Advanced Life Support

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http://advlifesupport.jsc.nasa.gov
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Advanced Life Support Roadmap

- AIR
  - Basic research
  - Concept feasibility proven
- WATER
  - Critical function verified
  - Component/breadboard validation (laboratory environment)
- CROP PRODUCTION
  - Fundamentals modeling
  - Operational envelope determination
- FOOD PROCESSING
  - Concept feasibility proven
  - Scale-up parameters determined
- SOLID WASTE PROCESSING (RESOURCE RECOVERY)
  - Basic research
- THERMAL CONTROL
  - Model development

RESEARCH AND TECHNOLOGY DEVELOPMENT
Advanced Life Support Topics

1. Fundamental Need for Advanced Life Support
2. ALS organization
   • Areas of research and development
   • Project management techniques
3. Requirements and Rationale
4. Past Integrated tests
5. The need for improvements in life support systems
6. ALS approach to meet exploration goals
   • Candidate groups of systems
7. ALS Projects showing promise to meet exploration goals
8. GRC involvement in ALS
# Human Life Support System Requirements

<table>
<thead>
<tr>
<th>Consumables</th>
<th>Kilograms per person per day</th>
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<tr>
<td><strong>Gases</strong></td>
<td></td>
</tr>
<tr>
<td>Oxygen</td>
<td>0.84</td>
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<tr>
<td><strong>Water</strong></td>
<td>23.4</td>
</tr>
<tr>
<td>Drinking</td>
<td>1.62</td>
</tr>
<tr>
<td>Water content of food</td>
<td>1.15</td>
</tr>
<tr>
<td>Food preparation water</td>
<td>0.79</td>
</tr>
<tr>
<td>Shower and hand wash</td>
<td>6.82</td>
</tr>
<tr>
<td>Clothes wash</td>
<td>12.50</td>
</tr>
<tr>
<td>Urine flush</td>
<td>0.50</td>
</tr>
<tr>
<td><strong>Solids</strong></td>
<td>0.6</td>
</tr>
<tr>
<td>Food</td>
<td>0.62</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>24.8</td>
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</table>

<table>
<thead>
<tr>
<th>Wastes</th>
<th>Kilograms per person per day</th>
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<tr>
<td><strong>Gases</strong></td>
<td></td>
</tr>
<tr>
<td>Carbon Dioxide</td>
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<tr>
<td><strong>Water</strong></td>
<td>23.7</td>
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<tr>
<td>Urine</td>
<td>1.50</td>
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<tr>
<td>Perspiration/respiration</td>
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<tr>
<td>Fecal water</td>
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<tr>
<td>Shower and hand wash</td>
<td>6.51</td>
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<tr>
<td>Clothes wash</td>
<td>11.90</td>
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<tr>
<td>Urine flush</td>
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<td>Humidity condensate</td>
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<td><strong>Solids</strong></td>
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<tr>
<td>Urine</td>
<td>0.06</td>
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<td>Feces</td>
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<tr>
<td>Perspiration</td>
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<td>Shower &amp; hand wash</td>
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<tr>
<td>Clothes wash</td>
<td>0.08</td>
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<td><strong>TOTAL</strong></td>
<td>24.9</td>
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Human Life Support System Requirements

Open-Loop Life Support System
Resupply Mass - 12,000 kg/person-year
(26,500 lbs/person-year)

- Water 89%
- Oxygen 2.5%
- Food (dry) 2.2%
- Crew Supplies 2.1%
- Gases lost to space 2.1%
- Systems Maintenance 2.1%

10,680 kg
(23,545 lbs)
(2827 gallons)
Mass Cost of Human Mars Mission Using Today’s Technologies

The NASA Exploration Team [NExT]
Advanced Life Support (ALS)

ALS research and technology development provides technology options that either address:

- **Bioastronautics Critical Path Roadmap (BCPR) risk**
- **Improved efficiency (lower mass, power and volume)**
  
  - Closure of the air, and water loops is critical
    
    • Solid Waste, Thermal Control improvements contribute to efficiency
  
  - Technology development is undertaken after rigorous systems analysis including the current baseline (ISS and Shuttle) systems.

  - Technology maturation is accomplished through validation and demonstration in integrated test beds and flight experiments
    
    • ALS takes technologies from very low Technology Readiness Level concepts (TRL 1-3) to mature technologies at TRL 6 via test and analysis
    
    • Make the technology available for consideration in an exploration vehicle
WHY MUST WE DEVELOP NEW ALS SYSTEMS?

Shuttle/ISS life support technologies are mass, power and resupply intensive.

Lunar and Mars missions
- a high degree of closure of oxygen and water regeneration loops and efficient low mass thermal management is required.
- subsequent closure of the food loop along with containment and recycling of solid wastes must be pursued.

Lunar or planetary bases - greater autonomy of life support system reduces the dependency on resupply missions, thereby increasing safety and reducing cost.

Pertinent Connections to BCPR

<table>
<thead>
<tr>
<th>Risk #</th>
<th>Risk Title</th>
<th>ISS</th>
<th>Moon</th>
<th>Mars</th>
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</thead>
<tbody>
<tr>
<td>43</td>
<td>Maintain Acceptable Atmosphere</td>
<td>G</td>
<td>Y</td>
<td>R</td>
</tr>
<tr>
<td>44</td>
<td>Maintain Thermal Balance in Habitable Areas</td>
<td>G</td>
<td>Y</td>
<td>R</td>
</tr>
<tr>
<td>45</td>
<td>Manage Waste</td>
<td>G</td>
<td>Y</td>
<td>R</td>
</tr>
<tr>
<td>46</td>
<td>Provide and Maintain Bioregenerative Life Support Systems</td>
<td>G</td>
<td>Y</td>
<td>R</td>
</tr>
<tr>
<td>47</td>
<td>Provide and Recover Potable Water</td>
<td>G</td>
<td>Y</td>
<td>R</td>
</tr>
<tr>
<td>48</td>
<td>Inadequate Mission Resources for the Human System</td>
<td>Y</td>
<td>R</td>
<td>R</td>
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</tbody>
</table>

Many enabling questions are addressed in the seven principal risks listed above.
This effort also addresses enabling questions for shared risks of other Bioastronautics disciplines.
ALS IMPLEMENTATION

Coordinating Center: JSC

The JSC EC Advanced Life Support Manager administers the overall Advanced Life Support Budget for JSC, ARC, KSC, MSFC, (GRC in 05)

Participants

– NASA Field Centers, including ARC, GRC, JPL, JSC, KSC, MSFC and their affiliated institutes.
– NASA Research Partnership Centers including BST, CAMMP, CSP, ES-CTSC, FTCSC, and WCSAR.
– Principal investigators with research and technology offerings sponsored through other programs such as EPSCoR and congressional earmarks.
– Contractors and small business concerns who respond to competitive contracts and SBIR/STTR program solicitations.
– Assistance and collaboration will be sought by experts within existing flight programs including ISS, Shuttle, and Project Constellation.

Funding

– Funding for tasks is implemented through the most appropriate method.
– Funding methods include: NASA Research Announcements, Technology Development Proposals, Technical Task Agreements, Competitive Procurements.

Leveraging

– SBIR, STTR, EPSCoR, GSRP, NRC, Code R/T/M, SFF, NASA CO-OP Program
Advanced Life Support Program Element Organization

Advanced Life Support Office (JSC)

Manager - B. M. Lawson
Dpty. Manager Research - D. Barta
Dpty. Manager Engineering - J. Chambliss
Schedule & Budget Analyst – P. Bashinski

Engineering Manager - S. Down
Systems Engineer – J. Keener
Administrative Assistant - C. Whatley

ALS Integration

Flight Experiments and Integrated Testing Manager
P. Bethke (acting) with D. Treat

Education/Outreach Manager
G. Koerner (acting)

Systems Integration, Modeling & Analysis (SIMA) Manager
Mike Ewert with T. Hanford

Supporting R&TD NASA Centers

ARC R&TD
M. Kliss, Lead

KSC R&TD
J. Sager, Lead

MSFC R&TD
J. Perry, Lead

External Principal Investigators

NRA
SBIR/STTR
GSRP
NRC, Other

External Research and Technology Development Groups

ALS NASA Specialized Center of Research & Training
C. Mitchell/Purdue Univ.

Environmental Systems Commercial Space Technology Center
(W. Sheehan, Univ. of Florida)

Center for Food & Environmental Systems for Human Exploration of Space (Tuskegee Univ.)
D. Mortley

Center for Space Sciences (Texas Tech University)
J. Smith

ALS Technical Elements

Air Revitalization Element
E. Smith, Lead
• Research
• Technology Devel
• Testing

Water Recovery Element
L. Shaw, Acting Lead
• Research
• Technology Devel
• Testing

Solid Waste Management Element
J. Fisher, Lead
• Research
• Technology Devel
• Testing

Crop Systems Element
R. Wheeler, Lead
• Research
• Technology Devel
• Testing

Thermal Control Element
D. Westheimer, Lead
• Research
• Technology Devel
• Testing

International ALS Working Group
NASA, Japan, Canada, ESA, Russia

Science & Technology Working Group
Al Sacco, Chair

External Advisory Group
Advanced Life Support (ALS) Areas

- Air Revitalization Systems
- Crop Systems
- ALS Flight Experiments
- Advanced Thermal Control Systems
- Advanced Water Recovery Systems
- Systems Integration Modeling & Analysis
- Solid Waste Management
- Integration & Test

Research Centers:
- JSC (38) 9 19
- ARC (39) 5 5
- KSC (46) 4 xx

Manpower:
- TDP (39)
- NRA (26)
Augmentation Major Products

**Air**
- Gas Supply (2)
- CO₂ Removal (3)
- Advanced CO₂ Reduction
- Regenerative Trace Contaminant Control
- Efficient, Low Noise Air Flow System

**Water**
- Advanced Biological Primary Water Processor
- Ultrafiltration
- Next Generation Phys/Chem Primary Water Processor
- Reverse Osmosis
- Brine Dewatering
- Post Processors
- Alternative Disinfection Technologies

**Bioregenerative Systems**
- Sustained Crop Production Testing
- Hypobaric Plant Test Chambers
- Mineral and Water Recycling Testing
- Vegetable Production Unit EDU
- Microbial Risk Assessments

**Thermal**
- Advanced Coldplate Development
- Humidity Control Device
- Structural Radiator Prototype
- Evaporator Prototype
- Sublimator Prototype

**Solid Waste**
- Compactor
- Stabilization & Containment
- Water Recovery Technology
- Mineralization Technology

**Ground Test**
- 20’ Chamber Certified for Reduced Pressure Testing.
### Past ALS Testing

**Lunar Mars Life Support Test Project**

<table>
<thead>
<tr>
<th></th>
<th>Phase I</th>
<th>Phase II</th>
<th>Phase II A</th>
<th>Phase III</th>
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<tbody>
<tr>
<td><strong>Duration</strong></td>
<td>15-days</td>
<td>30-days</td>
<td>60-days</td>
<td>91-days</td>
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<tr>
<td><strong>Dates</strong></td>
<td>Completed August '95</td>
<td>Completed July '96</td>
<td>Completed March '97</td>
<td>Completed December '97</td>
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<tr>
<td><strong>Crew Size</strong></td>
<td>1</td>
<td>4</td>
<td>4</td>
<td>4</td>
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<tr>
<td><strong>Technologies</strong></td>
<td>Air revitalization using crops with P/C</td>
<td>Regenerative P/C technologies</td>
<td>ISS life support technologies</td>
<td>Integration of physicochemical &amp; biological technologies</td>
</tr>
<tr>
<td><strong>Regeneration</strong></td>
<td>Air</td>
<td>Air &amp; water</td>
<td>Air &amp; water</td>
<td>Air, water, solid waste, food</td>
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</tbody>
</table>
Lunar Mars Life Support Test Project

Phases III: 91-day, 4-Person Tests

- Biological Water Recovery System
- Carbon Dioxide Removal System
- Carbon Dioxide Reduction System
- Oxygen Generation System
- Solid Waste Incinerator

Control Room

VPGC Wheat Harvest

Phase III Crew (left to right, Nigel Packham, Laura Supra, John Lewis, Vickie Kloeris)
ALS Integrated Test Plans Support the Exploration Timeline


- First Uncrewed CEV Flight
- 1st Crewed CEV Flight
- 1st Human Mission to Moon
- Lunar landing outpost
- Last year for lunar landing

CEV ECLSS Tech Test System A

Lunar Outpost
Tech. Test System B&C

Lunar Outpost Bioregenerative Test System C

6 year prime contractor lead-time
Advanced Life Support Approach for Supporting NASA Exploration

• Preliminary analysis shows the exploration program will require at least three different environmental control systems architectures
  – A) a short duration, open-loop system architecture;
  – B) a zero-g, medium duration system architecture; and
  – C) a partial-g, long duration system architecture.

• Technologies for these systems need to be matured to technology readiness level (TRL) 6, to lower program risk and to provide mature technology selections for the vehicles’ integrating contractors.

• A technology development program that will demonstrate these technologies on the ground in an integrated fashion prior to committing to flight designs is essential.
# Parameters for Human Life Support Across Mission Scenarios

<table>
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</thead>
<tbody>
<tr>
<td><strong>Duration (Human Tended)</strong></td>
<td>7 – 14 days (Roundtrip)</td>
<td>1 – 5 days</td>
<td>1 – 18 months</td>
<td>12 – 24 months (Roundtrip)</td>
<td>1 – 45 days</td>
<td>17 – 20 months</td>
<td>1 – 7 days</td>
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<tr>
<td><strong>Air Revitalization</strong></td>
<td>Open</td>
<td>Open</td>
<td>Closed</td>
<td>Closed</td>
<td>Open</td>
<td>Closed ISRU</td>
<td>Open</td>
</tr>
<tr>
<td><strong>Water Recovery</strong></td>
<td>Collection and Storage</td>
<td>Collection and Storage</td>
<td>Closed ISRU</td>
<td>Closed</td>
<td>Collection and Storage</td>
<td>Closed ISRU</td>
<td>Collection and Storage</td>
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<tr>
<td><strong>Waste Management</strong></td>
<td>Stored</td>
<td>Stored</td>
<td>Volume Reduction</td>
<td>Volume Reduction</td>
<td>Volume Reduction</td>
<td>Volume Reduction</td>
<td>Stored</td>
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<tr>
<td><strong>Food Systems</strong></td>
<td>Conventional Stored</td>
<td>Conventional Stored</td>
<td>Conventional Stored with Fresh Food Augmentation</td>
<td>Extended Shelf Life with Fresh Food Augmentation</td>
<td>Extended Shelf Life</td>
<td>Extended Shelf Life with Fresh Food Augmentation</td>
<td>Extended Shelf Life</td>
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<tr>
<td><strong>Thermal Systems</strong></td>
<td>LP-BR</td>
<td>LP-DR</td>
<td>HP-DR</td>
<td>HP-DR</td>
<td>LP-BR</td>
<td>HP-DR</td>
<td>LP-BR</td>
</tr>
</tbody>
</table>

Closed Air is 75% by Mass  
Closed Water is 90% by Mass  
ISRU –Investigate and utilize as appropriate  
Regenerative Systems will be selected over consumable systems  
System A: Short-duration, micro-g  
System B: Long-duration, micro-g  
System C: Long-duration, planetary surface, partial-g
Mars Mission Concepts
Mars Planetary Base – A Sustainable Presence

• Permanent presence
• Power and volume: significantly more is available
• Hypoogravity environment
• Types of systems:
  • Integration of physicochemical and biological technologies
  • Closure of air & water loop
• Food: staple foods grown, processed by food system, contribute substantially to caloric requirements and to air and water regeneration
• Solid waste management:
  • may be processed to recover resources
• EVA: Extensive with overnight stays
• Communication:
  • highest degree of crew autonomy
ALS Projects Showing Promise for Exploration

• ALS Proposed Projects show great promise to meet exploration goals
  – Sabatier- CO2 reduction
  – Advanced Trace Contaminant Control
  – Advanced CO2 removal and reduction system
  – Biological Water Processor
  – Rotating Reverse Osmosis
  – Vapor Phase Catalytic Ammonia Removal System
  – Cascade Distillation System
  – Low power two-phase Active Thermal Control System
  – Advanced thermal and humidity control
  – Multi application gravity insensitive heat pump
  – Solid waste management compaction
  – Dry and Wet Pyrolysis
  – Lyophilization (Freeze Drying)
  – Vegetable Production Unit

• Ground and Flight experimentation is needed to establish capabilities
• To evaluate technologies Systems Integrated Modeling and Analysis and integrated testing is needed
Glenn Research Center
Contribution to ALS

- FY05 ALS plans call for GRC support to provide expertise in assessing microgravity and fluid physics areas related to ALS technologies
  - GRC to provide design tools, experimentally validated components, trade studies and trouble shooting
  - Two-phase separation processes
    - Gas tolerant pumping assemblies
    - Evaporative cooling techniques
    - Condensing HXs
    - Gas/Liquid separation devices
    - Liquid/Solid Separation of waste products
  - Reactor bed processes in micro and partial gravity
    - Design tools and techniques to address fine generation
    - Fluid flow processes in filtration assemblies
  - GRC to serve as technical monitor for NSCORT effort related to biofilters for trace contaminant removal
    - Related to water distribution, choking or channeling and nutrient supply
Acronyms

- BST – Bioserve Space Technologies NASA Research Partnership Center, University of Colorado.
- BWP - Biological Water Processing
- CAMMP – Center for Advanced Microgravity Materials Processing. Northeastern University, Boston, Massachusetts.
- CSP – Center for Space Power. Texas A&M University.
- EPSCoR – Experimental Program to Stimulate Competitive Research.
- FTCSC – Food Technology Commercial Space Center. Iowa State University.
- GSRP – Graduate Student Researchers Program
- LTV - Lunar Transit Vehicle
- LLV - Lunar Landing Vehicle
- LO - Lunar Outpost
- MTV - Mars Transit Vehicle
- MLV - Mars Landing Vehicle
- MH - Mars Habitat
- NRC – National Research Council Fellowships
- PR - Pressurized Rover
- P-C - Physiochemical
- SBIR/STTR – Small Business Innovative Research/Small Business Technology Transfer
- SFF – Summer Faculty Fellowships
- WCSAR – Wisconsin Center for Space Automation & Robotics