Design and Implementation of a 3D-Printed In-Situ Laboratory Module for Sample Collection and Analysis

Figure. 1: The science module at the Mars Desert Research Station, Hanksville, Utah.

We present the design and implementation of a 3D-printed science module optimized for the collection and analysis of geological and environmental samples using an advanced in-situ laboratory system. The integration of 3D printing technology in the module's construction has enabled the development of lighter components with enhanced design flexibility, critical for field operations. The science module employs leadscrew-based mechanisms to facilitate both translatory and rotational motion, ensuring precise and controlled actuation. Limit switches are incorporated into the design to safeguard the module's operation.

The 3D-printed science module represents a significant advancement in the field of in-situ sample collection and analysis. Its innovative design, combined with the precision of its actuation mechanisms and the sophistication of its sensor integration, positions it as a valuable tool for field research and exploration

Module Design and Mechanisms:
The science module features a meticulously engineered science tray, which is controlled by an encoder, allowing for accurate positioning. This tray is designed to accommodate four beakers per site, each securely housed within elevated section walls. The tray also includes tube guides to streamline the transport of chemicals during experiments. For sample collection, a multi-auger system based on the Archimedes Screw principle has been integrated. This system comprises two augers, each equipped with covers to ensure precise deposition of samples into the designated beakers.

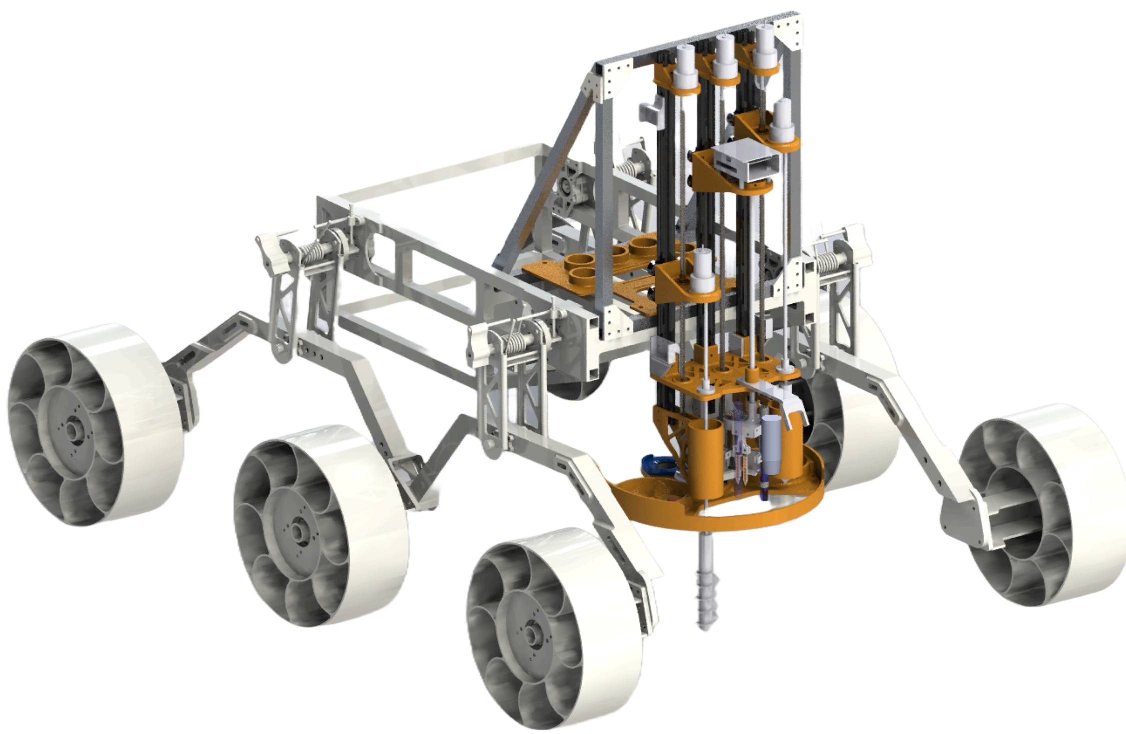


Figure.2: Rendered image of the science module; made using Solidworks

Optical and Sensor Integration:
The module is equipped with a network of strategically positioned cameras, including a high-resolution camera dedicated to stratigraphy. These cameras play a crucial role in both the navigation of the module and the detailed analysis of collected samples. The integration and actuation of the sensor suites, comprising the Habitability and Atmospheric analysis Node (HAN) and the Lithological and Environmental Integrated Analysis(LEIA) module, are managed through centralized ESP32 microcontrollers.

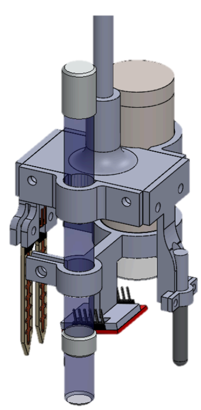
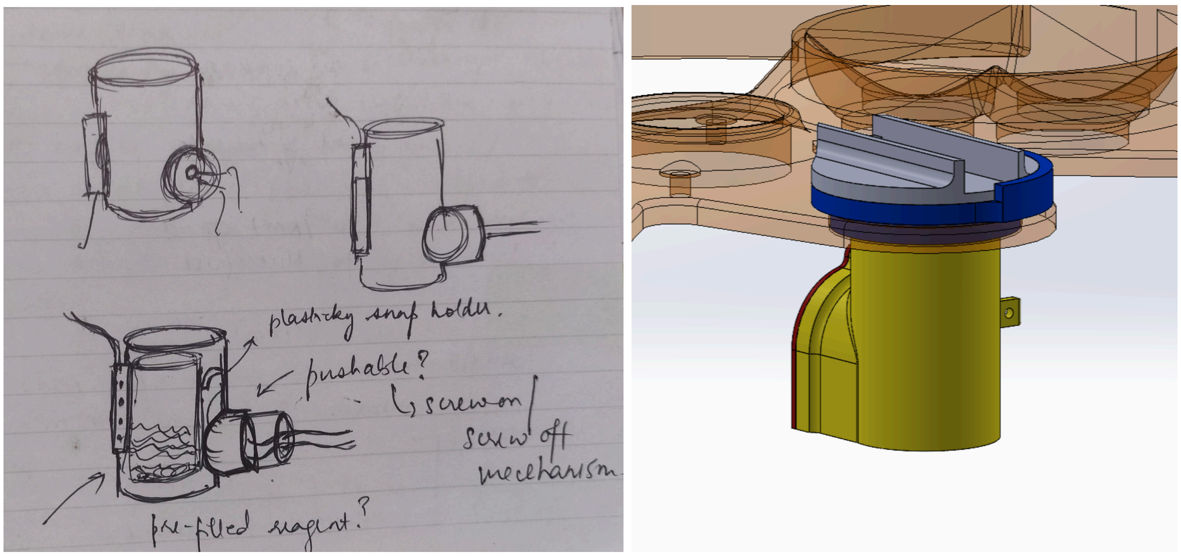


Figure.4: Lithological and Environmental Integrated Analysis (LEIA) module; made using Solidworks

Chemical tests are visualized using cameras and are additionally aided with a custom-built fully-enclosed fluorometer optimized for detecting genetic material with the help of the Acridine Orange dye test. The light source chosen are UV LEDs of wavelength 450 nm. Light is made to pass through a long pass filter of threshold 500 nm to filter source light and allow for emission spectra to pass through. The detector chosen for the same is a light dependent resistor (LDR) and is placed perpendicular to the light source. The design is compact and optimized for in-situ soil utilization, while also having a quick and easy assembly with components that effortlessly click into place.



a. b.

Figure.5: a) Initial ideation and sketching of the fluorometer; handsketched b) Final CAD of the fluorometer; made using Solidworks

Application of the module:
The module offers versatile applications across multiple industries. In agriculture, it can be used to assess soil quality, ensuring that the land is suitable for plantation and optimizing crop yields. By analyzing key soil parameters, farmers can make informed decisions about planting and resource management. Additionally, it can be employed in mining operations for conducting quality checks.

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