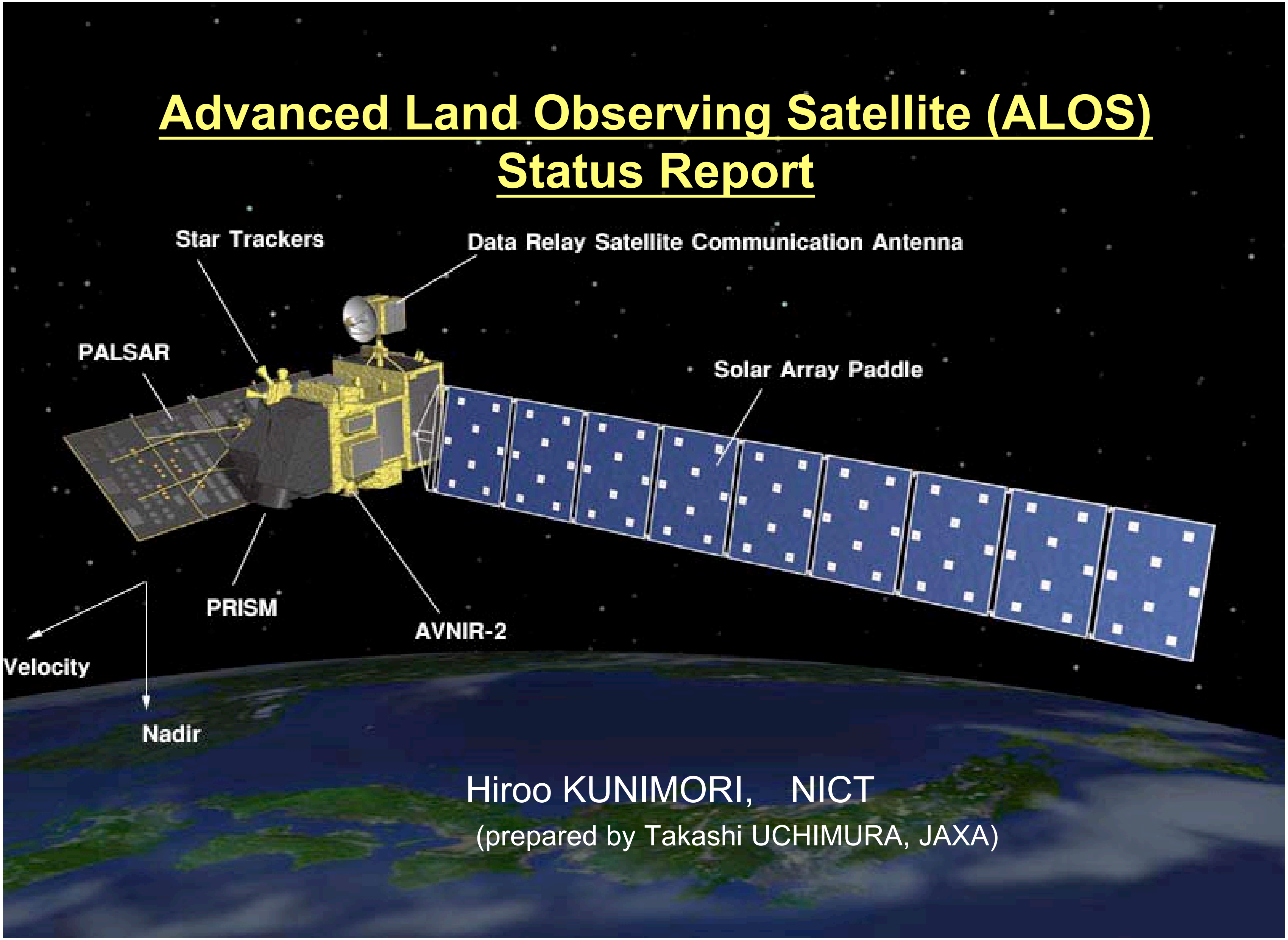
Advanced Land Observing Satellite (ALOS) Status Report



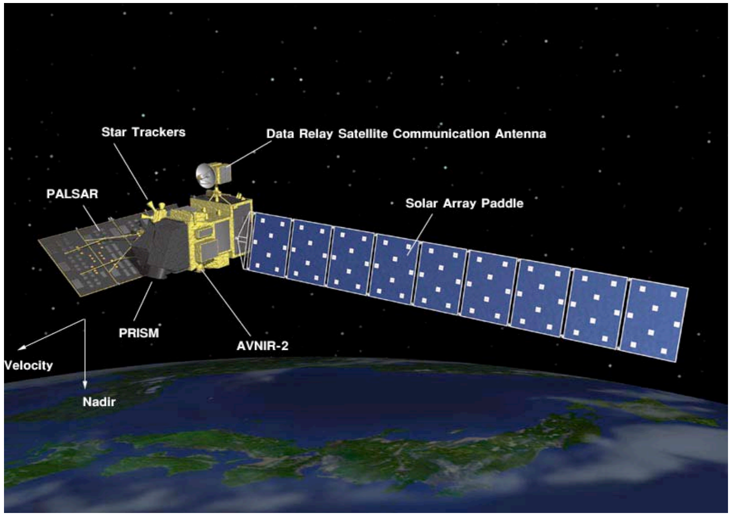
Hiroo KUNIMORI, NICT

(prepared by Takashi UCHIMURA, JAXA)

ILRS Mission Working Group@Vienna Austria,2005/4/25

Overview of ALOS Mission

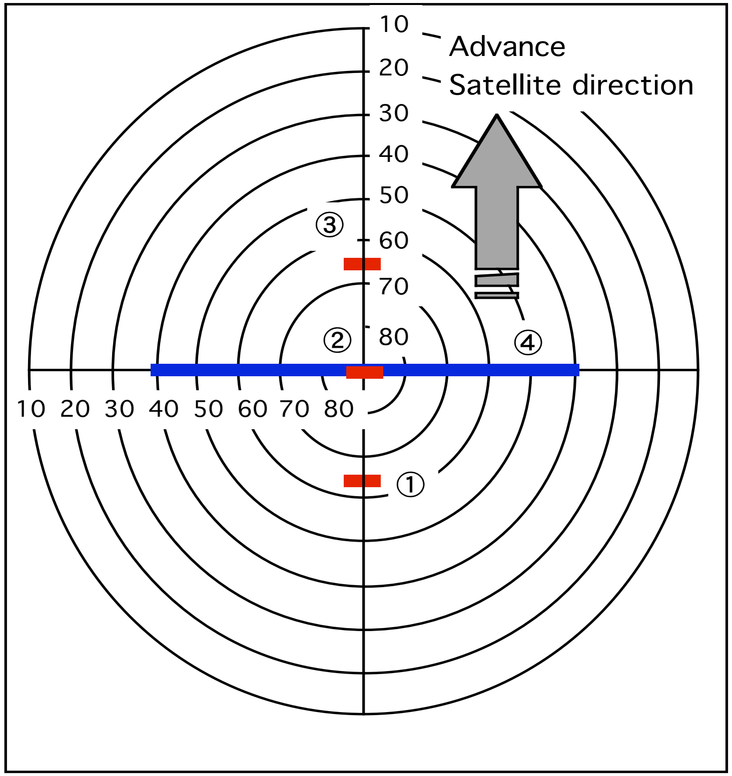
- Japanese Earth Resources Satellite Mission (Post JERS-1)
- Carries 3 Earth observation sensors
  - Panchromatic Remote-sensing Instrument for Stereo Mapping (PRISM)
  - Advanced Visible and Near Infrared Radiometer type2 (AVNIR-2)
  - Phased Array type L-band Synthetic Aperture Radar (PALSAR)
- S/Ka band transponder / GPS receivers / LRRA
- Sun synchronous/ sub-recurrent orbit
  - Inclination 98.6 deg, 690km Height
- Launch period
  - 2005/9/1 ~ 2005/9/30
- Launch Site
  - Tanegashima Space Center, Japan

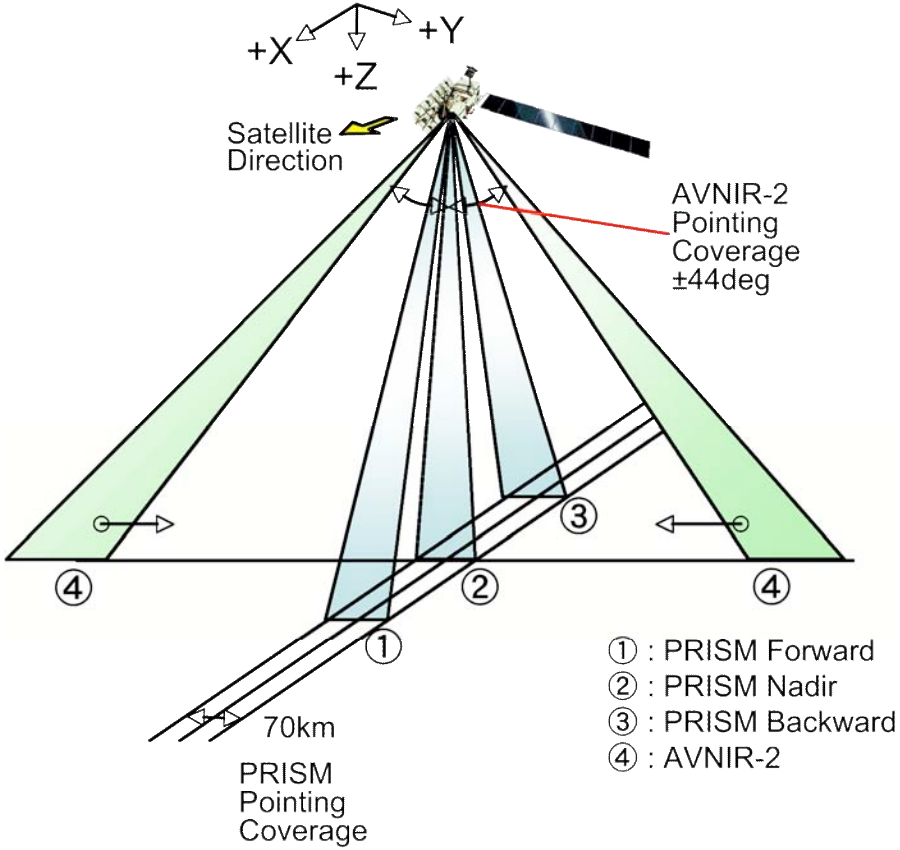


Restricted SLR operation

ALOS has two optical sensors: PRISM and AVNIR-2.
ALOS optical sensors are possibly vulnerable by the incidence power of the laser light wave.

Laser transmission restricted area from Sat-View





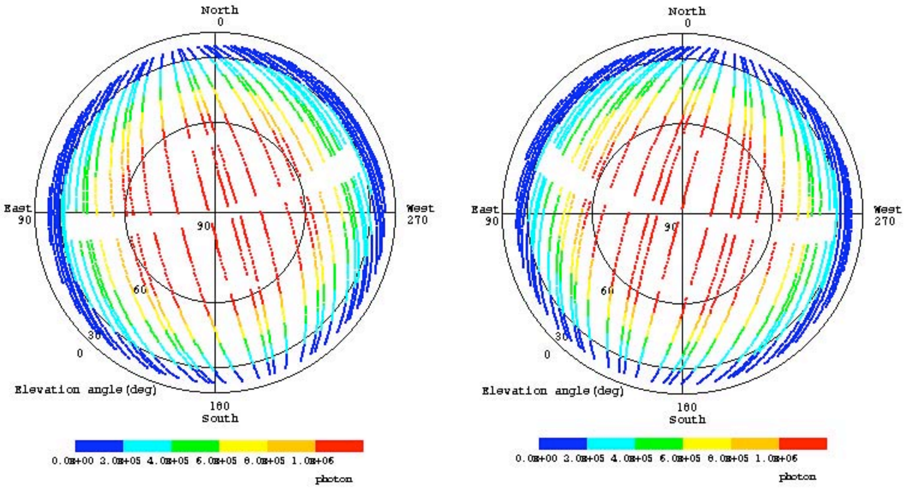
Station visibility

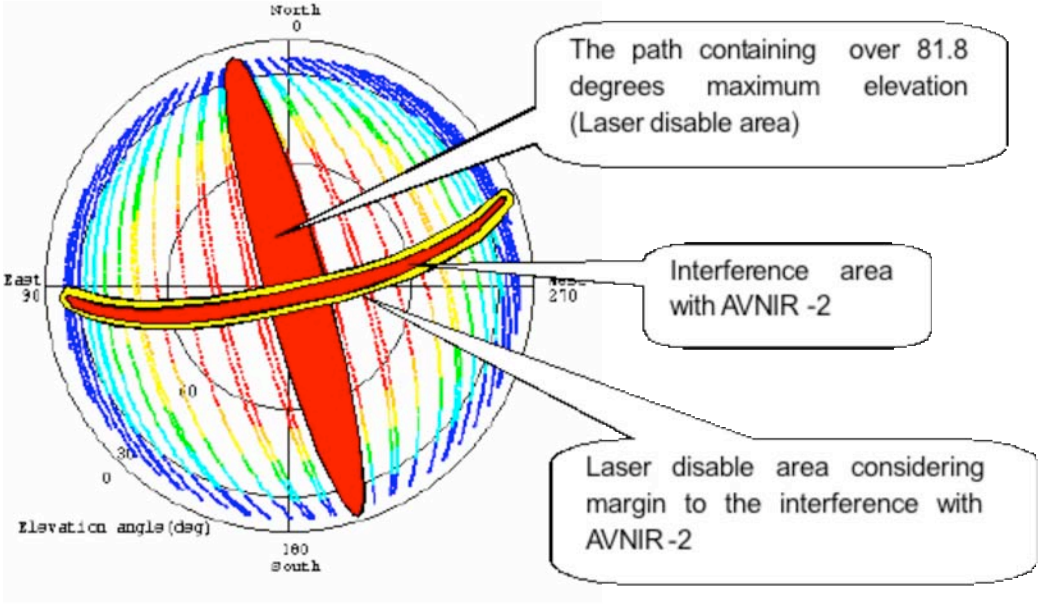
JAXA determines the limit of SLR operation in ALOS as follows;

- Passes in which the elevation exceeds 81.8 degrees. These passes will be deleted from Pass List.

- Interference area with AVNIR-2. The yellow part shows the laser disable area including margin for the interference area with AVNIR-2.

We provide the station with supplimentary information(SLRSUP) regarding restricted laser time taking account of a margin.





The path containing over 81.8 degrees maximum elevation (Laser disable area)

Interference area with AVNIR -2

Laser disable area considering margin to the interference with AVNIR -2

Consideration of Margin

Elements	Order	Margin	Remarks
Altitude Control Accuracy	±0.1deg	~0.5sec	
Sensor Alignment Accuracy	±0.1deg	~0.5sec	
Orbit Prediction Accuracy	3km(predictive 3 days before)	~1sec	Worst case
Laser Irradiation Control Error at Station	4Hz (0.25sec)	~1sec	Worst case; Repetition Rate 4Hz
	Total	~3sec+α	

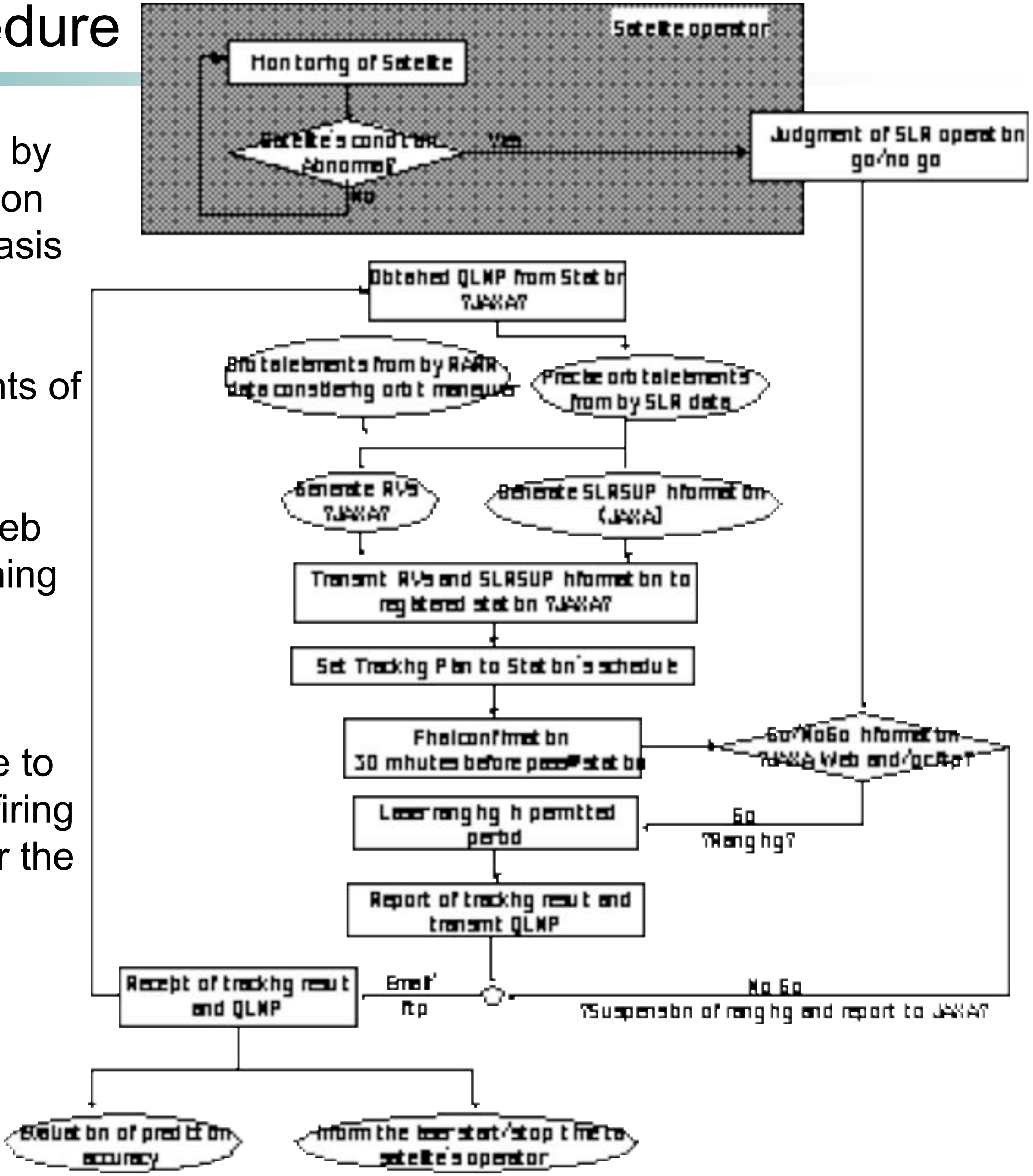
JAXA will add ±5sec margin to the actual interference period of AVNIR-2 when we generate SLRSUP information.

Tracking Schedule (SLRSUP)

JAXA Mission Control Center of ALOS will also issue a daily tracking schedule for each registered station. These schedules will be issued via ftp and/or by e-mail for each station, aiming to identify the pass to be tracked. We expect to use the format that has already been established by the ILRS on the GP-B Mission. The schedules will be issued on a daily basis. In order to participate in tracking of ALOS, we assume a station should obtain and process the tracking schedule automatically.

ALOS Tracking Procedure

- SLRSUP information will be sent by email message and/or ftp to station from JAXA directory on a daily basis with IRVs.
- Station has to confirm the contents of SLRSUP when receiving it.
- Station has to check ftp site or web page a 30 minutes before beginning of tracking and regular during observation.
- The registered stations also have to report the tracking result (Laser firing time and stop time) to JAXA after the end of operation. Format to be proposed.



Tracking Periods

- Early Phase ; Launch+30 days to Validation (About 3 months)
- Routine Phase ; Campaign will be carried out for about 1 month for calibration every six months

Rehearsal Plan

JAXA will conduct the data interface test and rehearsal with SLR station, Y-2 months to -1 month before Launch (currently June 1 to July 1,2005), according to acceptance procedure defined by ILRS.

-IRVs, QLNP, SLUSUP data interface test
-Tracking rehearsal using Ajisai to verify the tracking procedure

The detailed information of a Rehearsal will be informed by JAXA to ALOS tracking stations.

After launch, Dry-run procedure and verification schedule will be informed By JAXA to ALOS tracking stations.

JAXA agrees the draft form of agreement issues of Liability prepared by ILRS.

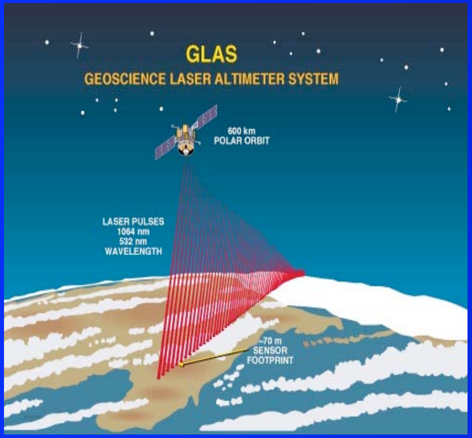
GLAS/ICESat Report

Missions Working Group

25 April 2005

Peter J. Shelus
Center for Space Research and McDonald Observatory
University of Texas at Austin, Austin, TX, USA
pjs@astro.as.utexas.edu

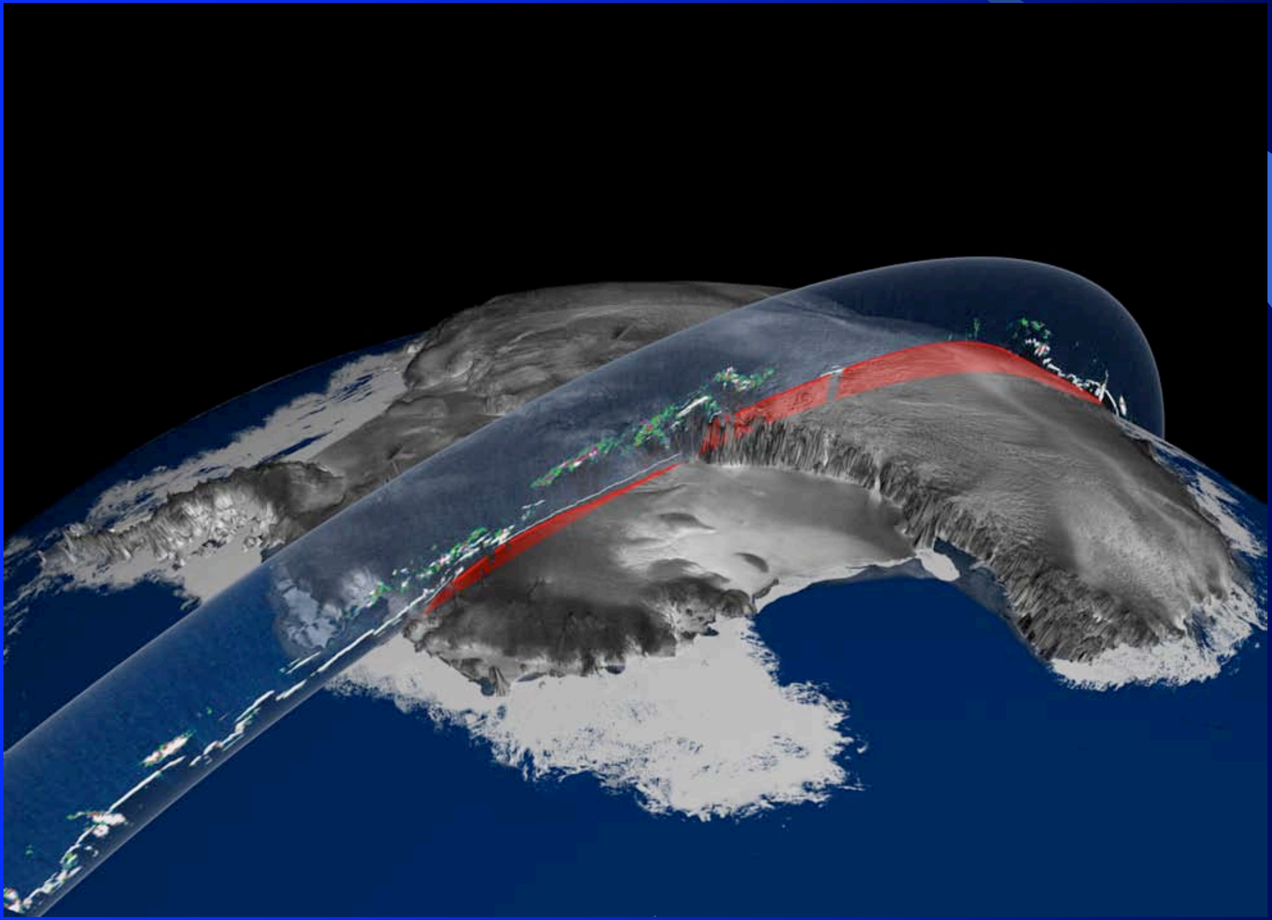
A Transition in Laser Ranging



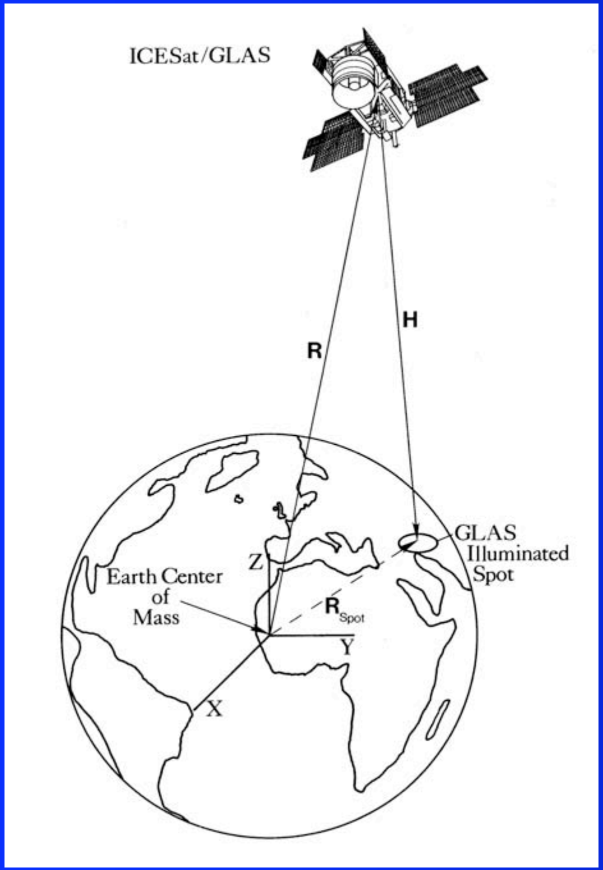
- Since the early 1960’s, laser ranging was an “upward looking” experiment, to artificial satellites and to the Moon
- Targets were “cooperative”, with optical retroreflector corners beaming input pulses back to their source
- A second phase began in the 1990’s with lasers in space, looking down at the object about which they are orbiting
- The experiments are mostly altimeters, lidars, ice, cloud and environmental monitoring

- GLAS is carried on the Ice, Cloud and land Elevation Satellite (ICESat), launched 13 January 2003 00:45 UTC from Vandenberg Air Force Base.
- GLAS is designed to measure ice-sheet topography and associated temporal changes, as well as cloud and atmospheric properties.
- In addition, GLAS over land and water will provide along-track topography.

ICESat - First Track Across Antarctica

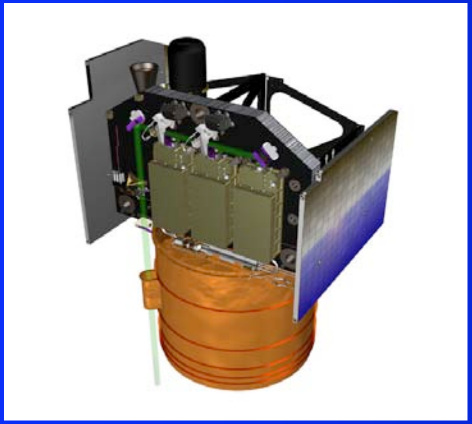


Satellite Altimetry



- An altimeter measures the distance from the instrument to a point on the surface that is illuminated by the instrument. The topography is described with respect to the satellite’s orbit
- **R** is the position vector of the satellite (determined by precision orbit determination, i.e., POD)
- **H** is the altitude vector (determined by precision attitude determination process, i.e., PAD)
- If **R** and **H** are known/measured, the spot on the surface is given by $\mathbf{R}_{\mathbf{spot}} = \mathbf{R} + \mathbf{H}$.
- Both POD and PAD are dependent on instrumentation to make relevant measurements

A “Problem” with Laser Ranging



- POD to many of these satellites are obtained from laser ranging
- Altimetry, off the “non-cooperative” surface, requires large optics and sensitive detectors on-board
- Should a laser station on the ground shoot “up the barrel” of such a target, on-board instrumentation could be damaged or destroyed
- How do we keep an SLR station from “shooting up the barrel”?

The ILRS SLR Network

ILRS Ranging

- There have been identified three types of restrictions with respect to an ILRS station tracking a vulnerable target
  - An angle restriction (for example, ICESat’s 70-degree elevation cutoff);
  - A “go/no-go” restriction (this gives a mission control center the ability to enact a global restriction on ranging to its spacecraft);
  - A pass-segment restriction (for example, ALOS’s requirements for its multiple sensor satellite).
- Some targets will require none, one, two or all three of the above.

ILRS Ranging to ICESat

Station	Pad ID	Passes	Normal Points	rms (m)
MDOL (G)	7080	88	929	0.018
YARL (G)	7090	53	1,832	0.021
GODL (G)	7105	38	1,341	0.015
MONL G)	7110	14	262	0.017
ZIML (R)	7810	49	789	0.024
ZIML (B)	6810	30	362	0.031
GRZL (G)	7839	43	2,098	0.015
Aggregate		315	7,613	0.020

Note: rms's have only been computed for observations taken during times of ICESat laser operations

Summary Remarks

- Nothing really new under the sun …
- As scientific experiments become more complicated, greater pressures are placed upon operational logistics in order to perform necessary operations, and yet retain personnel safety and instrumental integrity
- In this instance, i.e., laser ranging to vulnerable targets, a set of thorny logistical problems has been solved by a combination of computer power, internet communications, orbital dynamics and precisely defined inter-relationships among several reference frames.
- The results, specifically, for ICESat
  - More and better "science"

Lunar Reconnaissance Orbiter: Proposal for Laser Tracking

David E. Smith, GSFC
Maria T. Zuber, MIT

Lunar Reconnaissance Orbiter (LRO)

- Launch Oct 2008

- Six instruments

– LOLA	laser altimeter (Smith, Zuber)
– LROC	camera
– LEND	neutron detector
– Diviner	temperature sensor
– LAMP	Lyman Alpha
– CRaTER	Cosmic ray telescope

- Polar orbit at nominal 50 km altitude

LRO Tracking & Orbit Determination

- Tracking: S-band doppler (1 mm/s) and range (20 m)
- Orbit determination: 300 meters along track, 18 m radial

- Not adequate for the requested 30 meter resolution along track topography
- Have requested optical (laser) ranging to LRO to supplement S-band Doppler but NOT approved.

Laser Tracking Accuracy Desired

- Minimum precision of 10 cm, at 1 second rate
- Tracking time: ~ 1 hour (spacecraft on nearside of the Moon)
- Several 1-hour tracks per day
- Minimum of 1 operable tracking station.

Laser Tracking Options

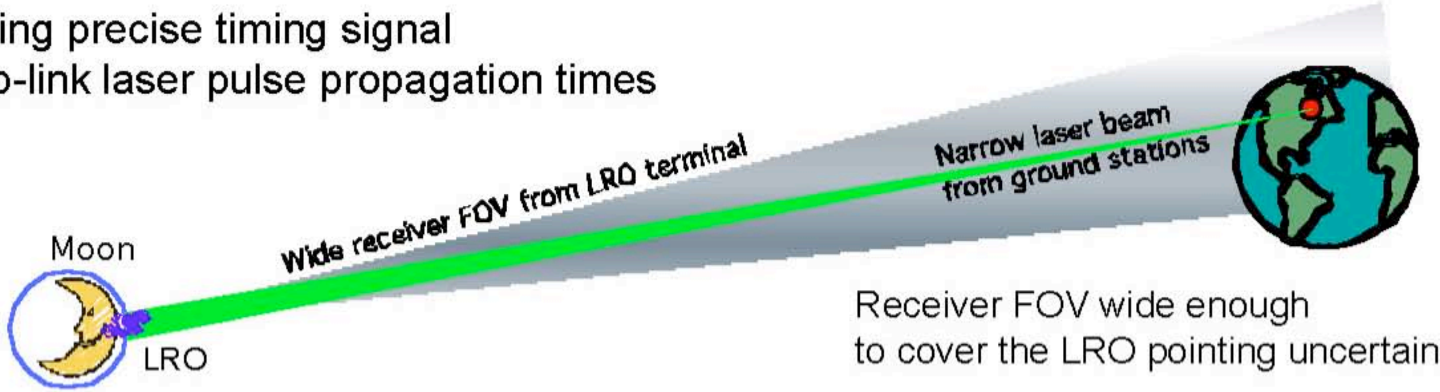
- One-way ranging; receiver only on spacecraft (Option 6) - requires high quality clock on s/c
- One-way ranging PLUS downlink laser beacon on spacecraft (Option 7) - calibrates one-way uplink
- One-way ranging PLUS laser reflector array on spacecraft - calibrates one-way uplink (Option 9)

Option 6

Earth - LRO One Way Laser Tracking

Approach

Sending precise timing signal
via up-link laser pulse propagation times

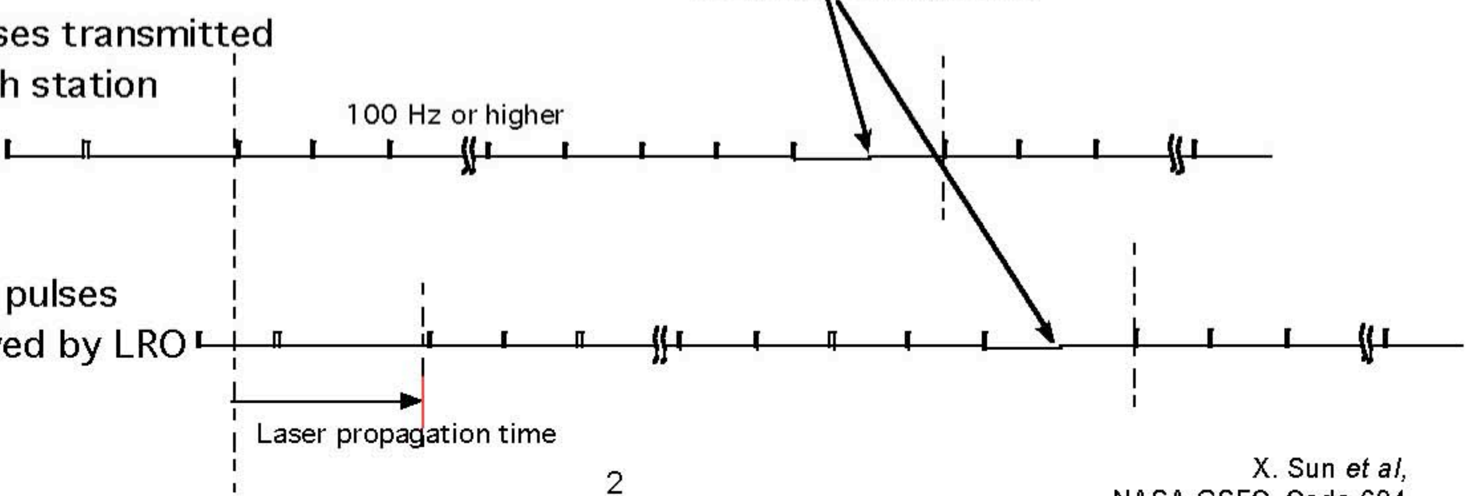


Receiver FOV wide enough
to cover the LRO pointing uncertainty

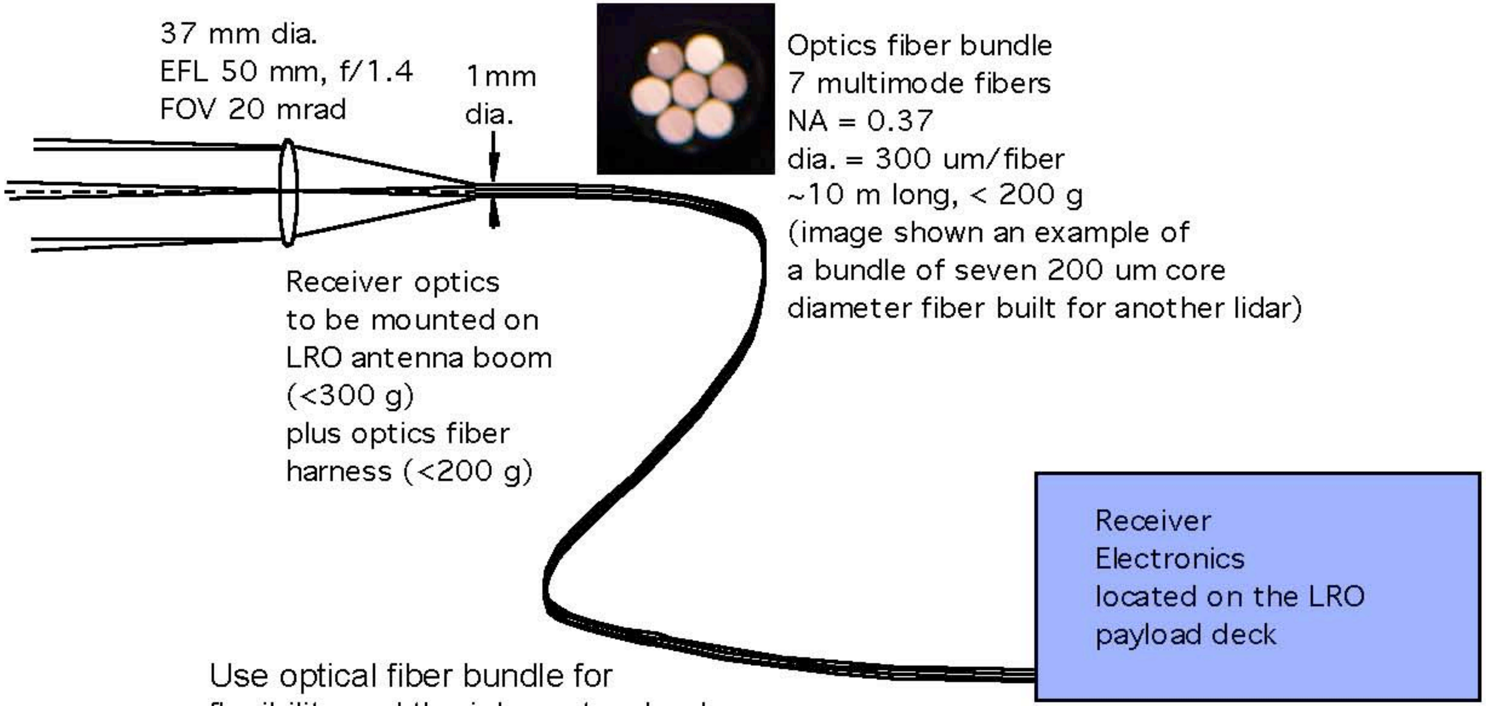
Signal format

(high pulse rate desirable
to reduce measurement error)

Periodic 'drop-out'
as unambiguous time mark



Laser Tracking Receiver Conceptual Design



37 mm dia.
EFL 50 mm, f/1.4
FOV 20 mrad

1mm
dia.

Optics fiber bundle
7 multimode fibers
NA = 0.37
dia. = 300 um/fiber
~10 m long, < 200 g
(image shown an example of
a bundle of seven 200 um core
diameter fiber built for another lidar)

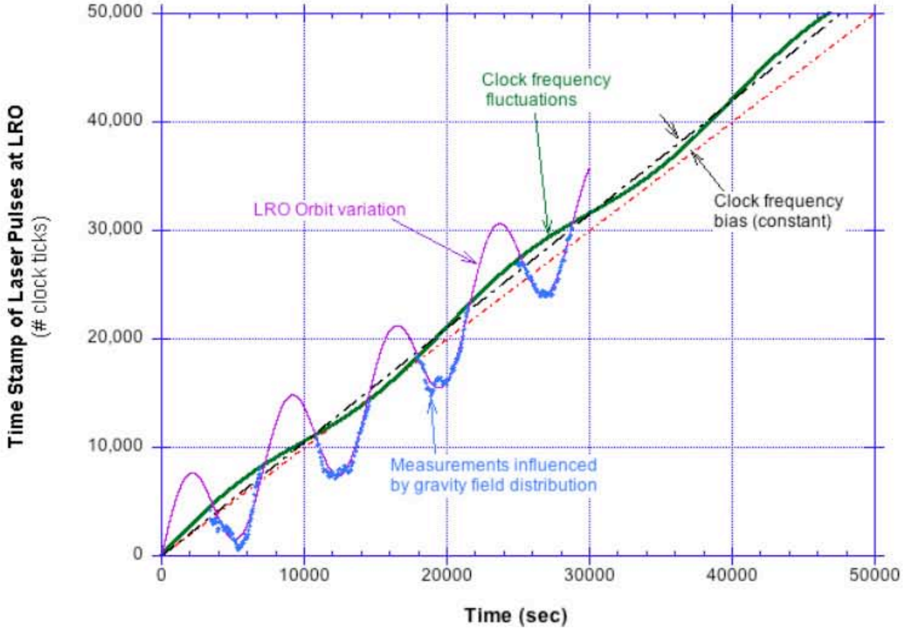
Receiver optics
to be mounted on
LRO antenna boom
(<300 g)
plus optics fiber
harness (<200 g)

Receiver
Electronics
located on the LRO
payload deck

Use optical fiber bundle for
flexibility and the inherent redundancy

Clock Frequency Stability Requirement

Illustration of the measurement concept

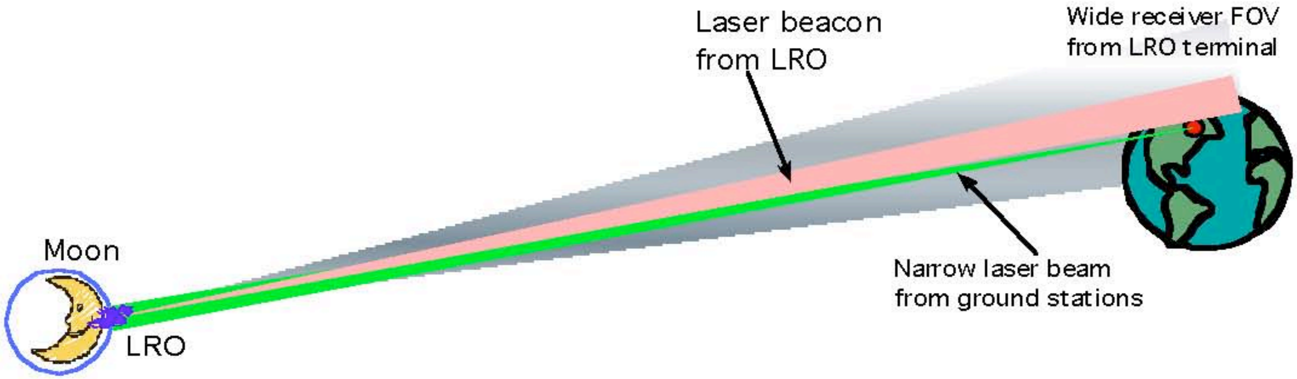


- Constant frequency bias may be determined from long term observation or periodic ground based calibration (e.g., occasional two way ranging)
- Frequency fluctuations at longer than 1/2 LRO orbit period (3600 sec) may be filtered out.
- Random clock frequency error at similar period as the gravity variation (10-1000 sec) must be <<1e-12 to measure lunar gravity field distribution.

Option 7

Earth - LRO One Way Laser Link Augmented with a Down Link Laser Beacon

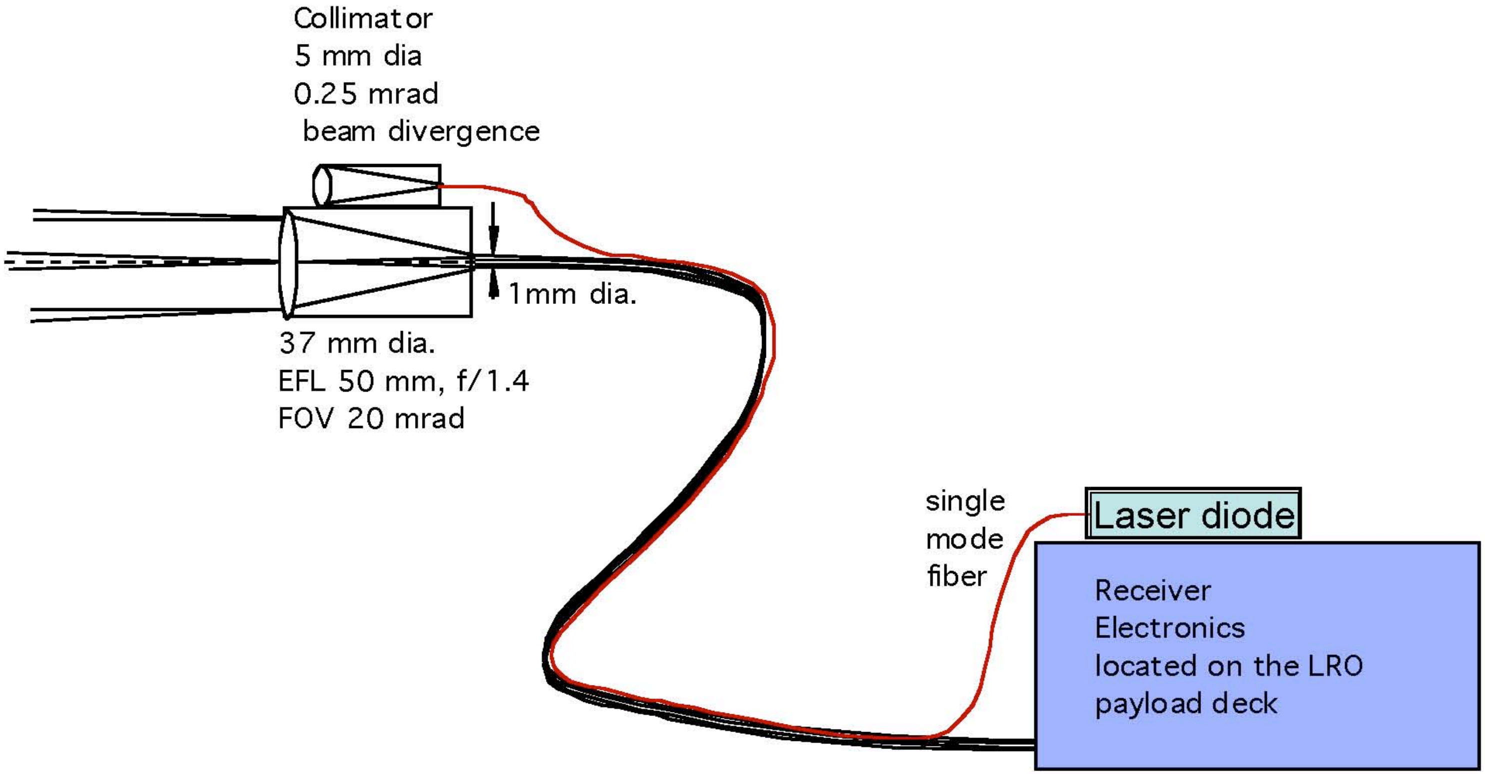
Measurement approach



- Same up link laser tracking system as in Option 6 but adding a laser beacon to the LRO terminal;
- The beacon may drift into the receiver field of view of the earth stations, forming a two way laser ranging measurement at discrete and randomly distributed points on LRO orbit path;
- The occasional two way laser link may serve to calibrate and validate the one way laser tracking measurements and to calibrate the on board clock frequency;
- The laser beacon may be imaged from earth during new moon at nighttime.

One-Way Laser Tracking LRO with Augmented Laser Beacon

- Receiver Conceptual Design



Option 9

Fixed Corner Cubes Mounted to Spacecraft

Set of fixed cubes mounted to s/c body or s/c antenna: one set on front of s/c. Approximately 20 x 5 cm cubes at each location.

- ~ 2 billion square meter lidar cross section
- With 5mJ 2khz laser, one return every ~10 seconds
- 10 cm accuracy range (assuming 1 ns laser pulsewidth)
- Night-time operation only
- Velocity aberration limits observability - adequate for calibration of uplink
- Not an adequate stand-alone tracking system
- Would require modifications to most ground stations.

Summary

- We are asking the LRO Project to augment the S-band tracking with laser tracking
- Several options have been studied; we are requesting that at a minimum the LRO carry a laser detector to enable 1-way ranging from existing ground stations.

Lunar Orbiter Laser Altimeter (LOLA)

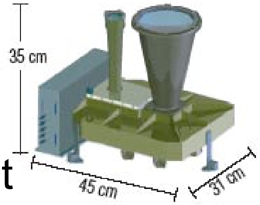
PI: David E. Smith, GSFC; Dep PI: Maria T. Zuber, MIT

Global topography; Polar illumination; Imaging of shadowed regions

Science Measurements

Local topography: ±10 cm vert., 25 m horiz.
Surface slopes: ±0.3 deg, bi-directional
Surface roughness: 30 cm in 5 m spot
Surface ice: 3 to 4% detection
Global coord. system: ±1m rad., 50 m horiz.

Instrument Description



10 cm range accuracy
5 measurements in 50 meter spot
140 measurements/sec
2.4 mJ NdYAG laser at 1064 nm
Mass: 9.6 kg; Power: 26 W
Vol: 45x31x35 cm^3

Data Products

1. Maps of lunar topography, surface slopes, surface roughness, surface brightness
2. 50 meter resolution maps of permanently shadowed areas at the pole
3. Locations suitable for safe landing
4. Locations of possible surface ice

Schedule

1. IPDR: 6/17/05
2. ICDR: 2 qtr 2006
3. Delivery: 10/07
4. LRO launch: 10/08
5. Initial lunar topo map after 30 days of mapping

3/26/2005

OICETS
Mission Support Request

Presented by H.Kunimori, NICT

Prepared by S.Nakamura, JAXA

OICETS Overview

- Optical Inter-orbit Communications Engineering Test Satellite
- To be launched in summer 2005 into a LEO(=610km) polar orbit
- Launch site: Baikonur Cosmodrome Kazakhstan by vehicle Dnepropetrovsk, the Ukraine

•Demostration of optical communications with ARTEMIS, (Geostationary, ESA), which mounted a compatible optical communication terminal.

Image Picture of OICETS in Orbit

OICETS OVERVIEW:
Mission Objectives (1)

- The system for optical inter-orbit link experiments consists of JAXA's OICETS, Data Relay Test Satellite (DRTS), Tracking and Control Center (TACC) and domestic Tracking and Control Stations (TACSs), and ESA's ARTEMIS and ground stations.
- The experiments between OICETS and ARTEMIS will be conducted with support from ESA ground stations. (Primary Experiment)
- Major experiment items considered are;
- (1) experiments for evaluating on-board equipments capabilities under space environment,
- (2) experiments for evaluating acquisition and tracking mechanism using stars and planets,
- (3) inter-orbit optical communications experiments,

OICETS OVERVIEW:

Mission Objectives (2)

- (4) measurement of micro vibration of satellite to evaluate the effect to communication link.
- (5) Precise orbit determination experiments only by laser ranging (Japanese stations +ILRS)
- (6) By operating inter-satellite optical communication equipment on the ground, tracking performance is confirmed / data of the atmosphere fluctuation for low orbit satellite at communication wavelength are acquired (NICT)

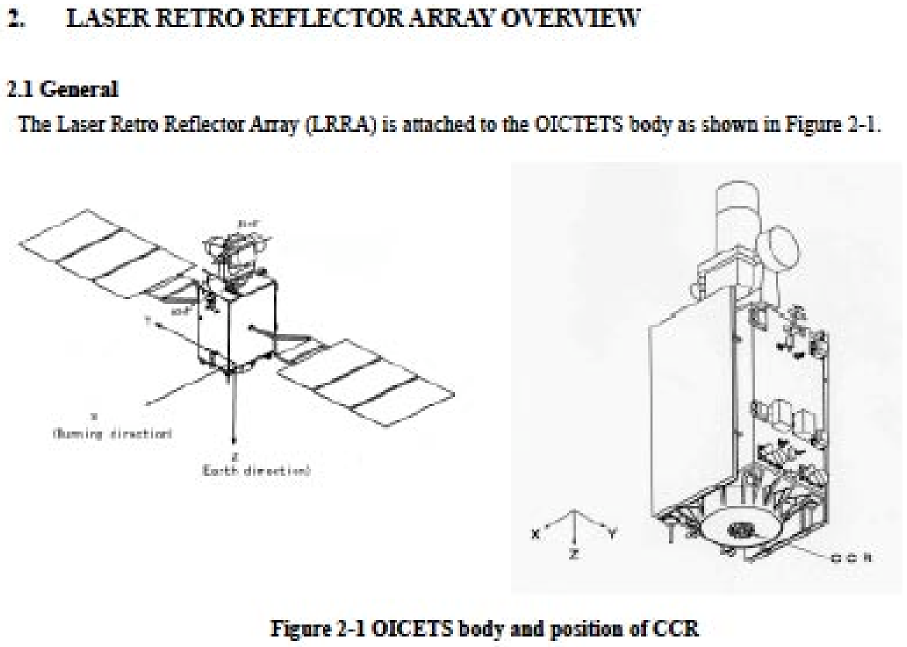
OICETS Overview continued

- Weight Appr. 550kg
- Design life: 1 year
- Optical Terminal LUCE:

(FL: Forward link to OICETS, RL: Retrurn Link to ARTEMIS)

- Wavelength 819nm(beacon), 801nm(FL)& 847nm(RL)
- Data Rate: 2Mbps(FL), 50Mbps(RL)
- Laser Retro reflector Array:
- 6 CCRs oriented along azimuth with elevation angle of 30 degrees, wavelengh 514,532, 800nm (specified)
- Material: SUPURASIL P-10 with back-metal coated.
- Accuracy: +/- 2 arcsec
- Effective area >1cm^2 (worst case by minimum incident angle)

LOCATION and Image of OICETS LRA

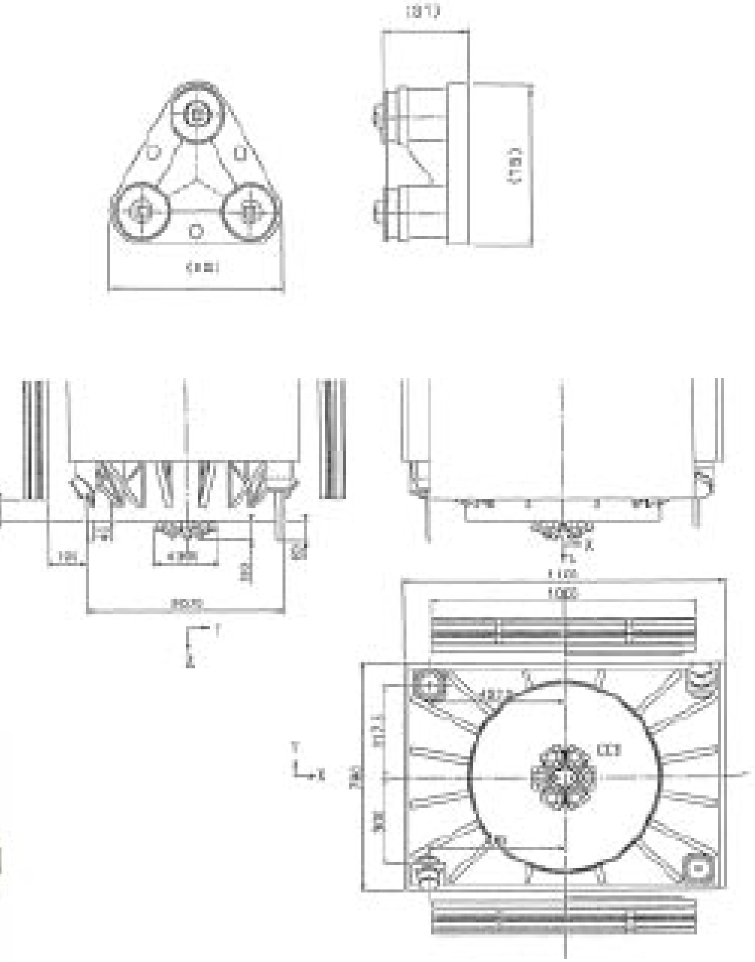


2. LASER RETRO REFLECTOR ARRAY OVERVIEW

2.1 General

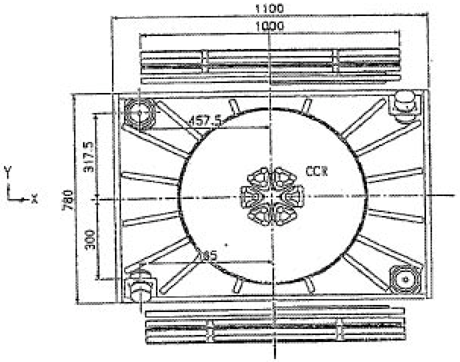
The Laser Retro Reflector Array (LRRA) is attached to the OICTETS body as shown in Figure 2-1.

Figure 2-1 OICETS body and position of CCR



Example of link analysis using CCR on OICETS

CW system :
Bistatic TX by NeLS terminal, RX by1.5m diameter telescope for TX/RX isolation.
Pulse system:
A dedicated satellite laser ranging system attached to a NeLS CPM and photon counting receiver commonly used.



OICETS
CCR Array

item	CWsystem	PulseSystem	(unit)
Laser power	43.0	23.0	dBm
Energy/pu;se	----	0.1	mJ
CW/Reprate	CW	2000	Hz
	20.000	0.200	W
Wavelength	1.550E-06	5.320E-07	m
Transmit Diameter	10	10	cm?
TX optical loss	-8.0	-8.0	dB
Beam divergence	19.7	100.0	?rad
Atm. Loss	-3.0	-3.0	dB
one-way distance	7.00E+05	1.00E+06	m
CCR area	2.00E+00	2.00E+00	m^2
CCR gain	184.3	202.9	dB
CCR Reflectivity	-2.0	-2.0	dB
Receiving Aperture	150.0	10.0	cm?
RX Gain	129.7	115.4	dB
RX optical loss	-5.0	-5.0	dB
Receiving Power	-65.0	-125.6	dBm
Photon/s	----	7.4E+02	cnts/s
Required Power	-70.0	-144.3	dBm
Transmission Rate	2.49E+09	----	bps
Margin	5.0	18.7	dB

Interface between GUTS mission control center and SLR stations

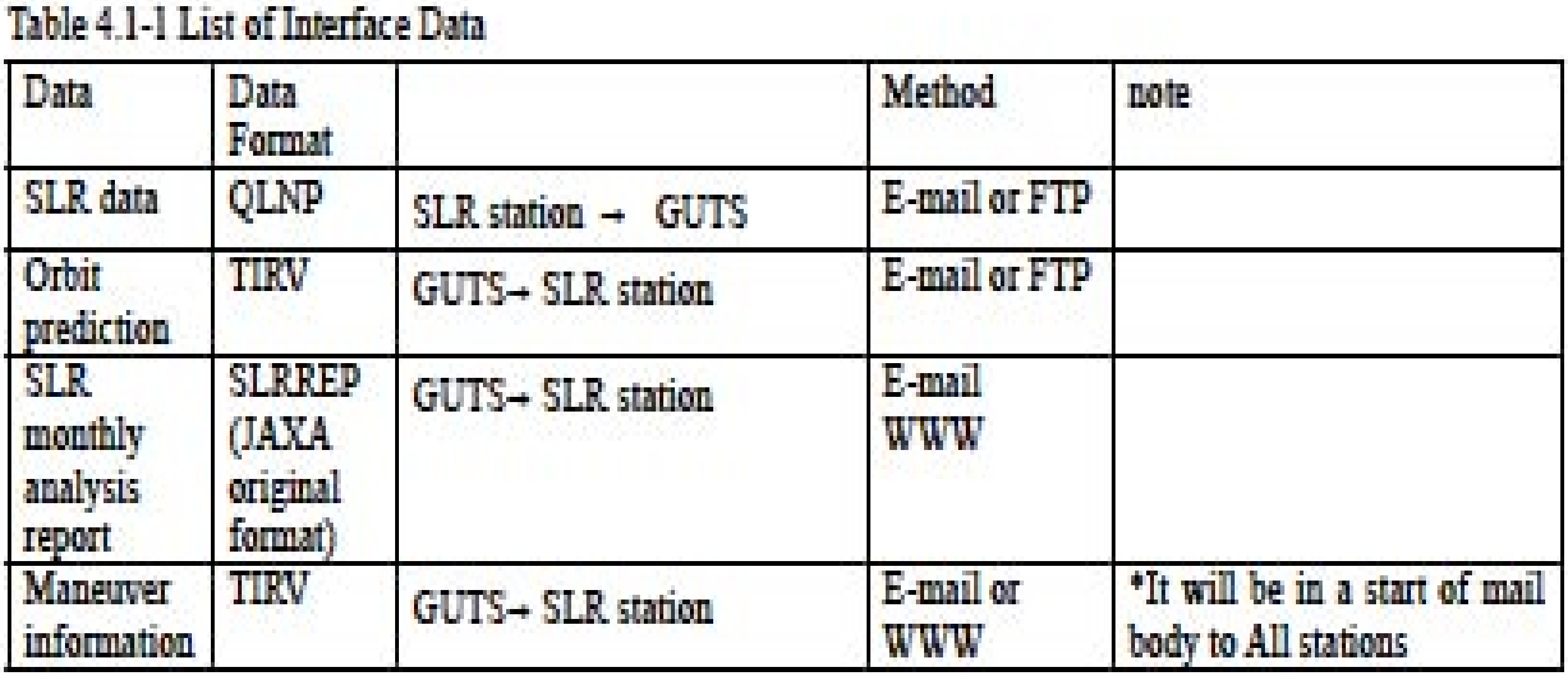


Table 4.1-1 List of Interface Data

Data	Data Format		Method	note
SLR data	QLNP	SLR station → GUTS	E-mail or FTP	
Orbit prediction	TIRV	GUTS→ SLR station	E-mail or FTP	
SLR monthly analysis report	SLRREP (JAXA original format)	GUTS→ SLR station	E-mail WWW	
Maneuver information	TIRV	GUTS→ SLR station	E-mail or WWW	*It will be in a start of mail body to All stations

Schedule

- After OICETS launch +(1-3) month check out phase, Laser ranging activity should start.
- When attitude of the satellite is in ground-satellite communication mode, in order to avoid the interference with optical sensor, and the satellite CCR not visible from station →We will use GO/NOGO key.