ILRS Missions WG Meeting

26 Oct 2015

Toshimichi Otsubo

and

Scott Wetzel

Matera, 1800-1900, 26 Oct 2015

Agenda (for 26 Oct 2015)

International Laser Ranging Service

(1) Opening/Welcome

New Members: A Boni, A Sokolov and Zhang Z

(2) Recently approved missions, (3) Future missions (5 min each)

PN-1A, B, C & D (Zhang Z): approved on 28 Apr 2015, more info required

Compass (Zhang Z)

NISAR (?)

LightSail-A/B (S Chait; read by T Otsubo)

COSMIC-2 (J Weiss)

SC Lomonosov (A Sokolov; read by T Otsubo)

(Sentinel-3A)

(Follow-on missions)

(4) Mission Support Request (MSR) Form: Revision Plan

(5) Others?

(6) Closure

(1) MWG Members

- Graham Appleby/NERC Space Geodesy Facility
- Giuseppe Bianco/Agenzia Spaziale Italiana (ASI)
- (new) Alessandro Boni/Istituto Nazionale di Fisica Nucleare (→ appoint Luca Porcelli soon)
- John J. Degnan/Sigma Space Corporation
- Julie E. Horvath/HTSI/SLR
- Georg Kirchner/Space Res. Inst., Austrian Acad. of Sci.
- Hiroo Kunimori/NICT
- John Mck. Luck/.
- David McCormick/NASA GSFC
- Jan F. McGarry/NASA GSFC
- Carey E. Noll/NASA GSFC
- Ron Noomen/Delft University of Technology
- (chair) Toshimichi Otsubo/Hitotsubashi University
- Erricos C. Pavlis/GEST/UMBC
- Michael R. Pearlman/Harvard-Smithsonian Center for Astrophy.
- Ulrich Schreiber/BKG/Geodaetisches Observatorium Wettzell
- Peter J. Shelus/University of Texas at Austin/CSR
- (new) Andrey Sokolov/SRI for Precision Instrument Engineering
- Vladimir P. Vasiliev/SRI for Precision Instrument Engineering
- (cochair) Scott L. Wetzel/HTSI/SLR
- (new) Zhongping Zhang/Shanghai Data Center

Updated: 9-Oct-2015 19:00:09

(3)-1 Sentinel-3A

2014-10-28 ESA (Féménias) presentation at ILRS MWG Meeting (read by Appleby)

2015-03-23 MSR submitted to ILRS CB

2015-06-09 → MWG (Chairs only)

where pending issues (damaging a detector) remains

2015-06-11 ILRS CB (Pearlman) requests the clarification of damage cases

2015-10-10 ILRS CB (Lemoine) sends a reminder

2015-10-14 ESA replies: 85 deg elevation limit

2015-12? Launch

Shall we ask them to revise the MSRF, then shall we proceed?

(3)-2 Follow-on/series missions

Current protocol: Once ABC-1 got approved, ABC-2, 3, … do not need to submit a MSR and are automatically (?) approved.

Question: Is it OK for ILRS?

Why:

The new satellite(s) may

- carry a (very) different retroreflector array.
  (← Array info should be stored on the ILRS website.)
- have a huge impact to ILRS tracking resources.
- require a different style of ILRS support.

Solutions: To be discussed with ILRS GB+CB.

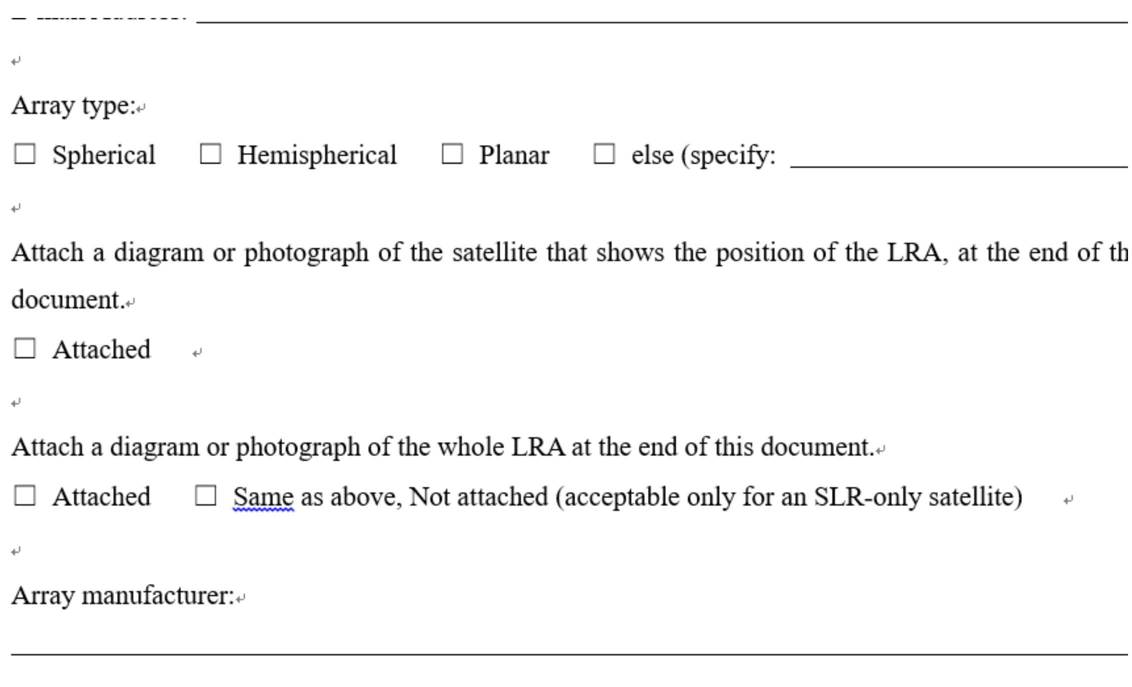
Any change in retro array? Significant change in the mission? → Sent to MWG.

Request a subset/update of the MSRF?

(Too much for MWG?)

(4) MSR Form

- **Revision plan being prepared.**
  - **Easy to fill in & easy to read.**
  - **Eliminate ambiguous questions.**



Array type:

☐ Spherical ☐ Hemispherical ☐ Planar ☐ else (specify: ____________

Attach a diagram or photograph of the satellite that shows the position of the LRA, at the end of th document.

☐ Attached

Attach a diagram or photograph of the whole LRA at the end of this document.

☐ Attached ☐ Same as above, Not attached (acceptable only for an SLR-only satellite)

Array manufacturer:

____

- **To-Dos**
  - **(Soon) Distribute our revision draft to the MWG members.**
  - **Get an approval from the MWG & CB/GB.**
  - **New version placed on the ILRS web.**

Closure

Next meeting:

Potsdam, Oct 2016 (in conjunction with the 20th Workshop)

Status and prospects of Compass and PN1 satellite missions

Zhang Zhongping

Shanghai Astronomical Observatory ,
Chinese Academy of Sciences

2015.10.26

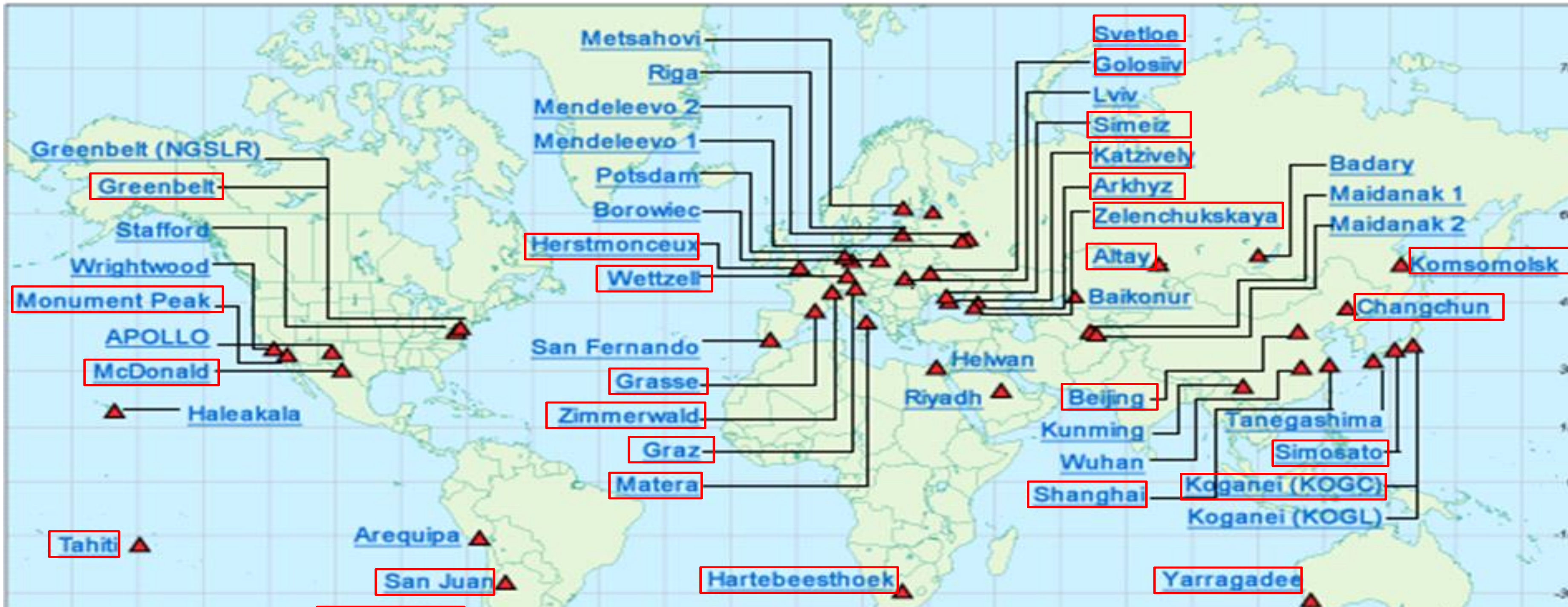
Contents:

1. Introduction

- Compass is the Chinese regional satellite navigation system, consisting of GEO, IGSO and MEO satellites with altitudes from 21,500 km (MEO) to 36,000 km (IGSO/GEO)
- Compass-M1, Chinese experimental GNSS satellite launched in April 2007, started being tracked by ILRS stations since December 2008 for the first time in China.
- From July 2012, Compass-G1/-I3/-I5/-M3 become ILRS missions for precision orbit determination (POD) and microwave measuring technique calibration.

LRAs for COMPASS satellites designed by SHAO

	MEO	GEO/IGSO
Size	32.6×28×3.0cm	49×43×3.0cm
Diameter of corner cube	33mm	33mm
Number of corner cube	42	90
Reflective area	360cm^2	770cm^2
Material	fused quartz	fused quartz
Divergence	7±1″	6±1″
Weight	2.45 kg	4.85 kg



- **At the end of 2014, there are:**
  - **7 stations track Compass-G1**
  - **11 stations track Compass-I3**
  - **18 stations track Compass-I5**
  - **27 stations track Compass-M3**

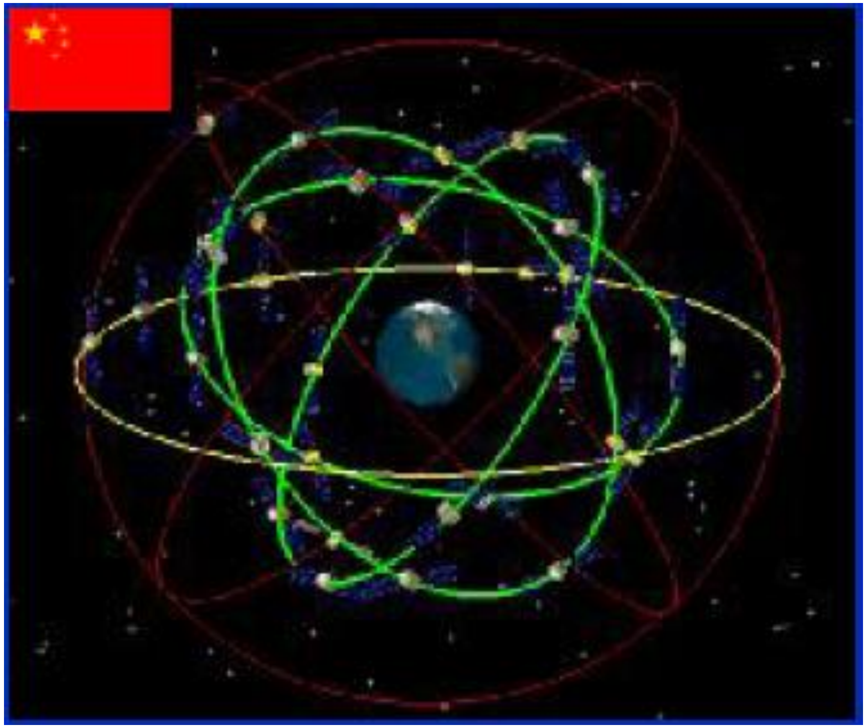
2. Status and prospects of new compass

- The new generation of experimental compass satellites (five satellites, two IGSOs and three MEOs) have been launched or will be launched in late 2015.
- Up to now there are two IGSOs and two MEOs on the orbit and is still in process of satellites testing.
- Request of being tracked by ILRS stations have been submitted to CB / MWG and approved.
- Now the preparative work for global laser tracking are still underway and once the requirements of orbit prediction for laser tracking are met, the CPF files will be submitted to EDC and the track campaign will start (maybe at the middle of November), including observed four satellites.

2. Status and prospects of new compass satellites

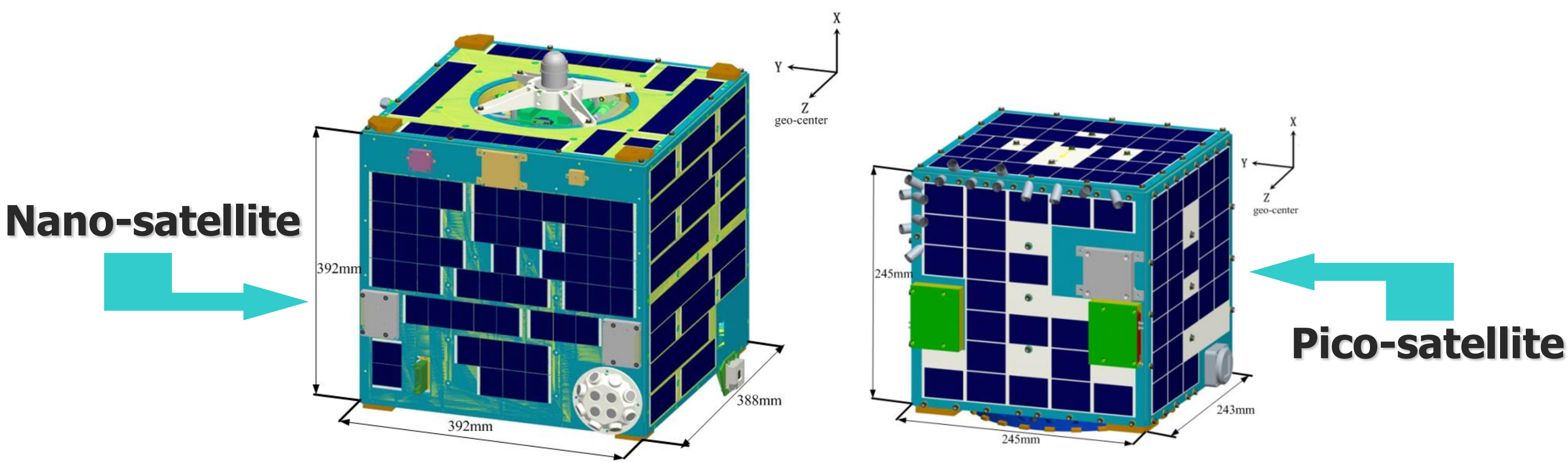
- After the five new compass satellites pass the technical validation, the batch of compass satellites (major MEO satellites) will be launched during the following five years.

- By the year of 2020, the global Compass constellation will be formed, including more than 30 satellites and the global navigation services will be provided.



3. Status of PN1-A/B/C/D satellites

- PN1 missions are the Chinese experimental satellites which are an initiative project of China aiming at precise orbit determination and thermosphere density detection.
- The missions consists of 1 nano-satellite with the mass of 15 kg and 3 identical pico-satellites with the mass of 5 kg at the orbital altitude of 530 km in a near-circular orbit.



3. Status of PN1-A/B/C/D satellites

- The PN1 satellites primarily carry 3 payloads as follows:

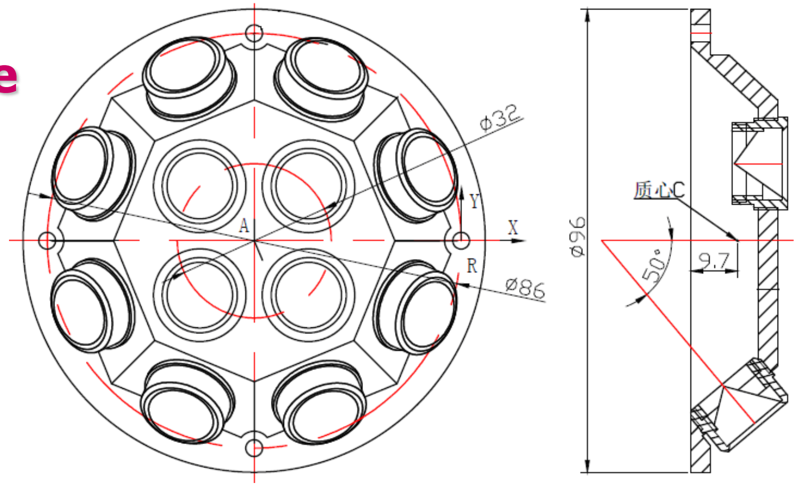
Payloads	Onboard
Multi-Mode Dual-Frequency GNSS Receiver	Nano, Pico
Atmospheric density Detector	Nano
Laser Retro-reflector	Nano, Pico
S/X VLBI Beacon	Nano

- The data from GNSS Receiver will be as the main observation for orbit determination and prediction and the LRAs will be also used for orbit determination and calibration.

- The satellites have been launched on Sept. 19 and now PN1-A has been in normal condition, the payload tests for PN1-B/C/D are still underway.

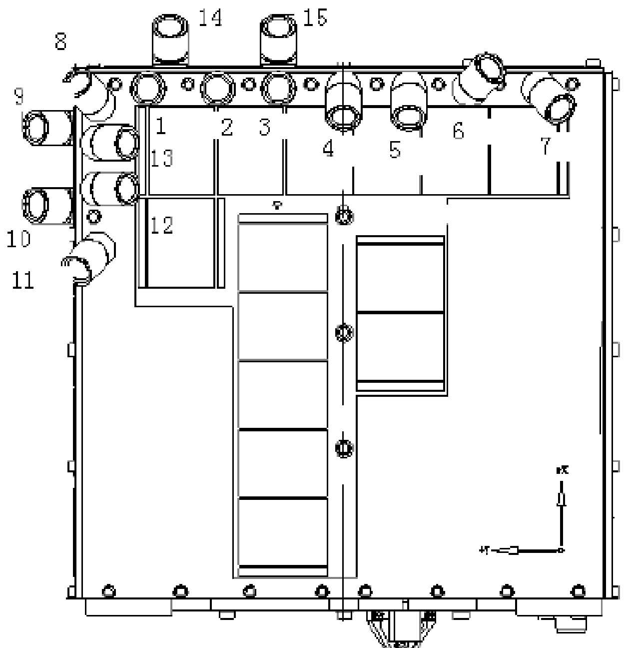
3. Status of PN1-A/B/C/D satellites

Laser retro reflector on Nano-satellite



The size of array is Φ96mm*20mm,
and the aperture of single cube corner is 13.6mm,
and the weight is about 115g,
and total of 12 corners

Laser retro reflector on Pico-satellite

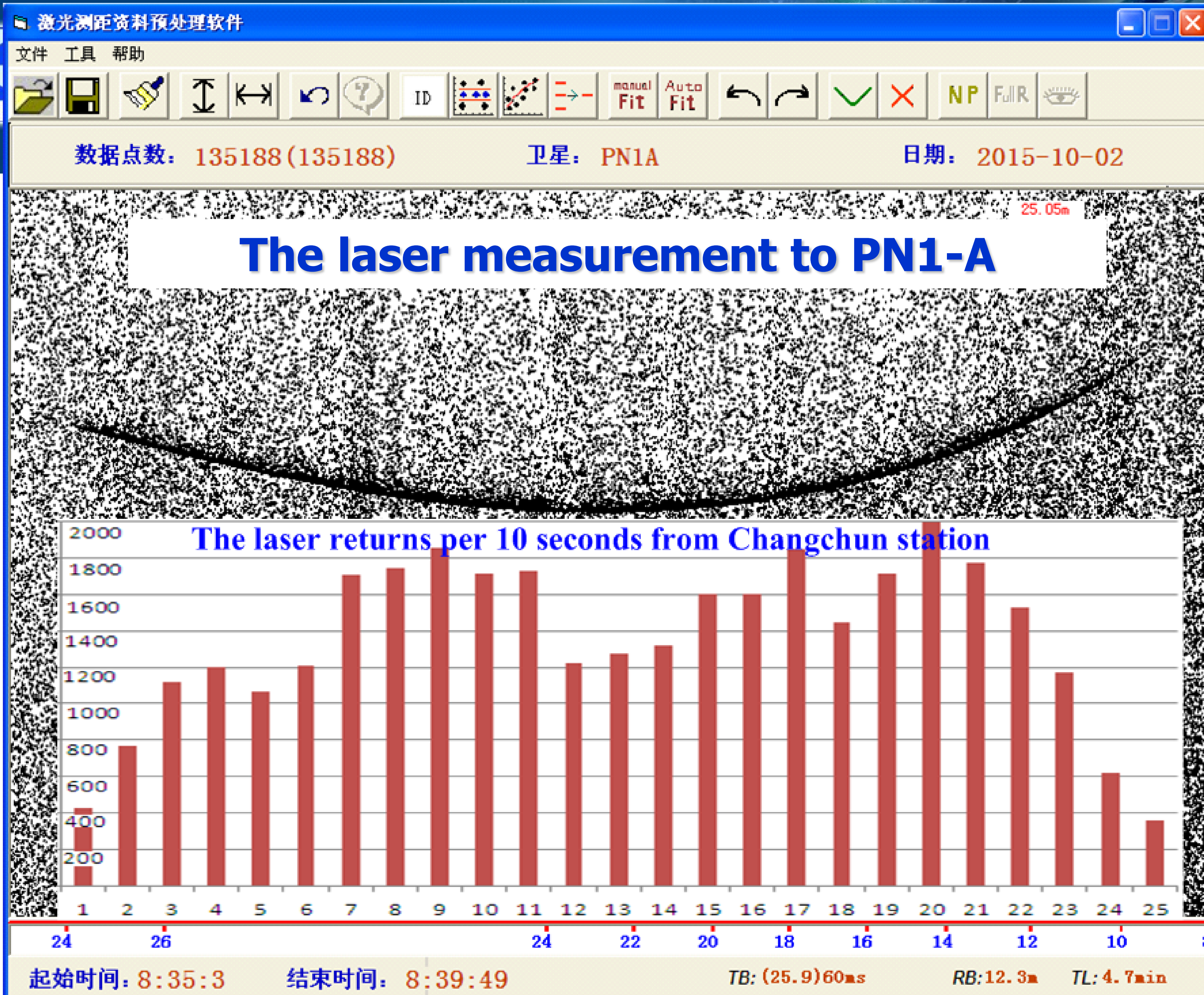


The cube corners are installed directly on the surface of satellite,
and the aperture of single cube corner is 10mm,
and total of 11 corners

3. Status of PN1-A/B/C/D satellites

- The preliminary laser observation has been performed for PN1-A (nano-satellite) at Shanghai and Changchun SLR station on October 02 to check the LRA by using the CPF files produced by Beijing Aerospace Control Center (BACC).
- From the laser measurement, the retro reflector on nano-satellite work well and the range residual is from -50m to 200m and the time bias is 20 ~ 30ms.
- From the statistic of laser echoes, the average return rate is about 10% for kHz repetition rate laser.

The laser measurement to PN1-A



4. Summary

- **More compass satellites will be participated in the International SLR observation and the opportunities to research on different kinds of GNSS satellites are provided.**
- **More stations which can track COMPASS satellites support the observations to Chinese satellites to support its POD and calibration.**
- **The laser track to Chinese nano- and pico- satellites will be performed to support of POD to give the chance to test of compact satellites and LRAs.**
- **From the preliminary measuring results, the orbit prediction is usable for laser tracking.**

Thank you！

LightSail-B Mission Overview

Sean Chait

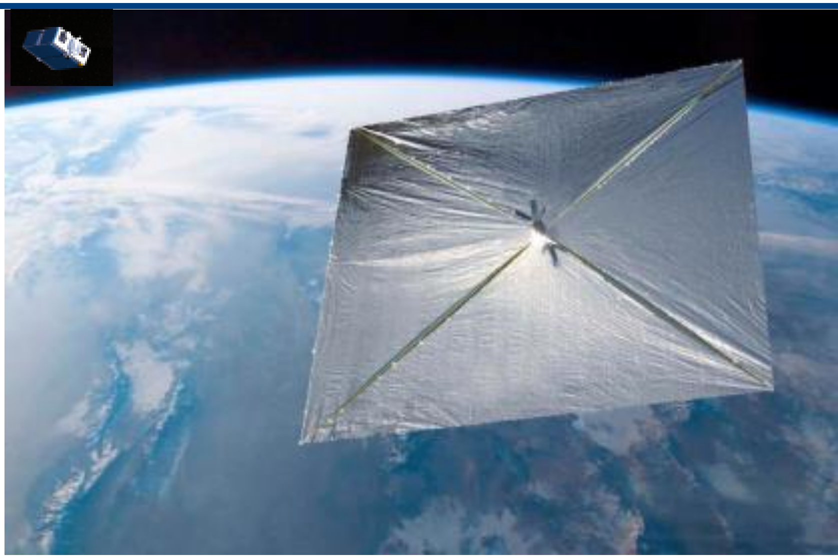
Dr. David Spencer

October 26, 2015

Space Systems Design Lab

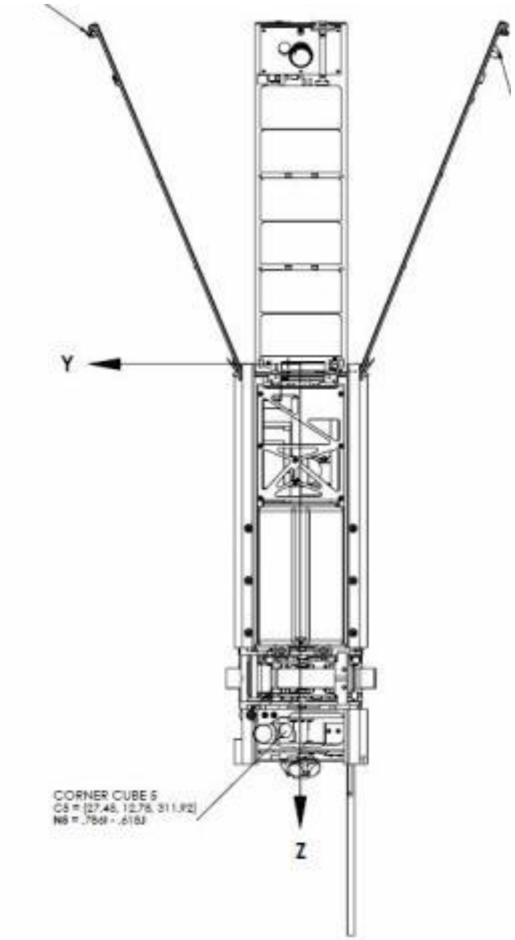
Georgia Institute of Technology

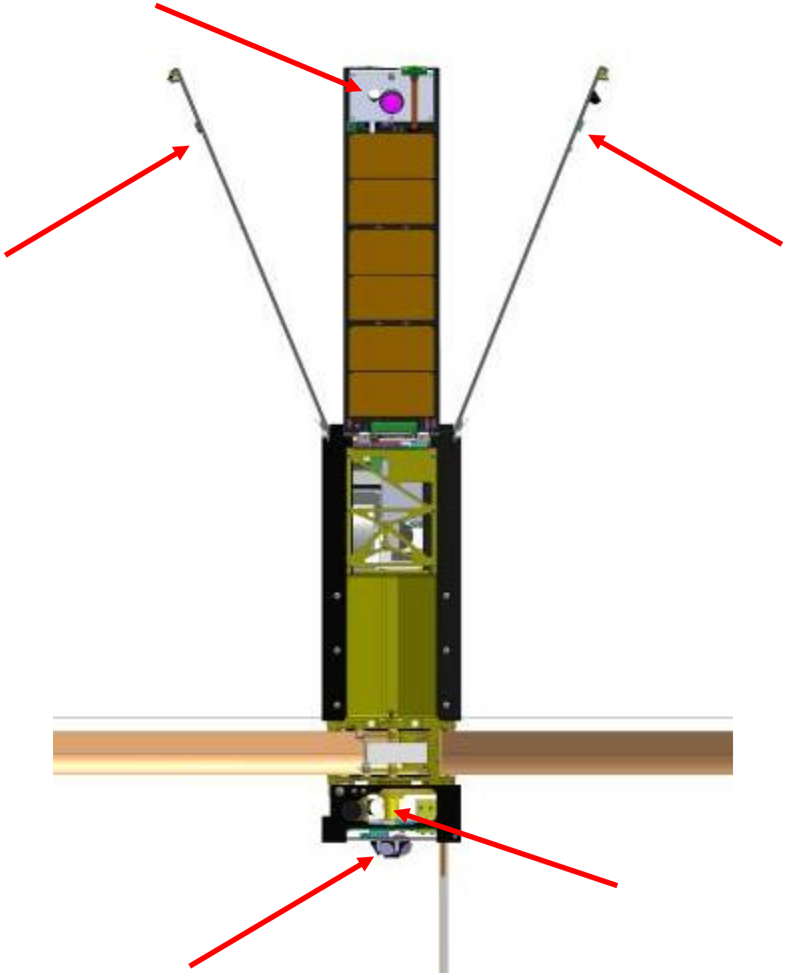
LightSail-B Mission Overview



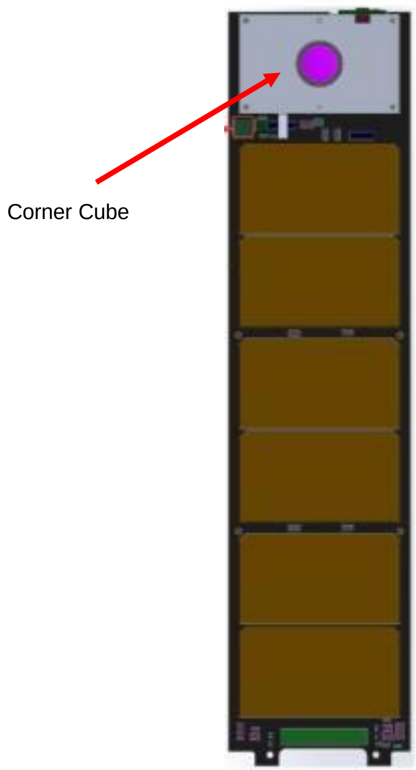
- LightSail-B Mission Objectives
  - Deploy 32 m^2 solar sail from 3U CubeSat
  - Demonstrate controlled orbit change using solar radiation pressure, increasing apogee
  - 30-day mission duration following sail deployment
- Planned launch date: Sept. 15, 2015
  - STP-2, SpaceX Falcon Heavy
  - Cape Canaveral AFS
  - Orbit: 720 km circular, 24° inclination
- LightSail-B will be deployed from the Prox-1 microsatellite
- Following spacecraft checkout and Prox-1 rendezvous, solar panel and solar sail deployment will be initiated via ground commands
- Sail orientation is controlled using torque rods and a single-axis momentum wheel
- Expected apogee rate of change: 700 m/day during first two weeks
- Possible extended mission: ground-based laser propulsion demonstration
- 13 total corner cubes for laser ranging, both solar panel and body mounted

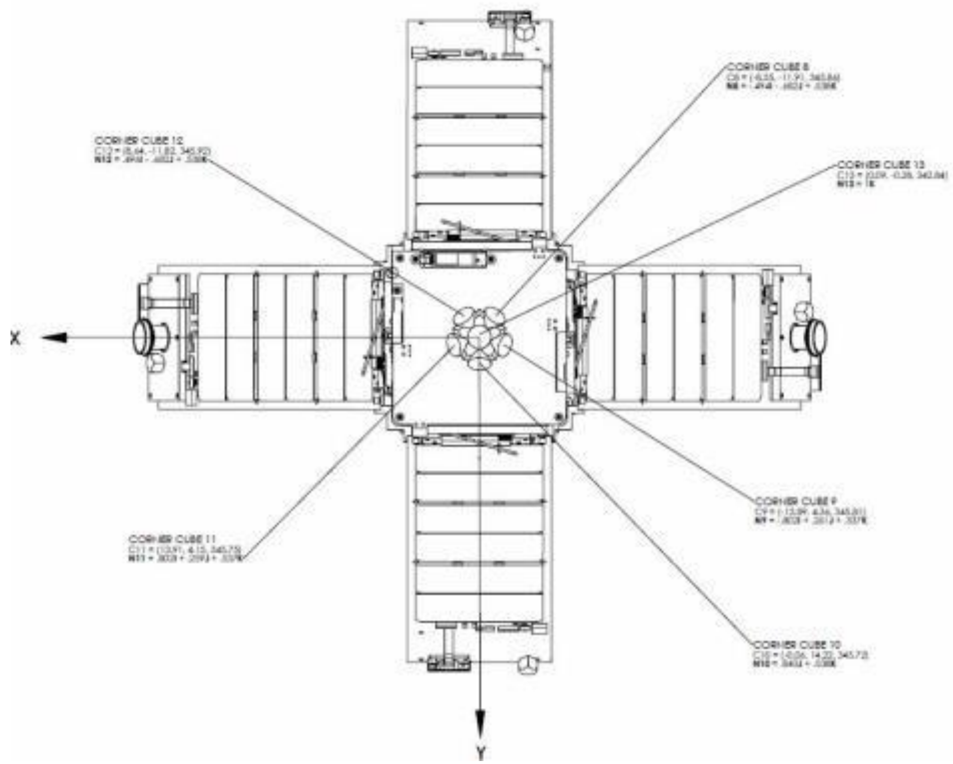
LS-B HARDWARE OVERVIEW (1 OF 3)



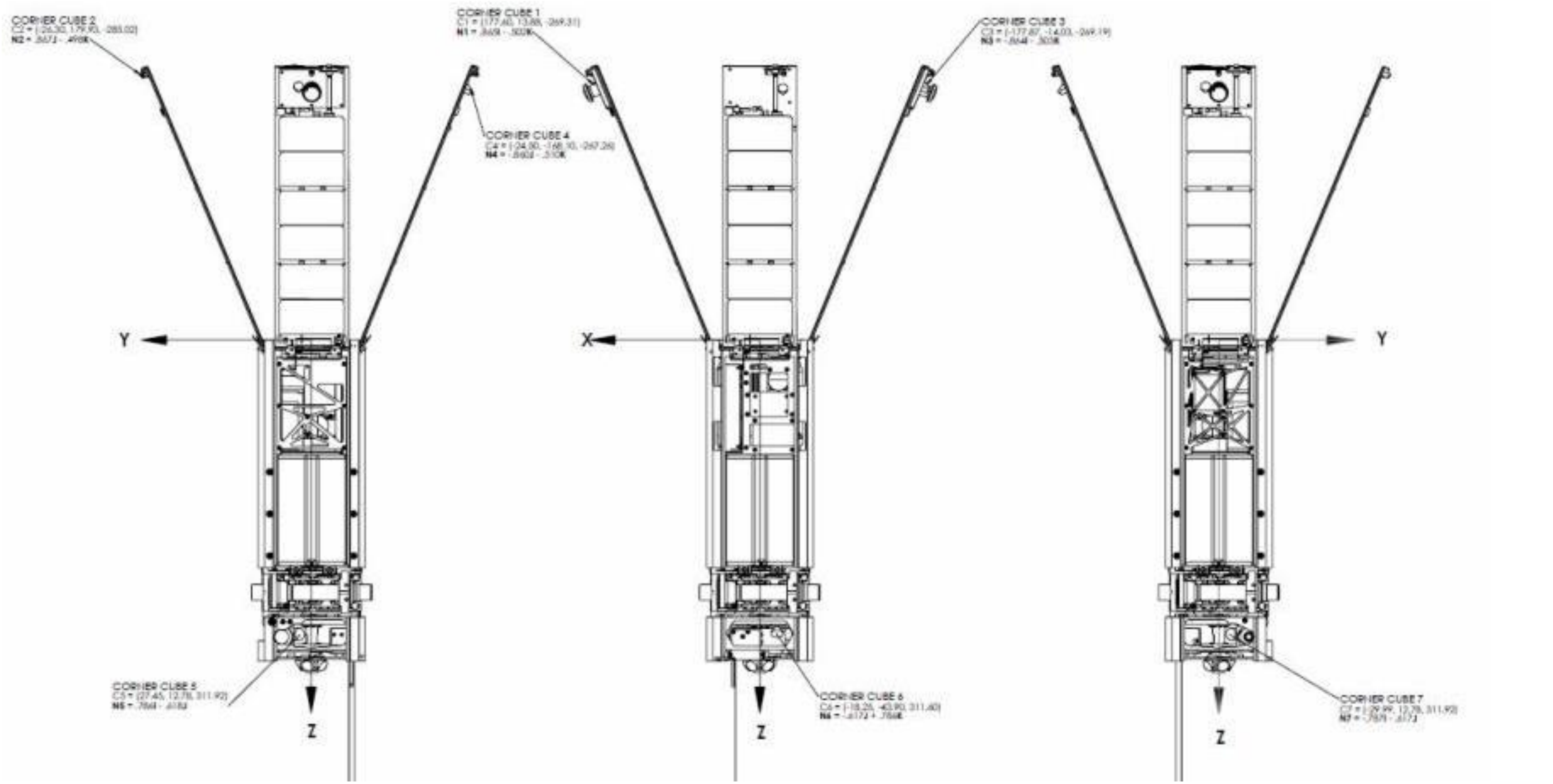


LS-B Hardware Overview (2 of 3)





LS-B Hardware Overview (3 of 3)

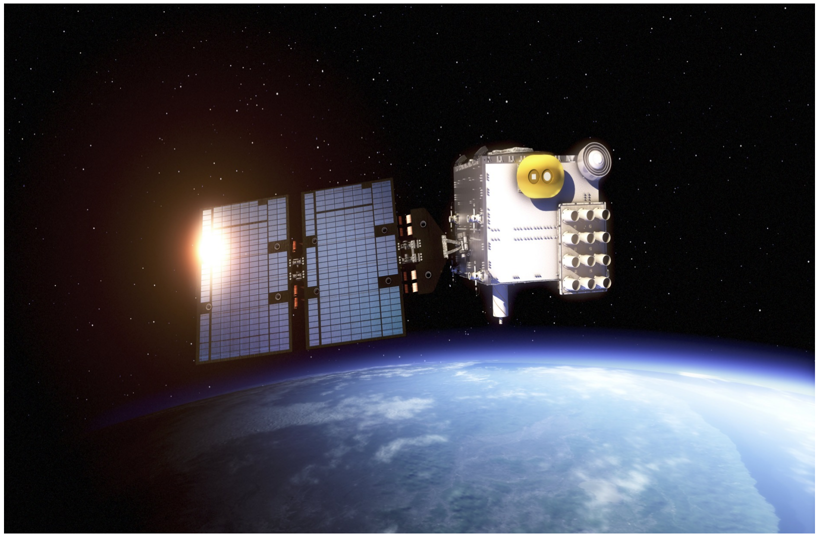


Lessons Learned From LightSail-A

- LightSail-A was in a highly elliptical orbit (350 by 700 km), low altitude resulting in a short orbital lifetime after sail deployment (< 2 weeks)
  - Meant as a spacecraft and sail deployment demo
  - LightSail-B will be in a much higher orbit (720 km circular) with re-entry predicted after 6 – 12 months

- Attitude Control/Orbit Prediction Issues
  - Software failure resulted in no attitude control of LightSail-A
  - Low altitude and lack of attitude control resulted in rapid orbit degradation and inability to precisely predict orbit decay
  - LightSail-B is undergoing a far more rigorous test program and its high altitude results in slower orbit decay even in event of ACS failure
  - Working with NASA Marshall Space Flight Center to increase reliability of orbit prediction methods

- Increase in number of corner cube reflector arrays
  - Six additional corner cubes added to LightSail-B to increase visibility to laser ranging stations



COSMIC-2 Status

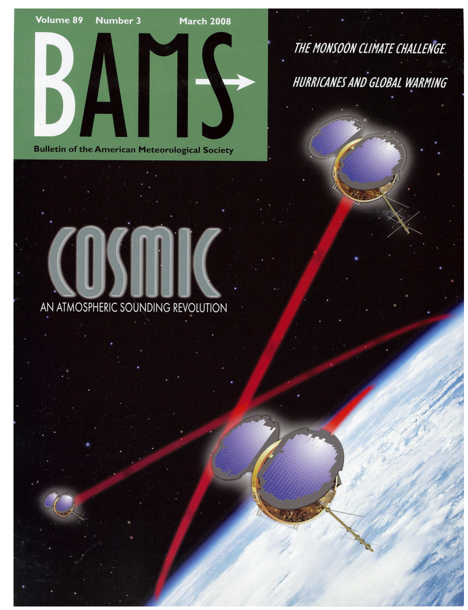
Jan Weiss

ILRS Workshop

October 26, 2015

Background

- Constellation Observing System for Meteorology, Ionosphere, and Climate (COSMIC)
- Primarily GNSS radio occultation (RO) mission for weather and space weather
  - Global profiles of pressure, temperature, moisture, ionosphere electron density, ionospheric scintillation
- COSMIC-1 demonstration mission
  - 6 satellites launched in 2006
  - 4 satellites still operating
  - ~1000 RO soundings per day

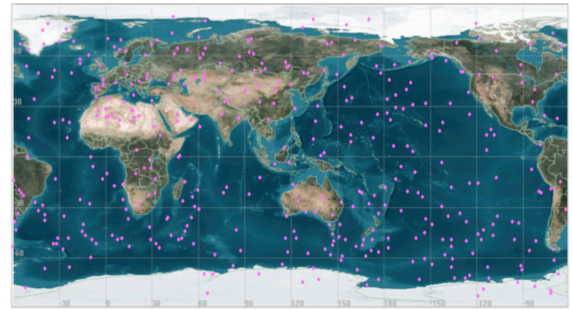


[BAMS March 2008]

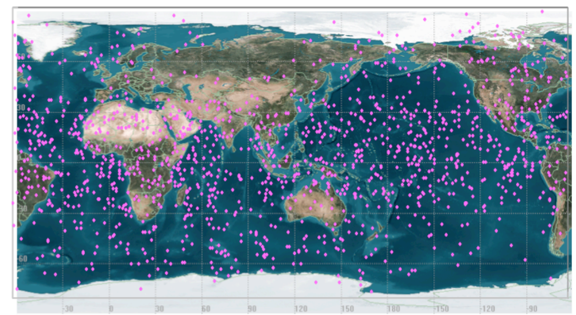
COSMIC-2 Overview

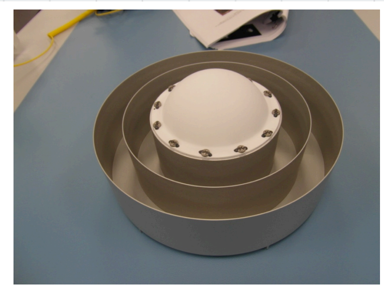
- US (NOAA, AF) and Taiwan (NSPO) partnership
- UCAR manages project on behalf of NOAA and provides operational data processing center
- Two sets of satellites
  - COSMIC-2 Equatorial
    - Launching September 2016
    - 6 satellites, low inclination (24 deg) at 520 km
  - COSMIC-2 Polar
    - Estimated launch ~2019 (not fully funded)
    - 6 satellites, high inclination (72 deg) at 800 km
  - Expect > 8000 RO soundings/day, 30 minute average latency
- GNSS payload
  - JPL/BRE TriG receiver, 2 POD choke-ring antennas, 2 phased array RO antennas, GPS+GLONASS
    - GPS L1C/A, L2P, L2C; GLONASS L1C/A, L2C/A
- Laser retro reflector
  - Designed and fabricated by Aerospace Corp.
  - Glass corner cubes 12.5 mm, 30 mm diameter housing
  - Flight heritage on PSSC-2 demonstration satellite
  - Usable above 47 deg elevation
- Additional payloads include RF beacon and ion velocity meter

FORMOSAT-3 Occultations – 3 Hrs Coverage



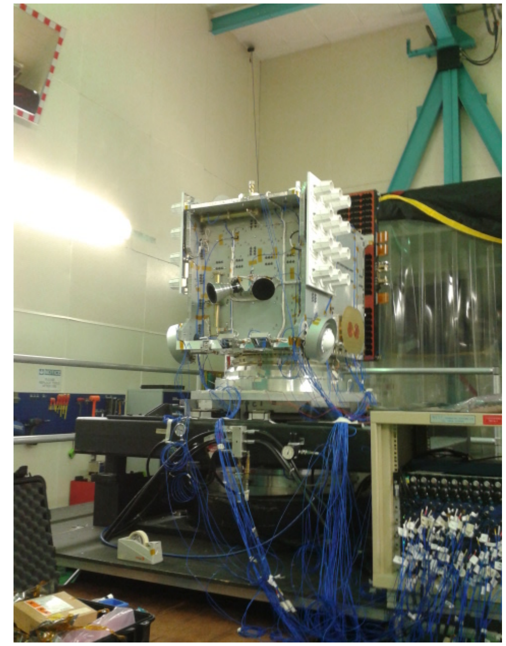
FORMOSAT-7 Occultations – 3 Hrs Coverage

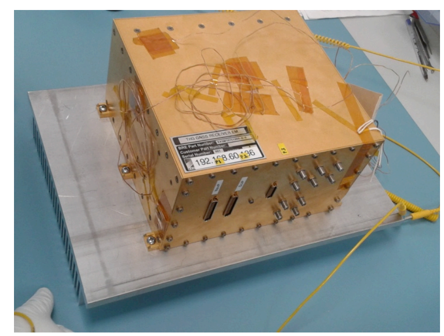




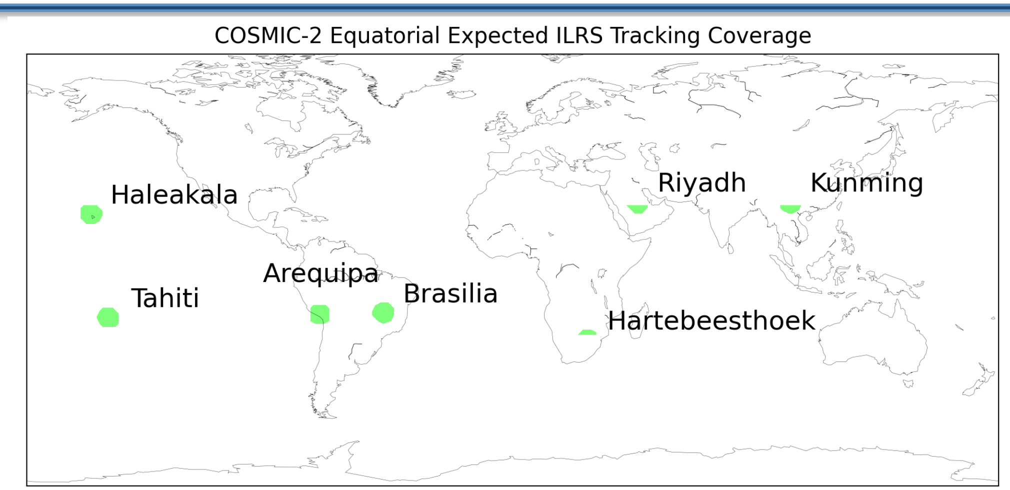
COSMIC-2 Overview

- Surrey Space Technology spacecraft bus
  - ~300 kg
  - 2x star camera, 2x sun sensor
  - Significant improvement over COSMIC-1
- First satellite assembled and tested in UK, remaining 5 in Taiwan
- Assembly of 4 satellites complete
- Launch on SpaceX Falcon Heavy from Kennedy Space Center
- NSPO will manage on-orbit satellite operations
- Post-launch orbit configuration
  - 800 km initial altitude, then reposition one at a time to 520 km
  - Transition takes 4-5 weeks
  - Transition at 12-16 week intervals
  - Close proximity for first 1-2 months supports cal/val



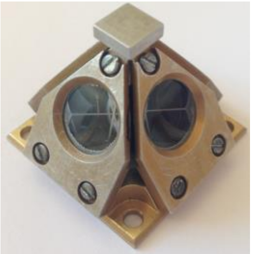


ILRS Tracking



- Suggest campaign for first spacecraft that transitions from parking to final orbit
  - Few weeks of tracking before and after transition
  - Use data to evaluate laser tracking performance, validate GNSS orbits
  - Then decide whether worthwhile to request further data
- ILRS support is very appreciated

JOINT-STOCK COMPANY «RESEARCH-AND-PRODUCTION CORPORATION “PRECISION SYSTEMS AND INSTRUMENTS»

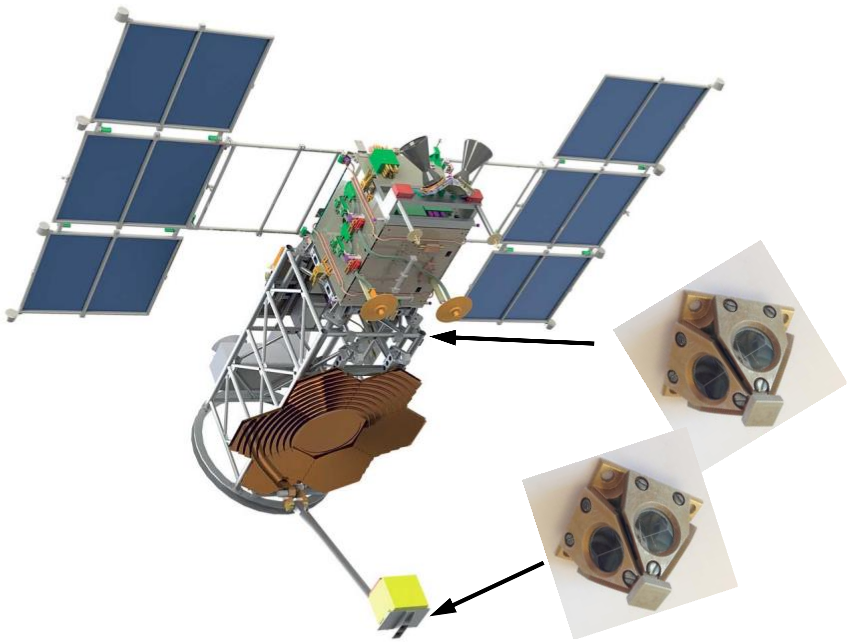


Retroreflector array for LEO satellites

Sokolov A.L., Sadovnikov M.A., Shargorodskiy V.D., Akentyev A.S.

Matera. 2015

SC «Lomonosov»

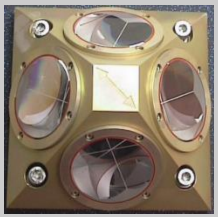
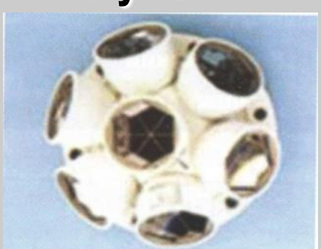


Orbit type	sun-synchronous
Orbit altitude	500 km
Inclination	97,6°
Spacecraft mass	620 kg
Exploitation period	3 years

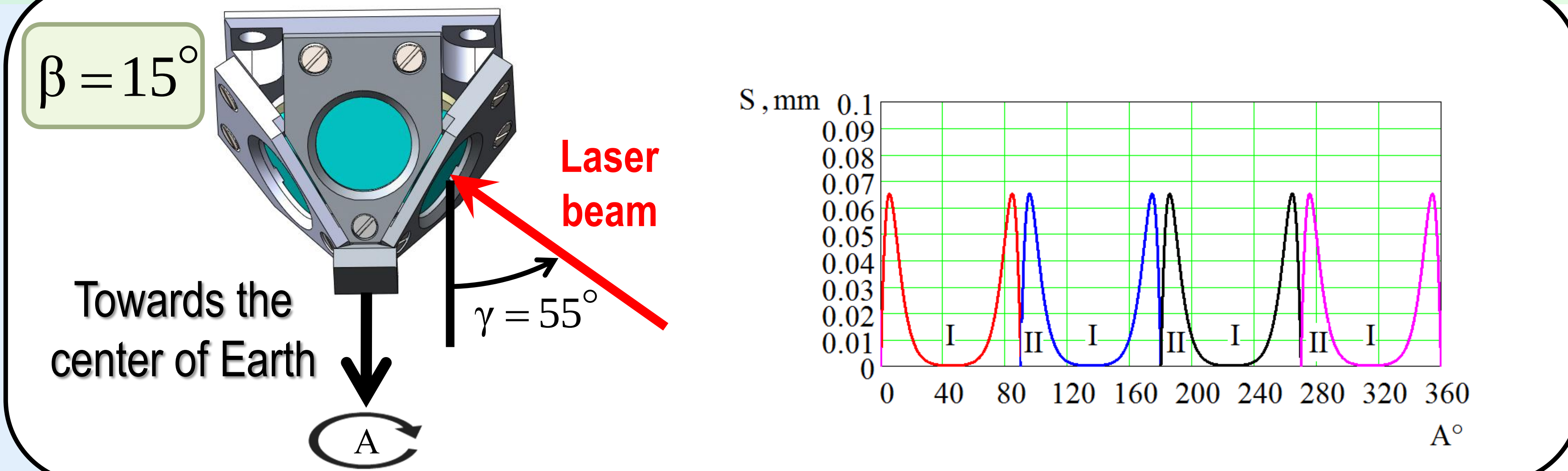
The project includes the following scientific equipment installation on-board the satellite intended for the following problems studies:

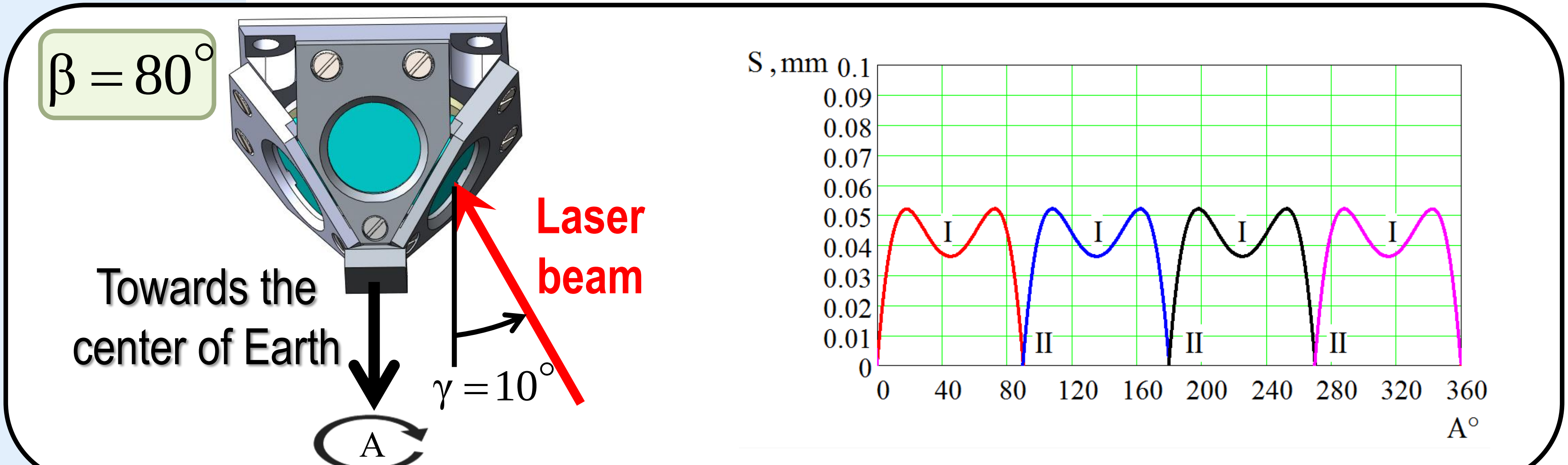
- The studies of the cosmic rays of the extremely high energy ($10^{19} – 10^{20}$ eV);
- The studies of the space gamma-bursts;
- The studies of the transient luminous phenomena in the upper atmosphere;

Retroreflector arrays comparison

Retroreflector array	Number of CCR	Mass	Size	Target error
Champ 	4	210 g	110x110x48 mm	5 mm
CryoSat-2 	7	300 g	∅114x50 mm	6 mm
Piramida 	4	30 g	40x40x30 mm	< 0.5 mm

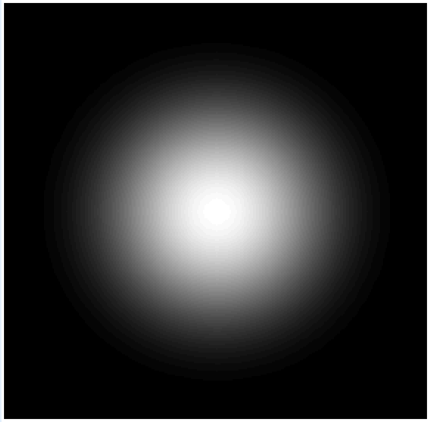
Target error

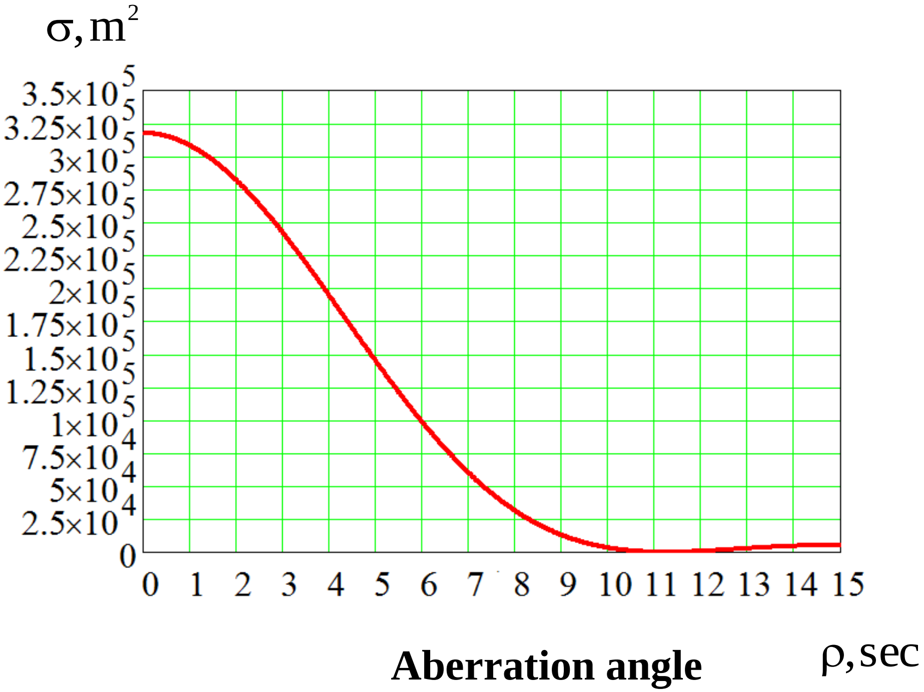




FFDP and cross-section of CCR

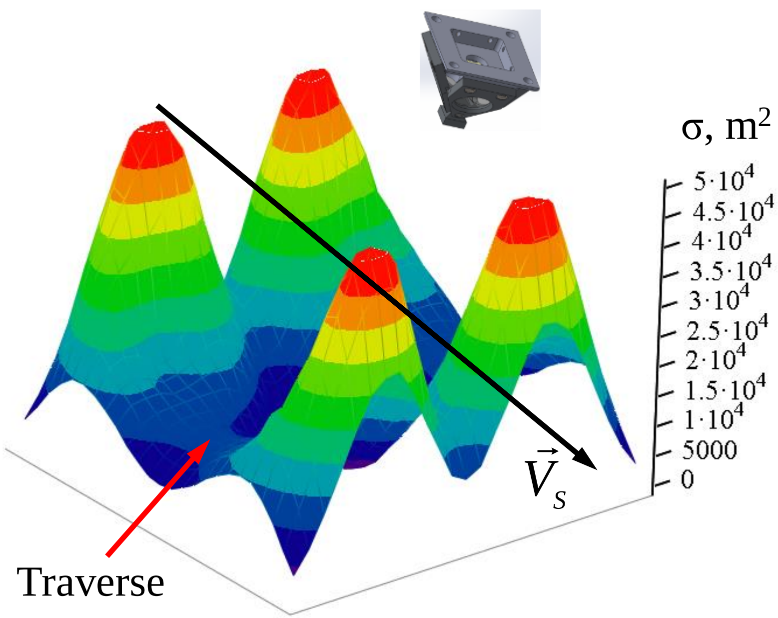
Aperture = 12 mm





Cross-section of “Pyramid”

Cross-section



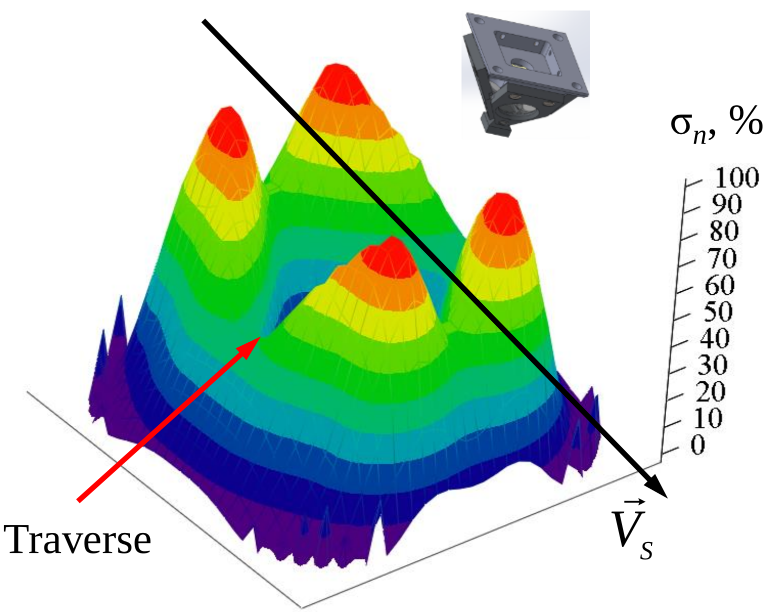
γ_{max} = 54°
A_{max} = 22°

σ_{max} = $4.9 \cdot 10^4$ m²
$\sigma_{traverse}$ = $1 \cdot 10^4$ m²

Normalized cross-section

$$\sigma_n = \frac{\sigma\, k^2 H^2}{\sigma_{max} R^2}$$

R – distance to the SC,
k – atmospheric attenuation;
H – SC altitude



γ_{max} = 36°
A_{max} = 30 °