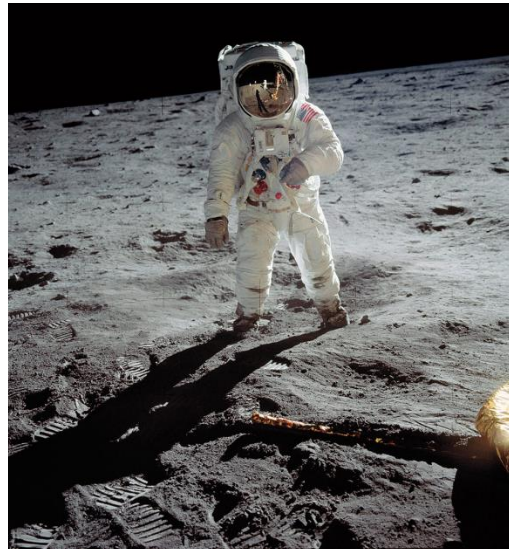
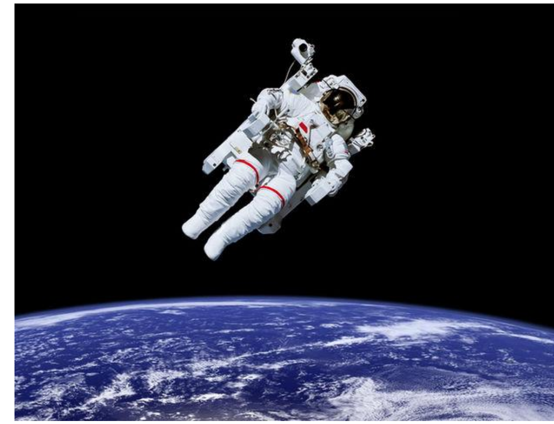
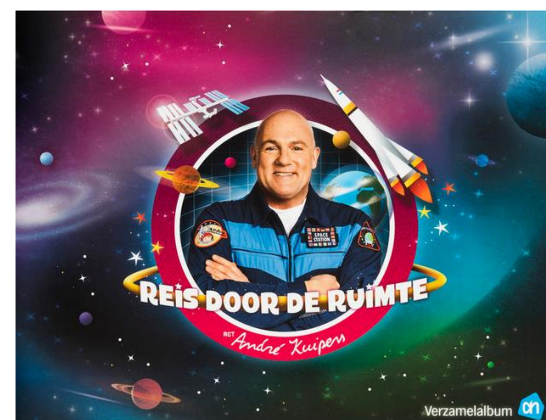
Radioprotection dans l`espace

Dr. Alessandra Menicucci, TU Delft

Human spaceflight







Looking down to Earth

Martine Aubry @MartineAubry · Jun 2

Bravo @Thom_astro pour vos exploits qui vont créer des vocations, merci pr ce cliché de @lillefrance #ThomasPesquet pic.twitter.com/eNnzOtJWDy

Looking down to Earth

Why space human exploration?

1962

We choose to go to the moon in this decade and do the other things, not because they are easy, but because they are hard, because that goal will serve to organize and measure the best of our energies and skills, because that challenge is one that we are willing to accept, one we are unwilling to postpone, and one which we intend to win."

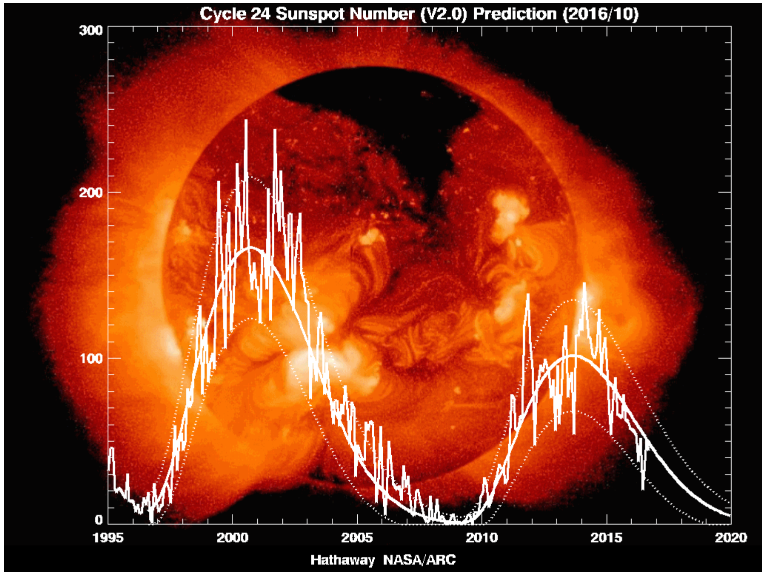
John F. Kennedy (U.S. President)

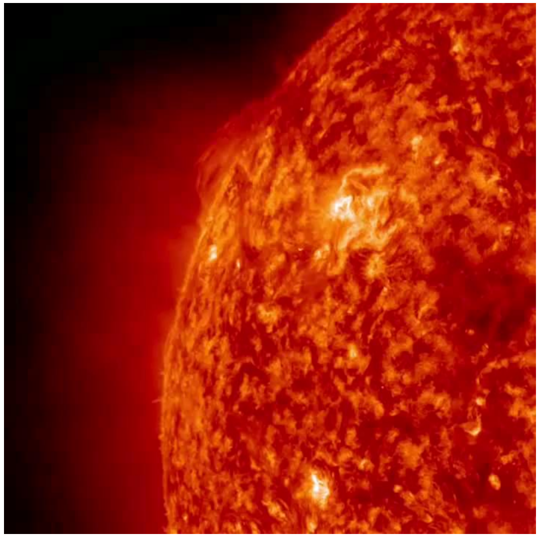
2016

"So first of all, why go anywhere, right?
I think there are really two fundamental paths. History is going to bifurcate along two directions: One path is we stay on Earth forever, and then there will be some eventual extinction event The alternative is to become a space-faring civilization and a multi-planet species"
Elon Musk (SpaceX CEO)

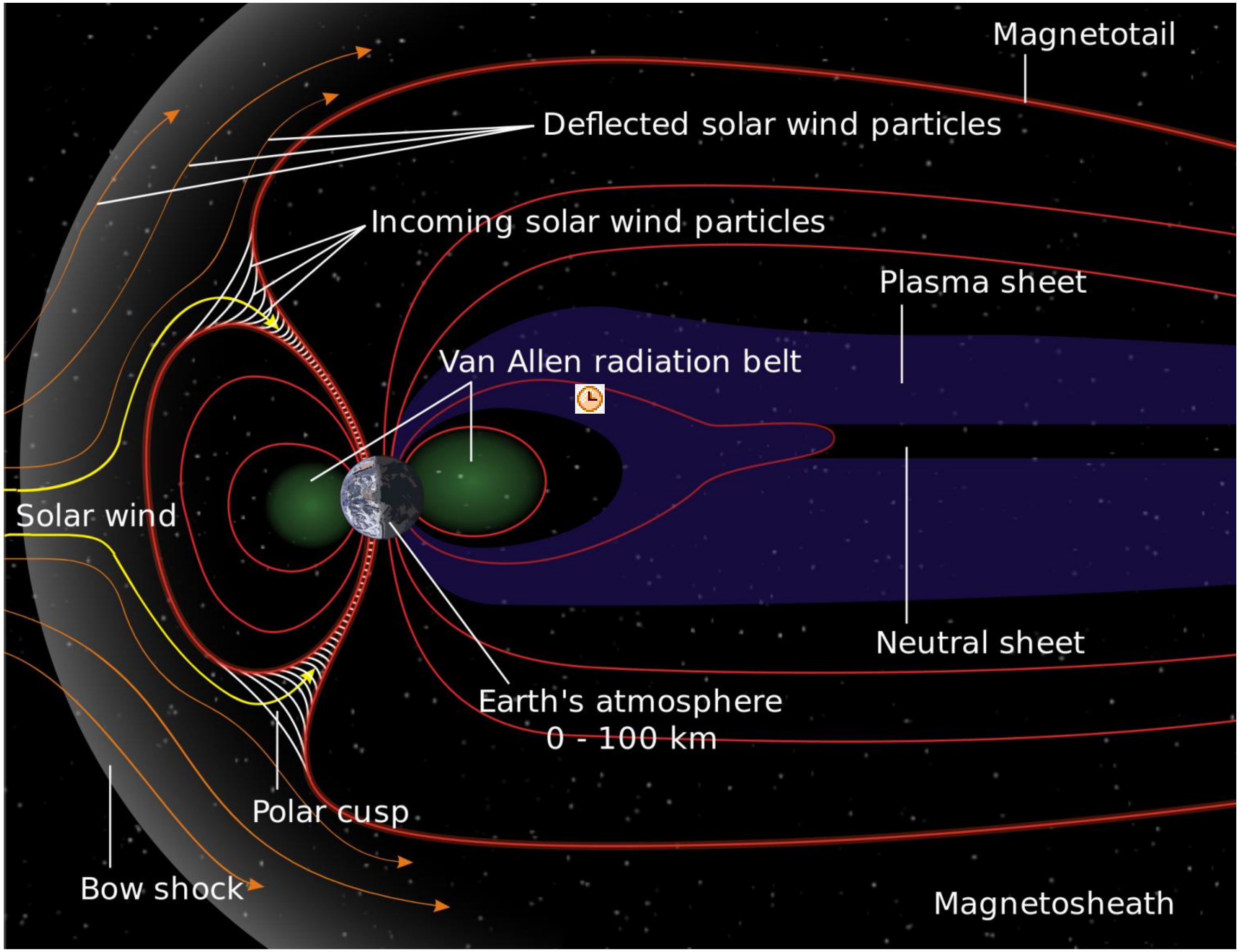
The Sun

- The Sun continuously emits radiation in the **solar wind**. Associated energies are low (100 eV and 3.5 keV).
- Occasionally a **Solar Particle Event (SPE)** occurs when radiation emitted by the Sun are accelerated either during a flare or by CME.
- SPE are mainly composed by protons but can include other nuclei such as helium ions and HZE ions.
- In August 1972 just in between Apollo 16 and 17 there was a big solar storm.



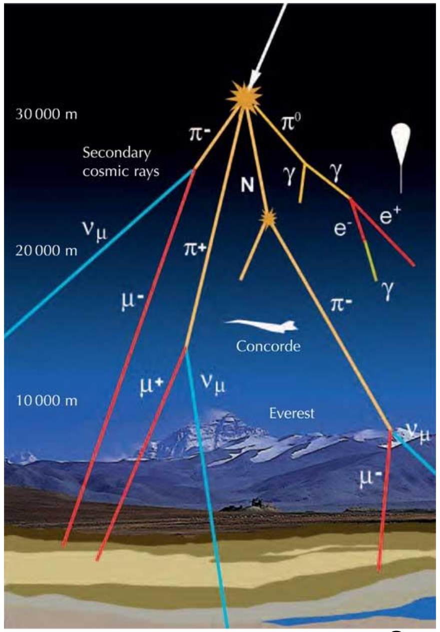


Earth magnetic field protect us



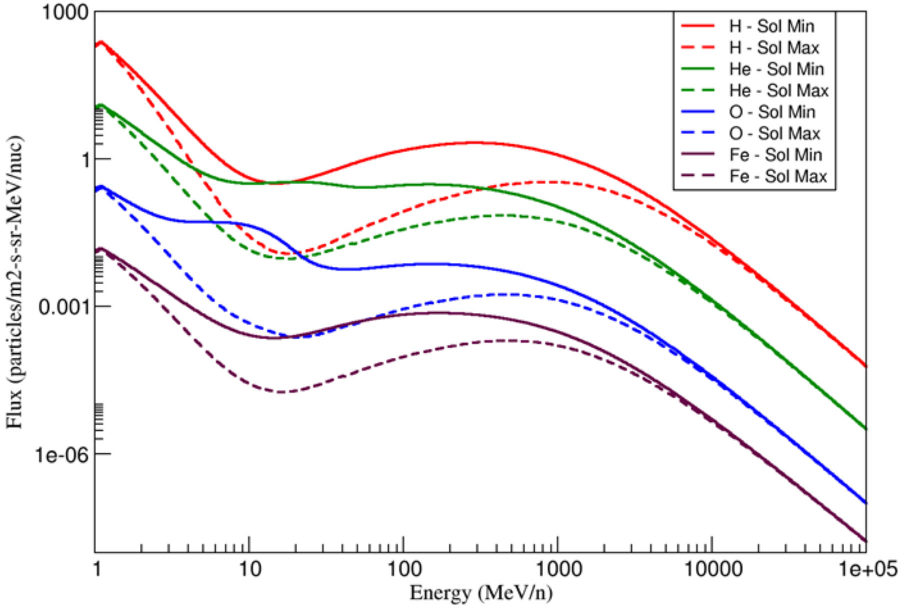
Cosmic rays

- Discovered by Hess in 1912.
- Cosmic rays are believed to be originated from Supernova explosion however the mechanism of acceleration is not completely understood (UHE GCR up to 3.5 $\times 10^{20}$ eV)
- Intensity is twice as strong during solar minimum (solar wind acts as shielding against them)
- Cosmic rays can generate secondary particles when interacting with matter (e.g. atmosphere, planets, shielding etc.)
- GCR are mainly composed by protons (85%). Only 1% of GCR have Z>2 but since they have high energy and charge contribute significantly to the biological damage.

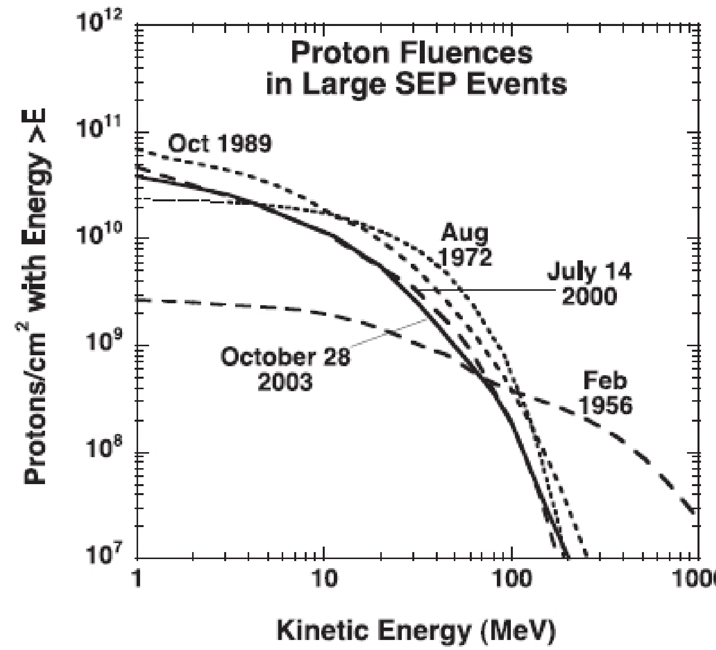


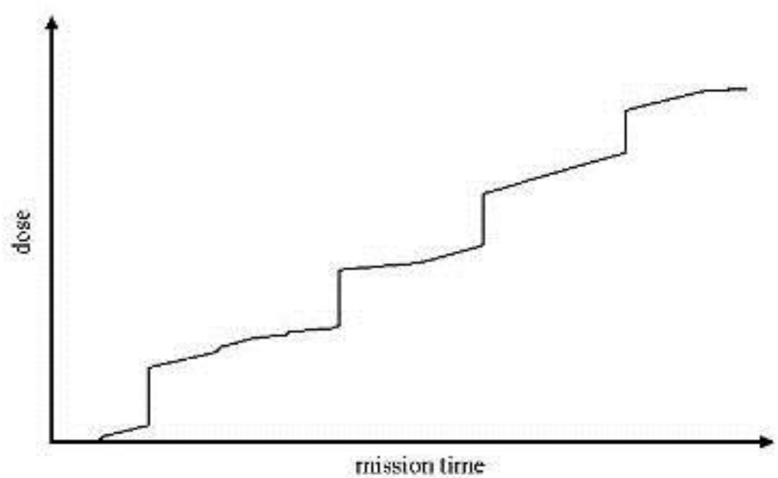
Shielding against GCR and SPE

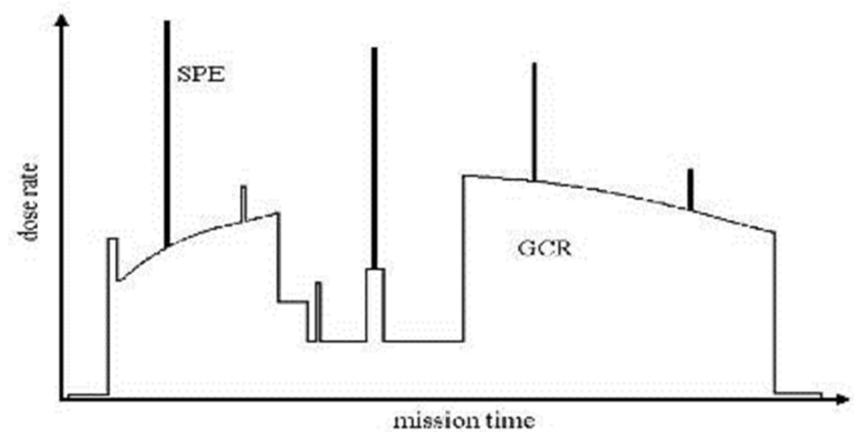
GCR



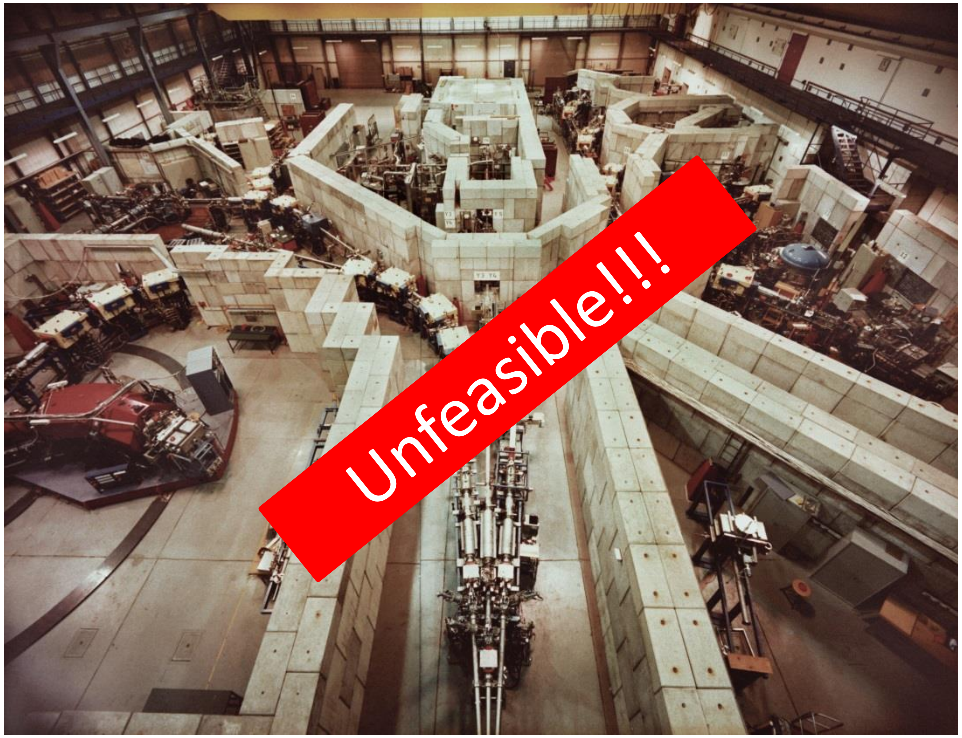
SPE





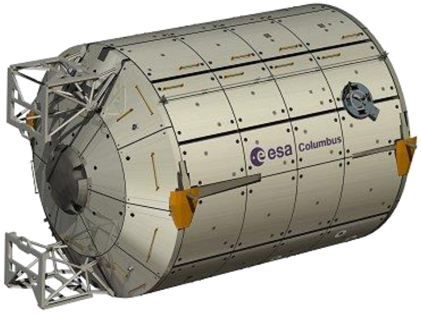


Adding mass to a spacecraft is expensive!



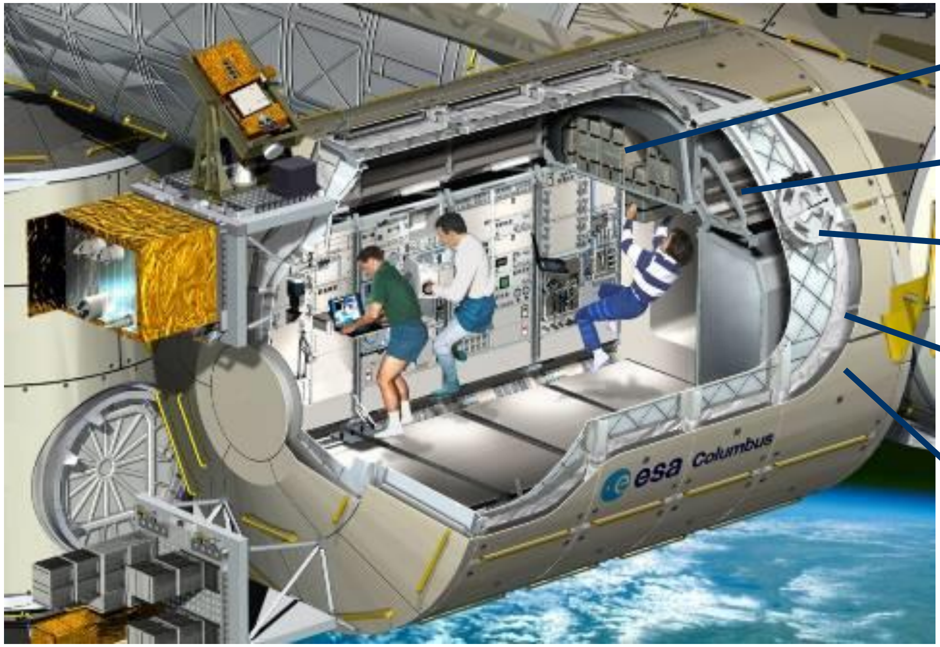
The response of materials and structures to ionizing radiation is extremely important

Columbus



Adding 1 g/cm^2 for radiation protection means $\Delta M = 1.04$ t and $\Delta € = 10$ M

Spacecraft structure is complex



Internal out-fit

Secondary Structure

Primary Structure

Thermal protection

Micro-Meteoroids and Orbital Debris (MMOD) protection system

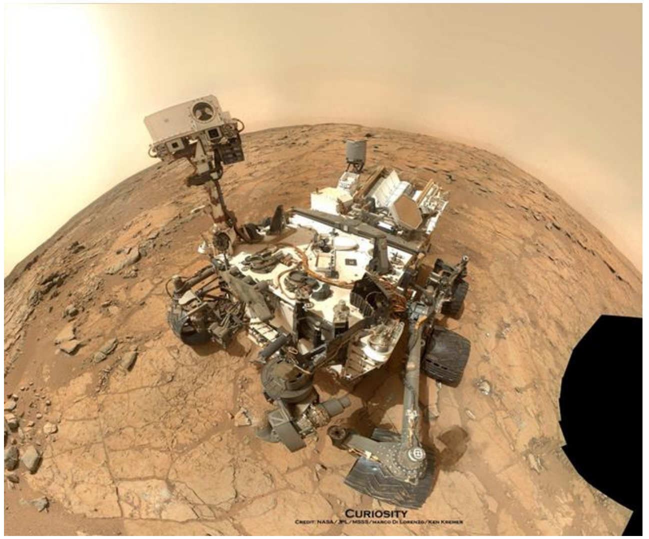
SHELL

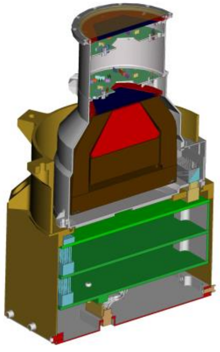
Integrated approach:

- Research for novel/innovative shielding materials
- Using multifunctional materials
- Considering the internal mass distribution (~15 g/cm2)

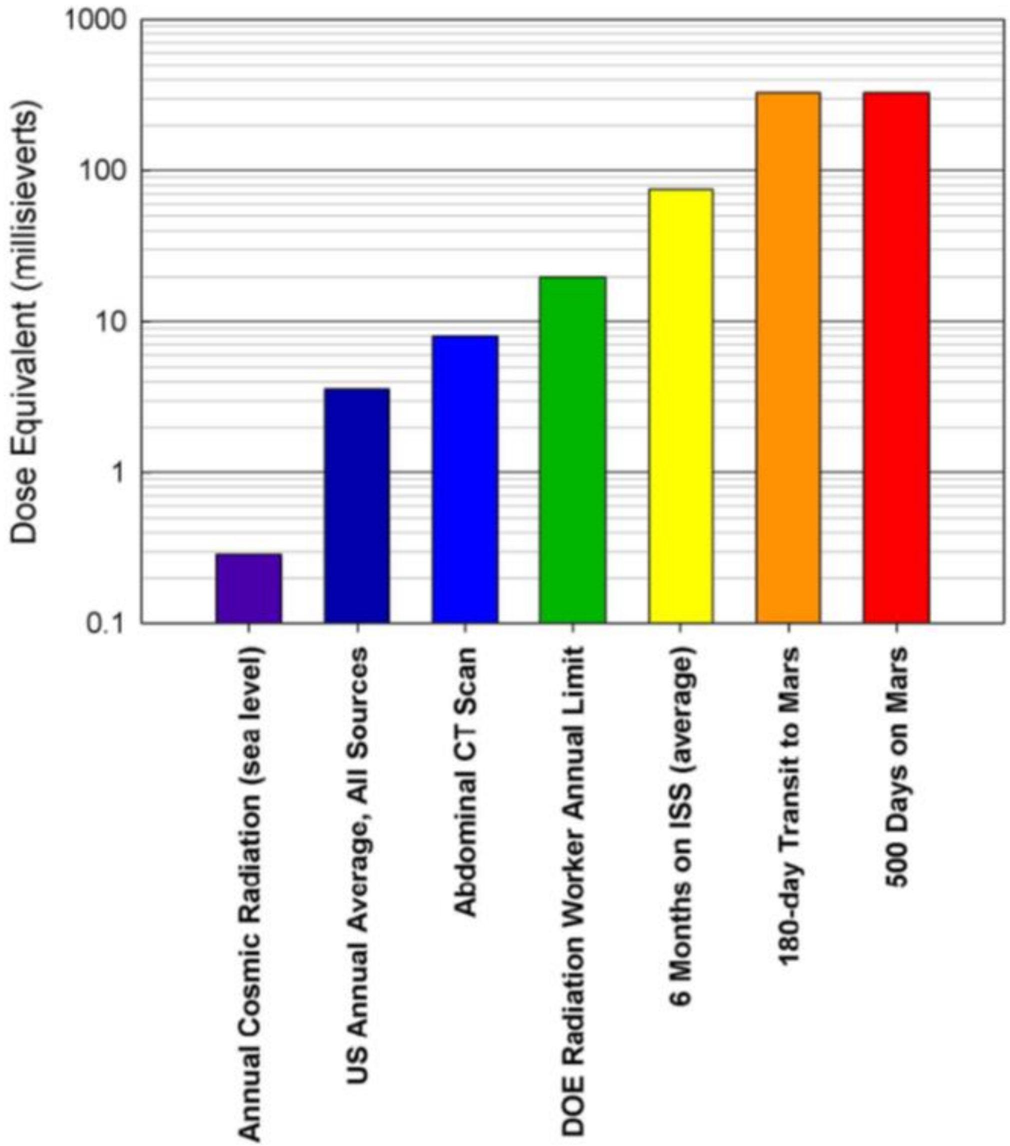
How much radiation in deep space?

- On 26th November 2011 Curiosity rover was launched to Mars. On-board it carried during the 253-day cruise to Mars, the Radiation Assessment Detector, which made accurate measurements



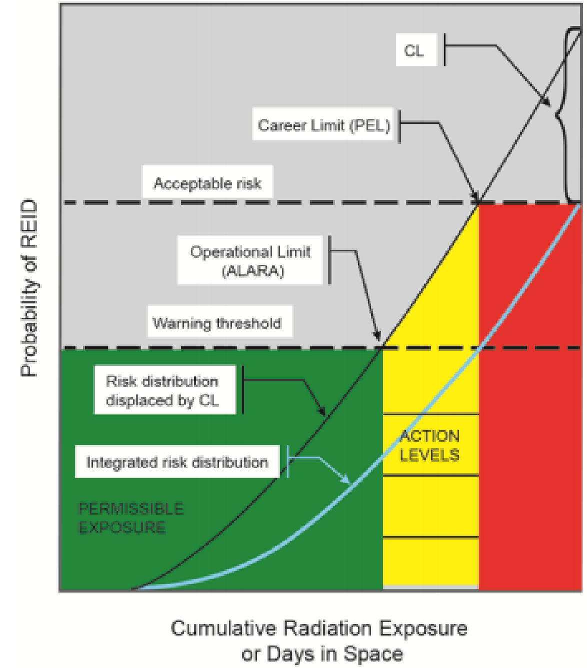


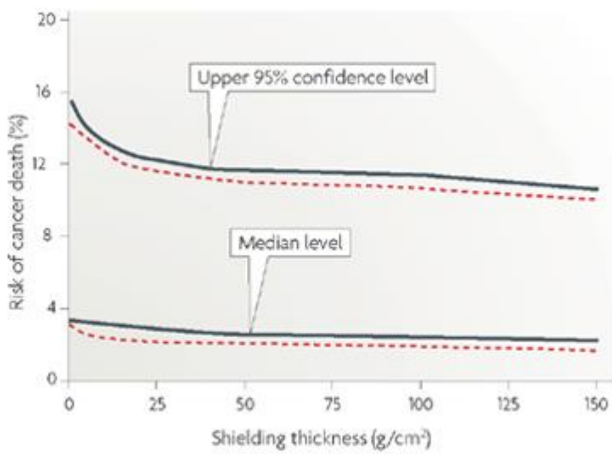
How much radiation in deep space?



Astronauts dose career limits

- In the process of "radiation risk estimation" the uncertainties are large.
- Within the effects, cancer is dominating the risk estimation.
- Risk of exposure-induced death (REID): cumulative cancer fatality risk .
- It is based on age- and gender-specific survival probability (Life-table)
- Exposure limit must not exceed 3% of REID. NASA's policy to ensure a 95% confidence level (CL) that this limit is not exceeded.





Limit	Value	Comment
Career	1 Sv (1000 mSv)	ICRP- no age or gender dependence
Blood Forming Organs (BFO)	0.25 Sv for 30 d; 0.5 Sv for Annually	ISS Consensus limits
Eye	0.5 Sv for 30 d; 1.0 Sv Annually	
Skin	1.5 Sv for 30 d 3.0 Sv for Annually	

Passive shielding material selection

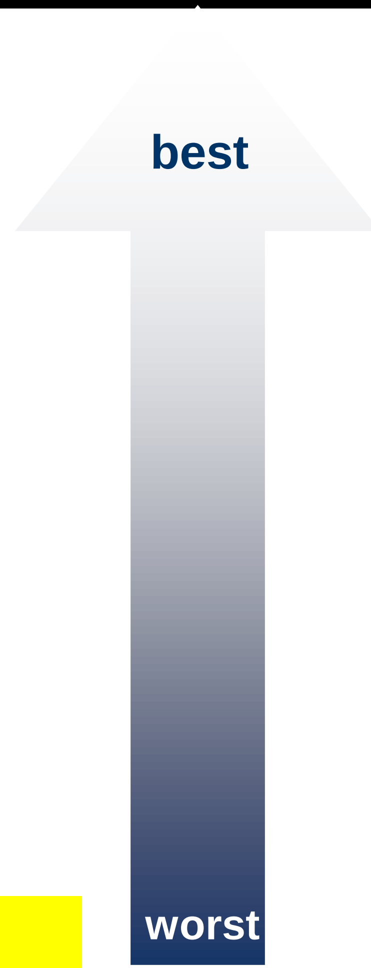
Bethe-Bloch → ~ Z A^{-1}

$$-\frac{dE}{\rho dx} = k \frac{Z}{A} \cdot \frac{z^{*2}}{\beta^2}\left(\log \frac{2\gamma^2\beta^2 m_e c^2}{I} - \eta\right)$$

Bradt-Peters ~ $A^{1/3}$

$$\sigma = \pi r_0^2 \left(A_T^{1/3} + A_P^{1/3} - b\right)^2$$

Material Index = $Z \rho^{-1} A^{-2/3}$



Liquid H_2

Polyethylene

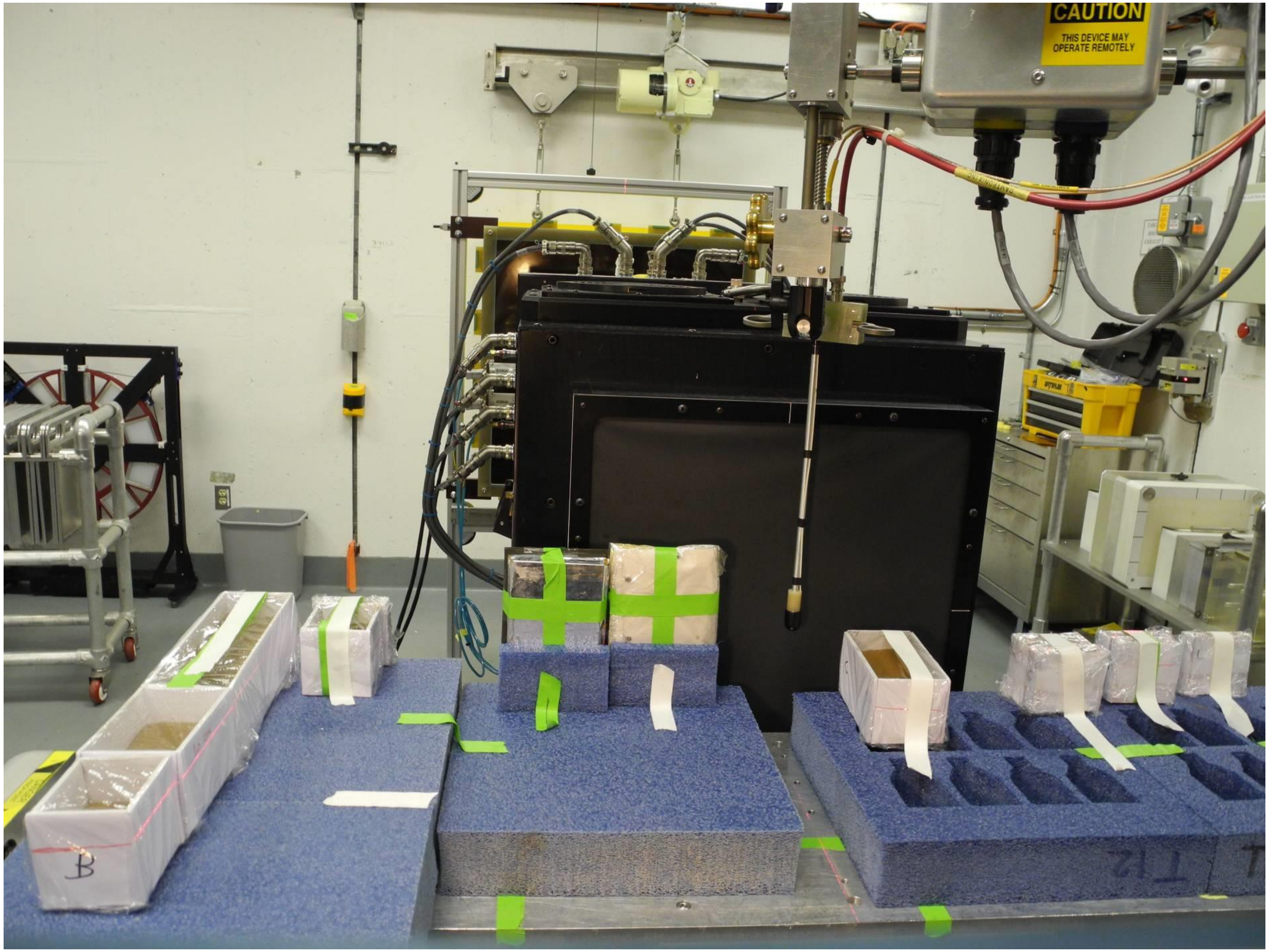
Water

RANGE OF INTEREST

Aluminum

Lead

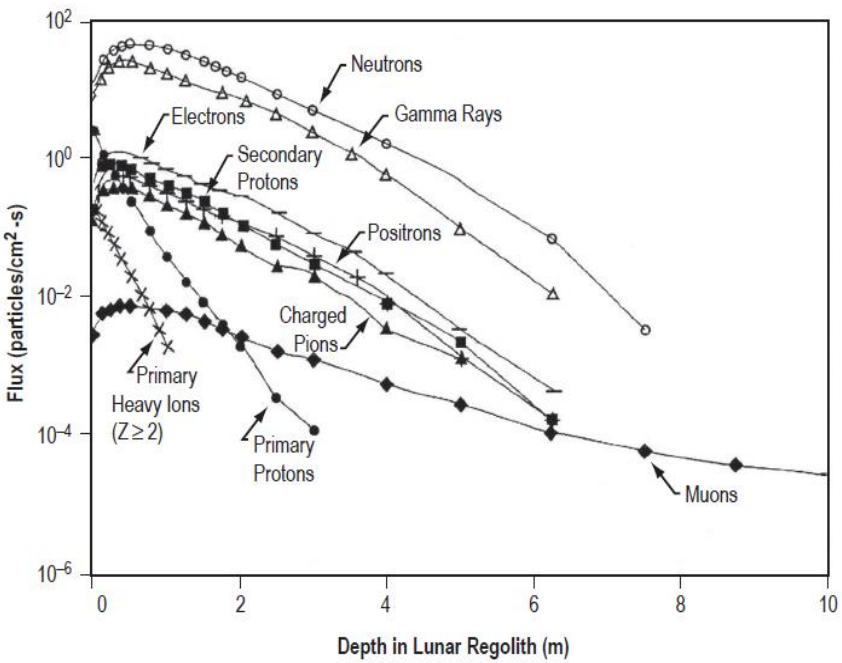
ROSSINI beam test campaign in 2012



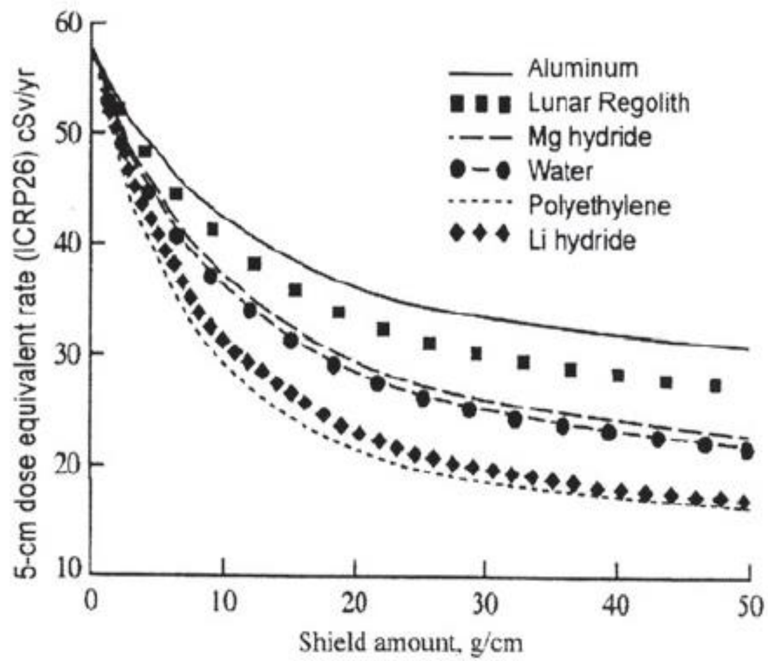
Mars and Moon regolith simulant

ISRU: In Situ Resources Utilization

- Constraints on mass makes the ISRU very interesting.
- However, incident fluxes of GCRs generate large fluxes of neutrons, gamma rays, and other secondary that diminish only slowly with depth

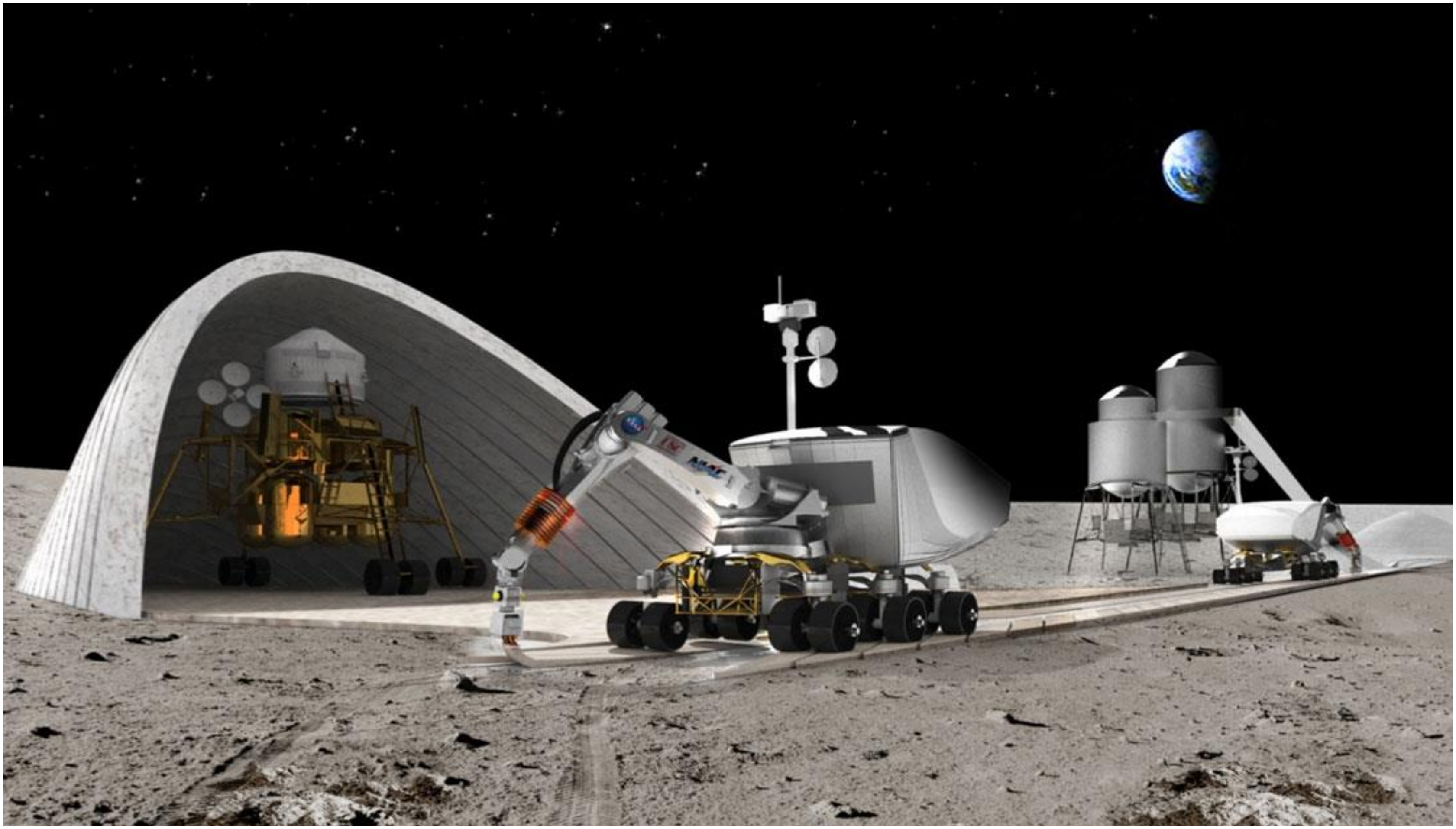


Armstrong, Science Applications International Corporation Report SAIC-TN-912 (1991)

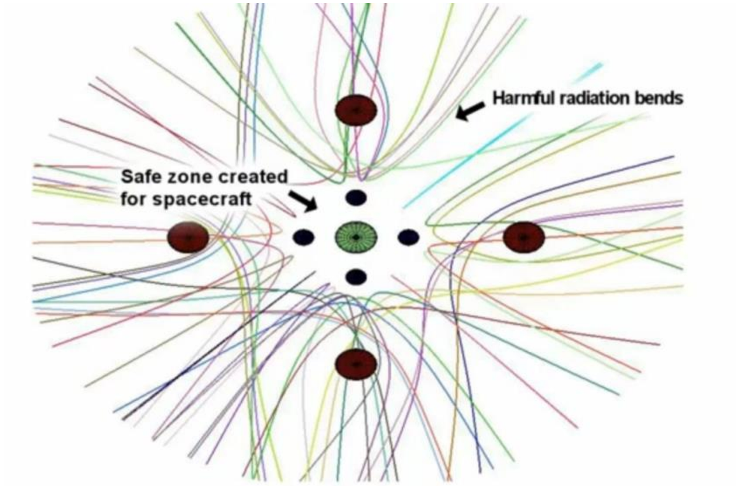


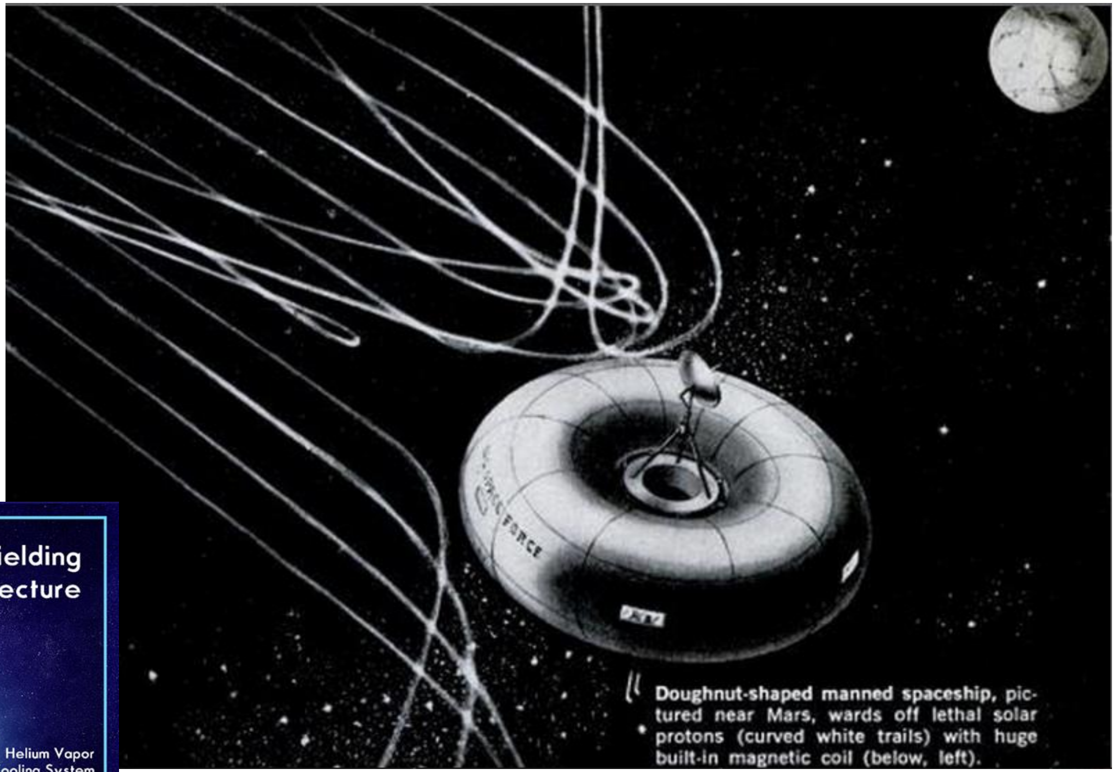
Simonsen, NASA CP 3360, p. 4347(1997)

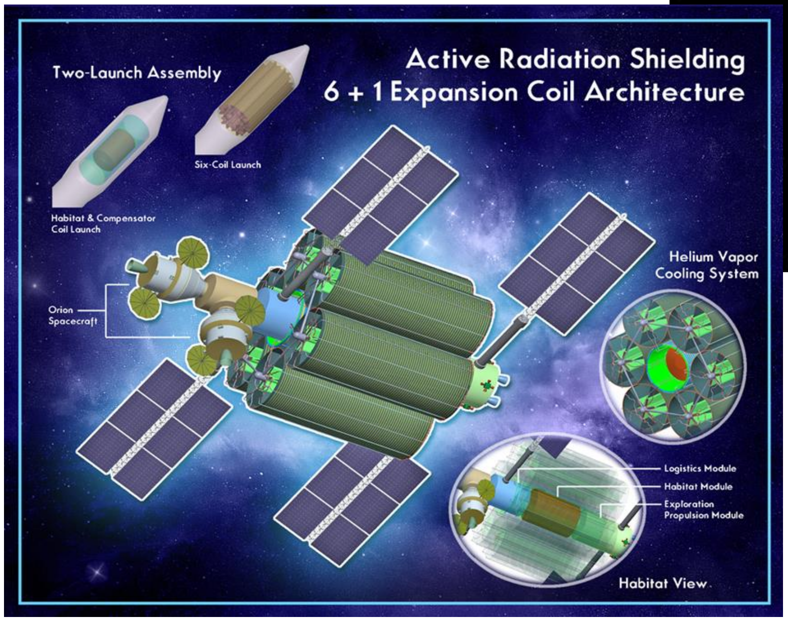
Robotic 3d printing technology to build planetary surface habitat



Active Shielding





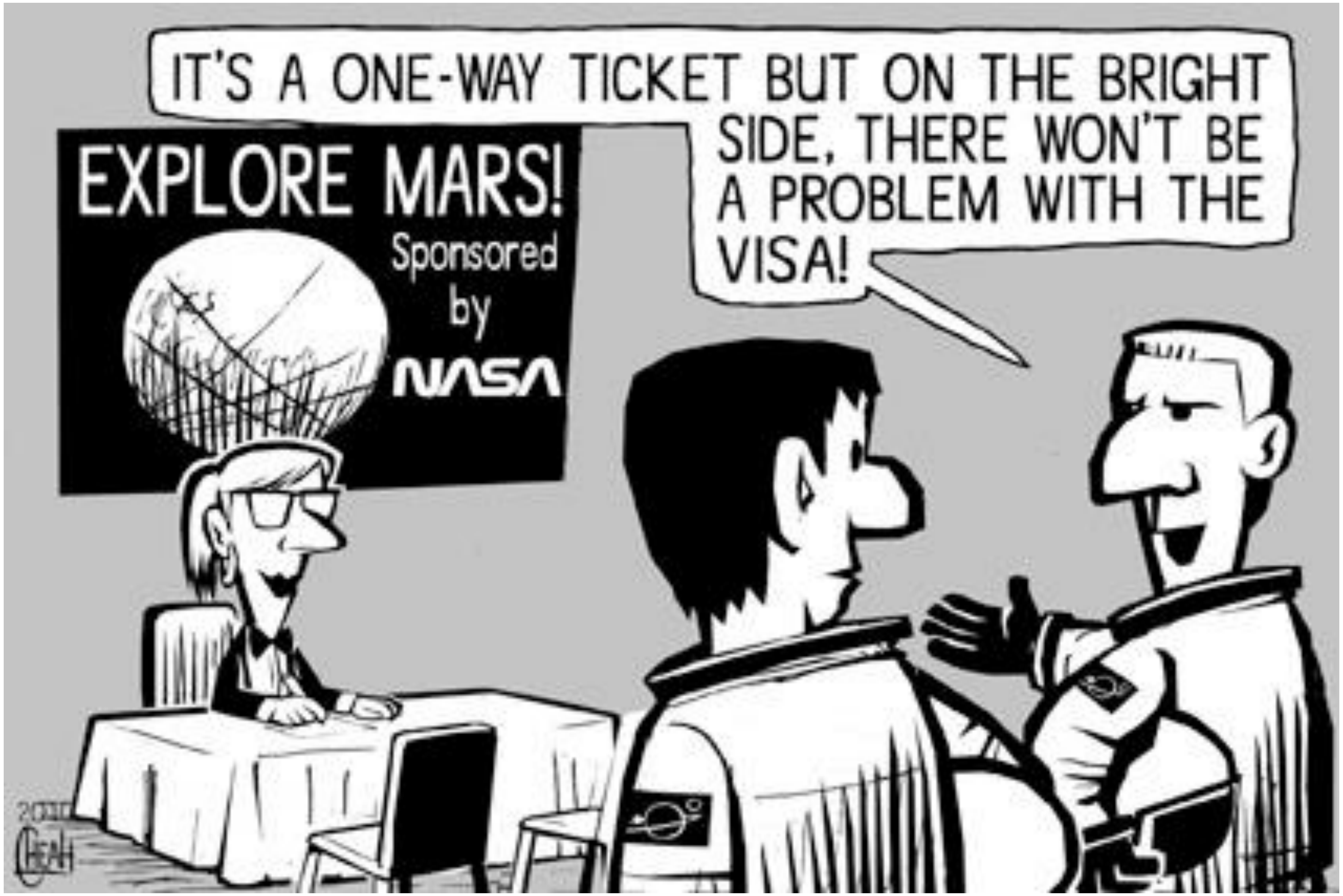


The idea of using a shielding system based on the generation of magnetic field to deflect space radiation is not new!

Conclusions

- In deep space missions we need to protect astronauts from Solar Particles and Galactic Cosmic rays. First are
- The Human Radiation Protection in space is implemented mainly with Shielding (and reduce the time of exposure).
- Although some progresses have been made on the Active Shielding, Passive Shielding remains as the only feasible solution for the time being.
- An optimisation of shielding materials/configuration is necessary especially for humans exploration missions (beyond ISS).
- The first results from the Radiation Monitor on-board of MSL/Curiosity leaves an open door to human exploration.
- New players with great plans and aggressive schedules are finally heating the discussion about space human exploration again.

Thank you for your attention! Questions?



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