Laser Ranging to Nano-Satellites in LEO Orbits: Plans, Issues, Simulations

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Objectives of Retros on Nano-Satellites

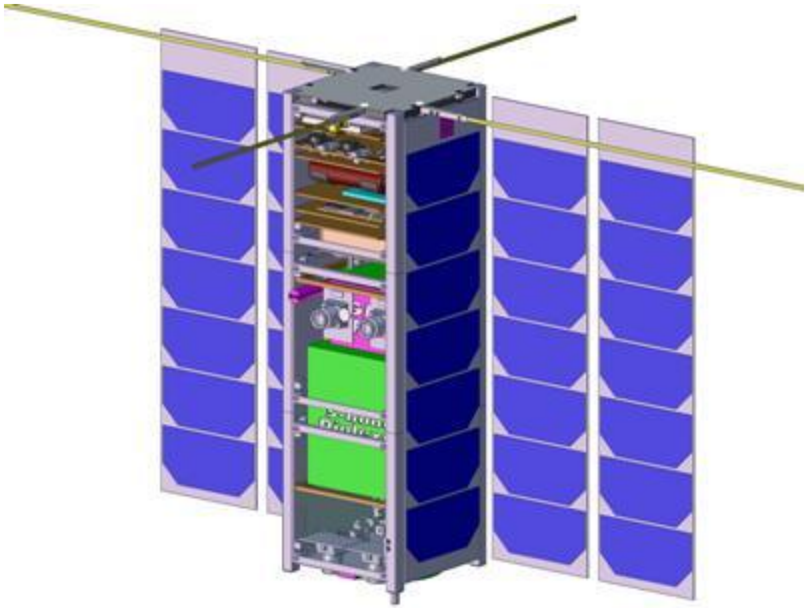
Planned Nano-Satellite missions:

- OPS-SAT	ESA	2015	600 km
- TechnoSat	TU Berlin	2015	≈600 km / TBD
- S-Net	TU Berlin	2016	620 km
- CubETH	ETH Zuerich	2016	≈450 km

Objectives for Retro-Reflectors / SLR:

- Independent POD, also after end-of-life
- On-orbit-verification of 0.5” (1.25 mm) or even 10 mm diameter COTS laser retro-reflectors
- Attitude determination using multiple laser retro-reflectors; verification of satellite attitude sensors via laser retro-reflectors

The OPS-SAT Mission



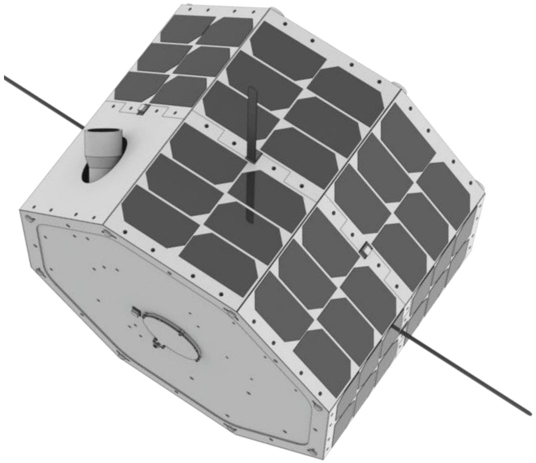
- Platform for Software Experiments
- Allows Exchange / Test of Software, including OS, File Transfers etc…
- Low-Cost mission; OTS parts
- Circular Orbit; ≈600 km; stabilized
- NanoSat: 30 x 10 x 10 cm
- On each side: One or more retros
- Each Retro: 10 mm or 0.5“
- Launch planned 2015

↓

Nadir Pointing

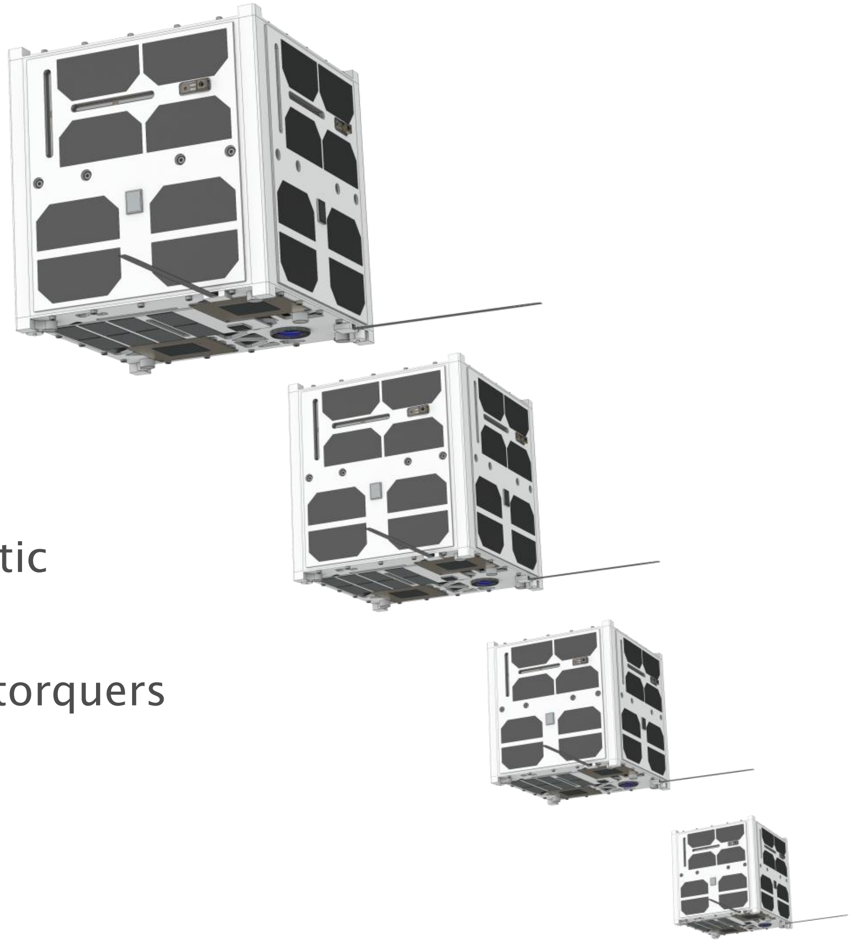
The TechnoSat Mission

Parameter	Value
Launch Date	2015
Design Lifetime	1 year
Mass	15 kg
Volume	400 $\times$400 $\times$300 mm (TBC)
Communication	UHF
ADC Sensors	Fibre-optic gyros, sun sensors, MEMS magnetic field sensors, MEMS gyros
ADC Actuators	Magnetic torquers
Payload	Several technology demonstration components, such as laser-retro-reflectors



S-Net: COM-Network of 4 satellites using S-Band

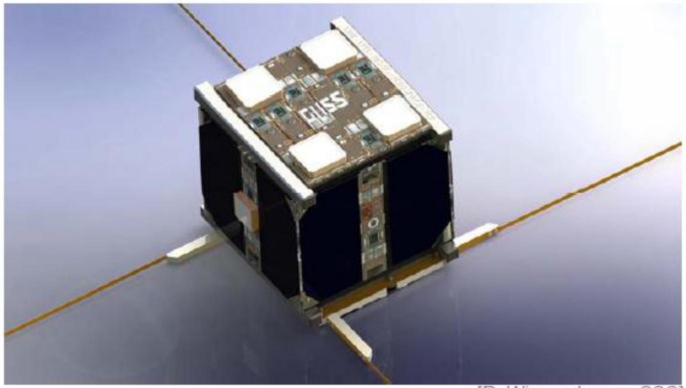
Parameter	Value
Launch Date	2016
Design Lifetime	1 year
Mass	8 kg (TBC)
Volume	240 ×240 ×240 mm
Communication	UHF
ADC Sensors	Sun sensors, MEMS magnetic field sensors, MEMS gyros
ADC Actuators	Reaction wheel, magnetic torquers
Payload	S-band transceiver, laser-retroreflectors, camera



ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

CubETH – Project overview and science goals

- Swiss CubeSat project
  - **Cooperation**
    - **ETH Zurich**
    - **Swiss Space Center EPFL**
    - **Universities of Applied Sciences (HSLU, HSR, HES-SO)**
    - **Swiss companies (u-blox, RUAG Space, Saphyrion)**
  - **Equipped with single-frequency GNSS receivers** (u-blox NEO-7N)



[R. Wiesendanger, SSC]

- Science goals
  - **POD (Precise Orbit Determination)**
    for a cube satellite based on single-frequency GNSS; post-processing and real-time
  - **Attitude determination**
    for a cube satellite based on single-frequency GNSS; post-processing and real-time (proof of concept)
  - **GNSS comparison and combination**
    with first GNSS receiver in space tracking GPS, GLONASS, QZSS, ready for Galileo and Compass
  - **Experimental measurements:**
    radio occultations, reflectometry, air density estimation (during re-entry phase only)

Defining a suitable Retroreflector for these LEOs

Goal: Single Retro-Reflector(s) for a ≤ 600 km Orbit of such Nano-Satellites

- Retro has to be big enough to deliver suffient return signal: ≥ LAGEOS signals
  => ALL SLR stations should be able to range

- Velocity aberration for this orbit: 25 – 50 µrad

- Has to be considered for all incident angles, no preferred orientation

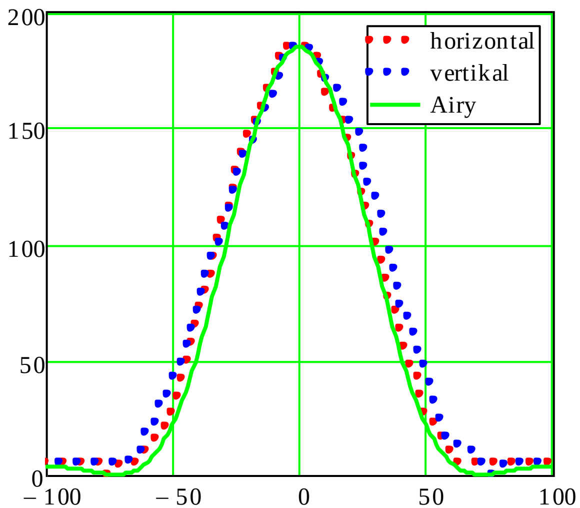
- Both stabilized **and** unstable orientation should be considered

- Satellite should be ‚visible‘ for SLR from any side, in any situation …

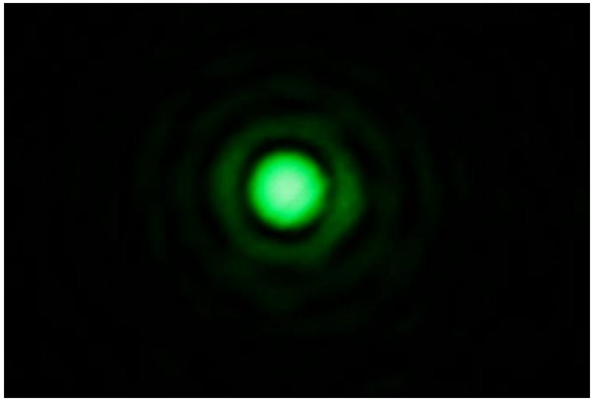
- **COTS** (**C**ommercial **O**ff-**T**he-**S**helf) retros should be used instead of special / expensive CCR

First tests with COTS 0.5“ retros: L. Grunwaldt, R. Neubert; GFZ

Radar cross sect. / 1000 m²



Aberration / µrad



0.5“ CCR (OTS optics)

0.5“ COTS Retro:

Far Field Diffraction Pattern

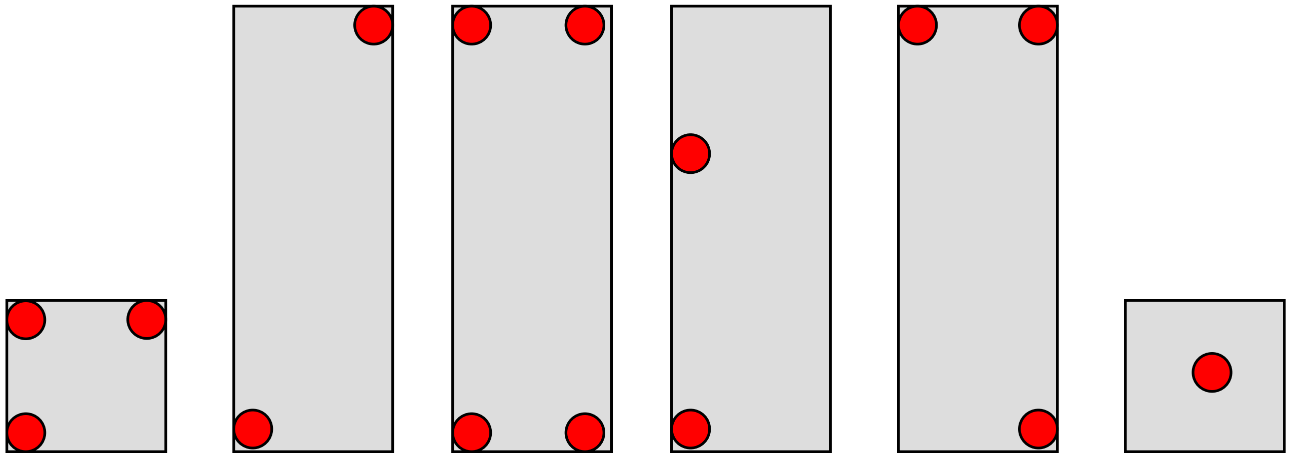
Conclusion for a 0.5“ COTS Retro:

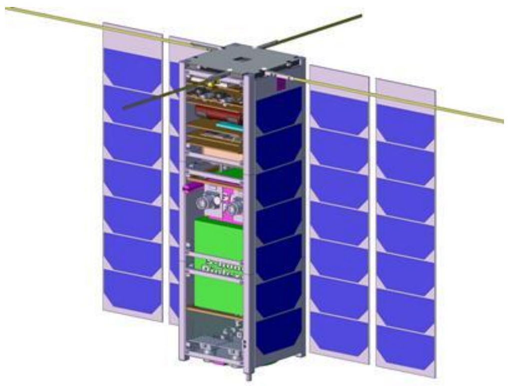
- 620 km orbit; 45° incidence;
- 25 – 50 µrad velocity aberration
- Signal: ≈ 2 x Lageos Signal
- No need for special retro shapes

Prices: ≈ 150 EUR / retro

- fused silica, aluminum coating, protective painting
- 0.5“ (1.25 mm) and 10 mm possible

OPS-SAT: Placing the retros: Example …





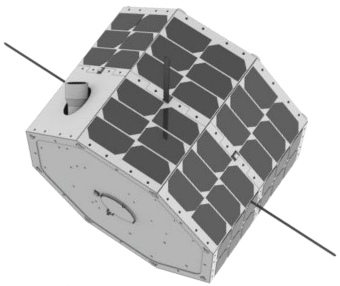
Nadir   4 sides: each 10 x 30 cm   Top

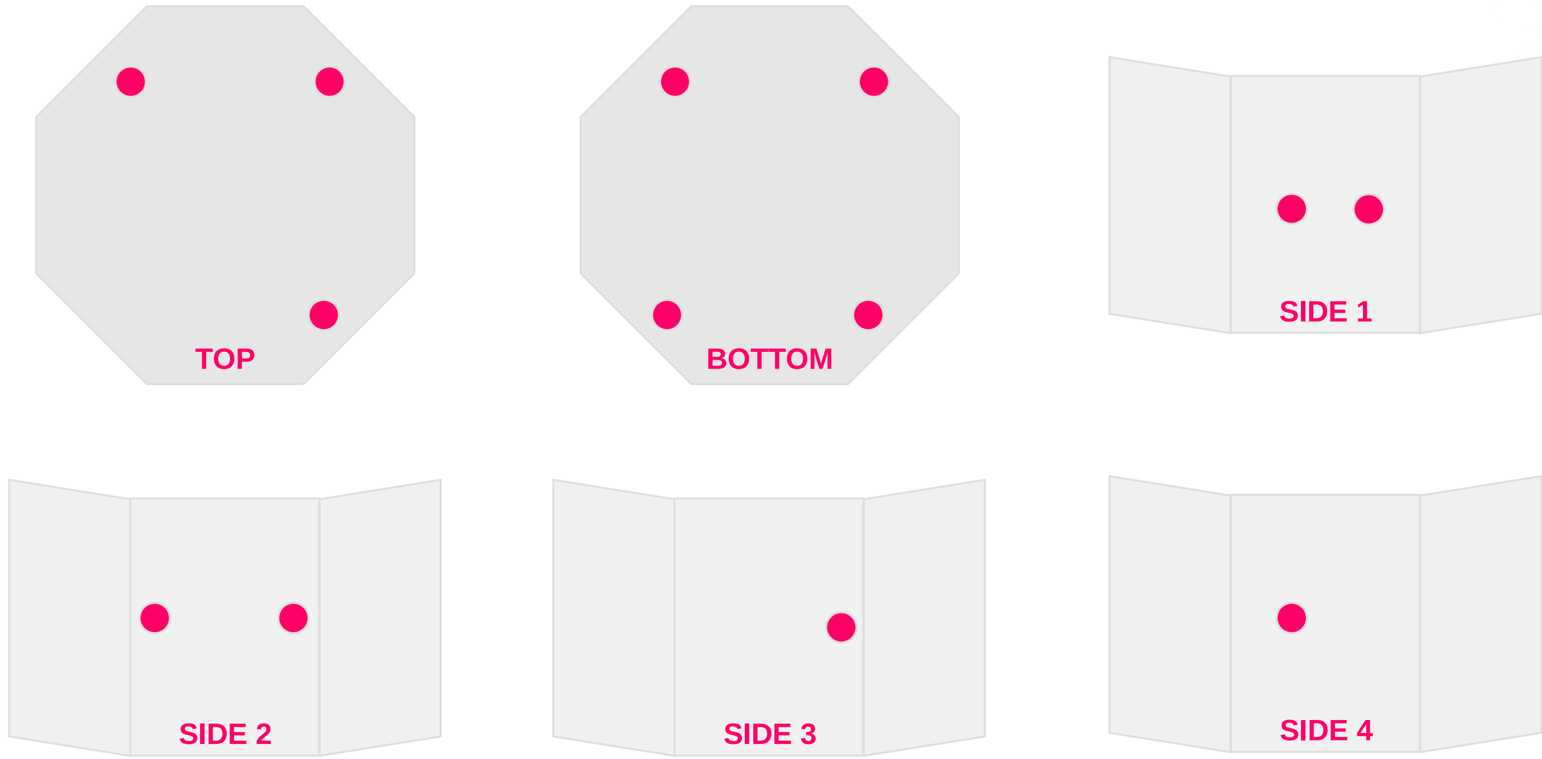
3   2   4   2   3   1   =>15 retros

1 – 4 Retros on EACH side: (Retro = ●)

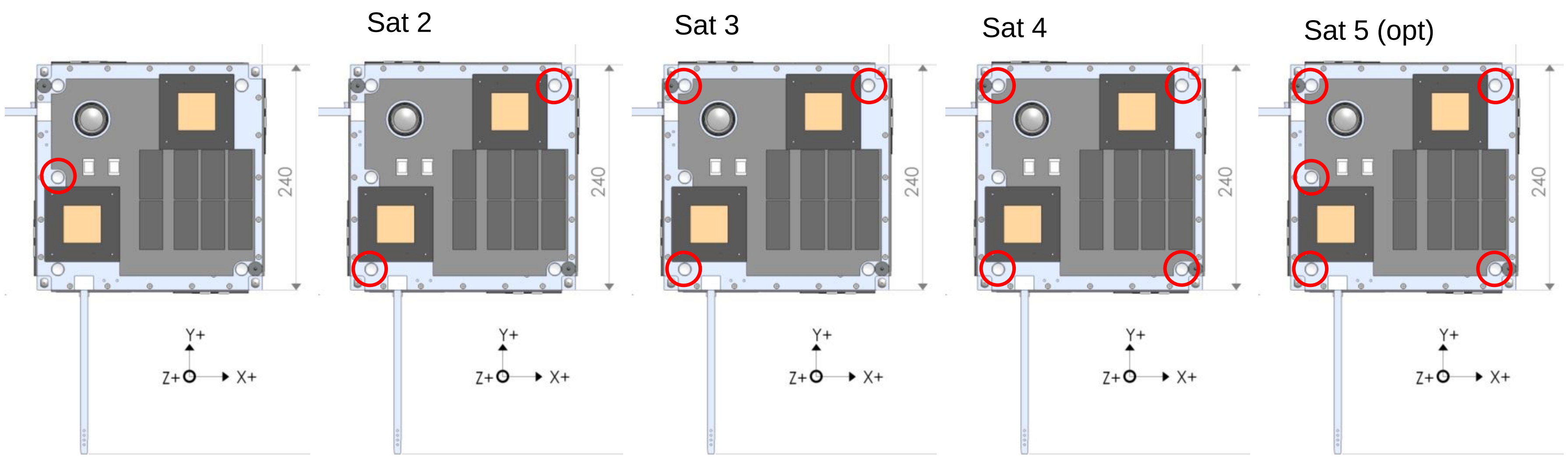
- All retros: 0.5“; fused silica; aluminum coated; recessed, no extension; 2 grams; or: 10 mm diameter
- All retros are coated; working ±45°
- Only ONE – and at least one - side ‚visible‘ at any time; (only small overlap):
    - Clear identification of each side possible (using also the possible sequences of visibility)
- Attitude can be determined for ALL orientations; accuracy: < 1° RMS

Possible distribution of Retro-Reflectors on TechnoSat





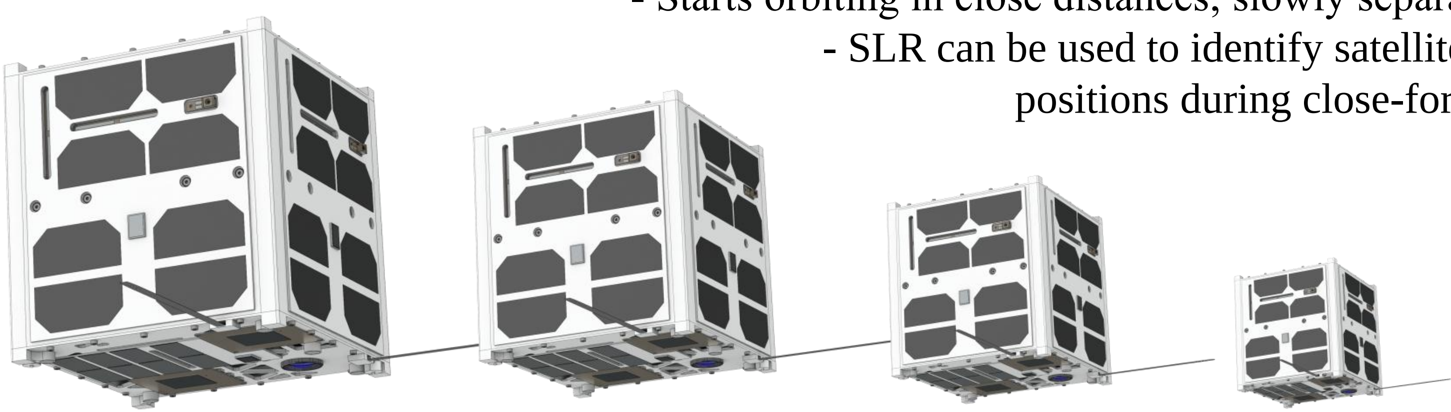
Possible Distribution of Retro-Reflectors on S-Net



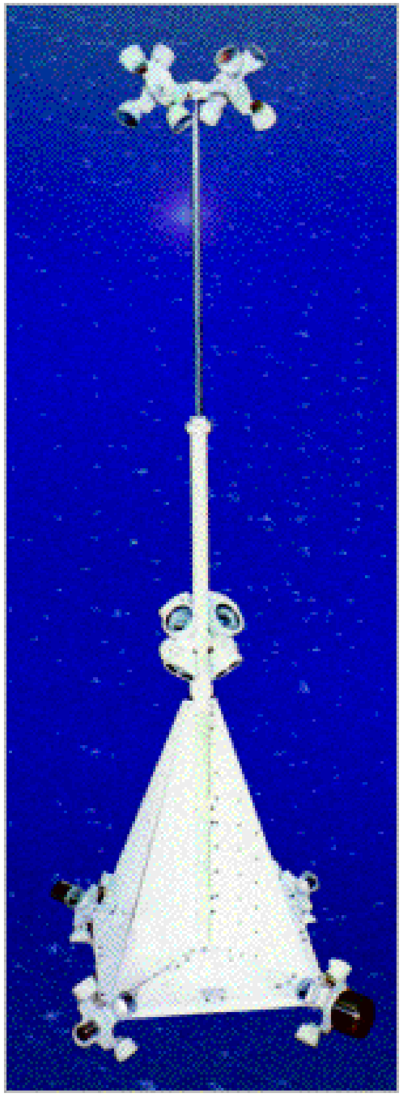
SATELLITE 1 **SATELLITE 2** **SATELLITE 3** **SATELLITE 4** **SATELLITE 5**

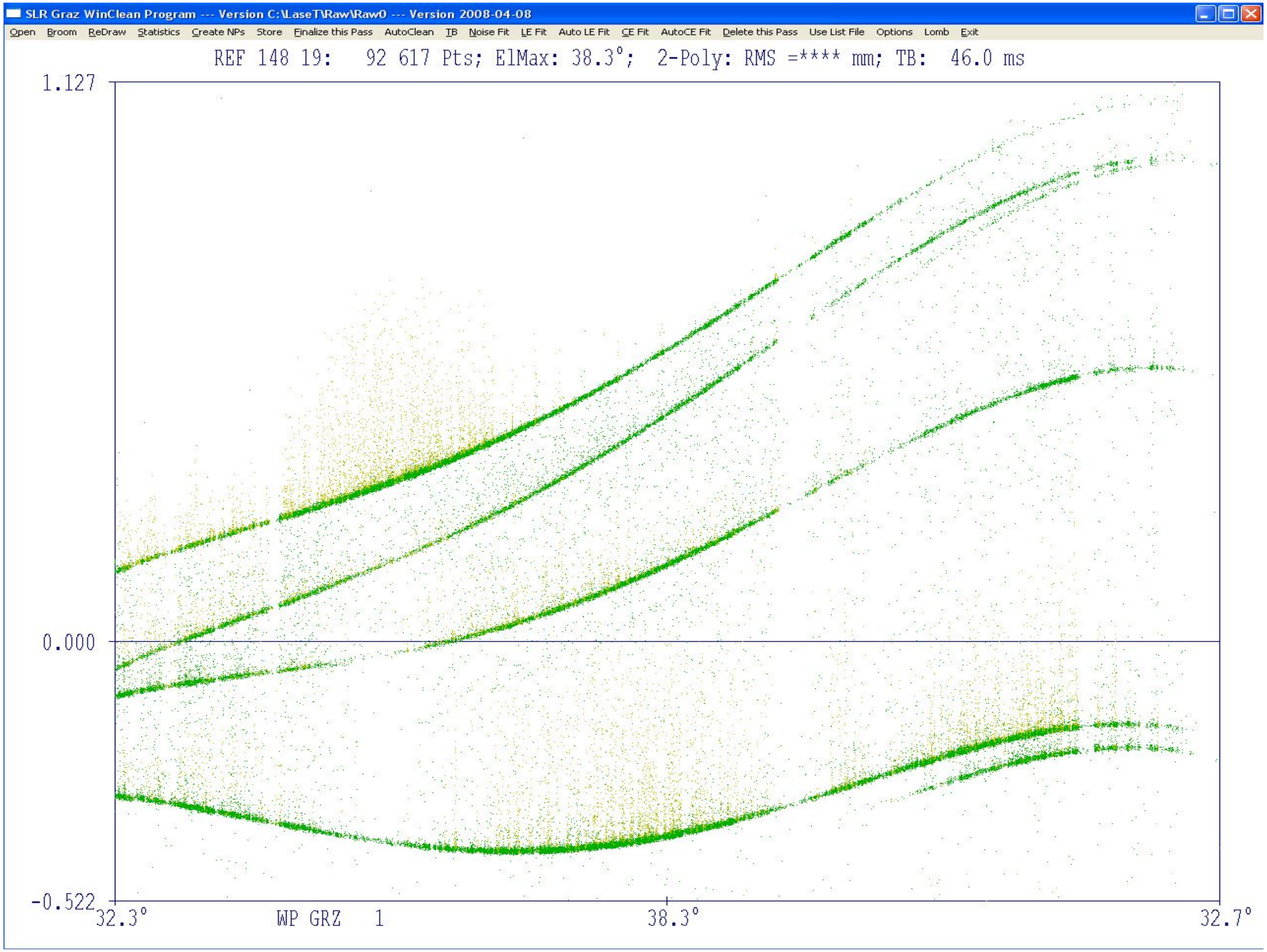
(OPTIONAL)

- S-Net is a 4-Satellite-configuration;
  - Starts orbiting in close distances; slowly separating…
    - SLR can be used to identify satellites, and to check positions during close-formation period



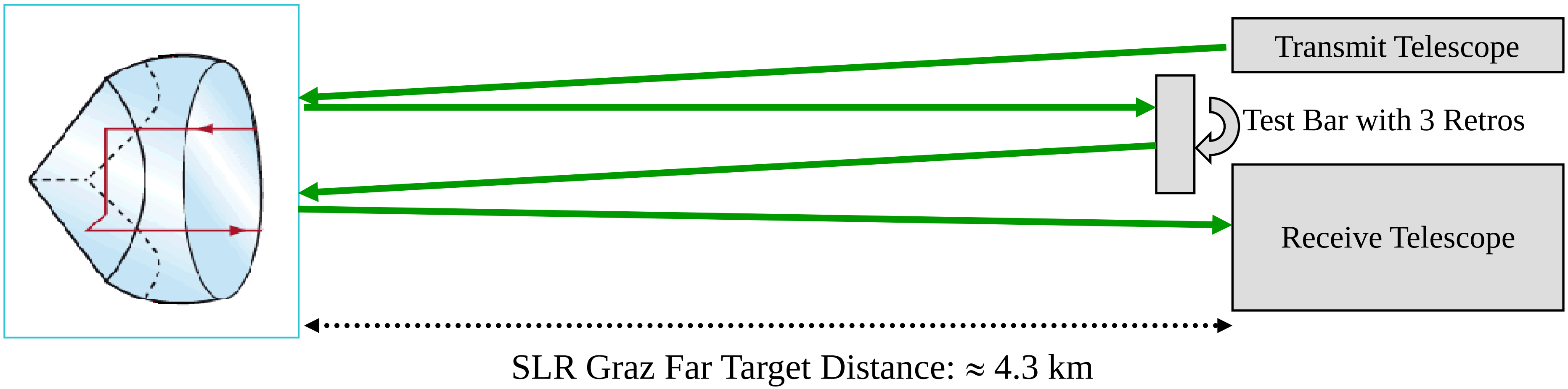
Reflector: 2008/day 148 / 19:00 UTC (Night)

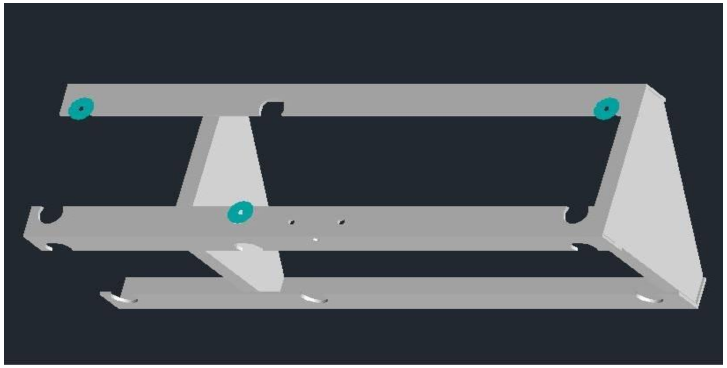




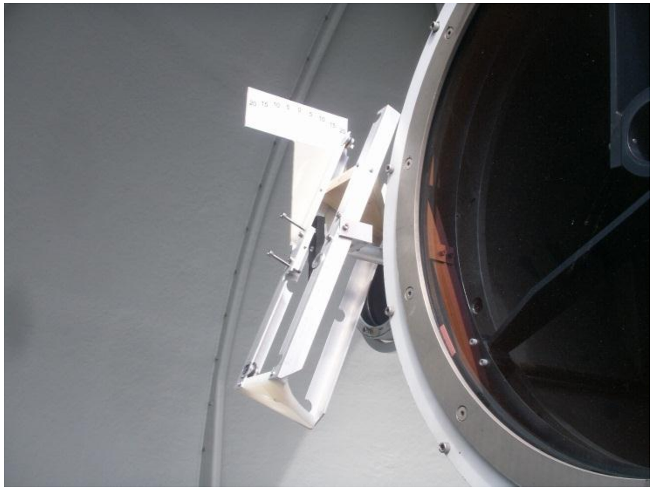
Reflector: Satellite, and screenshot of residuals: Allows attitude determination …

Graz: Measurement setup for attitude measurements



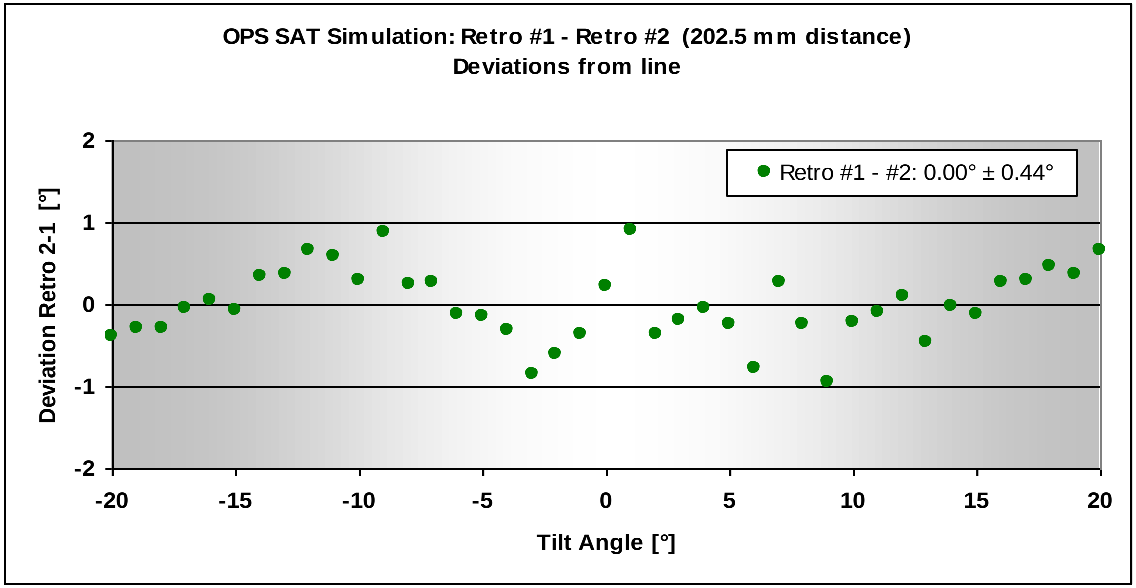


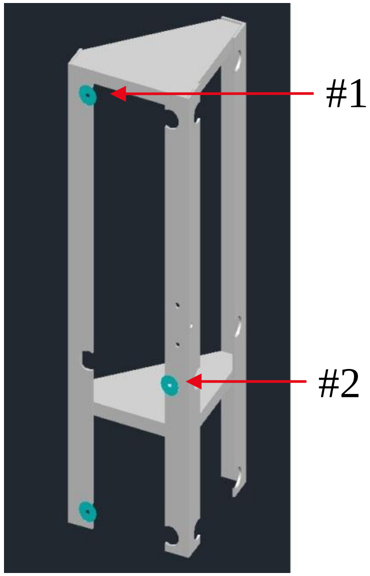
Test Bar with Retros / CAD plot: Allows different numbers and configurations of retro-reflectors



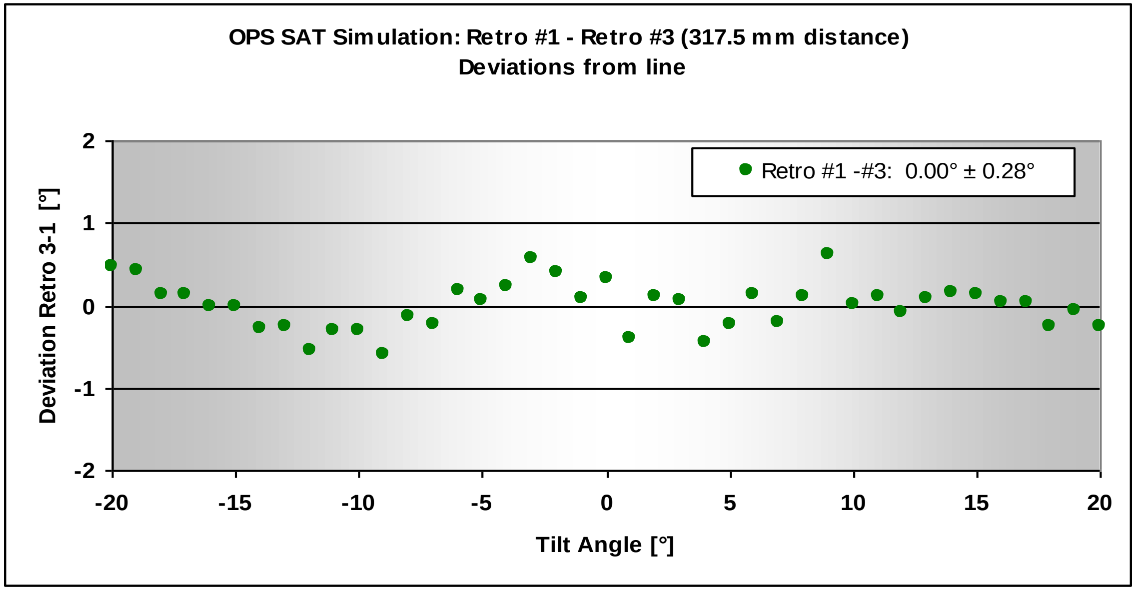
Test Bar with Retros, mounted on telescope

Attitude Measurement Results: < 1° RMS



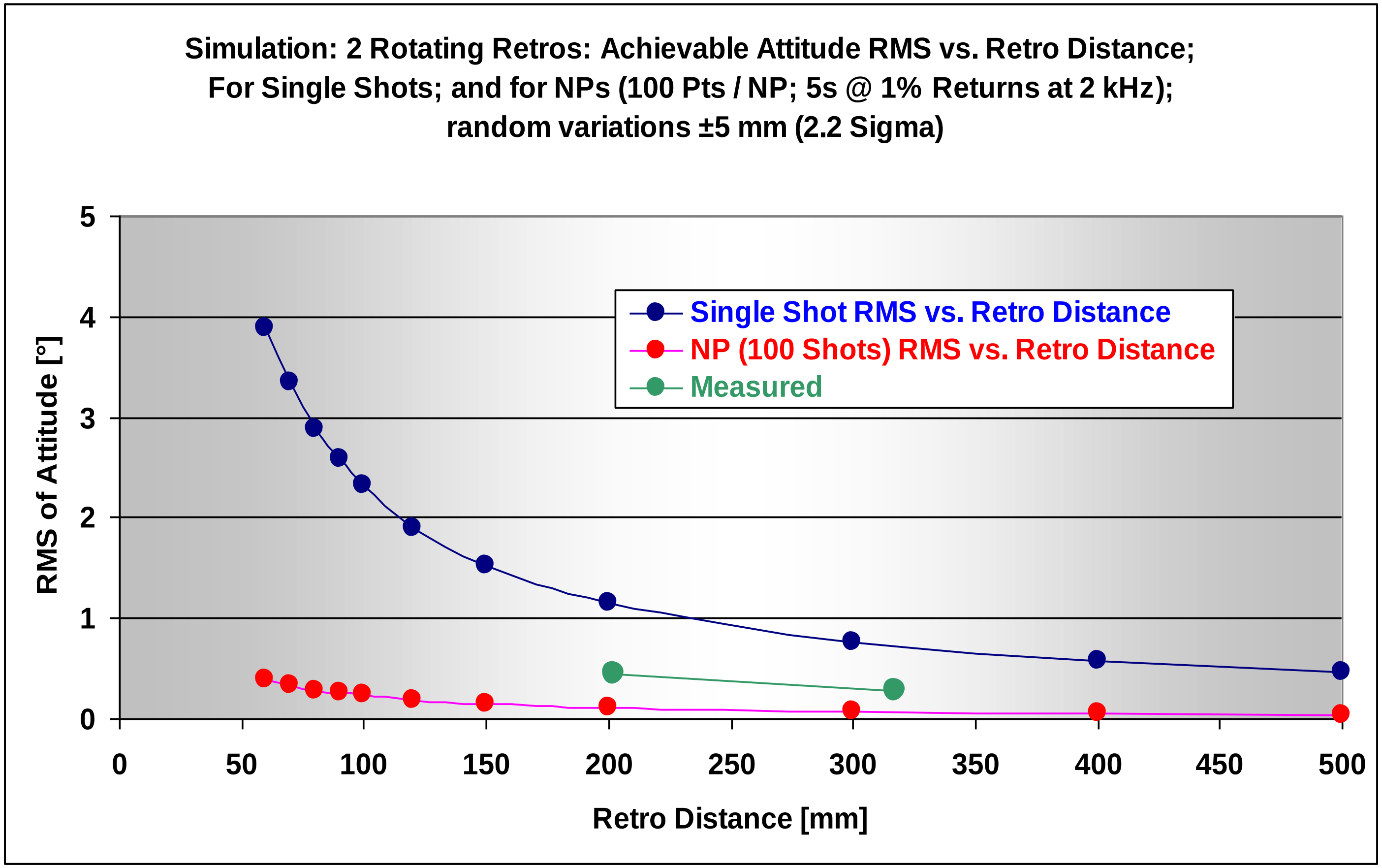


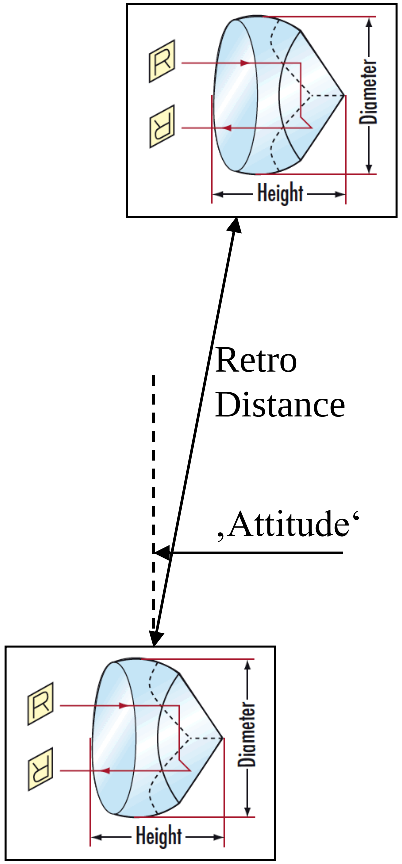
Retro Distance: 202.5 mm



Retro Distance: 317.5 mm

Attitude determination: Simulation & test results …



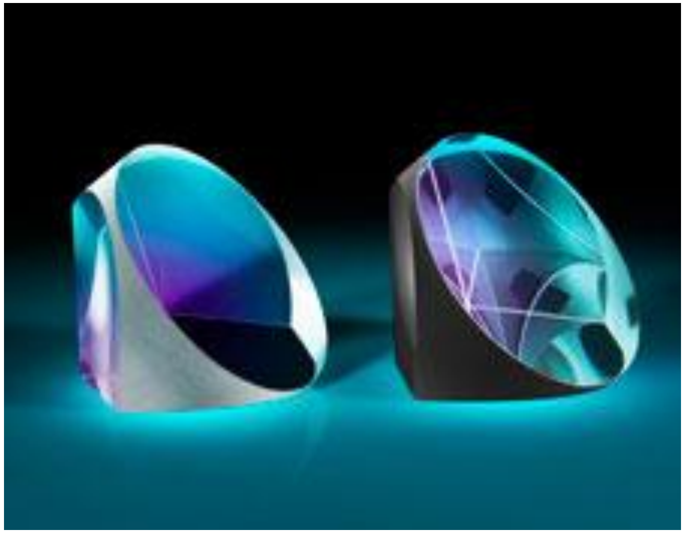


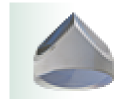
Simulation: Ranging to 2 retros, which are separated by some distance

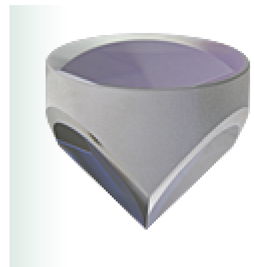
Simulating Laser Ranging, we ‚measure' the ‚attitude' (angle)

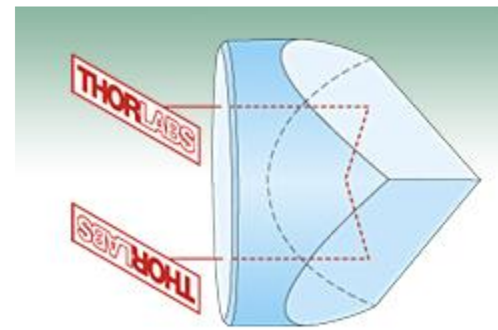
Goal: Estimate possible accuracy of attitude measurements

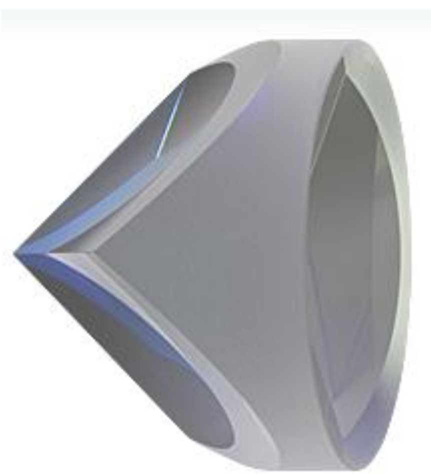
Below 50 mm retro distances: Single Returns from both retros start overlapping











Thank you !

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