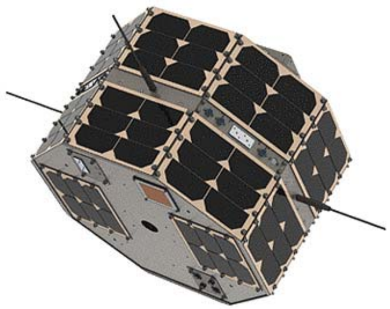


kHz SLR Application on the Attitude Analysis of TechnoSat

Peiyuan Wang, Hannes Almer, Georg Kirchner, Franz Koidl, Michael Steindorfer
Space Research Institute, Austrian Academy of Sciences
peiyuan.wang@oeaw.ac.at

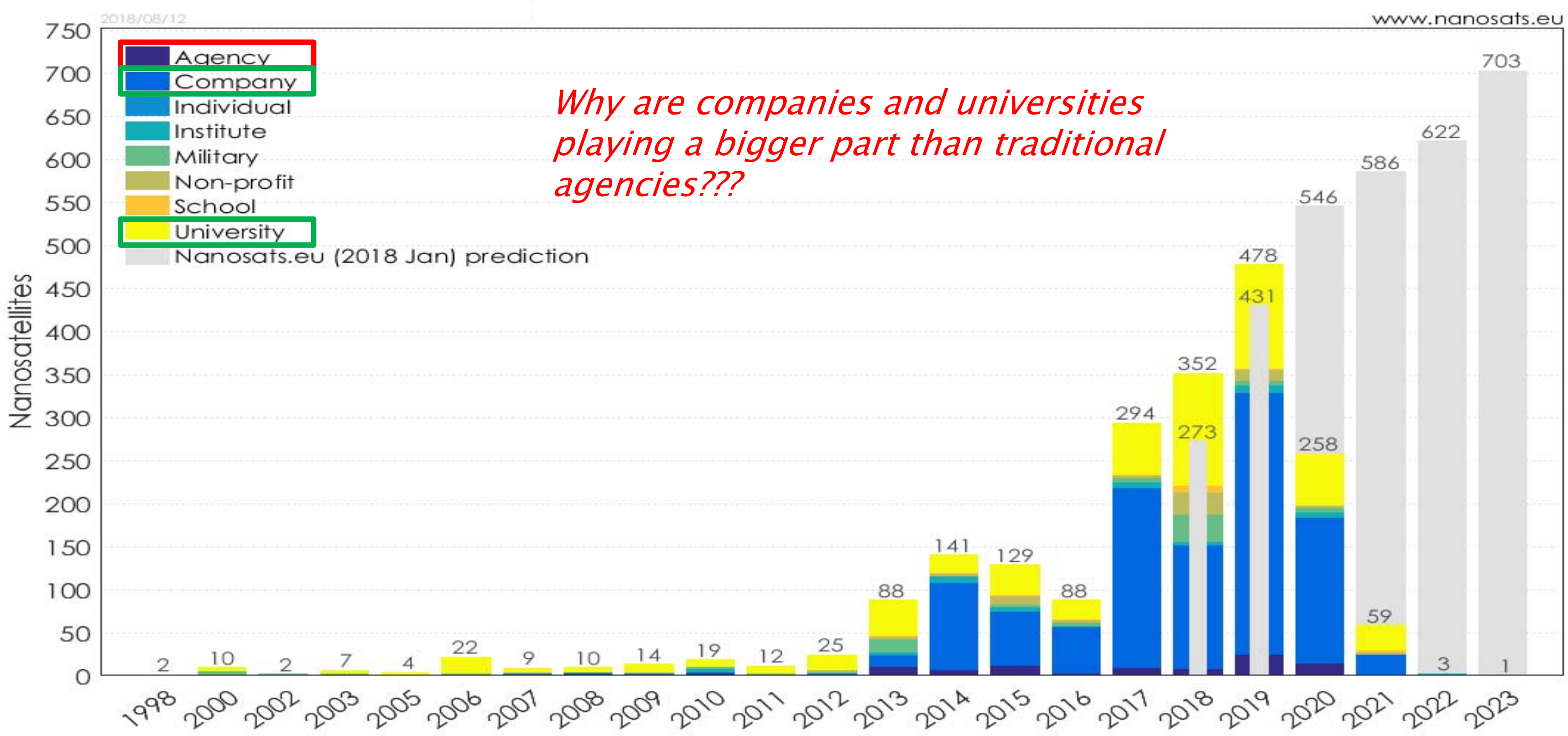
Merlin Barschke, Philip Werner, Mario Starke
Institute for Aeronautics and Astronautics, Technische Universität Berlin
merlin.barschke@tu-berlin.de

21st International Workshop on Laser Ranging, Canberra, 2018

Outline

- Nanosatellite and TechnoSat
- Attitude simulation
- Ground experimental measurement
- Attitude analysis based on SLR data

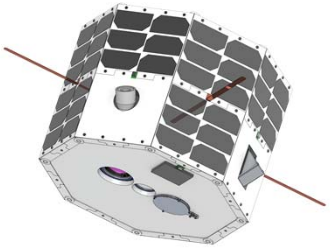
Nanosatellite Launches and Forecasts



TechnoSat

Parameter	Value
Orbit	600 km SSO
Launch date	July 14th, 2017
Launcher	Soyuz
Design lifetime	1 year
Spacecraft mass	20 kg
Spacecraft volume	465 x 465 x 305 mm^3
TM/TC link	Four UHF transceivers
Attitude actuators	Torque rods
Payloads	• Fluid-dynamic actuator • S-band transmitter • Reaction wheels system • CMOS camera • Particle detector SOLID • Star tracker STELLA • Corner cube reflectors

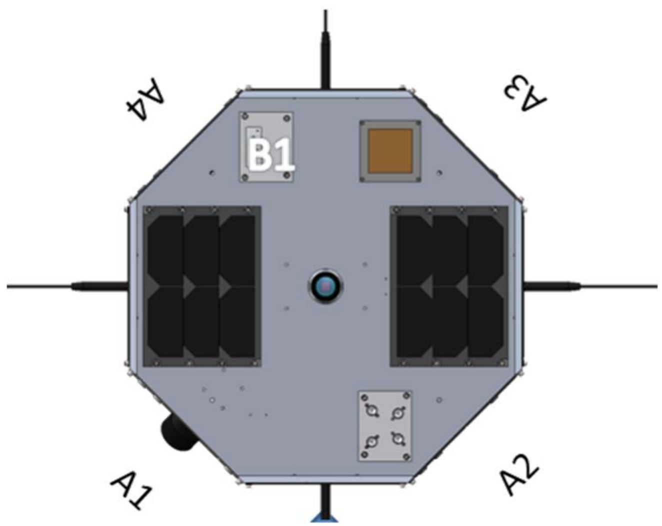
Together with other 72 satellites were launched July 14th, 2017



TechnoSat has geometry of octagonal prism structure

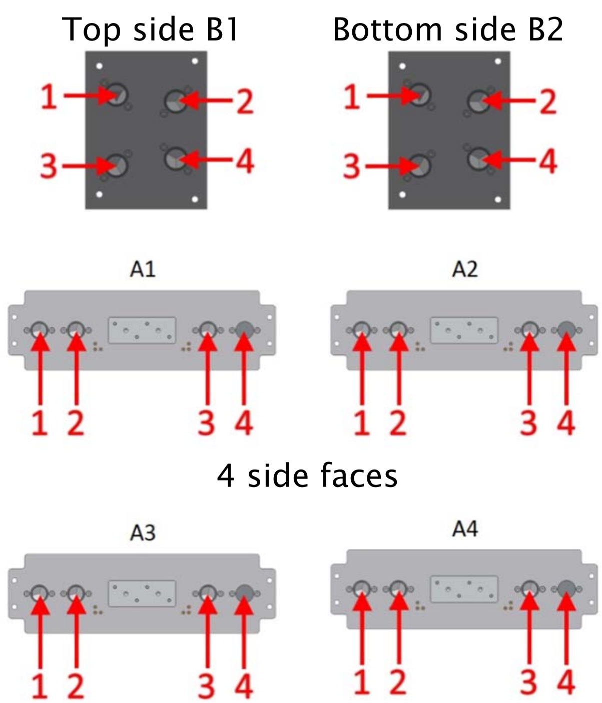
Successfully tracked by ILRS
Ref. EDC, updated on Oct. 25, 2018

24 candidate positions for CCR



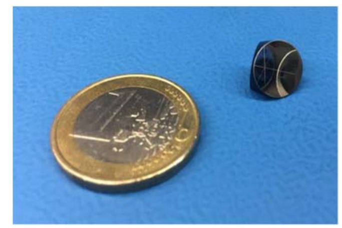
14 CCR uniquely distributed on 6 host faces

TechnoSat has geometry of octagonal prism structure



Goal of CCR payload

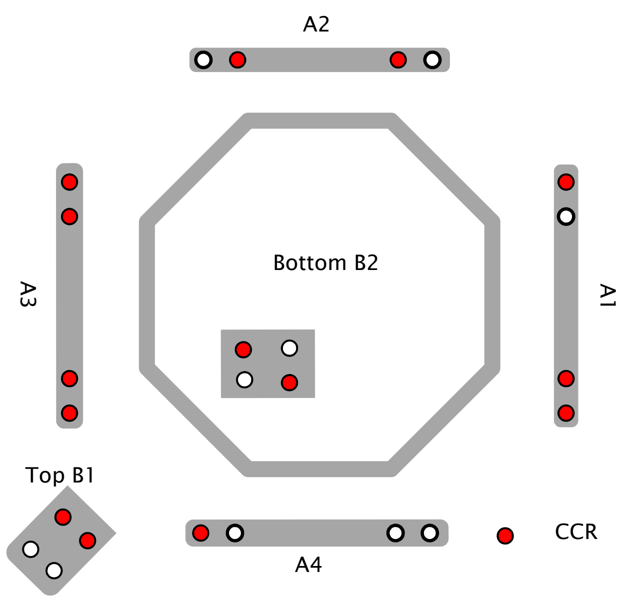
- Test COTS products
- Attitude & motion determination



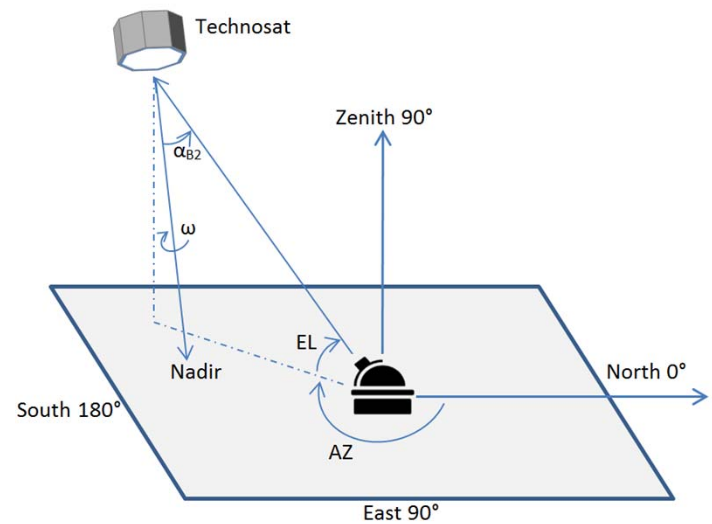
- Ø10mm
- COTS
- 20µrad
- Low cost

Unique SLR signature of each host side must be considered to achieve the goal of attitude and attitude movement determination

Assign unique CCR on each face



14 CCR uniquely distributed on 6 host faces
TechnoSat has geometry of octagonal prism structure

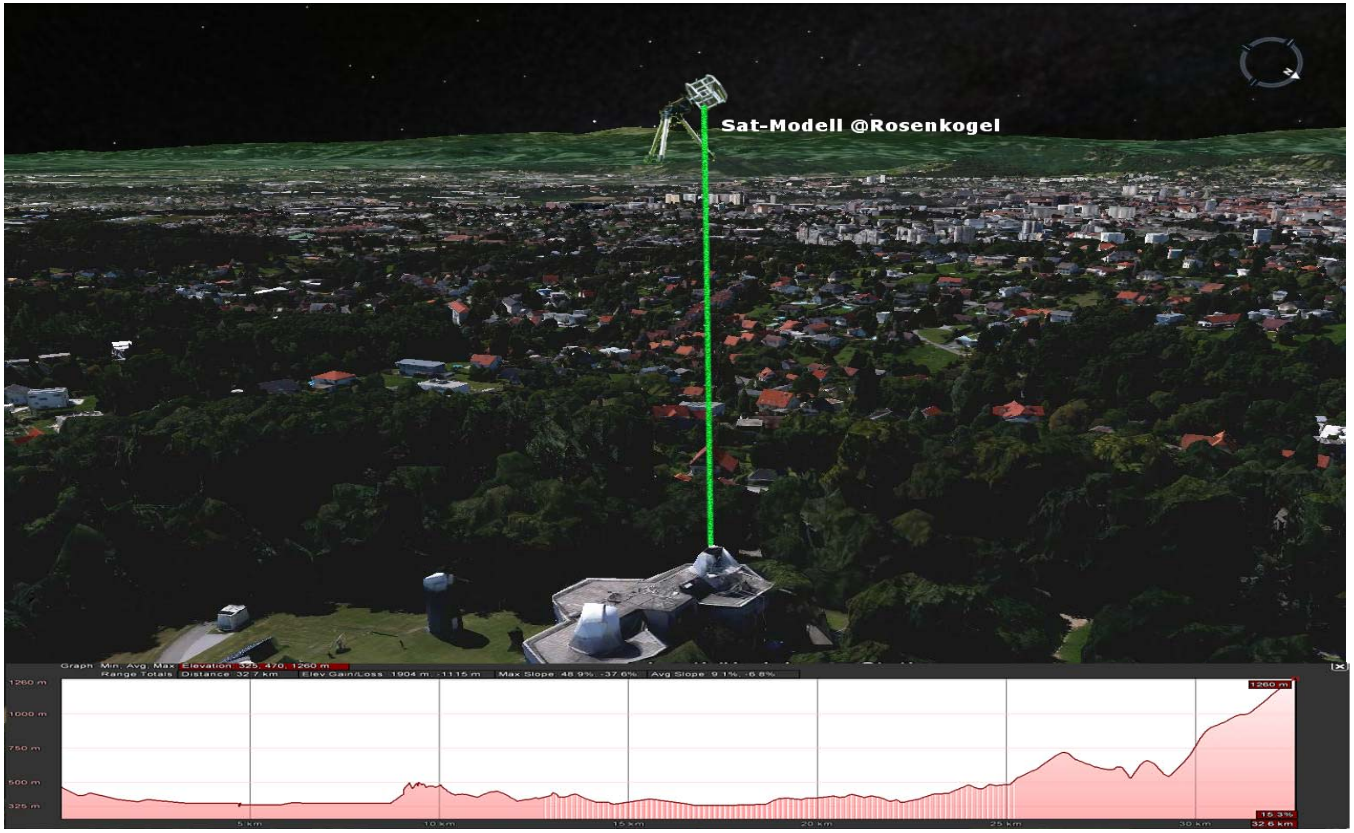


the effective optical cross section breaks down when $\alpha_{B2} > 45^\circ$

$$\alpha_{B2} = \sin^{-1}\left(\frac{R_E \times \sin(90^\circ + EL)}{R_E + H}\right)$$

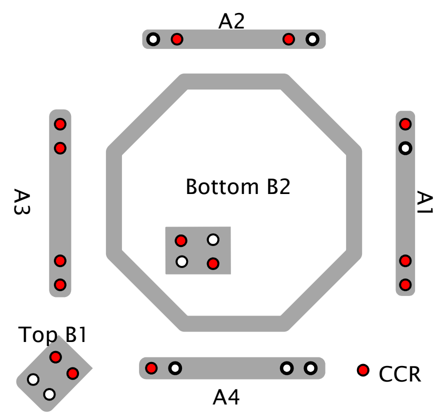
R_E - the Earth radius
EL - the elevation
H - the orbit height

Ground Verification

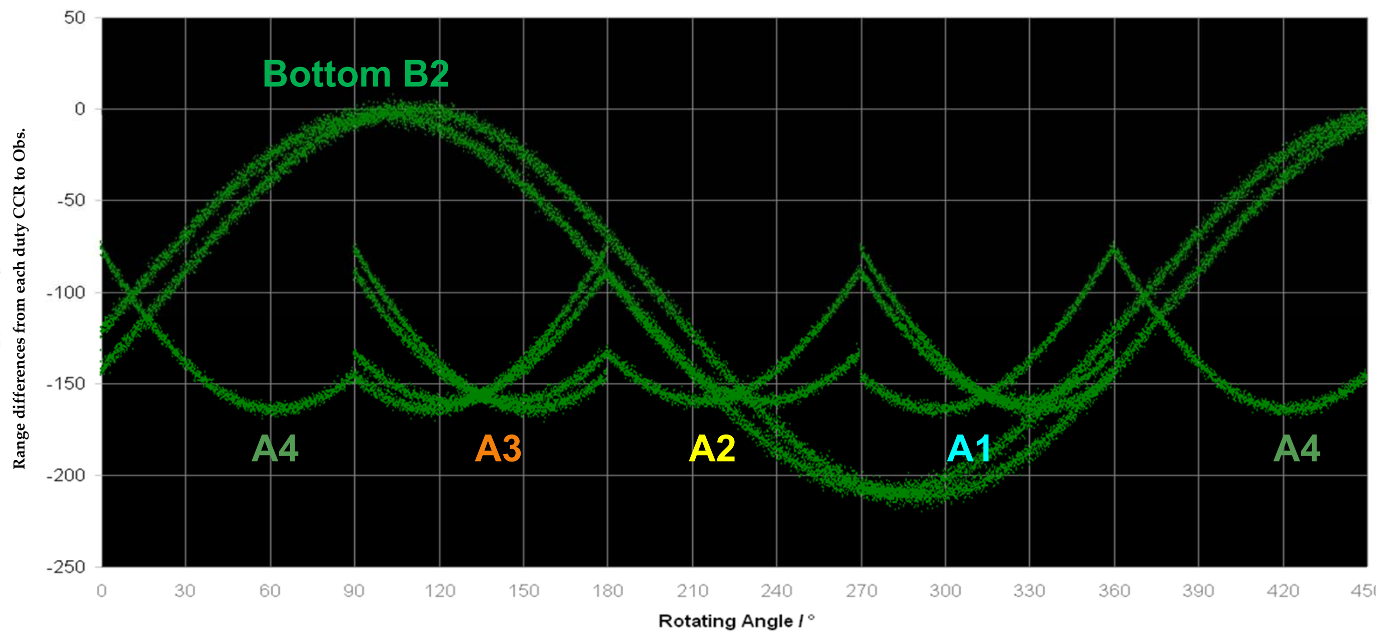


TechnoSat model was placed on a small mountain about 32 km away of Graz station; rotated by stepper motors simulating attitude motions while we measured the distance with our 2 kHz SLR system.

Simulation 1: Constant spinning rate and fixed position



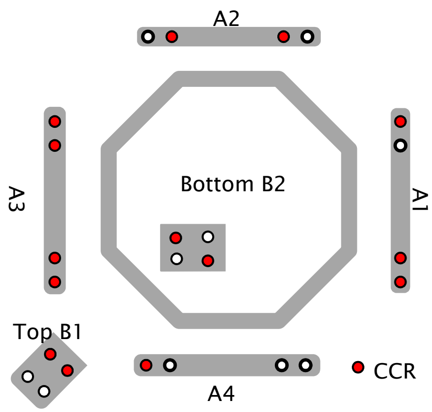
14 CCR uniquely distributed on 6 host faces
TechnoSat has geometry of octagonal prism



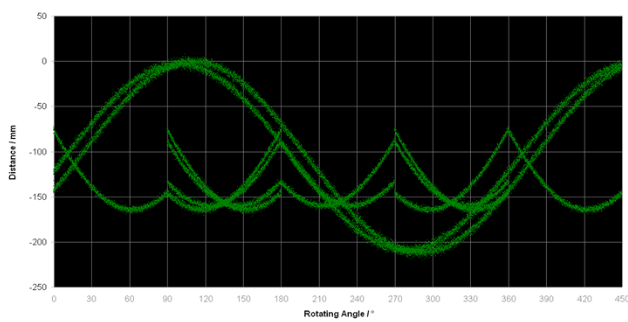
With constant spinning rate (22.5s) and fixed inclination (45°)

Simulation vs ground measurement

Constant spinning rate and fixed position

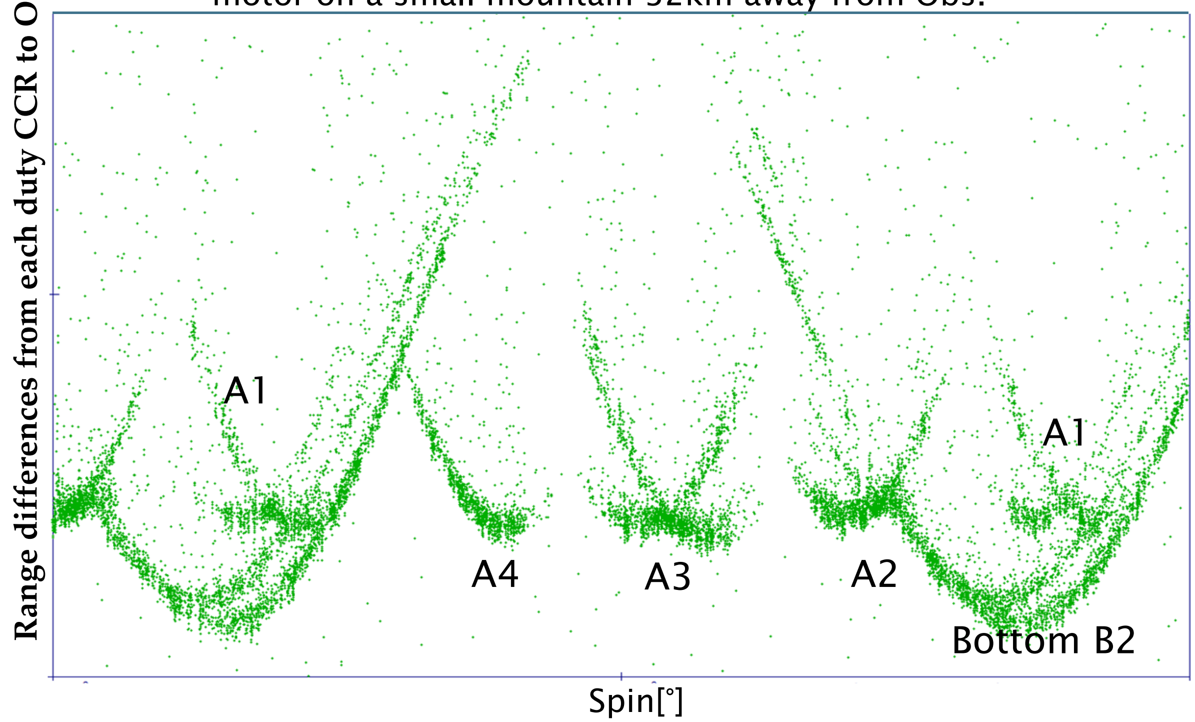


14 CCR uniquely distributed on 6 host faces
TechnoSat has geometry of octagonal prism structure

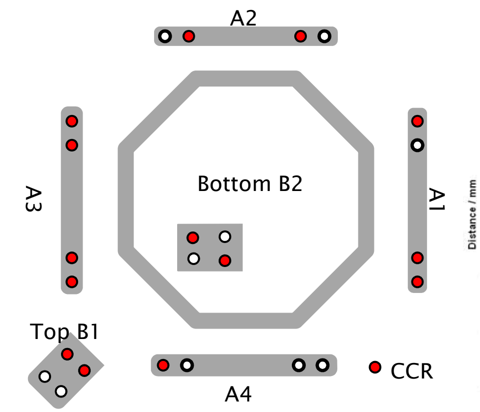


Simulated returns pattern when TechnoSat is spinning

Graz 2kHz measurements to TechnoSat model driven by step motor on a small mountain 32km away from Obs.



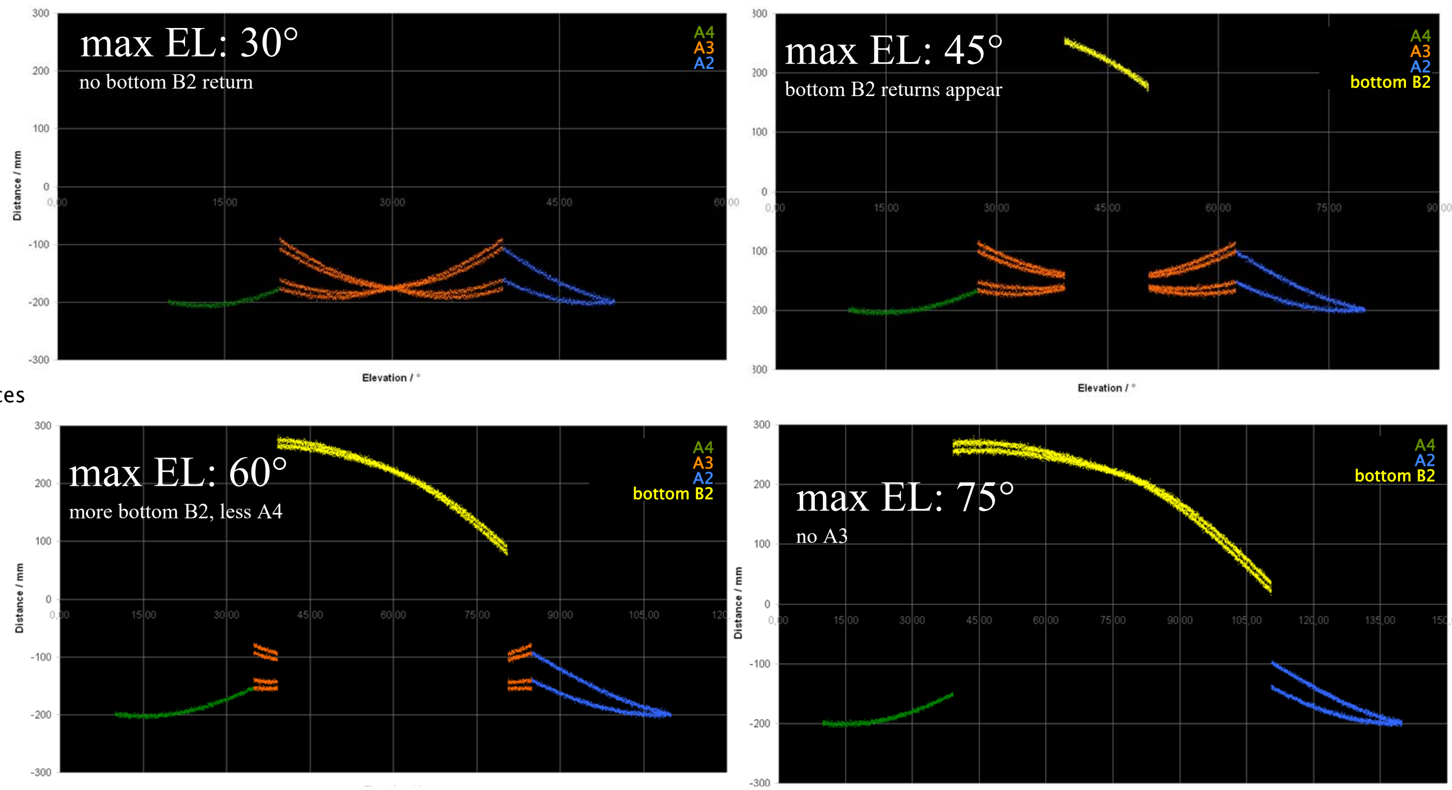
Simulation 2: No spinning and full pass



14 CCR uniquely distributed on 6 host faces

Simulation principle:

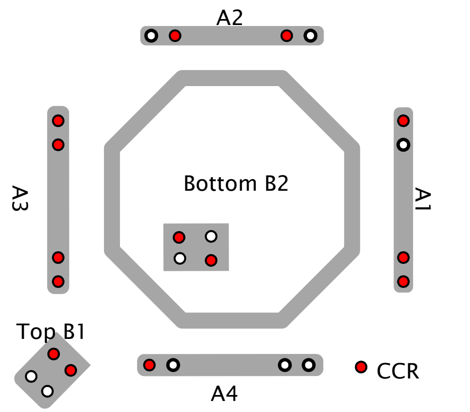
- TechnoSat passes Observatory;
- It has no spinning;
- First A4, then A3 (or bottom), then A2
- Returns based on laser incident angle to each face



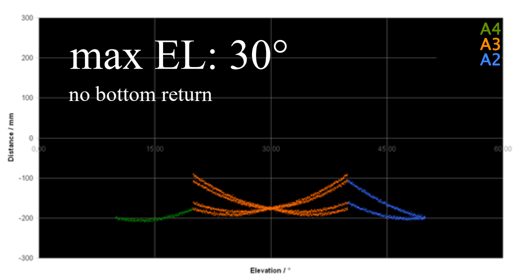
X- elevation; Y- range differences from each duty CCR to Obs.

Simulation vs ground measurement

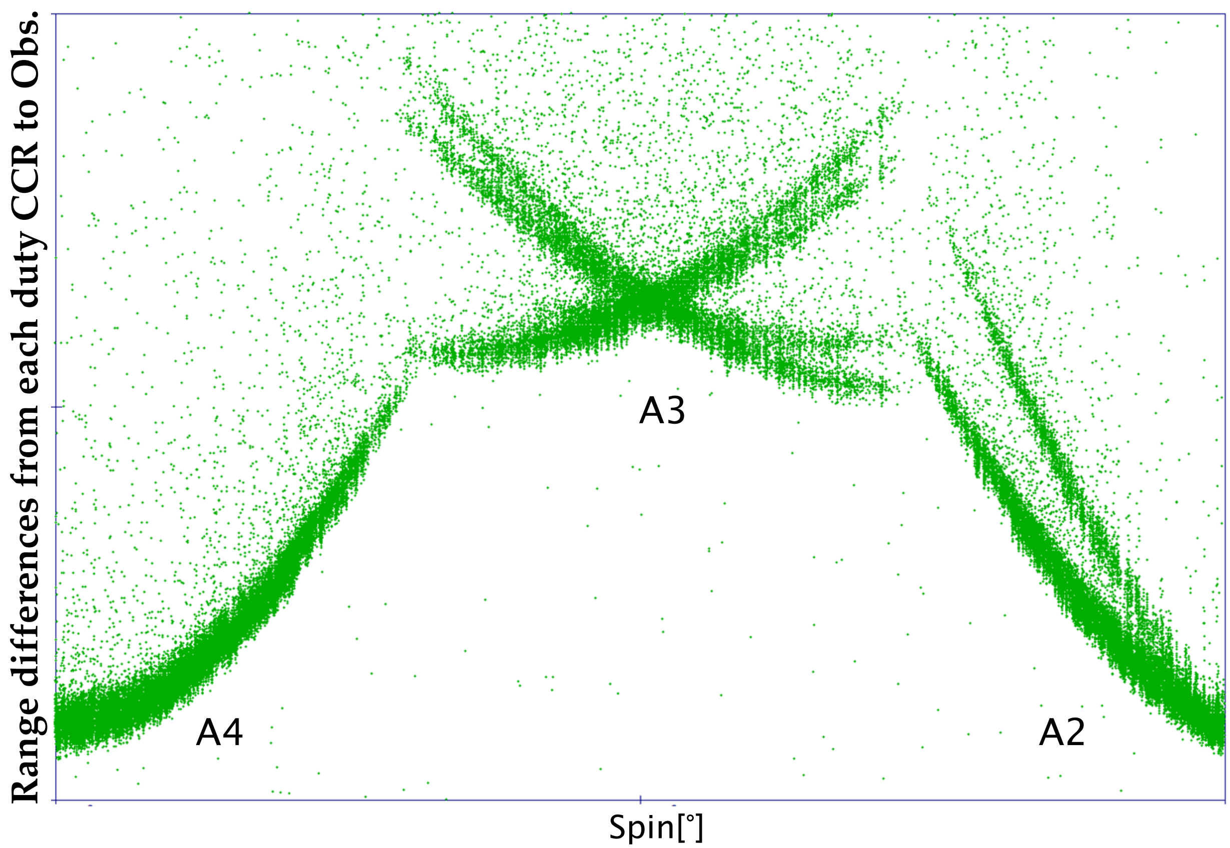
No spinning and full pass



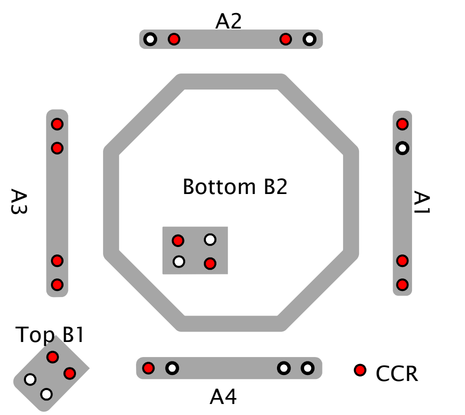
14 CCR uniquely distributed on 6 host faces



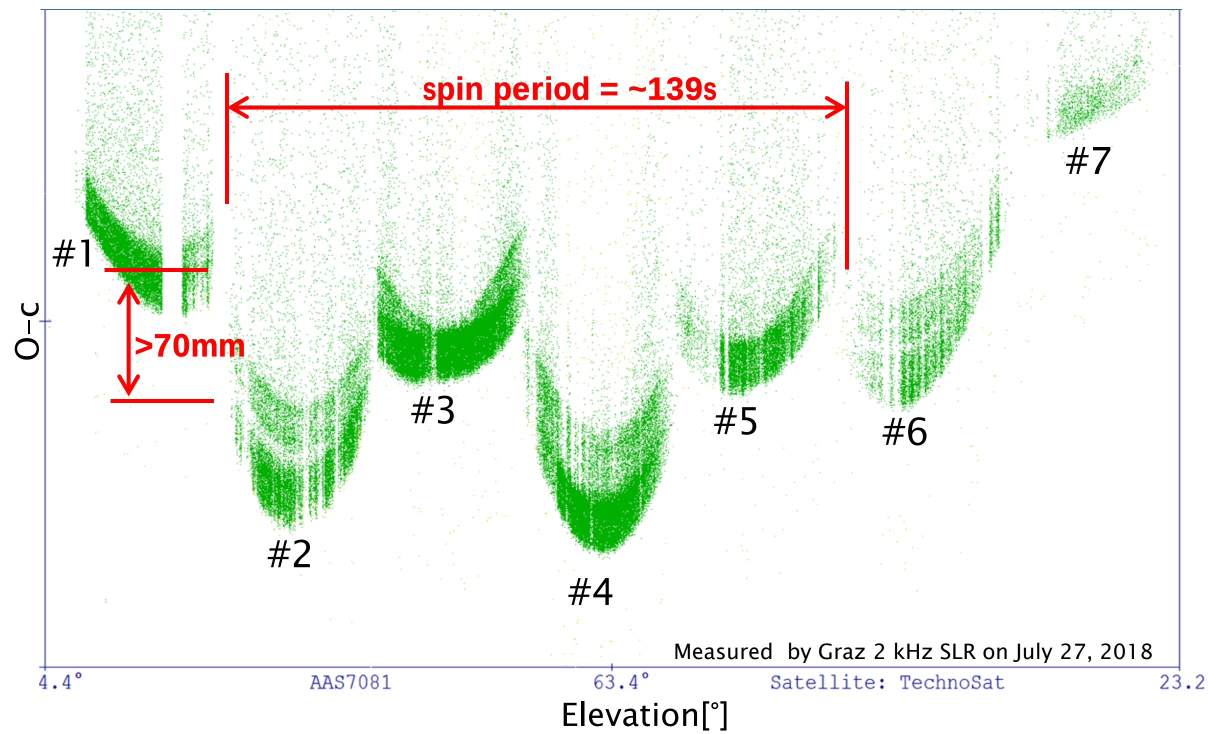
Simulated returns pattern of whole pass with
Max. 30 elevation when no spinning



Attitude Analysis of TechnoSat based on kHz SLR data



14 CCR uniquely distributed on 6 host faces

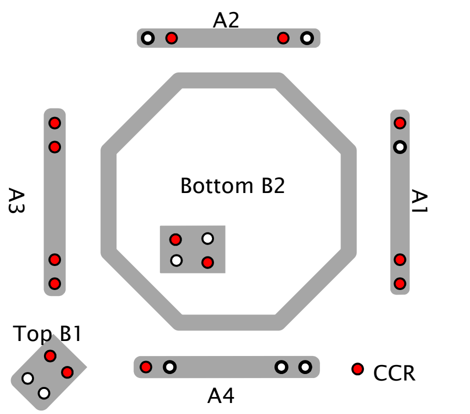


- Spin period ~139s;
- Spinning from side face A to Top/Bottom B, then back to A, because the big (>70mm) distance offset between faces.

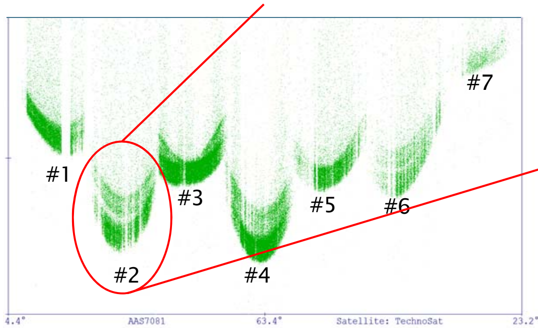
Any thing else???

Do you believe if I say #1~#7 are sequentially corresponding to B2 -> A1 -> B1 -> A3 -> B2 -> A1 -> B1

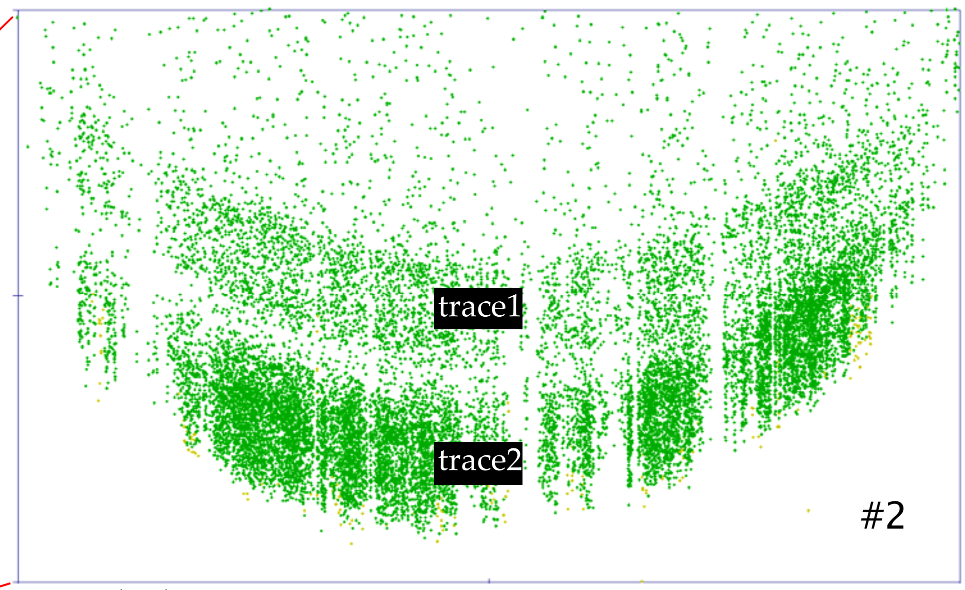
Measurement by kHz SLR



14 CCR uniquely distributed on 6 host faces



Measured by Graz 2 kHz SLR on July 27, 2018

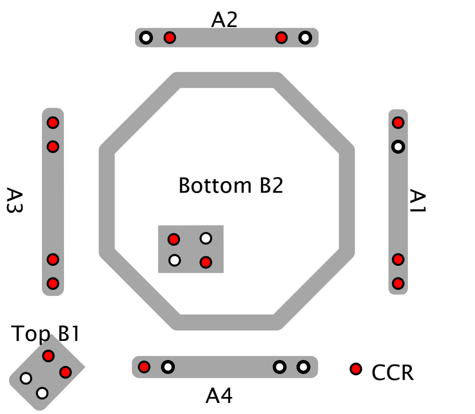


- includes two traces
- signal density: trace 2 > trace 1
- max. RMS : trace 2 > trace 1
- #2 == #6

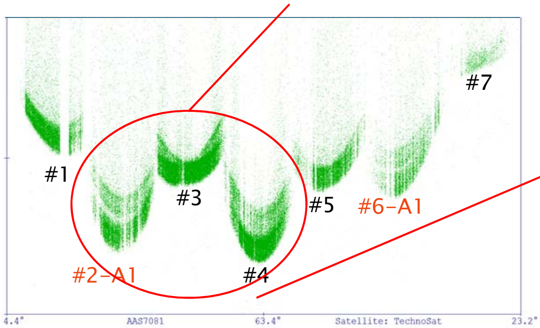
therefore

--- #2 (#6, same) should have 3 CCR → A1
--- #1/3/5/7can be only Top/Bottom side
--- #4 can only be only side face

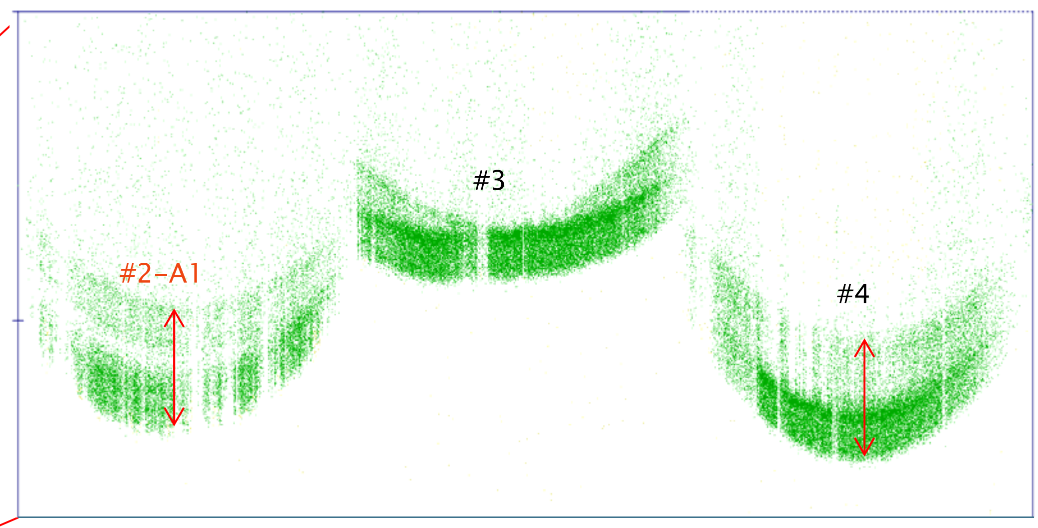
Measurement by kHz SLR



14 CCR uniquely distributed on 6 host faces



Measured by Graz 2 kHz SLR on July 27, 2018

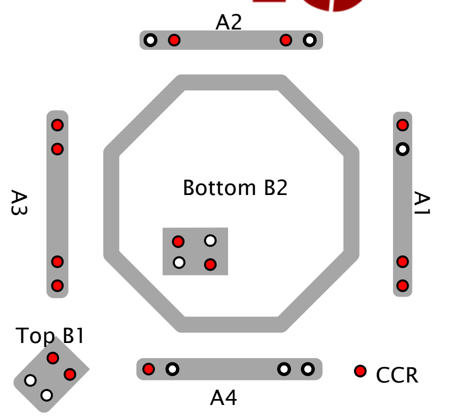


- #4 can only be only side face
- #4 has the same RMS characters as #2

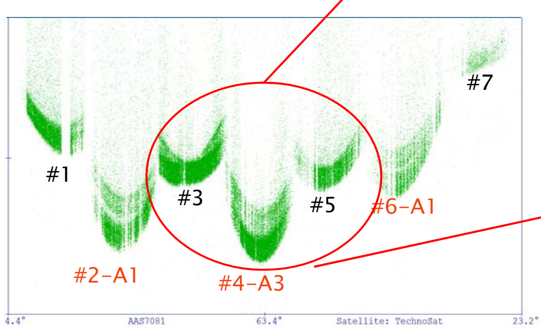
therefore

--- #4 should has CCR on both outer positions ⟶ A3

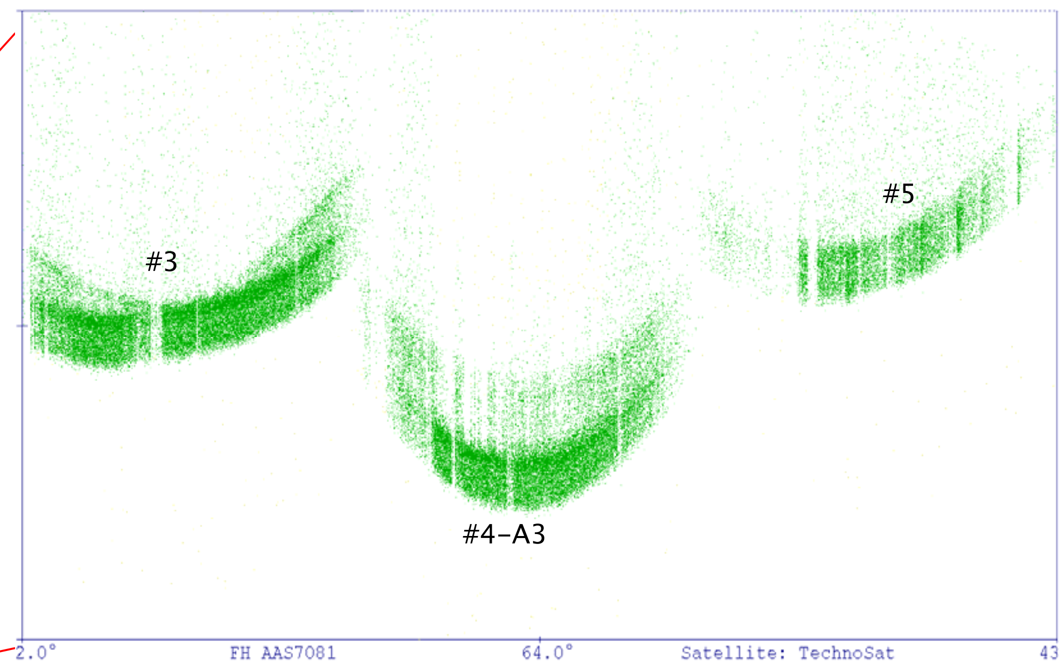
Measurement by kHz SLR



14 CCR uniquely distributed on 6 host faces



Measured by Graz 2kHz SLR on July 27, 2018

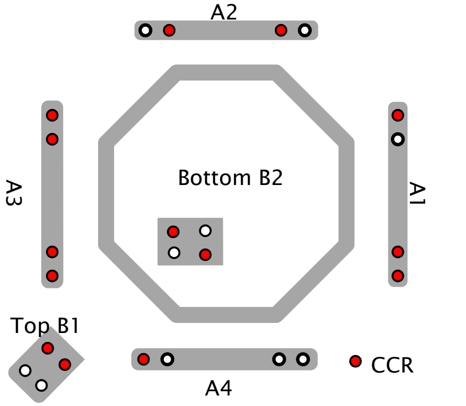


- #1/3/5/7 can be only Top/Bottom side
- #3 has the RMS close to the distance of two CCR on B2
- #3 has the bigger RMS than #5

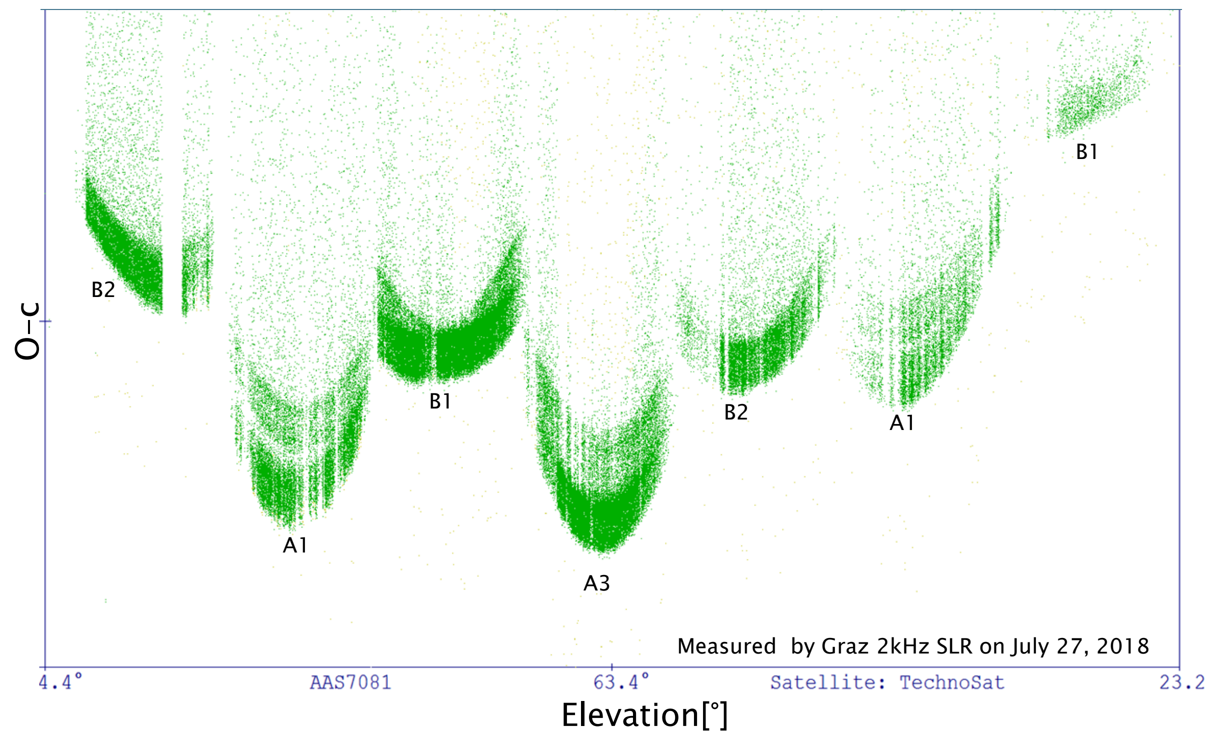
therefore

--- #3 ⟶ B2 ; #5 ⟶ B1

Attitude Analysis of TechnoSat based on kHz SLR data



14 CCR uniquely distributed on 6 host faces



B -> A1 -> T -> A3 -> B -> A1 -> T

Conclusion & Summary

- Easier: more sides, higher repetition rate
- Assumptions have been compared to onboard gyroscope
- TechnoSat experiment is convinced that COTS (Commercial-off-the-shelf) CCR bring
  - Ø10mm CCR is fully sufficient for SLR ranging to LEO ---24 stations were able to get returns;
  - Traditional benefits of SLR, --- orbit determination;
  - "Ahead of time" data production, --- attitude determination during/after the life time of satellite;
  - Significantly low cost for space activities --- few tens of dollars;
- All SLR data need to be analysed steps more --- higher time/degree resolution
  - Time when the face changes
  - Time of Max. or Min. pk-pk
  - Value of RMS vs. geometry distance projection