Agriculture for Space Exploration:
An Evolutionary Approach for Sustaining Space Agency Investments

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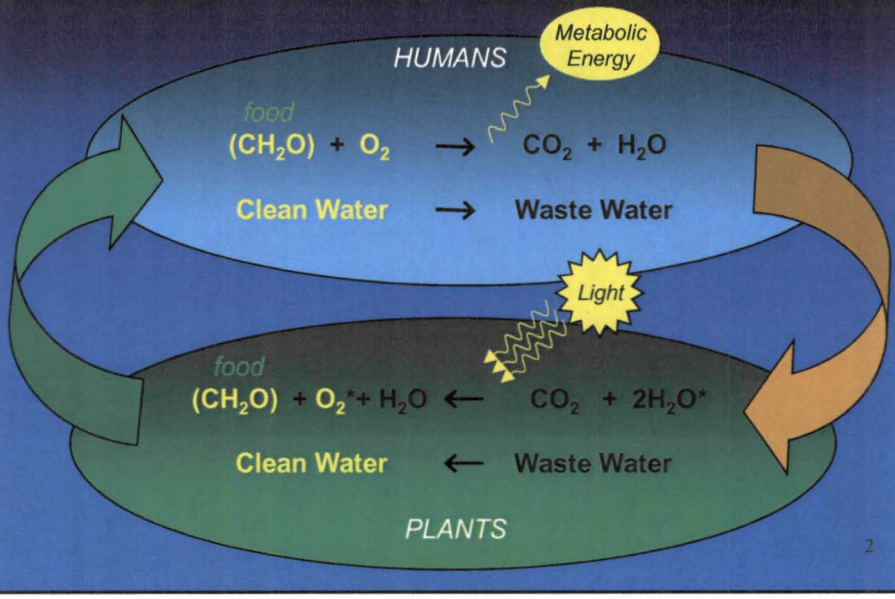
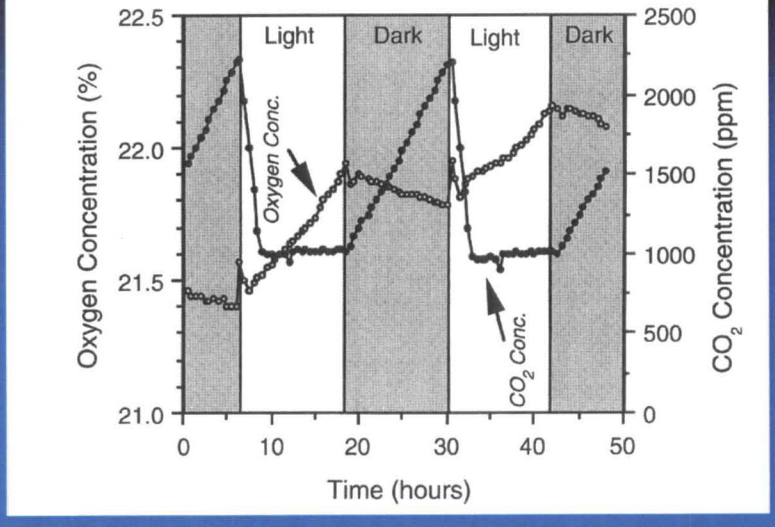
Plants in Space for Life Support



2

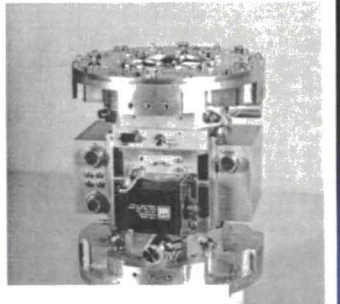
Closed System CO_2 Uptake / O_2 Production
(20 m^2 Soybean Stand)



Wheeler. 1996. In: H. Suge (ed.) Plants in Space Biology.

3

Photosynthesis in Space *(1966)*



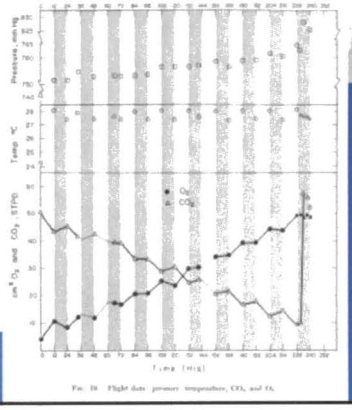


FIG. 11. Experimental apparatus mounted in OV1 satellite; note solar cell dome system.

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

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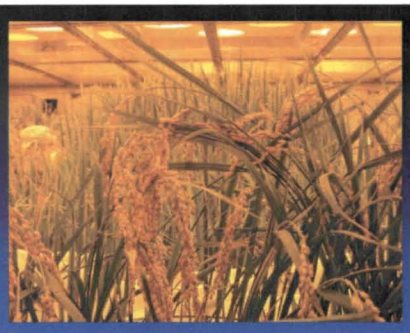
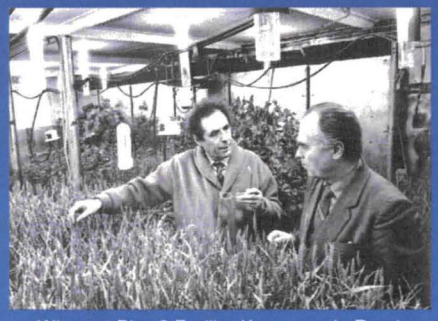
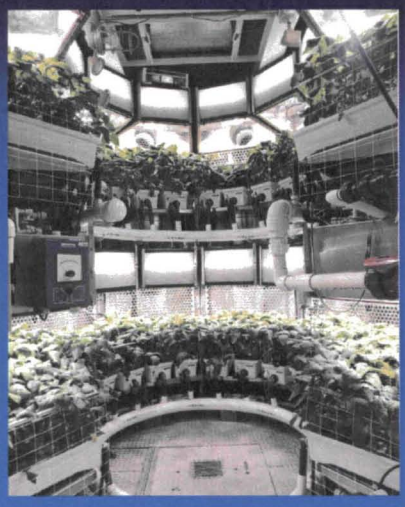
Previous Testing on Large Systems with Staple Crops



Rice at CEEF Facility, Rokkasho, Japan



Wheat at Bios-3 Facility, Krasnoyarsk, Russia
(Josef Gitelson and Henry Lisovsky)



Soybeans at NASA Kennedy Space Center, US

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Start ⇨ Vegetable Production Systems for ISS

Cosmonaut Gennady Padalka--Lada Chamber on ISS

Lada Chamber Ground Controls (0.025 m^2)

BPSe or VEGGIE Chamber by Orbitec (0.13 m^2)

WCSAR CPBF Chamber 0.25 m^2 growing area

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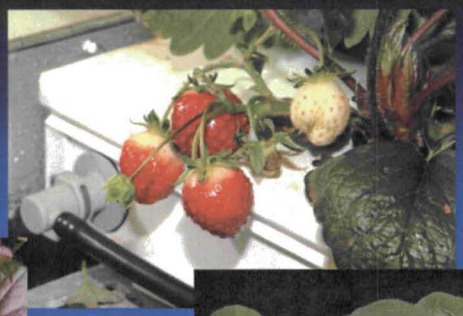
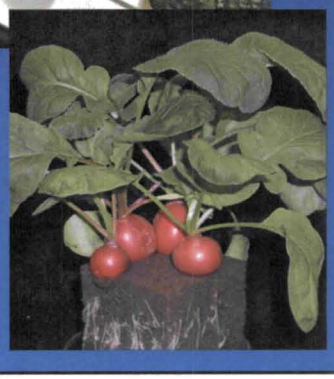
Early Missions--Supplemental Food Crops

- Provide fresh foods to supplement stowed foods
- Provide Bio-available nutrients and antioxidants as radiation countermeasure.





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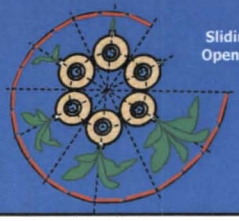
Expanded Food Production Systems for Transit / Near Earth Missions

"Salad Machine" (1.0-2.0 m^2)
Mark Kliss and Bob McElroy (NASA)

"Phytoconveyor" (0.4 m^2) Yuli Berkovich (IMBP)

Phytoconveyer Side View



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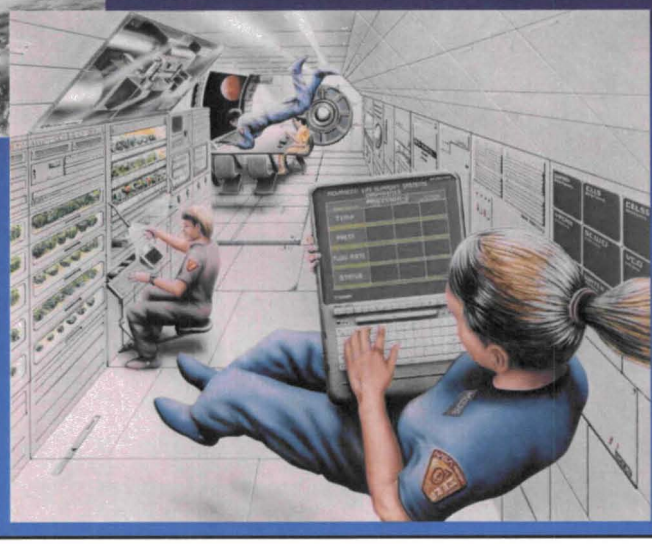
Vegetable Production for "Transit Missions"



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Deployable - Precursor Missions for Surface Settings

Small Deployable Greenhouse
at NASA Kennedy Space Center
(R. Wheeler, P. Fowler, V. Rygalov)

Placing Deployable Greenhouse
in Vacuum Chamber (NASA KSC)
(V. Rygalov, M. Dixon, J. Lawson)

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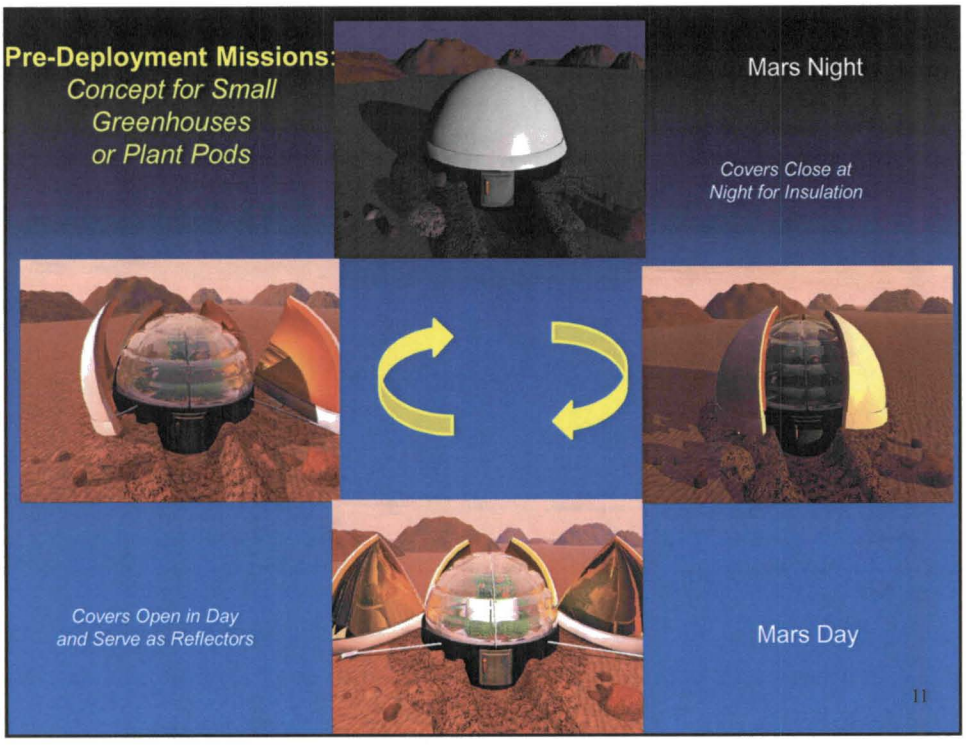
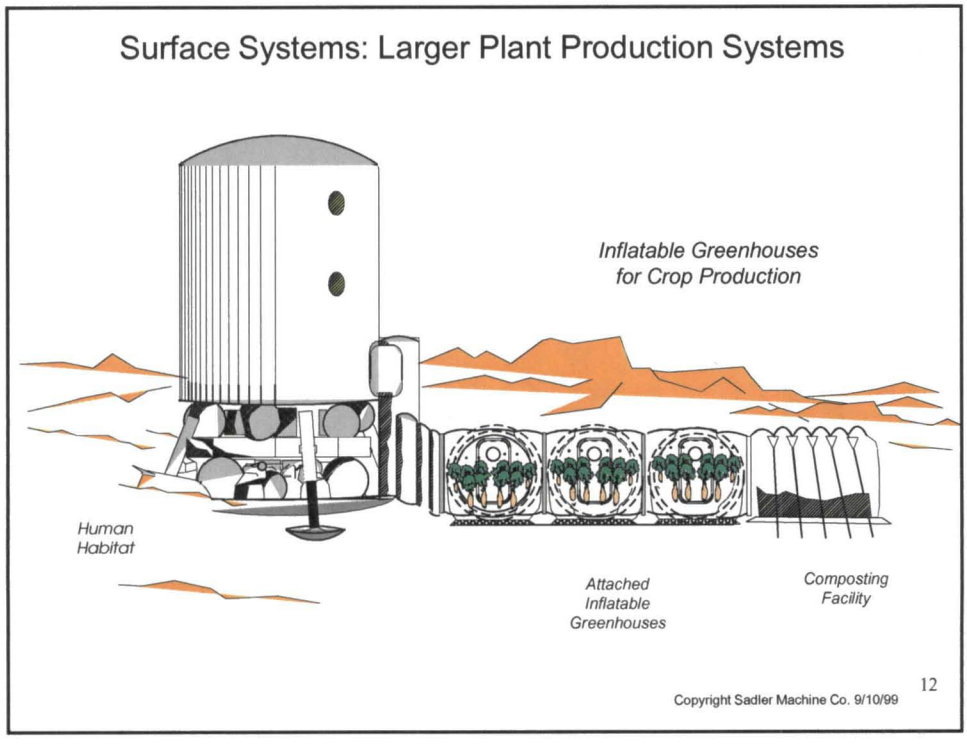
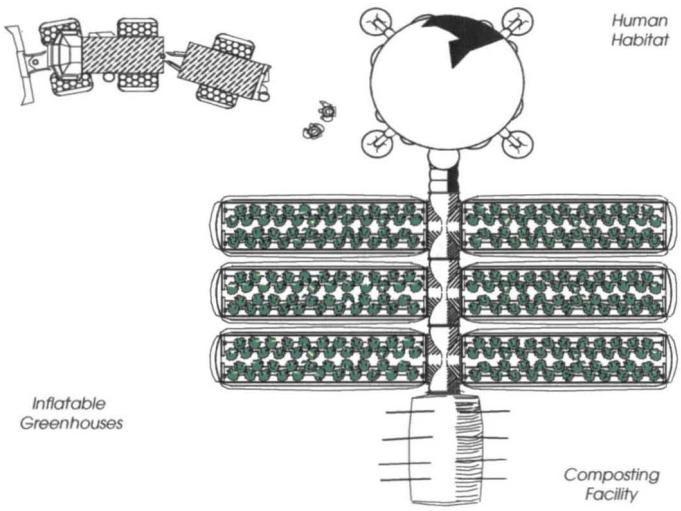

Pre-Deployment Missions:
Concept for Small Greenhouses or Plant Pods
Mars Night
Covers Close at Night for Insulation
Covers Open in Day and Serve as Reflectors
Mars Day
11


Surface Systems: Larger Plant Production Systems
Inflatable Greenhouses for Crop Production
Human Habitat
Attached Inflatable Greenhouses
Composting Facility
12
Copyright Sadler Machine Co. 9/10/99

Attached Inflatable Greenhouses



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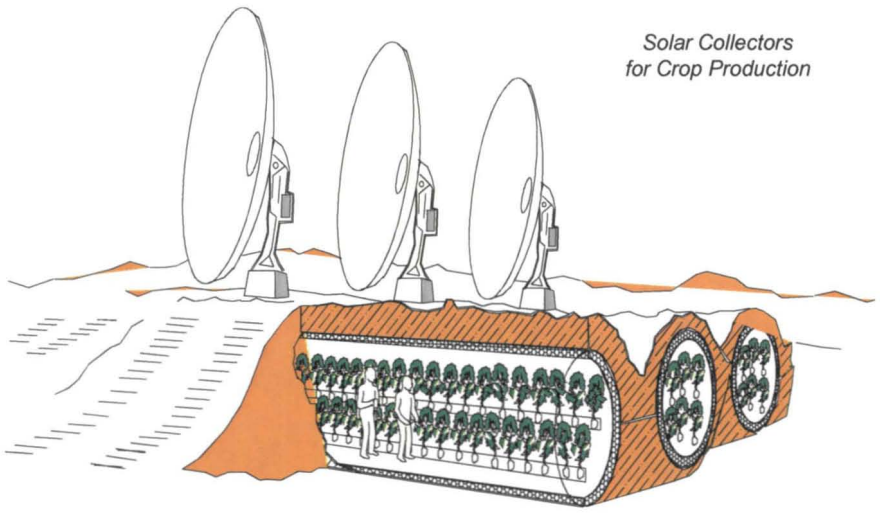

Buried Plant Growth Chambers

(for radiation shielding)

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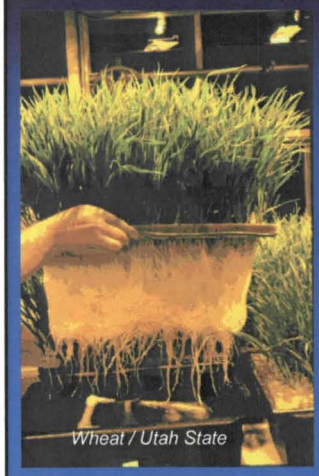
Surface Missions–Could Use Conventional Hydroponics



Conserve Water & Nutrients
Eliminate Water Stress
Optimize Mineral Nutrition
Facilitate Harvesting

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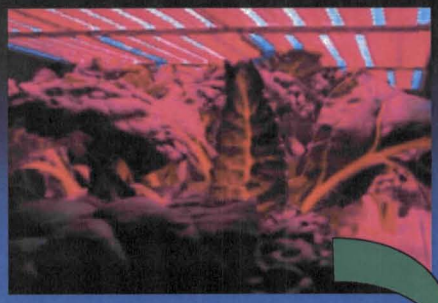
Energy Efficient Lighting will be Needed such as LEDs



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

John Sager, KSC, Testing Prototype Flight Plant Chambers with LEDs

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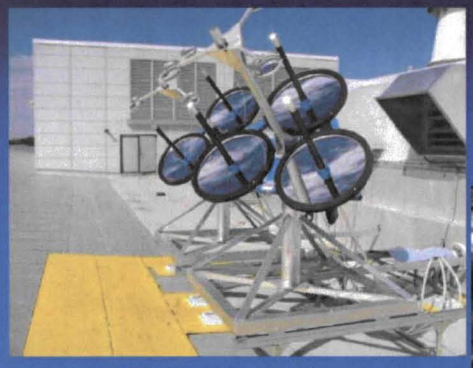
Solar Collector / Fiber Optics For Plant Lighting



2 m^2 of collectors on solar tracking drive (SLSL Bldg. KSC)

Up to 400 W light delivered to chamber (40-50% of incident light)

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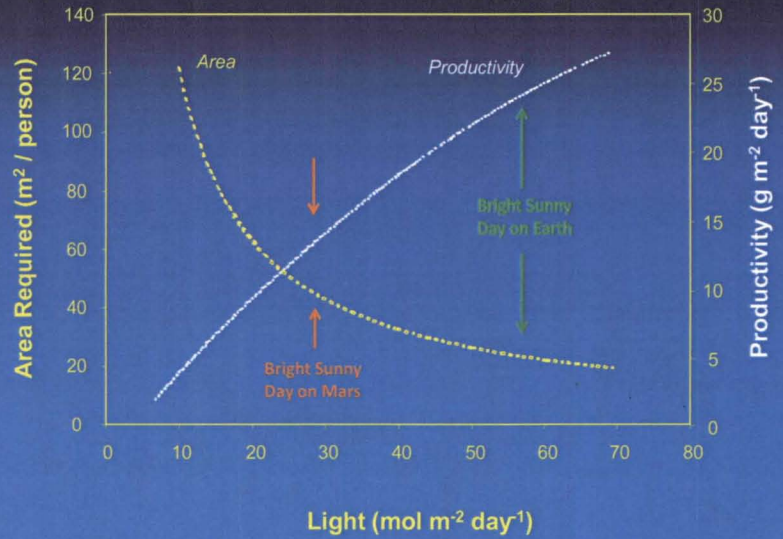
Light, Productivity, and Crop Area Requirements



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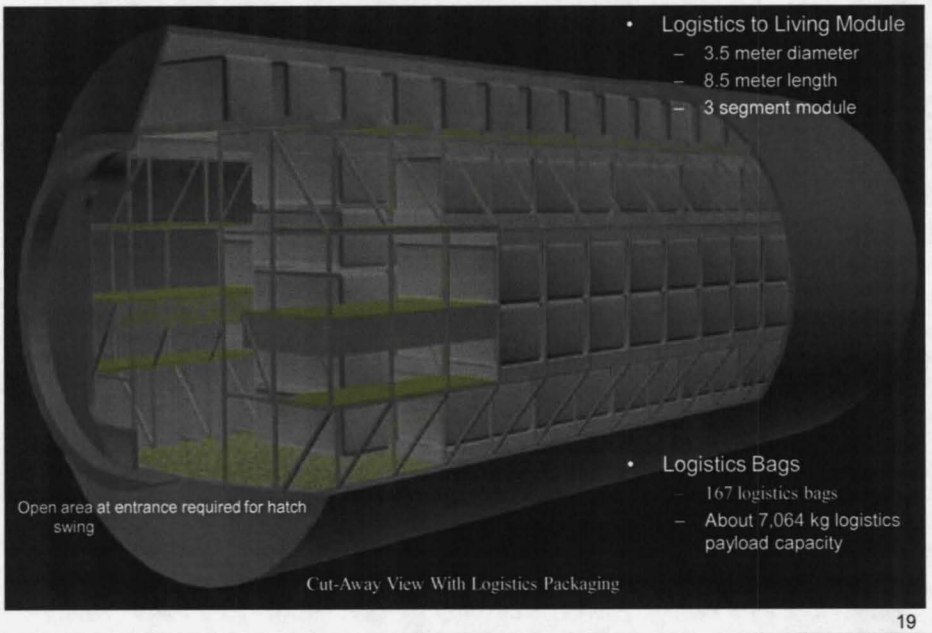
Logistics Module→ Surface Plant Module

NASA MSFC/ED03 Advanced Concept Office David Smitherman



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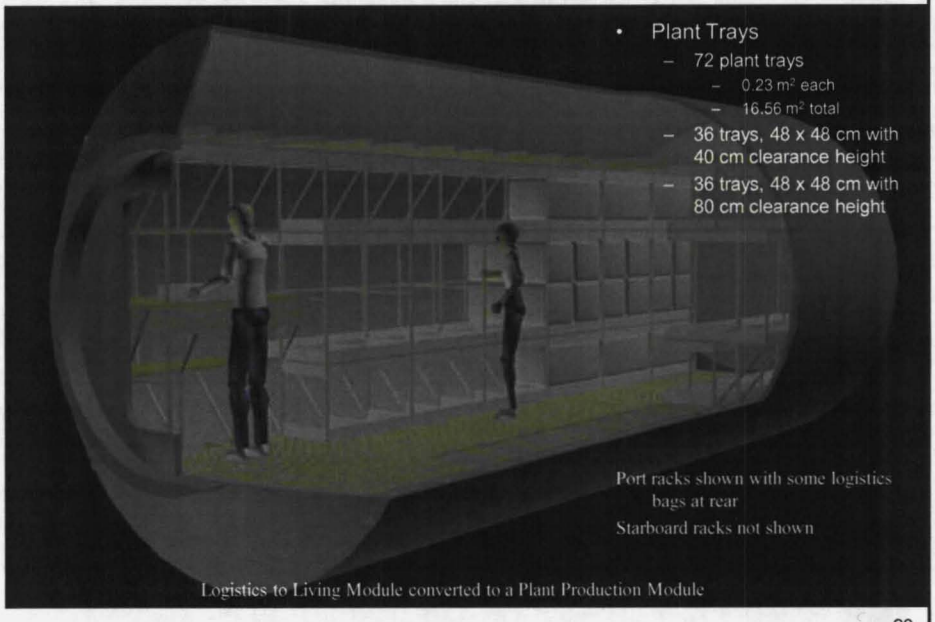
Logistics Module→ Surface Plant Module

NASA MSFC/ED03 Advanced Concept Office David Smitherman



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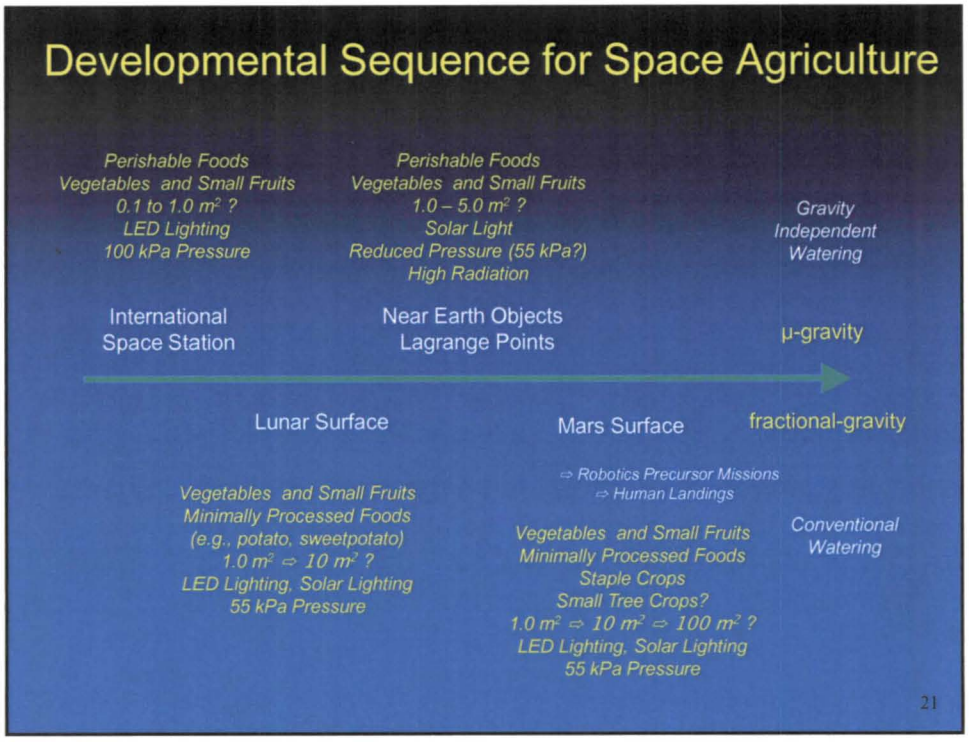
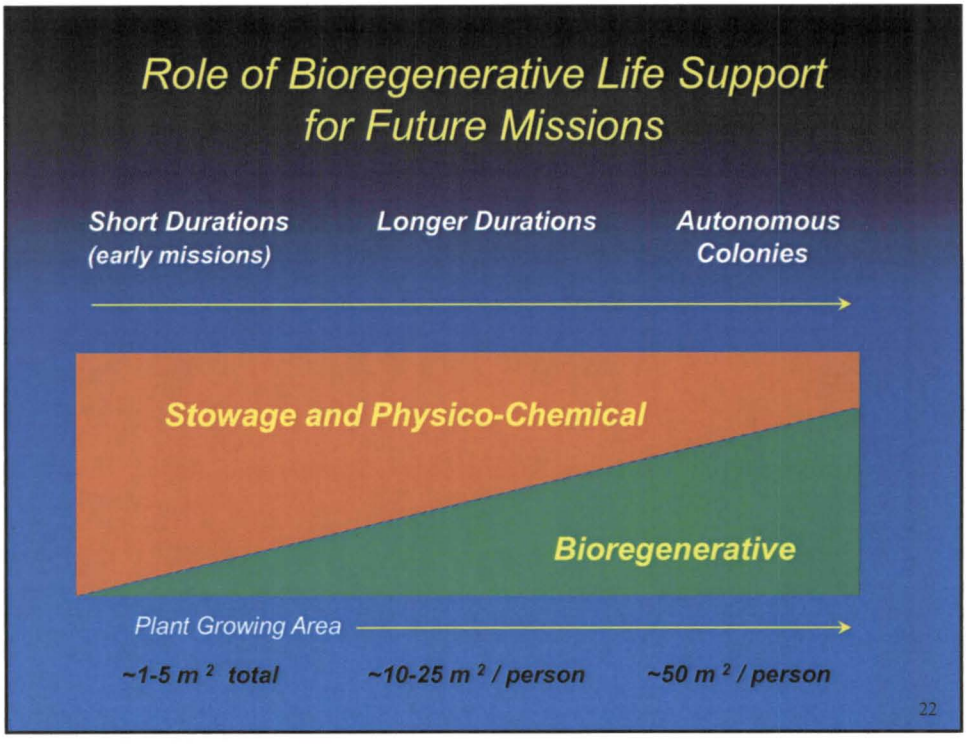

Developmental Sequence for Space Agriculture
Perishable Foods
Vegetables and Small Fruits
0.1 to 1.0 m² ?
LED Lighting
100 kPa Pressure
Perishable Foods
Vegetables and Small Fruits
1.0 – 5.0 m² ?
Solar Light
Reduced Pressure (55 kPa?)
High Radiation
Gravity
Independent
Watering
International
Space Station
Near Earth Objects
Lagrange Points
μ-gravity
Lunar Surface
Mars Surface
fractional-gravity
⇨ Robotics Precursor Missions
⇨ Human Landings
Vegetables and Small Fruits
Minimally Processed Foods
(e.g., potato, sweetpotato)
1.0 m² ⇨ 10 m² ?
LED Lighting, Solar Lighting
55 kPa Pressure
Vegetables and Small Fruits
Minimally Processed Foods
Staple Crops
Small Tree Crops?
1.0 m² ⇨ 10 m² ⇨ 100 m² ?
LED Lighting, Solar Lighting
55 kPa Pressure
Conventional
Watering
21


Role of Bioregenerative Life Support
for Future Missions
Short Durations
(early missions)
Longer Durations
Autonomous
Colonies
Stowage and Physico-Chemical
Bioregenerative
Plant Growing Area
~1-5 m² total
~10-25 m² / person
~50 m² / person
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Thanks to my colleagues at NASA's Kennedy Space Center

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