Space Life Support

- Overview
- Major Component Systems
- Open-loop Life Support
- Physico-Chemical
- Bioregenerative
- Extravehicular Activity
Essentials of Life Support

- **Air**
  - Constituent control
    - $CO_2$ scrubbing
    - Humidity control
    - Particulate scrubbing
    - $O_2, N_2$ makeup
  - Temperature control
- **Water**
- **Food**
- **Waste Management**
ISS Life Support Schematic


Space Life Support
Principles of Space Systems Design
# ISS Consumables Budget

<table>
<thead>
<tr>
<th>Consumable</th>
<th>Design Load (kg/person-day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxygen</td>
<td>0.85</td>
</tr>
<tr>
<td>Water (drinking)</td>
<td>1.6</td>
</tr>
<tr>
<td>Water (in food)</td>
<td>1.15</td>
</tr>
<tr>
<td>Water (clothes and dishes)</td>
<td>17.9</td>
</tr>
<tr>
<td>Water (sanitary)</td>
<td>7.3</td>
</tr>
<tr>
<td>Water (food prep)</td>
<td>0.75</td>
</tr>
<tr>
<td>Food solids</td>
<td>0.62</td>
</tr>
</tbody>
</table>
## Effect of Regenerative Life Support

- **Open loop life support** 100% resupply
- + Waste water recycling 45%
- + $CO_2$ absorbent recycling 30%
- + $O_2$ regenerate from $CO_2$ 20%
- + Food from wastes 10%
- + Eliminate leakage 5%
Air Revitalization Processes

From Peter Eckart, Spaceflight Life Support and Biospherics, Kluwer Academic, 1996
Cabin Atmospheric Pressure

- Past choices driven by minimum mass
  - Mercury/Gemini: 100% $O_2$ @ 3.5 psi
  - Apollo: 100% $O_2$ @ 5 psi
  - Skylab: 80% $O_2$/20% $N_2$ @ 5 psi
  - Shuttle/ISS: 21% $O_2$/79% $N_2$ @ 14.7 psi
- Issues of compatibility for docking vehicles, denitrogenation for EVA
- Current practice driven by avionics, concern for research protocols
**Oxygen Makeup Systems**

- **Gaseous O\(_2\)** storage (also N\(_2\))
  - Typical pressures 200 atm (mass optimized) to 500-700 atm (volume optimized)
  - 2 kg tank/kg O\(_2\)
- **Liquid O\(_2\)** storage (also N\(_2\))
  - Requires 210 kJ/kg for vaporization (~2W/person)
  - Supercritical storage T=-118.8°C, P=49.7 atm
  - 0.3-0.7 kg tank/kg O\(_2\)
- **Solid perchlorates** (“candles”)
  - LiClO\(_4\) \(\rightarrow\) LiCl + 2O\(_2\) +Q @ 700°C
  - 2.75 kg LiClO\(_4\)/kg O\(_2\) (Typically 12.5 kg with packaging)
Superoxides and Ozonides

- **O₂ generation**
  - \( \text{K} \text{O}_2 + 2\text{H}_2\text{O} \rightarrow 4\text{KOH} + 3\text{O}_2 \)
  - \( \text{K} \text{O}_3 + 2\text{H}_2\text{O} \rightarrow 4\text{KOH} + 5\text{O}_2 \)

- **CO₂ reduction**
  - \( 4\text{KOH} + 2\text{CO}_2 \rightarrow 2\text{K}_2\text{CO}_3 + 2\text{H}_2\text{O} \)
  - \( 2\text{K}_2\text{CO}_3 + 2\text{H}_2\text{O} + 2\text{CO}_2 \rightarrow 4\text{KHCO}_3 \)
**CO₂ Scrubbing Systems**

- **CO₂** production ~1 kg/person-day
- Lithium hydroxide (LiOH) absorption
  - Change out canisters as they reach saturation
  - 2.1 kg/kg CO₂ absorbed
  - Also works with Ca(OH)₂, Li₂O, KO₂, KO₃
- Molecular sieves (e.g., zeolites)
  - Porous on the molecular level
  - Voids sized to pass O₂, N₂; trap CO₂, H₂O
  - Heat to 350°-400°C to regenerate
  - 30 kg/kg-day of CO₂ removal; 200W
CO$_2$ Reduction

- Sabatier reaction
  - $CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$
  - Lowest temperature (250°C-300°C) with Ni catalyst
  - Electrolyze $H_2O$ to get $H_2$, find use for $CH_4$

- Bosch reaction
  - $CO_2 + 2H_2 \rightarrow C + 2H_2O$
  - 1030°C with Fe catalyst
  - C residue hard to deal with (contaminates catalyst)

- Other reactions possible as well...
Nitrogen Makeup

- Nitrogen lost to airlock purges, leakage (can be >1%/day)
- Need to replenish $N_2$ to maintain total atmospheric pressure
- Choices:
  - High pressure (4500 psi) $N_2$ gas bottles
  - Cryogenic liquid nitrogen
  - Storable nitrogen-bearing compounds ($NH_3$, $N_2O$, $N_2H_4$)
Water Revitalization Processes

Waste Management Processes

Bioregenerative Life Support Schematic

Life Support Systems Analysis (example)

Existing Pressure Suits

EMU
    Hamilton-Sundstrand

AX-5
    NASA Ames

Mark III
    NASA JSC

Orlan
    Russia

Space Life Support
Principles of Space Systems Design
Liquid Cooling Garment Designs

U.S. (ILC-Dover)  Russian
Pressure Suit Entry Systems

Waist Entry

Rear Entry
Pressure Suit Helmet Designs

Spherical Bubble with External Visor

Fixed Helmet with Faceplate

Hemispherical Bubble Helmet
Launch and Entry Suits

Shuttle Launch and Entry Suit (David Clark Co.)

Russian Sokol Launch and Entry Suit
Personal Rescue Sphere