The Martian

(2015, Ridley Scott)

Mistakes and Inconsistencies

Plastic sheet and duct tape to repair the breach in the airlock!?

Earth surface atmospheric pressure

1 bar = 100 kPa = 10^5 Pa = 10^5 N m^{-2}

D = 2m, R= 1m, $S=\pi R^2$ = 3.14 m^2

p = F/A, F=p.A, F= 10^5 x 3.14 = 3.1 x 10^5 N

Convert this in equivalent mass on Earth with g=9.81 ms^{-2}

F = mg, m=F/g = 32 x 10^3 kg, m = 32 tons.

Mars surface pressure

p= 0.006 bar = 600 Pa

F =600 x 3.14 = 1884 N

equivalent mass: m = 192 kg

Provided the plastic sheet would hold the entire 32 tons of pressure inside (which is impossible), it wouldn't flutter with that large inequality in pressure, no matter how strong the outside wind is.

The mass density of air on Mars is $\rho \simeq 0.020$ kg/m^3

Following Bernoulli's law: $P + \frac{1}{2} \rho v^2 + \rho g z = cst$

P = static pressure, $\frac{1}{2} \rho v^2$ = dynamic pressure P_{dyn}.

atm. pressure

For a horizontal displacement of wind at constant static pressure P, the pressure exerted by the wind will be:

$P_{dyn} = \frac{1}{2} \rho v^2$

The maximum wind speeds ever recorded on Mars by the Viking Landers in the 1970's were about 30 meters per second (108 km/h).

$P_{dyn} = 1/2 \times 0.02 \times 30^2 = 9$ Pa

Compared to Mars pressure 9/600=1.5%

Compared to habitat pressure (1 bar) $9/10^5$=0.009%

On Earth

At Earth surface, the largest horizontal pressure difference is about 10% (324 km/h typhoon wind).

The average sea-level air pressure reading is 1013.25 mb. The usual worldwide range in sea level air pressure is about 970 to 1040 mb.

The lowest sea level air pressure ever recorded was 870 mb in the eye of Typhoon over the Pacific Ocean, whereas the highest sea level air pressure ever recorded was 1084 mb in Siberia associated with an extremely cold air mass.

Mars's gravity is about 40% of Earth's ($3.71 ms^{-2}$)
Impact on atmospheric structure

Hydrodynamic drag force depends on atmospheric density

Dust in Mars atmosphere is made of very fine particles (almost smoke)
Wind cannot lift pebbles

$$F_D = \frac{1}{2}\rho v^2 C_D A$$

where

F_D is the **drag force**,

ρ is the density of the fluid,[10]

v is the speed of the object relative to the fluid,

A is the cross sectional area, and

C_D is the drag coefficient – a dimensionless number.

Sphere $C_D = 0.47$, $\rho = 0.02$ kg.m^{-3}, v=30 m.s^{-1}

$F_D = 0.5 \times 0.02 \times 30^2 \times 0.5 \times 1$

$F_D = 0.005 \times 900 = 4.5$ N

for m=80 kg

weight of astronaut = mg = 80 x 3.71= 297 N

$\Longrightarrow$ impossible to lift the astronaut.

Bright yellow-ish Sun!?


Daytime sky

Mars Spirit rover sunset, true colors

Rayleigh vs Mie Scattering

If the Martian atmosphere were free of dust, the daytime sky would appear blue, because of Rayleigh scattering by the molecules (primarily carbon dioxide) that make up the atmosphere. Because the atmosphere is thinner than earth's atmosphere, the Martian sky would be a darker blue than ours, much as the sky on earth appears at high altitudes with a similar density of air molecules.

It is believed that the color of the sky is caused by the presence of 1% by volume of magnetite in the dust particles that Mie-scatter red light.

Magnetite -- Iron Oxide Fe_3O_4

Natural Iron Oxides Dry Pigments: Yellow Ochre, Raw Sienna, Burnt Sienna, Raw Umber, and Burnt Umber

Gamblin Artists Colors Co.

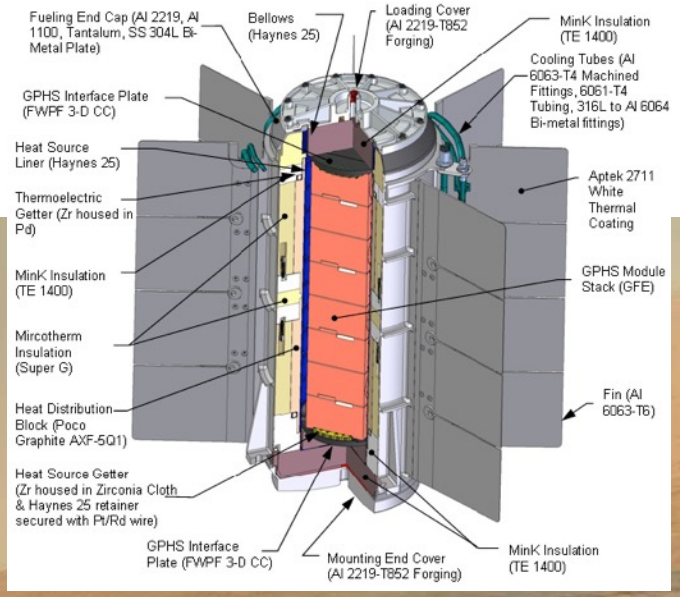
Sun – Mars distance $\simeq$ 1.5 Sun – Earth distance

Apparent angular diameter:
θ = diameter / distance

$$\theta_{Mars} = 0.666\ \theta_{Earth}$$

$\Longrightarrow$ Sun appears 30% smaller on Mars

MMRTG:
Multi-Mission Radioisotope Thermal Generator



The MMRTG is designed to produce 125 W electrical (2000 W thermal) power at the start of mission, falling to about 100 W after 14 years. With a mass of 45 kg the MMRTG provides about 2.8 W/kg of electrical power at beginning of life.

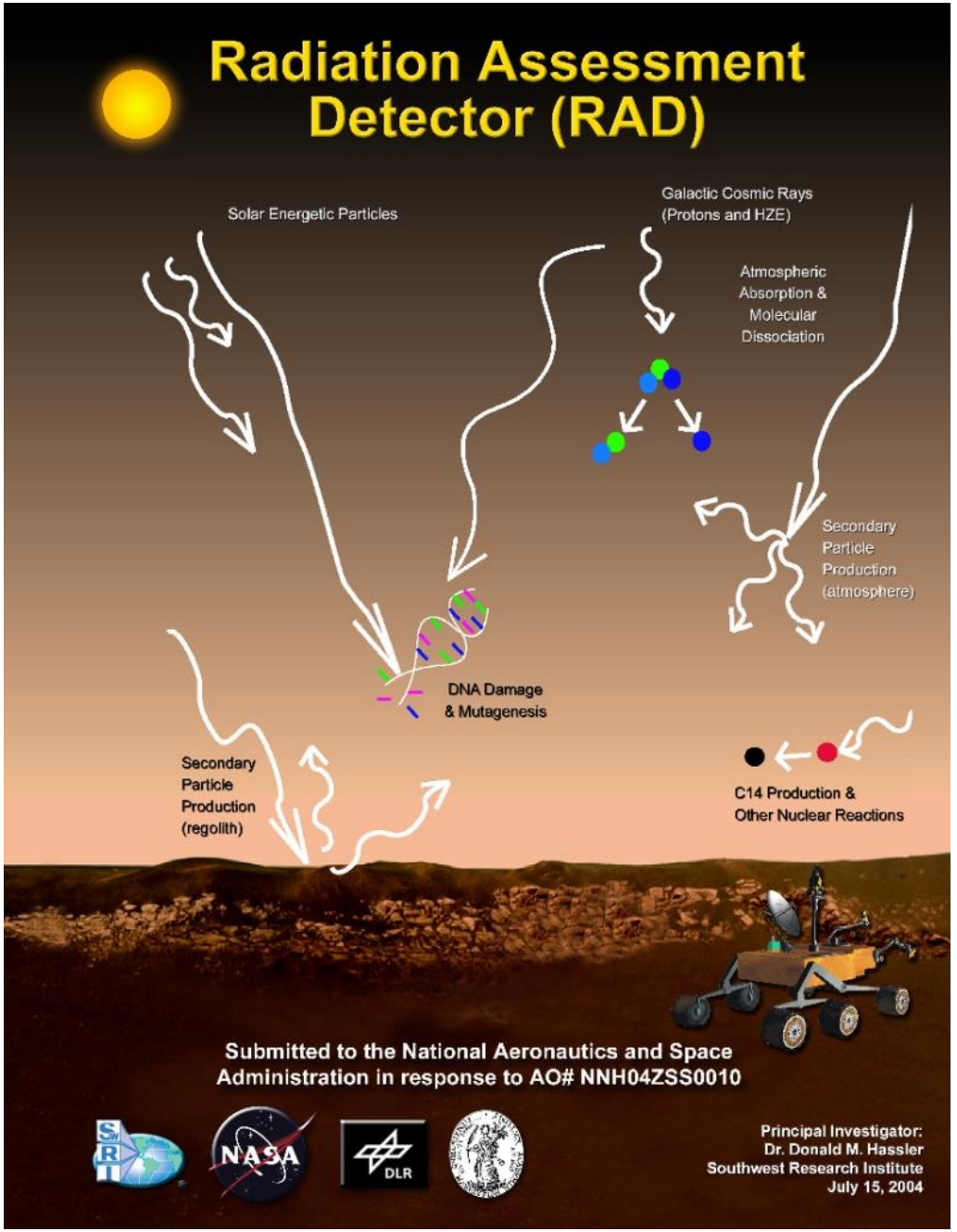
3478 g of ^{238}Pu

(4.8 kg PuO_2)

MSL Curiosity

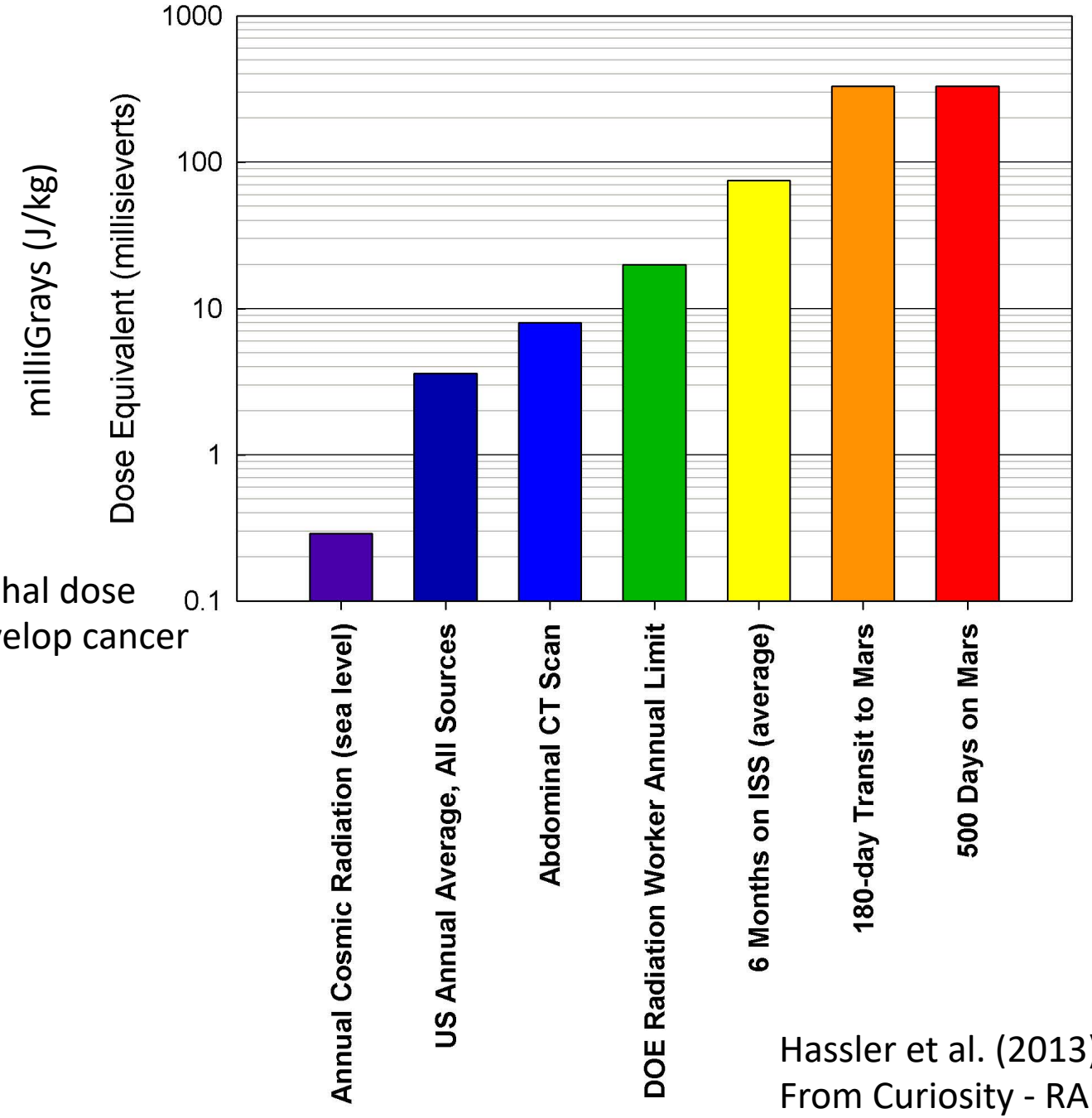
Particle radiation at the surface of Mars

There are two types of energetic particle radiation incident at the top of the Mars atmosphere, **Galactic Cosmic Rays (GCRs) and Solar Energetic Particles (SEPs)**. Both interact with the atmosphere and, if energetic enough, penetrate into the Martian soil, or regolith, where they produce secondary particles (including neutrons and γ-rays).



Shielding by Mars atmosphere

Typical **column depths of the Martian atmosphere are on the order of 20 g/cm^2**, thus energetic particles with energies < ~150 MeV lose all of their energy before **passing through this amount of material**. However, during “hard spectrum” events, ions can be accelerated to energies well above 150 MeV/nuc with substantial fluxes reaching the Martian surface. In all events, secondary neutrons produced by SEPs in the atmosphere can reach the surface.



8 Grays = lethal dose
1 Gray = develop cancer

Hassler et al. (2013)
From Curiosity - RAD

Deadly radiations?

Danger is coming from the Sun and cosmic background sources. Mars lost its protective magnetosphere.

Solar arrays vs MMRTG

Planet or dwarf planet	distance (AU)		Solar radiation (W/m²)	
	Perihelion	Aphelion	maximum	minimum
Mercury	0.3075	0.4667	14,446	6,272
Venus	0.7184	0.7282	2,647	2,576
Earth	0.9833	1.017	1,413	1,321
Mars	1.382	1.666	715	492
Jupiter	4.950	5.458	55.8	45.9
Saturn	9.048	10.12	16.7	13.4
Uranus	18.38	20.08	4.04	3.39
Neptune	29.77	30.44	1.54	1.47
Pluto	29.66	48.87	1.55	0.57

600 $W.m^{-2}$ assuming no absorption by atmosphere

$S=20\ m^2$, SA Efficiency = 10%

$\Longrightarrow$ 1200 W

Using hydrazine N_2H_4 to produce water? $N_2H_4 + O_2 \rightarrow 2H_2O + N_2$

Mars' soil contains 30 l of water / m3 (rover)

Martian surface dirt contains roughly 0.5% Calcium Perchlorate. This salt is toxic to plants (potatoes).

Health Effects of Hydrazine Exposure

Due to the extreme corrosive potential of this chemical and its reactivity with moisture and oxidants, Hydrazine in the environment is of great concern.

This substance is toxic to blood, kidneys, lungs, the nervous system and mucous membranes. Liquid and spray contact can produce tissue damage to mucous membranes particularly the eyes, nose, mouth, and respiratory tract. Skin contact may produce burns and inhalation of spray may produce irritation of the respiratory tract with repeated or prolonged exposures producing target organ damage. **Severe over-exposure can result in death (~1 g/m^3 for 1h).**

Protective Measures When Using Hydrazine

Individuals working with Hydrazine should wear the following protective equipment:

- Gloves
- Full Suit
- Approved/certified Vapor Respirator
- Face Shield
- Boots