THE KAGUYA(SELENE) MISSION: PRESENT STATUS AND LUNAR SCIENCE.

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Introduction: Lunar orbiter Kaguya(SELENE) has been successfully launched from TNSC on September 14, 2007. On October 4 the Kaguya has been inserted into large elliptical orbit circulating the Moon after passing the phasing orbit rounding the Earth with 2.5 times. After lowering the apolune altitudes the Kaguya has reached the nominal orbit with 100 km circular and polar on October 18. On the way to the orbit two subsatellites Okina and Ouna have been released into the elliptical orbits of 100 km perilune, and 2400 km and 800 km apolune, respectively. After the checkout of bus system the extension of four sounder antennas with 15 m length and the 12 m mast for magnetometer, and deployment of plasma imager were successfully carried out to start checkout of science instruments.

Nominal observation term for ten months has been started on December 21, 2007 after performance test for about 1.5 months. Seven lunar days of observation are already passing till now, and science data of each instrument are being acquired to study lunar science.

Science Instruments and Goals: 14 science instruments including high definition TV cameras are onboard the spacecrafts for science data collection and public outreach. Science instruments and experiments have been shown in Table 1 [1]. Global mapping of elemental abundance on the lunar surface are made by XRS and GRS using advantages to each instrument. Global mapping of major elements by XRS has never been tried till now, although only 10% of the lunar surface has been analyzed in the Apollo XRSs [2]. Global mineralogical distributions are being mapped by MI and SP measuring reflectance two- and one-dimensionally of the lunar surface, respectively. Topographic measurements to study the surface evolution of the Moon are participated by three instruments of TC, LRS, and LALT. Stereo images of the TC by two linear CCDs are being employed for global map of digital elevation. The LALT is a conventional altimeter using Nd:YAG laser. The LRS sounds lunar surface and subsurface within about 5 km to study lunar topography and tectonic activity of subsurface. The LRS equips function receiving radio waves to 30 MHz to detect natural waves emitted from Jupiter, Sun and others in electromagnetically quiet environment of lunar farside. VRAD and RSAT are onboard Okina, Ouna, and Kaguya to determine precise gravity field of the whole Moon. Two radio sources emit three S-band and an X-band radio waves to determine the satellites positions with accuracy of 10 cm by differential VLBI technique between subsatellites and ground VLBI stations referencing with the signals of pulsars. In order to track main orbiter flown on farside the RSAT is used to relay S-band signals. 4-way Doppler technique between main orbiter and a ground station via Okina are determining the gravity field of the farside. This is first experiment never performed till now.

LMAG, CPS, PACE, RS, and UPI are employed to observe the environments of the Moon and the Earth. The LMAG is used to measure magnetic field distribution or local remnant magnetization on the Moon with accuracy of 0.5 nT. In order to measure with reliable accuracy the magnetometers are attached on the top of extendable mast of 12 m length so distant to alleviate effects of electromagnetic disturbance from spacecraft. Primary purpose of CPS is to measure charged particles such as protons of cosmic-ray origin. This instrument can also detect alpha-ray from the lunar faults which presumably originated by tectonic activity. The PACE is investigating sorts, energy, and incident angles of environment particles of ions, electrons, and neutral atoms using mass spectrometers of time-of-flight type. The RS team tries to confirm tenuous ionosphere of the Moon, detection of which was reported by Soviet lunar orbiter Luna 19. The S-band and X-band radio waves passing through the limb of the Moon emitted from VRAD2 on Ouna are received on ground stations to detect which any variation exist in frequency of waves. The UPI instrument is an imager to observe plasma phenomena of terrestrial upper atmosphere such as aurora from lunar orbit.

HDTV cameras are onboard for public outreach and stunning movies of “Earthrise”, lunar surface etc. have already been broadcasted.

Table1. Science instruments and experiments

XRS	X-ray spectrometer
GRS	Gamma-ray spectrometer
MI	Multi-band imager
SP	Spectral profiler
TC	Terrain camera
LRS	Lunar radar sounder
LALT	Laser altimeter
RSAT	Relay satellites transponder
VRAD	Differential VLBI radio source
LMAG	Lunar magnetometer
CPS	Charged particle spectrometer
PACE	Plasma energy, angle, composision and experiment
RS	Radio Science
UPI	Upper-atmosphere and plasma imager
HDTV	High definition TV camera system

Detectors of these instruments are allocated on the panels of Kaguya spacecraft as shown in Fig. 1. The figure shows the schematic diagram of Kaguya on transfer orbit to the Moon before release of subsatellites. Most of instruments are fixed on the +Z panel which directs to the Moon to observe the lunar surface. Detectors observing the Sun and space are put on the –Z panel.

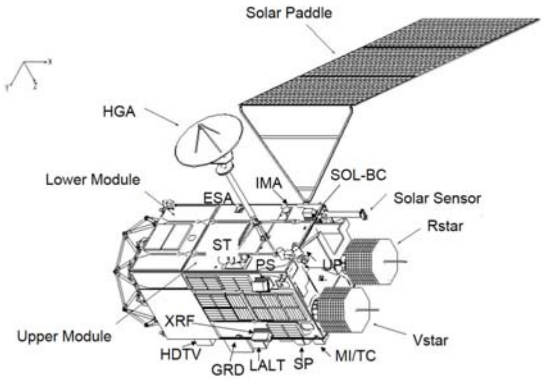

Fig.1. Configuration of Kagya (SELENE)

Science Targets: All instruments have highest-level quality in their specification which expect to get highest-level data for lunar science. First level of science can be achieved by integrating data obtained complementarily by plural instruments in a same category of useful characteristics.

Lunar chemical constituents: Second level of lunar sciences are studied integrating each category of science data. Lunar chemical constituent is a first priority target in studying origin of the Moon and Chemical distribution of the inner area of primordial solar system.Two categories of data, elemental abundance of lunar surface by XRS and GRS, and mineral composition by MI and SP define the rock types and their distribution on the lunar surface. Information of subsurface constituents in lunar crust can be acquired by investigating central peaks of craters formed by rebound of impact shock in crater formation, which are observed larger than 15 km in diameter on the Moon. Large basins such as South Pole Atkins in diameter of 2500 km are scooped to 12 km depth and expose interior materials of lower crust or extrude upper mantle of the Moon. These remote-sensing data reveal about 15 % volume of chemical constituent of the Moon.

Gravity field measurement deduces knowledge on polar moment of inertia of the Moon, to estimate the size of lunar core. Gravity data by Lunar Prospector estimates the iron core radius of 220 to 450 km[3]. Science results of Kaguya mission can not definitely estimate the whole abundance of the Moon, because the mission has never had any instruments of in-situ measurement of lunar interior. However, it is possible to improve intensively the knowledge on chemical constituent of the Moon by assuming mantle material constituent by Apollo seismological investigation.

Lunar interior structure: As mentioned in previous subsection, size of lunar core allows to be estimated using polar moment of inertia deducing from gravity field measurement. Shallow interior and subsurface structures can be investigated directly by LRS. Sounding by 5 MHz radio wave reveals subsurface layer structure such as density and/or material discontinuity up to about 5 km depth. Gravimetry data by RSAT and VRAD, and topographic ones by LALT will be used to estimate thickness of crust of whole Moon. Crust in basin area and mares in nearside is thin, and highland in farside is overlaid on thick crust. Kaguya mission definitely improve certainty of crustal thickness.

Dichotomy of nearside and farside: The dichotomy in the Moon is recognized in topography and rock distribution between nearside and farside. Large mares are occupied 60 % of lunar nearside. Large altitude difference more than 16 km is formed in farside. The dichotomy is investigated by geological study of material distribution and crustal thickness.

Differentiation in magma ocean: If the origin of the Moon is formation of “magma ocean”, many evidences must be retained on the lunar surface. Rock distribution must be identified as an evidence of differentiation of magma ocean. Formation of South Pole Atkins basin and large mares by flooded magma in nearside are main geological events after occurrence of magma ocean 4.6 billion years ago. Therefore, geological recovery or reburying of the basin and mares is necessary to reproduce magma ocean age. Detailed investigation on geology by Kaguya makes clear the origin of magama ocean. Magma ocean model has large advantage in giant impact origin for lunar formation. Short duration of accretion to the Moon after the giant impact allows to heat up the surface of the Moon enough realize magma.

Origin of lunar magnetic field: Apollo rock sample contains magnetic minerals assuming magnetization in weak but definite magnetic field**.** In early time the Moon may have definite magnetic field such in the Earth. LMAG Kaguya mission is searching weak magnetic remnant less than 10^{-5} Tesla collaborating with electron reflectometer.

Origin and evolution of the Moon: Ultimate targets in lunar science are “Origin and Evolution of the Moon”. Second level of science targets as mentioned in previous section may direct to the final target. Kaguya mission is expected to get new insight in lunar science. In-situ observation using lander system must be executed to study structure and material distribution of the lunar interior.

References:[1] Kato et al., Adv. Space Res., 42, 294-300, 2008. [2] Adler et al., Proc. LSC. 4th, 2783-2791, 1973, [3] Konopoliv et al., SCIENCE, 281, 1476-1480, 1998.