Rev.	ECO	Description	Author	Approved	Date
01	32-029	Initial Release for comment	JCKasper		6/3/05

CRaTER
Level 2
Mission Requirements Document

Dwg. No. 32-01205

Revision 01
June 6, 2005

Table of Contents

Preface

Revision 01 of this document is being circulated for comment.

1. LRO Measurement Objectives

The LRO will 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-M10, RLEP-M20, RLEP-T30)

1.1 RLEP-LRO-M10

LRO shall characterize the deep space radiation environment in lunar orbit, including neutron albedo (in particular at energies in excess of 10 MeV), (RLEP-M10)

1.2 RLEP-LRO-M20

LRO shall characterize the deep space radiation environment in lunar orbit, including biological effects caused by exposure to the lunar orbital radiation environment. (RLEP-M20, RLEP-T30)

2. CRaTER Level 1 Requirements

2.1 RLEP-LRO-M10

Measure and characterize that aspect of the deep space radiation environment, 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.

2.2 RLEP-LRO-M20

Investigate the effects of shielding by measuring LET spectra behind different amounts and types of areal density, including tissue-equivalent plastic.

3. CRaTER Level 2 Requirements

3.1 Cover LET Spectrum Range

3.1.1 Requirement

The telescope stack will contain adjacent pairs of thin (approximately 150 micron) and thick (1000 micron) Si detectors. The thin detectors will be used to characterize energy deposition between approximately 250 KeV and 75 MeV. The thick detectors will be used to characterize energy deposits between 4.5 MeV and 1.35 GeV.

3.1.2 Rationale

The thin detector is sensitive to incident particles with a high initial LET and the subsequent thick detector is sensitive to particles with a lower LET. The precise energy range of the detectors is determined by the noise floor (tens of KeV) and the maximum energy deposit expected by an iron nucleus at a large angle of incidence.

3.2 Resolve LET Spectrum

3.2.1 Requirement

The pulse height analysis of the energy deposited in each detector will have an energy resolution of at least 1/300 the maximum energy of that detector. Our goal is to measure the energy deposition of individual events to 1/1000 the maximum energy, or a minimum fidelity of 10 bits in the ADC. The values of the energy deposited in each detector for all events that meet the coincidence requirements will be sent back without reduction in fidelity or compression.

3.2.2 Rationale

A high resolution measurement of the energy deposited is required to characterize the LET spectrum and to distinguish between the effects of the primary radiation and secondaries produced through interactions.

3.2 Effects of Shielding

3.2.1 Requirement

The LET spectrum will be measured by pairs of detectors behind an aluminum shield of sufficient energy to block protons with energies below 10 MeV. The goal is to allow protons with energies of 5 MeV and above into the telescope, corresponding to a thickness of 0.030" for the aluminum wall on either end of the telescope.

3.2.2 Rationale

Solar and galactic cosmic rays with energies exceeding 10 MeV have the most significant biological effect. Since the typical flux of energetic particles increases rapidly with decreasing energy – especially during periods of heightened solar activity – a minimum energy must be set to prevent the desired events from being lost in the high rate of lower energy particles.

3.3 Effect on Humans

3.3.1 Requirement

The LET spectrum will be measured at different distances through a material with radiation absorptive properties representative of human tissue. The goal is to use two pieces of A-150 human Tissue Equivalent Plastic (TEP) of 27 mm and 54 mm in length.

3.3.2 Rationale

The TEP allows CRaTER to measure the resulting LET spectrum after the primary solar and galactic cosmic rays pass through human tissue. The volume of TEP under consideration will allow the instrument to measure the evolution of the LET spectrum over 10-100 MeV.

3.4 Energy Deposition in TEP

3.4.1 Requirement

Energy deposition in the Si detectors will be used to infer the rate of energy deposition in the TEP.

3.4.2 Rationale

This is an additional means of understanding the lunar radiation environment for humans.

3.5 Pathlength Constraint

3.5.1 Requirement

The uncertainty in the length of TEP traversed by a particle seen by detectors on either side of a section of TEP will be less than 10%. Given the size of the TEP components this requirement directly leads to the fields of view of the telescope. The CRaTER full-width fields of view shall be no more than 35 degrees on the zenith side and 80 degrees on the nadir side.

3.5.2 Rationale

This is a sufficient accuracy for subsequent modeling efforts to reproduce the observed LET spectra based on direct measurements of the primary particle spectrum.

3.5 Internal Calibration

3.5.1 Requirement

CRaTER will have the ability of conducting an internal calibration of the pulse-height analysis electronics system to verify the stability of amplification gain.

3.5.2 Rationale

An internal calibration of the electronics ensures that the accuracy of the LET measurements is stable over the mission.

4. CRaTER Driving Requirements on Spacecraft

Driving requirements on the spacecraft are a function of CRaTER instrument design characteristics that reflect the Level 2 requirements outlined in Section 3.

4.1 Fields of View and Fields of Regard

4.1.1 Requirement

Our goal is for these fields of view to never be obscured during normal spacecraft operations.

4.1.2 Rationale

If a component of the spacecraft is in the field of view of the instruments it will alter the composition and energy spectrum of the incident solar and galactic particles, thus contaminating the measurement of the LET spectrum.

4.2 Pointing

4.2.1 Requirement

During normal operation the spacecraft will point within 35 degrees of the lunar surface.

4.2.2 Rationale

The field of view of the nadir (lunar) pointing side of CRaTER will be no more than 80 degrees. The angle subtended by the lunar surface in the projected LRO orbit will be approximately 150 degrees. As long as the optical bench on LRO is pointed with 35 degrees of the lunar surface the nadir side of the telescope will be looking completely at the lunar surface.

4.3 Pointing Knowledge

4.3.1 Requirement

Spacecraft will provide knowledge of the pointing of CRaTER to within 10 degrees.

4.3.2 Rationale

Studies of the lunar radiation environment with the CRaTER observations will examine the possibility of directionality of the primary radiation. This could be due to alignment of solar energetic particles with the local magnetic field or obscuration of incident particles by a favorable Earth geometry.

4.4 Observations During Flares

4.4.1 Requirement

To the extent that any solar flares occur over the mission, CRaTER will continue to operate, and LRO will record CRaTER measurements, during particle enhancements at 1 AU associated with solar flares.

4.4.2 Rationale

The radiation environment during periods of intense solar activity is particularly important for understanding the risks associated with manned missions to the moon. Likewise these intervals of intense activity are the most difficult to model and their study would benefit from direct observations.

4.5 Event Rate

4.5.1 Requirement

LRO shall support an event rate from CRaTER of 1200 events per second.

4.5.2 Rationale

This is the event rate predicted during an intense particle event at 1 AU.

5. CRaTER Miscellaneous Requirements on Spacecraft

The numbers quoted in these sections are mainly taken from the most recent revision of the associated ICD. Links are provided to the most current appropriate ICD and should be followed to identify the current values. The ICDs and other supporting documents are on the CRaTER configuration database: http://snebulos.mit.edu/dbout/32-data.html.

5.1 Data Link and Data Rate

LRO shall provide a 1553B bus to support CRaTER telemetry. CRaTER will continually transmit 1200 events per second, with fill data in cases where 1200 events are not seen. 1200 events corresponds to approximately 100 kbs. The data ICD is located here: http://snebulos.mit.edu/projects/crater/file_cabinet/0/02001/02001_rA.pdf.

5.2 Mass Allocation

CRaTER target mass is approximately 5.6 kg. Total instrument mass is discussed in the mechanical ICD.

5.3 Power

CRaTER target power consumption is 6.0 W on average and 9.0 W peak. Instrument power consumption is discussed in the electrical ICD.

5.4 Thermal

CRaTER will be completely covered by MLI and thermally coupled to the spacecraft through the optical bench. The thermal design and interface to the spacecraft is outlined in the thermal ICD.

5.4 Microphonics

Mechanical vibrations in the instrument can translate into noise in the data. The level of microphonics harmful to the operation of CRaTER and the resulting requirement on the spacecraft is under study.

6. Ground System Requirements

6.1

Appendix A: Terms and Definitions

CRaTER: Cosmic Ray Telescope for the Effects of Radiation

ICD: Interface Control Document

LET: Linear Energy Transfer. The rate at which an ionizing energetic particle deposits energy in a material is a strong non-linear function of the incident particle, the composition of the target material, and the instantaneous energy of the incident particle. The linear energy transfer (LET) is the instantaneous rate of energy loss of a given particle per unit distance in a material. The LET distribution in a material is more important for evaluating the biological effects of a radiation source than the distribution of the actual energies of the incident particles. Here is a link to a discussion of energy loss of radiation in matter: http://oregonstate.edu/dept/nchem/textbook/chapter17.pdf

TEP: Tissue Equivalent Plastic.