Revolutionary Concepts for Human Outer Planet Exploration (HOPE)

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8 authors, including:

Patrick A. Troutman
NASA

Frederic H. Stillwagen
NASA

REVOLUTIONARY AEROSPACE SYSTEMS CONCEPTS

NASA RASC

HOPE
HUMAN OUTER PLANET EXPLORATION

Revolutionary Concepts for Human Outer Planet Exploration (HOPE)

Pat Troutman
NASA Langley Research Center

Kristen Bethke
Princeton University

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Presentation for
STAIF-2003
Fission Propulsion Systems for Human Missions

RASC NASA

Why Look at A Crewed Mission Beyond Mars?

- Science ?.......No
- Flags & Footprints?...........Been There, Done That
- Tourism ?.......No
- Our Destiny ? ……….We can argue all day
- Monoliths and Monkeys?.............
- Because it is Hard?....... The problem pushes us beyond our Mars mission “norms” with respect to architecture and technology….
  - “If I can make it there,
    I'll make it anywhere”

    as sung by Frank Sinatra

Analogous Task

Herding Cats

in a room with

Smoke & Mirrors

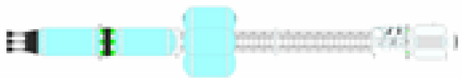
where the floor is covered with

Apples & Oranges

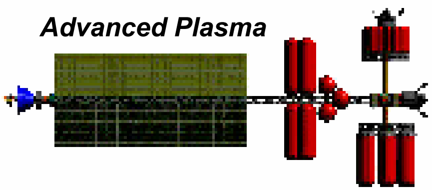
Human Outer Planet Exploration

Objective: ***Develop revolutionary aerospace systems concepts for human space exploration of the solar system beyond Mars orbit and identify critical technology requirements for the realization of these systems concepts.***

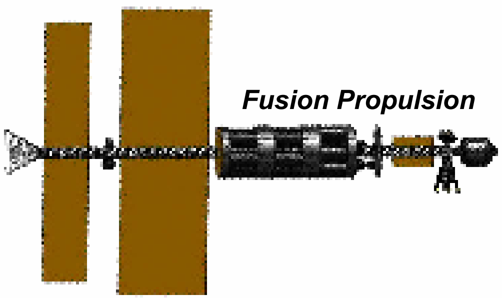
Bimodal Nuclear Thermal Rocket



Advanced Plasma

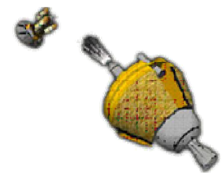


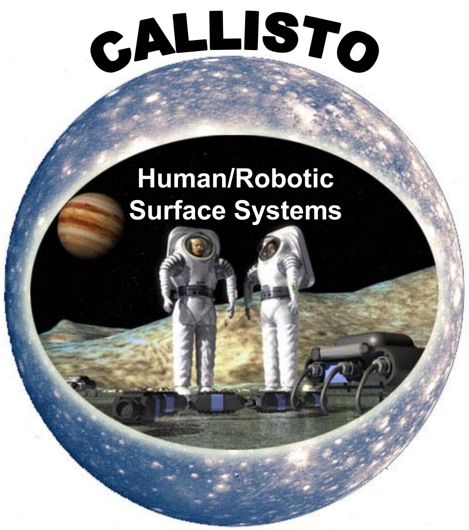
Fusion Propulsion

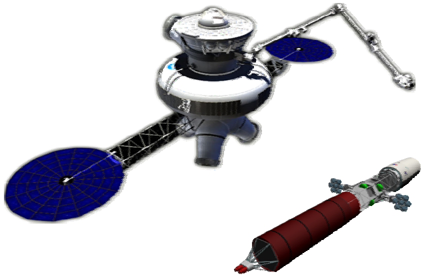


Apples-to-Apples Propulsion Technology Comparison

Precursor Missions







Supporting Infrastructure Requirements

JPL – JSC – GRC – MSFC - LaRC

PPO STPO Space Transportation Project Office Glenn Research Center · Advanced concepts · ASCAC

The Mission

2045 + :

- **Earlier robotic probes have identified what appear to be life forms floating in the oceans of Europa and embedded in the ice crust near an asteroid impact site on the surface of Callisto.**
- **A crewed expedition is to be sent to the surface of Callisto to teleoperate the Europa submarine and excavate Callisto surface samples near the impact site.**
- **The expedition will also establish a reusable surface base with an ISRU plant to support future Jovian system exploration**

Mission Requirements

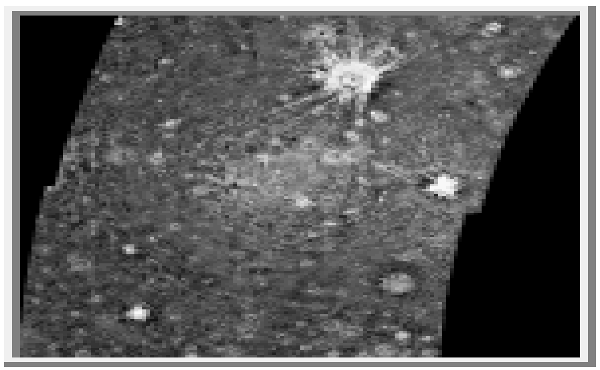
Mission Requirements:

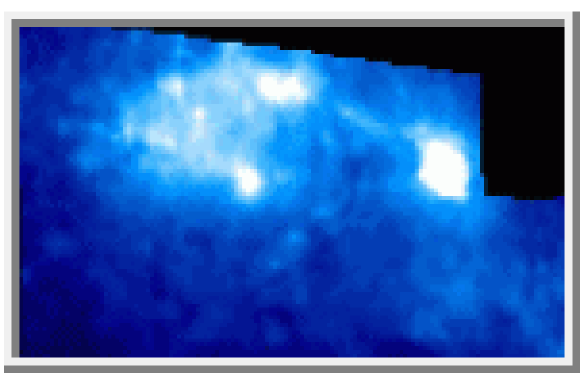
- Leave from Earth-moon L1
- Crew of 6 to the Jovian system, minimum of three to the surface of Callisto.
- Minimum surface stay time of 30 days
- Maximum crew mission time away from L1 is 5 years
- Max radiation exposure limits for crew must not be exceeded
- Maximum of one year accumulated time under 1/8th G during mission for each crewmember
- Deploy/construct surface habitat, reusable 3 crew lander and nuclear powered ISRU plant
- Tele-operate Europa submarine for 30 days
- Perform Callisto surface science

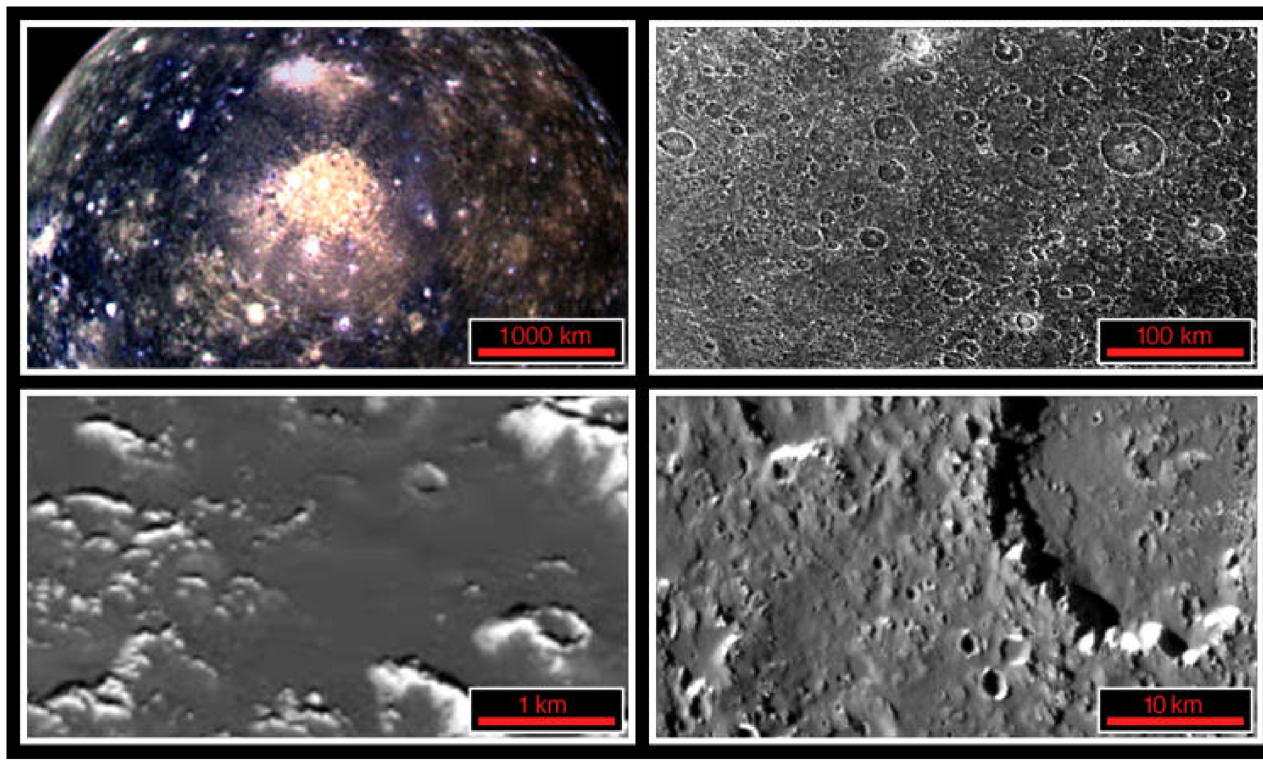
Mission Destination - Callisto

- Fourth moon of Jupiter: mostly outside of radiation belts
- About the size of the planet Mercury, surface at 1/8 G
- Most heavily cratered place in the solar system
- Covered with ice and asteroid dust

Asgard Impact Structure on Callisto







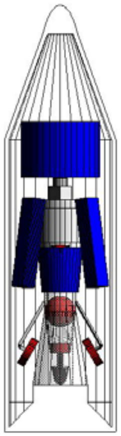
Callisto Precursor Mission Architecture

MITEE B Bimodal NTP System

While on Cruise: ~5KW$_{E}$,

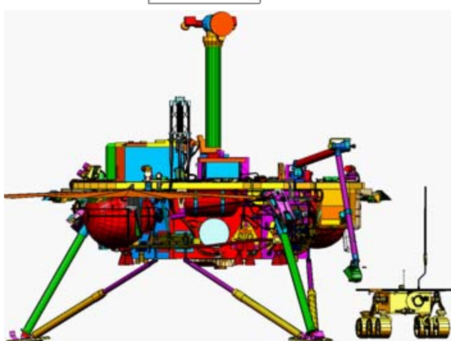
On Surface: ~20 KW$_{E}$ For Science, Communication & Controls

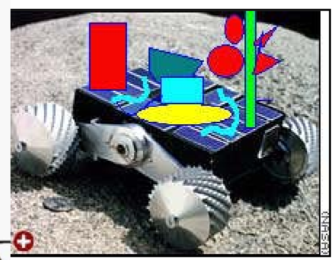
Earth

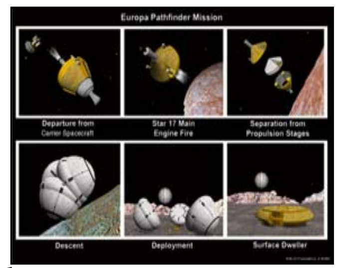


Conventional Launch Vehicle → ***Nuclear Safe Orbit*** → **NTP Burn** → **Coast: ~5KW$_{E}$ For Data & Controls** → **Orbit Callisto** → **Subsequent NTP Burn** → ***Land On Callisto***

Orbit Callisto → **Release Probe (Pathfinders)** → ***Land On Callisto***







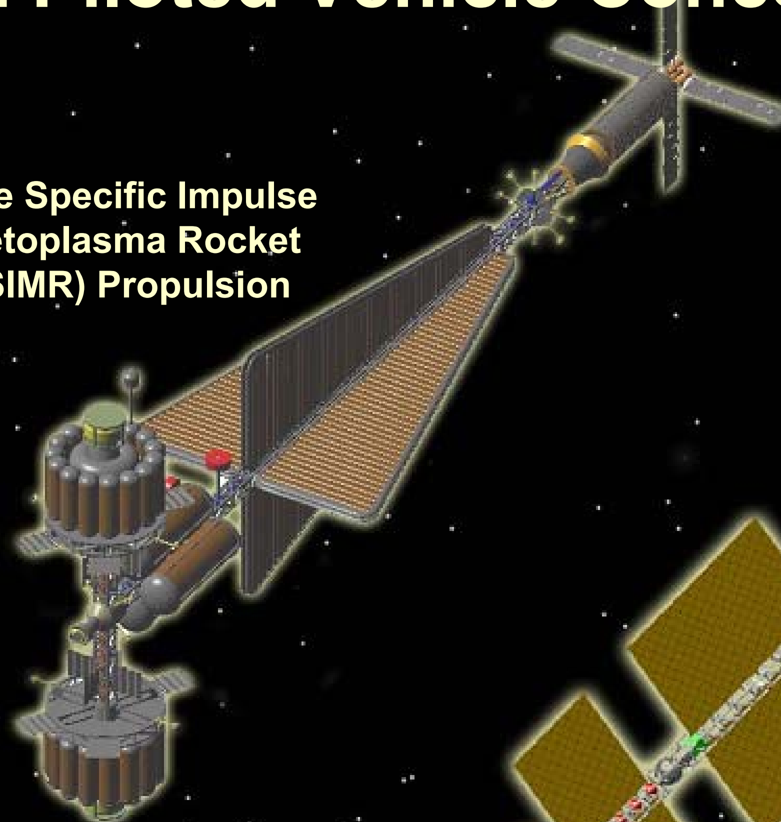
Land On Callisto
- ***Propulsive***
- ***Tether***
- ***Shock***

- **Precursor Mission to Callisto including landing and and exploration <4 years total time.**

Ram Manvi;08/22/02

HOPE Piloted Vehicle Concepts

"Bimodal" Nuclear Thermal Rocket (BNTR) Propulsion



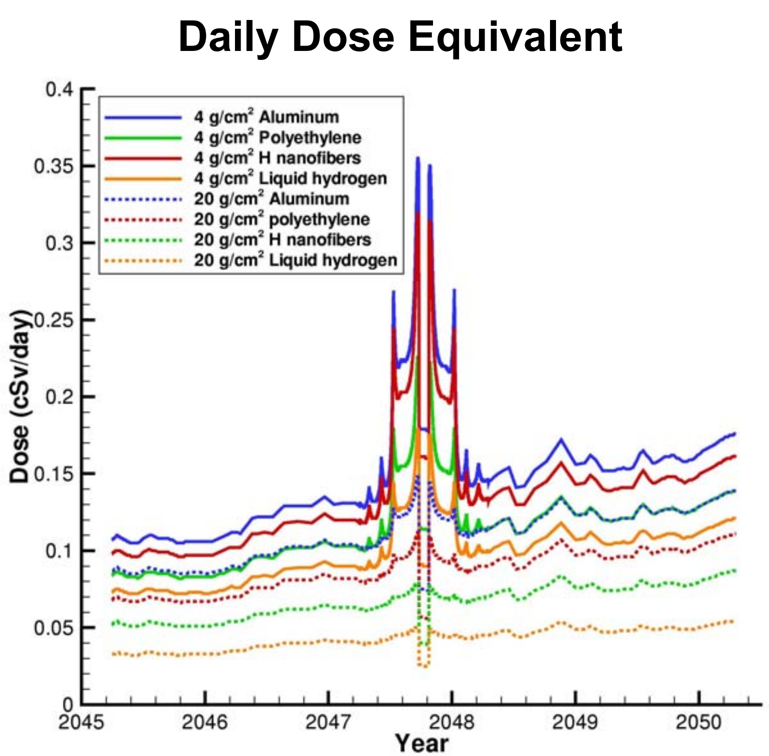
Variable Specific Impulse Magnetoplasma Rocket (VASIMR) Propulsion

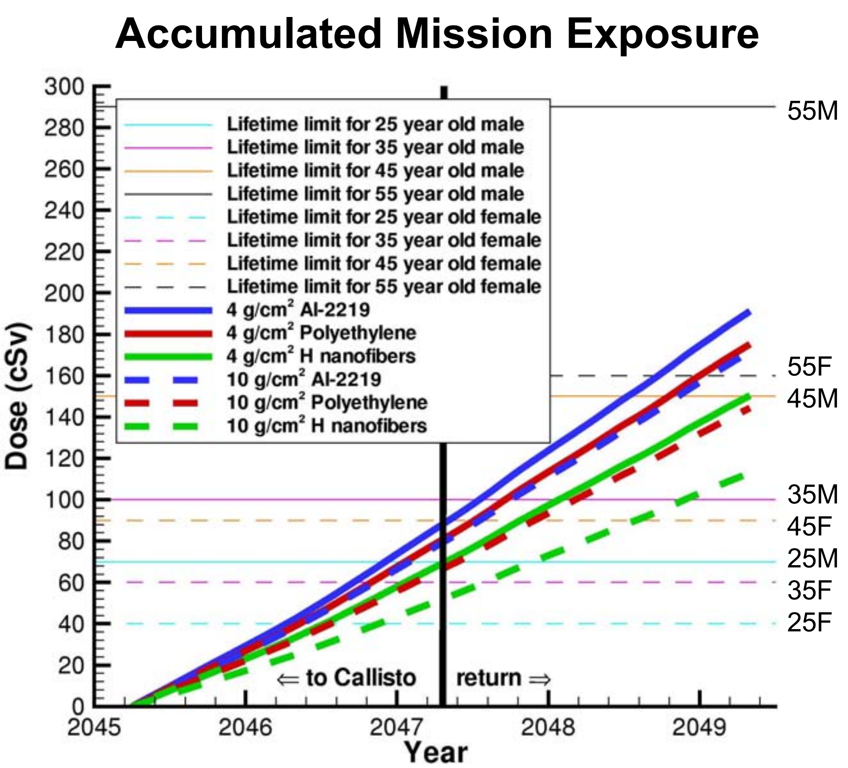
MagnetoPlasmaDynamic (MPD) Propulsion

Magnetized Target Fusion (MTF) Propulsion

Radiation Environment

Earth to Callisto and back (30 day stay)

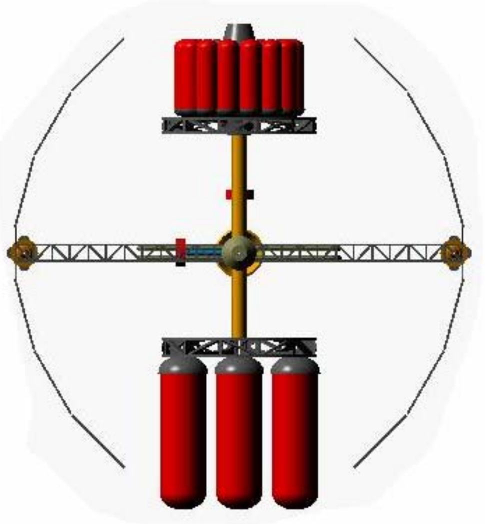




- Two year class missions can be supported by 35 to 45 year old crew members who have logged few hours in space

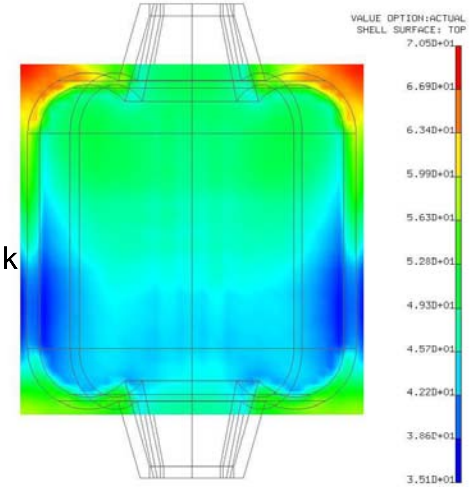
- Four year class missions will require advanced materials such as hydrogenated nanofibers or crew areas shielded by hydrogen tanks

Effects of Fuel Consumption on Radiation Exposure Rates

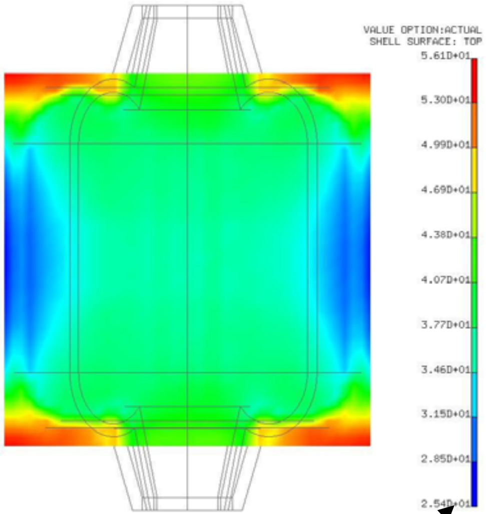


Front View

Half full tank



Full tank



Note differences in color scales

Comments on Fuel as Shielding

- Fuel congregates at far end of rotating arm from centrifugal forces
- Locate crew quarters near outer wall within the last remaining fuel
- Shielding model must account for fuel depletion
- Must be coupled to variability of space environment during mission duration

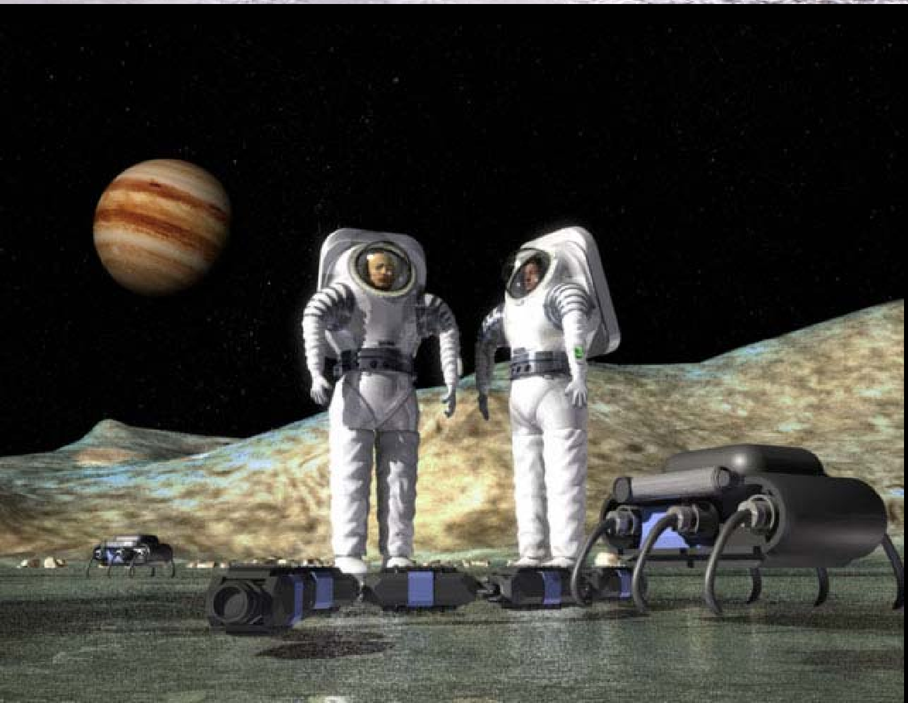
Qualitative Comparison Chart Across Vehicle Concepts

← Mission Design → ← Mission Performance →

Vehicle Option	Propulsion Technology TRL	Technology, Engineering & Physics Issues	Complexity of Vehicles	Supporting Infrastructure Requirements	# Vehicles to Perfrom Entire Mission	Initial Total Vehicle(s) Dry Mass at L1 (including payload)	Initial Total Propellant Load at L1	Total mass of all vehicles, propellant and payload initially at L1	Crew time in less than 1/8th G	Crew Time on Surface	Crew Trip Time Away from L1	Specific Impluse	Performance Margin	Crew Safety
BNTR Propulsion	Green	Green	Green	Yellow	Red	Yellow	Red	Red	Green	Yellow	Red	Red	Yellow	Red
NEP/MPD Propulsion	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Red	Yellow	Yellow	Yellow
NEP/VASIMR Propulsion	Yellow	Red	Red	Yellow	Yellow	Yellow	Yellow	Yellow	Green	Red	Red	Yellow	Red	Green
MTF Propulsion (30 day surface stay)	Red	Red	Yellow	Yellow	Green	Yellow	Green	Green	Red	Red	Green	Green	Green	Green
MTF Propulsion(180 day surface stay)	Red	Red	Yellow	Yellow	Green	Yellow	Yellow	Yellow	Red	Green	Green	Green	Green	Green

- **All vehicle options meet mission requirements**

Green: Better than other options
Yellow: Comparable across options
Red: Not as good as other options



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

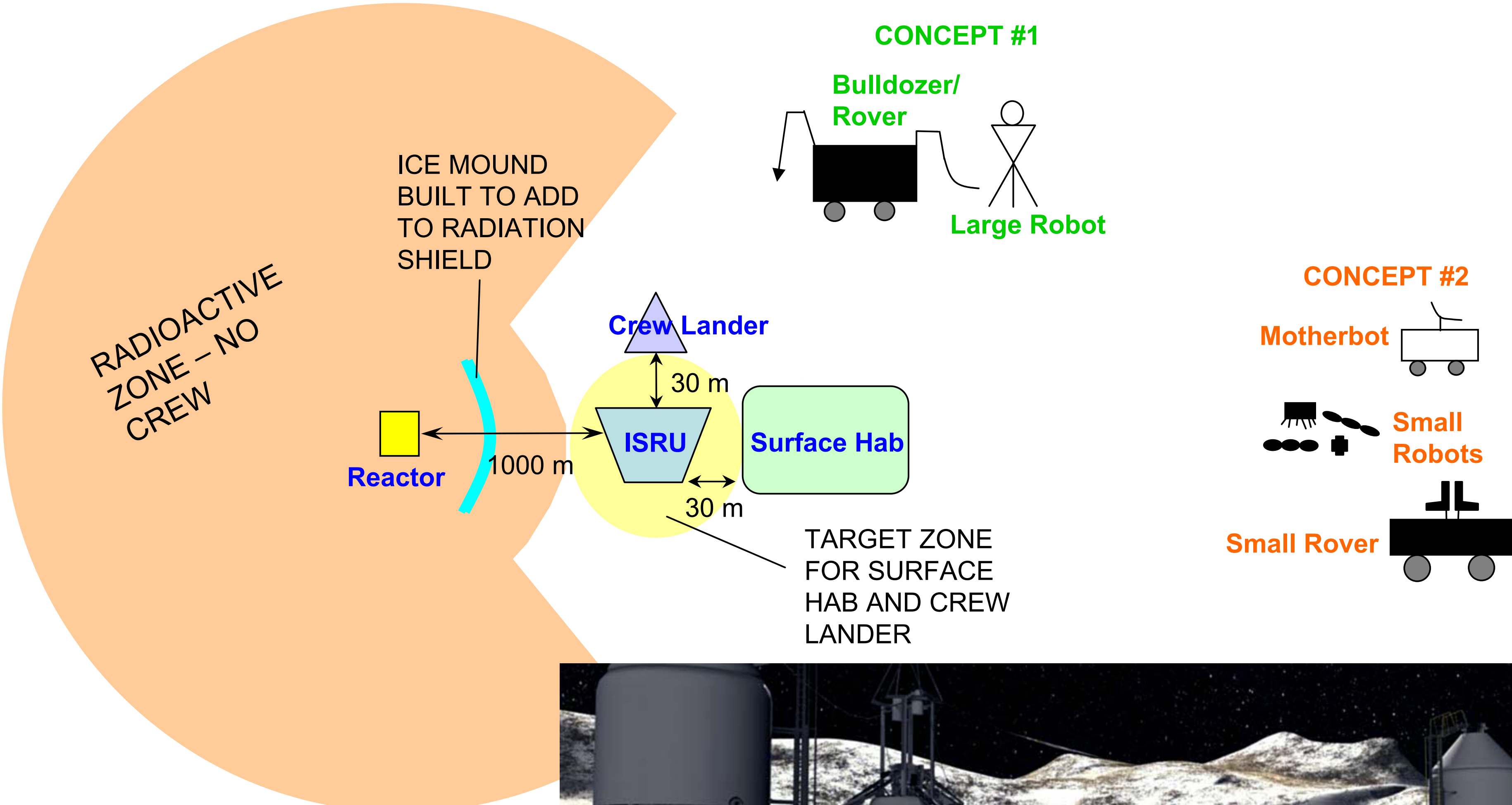
Technology Assumptions

- 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

Callisto Surface Operations Visualization

Surface System Architecture

Surface System Layout



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 of 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

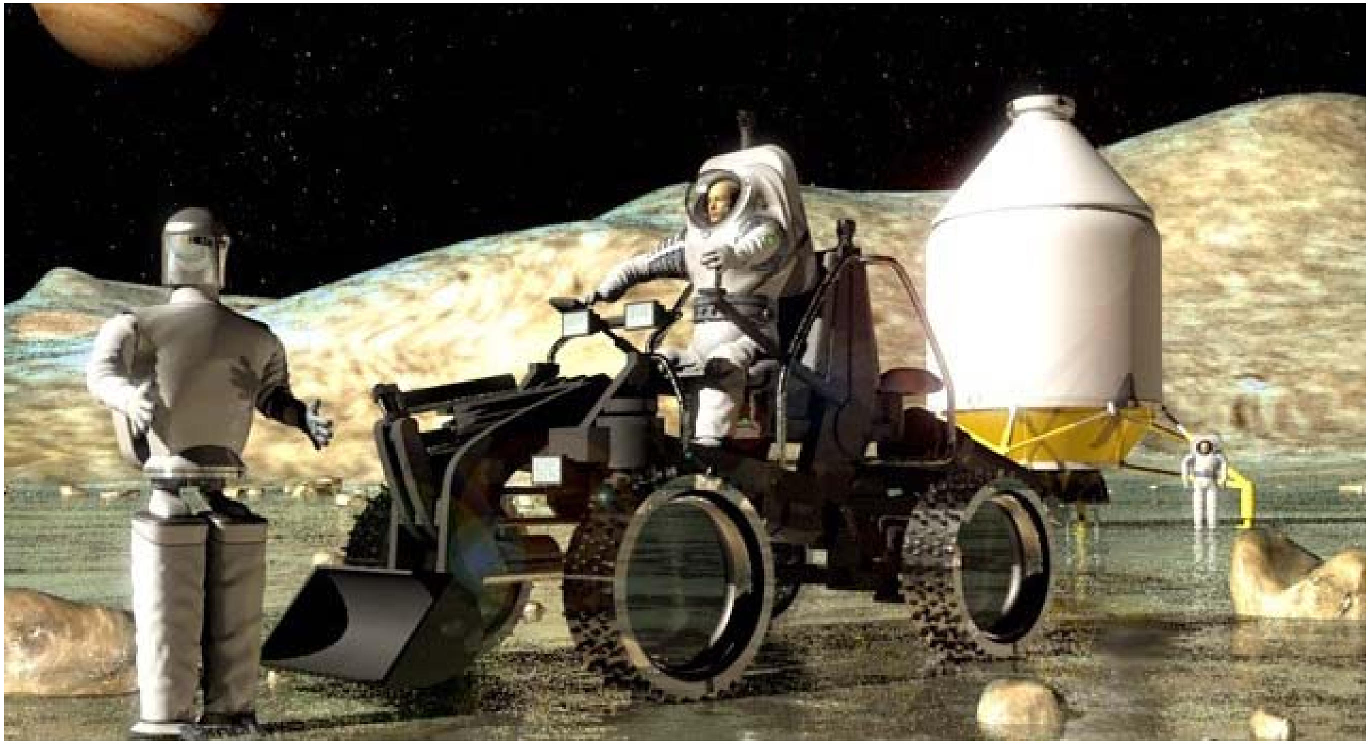
- Brayton Nuclear Reactor Power System (2 Reactors, ~ 400 kW_e total)
- Antennas and transmitters

Surface Hab

Crew Lander

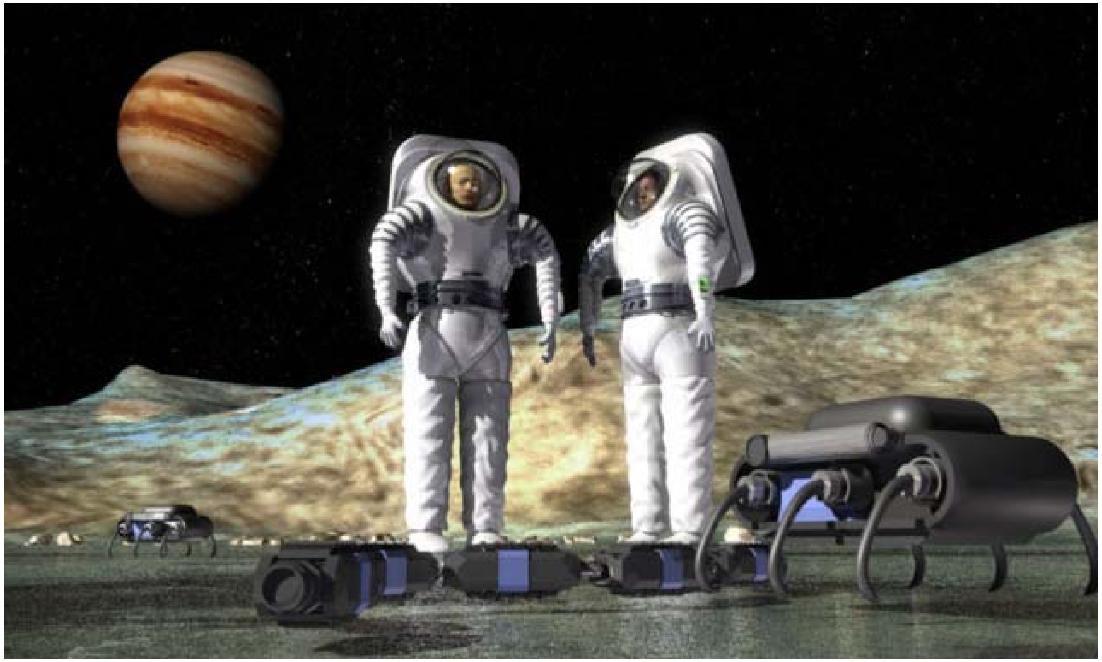
Large-Scale Concept: Unique Components

- 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?

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

Conclusion

Concepts and technology requirements to enable human exploration of the outer planets have been identified

Roundtrip crewed mission times from 2 to 5 years to the Jupiter system are achievable given significant advances in propulsion technologies

Anonymous quote:

“HOPE sees the invisible, feels the intangible and achieves the impossible”