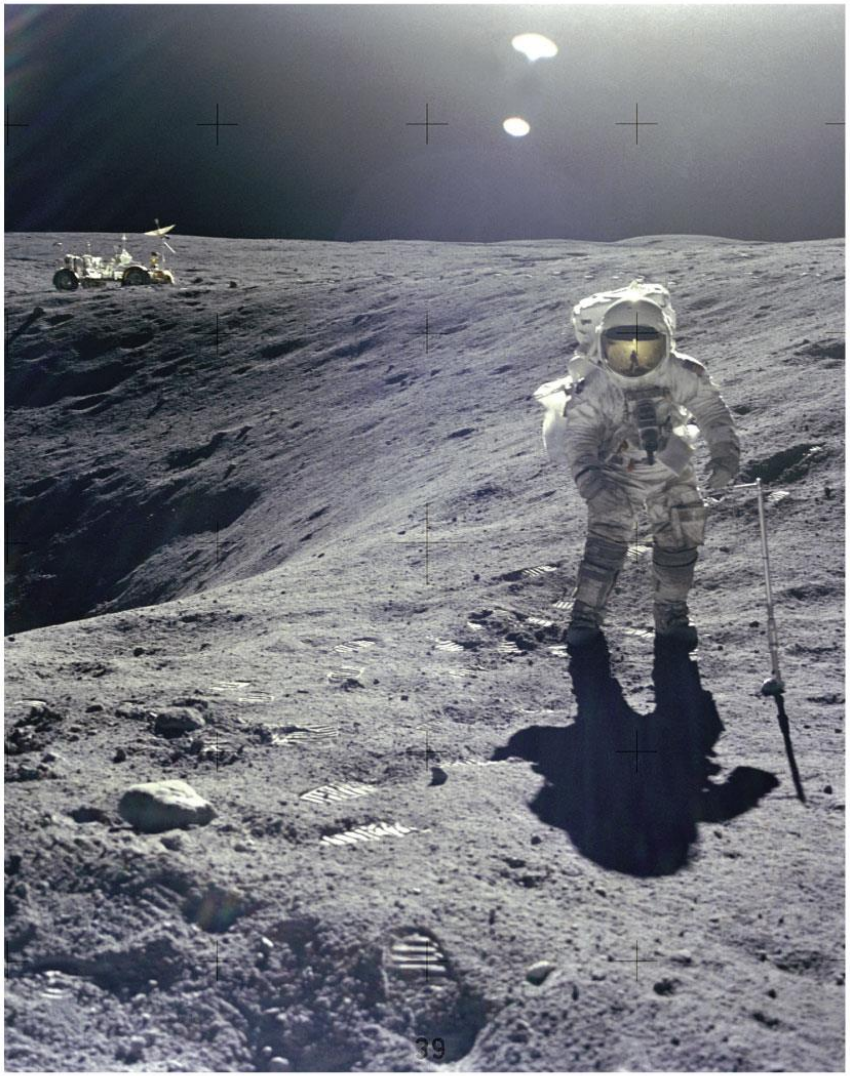
Diagnostic tools for environmental effects on surface exploration systems

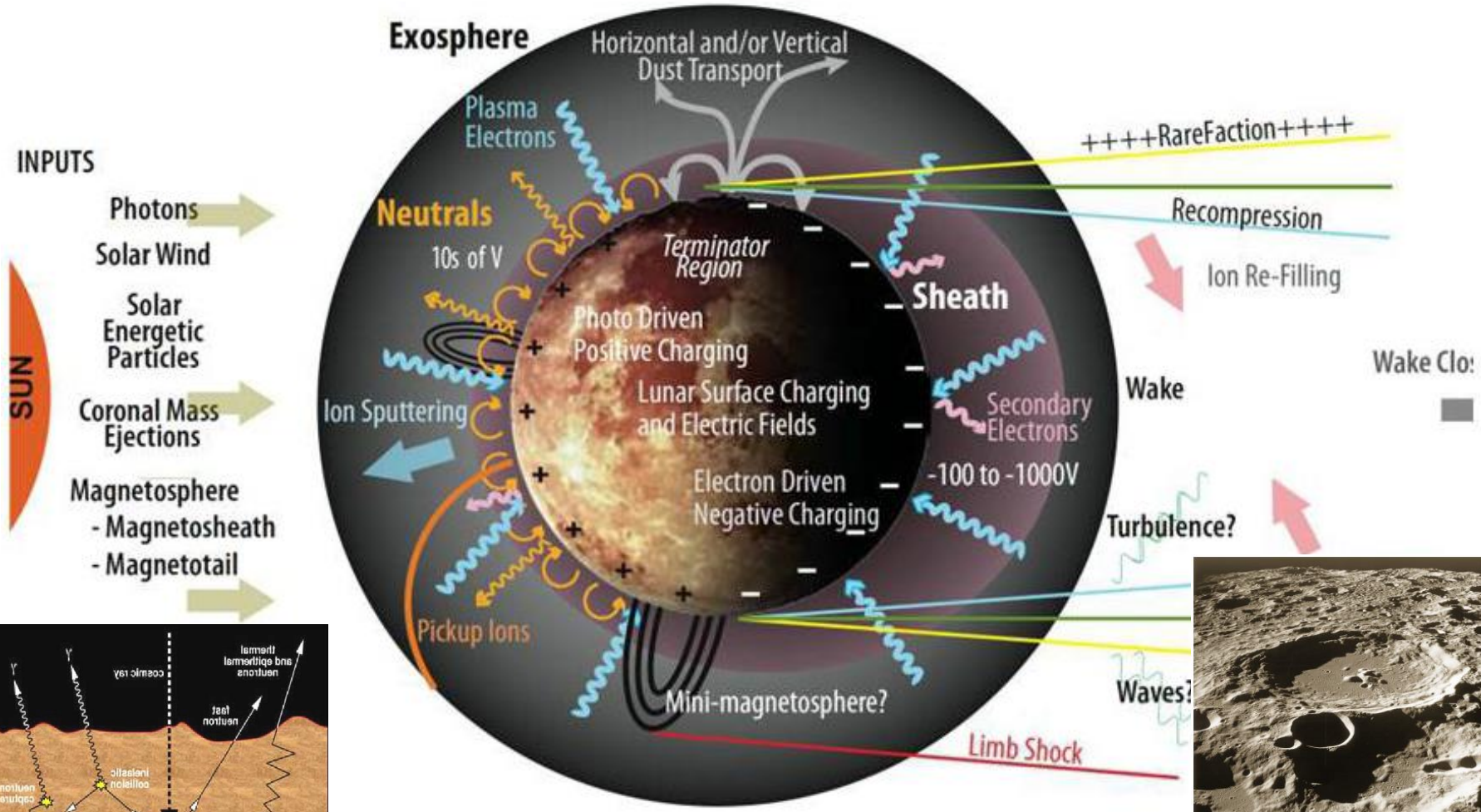
F. Cipriani, D. Rodgers, A. Hilgers, P. Jiggens, G. Drolshagen, Mark Millinger, Petteri Nieminen, Giovanni Santin, Hugh Evans and Eamonn Daly

ESTEC / TEC-EES Space Environment and Effects Section



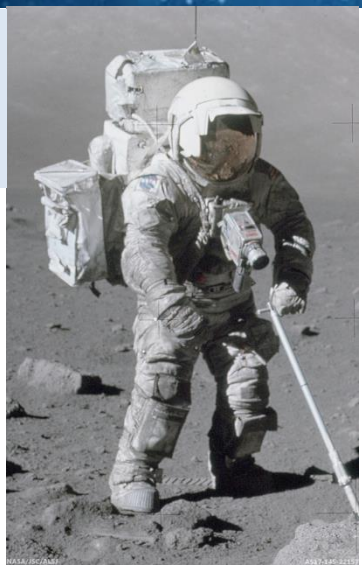
Moon 2020-2030, ESTEC, Noordwijk, The Netherlands, 14th -16th December 2015

Lunar environments : highly variable

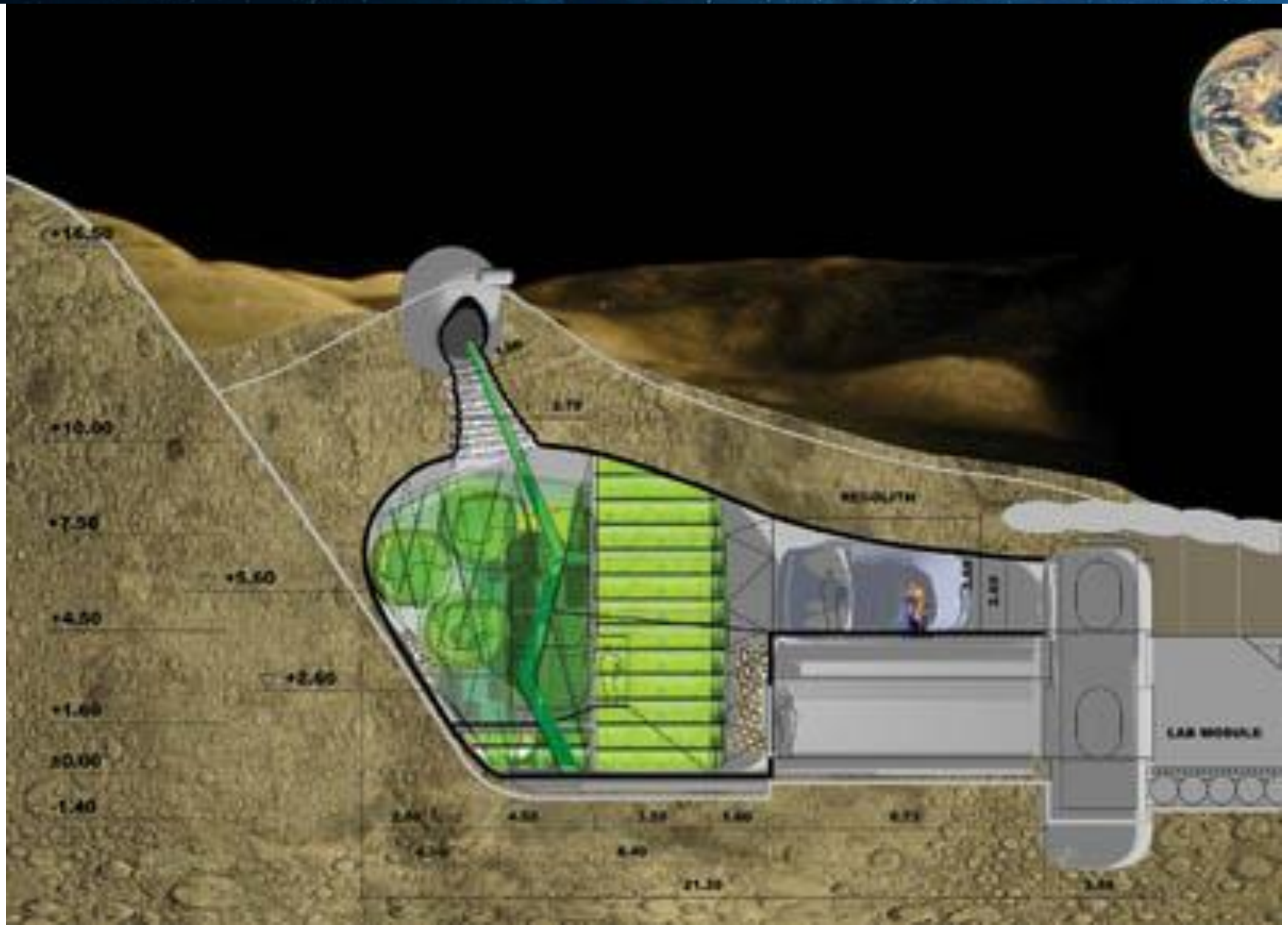


(Credits SSL/UC Berkeley)

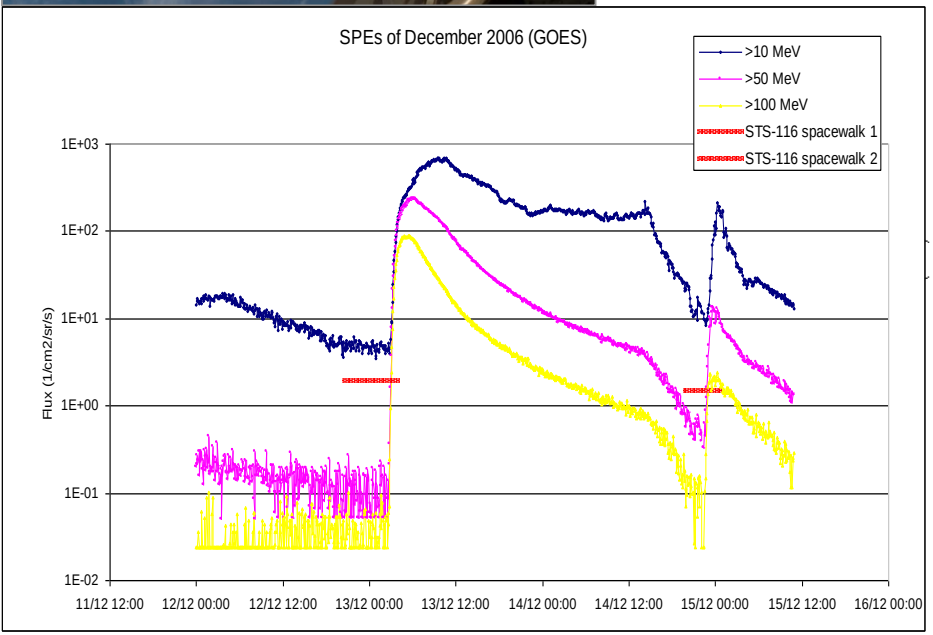
Radiation Environments and Effects

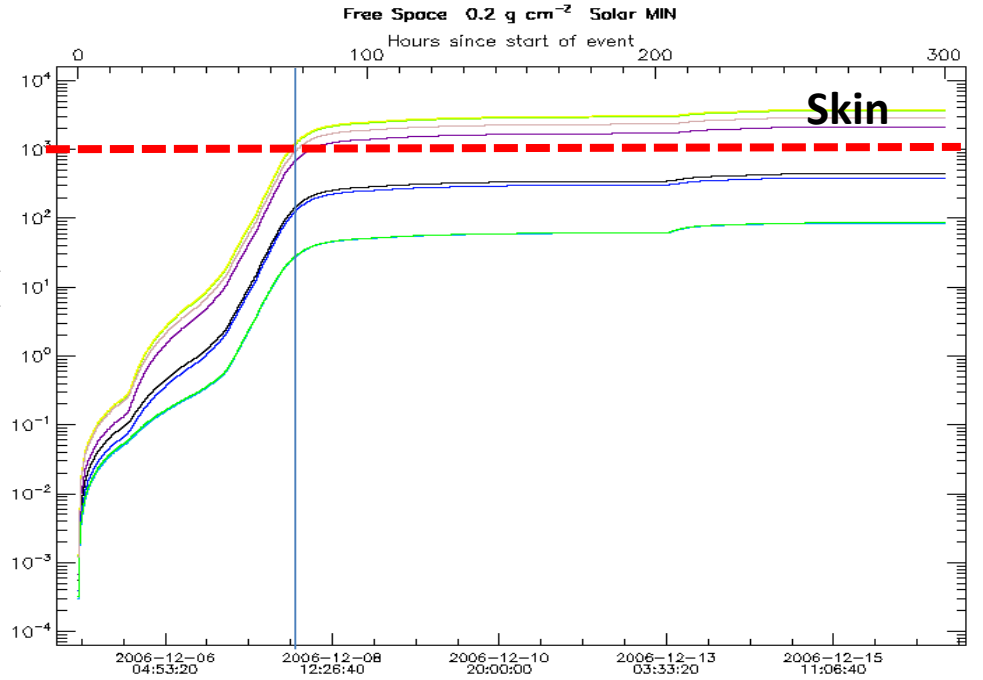


- Primary radiation: Cosmic Rays, Solar Energetic Particle Events
- Secondary radiation – backscatter from surface; radiation created in shielding (= “showers”, “spallation”)
- Shielding structures & validation needed
- Monitoring & warning systems needed


+10.00
+7.50
+5.60
+4.50
+2.60
+1.60
±0.00
-1.40
LAB MODULE

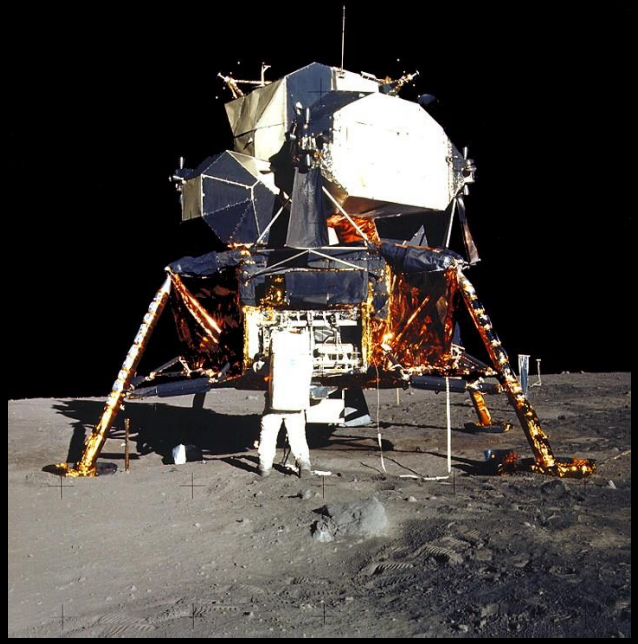
Radiation Environments and Effects



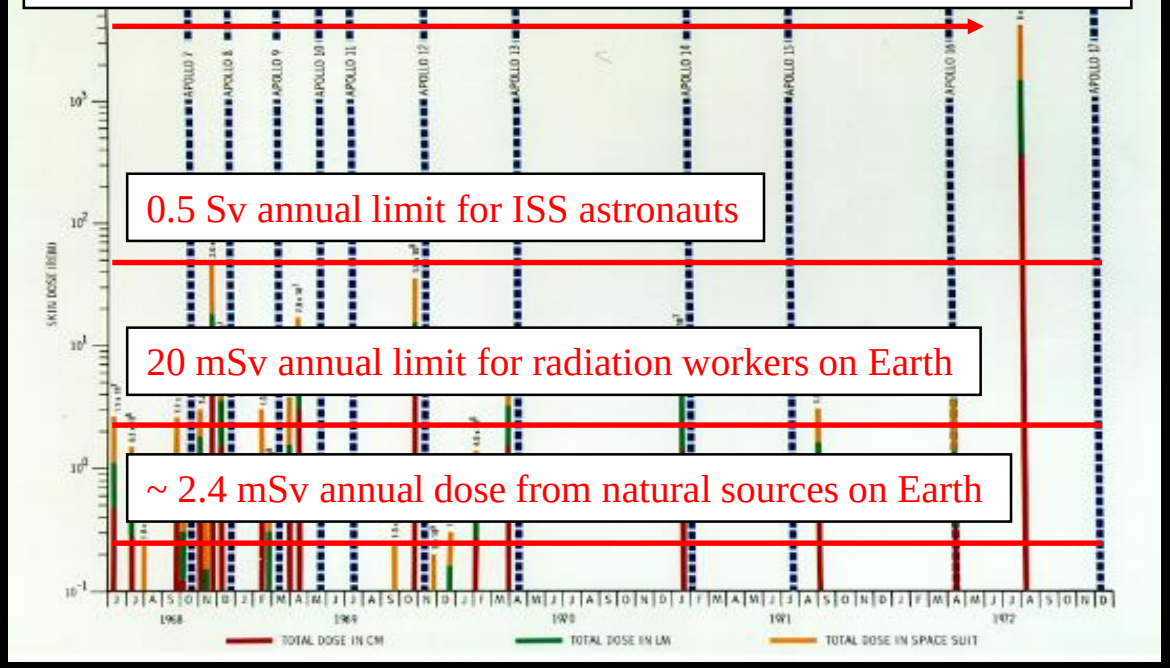


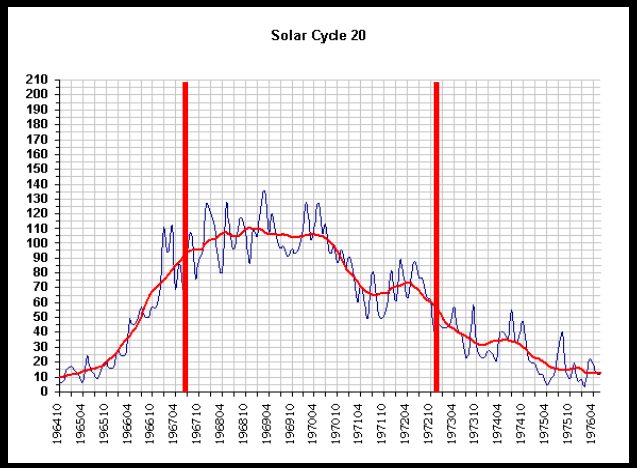
- Shielding : Physics is well understood, but key data are needed from high energy experiments for parameters
- **Simulation Tools : GRAS, GEANT4, MULASSIS and other simulation tools see** http://space-env.esa.int/
- In-situ measurements are needed : validation of secondary production

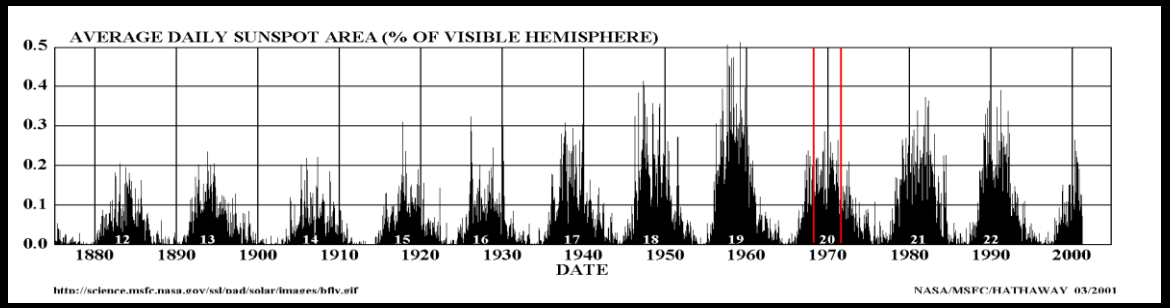
Apollo missions: Solar maximum



~ 40 Sv acute skin dose (without shielding) from August –72 SPE. Potentially very serious for the lander/EVA

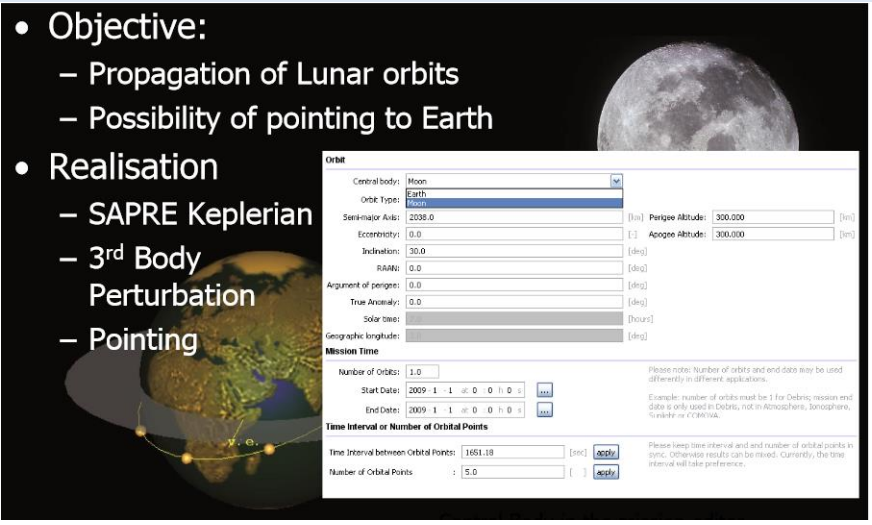






Micro-meteoroid Environments and Effects

- Objective:
  - Propagation of Lunar orbits
  - Possibility of pointing to Earth
- Realisation
  - SAPRE Keplerian
  - 3rd Body Perturbation
  - Pointing

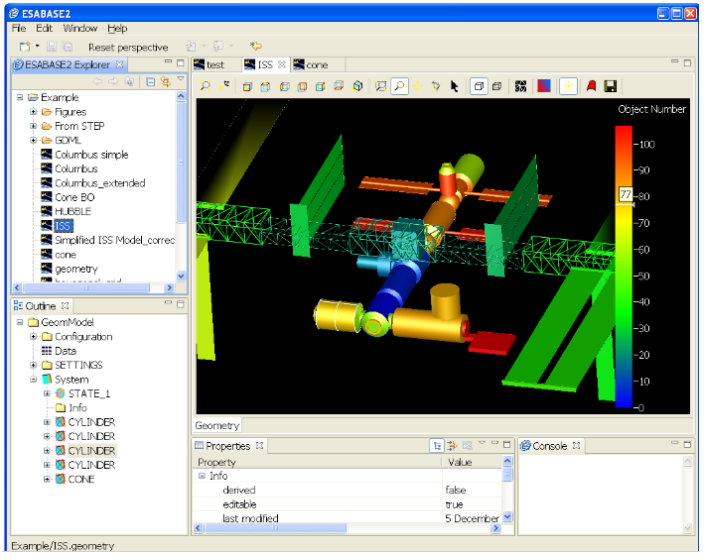


The lunar surface is continuously exposed to the interplanetary micrometeoroid background. Fast dust particles hit the lunar surface with a speed of approximately 17 km/s which leads to a variety of processes: Cratering, plasma generation and ejecta emission.

Impact Risk assessment :

- ESABASE2/DEBRIS module to assess impact fluxes on the transfer to the moon, in lunar orbit and approximately at the lunar surface
- Further developments are needed and foreseen to allow assessment of the impact risk for a structure at the lunar surface

http://esabase2.net/product/esabase2-debris/

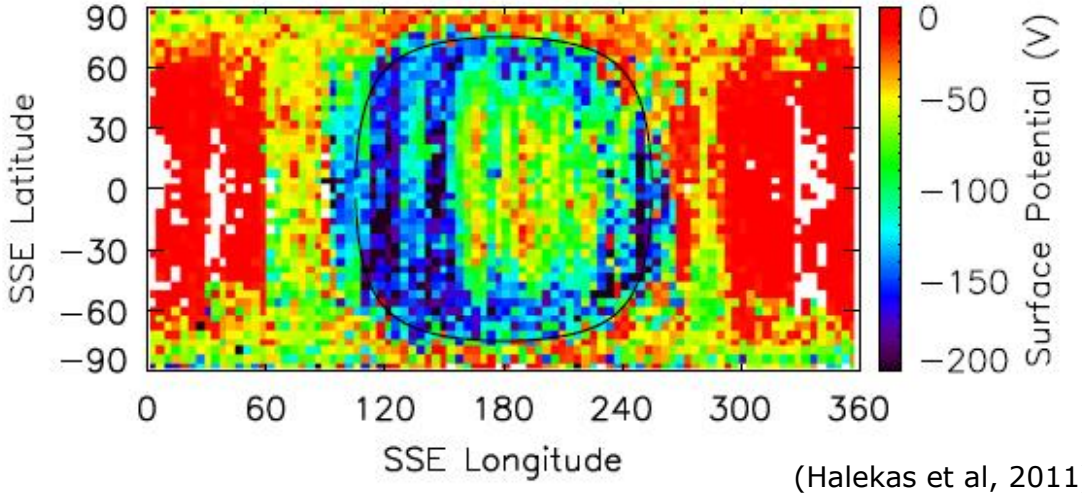


Plasma and Charged Dust Environments and Effects (large scale)

	Tail Lobe	Plasma Sheet	Solar Wind	Lunar Wake	SEP Event
Electron density	0.001-0.5 cm^{-3}	0.01-1 cm^{-3}	0.5 – 10 cm^{-3}	0.001-0.1 cm^{-3}	0.001-0.1 cm^{-3} in wake
Electron temperature	<100eV	100eV to 2keV	5-30eV	50-150eV	50 eV to 1keV in wake
Electrostatic surface Potential	~+200V (Day) / -150 to 0V (Night)	-1000 to 0V	<20 V	-200 to 0V	-1000 to -4000 V in wake
Experiment	CPLEE (Reasoner and Burke 1972) and LP/ER	LP/ER (Halekas et al 2005, 208)	SIDE (Hills et al 1972)	LP/ER	LP/ER

Adapted from Halekas et al, 2008

- Electrons accelerated by surface potentials : LP/ER (US)
- SW Ions reflected by surface potentials / magnetic anomalies: Kaguya (JAXA), Chandrayaan-1 (IRSO), ARTEMIS (US)



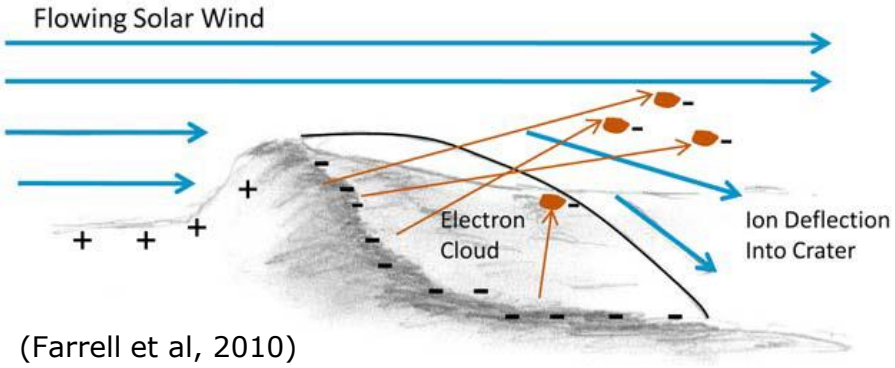
(Halekas et al, 2011)

Plasma and Charged Dust Environments and Effects

	Tail Lobe	Plasma Sheet	Solar Wind	Lunar Wake	SEP Event
Electron density	0.001-0.5 cm^{-3}	0.01-1 cm^{-3}	0.5 – 10 cm^{-3}	0.001-0.1 cm^{-3}	0.001-0.1 cm^{-3} in wake
Electron temperature	<100eV	100eV to 2keV	5-30eV	50-150eV	50 eV to 1keV in wake
Electrostatic surface Potential	~+200V (Day) / -150 to 0V (Night)	-1000 to 0V	<20		
Experiment	CPLEE (Reasoner and Burke 1972) and LP/ER	LP/ER (Halekas et al 2005, 208)	SIDE 1972		

Adapted from Halekas et al, 2008

- Ambipolar fields build-up and dust mobilization ?



(Farrell et al, 2010)

Plasma and Charged Dust Environments and Effects (local scale)

- Triboelectric charging is affecting dust interactions with materials-adhesion properties driven by microscale physics
- Effort needed to characterize close range interactions and derive efficient mitigation techniques (potentially a lot !)
- Risk assessment is relevant for long duration mission at the lunar surface

Sub-system	Effects due to dust exposure
Outer Garment	Dust accumulation /transfer to airlock habitat/ materials degradation
Bearings	Seal degradation/leaks/increased spares/maintenance
Visor coatings	Scratches/Severe abrasion/loss of coatings
Lighting	Reduced illumination due to dust coating illumination source

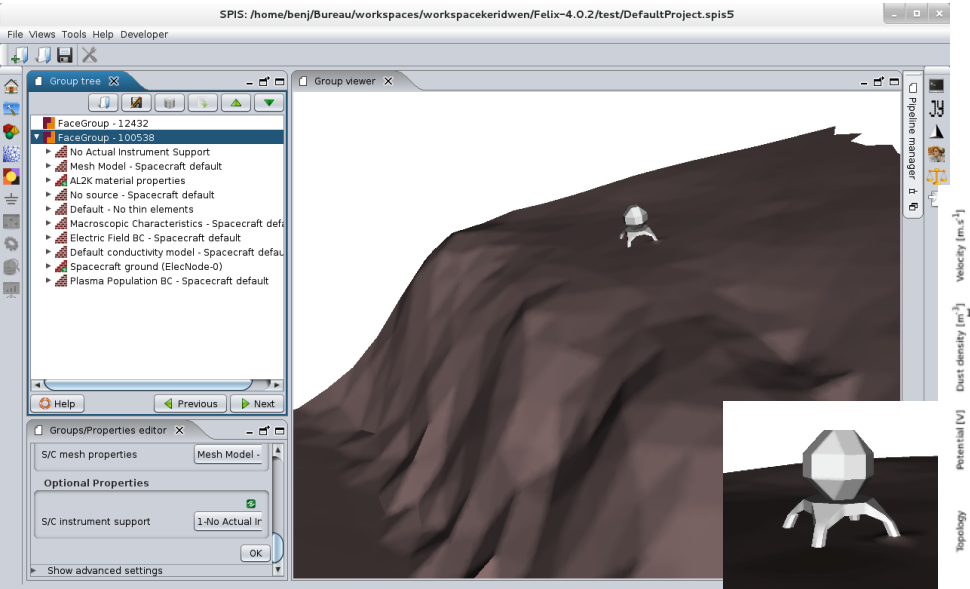
Gene Cernan, Apollo 17

Plasma and Charged Dust : Diagnostic tool

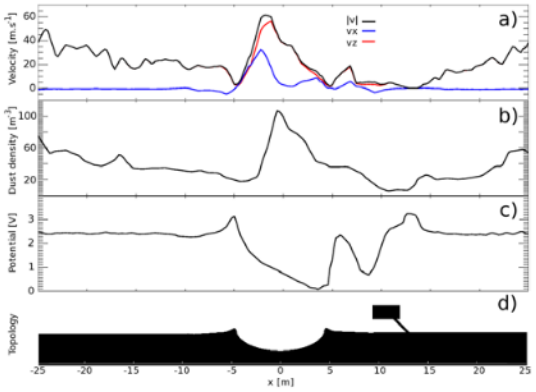
SPIS

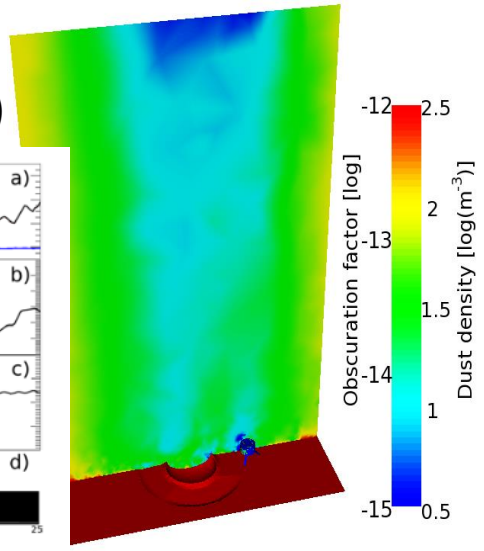
- Development of a simulation tool relying on best / up to date knowledge of physical processes involved in soil grains charging and transport
- Ability to define and simulate 3D geometries including (preliminary) metrics for assessment of contamination (surfaces obscurations, abrasion matrix)
- Successful assessment of code performances by comparison with previous results on lunar dayside charging (photoelectron sheath) and preliminary laboratory experiments (a lot to be done ..)

http://dev.spis.org/projects/spine/home/spis



Hess et al (2015)





Summary

- Lunar environments highly variable in time and space, not safe to explorers !
- Most of the physics is understood but lacking data to constrains parameters describing the effects at the surface
- More ground based and space based (including lunar) experiments are needed
- Further development for effects predictive tools
- **Environments monitoring and warning system needed**
- Effect tools : GRAS, MULASSIS, ESABASE2, and SPIS-DUST see http://space-env.esa.int/ and don't hesitate to contact us (Eamonn.Daly@esa.int)