SKGs, & ISECG "Landing Sites"

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Strategic Knowledge Gaps

- **SKGs define information that is useful/mandatory for designing human spaceflight architecture**
- **Perception is that SKGs HAVE to be closed before we can go to a destination, i.e. they represent Requirements**
- **In reality, there is very little information that is a MUST HAVE before we go somewhere with humans. What SKGs do is buy down risk, allowing you to design simpler/cheaper systems.**
- **There are three *flavors* of SKGs**

1. **Have to have**
   - Requirements
2. **Buys down risk**
   - LM foot pads
3. **Mission enhancing**
   - Resources

- **Four sets of SKGs**
  - Moon, Phobos & Deimos, Mars, NEOs

www.nasa.gov/exploration/library/skg.html

Lunar Science-Exploration SKGs

- **Revisited and revised in 2016**
- **Architecture was unchanged, so SKG changes were based on new data since the previous SKG revision.**
- **Effort led by LEAG.**

- **Three Themes**
  1. Understand the lunar resource potential
  2. Understand the lunar environment and its effect on human life
  3. Understand how to work and live on the lunar surface

Findings

- Recent missions produced data that was used to retire several of the SKGs defined by HAT and the 2011-2012 LEAG GAP-SAT analyses.
- Thanks to these missions, there are no strategic knowledge gaps (SKG) that would inhibit the flight of any human mission (e.g., sortie or human-tended surface facility) <28 days duration.
- However, there are several SKGs that should be addressed that would increase human safety not only at the Moon, but also in LEO, cislunar space, and beyond the Moon. This includes the development of infrastructure to monitor solar activity (e.g. solar storms). The Apollo astronauts were very lucky missing the August 1972 solar storm/SEP event.
- There are numerous SKGs that would enable and enhance more mature human exploration capabilities for the Moon and beyond.
- Future programmatic, competed (Discovery, New Frontiers) and international missions to the Moon should be examined for potential NASA contributions for retiring SKGs. This could take the form of contributed instruments to international missions and “credit” or contributed instruments toward NASA competed missions.

Open Science-Exploration SKGs

SKG Theme: Theme 1 Understanding the Lunar Resource Potential

SKG Categories:

I-B Regolith 1:Quality/quantity/distribution/form of H species and other volatiles in mare and highlands regolith. Apollo heritage.

I-C Regolith 2: Quality/ quantity/distribution/form of H species and other volatiles in mare and highlands regolith.

I-C Regolith 3: Preservation of volatile and organic components during robotic and human sampling, handling, storage, and curation.

I-D Polar Resources 3: Geotechnical characteristics of cold traps.

I-D Polar Resources 4: Physiography and accessibility of cold traps.

I-D Polar Resources 5: Charging and plasma environment within and near PSR.

I-D Polar Resources 6: Composition, Form, and Distribution of Polar Volatiles

I-D Polar Resources 7: Temporal Variability and Movement Dynamics of Surface-Correlated OH and H_2O deposits towards PSR retention.

I-E Composition/volume/distribution/form of pyroclastic/dark mantle deposits and characteristics of associated volatiles.

I-F Lunar ISRU Production Efficiency 1: Terrestrial testing

I-G Lunar ISRU Production Efficiency 2: Testing in lunar environment

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Open Science-Exploration SKGs

SKG Theme: Theme 2 Understand the lunar environment & effects on human life.

SKG Categories:

II-A-1 Solar activity/solar event prediction
II-A-2 Solar energetic particle storm-time warning system

II-B-1 Radiation environment at the lunar surface (Model)
II-B-2 Radiation environment at the lunar surface (Measurement)
II-B-3 Radiation shielding effects of lunar material (Model)
II-B-4 Radiation shielding effects of lunar material (Measurement)

II-C-1 Biological effects of lunar dust (Earth testing)
II-C-2 Biological effects of lunar dust (In situ testing)

II-D-1 Radiation and humans
II-D-2 Virus and humans
II-D-3 Dust and humans
II-D-4 Robot and computer compatibility

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Open Science-Exploration SKGs

SKG Theme: Theme 3 Understand how to work and live on the lunar surface

SKG Categories:

III-A-1 Technologies for excavation of lunar resources
III-A-2 Technologies for transporting lunar resources
III-A-3 Technologies for comminution of lunar resources
III-A-4 Technologies for beneficiation of lunar resources
III-B-1 Lunar geodetic control
III-B-2 Lunar topography control
III-B-3 Autonomous surface navigation
III-B-4 Autonomous Landing and Hazard Avoidance
III-C-1 Lunar surface trafficability – modeling
III-C-2 Lunar surface trafficability - in situ measurements
III-D-1 Lunar dust remediation
III-D-2 Regolith adhesion to human systems and associated mechanical degradation
III-D-4 Descent / ascent engine blast ejecta - in situ measurements

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Open Science-Exploration SKGs

SKG Theme: Theme 3 Understand how to work and live on the lunar surface

SKG Categories:

III-E Near-surface plasma environment and nature of differential electrical charging
III-F-1 Energy storage - non polar missions
III-F-2 Energy storage - polar missions
III-F-3 Power generation - non polar missions
III-F-4 Power generation - polar missions
III-F-5 Lander propellant scavenging
III-G Test radiation shielding technologies
III-H Test micrometeorite protection technologies
III-J-1 Fixed habitat
III-J-2 Mobile habitat
III-J-3 Semi-closed life support
III-J-4 Human mobility

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Open Science-Exploration SKGs

SKG Theme: Theme 1 Understanding the Lunar Resource Potential.

SKG Category: I-D Polar Resources 3. Geotechnical Characteristics of Cold Traps.

Narrative: Landed missions to understand regolith densities with depth, cohesiveness, grain sizes, slopes, blockiness, association and effects of entrained volatiles.

Enabling or Enhancing: Enhancing for short-duration (≤ 28 days) lunar missions. May be enabling if trafficability is an issue. Enabling for long-term, sustained human operations on the Moon.

Measurements or Missions Needed to Retire: Can be addressed partially through remote sensing, additional observations, and data analysis. Requires ground truth at the 10 meter scale (laterally) over 1-5 km baselines. Must determine trafficability, compressibility, rolling resistance, bulk density variations, and grain sizes. These properties need to be verified through in-situ observations. Minimal information will be provided by rover tracks. A scoop with a variety of end effectors could be an interesting assessment tool. In-situ GPR measurements would also have value to characterize subsurface properties. LRO is providing relevant data at the 10-20m scale, particularly LOLA observations for South Pole during Extended Science Missions. Data at the meter scale requires landed rover mission. Some information on surface roughness could be obtained at the 1m scale with an imaging radar.

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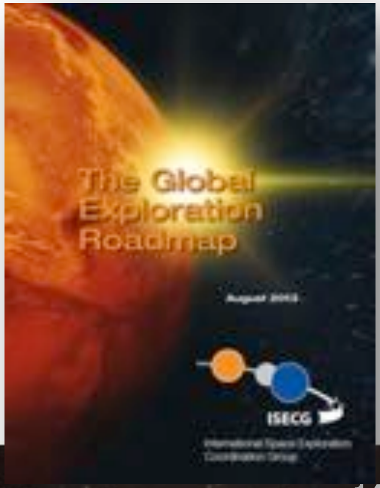
Background: ISECG & GER

- **ISECG is a non-political agency coordination forum of 15 space agencies**
  - Website: www.globalspaceexploration.org
- **Work collectively in a non-binding, consensus-driven manner towards advancing the Global Exploration Strategy**
  - Provide a forum for discussion of interests, objectives and plans
- **The Global Exploration Roadmap (GER) is a human space exploration roadmap, recognizing the criticality of increasing synergies with robotic missions while demonstrating the unique and important role humans play in realizing societal benefits. Last update 2013.**
- **The non-binding document reflects a framework for agency exploration discussions on:**
  - Common goals and objectives
  - Long-range mission scenarios and architectures
  - Opportunities for near-term coordination and cooperation on preparatory activities



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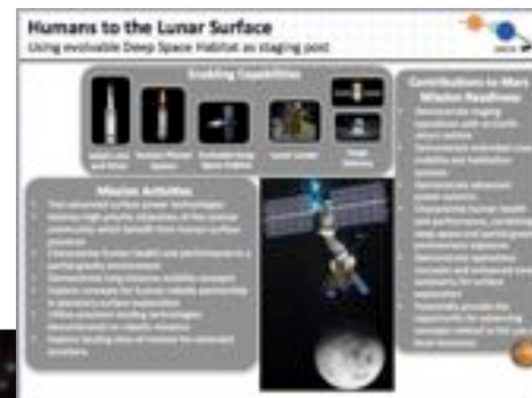
GER: Destination Reference Missions

Three ‘destination reference missions’ – used to scope engineering activities and foster discussions, not reflect specific missions

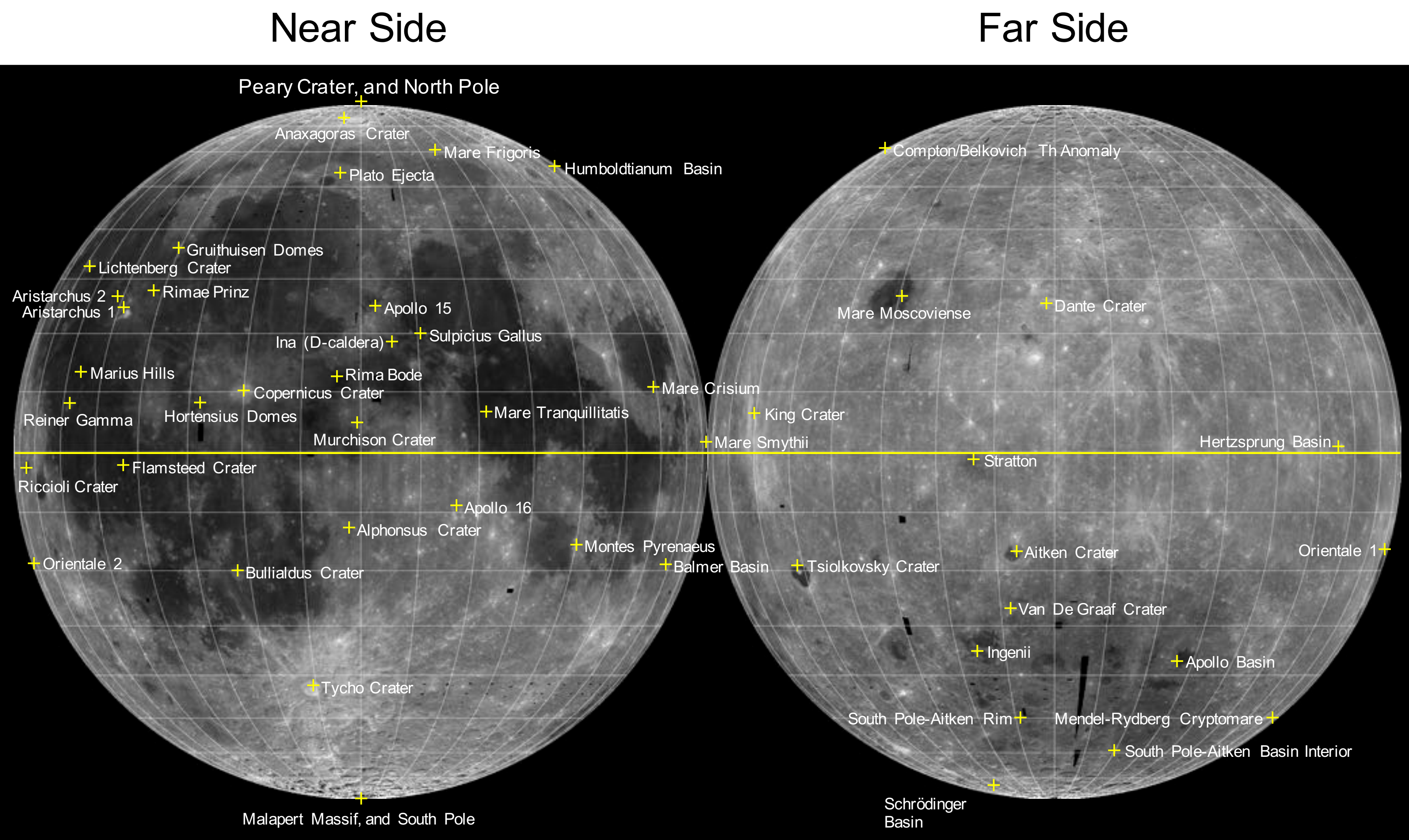
1. Deep Space Habitat (DSH) in the Lunar Vicinity
   - Crew of four
   - Initially annual missions lasting 30 days
   - Increase both duration & frequency later in the decade

2. Near Earth Asteroid
   - Boulder collected using SEP-based s/c
   - Crew of two visits asteroid boulder in lunar DRO

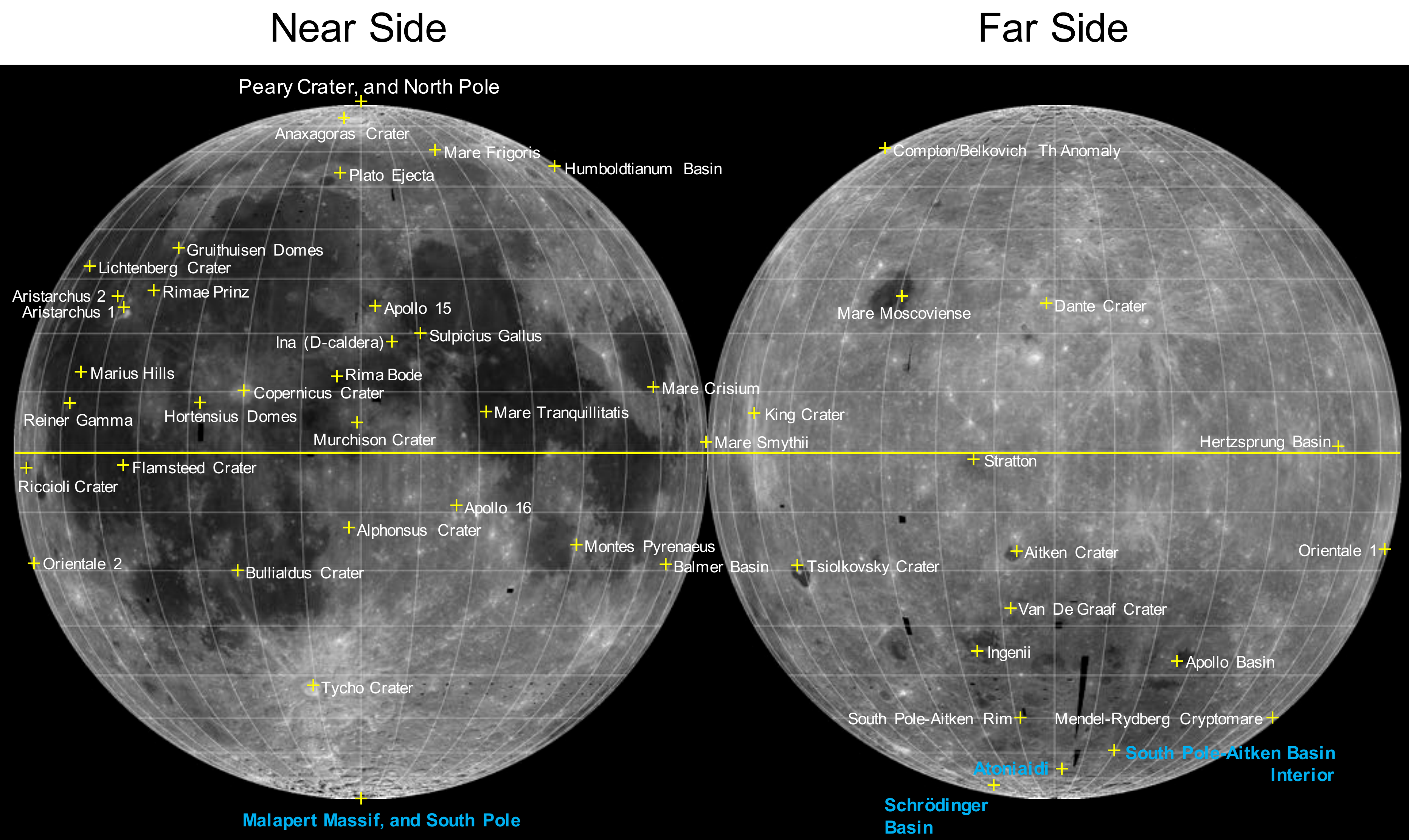
3. Lunar Surface
   - Five 28-day missions with a crew of four
   - One mission per year
   - Reuse pressurized rover for each mission
   - Rover is moved to next landing site in between crewed visits



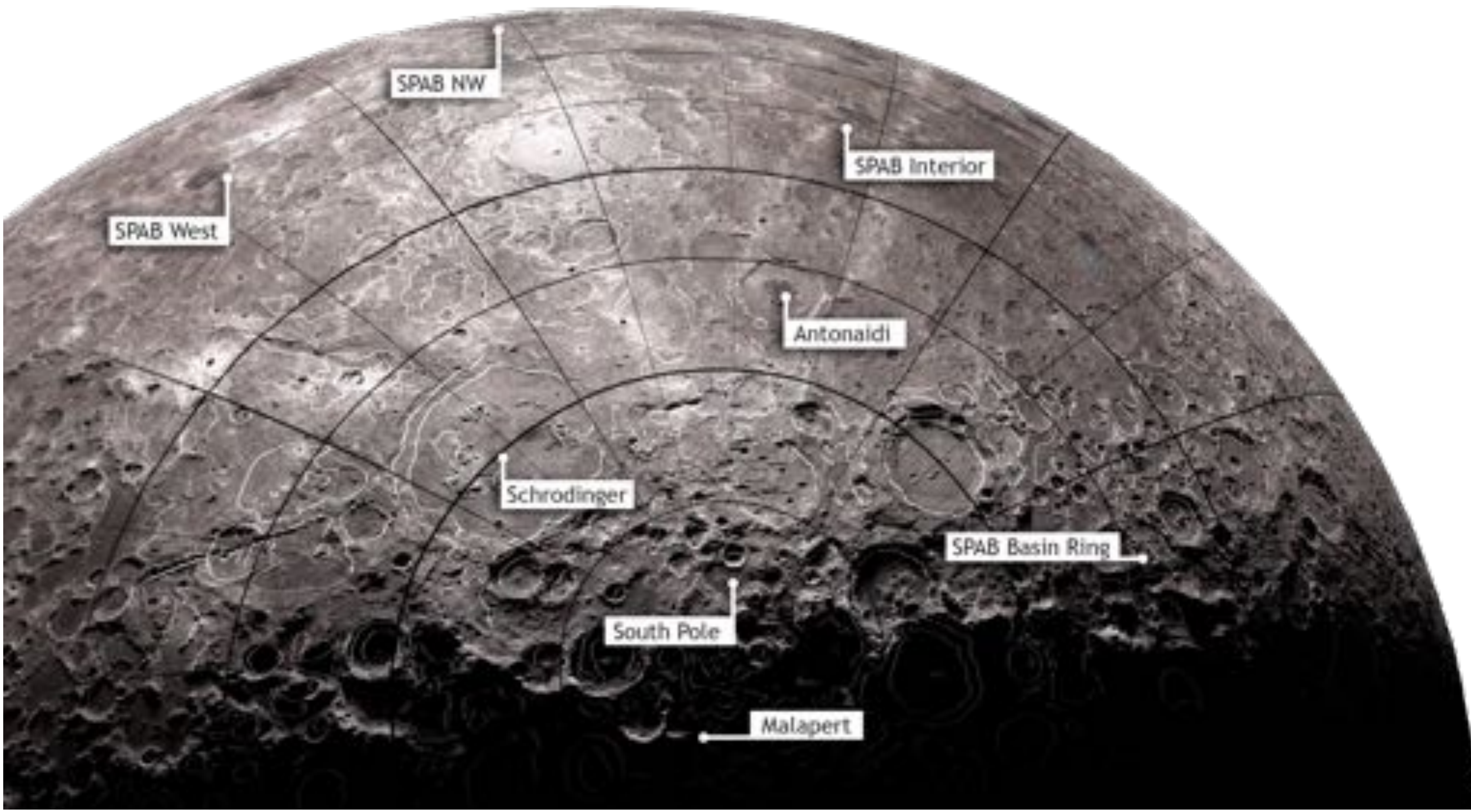
Constellation Program Office Regions of Interest



SPA Traverse



JAXA Proposed landing site candidates



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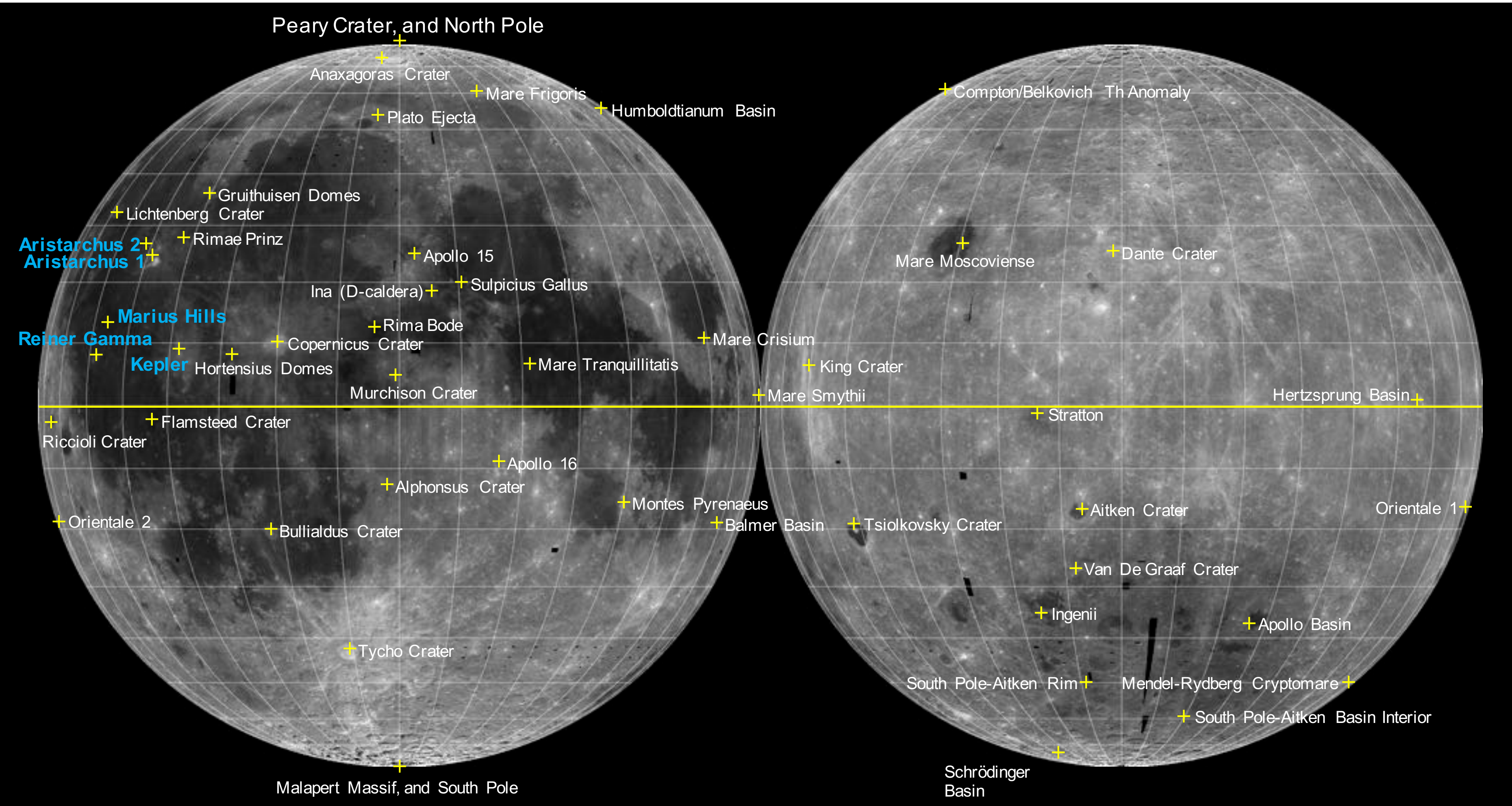
Near Side

Far Side



ISECG Science White Paper

- ISECG agencies acknowledge science communities as major stakeholders and scientific knowledge gain as an important benefit of, and justification for, human exploration activities
- A Science White Paper (SWP) has recently been developed by the international science community
  - ***Describes the international view of the science enabled by human exploration after ISS, as outlined in ISECG's Global Exploration Roadmap***
  - Tasked with considering the three destinations outlined in the GER
    - DSG in the lunar vicinity, Lunar surface, Asteroids
  - Engaged the scientific communities in identifying these opportunities
  - Additional community interaction and feedback provided by presenting initial science ideas at multiple major meetings
- SWP incorporated interdisciplinary scientific topics:
  - Encompass all relevant science communities and disciplines: planetary science, space science, life sciences, astrobiology, astronomy, physical sciences, etc.

SWP: Science Enabled by Humans at a Deep Space Habitat in the Lunar Vicinity

- **Lunar Surface Science using Telerobotics**
  - Facilitate access to challenging regions by low-latency telerobotics (e.g. permanently shadowed crater floors)
  - Set up surface instrumentation
- **Human-assisted lunar sample return**
  - Increased return through more and improved selection of lunar samples
  - Only need to get samples to the Deep Space Habitat, not all the way to Earth. They are returned with the crew in the Orion
- **Staging post for human/robotic missions**
  - Could provide repeat access with a reusable lander
  - Can act as a fuel/maintenance depot
- **Understand combined effects of radiation/fractional-gravity**
- **Additional Science Opportunities**
  - Astronomical Observations
  - Fundamental Physics
  - Collecting Interplanetary Material
  - Heliophysics
  - Monitoring Earth's Atmosphere
  - Deep Space Habitat as a Comm Relay
    - Enables government/commercial farside exploration
    - Lowers the bar for improved cubesat exploration

The lunar vicinity may not be the "ideal" location for all types of science instruments, yet the presence of humans and their associated infrastructure provides opportunities can yield Decadal relevant science

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- Two types of sessions: discipline-focused splinter sessions and cross-cutting discussions
  - The bulk of the workshop will consist of parallel discipline-focused sessions, where potential science areas enabled by exploration are presented, discussed, and eventually synthesized to instrument concepts
    - Heliophysics, Earth Science, Astrophysics & Fundamental Physics, Planetary Science, Life Sciences and Space Biology
  - Also have cross-cutting sessions, e.g. external payloads, telerobotic support, orbits

- Goal is to identify the science that the DSG can enable, the intruments it takes to take the data, and the associated resources the DSG would need to provide

Thank you!