ETS-VIII and its Laser Reflector Array

Japan Aerospace Exploration Agency (JAXA)

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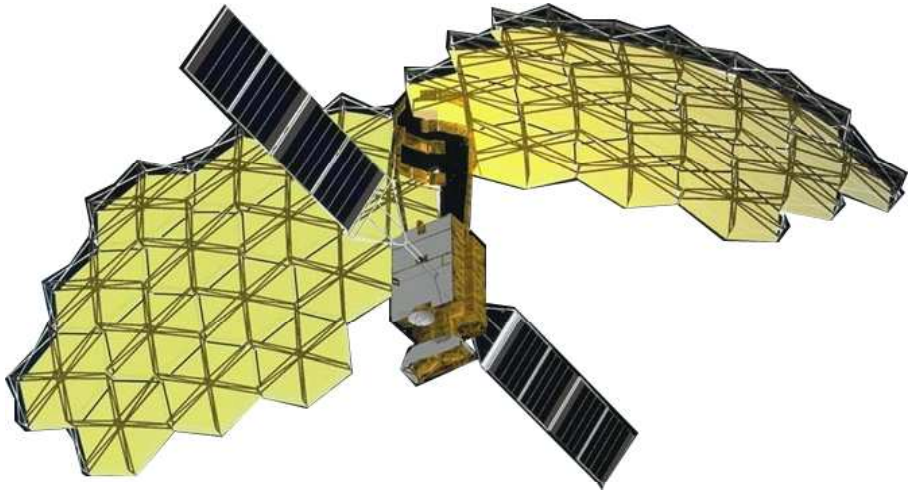
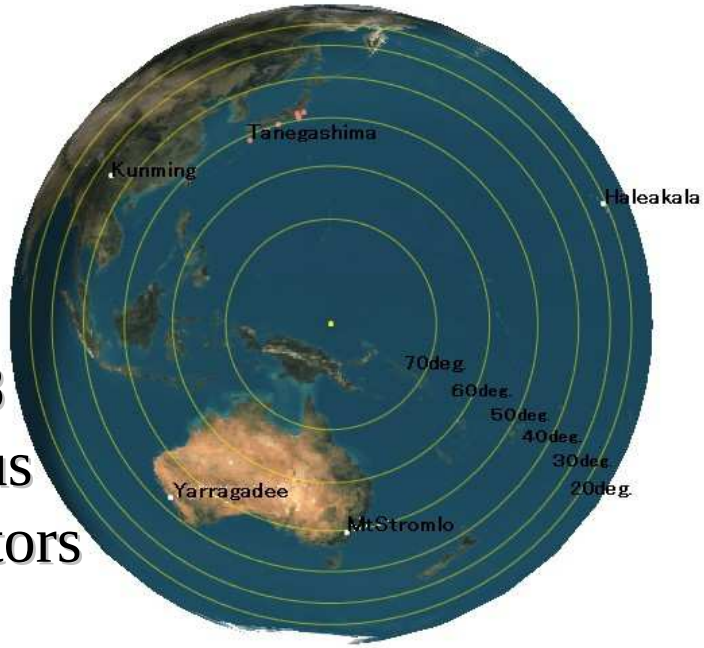


HTSI

Scott Wetzel

Review of ETS-VIII



1. Launch 18th/December/2006
   Geostationary Orbit at 146 E longitude

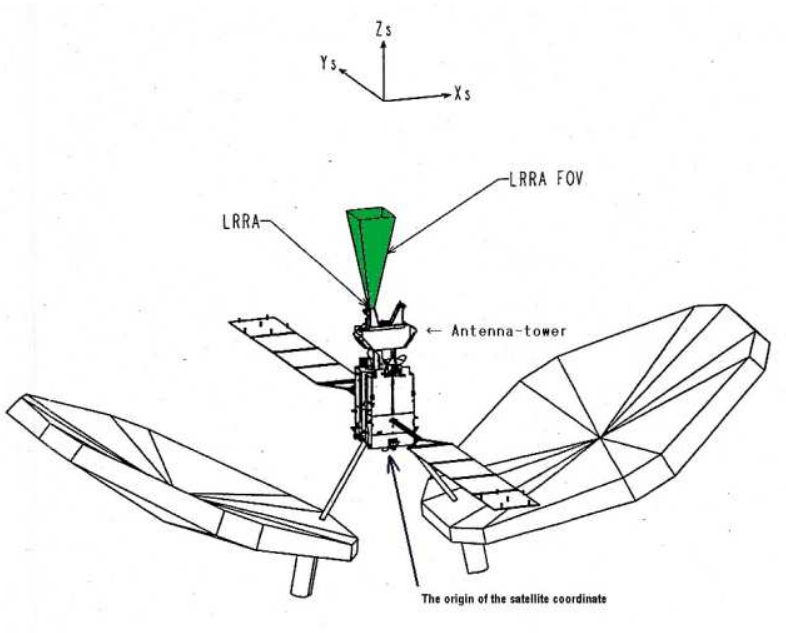
1. New Technology Demonstrated by ETS-8
   - An advanced 3-ton-class spacecraft bus
   - Large scale deployable antenna reflectors (size 19m*17m)
   - Communication technology to link geostationary satellite with hard-held terminals
   - Basic technology of geostationary satellite positioning system

1. Emphasis
   ETS-VIII have mounted SLR Laser Reflector, in order to determine orbit precisely.

Considering on Laser Reflector

There is few geostationary satellite which mounted SLR Laser Reflector.
We should consider some properties, that is

- Material
- Coated or Uncoated Cube?
- Cube Size?
- Array Size and Design
- Dihedral Angle?



On the other hand, there is restriction from ETS-VIII bus.

- Weight :within 3.5 kg
- Size : within 35 cm * 35cm Area
- Life : over 6 years including 3 years ground storage

Solutions for ETS-VIII's LR(1/3)

1. Material

   Body : Aluminum

   Cube : Quarts (Suprasil-1) ← Tolerant for cosmic radiation

1. Coated vs. Uncoated Cubes

   Optical efficiency : Uncoated cube is prefer

   Thermal stability : Uncoated cube is prefer

   Incident Angle : less than 10 deg for visible SLR stations.

   → Uncoated Cube has chosen.

1. Cube Size

Parameter studies has been carried out to evaluated optimum cube size.

Diameter (cm)	Cross Section σ (10^4 m^2)		σ/D^2	
	0 μ rad	20 μ rad	18 μ rad	20 μ rad
3.3	64.31	17.09		10.11
4.1	147.55	36.00	**15.39**	**14.06**
5.1	360.25	41.65	10.41	10.41

←Optimization

Solution for ETS-VIII's LR (2/3)

1. Array Size

From optical Radar Link Equation, we estimated expected return photo electrons.

$$n_{pe} = \eta \left(\frac{E_p}{\mathrm{h}\omega} \right) \gamma_t \tau_a \tau_c \left(\frac{\sigma}{\pi \left(\theta_t \gamma_{trb} \right)^2 R^2} \right) \gamma_r \tau_a \tau_c \left(\frac{A_r}{\pi R^2} \right) G$$

			Tanegashima	NICT(CRL)	Yarragadee	Mt. Stromlo
Zenith angle	θ_z	deg	39.74	42.85	49.31	41.16
Slant Range	R	m	3.714E+07	3.734E+07	3.780E+07	3.723E+07
Effective diameter of	D_r	m	1.00	1.50	0.76	1.00
Area of Secondary Mirror	S_{sub}	m^2	0.03	0.07	0.00	0.03
Area of Spider	S_{spi}	m^3	9.613E-03	9.613E-03	9.613E-03	9.613E-03
Effective Area of Telescope	A_T	m^2	7.458E-01	1.688E+00	4.440E-01	7.458E-01
Quantum Efficiency	η_Q	–	0.104	0.15	0.155	0.11
Laser Pulse Energy	E_p	J	0.25	0.05	0.2	0.02
Transmitter Optics	γ_t	–	0.50	0.30	0.94	0.41
Receiver Optics Transmission	γ_r	–	0.50	0.10	0.79	0.41
Atmosphere Transmission	τ_a	–	0.80	0.80	0.80	0.80
Optical Cross Section	σ	m^2	2.981E+07	2.942E+07	2.902E+07	2.981E+07
Beam Divergence (half angle)	θ_t	sec	5	2	5	2
Fitting Parameter	G	–	0.100	0.100	0.100	0.100
Signal Photo Electron (clear)	**n_{pe}**	**–**	**2.24**	**1.06**	**4.29**	**0.79**

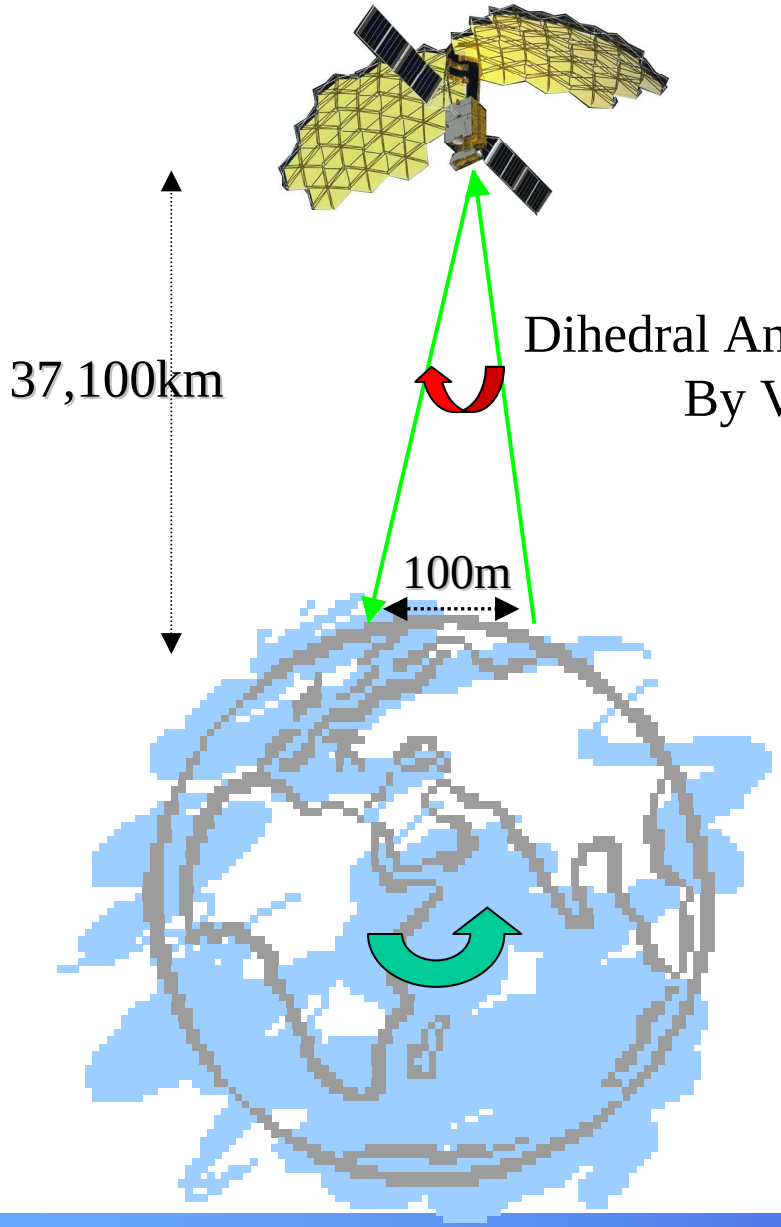
We have changed Cube Number as parameter; 1,2,3...N.
Till enough photo electron number, we have increased cube number.

As a result, Cube Number = 36.

Though there are unknown parameters, accuracy of this estimation is rough.

I was worried before start tracking for ETS-8.

Other Design of ETS-VIII's LRA



Dihedral Angle : about $2 * 10^{-6}$ rad

By Velocity Aberration and Sagnac Effect :

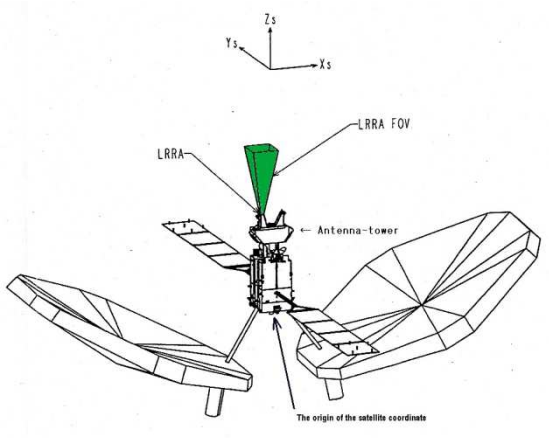
Laser Reflector of ETS-8

Radar Link Analysis

In order to get return photo electron,
At least 36 CCR, whose diameter is about 4 cm.

Restriction on ETS-8 Body

Weight :within 3.5 kg
Size : within 35 cm * 35cm Area



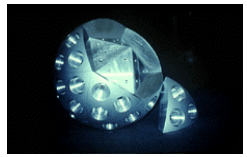
Finally, ETS-8's LRA is designed
Size 30cm * 26cm * 5.4cm,
Weight : within 3.1 kg

Incident Angle is less than 8 degree.
ETS-8's attitude is controlled

Roll	Pitch	Yaw
<±0.05	<±0.05	<±0.15deg

(3 sigma)

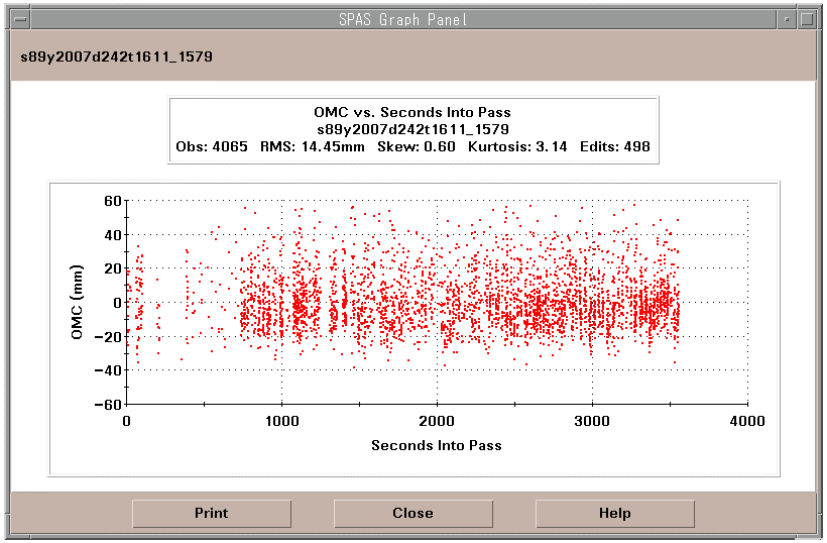
Ref: Orbit Altitude and Characteristic Laser Reflector

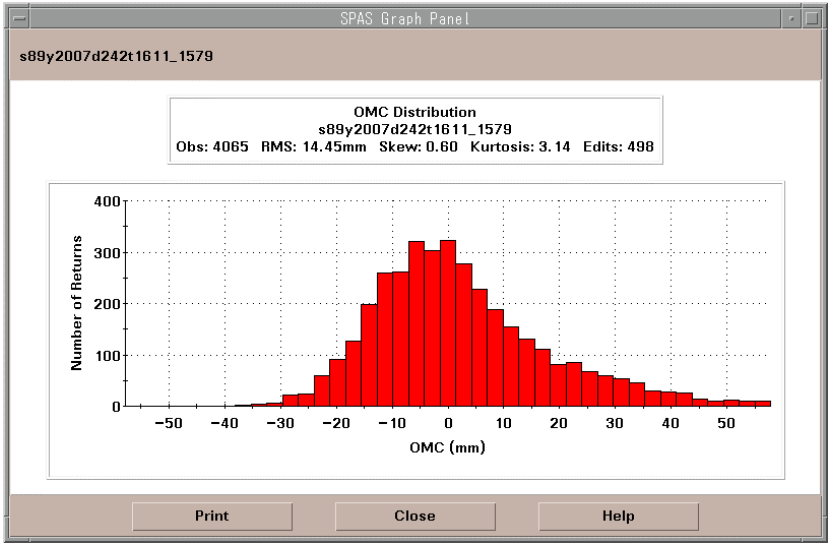
LEO	Less than 2,000 km	Starlette, LARETS, GFO-1, CHAMP, GRACE, ICESAT, AJISAI, ALOS, ANDE, Beacon-c, Envisat, Jason, Stella, TeraSar-X, ERS-2		 
MEO	From 2,000 km to 10,000 km	LAGIOS-1,2, Etalon		
HEO	Over 10,000 km	GPS35,36, GLONASS95,99,102 GIOVE-A	Coated with aluminum 32 CCR with 2.9cm diameter 24cm*20cm panel	
	GEO 36,000 km	ETS-VIII (Optus (Australia))	36 CCR with 4.1cm diameter 30cm * 26cm panel Uncoated	
Moon	356,400 km	Apollo11,14,15, Luna17, 21	100 CCR with 3.8cm diameter 46cm panel (Apollo 11, 14)	

Actual Tracking Results (1/2)

JAXA Tanegashima station have gotten return signals successfully.
Also, Koganei(Japan), Mt.Stromlo (Australia), Yarragadee (Australia), Changchun (China) have gotten return signals successfully.

Here, we show the tracking results at Tanegashima.
Period : 2007/August/30 From 10:40UT to 17:30UT.

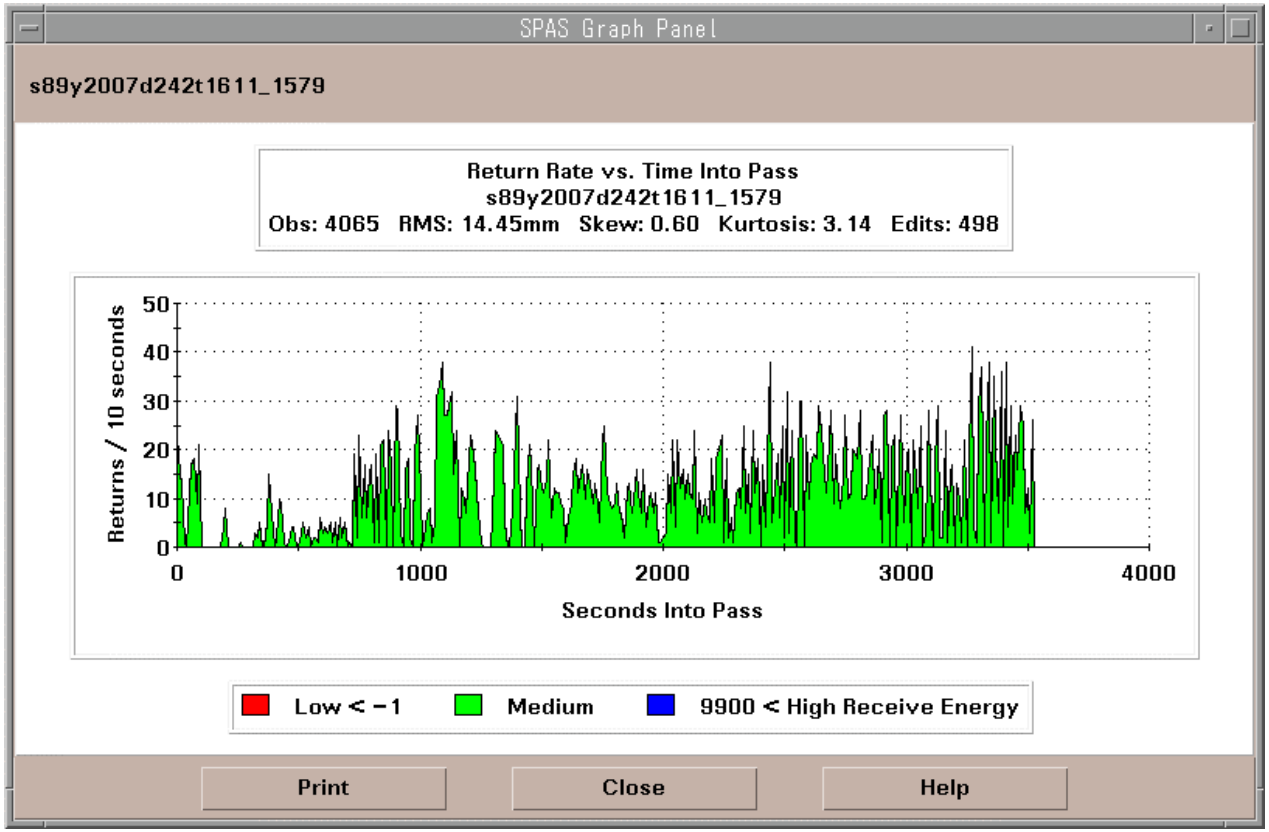




According law of large numbers,
distribution of residual close to Gaussian.
RMS about from 7mm to 16 mm

→ Data quality is good.

Actual Tracking Results (2/2)



Return rate: Tanegashima : Average 10% , Peak (max) over 30%

Through Private communications, we have gotten actual return rate at each SLR stations.

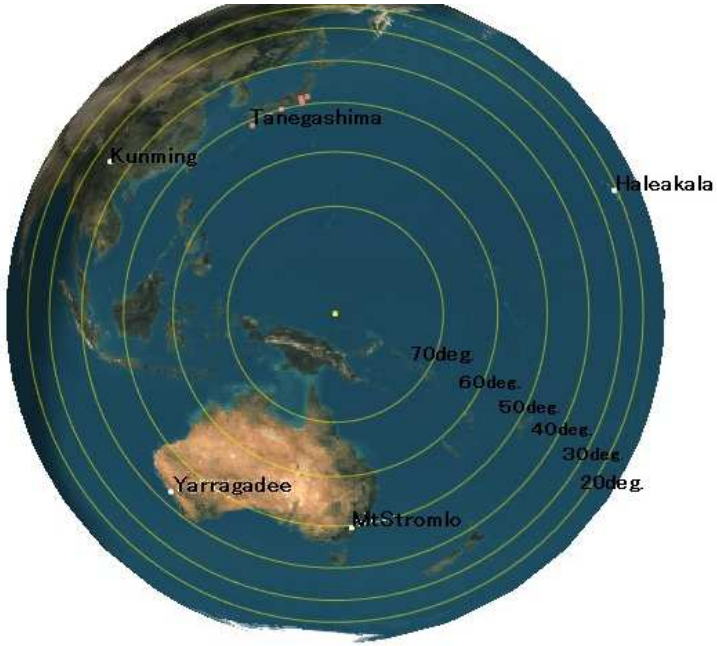
Note : Koganei 3%, Mt. Stromlo 2%, Changchun 1%

Summary

- I think ETS-8's LRA is "Well Considered LRA"
  - Material ← High tolerant for cosmic radiation
  - Cube Size ←Optimized
  - Uncoated Cube ← Considering Thermal Condition
  - High symmetry (6*6 array) Good Design
  - However, Lifetime will be evaluated future
- Return Signals have been gotten at Tanegashima, Koganei, Yarragadee, and Mt. Stromlo.
- I am performing scientific experiment using ETS-VIII's LRA now, and I will report results next ILRS meeting.
- Note that : This Tracking is helped by ILRS WPNW.

  I would like to express my thanks.

Visible SLR stations



		El	Slant Range	Inc Ang of LR
Tanegashima	Japan	50.26	37,139km	5.54
Koganei	Japan	47.85	37,295km	5.82
Yarragadee	Australia	40.69	37,804km	5.70
Mt.Stromlo	Australia	48.84	37,229km	5.70
Changchun	China	33.97	38,969km	7.19