

AGROSPACE. TERRITORY AND RESEARCH

2nd international workshop

Sperlonga 25-26 maggio 2006

Design and development of a martian inflatable greenhouse

 FEDERLAZIO


esa

Marzia Pirolli


AEROSKUR

AeroSekur



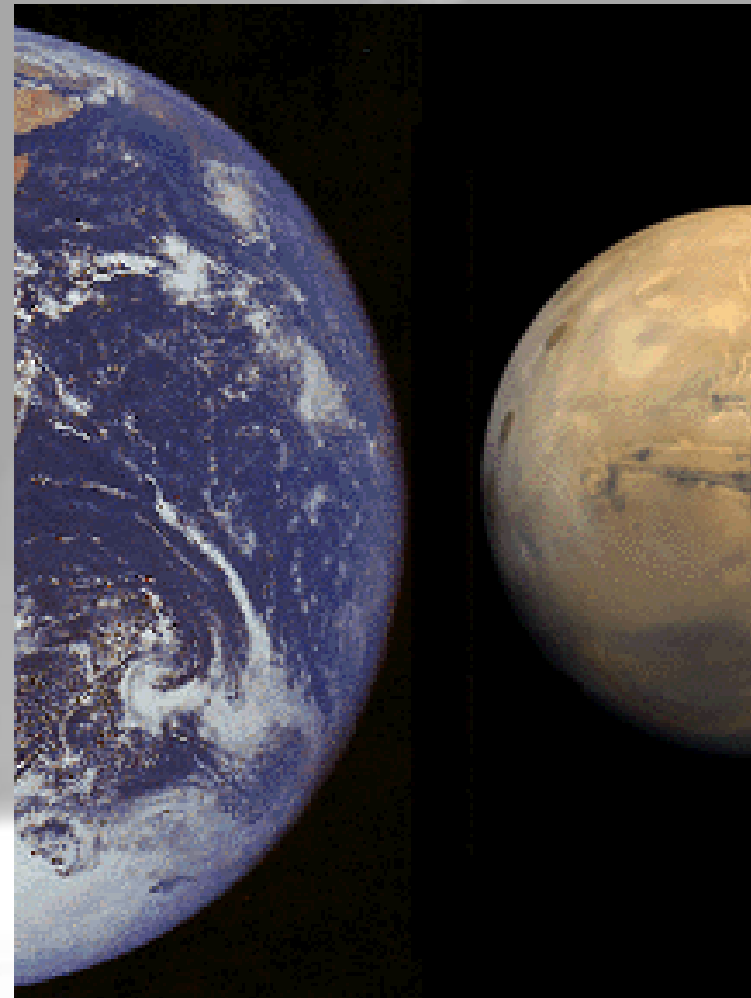
Aero Sekur mission is to provide **products** and **services** aimed to support **life** and **survival** of defence and security forces, as well as **operation** of air and battlefield vehicles, on the basis of **proven** and **best** mechanical, software, textile and advanced material technologies on a **National** and **International** perspective.




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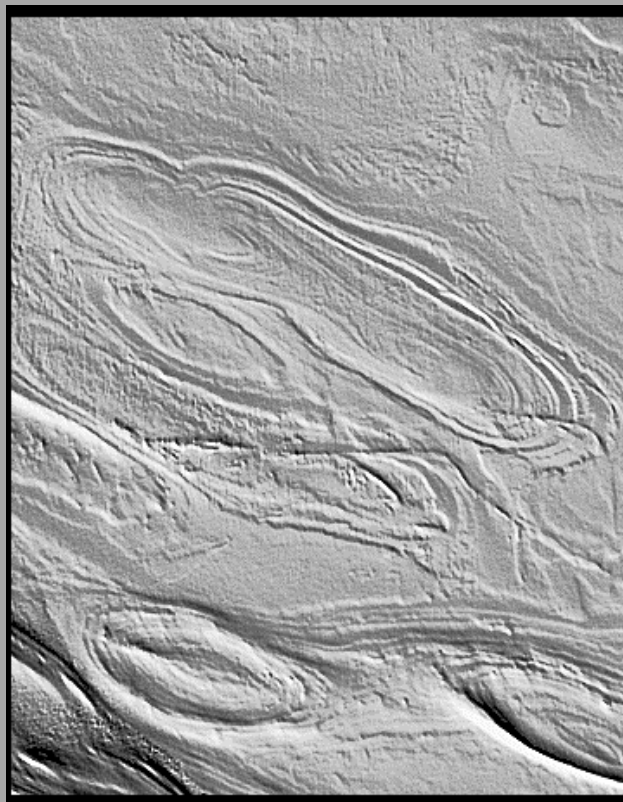
Earth and Mars: Differences...

	<i>Earth</i>	<i>Mars</i>
Mass (10^{24} kg)	5.97	0.642
Equatorial radius (km)	6378.1	3397
Mean Orbital distance (10^6 km)	149.60	227.92
Gravity (m/s^2)	9.78	3.72
Surface pressure (atm)	1.014	0.00636
Average surface temperature ($^{\circ}C$)	15	- 65
Length of day (hours)	24	24.65
Number of moons	1	2



...Analog

Landscapes



Valles Marineris



Quaidan Basin, Cina



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...Analog

Landscapes



Gusev Crater



Cerro Armazones, Chile



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...Analog



High mountains



Olympus Mons



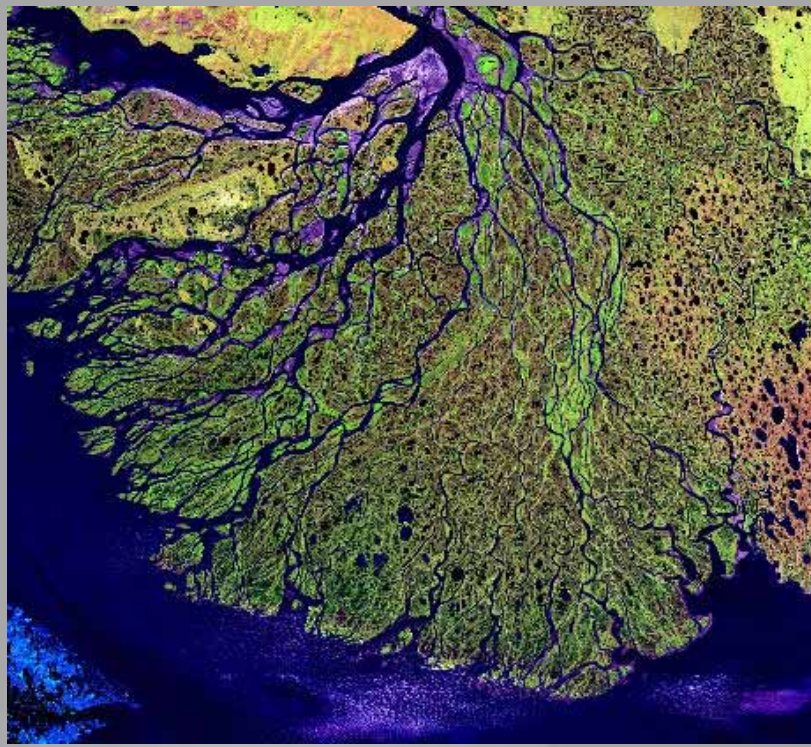
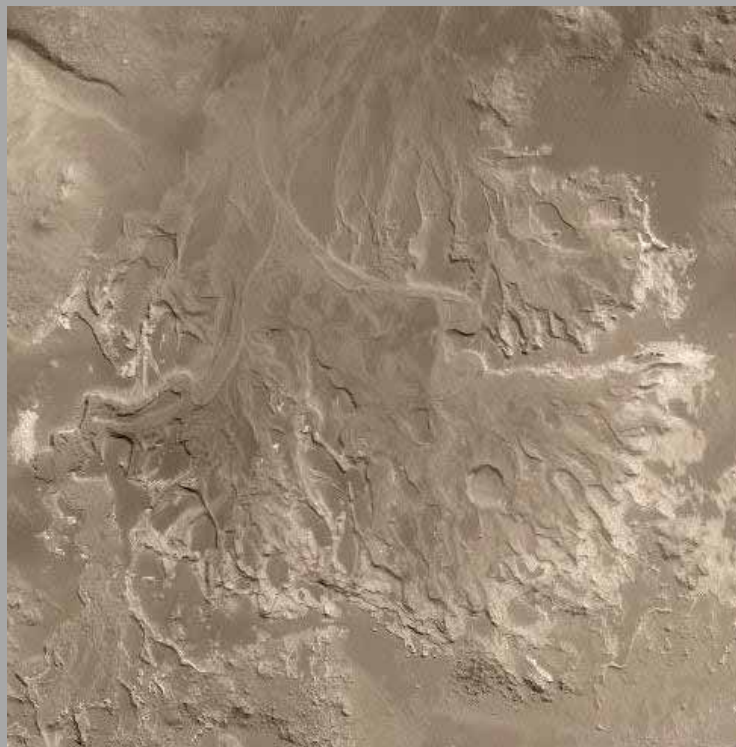
Kilimangiaro, Uganda



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...Analog

River's delta



Delta del Lena, Siberia



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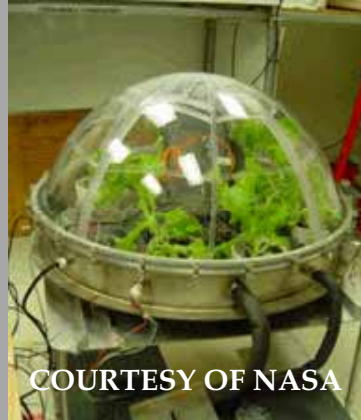
Mars Greenhouses: State of Art

Haughton Mars Project:

Field research project carried out near the Haughton impact crater on Canada's northern Devon Island.

Conducted jointly by SETI and Mars Institute, project goals are:

- develop and test new technologies and field operating procedures utilize in Mars-like environment
- study plants behavior in extreme landscapes.



Mars Greenhouse Project:

Low pressure greenhouse demonstrator developed at University of Florida.

Arizona University, Sadler Machine Co. and AeroSekur extreme environments greenhouse project:

Demonstrator of an inflatable greenhouse for extreme Mars-like landscapes.



Hydroponic culture

Soil less cultivation method, using a nutritive solution.

Seeds germinates in a perlite or rock wool substrate



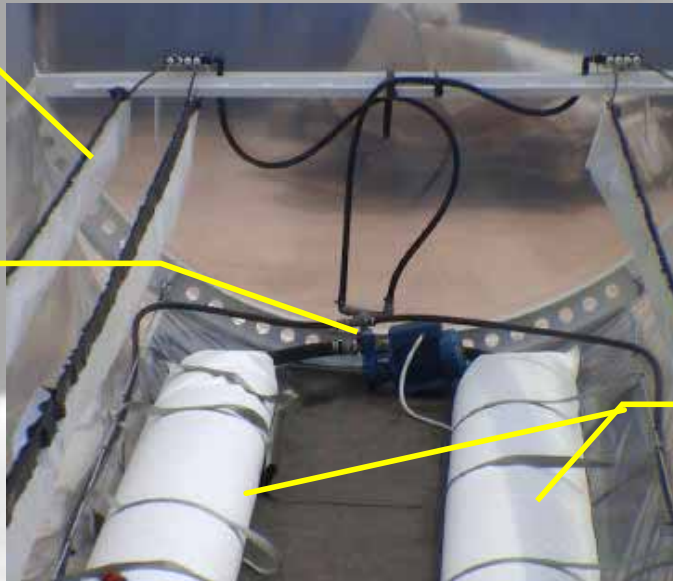
Plant roots are inserted in appropriate pots with constant slope to 1-1.5%, covered to avoid the exposure to sunlight.



Nutritive solution flow continuously feeding roots.

POT

Pump



Tanks for nutritive solution



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Plants for Mars

Possible environmental conditions:



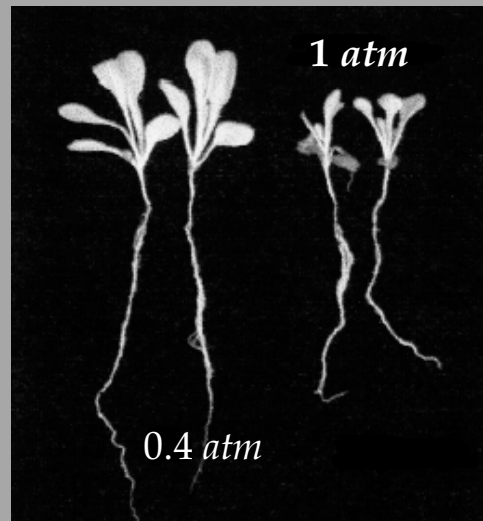
High pressure ($\sim 1 atm$)

Similar to Earth

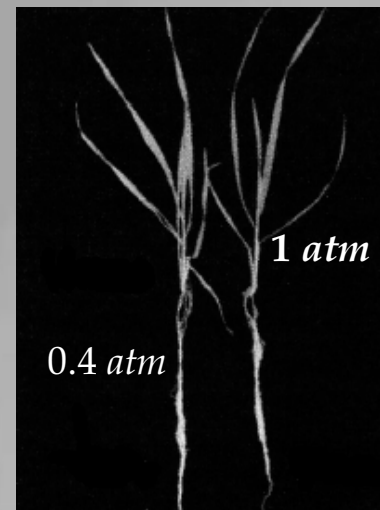
Low pressure ($\sim 0.4 atm$)

Optimal growth rate

LETTUCE



WHEAT



Tests carried out at laboratories of Horticultural Sciences and Biological & Agricultural Engineering Department of Texas university, demonstrate that plants grow better in low pressure atmosphere.

The Italian colours of Space exploration



Light and pressure

-Solar radiation on Earth:
1.36 kW/m².

-Solar radiation on Mars:

- 0.61 kW/m² outside the atmosphere

- 0.37 kW/m² on the surface (in absence of dust).

- Minimum solar radiation to correct vegetative growth:
0.3 kW/m².



In case of dust storm plants can suffer from lack of sunlight.



To avoid this problem an additional artificial lighting system is necessary.

Mars atmospheric pressure is 0.007 atm

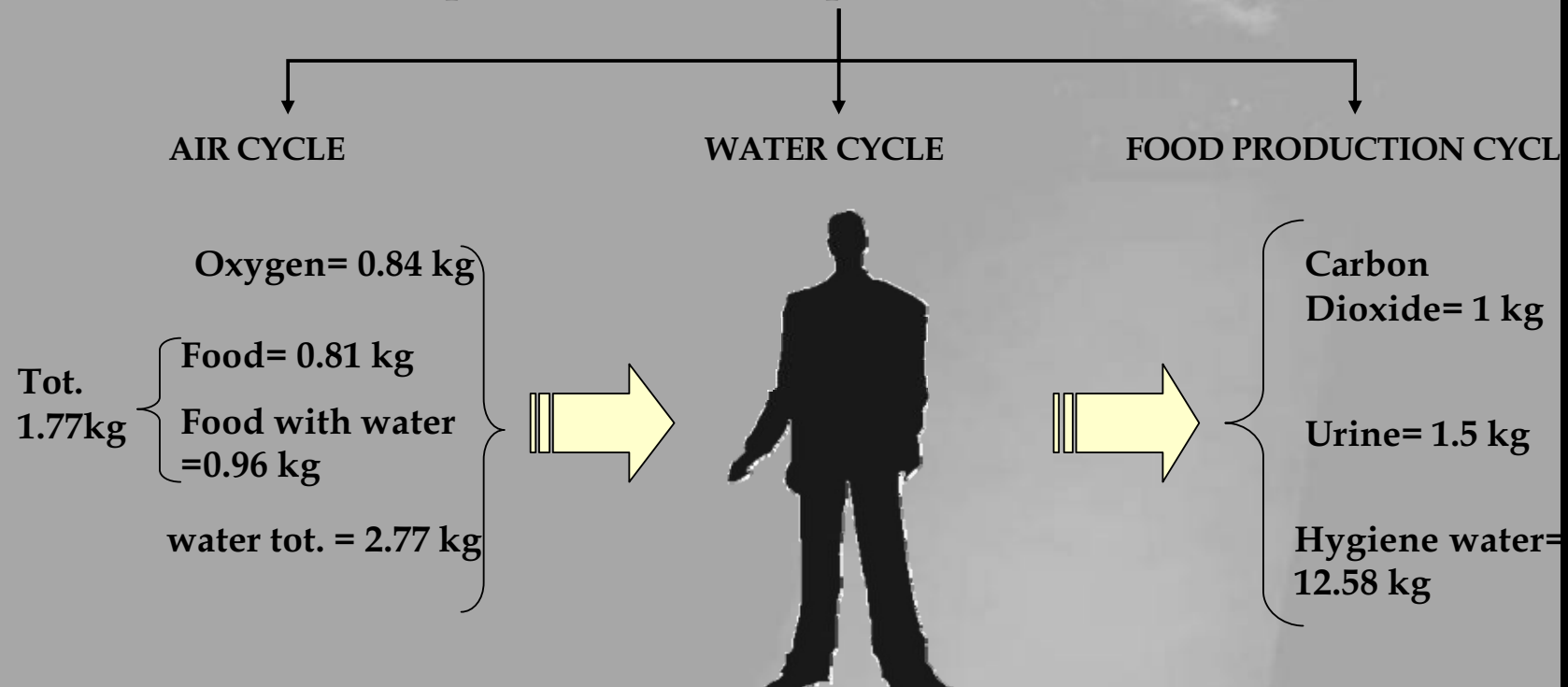


In order to reduce the load on the structure it's possible to consider an internal pressure equal to 0.4 atm.



The life support system

Bio-Regenerative life support system closes the three fundamental cycles for continuous human permanence in the space.



Amount of edible plant mass produced (E)

$$= 0.77 \times \text{PAR} \times t - 6.1 = 67 \text{ g}/(\text{m}^2\text{day})$$

Photo-synthetically Active Radiation

transmittance

t= 0.60 for greenhouses

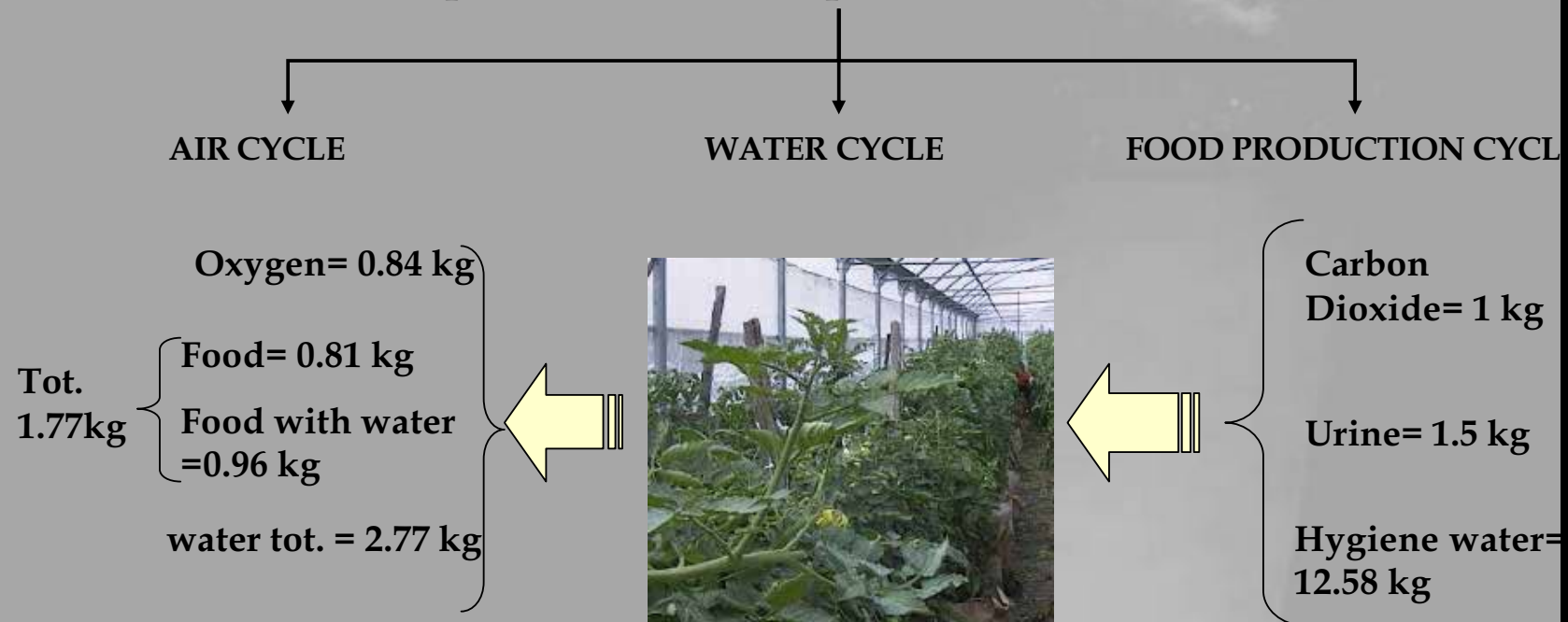
t=1 with artificial light



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Photo-synthetically Active Radiation

transmittance

t= 0.60 for greenhouses

t=1 with artificial light

The shape

Total food = 1.77 kg per day per person ? 0.97 kg (55%) = food produced in greenhouse

$$0.97 \text{ (kg)} \times 6 \text{ (persons)} \times 686.5 \text{ (m.y.)} = 3995.4 \text{ kg/m.y.}$$

Total growth area = $3995.4 / E \sim 86 \text{ m}^2$

Baseline: 90 m² divided in 3 greenhouses (redundant design)

In case of plant disease into one greenhouse two additional ones work..

In case of one greenhouse's damage two additional ones work.

Trade-offs: Scoring Method

Shape	Pressure distribution	Packing	Income and pre-room	Problem of sand
Sphere	5	4	1	5
Cylinder	4	5	4	5
Parallelepiped	2	3	5	2

1=worst >>> 5= best

The shape

Optimal shape is cylindrical. The shape is given by two hatches placed to the far ends.



AEROSOL

The shape

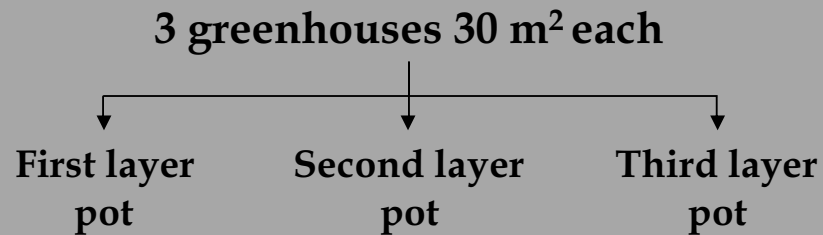
Optimal shape is cylindrical. The shape is given by two hatches placed to the far ends.



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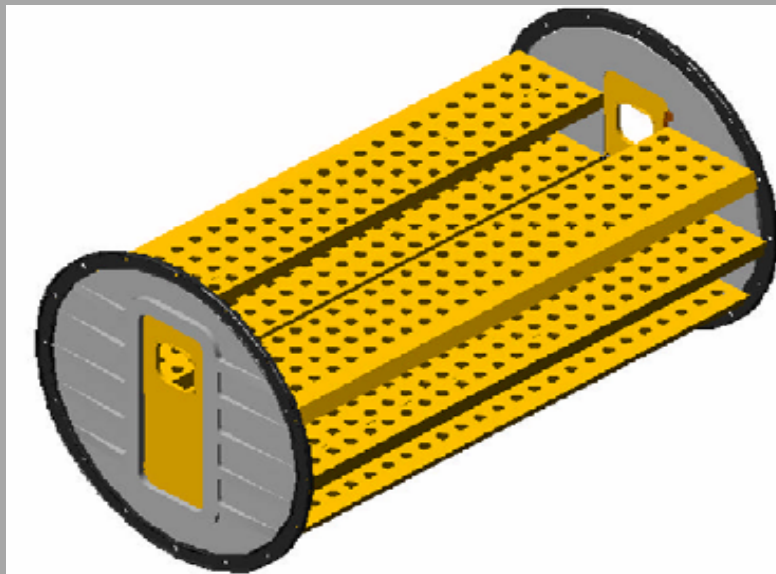
Structural design: Layout and overall dimension

6 persons \longrightarrow 90 m² growth area



6 greenhouses 15 m² each

Single layer



This layout is suitable for small plants like lettuce being the gap between two layer ~ 50 cm.



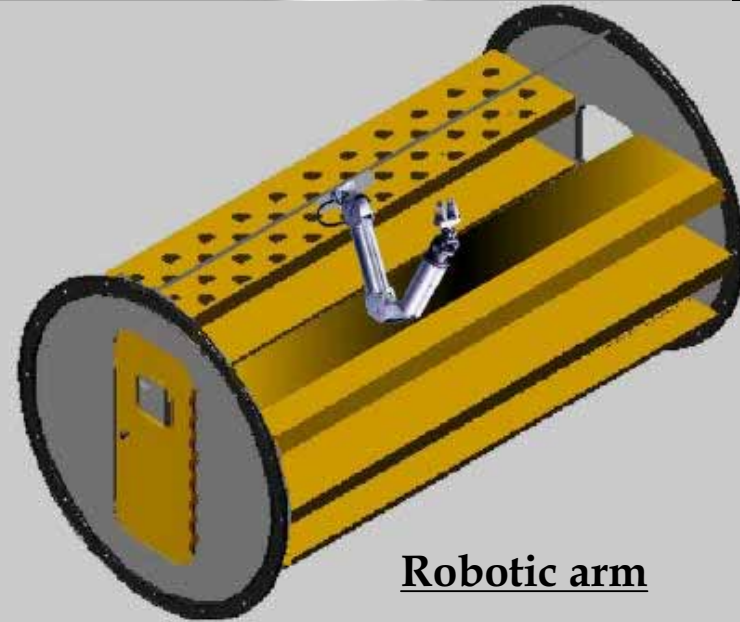
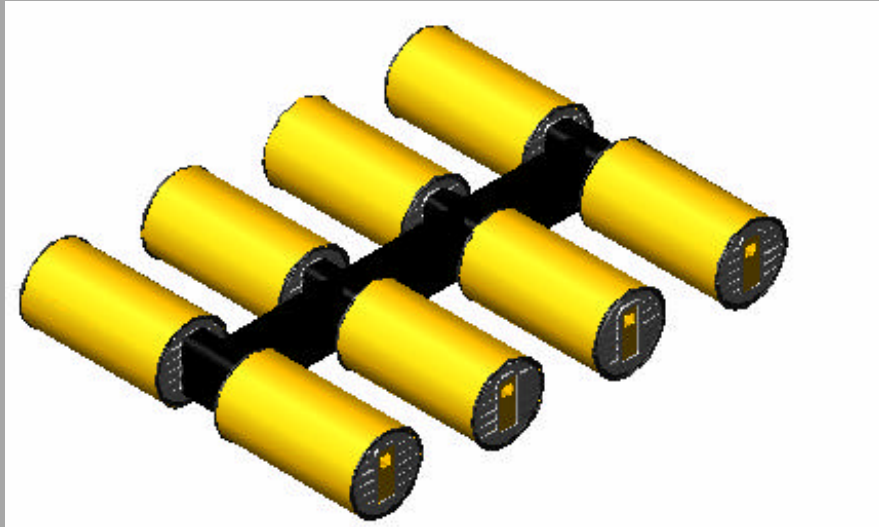
This layout is suitable for tall plants as tomatoes, wheat and cucumbers.



AEROSUR

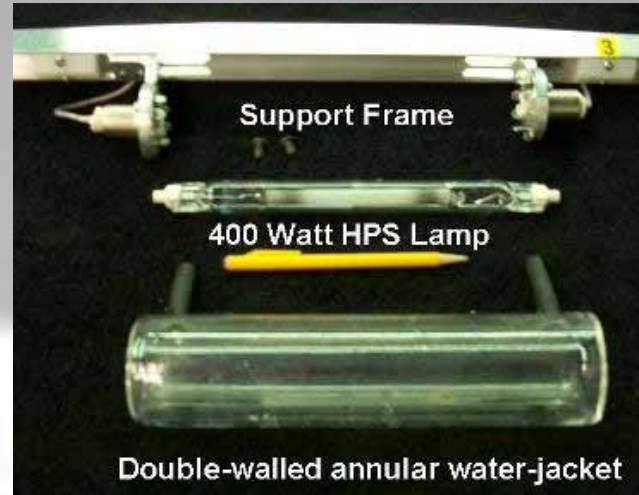
Optionals:

Corridor link between greenhouse modules



Robotic arm

Sadler
water-jacketed
lamps



COURTESY OF SADLER MACHINE CO.

Materials

Pressure's load on the structure:

$$p = p_{\text{int}} - p_{\text{ext}} = 0.4 - 0.007 = 0.393 \text{ atm} \quad \longrightarrow \quad p = 0.4 \text{ atm} = 4133 \text{ kg/m}^2$$

Opaque structure



Structural layer: Vectran®

Thermal insulation layer: Aerogel®

Airtight layer: Kapton®

Internal barrier layer: Aluminum-coated Zylon®



With an additional foam layer this structure can be use for lunar application too (buried layout).

Transparent structure
(Earth prototype)



Only one layer: F-Clean®

It's a fluorine based polymer made in Japan by Asahi Glass.

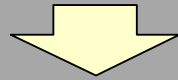


AEROSPACE

Opaque structure: tests on materials

Vectran®:

Tear strength test



Standard : UNI 4818-92.

400 N: Applied force in order to tear the sample.

Tensile test



Standard : Grab method UNI 5419-64.

1400 N: Applied force in order to damage the sample.



AEROSOL

Opaque structure: tests on materials

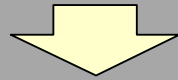


AEROSOL

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Kapton®:

Permeability test



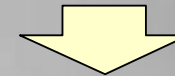
Oxygen permeability value

Kapton: 9.9 cc-mm/m²-24h-atm

HDPE : 41-59 cc-mm/m²-24h-atm

Nylon : 4-25 cc-mm/m²-24h-atm

Tensile elongation test

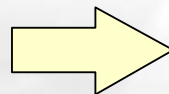


Normal stress applied: 230 MPa.

Elongation: 70%

Zylon®:

Tear strength test



1600 N: Applied force in order to tear the sample.

Numerical simulation

Numerical simulation with LS-DYNA to verify vectran's behavior:

Bases : Rigid material

Caps : elastic material  Carbon fiber

Structural layer : Vectran®

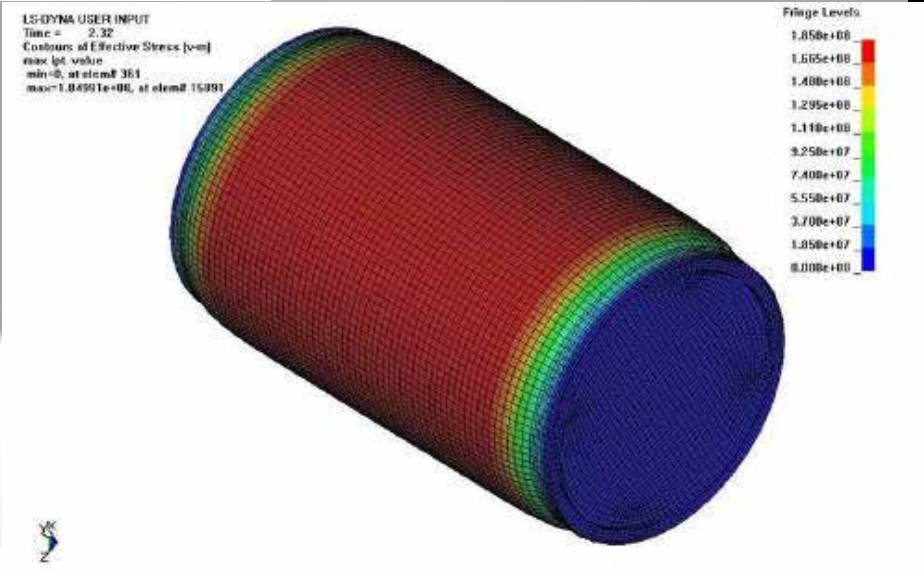
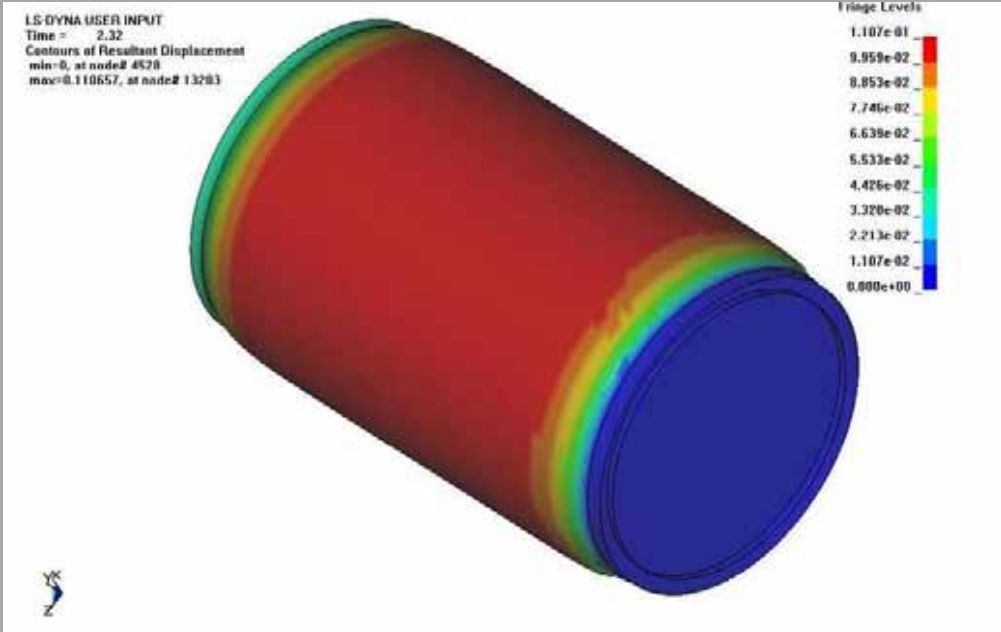
Mapped Mesh with quad elements

CONSTRAINTS: Fixed base

Note: Control volume technique has been used to simulate structure's inflation.



Numerical simulation



Numerical simulation

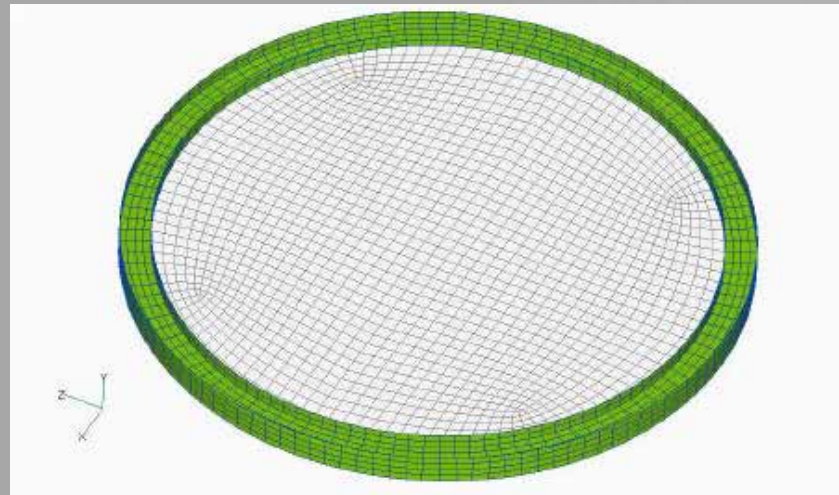
Numerical simulation with MSC.NASTRAN to verify caps' behavior:

The material is a sandwich:

Core = Nomex®'s honeycomb (5 cm thickness)

Skins = Carbon fabric (0.2 mm thickness)

Mapped Mesh with quad elements



RESULTS

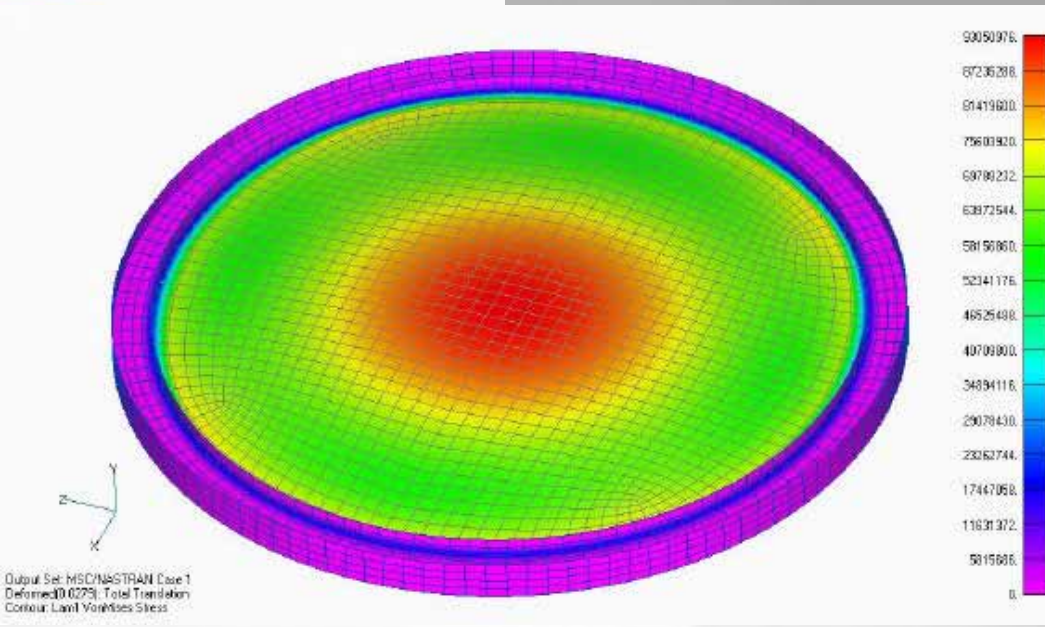
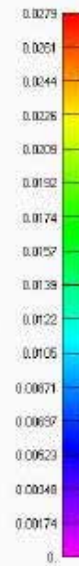
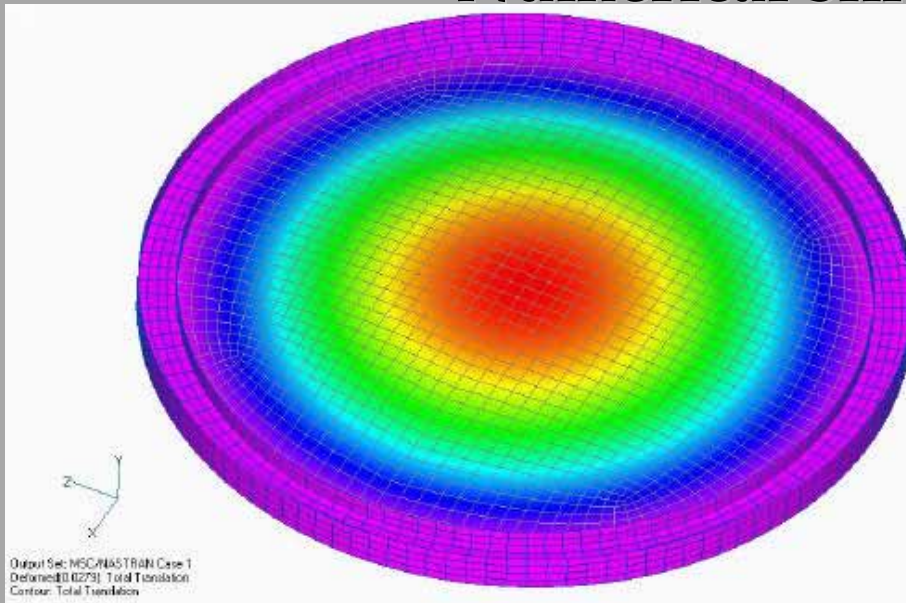
Max. displacement = 2.79 cm

Max. stress = 93 MPa



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Numerical simulation



Light

Concentration solar panel are able to supply power up to 0.3 kW per each module
 $300 \text{ W/m}^2 = 30000 \text{ lumen/m}^2$ necessary for a correct vegetative growth.

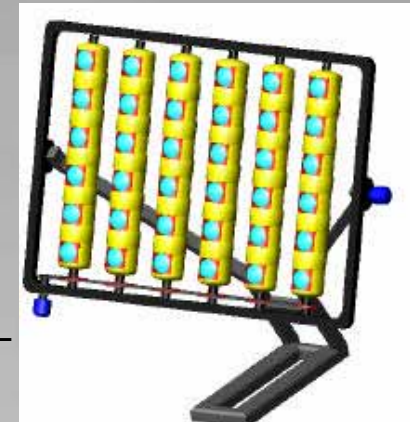
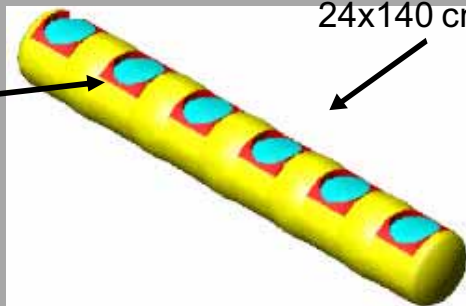
25 plants per m^2

With optic fibers it's possible to put one light on each plant

Lamp intensity is: $I = \frac{300}{25} = 12W$

CELL 22X22 cm

MODULE 6 CELLS
24x140 cm



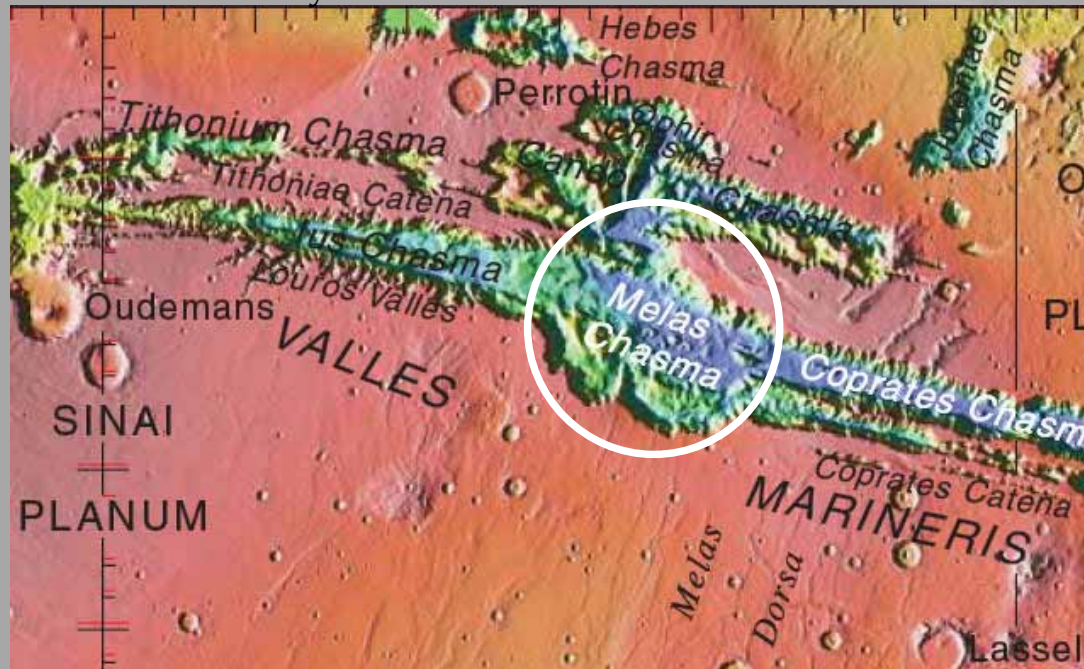
PANEL



Where on Mars?

Candidate Site: Melas Chasma

It's a valley into Valles Marineris area.



WHY?

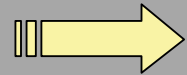
- Its surface contains approximately 70% of young material, maybe volcanic as
- There are alluviums or residual materials as a result of glaciers melting.
- There are rocks of volcanic origin eroded from atmospheric agents.
- Maybe in the past here there was a lake or a river.



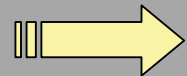
OUR GREENHOUSE:



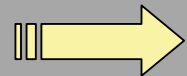
FUTURE DEVELOPMENTS:



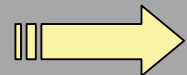
Design of a suitable transport module



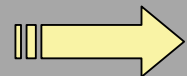
Detailed analysis of a modular-greenhouse system



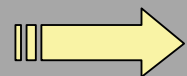
Detailed Thermal analysis



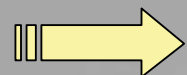
Design of a controlled environment conditioning system



Development of suitable sensors to monitor GreenHouse environment



Design of suitable robotic systems for monitoring and harvesting



Optimization of solar panels with an inflatable design

The End

