HOPE Surface Operations Concepts

Surface Operations

- What tasks will need to be completed on Callisto's surface?
- What surface systems will exist to enable the tasks to be completed?
- How will the tasks be distributed among the crew and the automated systems?

Surface Operations

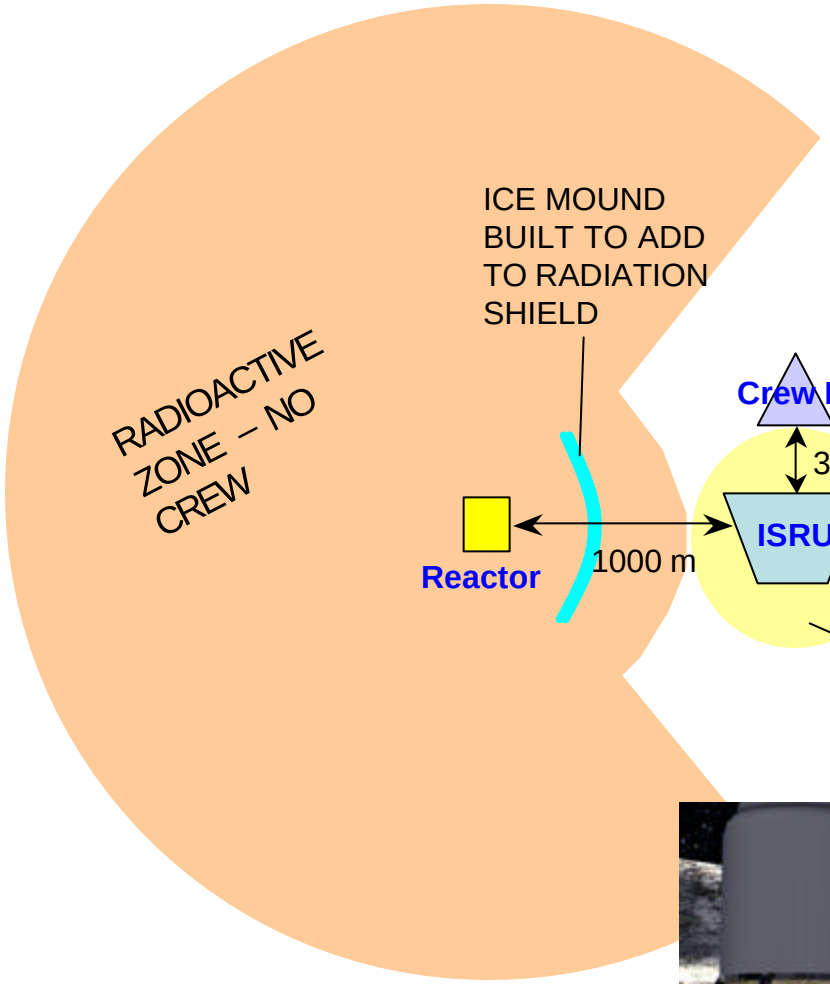
Driving Assumptions

Technology Assumptions

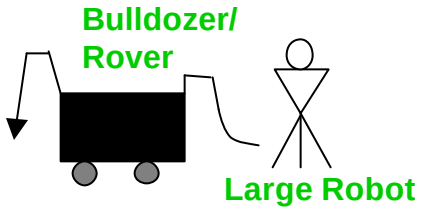
- Advanced space suits
  - Adequate radiation and cold temperature protection enable up to 15 ***3-hour excursions*** during a 30-day Callisto surface stay
- Precision landing capabilities
  - Landing target can be reached with an error of no more than 30 meters
- Autonomous deployment and operation of surface systems
  - Habitat, power system, ISRU system, and navigation/communication system can all be autonomously deployed before crew arrival
- Prevention of loss during liquid cryogen transfer over 30+ meters
- Super-cold materials
  - Metals that withstand 100 K enable surface vehicle mechanisms
  - Structural materials that are flexible at 100 K enable inflatable surface hab design
- Brayton nuclear reactor
  - Power system can deliver 400 kW_e power at a mass of 30kg/kW_e

Surface System Architecture

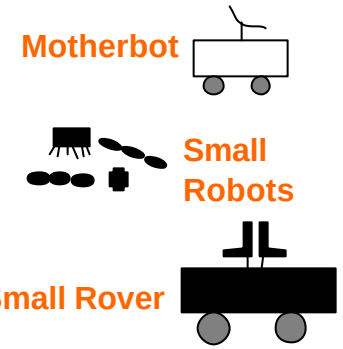
Surface System Layout



CONCEPT #1



CONCEPT #2



Surface System Architecture
Vehicle and Robotic Systems Concepts

Concept #1 - "Large-scale"

- Large autonomous vehicles
- Multi-task humanoid robots
- Many points of failure on each system

Concept #2 - "Small-scale"

- No large bulldozer or large regolith transporter
- Tasks distributed among many miniaturized, single-task robots
- Builds on micro-robots of precursor mission's Phase 2

Surface System Architecture

Common Components

- Crew Lander
- Surface Habitat
- ISRU Fuel Production Plant

} Common Descent Systems

- Brayton Nuclear Reactor Power System (2 Reactors, ~ 400 kW_e total)
- Antennas and transmitters

Surface Hab

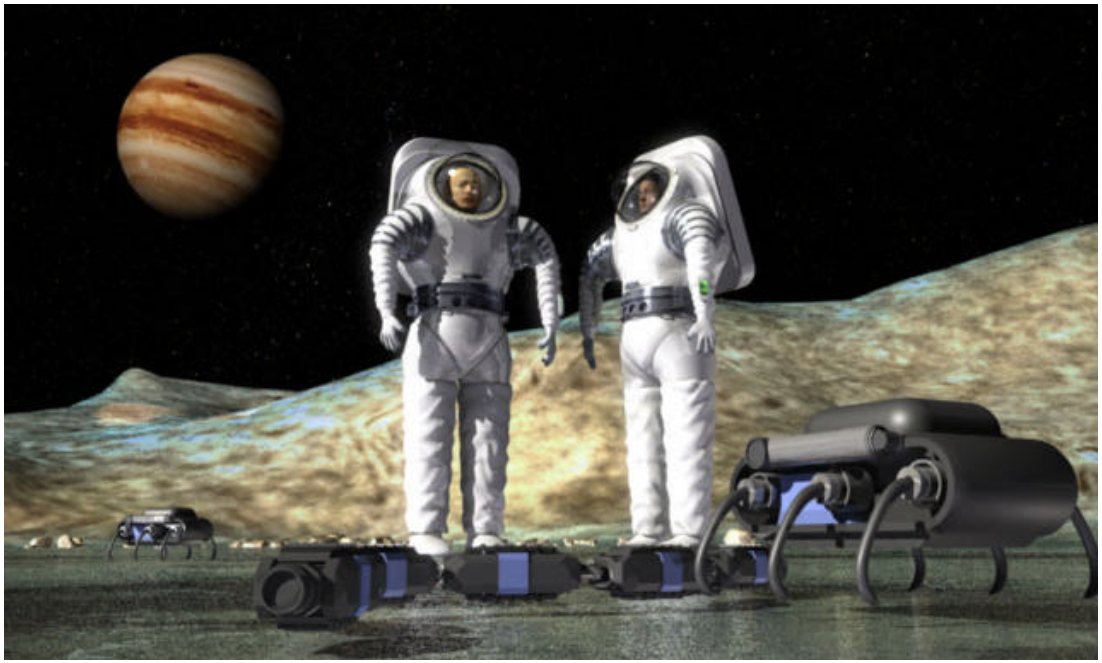
Crew Lander

Large-Scale Concept: Unique Components

- 2 unpressurized bulldozer/rovers
- 3 “Robonauts”

Small-Scale Concept: Unique Components

- Small rover - transports two crew members
- “Motherbot” platform - deploys and commands robots
- Miniature robots - transport surface material, perform science tasks

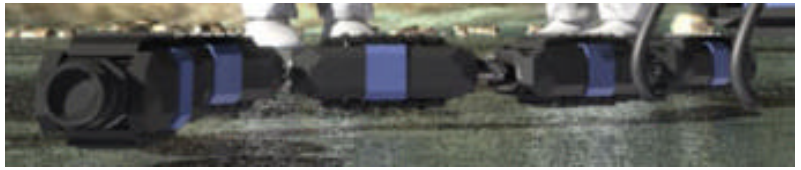


Small-Scale Concept: Miniature Robots

Crawling

Hovering

Burrowing



Linked as snake

Now that we have all these robots…

Why humans?

The roles of human and robotics:

Surface Operations

Robotics

- All set-up and deployment activities
- All transport of surface material to ISRU plant
- All sample collection
- Scout all EVA routes

Humans

- Outside on surface only for decision-making and analysis
- Interpret information from robots and direct their subsequent actions
- Respond to contingencies
- Select samples
- Discover what they are not told to look for

Autonomous Set-Up Tasks

- Deploy reactors and 1000-meter cable to power ISRU plant and surface hab
- Build ice mound to function as shielding for reactors
- Deploy surface communication system
- Transport surface material to ISRU plant
- Test operation of ISRU plant and begin fuel production; top off tanks in surface hab lander
- Inflate surface hab
- Ensure connection of surface hab to communication system and to reactors via ISRU

Science Tasks

CREW

- Select sites for traversal
- Select samples for retrieval
- Curate retrieved samples
- Examine samples - biomarker detection
- Select samples for return to Earth
- Monitor crew health
- Teleoperate robotic submarines in Europa's subsurface ocean

ROBOTICS

- Map area local to surface hab and catalogue field features
- Prepare surface for sample collection
- Collect samples
- Initial sample analysis in field
- Prevent forward and back contamination of and by samples