Mars as a place to live?
Past, present and future

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ESF/ESA/ESPI Conference Humans in Outer Space, Vienna, 11-12 October 2007

What defines a place to live ?

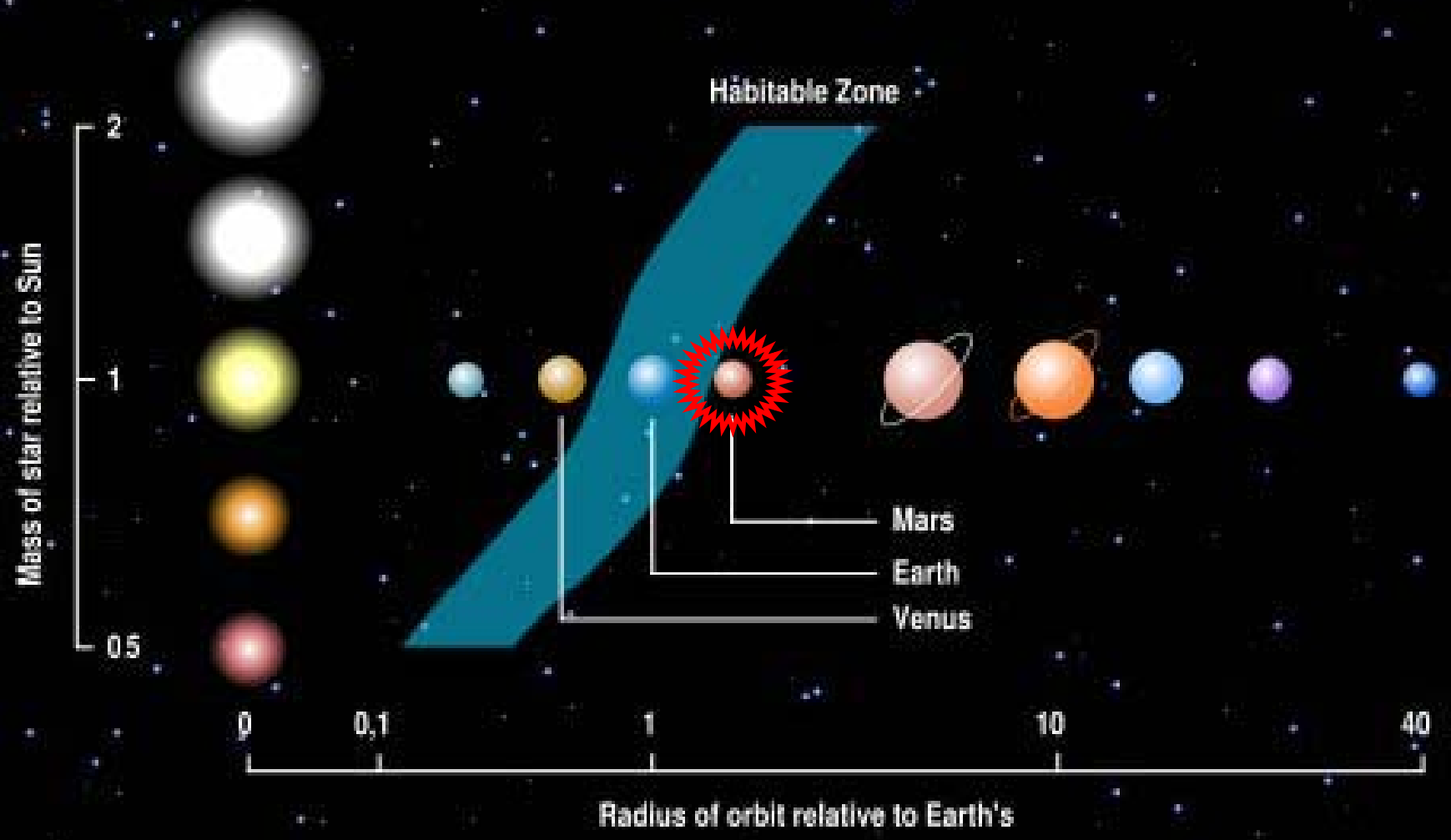
Habitability depends on the organisms under consideration

Humans
Temperature 15 to 35°C
CO_2 <10hPa
O_2 130 to 300 hPa
pH = ~neutral

Microorganisms
Temperatures -20 to + 113°C
CO_2 ≤100%
O_2 0 to several tens of percent
pH 0 to 13
Desiccation, radiation, etc. etc.

from C.S. Cockell, 2007

Regions of Habitability in a Solar System



where liquid water has been present over extended periods

Mars as a place to live ?

Past

Present

Future ?

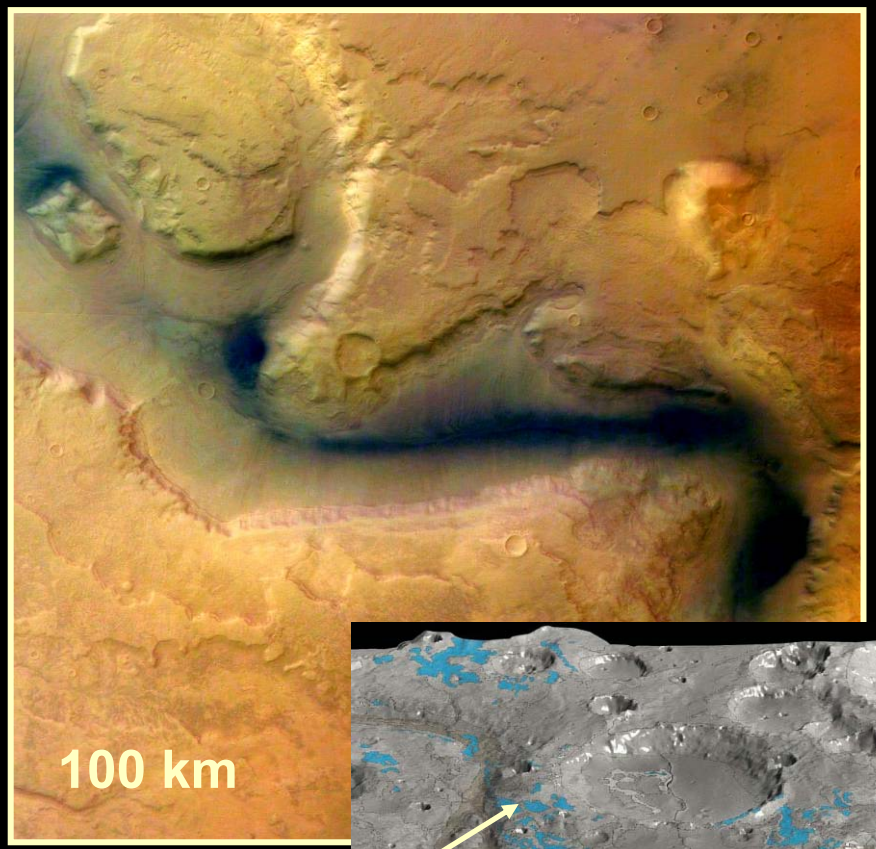
Past Mars (3.8 billion years ago)

Comparison of early Mars and early Earth

	Early Mars	Early Earth
Temperature	> 0 to 50 °C	> 50 °C
Oceans & rivers	yes	yes
Atmospheric O_2	very low	very low
UV radiation	high	high
Magnetic field	yes	yes
Volcanism	yes	yes
Life	? ? ?	yes

Past Mars as a place to live !

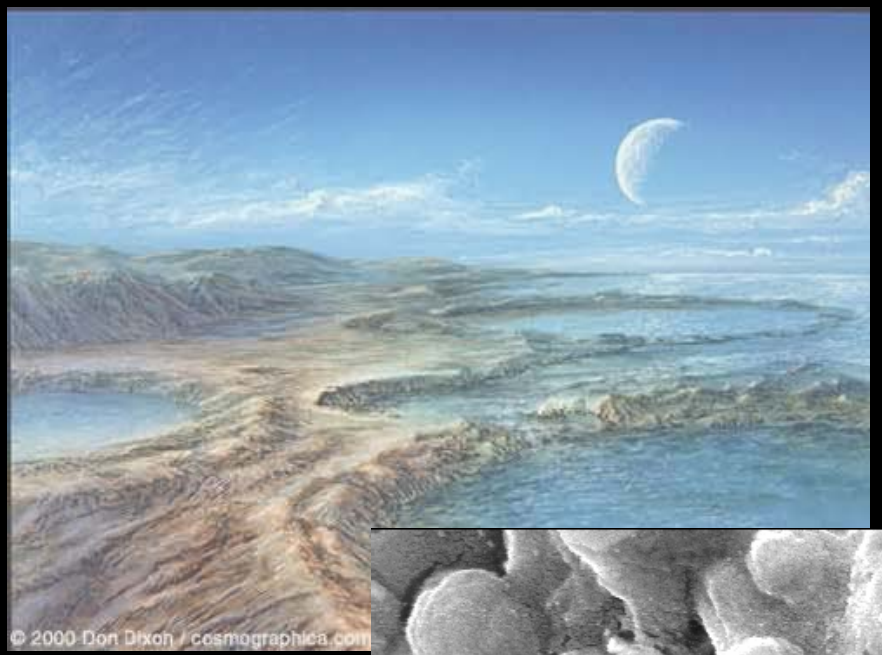
Early Mars

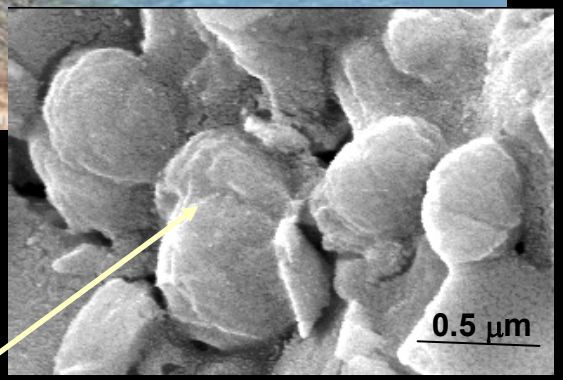


Clay sediment

Mars Express data

Early Earth





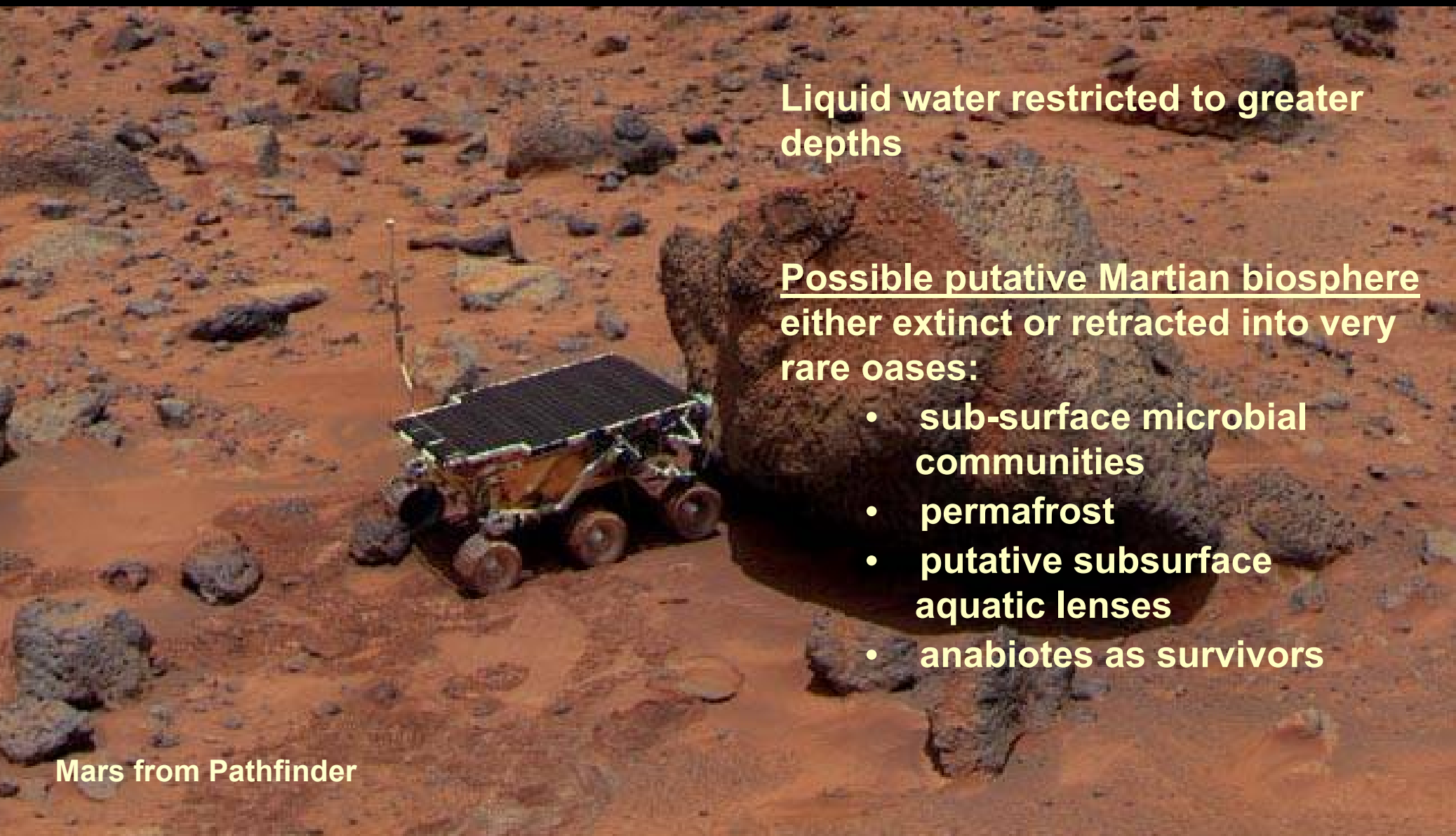
Dividing cells, 3.5 billion years old

from F. Westall

Present climate on Mars

Environmental element	Mars	Earth
Cosmic ionizing radiation	100-200 mSv/a	1-2 mSv/a
Solar particle events	up to ~ 0.1 Sv/h	not applicable
Solar UV radiation	$\lambda \geq 200$ nm	$\lambda \geq 290$ nm
Length of day	24h37'22.7"	23h56'4.1"
Gravity	0.377 x *g*	1 x *g*
Atmosphere	95.3 % CO_2 2.7 % N_2 1.6 % Ar 0.1 % O_2	78.1 % N_2 20.9 % O_2 0.03 % CO_2
Pressure	~ 6 hPa	1000 hPa
Diurnal temperature range	-90°C to +20 °C (Viking data)	10°C to 20°C (Standard atmosphere)
Others	Martian dust storms	

Present Mars, surface hostile for life



Liquid water restricted to greater depths

Possible putative Martian biosphere either extinct or retracted into very rare oases:

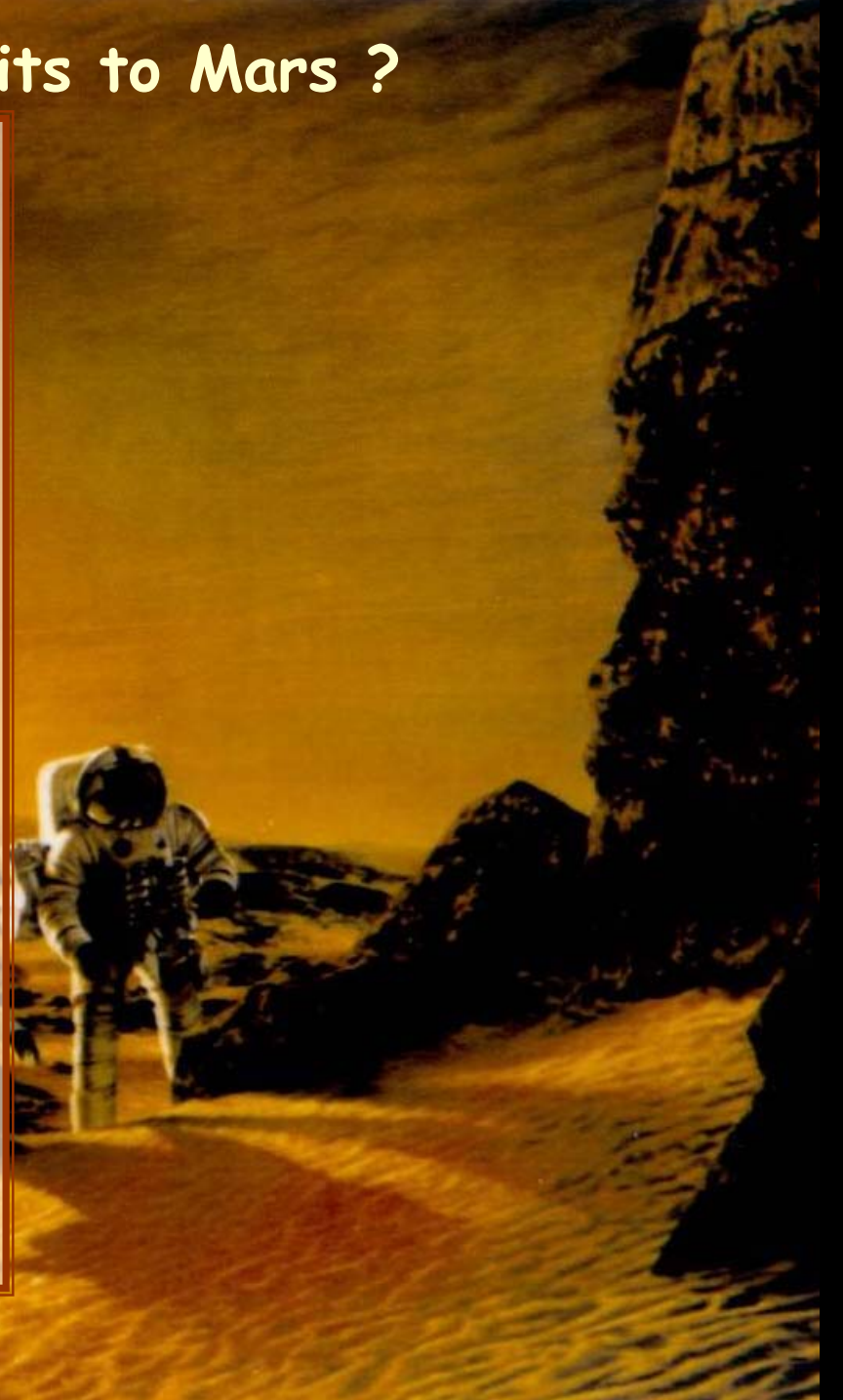
- sub-surface microbial communities
- permafrost
- putative subsurface aquatic lenses
- anabiotes as survivors

Mars from Pathfinder

Near future: Human visits to Mars ?

Major critical items for a human mission to Mars

- *Radiation health*: During interplanetary transfer and on Mars, solar particle events
- *Gravity effects*: Very long 0-gravity levels during interplanetary transfers; very high gravity levels at Mars arrival; reduced gravity (0.377 g) on Mars
- *Low pressure*: 6 hPa, mainly CO_2
- *Dust storms:* Toxicity of dust ?
- *Earth out of view*
- *Distance from Earth*: No mission abort and fast return capability; delays of up to 45 minutes in bi-directional communication



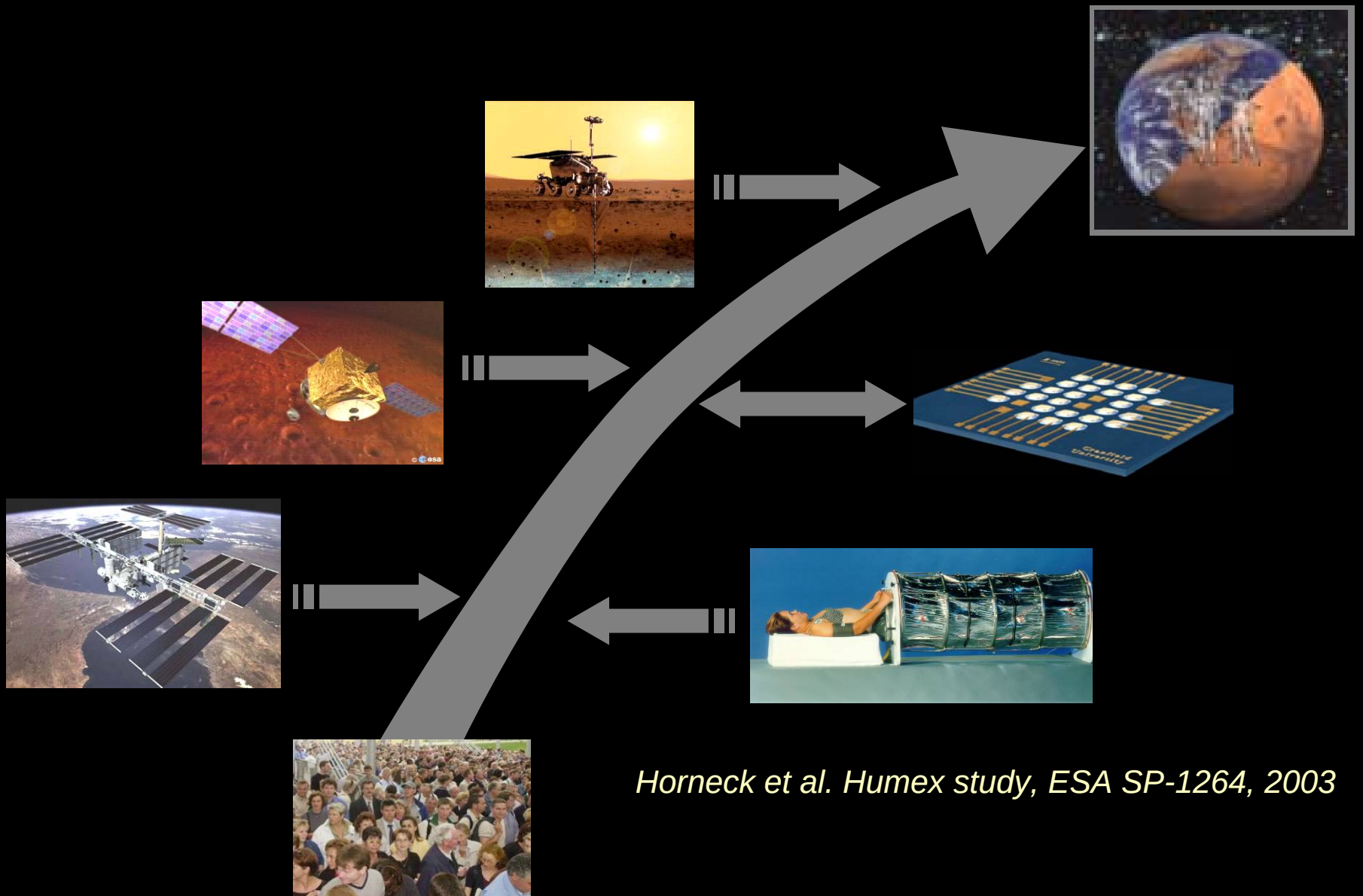
Radiation doses received during a Mars mission (Sv)

GCR:	Solar activity	Mission	Shielding	
			1 g/cm²	10 g/cm²
	Minimum	1000 d	0.993 ★	0.852 ★
		500 d	0.828 ★	0.687 ★
	Maximum	1000 d	0.402	0.364
		500 d	0.317	0.280

"Worst case" SPE:	Shielding		
	0.3 g/cm²	1 g/cm²	10 g/cm²
Interplanetary	4.21 ★	3.52 ★	1.26 ★
Martian surface	0.32	0.31	0.25

NCRP limits for LEO:	30 d	annual	career
	0.25	0.50	0.4-4.0

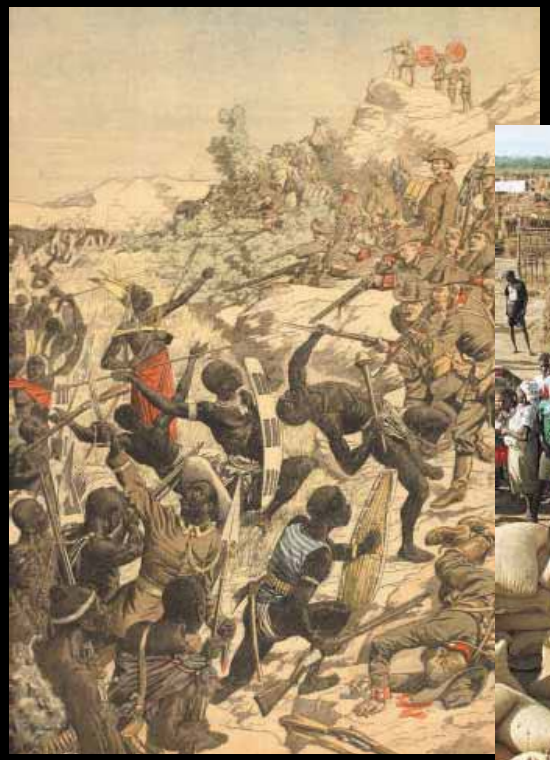
Research required in human health issues: HUMEX Roadmap

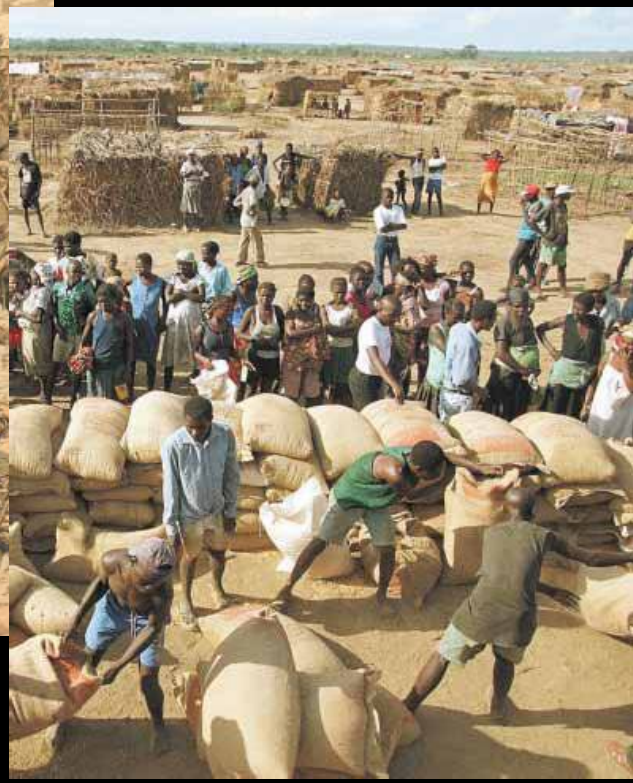


Horneck et al. Humex study, ESA SP-1264, 2003

Far future: Motivations for migrating to Mars

Catastrophes





Natural disasters

Anthropogenic disasters

Far future: Motivations for migrating to Mars

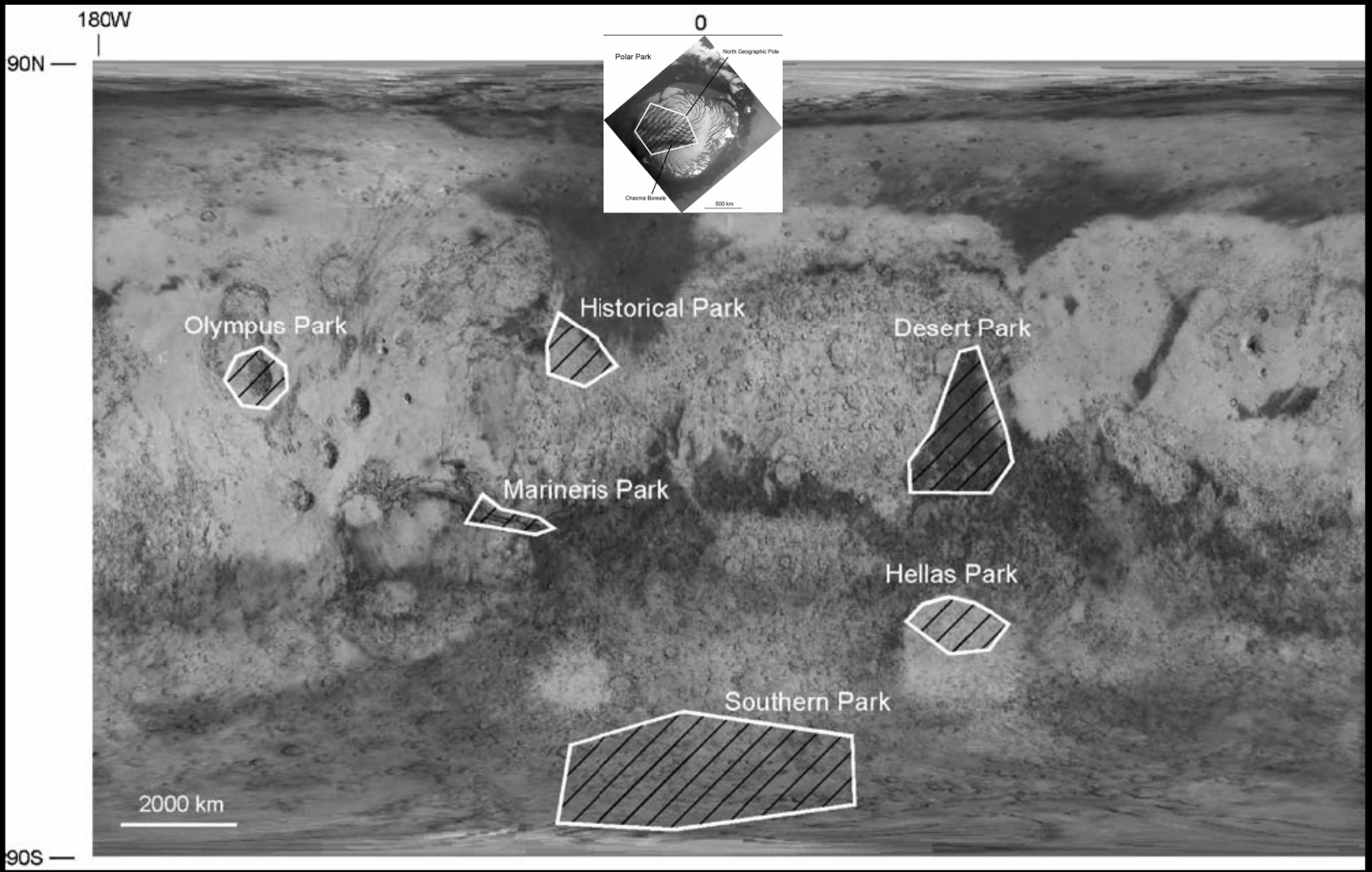
- Escaping deprivation or disasters
- Curiosity and spirit of research
- Urge to explore the unknown
- Globalization in business, science and lifestyle
- Extension of power

Responsibility when migrating to Mars

- To protect planet Mars
  - a putative Martian biosphere (COSPAR Planetary Protection guidelines)
  - Mars' intrinsic value (geological and natural beauty)
  - Mars' historical sites (previous landing sites)
  - for future generations (research, leisure or exploitation ?)

- To protect the Earth (upon return)

Responsibility when migrating the Earth: Planetary Parks



Cockell and Horneck, 2004