# The Importance of Lighting for Plants

*--Electric Lamp Options*

| *Lamp Type* | *Conversion* Efficiency* | *Lamp Life* (hrs)* | *Spectrum* |
|---|---|---|---|
| • Incandescent/Tungsten** | 5-10% | 2000 | Intermd. |
| • Xenon | 5-10% | 2000 | Broad |
| • Fluorescent*** | 20% | 5,000-20,000 | Broad |
| • Metal Halide | 25% | 20,000 | Broad |
| • High Pressure Sodium | 30% | 25,000 | Intermd. |
| • Low Pressure Sodium | 35% | 25,000 | Narrow |
| • Microwave Sulfur | 35-40%+ | ? | Broad |
| • LEDs (red and blue)**** | >40% | 100,000 ? | Narrow |

* *Approximate values.*

** *Tungsten halogen lamps have broader spectrum.*

*** *For VHO lamps; lower power lamps with electronic ballasts last up to ~20,000 hrs.*

**** *State-of-Art Blue and Red LEDs most efficient.*

# Direct Solar Radiation Options

## *Earth Radiation:*

| | |
|---|---|
| *- incident** | *~1350 W $m^{-2}$ total*<br>*~ 600 W $m^{-2}$ PAR* |
| *- daily PAR* | *~15 MJ $m^{-2}$ $d^{-1}$ (~60 mol $m^{-2}$ $d^{-1}$)* |

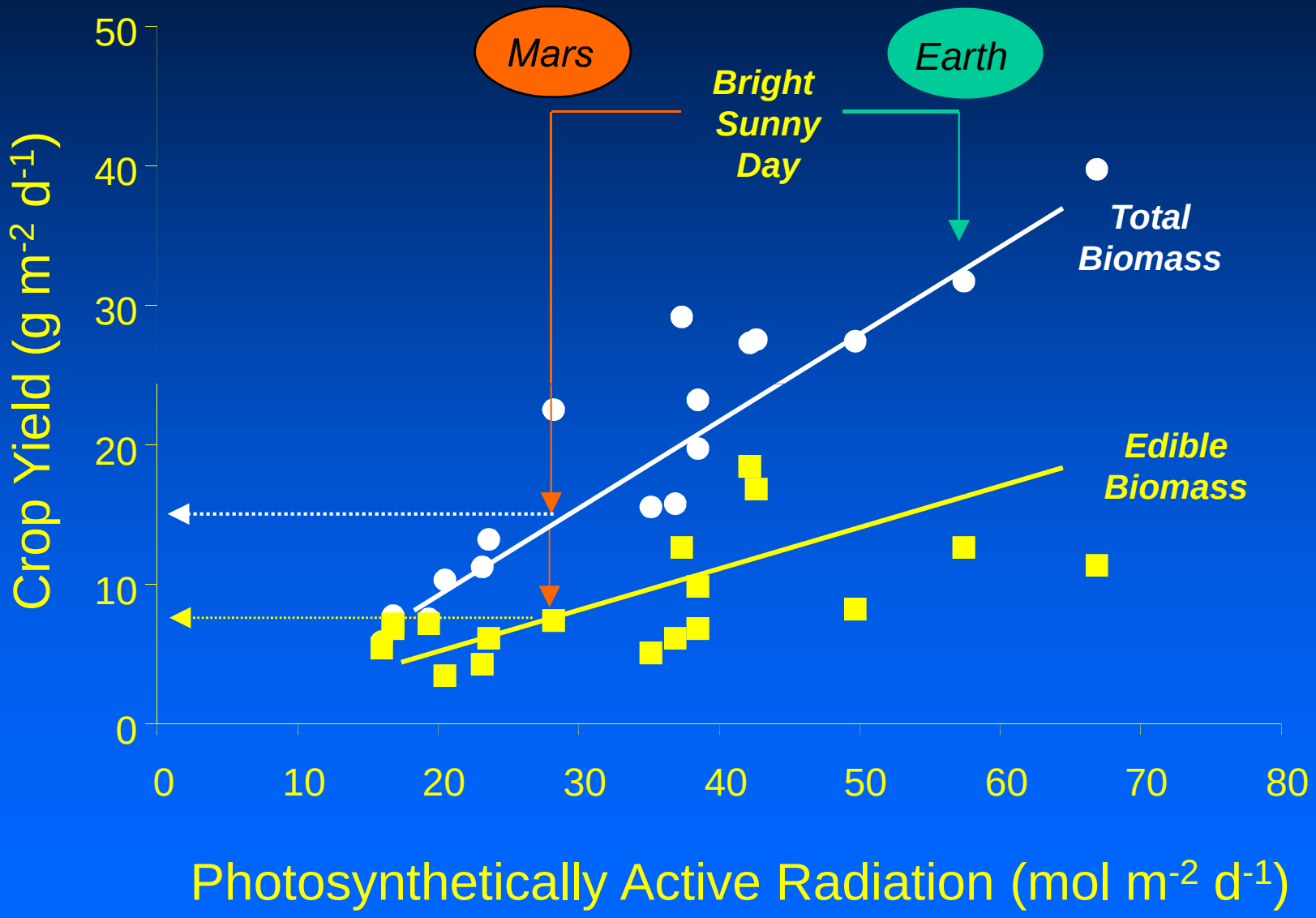
## *Mars Radiation (~44% of Earth's):*

| | |
|---|---|
| *- incident** | *~ 600 W $m^{-2}$ total*<br>*~ 260 W $m^{-2}$ PAR* |
| *- daily PAR*** | *~ 7 MJ $m^{-2}$ $d^{-1}$ (~26 mol $m^{-2}$ $d^{-1}$)* |

* *At outer edge of atmosphere*

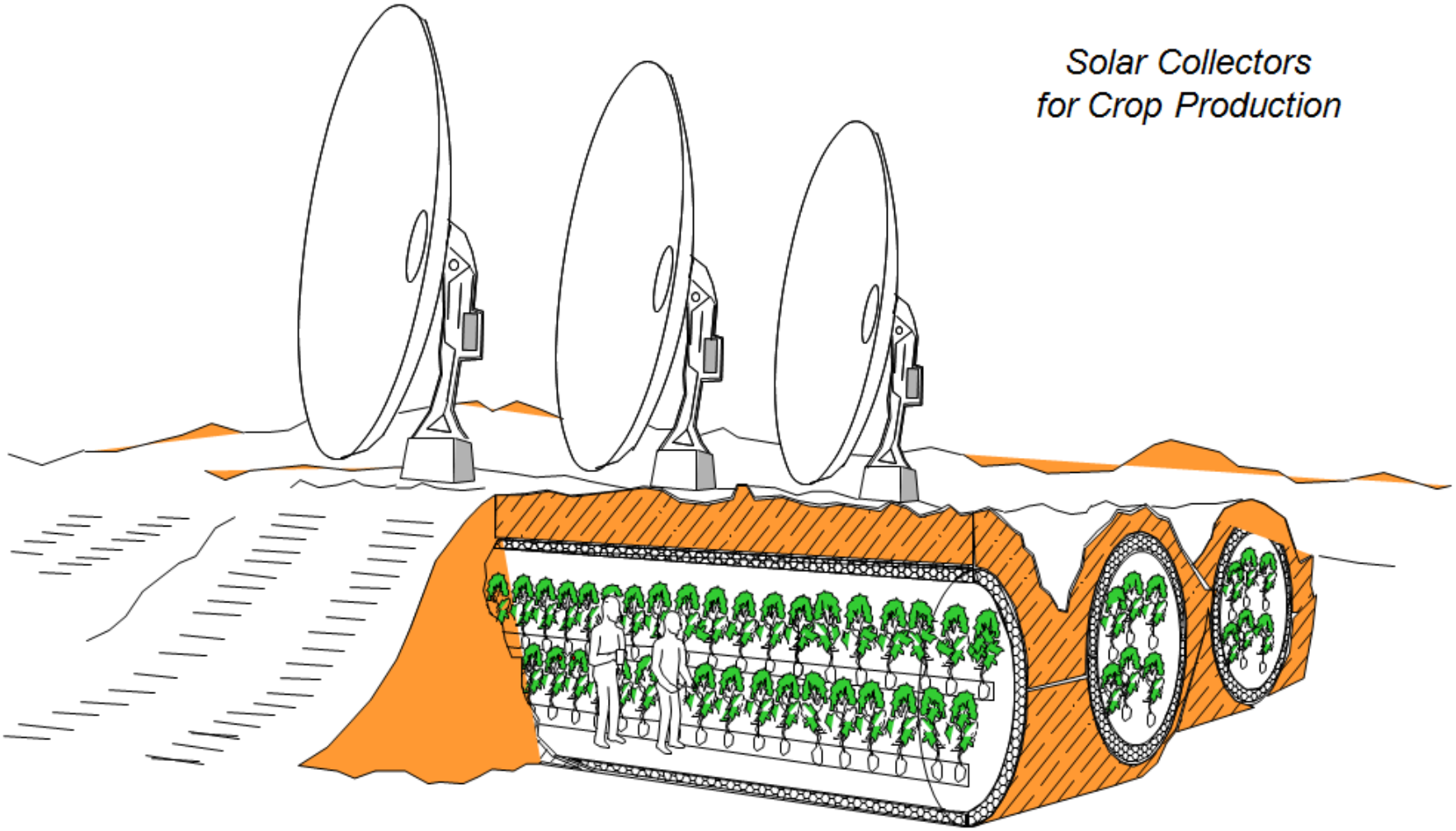
** *Surface irradiance estimated from Landis (1996); values dependent on latitude, time of year, and weather*

# Crop Yield vs. Light

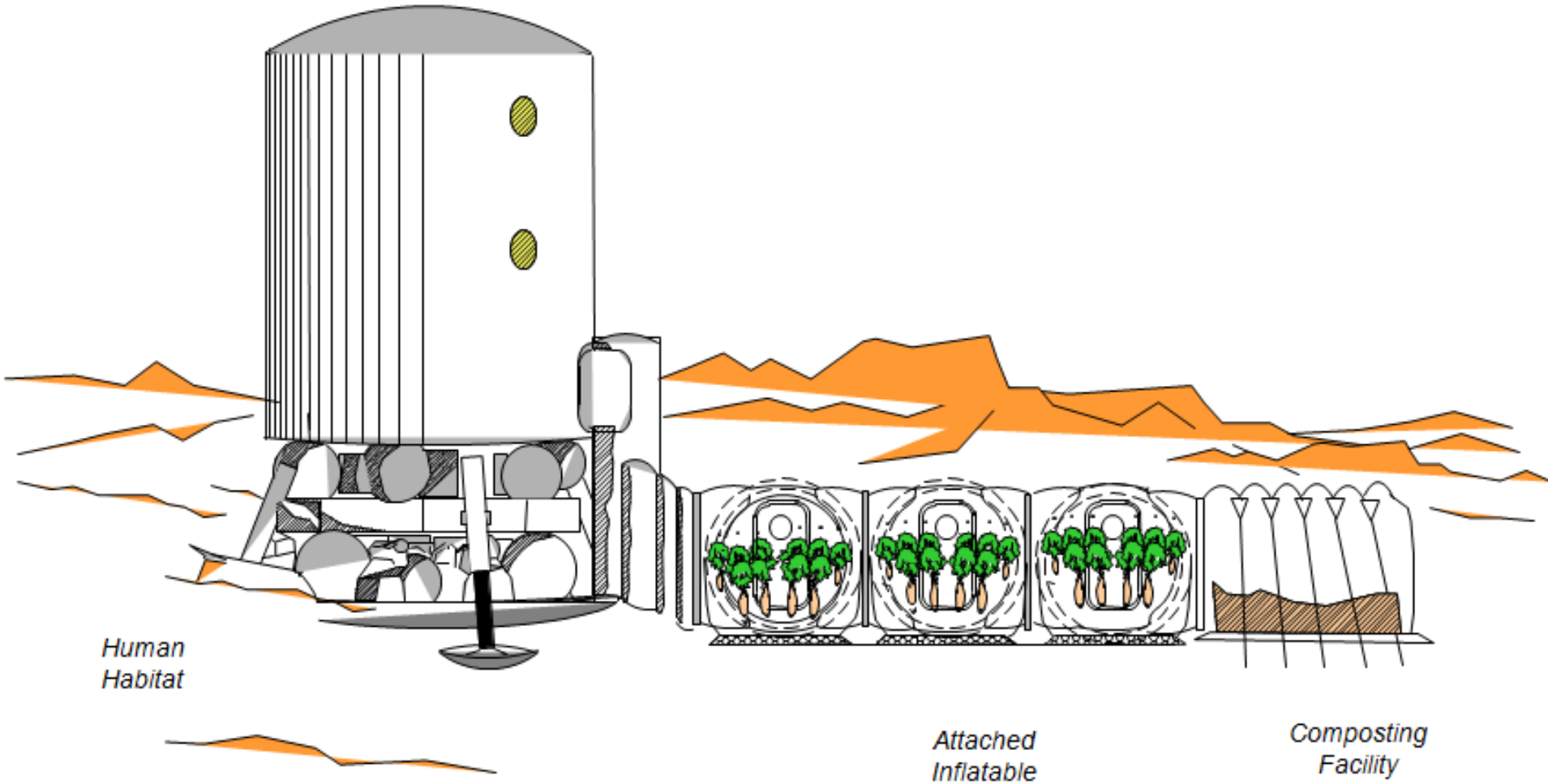


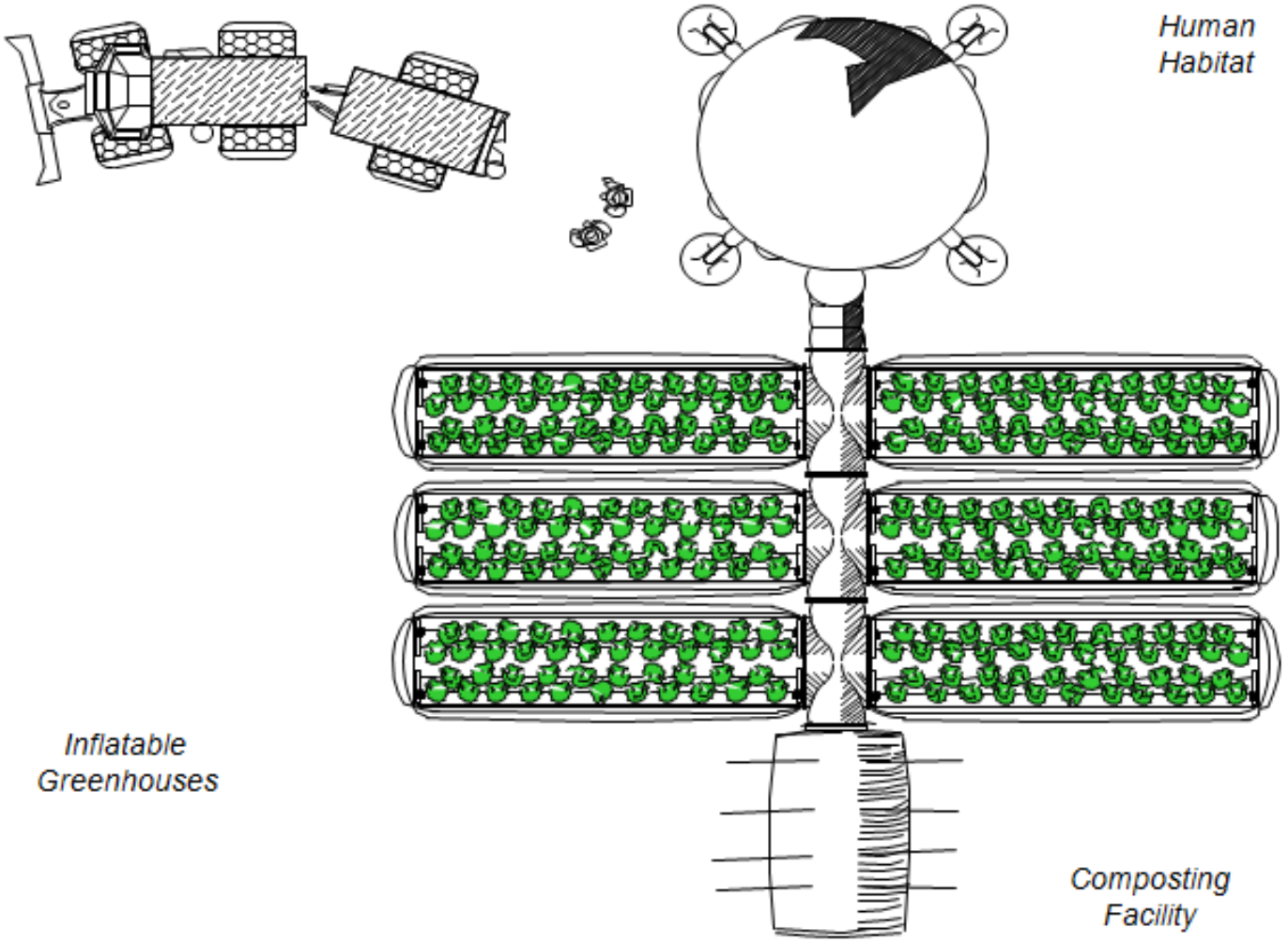
# Can “Greenhouses” be Used on Mars ?

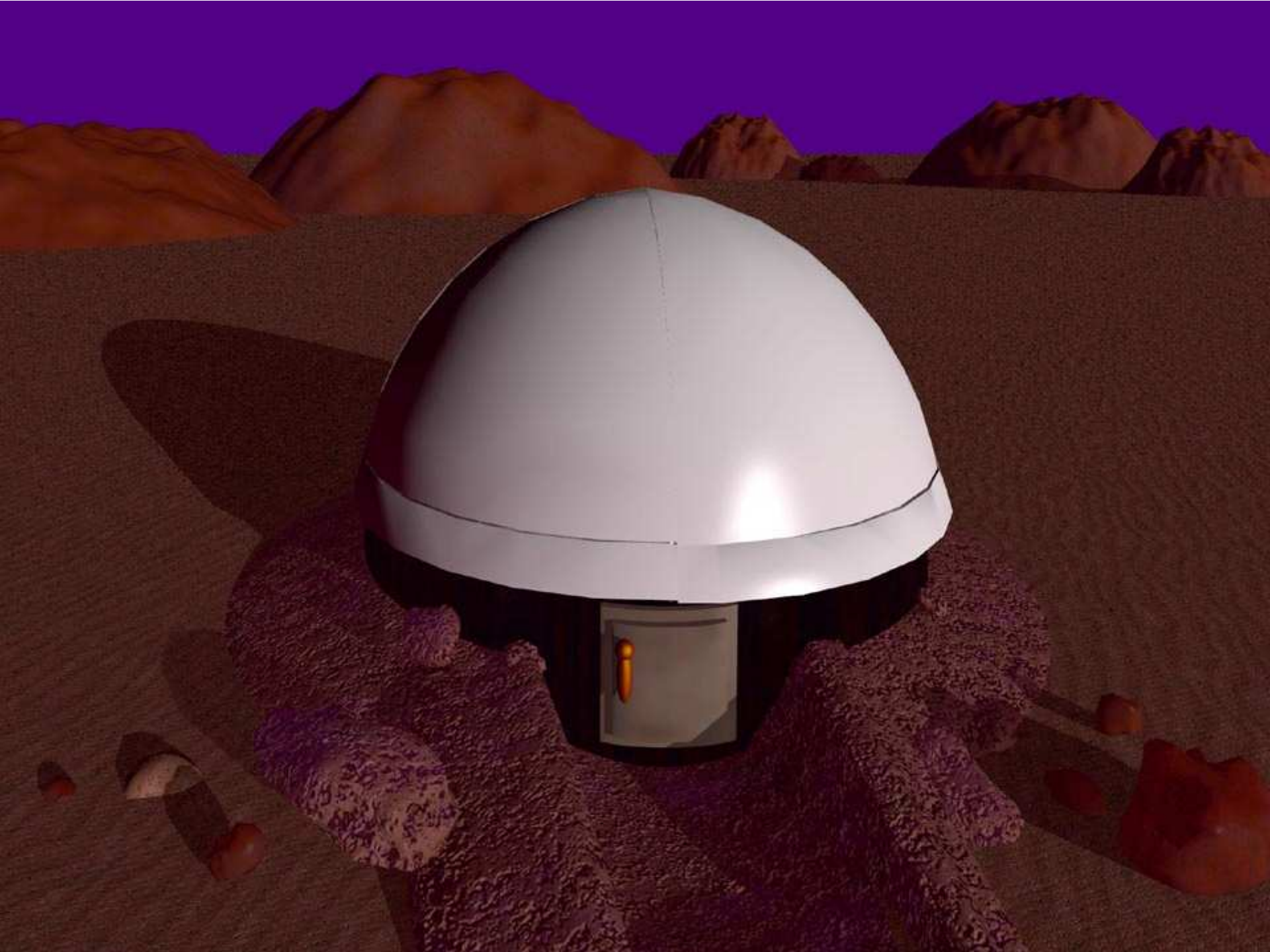
- Optimized Light Collection
  - Greenhouse Structural Design
  - Ancillary Collectors / Reflectors ?
- Thermal Management Challenges
- Materials Challenges:
  - Inflatable Systems (for reduced mass)
  - Resistance to Leakage
  - Resistance to UV
  - Temperature Tolerance

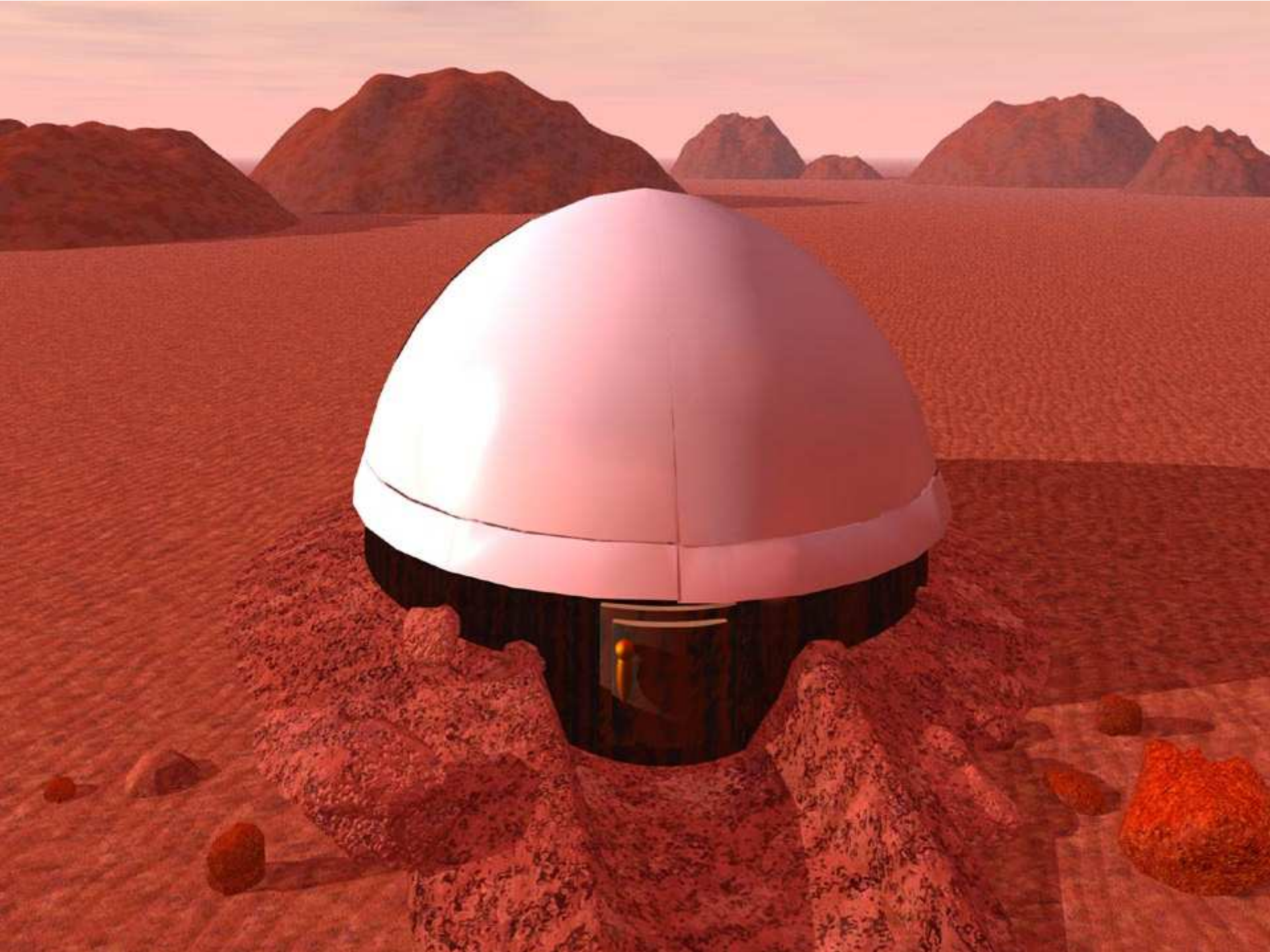


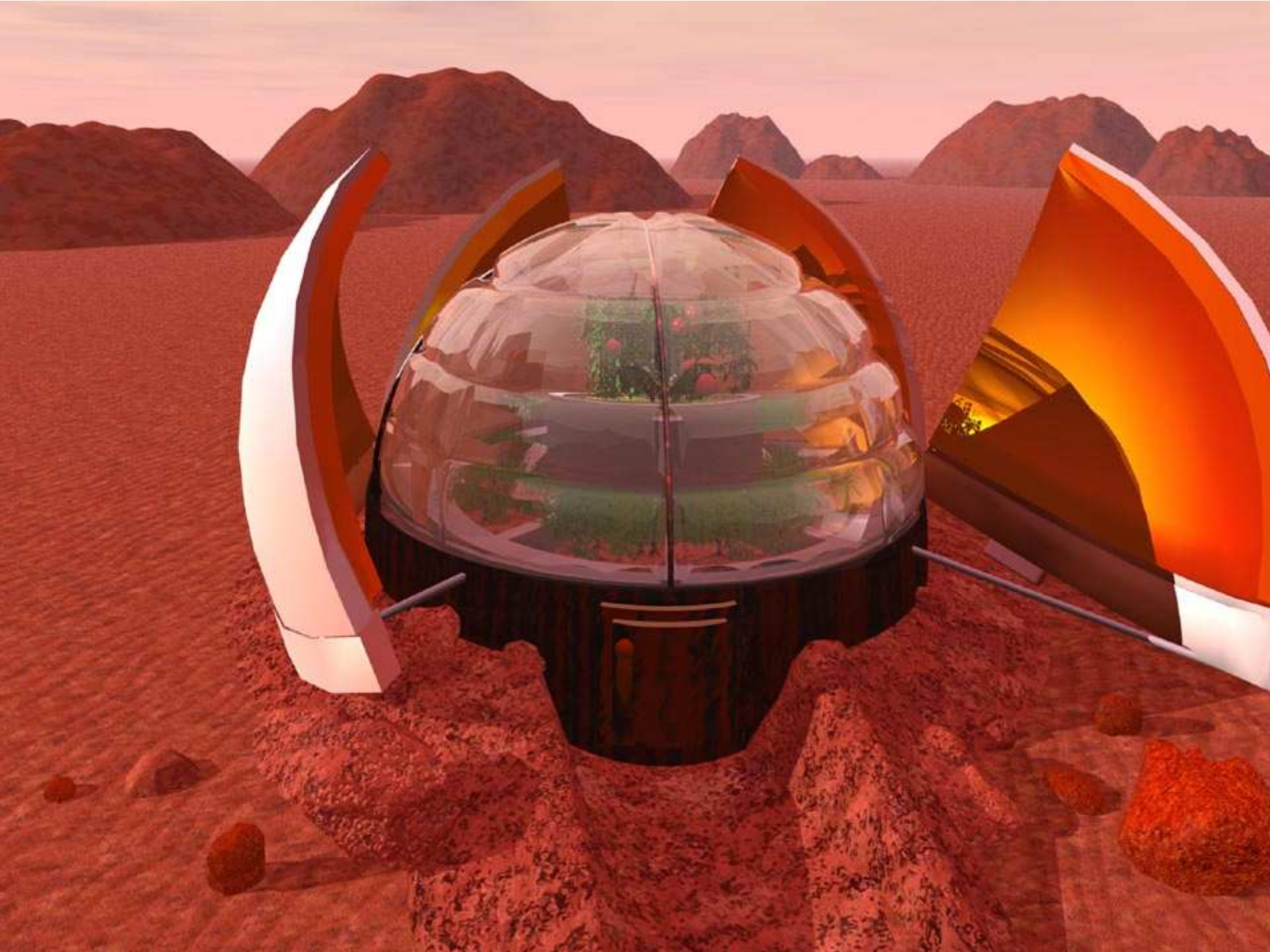
# *Inflatable Greenhouses for Crop Production*

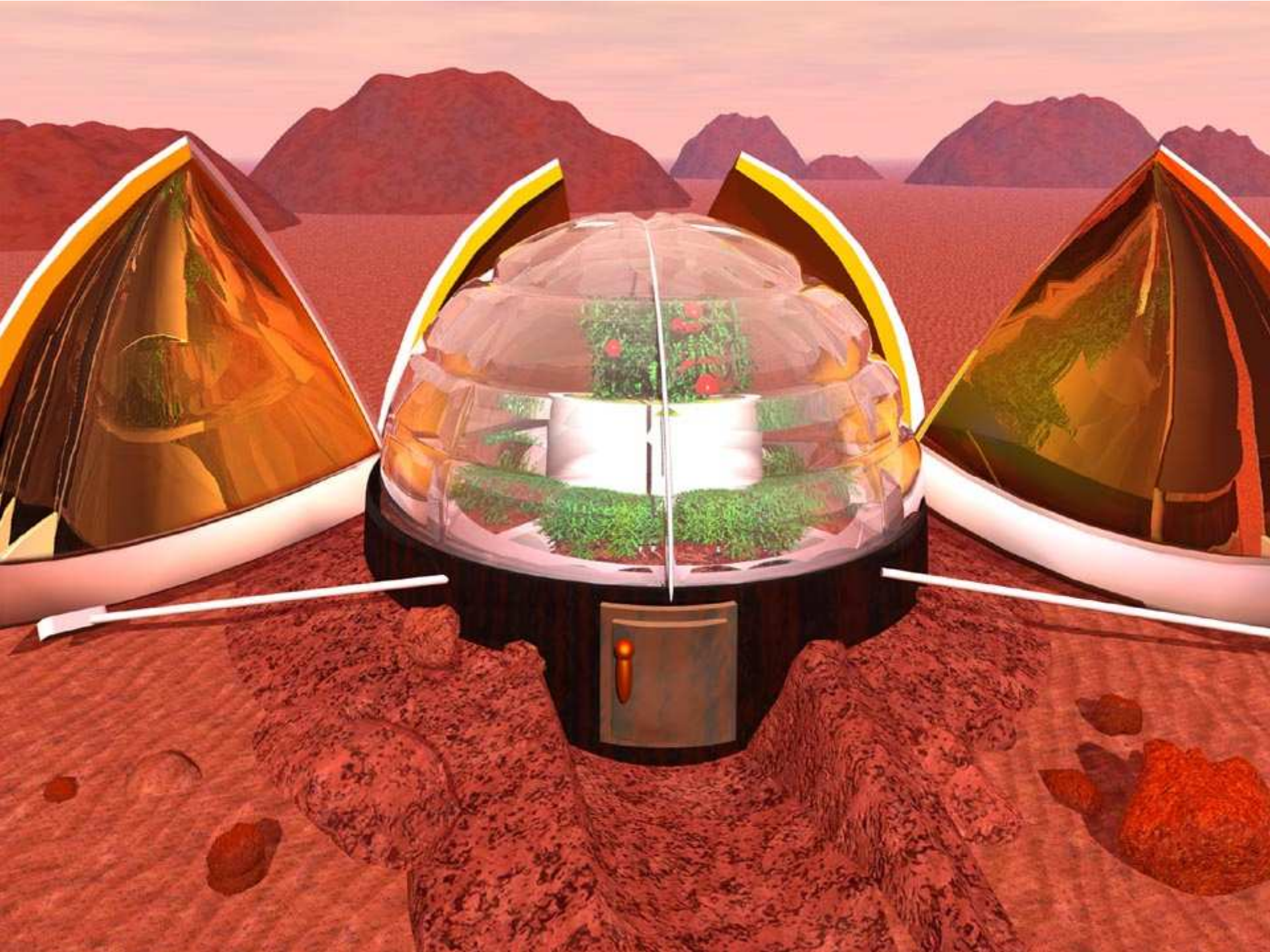


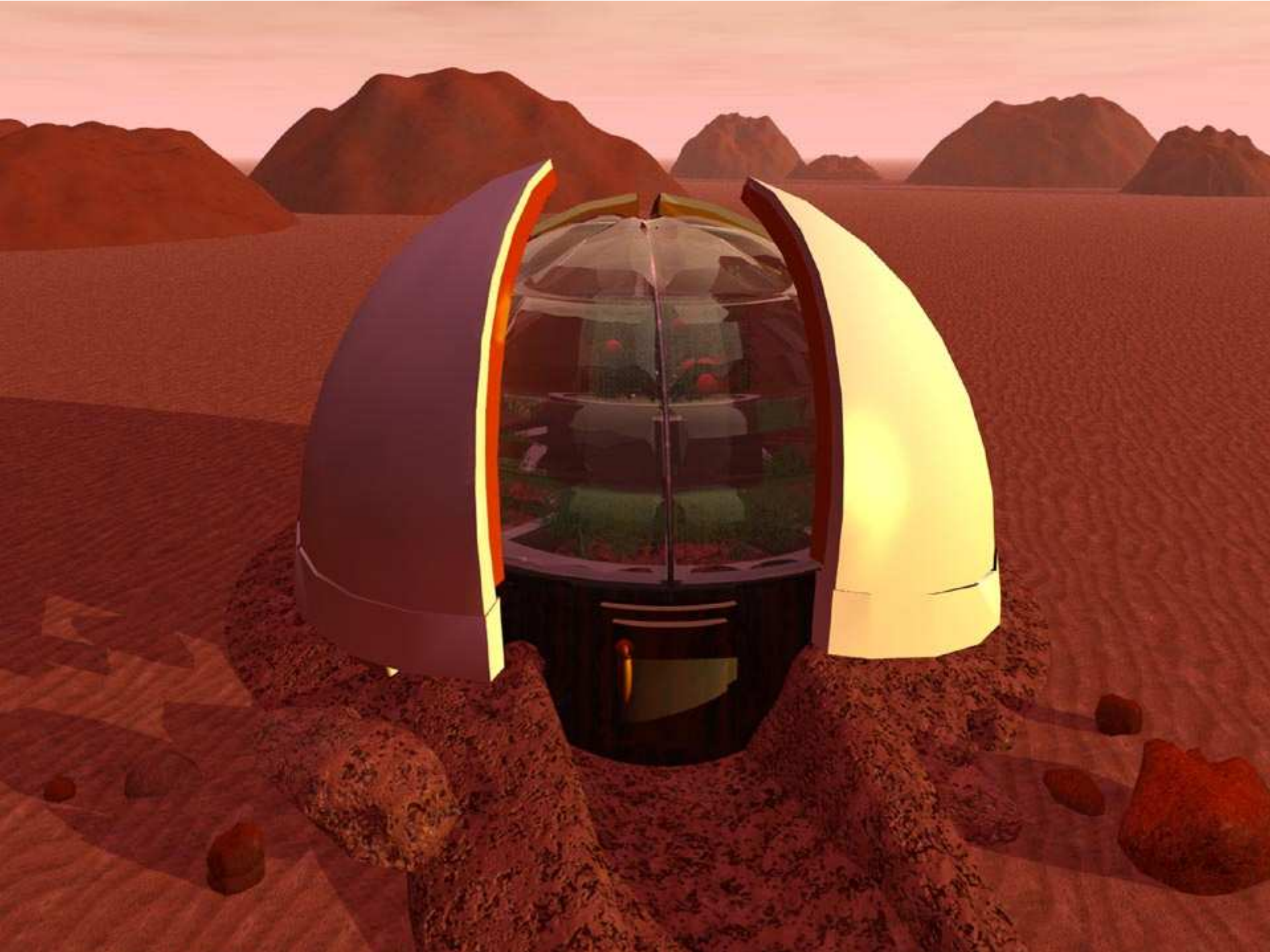


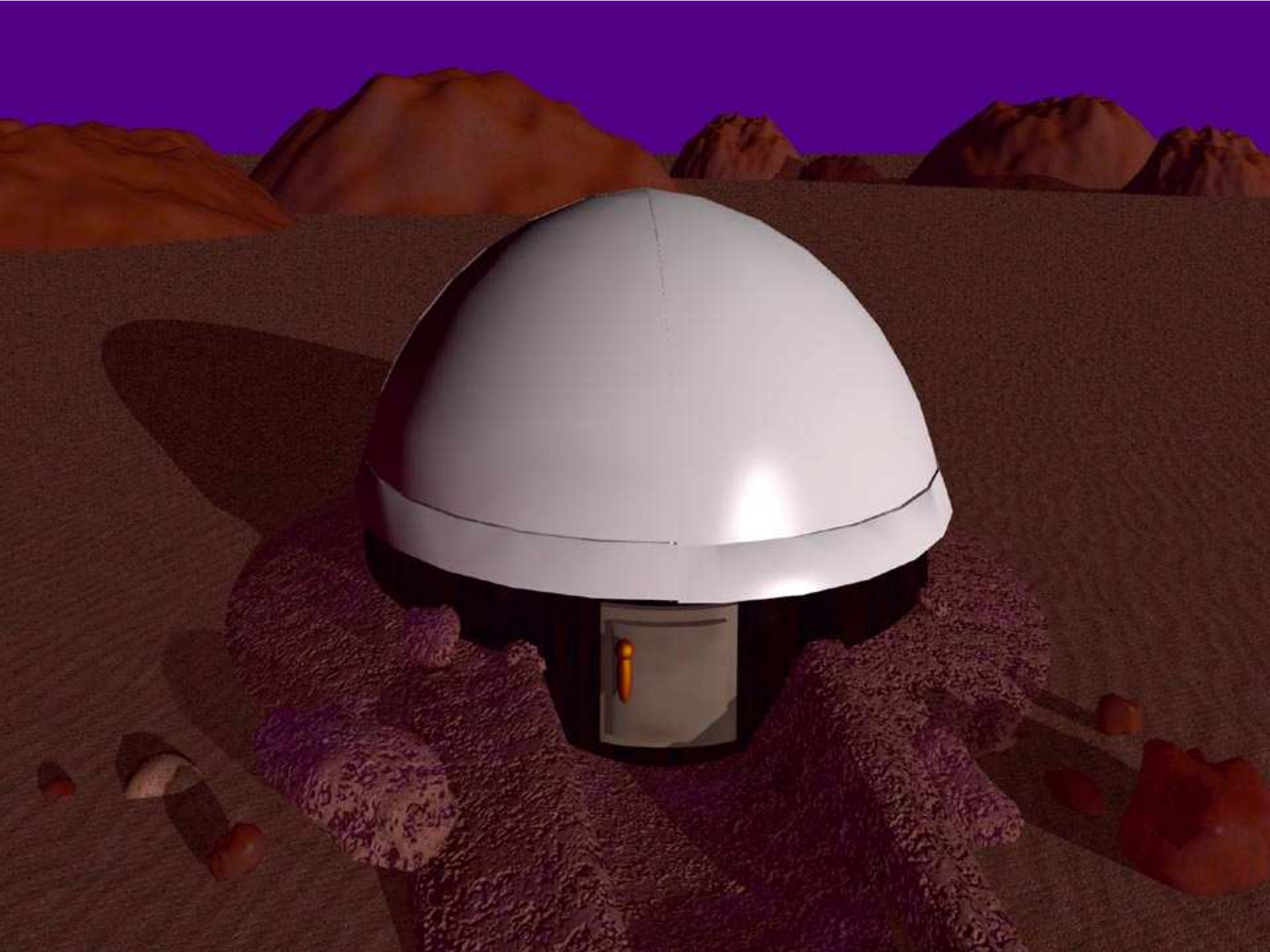












# Previous Studies with Plants and Pressure

- Wright Patterson Air Base, USA (1960s)
- Siegel et al. (1962, 1963)
- Burg and Burg (1965)
- Gale (1972, 1973)
- Rule and Staby (1981)
- Andre and Richaud (1985); Andre and Massimino (1992)
- Musgrave et al. (1988)
- Daunicht and Brinkjans (1992, 1996)
- Ohta et al. (1993)
- Goto et al. (1995, 1996), Iwabuchi et al. (1996)
- Corey et al. (1996, 1997)

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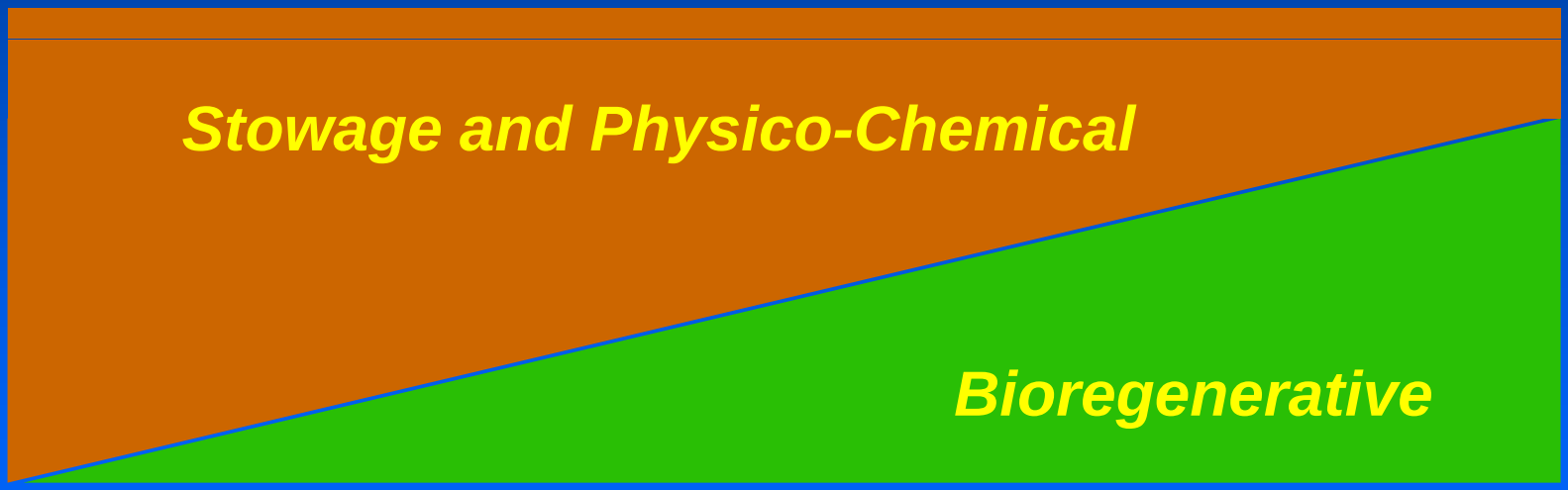
- *Studies Ongoing* : Texas A&M Univ. (USA)
  Kennedy Space Center, FL
  Univ. of Guelph (Canada)

# *Role of Bioregenerative Life Support for Future Missions*

***Short Durations (early missions)*** ***Longer Durations*** ***Autonomous Colonies***




*Plant Growing Area*

***~1-5 m $^2$ total*** ***~10-25 m $^2$ / person*** ***~50 m $^2$ / person***