Amine Swingbed Payload Technology Demonstration

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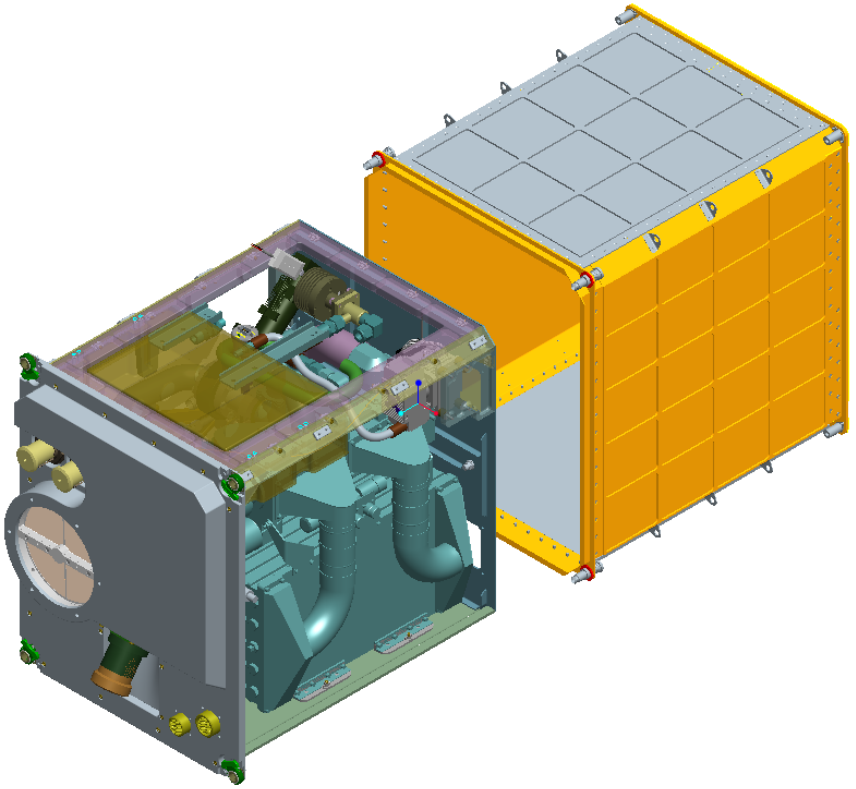
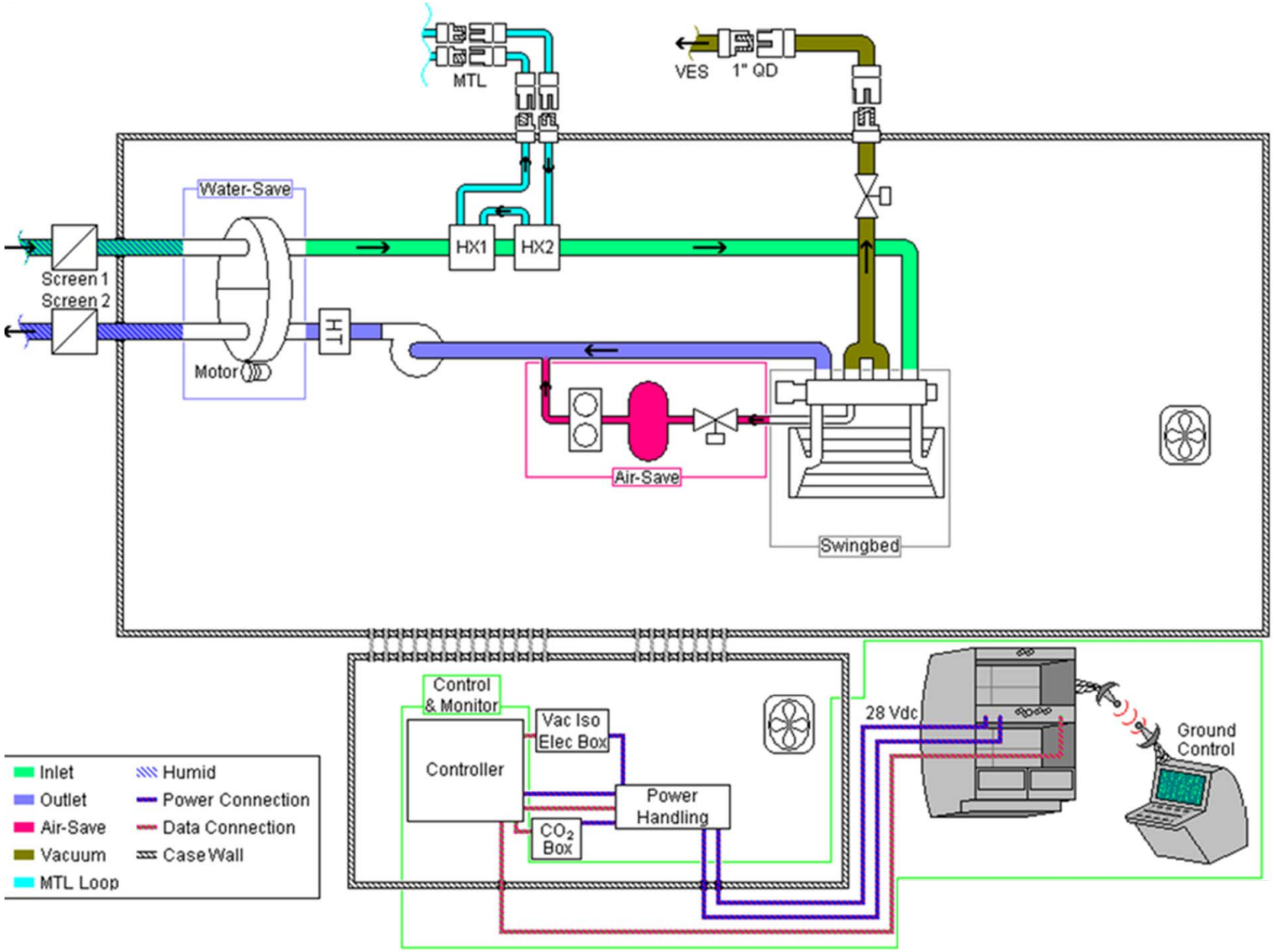
Amine Swingbed Technology

- The Amine Swingbed is an amine-based, vacuum-regenerated adsorption technology for removing carbon dioxide and humidity from a habitable spacecraft environment, and is the baseline technology for the Orion Program's Multi-Purpose Crew Vehicle (MPCV).
  - Uses a pair of interleaved-layer beds filled with SA9T, the amine sorbent.
  - A linear multiball valve rotates 270° back and forth to control the flow of air and vacuum to adsorbing and desorbing beds: one bed adsorbs CO_2 and H_2O from cabin air while the other bed is exposed to vacuum for regeneration by venting the CO_2 and H_2O.
  - The two beds are thermally linked, so no additional heating or cooling is required.
- The technology can be applied to habitable environments where recycling CO_2 and H_2O is not required such as short duration missions.

What is the Amine Swingbed Payload?

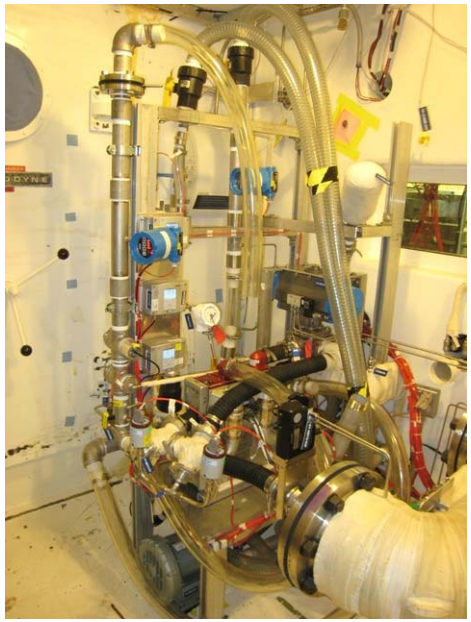
- The Amine Swingbed Payload consists of the swingbed itself, a desiccant wheel (to reduce water losses), an air-save tank and compressor (to reduce air losses), a blower, an air/liquid heat exchanger, a heater, various sensors, and a controller/power handler.
- Located in ExPRESS Rack 8 in the US Lab
- Controlled from the ground at JSC's Payload Operations Control Center (POCC).




MTL
VES
1" QD
Water-Save
Screen 1
Screen 2
Motor
HX1
HX2
HT
Air-Save
Swingbed
Control
& Monitor
Controller
Vac Iso
Elec Box
Power
Handling
CO_2
Box
28 Vdc
Ground
Control
Inlet
Outlet
Air-Save
Vacuum
MTL Loop
Humid
Power Connection
Data Connection
Case Wall

Technology Maturation for Orion

- Ground tests of the Amine Swingbed technology provide for:
  - detailed performance data
  - reduces technology risk
  - integrated technology evaluations (multiple components together in one test)
- Test conducted at JSC is more complicated and more integrated with other ARS systems than previous tests.
  - 2006/07/08: unmanned tests
  - 2008: human test subjects
  - 2009: reduced pressure, elevated oxygen
  - 2011: suited test subjects

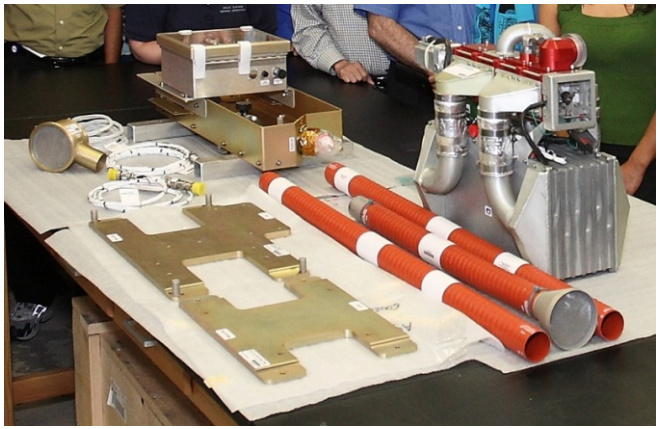
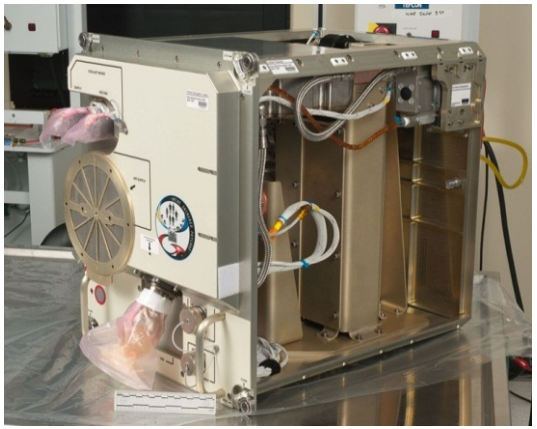
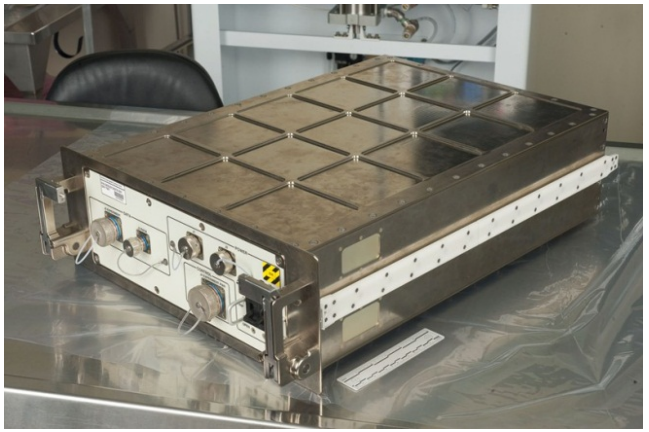


Orion technology demonstration on ISS

- Orion's Multi-Purpose Crew Vehicle (MPCV) is designed for short-duration missions where conserving resources (especially H_2O) is not critical, but maintaining low levels of CO_2 and comfortable humidity levels is.
- However, it is important for ISS to limit the amount of H_2O and air that are vented overboard because it is a long duration mission where resources are recycled as much as practical.
- To reduce H_2O and air losses while testing the Amine Swingbed on the ISS, new subsystems were developed, based on proven technologies, and were integrated with the Amine Swingbed.
  - Water Save subsystem
  - Air Save subsystem
- Using the ISS environment to test these subsystems integrated with the Amine Swingbed helps reduce risk for these technologies for potential future exploration missions.

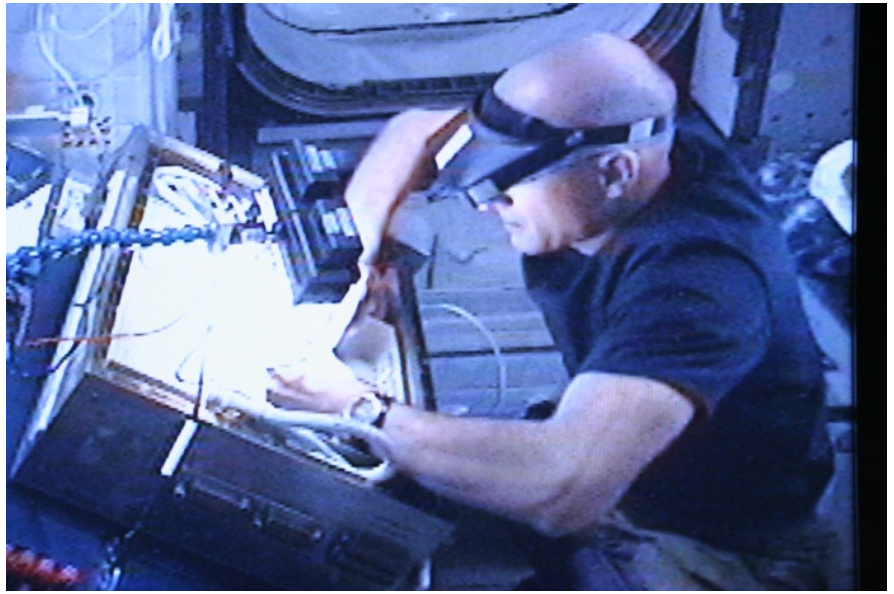
On-Orbit Payload Integration

- Due to logistical constraints (mass, volume), the Payload was delivered to ISS in two Phases
  - Phase A delivered Feb 2011
  - Phase B delivered July 2011
- On orbit was the first time that the Phase A equipment physically mated with the Phase B equipment.
  - Crew feedback was there was less than 1 mm of clearance. (Whew!)
- But no payload experience is complete without having to troubleshoot something, so . . . .

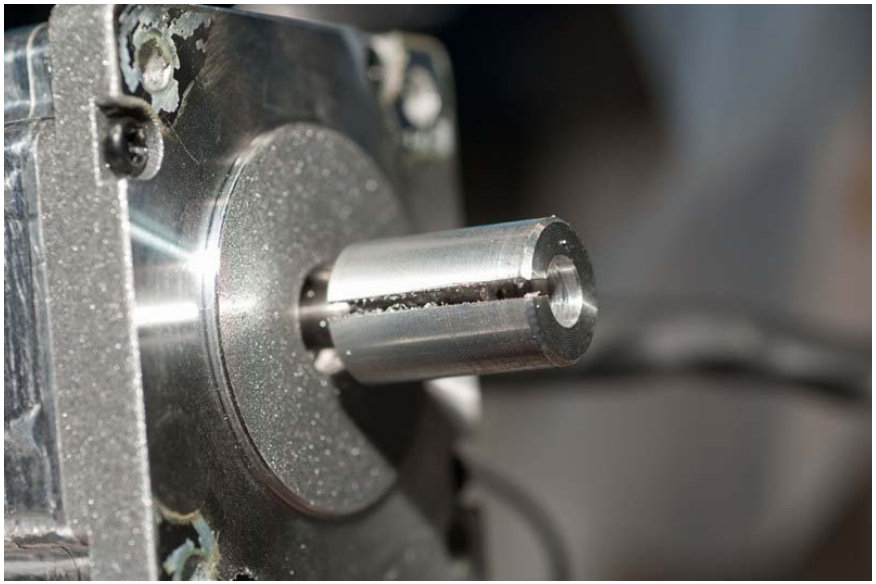
Anomaly and troubleshooting history

- ☹ GMT 2011/342: ISS Fire Alarm went off
- ☹ GMT 2012/013: Amine Swingbed valve stopped moving. Incorrect wiring = blown fuse.
- ☹ GMT 2012/041: Initial on-orbit electrical measurements indicated motor was wired wrong.
- ☹ GMT 2012/102: Motor rewire attempted, but visual indication and crewmember confirmed wiring was correct
- ☺ GMT 2012/159, 160: Installed new fuse on control board, replaced motor/gearbox assembly



Anomaly and troubleshooting history

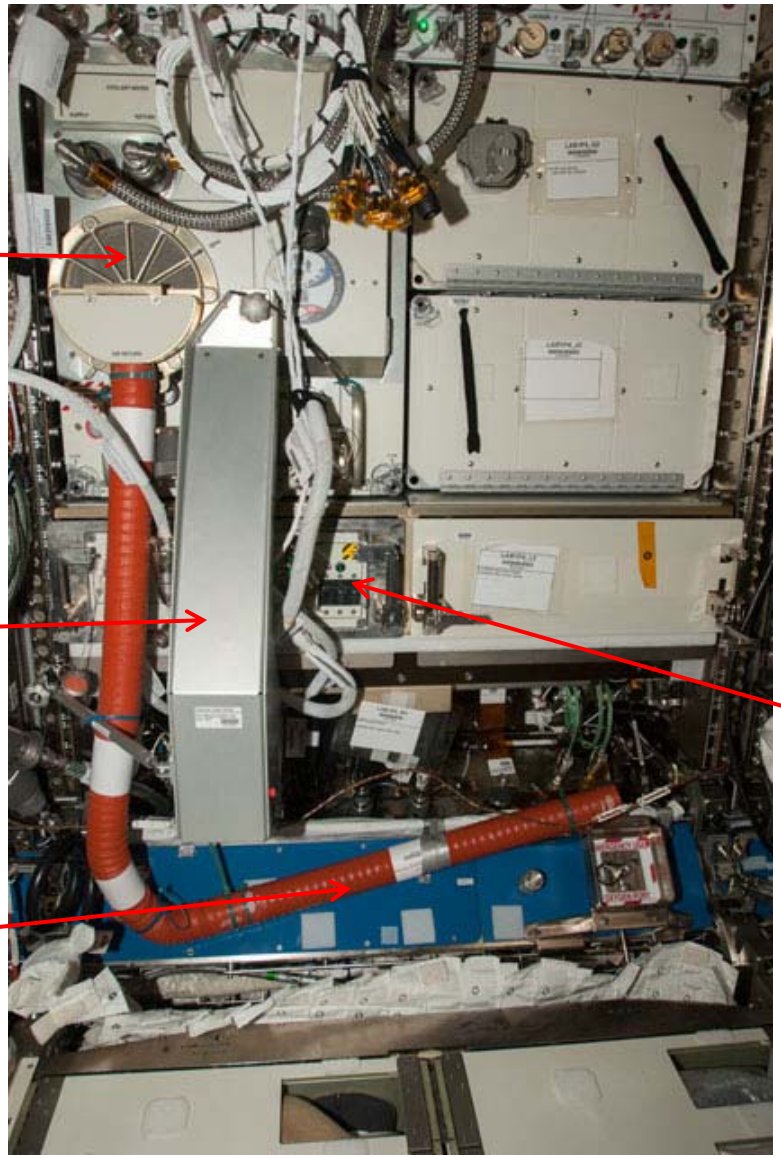
- ☺ GMT 2012/172: Final installation of payload into Express Rack 8 – successful.
- ☹ GMT 2012/175: Attempted Test Point 1. Proximity sensor failed to provide confirmation of complete rotation of valve. Mechanical cause: Set screws use to secure drive key inside gearbox were insufficiently torqued.
- ☹ GMT 2013/030: Torqued the set screws on the drive key, but valve failed to rotate properly, then stopped altogether. Possible cause: rotary valve failure, gearbox failure, motor failure.
- ☺ GMT 2013/059, 060: Evaluated valve torque resistance and replaced suspect gearbox with original gearbox – successful.
- ☺ GMT 2013/079: Payload installed into Express Rack 8.



Troubleshooting Ops

- Microgravity issues – assembly procedures.
- Clear instructions – “Just-in-time” videos.
- Direct communication with the crew.
  - More efficient, and when talking directly with crewmembers the actions are more coherent.
- More inflight anomaly resolutions.
  - Do whatever can be done on orbit before bringing it home.
- Engage the crew early.

On-orbit installation in the US Lab

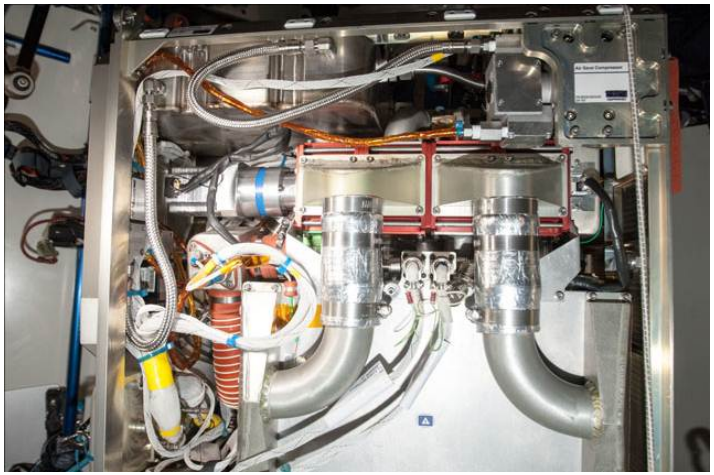


Air inlet

Vacuum interface

Air Return

Payload controller containing power and control functions and data collection

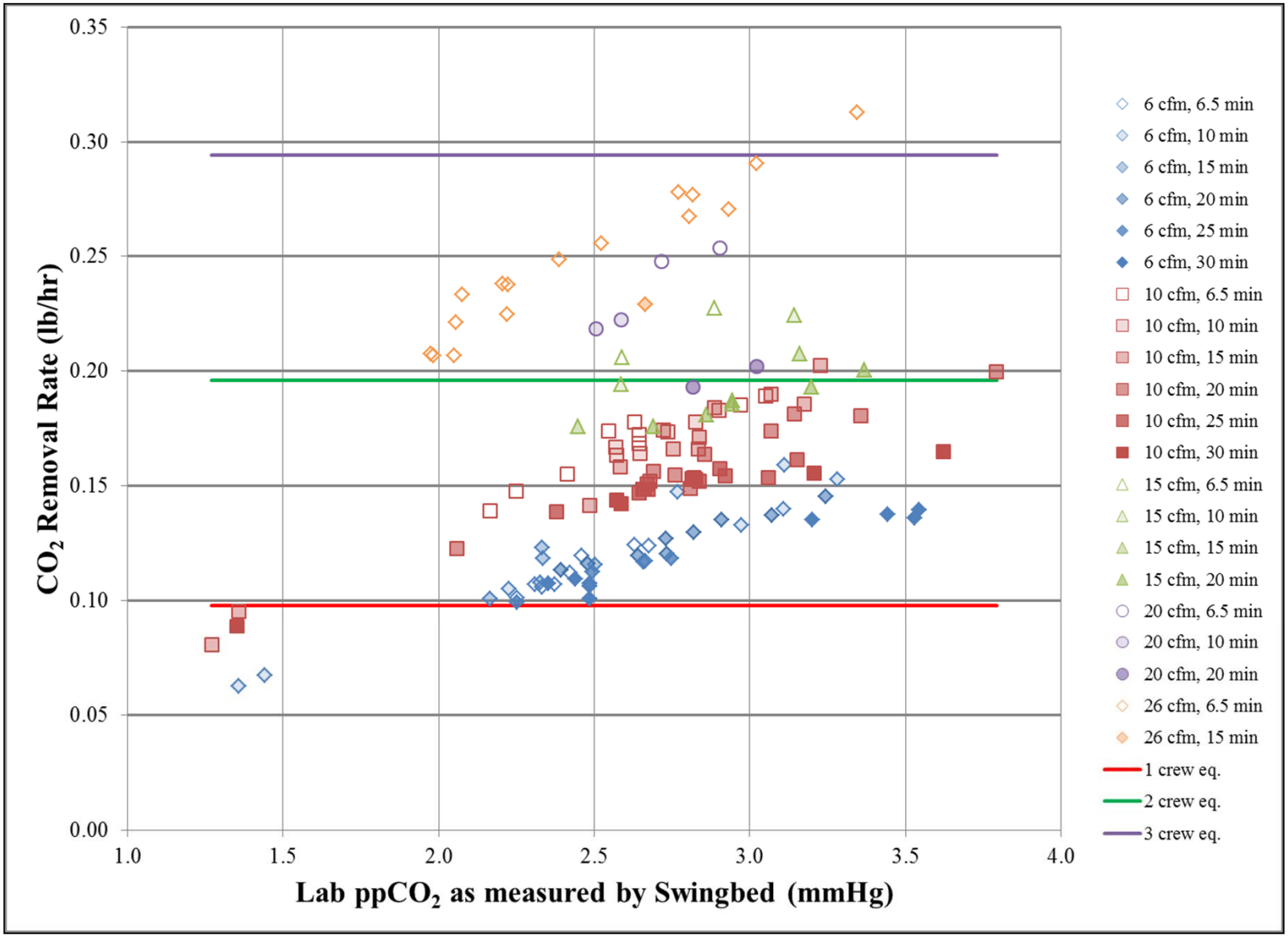


Swingbed inside locker chassis

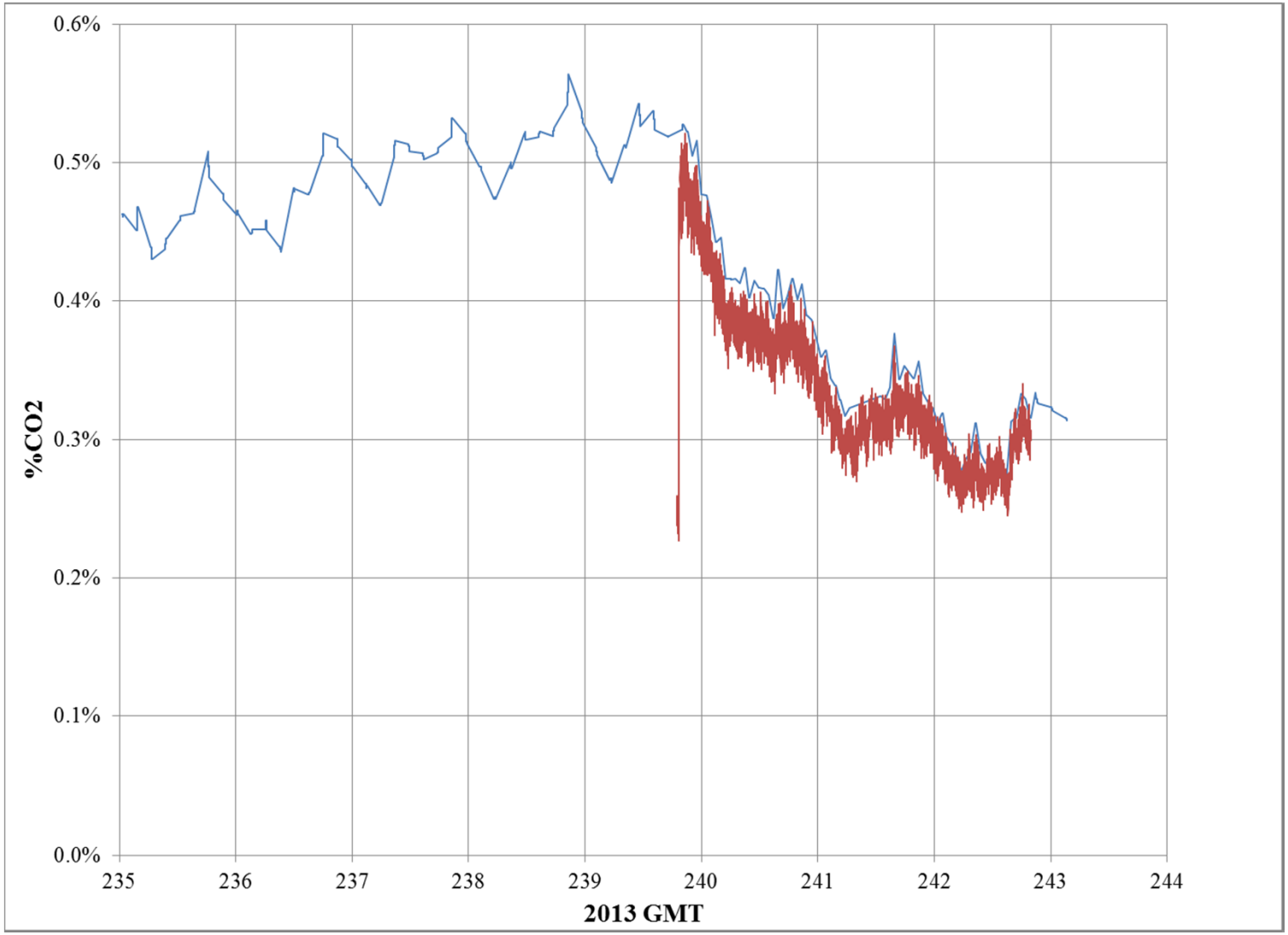
On-orbit operations

- The Amine Swingbed Payload is controlled by the Amine Swingbed team from the Payload Operations Control Center (POCC) at the Johnson Space Center in Houston by the Amine Swingbed team.
- Amine Swingbed Payload can run autonomously.
- Conducted 1000 hours of tests between May 2013 – February 2014, typically 8 – 16 hours at a time.
- Varied the air flow rate and rotary valve cycle period of the system.

CO_2 scrubbing performance



Case study: How much can Amine Swingbed impact ISS CO_2 levels?



Benefits of the Payload Experience

- Buys down risk for Orion
  - Important lessons related to motor/gearbox
  - If the rotary valve was the problem, could have major impacts to Orion
- Going through the Safety Review Process helps expand your on knowledge of your payload
- Team is better because of the payload experience
  - Technology development experts caught of glimpse of the Ops world

Amine Swingbed as an ISS Resource

- ISS Program will maintain the capability to operate the Amine Swingbed Payload through at least 2015.
  - Provide backup CO_2 removal for contingency ops.
  - Provide supplementary CO_2 removal.
- Recently supported Node 3 CDRA maintenance activity (April, 2014).
  - The Node 3 Carbon Dioxide Removal Assembly (CDRA) was taken offline for maintenance in April 2014. ISS program requested the Amine Swingbed Payload to provide supplemental and contingency CO_2 removal during this period.

Acknowledgements

- Su Curley, Amy Button, Melissa Campbell, Mary Walsh, Katie Collier, Courtney McManus, Javier Jimenez, John Graf, Liz Hayley, Daniel Molina, Adam Rawlin, Glen Steele, Erik Harvey, Bill Papale, Ed Hodgson, Matt Cates, Dan Sweeney, Jay Leggett, Denise Morris, Karen Somers
- Dan Burbank, Don Pettit, Joe Acaba, Kevin Ford, Chris Hadfield


KEEP CLEAR OF DOOR
WHILE IT IS OPERATING
THINK
SAFETY
THINK
SAFETY