Laser Tracking of Space Debris

Dr Ben Greene
EOS Technologies, Inc.
Tucson, Az 85705

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Key Space Traffic Control Issues

There is essentially universal agreement on the following key concerns:

- **Outdated regulatory framework**
- **Launch/reentry inadequately coordinated**
- **Inadequate space catalogues**
- **Debris mitigation and collision avoidance**
- **Preservation and protection of GEO orbits**

Coordinating Entities - Space Traffic

Global coordination is through UN Office of Outer Space Affairs, collaborating with national agencies and organizations such as:

- American Institute of Aeronautics and Astronautics
- International Academy of Astronautics
- Confederation Of European Aerospace Societies

EOS Space Science Activities

- Telescopes, domes and enclosures
- Laser guide star systems
- Space tracking systems and instrumentation
- Autonomous distributed tracking systems
- Space surveillance systems
- Transportable observatories
- High power laser systems

The Role for Laser Tracking

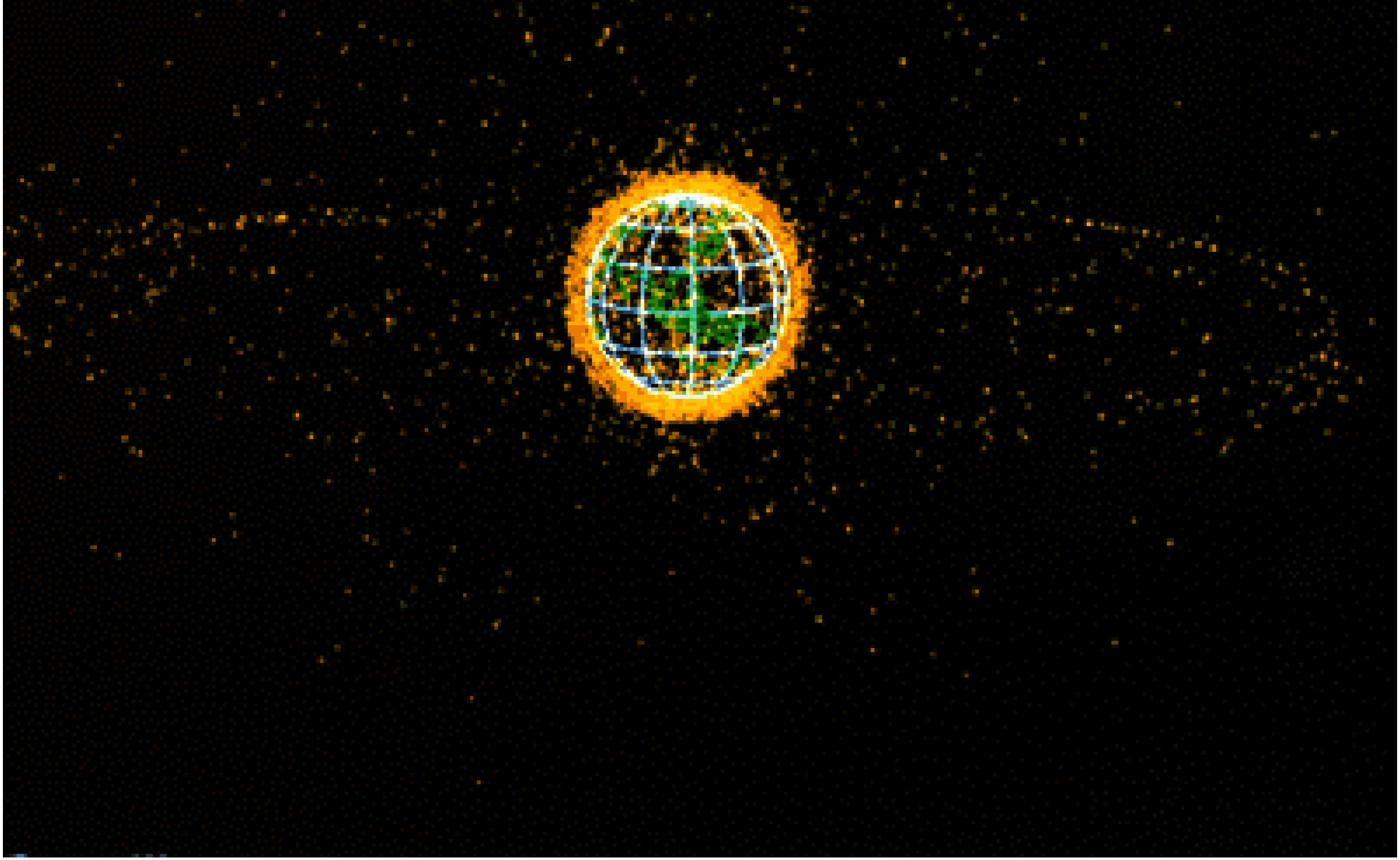
Radar systems can acquire ("find") small debris quickly, but are expensive, noisy, and inaccurate.

Optical [passive] trackers can find debris and are inexpensive, but are slow and inaccurate.

Lasers cannot "find" debris, but are fast, accurate and relatively inexpensive.

EOS has developed an operational concept based on radar and passive optical cueing of laser trackers. The laser systems provide real-time orbits with high accuracy.

The Debris Problem



Damage from Debris Collision

Debris matches all useful satellite orbits

- *<5 mm debris may be absorbed by cladding*
- *5 - 15 mm debris will damage and impair*
- *>15 mm debris will destroy a satellite*

Any solution must track 10 mm objects.

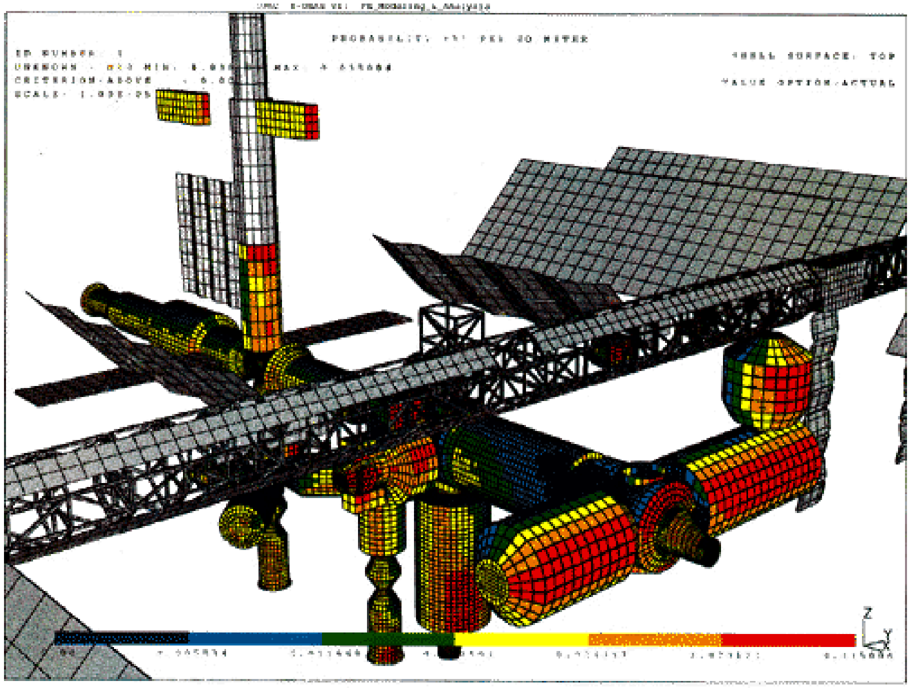
Any solution to the debris problem must also solve the catalogue problem.

General Collision Risks

- **Mission loss**. *Probability of loss in typical mission life is <0.05%.*
- **Damage**. *Probability of damage during mission is <0.5%.*
- **Commercial risk**. *Any major incident will take money from most space programs. The probability is high, and impacts almost the entire space industry.*
- **Perceptions and Capital Markets**. *Any incident involving significant loss of any kind due to space debris strike will impact markets. Issues of risk disclosure arise.*

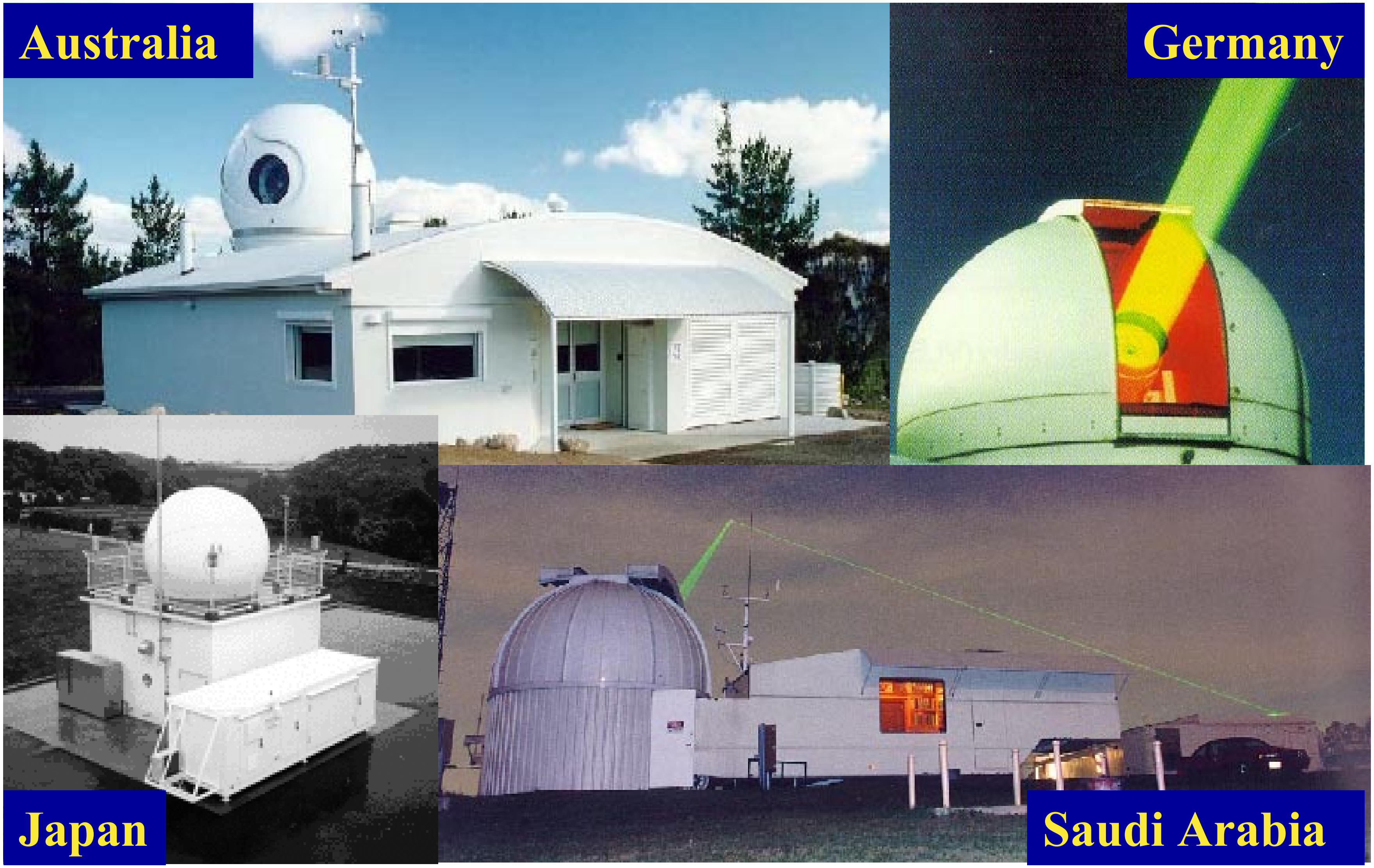
Shuttle and ISS Collision Risk

- *ISS is a multi-national project costing >A$200 billion to build, deploy and operate*
- *ISS and shuttle orbits at high risk due to debris, and their debris profile represents several* ***thousand*** *commercial satellites*
- *Both capital investment and* ***human life*** *are at stake with both missions*
- *Debris shielding is only totally effective for* ***debris <5 mm***



Heaviest Shielding in Areas Having Brighter Colors

EOS Space Laser Tracking Heritage



Debris Tracking - The Requirement

The first task for any debris mitigation approach must be to track and catalogue the debris. What cannot be tracked, cannot be avoided or evaded.

Compared to current capabilities, a system deployed for space debris hazard mitigation should have:

- **Object size < 10 mm : >10 times smaller**
- **Orbit error < 1,000 m : >10 times more accurate**
- **Capacity for 10 mm : >10 times as many objects**

Laser Tracking Improvements

"Conventional" SLR systems cannot range to small non-cooperative targets such as cm-scale debris.

EOS has obtained improvements of >>10^6 in link over conventional laser tracking systems.

This has been achieved at the same time as improvements such as:

- **Eyesafe transmissions**
- **Reliability increased**
- **Fully automated operations**

Laser Tracking Improvements

Key developments in the past 6 years:

- **Laser: kW systems @ 1.5 DL**
- **Telescopes: 100 nrad tracking**
- **Infrastructure: 100 nrad support**
- **High energy optics**
- **Adaptive optics and laser guide star**
- **Control systems and software**
- **Rapid orbit determination**

Next Generation Tracking Telescopes

***Production* technology now allows:**

- **< 0.04 arcsec servo following error**
- **< 0.05 arcsec tracking error in space**
- **< 5 um rms variation in axis intersection**
- **Stable tracking rates [100 nrad rms]**
- **Fast AO and laser guide star systems**
- **Autonomous operation**

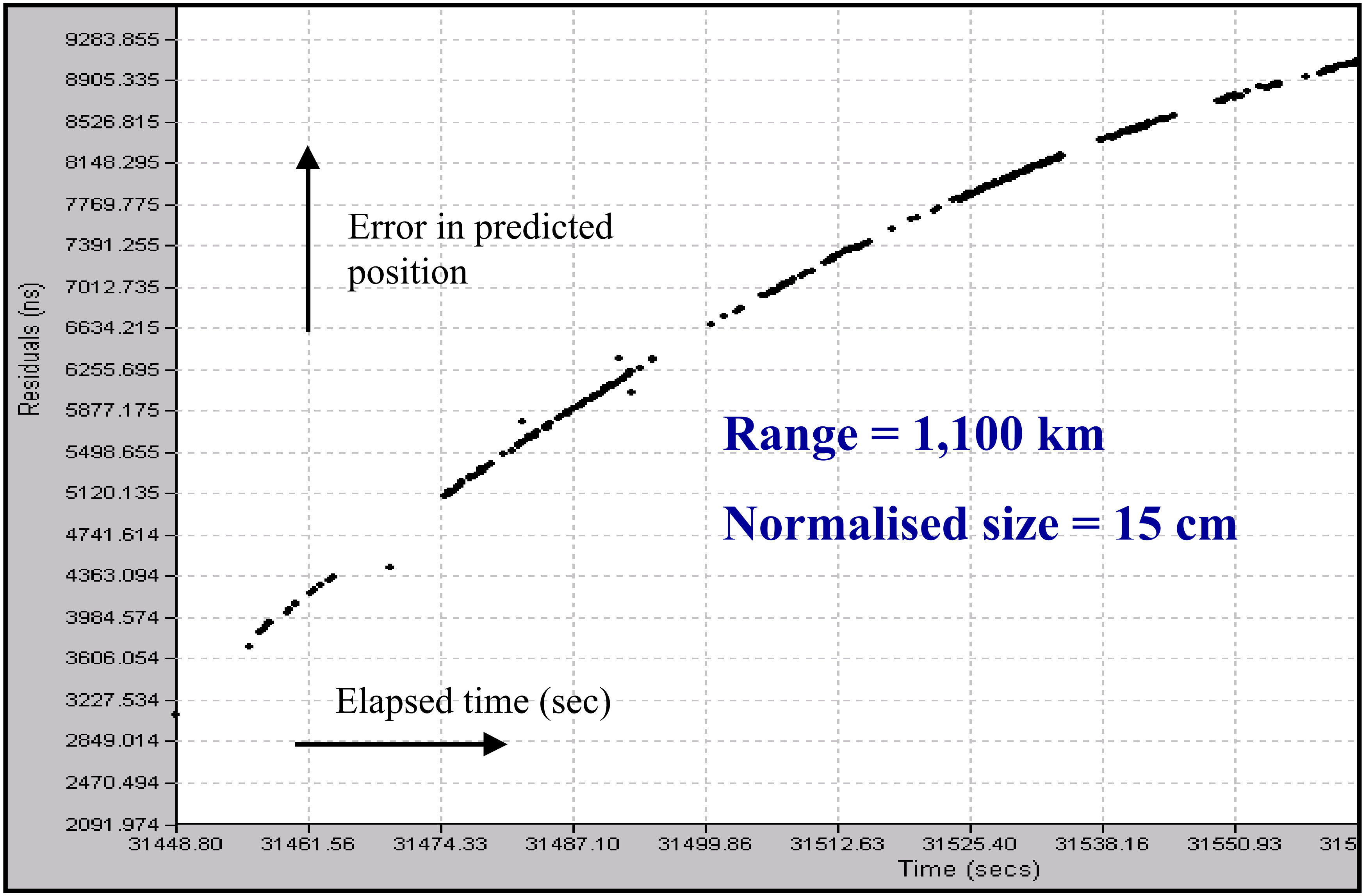
Tracking Enclosures

IceStorm enclosures are co-rotating facilities for high precision telescopes that allow:

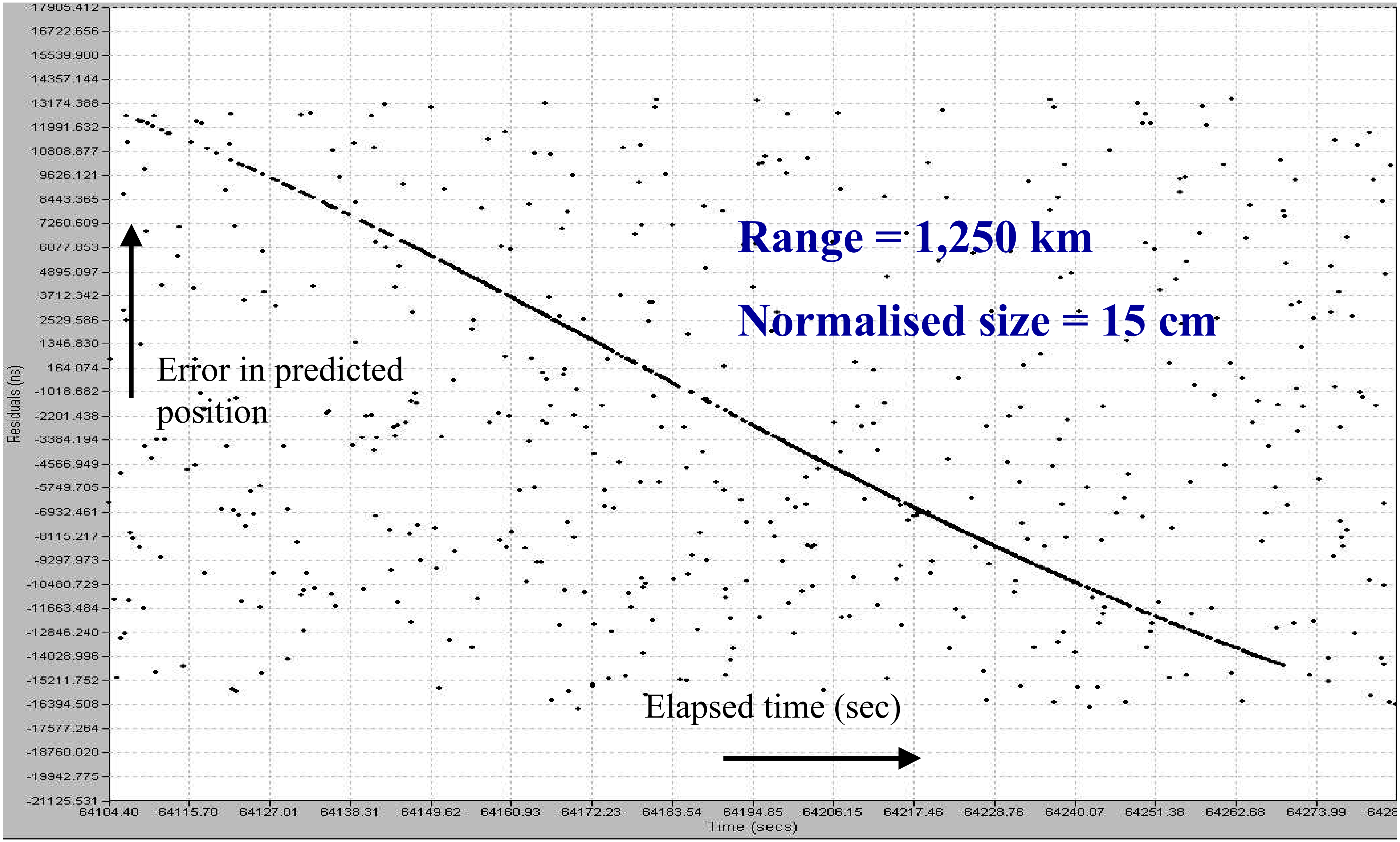
- **200 mph wind loading**
- **Severe ice loading**
- **Air temperature control**
- **Dome seeing control**
- **< 0.02 arcsec vibration to pier**
- **Unmanned operation**

Trial Facility - Mount Stromlo [Australia]

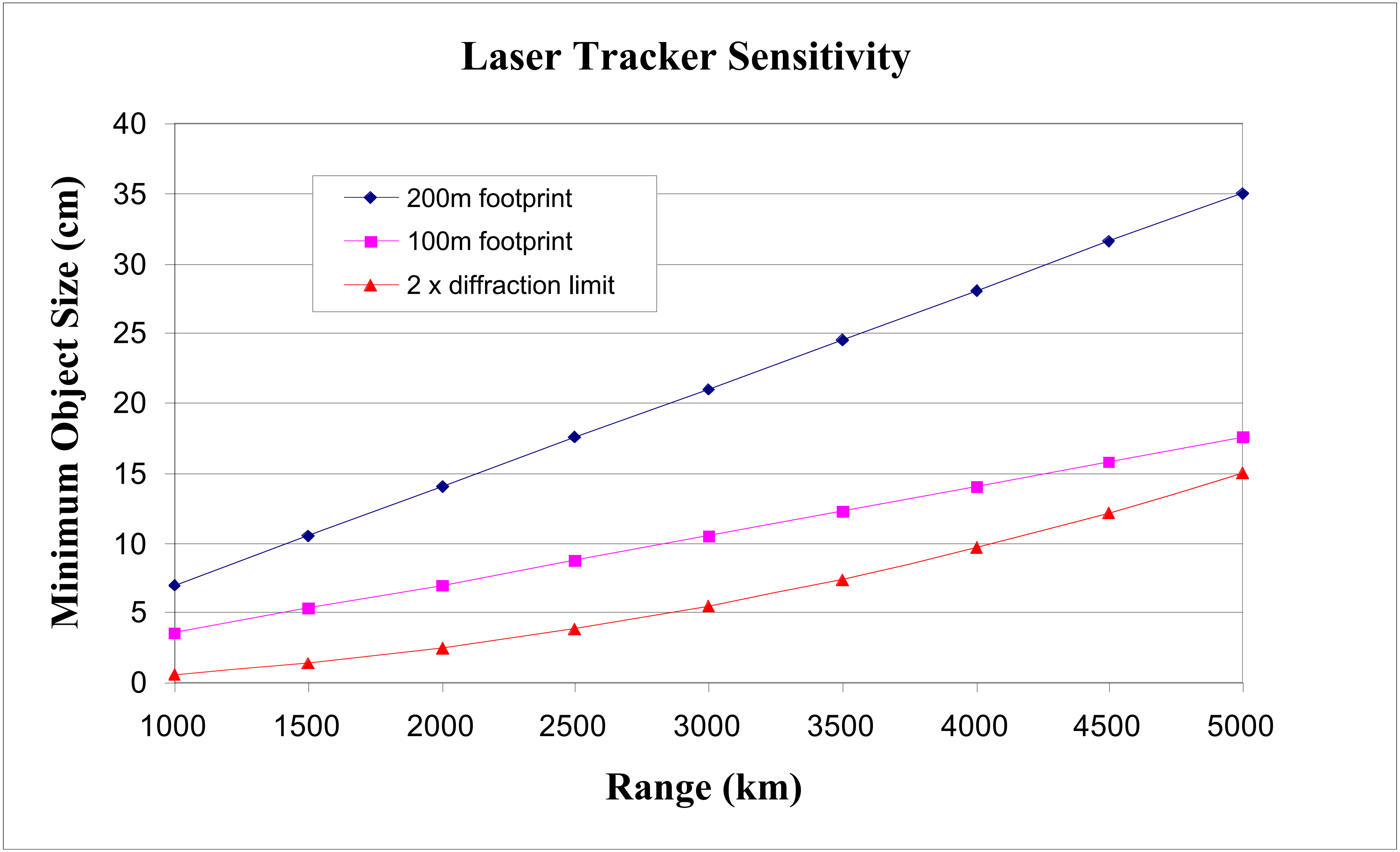
Actual Track of LEO Debris



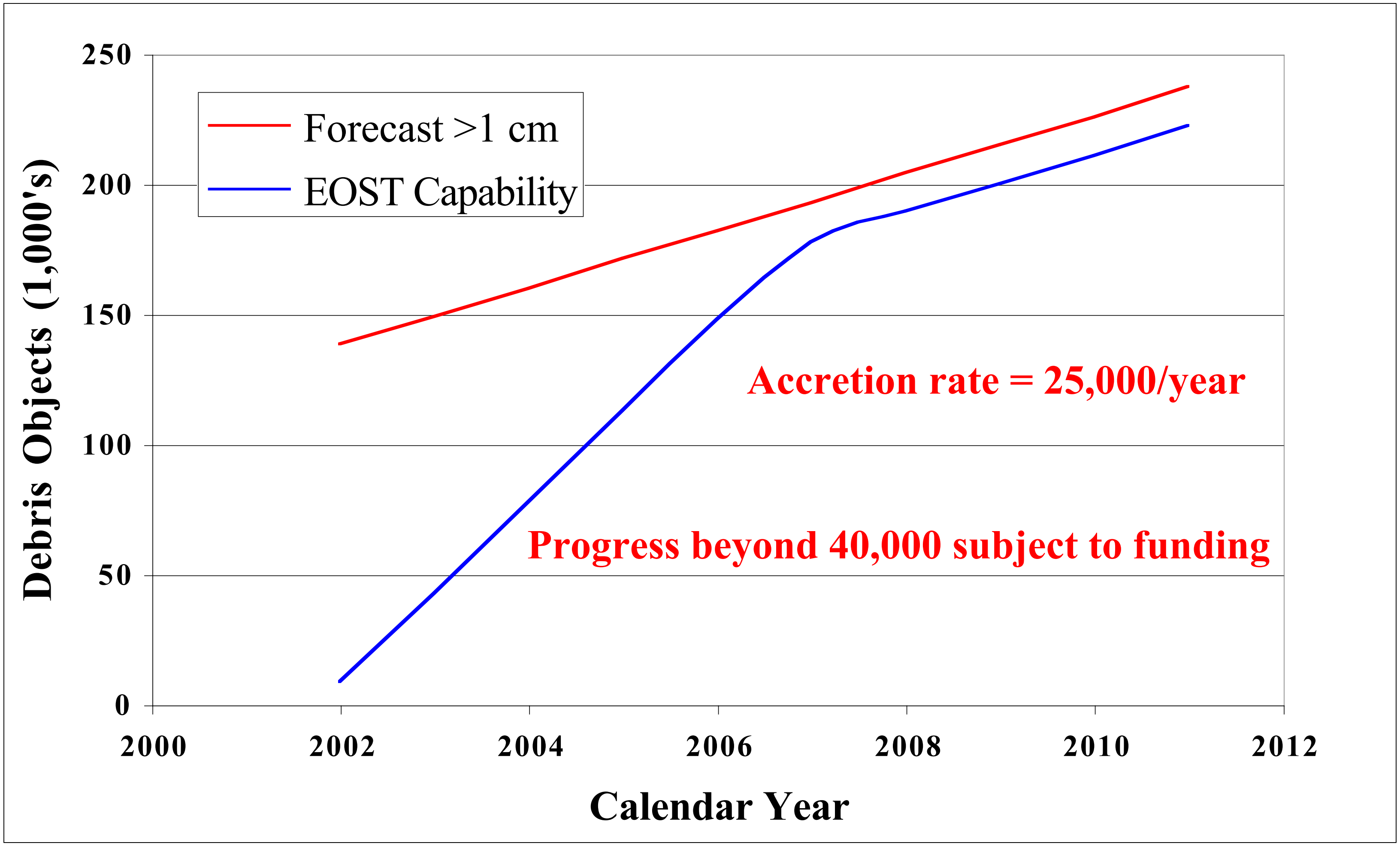
Actual Track of LEO Debris



System Performance [kW laser]



Laser Network Capacity



Summary

The laser ranging response to debris mitigation and collision avoidance

- **expansion to 150,000 LEO objects and 1 cm is viable**
- **accurate orbits and expanded and specialty catalogues will allow collision avoidance**

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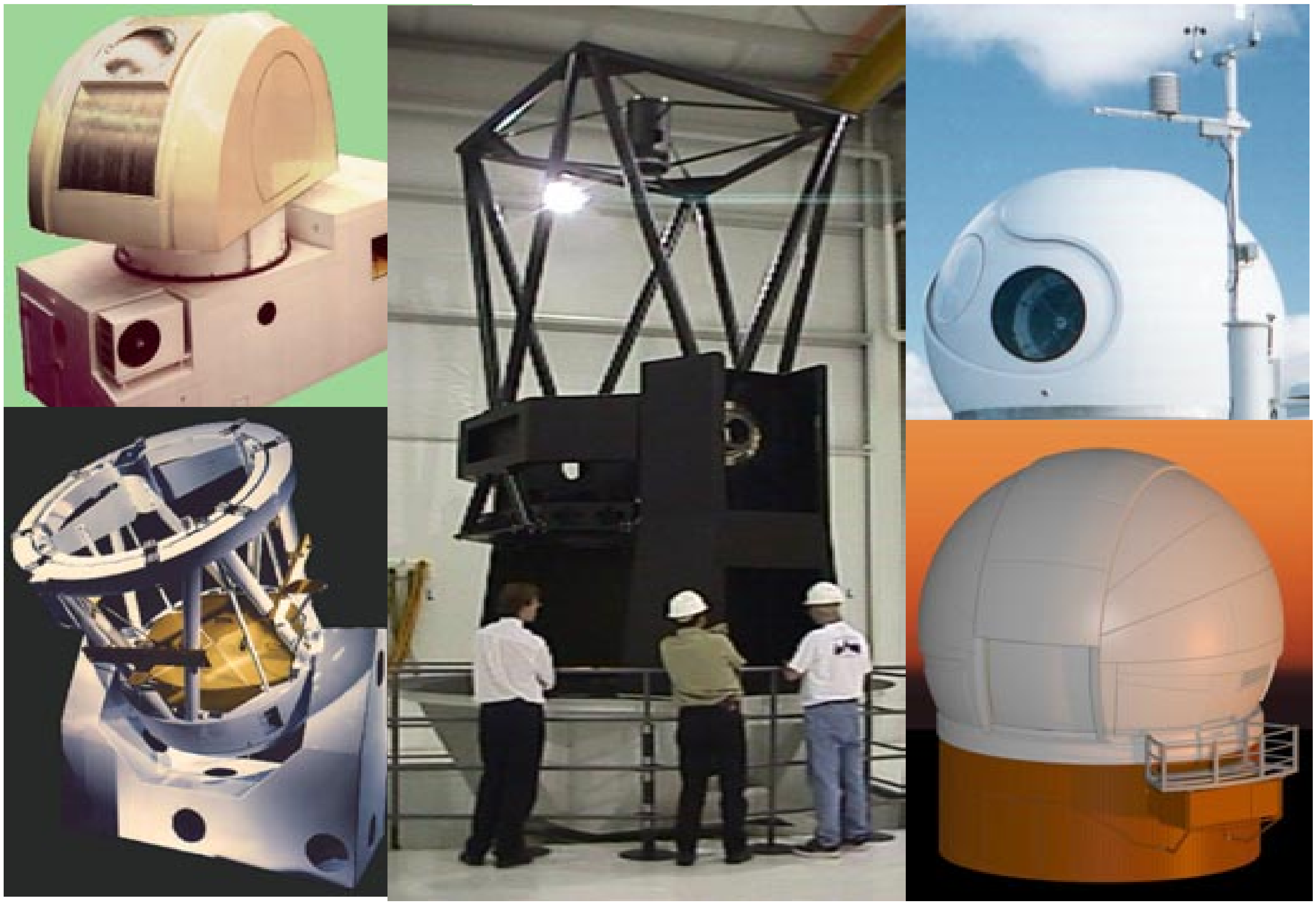
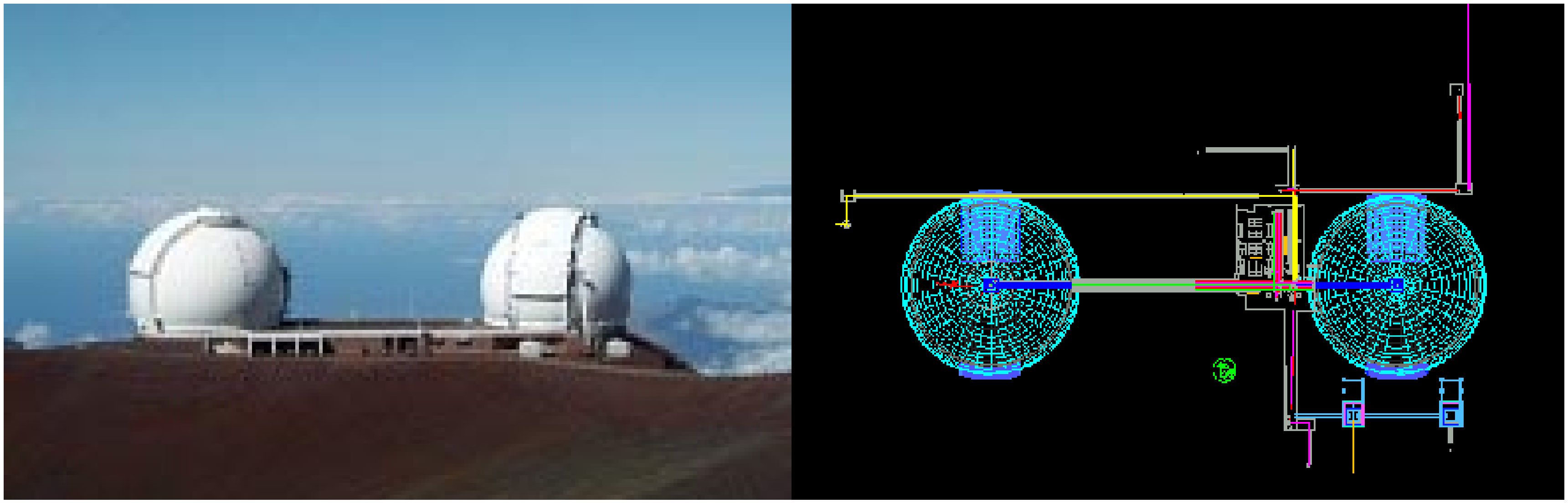
Typical Space Tracking Products



GEO Tracking and Imaging

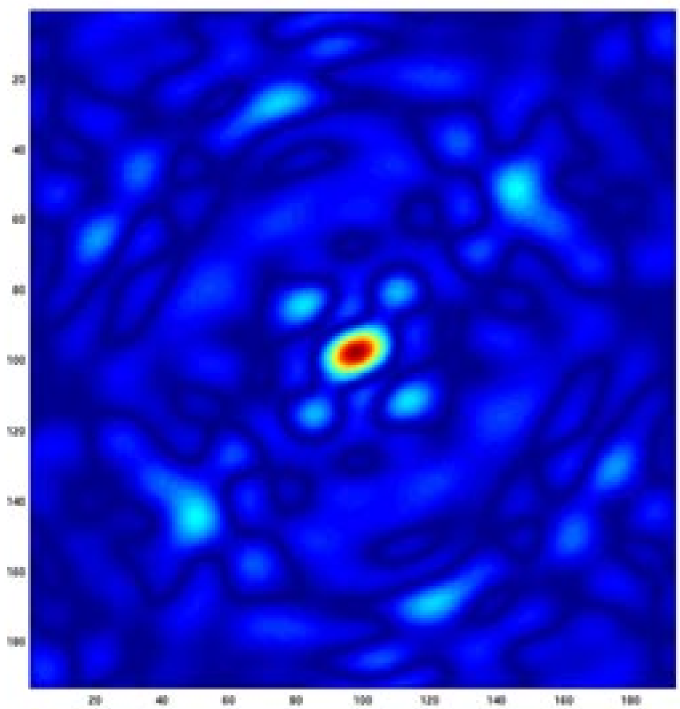


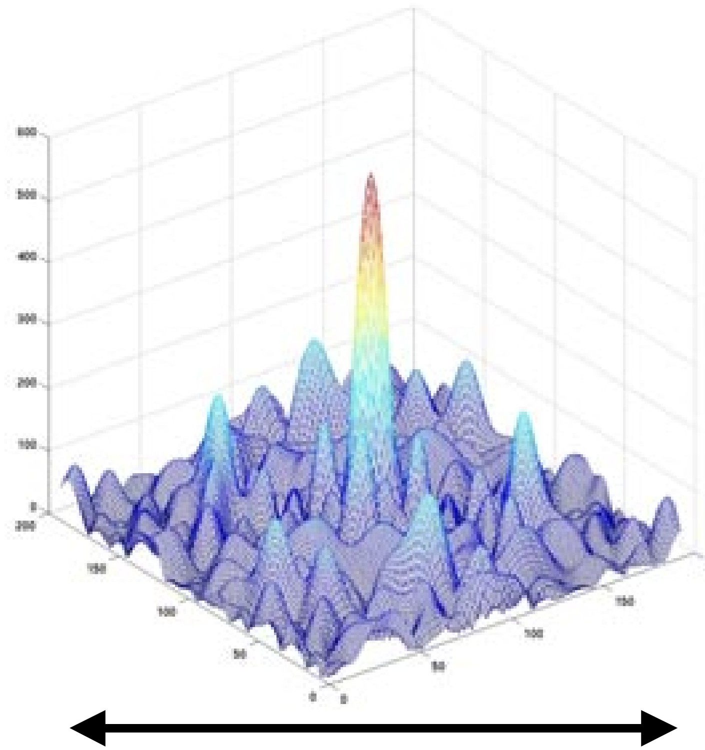
EOS is a principal contractor for the construction of the NASA/JPL Keck Interferometer ***Outrigger*** Telescope system. This system will create a telescope aperture of 100m using optical aperture synthesis.

Along with a similar instrument [ESO] in Chile, this will be the highest resolution telescope in the world. The system will be operational in 2004.

This technology can be applied to resolve images to 10 cm at GEO.

GEO Imaging



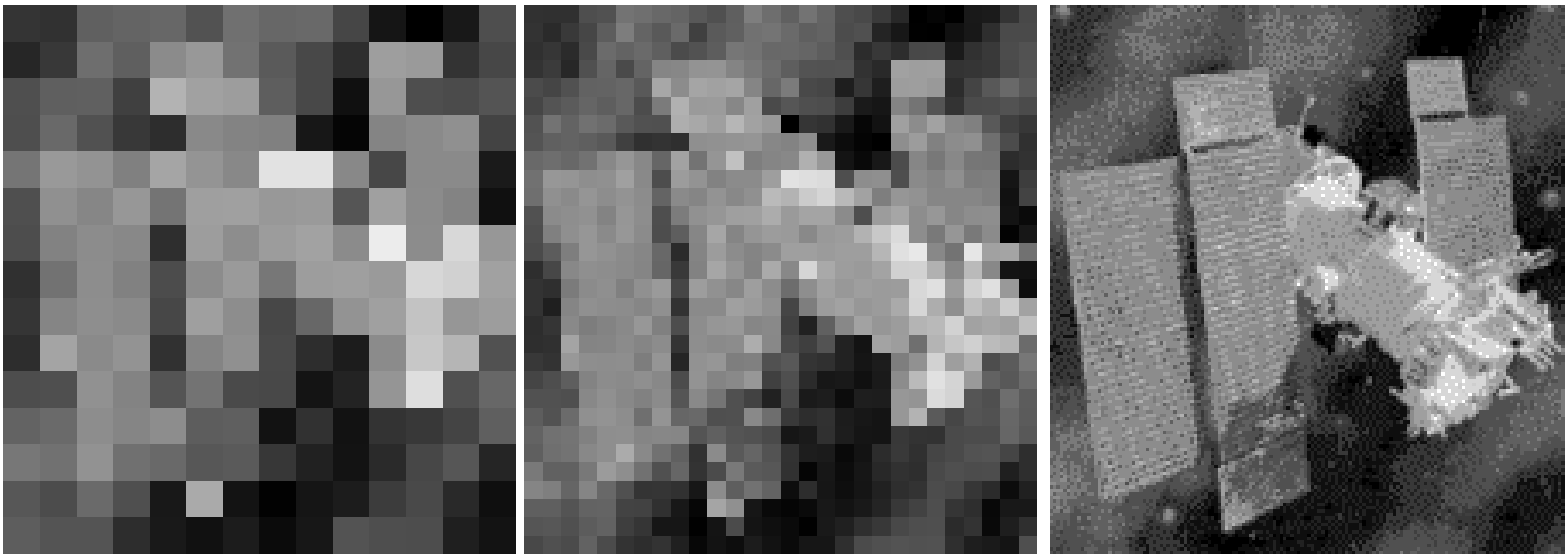


100 nrad

Resolution improvement from using aperture synthesis over 100m baselines.

GEO Imaging

Interferometers can detect, recognise, and identify small objects at GEO orbit. Baselines of 1,000m are feasible within this decade. The frames below simulate a 10m GEO satellite imaged by apertures up to 1,000m.



100m 200m 1,000m

GEO Orbit Protection

Improved electro optic surveillance, with both tracking and imaging to decimetre levels, will provide information on deployment, maneuver, and collision risk.