NC STATE UNIVERSITY

Department of Mechanical and Aerospace Engineering

LOW LIGHT ATMOSPHERIC AND MATERIALS ASSESSMENT ROVER & CARRIED RELAY FOR INTERMEDIARY ACTION

LLAMA & CRIA Designed and Manufactured by SUMMET³

Aerospace Engineering Capstone Senior Design 2021-2022

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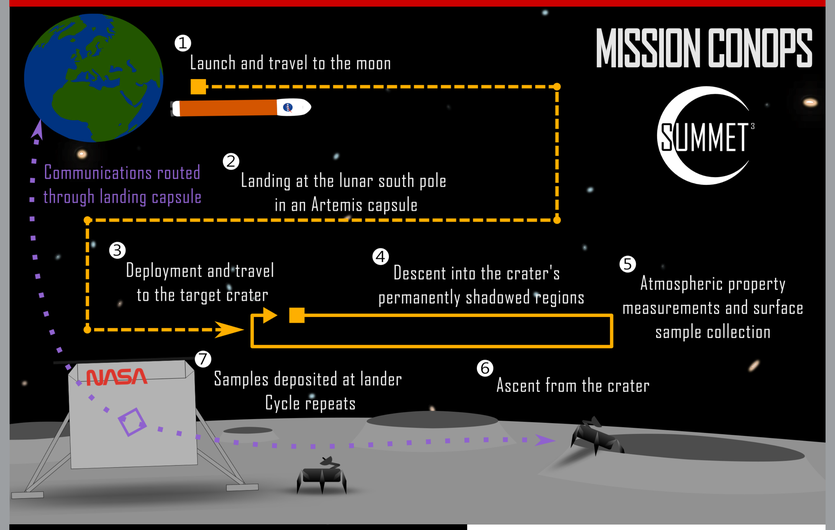
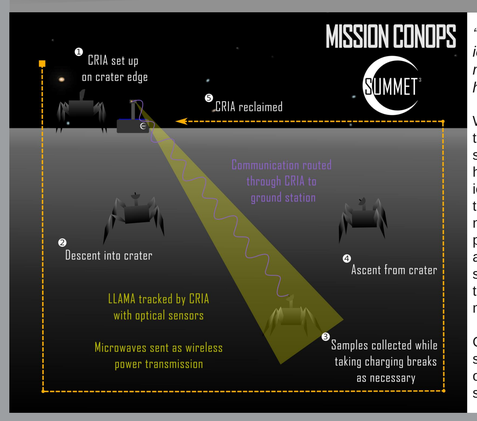
Scan for more information!

CONCEPT OF OPERATIONS



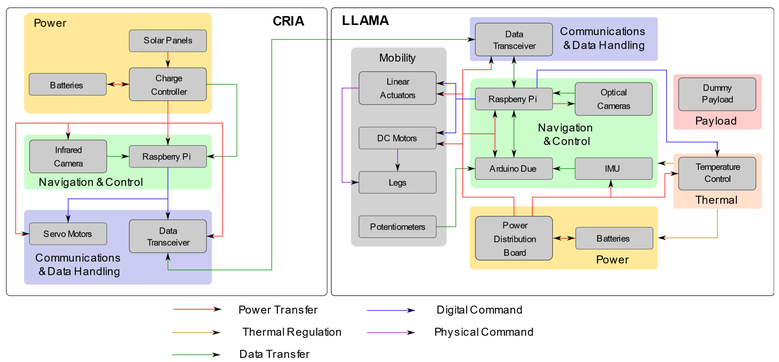


"The potential for material harvesting using water or ice deposits located in permanent shadow craters may provide a vital crutch to sustain permanent habitation on the lunar surface." - SUMMET³

We are developing LLAMA & CRIA to support long-term human habitation on the lunar surface and other suitable locations. One untapped resource for lunar habitation are sublunar surface volatiles such as water ice. In particular, these volatiles may be found under the mineral layers in permanently shadowed craters near the poles of the Moon. However, these craters present several challenges including extreme terrain, abrasive regolith, low temperatures, and a lack of sunlight. These challenges have prevented sustained terrain traversal for more conventional mobility methods such as wheels and tracks.

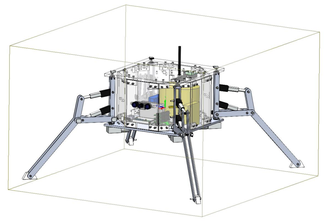
Our solution will make a mission into permanently shadowed craters more feasible, helping to solve one of the most immediate obstacles for permanent human settlement on the Moon - obtaining water and oxygen.

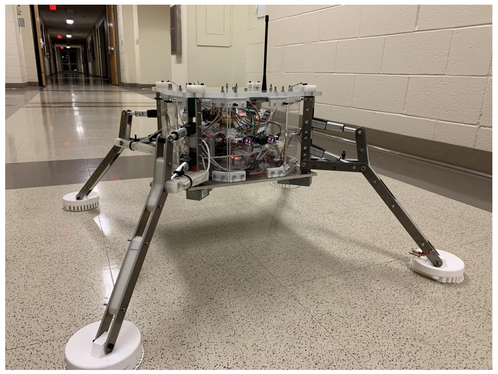
FUNCTIONAL BLOCK DIAGRAM



FINAL DESIGN

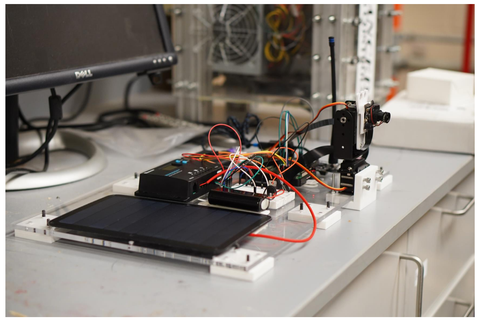
The final design of LLAMA weighs approximately 8 kg. The entire rover fits inside a bounding box of 73x73x47 cm with all actuators fully extended and each oriented along the corners of the base plate. Additionally, the CG of the final prototype relative to the aluminum base plate's center is:
X: -0.54 cm, Y: +5.35 cm., Z: -0.17 cm



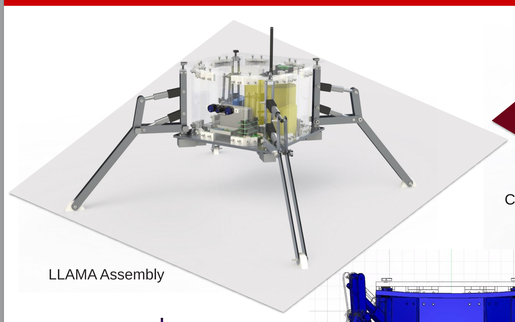


The control system consists of a Raspberry Pi 4B and 3 Adafruit DC & Stepper Motor Bonnets, an Arduino for reading the 12 potentiometers/joint angles, and an IMU for orientation feedback. Additionally, a radio transceiver is mounted to the top for communications and an IR camera is mounted to the front for hazard detection. The power system consists of a 5V battery pack for the Raspberry Pi and an 14.8V lithium-ion battery pack regulated to 12V to power our 8 linear actuators and 4 DC motors.

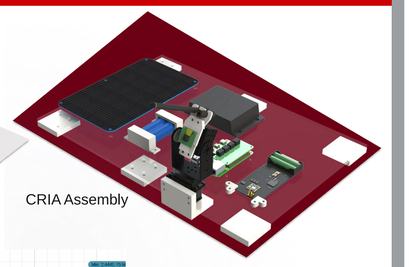
The final design of CRIA's power system consists of a solar panel, a charge controller, and a 7.2V lithium ion battery regulated to 5V. There is a radio board for communication and a Raspberry Pi 4B for control. The final components are an IR camera mounted on a 2-axis gimbal driven by two servo motors.



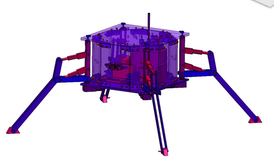
CAD MODEL AND SIMULATIONS



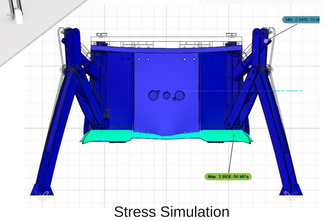
LLAMA Assembly



CRIA Assembly



Center of Gravity Simulation



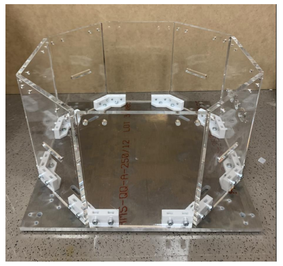
Stress Simulation

Raspberry Pi Thermal Simulation

MANUFACTURING

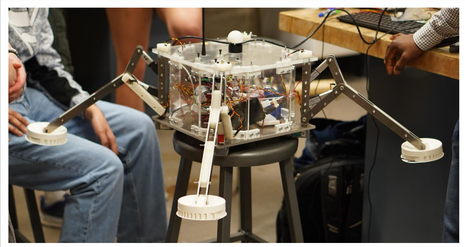
LLAMA consists of the octagonal core, four legs with one on each corner of the square base, and various brackets and component mounts. The hardware is stainless steel while the mounts and brackets are 3D printed PLA.

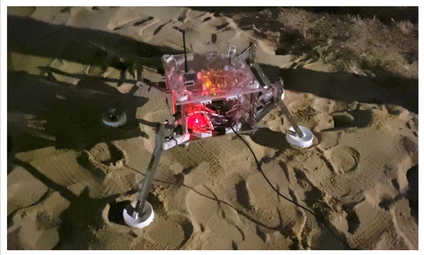
LLAMA has four legs, water-jet cut from 7075 aluminum. A total of 6 pieces of aluminum sandwich 6 3D printed PLA spacers, over a total three sections of the leg. A foot is connected to the end of the last segment. The hip section is driven by a DC motor, located underneath the base plate. This segment also holds two linear actuators. There are a total of 12 potentiometers, used at the hip, knee, and top to enable feedback control of each joint by reporting angles from an Arduino to a Raspberry Pi running a Simulink control system. The legs were designed to support a range of motion of 180 degrees, 46 degrees, and 30 degrees of hip rotation, hip elevation, and knee rotation, respectively.



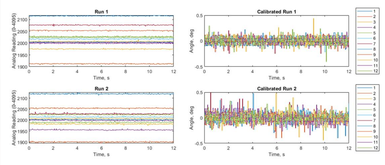
The core is designed to protect all internal components from any loading during all phases of the mission and to avoid external damage to the structure. It is comprised of a 1' x 1' x ¼" aluminum 7075 base plate, eight acrylic walls, and a 1' x 1' x ⅜" acrylic top. The walls are sandwiched between the base and top plate to provide structural support, with slots cut for wires and internal components. The acrylic was laser cut and the aluminum was cut with a water-jet.

PROTOTYPE TESTING





Initial testing consisted of a Simulink simulation of the rover for debugging the walking and rotation sequences. Afterwards, the IMU and potentiometers were calibrated and tested to verify accuracy. After debugging and calibration, the walking sequences were compiled and uploaded to the Raspberry Pi 4B for running and verification. Once the sequences were verified in the lab, the prototype was tested by running the sequences with LLAMA in a sand bed to simulate lunar conditions. Experimental observations were recorded during the test and used to refine the sequences



For the CRIA prototype, the camera gimbal was tested by shining a light source in the view of the camera while a Simulink tracking model was running. The camera is capable of viewing IR light, meaning that in a permanently-shadowed crater an IR emitter on LLAMA can be tracked. CRIA's ability to communicate with LLAMA via a radio transceiver was also successfully tested.