National Aeronautics and Space Administration

Strategic Knowledge Gaps

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The SBAG SKG SAT Charter

1. List of required knowledge / data sets / technology, traced to human exploration needs.
2. Gaps in that knowledge / data sets / technology relative to our current understanding and capabilities.
3. A timeline of when the missing knowledge / data sets must be acquired or technology developed in order to make architecture-specific decisions or in order to make subsequent measurement decisions. In the context of this timeline, the group should consider interdependencies among the acquisition of knowledge, data sets and development of technology.
4. Provide a list of existing and potential missions, experiments, modeling activities, technology, or any other activity that would fill the knowledge gaps. **Links of potential missions to past National Academy studies and the SBAG Roadmap should be explored.**

The SBAG SKG SAT Charter

5. If additional measurements are required to fill knowledge gaps, ide ntify the fidelity of the measurements needed, and if relevant, prov ide examples of existing instruments capable of making the measu rements. The group should identify any ISS role in filling the ga ps identified.

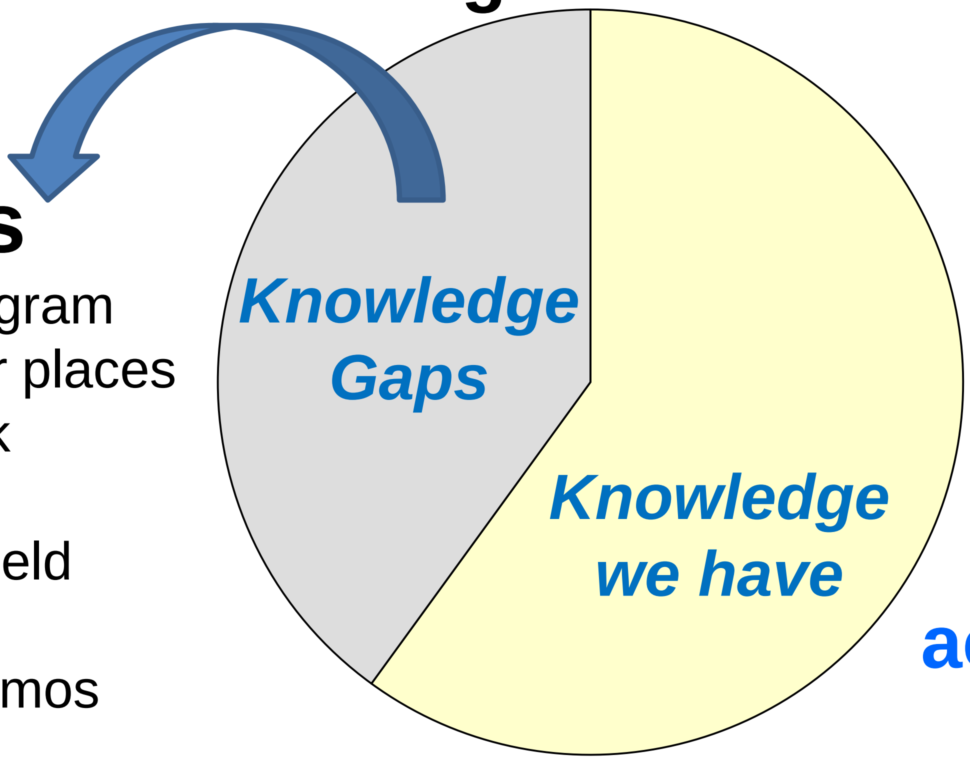
The group will assemble the information and findings into an appropria te set of power point charts and back up materials. It will also create a spreadsheet with the individual knowledge elements and whether t hat information is lacking, and if so how it could be filled.

SKG and GFA: Definitions

1. **Strategic Knowledge Gap (SKG): The Gaps in Knowledge Needed to Achieve a Human Spaceflight Capability.**
2. **Gap-Filling Activity (GFA): Work that contributes to closing an SKG.**

GFA areas

- Mars flight program
- Flights to other places
- Non-flight work (models, lab experiments, field analogs, etc.)
- Technology demos



Total knowledge needed to achieve a goal

SB SKG Themes and Categories

SB SKGs can be organized into several themes, which can be further divided into categories:

I. **Human mission target identification (NEOs).** The identification of multiple targets for human exploration is fundamental.

II. **Understand how to work on or interact with the SB surface.** Human presence may disturb the environment in non-intuitive ways. We need to understand how best to perform sample acquisition and handling, instrument placement, and proximity operations.

III. **Understand the SB environment and its potential risk/benefit to crew, systems, and operational assets.** The small body environment may include dust emitted periodically (for instance via levitation) or episodically (after impact or spin-up events). It may enhance or screen solar radiation. It may be gravitationally metastable.

IV. **Understand the SB resource potential.** ISRU is considered a "game changer" in how humans explore the Solar System by enabling an infrastructure that allows a sustainable human presence in space. The short-stay missions likely to be in the first wave of NEO or Phobos/Deimos visits may test or prepare that infrastructure but are unlikely to take advantage of it.

SB SKG Themes and Categories

SKG Themes	SKG Categories	Examples of SKGs
I. Human mission target identification (NEOs)	A. Constraints on targets B. NEO orbit distribution C. NEO composition/physical characteristics (population/specific targets)	I-A-1. Round trip limitations due to radiation exposure. I-A-2. Reachable objects within planned architecture I-B-1. Long-synodic period NEOs having multiple mission opportunities. I-B-2. Number of available targets at a given time. I-C-1. NEO size-frequency distribution. I-C-2. NEO albedos. I-C-3. NEO rotation state.

Venues/Contexts for Addressing SKGs

Venue/Context	Description
R&A	**Research and Analysis Programs** that support basic research, field work, and mission data analysis supported by PSD and HEOMD but in a broad programmatic context.
Earth-based	**Terrestrial** location for specific development and testing, including ground-based telescopes.
ISS	**International Space Station**
Robotic	**Space-based robotic missions** which can be telescopic or a precursor mission to a small body target.

Venue/Context Relevancy

Relevance	Description
● (red)	**Preferred Location/Context:** Provides the best location or context to obtain knowledge, including actual or flight-like conditions, environments, or constraints for testing operational approaches and mission hardware.
●	**Highly Relevant:** Provides highly relevant location/context to obtain knowledge, including flight-like conditions, environments, or constraints for testing operational approaches and mission hardware. This venue can serve as a good testing location with less difficulty and/or cost than anticipated for the preferred location.
⊙	**Somewhat Relevant:** Provides some relevant testing or knowledge gain (including basic analytical research and computational analysis). Conditions are expected to be not flight-like or of sufficient fidelity to derive adequate testing or operational performance data.
○	**Not Relevant:** Not an adequate location/context for testing or knowledge gain.

Strategic Knowledge Gaps

IV. Understand the SB resource potential

SKG	R&A	Earth-Based	ISS	Robotic Missions	Specific Target?	Narrative
A-3. Knowledge of extracting and collecting water in zero-g.	● (red)	⊙	● (red)	●	No	Techniques can be developed and tested on Earth preparing and heating meteorite analog and simulants, then optimally tested in the microgravity of ISS.
A-4. Caching and prepositioning and extracted resources.	○	○	⊙	● (red)	No	Techniques best tested in microgravity
A-5. Refining, storing, and using H & O in micro-g.	● (red)	⊙	● (red)	●	No	Refinement testing starting with extracted water from meteorite analogs and simulants to test processes on Earth, then deploy for testing at ISS. In-situ demonstration needed.

Determining a Timeline

Ranking Priorities

Rank	Description
Critical	Human exploration cannot proceed without closing of SKG.
High	Important for maximizing human safety and/or meeting mission objectives.
Enhancing	Enhances mission objective return.

Timeframe

Time	Description
Near	Needs to be addressed immediately or in the near-term: A target cannot be chosen without it.
Mid	Needs to be addressed in the mid-term: Must be completed before launch to human mission target,
Long	May be addressed in the longer term: May be completed after first launch.

Critical Items

Timescale	SKGs: Number and Name
Near	1. I-A Constraints on targets: Reachable targets within architecture and radiation exposure limits 2. I-B NEO orbit distribution
Mid	1. I-C-3: NEO rotation state 2. II-C-2: Geotechnical properties of SB surface 3. II-D-1:Anchoring for tethered activities 4. II-D-2:Non-contact proximity operations development 5. III-A-1: Particle environment, undisturbed 6. III-A-3: Particle environment post-disturbance 7. III-B-1: Local effects post-solar flare 8. III-B-2: Small body surfaces as secondary radiation sources 9. III-D-1: Local structural stability 10. III-D-2: Global structural stability
Long	1. III-A-2: Phobos/Deimos torus characterization

High Importance Items

Timescale	SKGs: Number and Name
Near	None identified at this time
Mid	1. I-C-1: NEO size-frequency distribution 2. I-C-2: NEO albedos 3. IV-A-1:Remotely identifying resource-rich NEOs 4. III-C-1: Small Bodies as shields against solar storms 5. II-C-1: Macroporosity of SB interior
Long	1. II-A-1:Biological effects of particulates 2. II-B-1:Mechanical/electrical effects of particulates 3. IV-B-2:Accessing resource material at depth

Enhancing Items

Timescale	SKGs: Number and Name
Near	None identified at this time
Mid	1. IV-A-5: Refining, storing, and using H&O at NEOs 2. IV-B-1: Phobos/Deimos subsurface resource potential
Long	1. II-E-1: Expanding habitat to SB interior 2. IV-A-2: Excavate/collect NEO material to be processed. 3. IV-A-3: Extract/collect resources in micro-g 4. IV-A-4: Prepositioning and caching extracted resources 5. IV-A-5:Refining, storing, and using H & O in micro-g. 6. IV-B-3:Refining, storing, and using H&O at Phobos/Deimos

4 potential HEO Goals in the Martian system

SKGs can only be defined w.r.t. a specific goal.

Goals evaluated, this study

Ref.	*Goal*	*MEPAG*	*Linkage*
A.	**Achieve the first human mission to Mars orbit**	**Goal IV-**	
B.	**Achieve the first human mission to the martian surface**	**Goal IV**	Group A SKGs also needed
C.	**Achieve the first human mission to the surface of Phobos and/or Deimos**		Group A SKGs also needed
D.	**Sustained human presence on Mars**	**Goal IV+**	Group A,B, (C?) SKGs also needed

SKG Path Forward

- **Goal is to revisit**
- **Are the same questions being asked by the Human Architecture Teams?**
  - Now that ARM Option B is the first human mission
- **Have any of the SKGs been closed by recent data analysis?**
- **Make all three SKGs consistent in format/depth**
- **Produce a stand alone Phobos/Deimos SKG list**
  - Work with MEPAG & SSERVI