

Calculation of Radiation Exposure on the Moon Surface by using PHITS

Tatsuto Komiyama, Haruhisa Matsumoto
IAT/JAXA

2008/2/14

JAXA Vision

Future Lunar Exploration and Utilization Activities (Image)

From near Earth to the lunar surface
Further advancement of humankind.

Space Solar Power Supply
- Moon as a place for technology development and demonstration
- Acquisition of technologies and resources for exploring the frontier
- Year 2025: International human lunar base (initial phase)

Robotics
- Robot that can work with people
- Remote operation
- Activities in permanently shadowed areas

Utilization of lunar resources
- Use of resources on site

Toward long term presence on the Moon
- Establishment of a lunar base
- Life support

2008/2/14

Method to Calculate Radiation Spectra on the Moon Surface

- GCR model
 - CREME86
 - Using spectra out of magnetosphere
 - Solar minimum
 - Proton - Ni
 - Solid angle: 2π
 - > 10MeV/n
- SPE model
 - CREME96 WORST DAY
- Radiation transportation
 - To calculate secondary neutrons and secondary photons from interactions between the moon surface and GCR/SPE by using radiation transportation code "PHITS". (considering gamma rays from activated nuclei)
- Geometry for calculation
 - Next slide

2008/2/14

Geometry to calculate secondary neutrons and photons

Particle irradiation surface (φ100cm)

Detector (radius: 5cm)

The moon surface (φ200cm×100cm)

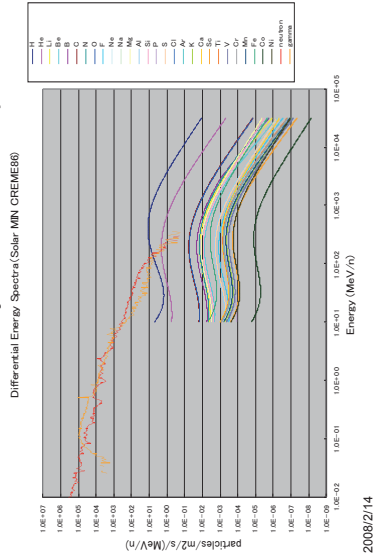
2008/2/14

Chemical Composition of the Moon Surface

- Fraction by number of atoms
 - O 60%
 - Si 17%
 - Al 4.5%
 - Ca 4.5%
 - Mg 5%
 - Fe 6%
 - Ti 1.5%
- Reference: Haskin, L., and P. Warren, Lunar chemistry, in Lunar Sourcebook, 357-474, Cambridge Univ. Press, New York, 1998.

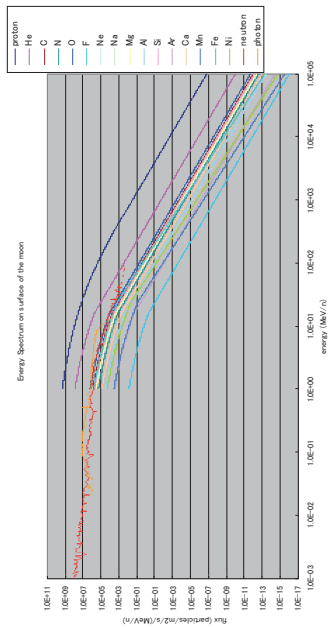
2008/2/14

Calculation Result GCR + secondary neutrons and photons



2008/2/14

Calculation Result SPE + secondary neutrons and photons



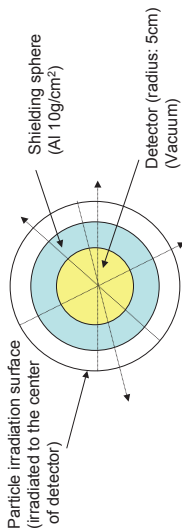
2008/2/14

Method to Calculate Radiation Spectra under 10g/cm² (Al) shielding

- Input: spectra of the previous slides
 - GCR
 - SPE
- Secondary neutrons and photons
- Radiation transportation
 - To calculate spectra of radiation transported through 10g/cm² (Al) shielding by using PHITS
- Geometry
 - Next slide

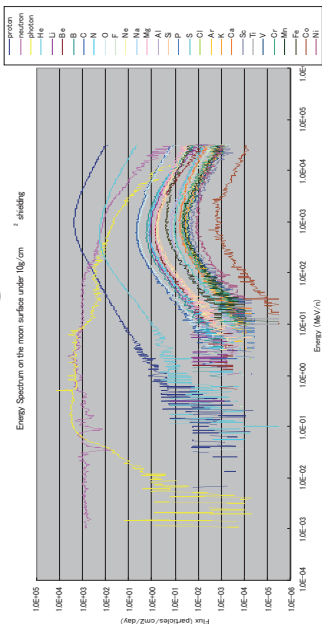
2008/2/14

Geometry to Calculate Radiation Spectra under 10g/cm² (Al) shielding



2008/2/14

Calculation Result Energy spectra under 10g/cm² (Al) shielding in Solar MIN@CREME86



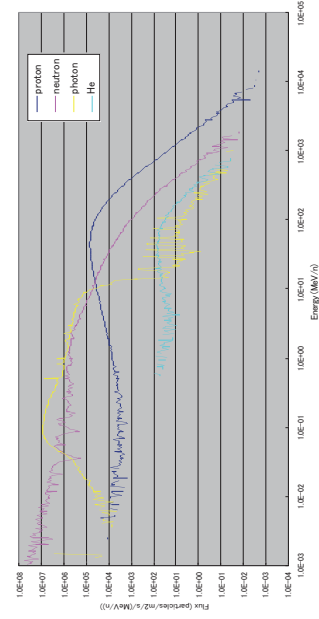
2008/2/14

Method to Calculate dose exposed on the Moon surface

- Using conversion coefficients from fluence to effective dose equivalent calculated by PHITS.

"Conversion Coefficients from Fluence to Effective Dose for Heavy Ions with Energies up to 30eV/A" T. Sato, et al., Radiat. Prot. Doseim. 109(2), 137-144(2003)
"Profile of Energy Deposition in Human Body Irradiated by Heavy Ions" T. Sato et al. J. Nucl. Sci. Technol. Suppl. 4 287-288(2004)

Calculation Result Energy spectra under 10g/cm² (Al) shielding in SPE Worst Day@CREME96



2008/2/14

Calculation Result Exposed Dose on the Moon Surface

Effective Dose Equivalent

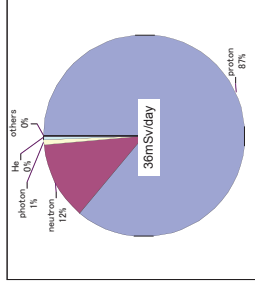
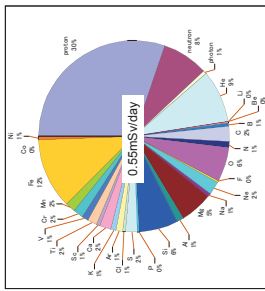
PHITS	No shielding		10g/cm ² (Al) shielding	
	GCR CREME86 MIN	SPE Worst day	GCR CREME86 MIN	SPE Worst day
	0.71 mSv/day	4100 mSv/day	0.55 mSv/day	36 mSv/day

In long term manned mission on the moon, shielding design and space weather forecast are expected to be very important.

2008/2/14

Calculation Result Contribution to dose

• under 10g/cm² (Al) shielding



2008/2/14

Future Works

- To calculate energy spectra and dose in various shielding thicknesses
- To calculate energy spectra and dose in various shielding materials

2008/2/14

Summary

- Radiation environment and exposed dose has been calculated by PHITS.
- It is suggested that shielding design and space weather forecast are to be very important in the long term manned space mission on the moon.
- Calculation of energy spectra and dose under various shieldings will be needed for conceptual design of the manned mission on the moon.

2008/2/14