Ground to Space to Ground Time Transfer over non-cooperative targets

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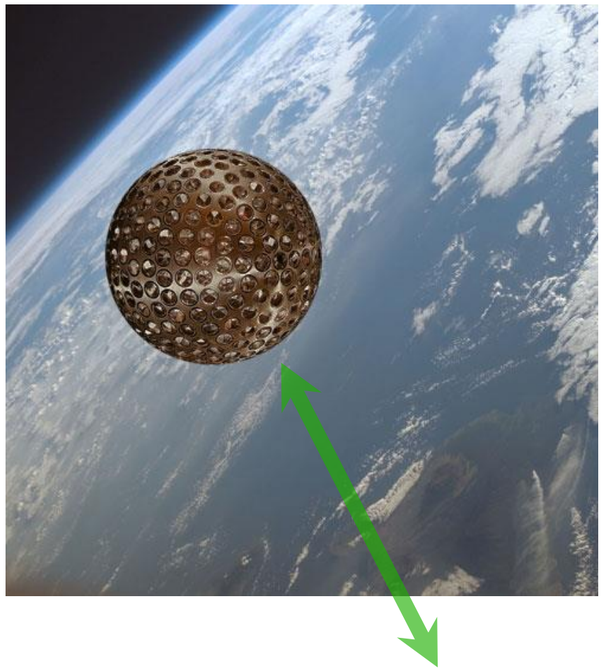
Satellite Laser Ranging provides the exact time of flight of ultrashort laser pulses for a ground to space link.



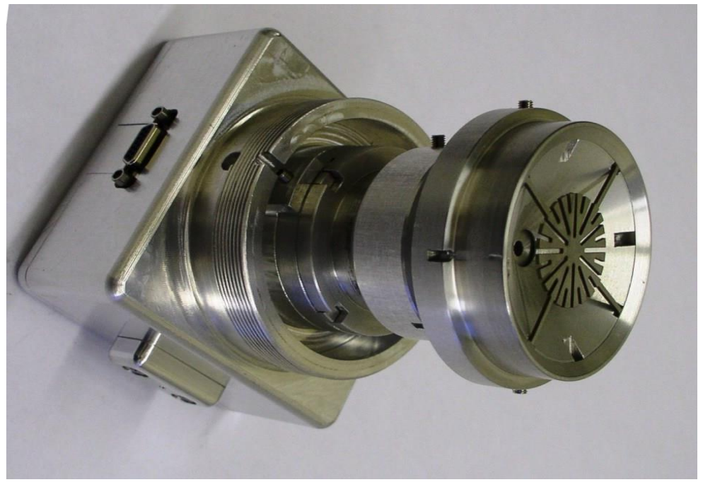
This allows time transfer between a single station on the ground and a suitable satellite.

Examples: T2L2 and the upcoming ACES

ELT Reflector

The reflector is required for the measurement of the 2-way path delay

The reflector reverses the direction of the laser beam, hence it is impossible to have more than one station detecting the laser pulse (unless there are closely collocated systems)

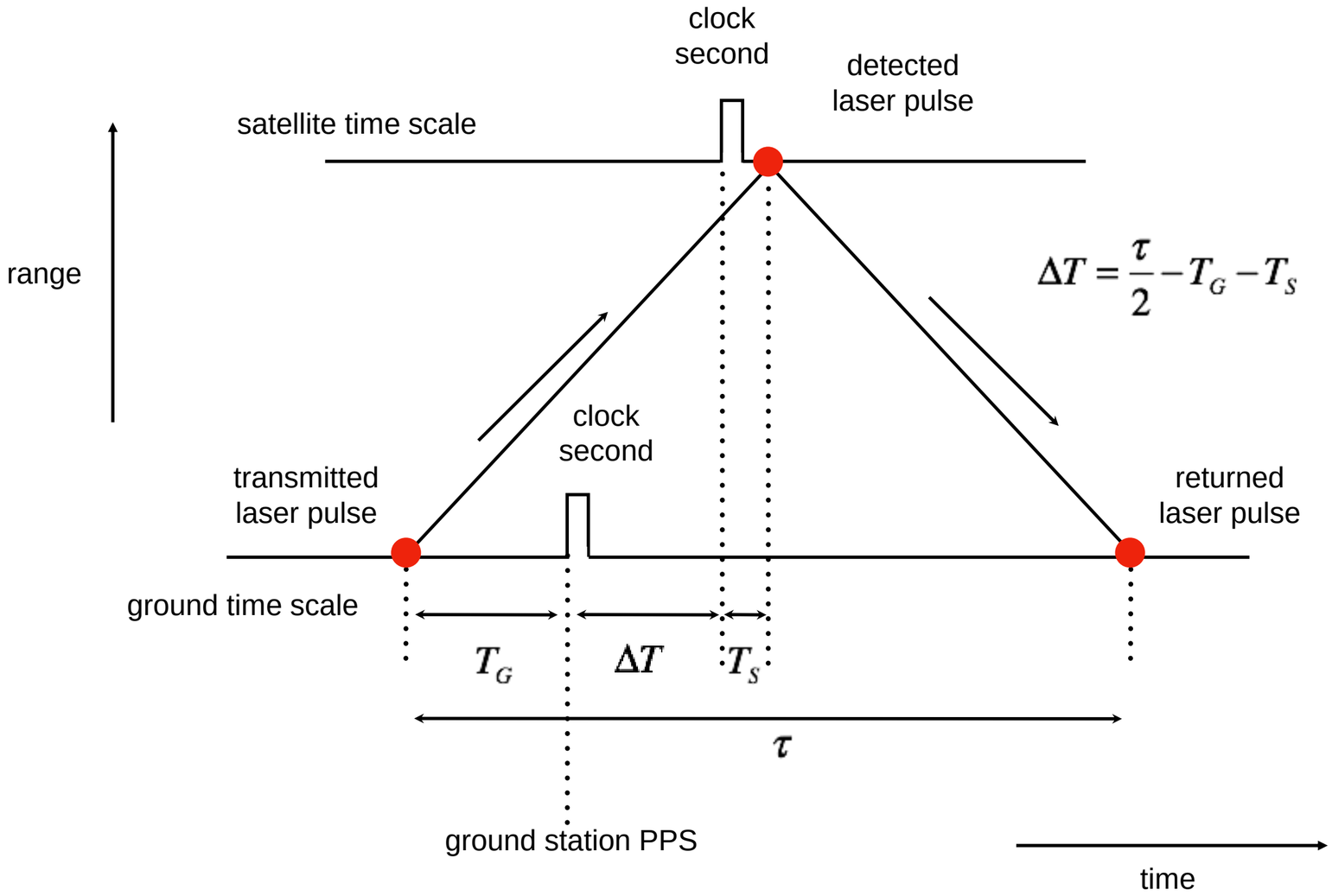


The photo-detector is required for the time tagging of the satellite clock

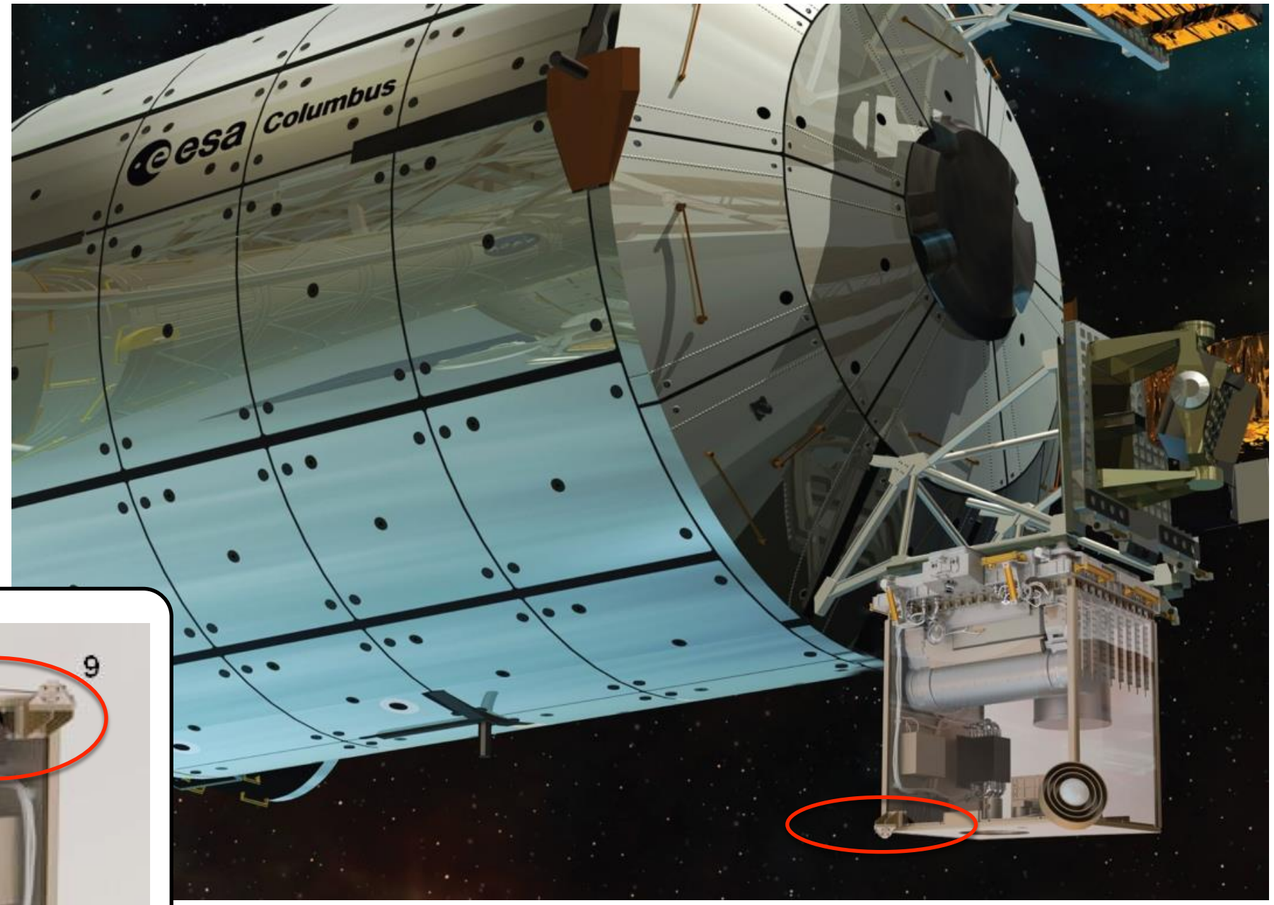
Photo-detector and reflector must be in close proximity

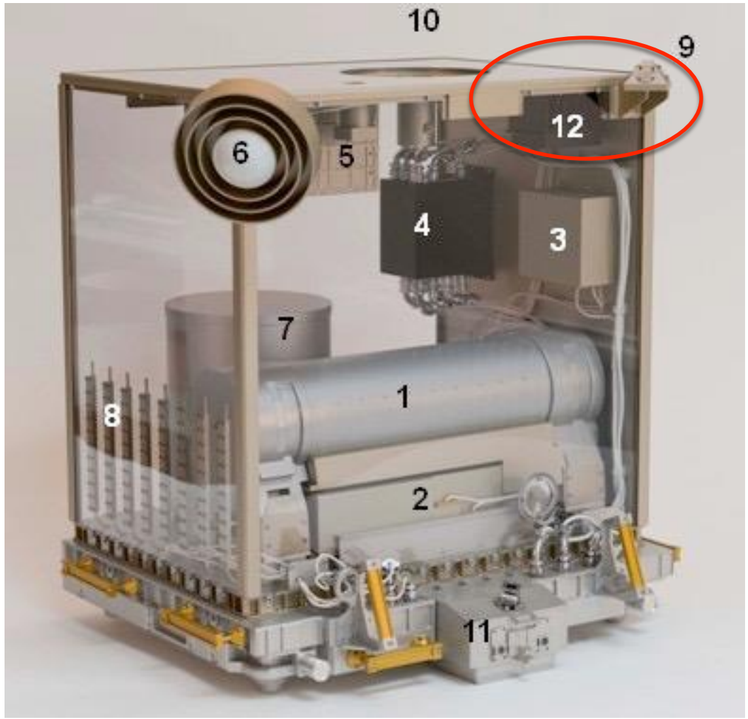
ELT Detector

Connecting a “local clock” to the world - The ACES mission



2WSTFT and ELT
are operated together





1. PHARAO Cesium Tube
2. PHARAO Laser Source
3. PHARAO computer
4. XPLC
5. MWL
6. GNSS Antenna
7. Space hydrogen Maser
8. Heat pipes
9. Laser corner cube reflector
10. MWL antennae
11. CEPA
12. ELT

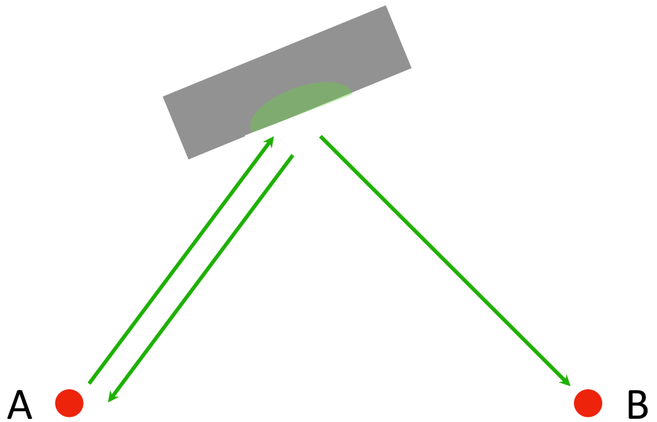
The payload has a volume of about 1m^3 and a mass of ~362 kg.

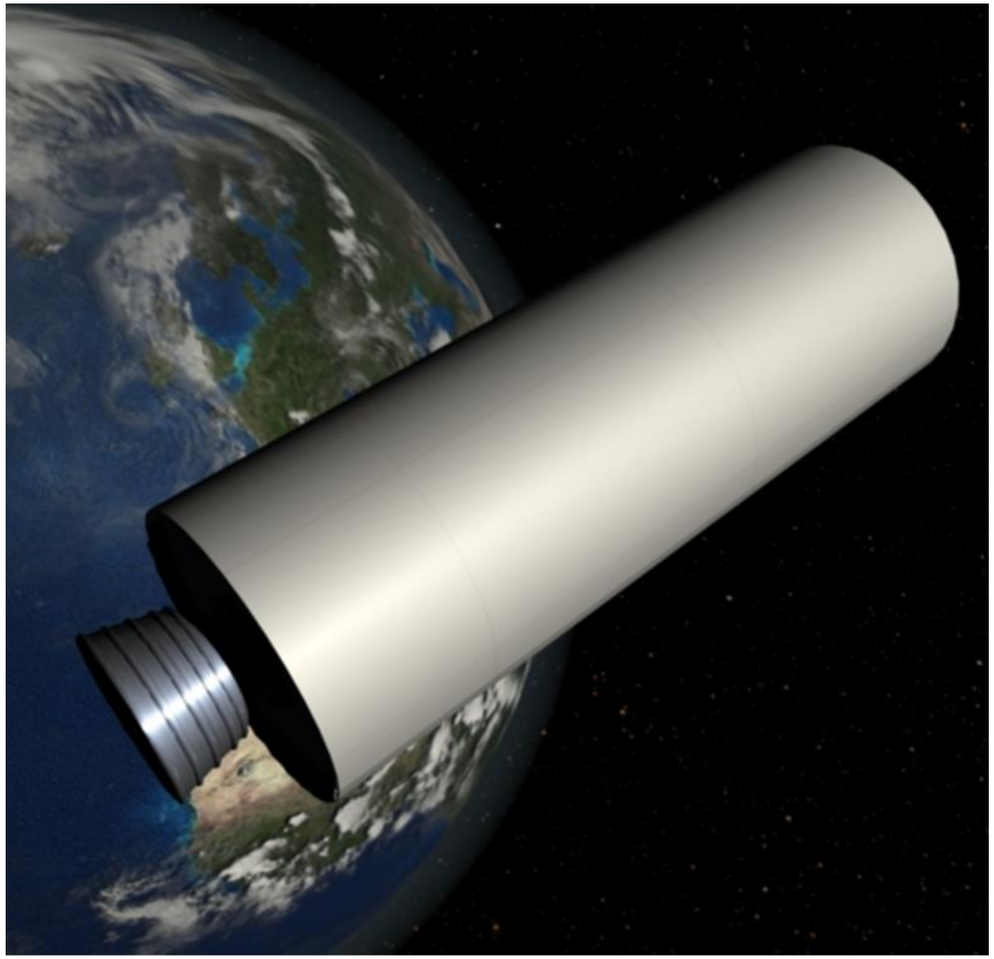
Space debris objects allow diffuse reflections and can be used to achieve time transfer between stations in common view on the ground

Each station performs 2-way ranging to the space object

In addition to that each station performs 1-way detection of the other stations

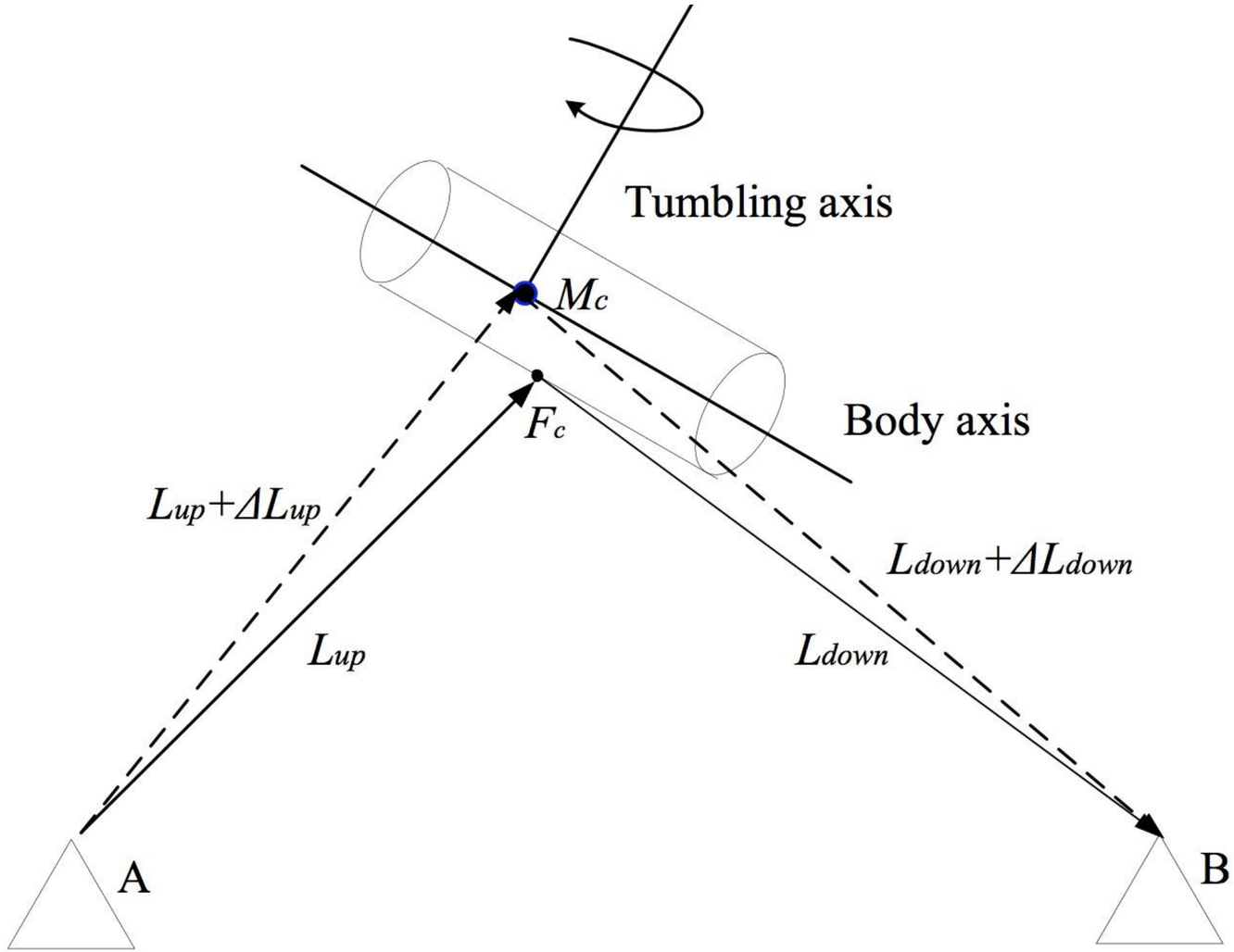
That is: 1 shot fired per station and 2 returns detected:





...and the same from B to A

In order to reduce the scatter, we need to model the tumbling motion:

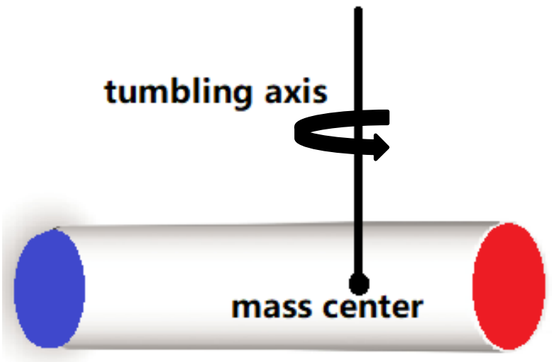


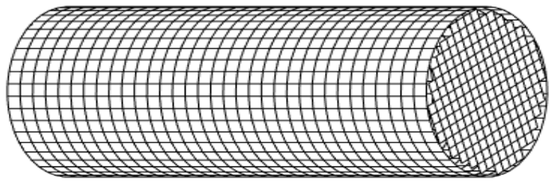
M_c mass center position

F_c the panels with max. surface radiance

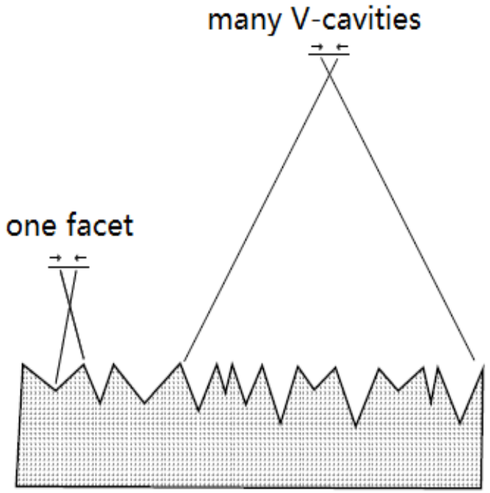
Assumptions for the Simulation:

1) The target is a cylinder
2) It is undergoing a uniform tumbling motion
3) The mass is unevenly distributed along the long symmetry axis and evenly distributed across the symmetry axis
4) (RA,DEC) of tumbling axis orientation are constant over a short time in inertial frame of reference
5) The true tumbling period is a constant over a short time
6) Diffuse reflection model



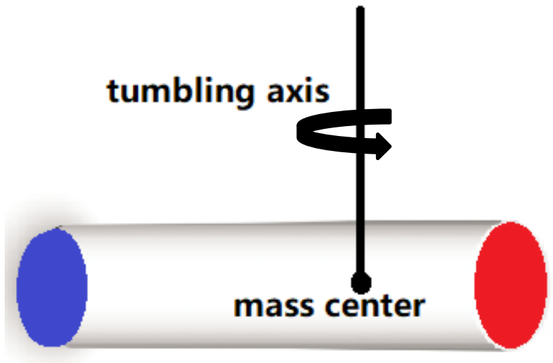


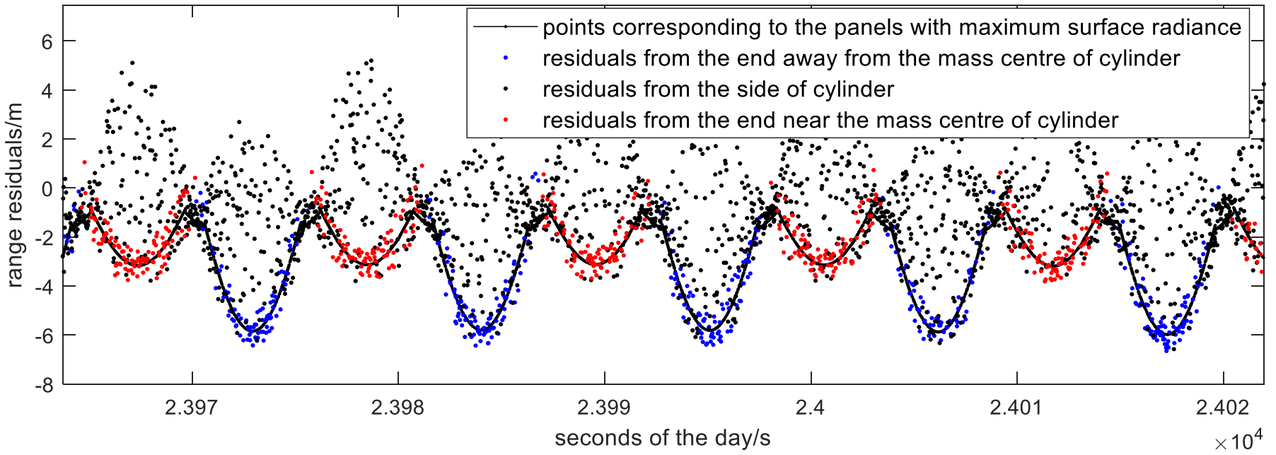
Surface is divided into many panels

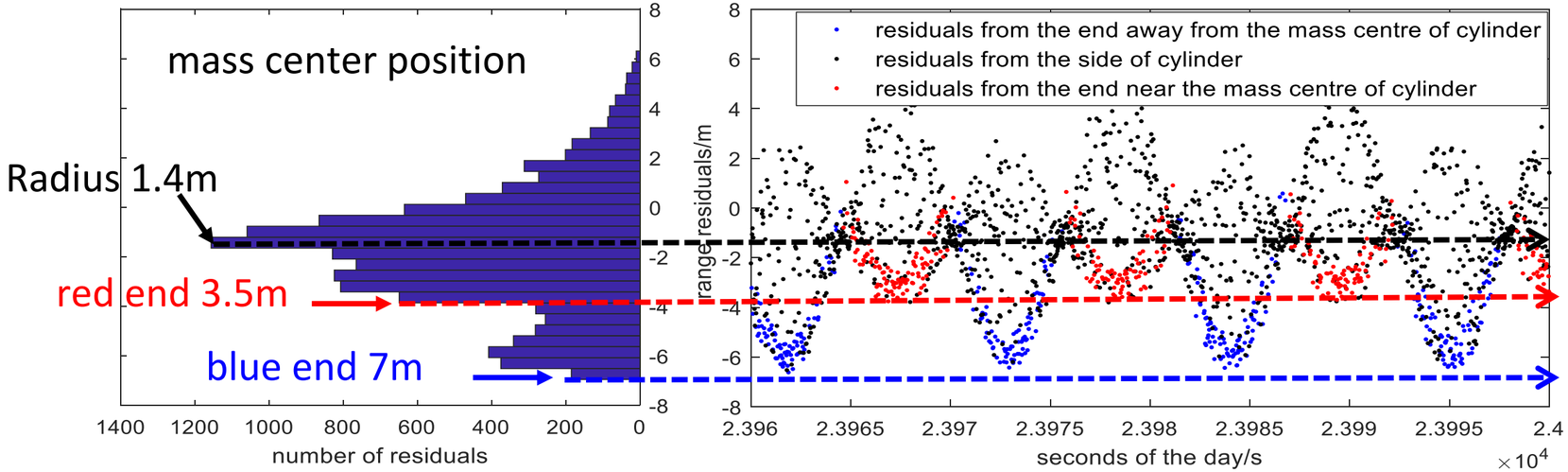


Each panel is composed of many V-cavities

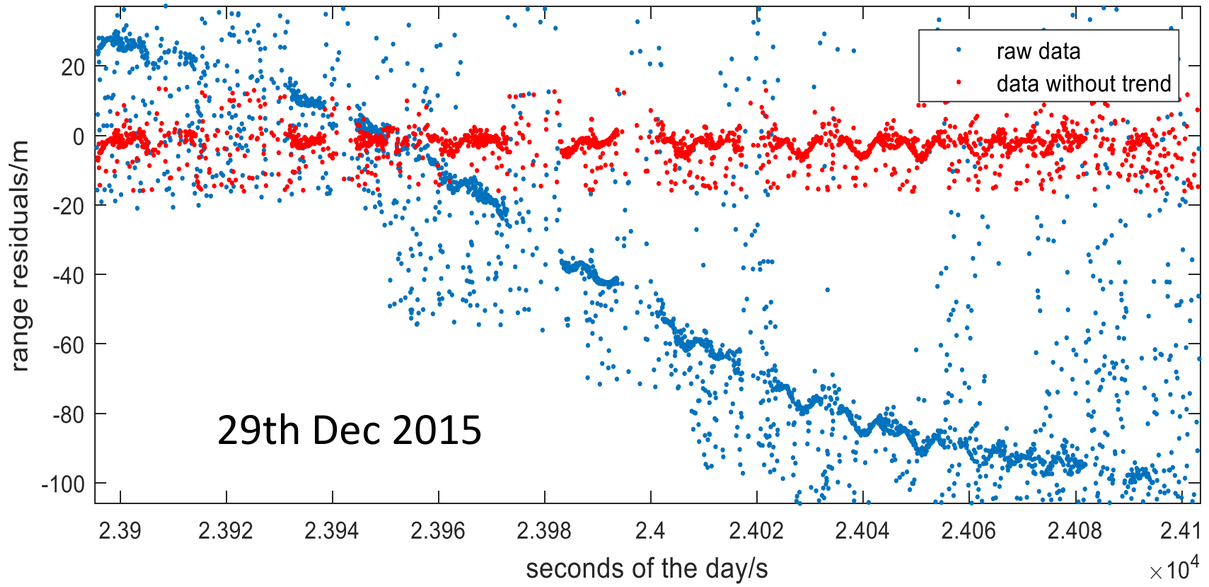
The reflectivity of two ends is larger than from the side of the cylinder
Radius=1.4m; mass center, 3.5+7=10.5m

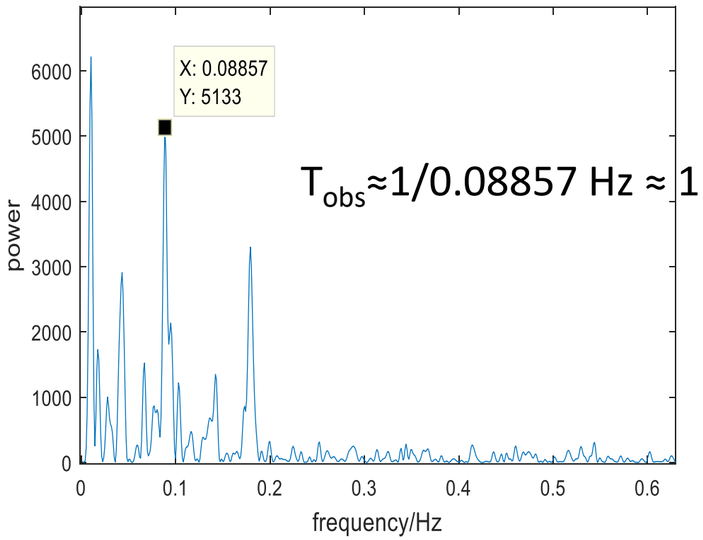




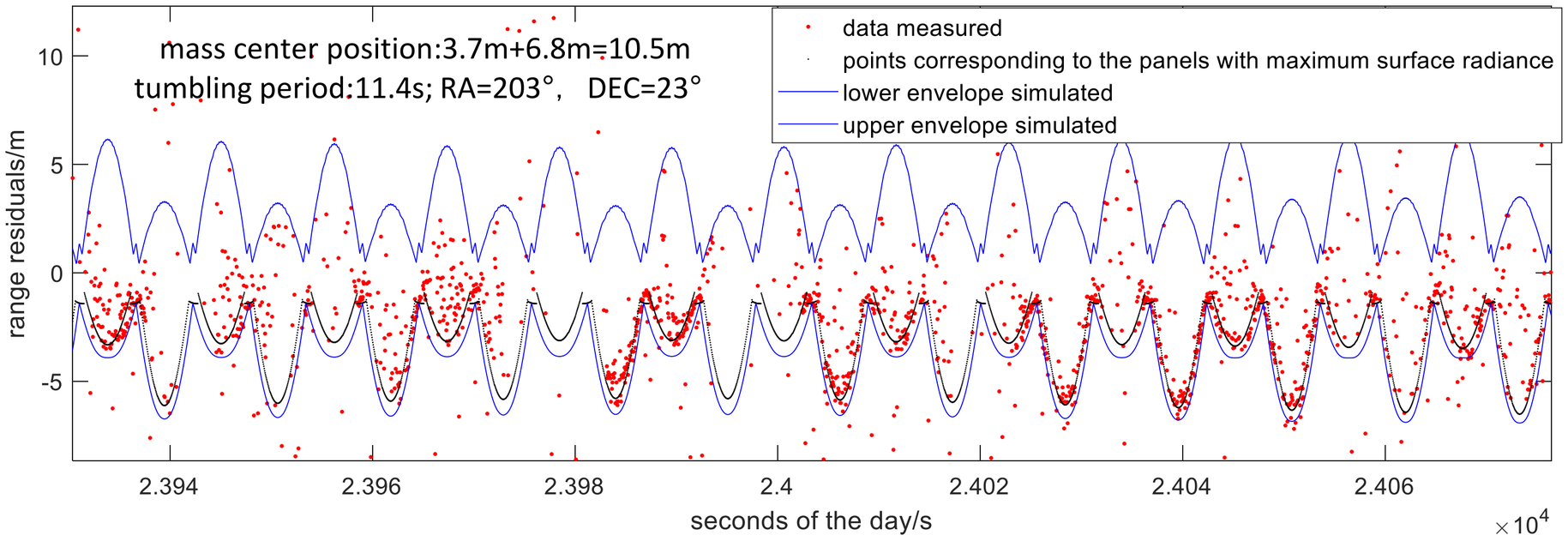


Residuals of 39679 measured by the Wettzell station （mono-static）





T_{obs}≈1/0.08857 Hz ≈ 11.3 s



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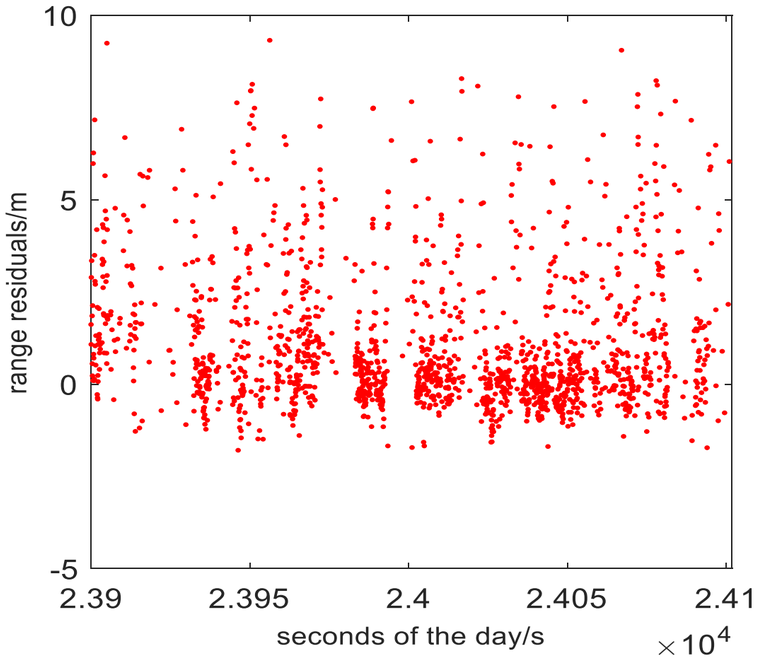
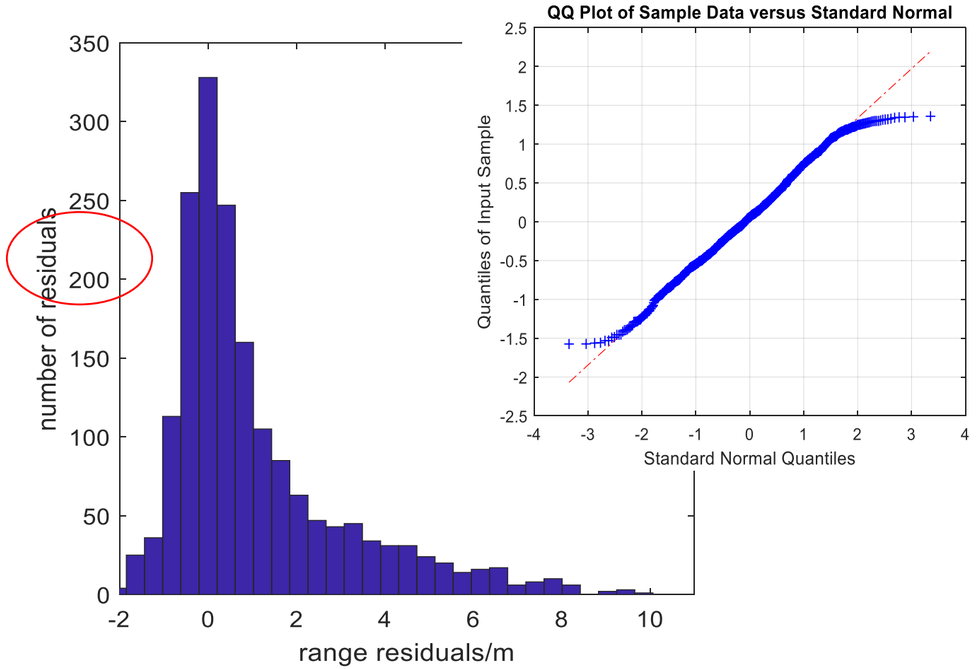
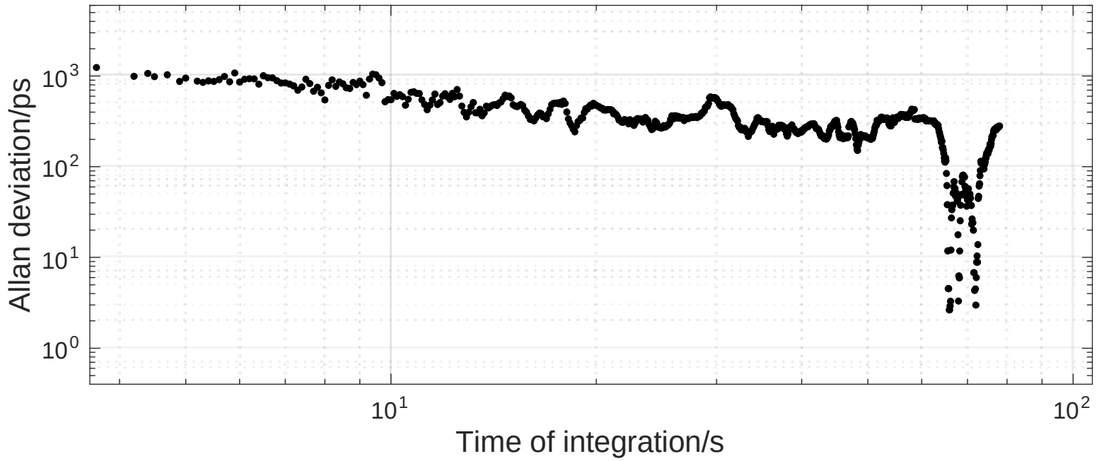
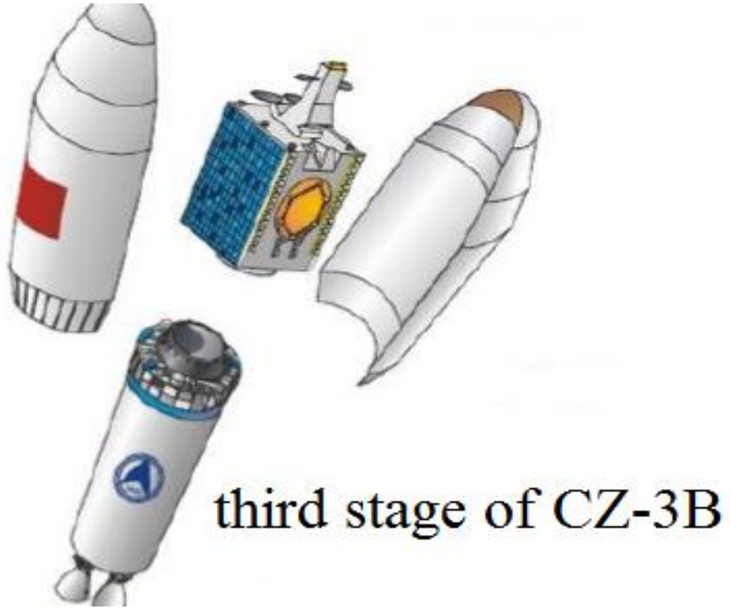
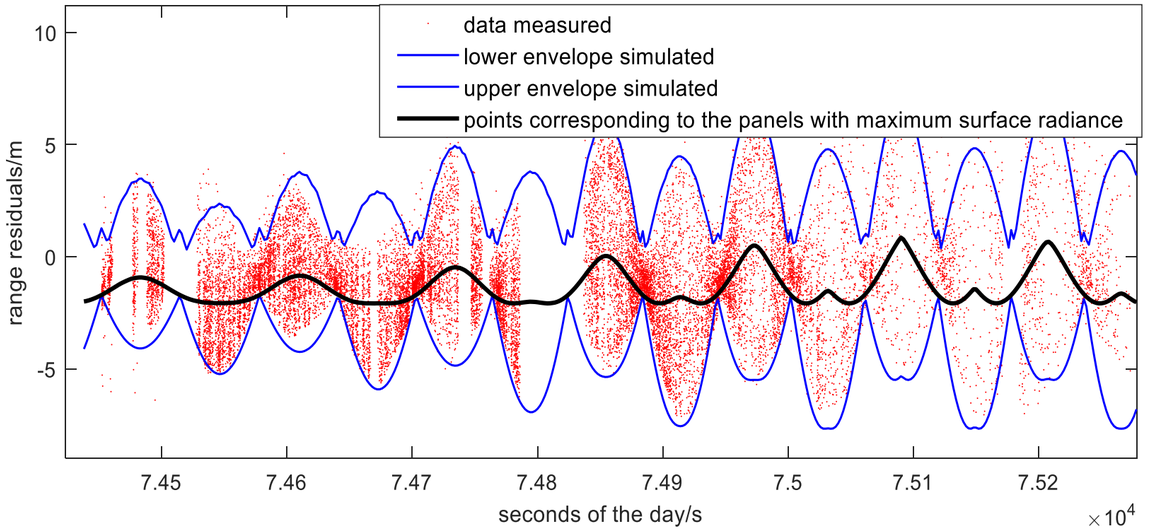






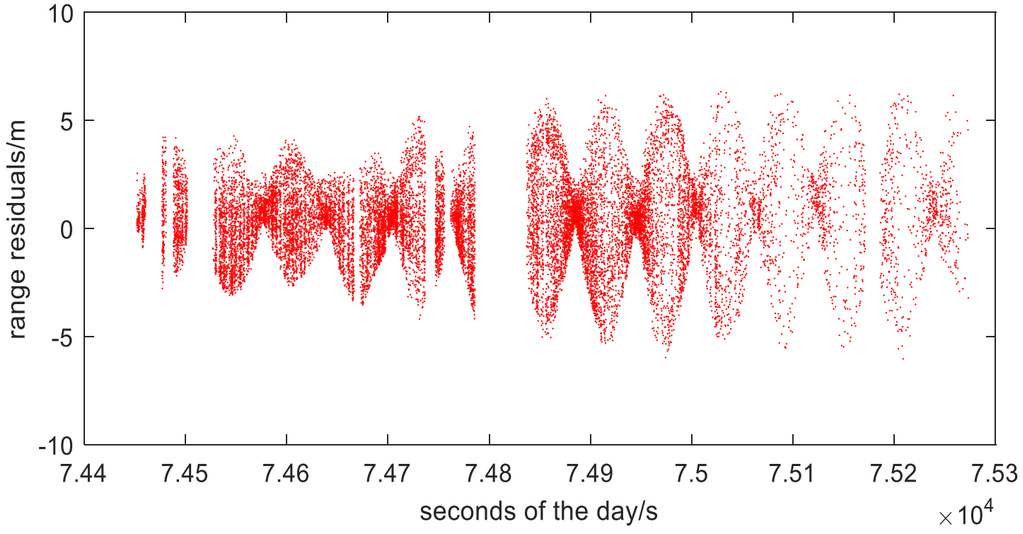
Residuals of 38253 measured by the Graz station （mono-static）

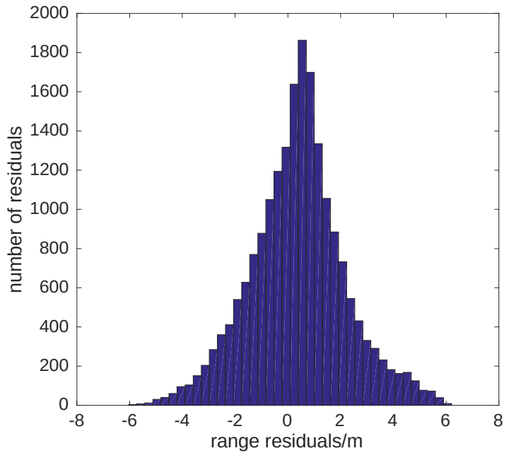




mass center position: 5.1m + 7.3 m = 12.4 m

tumbling period: 115.5s; RA = 20°， DEC = -34°





Summary:

- Time transfer via (suitable) space debris at the level of ≈100 ps appears feasible
- Mono-static ranging and modeling show promising results
- Bi-static time transfer (2 – stations in one location) are under test in Graz
- Model improvements to get a better tumbling attitude from light curves are the next step
- Final goal: Bi-static observations between Borowiec, Graz and Wettzell