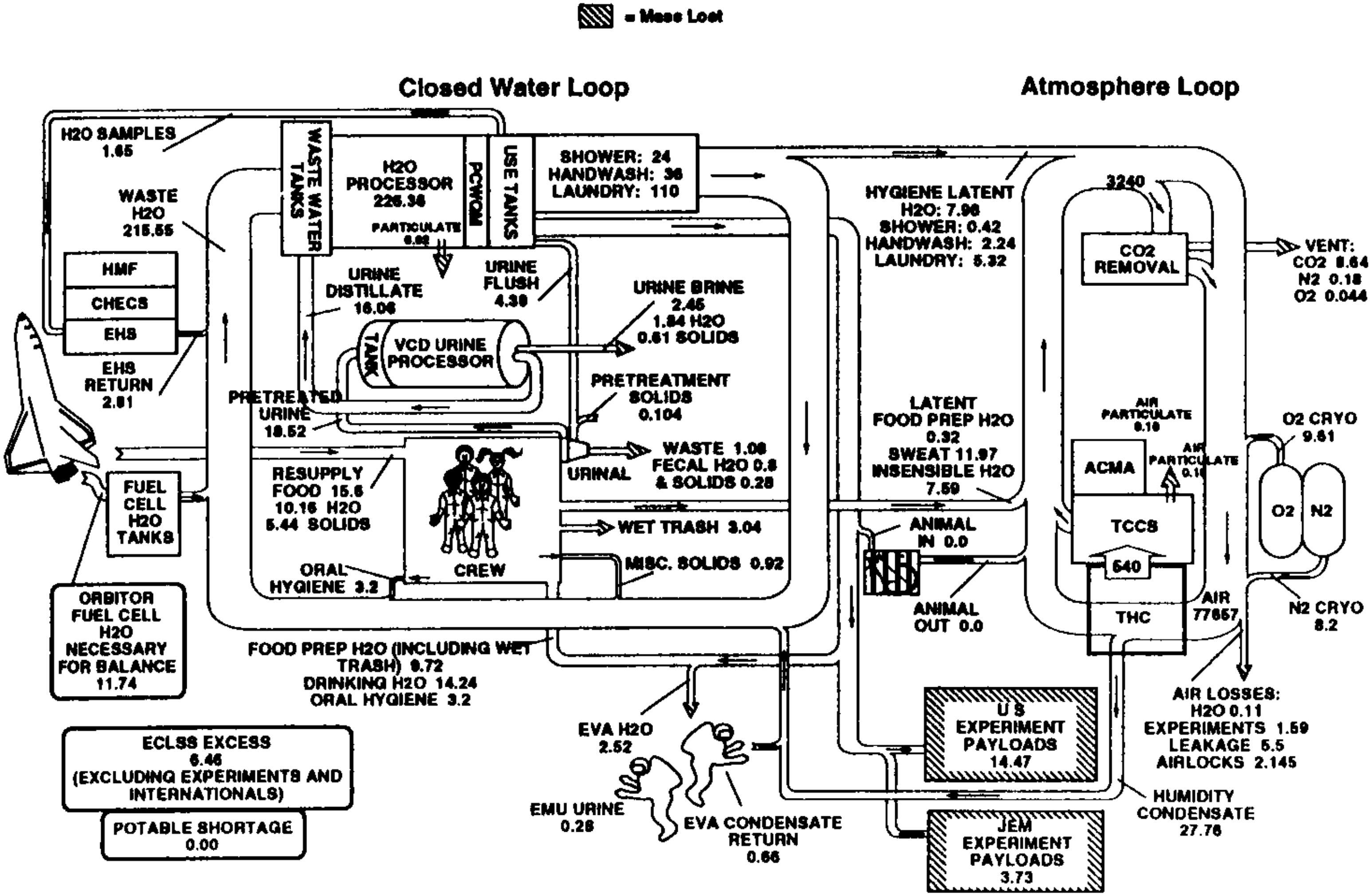
Space Life Support

- 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



From Peter Eckart, *Spaceflight Life Support and Biospherics*, Kluwer Academic, 1996

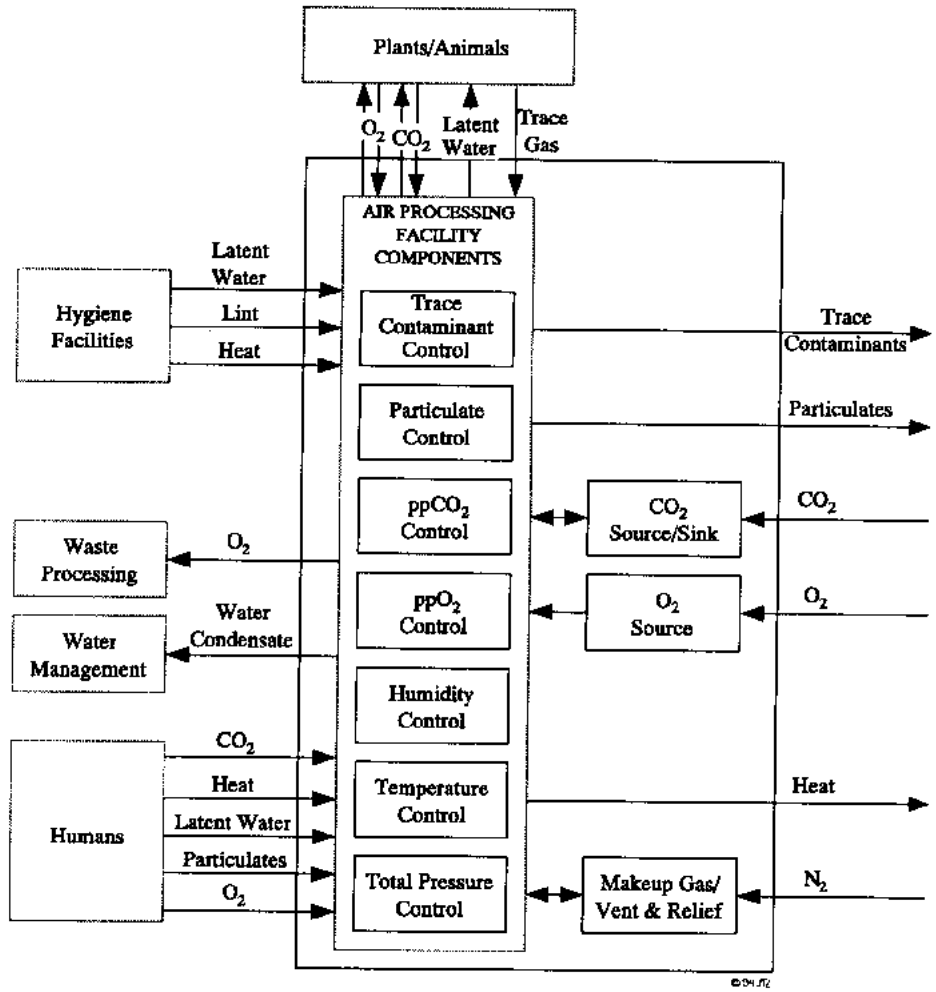
ISS Consumables Budget

Consumable	Design Load (kg/person-day)
Oxygen	0.85
Water (drinking)	1.6
Water (in food)	1.15
Water (clothes and dishes)	17.9
Water (sanitary)	7.3
Water (food prep)	0.75
Food solids	0.62

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



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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")
  - $LiClO_4$ --> 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
  - $KO_2 + 2H_2O \text{ --> } 4KOH + 3O_2$
  - $KO_3 + 2H_2O \text{ --> } 4KOH + 5O_2$
- CO2 reduction
  - $4KOH + 2CO_2 \text{ --> } 2K_2CO_3 + 2H_2O$
  - $2K_2CO_3 + 2H_2O + 2CO_2 \text{ --> } 4KHCO_3$

CO_2 Scrubbing Systems

- CO_2 production ~1 kg/person-day
- Lithium hydroxide (LiOH) absorption
  - Change out canisters as they reach saturation
  - 2.1 kg/kg CO_2 absorbed
  - Also works with $Ca(OH)_2$, Li_2O, KO_2, KO_3
- Molecular sieves (e.g., zeolites)
  - Porous on the molecular level
  - Voids sized to pass O_2, N_2; trap CO_2, H_2O
  - Heat to 350°-400°C to regenerate
  - 30 kg/kg-day of CO_2 removal; 200W

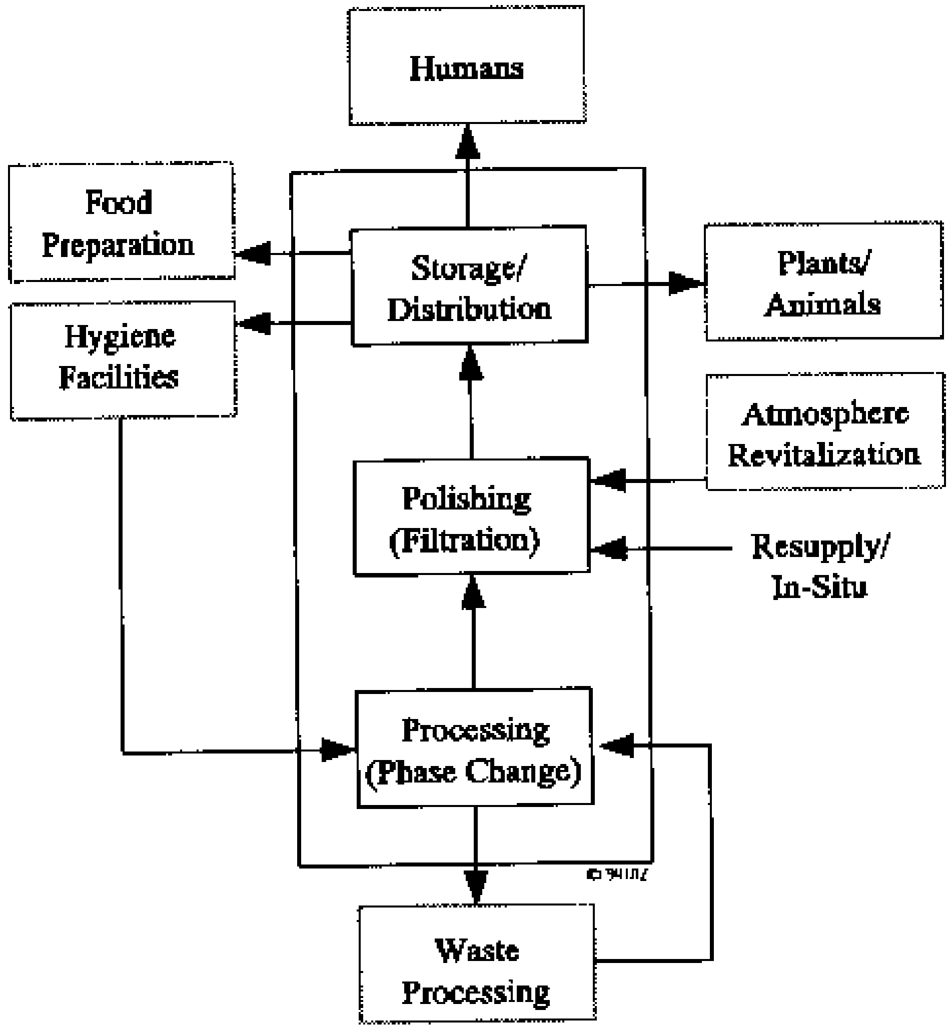
CO_2 Reduction

- Sabatier reaction
  - $CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$
  - Lowest temperature (250°-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



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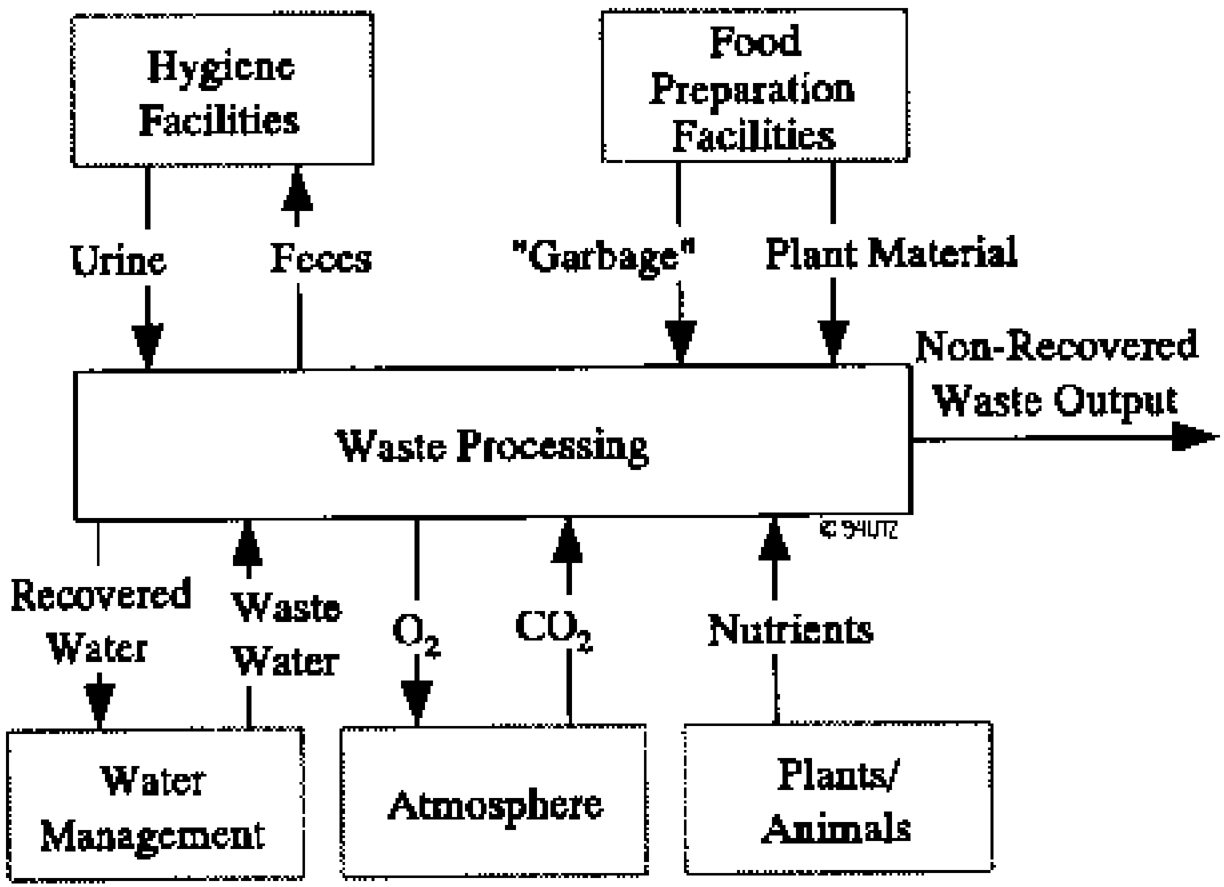
Waste Management Processes



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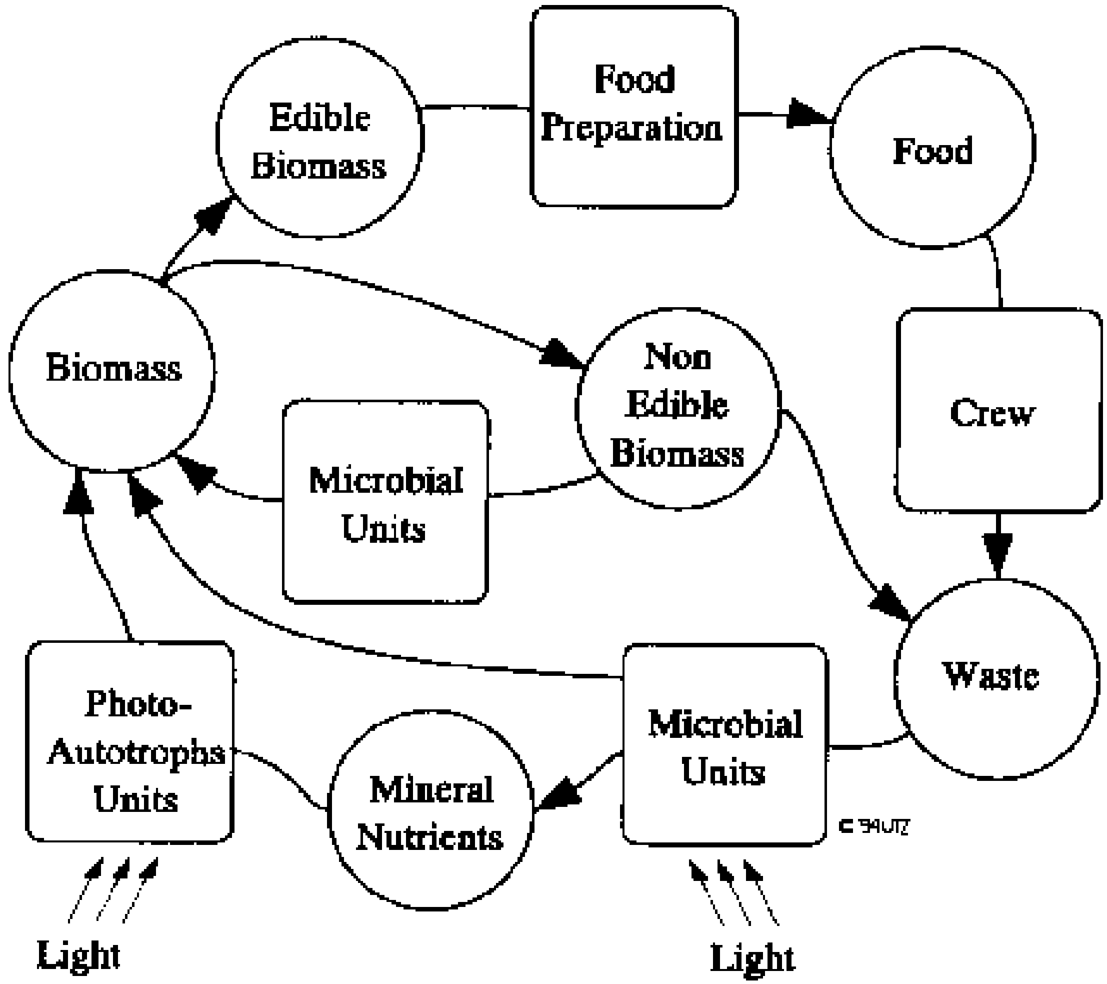
Bioregenerative Life Support Schematic



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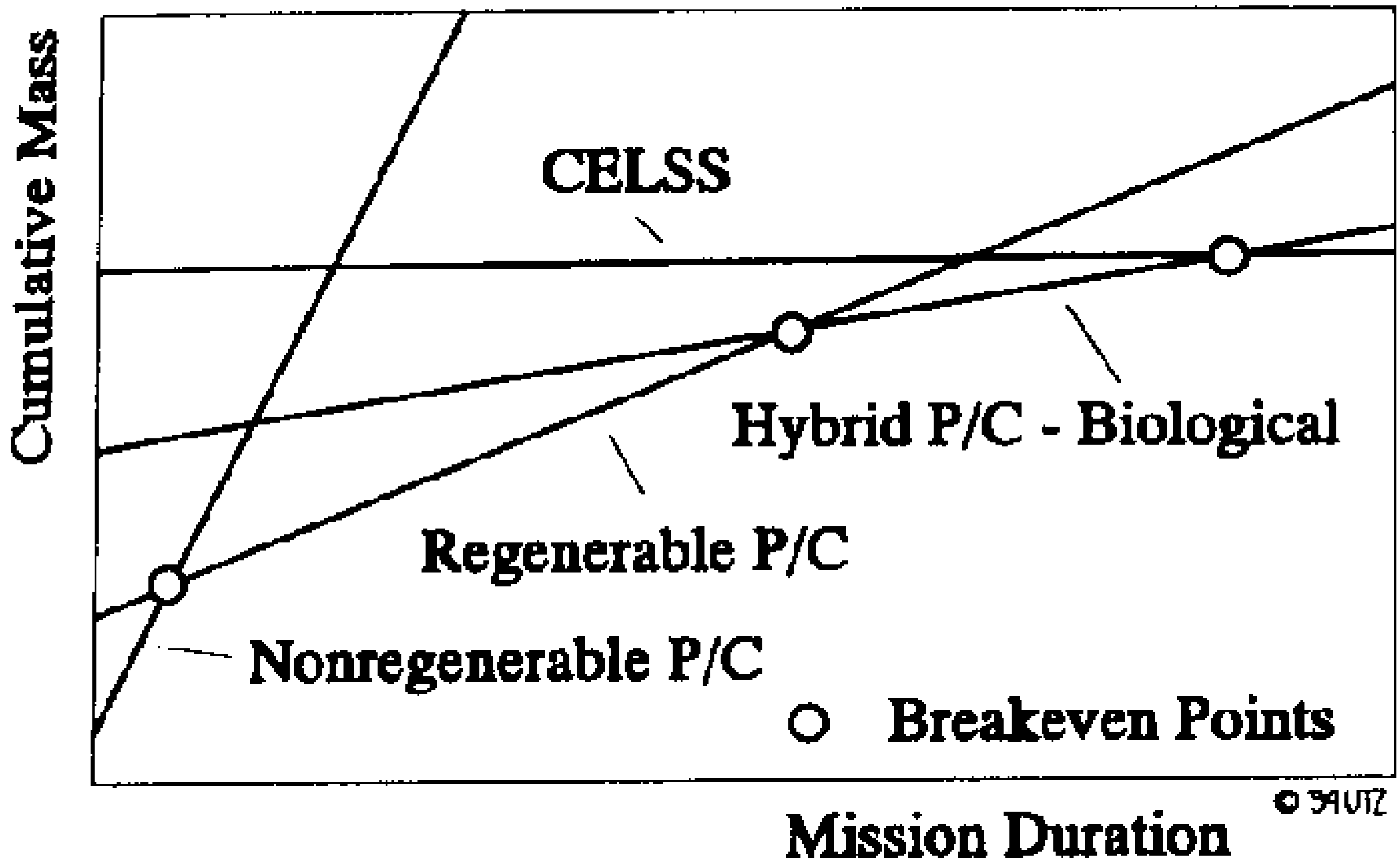
Life Support Systems Analysis (example)



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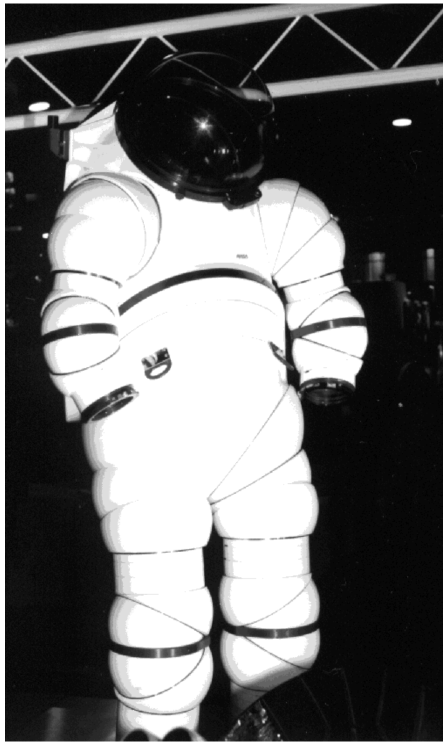
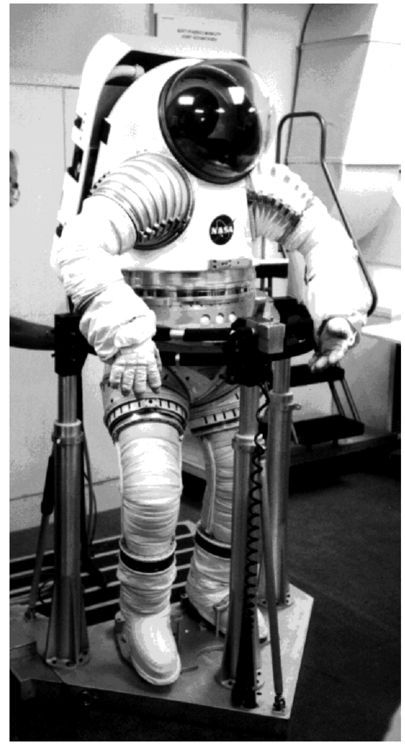
Existing Pressure Suits

EMU
Hamilton-Sundstrand



AX-5
NASA Ames



Mark III
NASA JSC

Orlan
Russia

Liquid Cooling Garment Designs

U.S. (ILC-Dover)

Russian

Pressure Suit Entry Systems

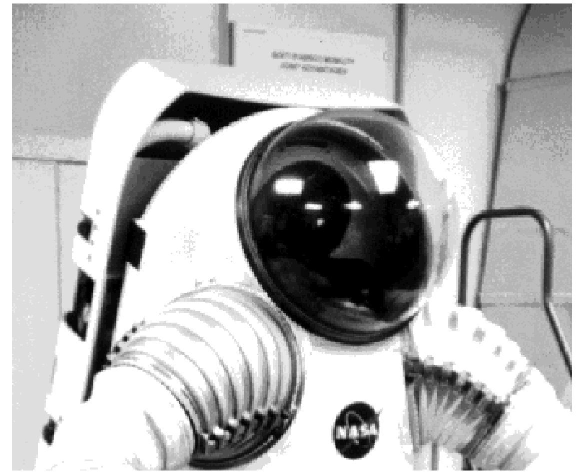
Waist Entry

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