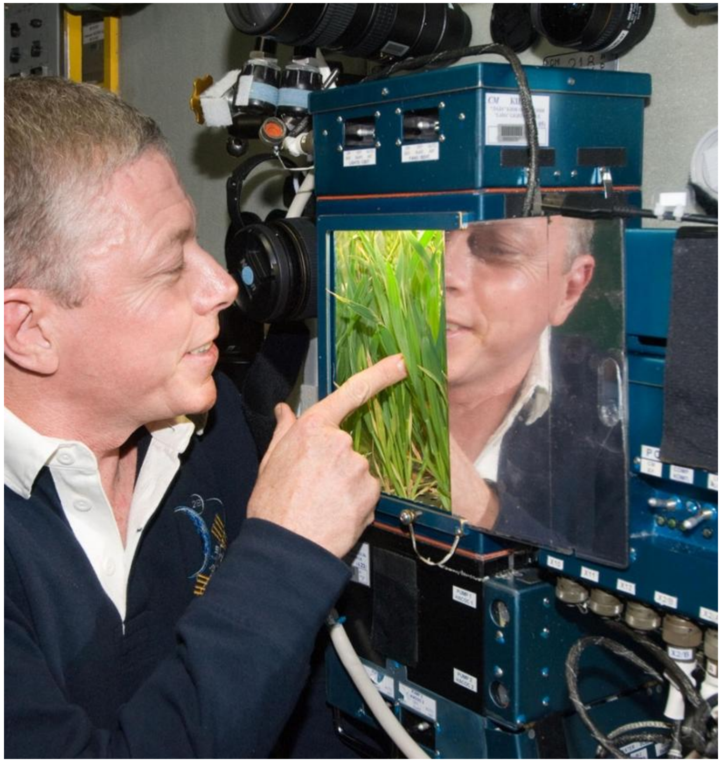
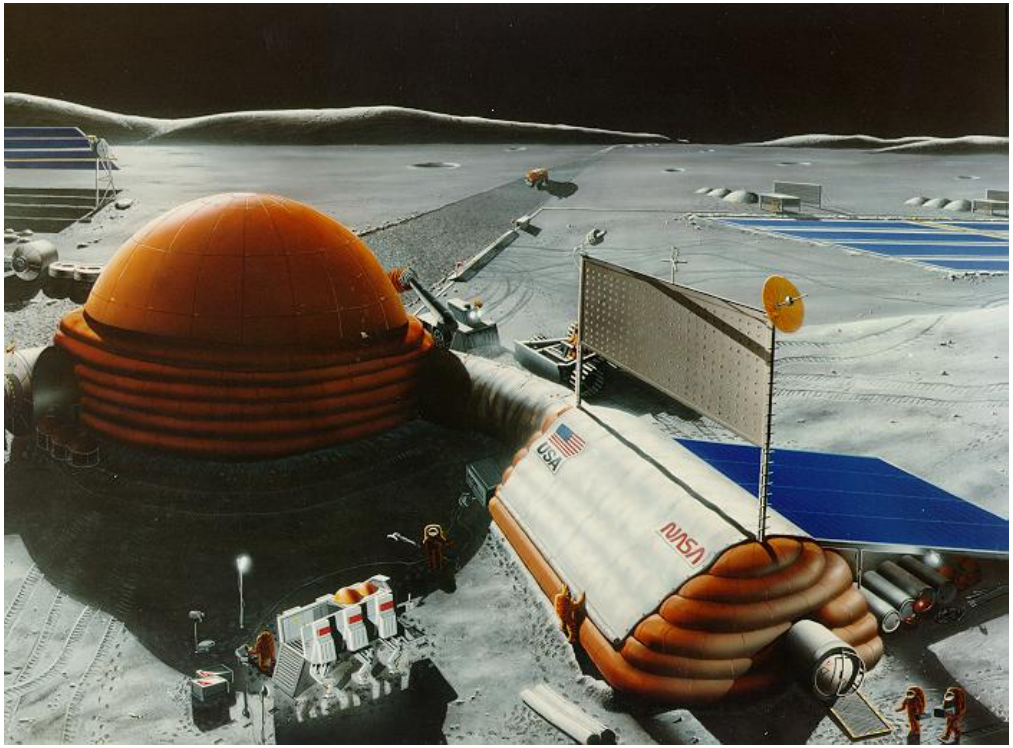
Coltivazione di piante per alimentazione in ambiente extraterrestre

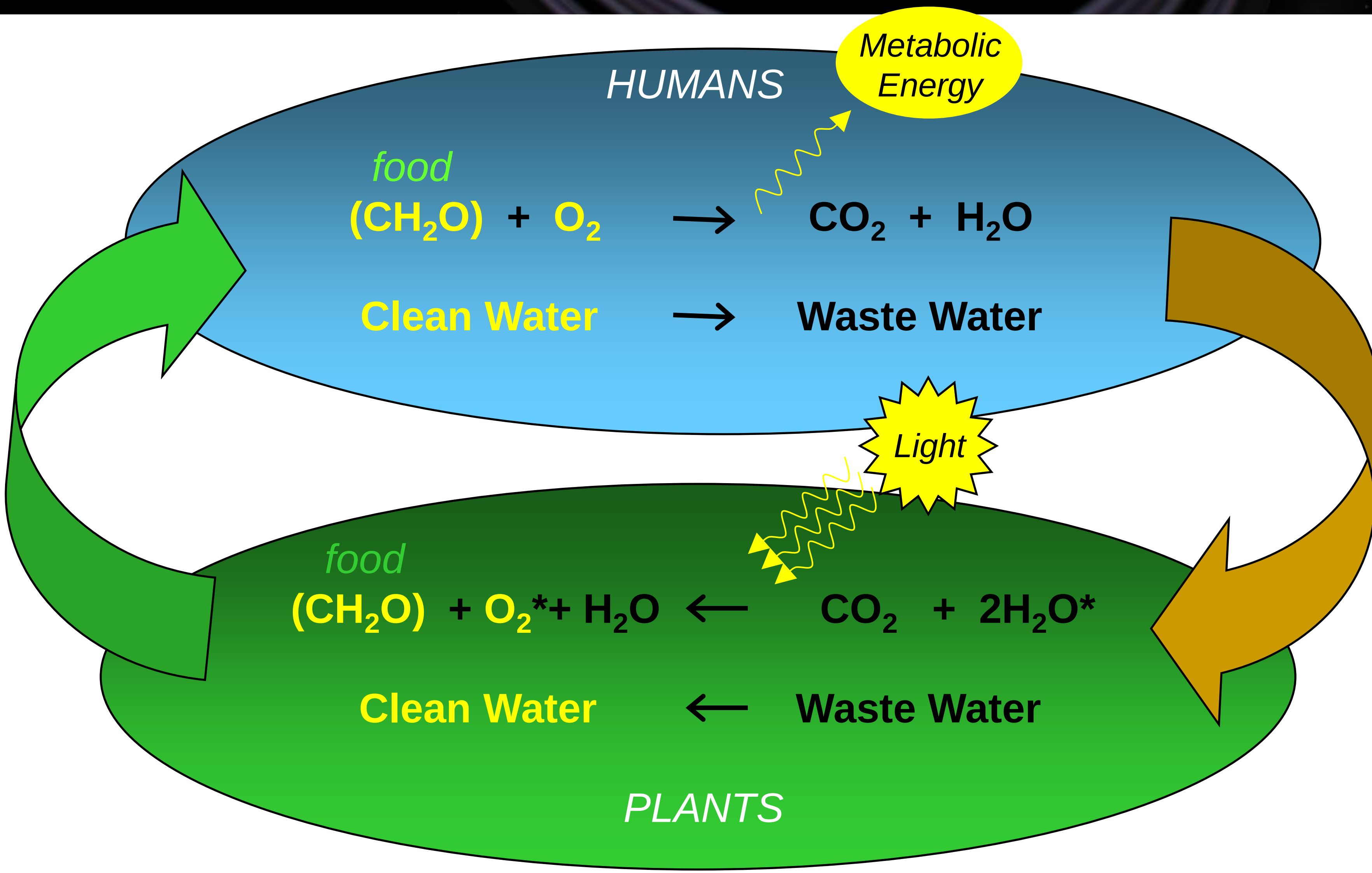
luigi cattivelli

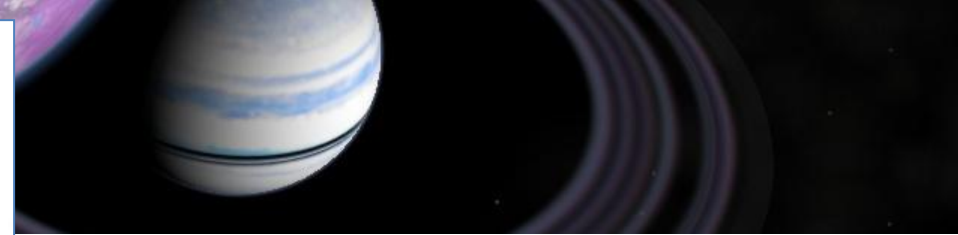
Space adaptation vs space farming





A bioregeneration life support system





Preparations for New Year's Eve dinner on the Moon in the year 2020.

Space Farming in the 21st Century

by Frank B. Salisbury and Bruce G. Bugbee

Dinner in Luna City

It's time to go to the restaurant for the last lunar meal of 2019. The menu (Table 1) gives us choices for three days.

Except for a few special ingredients imported from Earth, the items on the menu (Table 1) were prepared exclusively from crops grown in the lunar farms (Tables 2 and 3). Many other crops will also be developed as Luna City grows. We are always improving our repertoire.

from 21° CENTURY, 1988

Two strategic aims:

- **Long-term manned spaceflight will rely on the ability to produce food onboard the spacecraft, reducing the payload that must be launched into orbit and significantly increasing the quality of life for the crews.**

- **Farming on Moon or on Mars**

Space farming: limiting factors

- **Space**
- **Light**
- **CO_2**
- **Water**
- **Fertilization**
- **Soil**
- **Pathogen**
- **Wind/insect for impollination of allogamous plants**

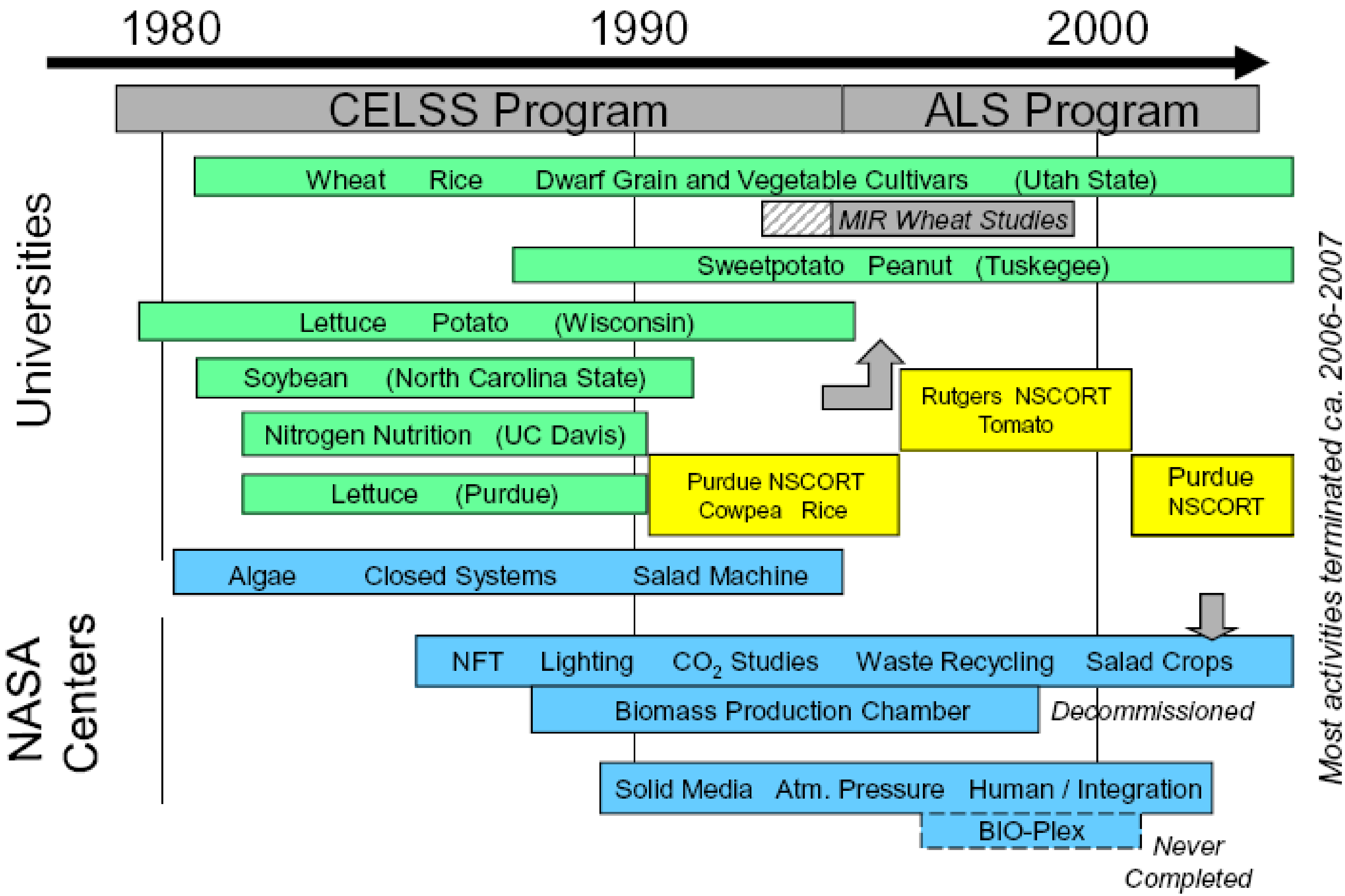


Figure 1. Time line of crop research and testing for NASA's Controlled Ecological Life Support System (CELSS) and later the Advanced Life Support (ALS) programs.

What plants should we consider?

Salad crops for early missions to supplement the meals (lettuce, carrot, onion, tomato, pepper, strawberry)

Staple crops for ater missions to provide more complete life support (wheat, potato, soybean, pea, sweetpotato, rice)

A “space plant” ideotype

Ideal space plants are short, grow in low light conditions, have few inedible parts, result in a quick and reliable harvest, and resist disease.

RESEARCH: SUPER DWARF CULTIVAR STUDIES: 'APOGEE' WHEAT

BACK TO DWARF

"Apogee": The point in an orbit farthest from the earth.

'USU-Apogee' was developed for high yields in space. Crops for the space station need to be short so they can be grown on shelves. 'USU-Apogee is half the height of normal wheat. It has few tillers (branches) and smaller leaves than wheat on Earth. Tillers and large leaves compete with other plants and reduce the yield of plant communities. Two small leaves are better than one large leaf.

"Perigee": The point in an orbit closest to the earth.

'USU-Perigee' and 'USU-Apogee' both came from a hybrid cross between 'Super Dwarf' Wheat and 'Parula'. 'Perigee' is shorter than 'Apogee' but has a slightly longer life cycle.

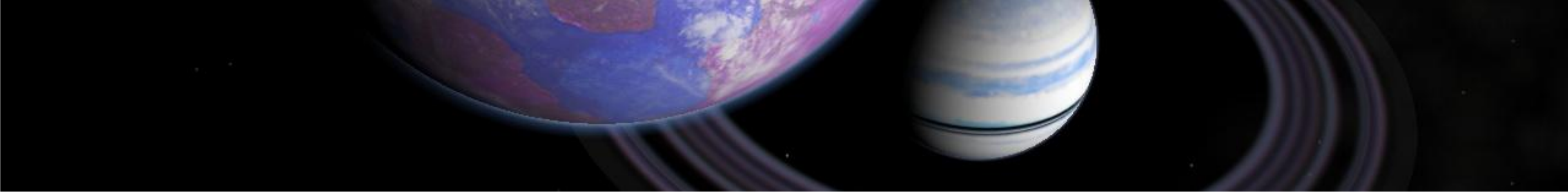
'APOGEE' GENERAL INFO / RECOMMENDED CULTURAL CONDITIONS:

HEIGHT:	40 to 48 cm tall (shorter at warmer temperatures)
LIFE CYCLE:	25 days to heading; 60 to 65 days to harvest
TEMPERATURE:	23 °C pre-anthesis; 17 °C post-anthesis
PPF:	300 to 2000 µmol m^{-2} s^{-1}
PHOTOPERIOD:	24-h (continuous light)

'PERIGEE' GENERAL INFO / RECOMMENDED CULTURAL CONDITIONS:

HEIGHT:	27 to 32 cm tall (shorter at warmer temperatures)
LIFE CYCLE:	30 days to heading; 65 to 70 days to harvest*
TEMPERATURE:	23 °C pre-anthesis; 17 °C post-anthesis
PPF:	300 to 2000 µmol m^{-2} s^{-1}
PHOTOPERIOD:	24-h (continuous light)
SPACING:	Plant seeds in rows 5 cm apart and 5 cm between seeds

Utah state university



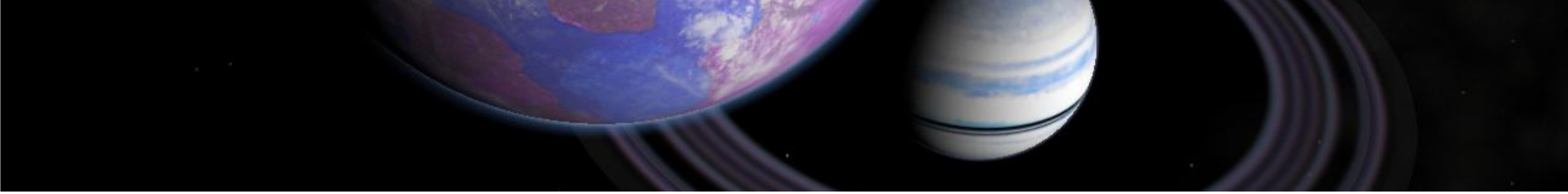
RESEARCH: SUPER DWARF CULTIVAR STUDIES: RICE

'Super Dwarf' rice is a mutant selection from *Oryza sativa* cv. Shiokari. Its short stature, high yield, high harvest index, and no extraordinary environmental requirements make 'Super Dwarf' rice an excellent model plant for yield studies in controlled environments. It does lack the enzyme 3ß- hydrozylase that catalyzes the conversion of GA_{20} (inactive) to GA_1 (active) so germination is poor; however, 90% germination can be achieved by germinating the seed *under water, without aeration, at 33°C.*

GENERAL INFO / RECOMMENDED CULTURAL CONDITIONS:

HEIGHT:	20 cm tall
LIFE CYCLE:	45 days to heading; 80 days to harvest
TEMPERATURE:	600 to 2000 µmol m^{-2} s^{-1}
PPF:	32/26 °C d/n pre-anthesis; 28/22 °C post-anthesis
PHOTOPERIOD:	12-h
PLANTING DENSITY:	500 to 1000 plants m^{-2}


Semi dwarf
Rice
Full dwarf
Rice
Super dwarf
Rice

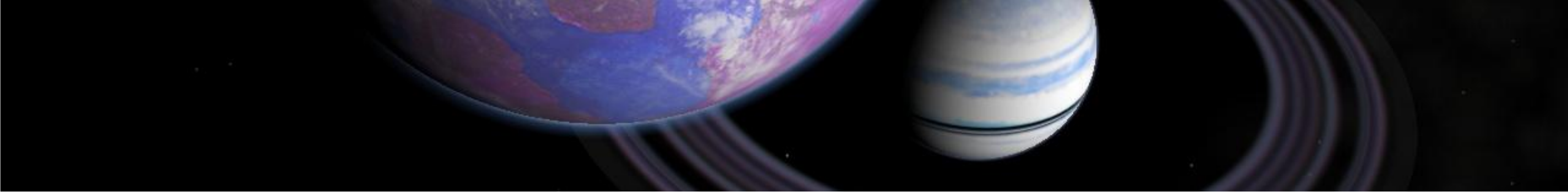


RESEARCH: SUPER DWARF CULTIVAR STUDIES: TOMATO

'Micro-Tina' was developed at the University of Florida - Bradenton, and extensively tested at Utah State University. Micro-Tina's short height, high yield, and good flavor make it excellent for fresh food in the space station.

GENERAL INFO / RECOMMENDED CULTURAL CONDITIONS:

HEIGHT:	20 to 25 cm
LIFE CYCLE:	flowering: ~ 25 days; red fruit: ~ 45 days after flowering
TEMPERATURE:	25 to 28 °C day; 20 to 23 °C night
PPF:	200 to 1500 μmol m^{-2} s^{-1}
PHOTOPERIOD:	16-h



RESEARCH: SUPER DWARF CULTIVAR STUDIES: 'EARLIGREEN' PEA

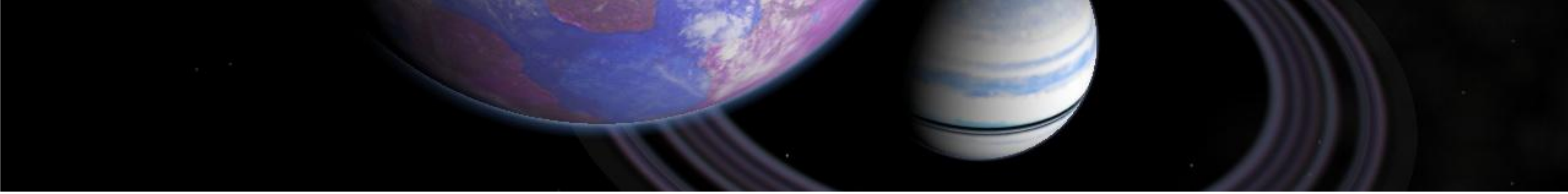
BACK TO DWARF

'Earligreen' Pea is ideal for controlled environment studies due to its fast life cycle, short height, and excellent growth in low light. 'Earligreen' peas typically grow 18 to 35 cm tall and flower 20 to 25 days after emergence with the first fresh seed ready at 40 days. Optimal temperature is 20 to 25˚C. 'Earligreen' grows well under a wide range of light levels (photosynthetic photon flux (PPF), 100 to 1000 µmol m^{-2} s^{-1}) and a photoperiod of 16 to 24 hours. Leaves display a characteristic silver speckling pattern.

'Earligreen' was developed in 1950 at the Morden research station in Manitoba, Canada. 'Earligreen' (PI 365417) is a hybrid of 'Engress' and an unknown early maturing field pea. C. Walkof from the Canada Department of Agriculture donated 'Earligreen' seed to the ARS-GRIN network in June of 1971. Germplasm has not been commercially available for at least 20 years.

GENERAL INFO / RECOMMENDED CULTURAL CONDITIONS:

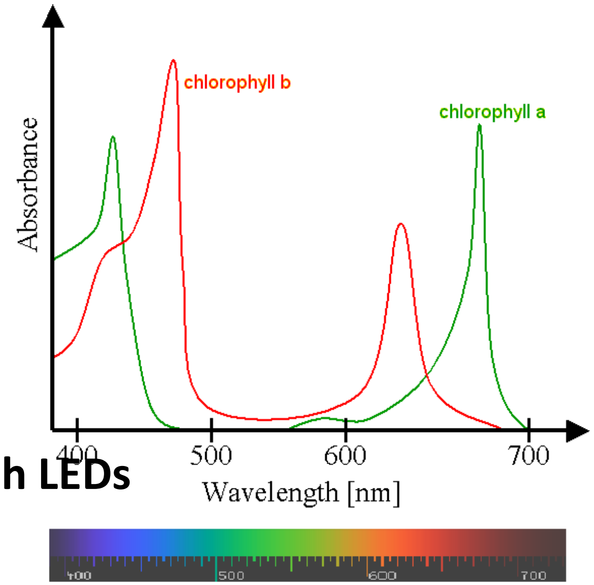
HEIGHT:	18 to 25 cm tall (shorter in lower light)
LIFE CYCLE:	24 days to first flower; 54 days to harvest
TEMPERATURE:	20 to 25 °C
PPF:	100 to 1000 µmol m^{-2} s^{-1} (grows extremely well in low light)
PHOTOPERIOD:	16 to 20 hours (day length sensitive)



Extremely dwarf genotypes of most major crop plants less than about 20 cm tall at maturity have been called SUPER-DWARF CROP PLANTS. Their yield in field studies is only about 25% of their tall counterparts; however, their yield increases to about 50% of taller cultivars when grown at high plant densities in near-optimal controlled environments. When yield is expressed on a unit volume basis, these cultivars often exceed all other genotypes. Multiple plants can be grown in small plots in small plant growth chambers. Harvest index up to more than 60%.

Growing Plants with LEDs

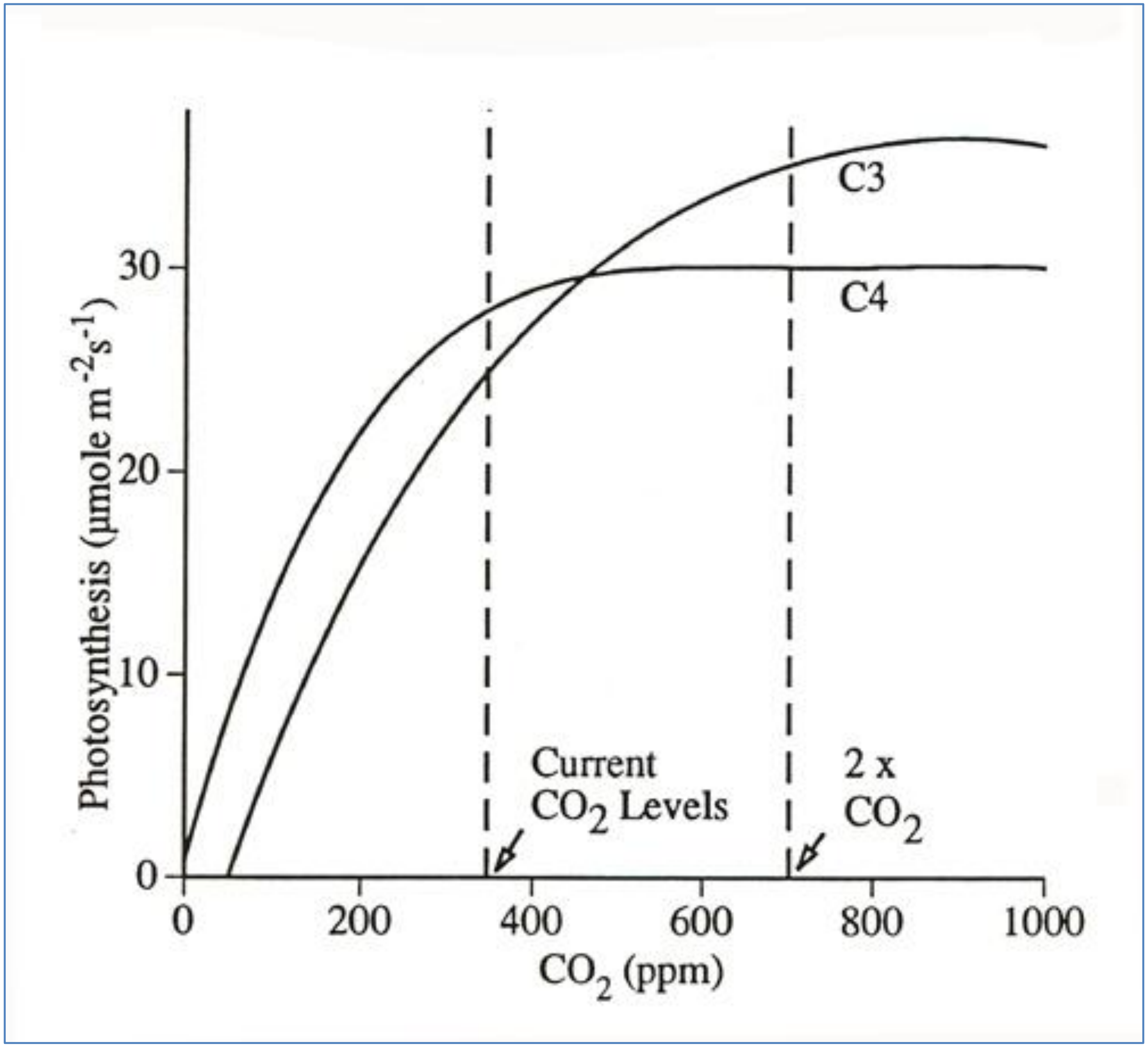
Growing Plants with LEDs



Red...photosynthesis
Blue...photomorphogenesis
Green...human vision

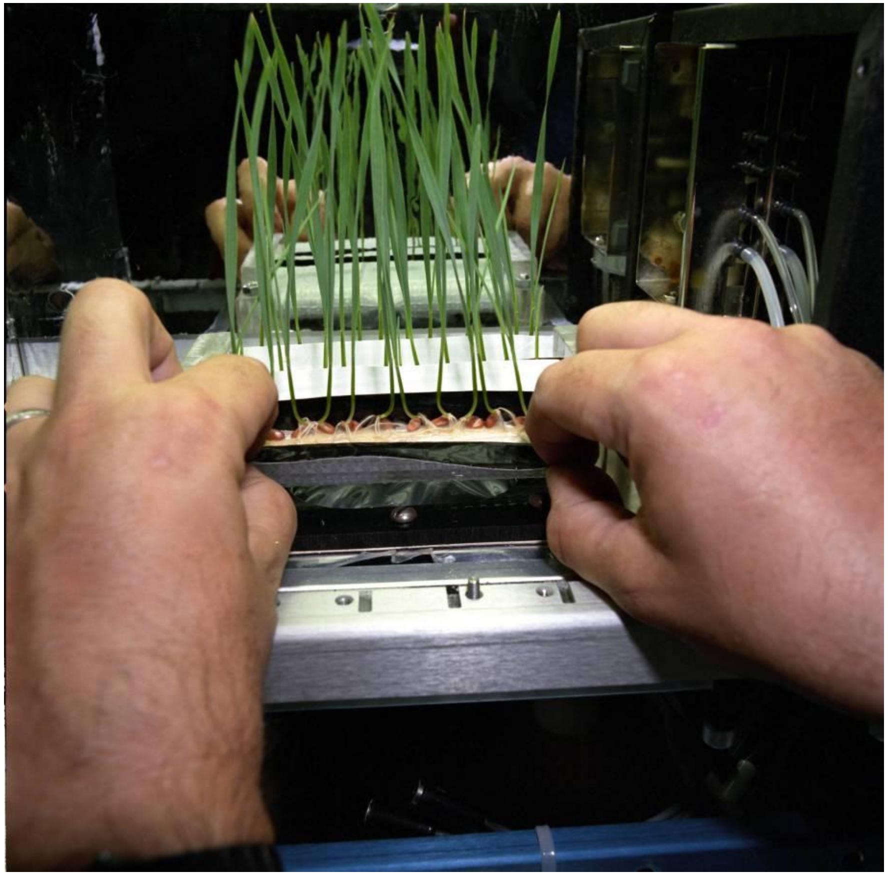
LEDs can be placed very close to (or even touching) plants, providing a concentrated light source with minimal wasted light.

CO2

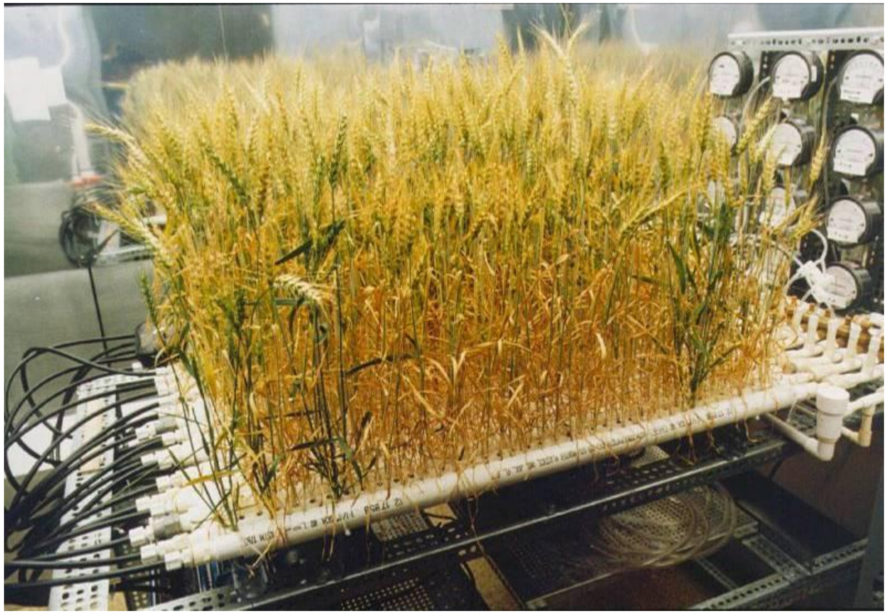


C3
C4
30
20
10
0
Photosynthesis (µmole m-2s-1)
Current
CO2 Levels
2 x
CO2
0
200
400
600
800
1000
CO2 (ppm)

Watering plants in weightlessness is a challenge !

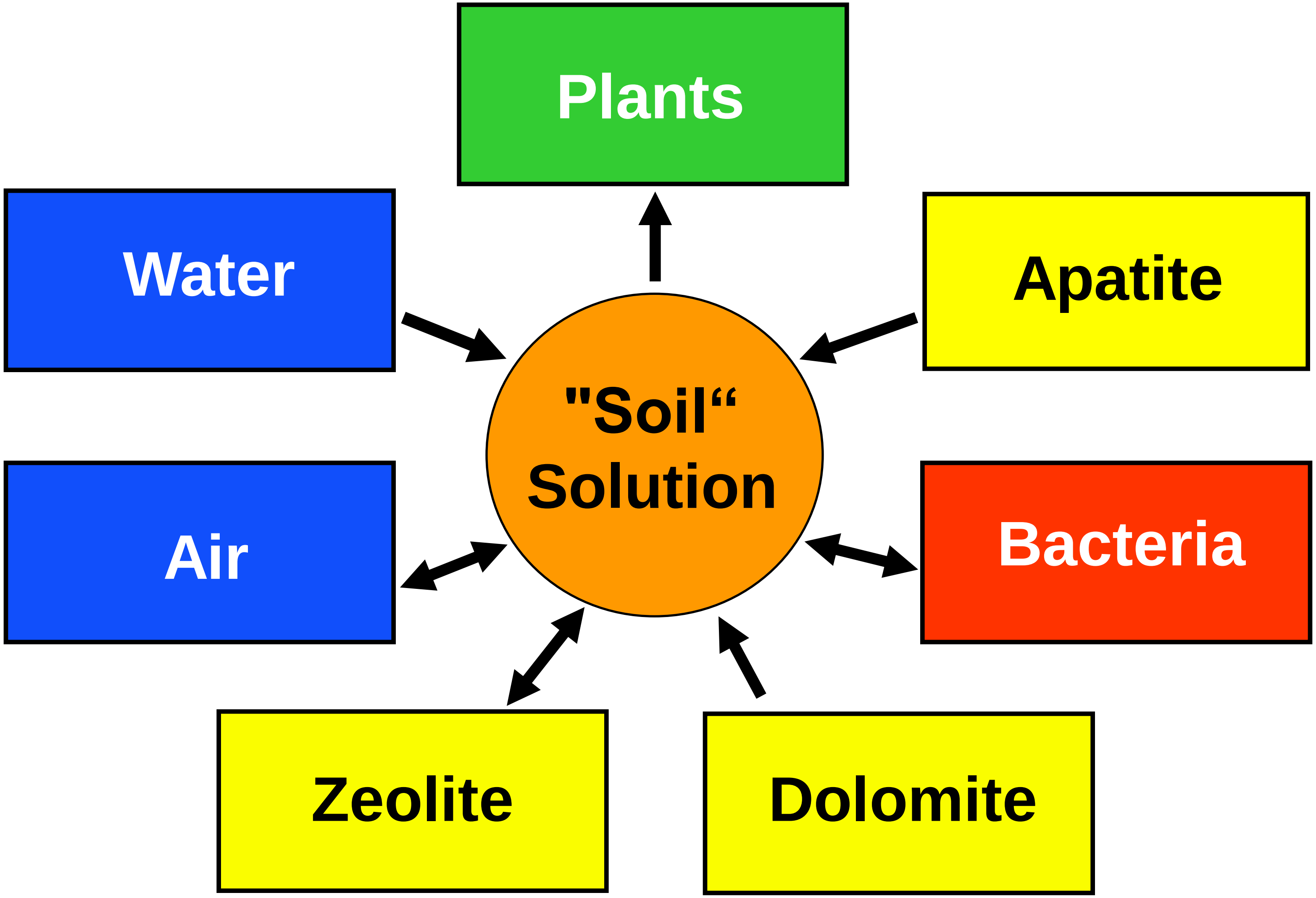


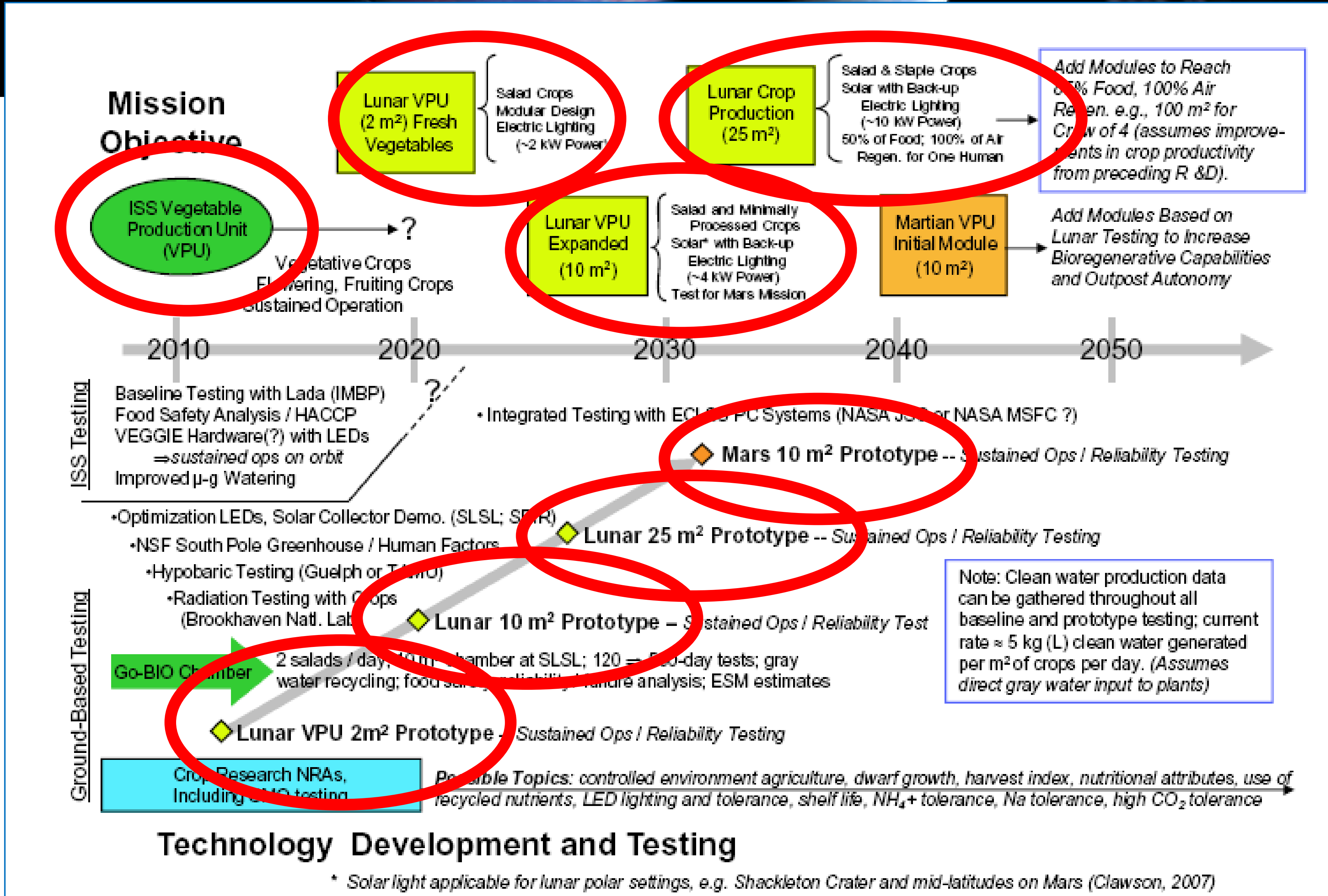
Porous Ceramic Tubes to Contain the Water



Corn treated with lunar material from Apollo 17 mission

NASA'S Zeoponic plant growth medium




Mission Objective
ISS Vegetable Production Unit (VPU)
?
Vegetative Crops
Flowering, Fruiting Crops
Sustained Operation
Lunar VPU (2 m²) Fresh Vegetables
Salad Crops
Modular Design
Electric Lighting
(~2 kW Power)
Lunar VPU Expanded (10 m²)
Salad and Minimally Processed Crops
Solar* with Back-up Electric Lighting
(~4 kW Power)
Test for Mars Mission
Lunar Crop Production (25 m²)
Salad & Staple Crops
Solar with Back-up Electric Lighting
(~10 kW Power)
50% of Food; 100% of Air Regen. for One Human
Add Modules to Reach
Martian VPU Initial Module (10 m²)
Add Modules Based on Lunar Testing to Increase Bioregenerative Capabilities and Outpost Autonomy
2010
2020
2030
2040
2050
ISS Testing
Baseline Testing with Lada (IMBP)
Food Safety Analysis / HACCP
VEGGIE Hardware(?) with LEDs
⇒sustained ops on orbit
Improved μ-g Watering
?
• Integrated Testing with
Mars 10 m² Prototype --
Lunar 25 m² Prototype --
Lunar 10 m² Prototype –
Lunar VPU 2m² Prototype -
Sustained Ops / Reliability Testing
Reliability Test
•Optimization LEDs, Solar Collector Demo. (SLSL;
•NSF South Pole Greenhouse / Human Factors
•Hypobaric Testing (Guelph or
•Radiation Testing with
(Brookhaven Natl. Lab
Go-BIO
2 salads / day
water recycling; food
analysis; ESM estimates
Note: Clean water production data can be gathered throughout all baseline and prototype testing; current rate ≈ 5 kg (L) clean water generated per m² of crops per day. (Assumes direct gray water input to plants)
Ground-Based Testing
Crop Research NRAs,
Including
recycled nutrients, LED lighting and tolerance, shelf life, NH₄+ tolerance, Na tolerance, high CO₂ tolerance
Technology Development and Testing
* Solar light applicable for lunar polar settings, e.g. Shackleton Crater and mid-latitudes on Mars (Clawson, 2007)

Technological developments

- **On board growth chambers**
- **On planet greenhouses**

Biomass Production System (BPS)

MAIN SPECIFICATIONS

- Size: double mid-deck locker
- Chamber shoot area: 964 cm^2
- Shoot height: 18.8 cm
- Temperature: 18 – 35°C ± .2°C
- Humidity: 65 – 90 % RH ± 10%
- Light: 0 – 350 µmol/m2/s
  - (cool white flourescent)
  - (with red/blue LED lights)
- CO2: 0 – 3,000 ppm
- Ethylene removal
- Video still imaging of chamber
- In-Flight Access: Allowed
- Express rack Ethernet communication interface
- Regenerable H2O recovery loop, H2O supply
- Replenishable CO2 supply

ORBITEC

BPS on ISS

Brassica, 36 Days after Planting

BPS Being Transferred from the Space Shuttle to the International Space Station (April 2002)

Wheat, 20 Days after Planting

Harvesting Brassica on ISS

Astrogarden Sample Crops

ORBITEC

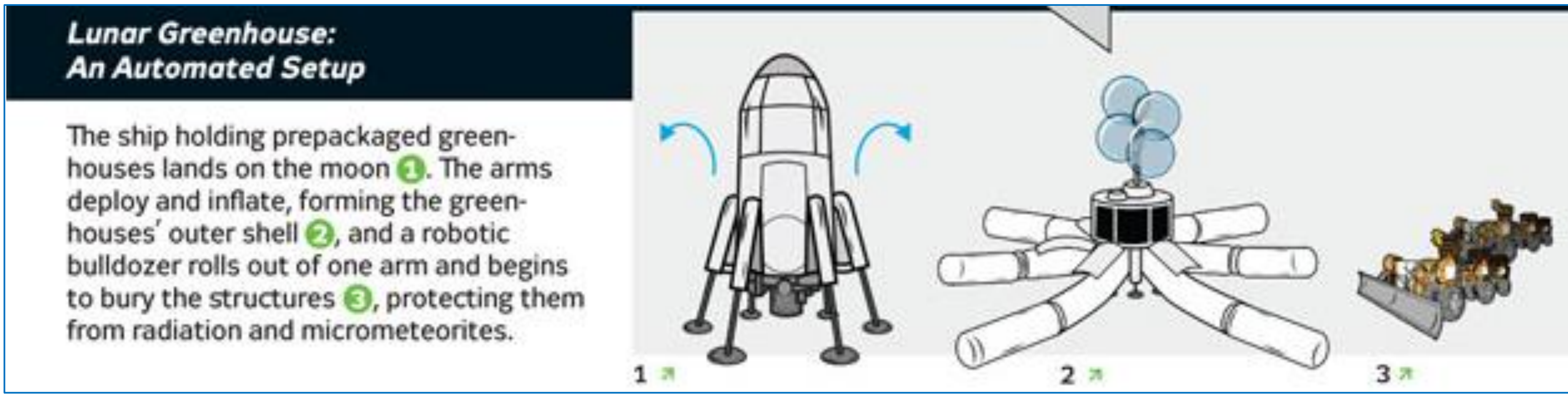
The “Salad Machine”

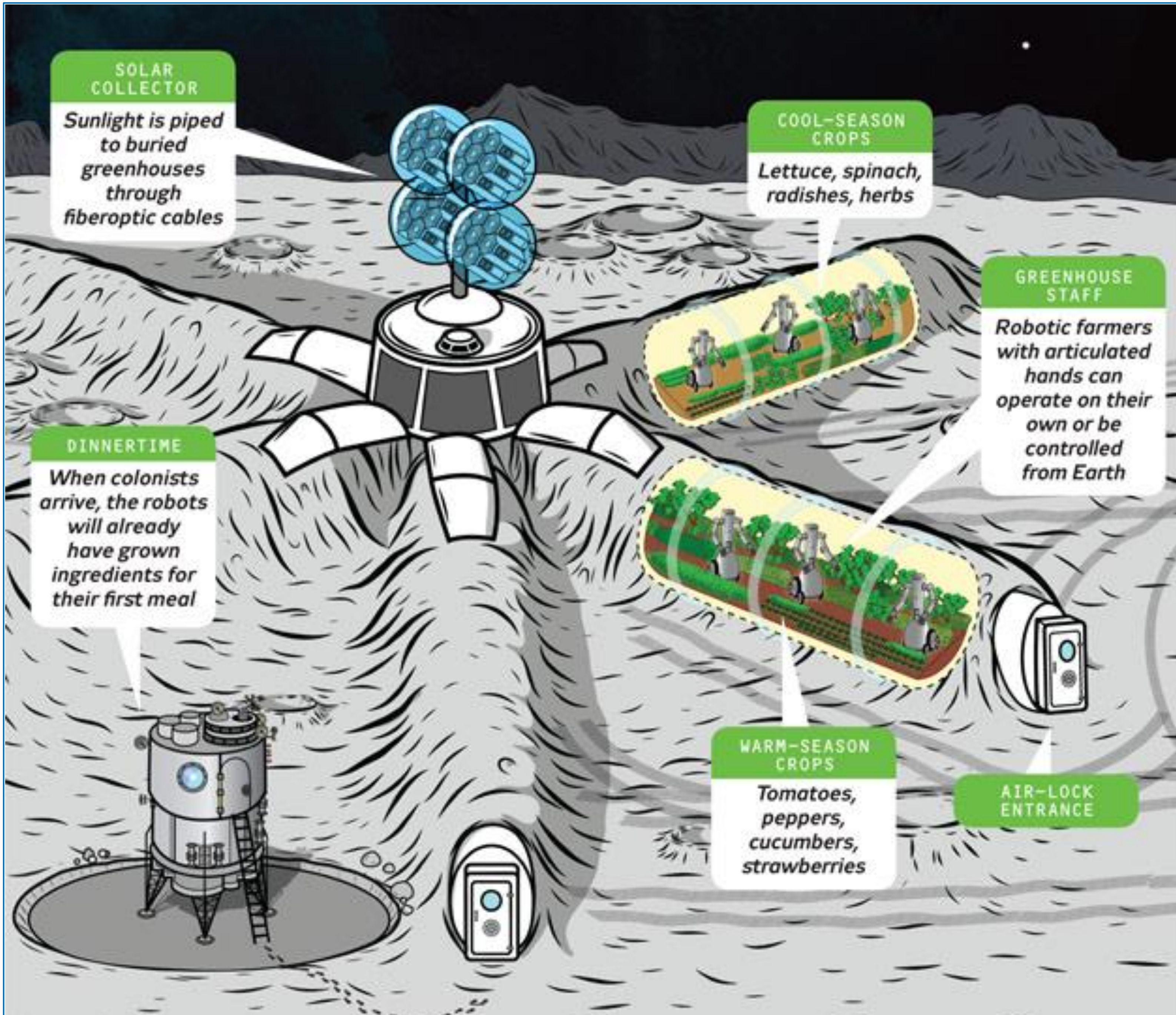
Proposed for the International Space Station to produce fresh salad crops for the Astronauts.

Deployable Greenhouse Concepts for the Moon and Mars

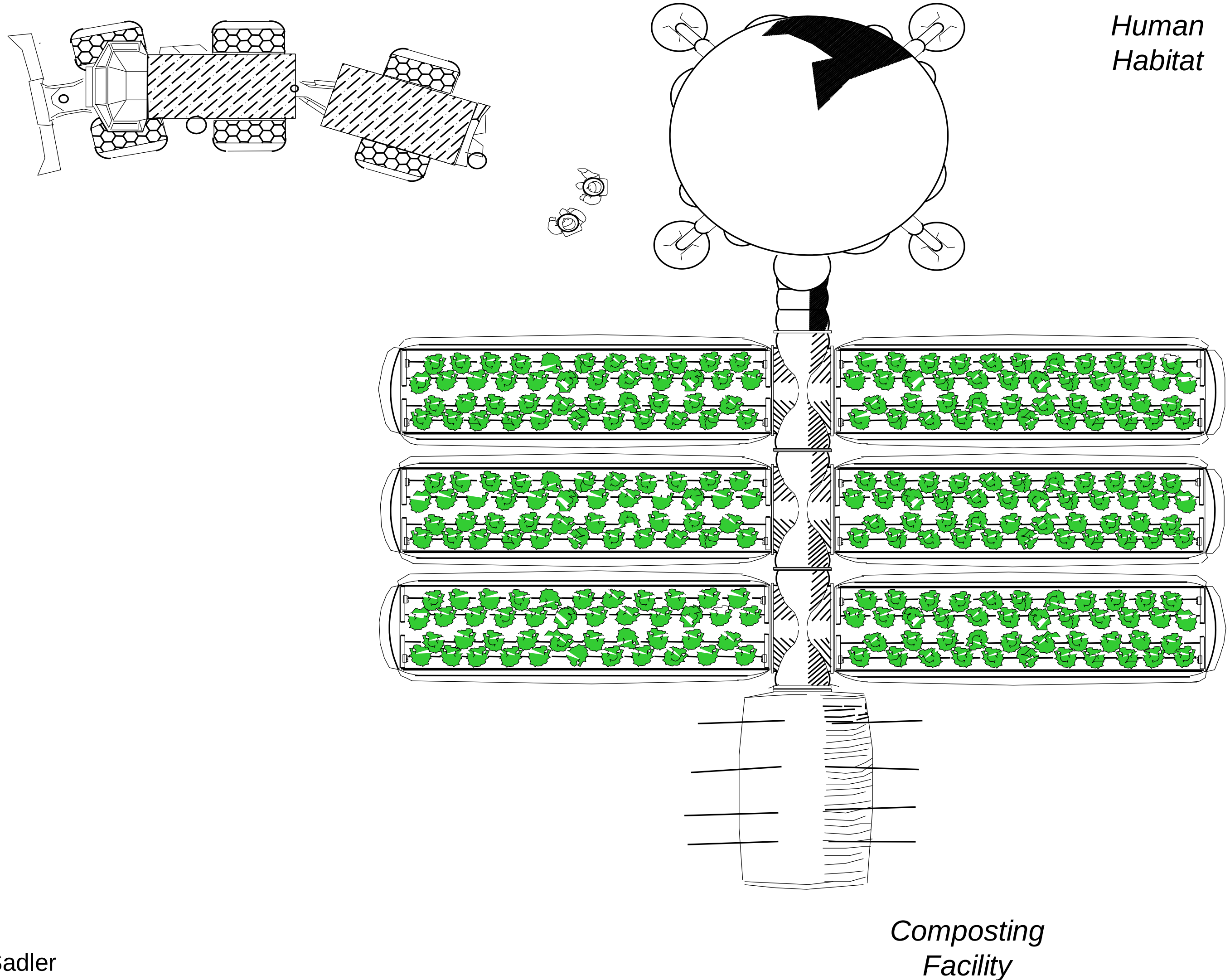
UA-CEAC/Sadler Lunar Habitat Deployment

http://www.youtube.com/watch?v=Z-0qJ4eZhs4&feature=related

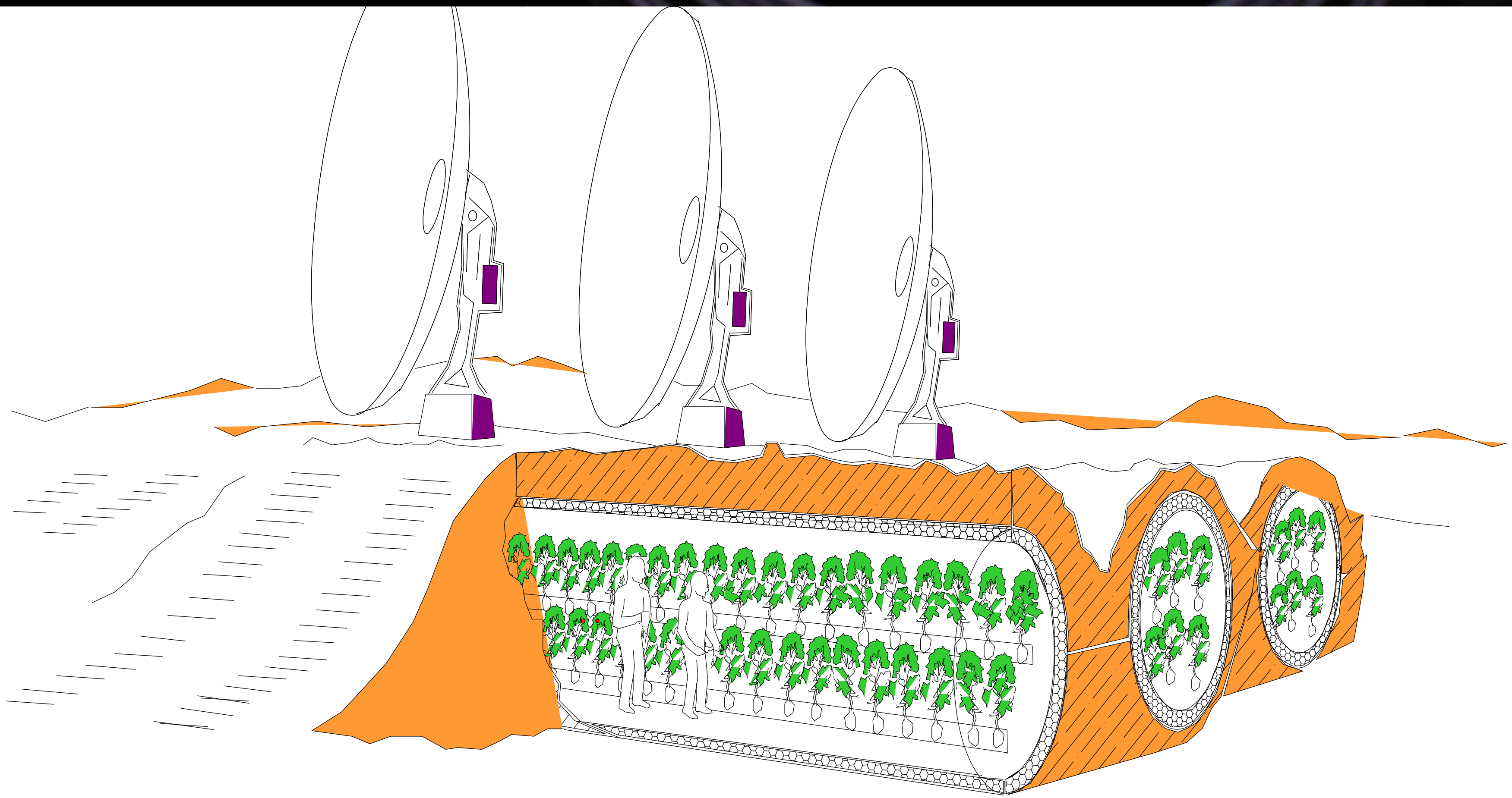



SOLAR COLLECTOR
Sunlight is piped to buried greenhouses through fiberoptic cables
COOL-SEASON CROPS
Lettuce, spinach, radishes, herbs
GREENHOUSE STAFF
Robotic farmers with articulated hands can operate on their own or be controlled from Earth
DINNERTIME
When colonists arrive, the robots will already have grown ingredients for their first meal
WARM-SEASON CROPS
Tomatoes, peppers, cucumbers, strawberries
AIR-LOCK ENTRANCE

Inflatable Greenhouses for the Lunar or Martian Surface



Buried Plant Chamber with Solar Collectors



Buried Plant Chambers Protected From Radiation

Lunar Greenhouse Prototype