SLR Graz: Laser Ranging to Space Debris Objects

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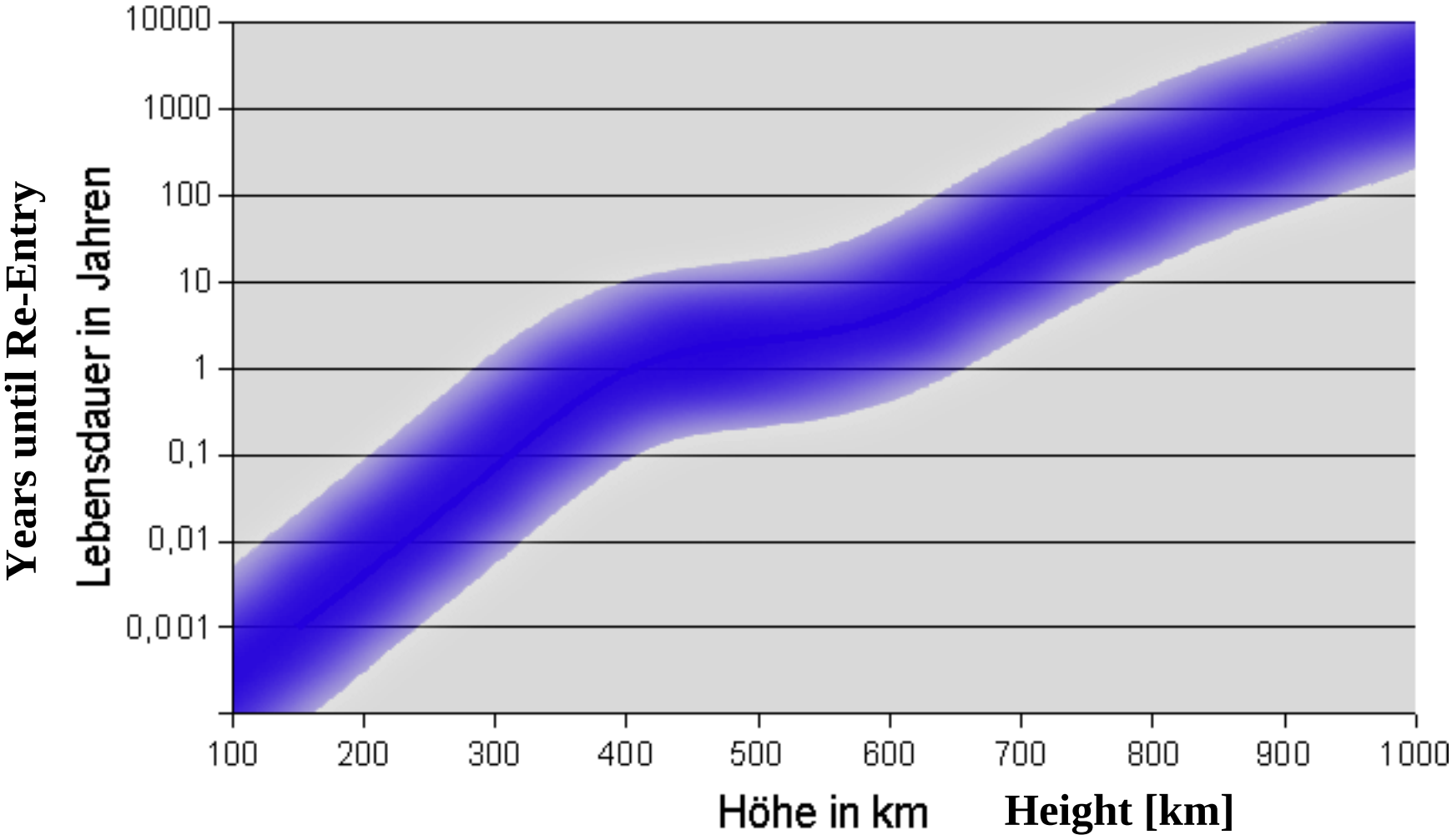
Overview

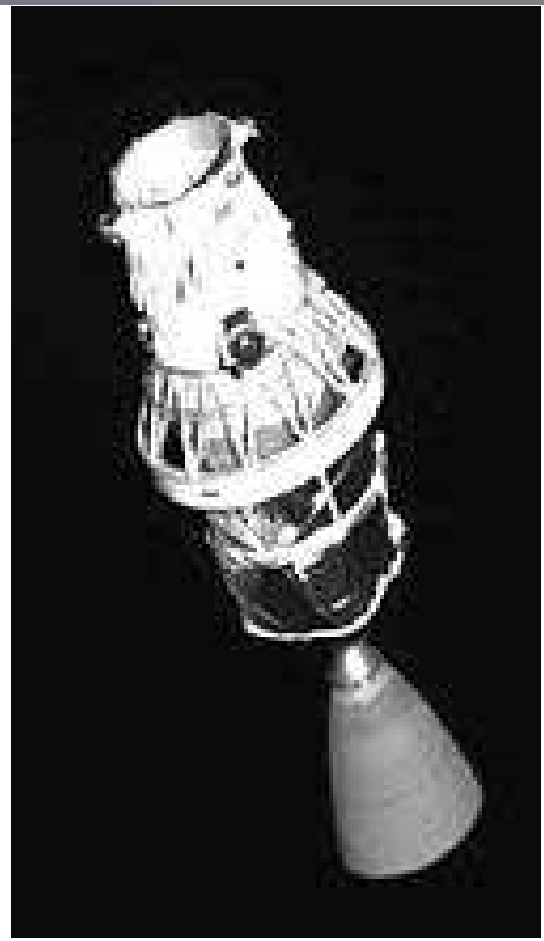
- General Space Debris Info
- Changes / Upgrades at SLR Graz for Space Debris Ranging
- First results in Graz, experiences
- ‚Bistatic' Laser Ranging to Space Debris
- Application of the resulting data
- Chances for SLR stations

General Information about Space Debris 3/3



- Life Time of Space Debris; Source: Wikipedia

General Information about Space Debris 2/3



- About 5000 launches since *Sputnik-1*
- About 1000 active satellites now
- More than 1000 inactive / dead satellites
- About 20.000 space debris objects tracked with radar
- > 600.000 objects with > 1 cm (estimated);
  - Due to collisions, explosions etc.
- > 80% of that in LEO orbits
- A few more collisions, and these orbits are unusable
- Space Debris in LEO orbits will remain there for long times …

- *Conclusions: Space Debris is a serious threat to all space missions; the most populated / endangered zone are LEO orbits (600-900 km)*
- THIS IS A REGION FOR SLR RANGING TO SPACE DEBRIS !!!

Changes / Upgrades at SLR Graz for Space Debris Ranging

LASER:

- Stronger laser; on loan from DLR Stuttgart:
- DPSSL; **25 mJ / 1 kHz / 10 ns / 532 nm**

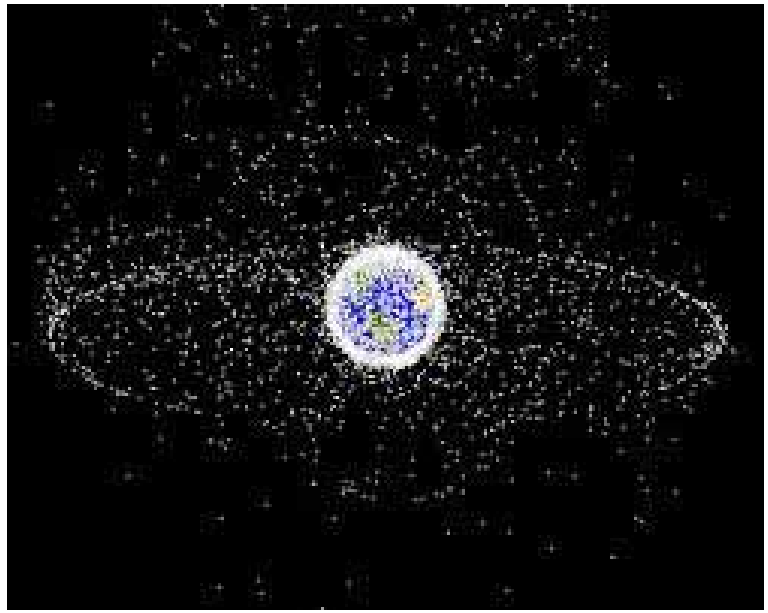
Detection package:

- New SPAD detector (SAP 500):
  - 500 µm diameter; passive quenching
  - 10 kHz dark noise, > 50% Q.E. @ 532 nm

Software:

- TLE => CPF conversion
- About 300 Space Debris objects added to tracking list
- Acquisition / Identification routines for 10 ns pulses
- Enhanced Overlap Avoidance routines etc.

STRATEGY



TLE (Two Line Element) predictions are not accurate:

up to ± 1 s time bias, up to ± 1 km range bias;

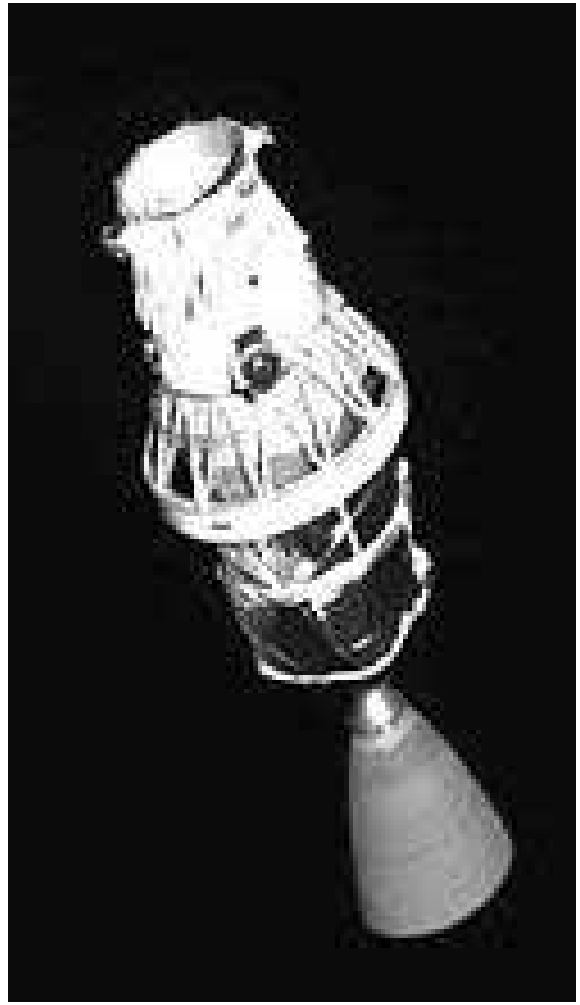
therefore:

- Only passes at early evening tracked;
  with debris objects in sun / Graz in darkness
- Satellites are then visible in our ISIT camera,
  TB/RB estimated in Real Time
- About 1.5 h per evening session available
- Only objects in stable, near circular orbits selected
- Overlap avoidance region had to be increased significantly:
  - Strong backscatter, lasting for > 500 µs (> 75 km distance)
    (instead of < 100 µs for Graz 0.4 mJ laser)

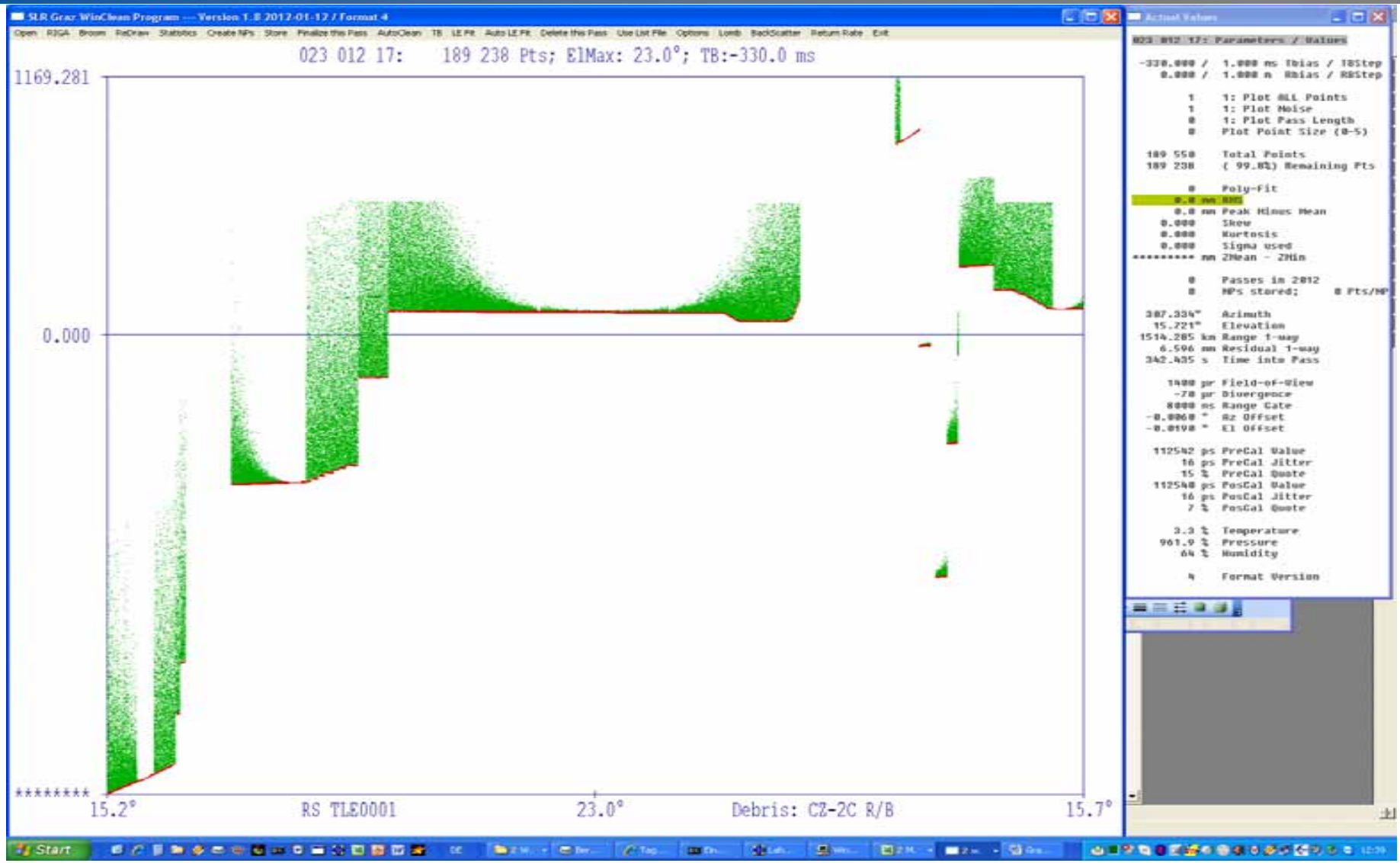
RESULTS

First Space Debris Laser Ranging in Graz: January 2012

- 85 passes from 43 different objects measured in 13 sessions, each ≈ 1.5 h (early evening)
- Distances from 600 km to > 2500 km
- RCS (Radar Cross Sections): From > 15 to < 0.3 m^2
- Ranging precision: ≈ 0.7 m RMS for most objects
- Difficult tracking due to low accuracy orbits ….

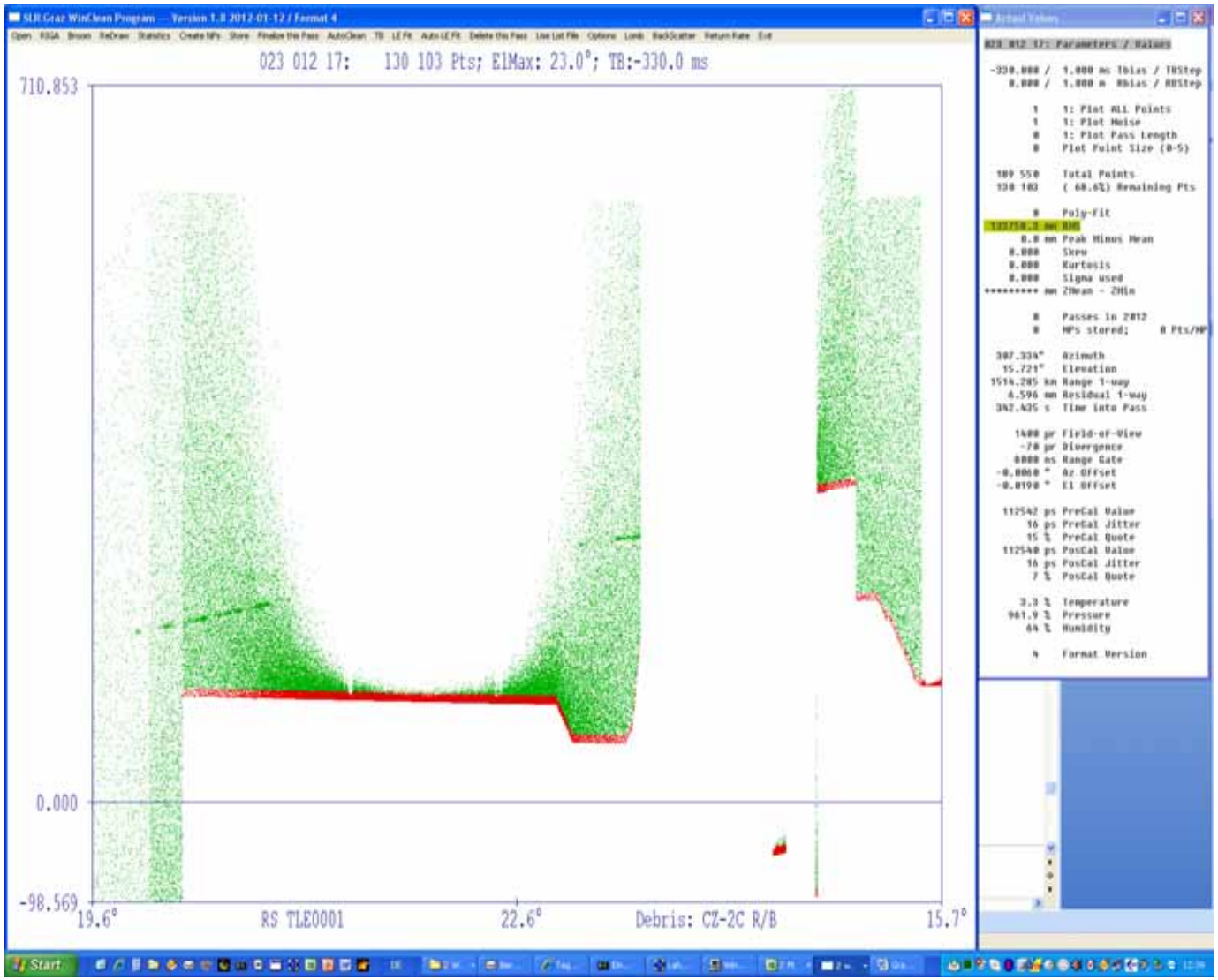


Graz Space Debris Measurements: First Example (12. Jan 2012)



- One of the first results; But: WHERE are the returns from the rocket surface ???

Space Debris Measurements in Graz: A closer look ….



CZ-2C-R/B:

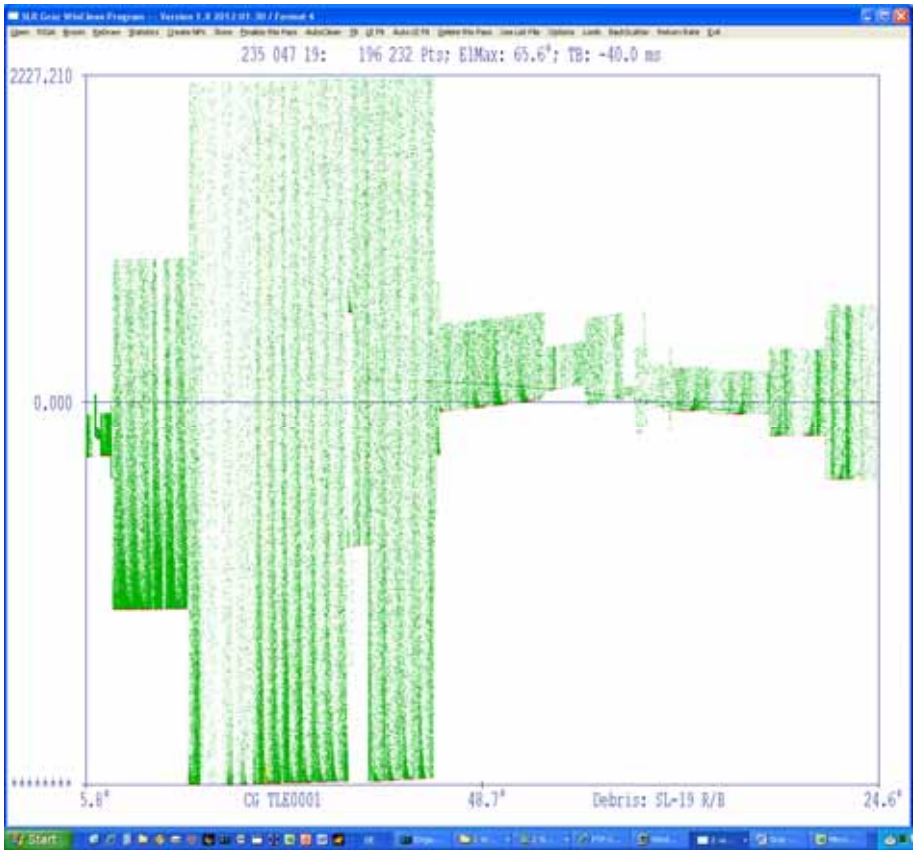
- Rocket Body
- Big RCS: 12 m^2
- Launched 2004;
- In 600 km Orbit

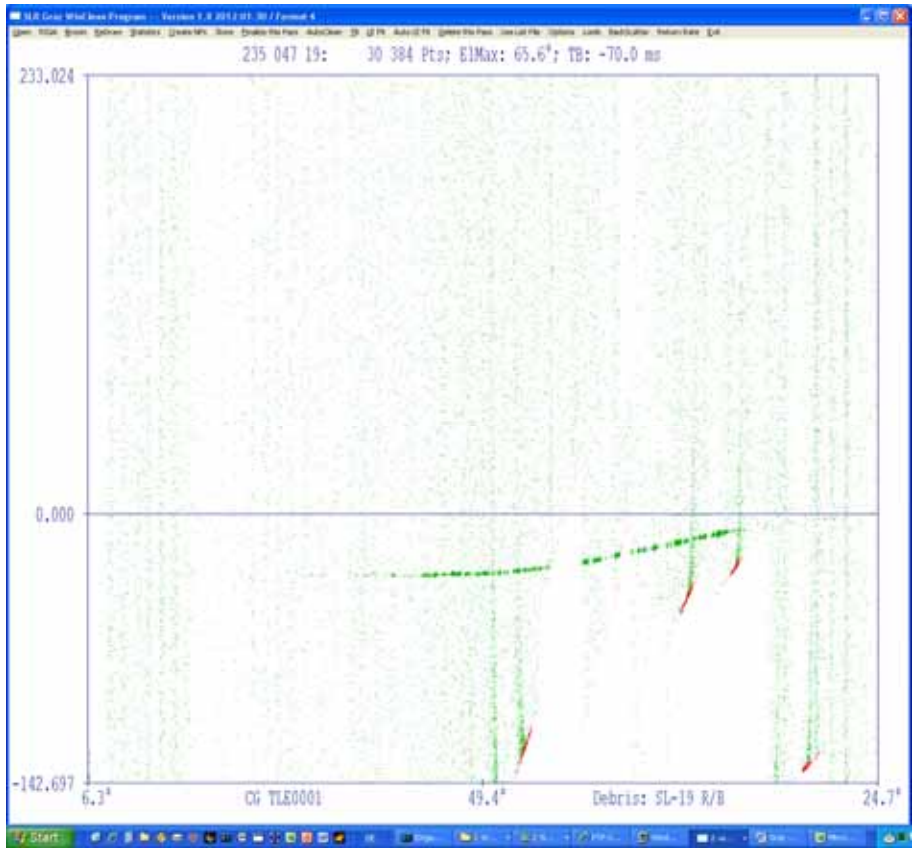
(RCS:

Radar Cross Section)

- Now the track is visible; about 1400 km distance: First nice success …

Space Debris measurements in Graz: New detection system developed





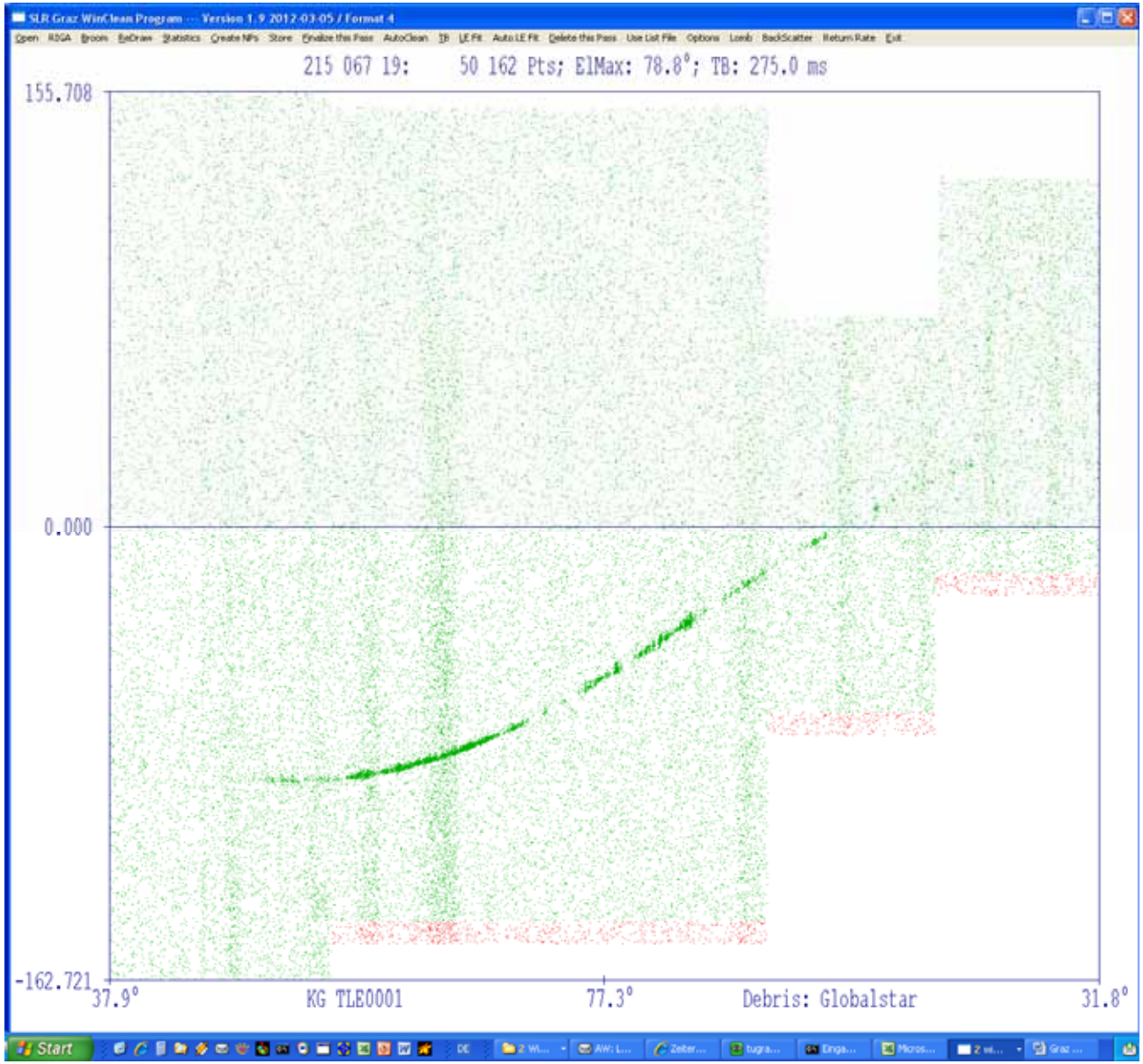
SL-19 R/B: Last stage of a small rocket, relatively small RCS (2 m^2);

2500 km to 1700 km distance

Time Bias: -66 ms; Range Bias: -60 m

Relatively nice orbit predictions – we have seen much worse offsets ☹ ☹ ☹

Space Debris Measurements in Graz: New detection system developed

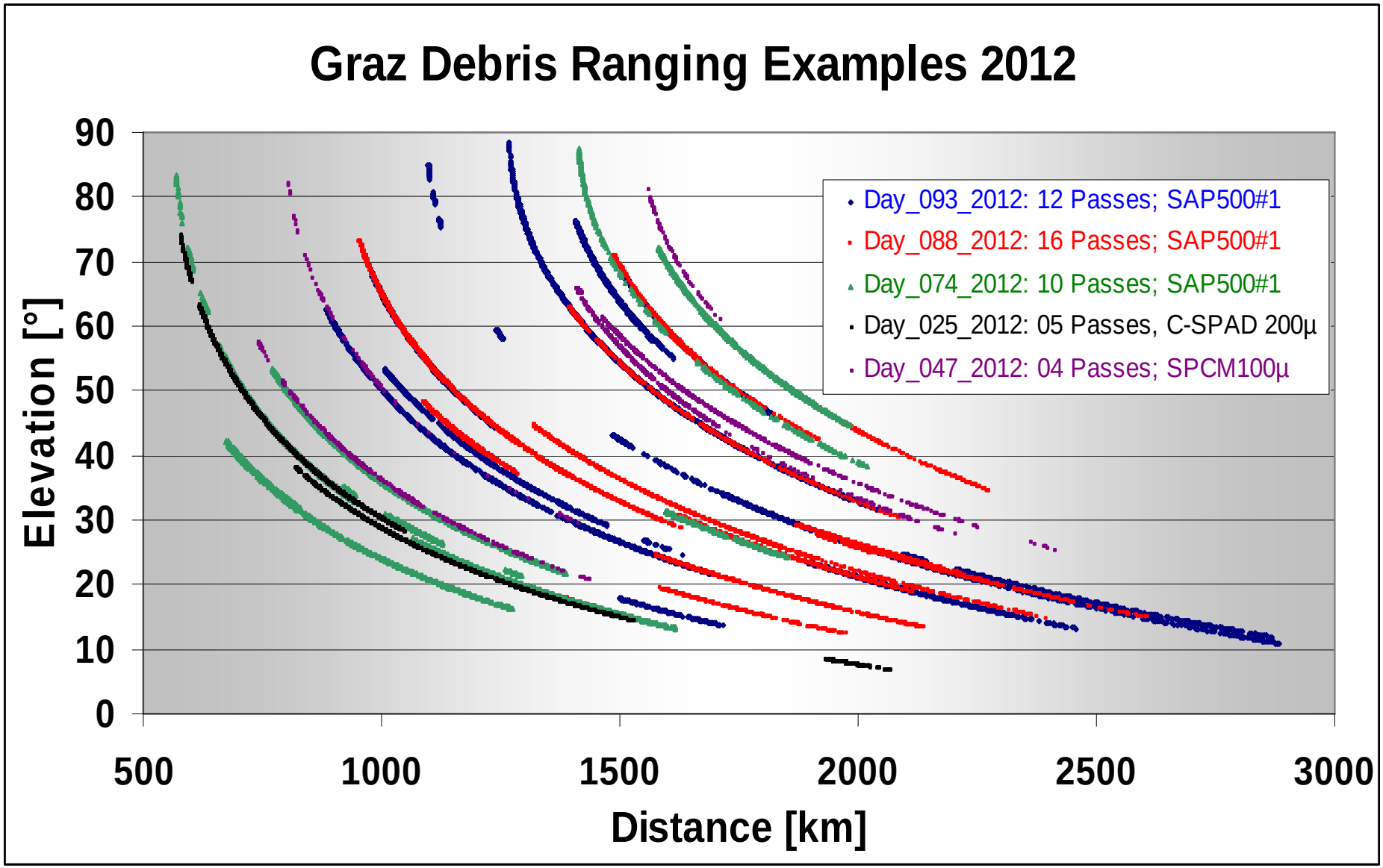


Globalstar M001:

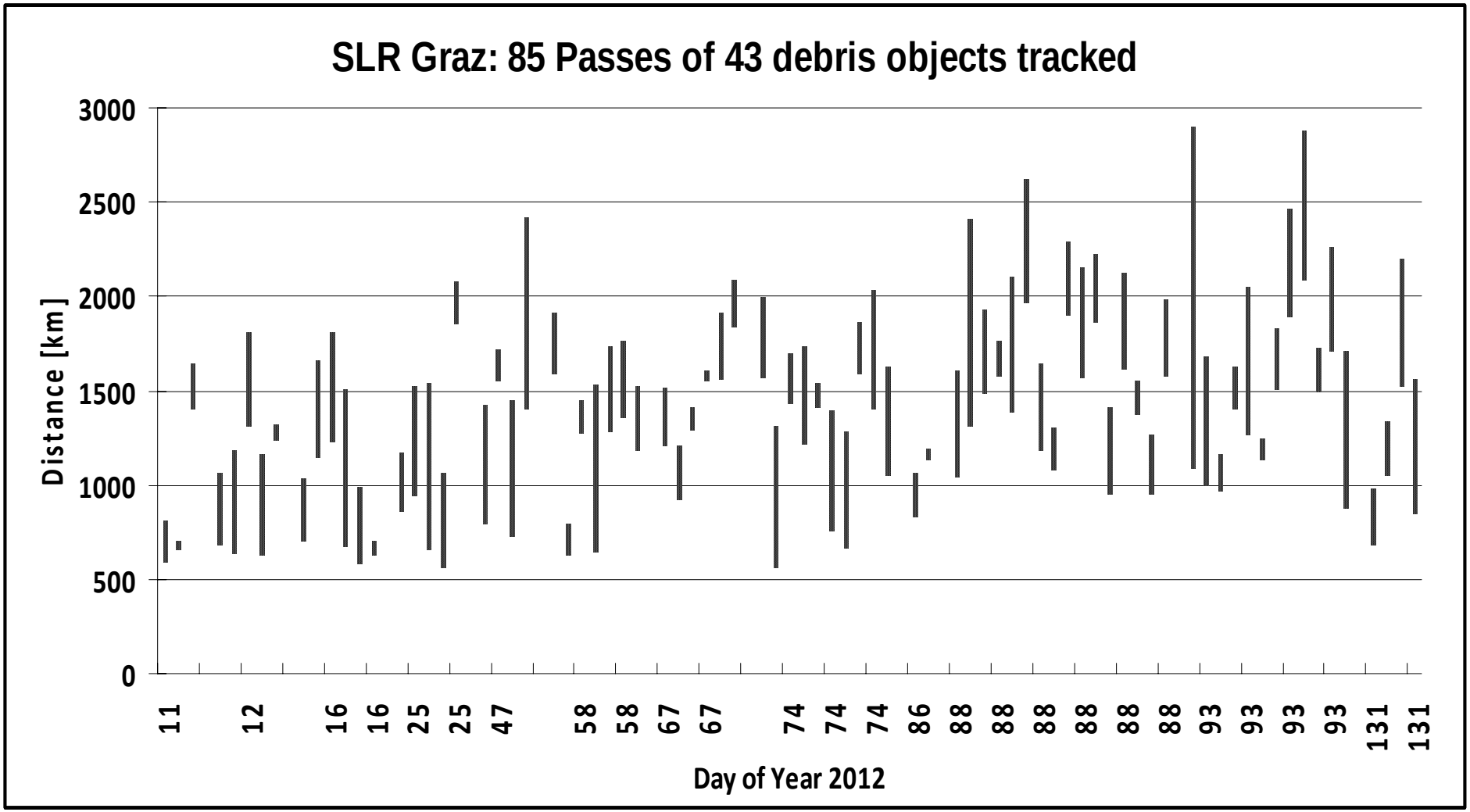
Old satellite

- RCS: 2 m^2
- Launched 1998;
- In 1516 km Orbit
- > 6000 Echoes
- 1550 -2050 km distance (slant range)
- Full pass tracked: Allows better orbit calculations

Space Debris Measurements Graz: Elevation vs. Distance



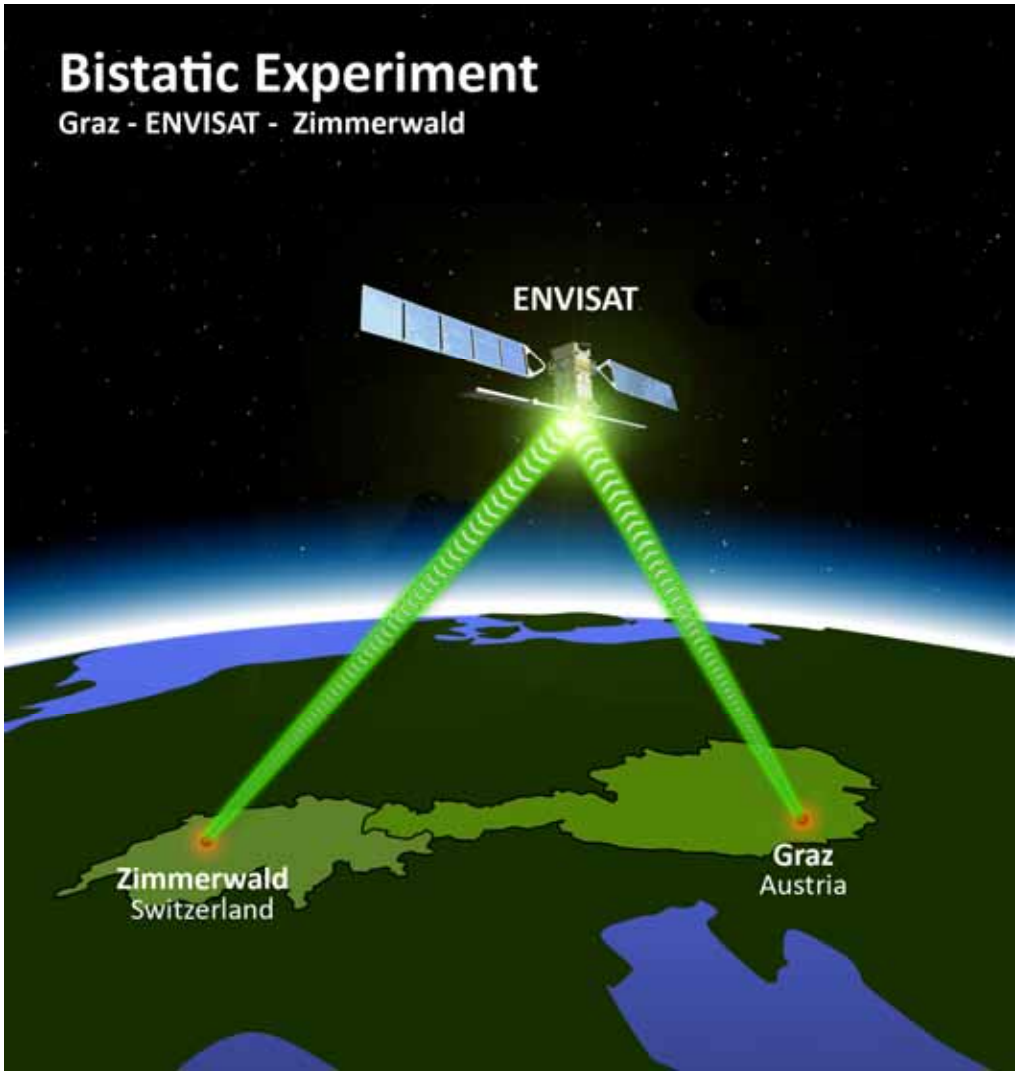
Space Debris Measurements Graz: Complete Statistics



Complete statistics of 3 months Graz Space Debris Ranging: Jan. 2012 – March 2012

13 early evening sessions, each ≈ 1.5 h;

Space Debris Measurements in Graz: Bistatic Experiment

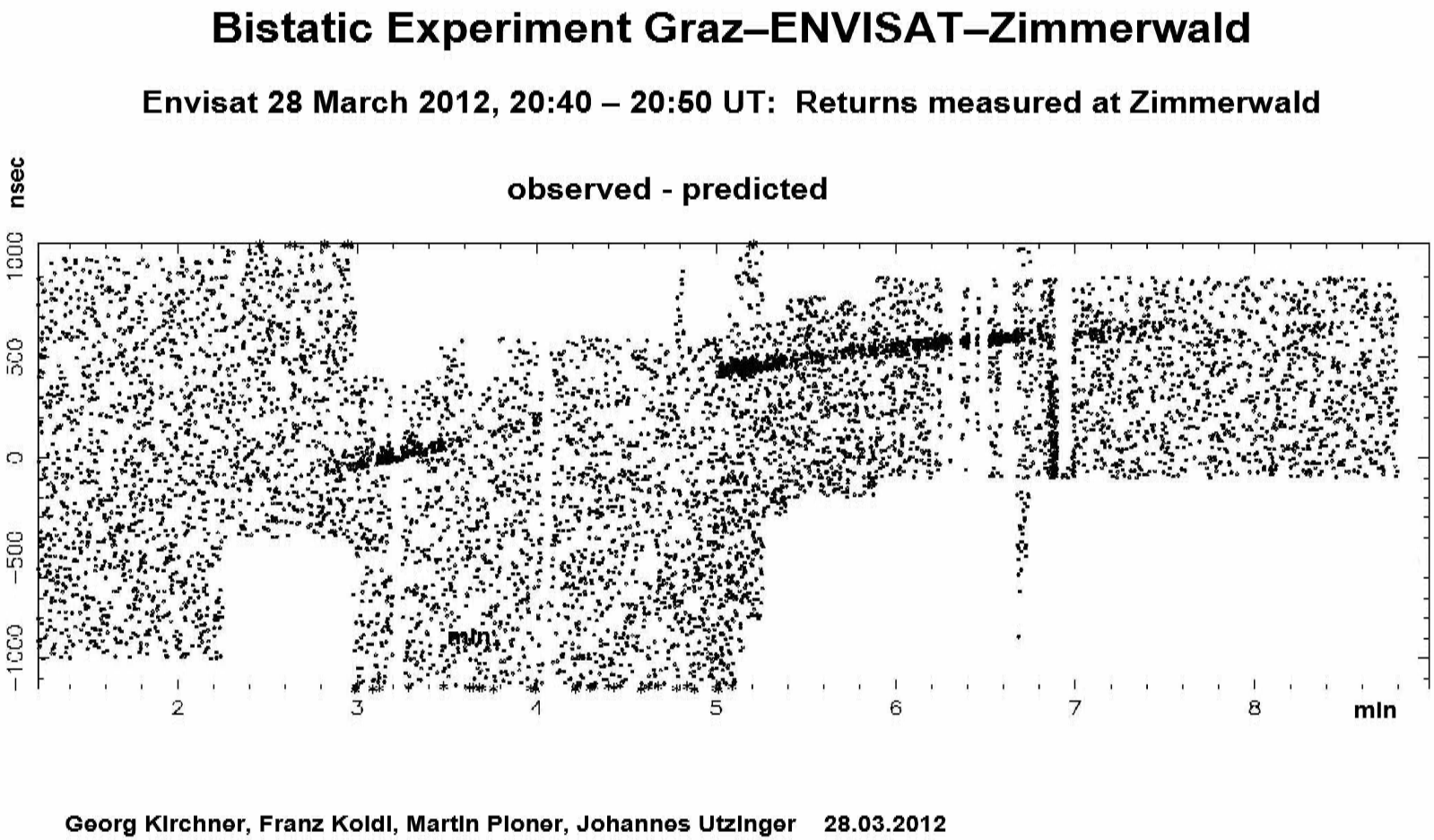


Bistatic Experiment

- Graz fired with strong laser to ENVISAT
- SLR Station Zimmerwald / Swiss:
    - Synchronized to Graz SLR station
    - Graz Photons detected in Zimmerwald
    - (reflected from satellite body)
- Both distances measured with sub-m:
    - a) Graz – ENVISAT
    - b) ENVISAT – Zimmerwald

- Due to diffuse reflection:
    - Possible for additional (SLR) stations
    - Allows triangulation …
    - Accurate orbit determination

Space Debris Measurements in Graz: Bistatic Experiment



Graz Photons received / detected in Zimmerwald

Conclusion 1: A promising method …

- Laser Ranging to Space Debris: Can improve Space Debris orbit predictions

  - Allows significant improvement of orbit predictions for selected debris targets
  - Multiple participating SLR stations: Even better orbits, solves weather problems…
  - Bi-Static / Multi-Static Debris Laser Ranging: => High accuracy orbits
    - Possible SLR stations with common-view possibility for LEO debris: e.g. Graz – Zimmerwald – Wettzell – Potsdam
    - High potential for additional / distributed / automatic receive-only telescopes
    - With 2 or 3 ‚firing' stations, and several such passive stations, all weather problems could be at least minimized …
  - Much cheaper than big radar stations (at least 1 order), ranges to 2500 km and more…

- Laser Ranging to Space Debris: Should also allow to *measure debris spin / tumbling*
  - Only few passive optical tests done (in Japan) to determine spin motions
  - With *Satellite* Laser Ranging, it is a ‚side effect'; done for many satellites in Graz …
  - With *Debris* Laser Ranging, we have a good chance for debris spin determination, too …

Conclusion 2: A new chance for SLR stations …

- An expected scenario:
  - Radar stations (U.S. Space Surveillance Network; TIRA near Bonn / Germany etc.) predict close approach between active objects / space debris (few days in advance)
  - Multiple SLR stations (those capable of tracking space debris) track these targets
  - The resulting data can be used to calculate a more precise orbit / collision scenario;
  - Based on these results, better collision-avoidance maneuvres can be scheduled - or omitted (saving fuel, increasing life time etc.)
  - With more stations participating: Less weather problems, better orbits
- Bi-Static / Multi-Static Debris Laser Ranging: => High accuracy orbits
  - Possible SLR stations with common-view possibility for LEO debris: e.g. Graz – Zimmerwald – Wettzell – Potsdam
  - High potential for additional / distributed / automatic receive-only telescopes
  - With 2 or 3 ‚firing' stations, and several such passive stations, all weather problems could be at least minimized …
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Conclusion 3: A new chance for SLR stations …

Laser Ranging to Space Debris: Should allow to *measure debris spin / tumbling*

- Only few passive optical tests done (in Japan) to determine spin motions
- With *Satellite* Laser Ranging, it is a ‚side effect'; done for many satellites in Graz …
- With *Debris* Laser Ranging, we have some chance for debris spin determination, too …

Conclusion for Space Debris Ranging with SLR stations:

- It is an extremely actual theme …. Fatal collisions already occured; more are expected …
- For SLR Stations: A lot more targets are on the sky ….
- For SLR Stations: A lot more chances / opportunities to get some money ☺


Thank you ! ☺