ILRS Missions Review

ILRS Missions Working Group

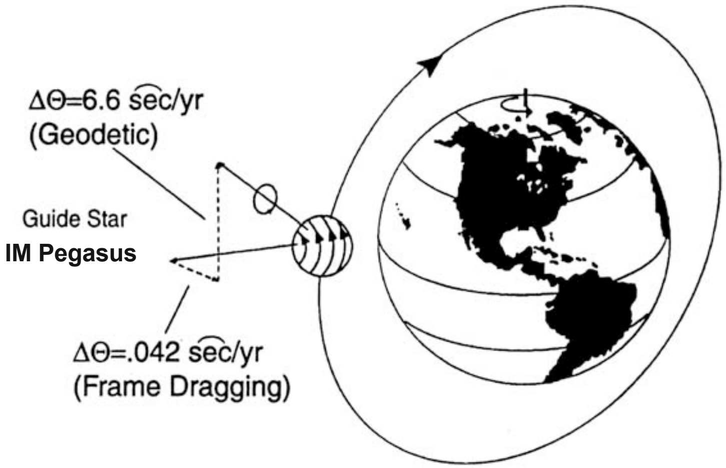
European Geosciences Union

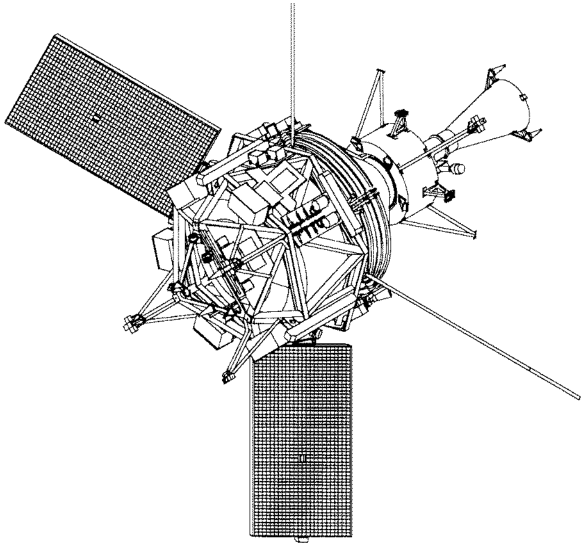
General Assembly

Vienna, 02-07 April 2006

Gravity Probe-B

- GP-B relativity experiment successfully launched and data collection phase concluded
  - Drag-free system operational but imposed some residual periodic accelerations along satellite spin axis
  - About 50 days starting 6/24/2005 close to being drag-free, providing useful gravity model testing (48 cm for EGM96, 7 cm for GGM02)
- SLR data for orbit verification
  - Inertial pointing attitude and limited field of view of the array limited laser tracks
  - Averaged 4-5 passes per day with 6-7 cm fits during best ‘drag-free’ interval





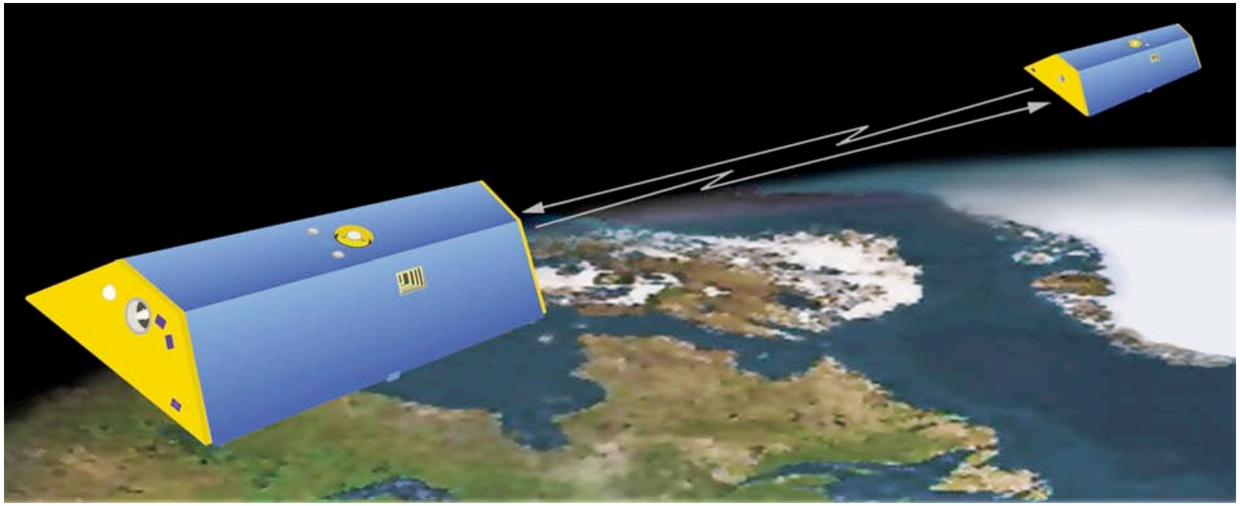
International Laser Ranging Service

CSR

GRACE

- GRACE-A and GRACE-B tracked ~4-5 times per day on average
  - Tracking between GRACE-A and GRACE-B now well balanced
    - About 3% difference only

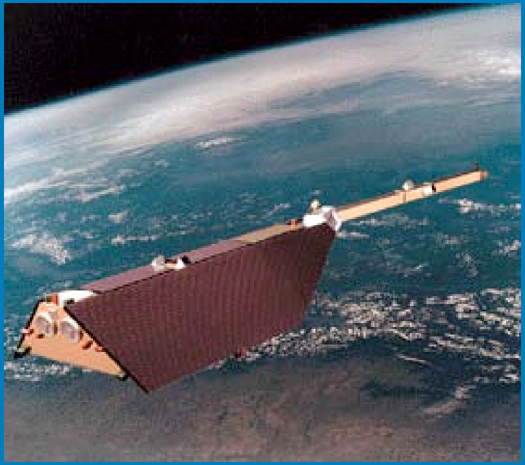
- 2-3 cm SLR RMS consistent with expected error for most accurate orbits



International Laser Ranging Service

CSR

CHAMP

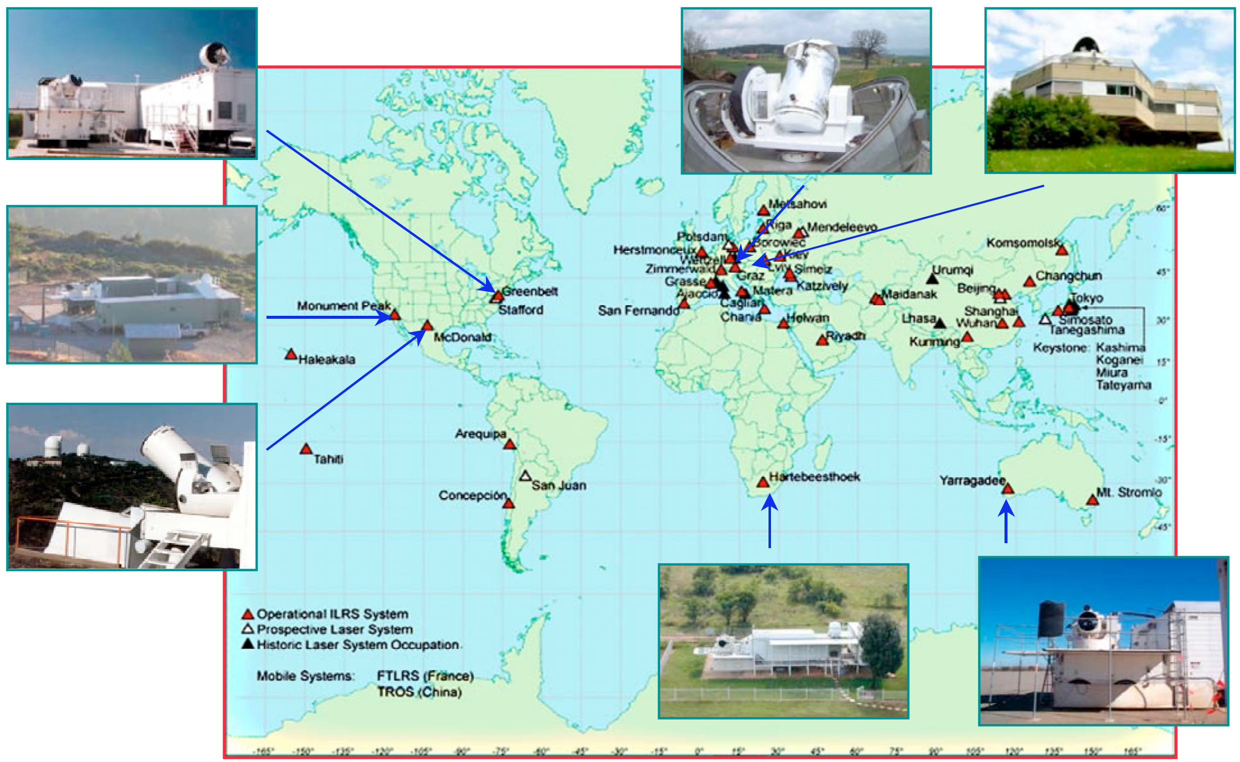


- A 5 year mission to resolve long-term temporal variations in the magnetic field, in the gravity field and within the atmosphere.
- File provided had a virus warning and could not be opened
- Stay tuned for further notice

GLAS/ICESat

Estimated orbit precision is 1-2 cm radially
(at ICESat altitude of ~600 km using GGM01)

Period	# Stations	# Passes	# Normal points	RMS (cm)
L1	2	21	312	1.44
L2A	2	8	261	1.66
L2B	1	3	37	1.73
L2C	2	23	250	2.60
L3A	1	6	48	2.69
L3B	5	37	998	1.91
L3C	6	68	1860	1.97
L3D	7	191	6278	2.48
L3E	6	78	2959	2.31
Total	7	435	13003	2.30



International Laser Ranging Service

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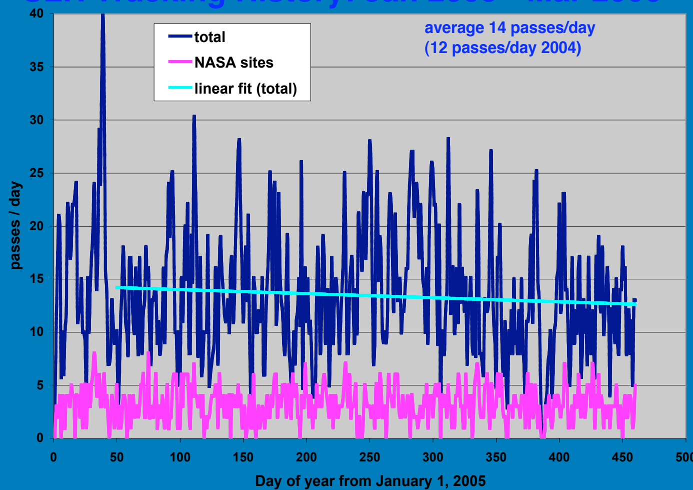
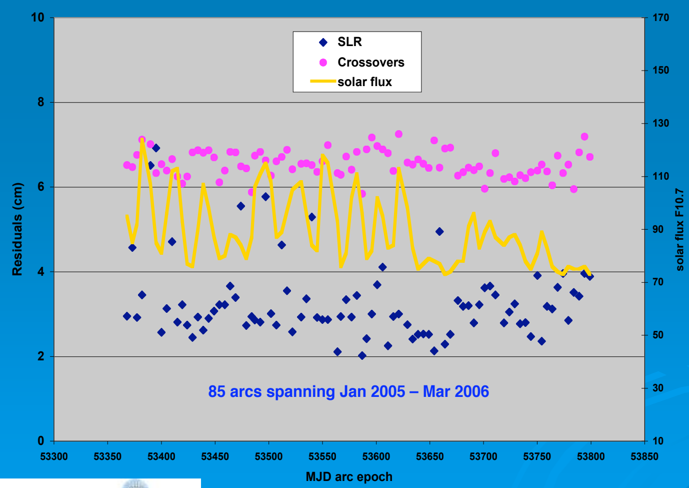
GEOSAT Follow-On (GFO)

SLR Tracking History: Jan 2005 - Mar 2006



Tracking Data Residuals



- 8th anniversary of launch in Feb. 2006
- Spacecraft showing signs of age:

  Power may be managed in the next year through shutting off ancillary systems (e.g. no direct real-time altimeter data transmissions to surface ships).

  Operations will continue for another year, and then will be reassessed.

  Altimeter data are used for mapping of mesoscale ocean variations in combination with Jason-1 & Envisat.

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Envisat/ERS-2

Institution	ERS-2		Envisat	
ESA/ESOC Michiel Otten	SLR+Altimeter	POD, Validation, Monotoring of altimer	SLR+Doris	POD, Validation Monitoring of altimeter
GFZ Rolf König	SLR+Prare	POD Altimetry Gravity field	SLR+Doris	POD Altimetry Gravity field
Newcastle Philip Moore			SLR+Doris	POD→ Graz
CNES Jean-Paul Berthias			SLR+Doris	POD for altimetry Like to get more SLR data
DUT Eelco Doornbos	SLR	Altimetry	SLR+Doris	Altimetry, Insar

Jason-1

- Tracking on Jason-1 continues to meet mission goal of 15+ good passes/day

TOPEX/Poseidon (mission ended Jan 06)		Jason-1	
Average number of passes/day	Fit RMS (mm)	Average number of passes/day	Fit RMS (mm)
24	22	19	16

- Improved fits to Jason-1 due to better models and S/C design
  - GRACE-based gravity model
  - Jason-1 LRA design supports higher precision ranging
  - GPS-based ‘reduced-dynamics’ orbits demonstrate fits < 10 mm

International Laser Ranging Service

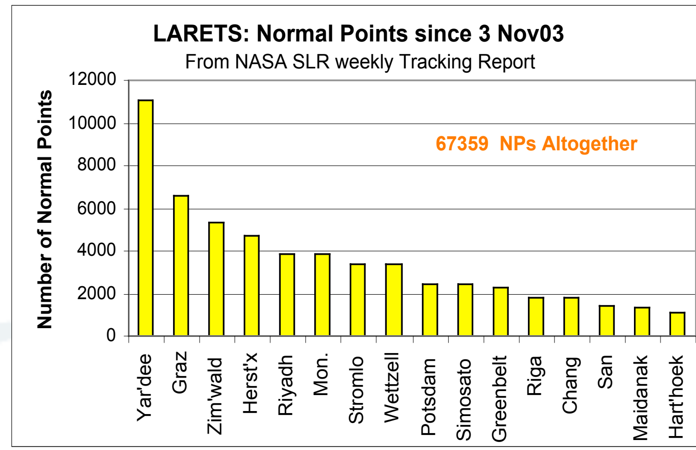
CSR

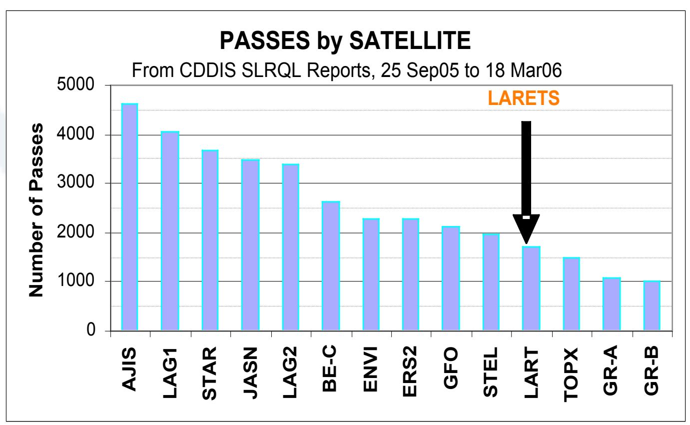
LARETS by Science Research Institute for Precision Instrument Engineering, Moscow

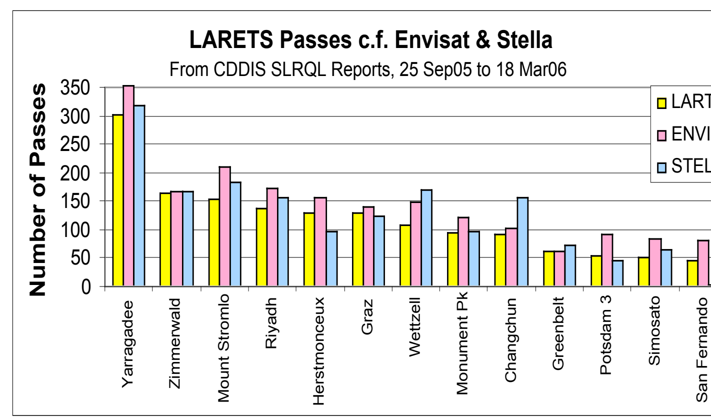
- Launch 23 Sep 2003, Altitude 691 km, Inclination 98.2°
- Passive sphere 215mm diameter, 60 cubes, mass 23.28kg, CoM correction 58±2 mm
- SLR Single Shot Precision typically 4.6mm (c.f. Grace 3.6mm, Lageos 8.8 mm, at Stromlo)
- Productivity reasonable c.f. similar orbits.

ANALYSIS CENTRE USAGE

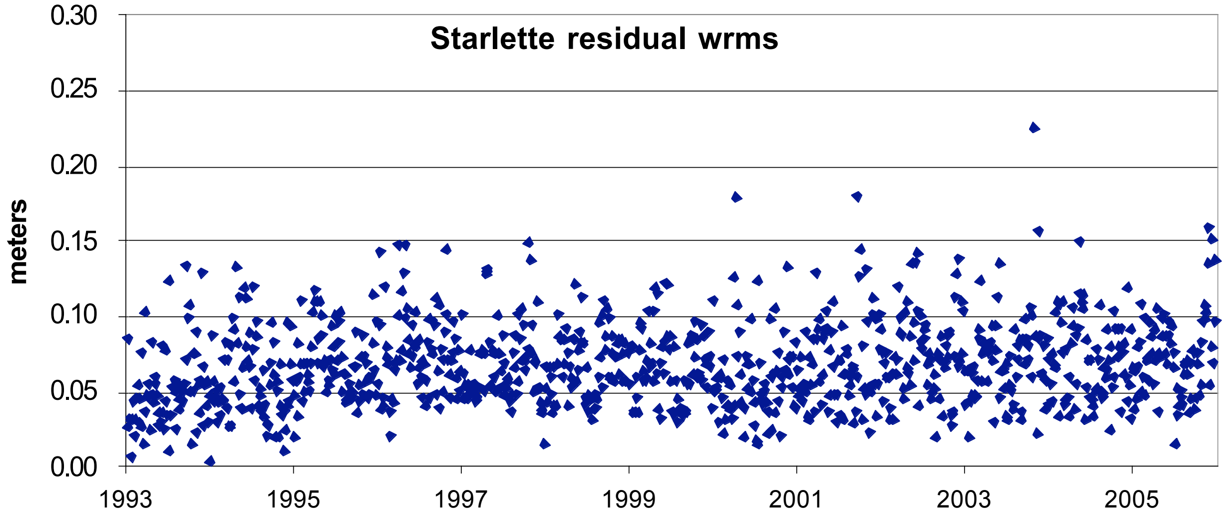
Only 3 ACs responded, NONE currently using SLR data ! (maybe SRIPIE for RF calibration)

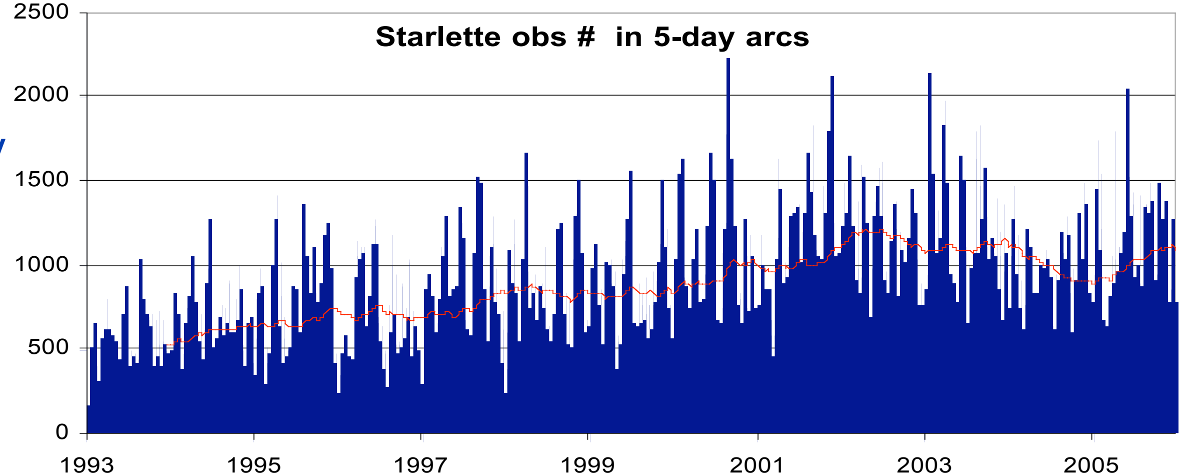






Starlette





- Starlette is very sensitive to zonal variations in the gravity field, more than the Lageos' and Ajisai

International Laser Ranging Service

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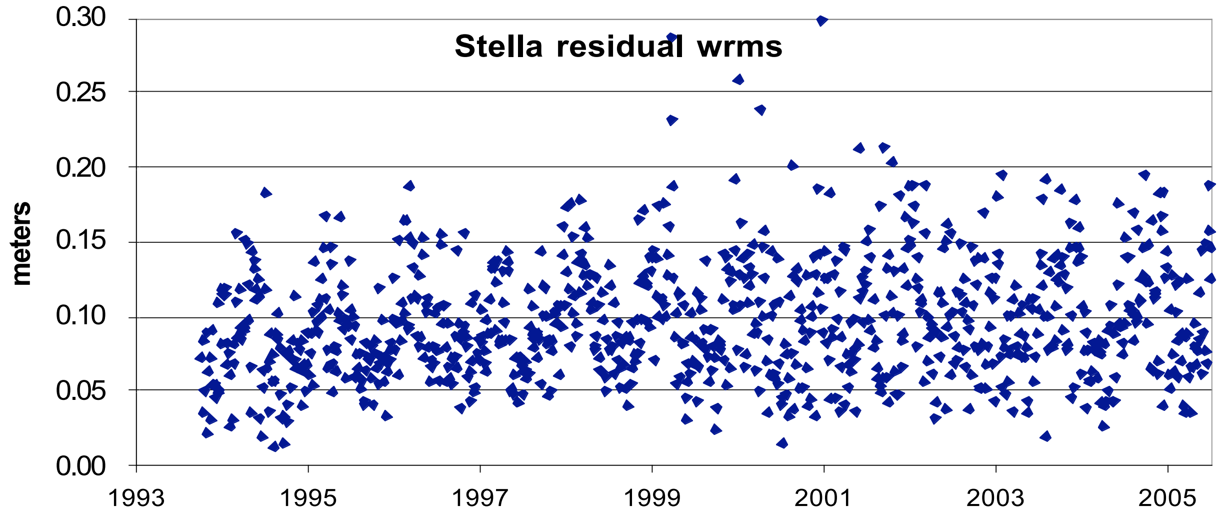
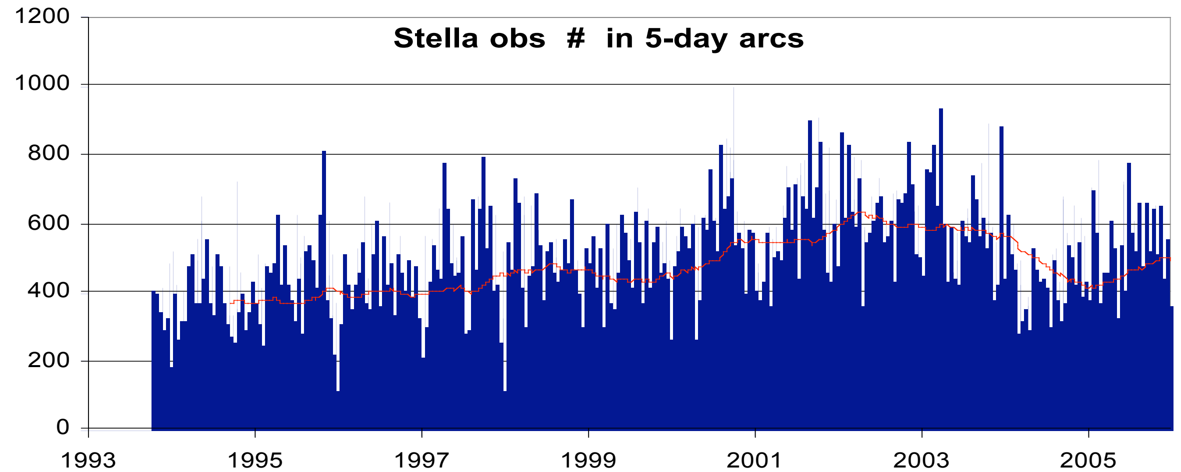
Stella





- Stella, Starlette's twin, is mainly used for gravity field recovery

International Laser Ranging Service

CSR

Meteor - 3M

- Designed to measure temperature and humidity profiles, clouds, surface properties, and high energy particles in the upper atmosphere.
- A secondary objective is the testing of the novel spherical retroreflector for precise laser ranging.
- From Frank Lemoine:
  - There appears to be a serious problem with this spacecraft. Our Russian colleagues have decided to continue trying until the end of this week. They are commanding the spacecraft from their Moscow ground station without success (that we know of). We are expecting a formal declaration from Moscow early next week. In addition, we have had no RF signal detection at Wallops, which would be a sign of progress.

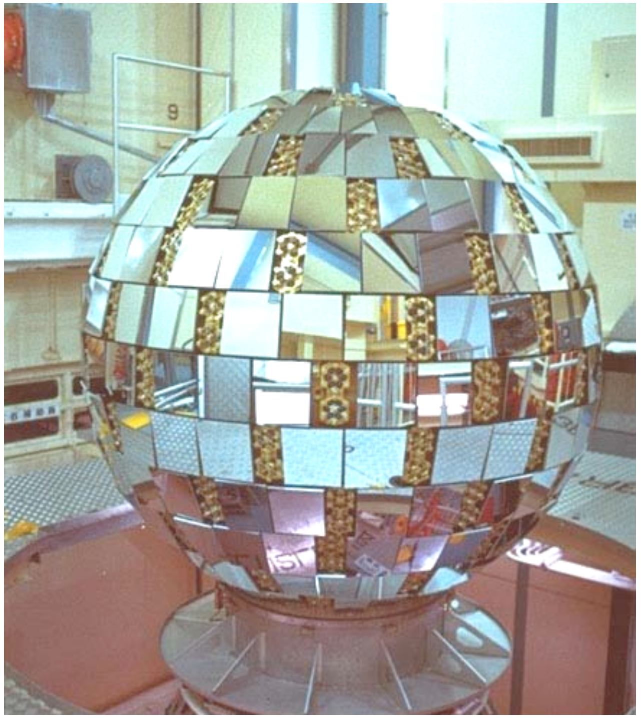
International Laser Ranging Service

CSR

AJISAI (aka EGS or EGP)

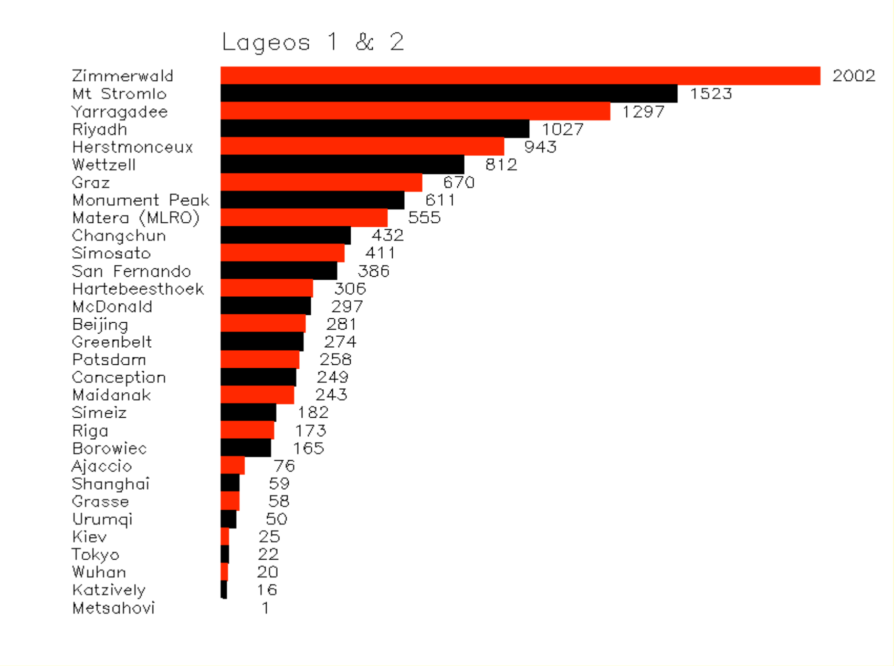
Experimental Geodetic Satellite/Payload

launched: 12 Aug 1986



- The third spherical satellite surviving > 18.6 years, and one of the most productive satellites.
- It has been used for
  - Determining the geopotential field,
  - Observing its spin rate & axis by unique photometric method and spin rate is decreasing at 30rpm now in comparison 40rpm at launch.
  - studying target signature effects for SLR (5 times larger than of LAGEOS), the latest paper:
    T. Otsubo, G. M. Appleby,"System-dependent Centre-of-mass Correction for Spherical Geodetic Satellites," Journal of Geophysical Research, Vol. 108, No. B4, 2201, 2003.
  - examining newly developed stations by NICT QC reports
  - and more …

LAGEOS 1+2

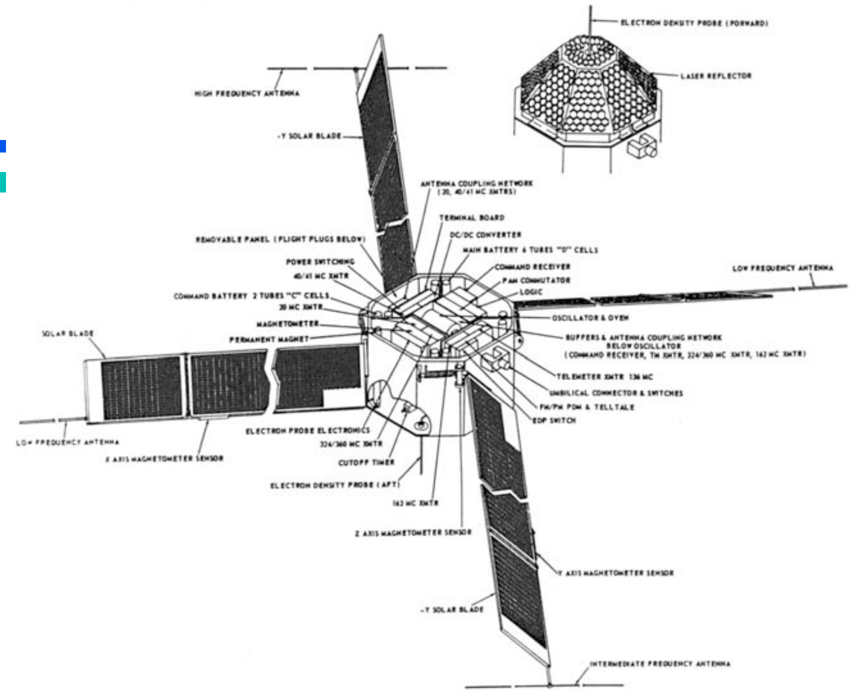


Some 20 or so ILRS stations make a major contribution to Lageos tracking, obtaining from 5 to 2 passes of the two satellites on average per day during this one-year, 2005, period.

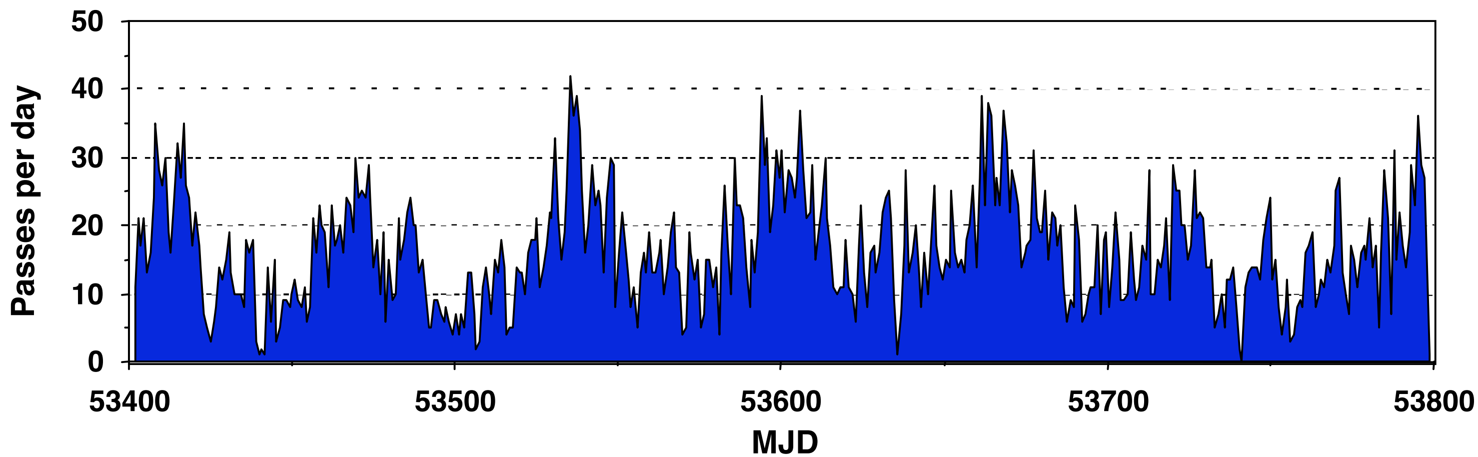
Precision of science products:
- Core site 3D positional WRMS ~5mm from weekly solutions;
- daily Xpole, Ypole, LoD: 0.1, 0.2 mas, 0.05ms

The primary science product:
- determination of the scale and origin of the terrestrial reference frame;
- realised through weekly official ILRS primary and backup coordinate and Earth orientation (xpole, ypole and LoD) solutions.
- Five or six ILRS analysis centres weekly process LAGEOS (and ETALON) data;
- Combination Centres (ASI, DGFI) form:
- combined solutions, weakly/minimally constrained for onward combination with other techniques;
- combined EOP solutions for IERS rapid services.

Beacon Explorer-C



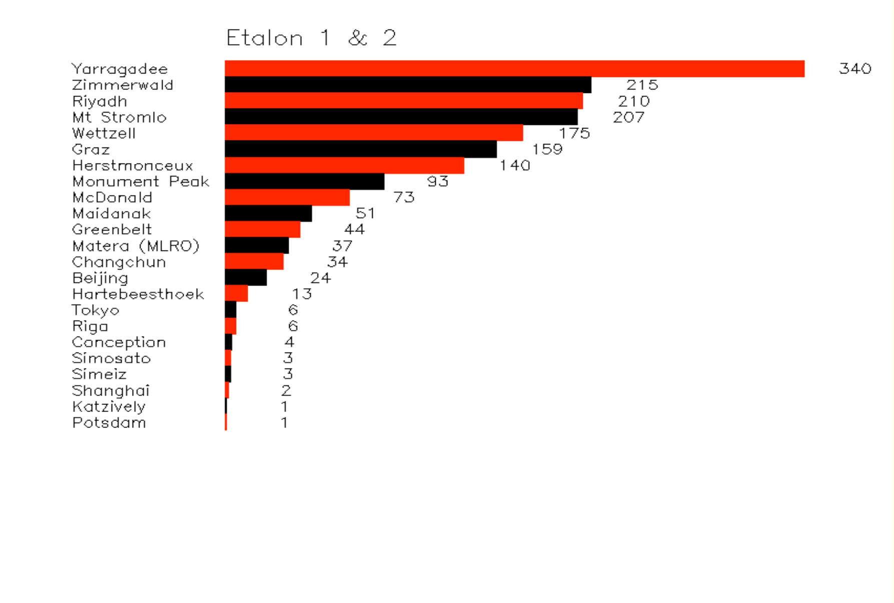
- BEC tracking used with Lageos-1 and 2, Starlette, Ajisai, and Stella for temporal gravity variability studies (Cheng et al., 2002)
- Average of 16-17 passes per day
  - Weighted RMS of fit ~9.5 cm, ranging from 4 to 26 cm
  - Southern latitude stations perform worst due to stabilization method (magnetic)



International Laser Ranging Service

CSR

ETALON 1+2

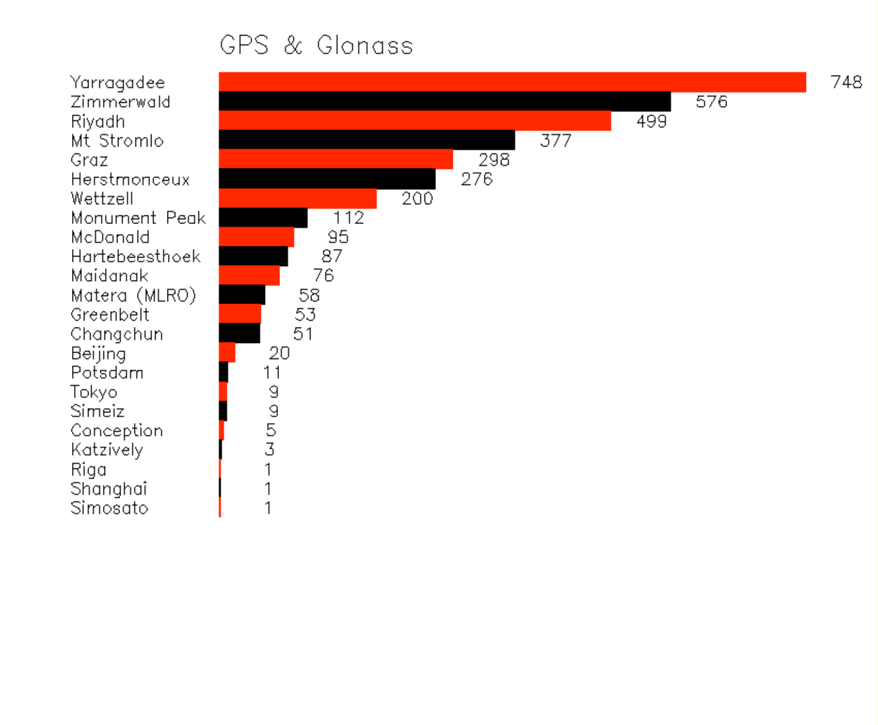


Some 10 ILRS stations make a significant contribution to Etalon tracking, obtaining from 1 to 0.1 passes of the two satellites on average per day during this one-year, 2005, period.

Precision of science products:
- daily Xpole, Ypole, LoD: 0.1, 0.2 mas, 0.05ms

The primary science product:
- augment LAGEOS determination of the scale and origin of the terrestrial reference frame
- realised through weekly official ILRS primary and backup coordinate and Earth orientation (xpole, ypole and LoD) solutions.
- Analyses suggest that including ETALON strengthens LoD determination;
- Two of the six ILRS analysis centres weekly process ETALON along with LAGEOS data towards the ILRS combination product;
- need more data and stations that regularly track;

GLONASS + GPS



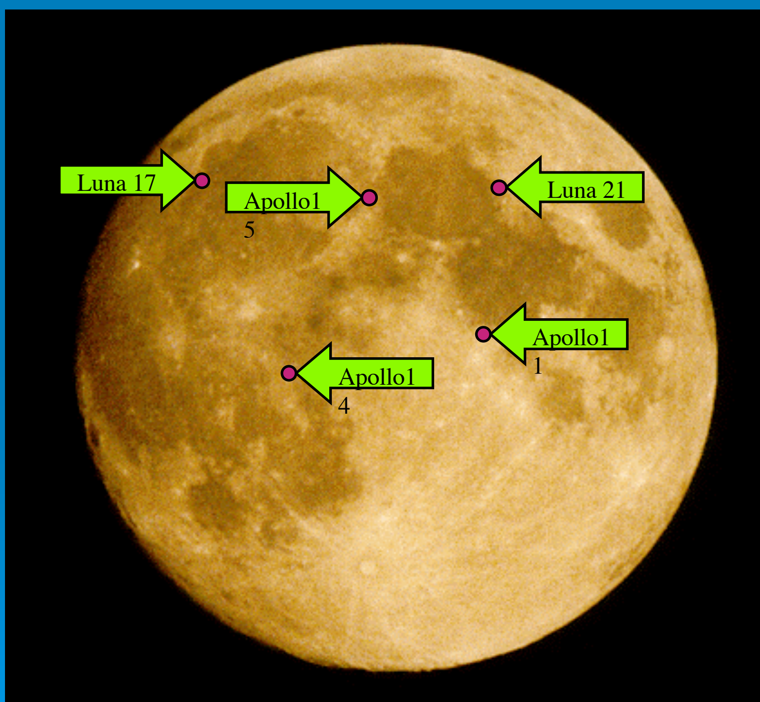
Some 14 ILRS stations make a significant contribution to GLO+GPS tracking, obtaining up to 0.5 passes of the five satellites on average per day during this one-year, 2005, period.
About 3x data yield from GLO cf GPS.
Tracking approximately doubled during the CONT05 campaign of Sept. 2005

Current ILRS GLONASS+GPS targets:

- GLO **87**, **89** and **95** (replaced **84** in Sept 2005);
- GPS **35**, **36**

The primary science products:

- Evaluation by precise laser range measurements of the accuracy of the IGS orbital ephemerides for these subsets of the GNSS constellations;
- Radial precision of those ephemerides is of order 10cm RMS;
- For the two GPS satellites, a radial bias of ~5cm exists in the IGS orbits – orbits determined by the GPS technique are 'too large';
- Testing laser array designs, for which there are at least three different ones for the GLONASS satellites.



Moon

- Science (Orbit, Relativity, Lunar Interior)
  - JPL (USA): Williams & Slava
  - Hanover (Germany) - Mueller
  - SAO (USA) - Chandler & Reasenberg
- Active Station (MLRS - USA)
- Up-grade (OCA - France, return 2006)
- Coming
  - MLRO (Italy) - Bianco
  - Apache Point (USA) - Murphy
  - Mt. Stromlo (Australia) - Green & Luck
  - Wettzell (Germany) - Schreiber
- Recent LLR Data Accumulation
  - 2005 (337 normal points)
  - 2004 (457 normal points)
  - 2003 (238 normal points)
  - 2002 (250 normal points)
  - 2001 (378 normal points)

“Thank You” to all the providers!

> GP-B	Ries/Chen (UT/CSR)
> GRACE	Ries/Chen (UT/CSR)
> CHAMP	Schreiber (Wettzell)
> ICESat	Schutz/Urban (UT/CSR)
> GFO-1	Lemoine (GSFC)
> Envisat	Gurtner (AUB)
> ERS-2	Gurtner (AUB)
> Jason	Ries/Chen (UT/CSR)
> Larets	Luck (EOS)
> Starlette	Bianco (ASI)
> Stella	Bianco (ASI)
> Meteor-3M	Lemoine (GSFC)
> Ajisai	Kunimori (NICT)
> LAGEOS	Appleby (NERC)
> Beacon-C	Ries/Chen (UT/CSR)
> Etalon	Appleby (NERC)
> GLONASS	Appleby (NERC)
> GPS	Appleby (NERC)
> Moon	Shelus (UT/CSR)

New Missions Accepted

ILRS Mission Working Group

European Geosciences Union

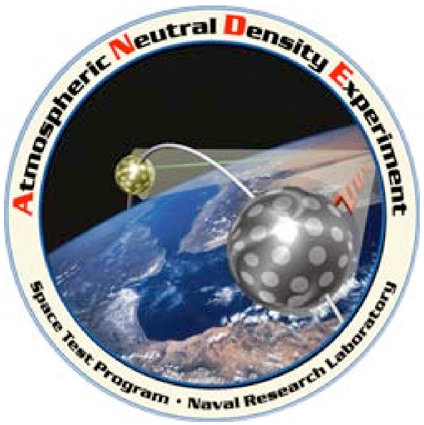
General Assembly

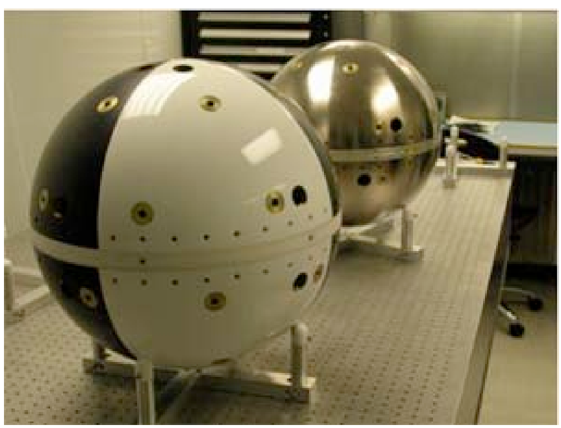
Vienna, 02-07 April 2006

International Laser Ranging Service

CSR

ANDE





- Provide total atmospheric density for the orbit
- Determination and avoidance of collisions
- Space to ground optical communication demonstration
- Validate fundamental theories on the calculation of the drag coefficient
- Provide a calibration object for the radar fence upgrade
- Establish a method to validate neutral density and composition derived from DMSPsSensors.

ILRS/MWG ANDE Decision

- Accept this mission for ILRS support
- Some comments
  - Another very low target (355 km), giving us both challenges and training
  - Some reflector and rotation data needed
  - Both satellites have corner cubes. How far will they be separated? If they are closer than 40km stations could potentially get returns from both satellites at the same time. Would that be a problem trying to figure out which return came which satellite?

OICETS

- Demonstrate optical communications with the ESA geostationary Advanced Relay and TEchnology MISsion (ARTEMIS).
- Verify technology for large volume optical communications between satellites
- Acquisition, tracking, and pointing technologies with respect to ARTEMIS
- Study the effects of micro-vibrations of the satellites on the communications link.
- SLR will provide the primary POD for OICETS.

ILRS/MWG OICETS Decision

- Accept this mission for ILRS support
- Some comments
  - OICETS has no means of POD except conventional microwave. The role of SLR is to increase the accuracy of the orbit. The project does not request high-priority of network support, but a middle-lower priority).
  - From the point of view of space geodetic products, the mission clearly is of limited value. However, it is an interesting project that potentially could get the ILRS a wider customer base.
  - the effort needed by the ILRS will depend heavily on prediction quality, which in turn depends on the tracking coverage and the modeling capabilities of the OICETS Project itself.
  - Time bias distribution might be an important issue.

MicroSCOPE

- Test of the Equivalence Principle (EP) with an accuracy of 10^{-15}.
- Two quasi identical differential micro-accelerometers including two cylindrical and concentric test masses.
- Specific drag compensation and attitude control system.
- Drag free system demonstration using FEEP (Field Effect Electrical Propulsion) is the secondary technological mission objective.

ILRS/MWG Microscope Decision

- Accept this mission for ILRS support
- Some Comments
  - There are 6 retroreflectors of unknown cross-section and field-of-view on various faces of the satellite. The satellite returns will probably blink on and off during tracking which could become an annoyance or a challenge for stations in the network
  - The ILRS needs to know more about the satellite's attitude regime to decide if this “blinking” potential will be a real issue
  - If it erists, will this “blinking” have an effect on orbit determination
  - What level of tracking might be needed to accomplish the science goals?
  - Is there a need for the ILRS network to go through a best-possible effort or can a more relaxed tracking coverage satisfy the requirements of the project?

Present Status of Advanced Land Observing Satellite (ALOS)

JAXA
Precise Orbit Determination Team
S.Nakamura & N.Kudo

ALOS Launch

- Launch date : January 24, 2006
- Launch vehicle : H2A
- Launch site : Tanegashima Space Center, Japan

ALOS launch delayed because transistors needed to be exchanged.

(Original launch period : 2005 Autumn)

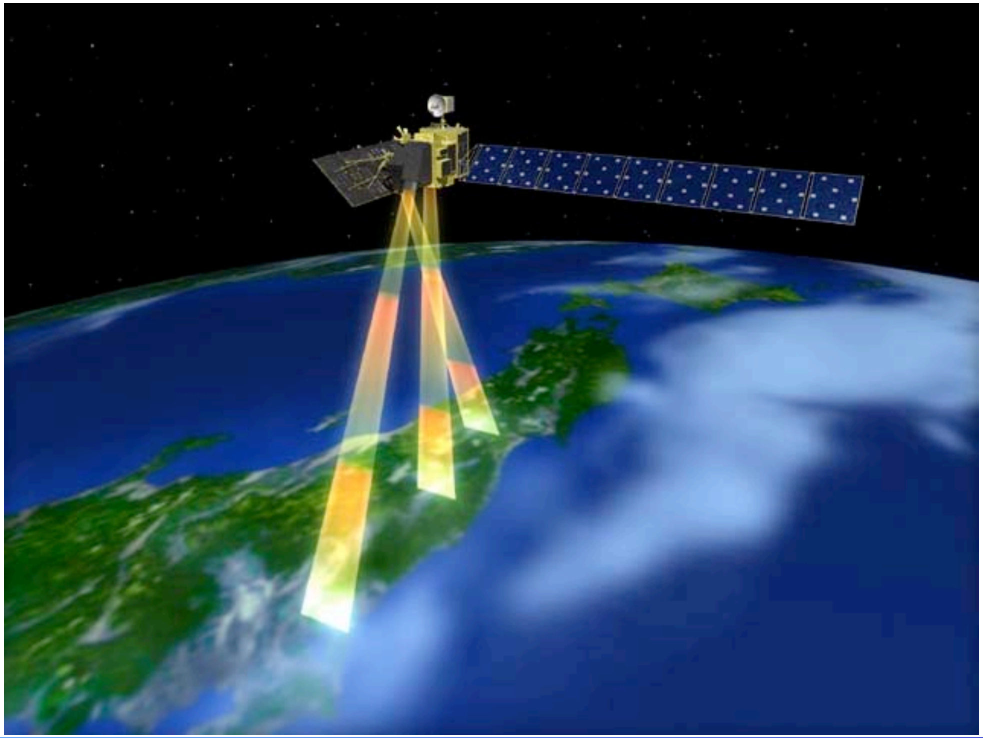
H-2A Launch Vehicle

ALOS Mission

Many world regions have not been mapped precisely.

Aim: obtain useful data for topography and land use.
produce 1:25000 maps on a global basis

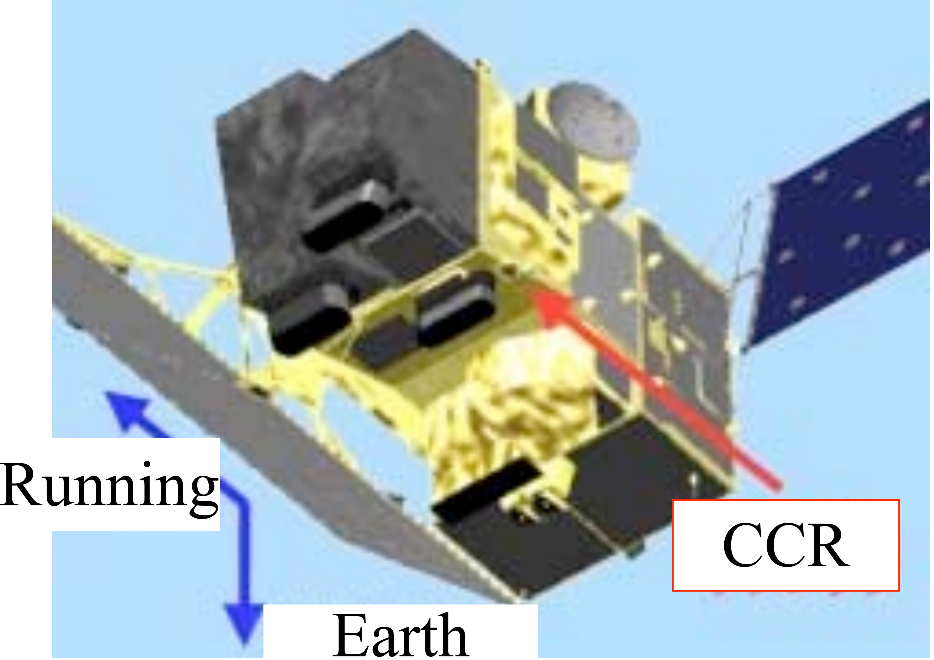
Therefore,
POD is required.



Review of ALOS

Characteristics of ALOS

Mass	4000kg
Orbit Altitude	690km (Frozen Orbit)
Orbit Inclination	98.2 deg



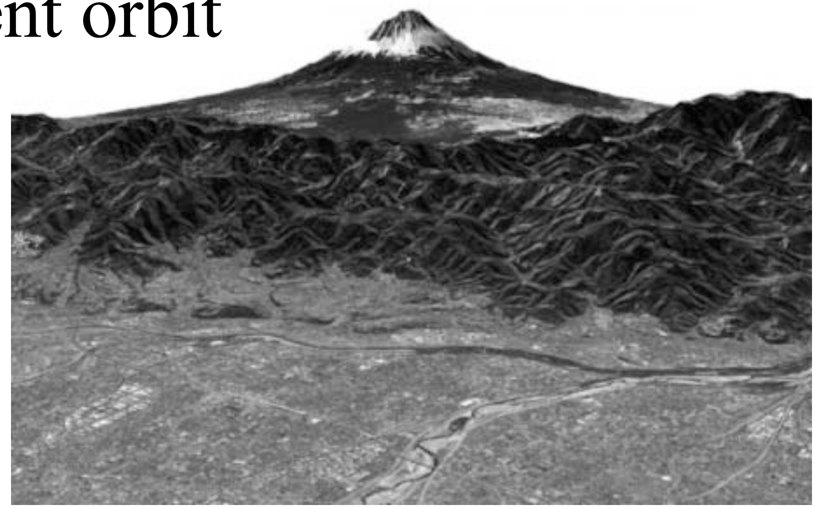
Overview of ALOS Mission

- ALOS earth observation sensors

Panchromatic Remote-sensing Instrument for Stereo Mapping (PRISM)
Advanced Visible and Near Infrared Radiometer type2 (AVNIR-2)
Phased Array type L-band Synthetic Aperture Radar (PALSAR)

- S/Ka band transponder / GPS receivers / LRRA
- Sun synchronous/ sub-recurrent orbit

View of Mt. Fuji observed by PRISM (15/Feb/2006) →



Present Status(1/4)

On JAXA SLR website,
we requested cooperation from SLR stations for ALOS restricted SLR operations(2005.Spring)

http://god.tksc.jaxa.jp/regi_form.html

We received offers from 11 SLR stations (2005 Summer).

JAXA checked the capability of performing SLR under restrictions and their current SLR systems.

JAXA lessened the selection criteria for cooperation stations because they were too demanding.

Present Status(2/4)

We selected the nine stations which can process SLR-SUP file. Because ALOS SLR has pass restrictions to avoid damage to earth observation sensors.

No	Station Name	Nation
1	Mt. Stromlo	Australia
2	Zimmerwald	Switzerland
3	Herstmonceux	UK
4	RIGA	Latvia
5	Koganei	Japan
6	Shimosato	Japan
7	NASA/MonumentPeak	U.S.A
8	NASA/Greenbelt	U.S.A
9	NASA/(Greenbelt)TLRS4	U.S.A

Present Status(3/4)

2006 2/27-3/3 : Rehearsal (using AJISAI)

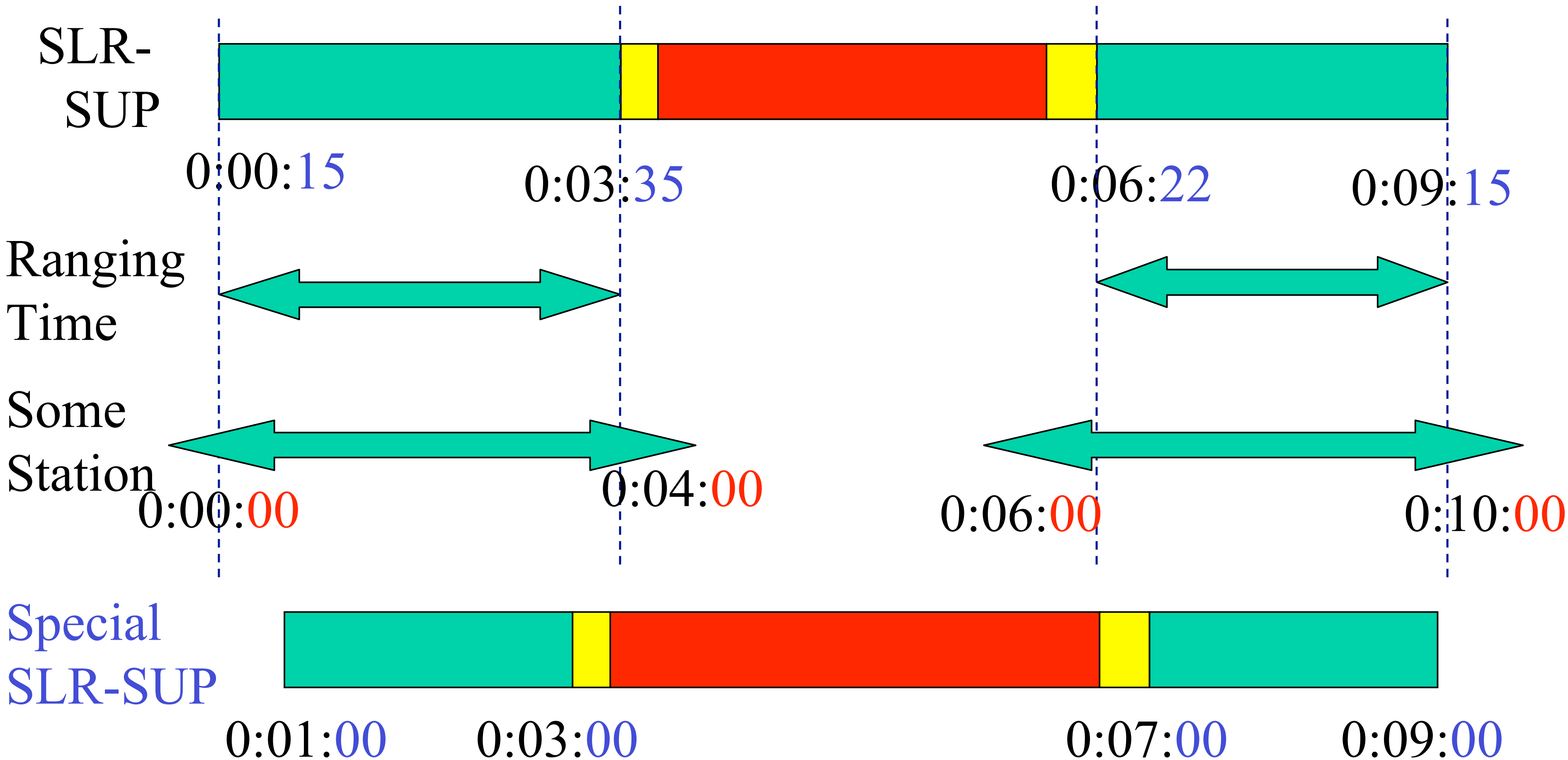
Purpose

- Confirm interface between JAXA and a candidate SLR station
- Confirm the SLR operation time line
- Perform an actual ranging with SLR restriction file
- Confirm the ranging interruption triggered by the Go/NoGo key
- Confirm the actual ranging time by QLNP

We have analyzed the rehearsal data. It seems that the data is almost good.

Present Status(4/4)

At Rehearsal using AJISAI, we found some problem.

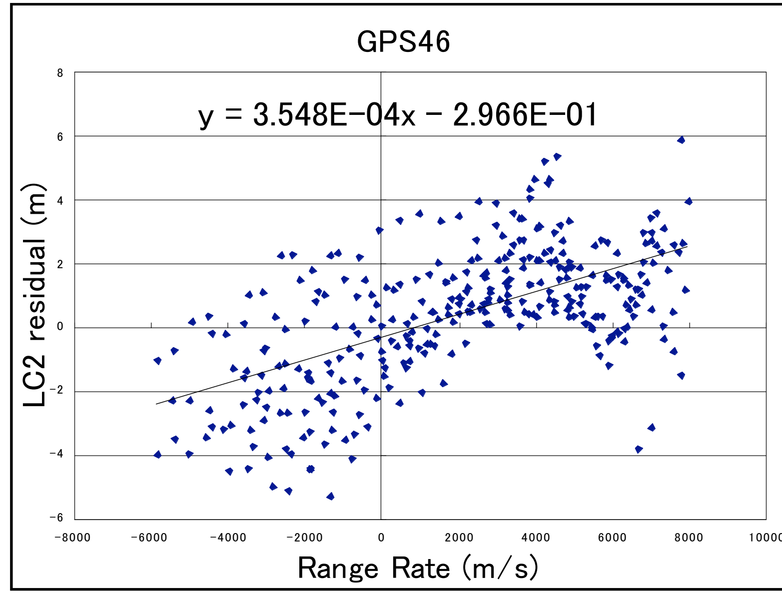


Now: Under procedure making document in JAXA

We will tell the results near future.

Necessity of SLR

Through the GPS analysis,
we found an offset for the position between pseudorange and carrier phase.



There was a difference of about 0.3 ms in time tag between pseudorange and carrier phase.

Offset (order of magnitude) =0.3ms*9km/s=27 cm

Which is the right position?

It can be judged by the result of SLR.

Future Plan

・April/end : Preliminary Run (using actual ALOS or OICETS)

We will carry out a preliminary run to confirm the work flow and control logic of participating stations. And we want to visit these stations in this event if we can. If there is no problem, we exchange an agreement on site.

・May/end : ALOS Tracking Campaign (about 3 weeks)

We will ask these stations to track ALOS during this campaign.

Complement

- After ALOS Tracking Campaign

The purpose of this tracking campaign is to evaluate the specifications of onboard GPS receivers. So we will not track ALOS after this campaign. However, we may ask these stations to track ALOS again if the GPS receivers need to be evaluated again.

Present Status of
Engineering Test Satellite-8 (ETS-8)

JAXA

Precise Orbit Determination Team

S.Nakamura & N.Kudo

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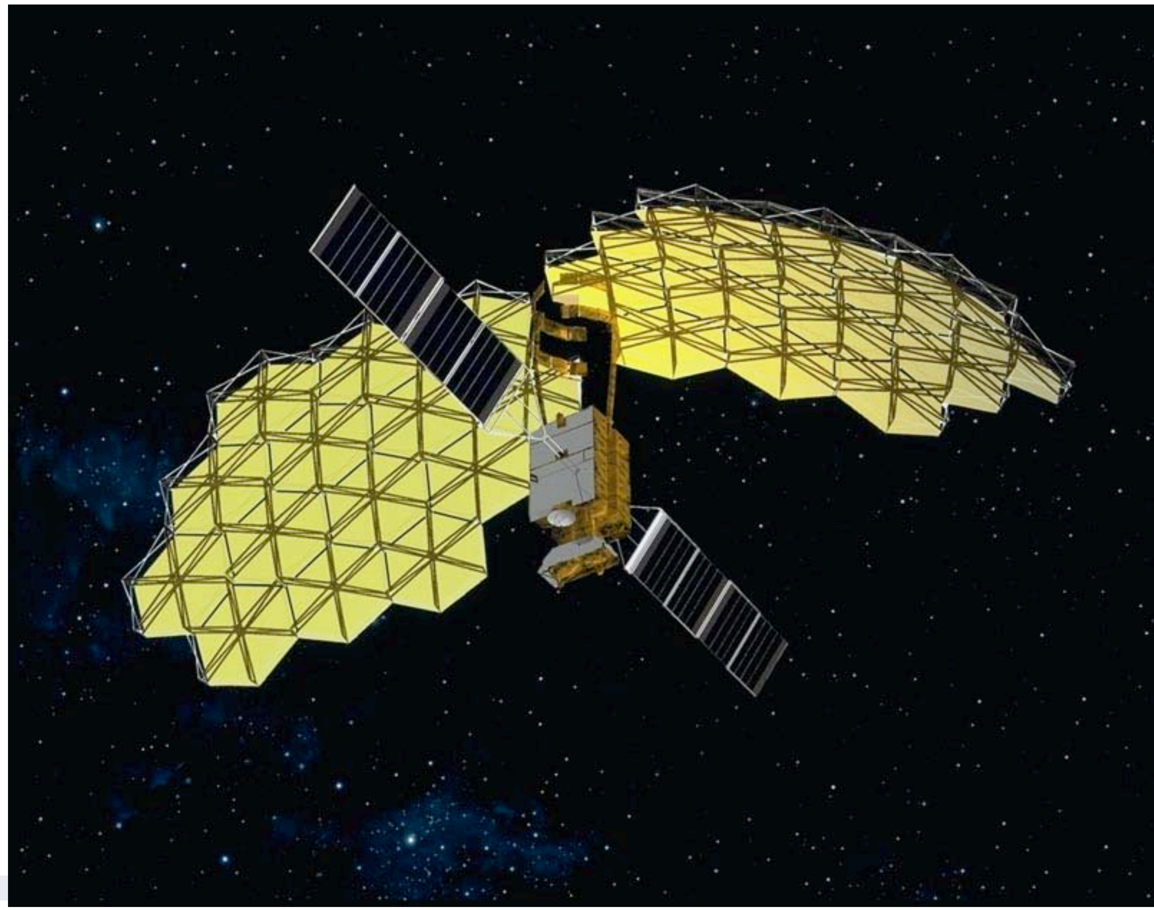


Purpose of this presentation

JAXA explained the ETS-8 and necessity of SLR Support at ILRS meeting 2003.

Almost all people may forget about ETS-8 because ETS-8 launch has been postponed for about 3 years.
Since ETS-8 will be launched this year, we would like to re-explain ETS-8 briefly for a reminder.

Note
At that ILRS meeting, we got a suggestion that Ranging for ETS-8 should be discussed on the West Pacific Ocean Sub Working Group.

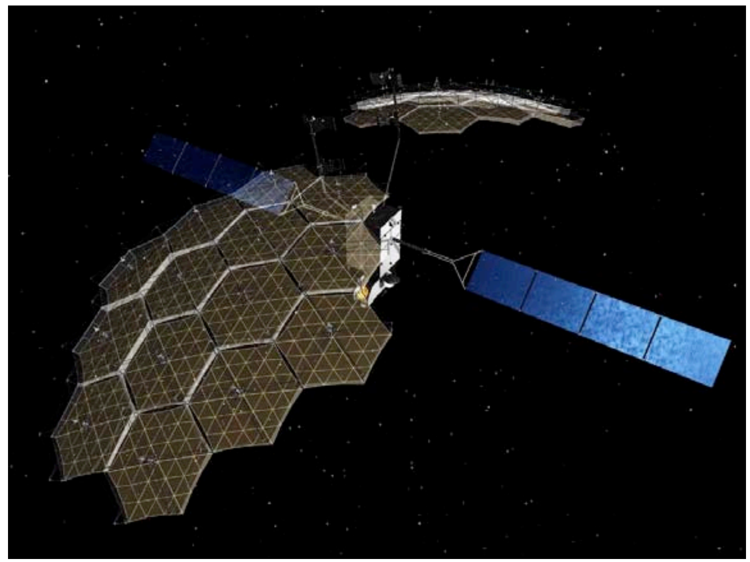
Review of ETS-8

Features of Satellite

1. Large satellite bus technology
2. Large-scale deployable antenna technology
3. Mobile satellite communications system technology
4. Basic positioning technology

⇩

ETS-8 mounts the
High Accuracy Clock (HAC) system
for the study of satellite
positioning system.



Necessity of SLR

Why JAXA needs ILRS support?

JAXA plans to conduct a time synchronization experiment for future positioning satellite technology, including

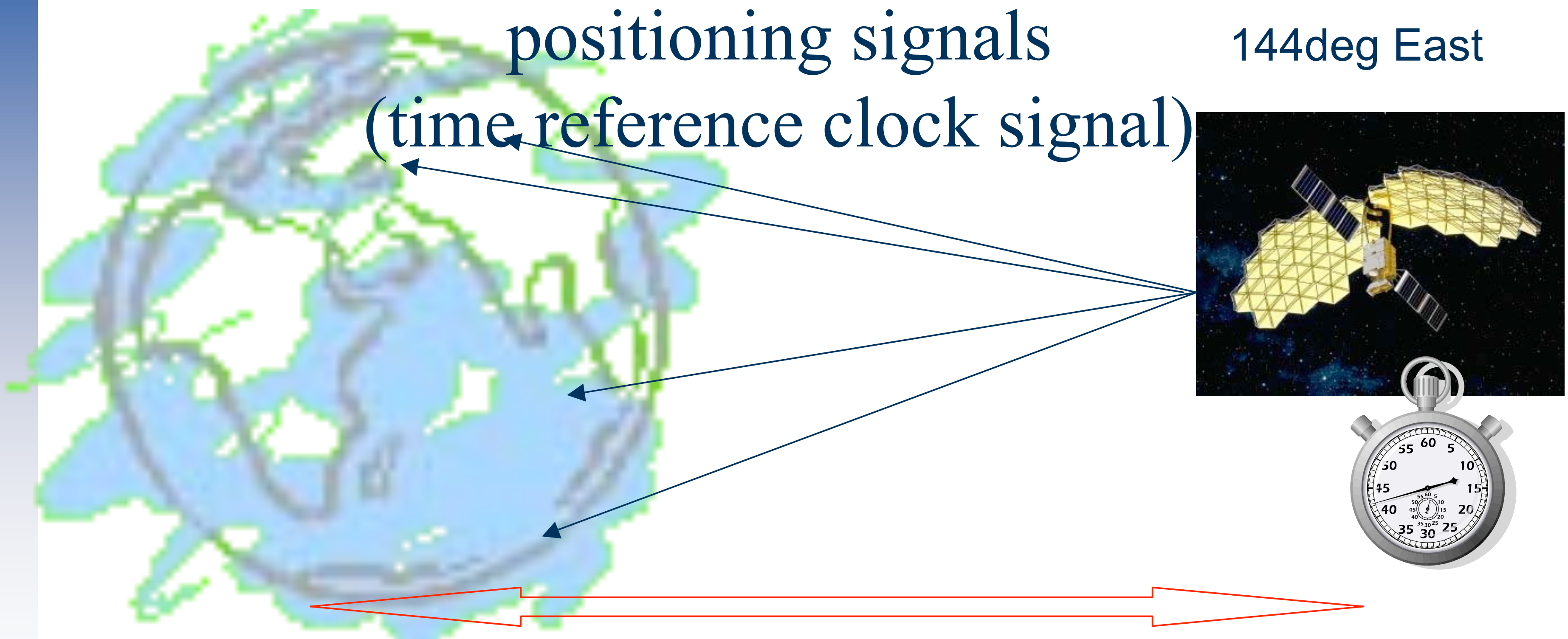
- Time synchronization experiment
- Time management

using atomic clock onboard a ETS-8.

⇩

Precise Orbit Determination is necessary

Necessity of SLR



10 ns Error is equivalent to 3 m Error

Accurately distance determination is needed.

Necessity of SLR

JAXA plans to confirm that a geostationary satellite is useful for the positioning accuracy improvement if it is used as a positioning satellite.

This clock management technology will be utilized in the future Quasi-Zenith Satellite (QZS) system, which has been researched in Japan.

Future Plan

The ETS-8 will be carried into geostationary orbit by H-IIA launch vehicle from Tanegashima Space Center in Japan.

The launch is scheduled for the winter of 2006.

JAXA will communicate with the Western Pacific Ocean Subgroup about cooperation.
The results of communication will be reported to the next ILRS meeting.

Present Status of Optical Inter-orbit Communications Engineering Test Satellite (OICETS)

JAXA
Precise Orbit Determination Team
S.Nakamura & N.Kudo

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Purpose of this presentation

OICETS was launched on August 23, 2005.
In the previous ILRS meeting, JAXA required support from ILRS.
However, circumstance has changed a little after OICETS launched.
Today, we would like to explain the present status and the future plan.

Review of OICETS

Characteristic value of OICETS

Launch Date	2005 /August/24
Configuration	Approx. 0.78*1.1*1.5m Box-type
Mass	581.50kg
Experiment Orbit Altitude	610km (Circular Orbit)
Orbit Inclination	97.83 deg

Main Experiment

- Inter-orbit optical communications with ARTEMIS (ESA)
- Communication engineering test with earth ground station

Present Status (1/2)

The distribution of the predicted orbit file (TIRV) has not started.

Why?

Standby angle of the optical sensor turned slightly to the earth direction.

OICETS project worried the damage.

JAXA has confirmed the safety:

Period : 2006/Jan – 2006/March

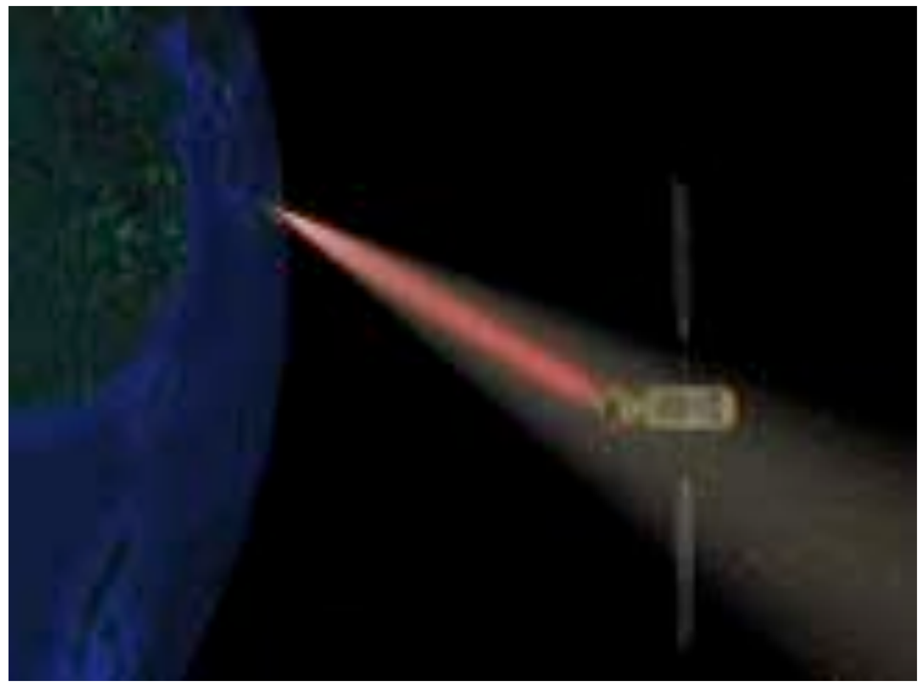
Method : Actual Laser Ranging by JAXA and NICT under satellite monitoring

Present Status (2/2)

Important Experiment (Communication engineering test with earth ground station) has started without using precise orbit (SLR).
Only during this experiment,
OICETS flies upside down.

SLR is inhibited

Note that
OICETS usually keeps its bottom face, on which a CCR is mounted, pointing to nadir.



Future Plan (1/2)

JAXA will distribute prediction files (IRV or CPF) from 6th April.

Method : EDU: predicts@dgfi.badw-muenchen.de

CDDIS: cddis.gsfc.nasa.gov

However, a communication engineering test with an earth ground station will be performed again in the near future.

When this experiment will start, we will stop distributing TIRV and inform to ILRS committee.

Future Plan (2/2)

Since all experiments has been performed without precise orbit determination by SLR, sometimes the experiment succeeded and sometimes failed.

If POD is performed by SLR, it is expected that the success rate of the experiment will improve.

However, we need Middle Priority.

Operation of OICETS may come to end next September because its design life is 1 year.

We don’t have much time left to perform SLR for OICETS.

Please participate in OICETS SLR operation.

METEOR-3 DEGRADATION

Recently there has been great difficulty tracking METEOR-3M, quite apart from its bad attitude in even more recent times.

Whilst browsing through Proc.14th Workshop in San Fernando (as one does), I was struck by this comment in Burmistrov et al's paper, at the bottom of p.451:

"A preliminary analysis of the campaign results shows that the initial cross-section value has gradually decreased; this is possibly due to the non-radiation-resistant glass used in the experimental retroreflector (the initially planned observation period was only 6 weeks - just to verify the design parameters)."