To the Moon, Mars, and Beyond

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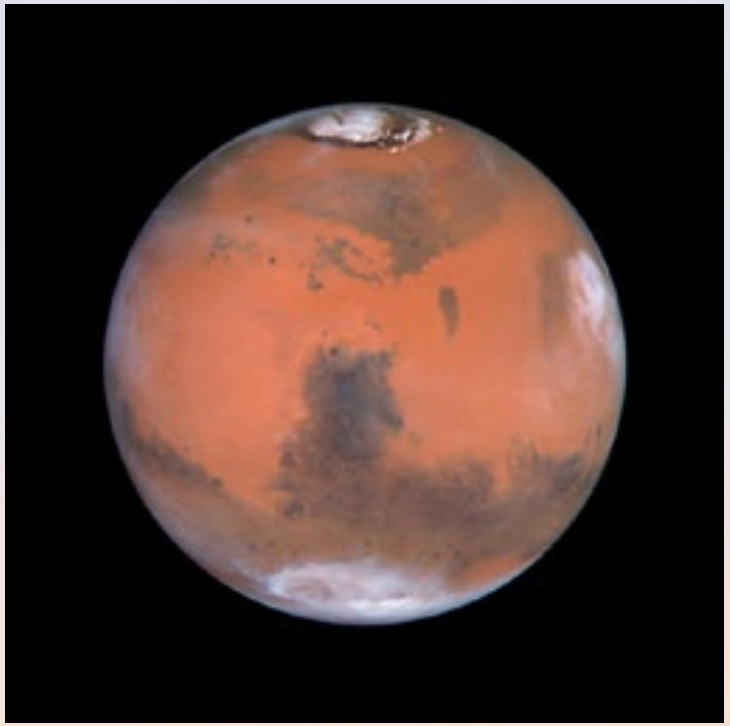
Why Go?

https://www.youtube.com/watch?v=LTk1SepOvXk



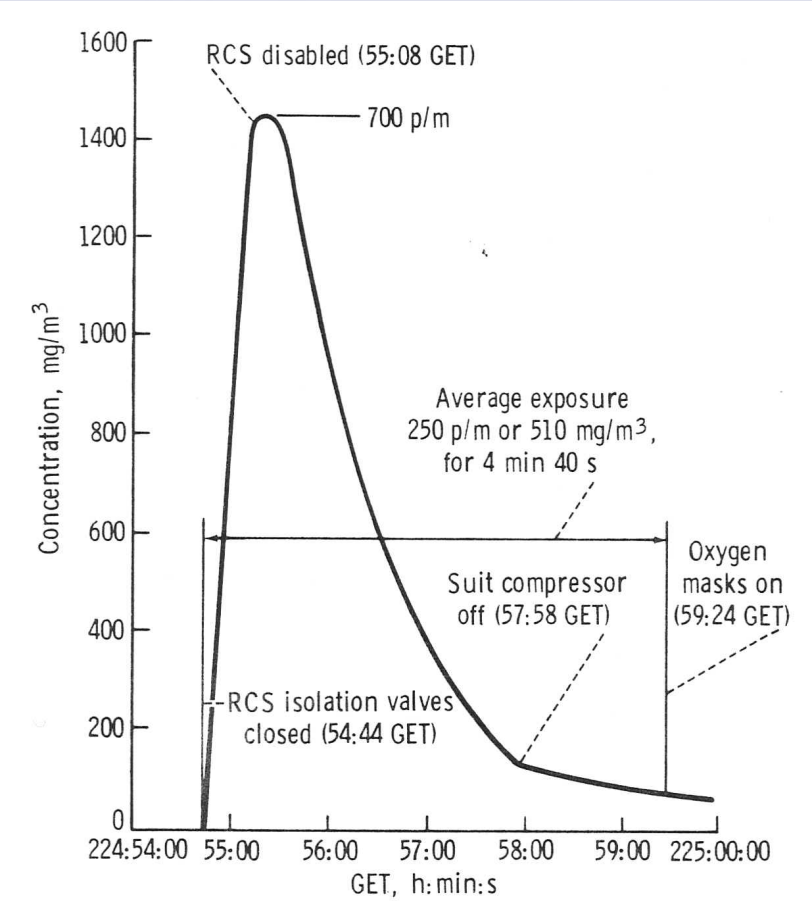
Toxicology and Environmental Chemistry at JSC

- Mission: To protect crews from toxic exposures during spaceflight
  - Unique application of standard risk assessment practices

Toxicological Risks to Spacecraft Air and Water

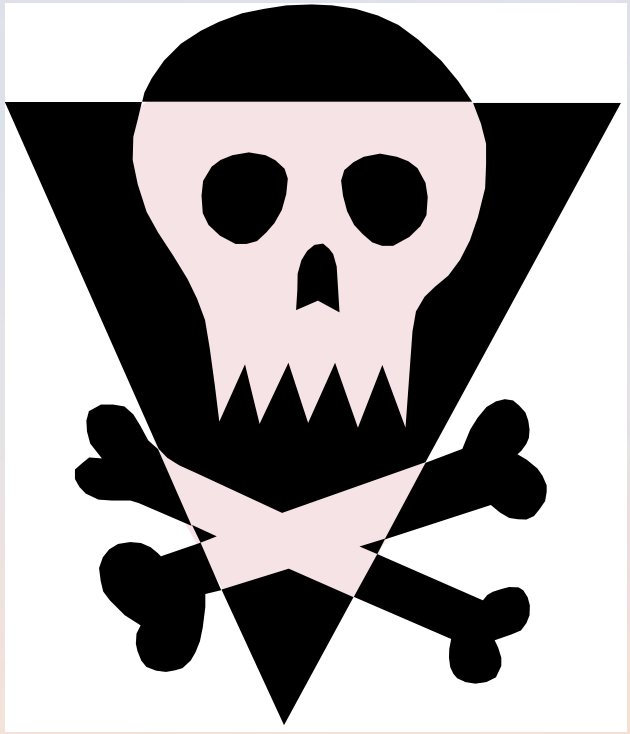
- Compounds used in systems
- Payload chemicals
- Utility chemicals
- Offgassed products
- Batteries
- Products of corrosion
- External contaminants
- Human metabolites
- Microbial metabolites
- Operational anomalies/hardware failures & repair
- Thermal degradation of electronic components
- Pollution in the source water

Apollo-Soyuz Landing



Assessing Known Health Hazards

- Payload/system chemicals
  - Composition
  - Volume
  - Concentration
- Irritancy Potential
  - Eye
  - Respiratory
  - Skin
- Systemic Toxicity



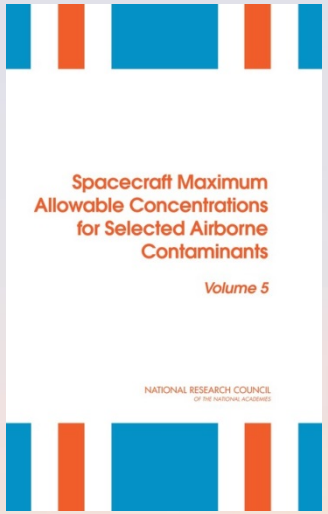
Toxicological Hazard Levels

Hazard Level	Irritancy	Systemic Effects	Containability/PPE
0	Slight-lasts <30 min-no therapy	None	+/-
1	Slight to moderate-lasts >30 min-therapy	Minimal effects-no potential for long-term effects	+/- Surgical masks, gloves, goggles
2	Moderate to severe-possible long-term effects	Minimal effects-no potential for long-term effects	+ Surgical masks, gloves, goggles
3	Moderate to severe-possible long-term effects	Appreciable effects-potential for long-term effects	+ Quick-don masks and gloves
4	Moderate to severe-possible long-term effects	Appreciable effects-potential for long-term effects	- Quick-don masks and ARS or evacuation

Setting Limits

- Spacecraft Maximum Allowable Concentrations (SMACs)
- Spacecraft Water Exposure Guidelines (SWEGs)

- Occupational limits (kind of…)
  - Continuous exposures but limited duration
  - Healthy adults
  - Incorporate emergency limits

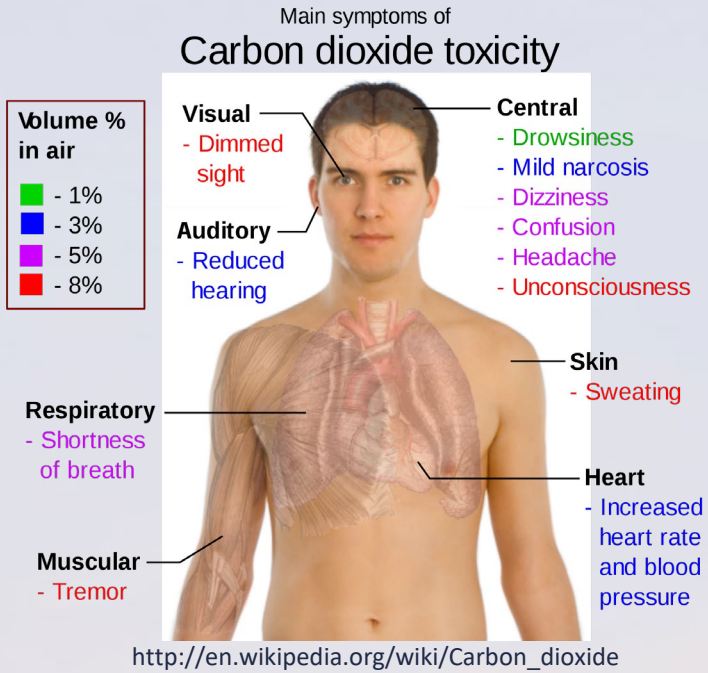


Unique Aspects of Spaceflight

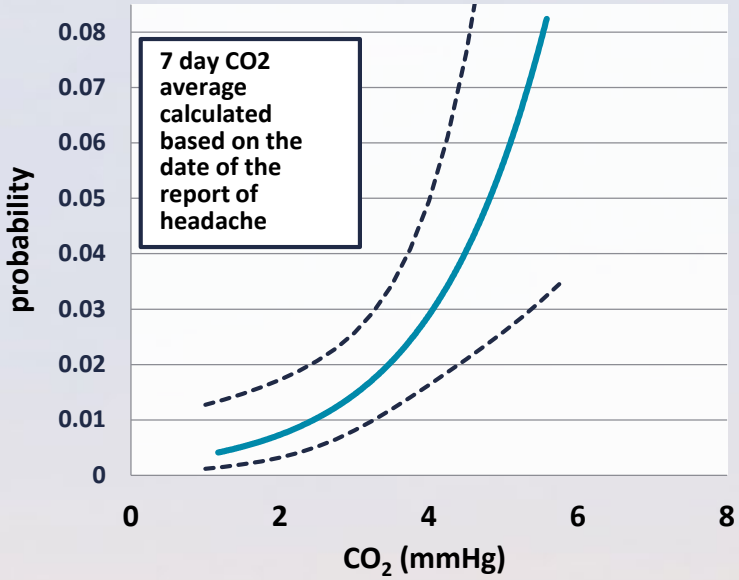
- MICROGRAVITY
  - Things float!
  - Generally limited to ground-based data
- Sensitivities
  - Bone and Muscle effects
  - Cardiovascular effects
  - Renal effects
  - Reduced RBC mass
  - Immune dysregulation
  - Organoleptic effects

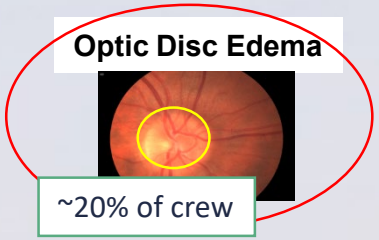
Spaceflight Factor	Chemical(s)
Reduced BMD	Cadmium
Renal effects	barium, chloroform, dichloroacetylene, methylene chloride, octamethyltrisiloxane, tert-butanol, trichloroethylene, ethylene glycol, and mercury
Cardiovascular effects	barium, freon 11, 12, 21, and 113
Blood cells/volume	benzene, bromotrifluoromethane, di-n-butyl phthalate, unsymmetrical dimethylhydrazine, 2-ethoxyethanol, isoprene, indole, nitromethane, and trichloroethylene
Immune effects	nickel, 2-mercaptobenzothiazole
Organoleptic effects	C1-C4 mono-, di-, and tri-alkylamines, ammonia, antimony, barium, cadmium, dichloromethane, and silver

Unique Aspects of Spaceflight

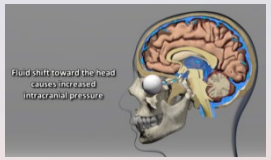


http://en.wikipedia.org/wiki/Carbon_dioxide





Increased Intracranial Pressure (ICP)



Outdoor ambient levels ~0.04% or 0.3 mmHg
Indoor levels 0.06-0.1% or 0.4-0.8 mmHg
OSHA PEL/NIOSH REL = 0.5% or 3.8 mmHg
ISS levels historically between **2.3 - 5.3** mmHg (0.5 ± 0.2%), with large fluctuations occurring over hours to days
Highest recorded in a U.S. spacecraft = 15 mmHg (2.0%) on Apollo 13

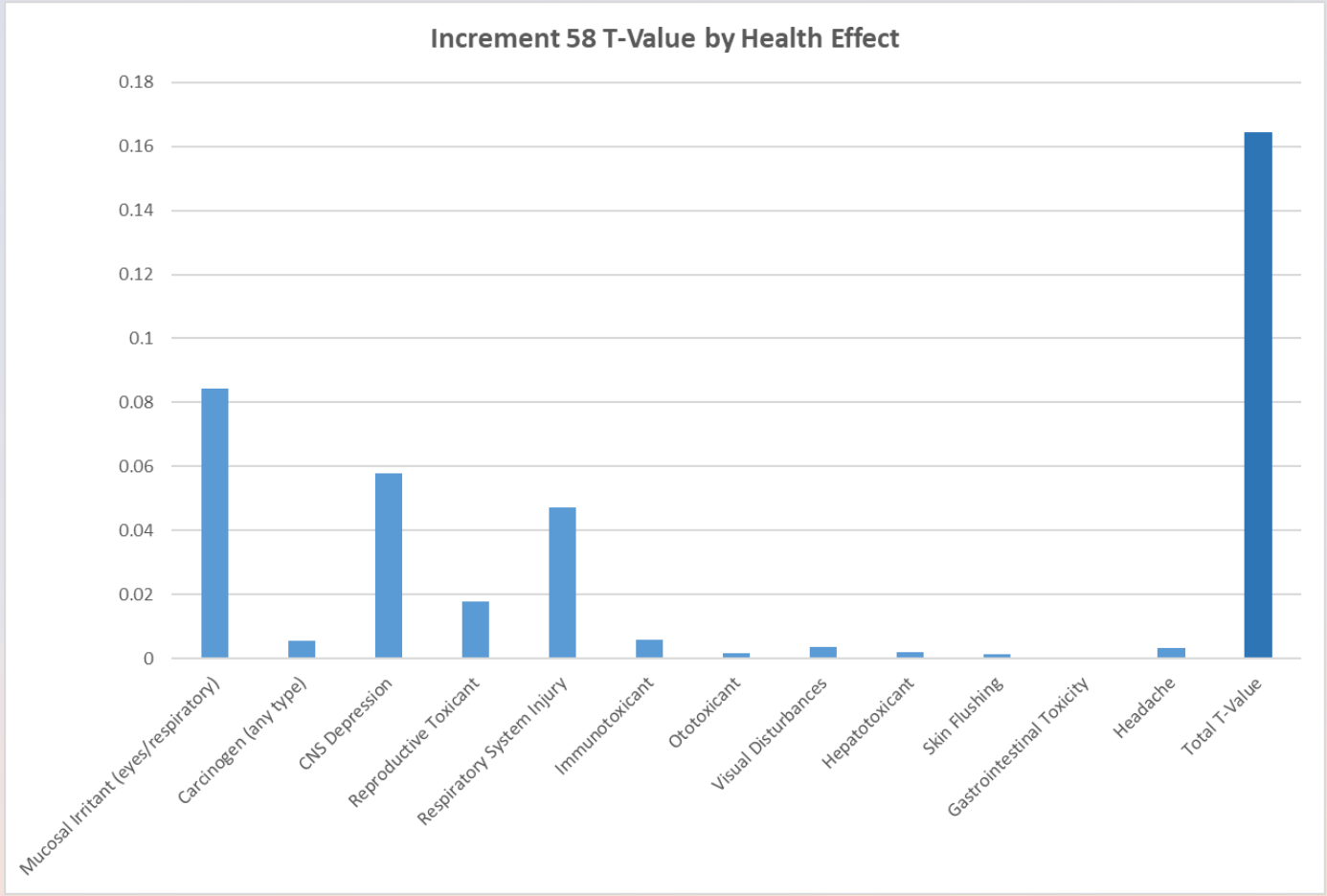
Dealing with Mixtures

- Toxicity hazard index (T values)
- $T = C_1/SMAC_1 + \ldots C_n/SMAC_n$, where the Cs are measured concentrations and SMACs are those appropriate to the exposure time of the crew
- Air is deemed safe if all group T values < 1

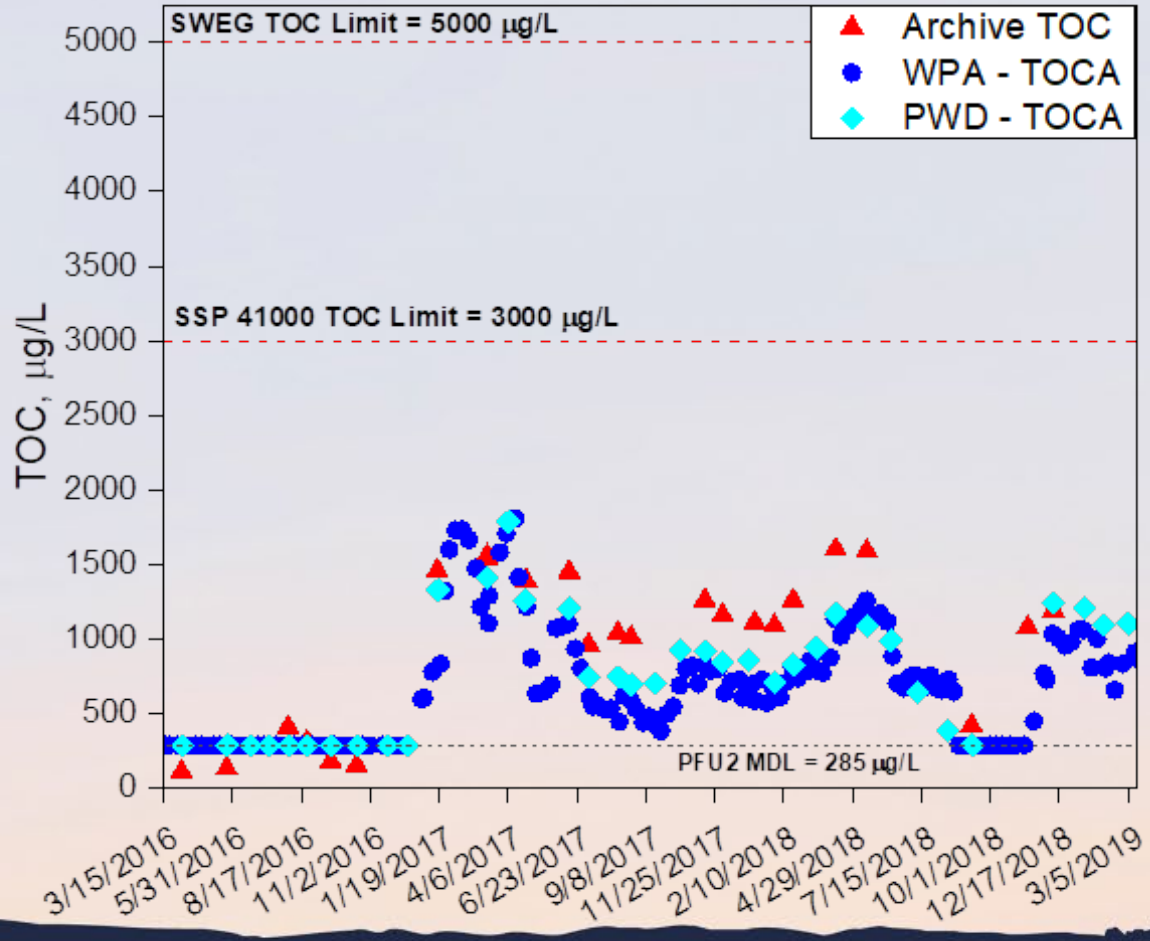
Monitoring

- Real-time
  - Air Quality monitor (AQM)
  - CO_2
  - Compound specific analyzer for combustion products (CSA-CP)
  - Total Organic Carbon (TOC) Analyzer
- Post-flight
  - Grab sample containers (GSCs)
  - Formaldehyde badges

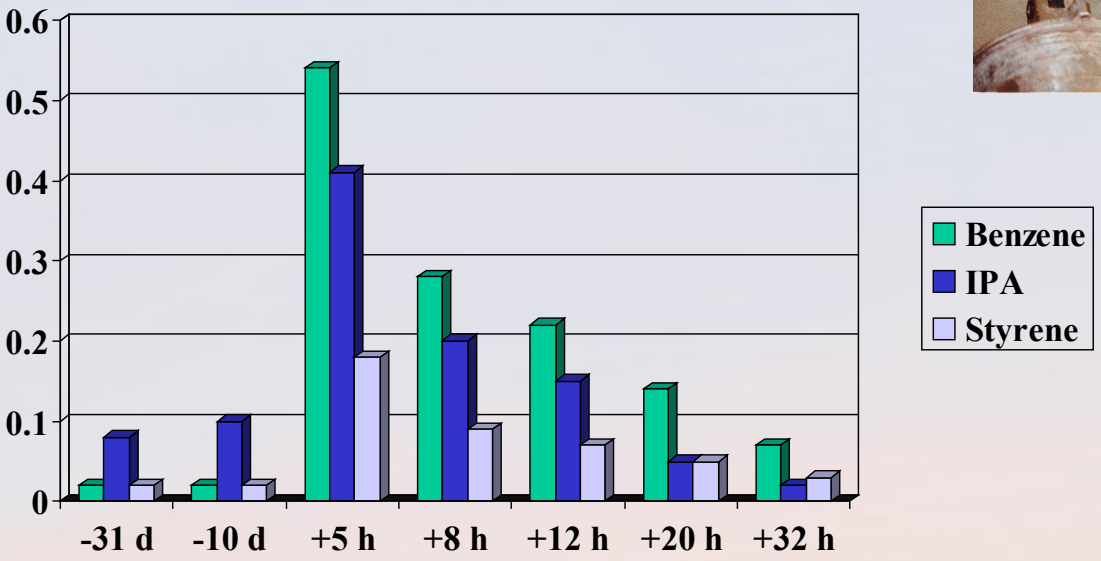
AQM Derived T Values by Health Effect

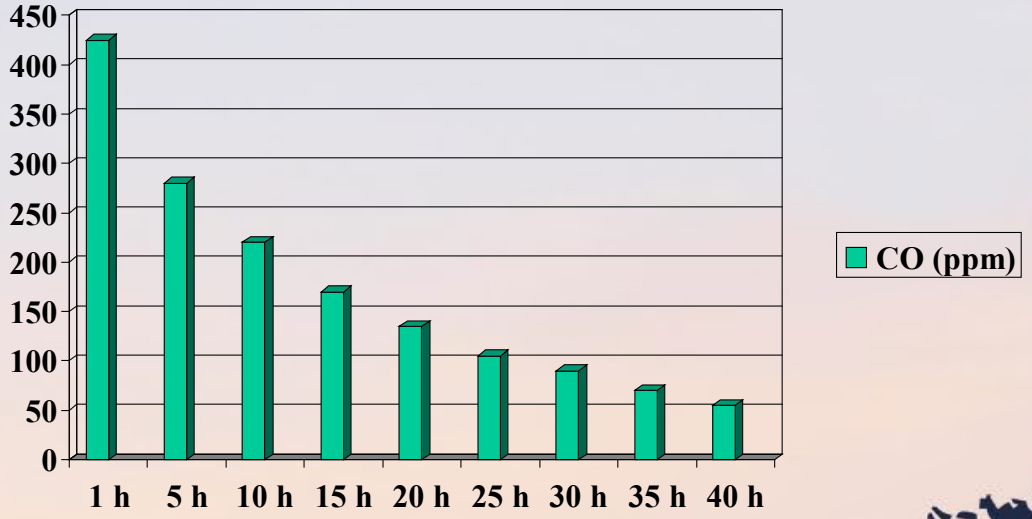


Total Organic Carbon Trending in ISS Potable Water



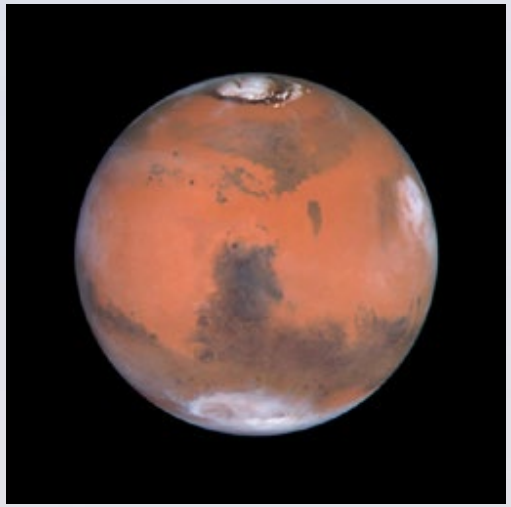
Toxicological Events



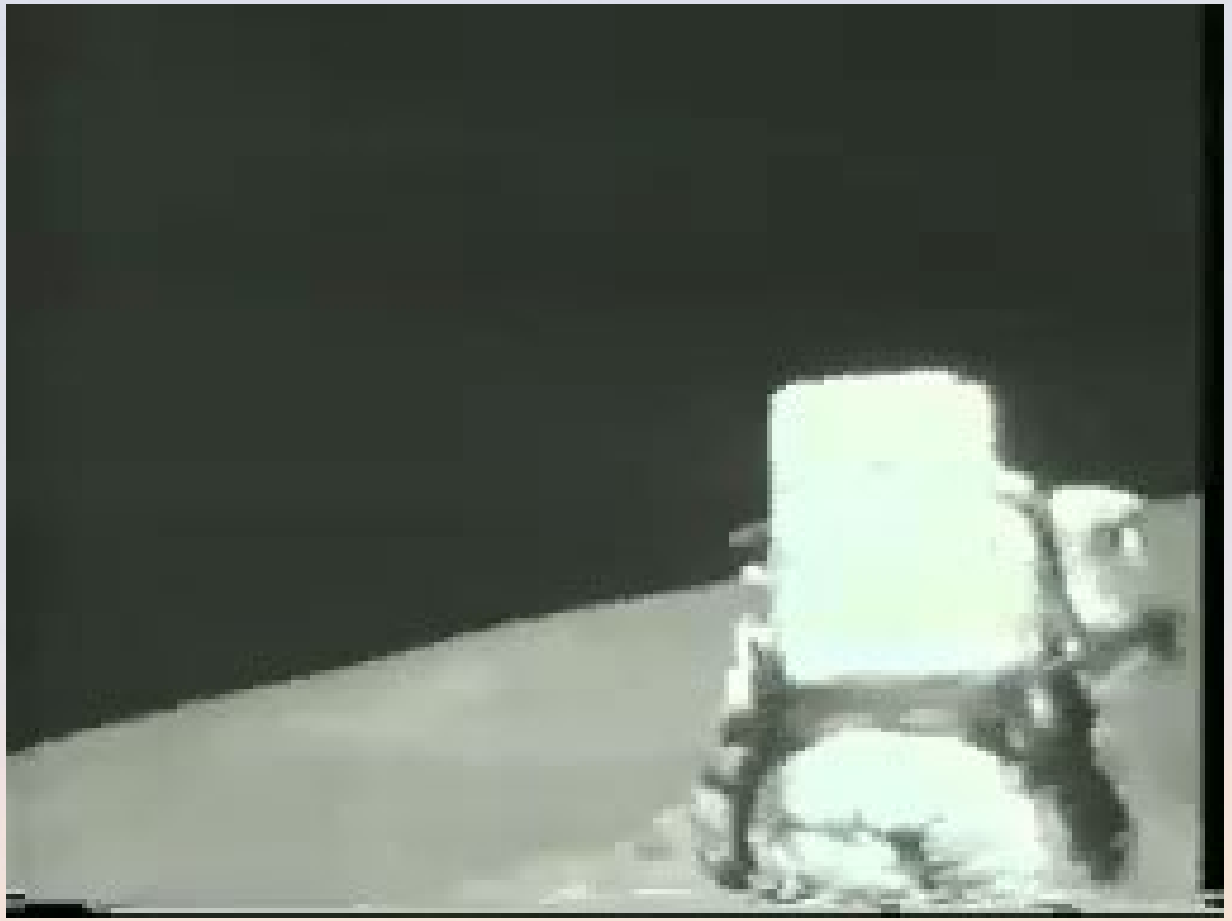


Future Challenges

- Industrial scale operations with toxic chemicals & *in situ* resources (water + volatiles?)
- Waste management and disposal (incineration?)
- Pollutant monitoring with on-site instruments
- Space Tourists (?)
- Hazards from *in situ* dust*
  - Inhalation
  - Eye/skin

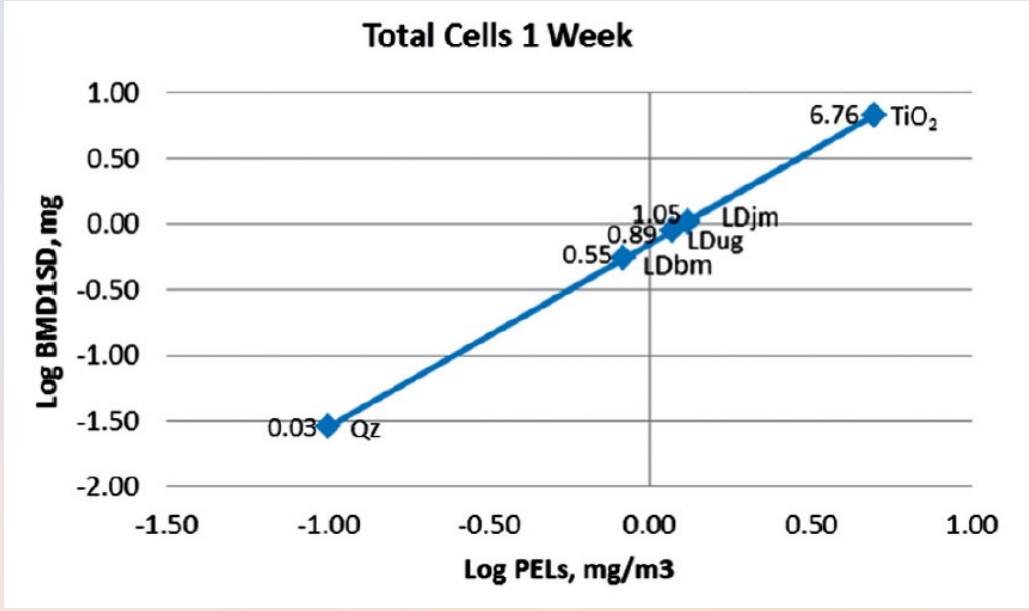


Lunar Dust



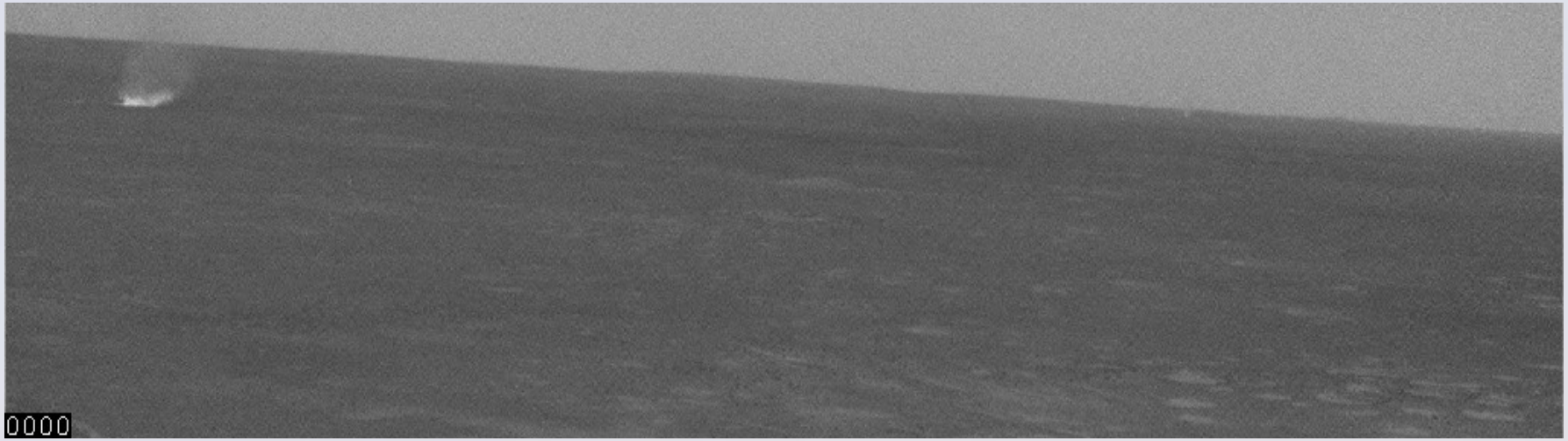
Dust Limits

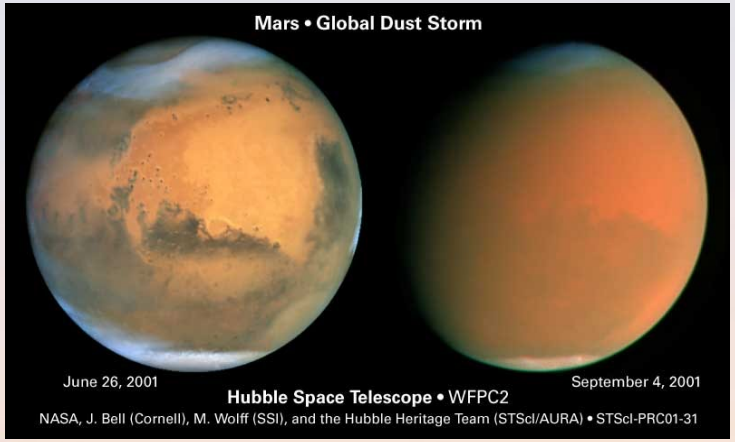
- Lunar Airborne Dust Toxicity Assessment Group (LADTAG) formed to address the problem of setting health standards for astronaut exposure to lunar dust – **0.3 mg/m³**

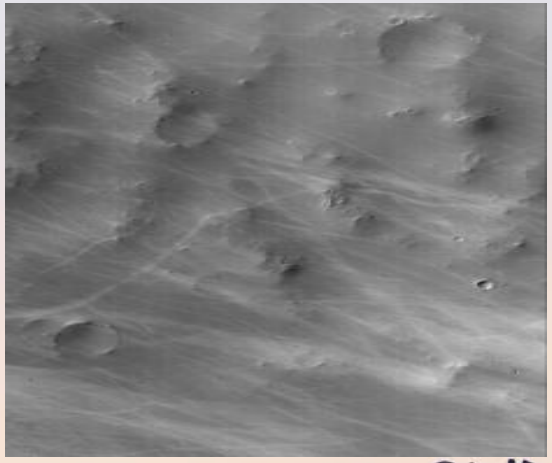


Titanium Dioxide < Lunar Dust < Silica

Unique Aspects of Martian Dust







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https://youtu.be/YOG3tAkPpPE