Towards development for laser transmitter of the MOLI mission

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Abstract: The Multi-footprint Observation Lidar and Imager (MOLI) is an Earth observation lidar mission onboard the Japanese Experiment Module Exposed Facility (JEM-EF) on the International Space Station. This project advanced to Phase A in October 2021, and the team began working on the next phase of the project with a formal budget. The mission instruments consist of a lidar as a laser altimeter and an imager. An outline of the mission will be reported

1. Introduction

JAXA MOLI (Multi sensing of Lidar and Imager) pre-project team is advancing the research and development of the MOLI mission, which involves simultaneously equipping the International Space Station with a lidar and an imager. The lidar to be mounted on MOLI was originally planned to have two footprints, however due to cost increases and several specification changes following a change of manufacturer, it has been limited to nadir observation only. As of March 2024, the project is in the preparation phase, and this paper introduces an overview of the mission and the research and development efforts towards the laser flight model being advanced by our organization.

2. System overview

MOLI employs a Q-switched laser to measure the vertical profile of the tree canopy height and ground height. Previous studies have shown that observations with a large laser beam footprint increase the error in tree height measurement due to the effect of ground surface tilt within the footprint. In order to reduce this error, the diameter of the footprint in MOLI was set to 25 m, whereas the diameter of the footprint in GED (Global Ecosystem Dynamics Investigation) is approximately 20 m.

MOLI set a target of ±3 m for the accuracy of forest canopy height estimation in the footprints. Accuracy of tree height tends to deteriorate for the S/N based on out-of-band noise is less than 10 (relative to the signal average) [2], so a system design that acquires sufficient signals is necessary. The other MOLI system specifications are summarized in Table 1. In addition, a 3-band imager with a surface resolution of 5 m will be installed for the purpose of confirming forest conditions including the phenology of the LIDAR observation points and identifying the observation location. The 3-band imager has wavelength bands of 550-630 nm (Green), 630-740 nm (Red), and 740-880 nm (NIR), respectively.

Table 1. MOLI nominal specification

Parameter	Value
Lidar	
Wavelength	1064 nm
Laser energy	30 mJ
PRF	150 Hz
Imager	
Band	550-630 nm 630-740 nm 740-880 nm Panchromatic
Resolution	5 m
Swath	1 km

3. Mission Objectives

The primary objectives of the MOLI mission are threefold: 1) to enhance the precision of 3D maps using lidar observation data, 2) to reduce the uncertainty in terrestrial biomass estimation through canopy height measurement, and 3) to demonstrate the technology for stable operation of high-brightness lasers in the space environment. The following details these objectives:

Enhancement of 3D Map Precision: This objective involves using a laser altimeter to detect ground surface heights, aiming to enhance the precision of digital maps that are critical for industry and disaster prevention. Current digital maps struggle with accurately representing ground surface heights in forested areas, primarily because these maps are generated by removing structures, such as buildings and trees, from a surface model that includes these elements. In forested regions, inaccuracies arise due to insufficient data on the height of the canopy that needs to be removed and the actual ground height underneath the forest canopy. These inaccuracies can lead to errors exceeding 10 meters locally. By integrating both a laser altimeter and an imager, we aim to showcase the capabilities of digital maps enhanced for better footprint localization accuracy and ground height precision.

High-Precision Forest Observation: Forest biomass acts as a significant CO_2 sink and is closely linked with canopy height. In pursuit of addressing global issues such as climate change, we are developing a method for high-precision biomass estimation that leverages this correlation. Although the most accurate biomass measurements are obtained by directly measuring the dry weight of trees, this approach is impractical across extensive areas. Consequently, inaccuracies in biomass measurement have emerged as a notable obstacle in carbon cycle analysis. MOLI is designed to address this by estimating forest biomass at numerous points (approximately 90 million points per year) through the measurement of canopy height derived from lidar waveform data.

Acquisition of Foundation Technology for Spaceborne Lidar: To prepare for future satellite deployment and enhancement of functions, we aim to demonstrate the foundational technology for operating high-brightness lasers continuously and stably in space. This is done using the JEM external platform.

4. Laser Transmitter and Power unit

MOLI's development encompasses a laser designed as a flight model, currently under investigation by our team. This laser transmitter employs a low-output, Q-switched Nd:YAG laser, subsequently amplified in a MOPA (Master Oscillator Power Amplifier) configuration. Designed to capture canopy height and the underlying ground surface, it boasts a pulse energy of up to 40 mJ, functioning at 150 Hz to maximize observation density along the ISS's trajectory. To ensure its operational integrity in space, the laser system is housed within a pressurized canister maintained at 1 atn.

The laser system is powered by a pulse power source capable of generating pulses with peak currents of 100 A. This space-grade pulse power source is housed in a pressurized enclosure and has been engineered using terrestrial technology adapted for operation in ISS orbit. It features protective shielding and fluid cooling. Electromagnetic compatibility (EMC) tests for both conducted and radiated noise, compliant with ISS standards (SSP30237, SSP30238), have been carried out, verifying that there are no significant deviations from the required norms. Continuous operational testing is currently underway, with the laser and its power source situated in a vacuum chamber, as depicted in Fig. 1, allowing for ongoing monitoring of the laser output.

5. Summary

This paper has presented an overview of the MOLI mission and the test summary of the laser transmitter being developed by our organization. Following a review meeting scheduled for June 2024, if the project transitions to the execution phase, we plan to commence the development of flight models.

6. References

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