ASCE Earth & Space Conference
A Virtual Conference | April 19–23, 2021
Engineering for Extreme Environments

Massless Exploration – Humans as a Solar System Species

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Introduction

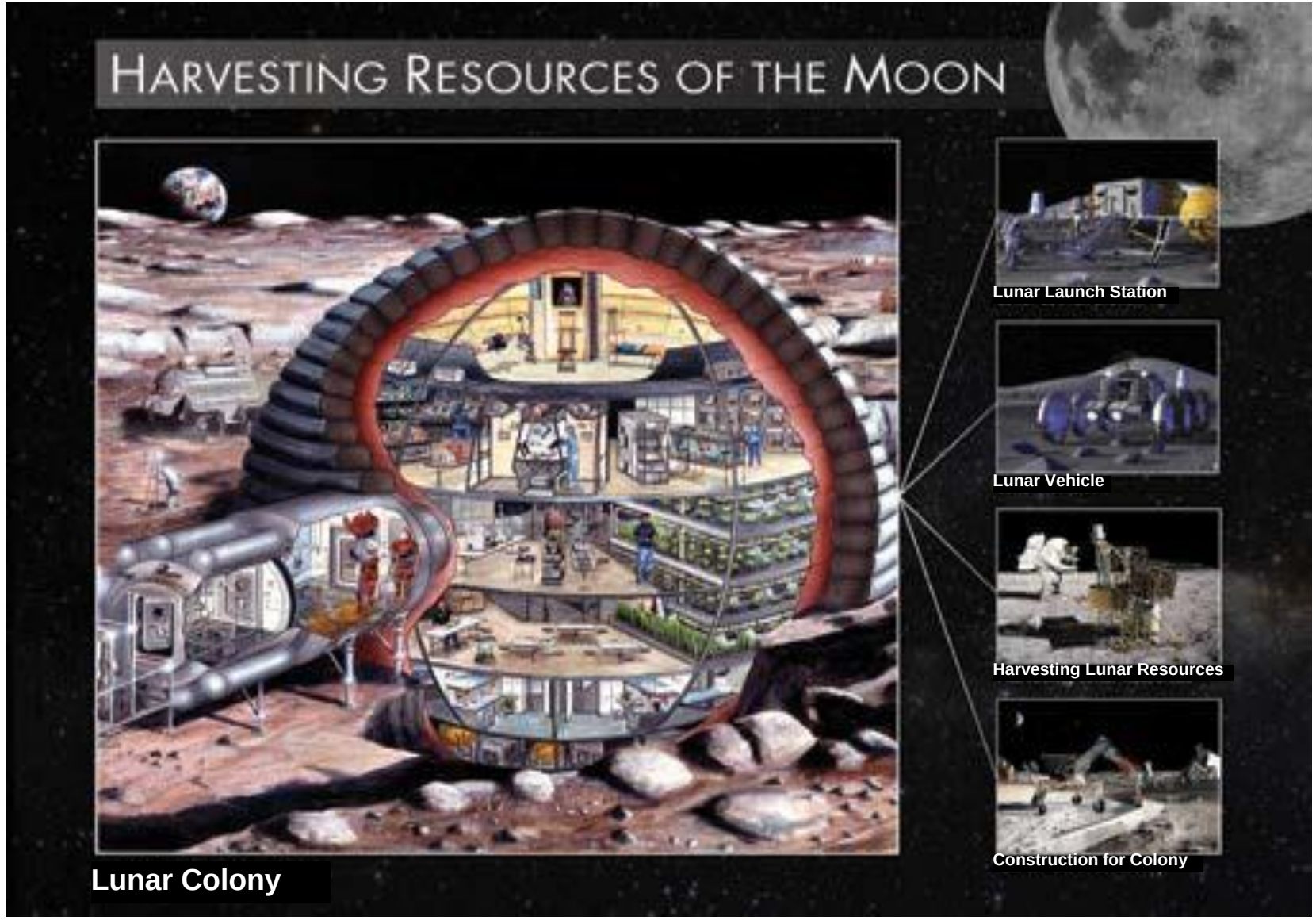
- **Massless exploration and in-situ resource utilization (ISRU).**
- **Sprints:**
  - **Lunar colony**
  - **Earth-Moon Lagrangian point hub**
  - **Mars - Phobos - Deimos**
  - **Jupiter – Voyage to Callisto**
- **Observations.**
- **Concluding remarks.**

Key drivers (1 of 2) -

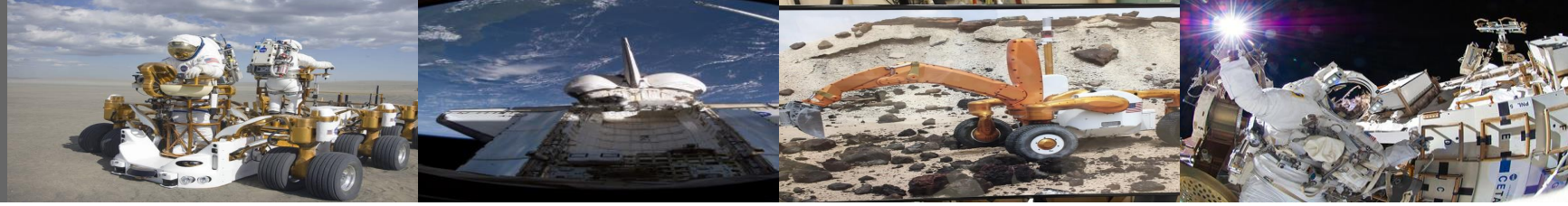
- **Provide economic and lifestyle benefit to people on Earth**
- **Enable space tourism and encourage homesteading – leading to future colonization**
- **Gain scientific knowledge that is of benefit to humanity**
- **Answer the big questions – to better understand the nature of the Universe**

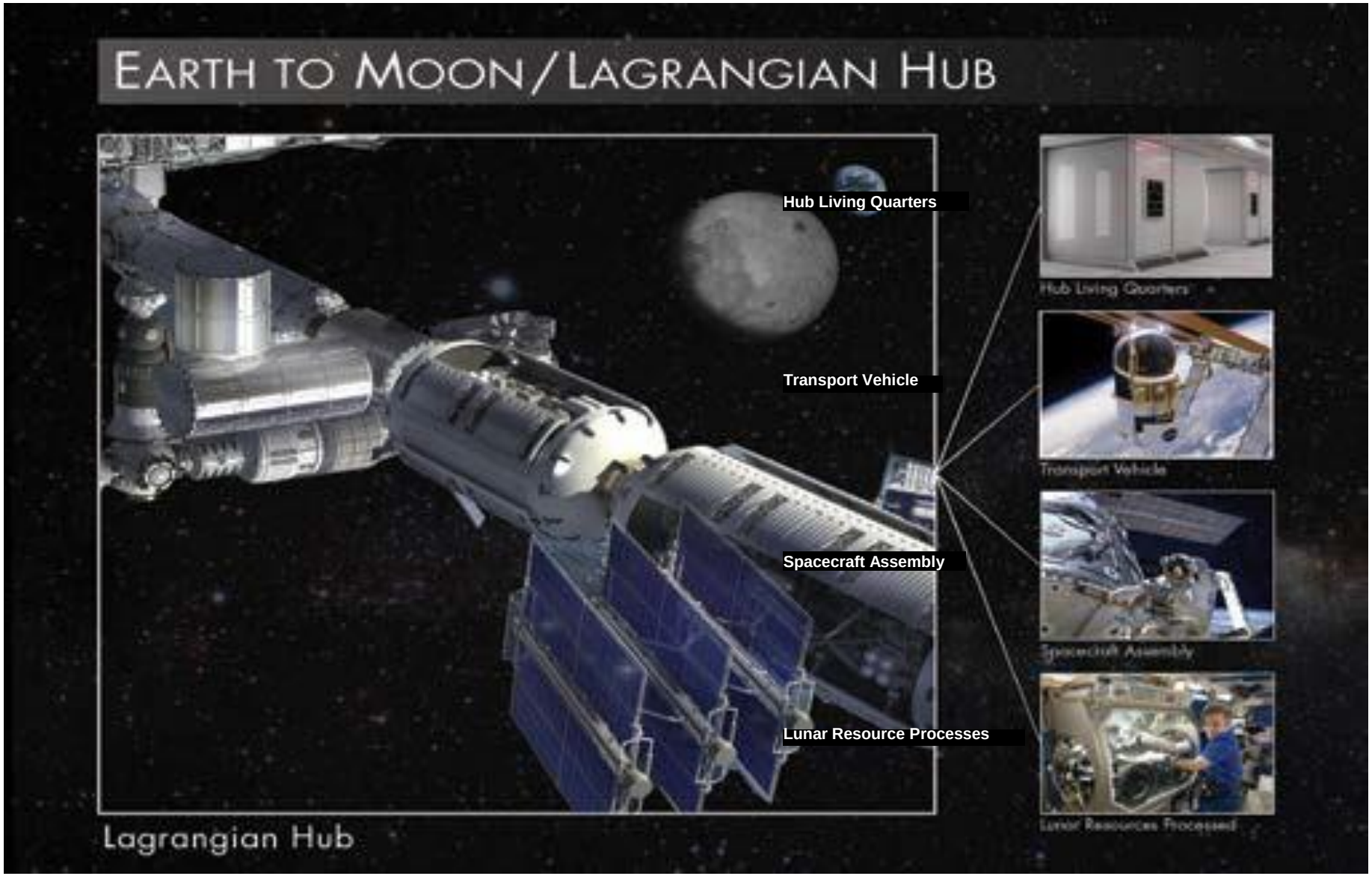
Key drivers (2 of 2) -

- **Enable the human expansion into the Solar System**
- **Bolster confidence for developing a space faring citizenry**
- **Ensure people can work, learn and live safely beyond Earth in sustainable ways**
- **Aid in cataclysmic disaster recovery (i.e., Earth collision with an asteroid or comet - space colonies can assist in disaster recovery)**
- **Expand the human experience.**

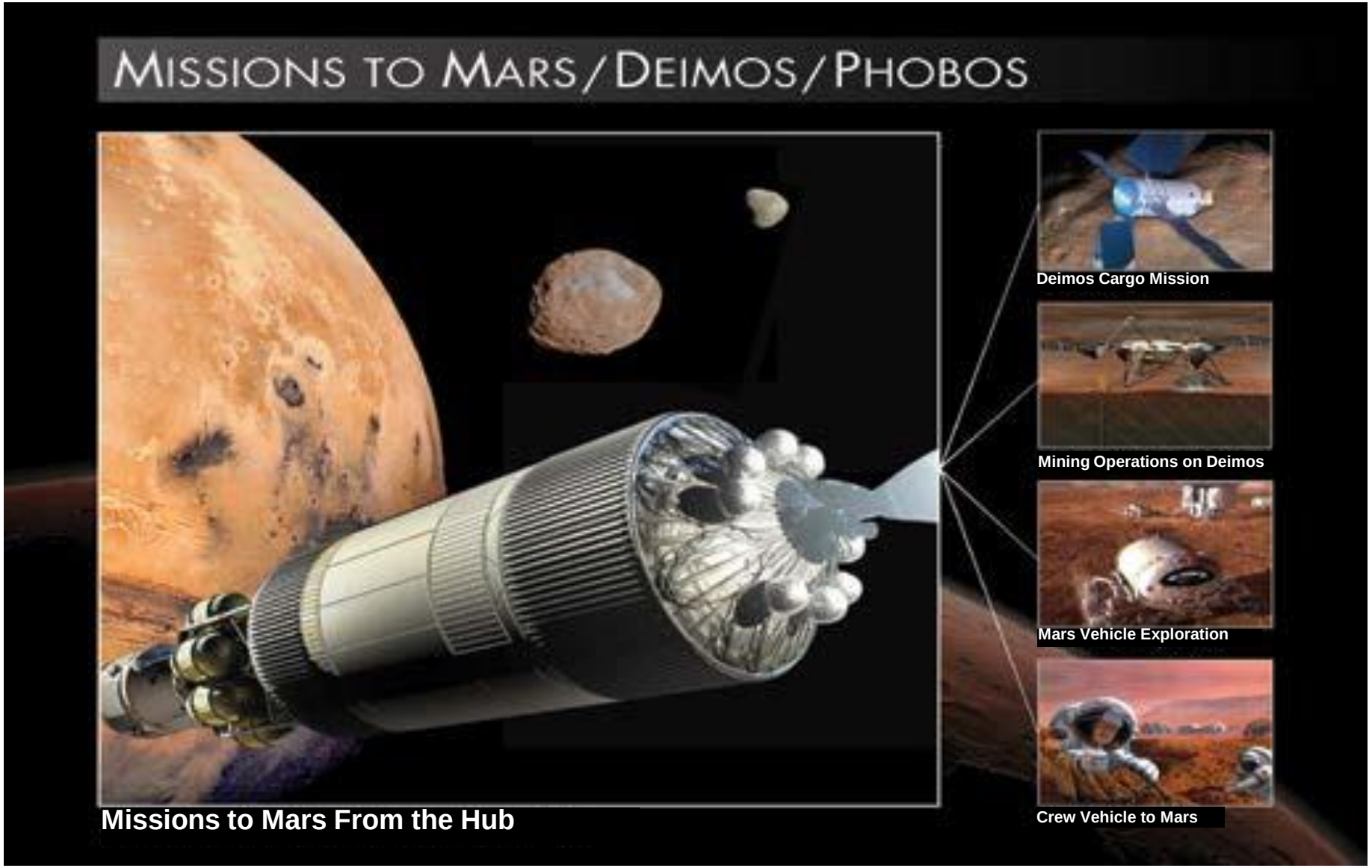

HARVESTING RESOURCES OF THE MOON
Lunar Launch Station
Lunar Vehicle
Harvesting Lunar Resources
Construction for Colony
Lunar Colony

- **Lunar vehicles for exploration, construction, and ISRU.**
- **Robotic assembly of habitats, etc.**



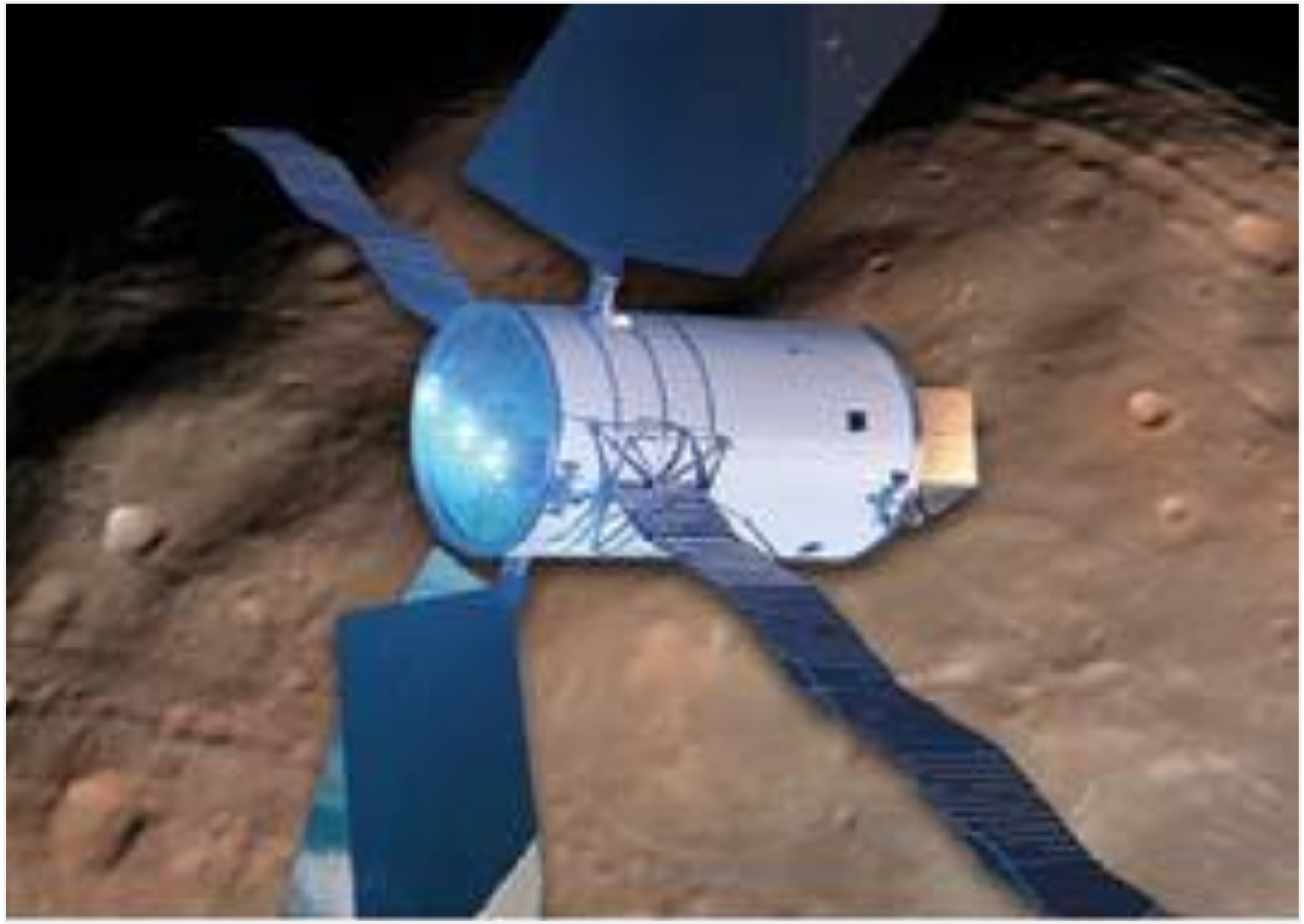

EARTH TO MOON/LAGRANGIAN HUB
Hub Living Quarters
Transport Vehicle
Spacecraft Assembly
Lunar Resource Processes
Lagrangian Hub

- **Pressurized construction and maintenance transport vehicle.**
- **The Hub is a location of Earth-Moon commerce.**



Missions to Mars From the Hub

- **Phobos and Deimos exploration and ISRU.**
- **Martian origins investigated.**

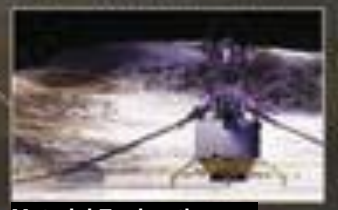


VOYAGE TO CALLISTO

Deep Space Crew Vehicle

Hovering Vehicle

Advanced Cryogenic Suits

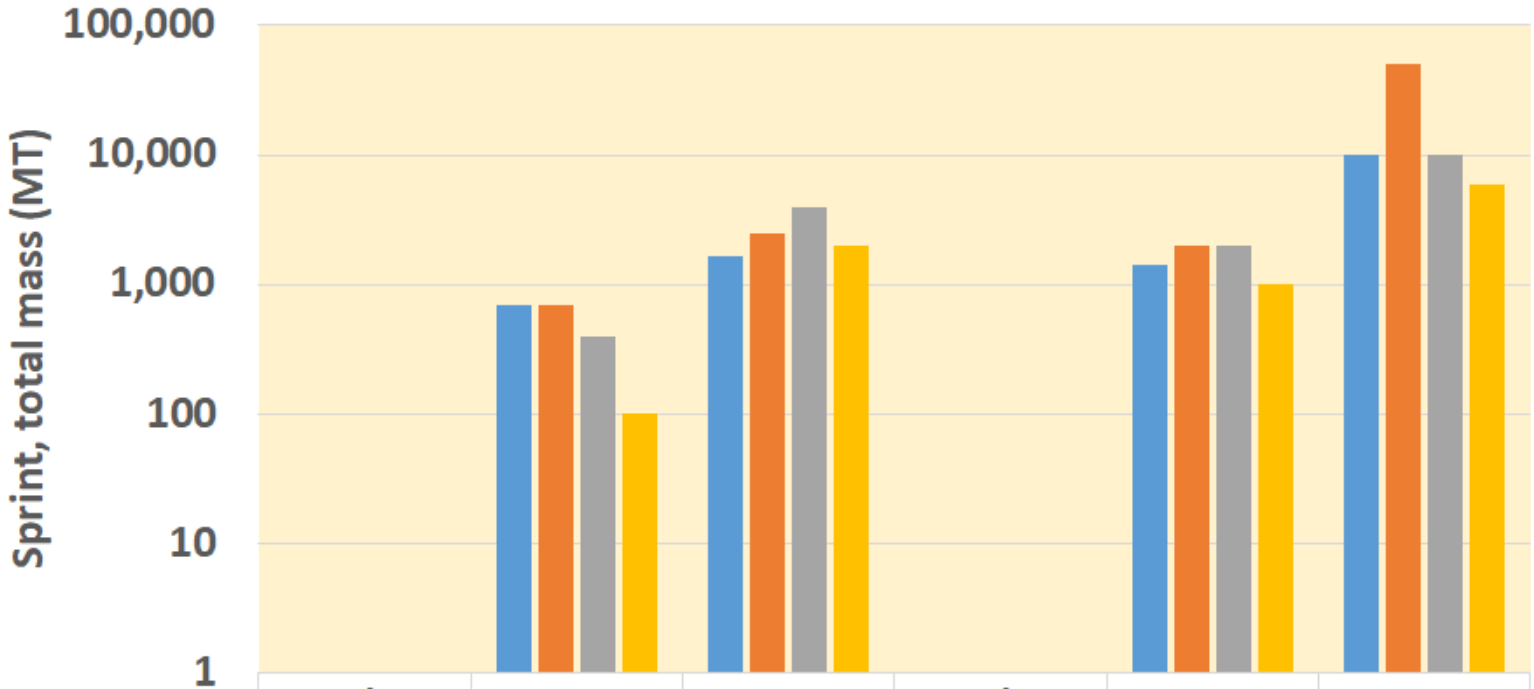


Material Exploration

3-D Printing of Replacement Parts

- **Callisto encampment for exploration and ISRU.**

Massless exploration, minimum and maximum mass estimates



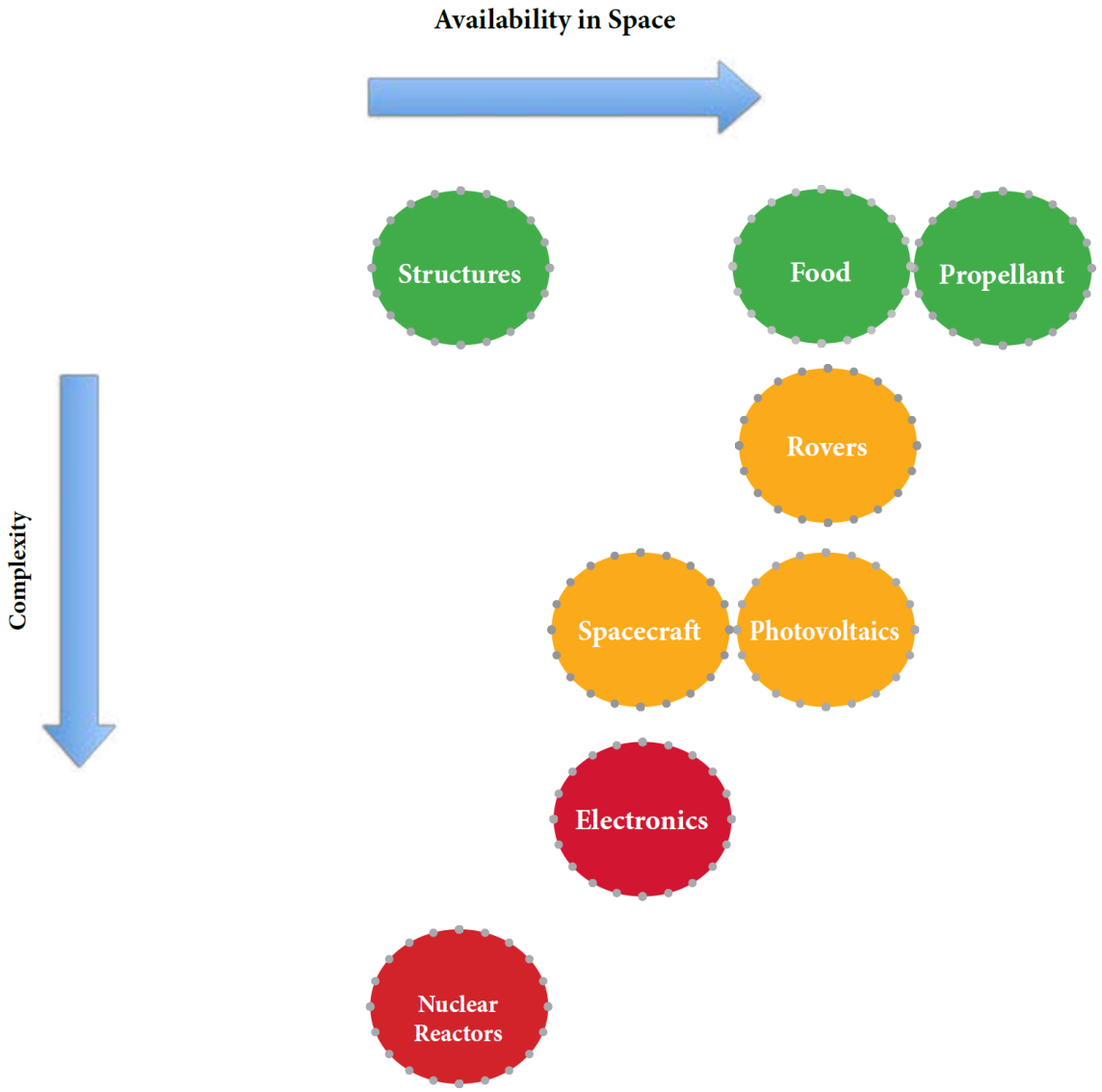
	Sprint, min	Surface	Orbit	Sprint, max	Surface	Orbit
Lunar		700	1,645		1,400	10,000
Libration		700	2,500		2,000	50,000
Mars		400	4,000		2,000	10,000
Jupiter		100	2,000		1,000	6,000

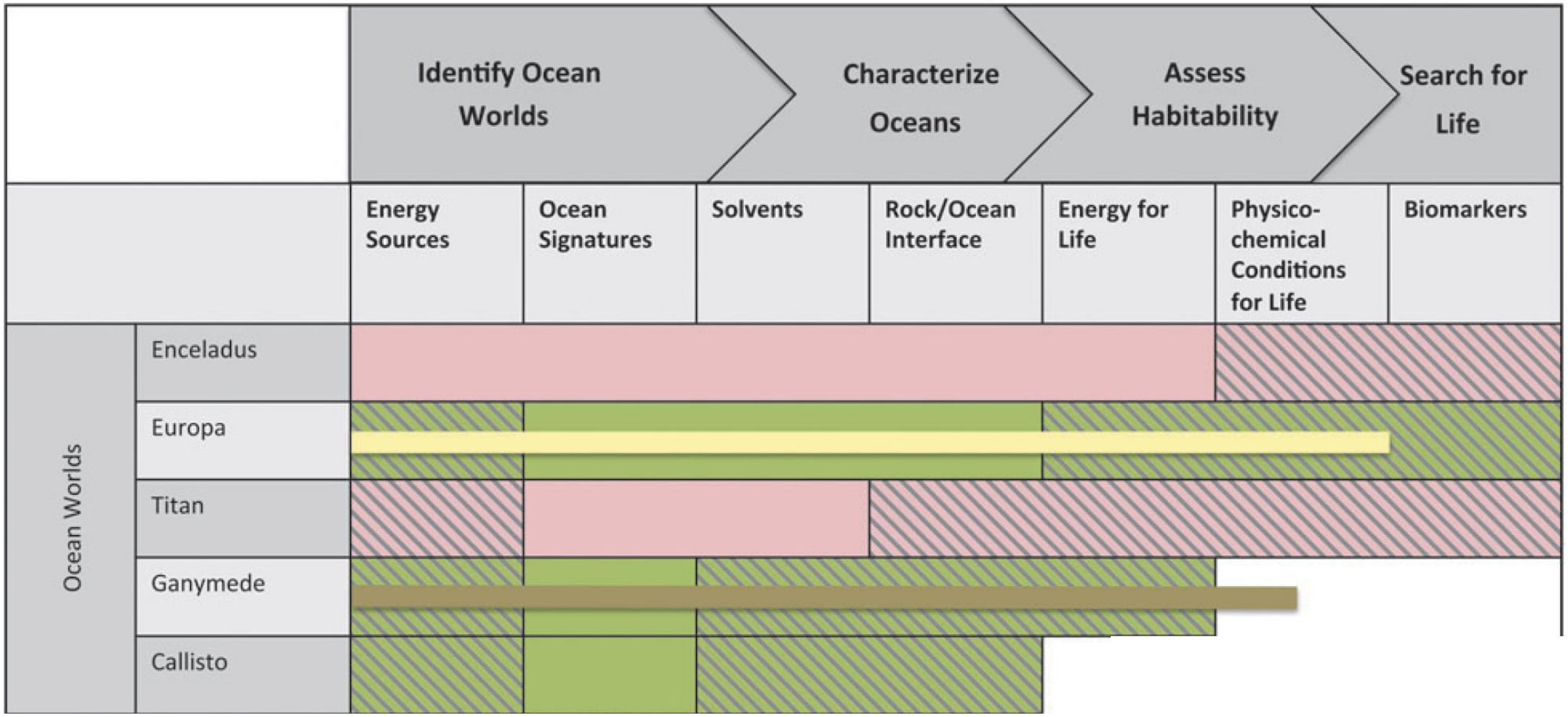
Conclusions

- Massless exploration, or the use of the vast resources available beyond Earth, will allow humanity to more effectively explore space and flourish in many regions beyond Earth.
- Human exploration of the solar system is the next step beyond our current set of robotic exploration and prospecting missions.
- We have used the extensive capabilities of robots to gather data on the mineralogical and chemical composition of the other planets and their gaseous atmospheres.
- Using this data, we can formulate plans to use these minerals and gases to sustain human life and bolster our exploration plans.

Back-up charts

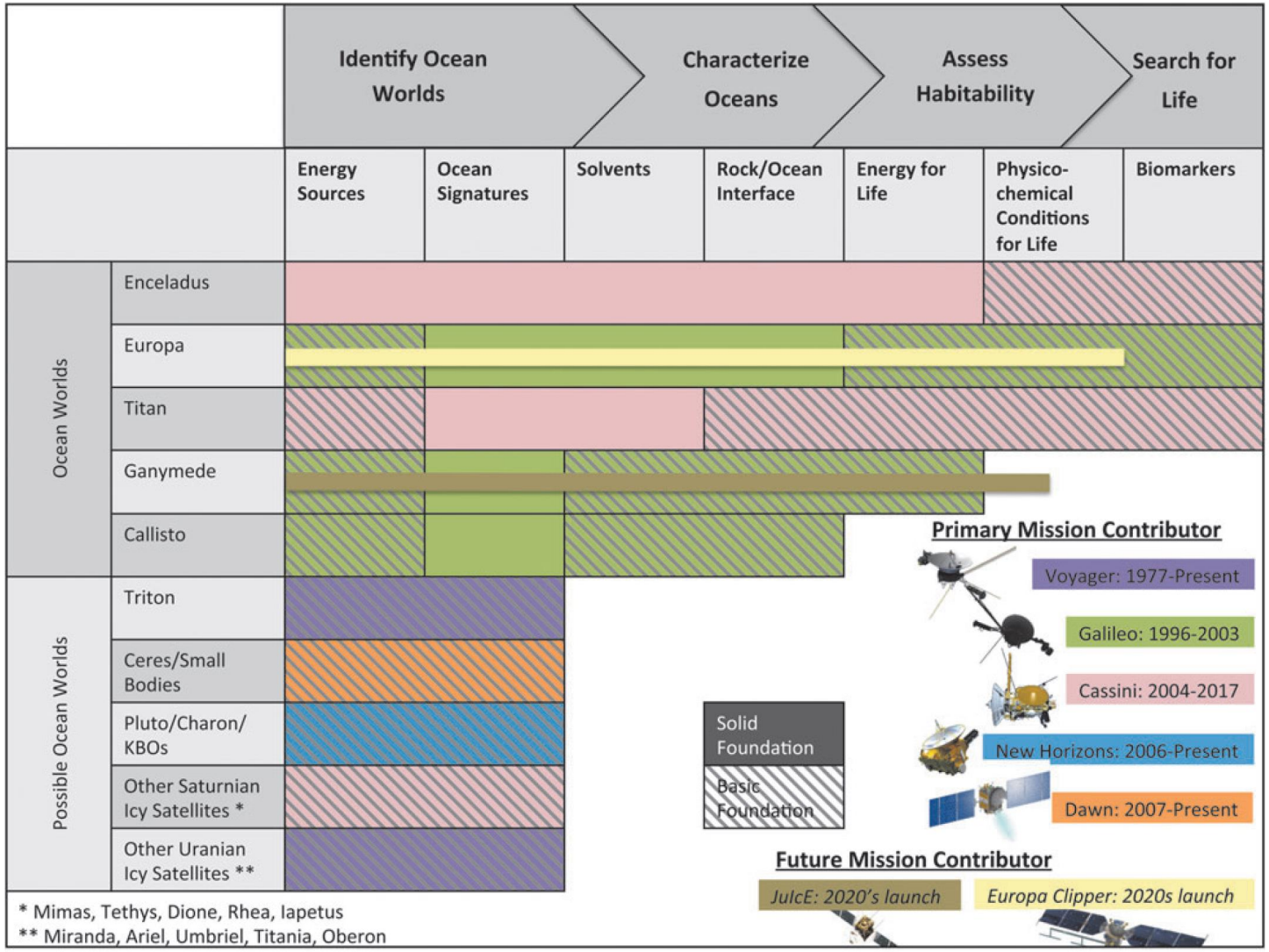
- **Complexity vs. Availability:**
  - **Earth supplied**
  - **Hybrid**
  - **Space in-situ**





The NASA Roadmap for Ocean Worlds, ASTROBIOLOGY, Volume 19, Number 1, 2019.

Results -
The NASA Roadmap for Ocean Worlds, ASTROBIOLOGY, Volume 19, Number 1 2019.



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Target	Earth – Moon (2025)	Earth-Moon Lagrangian Hub (2030 – 2045)	Hub (L2) Near Earth Asteroid Mars (2030 – 2045)		Hub (L2) Callisto (2060 – 2065)
Redundant Systems	Cross-trained personnel Two fault tolerant infrastructure (emergency back up systems) Spacecraft/ system components that can be repurposed in multiple ways	Lunar-derived propellants pre-positioned at Hub for travel to Mars	Separate missions so that each spacecraft has emergency rescue capability for the crew of the other Rapid production of space solar power to avert an impending energy crisis on Earth	Mars moons-derived propellants for Mars ascent-descent and travel to Callisto	Dissimilar power systems enabled by local environment as backup to main nuclear power (e.g., native H2/O2 fuel cells, electrodynamic tethers (see power entries)
Communications	Communication networks - high capacity communications systems Space Communication and Navigation (SCaN), (inter-planetary augmentation to the deep space network)		High data rate megabit/ gigabit/terabit per second data rates for space traffic control systems Optical communication systems High power science instruments (high power RF radar)		Utilizing quantum physics (quantum entanglement) for breakthrough/ disruptive technological advances

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Protective Systems	Use regolith for shielding	Magnetic field generating devices to protect against solar flares	Infrastructures to detect, assess and deflect asteroids to prevent disasters on Earth and other human colonies in the solar system Using in situ resources (propellants and propulsion structures) from the moon or the asteroid to deflect the asteroids	Portable magnetic field generating devices to protect against solar flares	
Space Suits	Made from thin, light weight Next generation space suits incorporating the technology of thin constricting, unpressurized spacesuits (see Dava Newman's work)	Protective and smart textiles more embedded and integrated into human diagnostic and health monitoring devices, feedback via alert systems, dispense drugs , first responder capability Embedded microchips to enhance learning, memory and health monitoring		Thin materials (pressurization may not be necessary) - with adequate thermal and radiation protection	




Industry/Co.	Established Earth	Established Space	Prospective Space	The Hook
Nanorobotics	●	●	●	Expands the market space for use in mfg. as well as medicine (in space and on Earth)
Clothing -Wearable Technologies	●	●	●	Mature market but always expanding and optimizing for greater performance. Human health monitoring, first response to injury, communication of injury, wearable computing/displays, augmented attachments (knowledge base). Prospecting to accommodate increased hazards and environmental challenges
Biomimetics	●	●		Paid to help space developers, builders, and growers and medical practitioners to optimize processes and to learn and apply adaptation principles quickly
Drone Technologies (robotics)	●	●	●	New market space enabling the transport of resources to meet demand; transport resources to Earth.
Computing	●	●	●	New market space – provide computing to operate equipment and facilities in space
Security	●		●	New market space – paid to keep international peace in space
Autonomous Mfg.	●	●	●	Little 3D robots building bigger 3D robots prototypes sent to near earth asteroids and Mars
Camera/Sensor Technology	●	●	●	To establish a stake in the market for residential and commercial wearable device industry, robotic industry
Heavy Vehicle Industry	●		●	New market – paid to optimize and adapt vehicle construction process using materials found in space as well as recycled space ships

Industry/Co.	Established Earth	Established Space	Prospective Space	The Hook
Consortium of Power Companies	●		●	Paid to manage and provide expertise for power generation and distribution plants, maintain power grid knowledgebase, optimize power grids as demand/supply increases
Construction	●		●	Paid to build/erect structures and infrastructures throughout the solar system
Logistics Providers (Amazon)	●			Paid to warehouse and route on demand items to settlers and explorers
Biomimicry	●	●	●	Paid to optimize engineering design and processes by observing and applying nature's solutions to typical problems encountered in the space environment
Mental Health	●		●	New market (space medicine) – paid to ensure mental health of settlers and explorers
Pharma	●		●	Paid to provide and manufacture drugs using in situ herbs/plants
Recreation	●		●	Paid to provide recreational facilities and activities
Volunteers			●	Category of individuals who are not seeking compensation but an opportunity to serve their country and be part of the experience
Education	●		●	Paid to establish international space universities and colleges – concentrated on subjects/disciplines needed for space exploration and colonization
Space Agriculture (Botany)	●		●	New market (space agriculture) Paid to cultivate/grow herbs, spices and plants for use in enhancing foods and manufacturing medicines




Sprint Summary - Systems - 1 of 3

Legend | Green cells indicate - Earth dependent

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Sprint Summary - Systems - 2 of 3

Legend | Green cells indicate - Earth dependent

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Key Industry Partners - 3 of 4

Legend
Established on Earth - has an established business on earth with products that could be transferred
Established industry in space - has an established business in space with products that could be expanded
Prospective in space – future opportunity that is not yet established

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Camera/Sensor Technology	●	●	●	To establish a stake in the market for residential and commercial wearable device industry, robotic industry
Heavy Vehicle Industry	●		●	New market – paid to optimize and adapt vehicle construction process using materials found in space as well as recycled space ships

Key Industry Partners - 4 of 4

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