An Update on Recent Results from the Japanese Kaguya Mission to the Moon

March 2008

JAXA 宇宙航空研究開発機構

KAGUYA Mission Objectives

Global survey of the Moon

To study the origin and evolution of the Moon by observing the distribution of the elements and minerals on the surface, the structure of the surface and subsurface, the gravity field, the remnant of the magnetic field

Data Acquisition for Future Moon Utilization

To be used for human activities on the Moon and the possibility of future utilization of the Moon

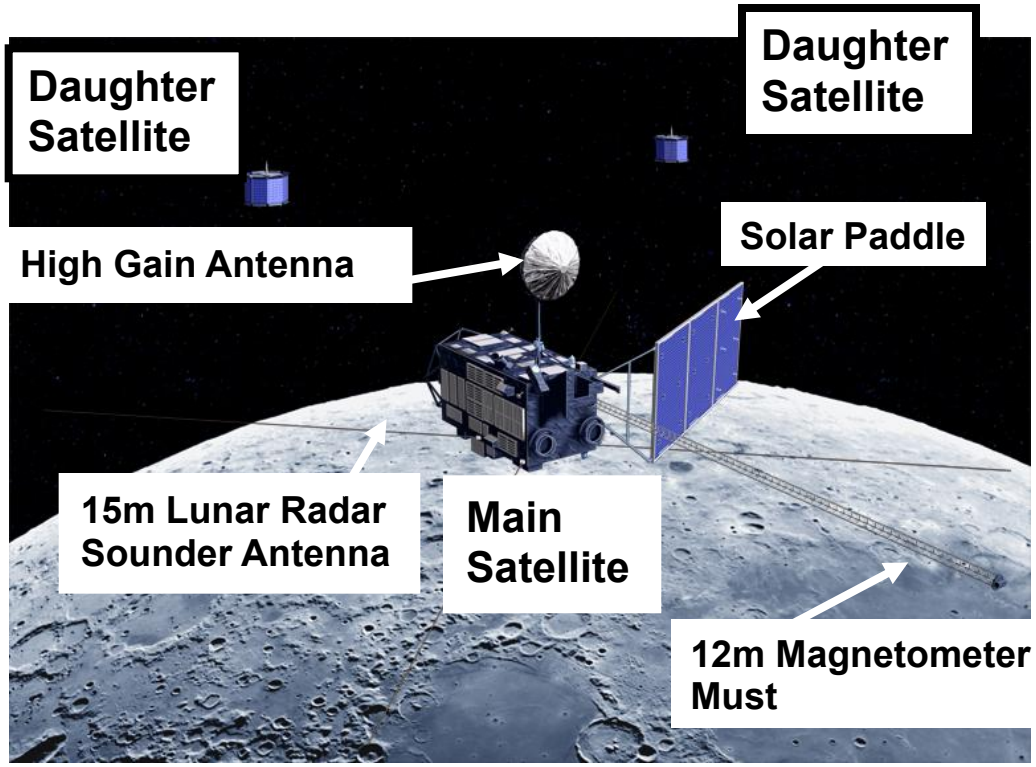
Technology Development for the Lunar Exploration

Technologies such as orbit control, attitude control, thermal control on lunar orbit to be developed

Public Outreach

To make a public outreach by taking the movies of the beautiful Earth Rising using its onboard High Definition Television System

KAGUYA Configuration and System Performance



On orbit Configuration

Main Satellite：KAGUYA

Mass： About 3ton（At launch）
（including daughter satellite50kg×2）
Dimension： About 2.1m×2.1m×4.8m
Attitude control 3axis Control
Power Generation： About 3.5 kW (MAX)
Mission Period： About 1Year
Orbit： 100km Altitude ／Inclination 90deg.

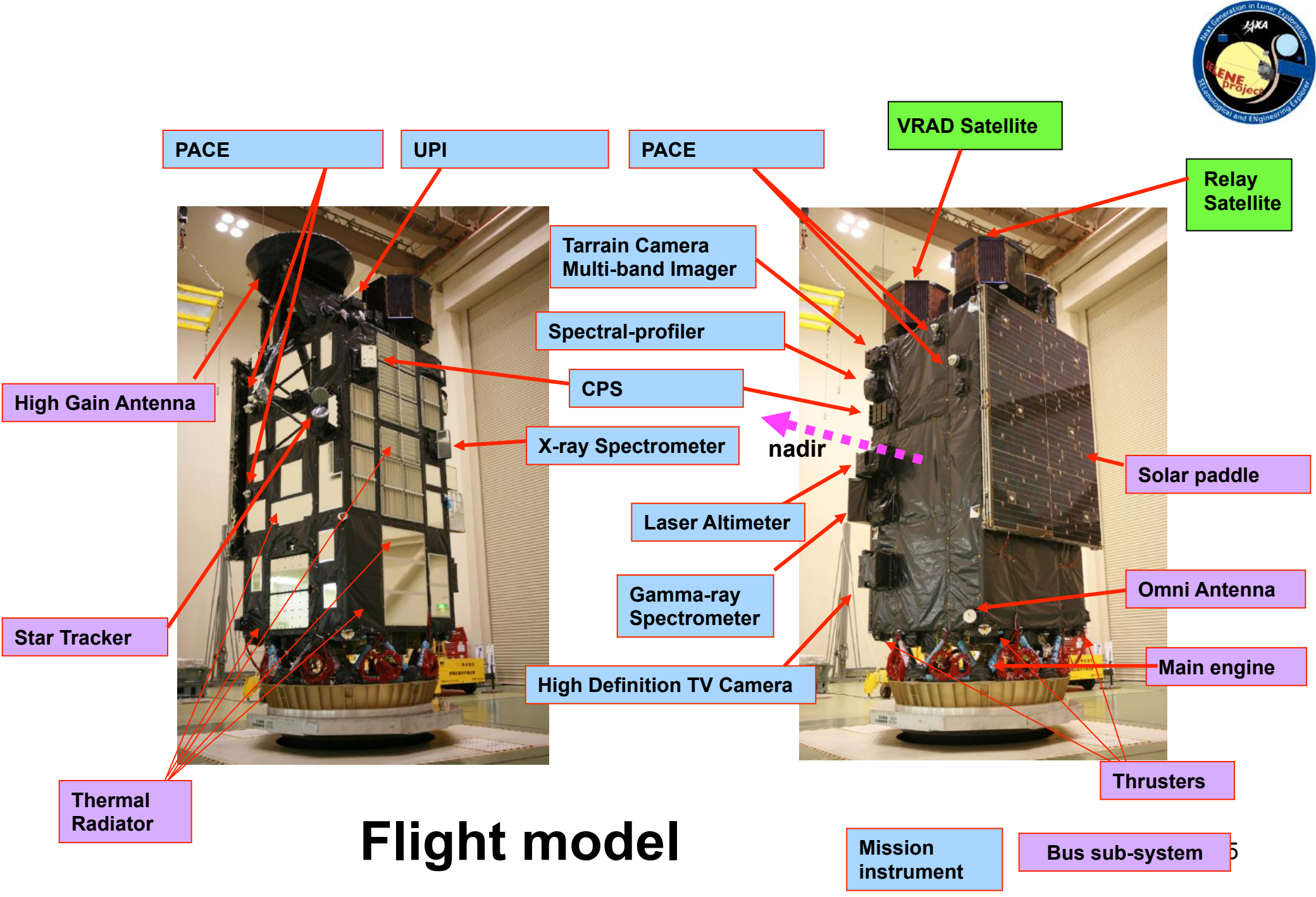
Daughter Satellites
Rstar(Relay satellite):OKINA
Vstar(VLBI Radio satellite):OUNA

Mass： About 50kg
Dimension： 約0.99m×0.99m×0.65m
（Octagonal column shape）
Attitude Control： Spin Stabilization
Power Generation： About 70W
Mission Period： About 1Year
Orbit（At Separation）：
(Rstar：OKINA) 100km×2400km
(Vstar: OUNA)： 100km× 800km

VRAD: VLBI RADio source
VLBI: Very Long Baseline Interferometry

SELENE Mission Instruments

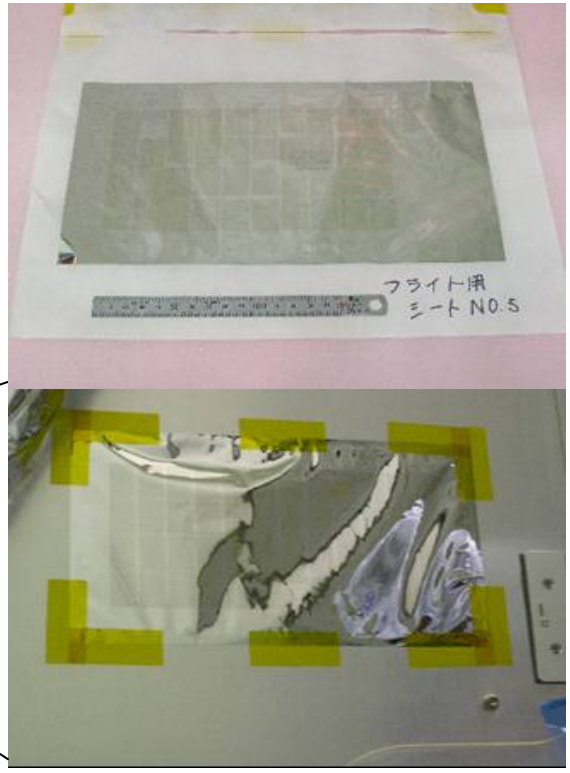
Category	Observation	Instrument	Measurement
Science of the Moon	Element Abundance	X-ray Spectrometer(XRS)	Al, Si, Mg, Fe, etc.
		Gamma-ray Spectrometer(GRS)	U, Th, K, H etc.
	Mineral Composition	Multi-band Imager(MI)	mineral distribution
		Spectral Profiler(SP)	mineral composition
	Topography, Geological Structure	Terrain Camera(TC)	geographical features
		Lunar Radar Sounder(LRS)	subsurface structure
		Laser Altimeter(LALT)	topography
	Gravity Field	Differential VLBI Radio Source(VRAD)	lunar gravity field
		Relay Satellite(RSAT)	far side local gravity field
Science on the Moon	Magnetic Field	Lunar Magnetometer(LMAG)	magnetic field
		Electron Energy Analyzer(part of PACE)	surface magnetic field
	Radiation Environment	Charged Particle Spectrometer(CPS)	energetic particles
	Plasma Environment	Plasma Energy Angle and Composition Experiment(PACE)	electrons and ions
	Ionosphere	Radio Science(RS)	ionospheric electrons
Science from the Moon	Solar-Terrestial Plasma Environment	Uppe-Atmosphere and Plasma Imager(UPI)	earth magnetosphere, aurora
		Wave Receiver(part of LRS)	planetary radiations
Publicity	Earth and Moon	High Definition TV(HDTV)	high-definition movie



Flight model

Wish Upon the Moon Campaign

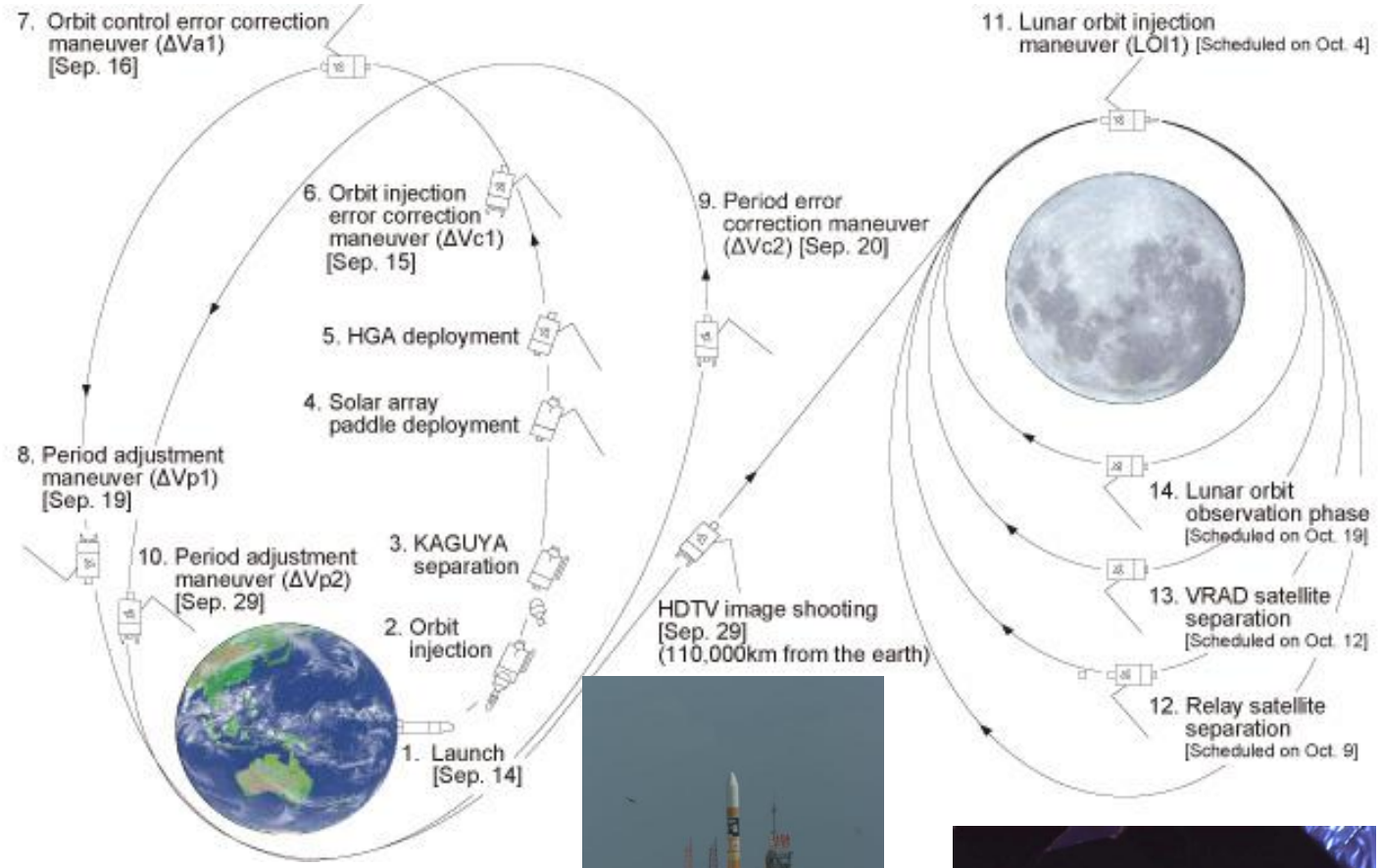
- 2006, Dec.1～2007, Feb.28
- 412,627person's names and messages (Domestic：234,498, Foreign：178,129)

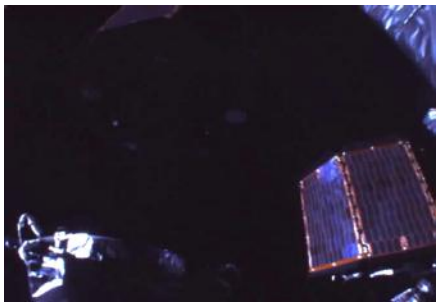


Name sheets on KAGUYA

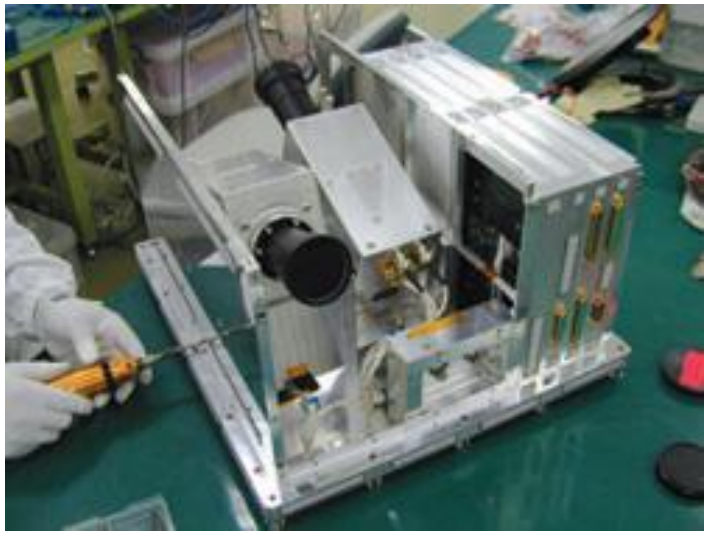
Sheet size 280mmx160mm
Character size: 70μm

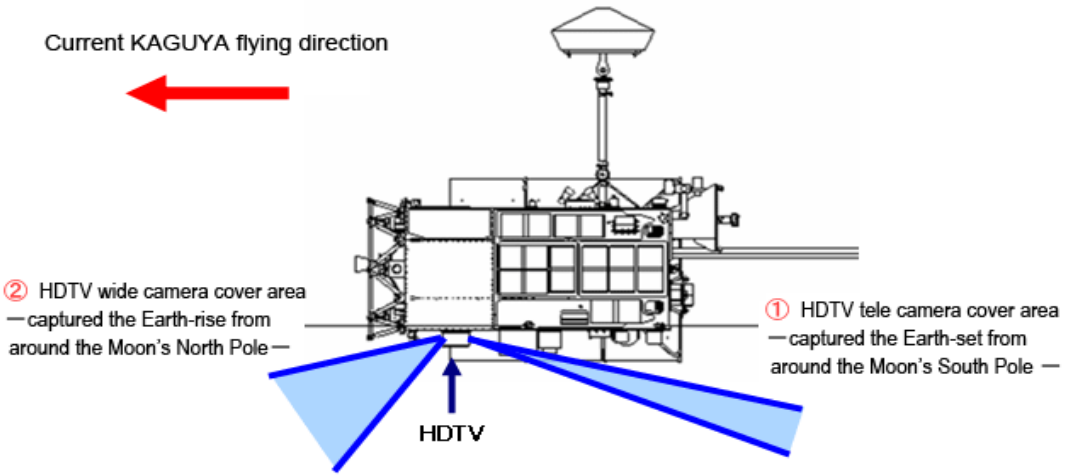
Road to the Moon





High Definition TV System

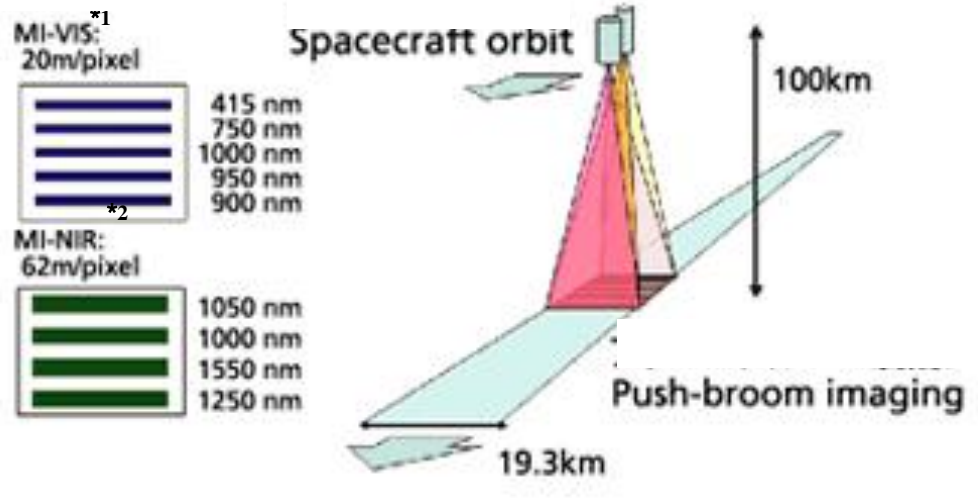


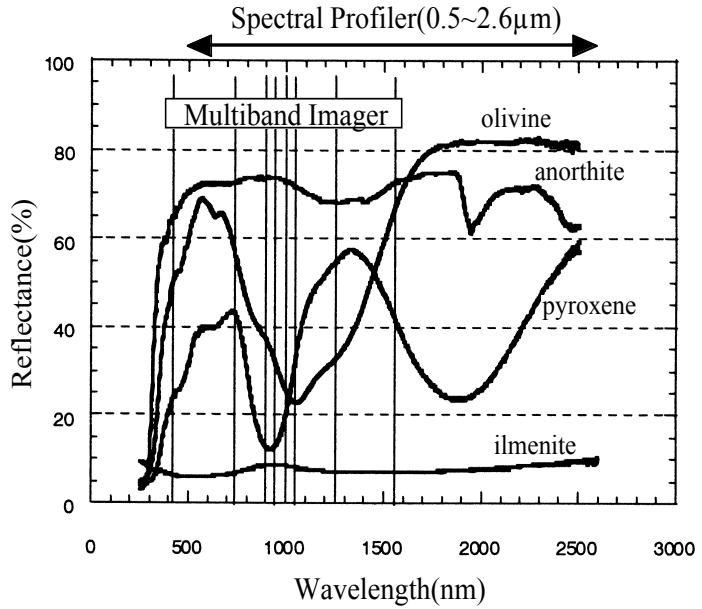


X-ray Spectrometer (XRS)	Global mapping of Al, Si, Mg, Fe distribution using **100 cm^2 CCD**, **spatial resolution 20 km**, Energy range 0.7-8 keV, 5 μm Be film, Solar X-ray monitor
Gamma-ray Spectrometer (GRS)	Global mapping of U, Th, K, major elements, distribution using **250 cm^3 large pure Ge crystal**, **Spatial resolution 100 km**, Energy range 0.1-10 MeV
Multi-band Imager (MI)	UV-VIS-NIR CCD & InGaAs imager, spectral bandwidth from0.4 to 1.6 microns, 9 bands filters, spectral resolution 20-30 nm, **spatial resolution 20-60 m**
Spectral Profiler (SP)	Continuous spectral profile ranging from 0.5 to 2.6 microns, spectral resolution 6-8 nm, **spatial resolution 500 m**
Terrain Camera (TC)	High resolution stereo camera, **spatial resolution 10 m**
Lunar Radar Sounder (LRS)	Mapping of subsurface structure using active sounding, frequency **5 MHz**, echo observation range **5 km**, resolution 75 m, Detection of radio waves (**10k-30MHz**) from the Sun, the Earth, Jupiter, and other planets
Laser Altimeter (LALT)	Nd:YAG laser altimeter, **100 mJ** output power, height resolution 5 m, spatial resolution **1600 m** with pulse rate 1 Hz, Beam divergence 3 mrad
Differential VLBI Radio Source (VRAD)	Differential VLBI observation from ground stations, selenodesy and gravitational field, onboard two sub-satellites, **3 S-bands and 1 X-band**
Relay Satellite Transponder (RSAT)	Far-side gravimetry using **4 way range rate** measurement from ground station to orbiter via relay satellite, perilune 100 km, apolune 2400 km in altitude, **Doppler accuracy 1 mm/s**
Lunar Magnetometer (LMAG)	Magnetic field measurement using flux-gate type magnetometer, accuracy **0.5 nT**
Charged Particle Spectrometer (CPS)	Measurement of high-energy particles, **1-14 MeV(LPD), 2-240 MeV(HID), alpha particle detector, 4-6.5 MeV**
Plasma Analyzer (PACE)	Charged particle energy, angle and composition measurement, **5 eV/q – 28 keV/q**
Radio Science (RS)	Detection of the tenuous lunar ionosphere using **S and X-band carriers**
Plasma Imager (UPI)	Observation of terrestrial plasmasphere from lunar orbit, **XUV(304A) to VIS**

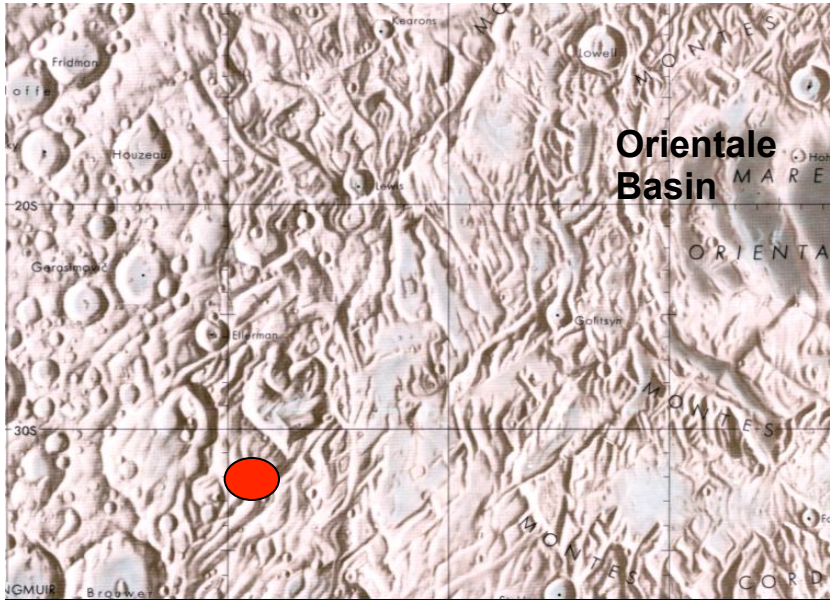
Multi-Band Imager

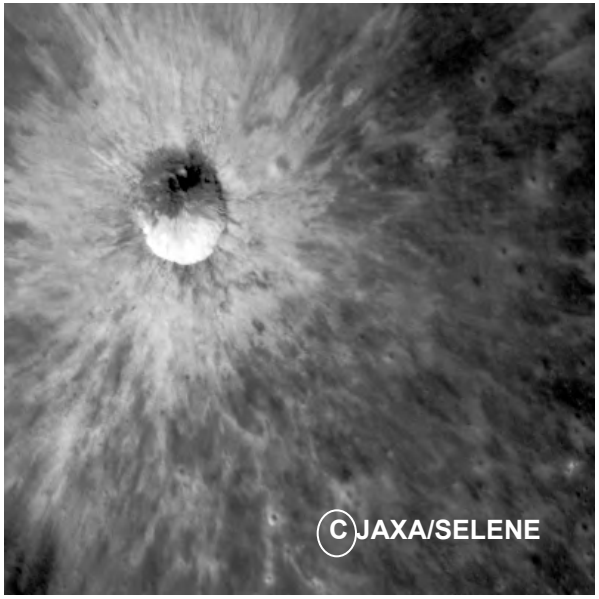
UV-VIS-IR imager
Spectral bandwidth ranging from 0.4 to 1.6 μm,
9 filters(bandwidth 10-30 nm)
Spatial resolution 20m

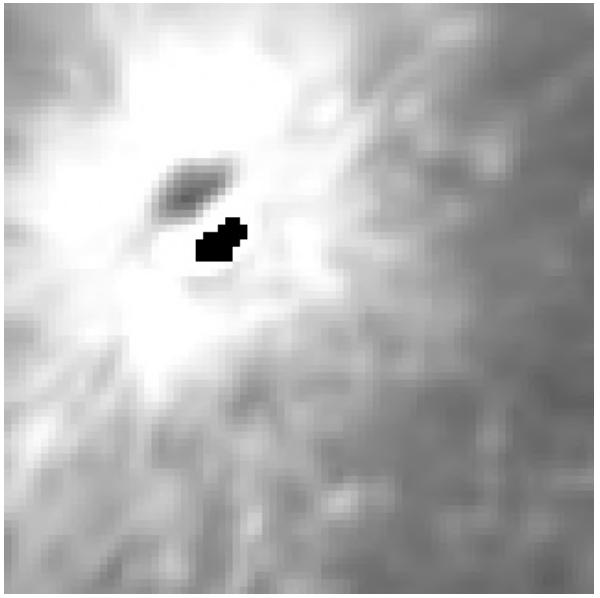




Typical Image by Multi-band Imager







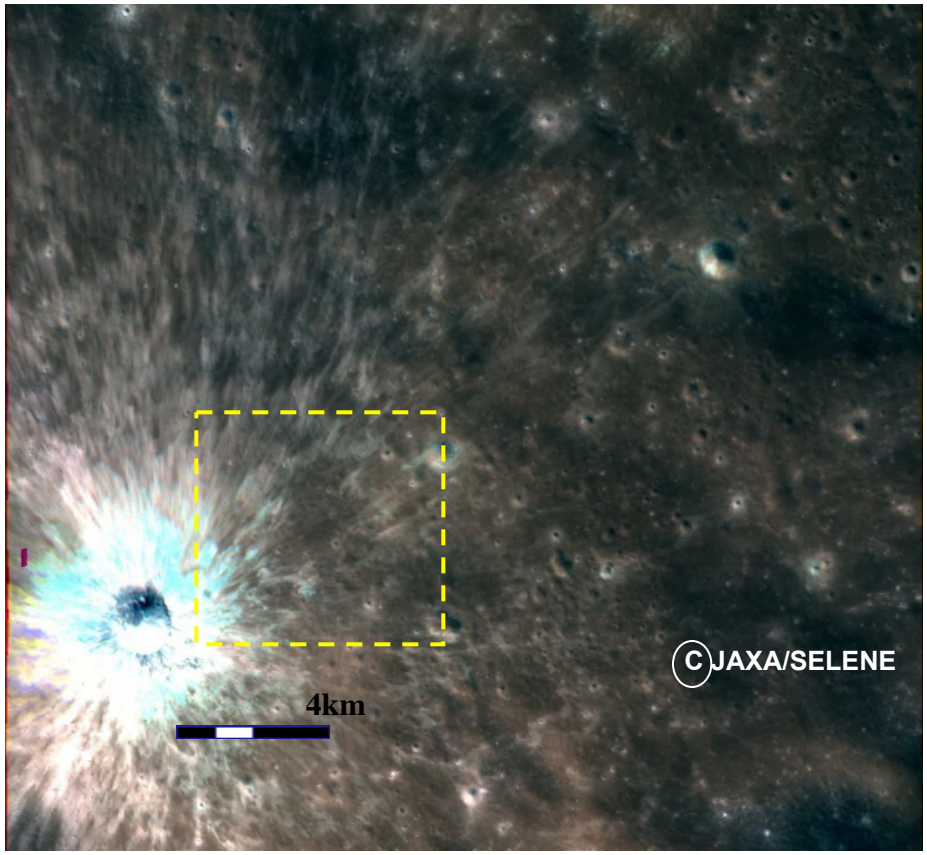
First light (●)
- location：South latitude 37deg. East longitude 240deg.
  (about 1000km south-west of the Orientale Basin)
- Date： 2007, Nov. 3

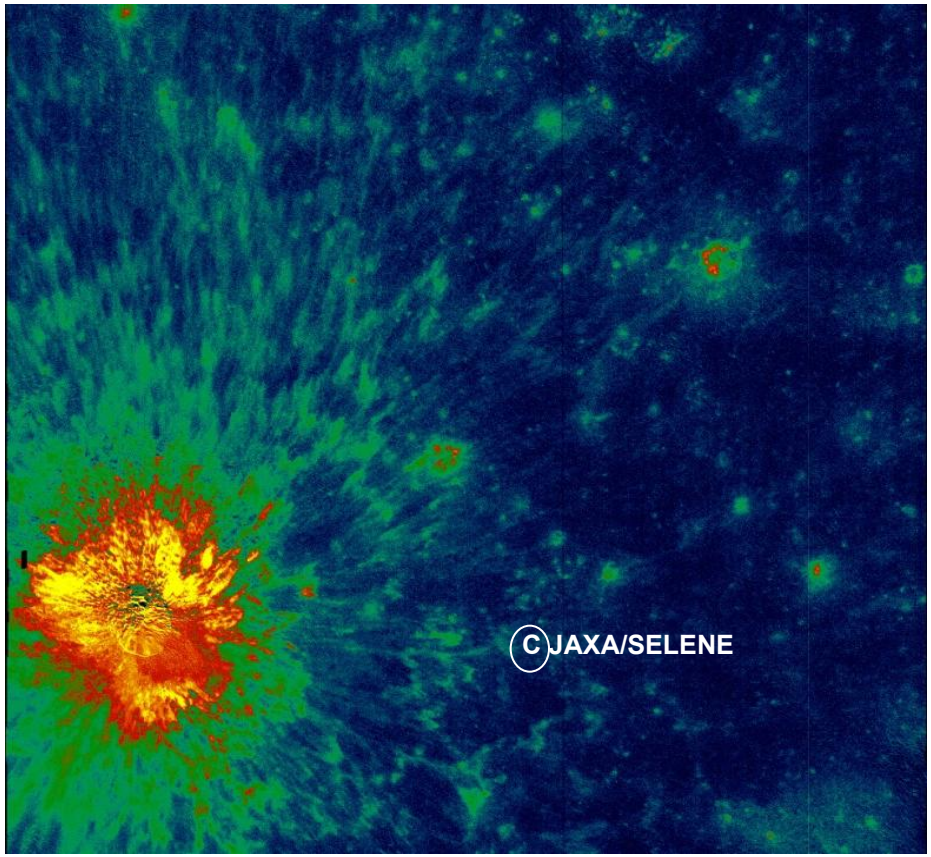
Multi-band Imager
(750nm single-band image,
20mspatial resolution)

Clementine UV-VIS image
(100m spatial resolution)

Reference
http://www.lpi.usra.edu/resources/mapcatalog

Example of Color Processing of MI Data





Low High

Pseudo -color image using 3 lines, showing an existence of ejectors.
（900nm→red、750nm→green 、415nm→blue）

Color-ratio image, 750nm/1000nm, characterizing ejected material from the crater.

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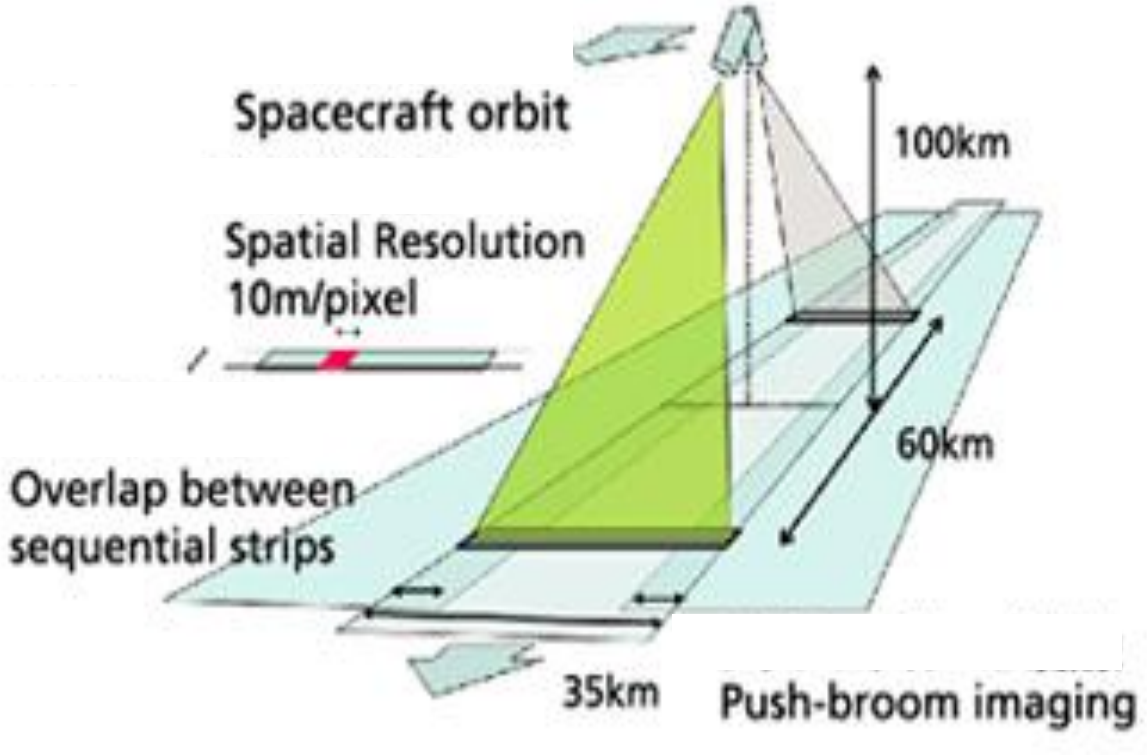
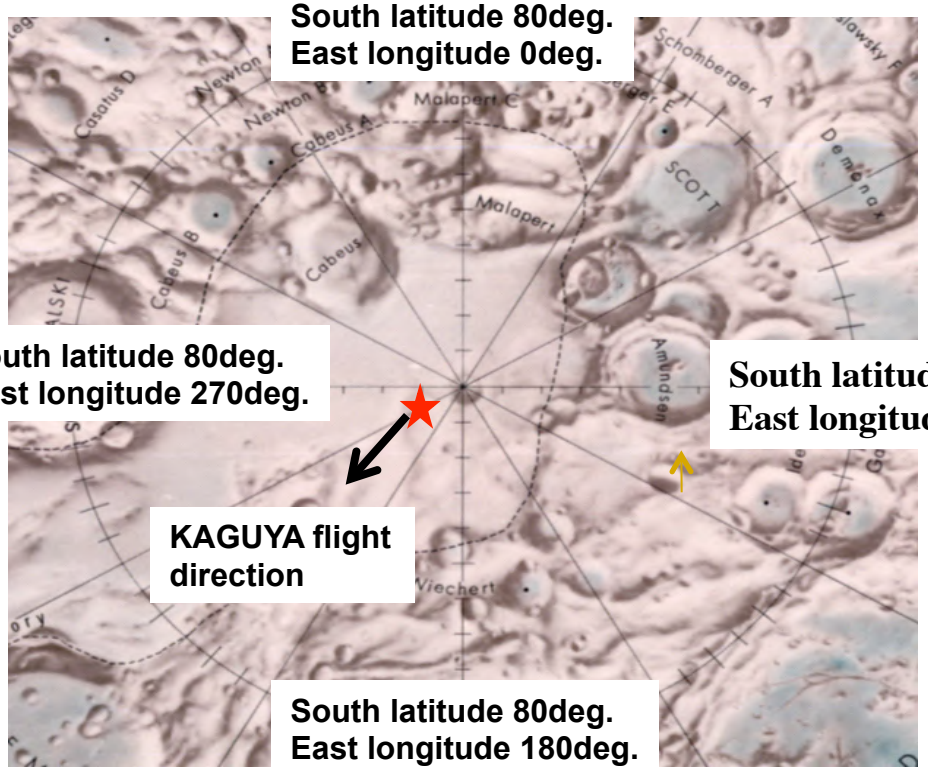
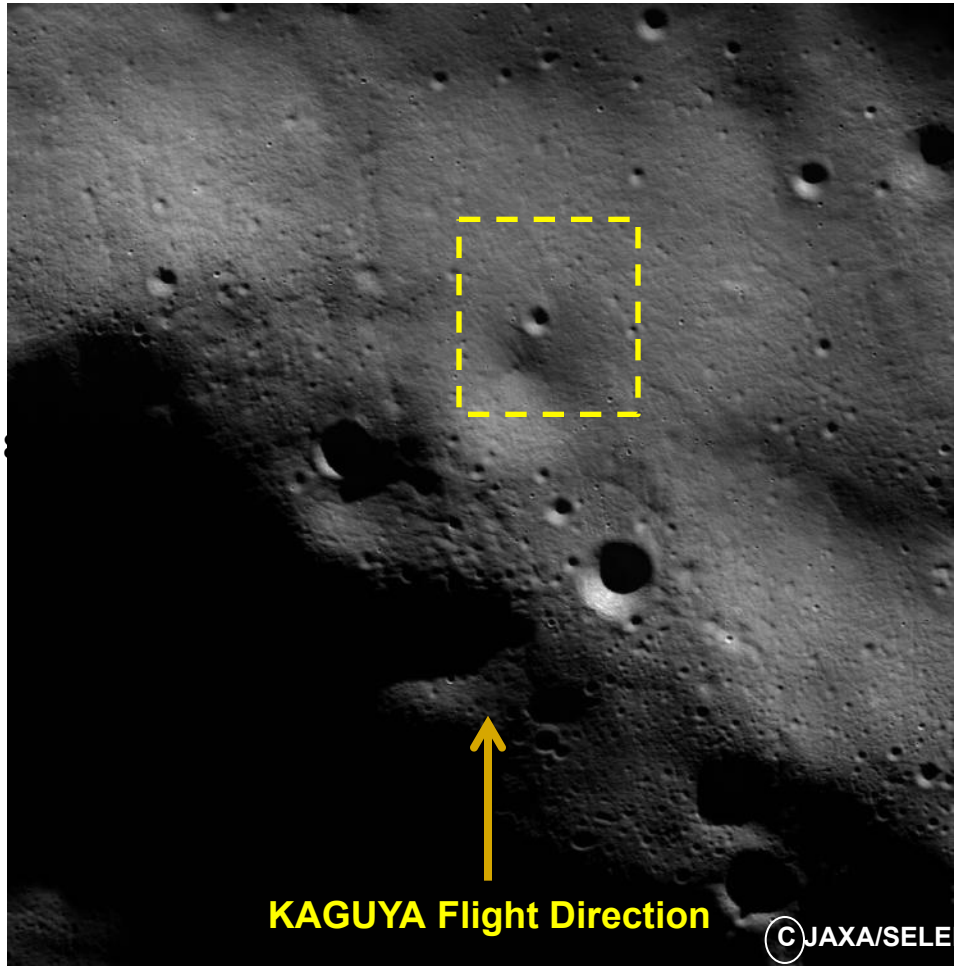
Terrain Camera

Stereo camera
Spatial resolution 10m



Typical data of TC（Nov. 3, 2007）



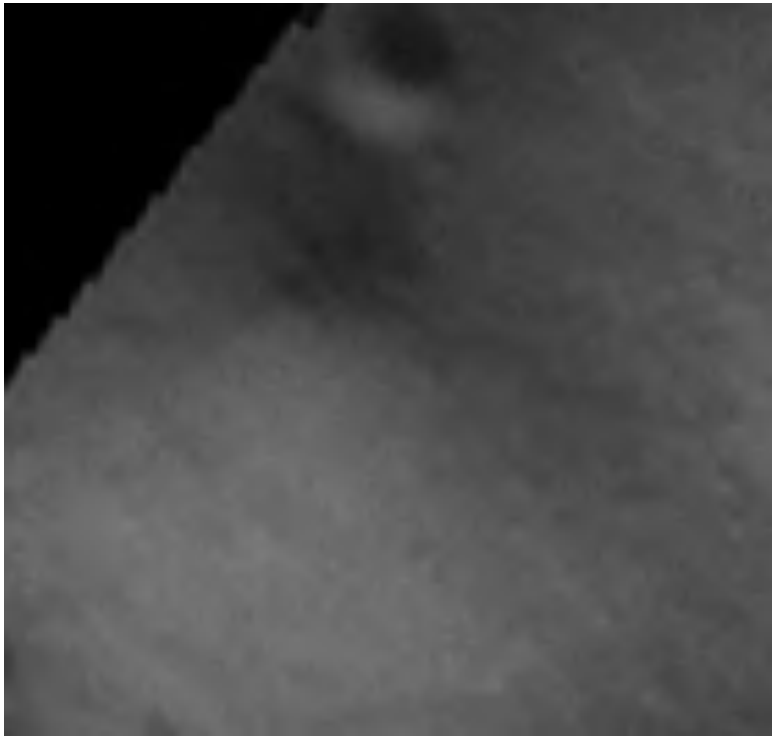


・First light point(★)
・Rear side、About 30km from the South pole
（South latitude 89deg.、East longitude 240 deg.）。
http://www.lpi.usra.edu/resources/mapcatalog

Comparison of the KAGUYA TC image with the Clementine HiRes. image

1km

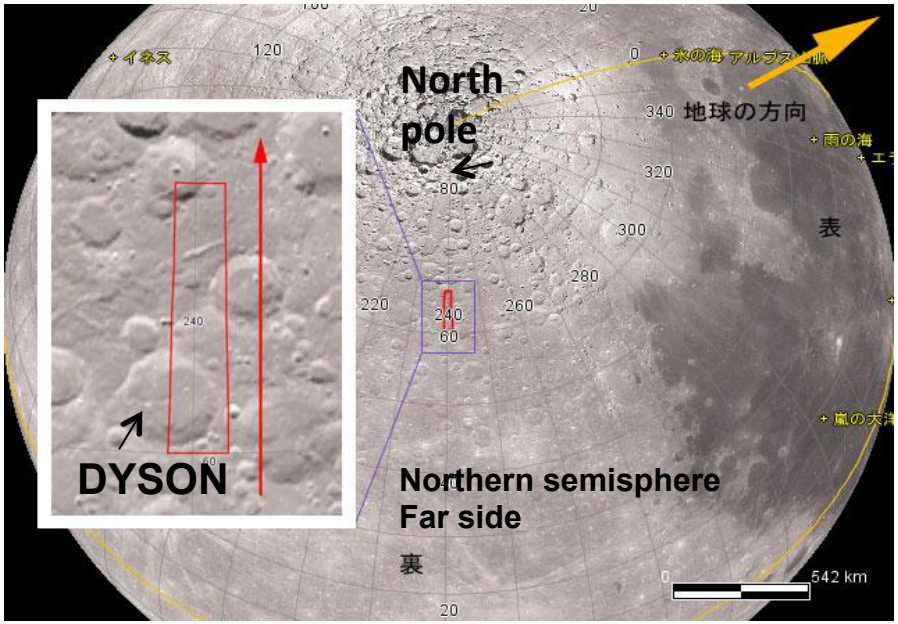
Terrain Camera

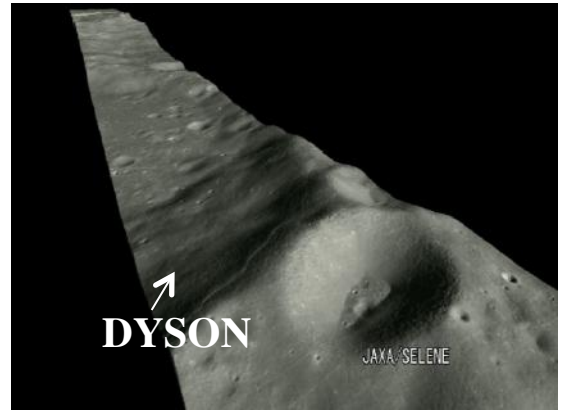


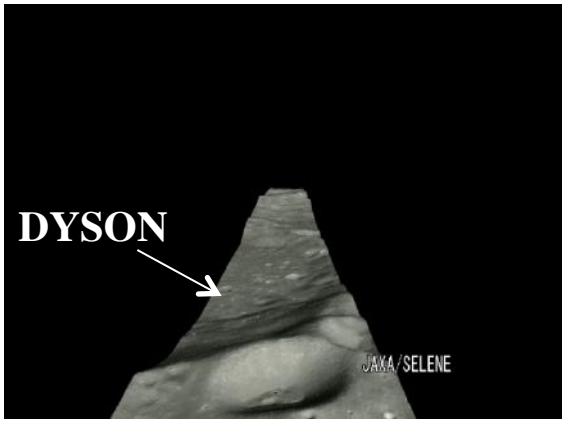
Clementine HiRes(high resolution) Camera
（Clementine digital Image model CD-CL_6022 version 1）

Smaller craters(10m order) and fine structure of the crater are identified by TC image.

Three-dimensional image processed by TC







・Date：2007,Sep 3
・Location： East longitude 240deg.
North latitude 60～66deg.
（Far side, Near DYSON crater）

（Lunar global image by Clementine/UVVIS）

Stereo image composed by TC
10m resolution stereo data

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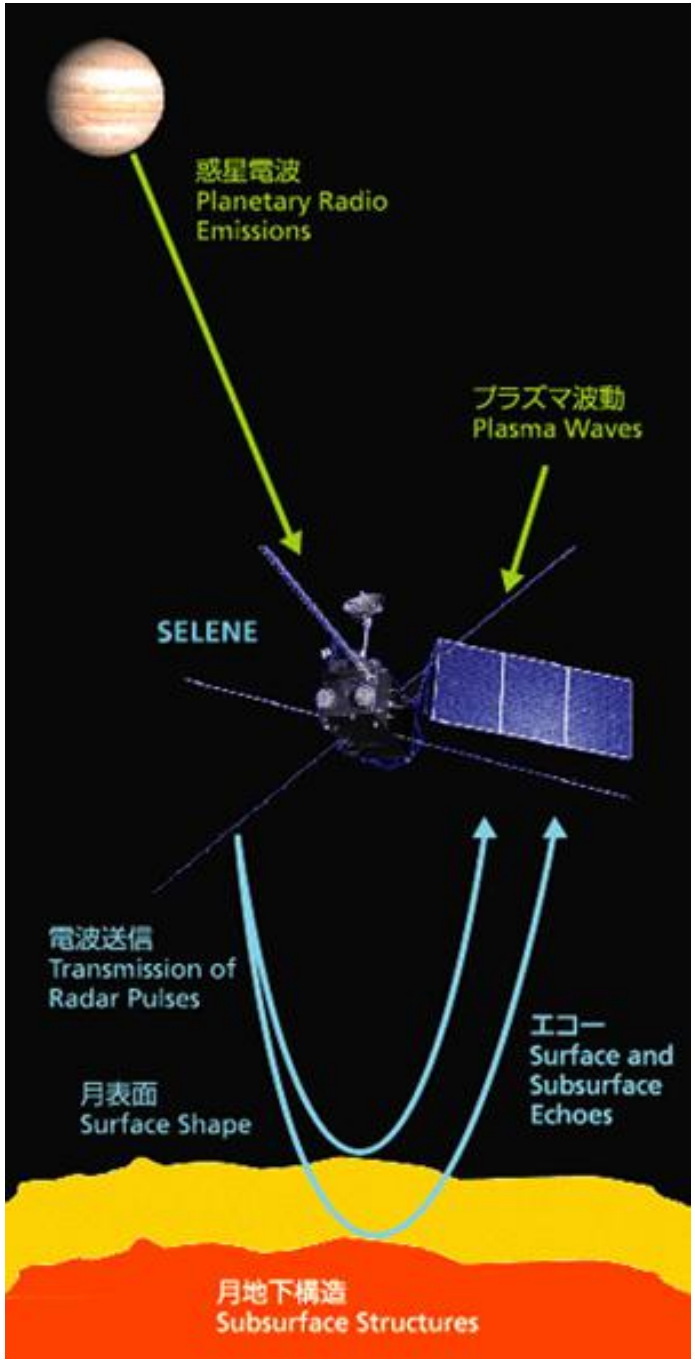
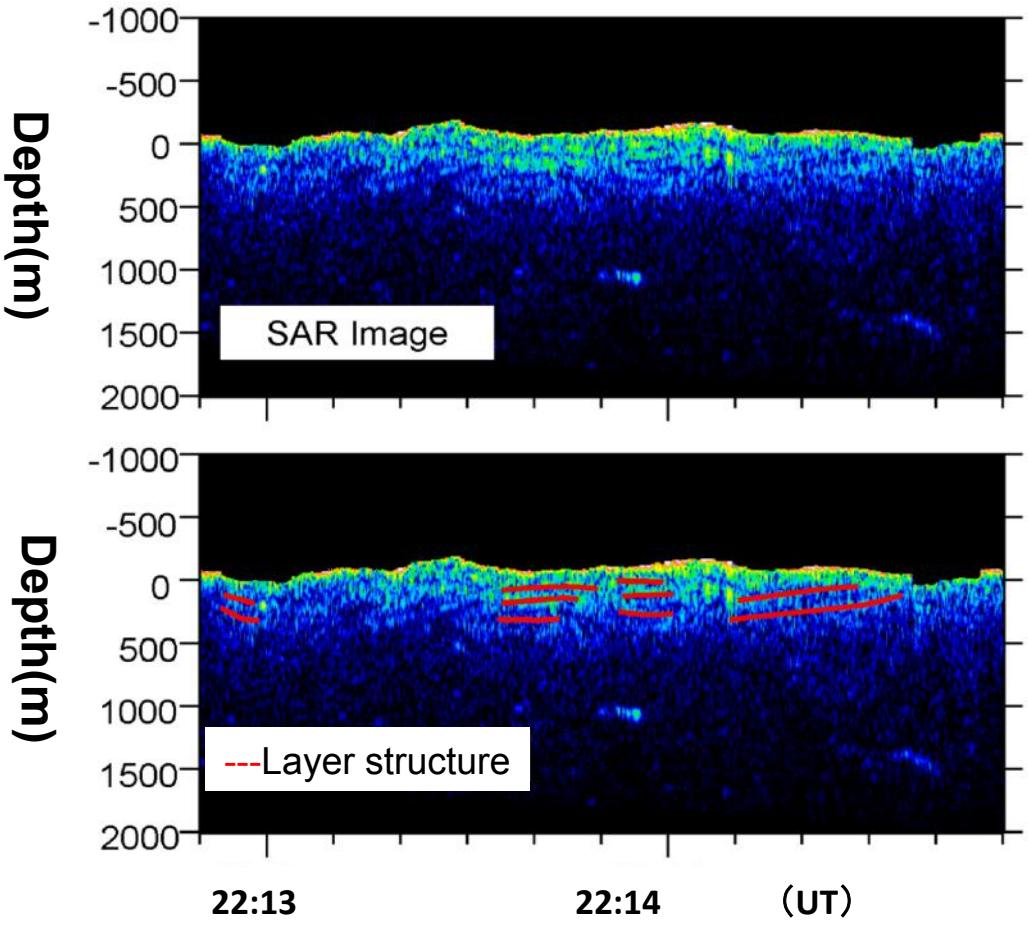


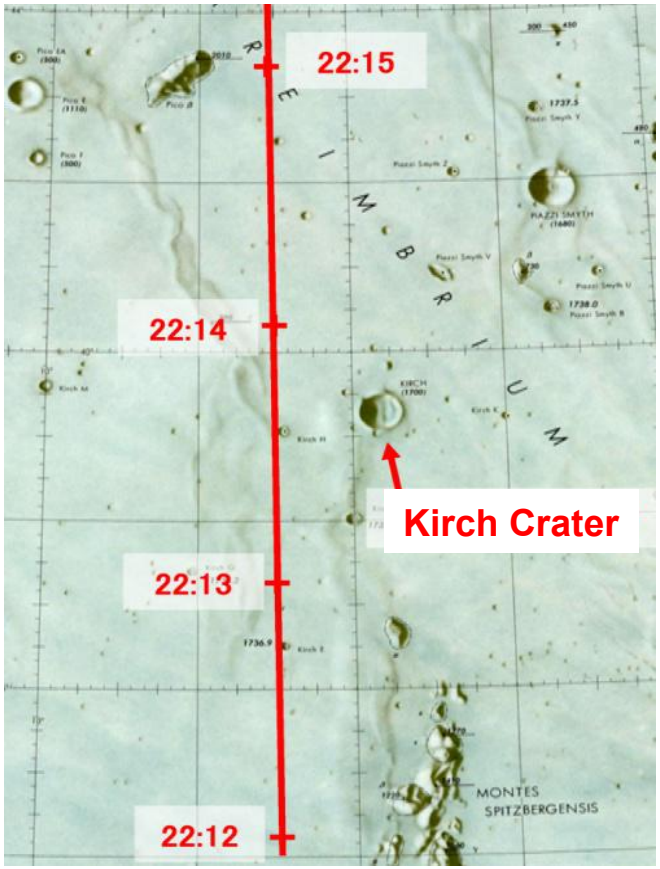
Lunar Radar Sounder

Mapping of subsurface structure using active sounder (frequency 5 MHz) Depth 5 km(resolution 100m)

Frequency	**5 MHz(main)**
Radiation power	**800 Watt**
Pulse width	**200 μsec**
Data rate	**492 kbps**

SAR image from Initial Observation of LRS





The synthetic aperture radar (SAR) image and strata identification of the northeastern part of the Mare Imbrium near the Kirch crater (39.2N, 5.6W, 11 km dia.) retrieved from the LRS sounder mode observation data on November 21, 2007, from 22:13 to 22:15.

4-way Doppler measurement using Relay Satellite Transponder

The first direct determination for the lunar far side orbit

RSAT-1 on Rstar

S-band forward-link for 4way-Dopp

S-band return-link for 4way-Dopp

S-band up-link for 4way-Dopp / 2wayRARR

S-band down-link for 2wayRARR

JAXA UDSC-64m

X-band down-link for 4way-Dopp

Moon

Main Orbiter above near side

RSAT-2 on Main Orbiter above far side

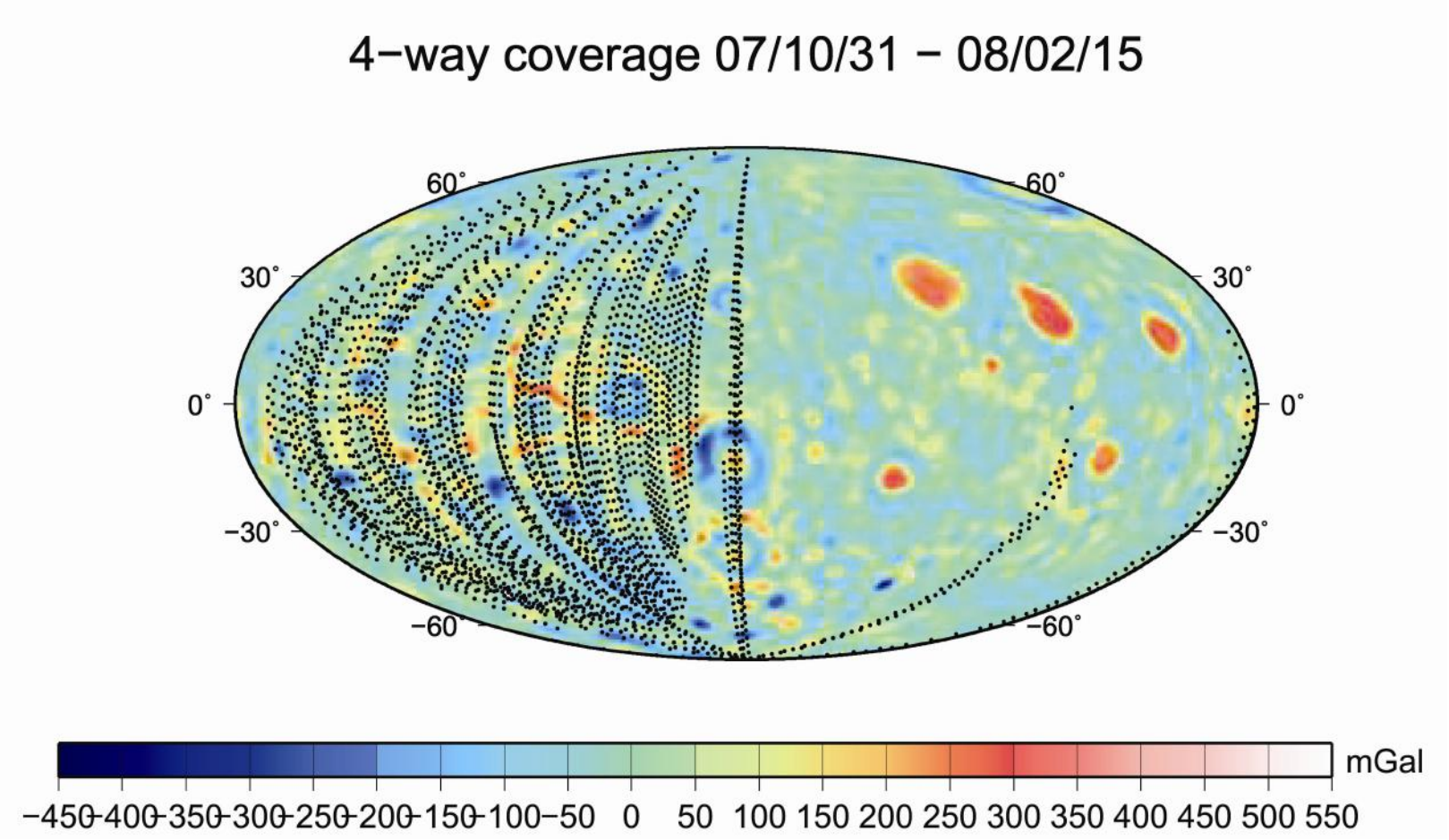
Earth

JAXA TACS

S-band for 2wayRARR

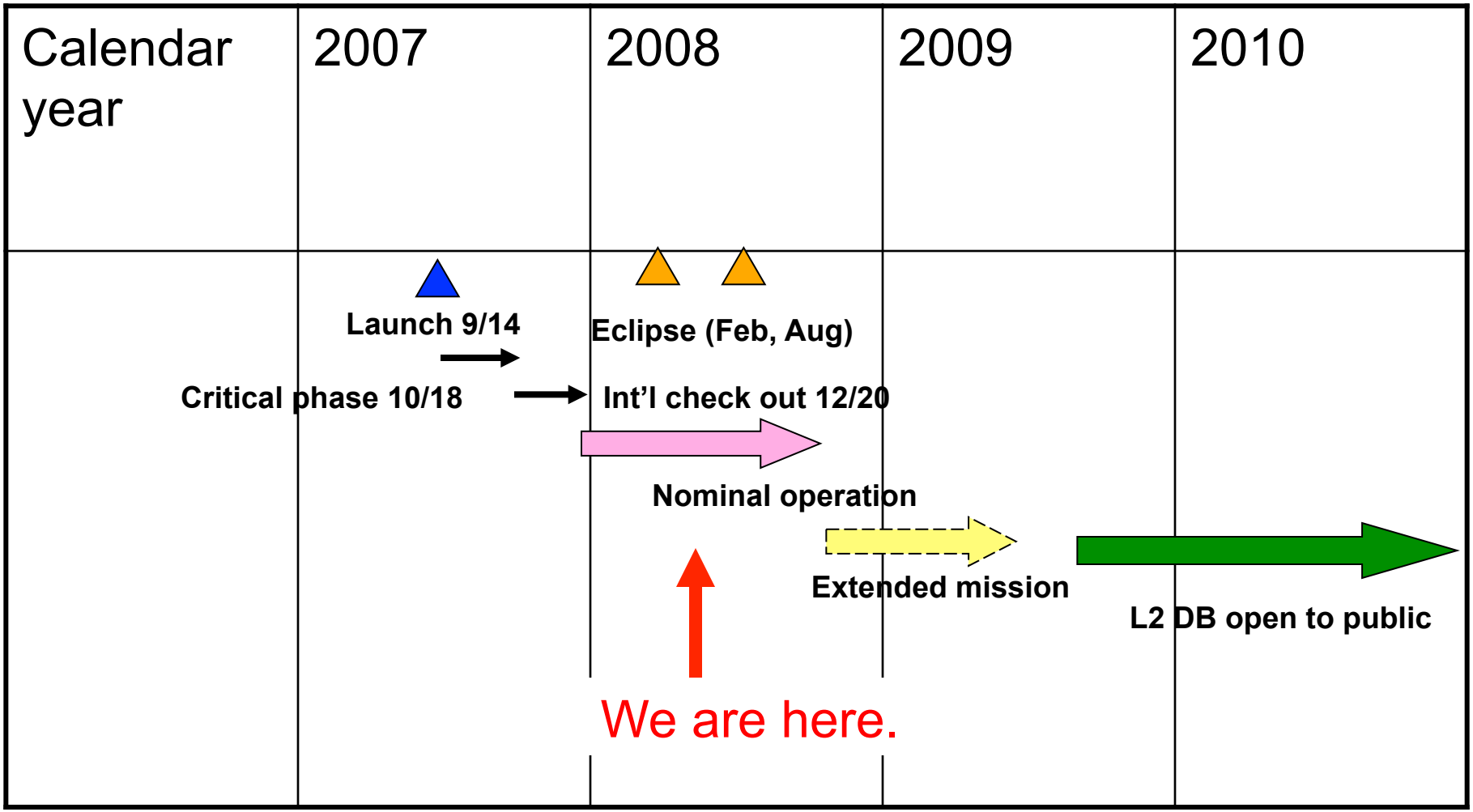
Dopp = Doppler measurement (ranging rate)
RARR = ranging and ranging rate (Doppler)

Coverage for Gravity Observation in the Far Side



Coverage more than 1/4, suggesting new findings for the far side gravity field.

Mission Operation Schedule



Concluding Remarks

1. **Scientific observation is under way as planned, and major scientific goals are expected to be fully achieved by the end of this year.**
2. **Extended mission will be conducted for further fruits.**
3. **We are now confident to contribute greatly to the lunar science, together with other lunar missions.**
4. **International collaboration for new lunar exploration and utilization for human society are now on the horizon.**

Thank you for your attention!