LRO/CRaTER Data Products

(Cosmic Ray Telescope for the Effects of Radiation)

Jody Wilson (UNH)
and the CRaTER Team
Jody.Wilson@unh.edu

http://crater-web.sr.unh.edu/  Jody.Wilson@unh.edu  http://ppi.pds.nasa.gov/
Outline

• How CRaTER works & purpose
• “Raw” Data
• Data Products (ADR)
• CRaTER Website
  
  http://crater-web.sr.unh.edu

• NASA PDS
  
  http://ppi.pds.nasa.gov/
CRaTER Instrument

- Six silicon detectors arranged in 3 pairs
- Thin (1,3,5)+ thick (2,4,6) detectors increase dynamic range
- Separated by Tissue Equivalent Plastic (TEP)
- Usually D1 faces zenith, D6 faces nadir (Moon)
- Records each time a particle passes through at least one detector
Measure Lunar radiation environment

Ever-present isotropic Galactic Cosmic Rays

- Very high energy (relativistic) atomic nuclei from outside the solar system

Intermittent storms of Solar Energetic Particles

- Can have very high fluxes
- Less energy per particle than cosmic rays, but still energetic
Exploration & Science

- Radiation *dose* rates (expectations for future astronauts)
- Effects of *shielding* on radiation dose
- Radiation *effects* on lunar surface
- Long-term changes in cosmic ray background
- Details of solar particles (solar flares)

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Shielding and Tissue Equivalent Plastic (TEP)

• Top two detectors (D1/D2): **skin or lense of eye** behind thin spacecraft wall

• Middle two detectors (D3/D4): **blood-forming organs**, shielded by 2” TEP

• Bottom two detectors (D5/D6) face the Moon ... even more shielded from Cosmic Rays, also detect radiation from the Moon

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Linear Energy Transfer

- **LET**: Energy deposited per unit length by cosmic ray passing through matter

- LET higher for ions with higher charge

- LET increases as ion slows
“Raw” (L2) Data

- Large daily text files with one or more lines of data taken every second of the LRO mission
- SEC (secondary) files: second-by-second number of particle detections in each detector (D1-D6)
  - Also contain instrument settings (not shown here)
“Raw” (L2) Data

PRI (primary) files: LET deposited in each detector for every particle detected by CRaTER

- 20 to 40 particles per second during quiet times
- Very large files with 1000’s of particles per second during solar particle events
- Used to produce LET spectra and cross-plots

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## Primary L2 data file

(column headers in .FMT files)

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Data Products Flow Chart

Particle-by-particle LET L2 Primary (PRI) Data

LET Spectra
Particle flux per LET energy bin
Integrated over time

Dose Rates
Energy Deposited per unit Mass
Integrated over all energies

Cross-plots = 2D LET Spectra

Dose Equivalent Rates
Linear Energy Transfer Spectra (LET)

- **LET**: Energy deposited per unit length by cosmic ray passing through matter

- **LET spectrum**: particle flux per LET energy bin
  - Integrated over time
  - Shows peaks (MIPs) from different elements in cosmic ray population

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LET Cross-Plots

Cross-plots: Two-dimensional LET spectra

- Particle-by-particle LET in two separate detectors
- Nuclei lose energy in TEP, so they deposit unequal energies in detectors

Location on plot tells

- Direction of arrival
- Element/species

Critical component of lunar proton mapping
Radiation Dose & Dose Equivalent

Dose = total energy deposited per unit mass

1 gray = 1 J/kg

Dose Equivalent: like dose, but weighted by the effect of radiation type on biological tissue

• Non-linear function of LET

1 sievert ~ 1 gray
Dose limits for Astronauts

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Hypothetical mission doses for solar min.

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<td>✓ Manageable</td>
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1. NCRP Report No. 98 (1989)
Dose Rates during LRO Mission

- Variety of solar particle events – some of them dangerous to deep-space astronauts

- Declining cosmic ray background dose rate due to increasing solar activity, interplanetary B field

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CRaTER Data Products
http://crater-web.sr.unh.edu/

Data
- Level 2 Data
  - Daily, Full (data files)
- Event Periods
  - SEP Events Visualization

Products
- Dose Rates
- Dose Equivalent
- Micro Dosimeter
- Linear Energy Spectra (LET)
- Cross Plot
- Lunar Albedo Maps
- Dielectric Charging (coming soon)
- Dose vs Depth (coming soon)

Ancillary Information
- Instrument
  - Housekeeping Data
  - HK Daily
- Ephemeris and Pointing
  - Daily LRO Ephemeris/CRaTER Telescope Pointing Vectors (data files)

Documentation
- Instrument Description
- Data Product Description

Publications, News and Media
- The CRaTER Special Issue of Space Weather
- Publications
- CRaTER Live Radio

Links
- PREDICCS
- UNH EOS
- NASA PDS PPI Node CRaTER Data Archive

Contact Us
- CRaTER PI, Nadia Schwaitron
- Legacy Data Product Website
- Webmaster for CRaTER Data Products

http://crater-web.sr.unh.edu/  Jody.Wilson@unh.edu  http://ppi.pds.nasa.gov/
CRaTER Data Products

http://crater-web.sr.unh.edu/

- L2 Data, Dose rates, Equivalent Dose, Micro-dosimeter, LET spectra, and Cross-plots
- Image plots and ASCII text files
- Time ranges from 1 week to whole mission
  - Option to include only solar particle events (SEPs) or times with only galactic cosmic rays (GCRs)
- Event List Visualization Page allows for quick navigation to a particular solar particle event
Dose rate plot customizations

For Dose (energy in D1-D6), Dose Equivalent (biological), or Micro Dosimeter (simple single detector) rates

Notice the changing shielding effectiveness of the TEP
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LET Spectra

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</tr>
</tbody>
</table>
LET Cross-Plots

- Cross-plot images are down-sampled to fit on a computer screen – 2 zoom levels
- Use text files (2-D tables) for quantitative analysis

http://crater-web.sr.unh.edu/  Jody.Wilson@unh.edu  http://ppi.pds.nasa.gov/
Cross-plot customizations

- Choose which detector pairs to plot
- Further option to require or exclude detection in 3\textsuperscript{rd} detector pair
  - “Triple coincidence” particles are less numerous, but can be more confidently identified

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http://ppi.pds.nasa.gov/
Cross-plot customizations

- Clicking on plot brings up element overlay

2083 day combined (GCR & SEP) cross plot data derived from 176483311 accumulated seconds from 2009-06-26 DOY:177 through 2015-03-09 DOY:068

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Additional webpage info

• Plots, tables updated daily (M-F)
• Select from 1 to 4 plots (LET, cross-plot, dose) to show at one time
• General descriptions of plots and calibration notes in the “Learn More” tab
• Clicking on LET spectrum or cross-plot brings up element-identification slider

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Data in NASA PDS
http://ppi.pds.nasa.gov/

- Data organized by year (2009-) then by Day-of-year (1-366)
- Directory for each day contains .FMT files with column names
- HK (housekeeping) files: instrument voltages, temperatures, crude pointing information
- Updated quarterly
Uses for Raw Data Files

• Plotting particles per second from SEC files using any plotting program: MS Excel, autoplot... (will be similar to dose rate plots)

• High resolution (time, energy) analysis of cosmic ray background or solar particle events (PRI files)

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Notes on using raw data

• Don’t use data during “pulser sweeps”
• Check LRO/CRaTER’s orientation (HK files)
  – Usually oriented with D1-zenith, D6-nadir
• CRaTER changes to lower-sensitivity modes during high-flux solar particle events

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Coming Soon

• Dose, LET and Cross-plot data products (LRO launch through 2014) about to be released on NASA PDS (in addition to UNH site)
• Updated maps of albedo protons from Moon
• New Data products
  – Electric charging of lunar surface vs. location & time (Talk on Thursday by Andrew Jordan)
  – Dose rates vs. depth in lunar soil

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