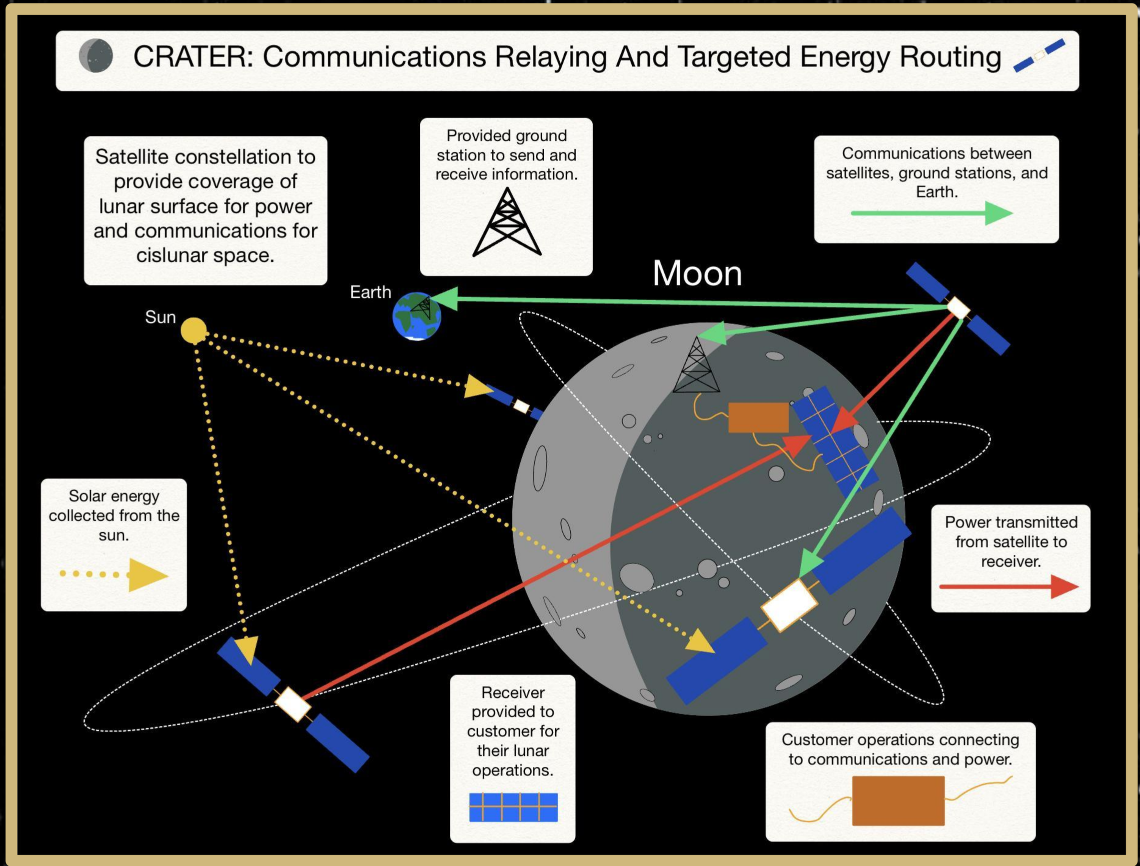
Communication Relaying And Targeted Energy Routing (CRATER)

Aerospace Engineering Capstone Project

University of Colorado Boulder, Smead Aerospace Engineering Sciences

Matt Brawley, Alec Church, Aadhit Gopinath, Abraham Jaet, Cameron King, Ashwin Raju, Nathan Tonella, Mark Walvoord, Henri Wessels

CRATER



Project Methodology

In order to develop the high level design, CRATER employed Multi-Objective Optimization (MOO).

MOO is a process to optimize complex systems with interdependent design variables. CRATER's approach to MOO is by listing different design variables for the three project focuses, developing models to relate the variables to constraints, and comparing the variables to requirements to develop an overall score.

MOO Development

The MOO constraints were orbiting distance, and stability index. This affected which orbit families were chosen. The orbit families used include distant prograde, distant retrograde, low prograde, butterfly, and halo.

The power model calculates the total amount of power transmitted to the ground station. The model assumes no atmospheric interference, gaussian beam, neglecting satellite controls.

The communication model is built using a standard satcom link budget at Ka band, but assumes atmospheric losses are negligible.

The return on investment model is based off of the estimated launch and build costs of each constellation. This takes into account orbit maintenance.

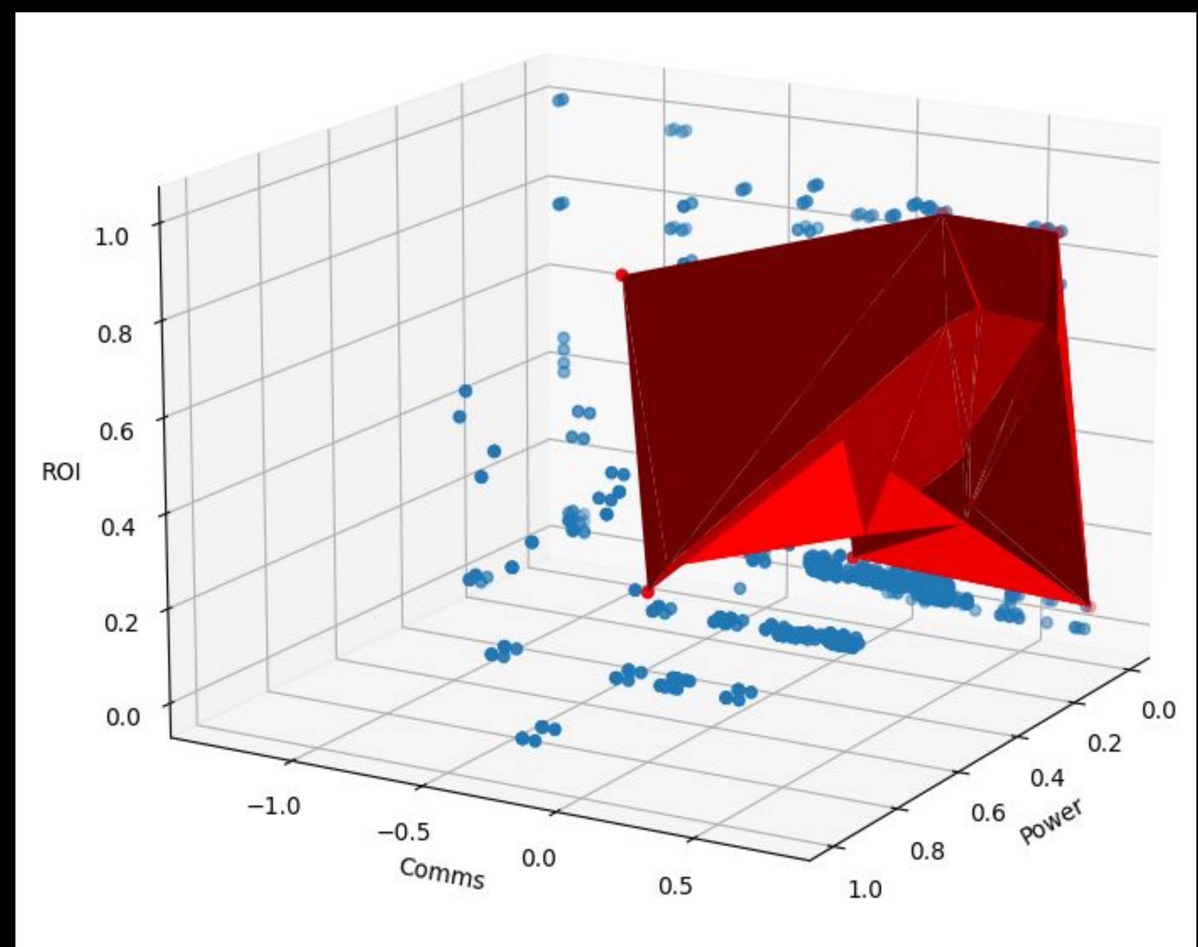
Overview and Goals

CRATER's goal is to develop a high-level design for lunar infrastructure to support future missions. The project focuses on three design areas: power transmission, communication and return on investment. CRATER proposes the novel implementation of laser power transmission with a high speed communication satellite constellation network to connect to a ground station near the South Pole of the Moon.

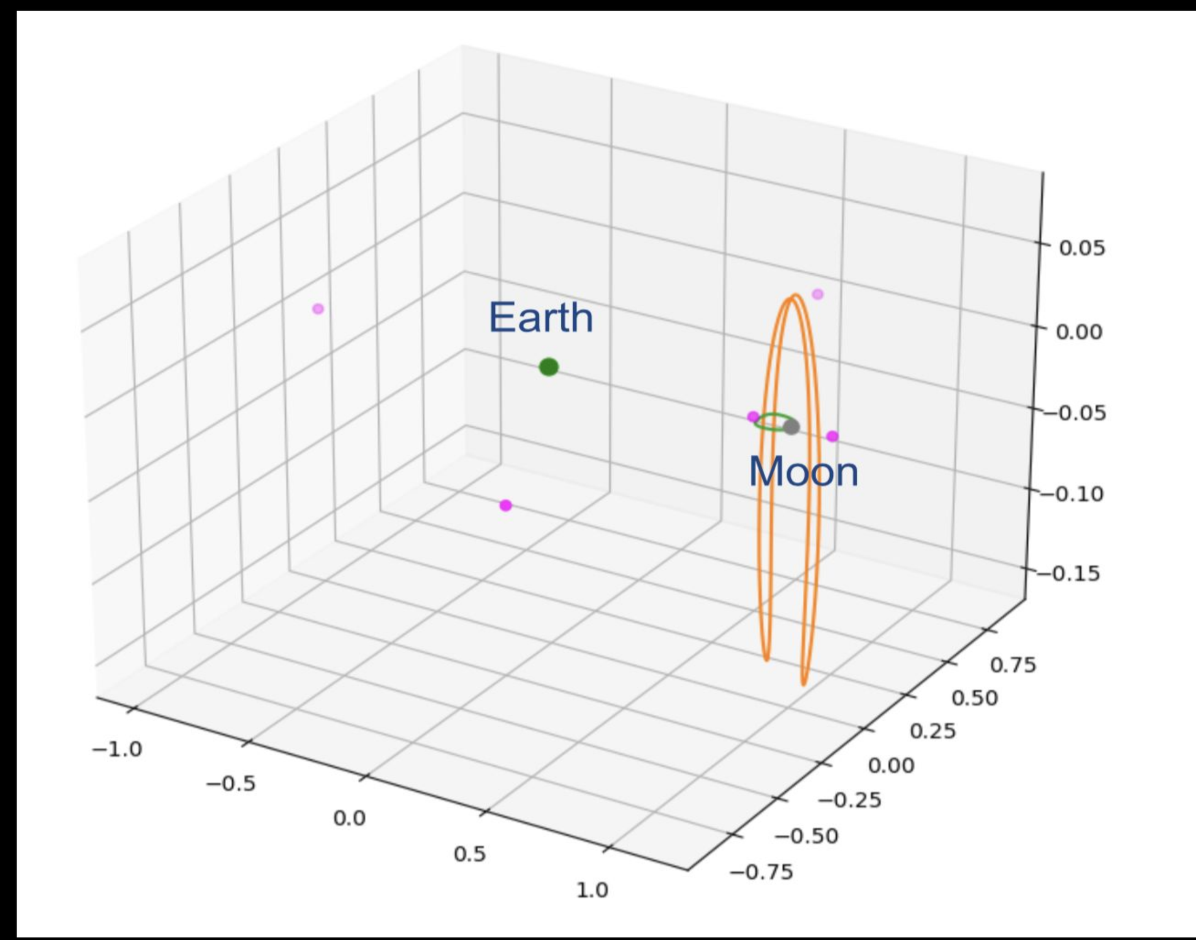
Multi-Objective Optimization Results

Multi-Objective Optimization (MOO), ran over a million design configurations testing different orbit families and number of satellites, calculating the possible data and power transmission rates. Of the million designs, 220,000 passed the initial constraints and were plotted on the objective space, with each axis representing power, communications, and ROI. 42 of these designs made it onto the pareto surface, meaning they were the optimal designs. From there, the design with the highest ROI score was selected since it was deemed important to show the economic return of the infrastructure.

Pareto Surface



Satellite Constellation



Satellite Design

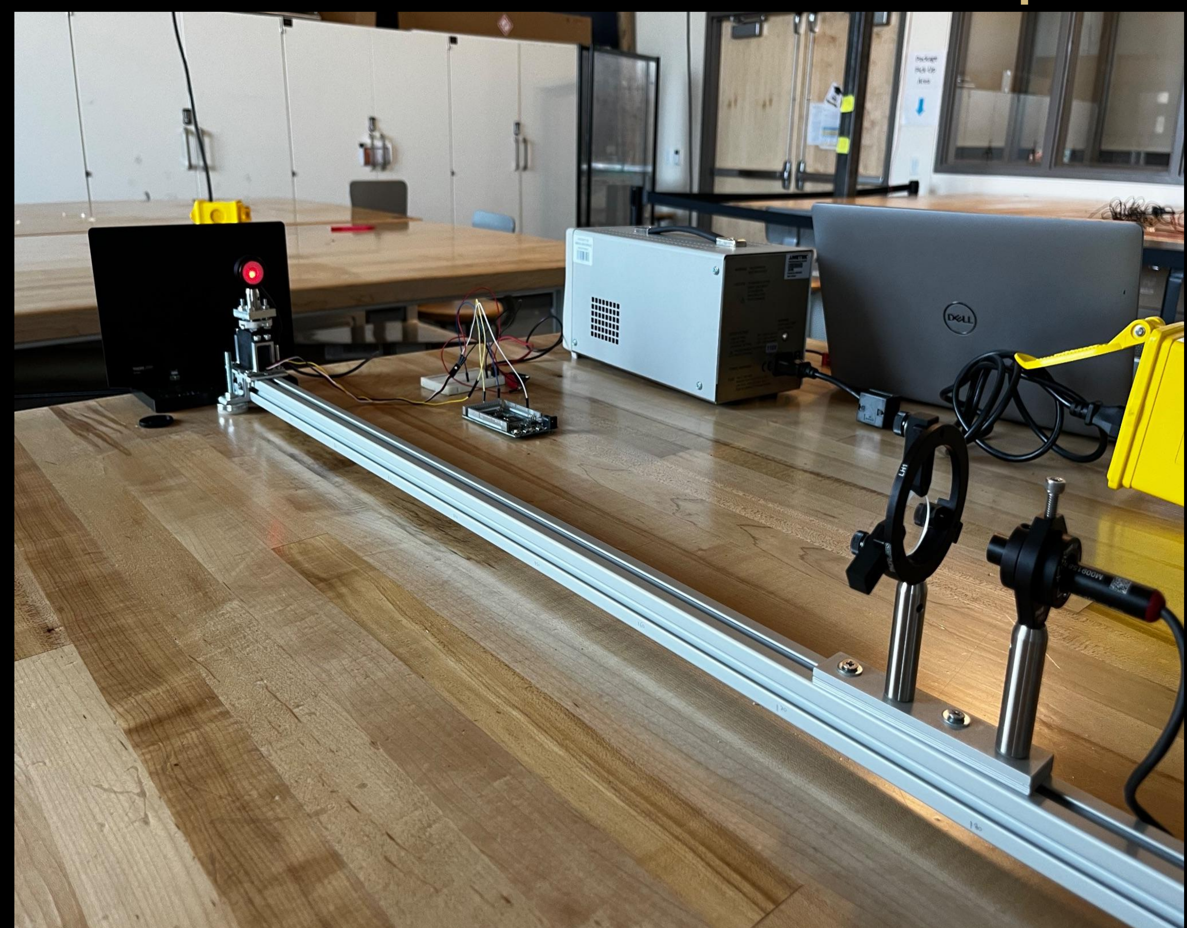
Power Results:
- 1.57 kWh / 24h received by groundstations

Comms Results
- 3e6 bps data rate
- 67% Lunar Coverage

Reintegration into MOO

Using the results of the hardware test, the power portion of the full MOO model can be updated to improve performance and decrease risk. This is done by proving our modeled assumptions match our hardware data, as seen with our hardware test results. Furthermore, experimental values for energy loss with incident angle can be used in the model in place of the initial assumed equation.

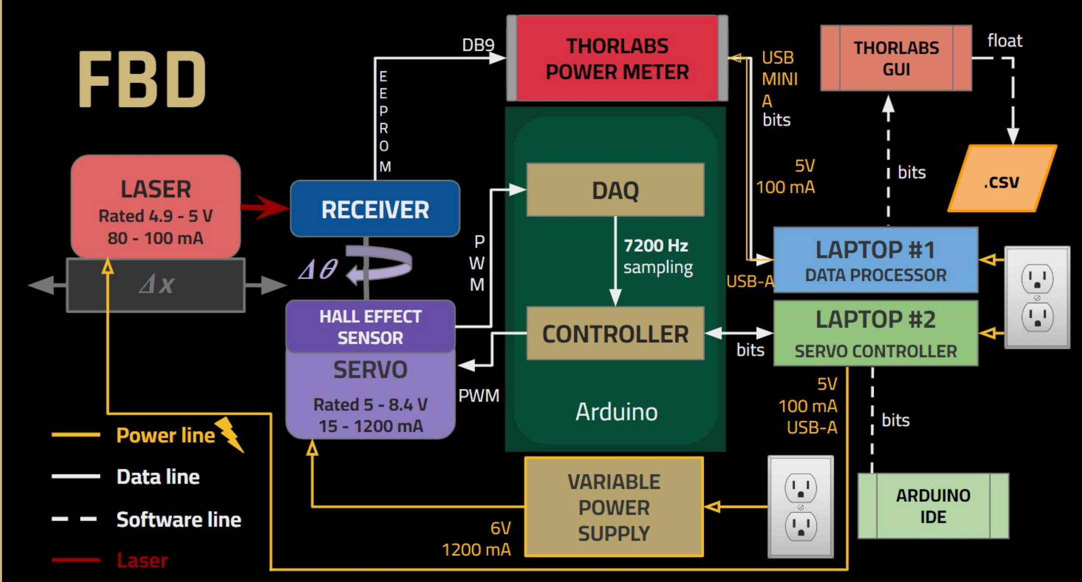
Hardware Testbed Setup



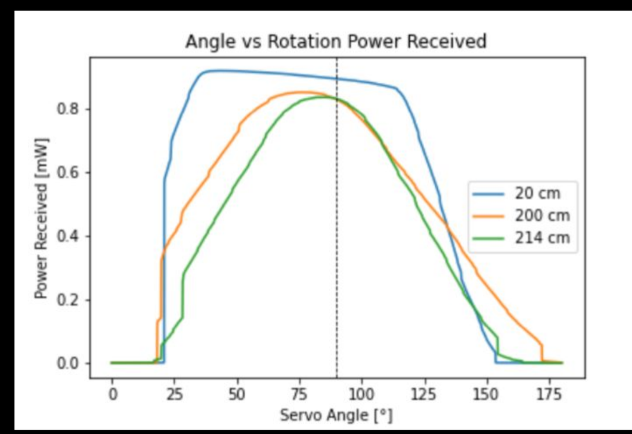
Hardware Tests and Design

1. Static Integration Test
2. Power vs Distance Test
3. Orbit Passover Test

FBD



Hardware Test Results



The test proves our assumption that non optimized spot sizes lead to severely decreased performance. The test also shows how the angle of the receiver relative to the laser affects the amount of power delivered.

Conclusion

Further development of MOO can create a more refined solution. Optimized code and search algorithms can allow for the processing of billions of combinations. However, even with 220000 combinations, MOO is an effective tool in developing satellite constellations when properly constrained. Policy and other aspects have been researched but could further be developed.

Acknowledgements

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