Design and Sizing of the Air Revitalization System for Altair Lunar Lander

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Introduction

- Overview of Altair Lunar Lander
- Goals and Background
- Modeling with Aspen Custom Modeler
  - Lander model
  - Astronaut model
- Initial Parametric Study
- Final Modeling
- Conclusions and Summary
Altair Mission Overview

http://external.jsc.nasa.gov/events/lssp0/
The Altair Lunar Lander

Crew Module

Airlock

http://external.jsc.nasa.gov/events/lsspo/
Goals and Background

- Control of cabin conditions is vital to insuring crew comfort. Includes:
  - Comfortable Relative Humidity (RH) range
  - Cabin ppCO$_2$ below threshold limit
  - Avoiding/minimizing condensation
- Aim to minimize mass/power/resource impacts
- Determine best operating parameters and sizing to maintain comfortable environment while maximizing mass savings.
Impact of mass savings

- Reduced mass → Reduced propulsion
  - Requirements for lift
- Reduced mass → Reduced costs
  - Cost of delivering payload to LEO ~ $10k/lb\(^1\)
- Reduced mass provides flexibility for additional modifications

Altair CO₂ & Humidity Control System Model

Dual-loop configuration with higher flow cabin loop for primary heat removal and lower flow suit loop for carbon dioxide and humidity control in both open cabin and suited configurations.

Cabin Loop

Astronauts modeled within Hierarchy block

2 PSA units control CO₂ and humidity

Blowers control total air flow within the Air Revitalization (ARS) loop
The Astronaut Model

- CO₂ and humidity production based on activity level
- O₂ consumption based on activity level
- 4 crew members
  - 2 crew on EVA
  - 2 stay in the vehicle (exercise)
- Activity profiles modeled using switch statements and various loop structures
Modeling Strategy

- Understand how PSA parameters affect CO$_2$, Humidity levels
  - Cycle time
  - Flow rate
- Consider bed size effect
Parametric Study of ARS architecture
Flow rate analysis

- Constant cycle time
- 2 units (CEV-sized beds) operating in parallel
- Cabin temp controlled by Cabin HX
  - Varies coolant flow rate to control cabin temperature
Cabin atmosphere dynamics vs. flow rate

2 CM leave for EVA
CM exercise
2 CM return from EVA
Cycle time analysis

- Constant flow rate – air pulled through loop by ARS fan
- 2 units (CEV-sized beds) operating in parallel
- Cabin temp controlled by Cabin HX
  - Varies coolant flow rate to control cabin temperature
Cabin atmosphere dynamics vs. cycle time

- 2 CM leave for EVA
- 9:00
- CM exercise
- 17:00
- 2 CM return from EVA
- 22:00
- 24:00
Summary of results: Parametric Analysis

- Flow exerts a greater effect on ARS performance than cycle time
- Conflict between regulating humidity and CO$_2$
  - High flows necessary to regulate CO$_2$ during high activity periods (exercise, EVA prep)
  - These flow rates dry out the cabin during sleep periods
- Variable air flow is necessary for control
  - Dependent on activity level
- By-pass valve is a simple solution
Updated control scheme

Cabin dew point controls
PSA bypass flow
24-hour Cabin ppCO₂ & humidity profiles

- **ppCO₂ (mmHg)**
  - With bypass
  - No bypass

- **Relative Humidity (%)**
  - With bypass
  - No bypass

**Timeline:**
- 0:00: 2 CM leave for EVA
- 9:00: CM exercise
- 22:00: 2 CM return from EVA
Bed sizing analysis

- 2 CM exercising 2 CM EVA
- Constant cycle time and flow rate
- Cabin temp controlled by Cabin HX
  - Varies coolant flow rate to control cabin temperature
24-hr relative humidity profiles

![Graph showing relative humidity profiles over 24 hours with different humidity levels represented by distinct lines. The graph includes lines for 90%, 80%, Full size, 70%, and 63% relative humidity.](image-url)
24-hr ppCO$_2$ profiles
24-hr condensate production profiles
Opportunities for Mass Reduction

- Reducing bed size shows limited impact upon removal efficiency
- None of the design requirements are violated
Conclusions

- ACM for design ARS Altair Lunar Lander
  - Proposed variable flow rate architecture
  - Defining target operating parameters
  - Sizing PSA units
- Demonstrated opportunities for mass reduction
  - Cost savings
  - Flexibility
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