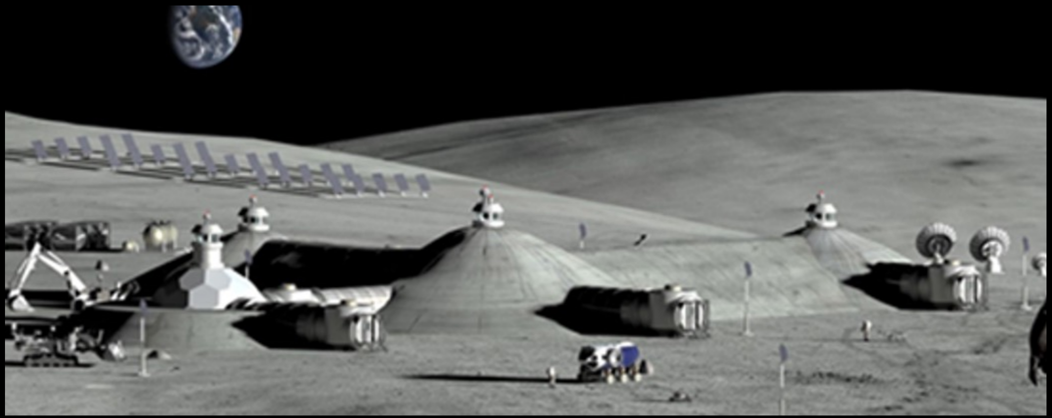

Robust Lunar Base Architectures using Smart Pico-Building Blocks

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Aerospace and Mechanical Engineering Department
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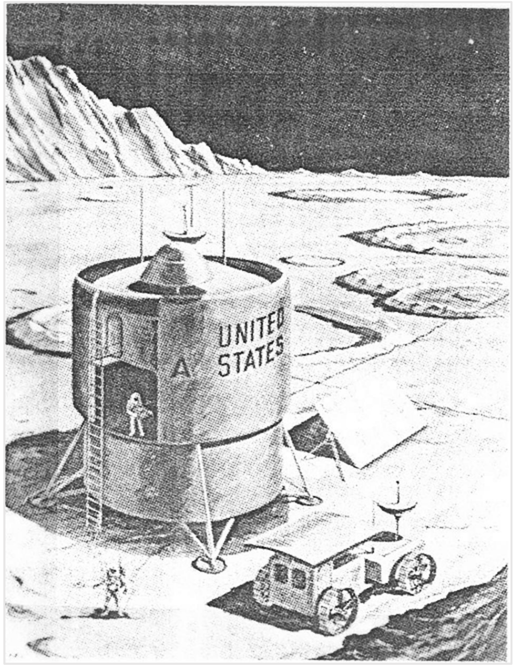
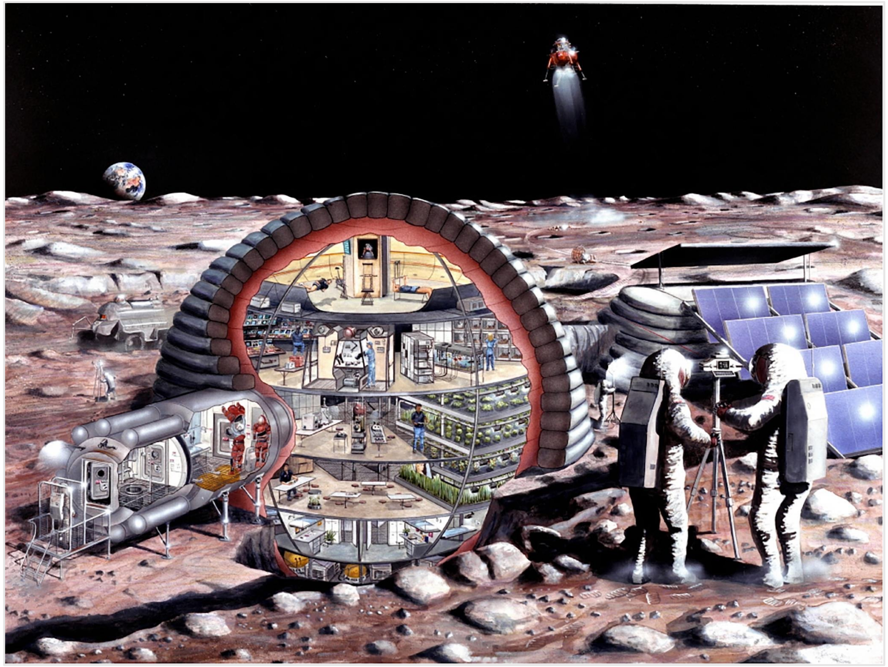
Motivation

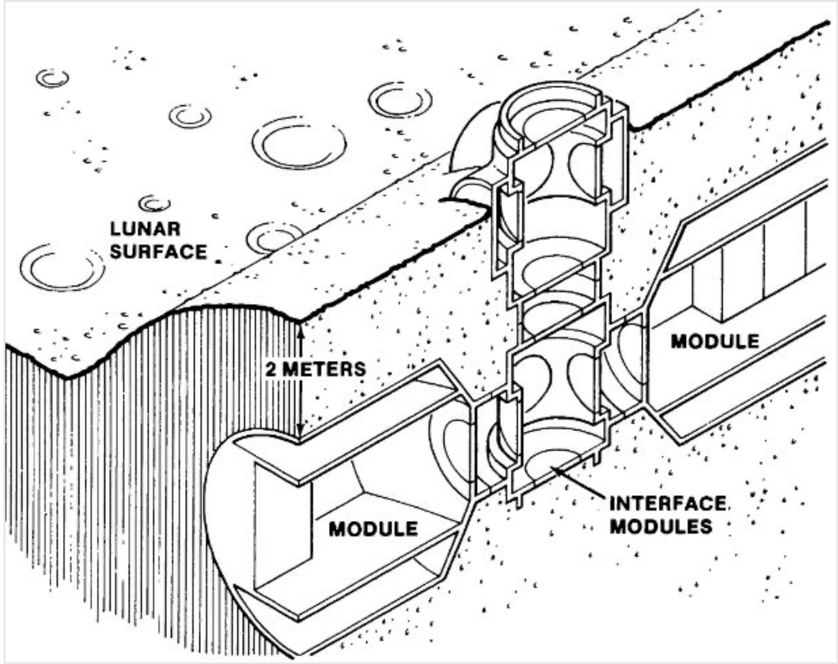
- Artemis Program - Establish a permanent habitat on the Moon



Rigid Structures
(LPI, NASA)



Inflatable Structures
(G. Kitmacher, NASA)

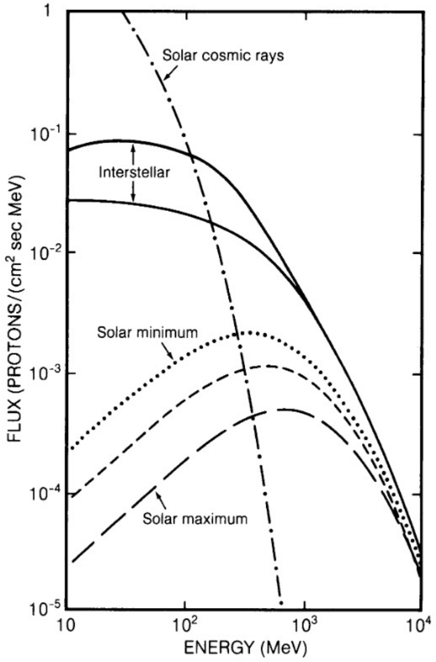


Underground Structures
(LPI, NASA)

Challenges

- Harsh environment + expensive launch budget

Meteorite Bombardment
(LPI, NASA)



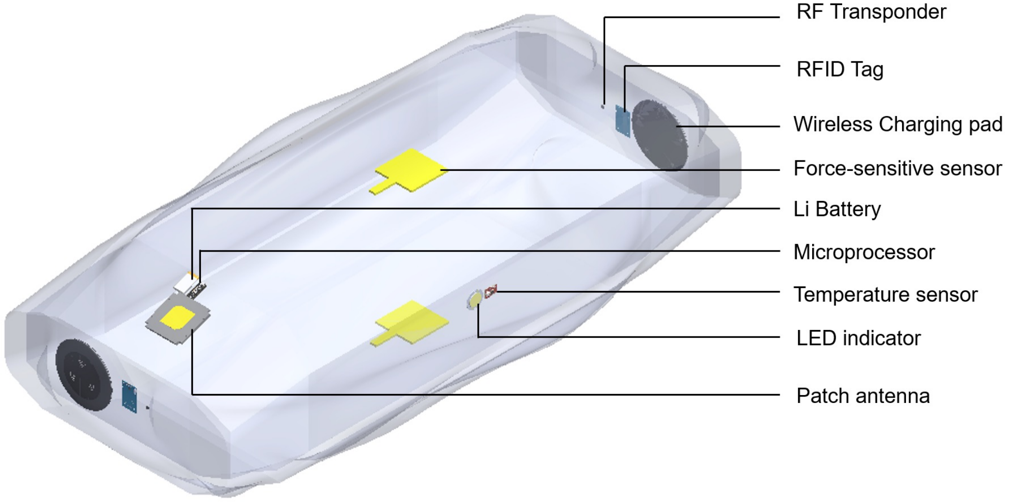
Lunar Surface Radiation
(LPI, NASA)

Saturn V Launch
(NASA)

Approach

- In-situ resource utilization (ISRU) with “smart” sandbags

Superadobes Built with Sandbags
(N. Khalili)



Embedded Electronics in
Smart Sandbags

Approach

Electrical Components	Usage	Application
Proximity Sensors	Detect presence of neighboring sandbags	Enable streamlined construction process involving multiple simple rovers
LED / LED Matrices	Indicate warnings, display info	Signage for machine/human vision
Thermocouples	Measure temperature	Monitor structure in/exterior temperature
Force Sensors	Detect presence of sandbags above	Facilitate construction process; monitor structural integrity;
Accelerometer	Determine orientation of sandbag; detect movement	Monitor structure integrity; monitor micrometeorite bombardment
Low range antenna	Communicate info to nearby system	Establish info channel across infrastructure; beacon presence for rover guidance
Localization module	Broadcast geolocation of self	Facilitate construction process; label/tag structure on habitat map

Approach

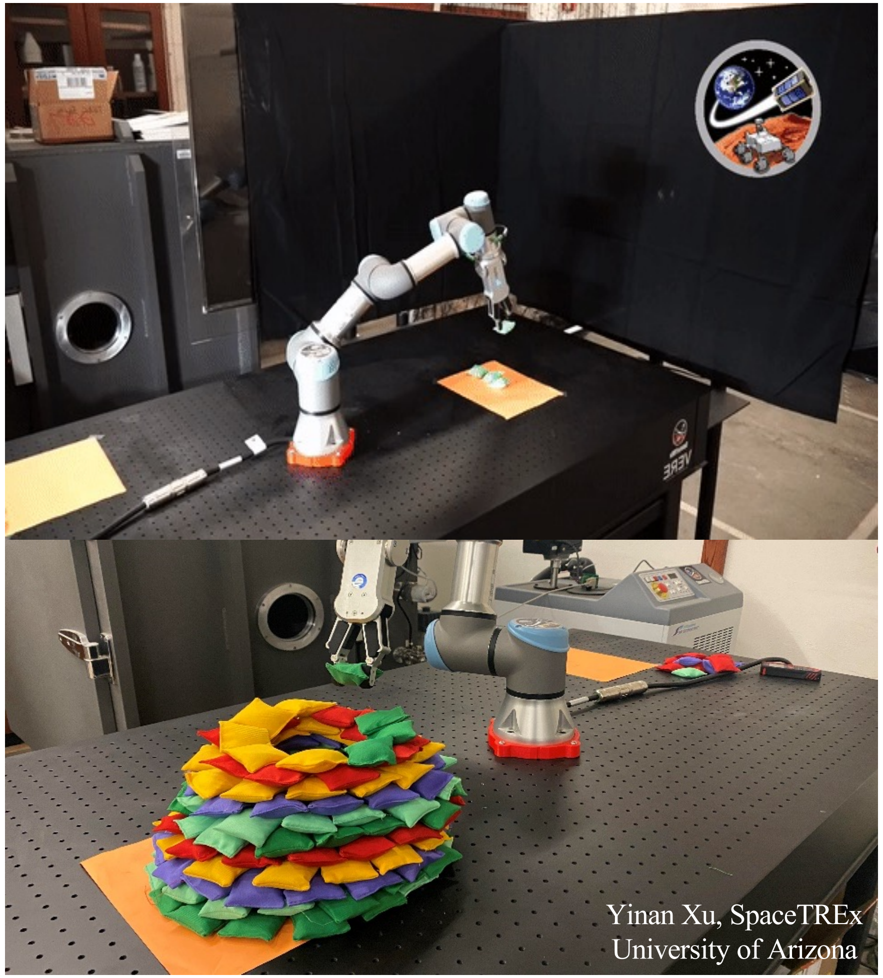
- Energy harvesting technologies to prolong sandbag lifetime

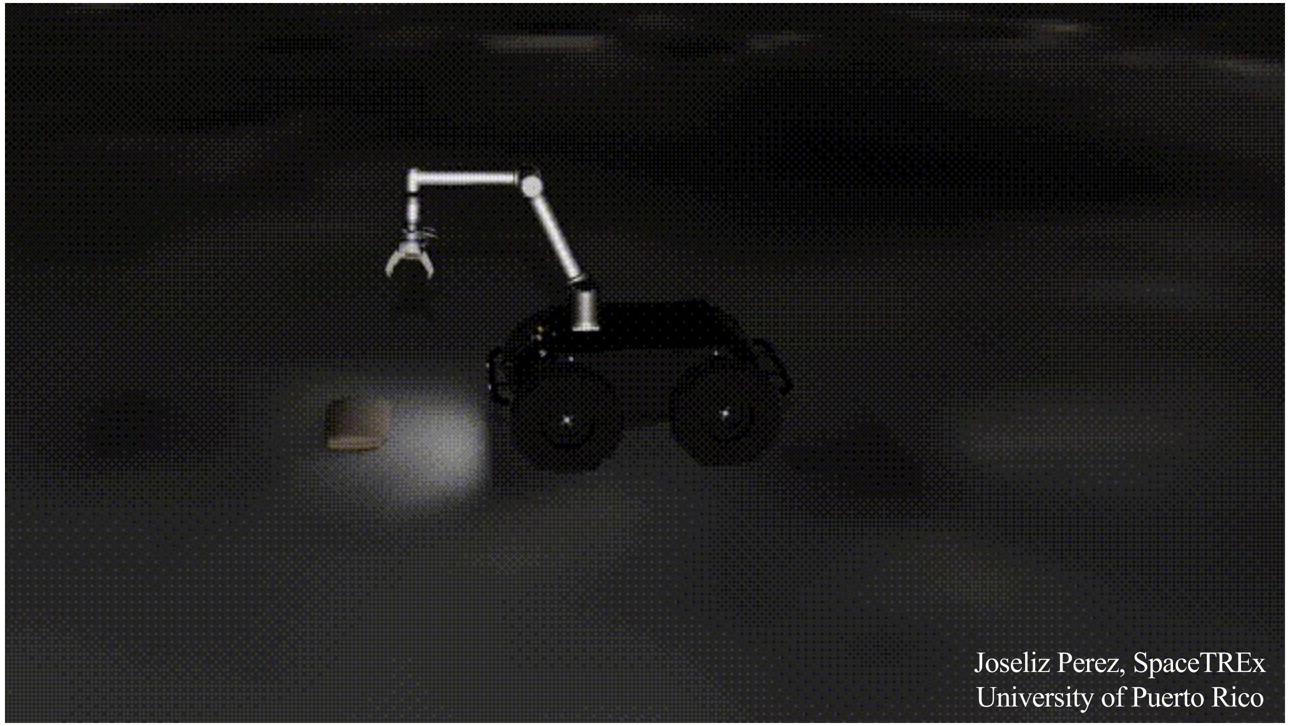
Charging Technology	Pros	Cons
Induction coupling	✓ Simple implementation ✓ High efficiency	- Precise alignment required - Short charging distance (mm to cm)
Magnetic resonance coupling	✓ Charges multiple devices simultaneously ✓ High charging efficiency ✓ Non-line-of-sight charging	- Limited charging distance (cm to m) - Complex implementation
RF radiation charging	✓ Long charging distance (m to km) ✓ No alignment required	- Line-of-sight transmission - Unsafe for human if high power - Low efficiency
Thermoelectric	✓ No extra infrastructure required ✓ Passive harvesting method	- Low power output - Somewhat complex implementation

Results

Demo: Sandbags implemented with force sensors

Results

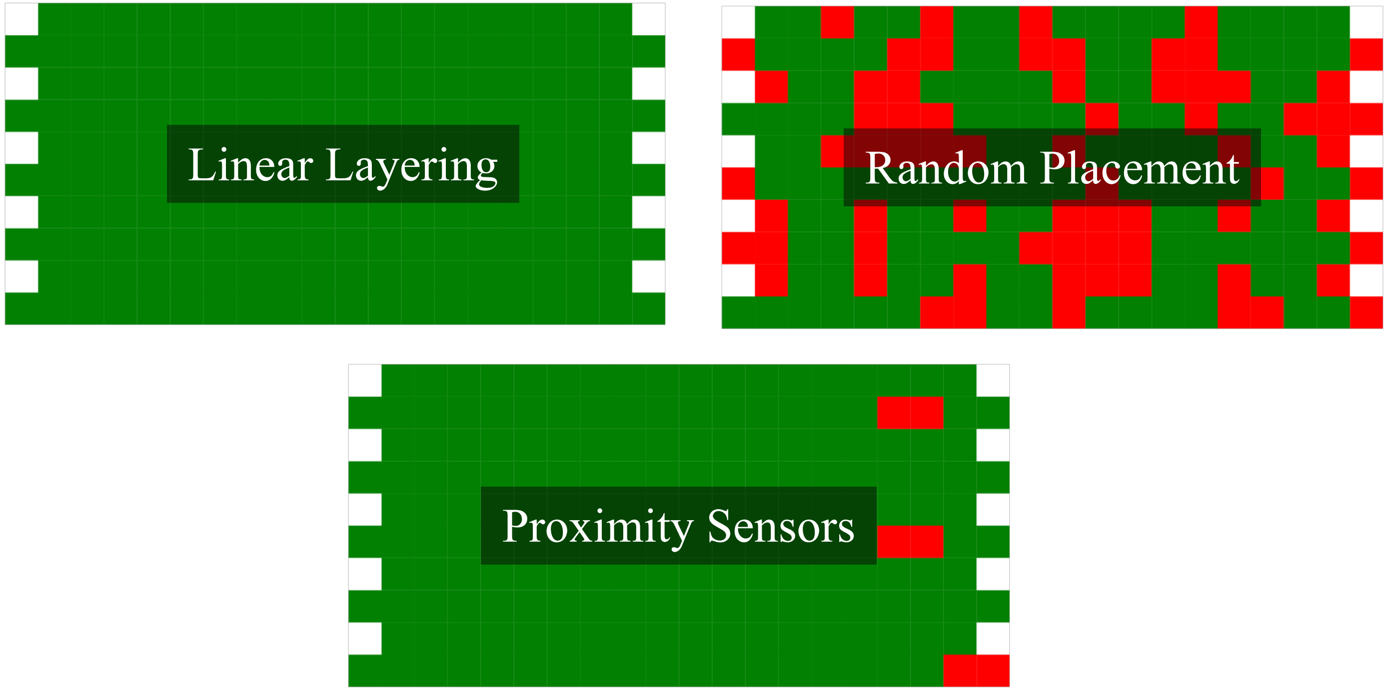




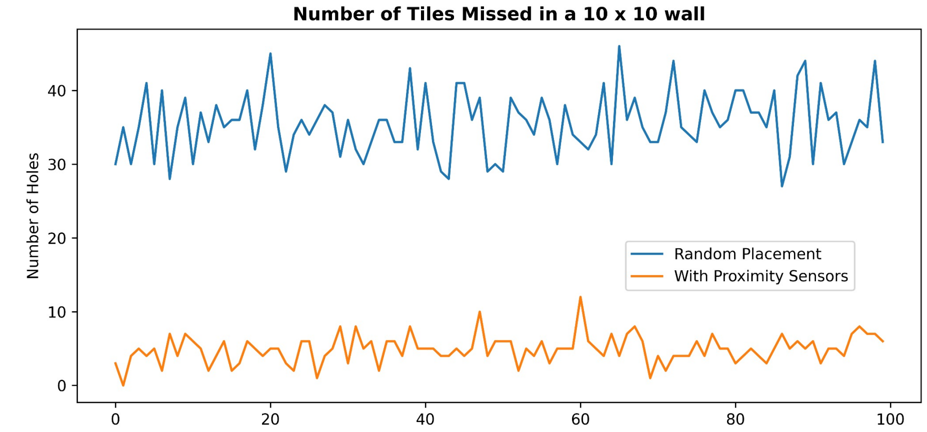
Superadobe construction using pick-and-place rovers

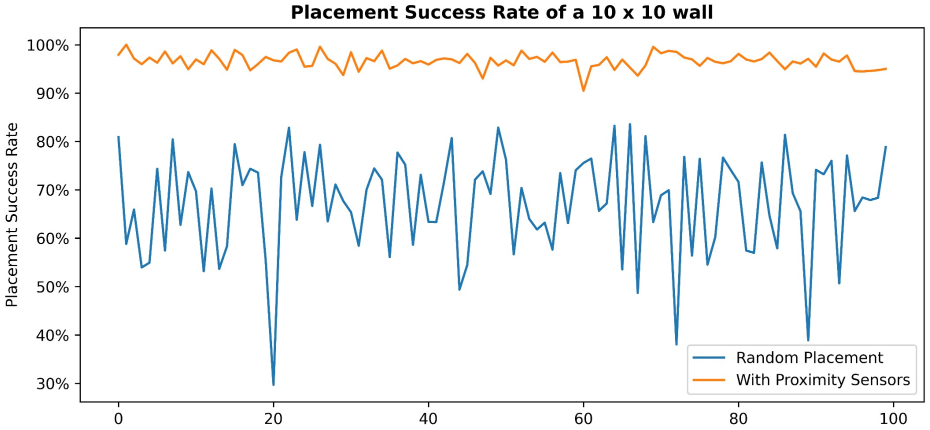
Results

- Proximity sensors improves construction process efficiency



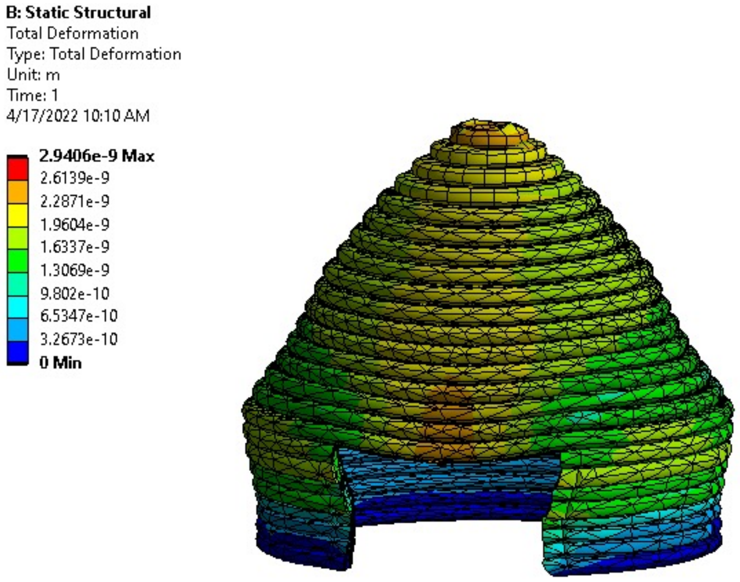
Simulation of constructing a 10x10 sandbag wall
(green = sandbag, red = holes)



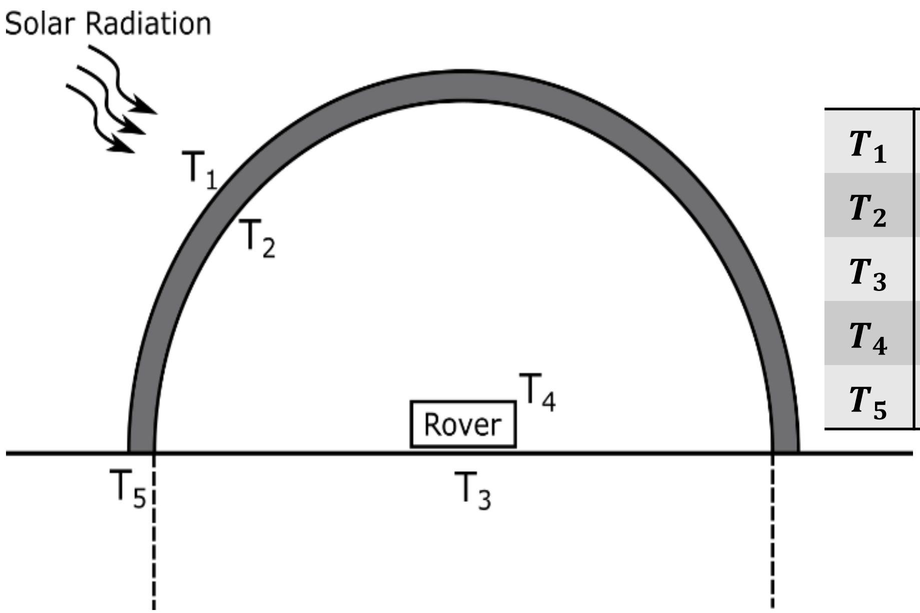


Results

- ANSYS simulation for sandbag structural and thermal analysis



Superadobe with
ANSYS static structural solver

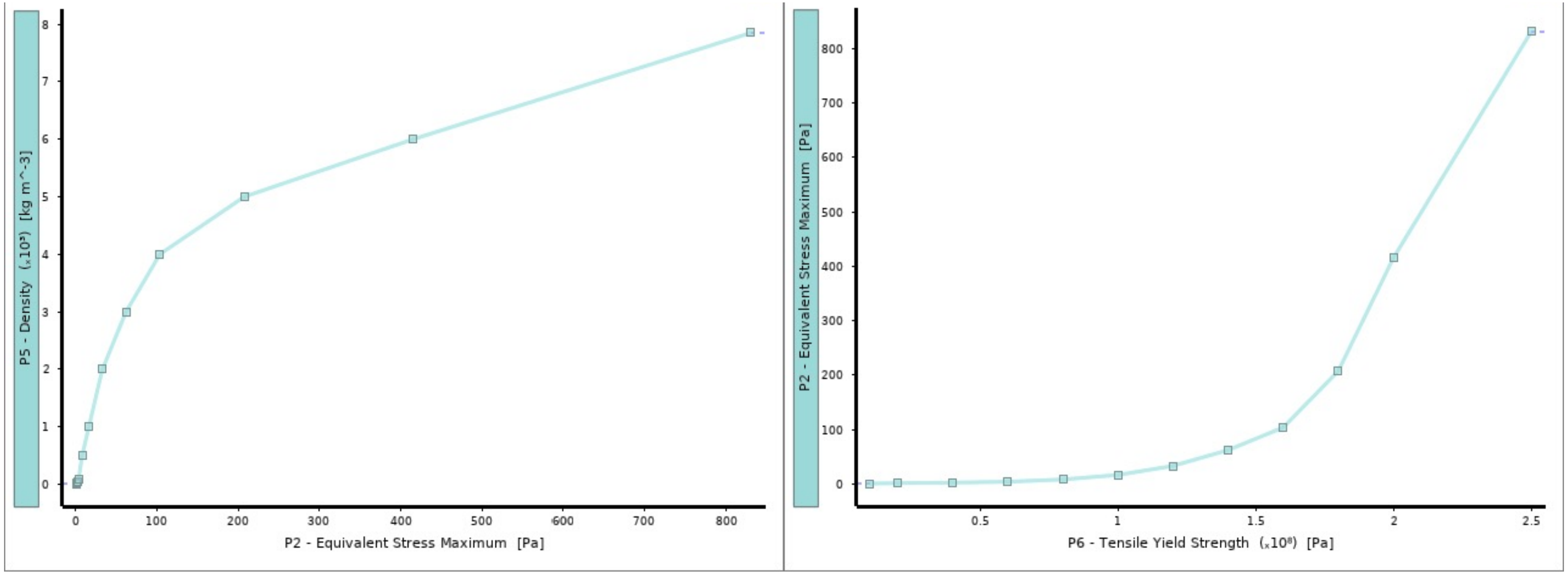


T_1	**External wall**
T_2	Internal wall
T_3	Internal ground
T_4	Rover surface
T_5	External ground

Superadobe physical thermal modeling

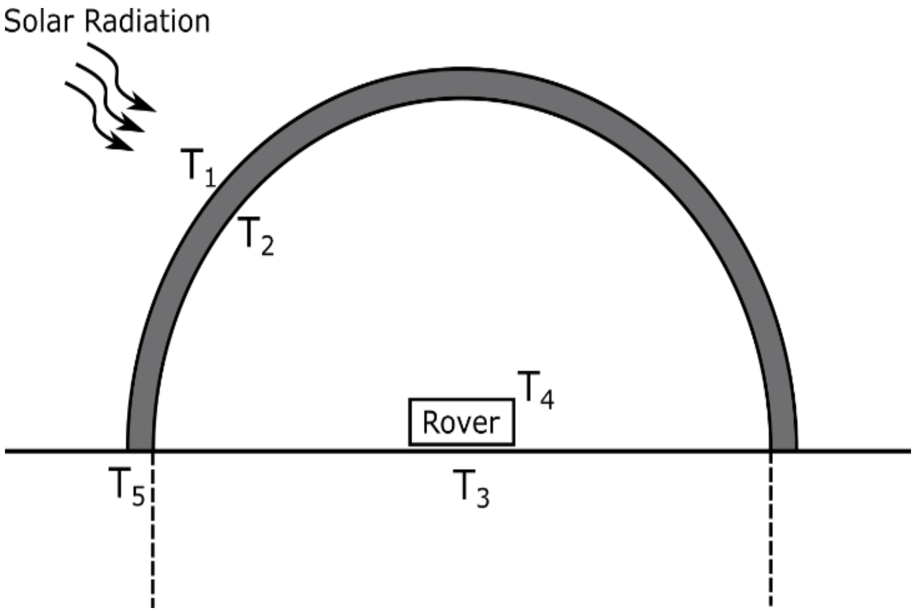
NASA Partner
SpaceTREx

Results



From the initial structural studies, the material density and yield strength has the most affect on the equivalent stress.

Results



Superadobe physical thermal modeling

T_1	**External wall**
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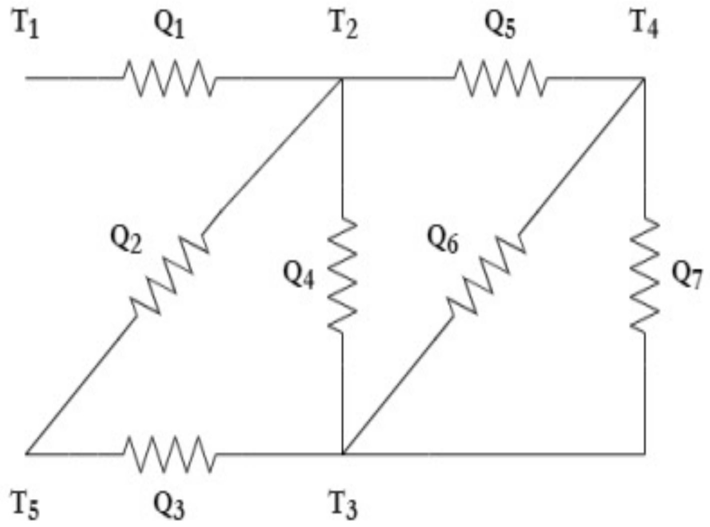


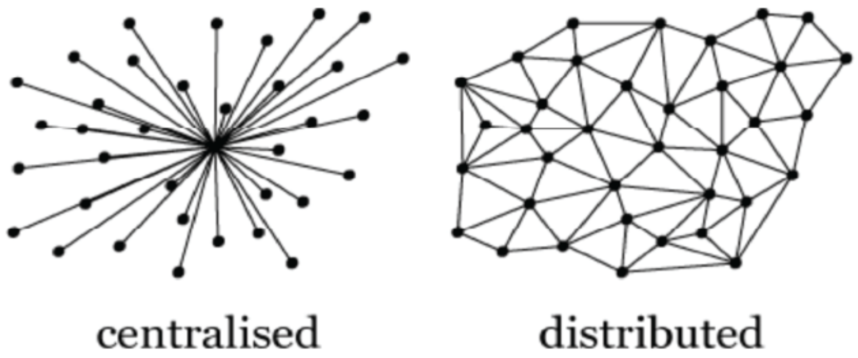
Superadobe thermal circuit

$$Q_1 = k_{12} A_{\text{dome}} (T_1 - T_2)/t_{\text{sand}}$$
$$Q_2 = k_{25} A_{\text{ring}} (T_5 - T_2)/h_{\text{dome}}$$
$$Q_3 = S k_{35} (T_3 - T_5)$$
$$Q_4 = \sigma \left[\epsilon_{\text{bag}} F_{23} A_{\text{dome}} T_2^4 - \epsilon_{\text{ground}} F_{32} \left(A_{\text{ground}} - A_{\text{rover}} \right) T_3^4 \right]$$

$$Q_5 = \sigma \left[\epsilon_{\text{bag}} F_{24} A_{\text{dome}} T_2^4 - \epsilon_{\text{rover}} F_{42} A_{\text{rover}} T_4^4 \right]$$
$$Q_6 = k_{34} A_{\text{rover}} (T_4 - T_3)/h_{\text{rover}}$$
$$Q_7 = \sigma \left[\epsilon_{\text{ground}} F_{34} A_{\text{ground}} T_3^4 - \epsilon_{\text{rover}} F_{43} A_{\text{rover}} T_4^4 \right]$$

Distributed Processing Network

- With microprocessors and antenna in sandbags, they could be utilized as a distributed processing network to offload routine and mundane tasks (e.g. monitor important parameters, structure maintenance)
- Centralized processing resource is vulnerable in the unforgiving lunar surface



Conclusion

- Smart sandbags to provide semi-permanent shelter
  - Cheaper alternative for expanding lunar habitat
- Smart sandbags offload tasks from mobile systems and astronauts
  - A more robust processing system
  - Versatility of sandbags with different config. of electronics

Future Work

- Test structural integrity of sandbag structures
  - Accurately scale down to simulate lunar gravity on Earth
- Prototype sandbags embedded with electronics
  - Material requirements
  - Mass/Volume/Cost estimates
- Investigate fibers from lunar regolith
  - Further step in ISRU

SpaceTREx

LABORATORY

Space and Terrestrial Robotic Exploration (SpaceTREx) Laboratory

ASTEROID
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Asteroid Science, Technology and Exploration Research Organized
by Inclusive eDucation (ASTEROID) Center


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