Introduction to Space Life Support

- Overview of life support systems
- Milestones in life support systems design
- Major requirements
- Case Study: International Space Station
Life Support Block Diagram
Introduction to Space Life Support

ENAE 697 - Space Human Factors and Life Support

Life Support Block Diagram

Atmosphere Management

Food Preparation

Humans

Hygiene Facilities

Water Management

Waste Management

O2

CO2

Water

Nutrients

Waste

Stores
Life Support Block Diagram

- **Atmosphere Management**
- **Humans**
- **Food Preparation**
- **Water Management**
- **O2 Reclamation**
- **Waste Management**
- **Hygiene Facilities**

- O2
- CO2
- Water
- Nutrients
- Waste
- Stores
Life Support Block Diagram

- Plants & Animals
- Atmosphere Management
- O₂ Reclamation
- Food Preparation
- Humans
- Water Management
- Hygiene Facilities
- Waste Management

O₂, CO₂, Water, Nutrients, Waste, Stores

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Essentials of Life Support

• Air
  – Constituent control
    • CO₂ scrubbing
    • Humidity control
    • Particulate scrubbing
    • O₂, N₂ makeup
  – Temperature control

• Water
• Food
• Waste Management
### Human Metabolic Inputs and Outputs

<table>
<thead>
<tr>
<th>Inputs</th>
<th>kg</th>
<th>Output</th>
<th>kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxygen</td>
<td>0.84</td>
<td>Carbon dioxide</td>
<td>1.00</td>
</tr>
<tr>
<td>Food solids</td>
<td>0.62</td>
<td>Respiration &amp; perspiration water</td>
<td>2.28</td>
</tr>
<tr>
<td>Water in food</td>
<td>1.15</td>
<td>Urine water</td>
<td>1.50</td>
</tr>
<tr>
<td>Food preparation water</td>
<td>0.76</td>
<td>Feces water</td>
<td>0.09</td>
</tr>
<tr>
<td>Drinking water</td>
<td>1.62</td>
<td>Sweat solids</td>
<td>0.02</td>
</tr>
<tr>
<td>Urine solids</td>
<td></td>
<td></td>
<td>0.06</td>
</tr>
<tr>
<td>Feces solids</td>
<td></td>
<td></td>
<td>0.03</td>
</tr>
<tr>
<td>(water subtotal)</td>
<td>3.53</td>
<td>(water subtotal)</td>
<td>3.87</td>
</tr>
<tr>
<td>Total mass</td>
<td>4.99</td>
<td></td>
<td>4.98</td>
</tr>
</tbody>
</table>

## Oxygen Requirements

<table>
<thead>
<tr>
<th>Category</th>
<th>Metabolic Load [kJ/(person\cdot day)]</th>
<th>Oxygen Requirements: [kg/(person\cdot day)]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Activity Metabolic Load *</td>
<td>10,965</td>
<td>0.78</td>
</tr>
<tr>
<td>Nominal Activity Metabolic Load **</td>
<td>11,820</td>
<td>0.84</td>
</tr>
<tr>
<td>High Activity Metabolic Load *</td>
<td>13,498</td>
<td>0.96</td>
</tr>
<tr>
<td>5\textsuperscript{th} Percentile Nominal Female</td>
<td>7,590</td>
<td>0.52</td>
</tr>
<tr>
<td>95\textsuperscript{th} Percentile Nominal Male</td>
<td>15,570</td>
<td>1.11</td>
</tr>
</tbody>
</table>

**Notes:**

* From Space Station Freedom Program via C. H. Lin (NASA/JSC), personal communication.
** From the Baseline Values and Assumptions Document, JSC-47804.

The assumed conversion factor from liters of O\textsubscript{2} to calories is 4.8 cal/L here. A pressure of 101.325 kPa and a temperature of 0 °C are the standard conditions.

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Water Requirements

- Potable water - 2 L/crew-day (2 kg/crew-day)
- Hygiene water
  - Nominal - 2.84-5.16 L/crew-day
  - Contingency - 2.84 L/crew-day
Metabolic Energy Requirements

• Men (W=mass in kg)
  – 18-30: 26W+1154 kcal/day
  – 30-60: 19.7W+1494 kcal/day

• Women (W=mass in kg)
  – 18-30: 23.5W+794 kcal/day
  – 30-60: 13.9W+1326 kcal/day

• Add 500 kcal/day for
  – EVA days
  – Moderate exercise days
  – End-of-mission countermeasure days
Life Support Design Rules of Thumb

- A crew member requires 5 kg of consumables/day
  - \( \sim 1/2 \) water, \( 1/3 \) food, \( 1/6 \) oxygen
  - (including water in food) 77% \( \text{H}_2\text{O} \), 17% \( \text{O}_2 \), 12% food solids
  - Dehydration reduces food mass by \( 2/3 \)
- Food solids produce about 5 calories/gm
- Respiration produces about 3.4 calories/gm \( \text{O}_2 \)
- Males need about \( 1/3 \) more calories than females
  - Or, males need \( 1/7 \) more than average, females \( 1/7 \) less
  - Males need one extra day/week of food, females one less
## ISS Water Usage

<table>
<thead>
<tr>
<th>Water use (kg)</th>
<th>Minimum</th>
<th>Nominal</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Food preparation</td>
<td>0.40</td>
<td>0.76</td>
<td>0.91</td>
</tr>
<tr>
<td>Drinking</td>
<td>0.21</td>
<td>1.62</td>
<td>1.77</td>
</tr>
<tr>
<td>Consumed total</td>
<td>0.61</td>
<td>2.38</td>
<td>2.68</td>
</tr>
<tr>
<td>Hygiene</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shower</td>
<td>1.82</td>
<td>2.73</td>
<td>2.73</td>
</tr>
<tr>
<td>Dishwash</td>
<td>3.63</td>
<td>5.45</td>
<td>5.45</td>
</tr>
<tr>
<td>Handwash</td>
<td>3.63</td>
<td>4.09</td>
<td>4.54</td>
</tr>
<tr>
<td>Urine flush</td>
<td>0.00</td>
<td>0.50</td>
<td>0.73</td>
</tr>
<tr>
<td>Clothes wash</td>
<td>0.00</td>
<td>12.50</td>
<td>12.50</td>
</tr>
<tr>
<td>Hygiene total</td>
<td>9.08</td>
<td>25.27</td>
<td>25.95</td>
</tr>
<tr>
<td>Grand total</td>
<td>9.69</td>
<td>27.65</td>
<td>28.63</td>
</tr>
</tbody>
</table>

ISS Configuration and Life Support Layout

ISS Life Support Systems

- ACS - Atmosphere Control and Supply
- THC - Temperature and Humidity Control
- AR - Atmosphere Revitalization
- FDS - Fire Detection and Suppression
- WM - Waste Management
- WRM - Water Recovery and Management
- VS - Vacuum Services
- EVA Support
- Other
USOS ECLSS Systems

ACS - Atmosphere Control and Supply

- Control total atmospheric pressure (monitor total pressure and add nitrogen)
- Control oxygen partial pressure (monitor ppO2 and add oxygen)
- Relieve overpressure
- Equalize pressures
- Respond to rapid decompression (detect and recover)
- Respond to hazardous atmosphere (detect, remove, recover)
ACS Pressure Control Assembly

Manual Pressure Equalization Valve

USOS Personal Breathing Apparatus (PBA)

Volatile Organics Analyzer (VOA)

• Control atmospheric temperature (monitor and remove heat)
• Control atmospheric moisture (monitor, remove, dispose of collected moisture)
• Circulate atmosphere intramodule
• Circulate atmosphere intermodule
 THC - Temperature and Humidity Control

CCAA* THC Fan Assembly

*Common Cabin Air Assembly

THC CHX* Schematic

*Condensing Heat Exchanger

IntraModule Ventilation (IMV) Hardware

AR - Atmosphere Revitalization

- Control CO2 (monitor, remove, dispose of)
- Control gaseous contaminants (monitor, remove, dispose of)
- Control airborne particulate contaminants (remove and dispose of)
- Control airborne microbial growth (remove and dispose of)
Air Revitalization Schematic

4BMS CDRA* Schematic

*4-Bed Molecular Sieve Carbon Dioxide Removal Apparatus

OGA-Oxygen Generator Assembly Schematic

Trace Contaminant Control Subassembly

TCCS Charcoal Bed Assembly

TCCS LiOH Bed Assembly

Other ISS Life Support Systems

- **FDS - Fire Detection and Suppression**
  - Respond to a fire (detect, isolate, extinguish, recover)
- **WM - Waste Management**
  - Accommodate crew hygiene and wastes
- **WRM - Water Reclamation and Management**
  - Provide water for crew use (monitor quality, supply potable and hygiene water, process wastewater)
  - Supply water for payloads
- **VS - Vacuum Services** (for payloads)
Russian Fire Safety Criteria

U.S. Fire Safety Criteria

Fire Detection and Suppression

WRM Architecture

Urine Processing Schematic

Vacuum Compression and Distillation Subassy

EVA Support Services

- Support denitrogenation (in suit, “campout”)
- Support suit servicing and checkout (provide water, oxygen, in-suit purge)
- Support station egress (recover airlock atmosphere and depress)
- Support station ingress (repressurize airlock and accept suit wastewater)
USOS ECLSS Functional Integration


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Other (Different) ECLSS Components

- Russian Segment
- Columbus Attached Pressurized Module (ESA)
- Japanese Experiment Module (JAXA)
- Mini-Pressurized Logistics Module (ASI)