Lunar Polar Exploration (LUPEX) Project – Observation Strategy for Search, Detect and Quantifying the Lunar Polar Water-. Y. Ishihara[1], M. Ohtake[1,2], and LUPEX Project Team, [1]JAXA Space Exploration Center, Japan Aerospace Exploration Agency (ishihara.yoshiaki@jaxa.jp), [2]The University of Aizu (makiko-o@u-aizu.ac.jp).

Introduction: Because of water presence [1-5] and continues sunlit, the lunar pole has been the focus of much attention as areas for future exploration. The knowledge of amount and distributions of water are important for not only scientific aspect but also planning and designing of future exploration (exp. manned exploration). In 2020s, as a first step, space agencies plan to do unmanned exploration for state and amount of water at lunar pole, and Japan Aerospace Exploration Agency (JAXA) and Indian Space Research Organisation (ISRO) also planned such unmanned joint exploration, and that is named as "Lunar Polar Exploration (LUPEX)".

Overview of LUPEX spacecraft and Instruments: LUPEX spacecraft consists of a rover and a lander. JAXA is mainly responsible for developing and operating the rover, and ISRO for developing and operating the lander. The rover and the lander will be integrated at the launch site and launched by the H-3 rocket at the JAXA's Tanegashima Space Center in Japan. Total mass (wet) of the spacecraft is about 6 ton. Mass of the rover is about 350 kg including all mission instruments. Nominal mission duration is from launch to 3.5 months from landing on the Moon. After the nominal mission, if rover is health, extra-mission is planed extend the mission until one year from landing.

Table 1 shows a mission instrument list on the LUPEX rover There are seven instruments in total. Resource investigation water analyzer (REIWA) and Advanced Lunar Imaging Spectrometer (ALIS) are developed by JAXA. Ground Penetrating Radar (GPR) and Mid-infrared Imaging Spectrometer (MIR) are developed by ISRO, Neutron Spectrometer (NS) by NASA and Exospheric Mass Spectrometer for LUPEX (EMS-L) by ESA, respectively. ISRO has been trying to finalize the selection of the mission instruments they develop, so instrument set may be some changes.

Table 1 Mission Instruments on the LUPEX rover

Mission Instruments	Development Organization
Resource Investigation Water Analyzer (REIWA)	JAXA
-Lunar Thermogravimetric Analyzer (LTGA)	JAXA
-Triple-Reflection Reflectron (TRITON)	JAXA
-Aquatic Detector using Optical Resonance (ADORE)	JAXA
-ISRO's Sample Analysis Package (ISAP)	ISRO
Advanced Lunar Imaging Spectrometer (ALIS)	JAXA
Ground Penetrating Rader (GPR)	ISRO
Mid-Infrared Imaging Spectrometer (MIR)	ISRO
Neutron Spectrometer (NS)	NASA
Exospheric Mass Spectrometer for LUPEX (EMS-L)	ESA

In addition to mission instruments, direct measurement of lunar water by conducting in-situ measurements to achieve the mission objectives, so the rover has a drilling system to excavate and sampling system to pick the regolith sample from a designated depth.

Operation Concept for Search, Detect and Quantify the Lunar Water: Figure 1 is an example of an exploration area and operation process of observation. The exploration area (a. in Fig.1), including waypoints for environmental and geological features, is selected in advance using previous lunar exploration data. A landing site that satisfies solar illumination, topographic condition (such as slope), communication, and other conditions close to the exploration area is selected (b. in Fig.1). The Integrated lander lands at the target point, then the rover is deployed to the lunar surface (c. in Fig.1). For up to a week, observations are performed to obtain reference data at around the landing site (d. in Fig.5). The observation/operation is divided in two stages operation. One is coarse observation (during rover traverse) for searching and detect water to determine the optimal drilling site and the other is fine observation for precise detect and quantifying water at the drilling site determined by coarse observation.

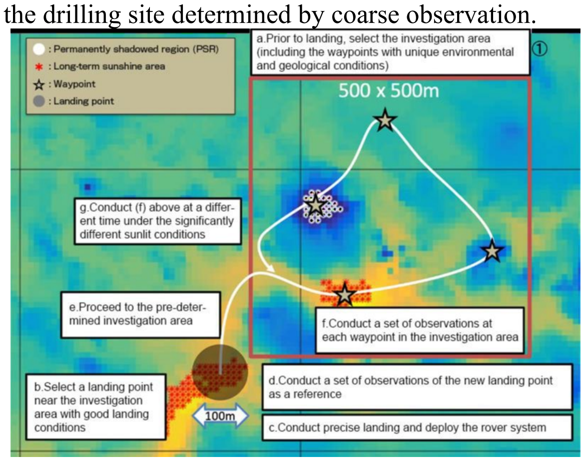

Fig. 1 Example of an exploration area and Observation/Operation.

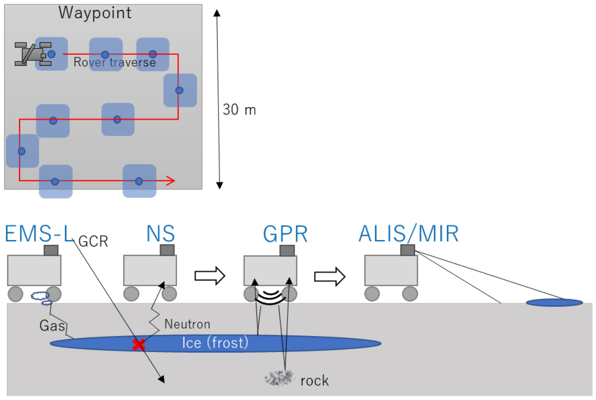

Fig. 2 Schematic image of the Coarse Observation

Coarse Observation. At a waypoint (about 30 x 30 m area), a scan observation will be conducted as follows.

- NS observation is continually conducted to detect hydrogen and to map those distribution.
- The presence and quantity of surficial water ice/frost and minerology at the area are measured by Infrared Spectroscopy (using ALIS and MIR).
- The pressure distribution and gas species of lunar exosphere are measured by EMS-L.
- Subsurface (~ 3 m in maximum) structure is observed by GPR.

(1) Rover moves forward by 2 m (with NS, GPR, EMS-L, and MIR observation) and then stops.
(2) After stopping, ALIS observation conduct (NS observation is continue) and then move.
(3) Rover stops after forward and repeats above steps (1) and (2) to explore moving within the waypoint (area of 30 x 30 meters).
(4) After completion of scanning entire area, then rover moves to the charging position.

Fine Observation. At a drilling point (is determined/selected by analysis of coarse observation), a drilling and direct quantification of water content will be conducted. The main instrument to use fine observation is REIWA and is consists of four different sensors: 1)LTGA, 2)TRITON, 3)ADORE, and 4)ISAP. And analysis flow as follows.

(1) Sample of lunar regolith on the surface of the drilling site is collected and transferred to the REIWA by the mechanism of the rover.
(2.1) Receive the sample to a container and the container is moved to the designated handover point with ISAP by the container handing unit on the REIWA.
(2.2) Start Raman spectroscopic observations by ISAP.
(2.3) After the observations are completed, the container is moved from the handover point with ISAP, the used sample is disposed out, and the container is returned to the stored position.

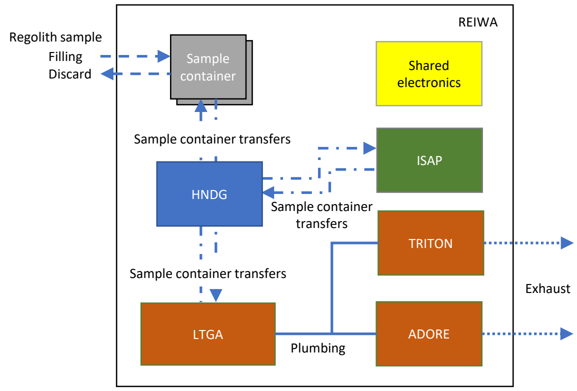

Fig. 3 Block diagram of REIWA

(3.1) Receive the sample to another container on the REIWA, and the container is handled to move to the sample heating unit in the LTGA.
(3.2) Measure the weight and temperature of the container at the same time as sample heating to estimate the content of volatile substances (with accuracy of 0.1 wt.%) in the sample from loss of mass by evaporation or sublimation (heating up to 500 K).
(3.3) Volatile gas generated by sample heating is analyzed by TRITON (during heating) and ADORE (after heating). Mass spectroscopy of gas species of volatile gas and time development are observed by using TRITON, and H_2O detection/quantification of volatile gas are done by ADORE. In addition, ADORE can measure the isotope ratio of volatized water.
(3.4) After the sample heating is completed, the container is moved from the sample heating unit, the used sample is disposed out, and the container is returned to the stored position for cooling.
(4) Subsurface lunar regolith is sampled by excavating at several points (maximum depth of 1.5 m) and then the sample is collected and transferred to REIWA by the mechanism of the rover.
(5) Repeat (2.1) to (2.3) or (3.1) to (3.4).
(6) After all observations are completed, then rover moves to the charging position or the next location to be drilled.

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