Design for microgravity has traditionally not been well integrated early on into the development of advanced life support (ALS) technologies. NASA currently has many ALS technologies that are currently being developed to high technology readiness levels but have not been formally evaluated for microgravity compatibility. Two examples of such technologies are the Vapor Phase Catalytic Ammonia Removal Technology and the Direct Osmotic Concentration Technology. This presentation will cover the design of these two systems and will identify potential microgravity issues.
NASA Workshop on Strategic Research to Enable NASA’s Exploration Missions

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Advanced Life Support

Water Recycling

• One of the “tall poles” in the development of a viable human Mars Exploration program is the development of applicable Advanced Life Support System.

• Of all the metabolic requirements water is the most significant

• Water accounts for 89% of the total metabolic resupply requirements to keep an astronaut alive in space.

• Using the Mars Reference Mission as a baseline and Mars Pathfinder launch cost data, the cost of supplying water for this mission in the open loop case is over $11 Billion.

Assumptions: 6 astronauts, flow=3.18kg/hr, duration=960 days, launch Cost= $150,000/kg
Advanced Life Support

• The ALS program supports fundamental research into the development of new technologies.

• It supports the development of these technologies to high technology readiness levels (TRL 5-6).

• It has not adequately supported the validation of the microgravity performance of these technologies (TRL 7 to 8).
Rule of Thumb Approach
Alternative Approaches?

- Integrate technology development and microgravity design early on in the design process.

- Complete a set of fundamental microgravity fluid physics experiments that will have broad applicability to ALS.
  - Workshop on Critical Issues in Microgravity Fluids, Transport and Reaction Processes in Advanced Human Support Technology

- Form teams with microgravity community to begin to generate answers to questions associated with existing technologies.
Case Study Examples

• Vapor Phase Catalytic Ammonia Removal
  – Currently a TRL 5 technology being developed for advancement to TRL 6

• Direct Osmotic Concentration
  – Currently a TRL 3 technology being developed for advancement to TRL 6
Vapor Phase Catalytic Ammonia Removal (VPCAR)
The VPCAR is designed to accept a combined waste stream (urine, condensate, and hygiene) and produce potable water in a single step.

- The system is designed to require no re-supply or maintenance.
- The technology is modular and can be packaged to fit into a volume comparable to a single Space Station rack.
- The technology has been the subject of many NASA trades studies and peer reviews.
VPCAR Flow Diagram

Symbol Key
- Pump
- Manual Valve
- Solenoid Valve
- Check Valve

Oxidation Reactor → After Cooler HX D → WFRD Evaporator → Oxide Feed

Facility Chilled Water → Feed Water

Pump A → S1 → S2 → S4 → S6 → N4

V1 → Flow Meter → N6

Vacuum Pump → N1

Feed Return → Flow Meter

Reduction Reactor → HX A

Concentrate → N2 → S6

Product → HX B

Check Valve

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WFRD Components
Rotor Assembly
Wiper Blades
Microgravity Evaporator
VPCAR Systems
Flight Verification
Topics

• Thermal properties of thin fluid films
• Two phase flow in open chambers
• Three phase flow
• Splashing in liquid/gas boundaries
• Centrifugal separations, what occurs during start and stop events
• Wiper blade fluid application
VPCAR Systems
Flight Verification
Topics (Cont.)

- Pumping of saturated fluids
- Surface tension directed flow stability
- Reaction kinetics in packed beds, effects of channeling and condensation
- Stability of packed beds during launch
- Deterioration of packed beds during operation
- Lubrication of rotating gears
Direct Osmotic Concentration (DOC)
DOC Description

- The DOC technology is a highly integrated membrane / distillation / oxidation based water processor.

- It incorporates a novel direct osmosis step, an osmotic distillation step, a reverse osmosis step, and a catalytic reactor post treatment step.

- The DOC technology is designed to accept separate hygiene and urine + condensate streams and produces potable water while requiring little re-supply or maintenance for a 3 year mission.
DOC Complete
Flow Diagram

- Urine Waste Stream
- Hygiene Waste Stream
- Feed Tank
- DO Module
- Osmotic Distillation Module
- Permeate Tank
- Recycle to Solid Waste Treatment
- OA Recycle
- RO Module
- Product Water
- Regenerative HX
- Ion Exchange Bed
- Gas/Liquid Separator
- O2 & CO2
- Preheater
- Catalytic Reactor
- O2
- Permeate
- OA Recycle
- RO Module
- Permeate
DOC Flight Verification
Topics

- Three phase flow
- Two and three phase flow in membrane elements
- Stability of packed beds
- Two phase flow in packed beds
- Multi Phase flow separation and mixing
- Cavitation control