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LUNAR RECONNAISSANCE ORBITER (LRO) REQUIREMENTS

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LUNAR RECONNAISSANCE ORBITER REQUIREMENTS

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1.0 INTRODUCTION AND SCOPE

This document identifies the Mission Requirements (Section 1) for the Lunar Reconnaissance Orbiter (LRO).

This document serves as the basis for assessments conducted by NASA Headquarters and provides the baseline for the determination of mission measurement success during the operational phase. Changes to requirements contained in this document require approval by the Exploration Systems Mission Directorate (ESMD), NASA Headquarters.

In January 2004, the President of the United States announced a new plan to advance the Nation's scientific, security, and economic interests through a robust space exploration program that integrates human and robotic exploration activities. This decision was documented by the "President's Space Exploration Policy Directive (NPSD31)(Goal and Objectives)," and "A Renewed Spirit of Discovery - The President's Vision for U.S. Space Exploration (January 2004)." The specific actions required to carry out this new exploration program have been further elaborated on in the NASA response document, "The Vision for Space Exploration," dated February 2004.

A joint Enterprise working group at NASA Headquarters subsequently established the Level 0 Exploration Requirements for the National Aeronautics and Space Administration effective May 4, 2004. The relevant Lunar requirements were flowed-down into the Exploration System of Systems (ESS), Robotic Lunar Exploration Program (RLEP) and Lunar Reconnaissance Orbiter (LRO) documents as shown in Figure 1.

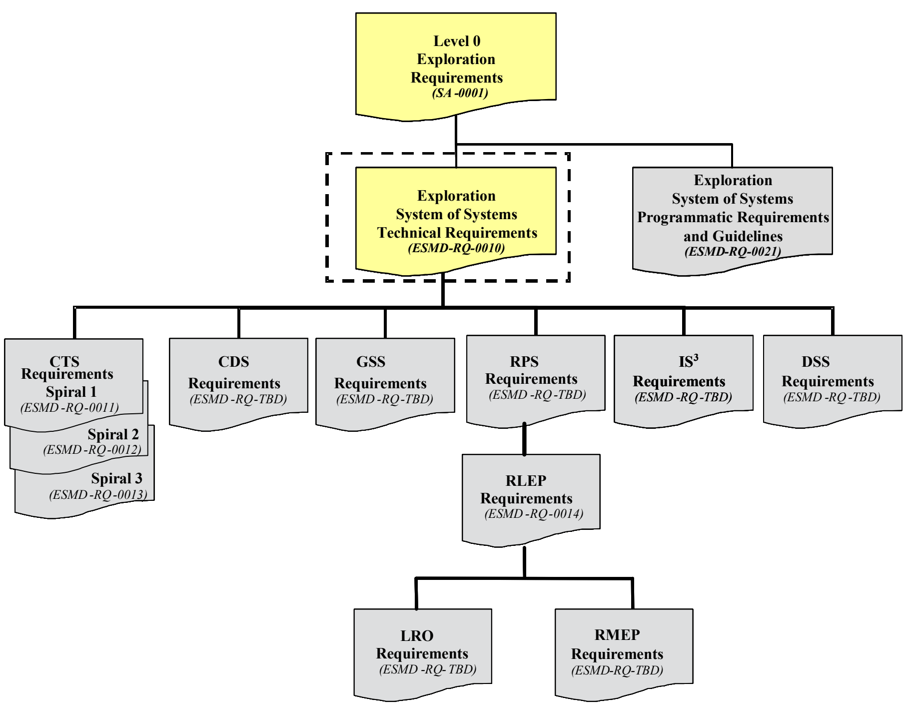

Figure 1-1 ESMD Requirement Flow-Down Diagram

The Robotic Lunar Exploration Program (RLEP) was established to implement the robotic mission specified in the Lunar Program Requirements above. This document contains all the Program unique requirements on the Lunar Reconnaissance Orbiter mission and the traceability from those Requirements.

1.1 PROJECT ORGANIZATION AND MANAGEMENT

The Lunar Reconnaissance Orbiter project is organized and managed within the Robotic Lunar Exploration Program at GSFC. Technical program management of LRO will be conducted within the structures, policies, and procedures defined for the implementation of all projects within the Robotic Lunar Exploration Program. These structures, policies, and procedures are defined within the RLEP Program Plan and are included herein by reference. The RLEP Manager located at GSFC has the end-to-end responsibility for program implementation, and programmatically reports to the RLEP Program Director at NASA ESMD Headquarters and administratively to the GSFC Director. The Robotic Lunar Exploration Program Office is directly funded by NASA HQ for implementation of the project. The LRO Project manager is administratively located in the Flight Program and Projects Directorate and reports to its Director. Programmatically, the Project Manager is responsible to the Robotic Lunar Exploration Program Manager at GSFC. The LRO Project Scientist at GSFC is accountable for the scientific integrity of the mission and reports administratively to the Chief of the Solar Systems Exploration Directorate at GSFC. The GSFC Program Management Council (PMC) is the governing PMC for certifying the Lunar Reconnaissance Orbiter readiness to the Associate Administrator(s) for the ESMD. The NASA Administrator is the approval authority for the initiation of the Project Implementation Phase, for launch, and for project termination.

1.2 PROJECT ACQUISITION STRATEGY

The LRO Project will provide the orbiter, Ground Systems, and Ground Network. The NASA Kennedy Space Center (KSC) will procure and deliver launch services and spacecraft integration support for the LRO. The Project will support and implement within its allocated resources NASA's measurement investigations selected through the Announcement of Opportunity (AO) process and facility investigations as directed by NASA.

Six institutional partners, under contract to the LRO project at GSFC, are responsible for delivery of the six scientific instruments to be flown on the LRO:

Goddard Space Flight Center - Lunar Orbiter Laser Altimeter (LOLA)

Northwestern University - Lunar Reconnaissance Orbiter Camera (LROC)

Institute for Space Research - Lunar Exploration Neutron Detector (LEND)

University of California, Los Angeles - Diviner Lunar Radiometer Experiment (DLRE)

Southwest Research Institute - Lyman-Alpha Mapping Project (LAMP)

Boston University - Cosmic Ray Telescope for the Effects of Radiation (CRaTER)

2.0 APPLICABLE DOCUMENTS

Document No.	Document Title
SA-0001	Level 0 Exploration Requirements for the National Aeronautics and Space Administration, Baseline Version, May 4, 2004
N/A	Objectives and Requirements Definition Team (ORDT) for the Lunar Reconnaissance Orbiter (LRO)
NPSD31	President's Space Exploration Policy Directive (Goal and Objectives)
ESMD-RQ-0010	Exploration System of Systems Requirements
ESMD-RQ-0014	Robotic Lunar Exploration Program (RLEP) Requirements
N/A	Report of the President's Commission on Implementation of the United States Exploration Policy, A Journey to Inspire, Innovate, and Discover. June 2004
N/A	National Aeronautics and Space Administration, The Vision for Space Exploration. February 2004.
NNH04ZSS003O	Announcement of Opportunity, Lunar Reconnaissance Orbiter (LRO) Measurement Investigations
N/A	Lunar Reconnaissance Orbiter (LRO) Payload Proposal Information Package (PIP)

3.0 REQUIREMENTS

3.1 LRO LEVEL 1 REQUIREMENTS

NASA established an external group, LRO Objectives/Requirements Definition Team (ORDT), to define specific LRO measurement objectives. The ORDT proposed measurement requirements were reviewed by the Exploration Systems Review Board and subsequently recommended for approval by the Enterprise Associate Administrators (AA) most directly involved in the mission approve them. The AAs for Exploration Systems, Space Science, Biological and Physical research, and Space Flight jointly approved them on May 24, 2004. The initial requirements development process is illustrated in Figure 3-1.

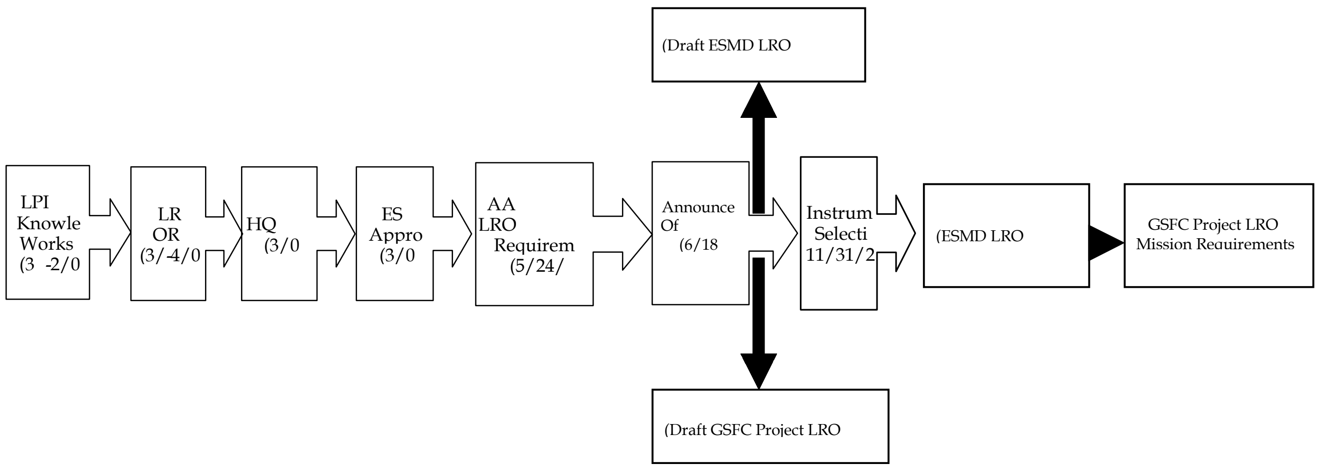

Figure 3-1. LRO Requirement Definition Flow Diagram

The LRO Level 1 requirements are divided into two sections: Measurement Requirements and Project Requirements.

3.1.1 Measurement Requirements

From the results of the ORDT, NASA has established the following investigation measurement objectives for LRO as finalized in the LRO AO.

RLEP-LRO-M10 The LRO shall characterize the deep space radiation environment in lunar orbit, including neutron albedo.

Rationale : The ORDT specified that LRO should characterize the global lunar radiation environment, in particular at energies in excess of 10 MeV, and its biological impacts and potential mitigation, as well as investigate shielding capabilities and validation of other deep space radiation mitigation strategies involving materials.

RLEP-LRO-M20 The LRO shall characterize the deep space radiation environment in lunar orbit, including biological effects caused by exposure to the lunar orbital radiation environment.

Rationale : The ORDT specified that LRO should characterize the global lunar radiation environment and its biological impacts and potential mitigation, as well as investigate shielding capabilities and validation of other deep space radiation mitigation strategies involving materials**.**

RLEP-LRO-M30 The LRO shall collect global geodetic data using spatially resolved topography with a 10m vertical accuracy with a 2km cross-track and 30m along track sampling at the equator.

Rationale : The ORDT specified that LRO should determine the global geodetic grid for the Moon in three dimensions with high spatial resolution as specified in the data product table.

RLEP-LRO-M40 The LRO shall obtain geodetic lunar global topography (at landing-site relevant scales - 30m down-track and 50m cross-track) with spatial resolution of 50m at the polar regions (within 5 degrees of the poles), and 1km at the equator.

Rationale : The ORDT specified that LRO should determine the global geodetic grid for the Moon in three dimensions with high spatial resolution.

RLEP-LRO-M50 The LRO shall obtain temperature mapping from 40 - 300K in the Moon's polar regions (within 5 degrees of the poles) to 300m spatial resolution and 5K precision for a full lunar cycle.

Rationale : The ORDT specified that LRO should assess the resources in the Moon's polar regions (and associated landing site safety evaluation), including characterization of permanently shadowed regions and evaluation of any water ice deposits.

RLEP-LRO-M60 The LRO shall obtain landform-scale imaging of lunar surfaces in permanently shadowed regions at 50m spatial resolution.

Rationale : The ORDT specified that LRO should assess the resources in the Moon's polar regions (and associated landing site safety evaluation), including characterization of permanently shadowed regions and evaluation of any water ice deposits.

RLEP-LRO-M70 The LRO shall identify putative deposits of appreciable near-surface water ice in the Moon's polar cold traps at a 100m spatial resolution.

Rationale : The ORDT specified that LRO should assess the resources in the Moon's polar regions (and associated landing site safety evaluation), including characterization of permanently shadowed regions and evaluation of any water ice deposits.

RLEP-LRO-M80 The LRO shall assess meter-scale features of the lunar surface to enable safety analysis for potential lunar landing sites over targeted areas of 100km^2 per the LRO Landing Site Target Specification Document.

Rationale : The ORDT specified that LRO should assess the resources in the Moon's polar regions (and associated landing site safety evaluation), including characterization of permanently shadowed regions and evaluation of any water ice deposits.

RLEP-LRO-M90 The LRO shall characterize the Moon's polar region (within 5 degrees of the poles) illumination environment at relevant temporal scales (i.e., typically that of hours) to a 100m spatial resolution and 5 hour average temporal resolution.

Rationale : The ORDT specified that LRO should assess the resources in the Moon's polar regions (and associated landing site safety evaluation), including characterization of permanently shadowed regions and evaluation of any water ice deposits.

RLEP-LRO-M100 The LRO shall obtain high spatial resolution global resources assessment including elemental composition, mineralogy, and regolith characteristics to a 20% accuracy and a 5km resolution.

Rationale : The ORDT specified that LRO should obtain high spatial resolution assessments of global lunar resources.

RLEP-LRO-M110 The LRO shall obtain high spatial resolution hydrogen mapping of the Moon's surface to a 20% accuracy and 5 km resolution at the poles.

Rationale : The ORDT specified that LRO should obtain high spatial resolution assessments of global lunar resources.

3.1.2 Project Requirements

From the results of the ORDT and review by NASA's internal SMD and ESMD organizations, NASA has established the following project requirements for LRO which are summarized in this section:

RLEP-LRO-P10 Planetary Protection The LRO will be classified as a Planetary Protection Category I mission.

Rationale : Document location of LRO end-of-mission impact in Final Report.

RLEP-LRO-P20 Mission Lifetime The LRO mission shall have 1 year mission lifetime with a 5 year potential for an extended mission.

Rationale : The 1 year lifetime was recommended by the ORDT for acquiring the desired measurements. The additional lifetime objective provides program resiliency and flexibility as required by RLEP-P20 and RLEP-P30 and as recommended by the Space Communications Architecture Working Group (SCAWG). The extended mission options include communications relay for future RLEP program landed assets, or extended required measurements, or targeted measurements.

RLEP-LRO-P30 Launch Date The LRO shall be launched in late 2008.

Rationale : The launch year is per the President's vision.

RLEP-LRO-P40 Launch Site The LRO shall be launched from Cape Canaveral AFS.

RLEP-LRO-P50 Launch Vehicle The LRO shall be launched on an Intermediate-class launch vehicle.

RLEP-LRO-P60 Orbit - The LRO shall collect the measurement data, specified in this document, for one Earth year in a 50 km (nominal) near-circular polar lunar orbit.

RLEP-LRO-P70 Spacecraft Pointing The LRO spacecraft shall be a 3-axis stabilized nominally nadir-pointing platform.

RLEP-LRO-P80 Spacecraft Instrument Accommodations The LRO shall include an instrument complement consisting of the Lunar Orbiter Laser Altimeter (LOLA), the Lunar Reconnaissance Orbiter Camera (LROC), the Lunar Exploration Neutron Detector (LEND), the Diviner Lunar Radiometer Experiment, the Lyman-Alpha Mapping Project (LAMP), and the Cosmic Ray Telescope for the Effects of Radiation (CRaTER) as selected for measurement investigations.

Rationale : Preliminary requirement protected for a maximum mass of 100 kg, a maximum power consumption of 100W, and maximum measurement data output of 900 Gb/day.

RLEP-LRO-P90 Measurement Investigation Requirements The LRO investigation teams will be responsible for collecting the measurement, engineering, and ancillary information necessary to validate and calibrate the measurement data prior to delivery to the PDS.

RLEP-LRO-P100 Measurement Investigation Requirements Data products delivered to the PDS will be documented, validated, and calibrated in physical units useable by the exploration and science communities at large.

RLEP-LRO-P110 Measurement Investigation Requirements The time required to complete this process and make the data available to the Moon/Mars exploration communities and the general public will be six months or less.

RLEP-LRO-P120 Data Policies and Validation Requirements PIs selected for measurement investigations will plan to archive their Data Products and supporting data in the Planetary Data System (PDS) in a PDS-compliant data format.

RLEP-LRO-P130 Data Policies and Validation Requirements Plans will conform to policy and requirements for the validation and archiving of data presented in the document, "LRO Data Management Plan".

RLEP-LRO-P140 Data Policies and Validation Requirements Initial data analyses for the LRO measurement investigations will be accomplished by the PIs and their teams.

RLEP-LRO-P150 Communications Compatability The LRO should strive to establish as much as practical interoperable communications with any contemporaneous ESS systems and other NASA internal and/or external Lunar missions where it would be advantageous to the exploration effort.

RLEP-LRO-P160 Technology Demonstration The LRO shall accommodate the NAWC provided Mini-RF device in order to provide the opportunity for demonstration of this technology in the lunar orbital environment provided it does not increase the project cost, delay the launch date, adversely impact the achievement of full mission success, or increase the overall risk posture of the primary mission.

3.1.3 LRO Requirements Traceability

RLEP Parent Requirement	LRO Child Requirement
RLEP-M10	RLEP-LRO-M10
RLEP-T30 RLEP-M20	RLEP-LRO-M20
RLEP-M30	RLEP-LRO-M30
RLEP-M30	RLEP-LRO-M40
RLEP-M60	RLEP-LRO-M50
RLEP-M40	RLEP-LRO-M60
RLEP-M50	RLEP-LRO-M70
RLEP-M40	RLEP-LRO-M80
RLEP-M40	RLEP-LRO-M90
RLEP-M50 RLEP-M80	RLEP-LRO-M100
RLEP-M50	RLEP-LRO-M110
RLEP-***PTBD***	RLEP-LRO-P10
RLEP-P30 RLEP-P20	RLEP-LRO-P20
RLEP-P10	RLEP-LRO-P30
RLEP-P10	RLEP-LRO-P40
RLEP-P20	RLEP-LRO-P50
RLEP-P10	RLEP-LRO-P60
RLEP-P20	RLEP-LRO-P70
RLEPP10	RLEP-LRO-P80
RLEP-P40	RLEP-LRO-P90
RLEP-P40	RLEP-LRO-P100
RLEP-P40	RLEP-LRO-P110
RLEP-P40	RLEP-LRO-P120

RLEP Parent Requirement	LRO Child Requirement
RLEP-P40	RLEP-LRO-P130
RLEP-P40	RLEP-LRO-P140
RLEP-PG30	RLEP-LRO-P150
RLEP-T100	RLEP-LRO-P160

3.1.4 Additional Investigations

NASA may solicit additional participation in the LRO mission (e.g., Interdisciplinary Scientist or Participating Scientist investigations) through future NASA Announcements of Opportunity (AOs) or Research Announcements (NRAs).

4.0 LRO INSTRUMENT COMPLEMENT

The LRO will accomplish its measurement objectives (Section 3.0) by conducting a program of global mapping, regional survey, and globally distributed targeted exploration observations for one year or more and by analysis of the returned data. The selected investigations are specified here.

4.1.1 Lunar Orbiter Laser Altimeter

The Lunar Orbiter Laser Altimeter (LOLA) will determine the global topography of the lunar surface at high resolution, measure landing site slopes, and search for polar ices in shadowed regions.

4.1.2 Lunar Reconnaissance Orbiter Camera

The Lunar Reconnaissance Orbiter Camera (LROC) will acquire targeted images of the lunar surface capable of resolving small-scale features that could be landing site hazards, as well as wide-angle images at multiple wavelengths of the lunar poles to document changing illumination conditions and globally identify potential resources.

4.1.3 Lunar Exploration Neutron Detector

The Lunar Exploration Neutron Detector (LEND) will map the flux of neutrons from the lunar surface to search for evidence of water ice, and provide measurements of the space radiation environment which can be useful for future human exploration.

4.1.4 Diviner Lunar Radiometer Experiment

Diviner will map the temperature of the entire lunar surface over a full diurnal cycle to define the thermal environments of potential landing sites identify potential landing hazards and to identify cold-traps and potential ice deposits.

4.1.5 Lyman-Alpha Mapping Project

The Lyman-Alpha Mapping Project (LAMP) will observe the entire lunar surface in the far ultraviolet. LAMP will search for surface ices and frosts in the polar regions and provide images of permanently shadowed regions illuminated only by starlight.

4.1.6 Cosmic Ray Telescope for the Effects of Radiation

The Cosmic Ray Telescope for the Effects of Radiation (CRaTER) will investigate the effect of galactic cosmic rays on tissue-equivalent plastics as a constraint on models of biological response to background space radiation.

5.0 LRO MISSION SUCCESS CRITERIA

Based on sections 3.1.1 Measurement Requirements and 3.1.2 Project Requirements herein, the following mission success criteria have been established for the LRO Project.

5.1 FULL MISSION SUCCESS CRITERIA

For Full Mission Success, the following criteria must be met: (TBR16)

- Operate the orbiter and all six instruments in the Primary Mapping Orbit in mapping modes over the one year of the Primary Measurement Phase.
- Each instrument shall have capabilities that meet or exceed their respective measurement requirements [3.0].
- Return, over the one-Earth-year Primary Operations Phase, representative data sets for each instrument for a total measurement data volume return of (TBR18) Tbits or more. Included in the returned data volume shall be information describing TBD globally distributed regional and local targets.
- Process, analyze, interpret, and release data in a timely manner, including archival of acquired data and standard data products in the PDS within 6 months of acquisition.
- Release specific requested data and level 3 products to ESMD for use in future mission planning.

5.2 MINIMUM MISSION SUCCESS CRITERIA

For Minimum Mission Success, the following criteria must be met: (TBR22)

- Operate the orbiter and its payload in the mapping mode in the Primary Mapping Orbit during the one year of the Primary Measurement Phase.
- Instruments shall have capabilities that meet their respective measurement requirements [3.0].
- Return TBD1 Tbits of data from the following Instruments: (TBD7) or from their combined operations, plus TBD9 Tbits of representative measurement data over the one-year Primary Operations Phase from at least 1 of the other instruments (TBD10).

- Included in the returned data volumes shall be information describing TBD or more globally distributed targets.
- Process, analyze, interpret, and release data including archival of acquired data and standard data products in the PDS.
- Release specific requested data and level 3 products to ESMD for use in future mission planning.

5.3 MEASUREMENT DATA DESCRIPTION

5.3.1 Measurement Data Management

Each PI or Facility Team Leader shall be responsible for initial analysis of the investigation data, the subsequent delivery of the data products and software to the Planetary Data System (PDS), the publication of scientific findings and communication of results to the public.

It is NASA policy that investigators do not have exclusive use of data taken during the course of their investigation for any proprietary period. After a short period for verification and validation, not to exceed six months after the measurement data and ancillary information are first available to the investigation team, each Principal Investigator (PI) or Facility Team Leader must deposit the validated data in the PDS in a compliant data format. Analysis, preparation, distribution and archiving of all investigation team data products are to be completed within six months of the end of the mission phase during which the investigation measurement data were acquired. Derived data products shall be archived in the PDS as soon as they are available, on a time scale commensurate with the level of data processing to be identified in the Project Data Management Plan. The following table 5-1 describes the measurements and associated data product each instrument is making.

Table 5-1 LRO Data Products

LRO Measurement Objective	LRO Instrument	Data Product
RLEP-LRO-M10	LEND	Radiation Data Product for global distribution of neutrons at Moon's orbit with spatial resolution of 50 km at different energy ranges from thermal energy up to >15 MeV separately for periods of quiet Sun and for periods of Solar Particle Events.
	CRaTER	Measure and characterize that aspect of the deep space radiation environment, Linear Energy Transfer (LET) spectra of galactic and solar cosmic rays (particularly above 10 MeV), most critically important to the engineering and modeling communities to assure safe, long-term, human presence in space.
RLEP-LRO-M20	CRaTER	Investigate the effects of shielding by measuring LET spectra behind different amounts and types of areal density, including tissue-equivalent plastic.
RLEP-LRO-M30	LOLA	Provide global digital elevation model of the moon with 1 m vertical resolution and 100 m horizontal resolution with 1 km average cross track sampling at the equator.
RLEP-LRO-M40	LOLA	Provide global topography with 1 m vertical resolution and 100 m horizontal resolution with 1 km average cross track sampling at the equator.
	LROC	For areas of high interest (targets), provide 2m scale Digital Elevation Models (DEM) for areas 5km x 5km.
	LROC	Acquire 100m/pixel global stereo imaging reducible to 1km/pixel global topography in EDR format (no maps). Back up for LOLA data, if needed WAC.
RLEP-LRO-M50	Diviner	Direct temperature mapping at ~300M spatial resolution with minimum detectable temperature of 24K over an entire diurnal cycle enables the detection and characterization of cold traps in polar shadowed regions.
RLEP-LRO-M60	LOLA	Provide digital elevation model of topography in permanently shadowed polar regions with 50m horizontal resolution, 1m vertical resolution.
	LAMP	Albedo maps of all permanently shadowed regions with resolutions down to 500 m.

RLEP-LRO-M70	LOLA	Provide reflectance data from the permanently shadowed regions (PSRs) to identify surface ice signatures at a limit of 4% ice surface coverage by area.
	LEND	Develop maps of water ice column density on polar regions of the Moon with spatial resolution from 5-20km.
	LAMP	Develop water-frost concentration maps of the lunar polar regions. Mapping resolutions as good a s 3km for frost abundances down to 1.5%.
RLEP-LRO-M80	LROC	Provide up to 50 Mosaics of selected potential landing sites with 1 m/pixel resolution.
	TBD	Provide crater size density and size distribution maps of up to 50 potential landing sites.
	Diviner	Determine rock abundances of up to 50 selected potential landing sites.
	LOLA	Provide topography, surface slopes, and surface roughness at 25-m spacing over a 70-m wide field of view (FOV) swath at up to 50 selected potential landing sites.
RLEP-LRO-M90	LROC	Provide uncontrolled illumination movies , 1 each of North and South Lunar Poles over the course of 1 lunar year at an average time resolution of 5 hours or better. (Wide Angel Camera [WAC])
	LROC	Provide 1 m/pixel resolution summer (uncontrolled) mosaics of the lunar poles (+/- 4 degrees). (Narrow Angle Camera [NAC]). There will be some gores in the data due to tolerance (20km) of the nominal 50km orbit altitude.
	LOLA	LOLA will map the polar regions poleward of latitudes 86° with a vertical resolution of 10 centimeters (cm) and a spatial resolution of 25 to 35 m after one year, which will identify potential sites of opti mal solar power generation
	Diviner	Provide illumination ma p derived from Illumination and Scattering Model (Includes slopes, raytraced shadows, and full 3-D radiosity solution for scattered solar and infrared radiation), and 1-D lunar thermal model
RLEP-LRO-M100	LROC	Global imaging 400m/pixel in the ultraviolet (UV) bands and 100m/pixel in the visible bands, te n uncontrolled demonstration multi -spectral mosaics for high priority targets.
	Diviner	Fine-component thermal inertia and lambert albedo from surface temperature, solar reflectance and topography measurements
RLEP-LRO-M110	LEND	Determine hydrogen content of subsurface at polar regions with spatial resolution from Half-Width Half-Maximum (HWHM)=5km and with variation sensitivity from 100 parts per million (ppm)

Because of their exceptional value for public engagement, representative images will be made available publicly throughout the mission, shortly after reception on the ground. Release of LRO data by the LRO measurement investigation teams and team leads, and by the LRO Project will comply with the policies for release of data and public information presented in the “Robotic Lunar Exploration Program Data Management Plan.” In addition, through the LRO Project, NASA reserves the right to direct the acquisition of data, to direct or conduct data processing, and to release data needed for mission operations, programmatic planning, and support of public engagement. The number and extent of such directives will be consistent with other LRO mission objectives and with Project resources.

5.3.2 Data Management Plan Description

In accord with the LRO Project, each measurement investigation will develop and implement data management plans for the investigation development, operations and analysis phases, including calibration, instrument operations (if applicable), data processing, analysis, interpretation, data release and archiving activity. The LRO project will develop a data management plan to address the total activity associated with the flow of measurement data, from acquisition, through processing, data product generation and validation, to archiving and preservation. This LRO Project Data Management Plan and all LRO measurement data management activities will be consistent with the policy and requirements presented in the document “Robotic Lunar Exploration Program Data Management Plan,” augmented by policies and requirements presented in the “Lunar Reconnaissance Orbiter - 2005 Announcement of Opportunity.”

6.0 COST CONSTRAINTS

The total costs for the LRO project shall not exceed TBD12, including the launch vehicle. This cost is planned as TBD13 through development and launch (Phase A-D), and TBD14 operations (Phase E).

7.0 EXTERNAL AGREEMENTS

NASA requires an LOA, MOU, or IA between NASA and each of the foreign agencies for delivery of hardware, software products, or services. The Program Executive working with External Relations Office will facilitate. In order to establish a working environment conducive to free and open exchange of information between LRO and the foreign partners, Technnology Transfer Agreements (TTAs) will be established with each participating member. Those foreign partners identified to participate in LRO include:

Russian Space Agency.

8.0 EDUCATION AND PUBLIC OUTREACH

The public outreach component of the LRO project willl be implemented as apart of a unified program level Education and Public Outreach activity organized, managed and funded by the Robotic Lunar Exploration Program with funds as allocated for this purpose. In addition, Principal Investigators of instruments selected through the AO will conduct local EPO activities that will be coordinated with the RLEP EPO activities.

9.0 SPECIAL INDEPENDENT EVALUATION

An Independent Review Team (IRT) will be established to provide an external, project-independent, assessment of the project progress, technical and programmatic performance, and readiness. Chartered by the Office of Program Anaylsis and Evaluation and the Exploration Systems Mission Directorate, this team will be managed through the LaRC Independent Projects Assessment Office (IPAO). The team will participate in reviews at project transition gates. To avoid increasing both the cost burden and time demands on the Project, the independent reviews will be combined with the major project reviews. The IRT reports to the Exploration Systems Mission Directorate, the GSFC PMC, and Agency PMC as required. The IRT satisfies the requirement for Independent Assessment (IA), Non-Advocate Review (NAR), Independent Implementation Review (IIR) and Enterprise Independent Review (EIR) teams.

10.0 TAILORING

The LRO mission will be conducted in a manner compliant with NPR 7120.5C.

11.0 APPENDIX A: GLOSSARY AND ACRONYMS

Abort Termination of the nominal mission that allows the crew to be returned to Earth in the portion of the space system used for nominal reentry and touchdown (see Abort to Earth, Abort to Orbit).

Abort to Earth Early mission termination, with direct return to the Earth's surface as the immediate objective.

Abort to Orbit An early mission termination that has an immediate objective of placing a crewed flight system in Earth (or destination vicinity) orbit, prior to return to the Earth's surface.

Annunciate To provide a visual, tactile or audible indication.

Ascent The function of liftoff from the Earth (or mission destination) surface, to spacecraft insertion into Earth/destination orbit.

Automated control Automatic, as opposed to human operation or control of a process, equipment or a system; or the techniques and equipment used to achieve this. Automation is the control or execution of actions with no human interaction. Automated control does not exclude the capability for manual intervention / commanding, but manual intervention / commanding is explicitly not required to accomplish the function.

Autonomous experiments Defined as a flight experiments operating independent of external commands or control (i.e. commands from mission control on Earth). Autonomous experiments can be fully automated or require some degree of manual commanding/intervention.

Autonomous operations Defined as a flight vehicle operating independent of external communication, commands or control (i.e., commands from mission control on Earth). Autonomous operations can be fully automated or require some degree of manual commanding/intervention by the onboard crew. Autonomous operations that do not require onboard crew involvement are, by definition, automated; therefore, the term "autonomous operations" used in the requirements assumes onboard crew involvement in the operations.

Berthing A method of mating two or more Exploration elements in space. During a berthing operation, the two elements are mechanically connected prior to the structural capture and final mating (i.e., one element grapples the other with a robotic arm). One element controls the trajectory and attitude of the other element for the contact and capture. Final mating is generally performed by the berthing mechanism (also see docking).

Cargo Delivery System (CDS) The CDS encompasses the capability to deliver all non-CEV flight elements needed to accomplish human exploration objectives. At such time as CDS elements dock with the CEV, they are part of a human crew occupied system, and are considered part of the CTS.

Cargo Launch Vehicle The Cargo Launch Vehicle is an element of the Cargo Delivery

System. The Cargo Launch Vehicle will perform the ascent function for non-crewed elements of the CTS (EDS, LSAM), into an Earth Orbit. Since the Cargo Launch Vehicle will not carry human crew, it will not require Human-Rating.

Catastrophic Hazard A condition that may cause death or permanently disabling injury, major system or facility destruction on the ground, or major systems or vehicle destruction during the mission. (From NPR 8715.3 Safety Manual)

Consumables Resources that are consumed in the course of conducting a given mission. Includes propellant, power, habitability items (e.g., gaseous oxygen), and crew supplies.

Contingency EVA Capability An EVA capability provided to deal with critical failures or circumstances, which are not adequately protected by redundancy or other means.

Crew Exploration Vehicle (CEV) The CEV provides crew habitation and Earth reentry capability for all Exploration Spirals.

Crew Exploration Vehicle Launch Segment (CEVLS) The CEVLS consists of a Crew Exploration Vehicle (CEV), a Crew Launch Vehicle (CLV), and all the dedicated ground support infrastructure necessary to launch the CEV to Earth orbit.

Crew Launch Vehicle (CLV) The CLV is an element of the CTS. The CLV will be human-rated, and will deliver the CEV into a mission-specific Earth Ascent Target Orbit.

Crew Member Human onboard the spacecraft or space system during a mission.

Crew Survival Capabilities designed to keep the crew alive through means such as abort, escape, safe haven, emergency egress, and rescue in response to a Catastrophic Hazard.

Crew Transportation System (CTS) The CTS encompasses the flight elements needed to deliver a human crew from Earth to a mission destination, and return the crew safely to Earth. The CTS must interact with the Ground Support System (GSS) during all Spirals; current architectures require delivery of the EDS and LSAM to Earth orbit through use of the CDS.

Critical Hazard A condition that may cause a severe injury or occupational illness, loss of mission, or major property damage to facilities, systems, or flight hardware.

Day Defined as an Earth day of 24 hours.

Destination Surface System (DSS) The DSS encompasses all elements (exclusive of the surface lander that transports the crew to the destination surface) necessary to enable a long-duration human exploration mission. Examples of DSS elements include a long-duration habitation module, surface power capability, and surface transportation systems. DSS elements will be delivered to the destination surface via the CDS. It is likely that these assets will be pre-deployed in advance of the crew that will utilize them to execute a given Exploration mission.

Destination Surface to Destination Vicinity Phase Starts with the initiation of the ascent

(T0) from the destination surface. Representative mission activities include: ascent, abort, and orbit insertion or libration capture. Phase ends after successful destination vicinity insertion/capture.

Destination Vicinity Operations Phase (A) Starts at the successful insertion/capture at the destination vicinity. Representative mission activities include: loiter and phasing, vehicle and system checkout, crew-cargo transfers, undocking and separation. Phase ends at the successful separation of surface lander system for descent burn.

Destination Vicinity Operations Phase (B) Starts after the successful destination orbit insertion or libration point capture, following ascent from destination surface. Representative mission activities include: phasing, vehicle-system checkout, crew-cargo transfer, undocking and separation maneuver, element disposal and/or safing. Phase ends at the completion of the Trans-Earth Injection burn.

Destination Vicinity to Earth Phase Begins with completion of Trans-Earth Injection burn and includes mid-course corrections, cruise to Earth vicinity, element separation and element disposal. Ends with arrival at Earth entry interface or insertion to Earth orbit.

Destination Vicinity to Destination Surface Phase Starts at the initiation of the descent burn from destination vicinity (destination deorbit burn or libration departure burn to destination). Representative mission activities include: descent to destination surface, descent aborts, landing, propulsion system shutdown and safing. For libration architectures, additional activities include orbit capture, phasing, and de-orbit maneuvers. Phase ends when the vehicle has completed all landing activities on the destination surface, including propulsion system shutdown and safing.

Docking A method of mating two or more Exploration elements in space. In a docking operation, the structural mechanisms are brought into contact and captured through independent control of the two vehicles' flight path and attitude. Final mating is generally accomplished by the docking mechanism (also see Berthing).

Earth Ascent Target Orbit The planned orbit, at conclusion of the ascent function.

Earth Departure Stage (EDS) EDS will be used to provide the propulsive force needed to transfer the various flight elements to destination phasing orbits (including the CEV and LSAM).

Earth-Moon Transit Transit of a spacecraft between Earth vicinity and Lunar vicinity in either direction.

Earth Orbit Operations Phase (A) Starts with completion of Earth orbit insertion. Representative activities include: phasing, rendezvous, docking and loiter. Ends with completion of a burn to leave Earth orbit (i.e., Trans-Lunar Injection burn or de-orbit burn).

Earth Orbit to Destination Vicinity Phase Starts after completion of vehicle injection burn (i.e., Trans-Lunar Injection) and includes mid-course corrections, element separation/disposal, and cruise to destination vicinity. Ends with successful insertion/capture at destination vicinity.

Earth to Orbit Phase Starts with liftoff. Representative activities include liftoff through ascent to orbit, ascent crew escape/abort and re-entry/descent during aborts, disposal of elements. Ends with insertion into a stable, 24 hour Earth orbit (i.e., at least 24-hour stability) or return to Earth (in the event of an abort).

Earth Re-entry Phase Direct re-entry returns from beyond Earth orbit begin with arrival at Earth entry interface; Earth-orbit Aerocapture return begins with completion of Earth orbit injection. In either case, phase includes descent through the atmosphere and ends with landing on the Earth's surface. This phase encompasses activities necessary to successfully execute direct-to-Earth aborts during ascent and direct entry return from beyond Earth orbit.

Earth Reference Orbit The orbit designated for assembly of Exploration System elements prior to departure for exploration destinations, defined by the following parameters: Inclination: 28.5-29.0 degrees; Launch Azimuth: 90+/- 5 degrees; Altitude: 307 km - 407 km.

Element A set of functional capabilities necessary to satisfy system-level mission objectives within a given architecture. CTS elements currently include the Crew Exploration Vehicle, Earth Departure Stage, and Lunar Surface Access Module. Elements can perform all system functions within a mission phase, or through mated operations with other exploration elements (as part of a segment).

Emergency Egress The timely and unassisted crew exit of a vehicle (i.e., in response to a Catastrophic Hazard).

Entry footprint Region on Earth’s surface defined by the boundaries of the Earth entry corridor for a given vehicle.

Equatorial Region of the Moon Defined as the area between 0-20 degrees lunar latitude (threshold), with an objective of 0-30 degrees **(TBR-7)**.

Escape Removal of crew from the failing spacecraft, due to an imminent catastrophic condition, thus placing them in a safe situation suitable for survivable return to Earth and rescue. Escape includes, but is not limited to, those capabilities that utilize a portion of the original space system for the removal (e.g., escape pods).

Exploration Spiral 1 (Crew Exploration Development and Test) Encompasses the capabilities necessary to insert humans into Earth orbit and return them safely to Earth, employing a post-Space Shuttle flight system. The flight elements of the Exploration Spiral 1 Crew Transportation System are the Crew Exploration Vehicle and Crew Launch Vehicle. Robotic Precursor Missions that are scheduled to launch prior to the Earth orbit demonstration of the Spiral 1 CTS are considered Exploration Spiral 1 missions.

Exploration Spiral 2 (Global Lunar Access for Human Exploration) Encompasses the capabilities necessary to execute human lunar exploration anywhere on the surface of the moon. Lunar global access exploration missions will be 4-7 days in duration on the lunar surface, and do not require pre-deployed surface systems (e.g., Habitation Module or Surface Power). Robotic Precursor Missions scheduled to launch after the Spiral 1 CTS flight demonstration, and prior to the first Spiral 3 Lunar mission are considered Exploration Spiral 2 missions.

Exploration Spiral 3 (Lunar Base and Mars Testbed) Encompasses the capabilities necessary to execute a long-duration human lunar exploration campaign. This campaign requires development of extensive surface systems (e.g., habitation and surface power system). Robotic Precursor Missions that are scheduled to launch after the last Spiral 2 extended- duration lunar mission, and prior to the initial Exploration Spiral 4 mission are considered Exploration Spiral 3 missions.

Extended-Duration (Lunar Mission) Human missions to the lunar surface ranging from 4 days (96 hours) through 7 days. This capability is an objective of Exploration Spiral 2. Extended-duration lunar missions do not require pre-deployed Surface Systems (e.g., habitation modules or surface power system).

Extra-Vehicular Activity (EVA) Operations performed by crew members outside the pressurized environment of a flight vehicle or habitat (during space flight or on a destination surface).

Failure Tolerance Failure tolerance is a term used to describe minimum acceptable redundancy. It may also be used to describe similar systems, dissimilar systems, cross-strapping, or functional interrelationships that ensure minimally acceptable system performance despite failures. It is highly desirable that space flight systems performance degrades in a predictable fashion that allows sufficient time for failure detection and, when possible, system recovery even when experiencing multiple failures.

Genomics Genetic mapping and DNA sequencing of genes, with applications of the data in medicine or biology.

Geodetic Referenced to the global center of mass of any body (does not refer only to the Earth).

Ground Operations Phase Begins with the start of mission planning. Representative activities include: mission planning, training, receipt of government hardware/software, acceptance, test, checkout, repair, inspection, assembly, integration, servicing and countdown activities. Also includes ground contingency, emergency, abort and turnaround operations. Phase ends with vehicle liftoff.

Ground Support System This system provides all common ground-based capabilities on the Earth surface (e.g., mission control, launch-site processing) needed to execute Exploration missions. The GSS is not all the ground-based capabilities because some hardware is considered IS^3. Facilities and capabilities that are unique to a single Exploration System, such as the CTS, will be included as part of the system it supports.

Guidance and Control The process of directing the movements of a space vehicle, including selection of a flight path and making changes in attitude and speed.

Habitation The provision for and management of the crew environment (i.e., through the use of life support systems, thermal control, etc.) in a crewed vehicle or habitat.

In-Space Support System (IS^3) Encompass capabilities provided by space-based infrastructure elements (e.g., communications, navigation, surveillance), that are placed in orbital or lunar/planetary locations, and their corresponding ground-based operation (e.g., a ground station or antenna). These capabilities are exclusive of those provided by elements of the DSS.

Inclination The angle between the plane of an orbit and a reference plane, most frequently the equator of the central body (e.g., the Earth's equator for geocentric orbits).

Independent Technical Authority (ITA) A responsibility owned by the NASA Chief Engineer, which is then delegated through the issuance of warrants. A warrant holder is designated as compliance officer over an identified set of engineering and technical requirements or standards.

Initial Lunar Phasing Orbit Used in Spiral 2 and 3 to define the orbit from which the CEV will assume delta V responsibility for inbound rendezvous and docking with the LSAM in lunar orbit. Defined by the following parameters: Altitude: 100 km x 500 km +/- **(TBD-6)** km **(TBR-34)**; Maximum inclination error with respect to the Lunar Reference Orbit; 0.5 degrees **(TBR-28)**.

Initial Operational Capability (IOC) The capability achieved when an element, segment, or system (e.g., the CEVLS) passes its initial Flight Readiness Review in connection with a given Exploration Spiral.

Integrated Logistics Support (ILS) Is an approach that enables disciplined, unified and iterative management of support considerations into system and equipment design. ILS includes development of support requirements that are related to readiness objectives, to design, and to each other. Requirements in turn drive acquisition of required support; ILS is then employed during the operational phase.

Launch Availability The likelihood that a given launch will be achieved without a scrub once the mission timeline (first element launch for a multiple launch mission) or the launch countdown call to stations (for a mission scenario involving a single launch) has commenced. Launch availability is composed of four elements: system availability, launch probability, launch site weather constraints and abort weather constraints. Launch Availability can be expressed as:
P(LA) = P(SA) x P(LP) x P(LW) x P(AW)

Where:
P(LA) = Launch Availability (overall probability of achieving a launch)
P(SA) = System Availability (probability of hardware being acceptable for launch)
P(LP) = Launch Probability (probability that the vehicle limits are not violated by upper level winds or other natural environment phenomena)
P(LW) = Launch Weather (probability that other launch site weather constraints are not violated)
P(AW) = Abort Weather (probability that abort weather constraints are not violated)

Launch Azimuth The angle formed by the projection of the flight path of the launch vehicle onto the surface of the earth's ellipsoid and the North direction, measured clockwise in degrees.

Launch Opportunity The period of time during which the relative position of the launch site and orbital plane permit a launch vehicle to perform the ascent function.

Life Support A subset of crewed vehicle (or habitat) habitation functions (i.e., a subsystem) that provides and manages breathable air, contamination control, potable water, fire detection/suppression, cabin pressure/temperature/humidity, environmental monitoring, etc.

Long-Duration (Lunar Mission) Human missions to the lunar surface that require pre-deployed Surface Systems. This capability is a requirement in Exploration Spiral 3, and encompasses surface stays from 42 days (threshold) **(TBR-3)** up to 98 days (objective) **(TBR-70)**.

Low Earth Orbit (LEO) An orbit around the Earth with a minimum orbital altitude of 170 km and is a stable orbit that will not decay rapidly because of atmospheric drag.

Lunar Architecture Focused Trade Study Ongoing engineering analysis of lunar architecture and mission design options, in support of Exploration architecture decision-making. Results of this study are captured in document ESMD-RQ-0005, "Lunar Architecture Focused Trade Study Final Results".

Lunar Ascent Orbit Used in Exploration Spirals 2 and 3 to define the orbit that the LSAM must achieve when launching from the lunar surface. Defined by the following parameters: Altitude: 100 km +/- **(TBD-8)** km; Inclination angle (wedge angle) with respect to Lunar Reference Orbit: Maximum of 10 degrees **(TBR-71)**.

Lunar Day The period of time it takes for the Moon to make one complete orbit around the Earth, due to tidal locking. It is marked from a New Moon to the next New Moon. A lunar day is officially 29 days, 12 hours, 44 minutes and 3 seconds long.

Lunar Reference Orbit Used in Exploration Spirals 2 and 3 to define the lunar orbit for rendezvous and docking of Exploration elements. Defined by the following parameters: Altitude: 100 km +/- **(TBD-8)** km; Inclination: Optimized for the mission.

Lunar Surface Access Module (LSAM) Provides crew transport to the lunar surface from the Lunar Reference Orbit and return from the surface to the Lunar Ascent Orbit; also provides limited surface habitation and EVA capabilities.

Mating The act of mechanically connecting together two major elements of a system. Mating can be performed in space, through docking or berthing, or on the ground through docking, berthing, or other interfaces.

Mission Refers to the sequence of events that must take place to accomplish prescribed scientific, technological, or engineering objective(s). Includes transportation of a flight system (robotic or human-crewed) to a destination, and operational activities at the destination (e.g., the Martian surface).

Mission Capable Refers to the status of an Exploration flight element or mated elements, which have sufficient consumables to fully execute its intended mission from its current location in space.

Mission Opportunity Refers to the Earth departure window to conduct a mission to another planetary destination such as the Moon or Mars. Typically constrained by orbital mechanics and the design of the Exploration System. If assembly of elements in Earth orbit is required, then "Mission Opportunity" refers to the departure window from Earth orbit based on the capability of the Exploration System.

Mission Phase Definitions Used as the basis for functional flow and decomposition of reference Spiral 3 human exploration mission. The Mission Phases identified were Ground Operations, Earth to Orbit, Earth Orbit Operations, Earth Orbit to Destination Vicinity, Destination Vicinity Operations (A), Destination Vicinity to Surface, Surface Operations, Destination Surface to Destination Vicinity, Destination Vicinity Operations (B), Destination Vicinity to Earth, Earth Reentry, and Recovery (see associated definitions).

Net Habitable Volume The functional pressurized volume left available to the crew after accounting for the loss of volume due to deployed equipment, stowage, trash, and any other items which decrease functional volume. The gravity environment corresponding to the habitable volume must be specified.

Objective Used in requirements language to define the desired capability above the threshold that should be evaluated for feasibility and affordability. Capabilities above the objective are not expected to be pursued or analyzed.

Payload The onboard scientific and exploration utilization (i.e. ISRU) equipment carried by a given spacecraft, generally quantified in terms of mass and volume. Also expressed as the entire mass delivered by a launch vehicle, to orbit.

Polar Regions of the Moon Defined as the area between 80-90 degrees **(TBR-74)** lunar latitude (threshold), with an objective of 70-90 degrees **(TBR-76)**.

Probabilistic Risk Assessment A comprehensive, structured, and logical analysis methodology employed to identify and assess risks in technologically complex systems. Probabilistic Risk Assessment results can be used to develop or validate Fault Trees and Failure Modes analysis. They also can be used as a tool for making design and logistics decisions.

Proteomics Analyzing structure, function, and interactions of the proteins produced by the genes of a particular cell, tissue or organism, with applications of the data to medicine or biology.

Proximity Operations Phase of flight operations (near the end of rendezvous and prior to docking; or after undocking) during which two space vehicles are at close ranges (< 1 km) and low relative velocity.

Recovery Phase Begins with completion of Earth surface landing and includes recovery forces operations, vehicle safing, vehicle configuration for recovery, crew egress, crew return to post-mission facilities. Ends with vehicle recovery to post-mission facilities for refurbishment or disposal.

Regolith Fine-grained powdery layer on the lunar surface above the bedrock.

Remotely Commanded Operations The capability to operate a vehicle, system, or subsystem from an external location (e.g., mission control). Remotely commanded operations do not require the presence of an onboard crew.

RescueThe process of locating the crew, proceeding to their position, and transporting them to an appropriate location.

Robotic Precursor Mission A robotic spacecraft mission that supports The Vision by achieving scientific objectives and/or through preparing for future human exploration activities.

Robotic Precursor Phase Exploration missions accomplished by robotic systems, to prepare for and support future human exploration missions.

Robotic Precursor System Robotic spacecraft that are developed to execute missions that prepare for and support future human exploration, and to accomplish measurement objectives.

Safety-Critical Software Software is safety-critical if it meets at least one of the following criteria:

1. Resides in a safety-critical system (as determined by a hazard analysis AND at least one of the following:
    a. Causes or contributes to a hazard.
    b. Provides control or mitigation for hazards.
    c. Controls safety-critical functions.
    d. Processes safety-critical commands or data.
    e. Detects and reports, or takes corrective action, if system reaches hazardous state.
    f. Mitigates damage if a hazard occurs.
    g. Resides on the same system (processor) as safety-critical software.
2. Processes data or analyzes trends that lead directly to safety decisions (e.g., determining when to turn power off to a wind tunnel to prevent system destruction.)
3. Provides full or partial verification or validation of safety-critical systems, including hardware or software subsystems.

Segment Used in the CTS requirements development process to express the identity of two or more elements mated together and operating jointly in a given set of mission phases. Segments defined this way facilitate functional decomposition of capabilities throughout the reference Exploration Spiral 3 mission. For example, the In-Space Transportation Segment is comprised of the CEV and an Earth Departure Stage, and comprises the CTS from the Earth Orbit Operations Mission Phase until CEV-EDS separation during the Destination Vicinity Operations Mission Phase. Other segments were defined as the CEV Launch Segment (CEV and CLV operating through separation in Earth orbit), the Destination Transportation Segment (CEV and

LSAM operating in the lunar vicinity), and the Earth Return Segment (CEV only, upon separation from LSAM Ascent Stage).

Spiral Development Process A phased system of systems development process that allows increasing capabilities to be achieved in support of long range objectives. While work can be accomplished concurrently against the objectives associated with multiple spirals, the completion of all objectives for a given spiral is considered necessary to enable achievement of the succeeding spiral. See associated definitions for Exploration Spirals.

Strategy to Task to Technology Process (STTP) Use of engineering analysis to validate architectural and mission design approaches, and identify technology investment needs.

Surface Operations Phase Starts at the completion of landing on the destination surface, including propulsion system shutdown and safing. Representative mission activities include: measurement operations, system and operational testing, surface EVA, assembly and maintenance, vehicle checkout, and preparation for ascent. Phase ends at initiation of ascent from the destination surface (i.e., T0).

System A set or arrangement of interdependent elements/segments that are used to accomplish mission objective(s). Exploration systems are Crew Transportation, Cargo Delivery, In-Space Support, Destination Surface, Robotic Precursor, and Ground Support. These systems comprise the Exploration System of Systems.

System of Systems A set or arrangement of interdependent systems that are related or connected to provide a given capability. The loss of any portion of the System of Systems will degrade the performance or capabilities of the whole. The systems contained in the Exploration System of Systems (ESS) are: the Crew Transportation System, Cargo Delivery System, In-Space Support System, Destination Surface System, Robotic Precursor System, and Ground Support System. Requirements, constraints, and guidelines that apply to all human and robotic exploration systems are levied against the Exploration System of Systems, and may apply against any or all Exploration Spirals, as specified. The term "System of Systems" is sometimes expressed synonymously as "Super-system".

Threshold Used in requirements language to define the minimum capability necessary to satisfy the requirement.

Transfer Volume The passageway between two connected element that can contain crew.

Wedge Angle The angle existing between two orbital planes. A plane change maneuver must be accomplished (i.e., through the use of delta-V capability) to negotiate the wedge angle between a given initial orbit plane (e.g., the Earth Reference Orbit) and a desired target orbital plane (e.g., the Lunar Reference Orbit).

AA Associate Administrators
AFS Air Force Station
AIM Advanced Integrated Matrix

AO Announcement of Opportunity
CDS Cargo Delivery System
CE&R Concept Exploration and Refinement
CEV Crew Exploration Vehicle
CEVLS Crew Exploration Vehicle Launch Segment
CLV Crew Launch Vehicle
CG Center of Gravity
CRaTER Cosmic Ray Telescope for the Effects of Radiation
CTS Crew Transportation System
DI Digital Model
DSN Deep Space Network
DSS Destination Surface System
EDR Experimental Data Record
EDS Earth Departure Stage
EI Entry Interface
EIR Enterprise Independent Review
ECLSS Environmental Control/Life Support System
EPO Education and Public Outreach
ESMD Exploration Systems Mission Directorate
ESS Exploration System of Systems
EVA Extra-Vehicular Activity
FOM Figures-of-Merit
FOV Field of View
GCR Galactic Cosmic Ray
GSFC Goddard Space Flight Center
GN&C Guidance, Navigation, and Control
GSS Ground Support System
HR&T Human & Robotic Technology
HWHM Half Width and Have Maximum (of the instrument field of view)
IA Independent Assessment
IA International Agreement
IIR Independent Implementation Review
INSTEP In-Space Technology Experiments Program
IOC Initial Operational Capability
IPAO Independent Projects Assessment Office
IRD Interface Requirements Document
ILS Integrated Logistics Support
IRT Independent Review Team
IS^3 In-Space Support System
ISRU In-Situ Resource Utilization
ITA Independent Technical Authority
JIMO Jupiter Icy Moon Orbiter
K Kelvin
km Kilometers
KPP Key Performance Parameters
KSC Kennedy Space Center
LAMP Lyman-Alpha Mapping Project

LAWG Lunar Architecture Working Group
LEND Lunar Exploration Neutron Detector
LEO Low Earth Orbit
LET Linear Energy Transfer
LExSWG Lunar Exploration Science Working Group
LOA Letter of Agreement
LOLA Lunar Orbiter Laser Altimeter
LRO Lunar Reconnaissance Orbiter
LROC Lunar Reconnaissance Orbiter Camera
LRL Lunar Robotic Lander
LRO Lunar Robotic Orbiter
LROC Lunar Robotic Orbiter Camera
LSAM Lunar Surface Access Module
LSI Landed Surface Interrogator
m Meters
M Meters
MEPAG Mars Exploration Program Analysis Group
MeV Mega-electron Volts
mm Millimeters
MOU Memorandum of Understanding
NAC Narrow Angle Camera
NAR Non-Advocate Review
NEDD Natural Environments Definition for Design
NODIS NASA Online Directives Information System
NP NASA Publication
NPD NASA Policy Documents
NPR NASA Procedural Requirement (Document)
NPSD National Security Presidential Directive
NRA NASA Research Announcements
OAG Operations Advisory Group
ORDT Objectives and Requirements Definition Team
OSMA Office of Safety and Mission Assurance
OSP Orbital Space Plane
PDR Preliminary Design Review
PDS Planetary Data System
PI Principal Investigator
PIP Proposal Information Package
PMC Program Management Council
ppm Parts Per Million
PRA Probabilistic Risk Assessment
PSR Permanently Shadowed Regions
RFP Request for Proposals
RLEP Robotic Lunar Exploration Program
RPS Robotic Precursor System
SMD Science Mission Directorate
SNR Signal-to-Noise Ratio
SPE Solar Particle Event

SRR System Requirements Review
STD Standard (Document)
STTP Strategy to Task to Technology Process (or Panel)
TBD To Be Determined
TBR To Be Resolved
TPS Thermal Protection System
TRL Technology Readiness Level
TTA Technology Transfer Agreements
WAC Wide Angle Camera
UV Ultraviolet