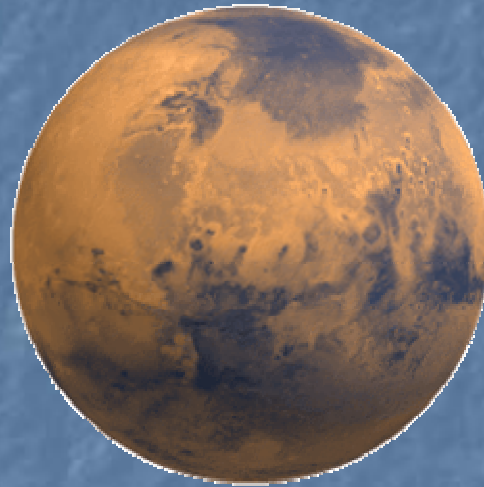


Atmosphere Control of a Mars Greenhouse

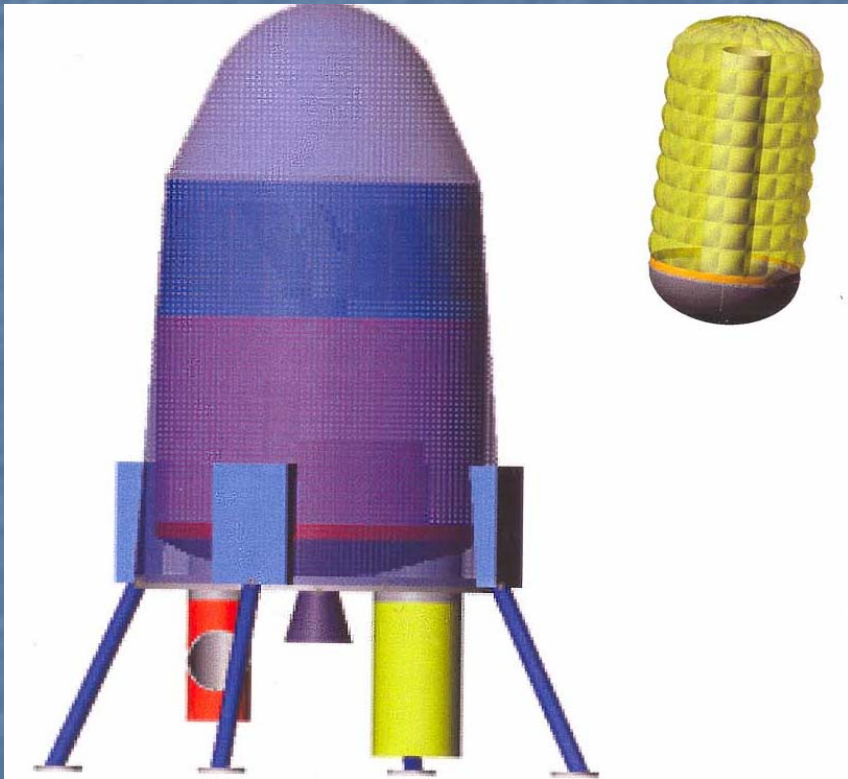


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ASEN 5519

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Mars Deployable Greenhouse



- NASA Design Competition – MarsPort
- 2001 – 2002 School Year
- 8 Team members, including PhD student
- Support human exploration on Mars

Mars Environment

Atmospheric Constituents	Percent Abundance
Carbon Dioxide (CO ₂)	95.32
Nitrogen (N)	2.7
Argon (Ar)	1.6
Oxygen (O ₂)	0.13
Carbon Monoxide (CO)	0.07
Water (H ₂ O)	0.03

(Owen, 1992)

- Average temperature range: 186 – 268 K
 - -87°C - -5°C
- Avg. pressure: 6 mbars
 - Earth ~ 1013.25 mbars
- Day: 24.66 hours
- Surface gravity: 3.69 m/s²
- Surface density: 0.02 kg/m³
 - Earth ~ 1.217 kg/m³

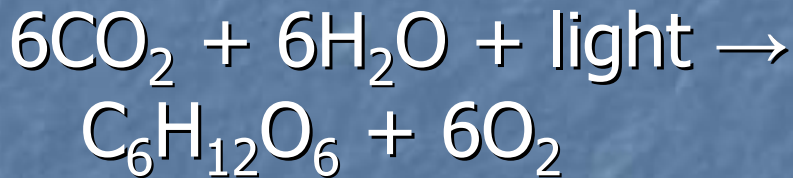
(Kieffer et al., 1992)

Plant Growth Requirements

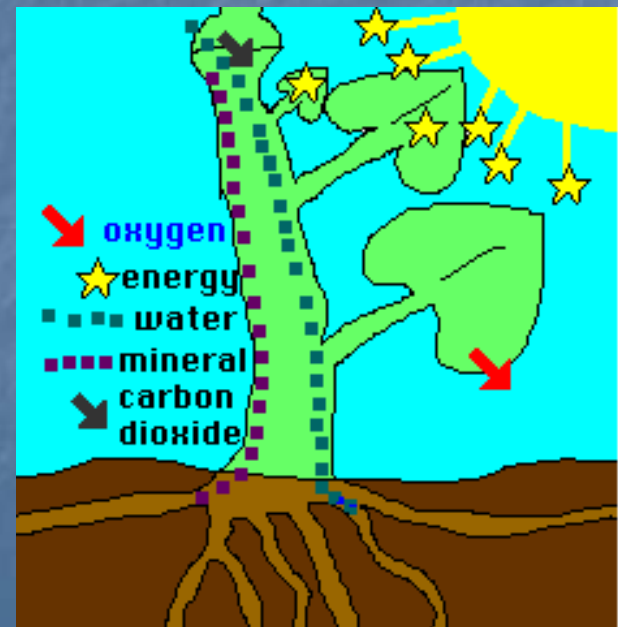
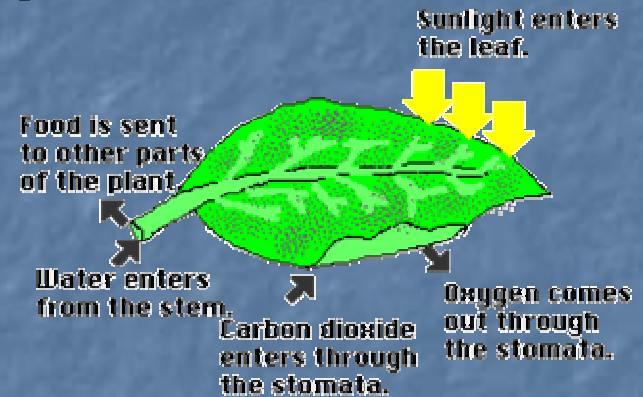
	Vegetative (leaf, lettuce)	Root (onion, carrot)	Fruit (tomato, pepper)	Sprout (bean, alfalfa)
Light ($\mu\text{mol}/\text{m}^2\text{g}$)	250 - 275	275 - 400	300 - 400	0 - Ambient
Photoperiod (hr)	18 - 24	18	18	12 - 18
Temperature ($^{\circ}\text{C}$)	22 - 28	15 - 25	20 - 28	20 - 28
Humidity (%Rh)	50 - 85	50 - 70	50 - 75	~ 90
Volume of Root Zone	15x15x15 cm	5x5x15 cm	30x30x30 cm	10x10x5 cm
Contamination Control	Ethylene/ Gaseous Ammonia	TBD	Ethylene	Ethylene (Eckart, 1996)

Plant Growth Requirements

- Equation of Photosynthesis



- Need O_2 during night to burn carbohydrates stored in their roots
 - Minimum of 5 kPa for healthy plant growth



Environmental Parameters

MarsPort Design Parameters

Environment Controls

- Ventilation
- Temperature Control
- Gas Composition
- Relative Humidity

Atmospheric Management

- Separation/Storage of O₂
- Restoring consumed CO₂
- Conserving, restoring and recycling H₂O

Temperature	10 – 30 °C
Relative Humidity	40 – 90%
CO ₂ Partial Pressure	0.1 – 3 kPa
O ₂ Partial Pressure	> 5 kPa
Inert Gas Composition	Optional
Ethylene Gas	< 50ppb (at 100 kPa)

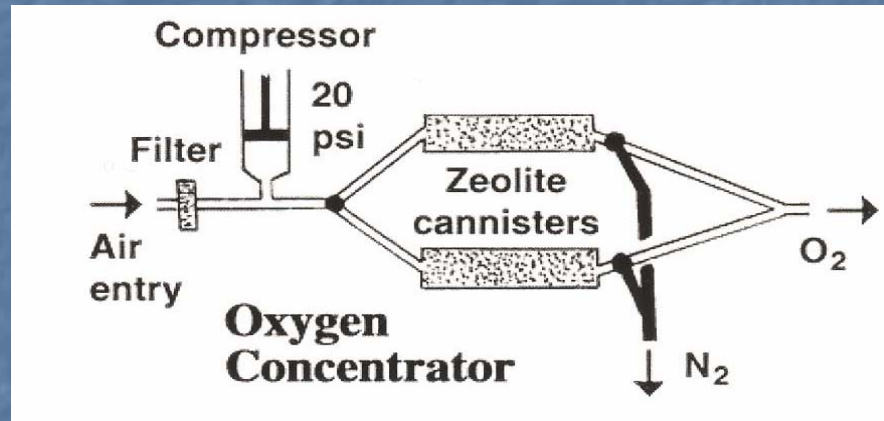
Atmosphere Separation Technologies

Zeolites	<ul style="list-style-type: none">■ minerals with ability to absorb different gases based on the crystalline structure of the mineral■ changing the size of spacing within structure will allow different molecular sizes to fit inside
Membrane	<ul style="list-style-type: none">■ separate gases by allowing certain molecules to pass more freely than others■ molecules that are polar (CO₂) easier to separate
Distillation	<ul style="list-style-type: none">■ cryogenic air separated based on boiling points■ process uses large amounts of energy to cool air to a liquid state
Oxidation	<ul style="list-style-type: none">■ reacting organic molecule and oxygen releases H₂O and CO₂■ does not recover O₂ produced by photosynthesis
Freeze Out	<ul style="list-style-type: none">■ CO₂ frozen from atmosphere when in contact with surface below its deposition temperature■ does not accomplish O₂ separation due to the presence of a buffer gas such as nitrogen

Trace Contaminant Control Technologies

Absorption	<ul style="list-style-type: none">■ pass contaminated air over a bed of sorbents that filters the ethylene (Potassium permanganate) (Atwater et. al, 1989)■ ~ <u>100 lbs.</u> of sorbent treats up to 100,000 ft³ for up to 3 mo.
Biofilters	<ul style="list-style-type: none">■ microorganisms, found in soils, remove ethylene in <u>small</u> concentrations (Cowan,Tabwekar)
Freeze Out	<ul style="list-style-type: none">■ reducing a gas to a liquid and passing it near a cold plate to separate out volatile compounds, contaminants not destroyed■ Ethylene liquefies at 169.4 K, CO₂ at 194.7 K – CO₂ would also be frozen out (CRC Handbook of Chemistry and Physics, 73rd edition)
Oxidation	<ul style="list-style-type: none">■ organic compounds broken down into H₂O, CO₂ and N₂■ catalysts are available to accelerate oxidation process■ ozone is most effective catalyst, but can also cause destruction of human and plant tissues■ TiO₂ absorbs light in UV spectrum, creates ionic potentials at surface of the catalyst that oxidize contaminants at low temps. (Baskaran et al., 1998)

Selection of Atmosphere Control Technology



■ Zeolites

- By pressurizing the zeolite, the structure absorbs N_2 and CO_2
- Once zeolite becomes saturated, flow is switched to a second chamber
- O_2 leaves concentrator in pressurized state → injected into habitat or a storage module

Selection of TCC Technology

- Oxidation using a **TiO₂ photocatalyst**
- Contaminated air is passed through a series of titanium oxide plates (Baskaran et al., 1998)
 - UV light applied to add energy to perform oxidation
- Airborne pathogens are killed by the UV light
 - Molds, fungus, bacteria, viruses, dust mites and spores
 - Hydrocarbon Gases are removed (ethylene gas)
 - Most odors are removed (<http://www.kesmist.com/tio2w.htm>)

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7. Baskaran, S., Song, L., et al. (1998). "Titanium Oxide Thin Films on Organic Interfaces through Biomimetic Processing." J. Am. Ceram. Soc. 81(2): 401 – 408
8. CRC Handbook of Chemistry and Physics, 73rd edition
9. <http://www.kesmist.com/tio2w.htm>

Questions?