The Origins, Worlds, and Life Report: Relevant aspects for humans at Mars

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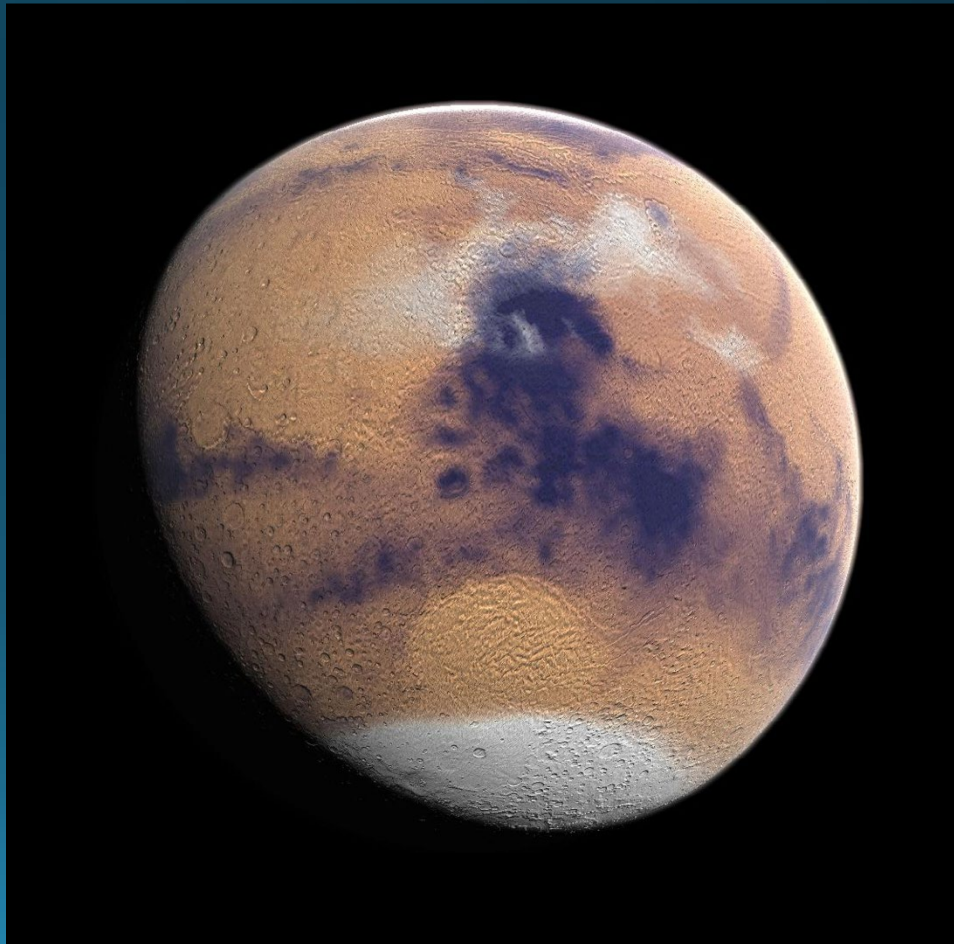

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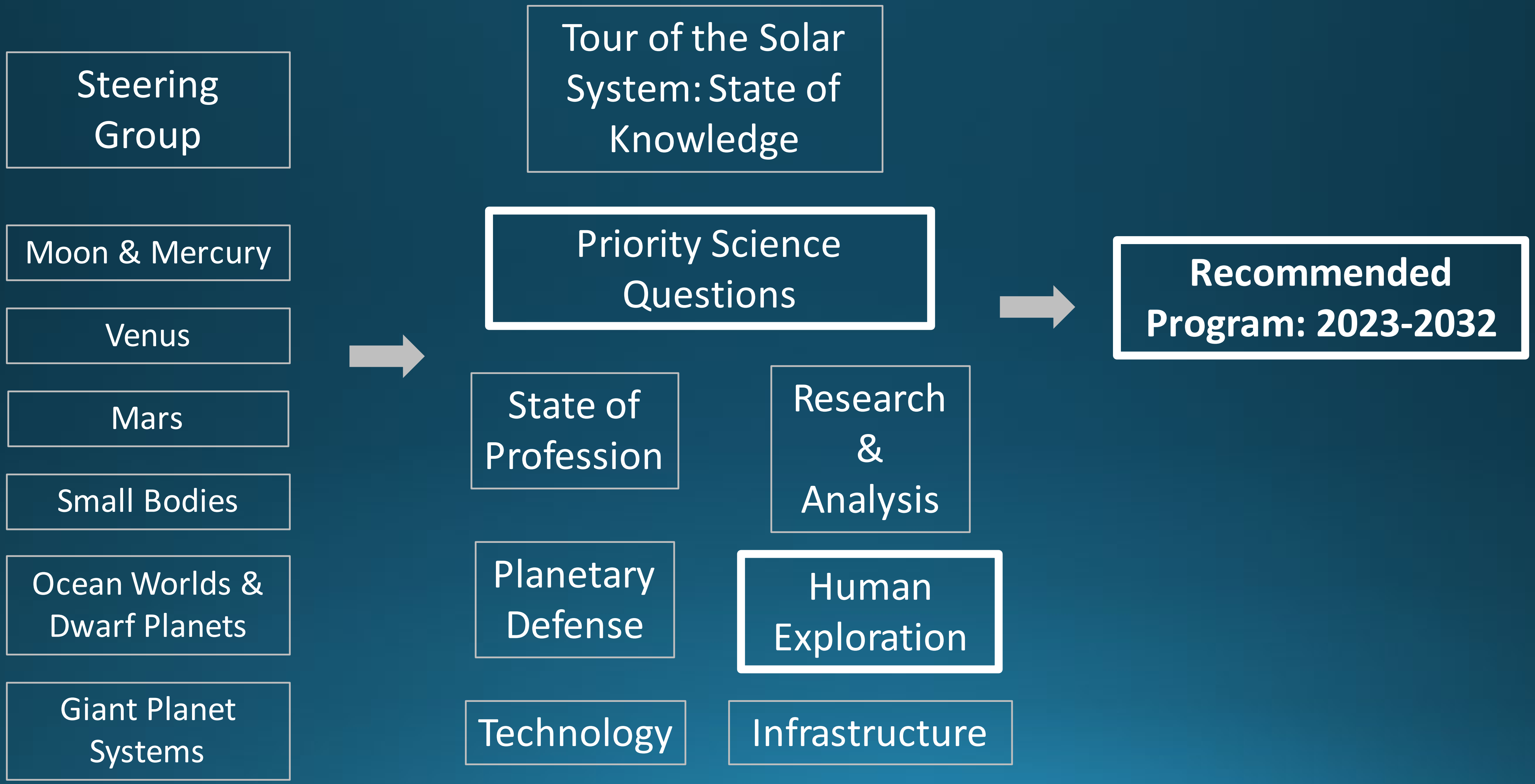
Survey and Report Organization



Some key messages

1) Strong support for a robotic Mars Sample Return

Mars Sample Return

- The DS report recommended that:

  “The highest scientific priority of NASA’s robotic exploration efforts in the coming decade should be completion of Mars Sample Return as soon as is practicably possible with no increase or decrease in its current scope”

- The Decadal Survey Committee endorsed the existing architecture - which has been in place since the 1970’s: Collect high-quality samples; 2) get them off the surface; 3) get them to Earth

- The DS Committee did not perform an assessment of the MSR costs
  - The MSR costs in the DS report were provided to the Committee by NASA

Some key messages

1) Strong support for a robotic Mars Sample Return
2) The importance of the Mars Exploration Program

Mars Exploration Program (MEP)

The Mars Exploration Program is a scientific success story whose stability enables:

- Strategic science planning across decades
- The development of a multi-generational science community that defines the program goals
- Multi-mission coordination
- International collaboration

NASA should maintain the Mars Exploration Program which should:

- **Continue to be managed within the PSD**
- **Maintain its focus on the scientific exploration of Mars.**
- **Develop and execute a comprehensive architecture of missions, partnerships, and technology development**




Some key messages

1) Strong support for a robotic Mars Sample Return
2) The importance of the Mars Exploration Program
3) Science should drive human exploration
4) Experience gained by human exploration at the Moon will guide the human exploration of Mars
    - Technical challenges
    - Human factors challenges
    - Programmatic challenges

Some key messages

5) In addition to providing scientific knowledge, precursor robotic science missions will continue to play critical role in reducing the cost and risk of human missions to Mars

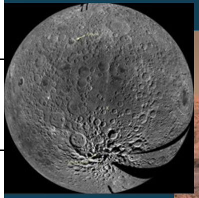
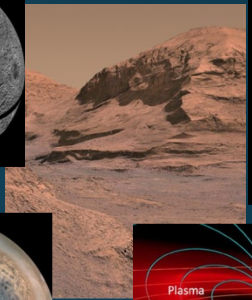
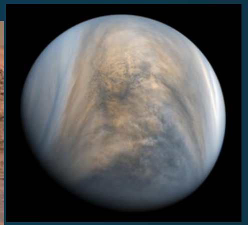
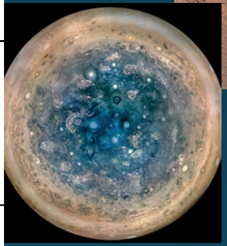
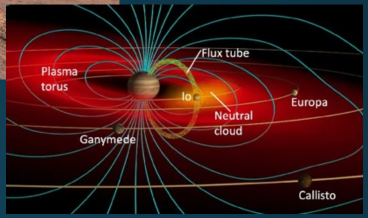
6) Much of the Committee’s efforts focused on Artemis and the Moon, but the findings and recommendations are directly relevant to human missions to Mars

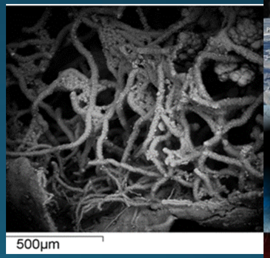
Science as the driver

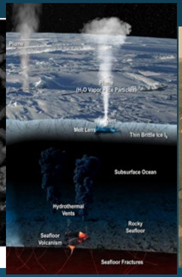
- Science questions, and the role Mars plays in addressing them, are outlined in the science question chapters

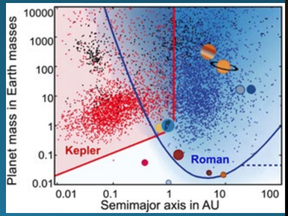
Themes	Priority Science Question Topic and Scope
A) Origins	**Q1. Evolution of the protoplanetary disk** What were the initial conditions in the Solar System? What processes led to the production of planetary building blocks, and what was the nature and evolution of these materials?
	Q2. Accretion in the outer solar system How and when did the giant planets and their satellite systems originate, and did their orbits migrate early in their history? How and when did dwarf planets and cometary bodies orbiting beyond the giant planets form, and how were they affected by the early evolution of the solar system?
	Q3. Origin of Earth and inner solar system bodies How and when did the terrestrial planets, their moons, and the asteroids accrete, and what processes determined their initial properties? To what extent were outer Solar System materials incorporated?
B) Worlds & Processes	**Q4. Impacts and dynamics** How has the population of Solar System bodies changed through time, and how has bombardment varied across the Solar System? How have collisions affected the evolution of planetary bodies?
	Q5. Solid body interiors and surfaces How do the interiors of solid bodies evolve, and how is this evolution recorded in a body’s physical and chemical properties? How are solid surfaces shaped by subsurface, surface, and external processes?
	Q6. Solid body atmospheres, exospheres, magnetospheres, and climate evolution What establishes the properties and dynamics of solid body atmospheres and exospheres, and what governs material loss to space and exchange between the atmosphere and the surface and interior? Why did planetary climates evolve to their current varied states?
	Q7. Giant planet structure and evolution What processes influence the structure, evolution, and dynamics of giant planet interiors, atmospheres, and magnetospheres?
	Q8. Circumplanetary systems What processes and interactions establish the diverse properties of satellite and ring systems, and how do these systems interact with the host planet and the external environment?
C) Life & Habitability	**Q9. Insights from Terrestrial Life** What conditions and processes led to the emergence and evolution of life on Earth, what is the range of possible metabolisms in the surface, subsurface and/or atmosphere, and how can this inform our understanding of the likelihood of life elsewhere?
	Q10. Dynamic Habitability Where in the solar system do potentially habitable environments exist, what processes led to their formation, and how do planetary environments and habitable conditions co-evolve over time?
	Q11. Search for life elsewhere Is there evidence of past or present life in the solar system beyond Earth and how do we detect it?
All Themes	**Q12. Exoplanets** What does our planetary system and its circumplanetary systems of satellites and rings reveal about exoplanetary systems, and what can circumstellar disks and exoplanetary systems teach us about the solar system?

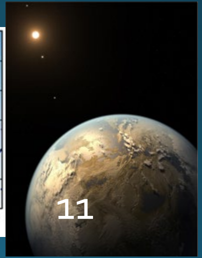










Science Question Chapters: Key Takeaways

- **Crucial role of sample return and in situ analyses**
- Dearth of knowledge of the ice giant systems
- Importance of primordial processes to compositional reservoirs, planetary building blocks and primitive bodies, and early solar system dynamical evolution
- Interplay of internal and external processes that affect planetary bodies
- **Varied evolutionary paths of the terrestrial planets**
- **Central question of how life on Earth emerged and evolved, and the compelling rationale to study habitable environments at Mars and icy ocean worlds**
- **Desire to make substantive progress this decade in understanding whether life existed (or exists) elsewhere in the solar system**

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- Science questions, and the role Mars plays in addressing them, are outlined in the science question chapters
- Committee gave special attention to the *role* science should play in human exploration
- We began by considering what makes a program sustainable
  - We defined “sustainable” as meaning that there are widely accepted reasons to continue human exploration that justify long-term investment
  - These include:
    - Ongoing scientific discoveries
    - Potential commercial and technology development
    - Educating the next generation of STEM professionals and a scientifically literate public

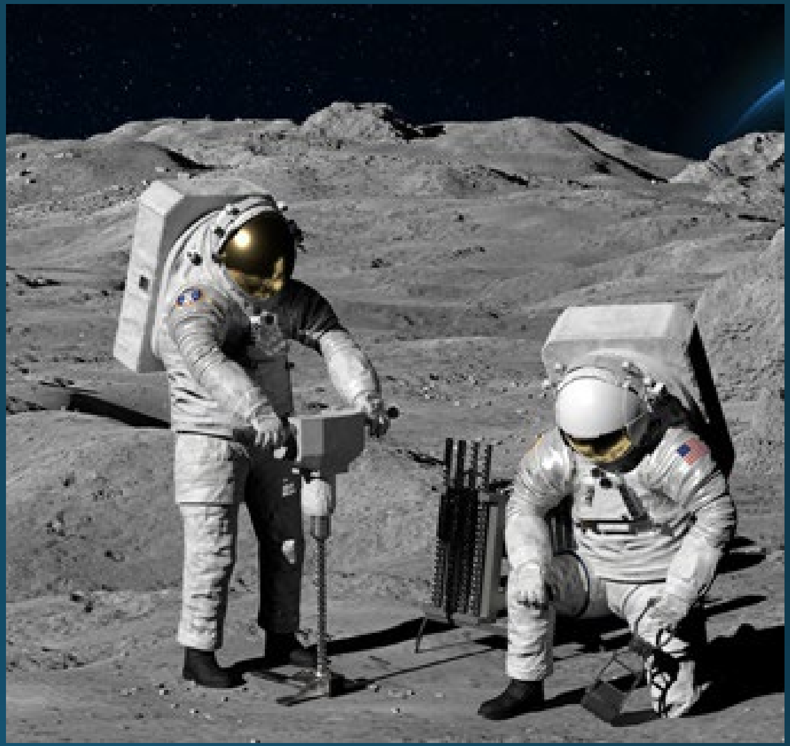
Science as the driver

- The report notes that:

  "The promise of exciting discovery is a core element of ambitious and enduring space programs, as evidenced by the success of sustained robotic programs such as the Hubble Space Telescope and the Mars Exploration Program."

Science-related Findings

- A crucial driver of sustained human exploration is the ability of human explorers to conduct and enable the highest quality science



Examples of human contributions to exploration
Astronauts are well-equipped to conduct sorties and sample and return intact cores deeper (>1 m) than easily accomplished by robotic missions
Astronauts can collect more and better geologic samples than robotic missions by virtue of their ability to rapidly assess geologic context to select the optimal samples, conduct traverses to allow for increased sample diversity, and deploy sophisticated in situ monitoring to conduct life detection investigations
Astronauts can efficiently deploy stations over a wide area

Science-related Recommendations

- Human exploration is aspirational and inspirational, and NASA's Moon-to-Mars plans hold the promise of broad benefits to the nation and the world
- A robust science program provides the motivating rationale for sustained human exploration

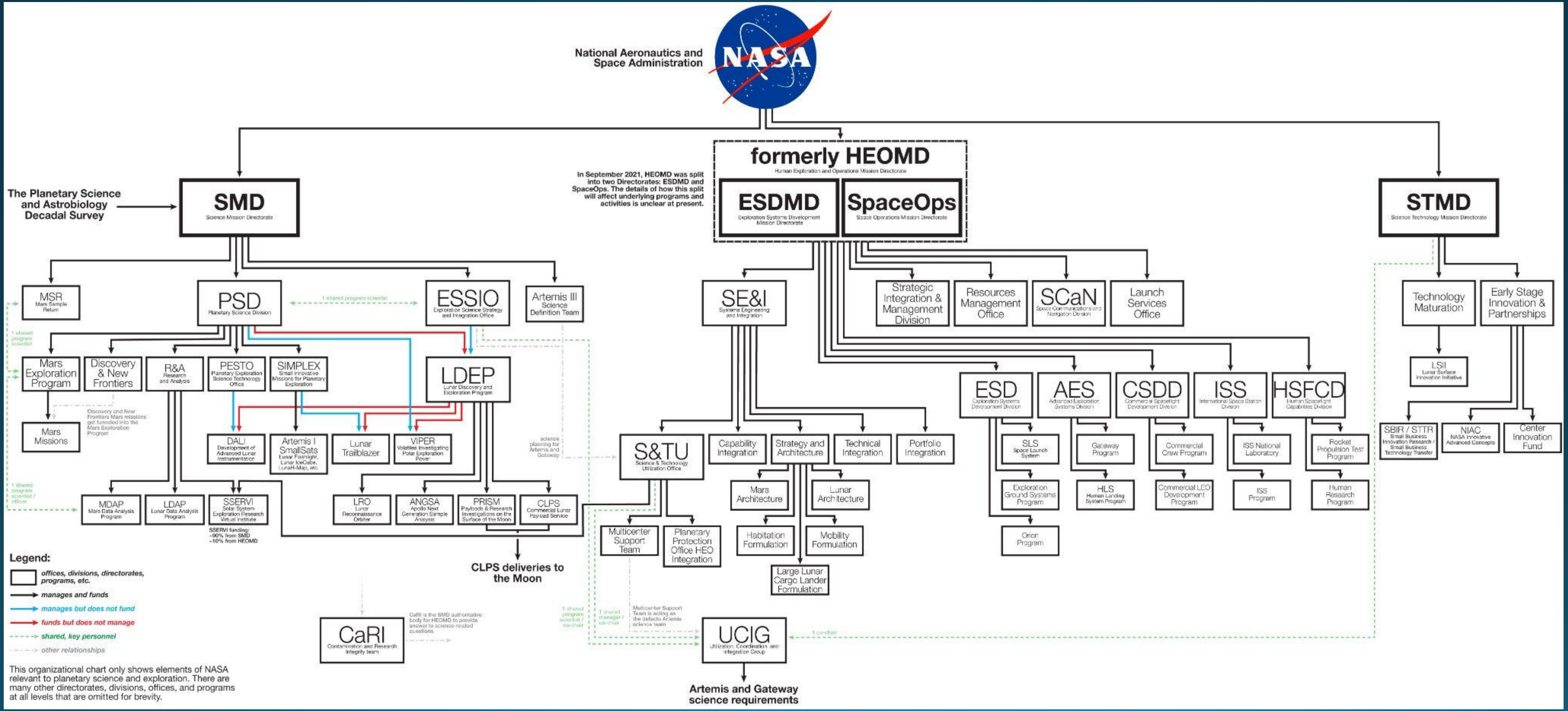
- **Conducting decadal-level science should be a central requirement of the human exploration program**
- **NASA should engage with the science community to 1) define scientific goals for its human exploration programs at the early stages of program planning; and 2) ensure scientific expertise in field geology, planetary science, and astrobiology in its astronaut teams**

Programmatic issues

- Developing communication and trust between the scientific, engineering, and human exploration communities is essential
- The appropriate management philosophy and approach is fundamental to success

Programmatic issues

- Develop an effective management structure……



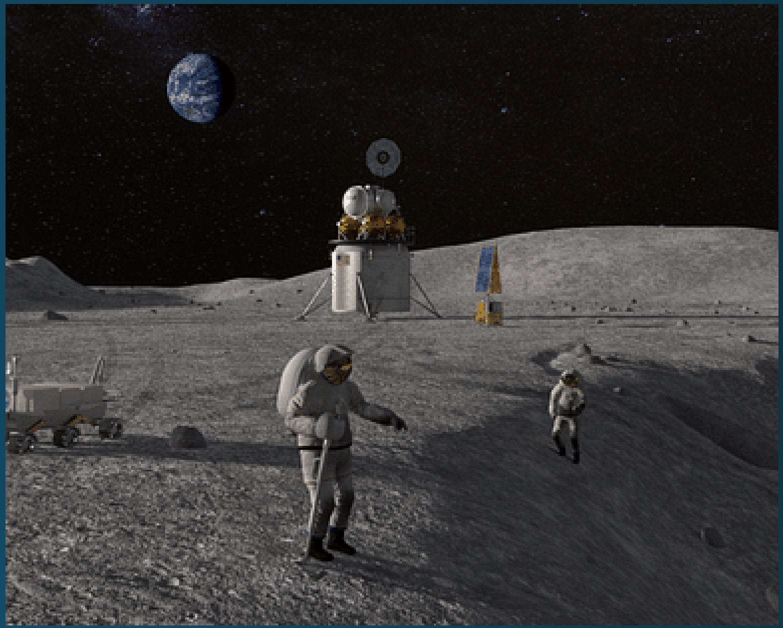
Programmatic-related Findings

- The systems engineering approach needed to incorporate science objectives and requirements needs to occur in the early stages of human mission planning and hardware development. The later such integration occurs, the greater the risk of prohibitive expense associated with scientific requirements and/or the exclusion of priority science altogether.
- NASA has not yet developed a planetary protection plan and related research activities specifically tailored to human missions to Mars
- SMD has not formulated an Artemis Science Team nor developed a plan for creating the science capabilities required for achieving high priority lunar science through human exploration

Programmatic-related Recommendations

- **NASA should adopt an organizational approach in which SMD has the responsibility and authority for the development of Artemis lunar science requirements that are integrated with human exploration capabilities. NASA should consider establishing a joint program office … to develop program-level requirements across SMD, ESDMD, SpaceOps, and other Directorates as appropriate**

- **PSD should have the authority and responsibility for integrating science priorities into the human exploration plans for Mars**



Concluding thoughts

- Need to complete MSR and maintain a robust Mars Exploration Program
- Need to deeply embed science into the human exploration of the Moon and Mars
- Develop strong communication and build mutual understanding and trust
- Build a sustainable program that the public understands and supports
- Need to create a credible path for humans to Mars – it can’t just be a slogan