



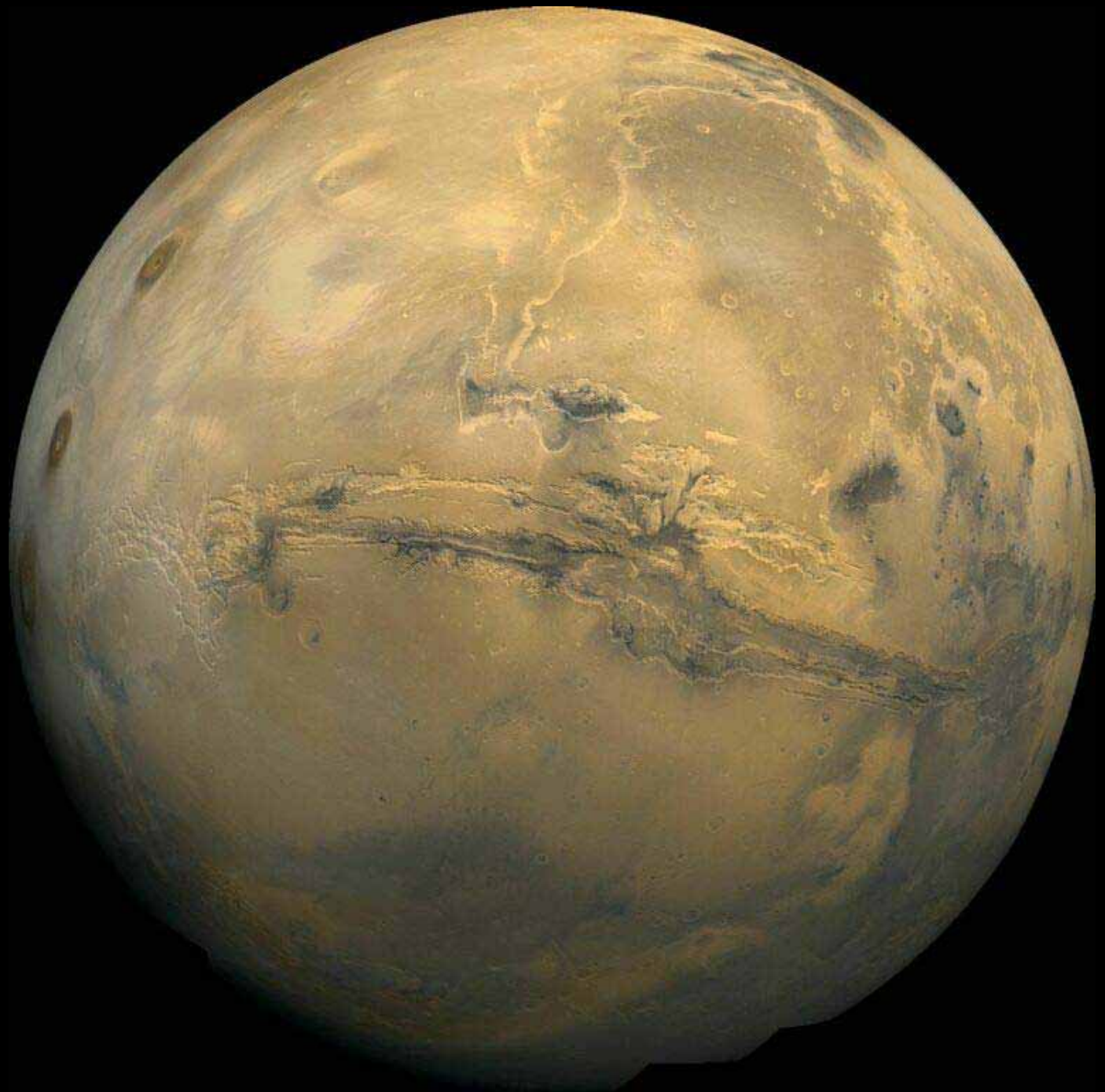
Toward A Mars Greenhouse

**Philip A. Fowler
Dynamac Corp**

“Mars, new Earth for Local Agriculture”

Fondi (LT) – Italy

May 21st, 2004



Mars Mission Options



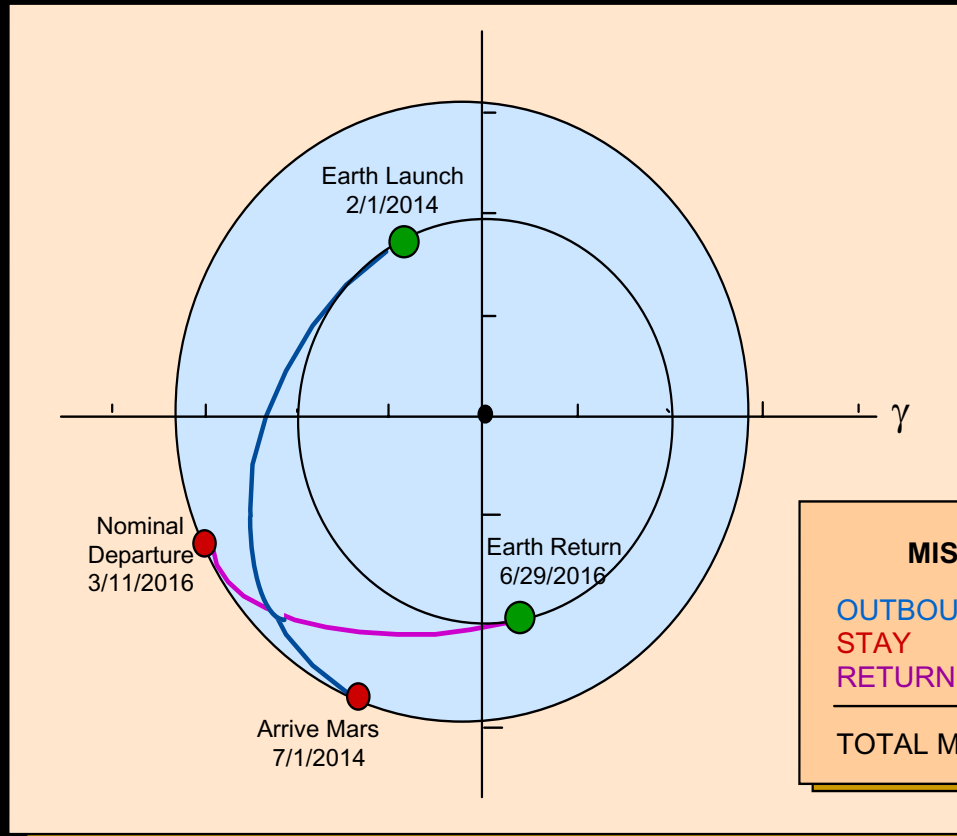
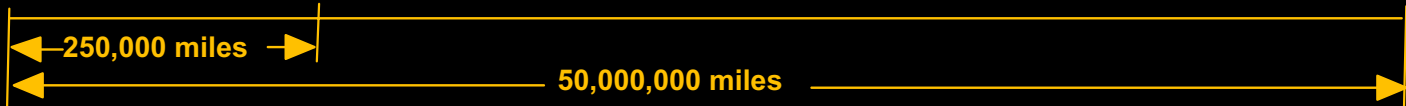
Earth



Moon



Mars



MISSION TIMES	
OUTBOUND	150 days
STAY	619 days
RETURN	110 days
<hr/>	
TOTAL MISSION	879 days

Human Life Support Requirements:

Inputs

	Daily Req.	(% total mass)
Oxygen	0.83 kg	2.7%
Food	0.62 kg	2.0%
Water (drink and food prep.)	3.56 kg	11.4%
Water (hygiene, flush laundry, dishes)	26.0 kg	83.9%

TOTAL 31.0 kg

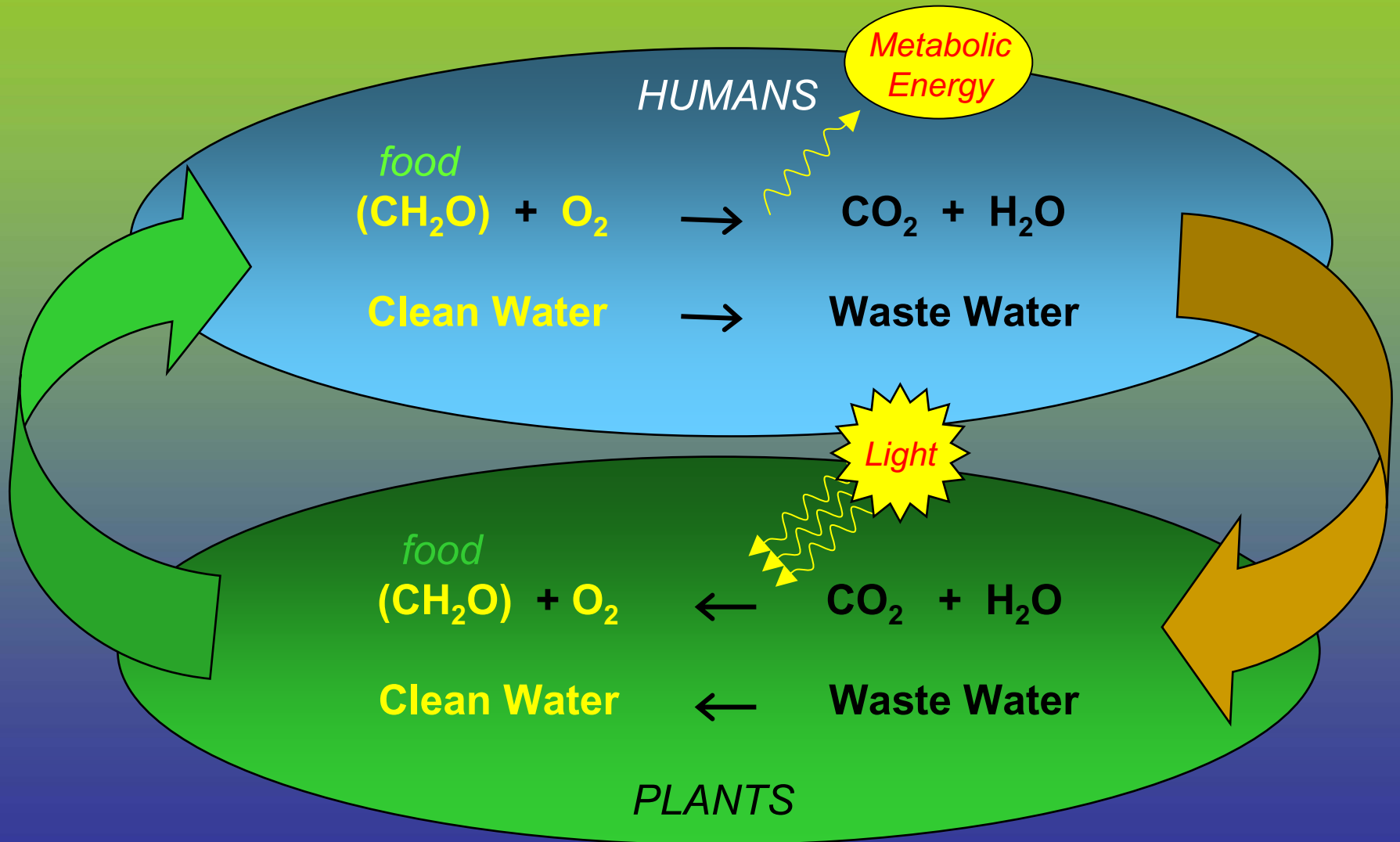
Outputs

	Daily	(% total mass)
Carbon dioxide	1.00 kg	3.2%
Metabolic solids	0.11 kg	0.35%
Water (metabolic / urine)	29.95 kg	96.5%
(hygiene / flush)		12.3%
(laundry / dish)		24.7%
(latent)		55.7%
		3.6%

TOTAL 31.0 kg

Source: NASA SPP 30262 Space Station ECLSS Architectural Control Document
Food assumed to be dry except for chemically-bound water.

Plants for Human Life Support



Constraints for Crop Production on Mars:

(“Economics” of Life Support)

- Energy Requirements
- System Mass
- System Volume
- Crew Time
- System Reliability
- Autonomy

These Apply for All Life Support Technologies

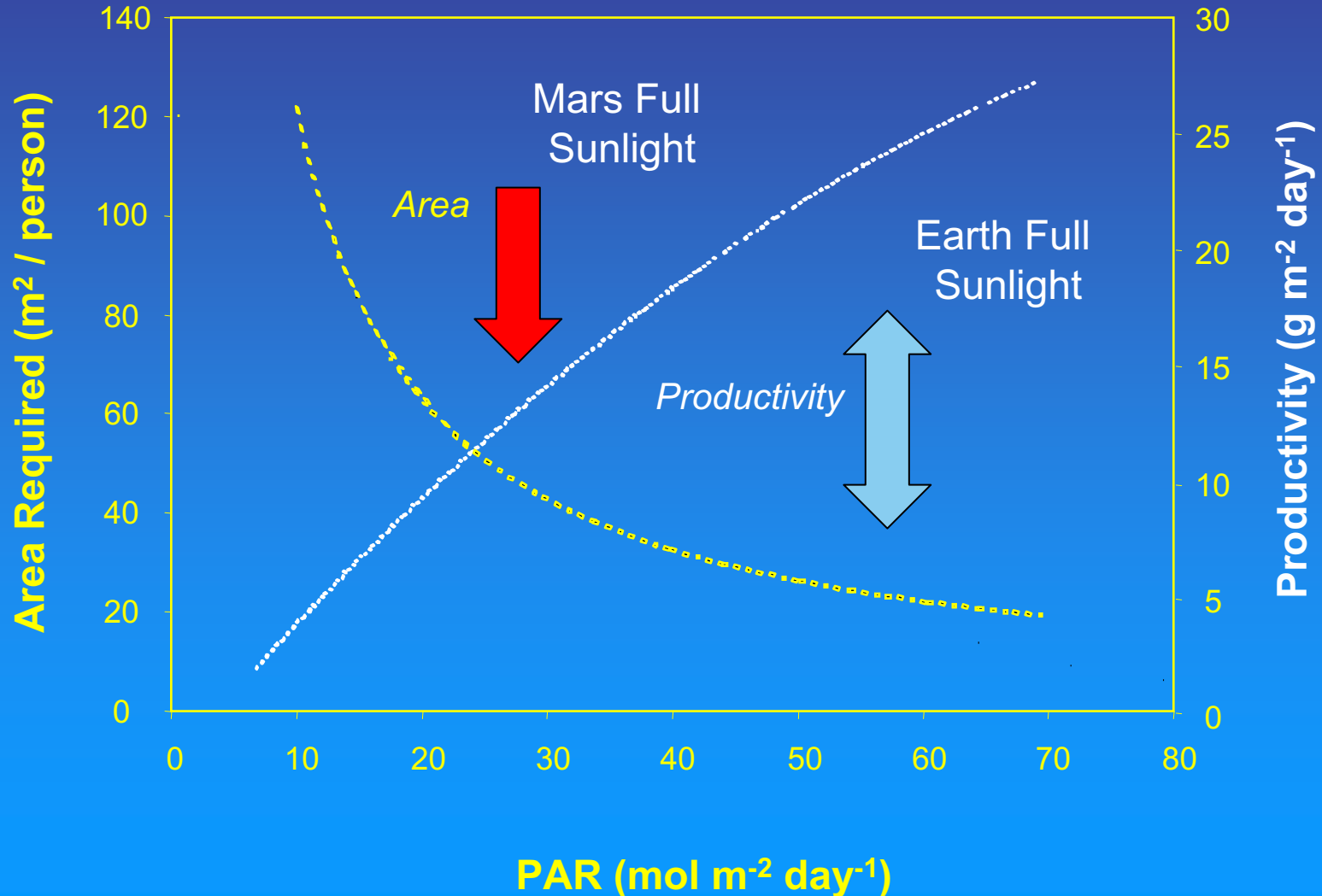
For Plants, Lighting Dominates These Costs !

Horticultural Challenges for Going to Mars:

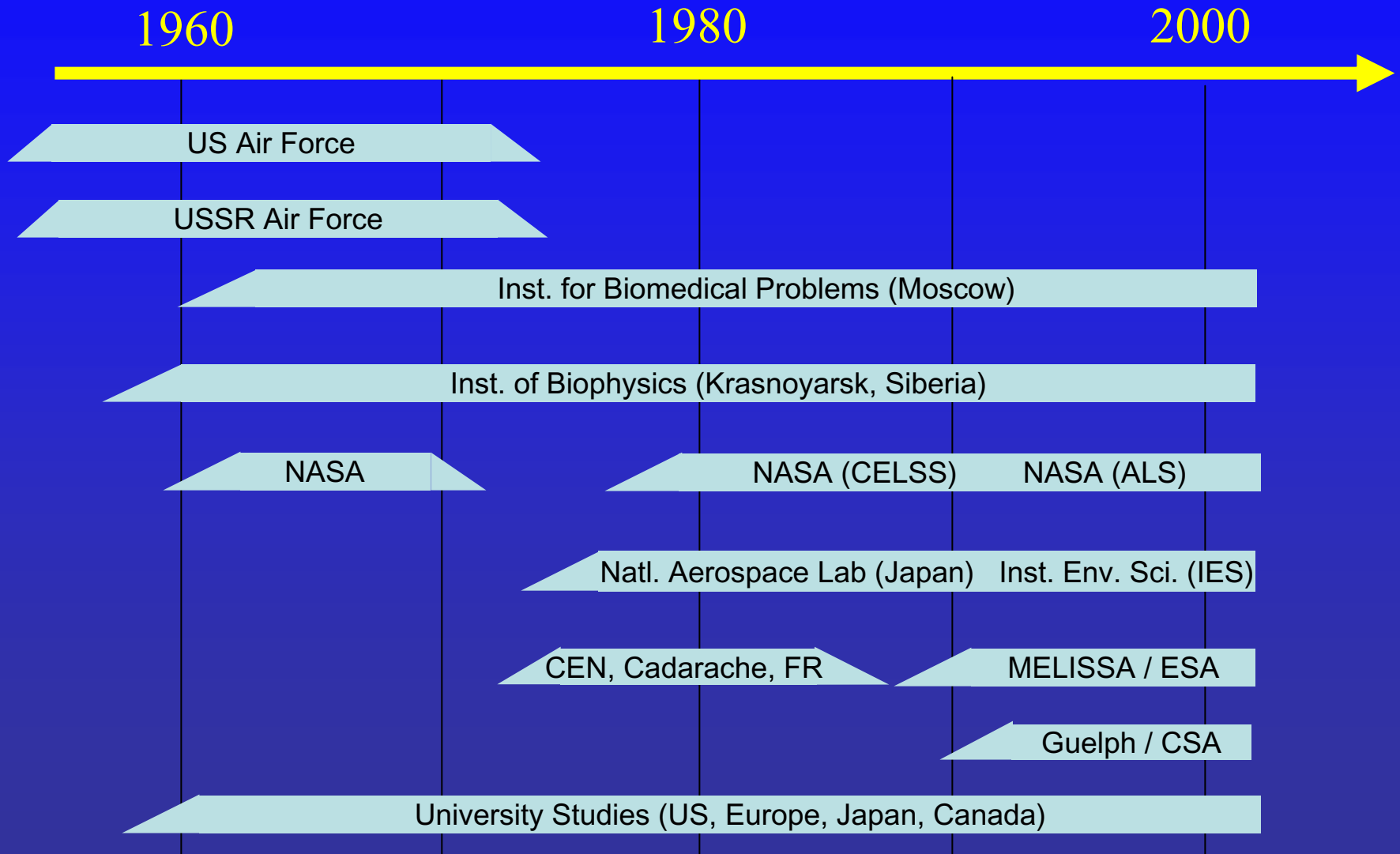
Agricultural Engineering

- Improved Planting/Harvesting Approaches
 - Mechanization / Automation
- Improved Lighting Systems
 - More Efficient Electric Lamps
 - Light Collecting / Conduit Systems
 - Transparent / Inflatable Materials
- Improved Environmental Monitoring and Control
- Water Recycling and Nutrient Solution Mgmt.

Effect of Light (PAR) on Productivity and Crop Area Requirements



Testing with Plants and Algae for Life Support



Early Plant Experiments in Space

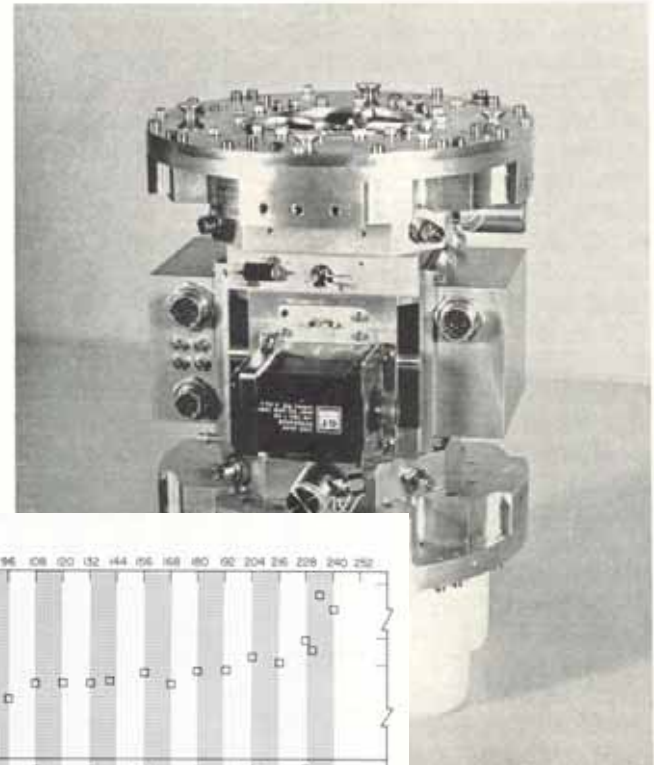
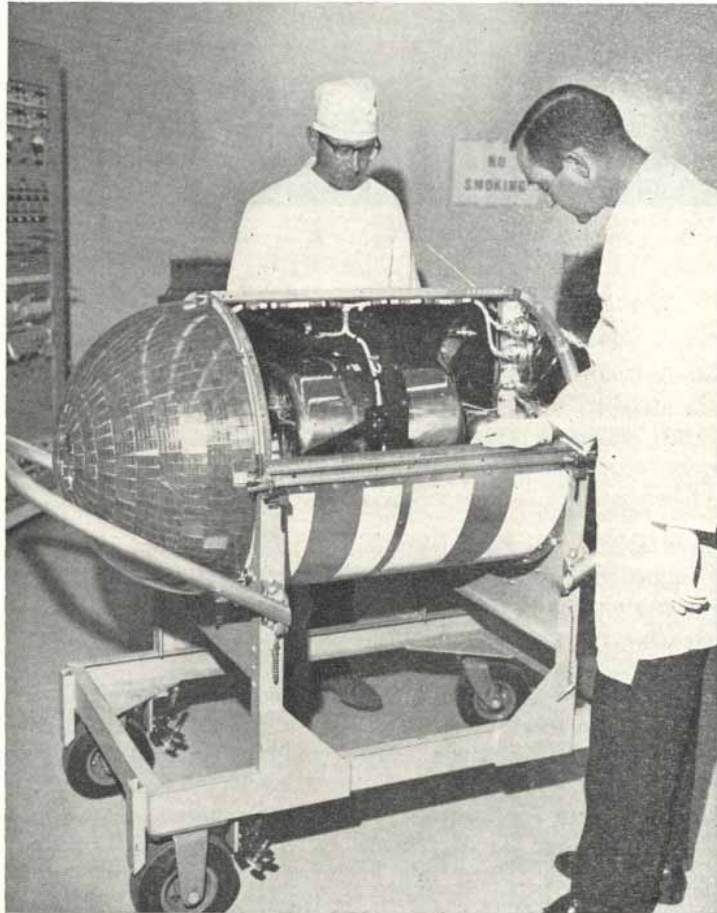


FIG. 11. Experimental apparatus mounted in OV1 satellite; note solar cell dome power system.

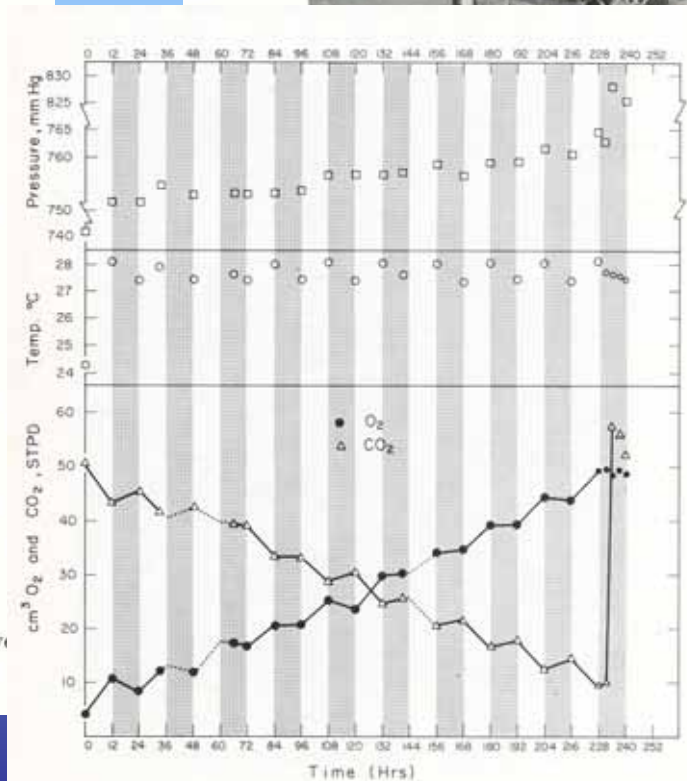
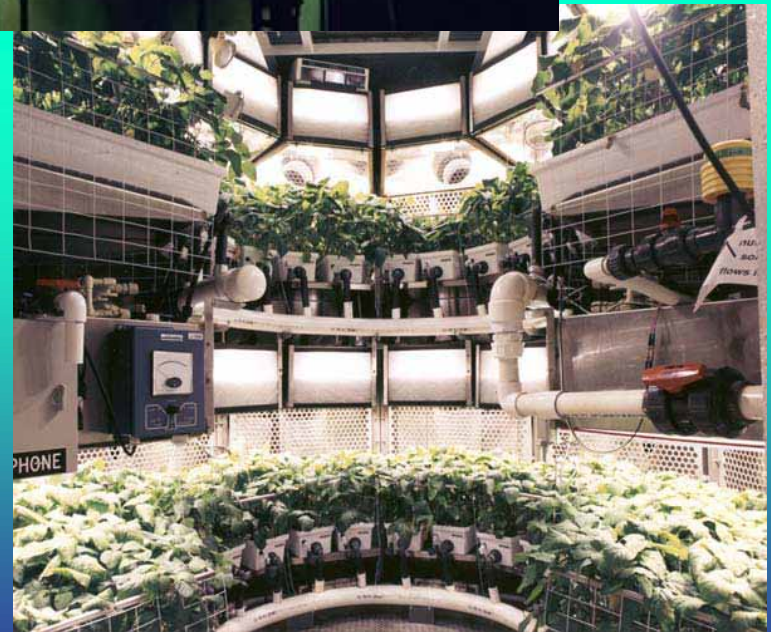
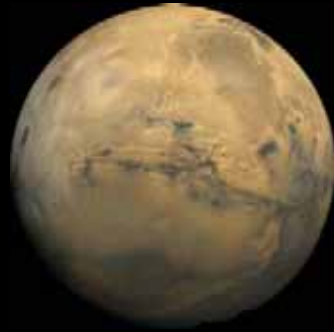


FIG. 19. Flight data: pressure, temperature, CO₂, and O₂.

C.H. Ward, S.S. Wilks, and H.L. Craft. 1970.
Dev. Indust. Microbiol. 11:276-295

Some Findings from NASA Testing
→ Closed System Studies:





**What Will it Take to Grow
Plants for on Mars ?**

Can Low Pressures Be Used for Crop Production Systems ?

- Reduced Structural Mass
- Reduced Gas Leakage (and Resupply)
- Wider Selection for Transparent Materials
- ISRU on Mars

Small chamber Work



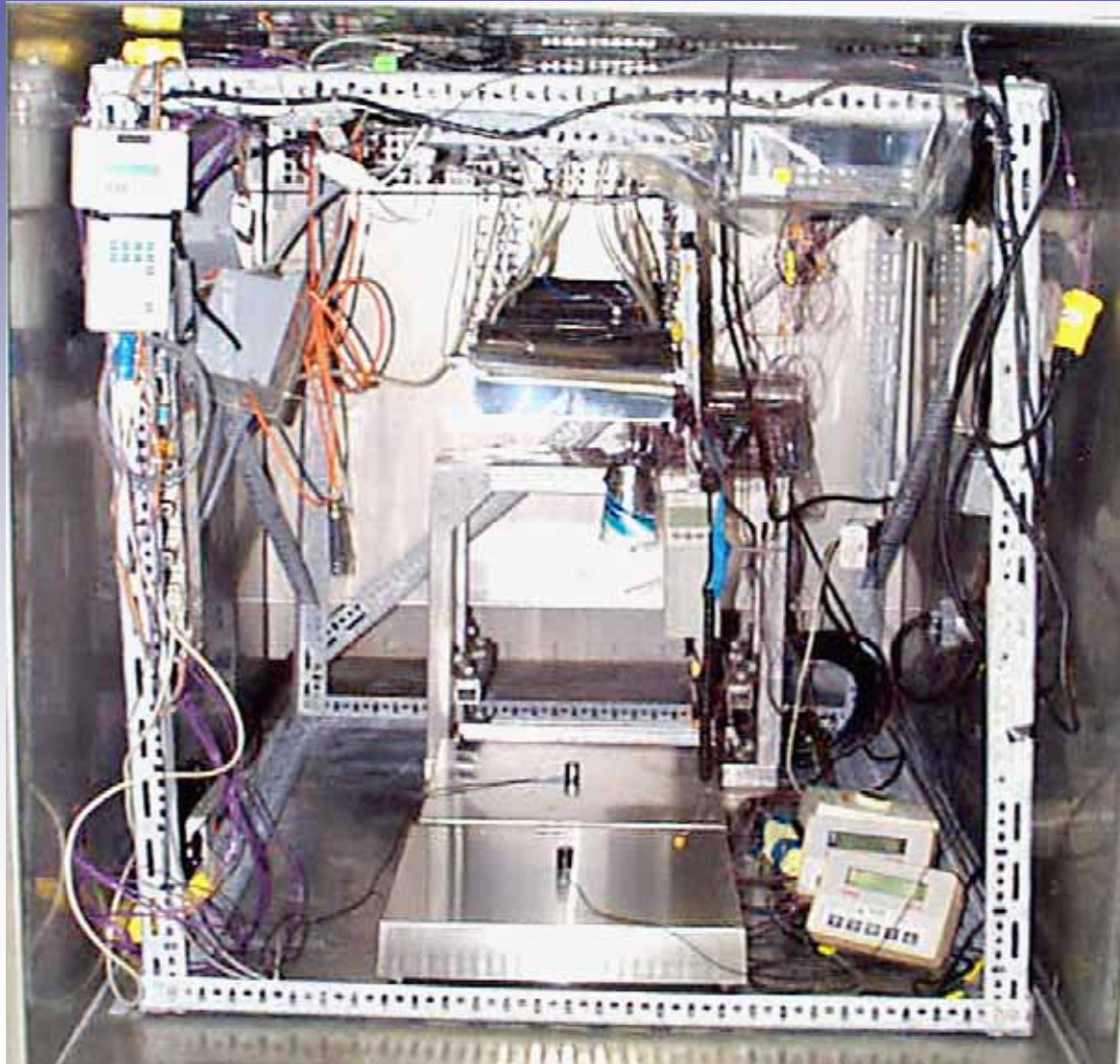
Bell Jar Test



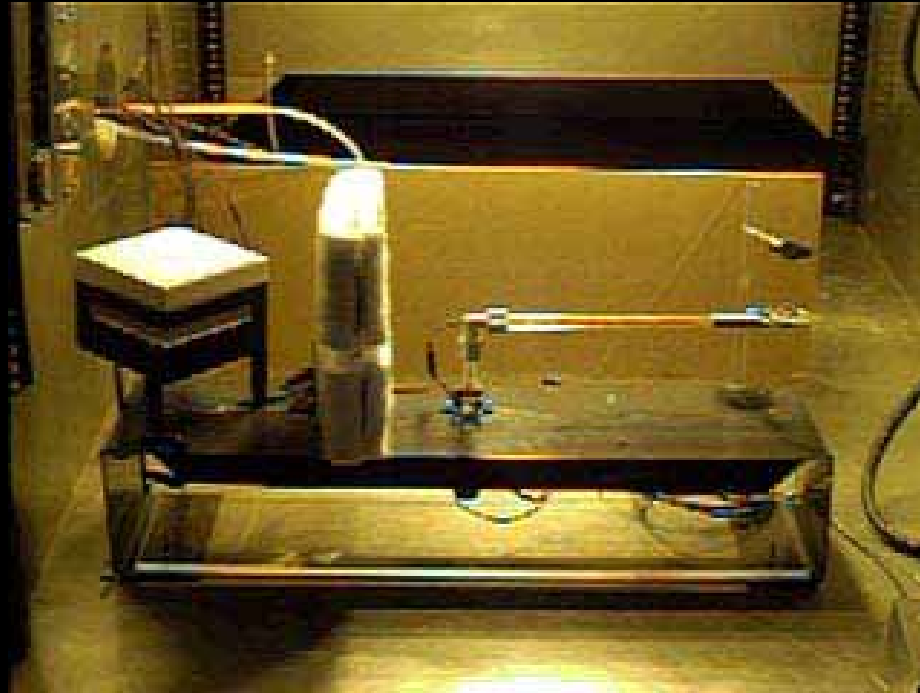
Early Hypobaric Test (Thermotron)



Later Thermotron Test



Boundary Layer Test



The Guelph Effort

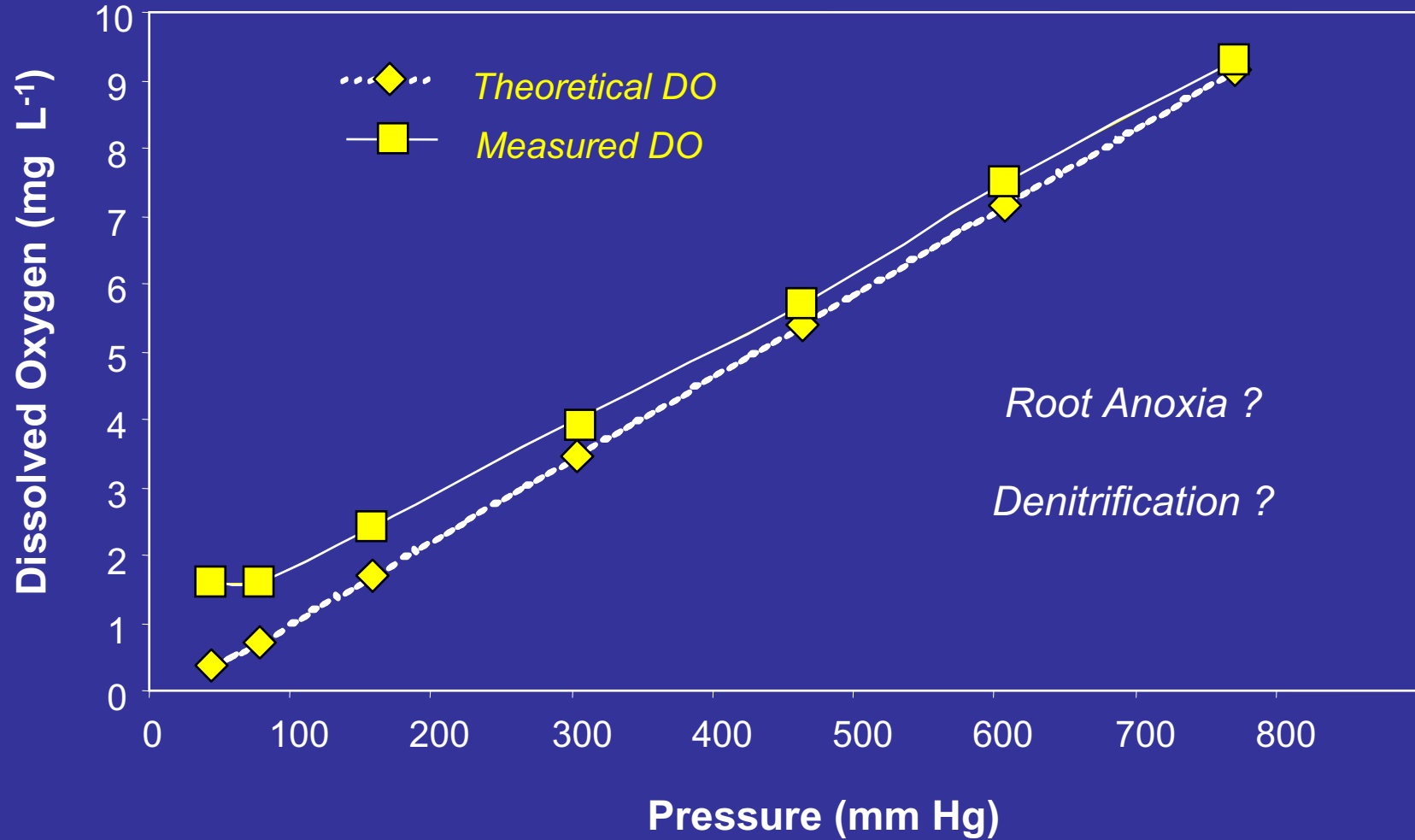


Large Chambers

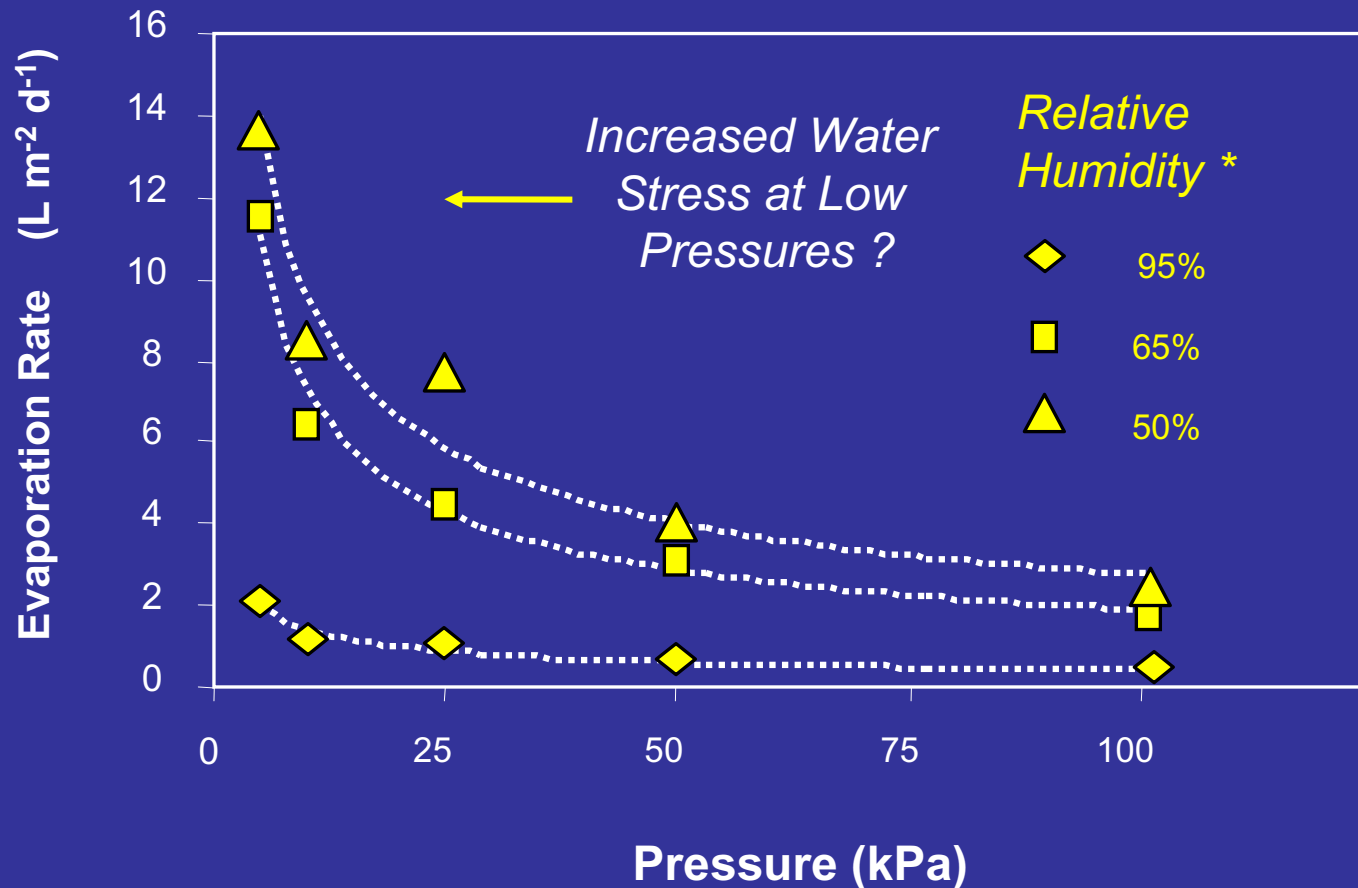


Small Chambers

Dissolved Oxygen vs. Pressure (pO_2)

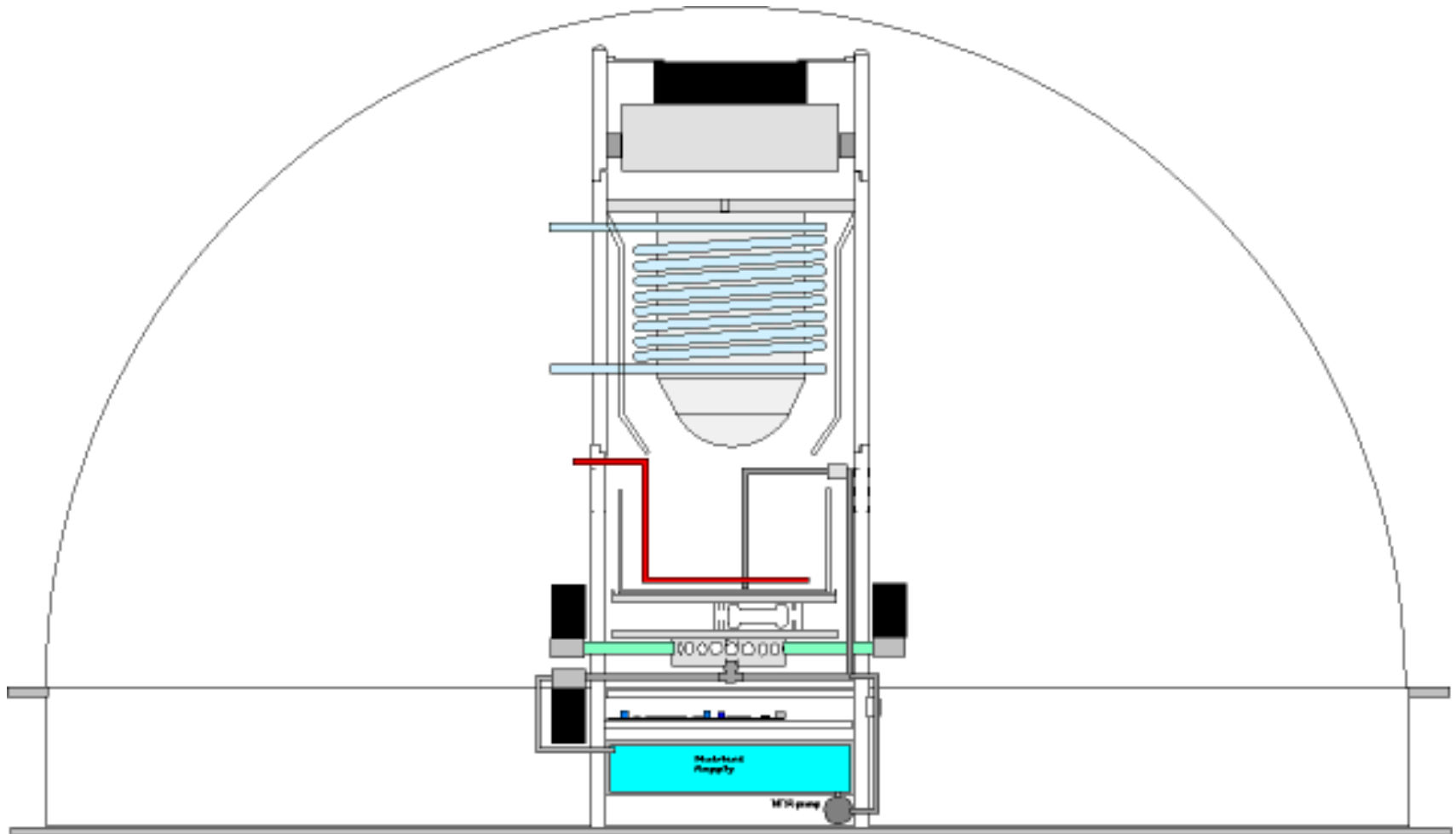


Water Evaporation Rates vs. Pressure



* Temperature $\approx 25^{\circ}\text{C}$

What the Tests Designed



How Dr Rygalov thought it should work



What the design became



Testing in Progress



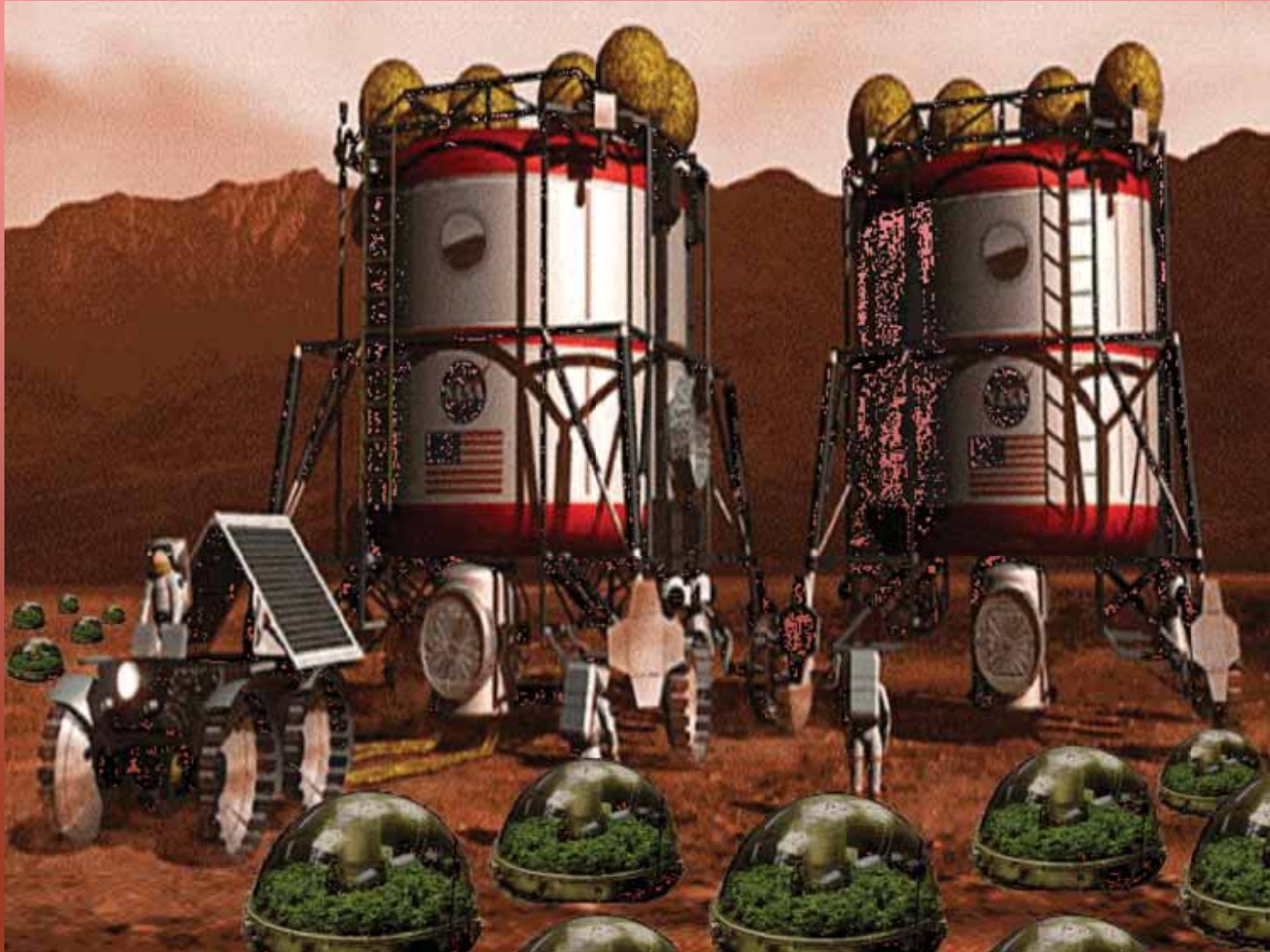
Testing in Thermotron



Stand Alone Dome



Send to Mars?



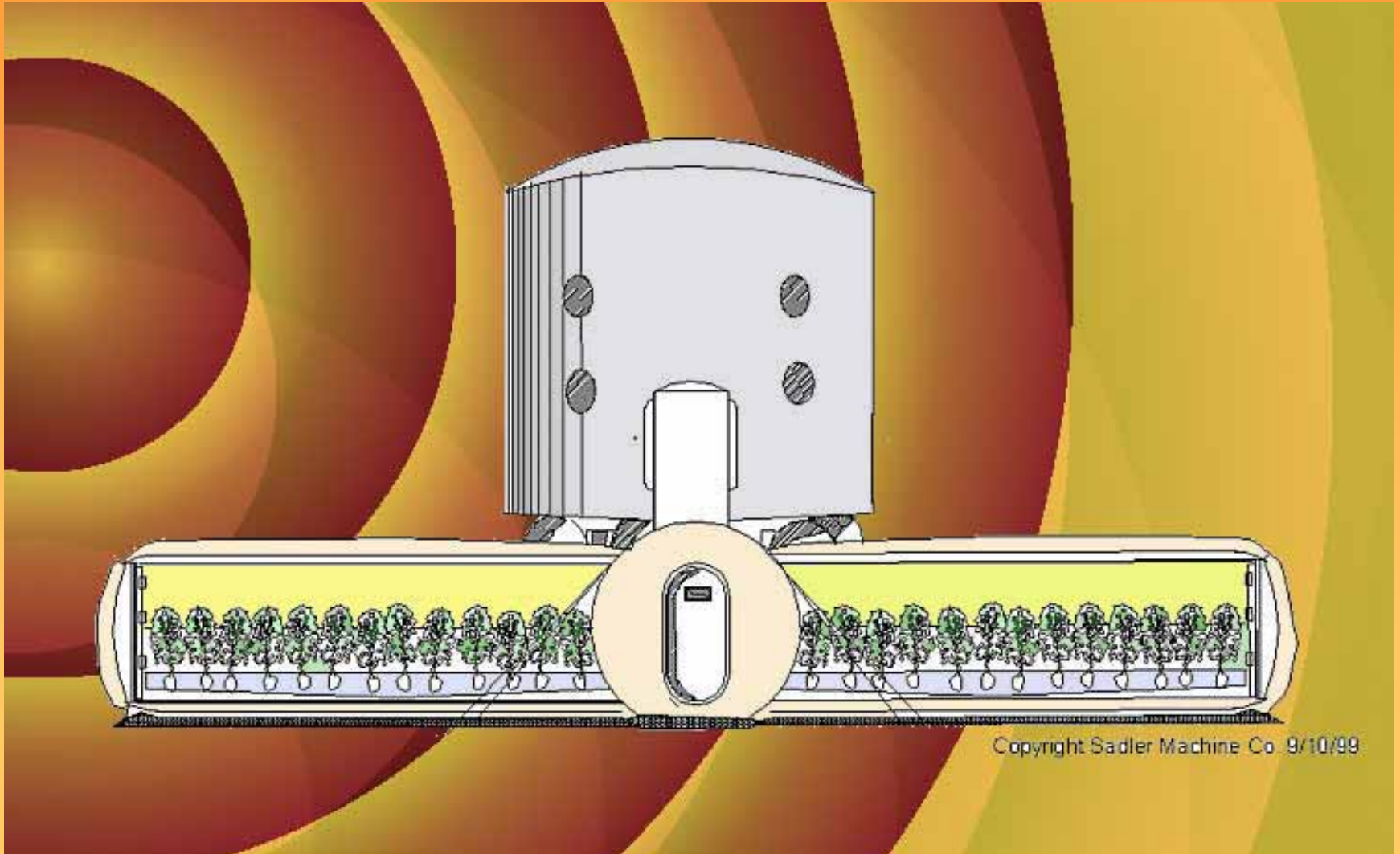
Growing Plants on Mars



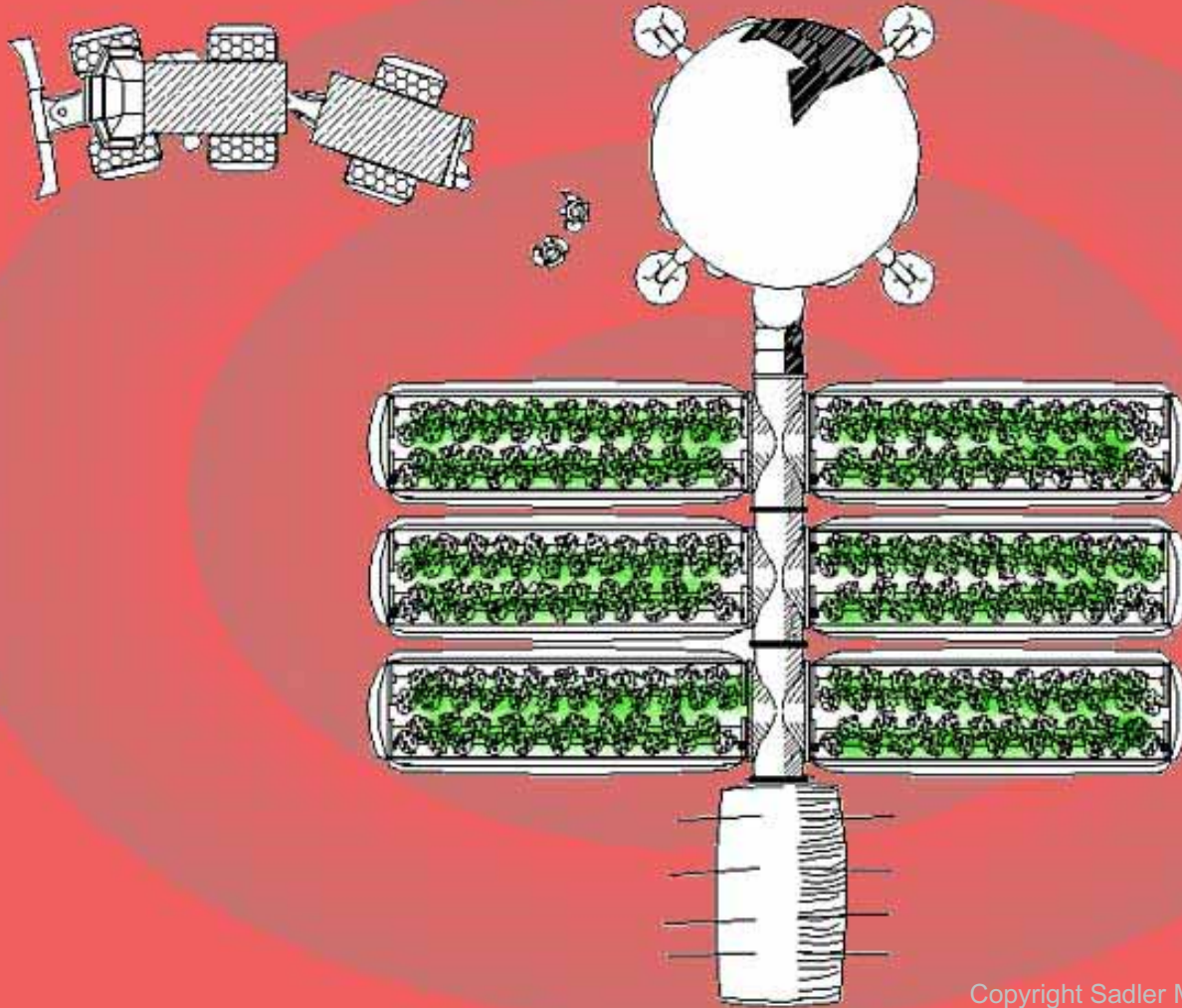
The Dome on Mars



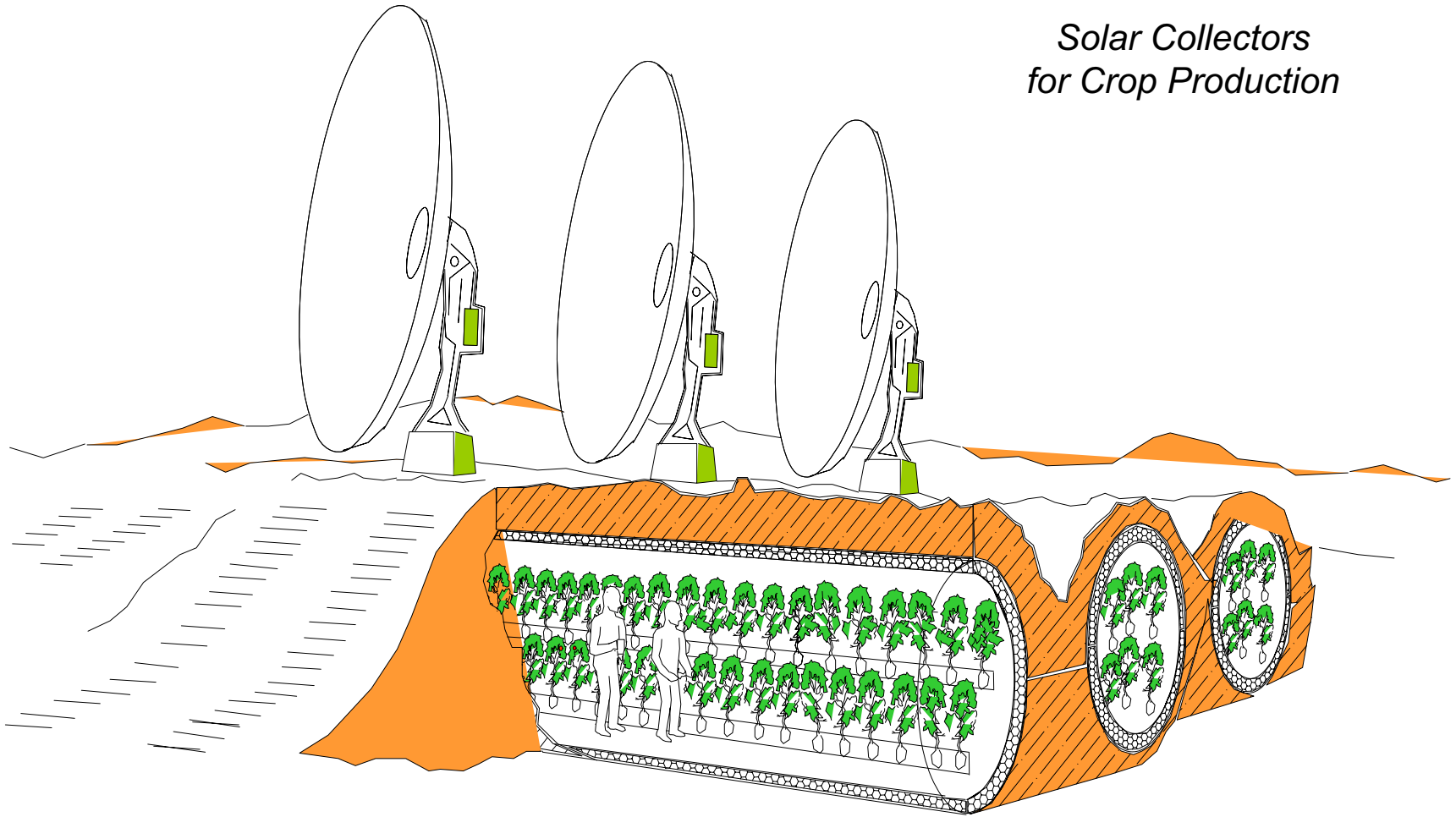
More ideas for Greenhouses



More Greenhouses



*Solar Collectors
for Crop Production*

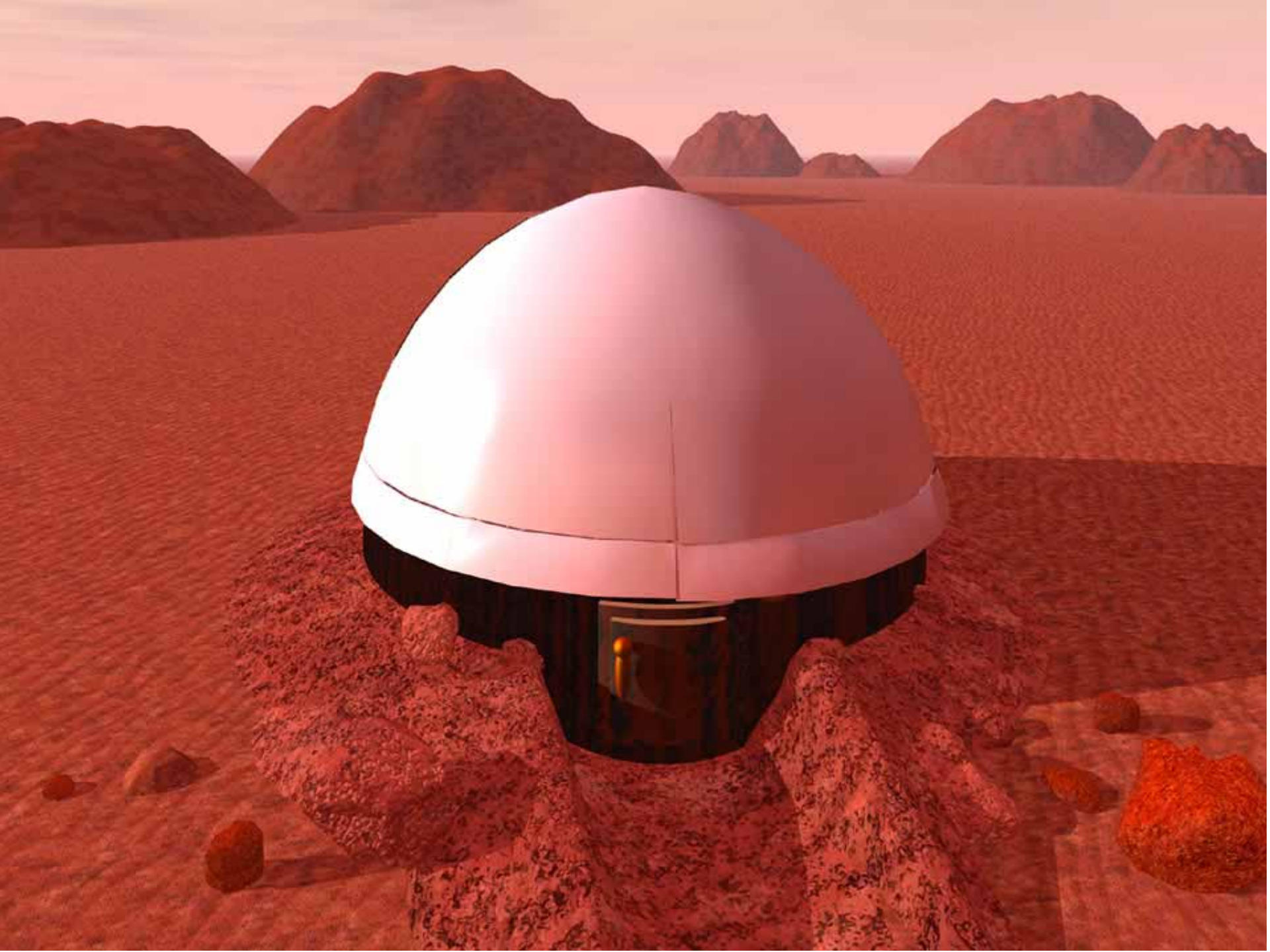


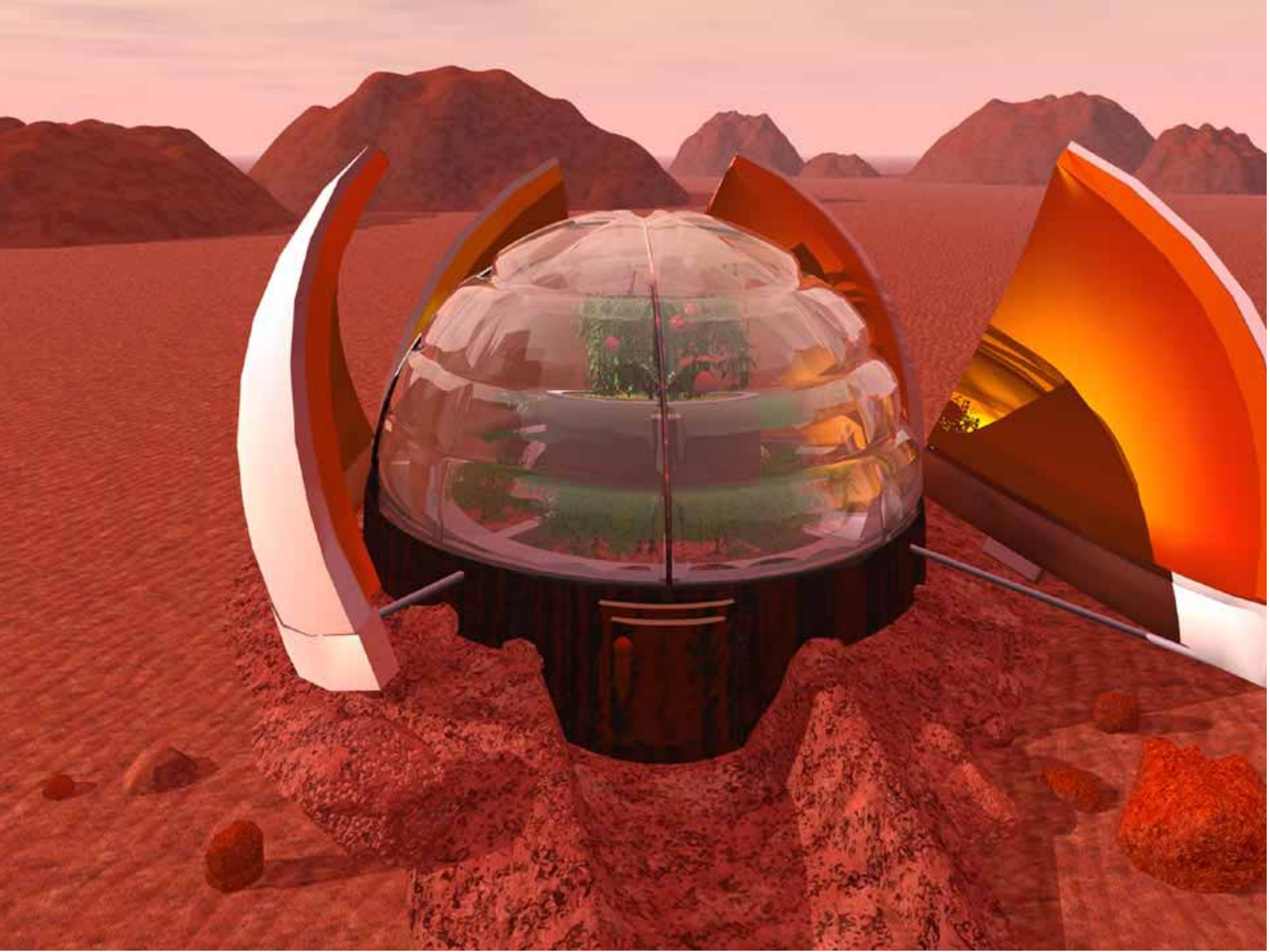
*Buried Plant
Growth Chambers*

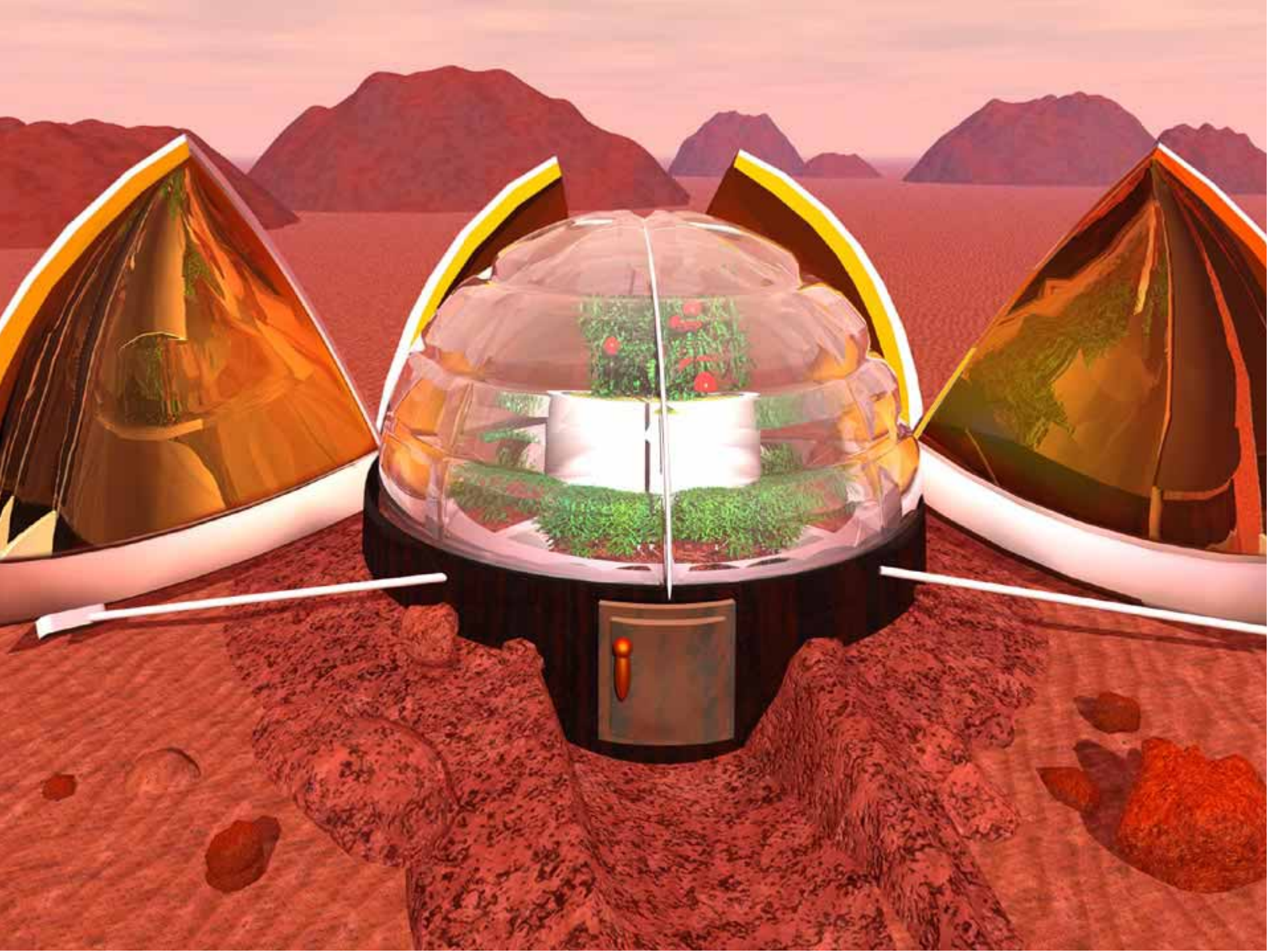
Geodesic Domes?

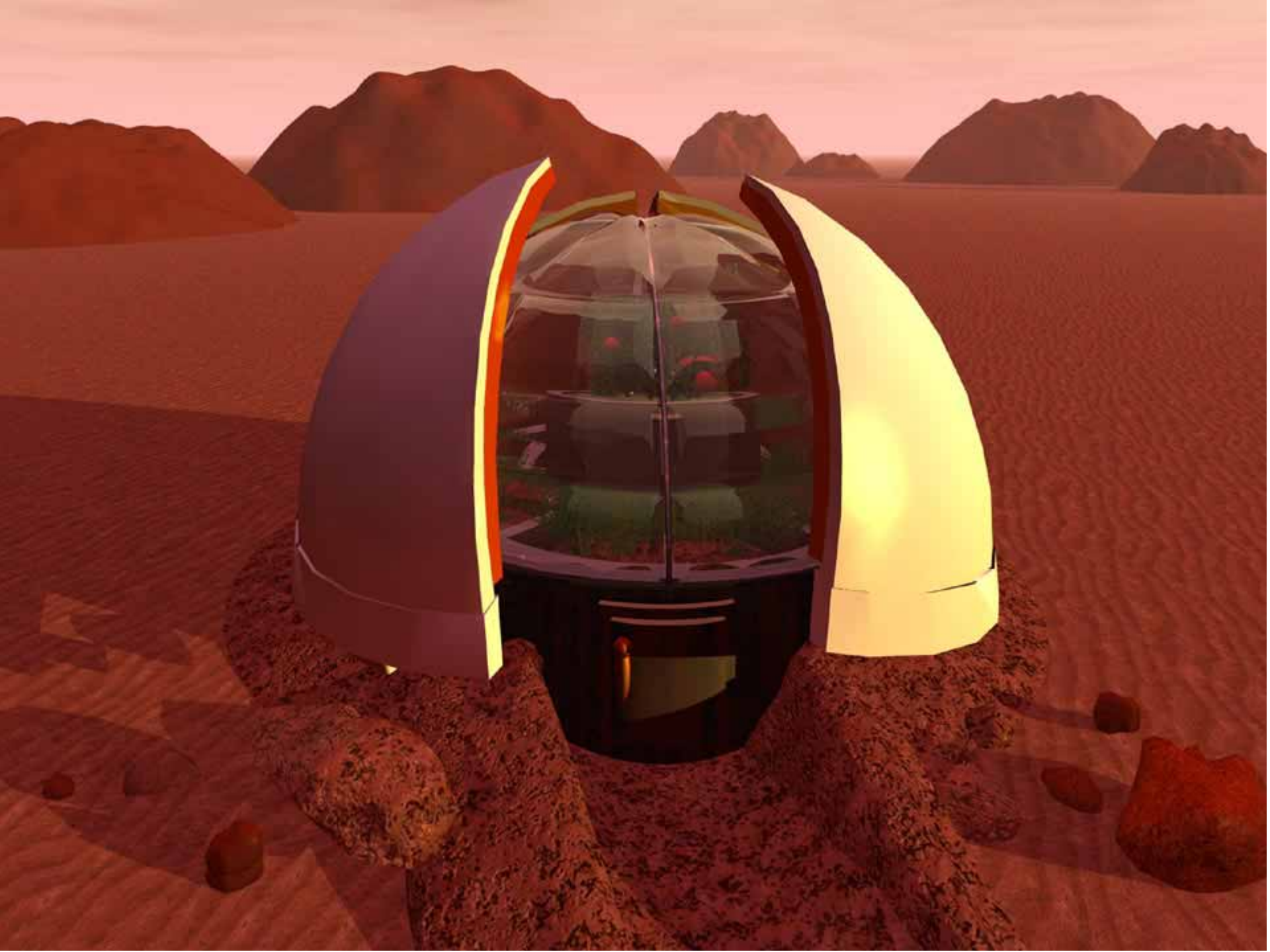


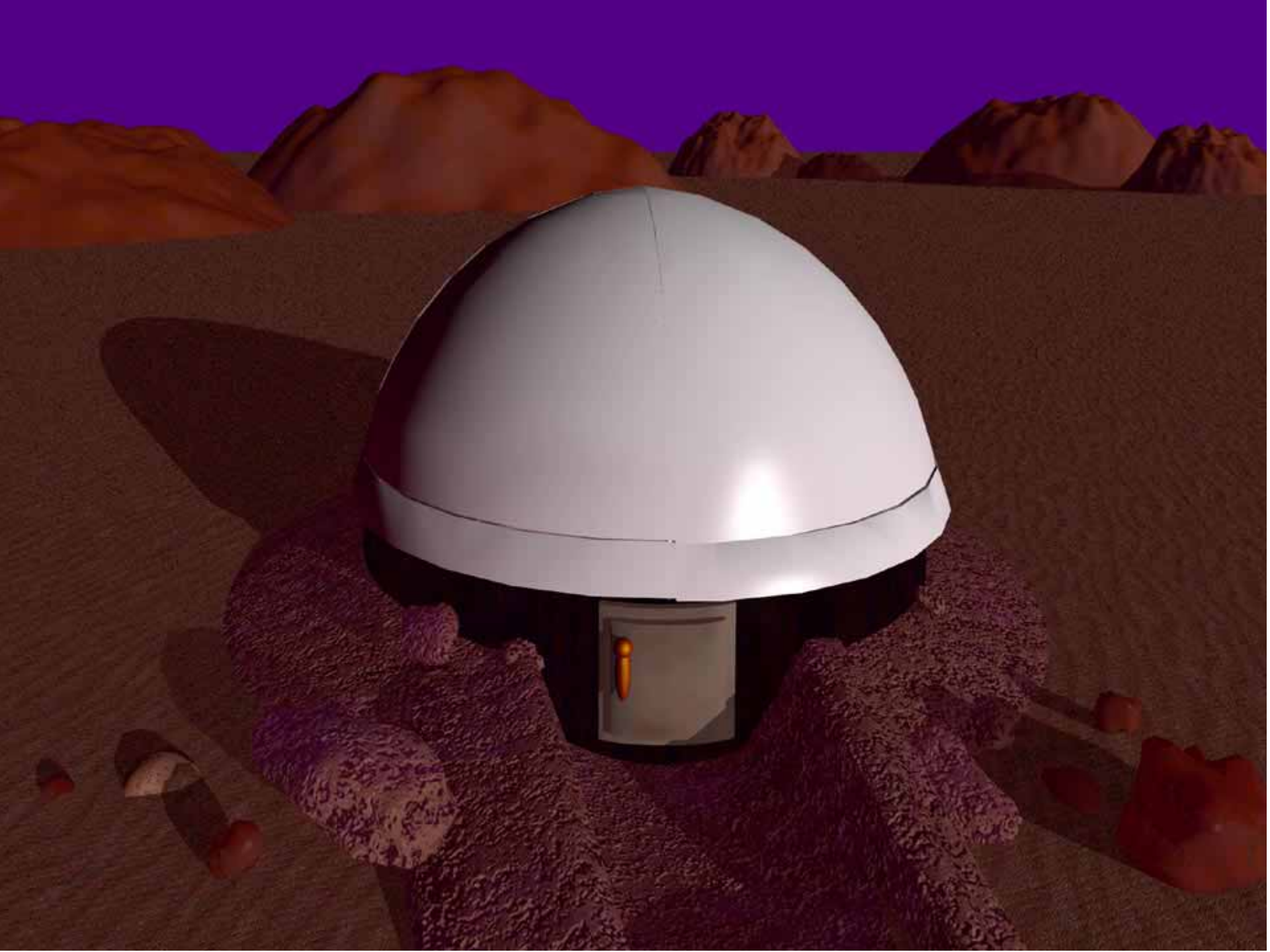












Targets for Plant-Related Life Support Applications

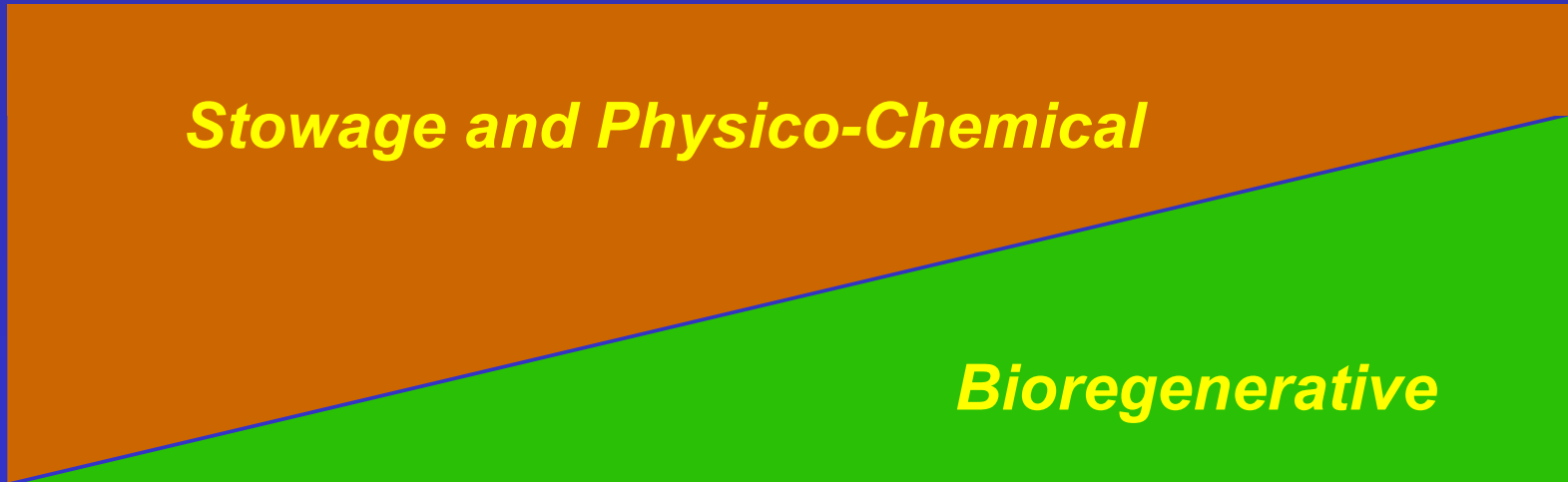
Mission	Plant Contribution	Comments
ISS	- Dietary Supplement	Salad Machine Electric Lighting
Transit Vehicles	- Dietary Supplement - Water Processing?	Salad Machine Electric or Direct Lighting ?
Planetary Surface (Near- Term)	- ~5-10% Food Prod. - Water Processing	Large Garden System Electric Lighting or Small Greenhouses
Planetary Surface (Mid-Term)	- ~50% Food Prod - ~100% O ₂ Production - Water Processing	Intermediate Greenhouse Suplmt. Electric Lighting
Planetary Surface (Far-term)	- 90% Food Prod. - Plants for O ₂ - Water Processing	Large Greenhouse Suplmt. Electric Lighting Nuclear Power ?

Role of Bioregenerative Components for Future Missions

*Short Durations
(early missions)*

Longer Durations

*Autonomous
Colonies*



Plant Growing Area



~1-5 m² total

~10-25 m² / person

~50 m² / person



***Lettuce:
The Movie***

Web Site

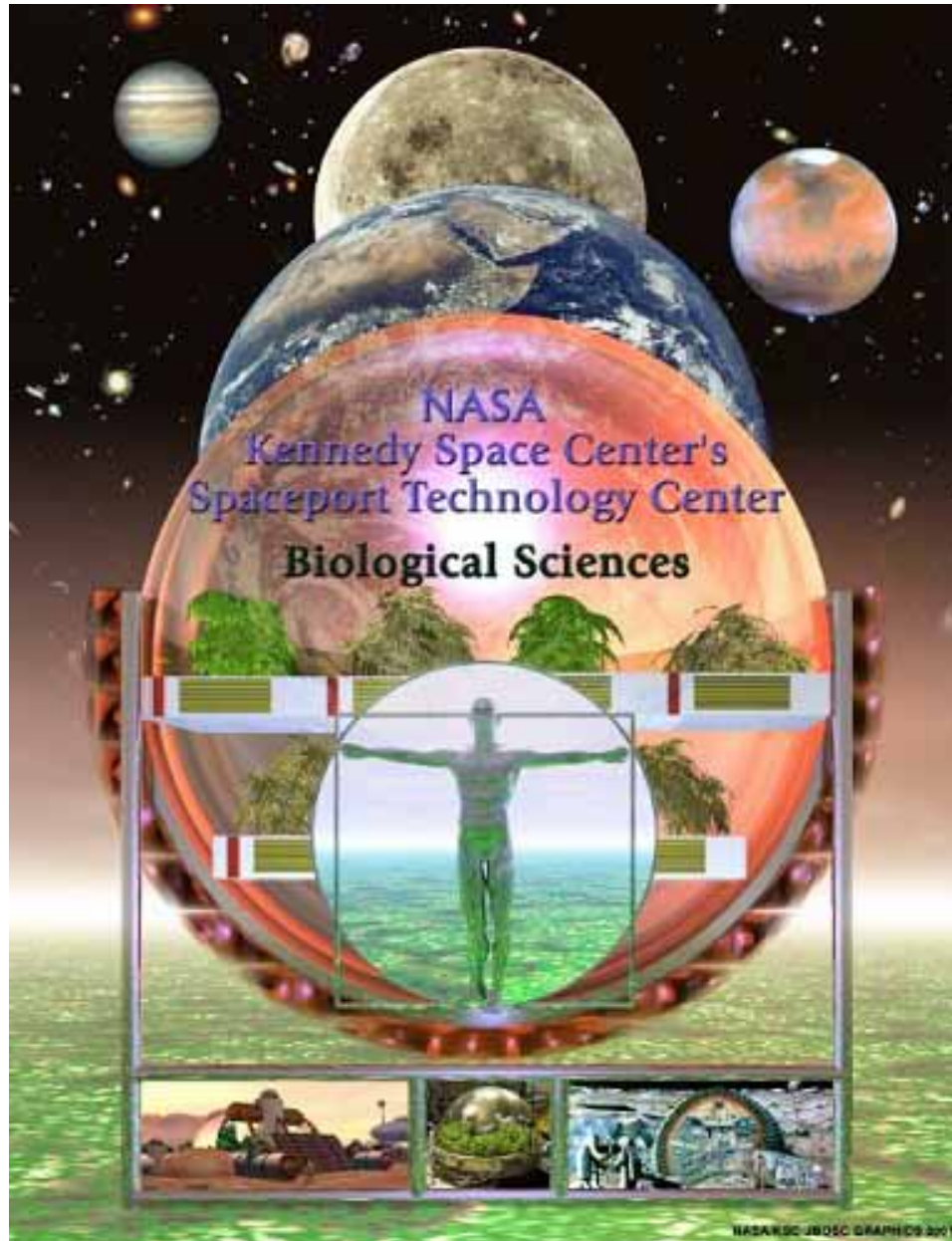
<http://science.ksc.nasa.gov/biomed/marsdome>

Space Life Science Lab



CONCLUSIONS

- Low Pressure Greenhouse systems will reduce overall system mass.
- The level of pressure has not been determined.
- The question of the internal pressure is critical for design of the components of the greenhouse.
- Environmental control system must be designed with the needs of the plant in mind.
- There is much more work to do.



Contributors

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