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Strategic Knowledge Gaps

In order to prepare for future human missions, system and mission planners desire data that characterize the environments, identify hazards, and assess resources. Recent, currently operating, and future science missions are invaluable resources for providing this data. The knowledge developed from this data will inform the selection of future landing sites, inform the design of new systems, and reduce the risk associated with human exploration. While some data can be obtained through ground-based activities, other data can only be gained in space by remote sensing, in-situ measurements or sample return.

Recognizing that much of the information desired by human mission planners is of equal interest to the science community, ISECG participating agencies have worked with relevant groups to identify Strategic Knowledge Gaps (SKGs) associated with future human destinations. In consultation with key independent analysis/assessment groups from NASA, ESA Topical Teams, and JAXA experts, the list has been integrated and grouped by areas of knowledge for each destination. The list of SKGs has been prioritized on the basis of crew/mission risks, relevance to mission scenario, and applicability to more than one destination.

The list of SKGs has been summarized and the high-level SKGs are reported in the following tables. It contains information on the gaps and their priority. It also identifies specific measurements which would contribute to filling the gaps. Lastly, the list gives insights into how recent and planned robotic missions and ground-based activities will contribute information related to the gaps, and where additional measurements will be useful to fill the gaps.

Whether robotic mission formulation is primarily for scientific investigation or to prepare for human exploration, there are opportunities to significantly increase the benefit to each community. The SKG analysis will support the identification of the appropriate steps toward further coordination in order to increase the value of space exploration investments to our global stakeholder community. The SKG work is intended to inform the definition of objectives for future robotic missions and ground-based activities.

NOTE: The current Summary Tables do not report the prioritisation which is under review by the ISECG participating agencies. As soon as available, an updated version of this file will be made available on this website.

Summary Table

The following tables report the high level SKG for each exploration destination (Moon, Mars, near earth asteroids and lunar vicinity) and those which apply to all destinations.

For each SKG, the reader will find:
1) in the first column, the knowledge area to which it is associated.
2) in the second column, a brief description of the SKG.
3) in the third column, specific measurements which would contribute to filling the gap.
4) in the fourth column, insights into how past, on-going or future robotic missions and ground-based activities contribute information related to the gap and an indication in the very last right column where additional measurements will be useful to fill the gap.

4) Mission or ground based activity addressing the SKG			
Mission	**Ground based activity** (Please note that since ground based activities are not always carried out under the responsibility of space agencies, this part of the mapping is probably incomplete)		**Additional Measurements:** **R = Robotic mission** **SR = Sample Return** **G = Ground based activities**
Concluded / In ops	**Under development**	**Under study**	**R/ SR/ G**

R = need for additional data collected by robotic mission
SR = need for additional data collected through sample return
G = need for additional data from ground-based activity (laboratory analysis, modelling, data analysis, other…)
TBR = To Be Resolved / Open question

The colour code (different shades of green indicate the level of maturity of the mission or the ground based activity).

MOON					
1) Knowledge Domain	**2) Strategic Knowledge Gap: Description and Priority**	**3) Target measurement**	**4) Mission or ground based activity addressing the SKG**		**Additional Measurements:** **R = Robotic mission** **SR = Sample Return** **G = Ground based activities**
Resource Potential	**Solar Illumination Mapping:** Combined elevation-illumination models to map solar energy incidence over time.	Data is in hand but R & A resources are required to reduce and leverage the data. LRO extended mission enables detailed multi-temporal mapping of lunar poles.	NASA LRO JAXA Kaguya Roscosmos Luna-26	NASA–R&A ESA-R&A	No additional measurements needed.
Resource Potential	**Regolith Volatiles from Apollo Samples:** Quality/ quantity/ distribution/ form of H species and other volatiles in mare and highlands regolith.	Measure volatiles and organics returned in “pristine” Apollo samples (core vacuum sample containers 69001, 73001). Measure the extent of disruption of volatiles during handling and processing.		NASA-R&A UK OU-R&A	**G**
Resource Potential	**Regolith Volatiles from Robotic Missions:** Quality/ quantity/ distribution/ form of H species and other volatiles in mare and highlands regolith.	Robotic in situ measurements of volatiles and organics on the lunar surface and eventual sample return of “pristine” samples.	Roscosmos Luna-25/ Luna-27 Roscosmos Luna-28/ Luna 29		**R, SR**
Resource Potential	**Lunar Cold Trap Volatiles:** Composition/ quantity/ distribution/ form of water/ H species and other volatiles associated with lunar cold traps.	In-situ measurement of volatile characteristics and distribution within permanently shadowed lunar craters or other sites identified using remote sensing data (e.g. from LRO).	Roscosmos Luna-25/ Luna-27 NASA-CSA RESOLVE Roscosmos Luna-28/ Luna-29		**R, SR**

Resource Potential	**Resource Prospecting:** Composition/volume/distribution/form of pyroclastic/dark mantle deposits and characteristics of associated volatiles.	Required robotic exploration of deposits and sample return.			**R, SR**
Environment & Effects	**Radiation at the Lunar Surface**	Direct measurement primary and albedo/ secondary radiation on the lunar surface over a solar cycle	NASA LRO (LEND) JAXA SELENE 2		**R**
Environment & Effects	**Toxicity of Lunar Dust :** Physical and chemical properties of dust in relation to potential toxicity	In situ measurements and ground based testing with lunar samples and simulants. Particle characterization, activation of lunar dust to radiation (protons, SPEs, GCRs, micrometeroid impacts…), free radical generation and passivation.	Roscosmos Luna-27	EC FP7 Proposal	**R, SR, G**
Environment & Effects	**Micrometeoroid Environment:** Micrometeorite flux environment data such as size, velocity, mass, and direction at the lunar surface.	Measure the micrometeorite flux at the lunar surface using existing technologies.	Roscosmos Luna-26/ Luna-27		**R**
Live & Work on Lunar Surface	**Geodetic Grid and Navigation**	Based on existing data sets, improve the geodetic grid associated DTMs with 1-2m/px resolution.	NASA LRO JAXA Kaguya Roscosmos Luna-27	USGS	No additional measurements needed.
Live & Work on Lunar Surface	**Surface Trafficability:** Characterization of geotechnical properties and hardware performance during regolith interactions on lunar surface.	In situ characterization of geotechnical properties using both conventional (e.g. cone penetrometer) and inferred measurements (e.g. wheel torque, pad impression, etc.). Measurements should enable an assessment of cohesion, bearing strength, etc.	Roscosmos Luna-27 JAXA SELENE 2 NASA-CSA RESOLVE	NASA LASER R&A?	**R, G**
Live & Work on Lunar Surface	**Dust & Blast Ejecta:** Regolith adhesion and blast ejecta characteristics resulting from human- and robotic-based activities and exploration systems.	In situ measurements and modeling of descent/ascent engine blast ejecta velocity, departure angle and entrainment mechanism. Metric camera measurement of actual landing conditions and in-situ measurements of witness plates. Laboratory and in situ measurement of grain charging and attractive forces under appropriate plasma conditions to account for electrical dissipation.	JAXA SELENE 2	NLSI NASA LASER R&A	**R, G**

Live & Work on Lunar Surface	**Plasma Environment & Charging:** Determining near-surface plasma environment and nature of differential electrical charging at multiple lunar localities (includes PSRs).	In situ measurements of charges, electric fields, velocity variations, plasma properties with time/location and for different illumination conditions.	NASA ARTEMIS NASA LADEE Roscosmos Luna-25/ Luna-26/ Luna-27 JAXA SELENE 2	Theoretical activities (FMI & Onera) – Simulation tool development (SPIS) by Onera. Experimental activity by ALTA.	**R**
Live & Work on Lunar Surface	**Lunar Mass Concentrations and Distributions (i.e. Gravitational anomalies)**	Gravity field measurements via precision radio science and altimetric crossover analysis.	NASA LRO, GRAIL JAXA Kaguya Roscosmos Luna-27		No additional measurements needed.

MARS System				
1) Knowledge Domain	**2) Strategic Knowledge Gap: Description and Priority**	**3) Target measurement**	**4) Mission or ground based activity addressing the SKG**	**Additional Measurements: R = Robotic mission SR = Sample Return G = Ground based activities**
Atmosphere	**Upper Atmosphere - Global temperature field:** Reduce uncertainty in atmospheric temperature to improve confidence in the tails (>99% level) through observations of the global atmospheric temperature field (both the climatology and the weather variability). Full diurnal coverage is especially lacking so that any time of day can be selected for aerocapture, landing or launch.	Global Temperature Field. Precision/Coverage: ≤5 km vertical, ≤10 km horizontal, global, at all local times, from 20 km to > 80 km.	NASA MGS, MRO ESA Mars Express ESA-Roscosmos ExoMars 2016 (EDM, TGO)	**R**
Atmosphere	**(Upper) Atmosphere - Global aerosol profiles and properties:** Understand and model the performance of guidance and control systems (particularly pinpoint landing sensors).	Aerosol Profiles and properties, including optical properties, particle sizes, and number densities, from surface to >60 km. Precision/Coverage: <5 km vertical resolution, global coverage, including all local times.	ESA Mars Express ESA-Roscosmos ExoMars 2016 (TGO)	**R**
Atmosphere	**Upper Atmosphere - Global winds and wind profiles:** Characterize winds (important for model validation as well as pinpoint landing).	Global coverage (above 15 km) of wind velocity and direction. Precision/Coverage: global distribution; precision of 2-3 m/s, for both horizontal components, vertical resolution of 5 km. TES /Mars Climate Sounder-like horizontal resolution and spacing in longitude and time.		**R**

Atmosphere	**Atmospheric Modelling:** The atmospheric models for Mars have not been well validated due to a lack of sufficient observational data, and thus confidence in them (for use in mission planning, including entry, descent and landing) is limited.	There are several models to improve: • MGCM (Mars General Circulation Models) provide global temperature and wind fields from the surface to aerobraking altitudes. • Mesoscale models provide local and regional weather and climate conditions that account for the local topography. • LES (Large Eddy Simulations) provide the small-scale local conditions (such as dust devils) that are superimposed on the regional weather. Data Assimilation quantitatively combines observations and model fields to produce a model output (reanalysis) containing the weather from the measurements and complete set of atmospheric fields from the model. Density, pressure, temperature, and wind data, trajectory performance information.	NASA Viking, Pathfinder, MGS, MERs,Phoenix, MRO, MSL ESA Mars Express ESA-Roscosmos ExoMars 2016 (TGO, EDM), 2018 (rover)	**R, G**
Atmosphere	**Orbital Particulates:** We have insufficient information about the orbital particulate environment in high-Mars orbit that may impact the delivery of cargo and crew to the Martian system. Particulate environment near Phobos and Deimos (especially in and around the equatorial plane of Mars).	Spatial variation in size-frequency distribution of Phobos/Deimos ejecta particles in Mars orbit.	ESA Mars Express ESA-Roscosmos ExoMars 2016 (TGO)	
Atmosphere	**Lower Atmosphere - Dust Climatology:** To understand the statistics of dust events.	Measurement Type: Dust and aerosol activity climatology. Other Considerations: These observations are needed simultaneously with all other observation types.	NASA Viking, Pathfinder, Phoenix ESA Mars Express ESA-Roscosmos ExoMars 2016 (EDM), 2018 (landing platform) ESA Inspire	**R**

Atmosphere	**Lower Atmosphere - Global surface pressure; local weather:** To validate global model extrapolations of surface pressure.	Measurement Type: Surface Pressure; Precision/Coverage: Full diurnal cycle, Sampling rate > 0.01 Hz and a precision of 10-2 Pa. Lander measurements simultaneous with temperature and dust from orbit, from multiple locations for multiple Martian years. Other Considerations: The pressure is needed at all local weather stations.	ESA Mars Express	**R**
Atmosphere	**Lower Atmosphere - Global surface pressure; local weather:** To validate regional and local model atmospheric conditions.	Measurement Type: Surface meteorological packages (including T, surface winds, relative humidity, aerosol column), Upward-looking remote sounder for high vertical resolution T and aerosol profiles below ~10 km. Precision/Coverage: Full diurnal cycle, sampling rate > 0.01 Hz. Lander measurements simultaneous with temperature and dust from orbit.	ESA-Roscosmos ExoMars 2016 (EDM)	**R**
Atmosphere	**Lower Atmosphere - Global surface pressure; local weather:** Local Weather at multiple sites, including human landing site in order to validate model boundary schemes.	Surface meteorological packages (including T, surface winds, relative humidity), upward-looking remote sounder for high vertical resolution T and aerosol profiles below ~10 km. Plus Upward looking temperature, aerosol profiles. Measurement Location/Duration: below 10 km, high vertical resolution [TBD], full diurnal cycle. Lidar, sun tracking visible (near UV/IR) filters, camera (or bolometer?), upward pointing mid-IR radiometer or spectrometer".	NASA MSL	**R**
Atmosphere	**Lower Atmosphere - Surface winds:** Characterize winds (important for model validation as well as pinpoint landing).	Measurement Type: Vertical Profiling at Lower Levels (0-15 km). Precision/Coverage: 1 to 5 vertical levels in representative regions (plains, up/down wind of topography, canyons); precision of 2 m/s, for horizontal components; resolution 1 km vertical, 100 m horizontal. In years with and without a major dust storm: hourly profiling, continuous daily observations. Other Considerations: Would like to measure vertical winds in the planetary boundary layer (PBL); these get large in strongly convective mixed layers; would like to measure the turbulent winds in the daytime PBL; requires high	NASA MSL	**R**

		frequency sounding; simultaneity with global wind and temperature and aerosol measurements made from orbit; simultaneity with very near-surface wind measurements made by landers/rovers at the same location, cloud tracking by moderate and high resolution imaging from orbit.		
Atmosphere	**Lower Atmosphere - EDL profiles:** Reduce uncertainty in atmospheric temperature to improve confidence in the tails (>99% level) through observations of vertical temperature profiles.	Measurement Type: High Vertical Resolution Temperature Profiles. Precision/Coverage: ≤1 km vertical, global, at several local times, from ground to 20 km.	ESA-Roscosmos ExoMars 2016 (EDM)	**R**
Atmosphere	**Lower Atmosphere - Atmospheric Electricity conditions:** Electrical properties of the Martian environment.	AC electric fields from the surface to < 50 km; 10 uV/m - 10 V/m, 10 Hz-200 MHz with as much as 20 Hz bandwidth resolution and intermittent waveform capture. Quasi-static DC electric fields at the surface and at low altitude (<10 km); 5 V/m - 80 kV/m with 10% resolution, from DC-10 Hz. Ground electrical conductivity from surface to <10 km; >1E-13 S/m. Dust grain charge from surface, low altitude balloon or airplane (<10 km); >1E-17 C for grains 1-100 um radius. Atmospheric electrical conductivity from the surface to < 10 km; 1E-15 to 1E-10 S/m with 10% resolution.	ESA-Roscosmos ExoMars 2016 (EDM)	**R**
Environment & Effects	**Radiation:** Neutrons with directionality.	Measure neutrons with directionality from <10 keV to >100 MeV (The MSL RAD measures neutrons with > a few MeV, but no directionality).	NASA MSL ESA Inspire	**TBR**
Environment & Effects	**Simultaneous spectra of solar energetic particles in space and in the surface.**	Simultaneous orbital and surface measurements of spectra of solar energetic particles before and after atmospheric transmission (The MSL RAD measures the charged particle spectra).	NASA MSL ESA Mars Express	**TBR**

Environment & Effects	**Spectra of galactic cosmic rays on the surface.**	Measure spectra of galactic cosmic rays after atmospheric transmission including secondary particles from interaction with regolith. Identification of charged particles at the surface from hydrogen to iron and measure particle energies from 10 MeV/nuc to 400 MeV/nuc along with LET measurement during solar min.	NASA MSL	**R**
Environment & Effects	**Toxicity of dust to crew:** Dust physical, chemical and electrical properties.	Assay for chemicals with known toxic effect on humans. Of particular importance are oxidizing species (e.g., CrVI) associated with dust-sized particles. May require a sample returned to Earth as previous assays haven't been conclusive enough to retire risk. Fully characterize soluble ion distributions, reactions that occur upon humidification and released volatiles from a surface sample and sample of regolith from a depth as large as might be affected by human surface operations. Previous robotic assays (Phoenix) haven't been conclusive enough to significantly mitigate this risk. Analyze the shapes of Martian dust grains with a grain size distribution (1 to 500 microns) sufficient to assess their possible impact on human soft tissue (especially eyes and lungs).	NASA Phoenix, MSL	**R, SR**
Environment & Effects	**Dust Effects on Engineered Systems:** Dust and regolith physical, chemical and electrical properties of the Martian environment.	Electric field measurement, atmospheric/surface conductivity; long-term (Martian year) atmospheric/surface electrical monitoring. Chemistry, mineralogy, particles shape and size distribution measurements. Layering, heterogeneity & shear strength via purpose-designed trenching.	NASA MERs, Phoenix, MSL ESA-Roscosmos ExoMars 2016 (EDM) & 2018 (rover)	**R**
Contaminatio n	**Forward Contamination to Mars:** Potential consequences of the delivery and subsequent dispersal of a large bioload associated with a future human mission to the Martian surface. Identify and map special regions. Microbial survival in Mars conditions. Model induced special regions.	Orbital measurements for signs of recent water activity. Orbital and lander measurements for presence of ground ice. Ground based research and modelling.	NASA Mars Odyssey, MRO, Phoenix ESA Mars Express	**R, G**

Contamination	**Back Contamination to Earth – Biohazards:** We do not know whether the Martian environments to be contacted by humans are free, to within acceptable risk standards, of biohazards that might have adverse effects on some aspect of the Earth's biosphere if uncontained Martian material were returned to Earth. Determine if there are biohazards.	Substantially benefits from returned samples, allowing use of the full analytical capabilities of terrestrial laboratories and an analytical approach that could be both comprehensive and adaptive, with the analytical strategy changing as more is learned about Mars through the returned samples.	NASA Phoenix, MSL ESA-Roscosmos ExoMars 2018 (rover) NASA Mars 2020	**R, SR**
Resource Potential	**Atmospheric ISRU:** Dust physical, chemical and electrical properties. Dust distribution in the atmosphere. Atmospheric chemistry.	Particle shape and size distribution, column abundance and size-frequency distribution, resolved at less than scale height, trace gas abundances.	ESA-Roscosmos ExoMars 2016 (TGO, EDM) NASA Mars 2020	**R**
Resource Potential	**Surface ISRU:** Hydrated mineral compositions and occurrences	Mineralogy including minor components. Detect mineral phases present at the 1% level. Achieve ±2% accuracy in volume % for phases present at 10% level, averaged over all measurements. Elemental and mineral chemistry including minor components. Detect elements present at the 0.1% level. Achieve ±0.2 weight % accuracy for elements present at 1% level, averaged over all measurements. Energy needed to evolve water. Occurrences and internal structure of deposits at ≤5 m/pixel, goal 2 m/pixel. Spectral range 0.4-2.5 µm, goal 0.4-3.1 µm. Spectral sampling adequate to distinguish major mineral classes including olivine, pyroxene, ferric minerals, phyllosilicates, and hydrated sulfates, silica, and carbonate.	NASA MRO ESA Mars Express ESA-Roscosmos ExoMars 2016 (TGO), 2018 (rover)	**R**
Resource Potential	**Surface ISRU:** Shallow water ice composition, properties and occurrences.	Evolved volatiles. Energy requirements for extraction and other phases present. Mechanical properties. Abundance of ice within upper meter and variation with depth.	NASA Phoenix ESA Mars Express ESA-Roscosmos ExoMars 2016 (TGO), 2018 (rover)	**R**

Landing Sites	**Landing Sites and Hazards:** Regolith physical properties, structure, composition, presence of ice. Surface obstacles or hazards (rocks, slopes).	Geotechnical, trafficability and thermal characterisation of the regolith, composition, particle size and distribution, gas permeability, ice composition and distribution. Establish quantitative terrain knowledge.	NASA MERs, MRO, MSL ESA Mars Express ESA-Roscosmos ExoMars 2016 (EDM), 2018 (rover) NASA Mars 2020	**R**
Phobos/ Deimos	**Surface composition**: Mineralogical & chemical composition.	Elemental / chemical composition; spatial distribution of major geologic units; ISRU potential.	NASA MGS (TES) ESA Mars Express ESA Phootprint	**R**
Phobos/ Deimos	**Radiation, electric field and plasma environments:** In space radiation environment at Phobos and Deimos surface and subsurface. Electrostatic charging & plasma fields.	Total dose from solar particles, galactic cosmic rays and secondaries. Electric fields in proximity to surface, plasma emanating from surface.	ESA Mars Express	**R**
Phobos/ Deimos	**Gravitational fields of Phobos and Deimos**	Spherical harmonic terms of moons' gravitational fields.	ESA Mars Express	**R**
Phobos/ Deimos	**Regolith properties:** Regolith mechanical & geotechnical properties. Particulate physical, chemical and electrical properties.	Size-frequency distribution; density, compressibility, adhesion; spatial variation in thickness/properties. Cohesion, adhesion and their interaction of particulates to precursor spacecraft and science packages and/or rovers.	ESA Phootprint	**R**
Phobos/ Deimos	**Thermal environment**	Temperature variation diurnally, with depth.	ESA Mars Express ESA Phootprint	**R**

Near Earth Objects (NEOs)				
1) Knowledge Domain	**2) Strategic Knowledge Gap: Description and Priority**	**3) Target measurement**	**4) Mission or ground based activity addressing the SKG**	**Additional Measurements: R = Robotic mission SR = Sample Return G = Ground based activities**
Human Mission Target Identification	**Human Health/Mission Cost/Feasibility:** Establish the functional relationship between mission duration and space radiation health risks.	Laboratory radiation studies on tissue etc., determination of cancer risk, sensitivity of results to weightless conditions are testable using existing ground and space-based assets. Energetics of rendezvous mission is calculable given a target orbit.	NSRL-BNL (US) Chiba (Japan) GSI (Germany)	**G**
Human Mission Target Identification	**NEO Orbit Distribution:** Long-synodic period NEOs having multiple mission opportunities. Number of available targets at a given time.	An infrared survey space telescope in a stable environment with wide instantaneous visibility is best used to identify long-synodic targets in a timely fashion. These are not efficiently observable from Earth-based telescopes because they are in twilight or daytime.	NASA NEO WISE CSA NEOSSAT ESA Gaia B612 – Sentinel NASA-CSA NEOCam	**R**
Human Mission Target Identification	**NEO Composition/Physical Characteristics:** NEO size-frequency distribution.	Knowledge of NEO SFD is determined by observations from an infrared telescope survey mission but also using studies of NEO source populations in the main belt and Jupiter-family comets from Earth-based telescopes, all of which is folded into theoretical modelling.	B612 – Sentinel	**R, G**

Human Mission Target Identification	**NEO Composition/Physical Characteristics:** NEO albedo.	Depending upon the visibility of NEOs from different assets, different assets with infrared capabilities need to be engaged.	ESA Gaia B612 – Sentinel	**R**
Human Mission Target Identification	**NEO Composition/Physical Characteristics**: Rotation State.	Light curve and radar observations from different ground (Earth based telescopes) and space based assets. Depending upon the visibility of NEOs from different assets capable of making light curve observations, all such assets should be engaged.	e.g. Goldstone Observatory (US); Bisei Spaceguard Center (Japan), Observatoire du Pic du midi (France)	**R, G**
Potential Resource	**NEO Water Resources:** High-albedo NEOs are less likely to contain surface or near-surface hydrated minerals. Low-albedo NEOs are more likely to have water/OH-bearing minerals.	Remotely identifying water-rich NEOs through spectroscopic measurements. Laboratory work may be needed to better understand how to spectroscopically identify those dark NEOs that are water-rich.	NASA OSIRIS REx JAXA Hayabusa-2 ESA Marco Polo-R	**R, G**
Potential Resource	**Phobos/Deimos Water Resources:** Subsurface resource potential.	This might be determined via remote observation (neutron spectrometer), but may requires a mission to Phobos/Deimos with the capability of drilling and making observations beneath their surfaces.	ESA Phootprint	**R**
Environment & Effects	**Particulate Environment:** Particulate Environment in the proximity of small bodies.	Develop models based on remote and past in-situ observations by spacecraft, obtain in-situ observations in the vicinity of small bodies including Phobos/Deimos. Modelling and impact laboratory experiments.	NASA OSIRIS REx JAXA Hayabusa-2 ESA Phootprint ESA Marco Polo-R	**R, G**

Environment & Effects	**Radiation Environment:** The ionizing radiation environment at small bodies surfaces, including contributions from secondary charged particles and neutrons produced in the regolith.	Modelling and monitoring by existing space-based solar observatory assets. Laboratory measurements.		**R, G**
Environment & Effects	**Mitigation Strategies to Preserve Human Health:** Small bodies as shields against solar storms.	Modelling and in situ measurements of shielding, even without storms.		**R, G**
Environment & Effects	**Local and global stability of small bodies.**	Quantitative optical observations of fresh craters and mass wasting. Controlled small impacts and assessment. Observations pre and post sampling.	JAXA Hayabusa-1 ESA Rosetta-Philae NASA OSIRIS Rex NASA ISIS (InSight) JAXA Hayabusa-2 ESA Marco Polo-R	**R**
Live & Work on Small Bodies' Surface	**Hazards to equipment and mitigation:** Mechanical/electrical effects of small bodies' surface dust.	Laboratory experiments using meteoritic analogues and simulants.		**G**
Live & Work on Small Bodies' Surface	**Small Bodies' Surface Mechanical Properties:** Macro-porosity of small bodies' sub-surface.	In-situ measurements using radar and/or seismic techniques.	JAXA Hayabusa-1 ESA Rosetta-Philae NASA OSIRIS REx JAXA Hayabusa-2 ESA Marco Polo-R	**R**
Live & Work on Small Bodies' Surface	**Small Bodies' Surface Mechanical Properties:** Mechanical strength of small bodies' sub-surface materials.	In situ characterization of geotechnical properties using both conventional (e.g. cone penetrometer) and inferred measurements (e.g. physical contact impression, etc.). Measurements should enable an assessment of cohesion, bearing strength, etc.	JAXA Hayabusa-1 NASA OSIRIS REx NASA ISIS (InSight) JAXA Hayabusa-2 ESA Marco Polo-R	**R**

Lunar Vicinity				
1) Knowledge Domain	**2) Strategic Knowledge Gap: Description and Priority**	**3) Target measurement**	**4) Mission or ground based activity addressing the SKG**	**Additional Measurements: R = Robotic mission SR = Sample Return G = Ground based activities**
Environment & Effects	**Micrometeoroid Environment:** Micrometeorite flux environment data such as size, velocity, mass, and direction in the lunar vicinity.	Measure the micrometeorite flux in the lunar vicinity using existing technologies.		**R**
Environment & Effects	**Lunar vicinity (e.g. Earth-Moon Lagrange points, high and low lunar orbits, distant retrograde orbits, in transit) radiation field**	In-situ (e.g. Earth-Moon Lagrange points, high and low lunar orbits, distant retrograde orbits, in transit)SEPs fluxes and dynamics.		**R**
Environment & Effects	**Lunar vicinity (e.g. Earth-Moon Lagrange points, high and low lunar orbits, distant retrograde orbits) gravitational field**	In-situ radio-science measurements.		**R**

All Destinations				
1) Knowledge Domain	2) Strategic Knowledge Gap: Description and Priority	3) Target measurement	4) Mission or ground based activity addressing the SKG	Additional Measurements: R = Robotic mission SR = Sample Return G = Ground based activities
Environment & Effects	**Solar event prediction**: Establish space weather modelling, forecasting and monitoring capabilities to warn transit/surface crews of potentially hazardous solar events. The goal of these systems should be to provide as early a warning as possible of dangers. Two time scales for consideration: alert on ~5- 10 days as active regions rotates into moon-view (Sentinel monitor) and 10's of minutes to protect from an immediate release of an Earth-directed CME and associated Solar Energetic Particles (SEPs).	Measurements of relativistic electron signatures may improve near term forecasting. Dedicated satellites are necessary to investigate basic mechanisms of SPE formation and provide early detection.	NASA STEREO, SDO, LRO CRaTER NASA-ESA SOHO ESA Solar Orbiter	**R, G**
Environment & Effects	**Spectra of galactic cosmic rays in space**	Measure spectra of galactic cosmic rays (This can be done near Earth if no magnetospheric interference). Identification of charged particles from hydrogen to iron and measure particle energies from 10 MeV/nuc to 400 MeV/nuc along with LET measurement during solar min.	NASA ACE, LRO (CRaTER), MSL (RAD)	**R**