

**Ground-based demonstration
chambers in NASA's Advanced Life
Support Project**

Crew and Thermal Systems Division

Russ Fortson

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Ground-based demonstration chambers in NASA's Advanced Life Support Project

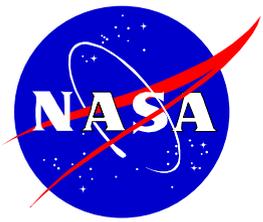
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Johnson Space Center

Houston, TX, USA





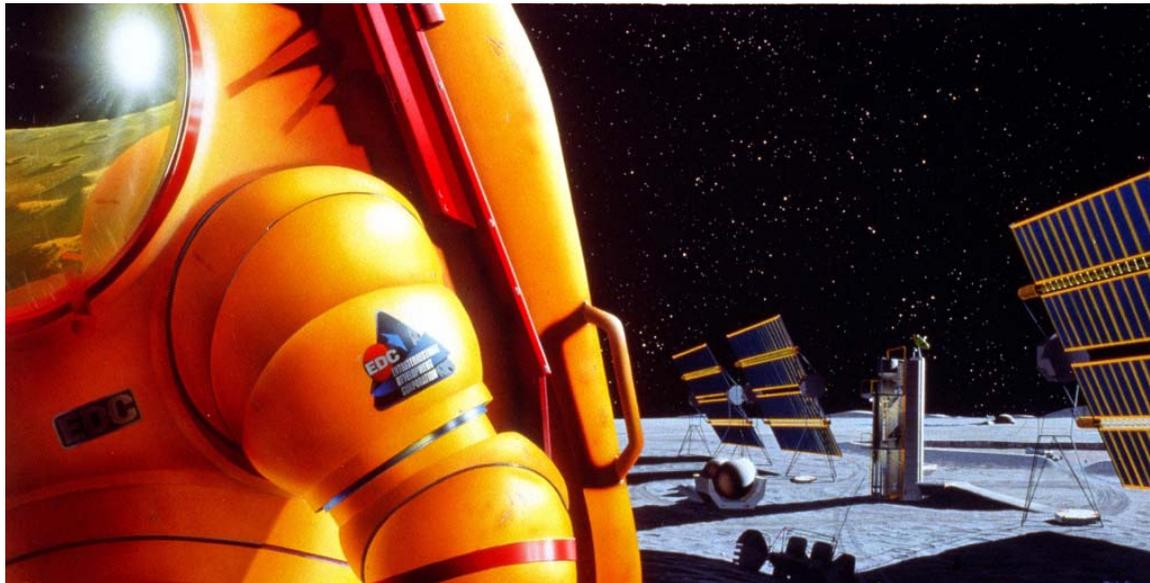
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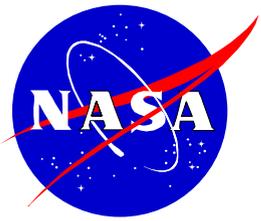
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- Overview of the Advanced Life Support project
- ALS at the Ames Research Center
- ALS at the Kennedy Space Center
- ALS at the Johnson Space Center
- Future plans





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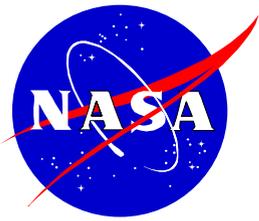
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Overview of the Advanced Life Support project

- **Advanced Life Support (ALS) is part of the Advanced Human Support Technology (AHST) program under the Biological and Physical Research Enterprise**
 - Annual funding of approximately \$25M (USD)
- **ALS systems consist of regenerative technology for long duration space missions**
 - Both biological and physicochemical processes are used to recycle air, water, waste and to grow crops for food
- **Complete ALS is composed of many components**
 - Air, Water, Plants, Food, Thermal, Solid Waste, Human Factors, Computer Controls, and Integration



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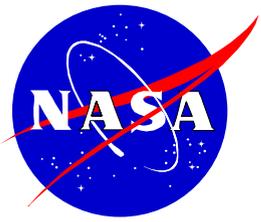
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Overview of ALS (continued)

- **ALS work has been conducted by NASA for years**
 - Initially focused on physicochemical systems
 - Later (and current) work focused on hybrid (biological / physicochemical) systems
- **ALS research has typically been focused on long duration exploration missions**
 - Mars
 - Earth's moon
- **Recent research is also looking for more near-term applications**
 - ISS
 - Mars transit vehicle
- **Work is divided among different NASA Field Centers, and integrated by the Johnson Space Center**
- **University and commercial partners also involved**



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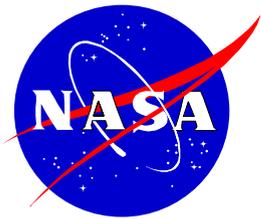
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Ames Research Center

- **Focuses mainly on physicochemical processes for air revitalization, water recovery and solid waste processing**
- **Currently, one controlled environment chamber used for testing the effects of waste gases on plant/biological processes**





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Ames Research Center Dose Response Chamber

- **Called the Dose Response Chamber, it has the following characteristics**
 - Monitoring uptake of flue gases, CO and NO_x by living systems (higher plants, ciliates, microbes etc)
 - Monitoring key plant physiological parameters (photosynthesis, respiration, transpiration, etc)
 - Performing eco-toxicological and eco-stimulatory studies
 - Performing waste integration/crop production studies



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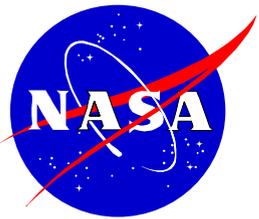
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Ames Research Center Dose Response Chamber





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Ames Research Center Dose Response Chamber

• Chamber Specifications

Parameter

Air temperature

Canopy temperature

Chamber pressure

Relative humidity

Photon flux, PAR

Control Range

15-40°C ± 1°C

15-40°C ± 1°C

90-125 kPa

45-95% ±5%

400-1000 $\mu\text{mol m}^{-2} \text{s}^{-1}$ ±50 $\mu\text{mol m}^{-2} \text{s}^{-1}$

• Chemical Measurements

Chemical

CO₂

O₂

CO

NO_x

Transpired H₂O

Control Range

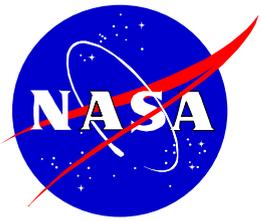
0-2000 $\mu\text{mol mol}^{-1}$ ±20 $\mu\text{mol mol}^{-1}$

0-3000 $\mu\text{mol mol}^{-1}$ ±30 $\mu\text{mol mol}^{-1}$

0-10000 $\mu\text{mol mol}^{-1}$ ±50 $\mu\text{mol mol}^{-1}$

0-10000 $\mu\text{mol mol}^{-1}$ ±50 $\mu\text{mol mol}^{-1}$

0.2-20 ml min^{-1} ±0.02 ml min^{-1}



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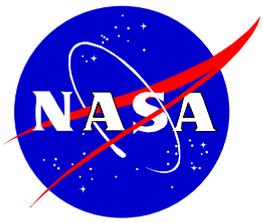
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Kennedy Space Center

- **The Kennedy Space Center focuses mainly on biological processes**
 - Plant growth
 - Biological water processing
 - Biological solid waste processing
- **A variety of chambers (custom and commercial) are used**
 - 15 commercial chambers with varying modifications
 - 1 large custom chamber (previously a hypobaric chamber)



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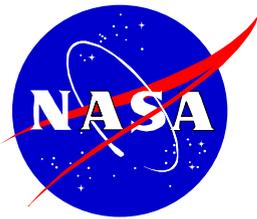
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- **The Biomass Production Chamber (BPC) is a converted hypobaric chamber built to test Mercury and Gemini capsules**
- **Converted in the late 1980's into a 2-story plant growth chamber**





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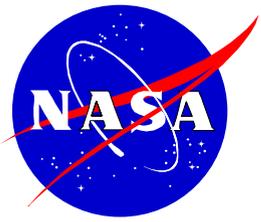
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- **Biomass Production Chamber specifications:**
 - 7.5 m high, 3.7 m diameter
 - 20 m² growing area
 - 2 stories to chamber, each with 2 levels of plant growth giving 2 distinct aerial zones and 4 distinct root zones
 - 1 hydroponic (thin film) nutrient delivery system (NDS) per root zone
 - Air temperature control range 10° - 35°C (or higher)
 - Relative humidity control range 70% - 95%
 - Nutrient temperature control range 15° - 22°C
 - Variable HPS lighting 200 - 700 μmol/m²/s PPF (at tray level)
 - Condensate recycled to the nutrient delivery system
 - CO₂, pH, electrical conductivity controllable within normal plant growth ranges



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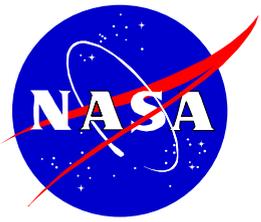
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- The BPC has been used for long-term plant growth tests
- Multiple crops (potatoes and wheat) grown over multiple life cycles
- Recycled plant nutrients (from previously harvested inedible biomass) used to supplement NDS





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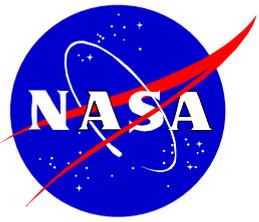
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- **A variety of commercial chambers are used**
- **Nearly all have been modified in some way**
 - **Examples include CO₂ control, nutrient delivery systems, alternative lighting systems, alternative temperature/RH controls**
- **One chamber used to simulate the middeck environment of the Space Shuttle orbiter**
- **Remaining chambers used for fundamental biology or plant research directly or indirectly supporting ALS**





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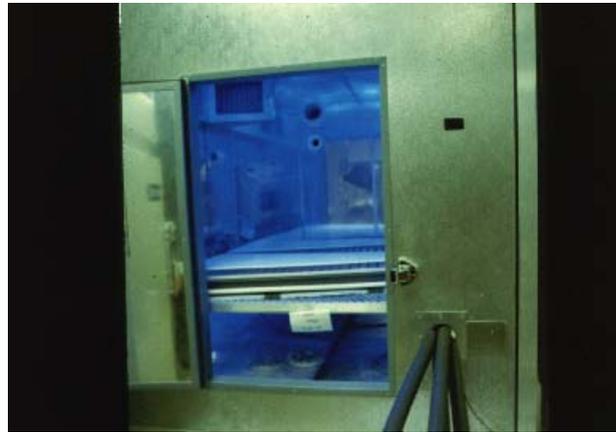
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- **Commercial chambers are from a variety of manufacturers**
- **Chamber sizes include walk-in, reach-in, and small incubators**





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- More chambers





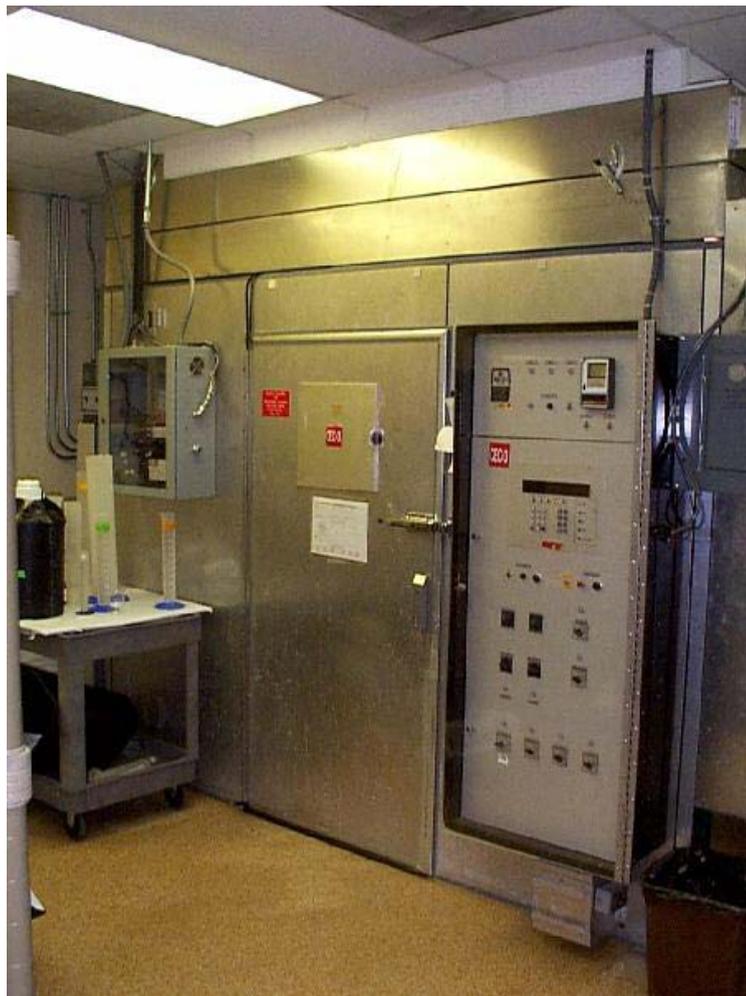
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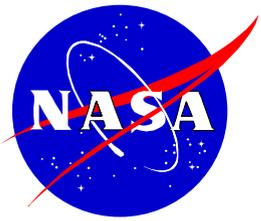
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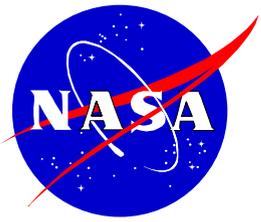
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- **JSC responsible for management of the ALS project agency-wide**
- **Involved in all technical areas of ALS**
- **Air revitalization, water recovery and food processing are areas of specific focus**
- **Technologies are integrated and tested with humans**
 - **Lunar-Mars Life Support Test Project 1995-1997**
 - **BIO-Plex in current plans**
 - **Specific technologies adapted to flight experiments**



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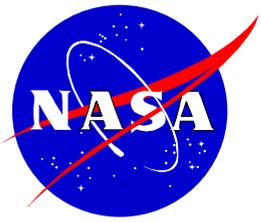
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- **JSC has long history with physicochemical life support systems**
- **More recently biological processes have been studied for water recovery**
- **Also involved with plant growth – solid substrates (planetary regolith, zeoponics) and hydroponics**





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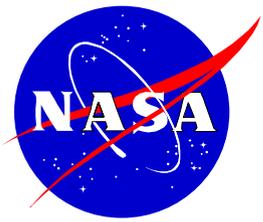
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- **JSC uses a variety of controlled environment chambers in the ALS project, commercial and custom**
- **Several commercial reach-in chambers of varying size used for plant growth studies, including flight hardware prototyping**
- **Former vacuum chamber converted to a walk-in plant growth chamber (Variable Pressure Growth Chamber)**
- **Another vacuum chamber used for integrated life support system tests (known as the 20' chamber)**
- **Large multi-chamber complex currently under construction for long-term integrated life support tests (Bioregenerative Planetary Life Support Systems Test Complex – BIO-Plex)**



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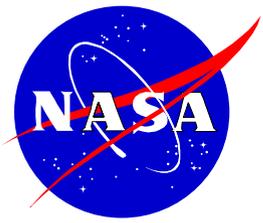
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- **Commercial growth chambers are used for a variety of plant growth studies**
 - Solid substrate development
 - Cultivar evaluation





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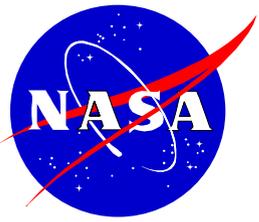
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- **More commercial chambers**
 - CO₂ control system added to several chambers
 - NDS varies depending on the test
 - » Thin film, solid substrate





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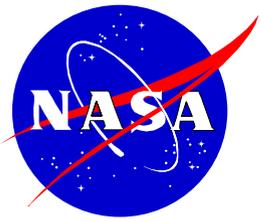
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- **Two small chambers are used to develop hardware and techniques for possible flight experiments**
 - Different lighting
 - Cultivar development
 - NDS development





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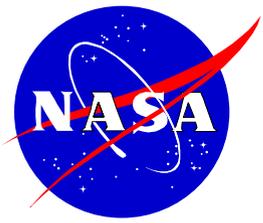
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- **Variable Pressure Growth Chamber (VPGC) used for large scale crop testing**
 - 11.2 m² of growing area
 - Variable pressure range 70 - 101 kPa
 - Air temperature range 18 – 35°C
 - Relative humidity 50 – 85%
 - Air velocity 0.1 – 1.0 m s⁻¹
 - Oxygen 18.5 – 29.0%
 - Carbon Dioxide 350 – 2500 μL L⁻¹
 - Ethylene detection (10 ppb) plus scrubbing
 - PPF 0 – 1500 μmol/m²/s (high pressure sodium)
 - Growing height 20 – 50 cm
 - Nutrient chemistry controlled in normal plant growth ranges



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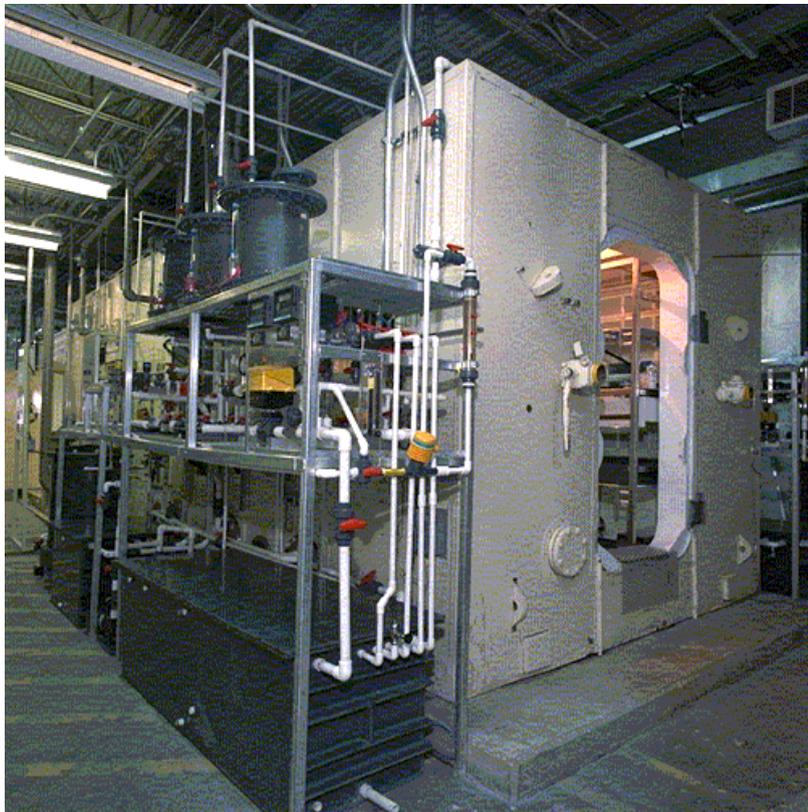
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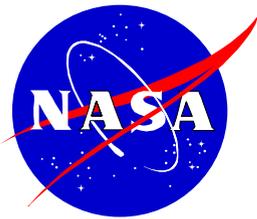
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- Variable Pressure Growth Chamber**





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- **Lunar Mars Life Support Test Project (LMLSTP) 1995-97 looked at integrating various advanced life support technologies with human test subjects**
- **Phase 1 lasted 15 days with one crew member**
 - Took place in VPGC
 - Tested the ability to control plant photosynthesis in response to crew need
- **Phase 2 lasted 30 days with 4 crew members**
 - Took place in the 20' chamber
 - Tested physicochemical processes for air/water recovery
- **Phase 2A lasted 60 days with 4 crew members**
 - Tested air/water recovery technologies baselined for ISS
- **Phase 3 lasted 91 days with a crew of 4**
 - Integrated biological and physicochemical processes for air/water recovery
 - Used both 20' chamber and VPGC
 - Initial attempts at solid waste processing using incineration (ARC)
 - Recycled nutrients (from KSC) used in VPGC to grow wheat for partial air revitalization and bread making
 - Lettuce production using LED lighting in small chamber within the 20' chamber



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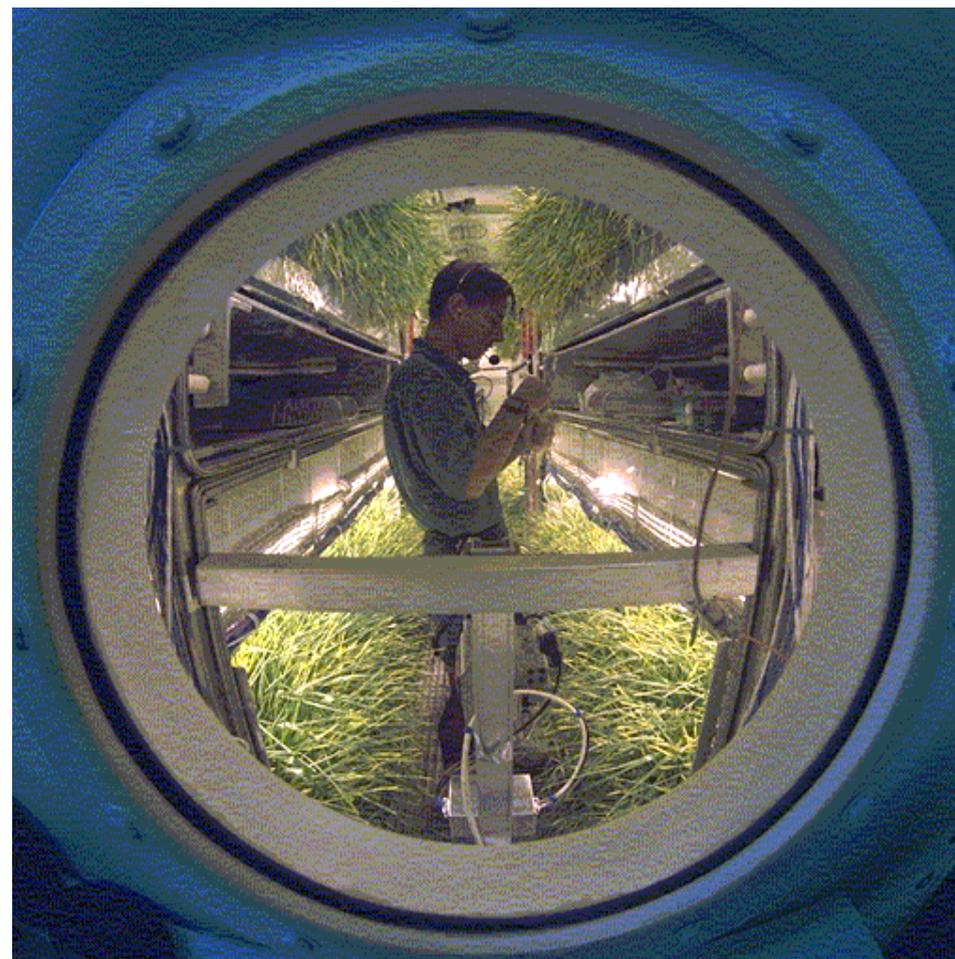
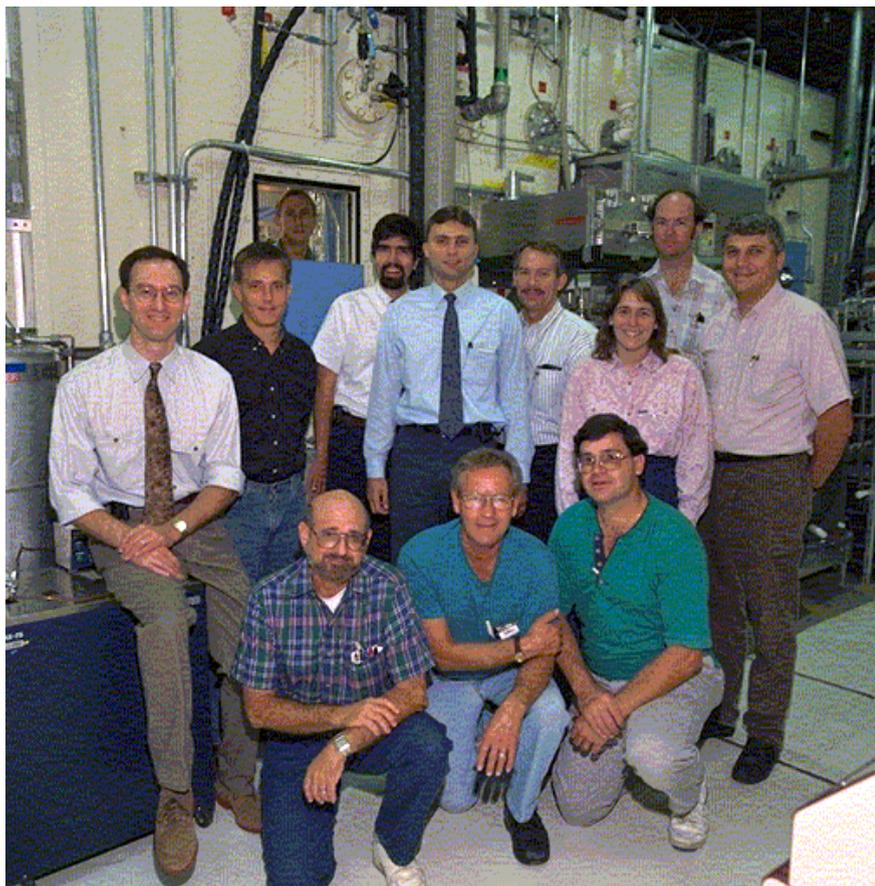
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- **LMLSTP Phase 1 (15 days)**





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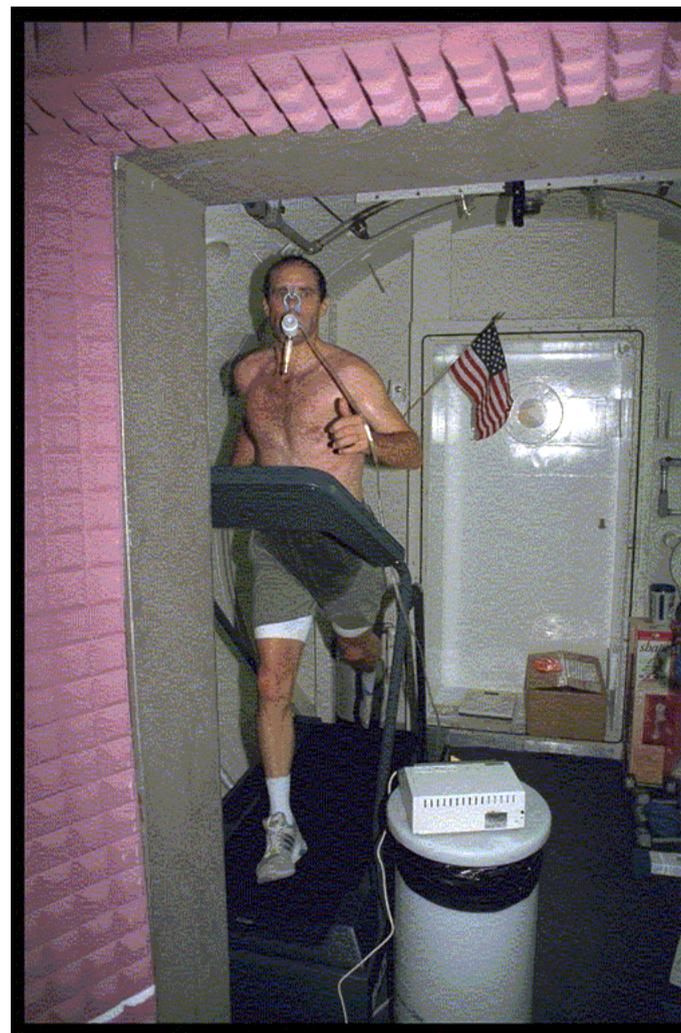
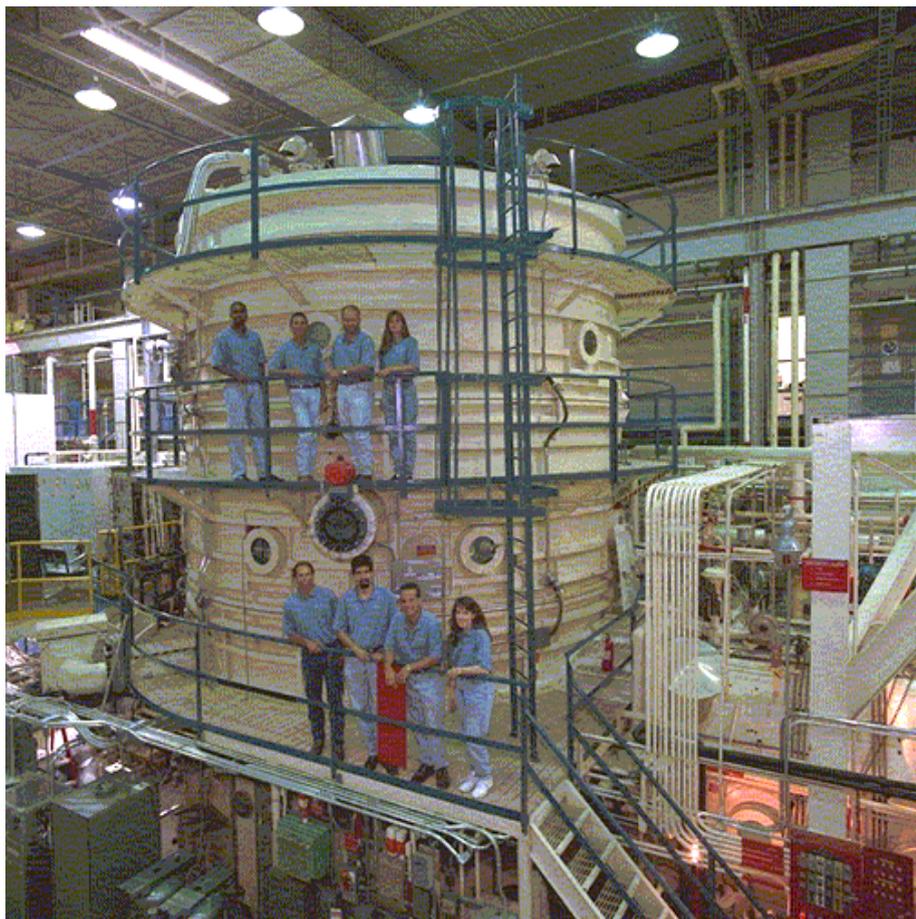
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- LMLSTP Phase 2 (30 days)





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- LMLSTP Phase 2A (60 days)**





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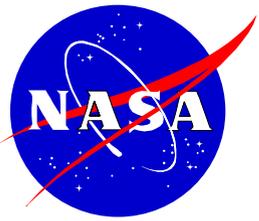
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- LMLSTP Phase 3 (91 days)





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- **Bioregenerative Planetary Life Support Systems Test Complex (BIO-Plex) planned as the next large-scale integration facility**
- **Planned for complete regenerative life support functionality**
 - **air, water, plant growth, food processing, solids processing, thermal control, computer controls, human accommodations, and science experiments**
- **Five chambers connected to a central tunnel**
 - **Each chamber 4.6 m in diameter and 11.3 m in length**
 - **Central tunnel is 3.6 m in diameter and 19.2 m in length**
 - **1 habitation chamber, 1 life support chamber, 2 biomass production chambers and 1 laboratory chamber, plus a 3.6 m by 4.6 m airlock**



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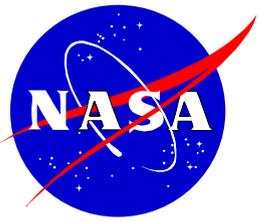
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- **Facility development currently on hold until Oct. 2002**
- **Four of five chambers in place awaiting outfitting**
 - second biomass production chamber to be added later
- **Power and emergency systems being installed**
- **Ventilation to be installed next**
- **After basic facility infrastructure, then life support system “test articles” will be added**
- **Test articles will be changed after each test**
- **Four tests presently planned**
 - 120 day initial checkout with 3 chambers
 - 2 - 240 day tests with 4 and 5 chambers
 - 540 day “capstone” test with 5 chambers



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- **Facility checkout in 2006**
 - Insures basic facility infrastructure is safe for test article buildup
- **Test article buildup and checkout 2006-2008**
- **BIO-Plex testing to start in 2008**





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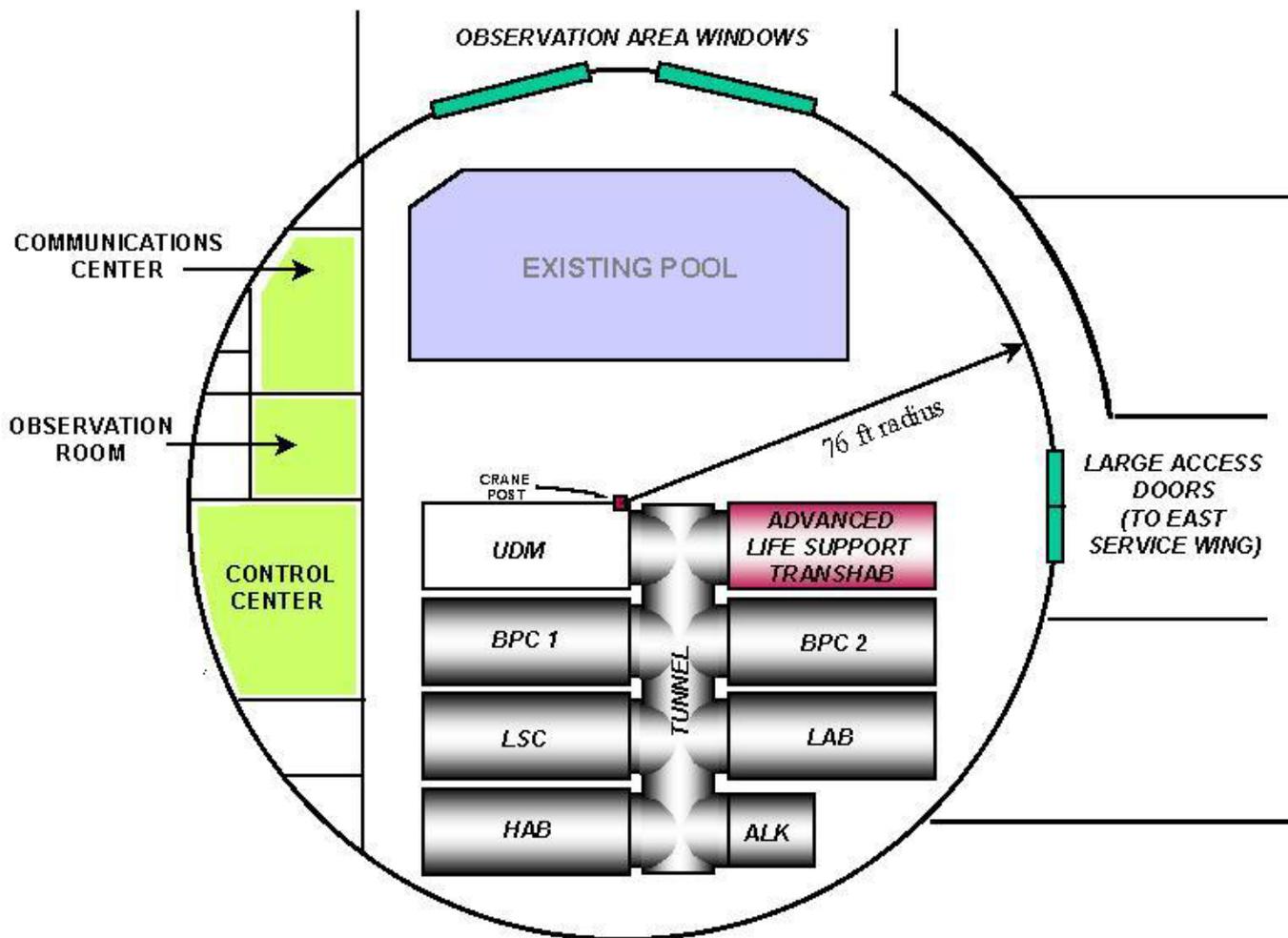
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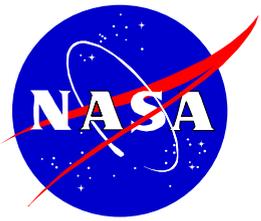
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- BIO-Plex layout





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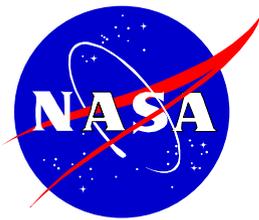
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- **One Biomass Production Chamber (BPC) in design**
- **Second BPC will be designed in the future after initial concepts are tried with BPC1**
- **Capable of multiple crops with a total of 75 m² of growing area**
- **10 separate growing areas, 4 with adjustable heights, 6 with fixed height**
- **Each growing area has separate NDS, lighting, air temperature and RH control**
- **Common gaseous environment with CO₂ controlled to 1200 ppm**



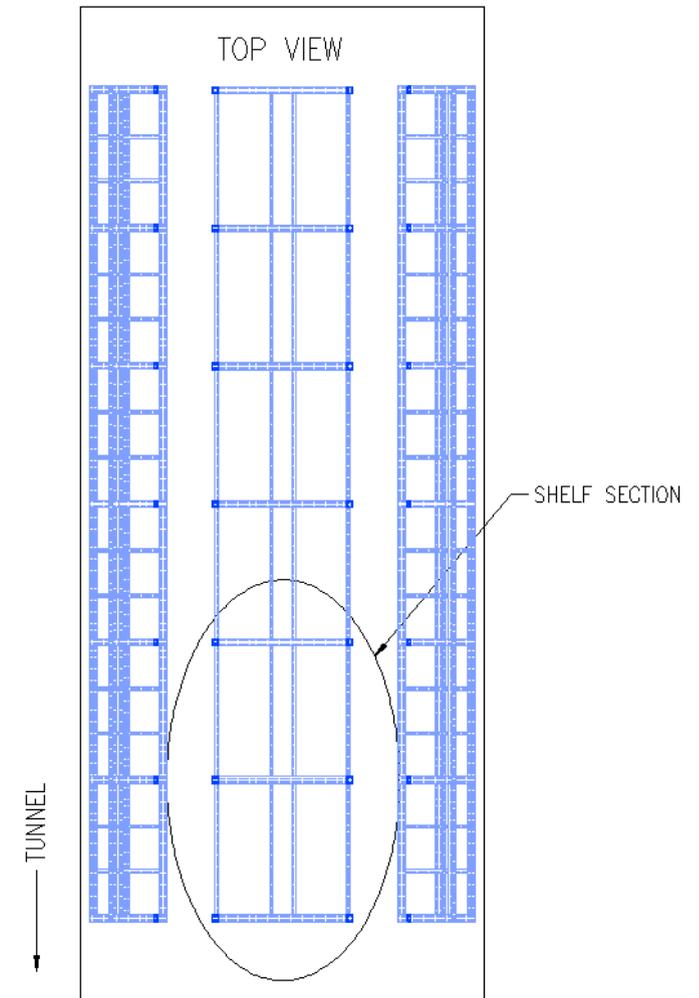
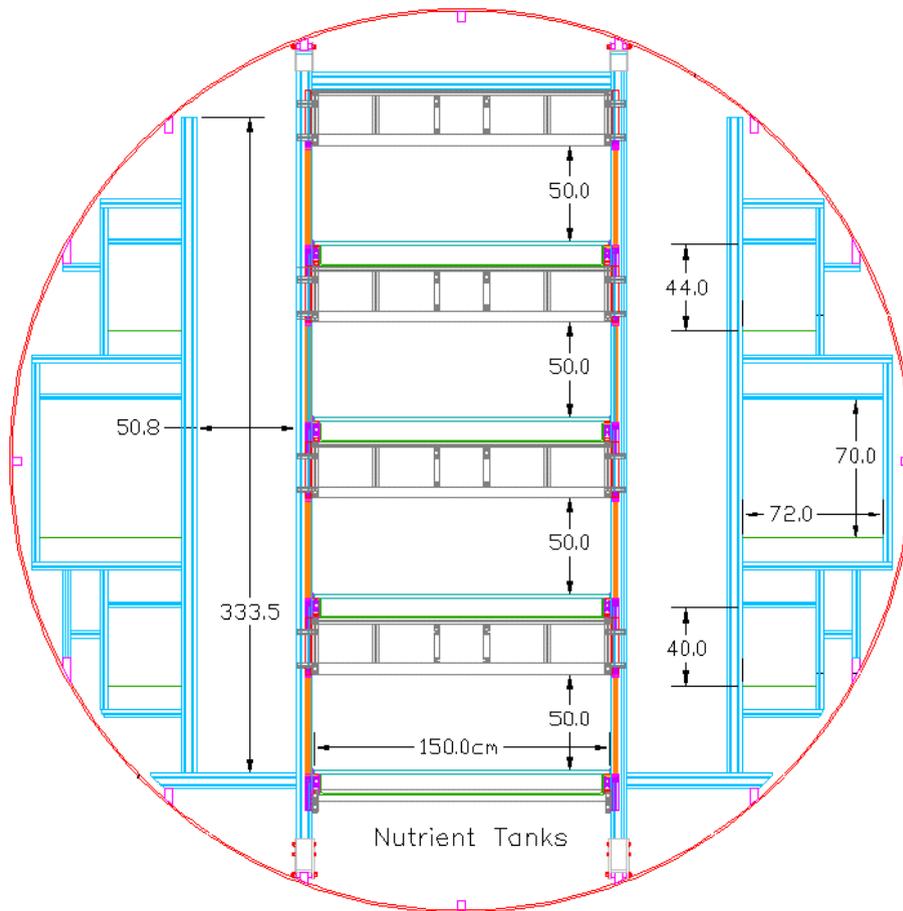
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Questions?

