



Radiation Shielding: Lunar Simulant Requirements



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January 25, 2005



The Interplanetary Radiation Environment

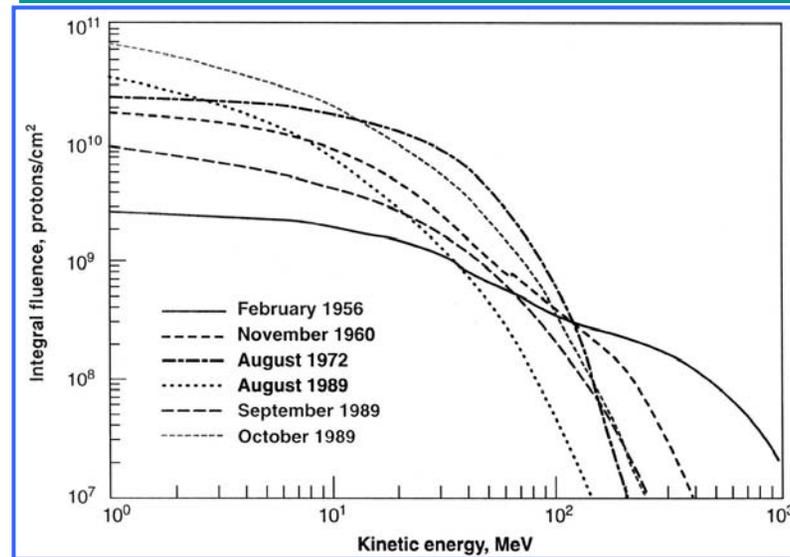
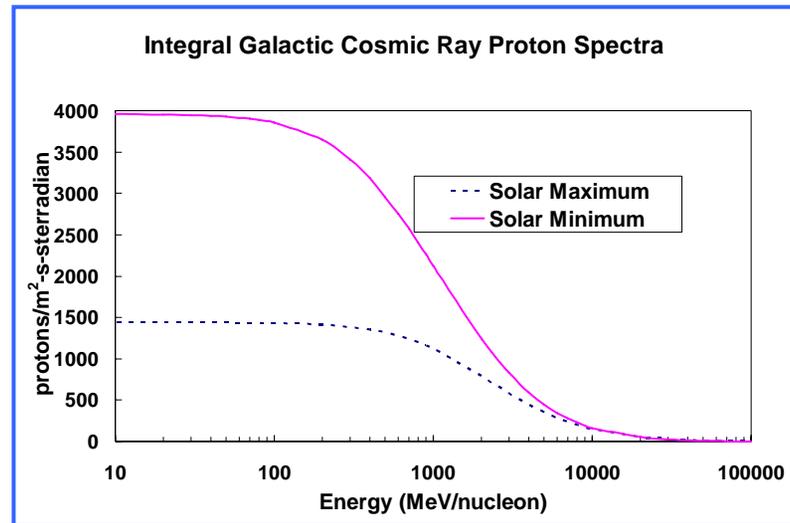


➤ Galactic Cosmic Rays (GCRs)

- Median energy ~ 1800 MeV/nuc
- Continuous flux, varies with the solar cycle

➤ Solar Energetic Particles (SEPs)

- Sporadic, lasting hours to days
- Soft spectra with highly variable composition





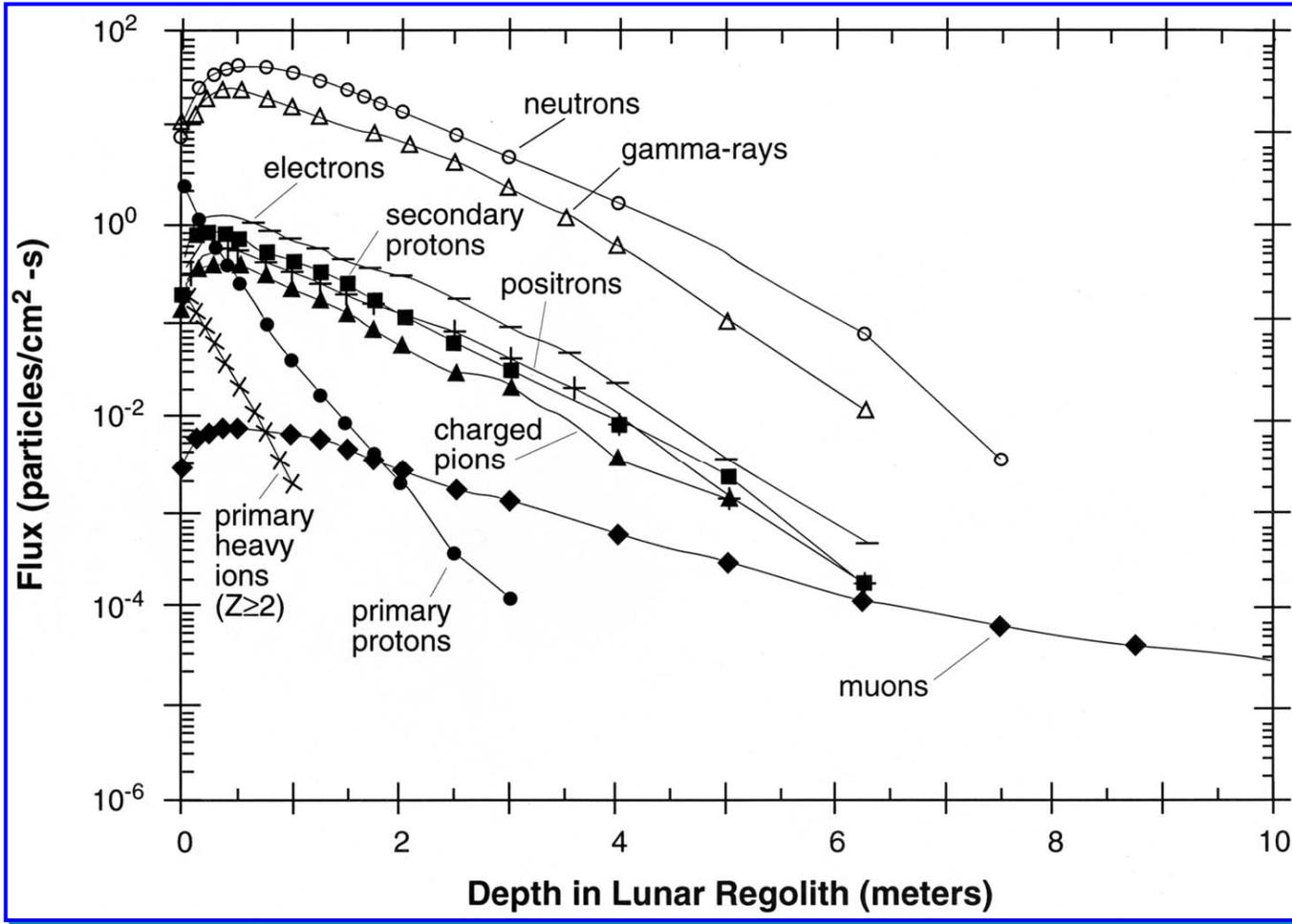
Material Shielding Considerations



- **Solar Energetic Particles**
 - Stopping them
 - Limiting neutron generation
- **Galactic Cosmic Rays**
 - Breaking up heavy nuclei
 - Limiting neutron generation
- **Hydrogen with carbon and possibly boron**



GCR Shielding Properties of Lunar Regolith

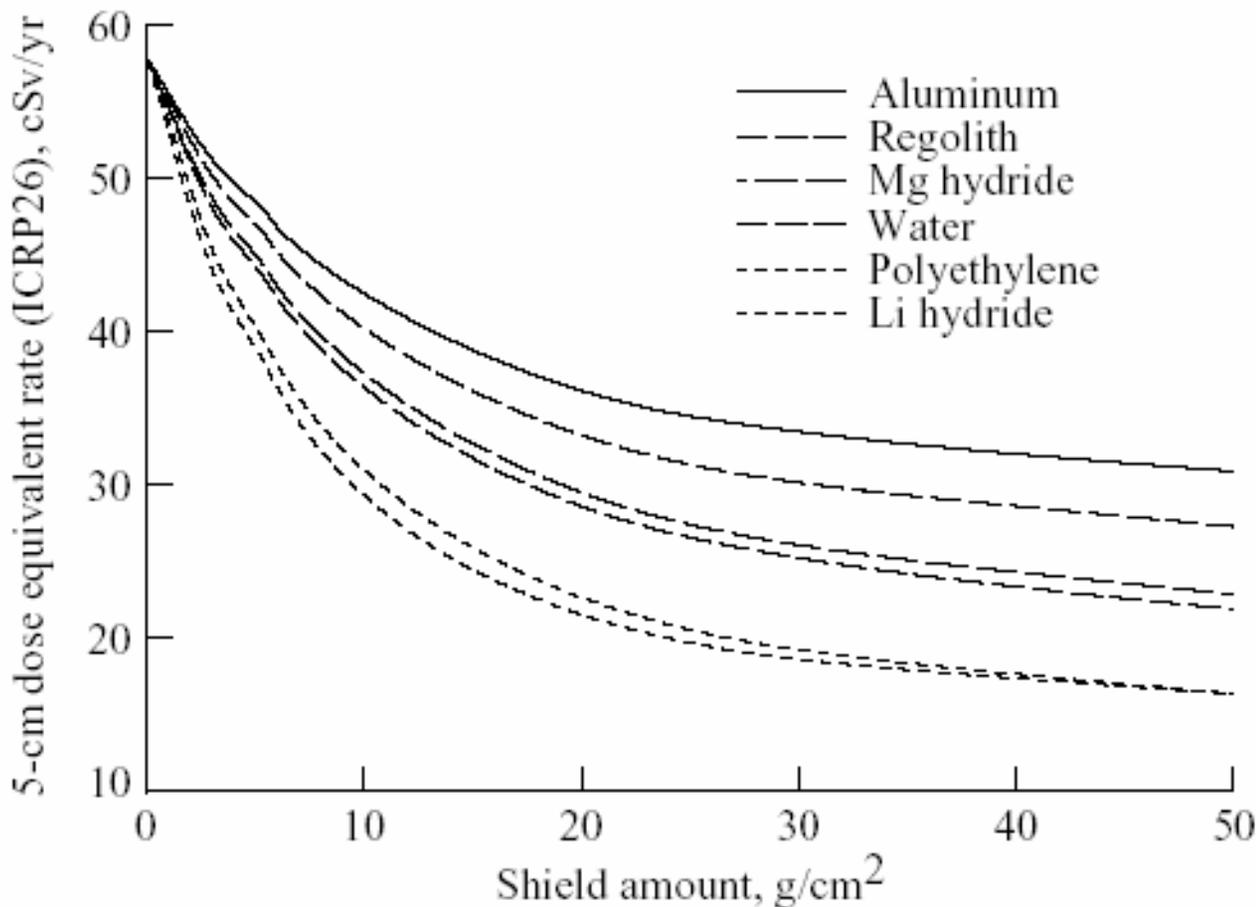


Taken from Parnell, Watts and Armstrong (1998)

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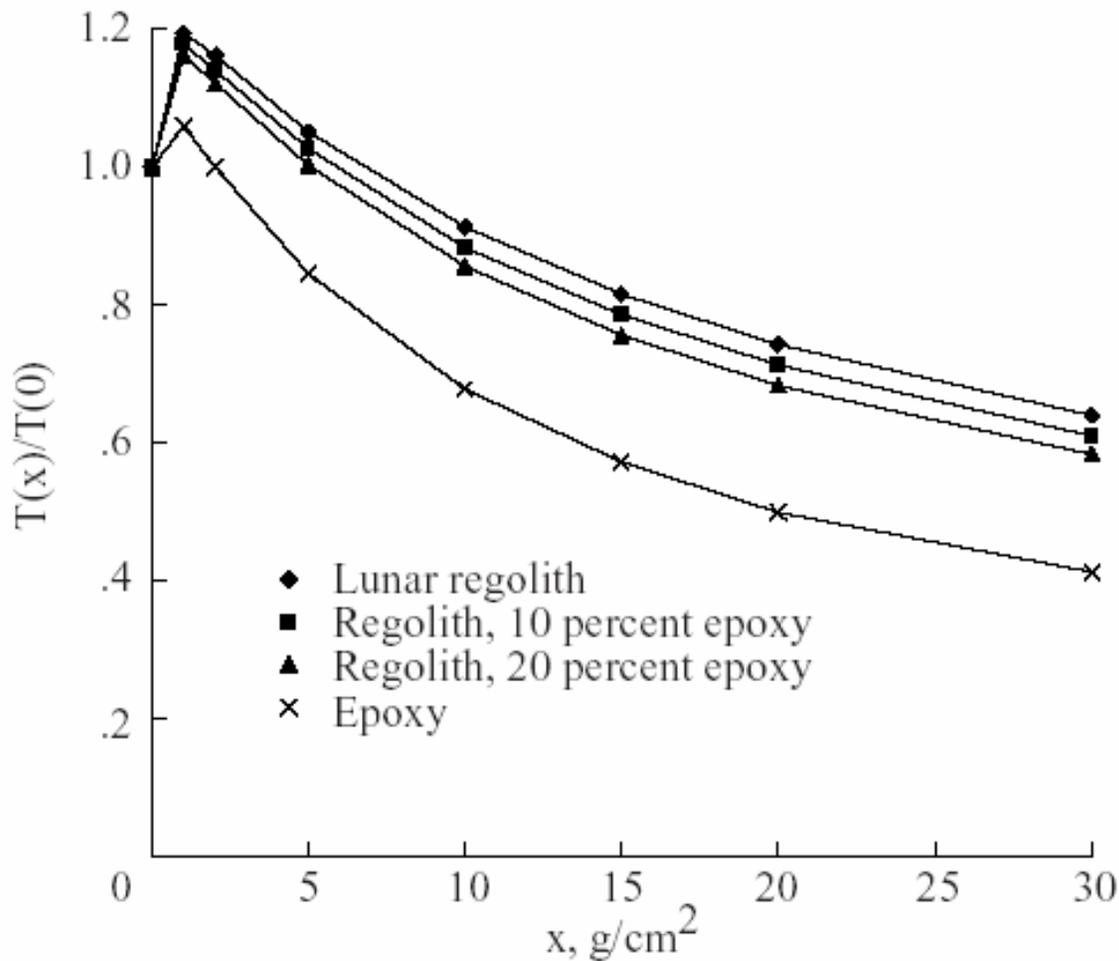


GCR Shielding Performance of Lunar Regolith





GCR Performance of Regolith Mixes



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Taken from Wilson et al. NASA Conf. Pub 3360 (1997)



Shielding from the 1972 SEP Event



Shielding	Effective Dose (cSv)	Avg. BFO Dose Eq. (cSv)
1 g/cm² Al	337.5	111.0
2 g/cm² Al	200.2	91.3
5 g/cm² Al	88.5	56.3
10 g/cm² Al	40.2	30.5



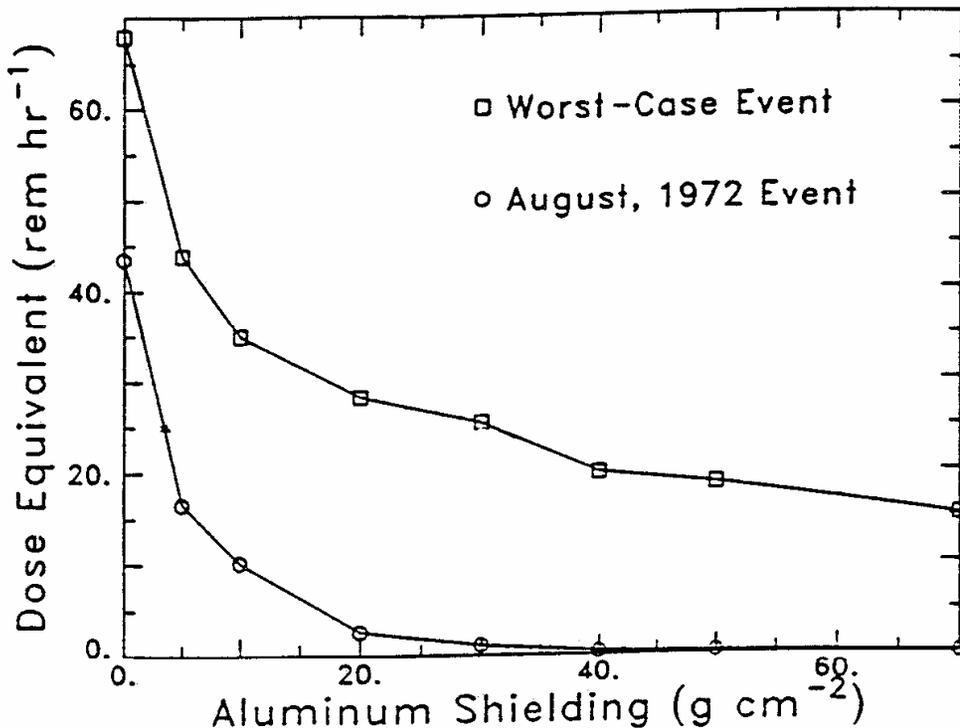
Shielding from the Carrington SEP Event (9/89 spectrum assumed)



Al Shielding	Skin Dose (cGy)	Eye Dose (cGy)	Bone Marrow Dose (cGy)
1 g/cm²	3539	2337	281
5 g/cm²	665	602	171
10 g/cm²	282	273	109



SEP Dose Equivalent Rates



Dose equivalent at 5 cm tissue depth versus aluminum shielding thickness for August, 1972 and composite worst-case solar energetic particle events.



Lunar Mission Concept



- Missions of up to 90 days to one base with excursions to conduct “field geology”
- Deep trench to study layering
 - Habitat to be buried in this trench
- Lunar ‘RV’ for excursions of up to 14 days
 - Must carry radiation shielding
- 14 day stays in the buried habitat
 - Study collected samples



Conclusions



- Regolith Simulant for Shielding Should:
 - Have the correct elemental composition
 - Should handle like regolith
 - Typical density of regolith
 - Typical mix of particle sizes and shapes
 - Should process like regolith
 - Have typical sintering characteristics
 - Should bind like regolith (i.e. in concrete, with epoxy or polyethylene).
 - Needed in metric ton quantities