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A CONCEPTUAL STUDY OF HIGH SPATIAL RESOLUTION NEUTRON IMAGING FOR WATER EXPLORATION ON THE MOON WITH A FULL SATELLITE SYSTEM DESIGN

Abstract

NASA's Artemis program places importance on water resources on the Moon, and exploration with the high spatial resolution is expected to identify potential drilling points. In this mission, we focus on neutrons leaking from the lunar surface, which have information on the amount of water in the ground, and propose a thermal neutron imaging system that can achieve both high spatial resolution and sufficient statistical reliability. We conceptually designed a lunar orbiter that observes water distribution from a lunar polar frozen orbit. We will also use the satellite to measure neutron lifetime, an unsettled problem in physics.

The lunar surface at polar regions was found to contain water, and detecting its distribution is crucial for future space missions. Galactic cosmic rays generate fast neutrons within the lunar subsurface (1 m), and when colliding with hydrogen in water, they lose energy and leak into space as thermal and epithermal neutrons. Neutron measurements give information about deeper underground than electromagnetic waves, but achieving high spatial resolution is challenging, limiting spatial resolution of past missions to no smaller than 10 km. The proposed satellite will use an imaging system for thermal neutron to identify the direction of arrival with maintaining a wide field of view. It will target a high spatial resolution of 5 km and sufficient statistical reliability using a lightweight and compact optical system. The satellite will also measure neutron lifetime as a third method to distinguish measured differences from two established methods on the ground.

The satellite is designed to observe water resources for one year, and will be placed in a lunar polar frozen orbit. After several design iterations including the full bus system, the entire satellite system is designed to weigh 47 kg, with the propulsion system weighing 14 kg and the mission system weighing 13 kg. The neutron imaging system incorporates a new method that combines lightweight, small Wolter type II telescope utilizing micromachine technology and a multilayer film. Additionally, an arrayed scintillator detector has been installed to detect neutrons. To meet mission requirements from simulations of neutron flux and ray tracing, four telescopes have been placed on one side of the satellite. The satellite is assumed to be inserted into lunar orbit with a future transportation service and maneuver into a mission orbit of 20 x 2000 km. The proposed satellite won the first award at the Satellite Design Contest in Japan in 2022.