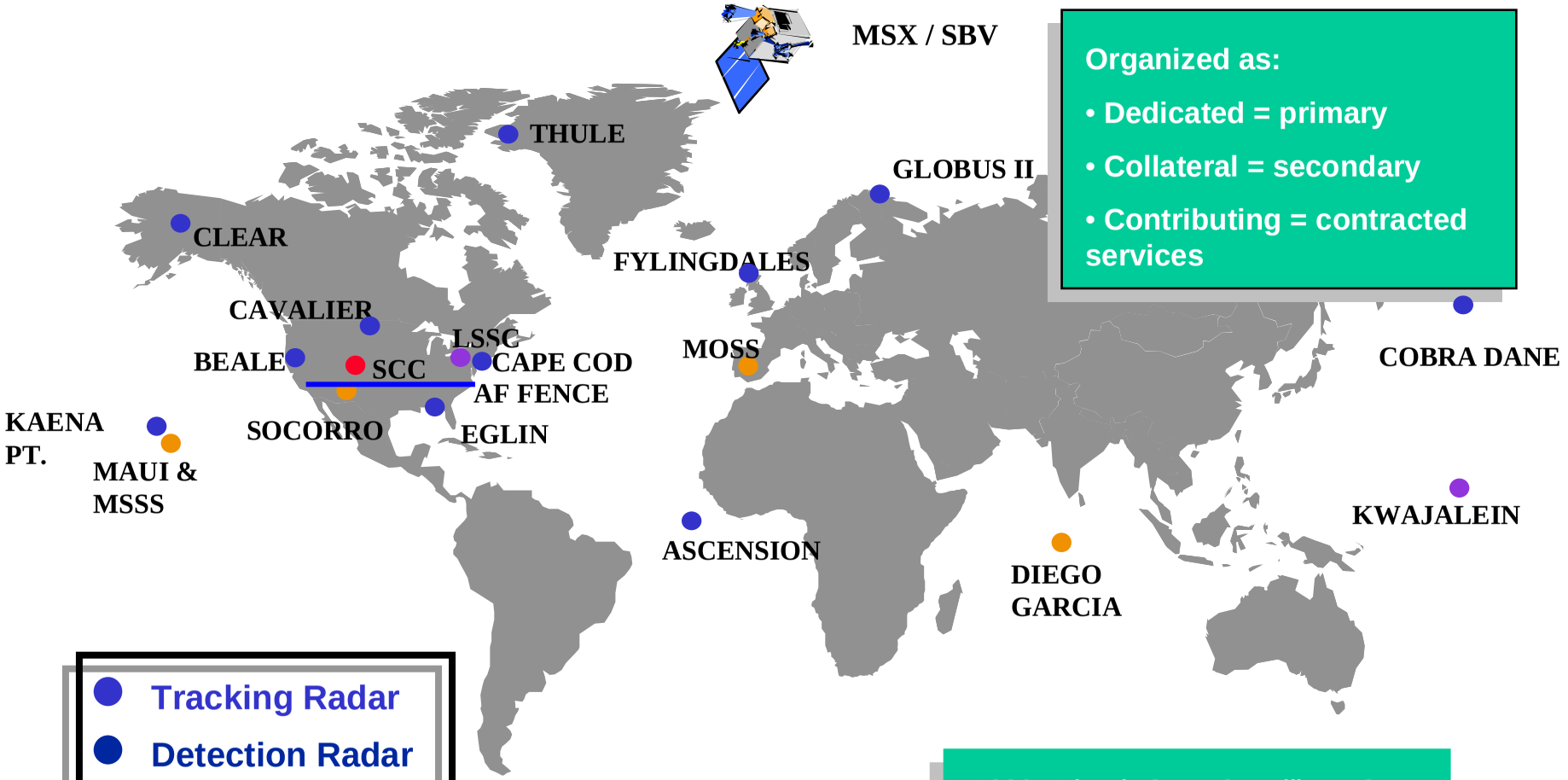
Space Surveillance Network: LEO (> 5 cm), GEO (> ~1 m)

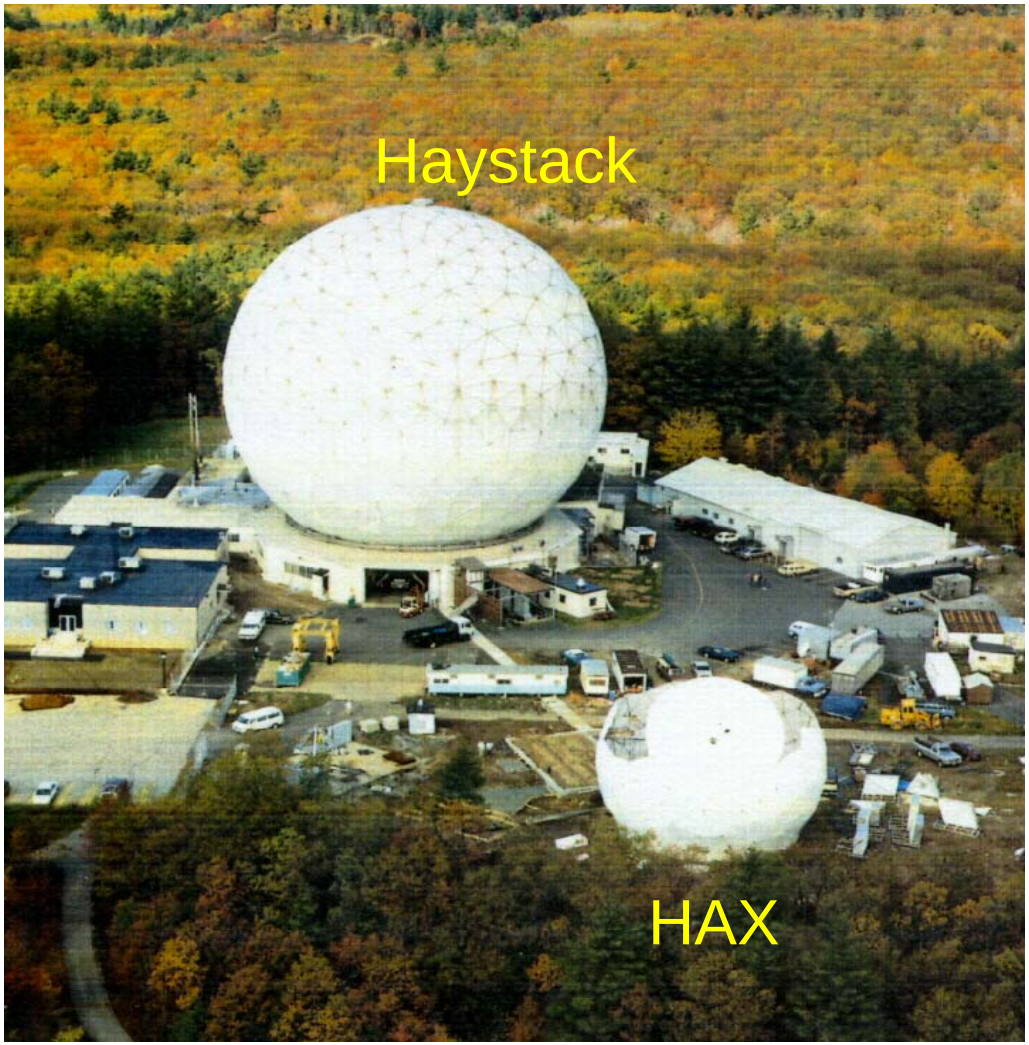


Organized as:

- **Dedicated = primary**
- **Collateral = secondary**
- **Contributing = contracted services**

LSSC = Lincoln Space Surveillance Center
Millstone, Haystack, HAX
MSSS = Maui Space Surveillance System
(former AMOS/MOTIF site)

Haystack/Haystack Auxiliary: LEO (05.-10 cm)



- **Haystack and HAX measurements have been NASA's main source of data on debris between 0.5 – 10 cm.**
- **Haystack (X-band; 0.058° FOV) has collected data since 1990**
- **Haystack Auxiliary (HAX) (Ku-band ; 0.1° FOV) has collected data since 1993**
- **Currently ~600 hrs of data per year on each radar are collected under joint NASA-DoD program**

Goldstone Bistatic Radar Complex: LEO (0.2 – 1 cm)

- **X-band Transmitter: 70 m dish antenna**

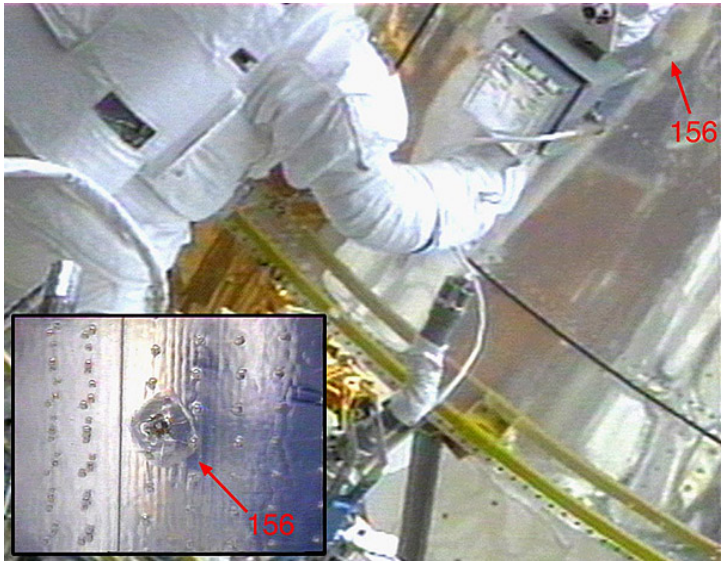
  Receiver: 35 m dish antenna

  (separated by 0.5 km)

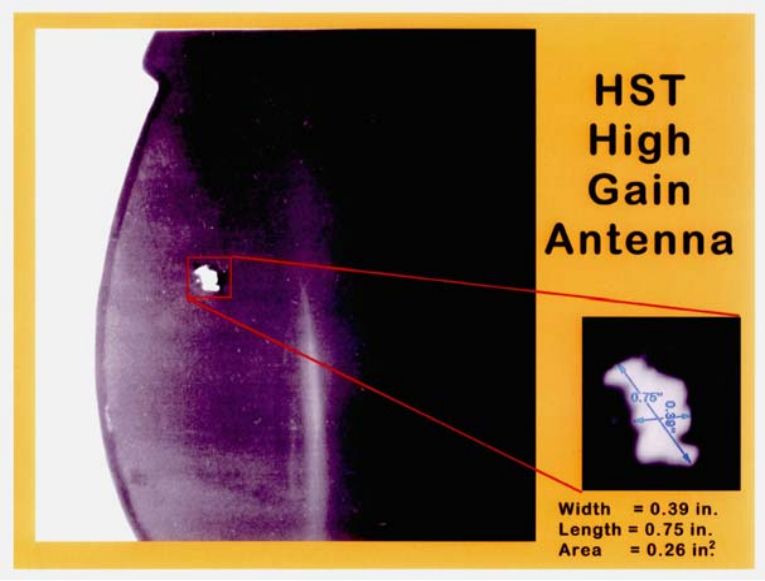
- **Goldstone has the capability of detecting debris as small as 2 mm diameter at low altitudes; can reach as high as 4000 km**

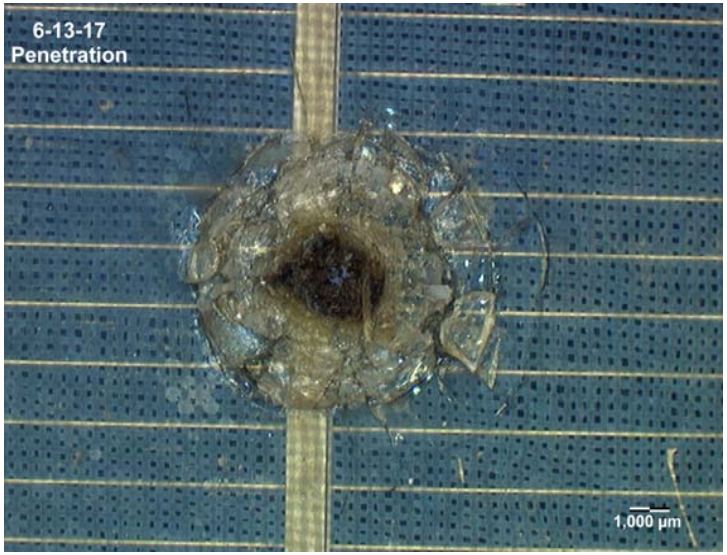
- **Goldstone is available for only 100-200 hours each year and has a very small (0.02°) FOV**

Spacecraft Surface Examinations: LEO (≤ 0.1 cm)



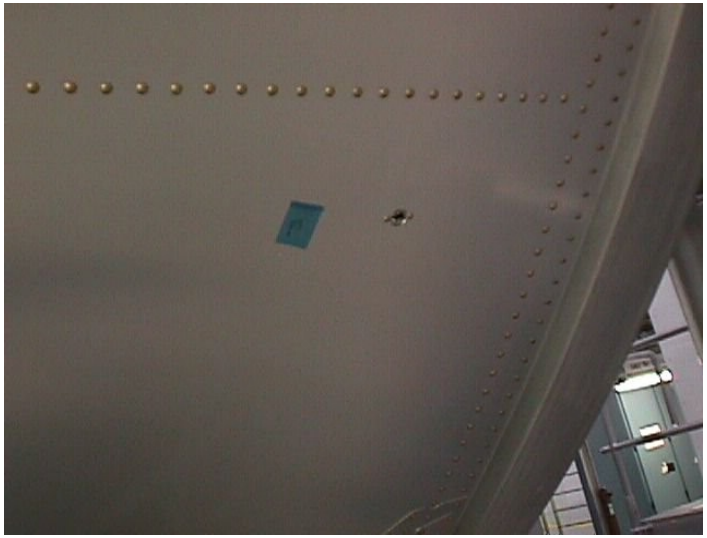
HST





Mir

ISS
MPLM



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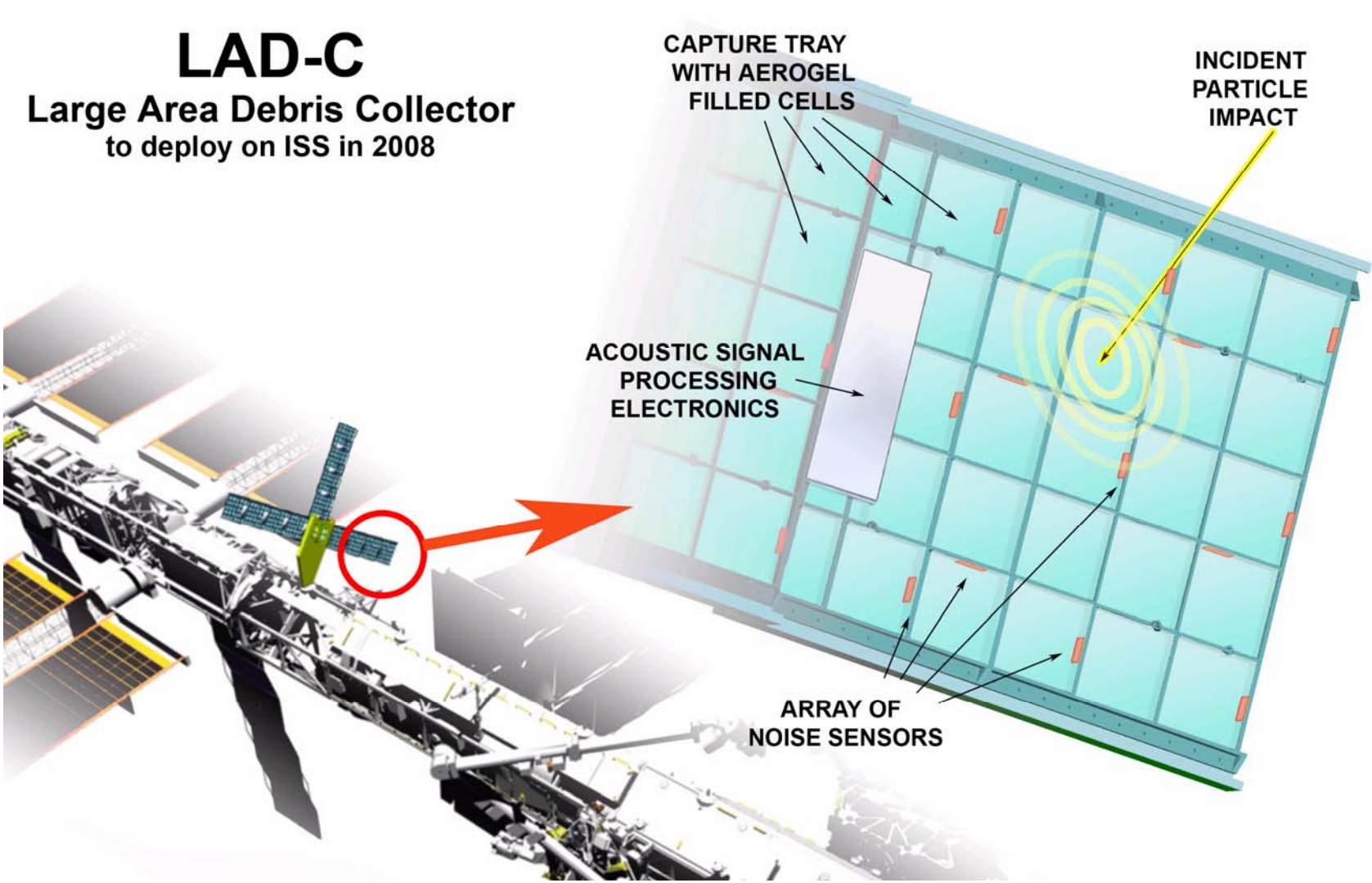
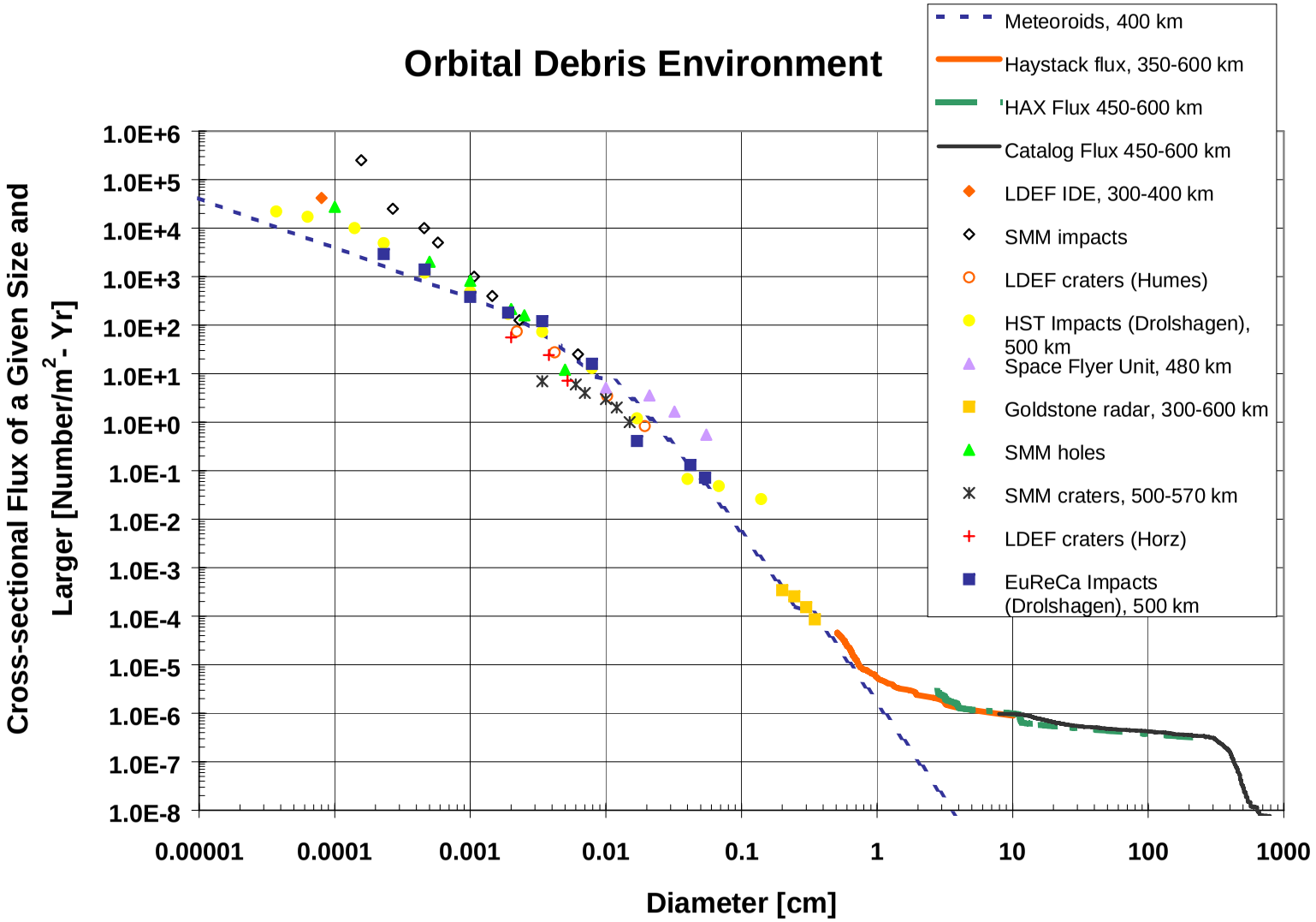
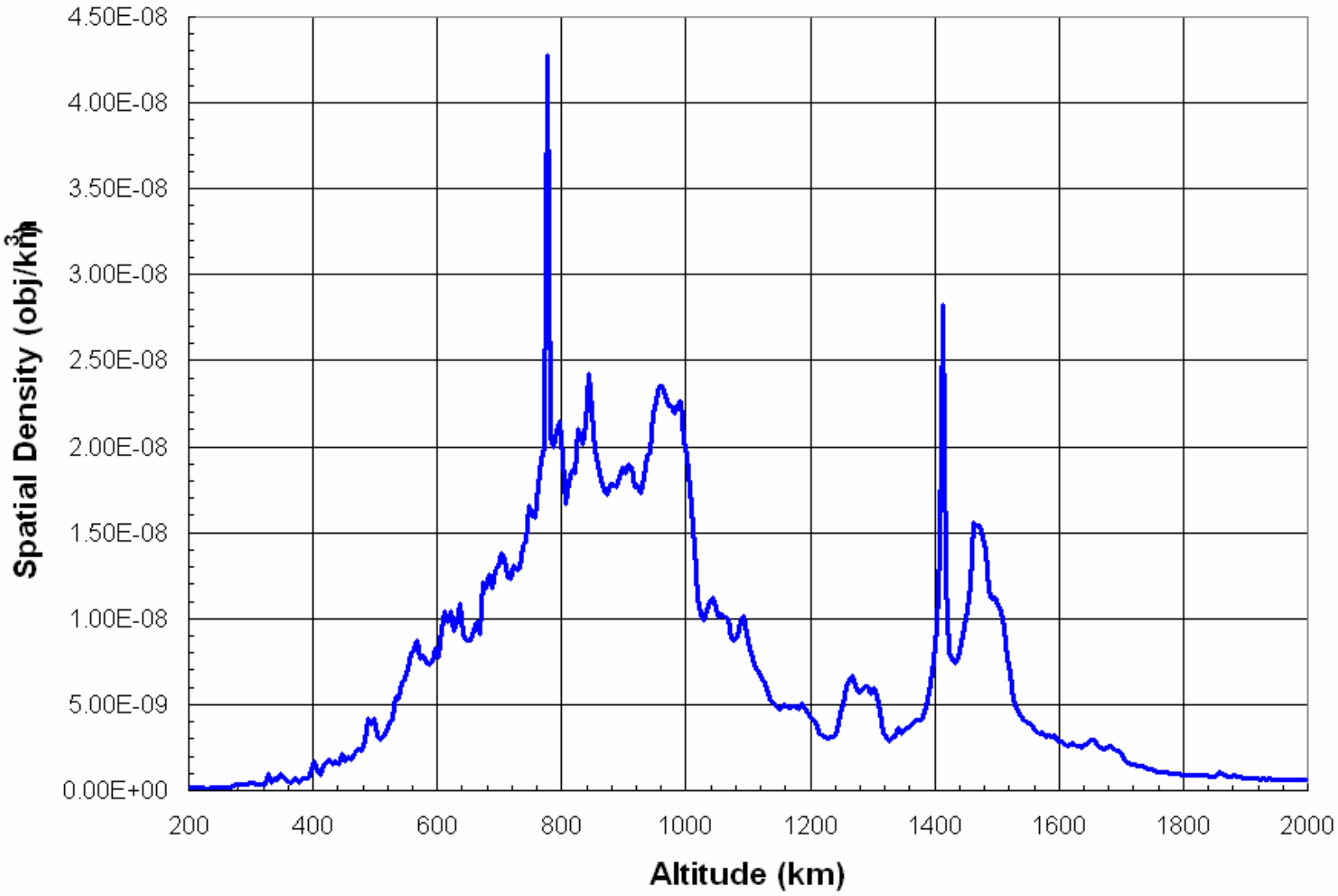
Large Area Debris Collector (LAD-C): LEO (> 0.01 cm)



LEO Environment Definition

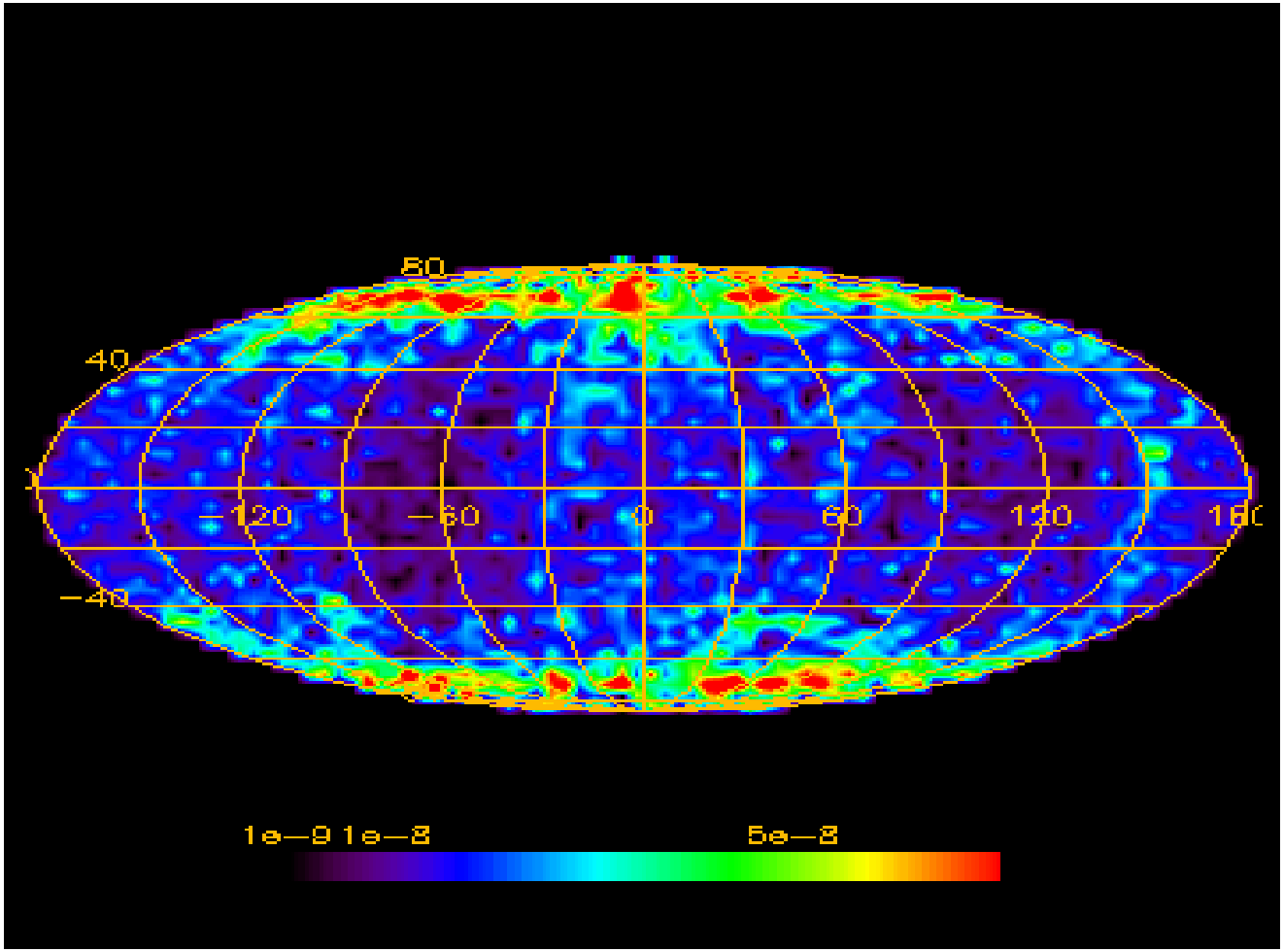


Satellite Density in LEO: Altitude Distribution



Satellite Density in LEO: Spatial Distribution

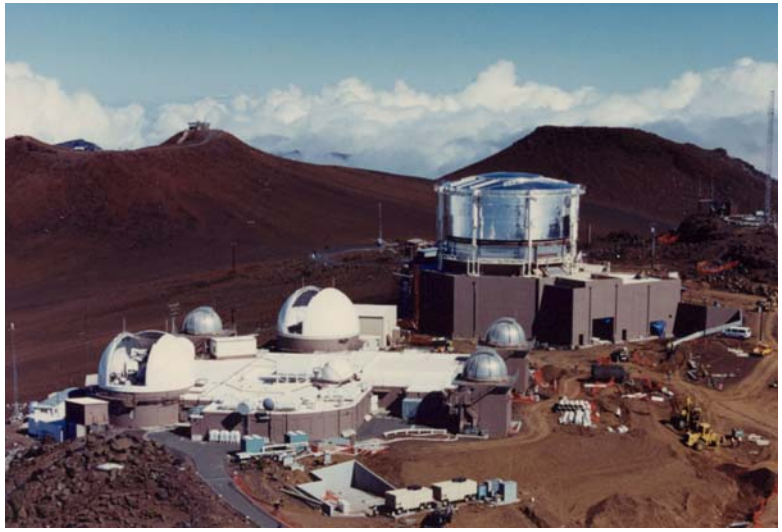
Spatial density of cataloged objects between 800 and 900 km

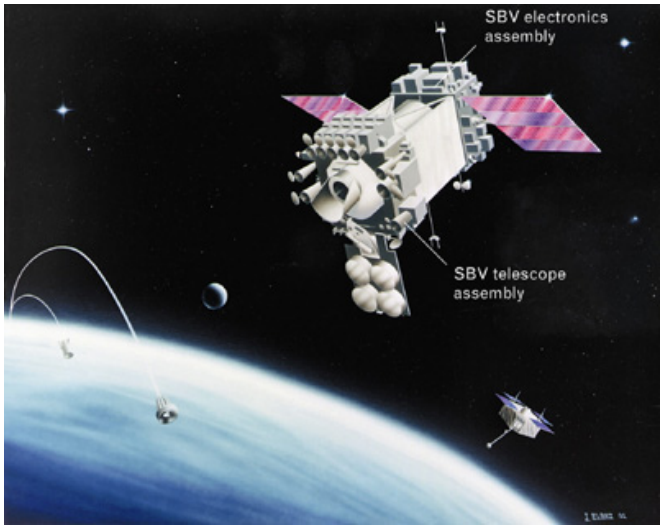


High Earth Orbits: MEO and GEO

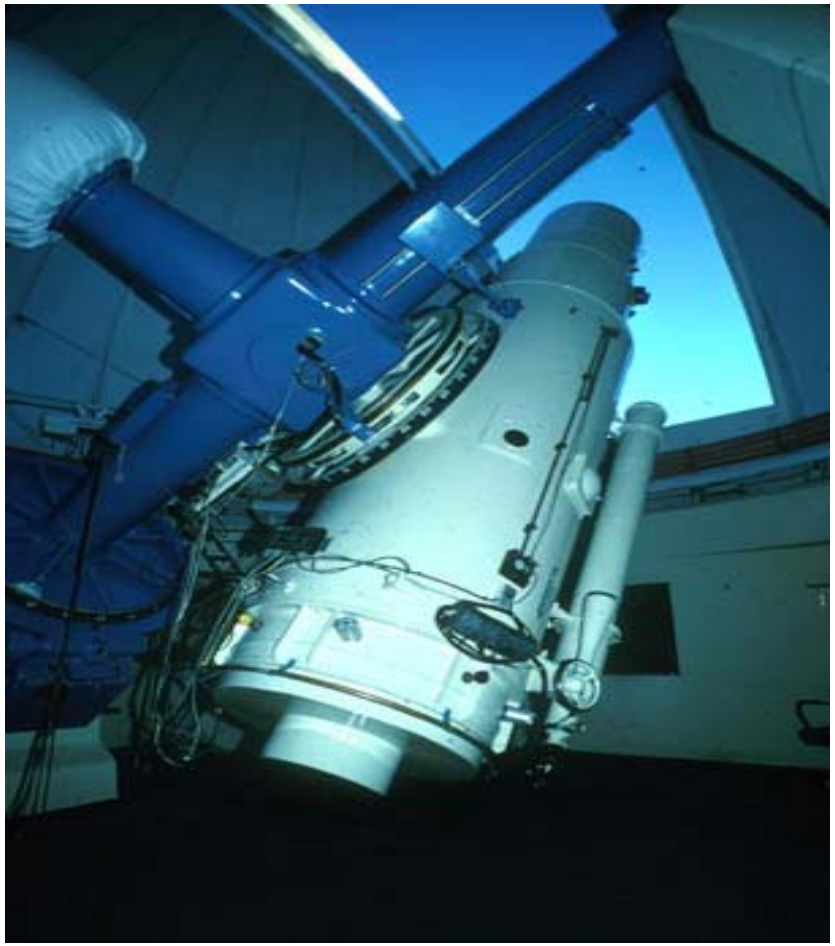
- **The primary environment characterization and satellite cataloging for high Earth orbits are provided by a collection of ground-based optical and radar sensors and the Space-Based Visible instrument on the MSX spacecraft.**

- **The smallest objects typically seen by these sensors in high Earth orbits are typically tens of centimeters in diameter; nearly 1 m in GEO.**

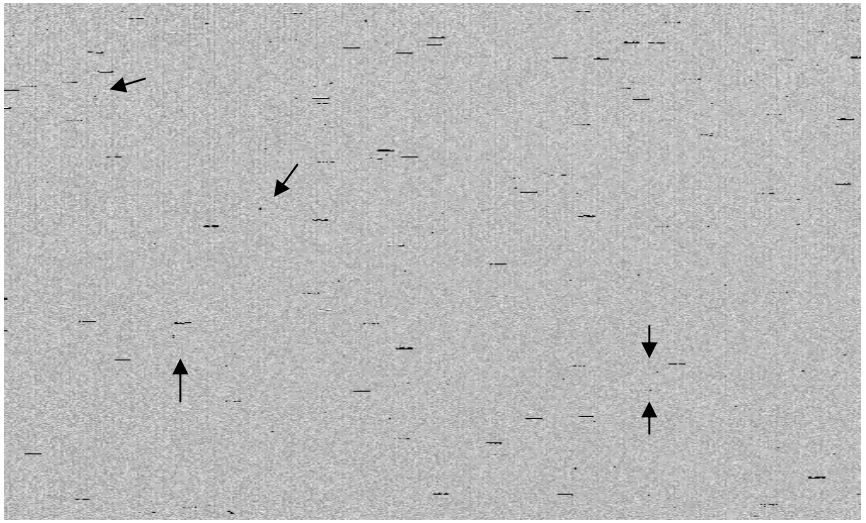




NASA Michigan Orbital Debris Survey Telescope: GEO (> 20 cm)



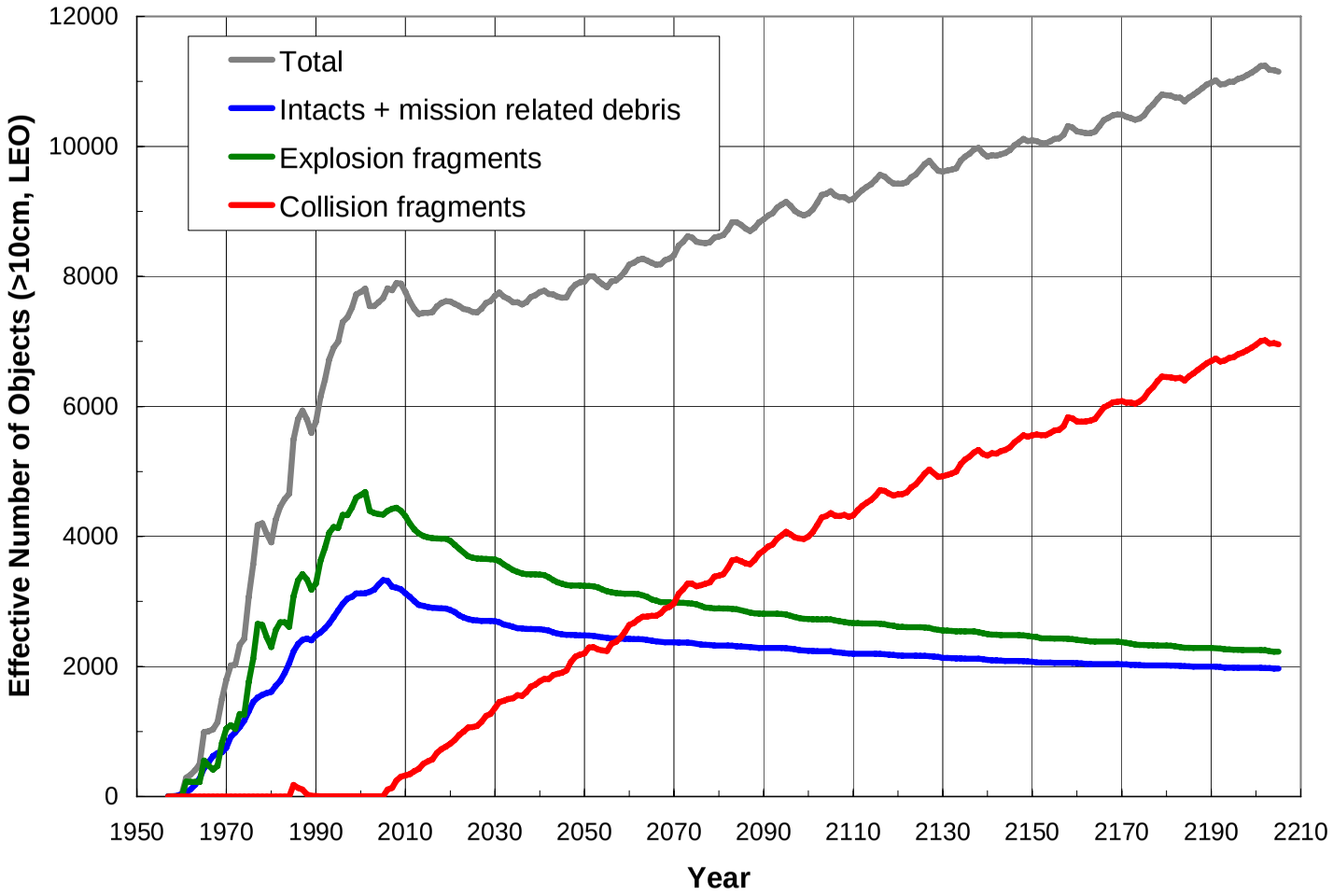
- **Location: Cero Tololo Inter-American Observatory, Chile**
- **0.6/0.9 m Curtis Schmidt telescope**
- **Comprehensive surveys of the GEO region since 2001**



Meter-Class Autonomous Telescope: GTO and GEO (> 10 cm)

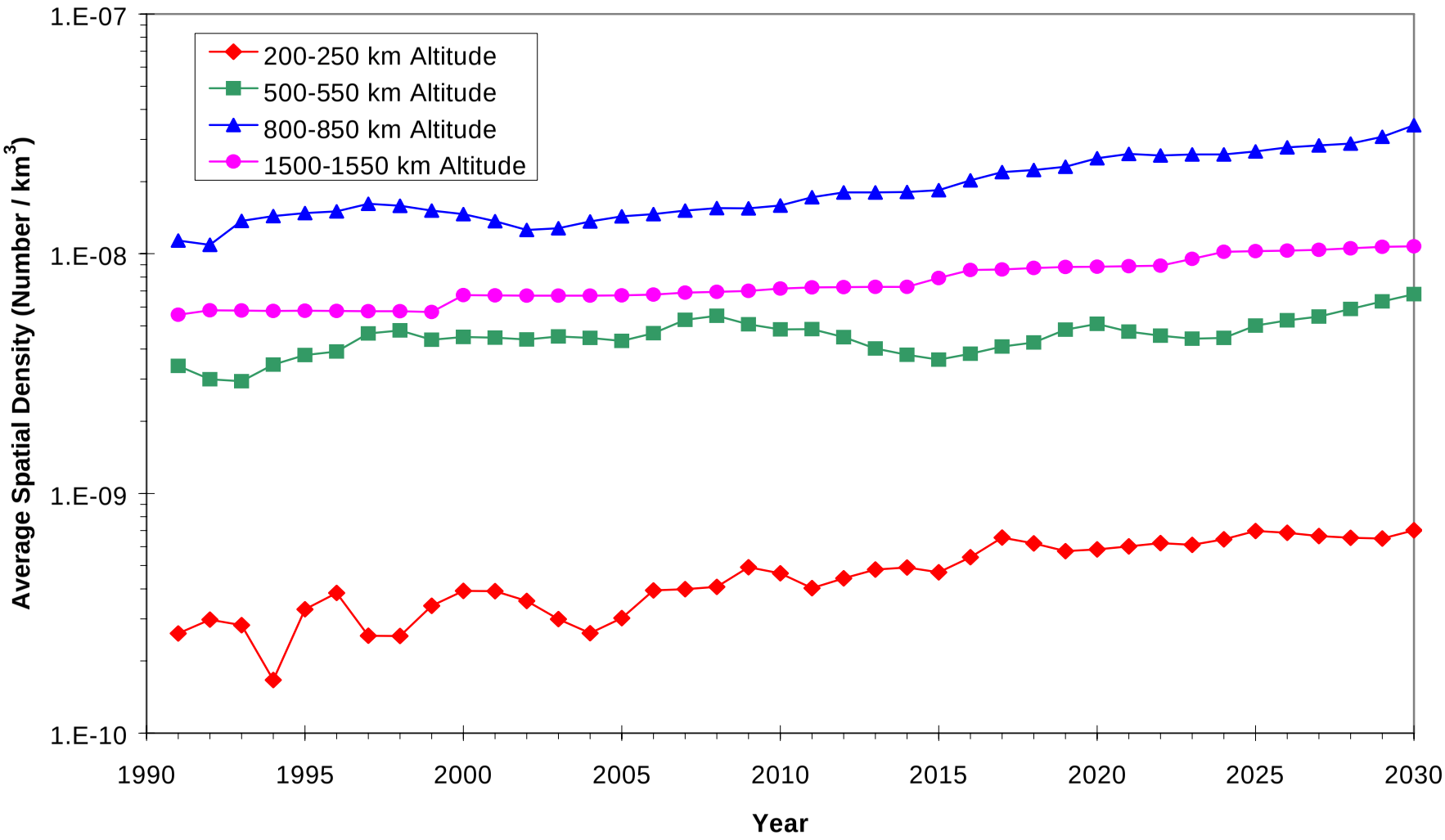
- **Joint NASA-DoD project to deploy a 1-meter, remotely controlled telescope on the Kwajalein Atoll, Pacific Ocean.**
- **Principal objective will be to detect small objects in low inclination orbits, including GTO and the GEO region.**
- **Deployment possible by 2008.**

Future LEO Environment with No New Launches

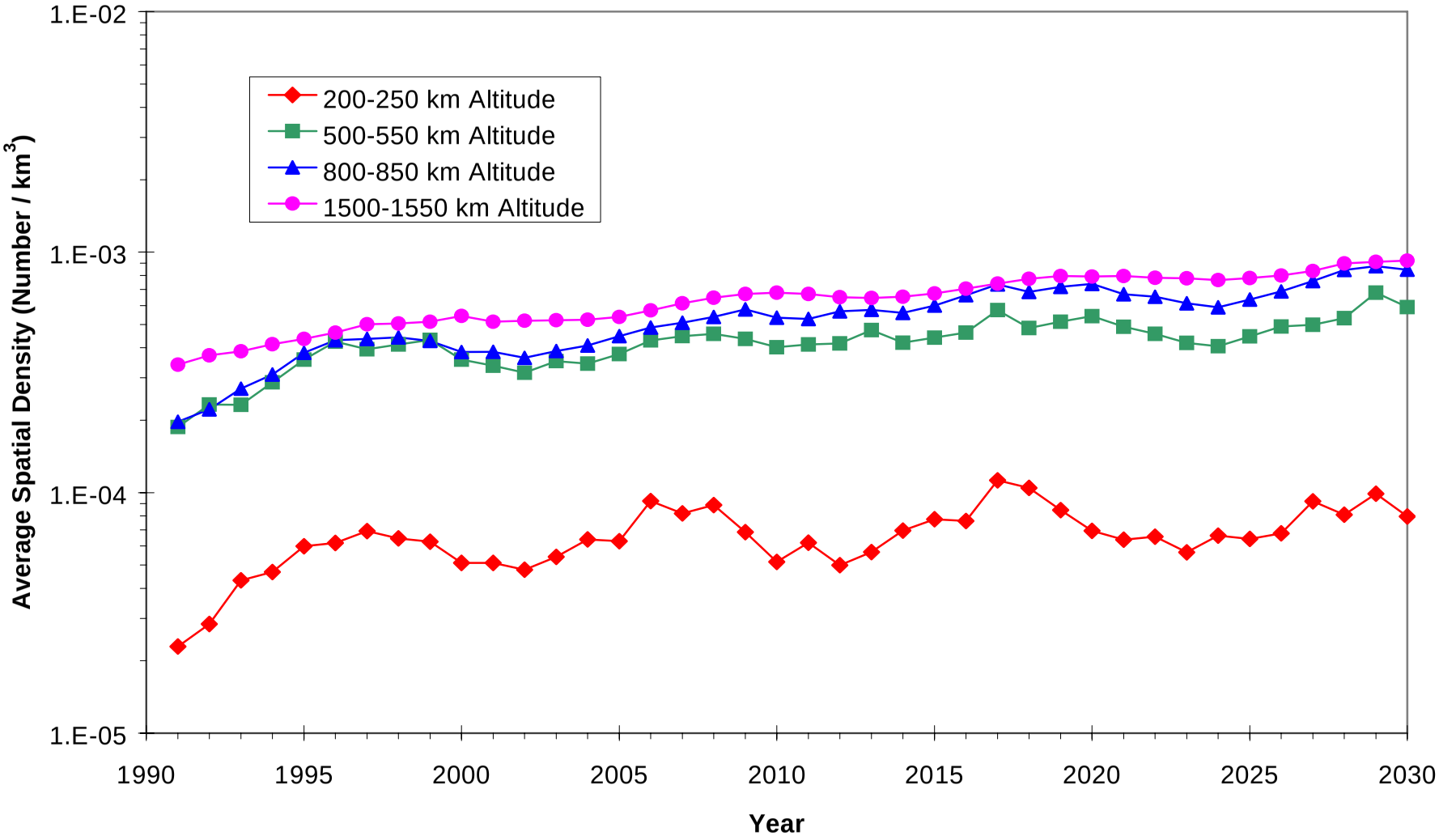


No new space launches after 2005

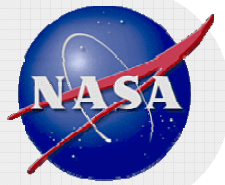
Future LEO Projection: >10 cm



Future LEO Projection: >1 mm



Summary



- **The current Earth satellite population in LEO for all sizes is relatively well-established by a combination of deterministic and statistical means. At higher altitudes, the population of satellites with diameters of less than 1 m is not well defined.**

- **Although a few new sensors might become operational in the near- to mid-term, no major improvement in environment characterization is anticipated during this period.**

- **With the increasing deployment of micro- and pico-satellites and with the continued growth of the small debris population, a need exists for better space surveillance to support spacecraft design and operations.**