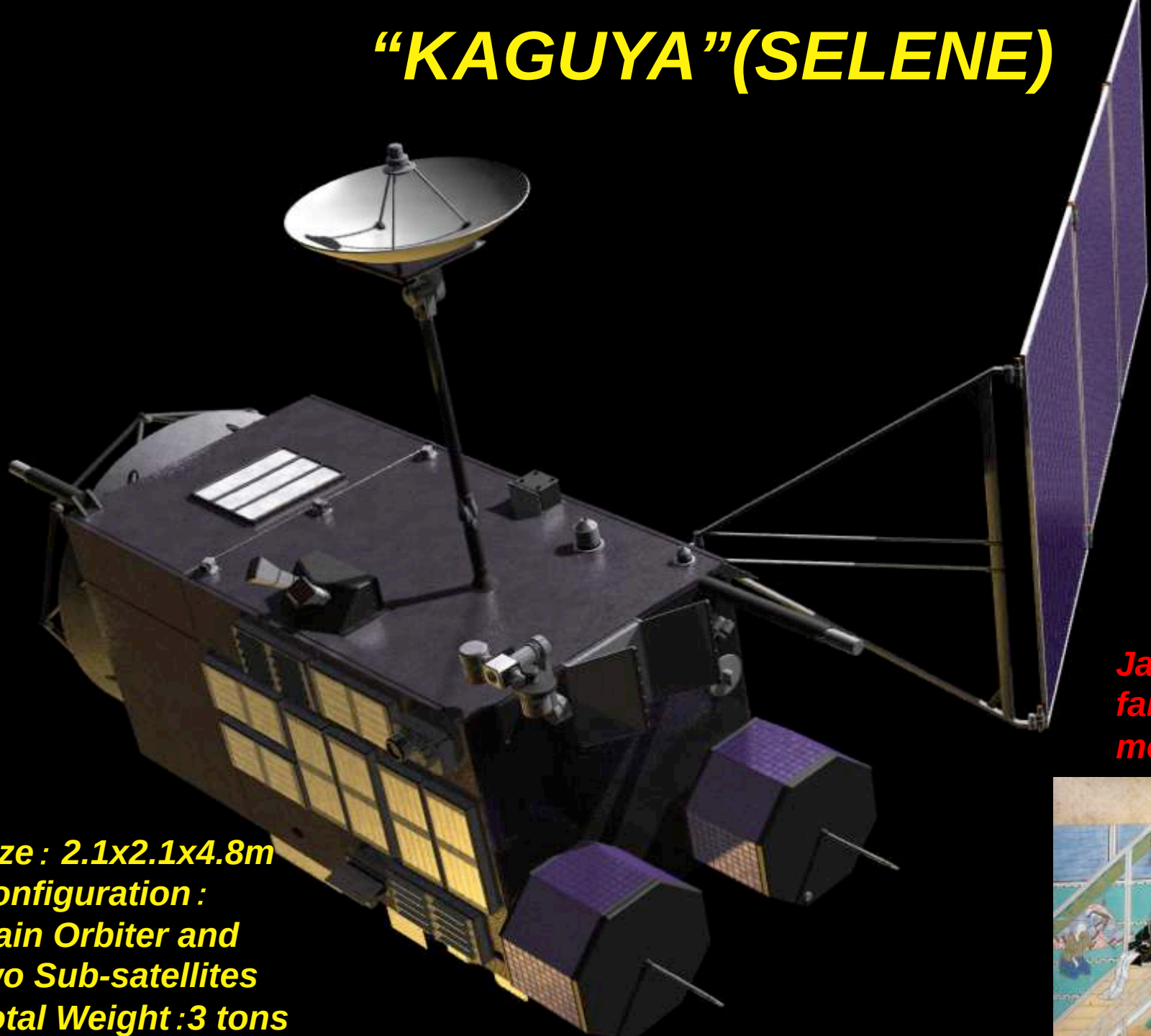
KAGUYA MISSION SUMMARY

Oct. 2009

“KAGUYA”(SELENE)

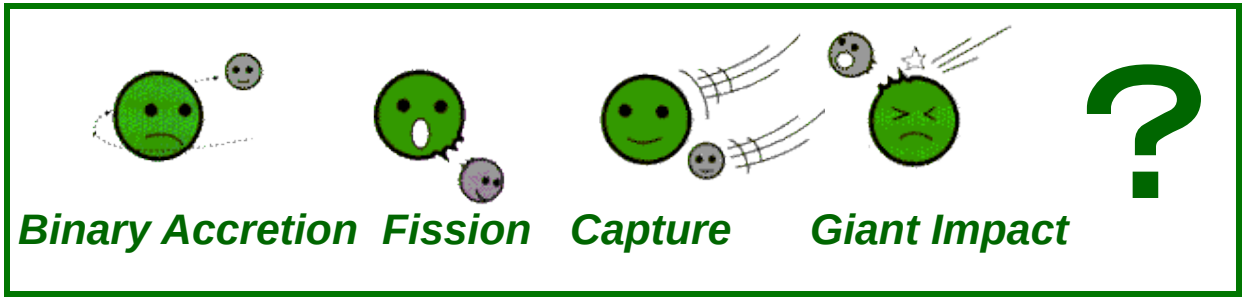


Size : 2.1x2.1x4.8m
Configuration :
Main Orbiter and
two Sub-satellites
Total Weight :3 tons

Japanese oldest fairy tale”Taketori-monogatari”

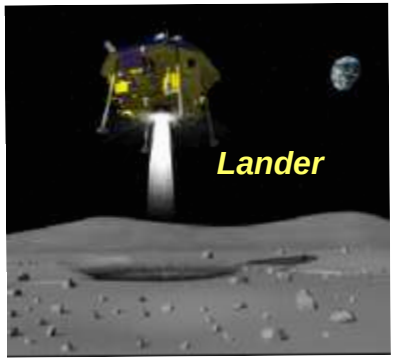
Mission Objectives

1. **Study of the origin and evolution of the Moon.**



Giant impact of a mars-sized planetary body

2. **Data acquisition for future Moon utilization.**
3. **Technology development for lunar exploration.**
4. **Public outreach using impressive images by high definition TV cameras and other imaging instruments.**



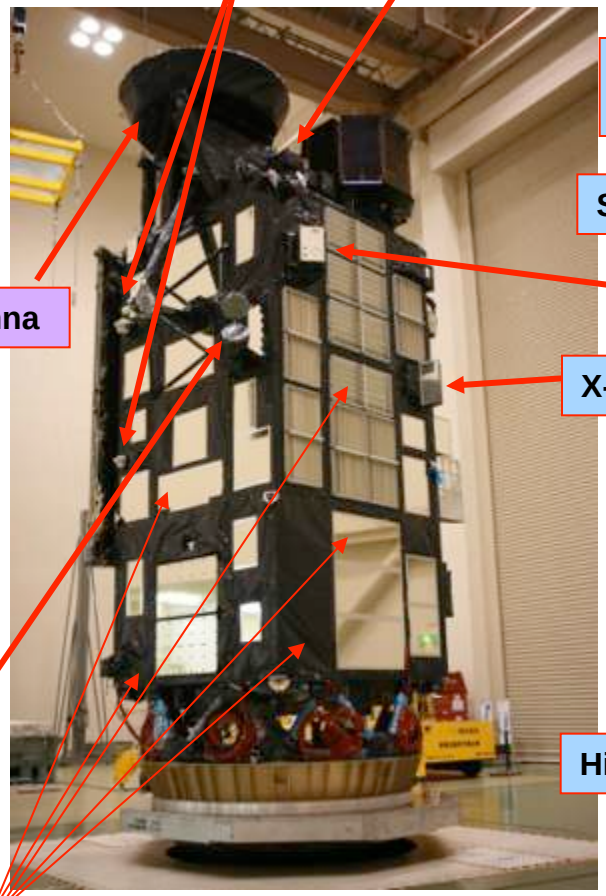
Technology development

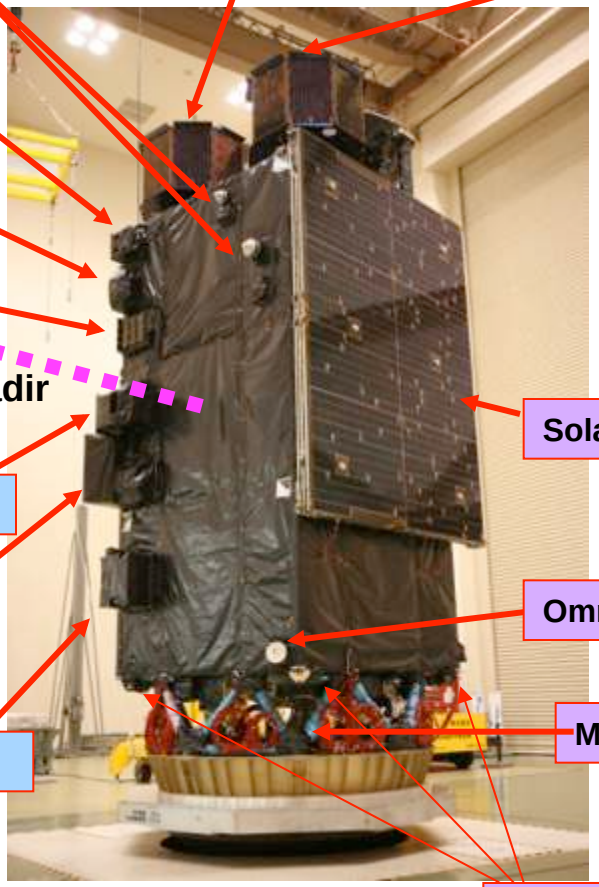
Public outreach

Mission Instruments

Observation	Instrument/method	Characteristics
Element Abundance	X-ray Spectrometer (XRS)	CCD 100 cm^2, Energy range 0.7~10 k eV, Resolution<180 eV, 5 μm Be film, Solar x-ray monitor, Calibrator with sample, Global mapping of Al, Si, Mg, Fe distribution, Spatial resolution 20 km
	Gamma-ray Spectrometer (GRS)	High pure Ge crystal 250 cm^3, Energy range 0.1~10 MeV, Resolution 2~3 keV, Stirling refrigerator 80°K, Global mapping of U, Th, K , O, Al, Ca, Fe, Mg, etc., Spatial resolution 130~150 km
Mineral Composition	Multi-band Imager (MI)	UV-VIS IR imager, Si-CCD and InGaAs, 9 bands in 0.4-1.6 μm (Si: 415, 750, 900, 950, 1000; InGaAs: 1000, 1050, 1250, 1550 nm), Band width 10~50 nm, Spatial resolution 20~60 m
	Spectral Profiler (SP)	Spectrometer, Si pin photo-diode and InGaAs, Band 0.5 to 2.6 μm, Spectrum Sampling 6~8 nm, Spatial resolution 500 m, Calibration by halogen lamp, Observation of standard lunar site
Topography and Geological Structure	Terrain Camera (TC)	High resolution stereo camera(±15°), Si-CCD, Spatial Resolution 10 m
	Lunar Radar Sounder (LRS)	Mapping of subsurface structure, Frequency 5 MHz(4~6 MHz swept in 200 μs every 50 ms), four-15 m antennas, 5 km depth with 100 m resolution, Observation of natural waves (10 Hz~30 MHz)
	Laser Altimeter (LALT)	Nd:YAG laser altimeter (1064 nm, 100 mJ, 15 ns), Si-APD, Beam divergence 3 mrad (30 m spot), Height resolution 5 m, Spatial resolution 1600 m (pulse rate 1 Hz)
Gravity Field	Differential VLBI Radio Source (VRAD)	Radio sources on Relay Satellite and VRAD Satellite(3 S-bands, 1 X-band), Several tens of mW, Differential VLBI observation from ground (3 stations or more)
	Relay Satellite (RSAT)	Far-side gravimetry using 4 way Doppler measurement, S uplink, S spacelink, X downlink, Perilune 100 km and Apolune 2400 km at orbit injection, Doppler accuracy 0.2 mm/s (18 sec)
Magnetic Field	Lunar Magnetometer (LMAG)	3- axis flux gate magnetometer, Accuracy 0.1 nT, 32 Hz sampling, Mast 12 m, Alignment monitor
Lunar Environment	Charged Particle Spectrometer (CPS)	Measurement of high energy particles, Si-detectors, Wide energy range, High energy range, Alpha particle detector 4～6.5 MeV, 400 cm^2
	Plasma Analyzer (PACE)	Plasma energy and composition measurement, 5 eV/q～28 keV/q(ion), 5 eV~15 keV(e)
	Radio Science (RS)	Detection of tenuous lunar ionosphere using S and X band coherent carriers
Earth Plasma Environment	Plasma Imager (UPI)	Observation of plasmasphere and aurora, XUV(834 A) and visible(5 bands)
Earth and Moon	High Definition TV (HDTV)	Observation of the earth and lunar surface in super-high resolution for publicity

Configuration of Onboard Instruments

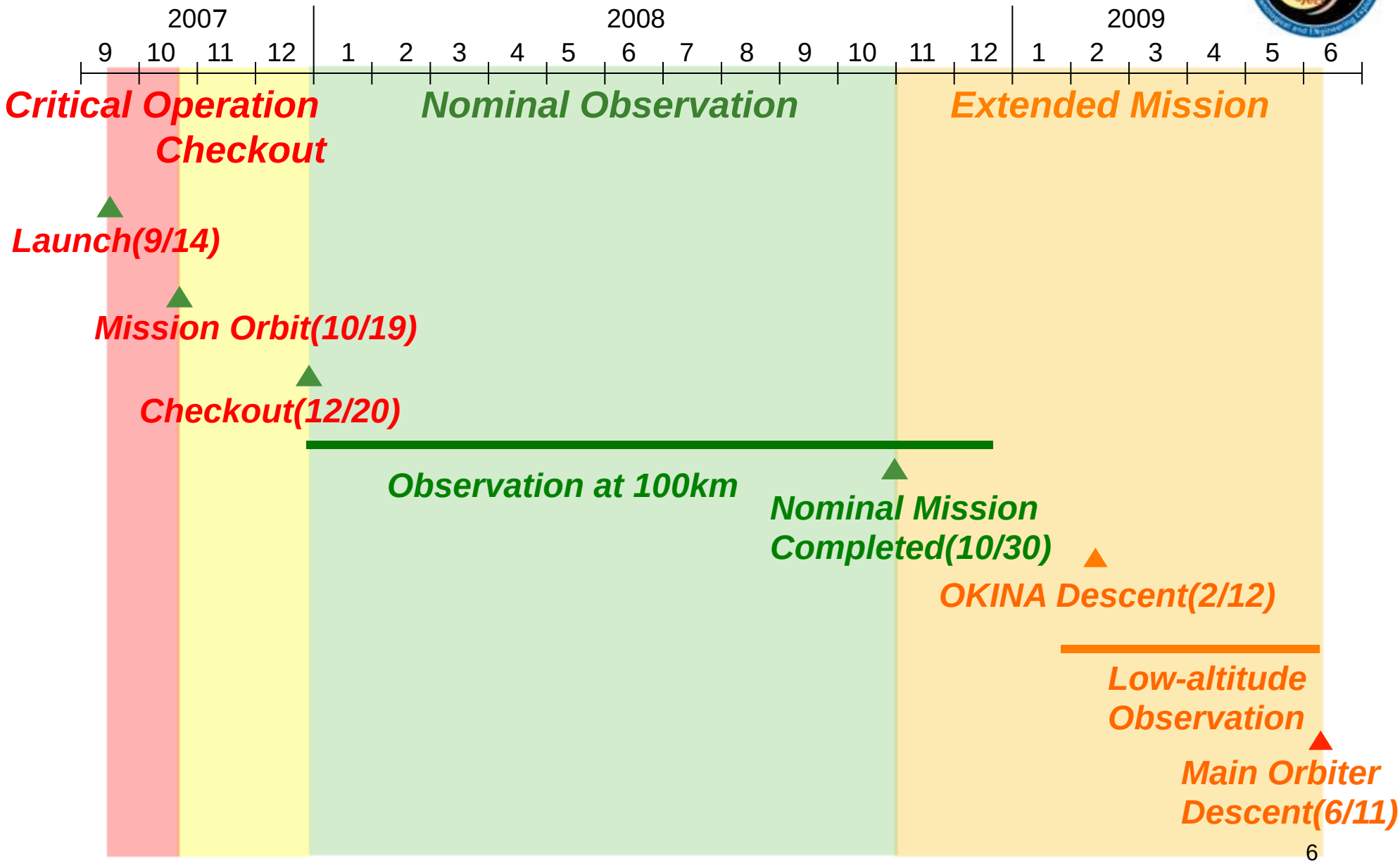




PACE
UPI
PACE
VRAD Satellite
Relay Satellite
Tarrain Camera
Multi-band Imager
Spectral-profiler
CPS
High Gain Antenna
X-ray Spectrometer
nadir
Solar paddle
Laser Altimeter
Gamma-ray
Spectrometer
Omni Antenna
Star Tracker
High Definition TV Camera
Main engine
Thrusters
Thermal
Radiator

Mission instrument
Bus sub-system

Over-all Mission Operation



Launch

Sep.14

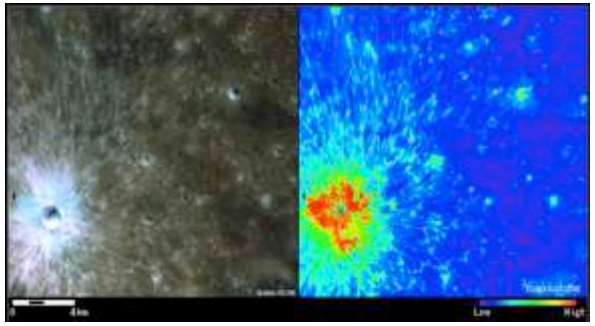
Lunar Orbit Insertion

Oct.4

Oct.19

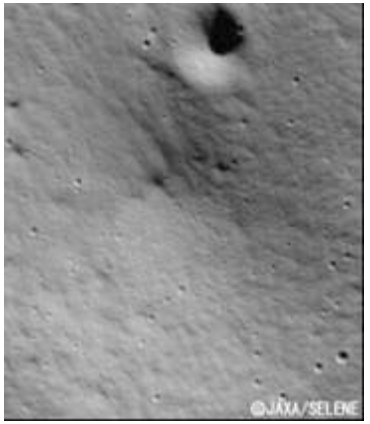
Critical Operation for Lunar Orbit Insertion

Checkout and Initial Data Acquisition

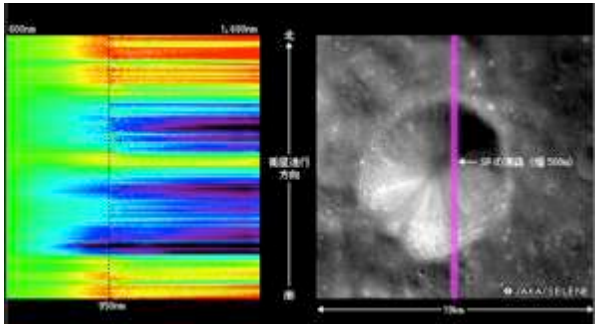


Mineral assemblage near a crater observed by Muti-band Imager

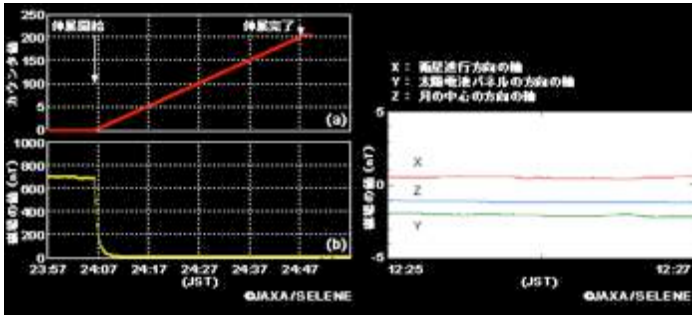
Scientists at first data acquisition



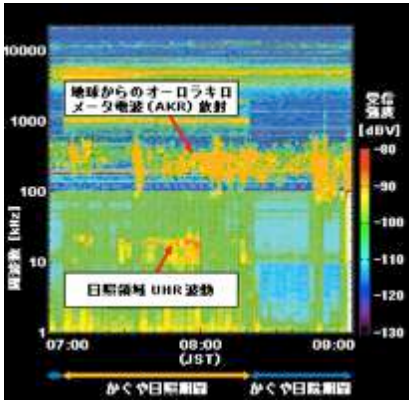
High-resolution image by Terrain Camera



Mineral identification crossing a crater observed by Spectral Profiler



Initial magnetic field data obtained at mast deployment

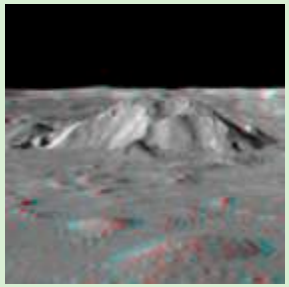


Electromagnetic environment observed by LRS wave receivers

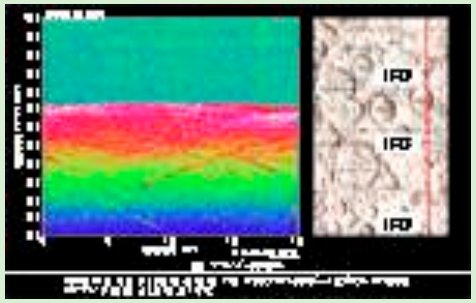
Nominal Observation Phase

2007 2008

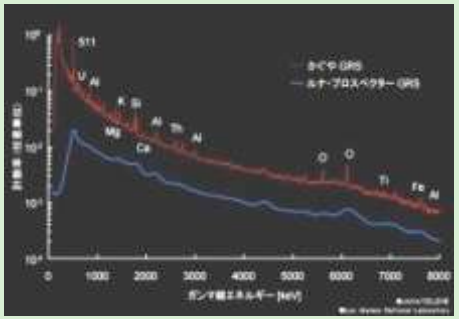
12	1	2	3	4	5	6	7	8	9	10



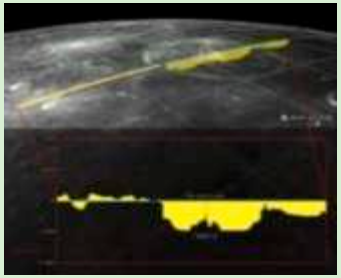
Topographic image



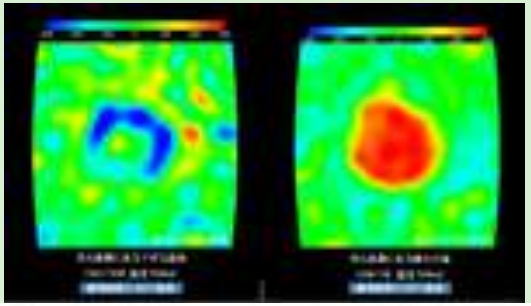
Sub-surface structure



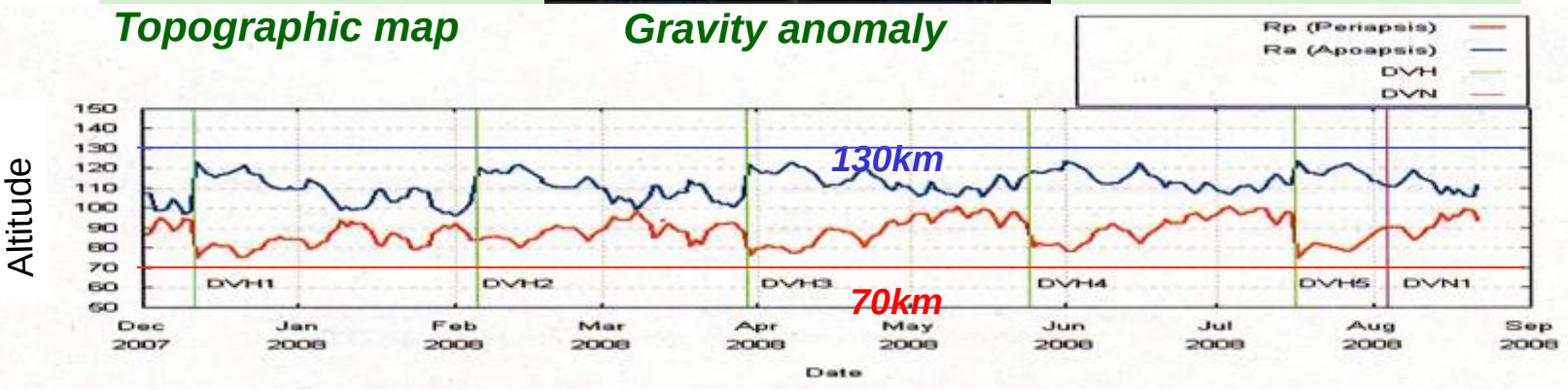
Elemental abundance



Topographic map



Gravity anomaly



Extended Mission Phase

2008 2009

11	12	1	2	3	4	5	6

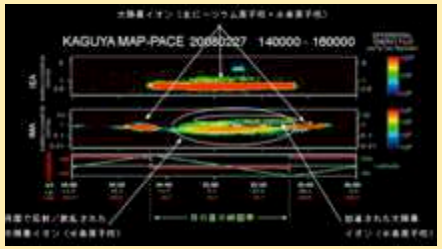
100km Altitude

50km altitude

30-10km altitude

OKINA Descent(Feb.12))

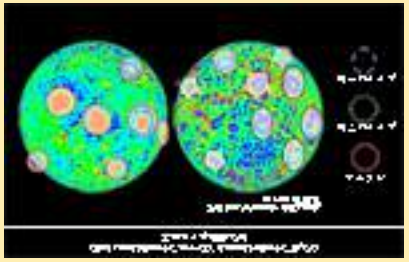
Descent



Plasma environment

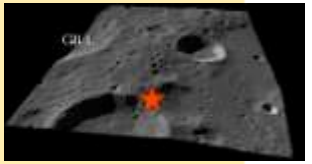
Publication of major results

Low altitude observation

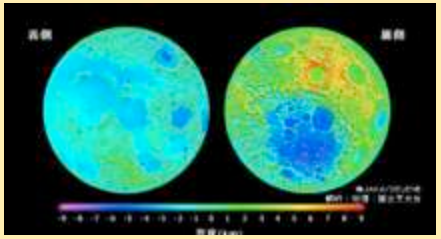


Gravity field(far and near side)

Diamond ring(Feb.24)



Touch down（June 11）

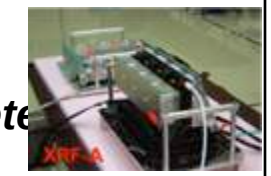


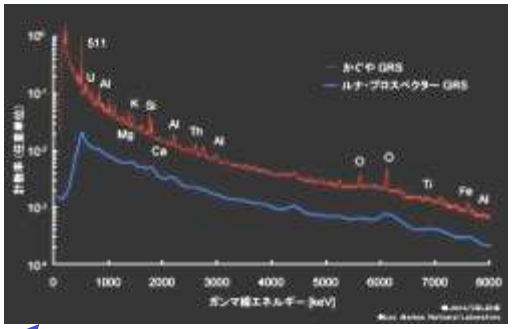
Topographic map(far and near side)

Major Results of Bus System Operation (Nominal Observation Phase)

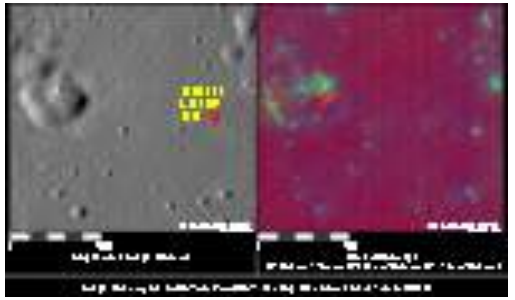
Function	Performance
Orbit Maintenance	altitude control maneuver 5 times, keeping 100±30 km as planned plane control 3 times as planned
Attitude Control	three axis control (moon pointing) within ±0.1° as planned RW#1 failed July 2008, but three others worked, satisfying observation requirements.
Power Generation and Supply	Power generation as planned DOD<21% (nominal operation) in specification DOD<60% (eclipse) in specification
Data Management	worked as planned
Thermal Control	within specification

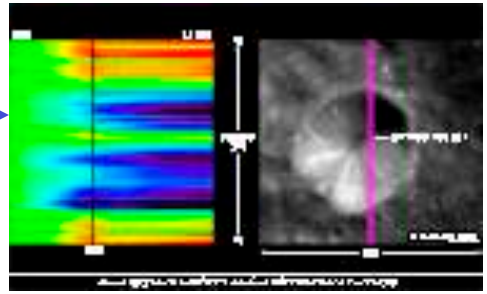
Major Results of Mission Instruments (1/3)

Instruments	Major Results
X-ray Spectrometer 	Unsatisfactory results by CCD noises due to radiation damage and extremely low solar activities
Gamma-ray Spectrometer 	Element abundance for K,Th, U, Ca, Si, Ti etc., were obtained as planned.
Multi-band Imager 	Mineral distribution was measured as planned.
Spectral Profiler 	Mineral composition was measured as planned.

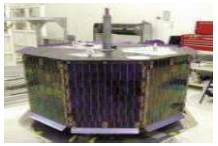
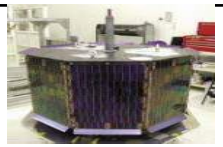


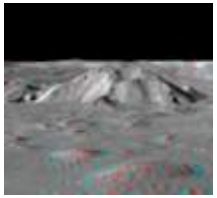
Typical energy spectrum


Data for Apollo 11 Landing site

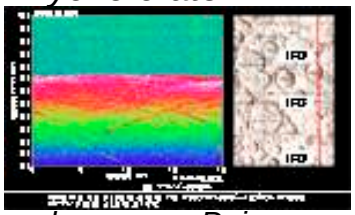

Typical example of spectrum crossing a crater

Major Results of Mission Instruments (2/3)

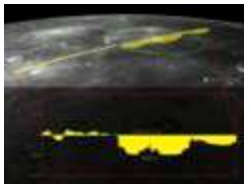
Instruments	Major Results
Terrain Camera 	***Geological features were observed as planned.***
Lunar Radar Sounder 	***Subsurface structure was observed as planned.***
Laser Altimeter 	***Topographical data were obtained as planned.***
Relay Satellite 	***Gravity field including gravity anomalies in the far side was measured as planned.***
Differential VLBI Radio Source 	***Gravity field of the Moon was measured as planned.***



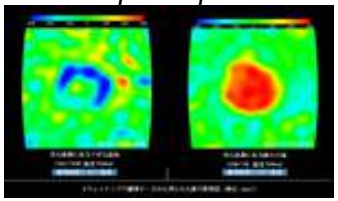
Tycho crater



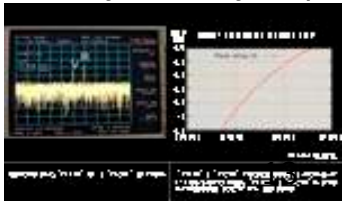
Radar echoes near Poisson crater



Cross-section of Theophilus Crater

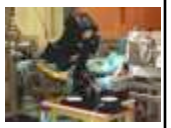


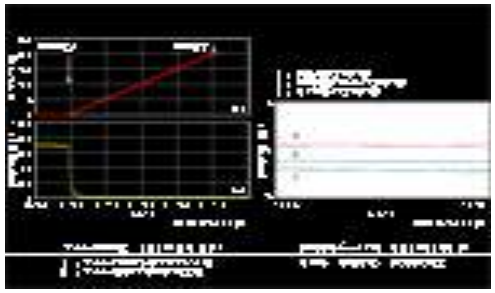
Gravity anomaly map



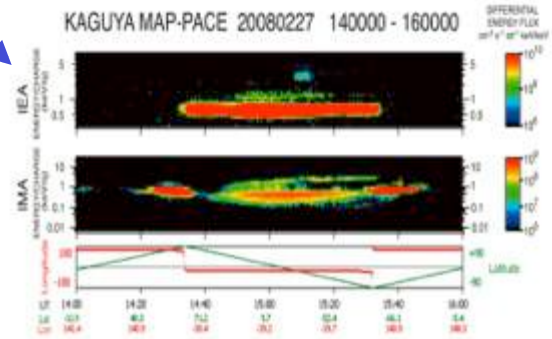
Signals from sub-satellites

Major Results of Mission Instruments (3/3)

Instruments	Major Results
Lunar Magnetometer 	Magnetic field was measured as planned.
Plasma Energy Angle and Com-position Experiment 	Plasma environment surrounding the Moon was measured as planned.
Charged Particle Spectrometer 	Cosmic radiation (electron and proton) and alpha particles from the Moon surface were measured. Cosmic ray telescope (heavy ions) did not work.
Radio Science 	Surface electrons were detected as expected.
Upper-Atmosphere and Plasma Imager 	Earth plasma environment was observed as planned. Gimbals had limited capability since June 2008.
High Definition TV Camera 	Earth and lunar surface were observed as planned.



Initial magnetic field data

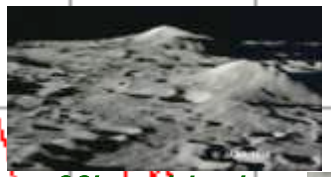


Energy spectrum of solar wind ions

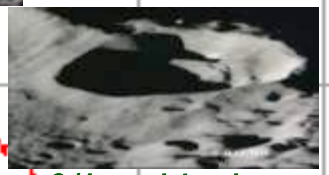
Full earth-rise

Controlled Descent

Operations center at touch down



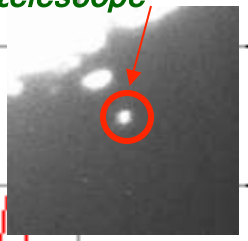
28km altitude



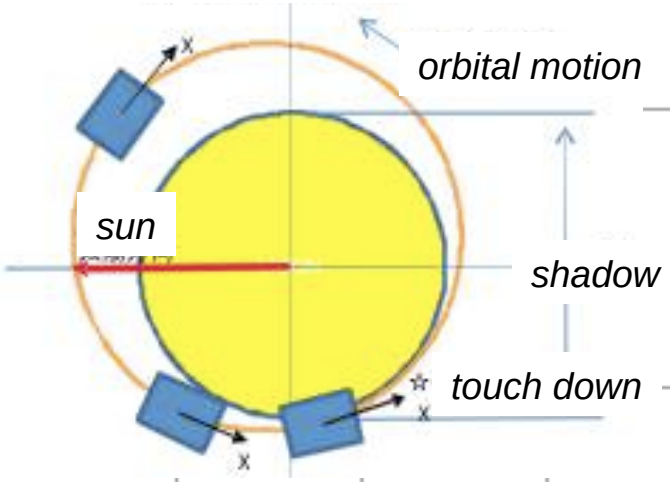
21km altitude

16km altitude

Flash observed from ground telescope



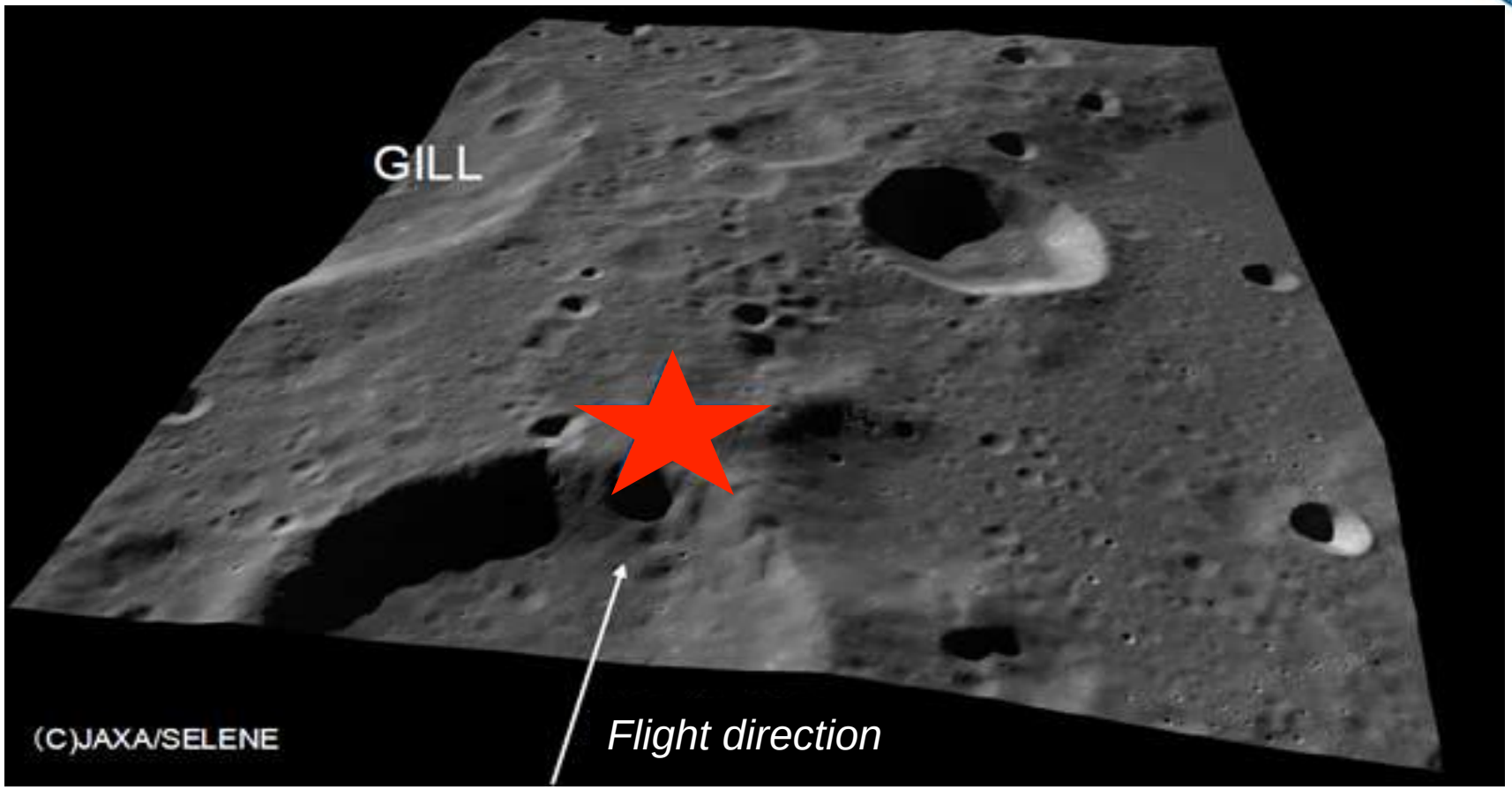
Deceleration near apolune



range[km]

hh:mm

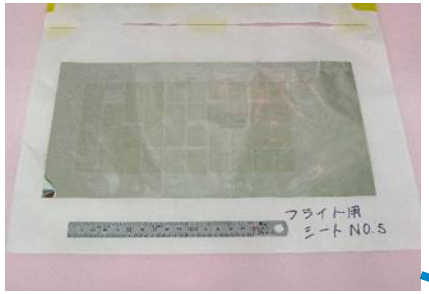
Touch down near GILL Crater



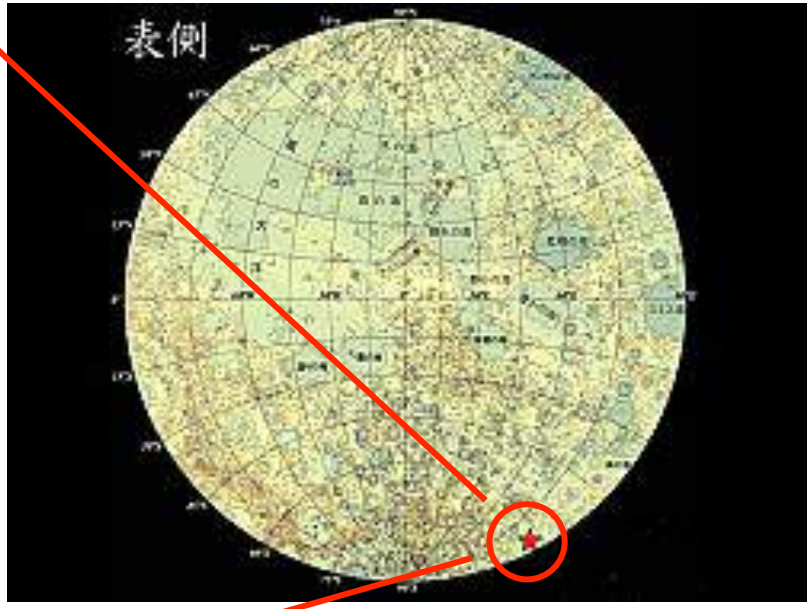
★	*Touch down time*	*03:25, June 11, 2009 JST*
	Position	*65.5S 80.4E*
	Height	*900m approx. from average surface*

Wish Upon the Moon Campaign

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



Sheet size : 280mmx160mm
Character size: 70μm



Summary

1. *KAGUYA(SELENE) project was started in 1999 and was completed in 2009 after 1.5 years' mission operation.*
2. *It was the largest and most sophisticated lunar mission since the Apollo program.*
3. *During the 1.5 years mission, it collected scientific data on elemental abundance, surface and subsurface structure, gravity fields, magnetic field, and lunar environment for lunar science. It also observed the solar-terrestrial plasma environment from the lunar orbit.*
4. *The high-quality motion pictures of the earth and the Moon were obtained by the HDTV cameras for publicity and educational purposes.*
5. *The major part of the scientific data are open to public in November 2009. The huge amount of the data will be used to study the origin and evolution of the Moon, and to investigate the future plan for the lunar exploration and utilization*