

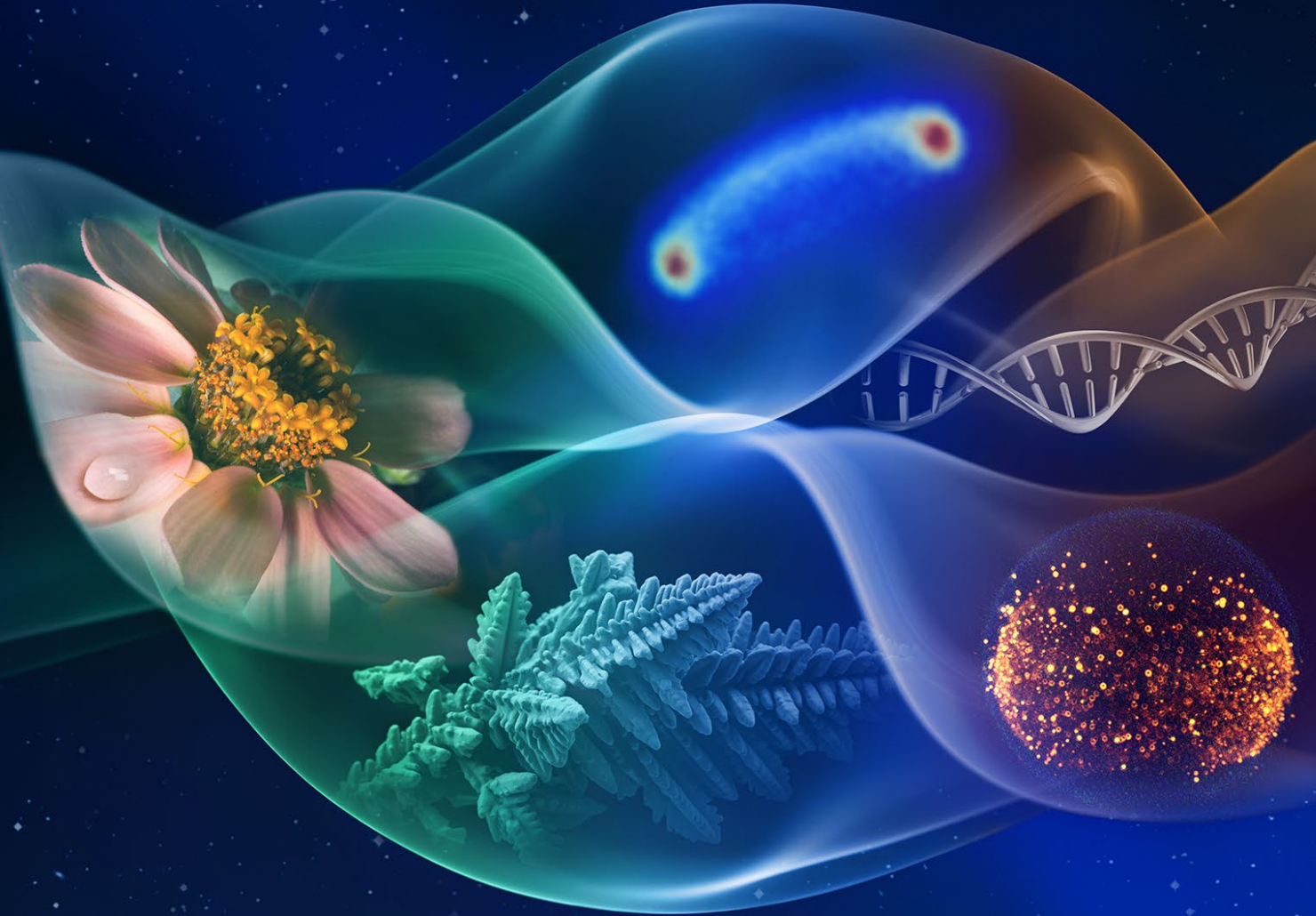


BPS

BIOLOGICAL AND
PHYSICAL SCIENCES

Progress Toward KSQs for Physical Sciences

NASA MSFC EM31
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Key Science Questions (KSQs) from the 2023 Decadal Survey

KSQ 01	▶ How does the space environment influence biological mechanisms required for organisms to survive the transitions to and from space, and thrive while off Earth?
KSQ 02	▶ How do genetic diversity and life history influence physiological adaptation to the space environment?
KSQ 03	▶ How does the space environment alter interactions between organisms?
KSQ 04	▶ What are the important multi generational effects of the space environment on growth, development, and reproduction?
KSQ 05	▶ What principles guide the integration of biological and abiotic systems to create sustainable and functional extraterrestrial habitats?
KSQ 06	▶ What principles enable identification, extraction, processing, and use of materials found in extraterrestrial environments to enable long-term, sustained human and robotic space exploration?
KSQ 07	▶ What are the relevant chemical and physical properties and phenomena that govern the behavior of fluids in space environments?
KSQ 08	▶ What are the mechanisms by which organisms sense and respond to physical properties of surroundings and to applied mechanical forces, including gravitational force?
KSQ 09	▶ What are the fundamental principles that organize the structure and functionality of materials, including but not limited to soft and active matter?
KSQ 10	▶ What are the fundamental laws that govern the behavior of systems that are far from equilibrium?
KSQ 11	▶ What new physics, including particle physics, general relativity, and quantum mechanics, can be discovered with experiments that can only be carried out in space?

What principles enable identification, extraction, processing, and use of materials found in extraterrestrial environments to enable long-term, sustained human and robotic space exploration?

Water / Ice:

- Detection – Robust spectroscopy solutions, both orbital and local, with production feedback for validation
- Excavation – While excavation is led by KSC, there are still numerous techniques being evaluated, trades need to be carefully considered and curated for future comparison studies as the mission environment changes
- **Extraction** – Volatile extraction and collection has several hurdles and complications:
 - Loading of excavated material into a hopper solution
 - True regolith flowability is very different in reduced gravity and with the unweathered morphology of the particulates
 - When comparing to terrestrial based excavation, systems will need to be more numerous, mobile, and specialized, pushing the SOA in ways that will require some initial investments before we'll see the terrestrial ROI
 - Wear-resistant sifting solutions and process encapsulation
 - How are we heating the collected and enclosed regolith?
 - How are we storing volatile products collected?
 - What additional techniques might be required for further refinement?

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While NASA is working numerous techniques and technologies to remove specific materials from the lunar regolith, many of these will need to be further refined and would benefit greatly from the microgravity material science community.

We will need to understand how to:

- Mitigate wear on mechanical systems
- Continue building out autonomous pre-processing techniques
- Functionally integrate science technology developments by seeking infusion points

Some of the technologies that will benefit from BPS soft and active matter research include:

- Molten Regolith Electrolysis (MRE)
- Molten Salt Reactor (MSR)
- Carbothermal Reduction