A LUNAR CAPABILITIES ROADMAP

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SYSTEM TECHNOLOGIES
Testing system performance in lunar-type environment

Descent, landing, ascent

Mobility/ Roving

ENVIRONMENTAL CHARACTERIZATION
Identifying **locations of interest**

Locations

WARNING: ENVIRONMENTAL HAZARD AHEAD

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- a. Solar wind (plasma)
- b. Cosmic rays
- c. Micrometeorites
- d. Dust
- e. Permanently shaded regions
- f. Vacuum
- g. 1/6 g
- h. Variable thermal regime
- i. Long nights
- j. Synchronous rotation

Scientific investigations

Extractable resources

Reduced environmental hazards

SUBSYSTEM TECHNOLOGIES

Energy
1. Primary power generation
   - a. Solar
   - b. Nuclear (fission/fusion)
   - c. Radioisotope
   - d. Chemical
   - e. Hybrid
2. Storage
   - a. Batteries
   - b. Ultracapacitors
   - d. Flywheels
   - c. Regenerative fuel cells
3. Thermal management
   - a. Control
     - i. Heat acquisition
     - ii. Heat transport
     - iii. Heat rejection
     - iv. Storage
   - b. Protection

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Communications
- a. Line-of-sight (to Earth)
- b. Orbital satellite relay
- c. Large bandwidth (e.g., laser comm.)

Guidance, navigation, and control
- a. orbital maintenance
- b. landing precision

Command and data handling

INTELLIGENT SYSTEMS

Robotics
- a. Precurser
- b. Interaction with humans, equipment, and terrain
  - i. Safety
  - ii. Non-human-like locomotion and manipulation (to traverse difficult areas and situations)
- c. Object and situation recognition
- d. Force and tactile sensing
- e. Compact instrumentation
- f. Environment resistance

Autonomous Systems
- a. Full
- b. Shared autoomy
- c. Adaptibility (variable autonomy)

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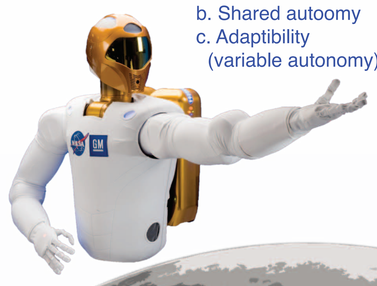

MINING/ISRU

Planetary protection

Sampling and handling
- a. contamination prevention

Manufacturing
- a. 3D printing

Manipulation, extraction, beneficiation, storage, and transport
- a. Regolith
- b. Paved or sintered roads and landing pads
- c. Water (H-OH)
- d. ilmenite - iron and titanium
- e. oxygen from regolith

video

LIFE SUPPORT

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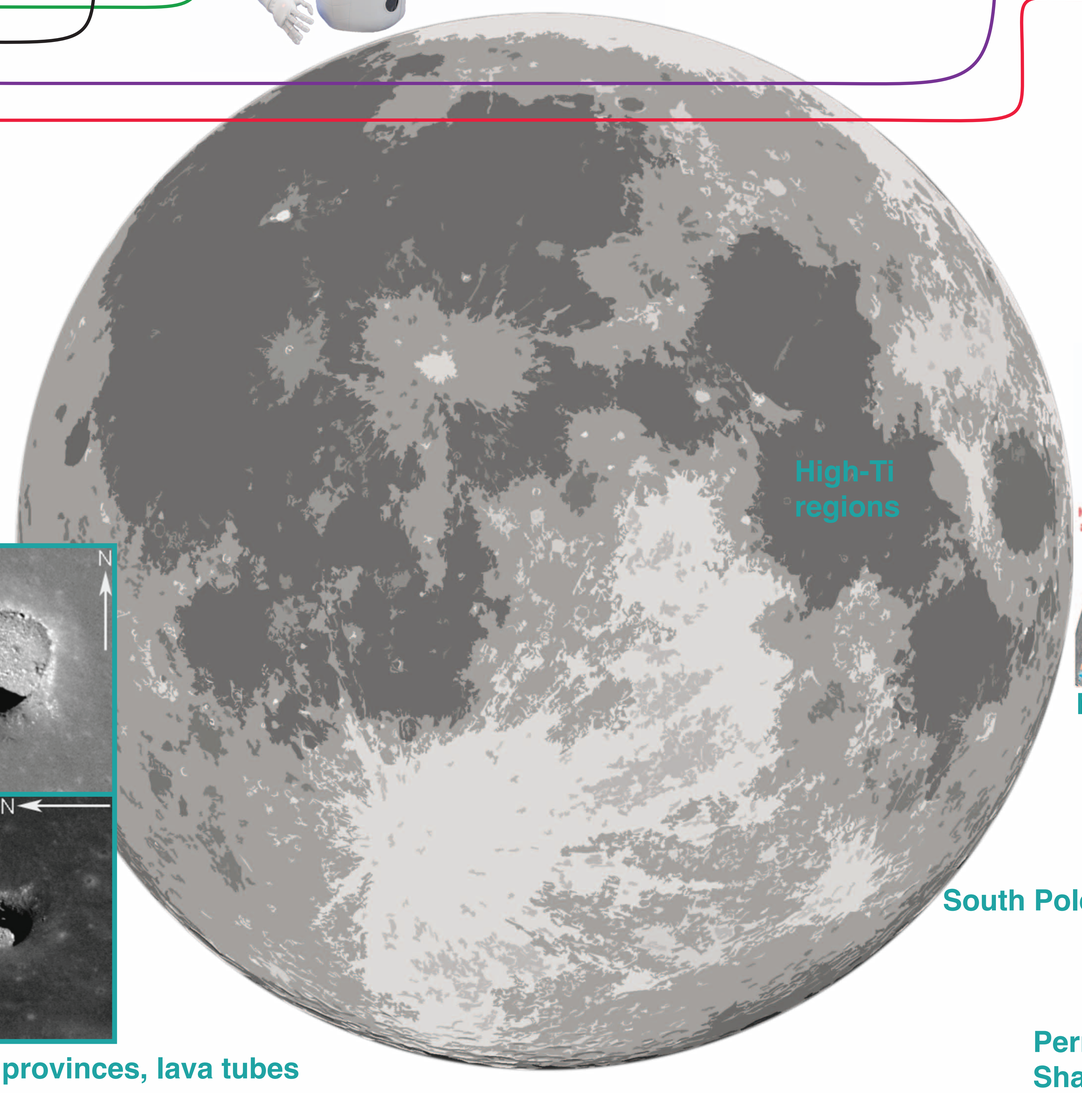
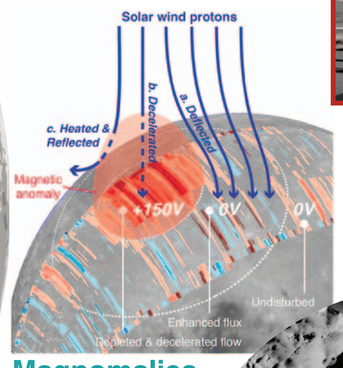
Habitats & Spacesuits
- a. Materials
- b. Structure
  - i. Expandable technologies
- c. Adaptibility
  - i. ability to easily transition between being vacant and occupied
  - ii. provisioning, sparing, maintenance, and repair

Locations
- a. Lava tube
- b. PSRs
- c. Magnomalies

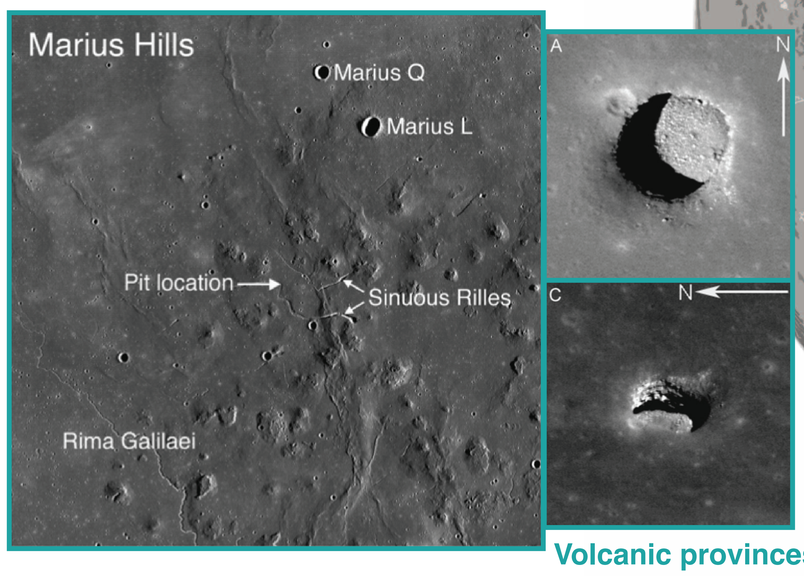
Agriculture

Dust mitigation
- a. electrostatic manipulation
- b. dust insensitive technologies



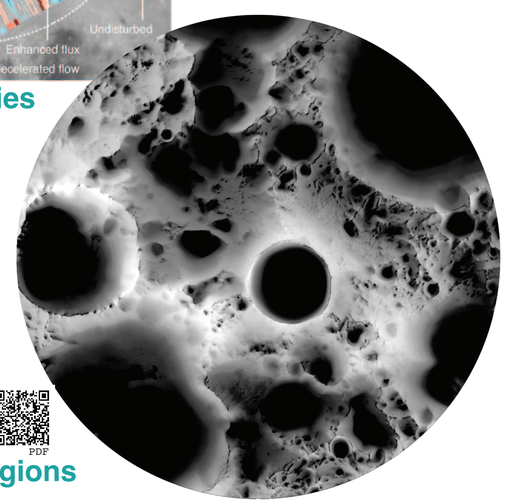


Magnomalies



Volcanic provinces, lava tubes

South Pole-Aitken



Permanently Shadowed Regions

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