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

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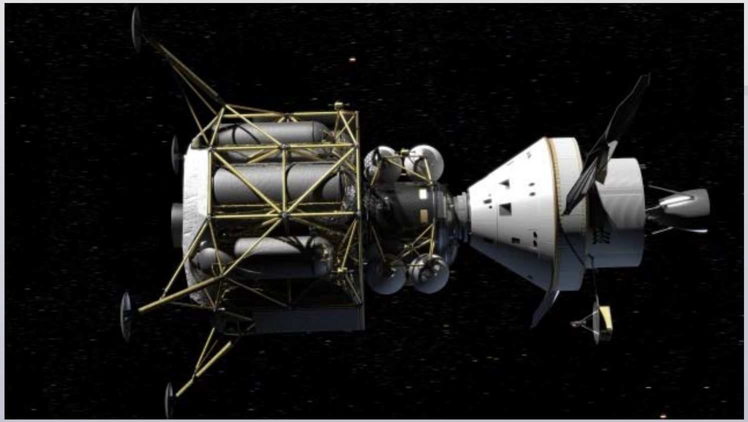
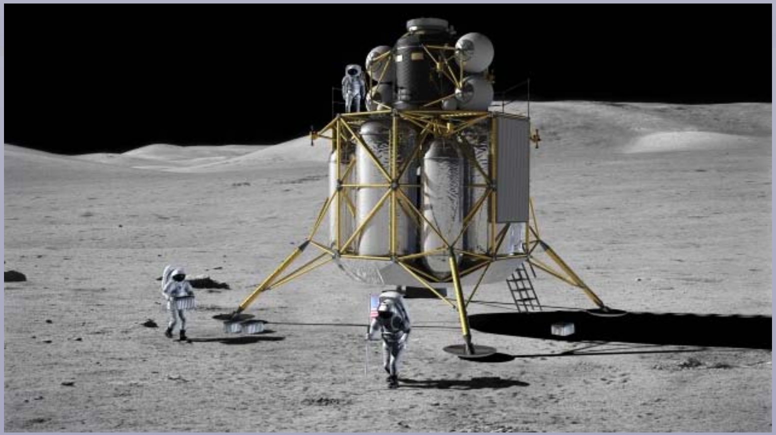
Introduction

- 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

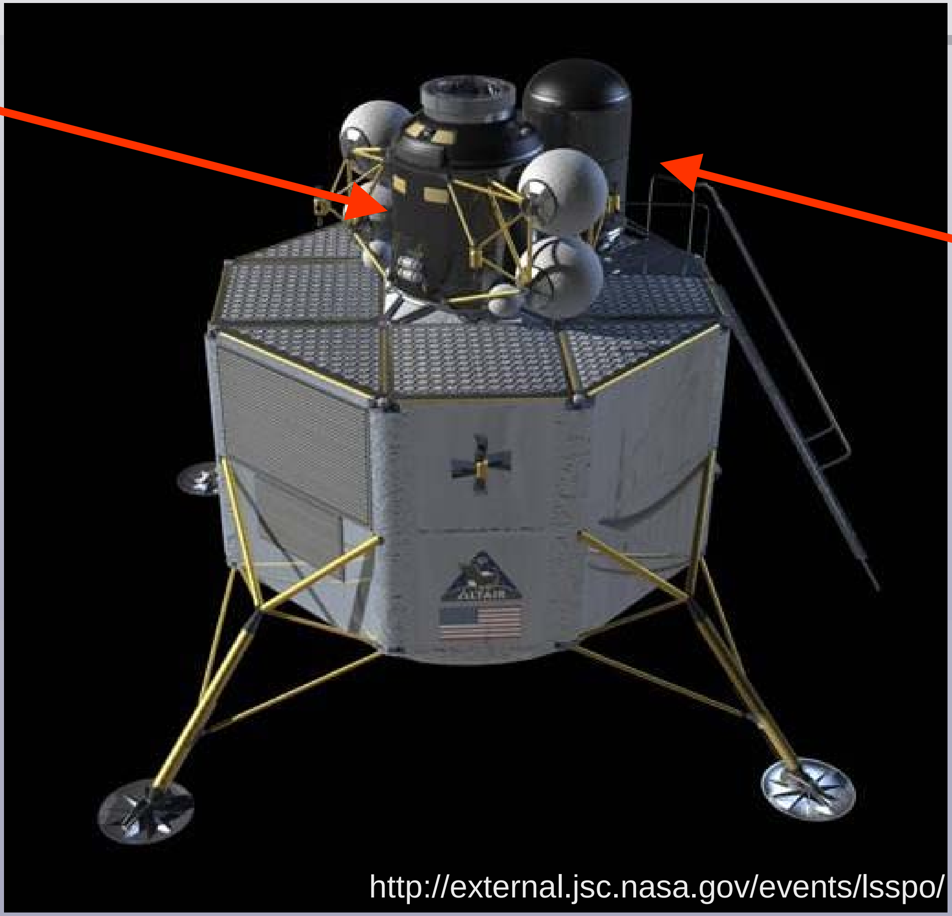
Altair Mission Overview





http://external.jsc.nasa.gov/events/lsspo/

The Altair Lunar Lander



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.

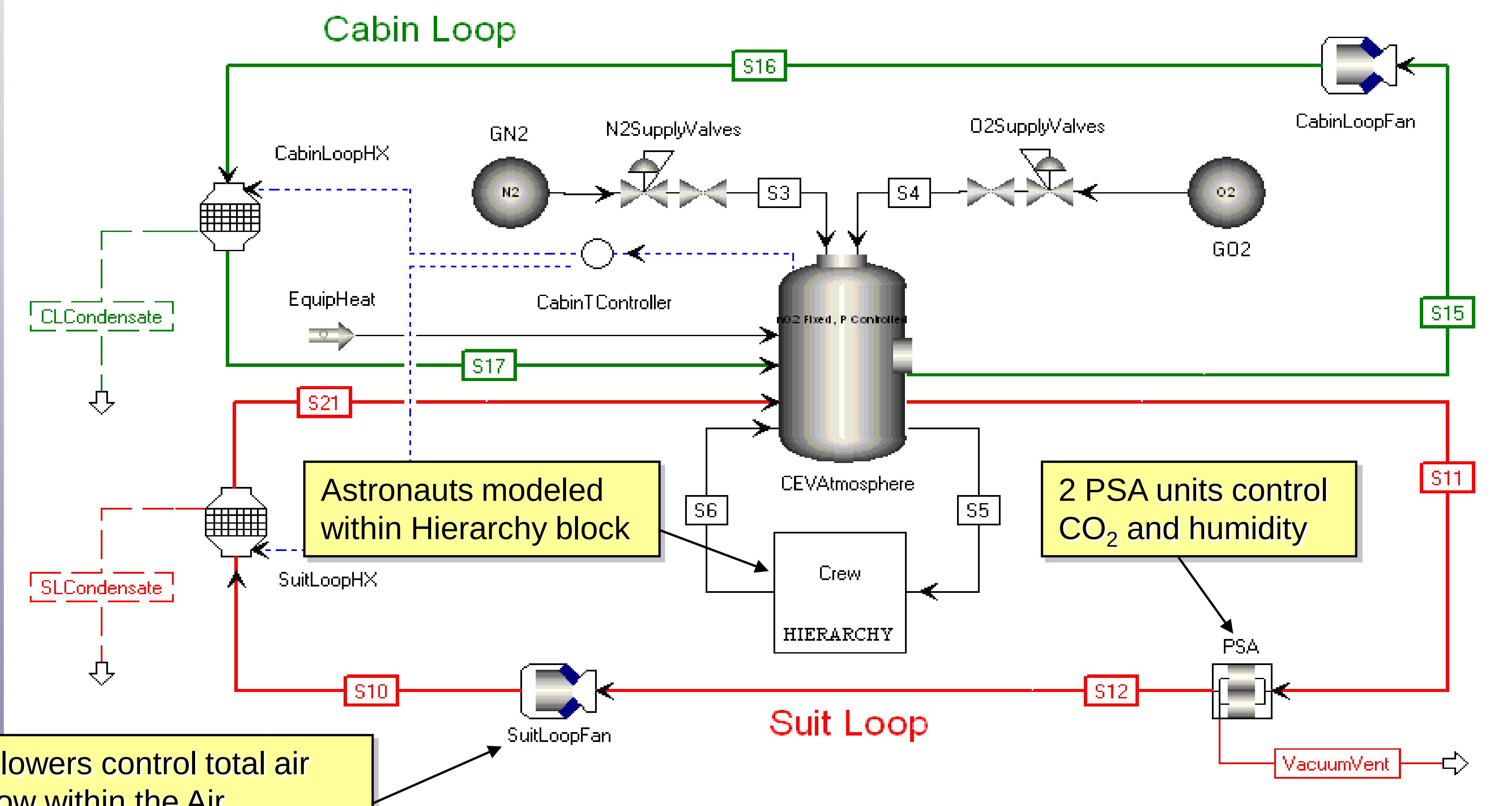
Impact of mass savings

- 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

[1]Nix, M.B. and William J.D. Escher (1999). "Spaceliner Class System Operability Gains via Combined Airbreathing/Rocket Propulsion: Summarizing an Operational Assessment of Highly Reusable Space Transports", Paper # 99-2355, 35th AIAA/ASME/SAE/ASEE/ Joint Propulsion Conference and Exhibit, Los Angeles CA.

Altair CO_2 & 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.

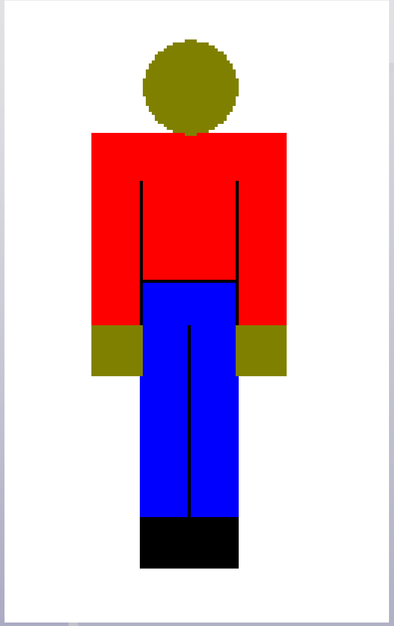


Astronauts modeled within Hierarchy block

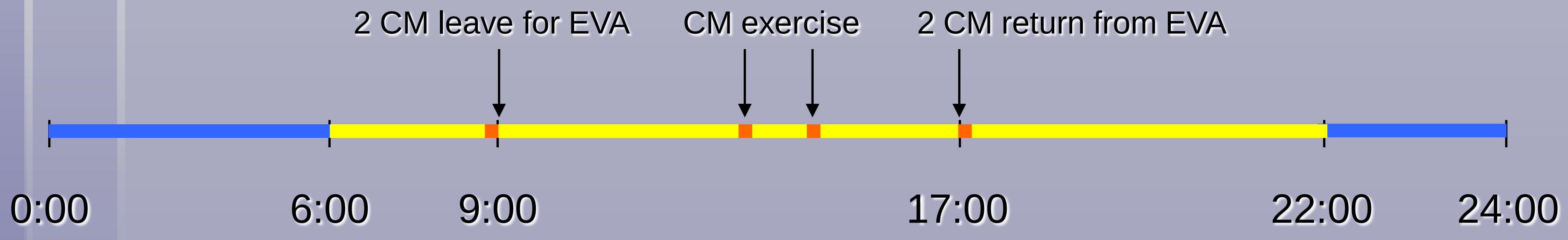
2 PSA units control CO_2 and humidity

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

The Astronaut Model



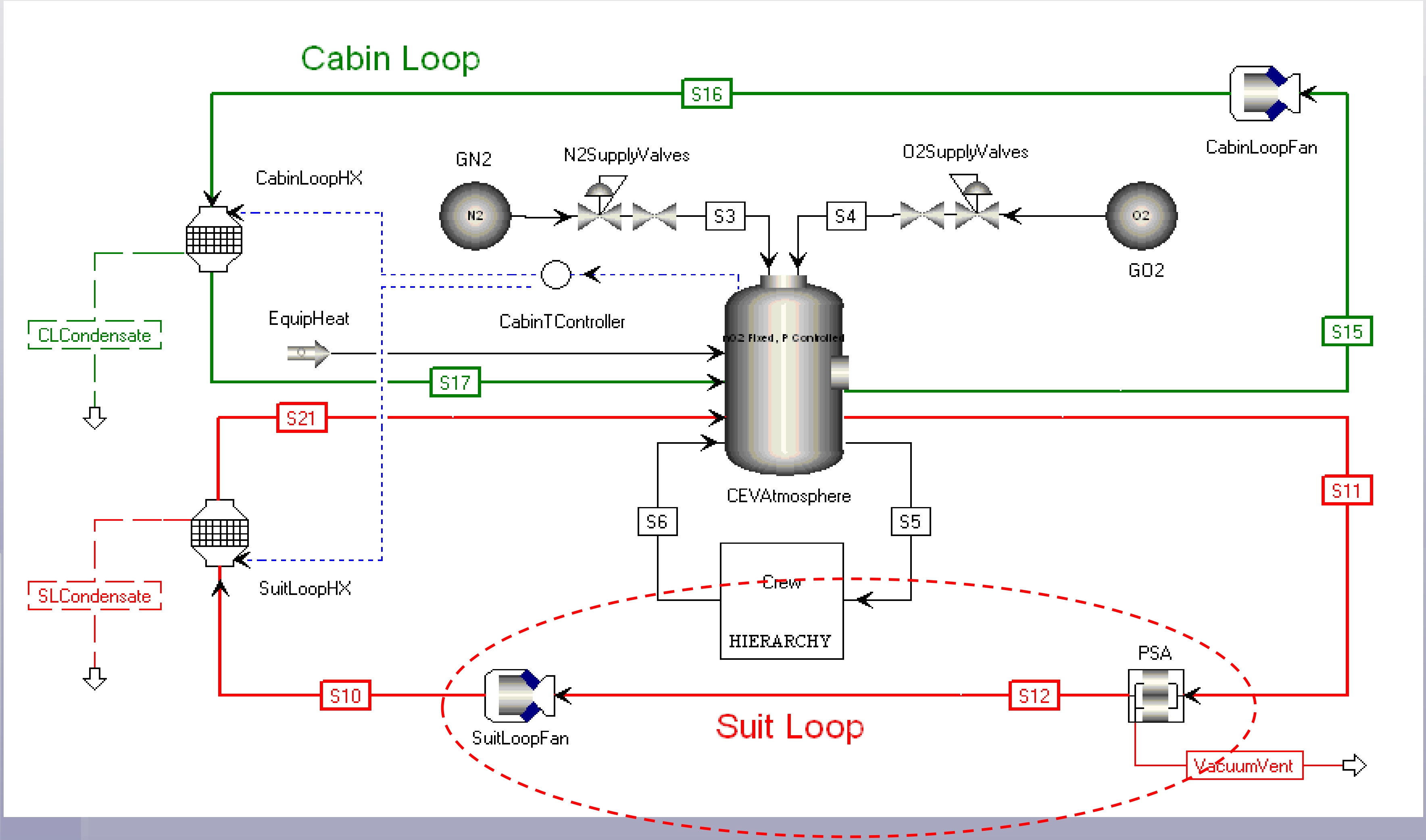
- CO_2 and humidity production based on activity level
- O_2 consumption based on activity level
- 4 crew members
  - 2 crew on EVA
  - 2 stay in the vehicle (exercise)
- Activity profiles modeled using switch statements and various loop structures



Modeling Strategy

- Understand how PSA parameters affect CO_2, Humidity levels
  - Cycle time
  - Flow rate
- Consider bed size effect

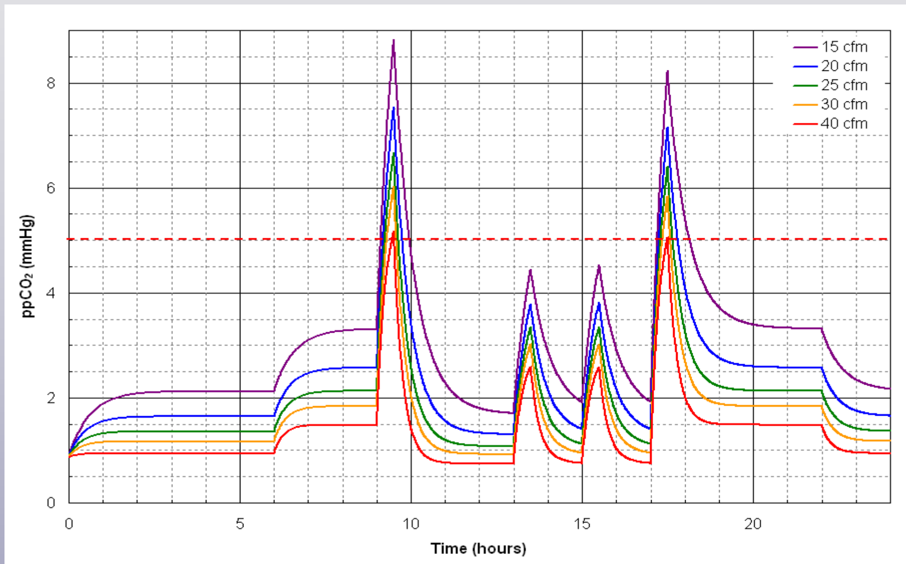
Parametric Study of ARS architecture

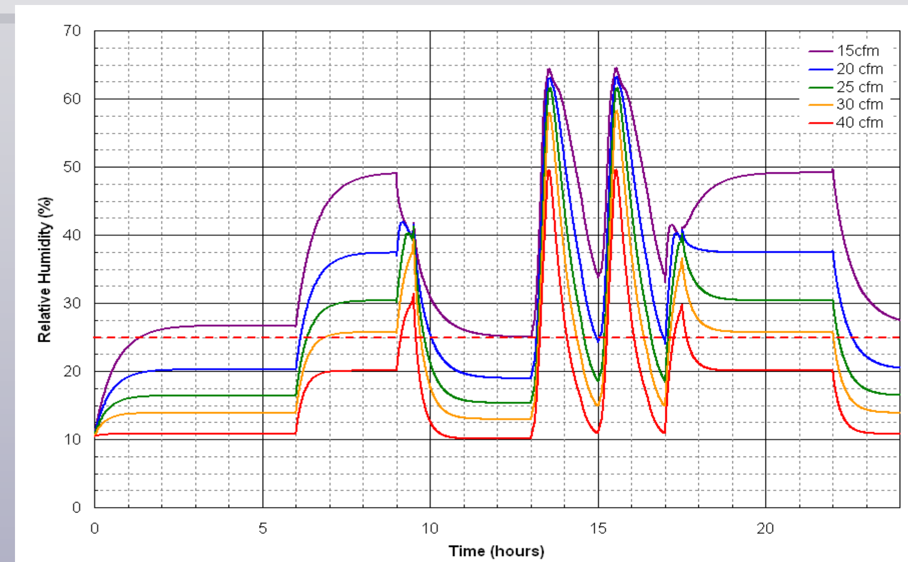


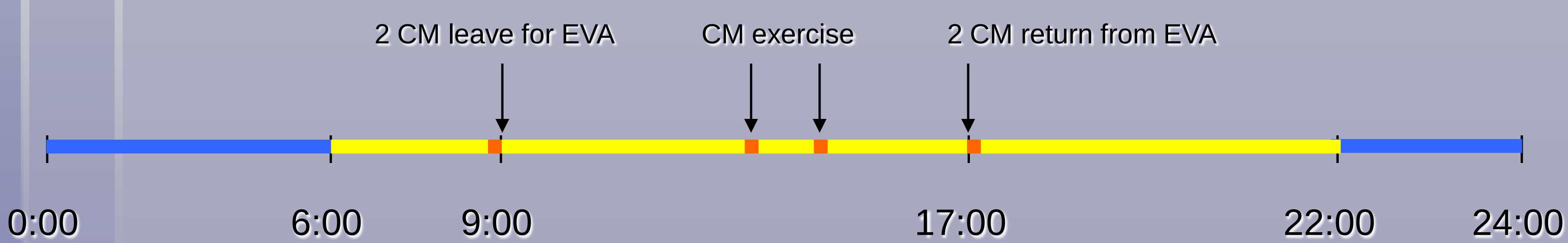
Flow rate analysis

- 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



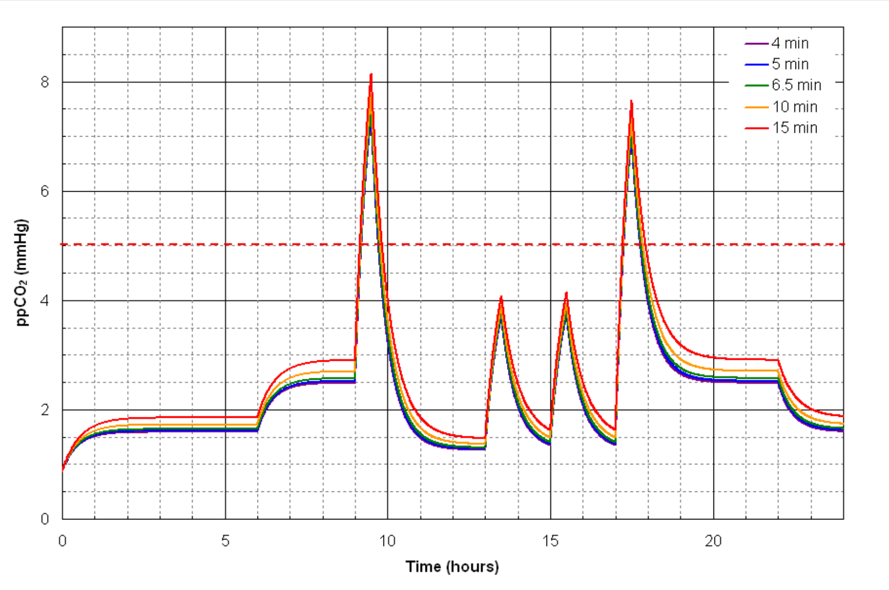


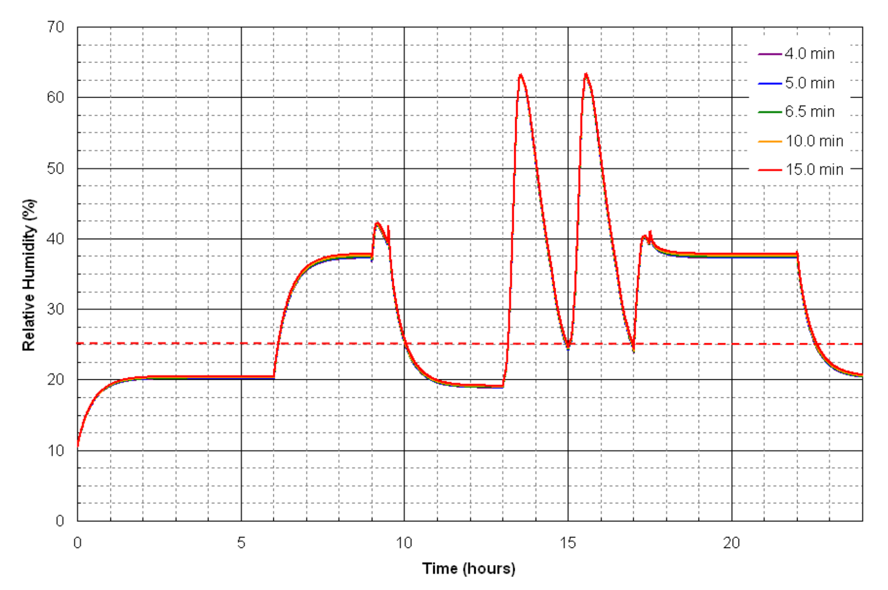


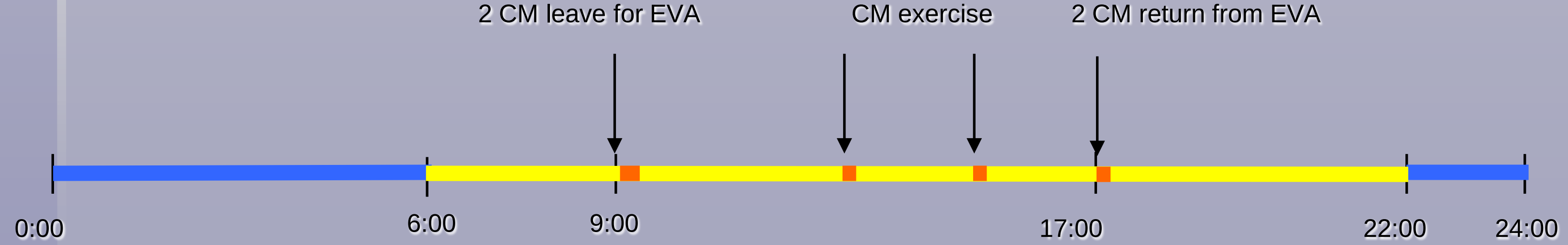
Cycle time analysis

- 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





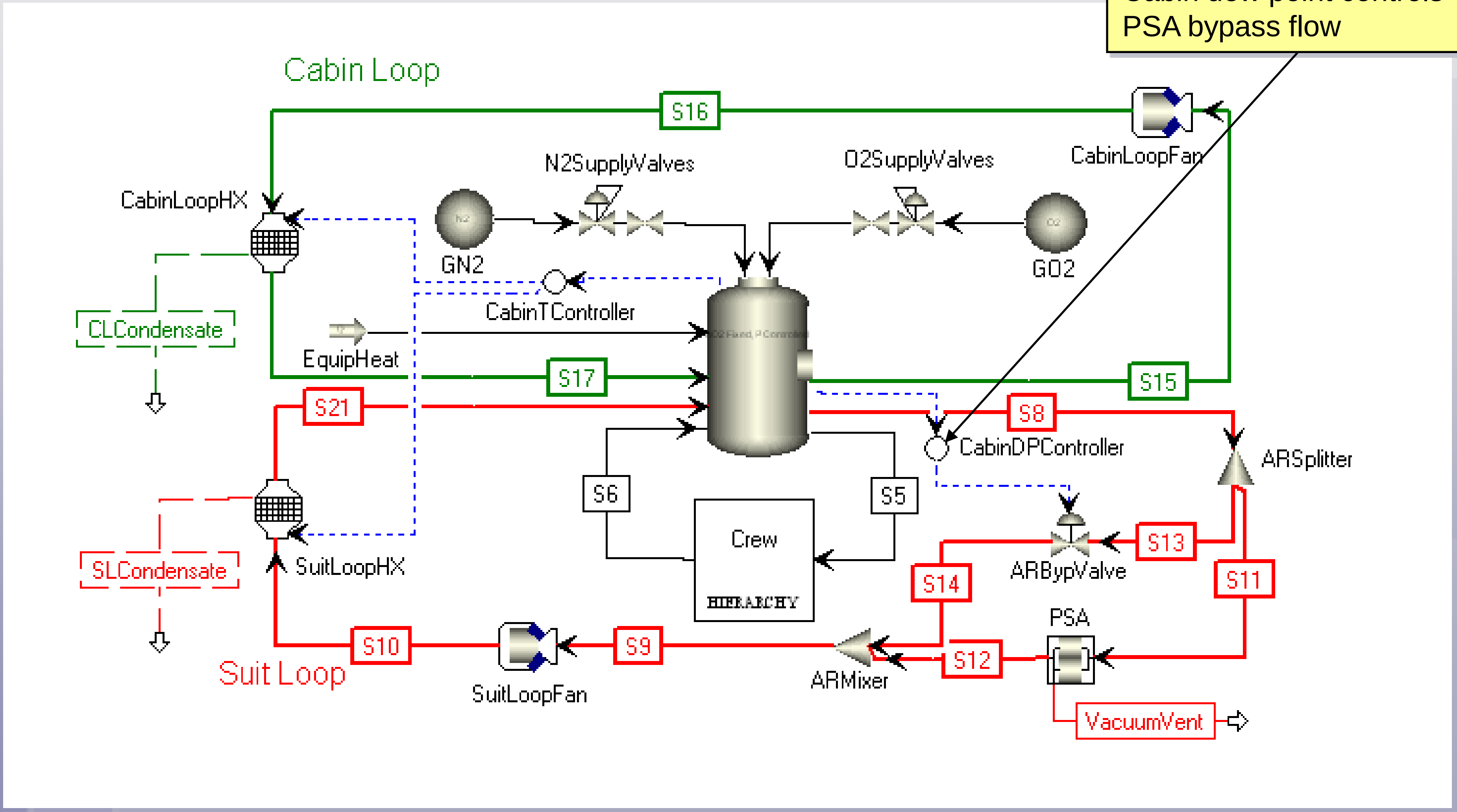


Summary of results: Parametric Analysis

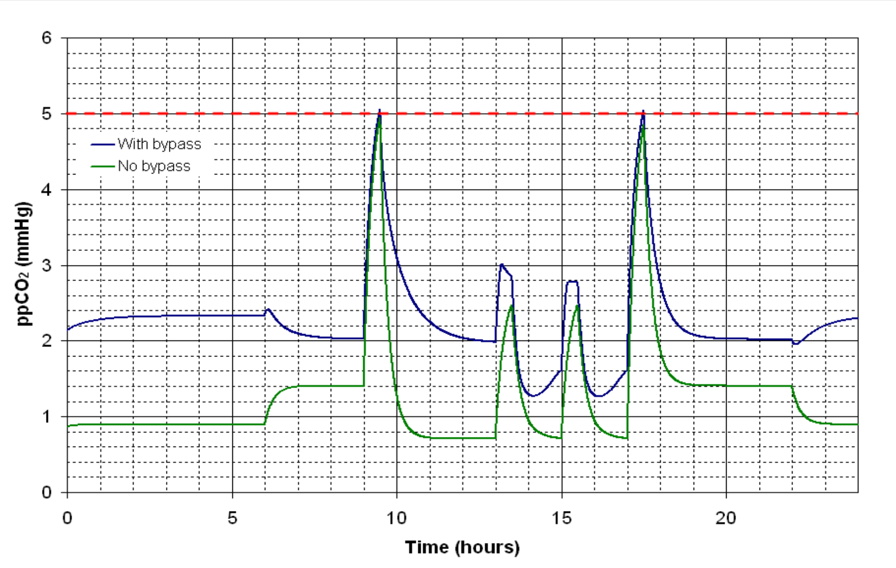
- Flow exerts a greater effect on ARS performance than cycle time
- Conflict between regulating humidity and CO_2
  - High flows necessary to regulate CO_2 during high activity periods (exercise, EVA prep)
  - These flow rates dry out the cabin during sleep periods
- Variable air flow is necessary for control
  - Dependent on activity level
- By-pass valve is a simple solution

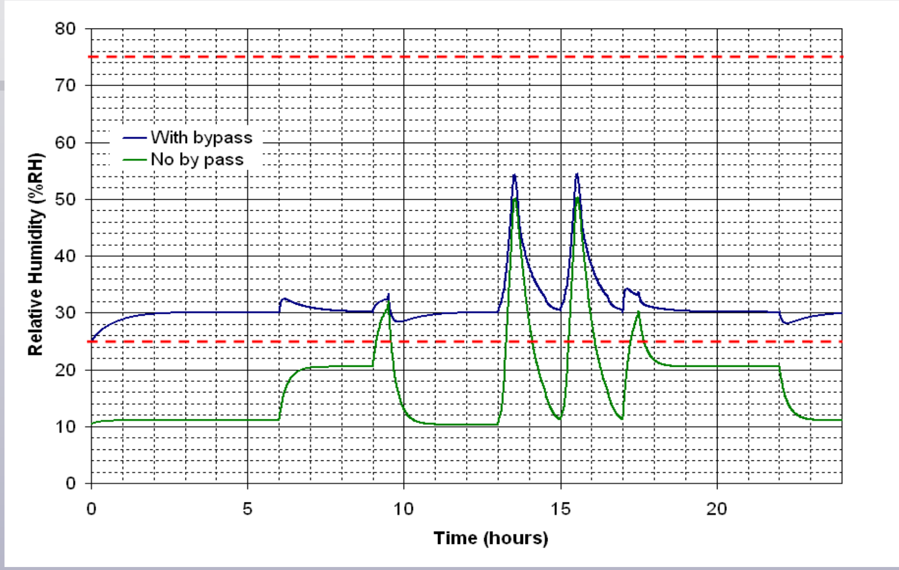
Updated control scheme

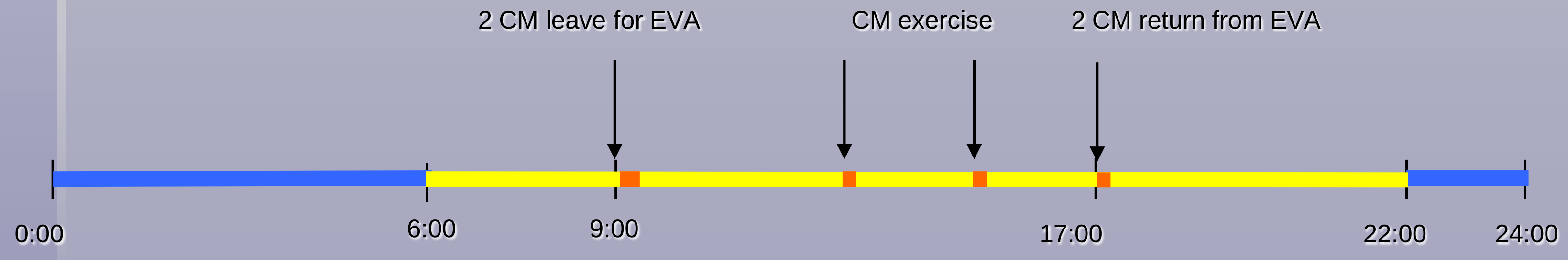
Cabin dew point controls PSA bypass flow



24-hour Cabin $ppCO_2$ & humidity profiles



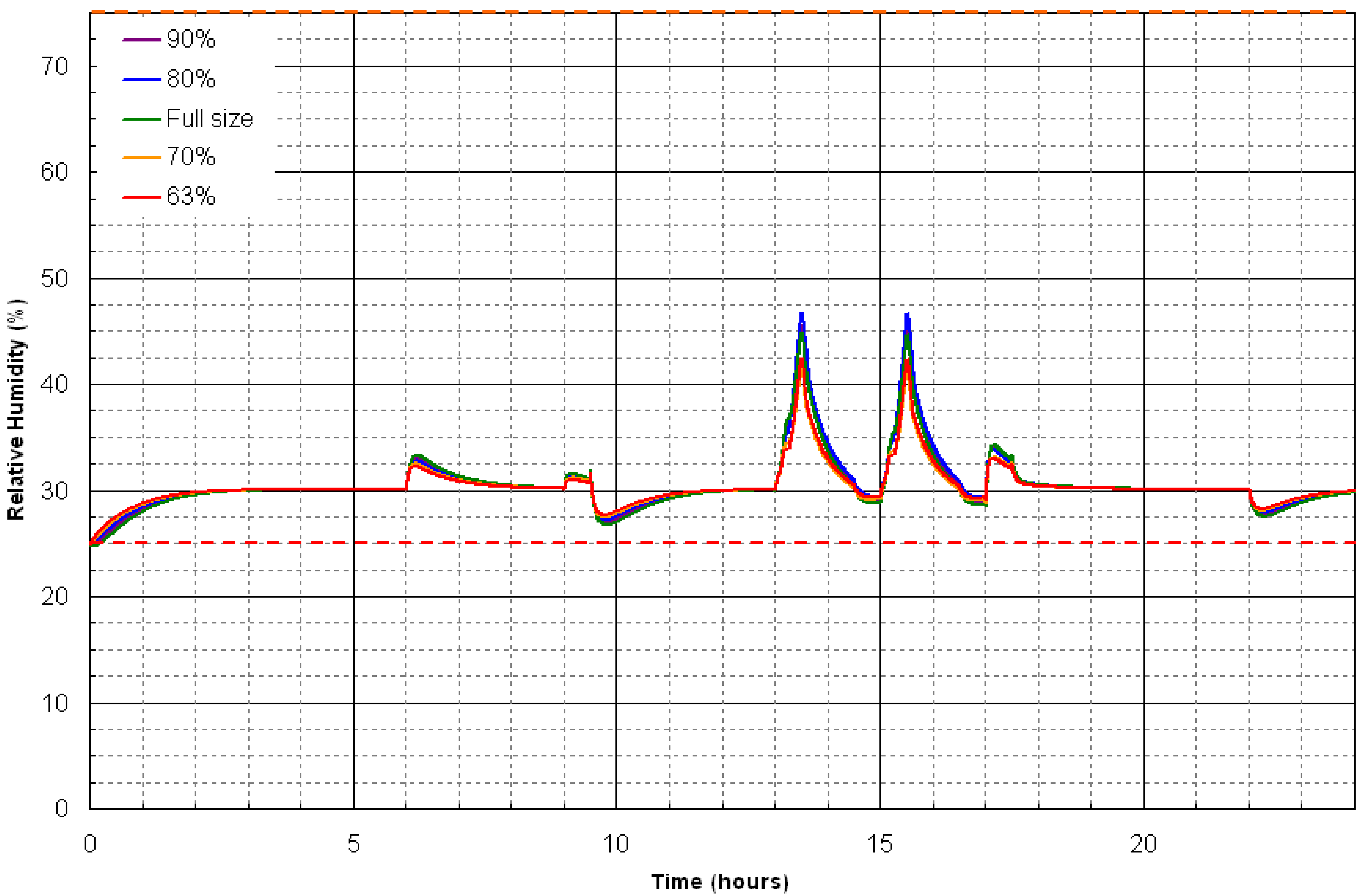




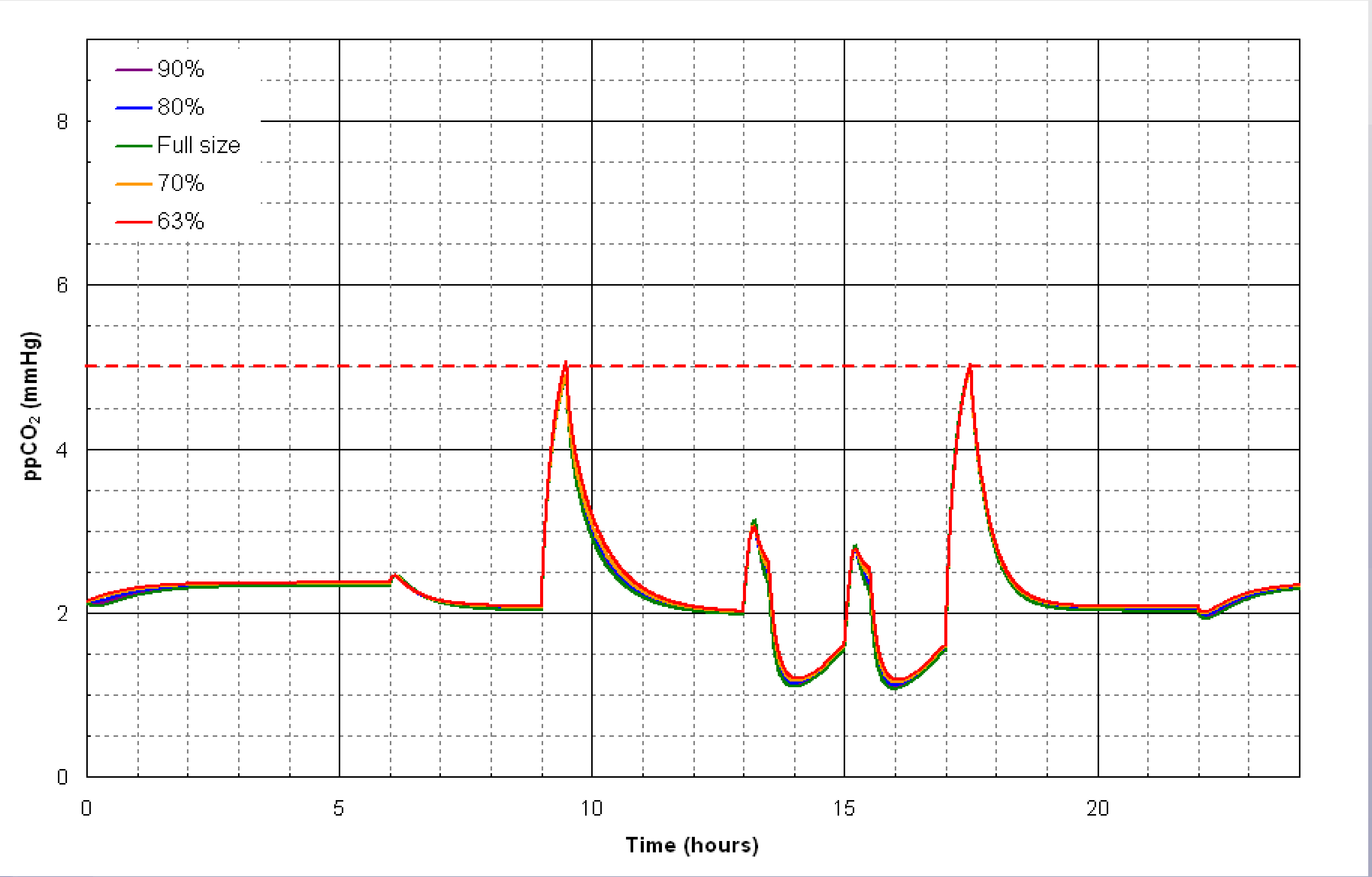
Bed sizing analysis

- 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

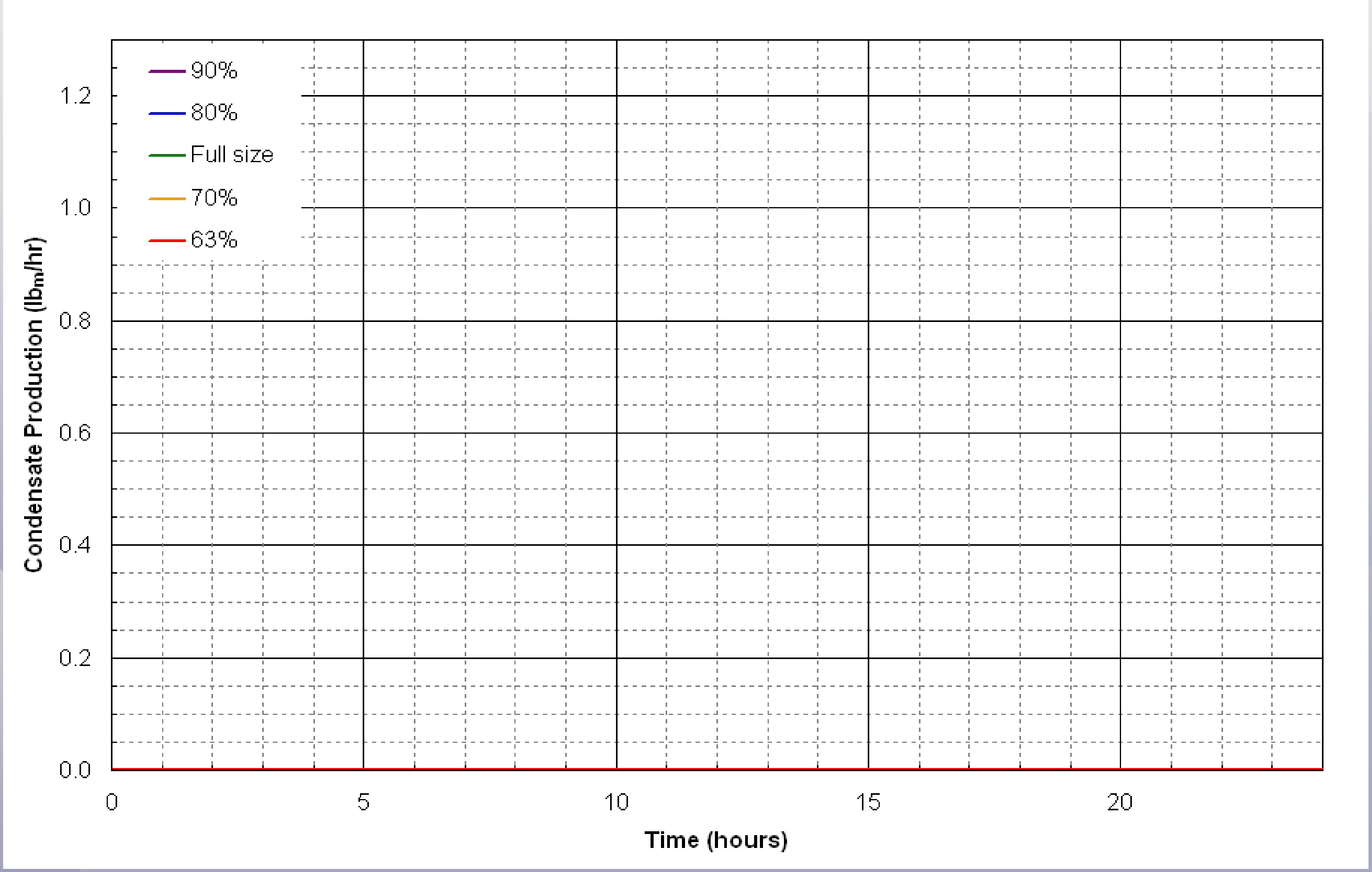
24-hr relative humidity profiles



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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