Main Title:
Exploration Portable Life Support System (xPLSS)

EVA Technology Workshop 2017

October 17, 2017
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NASA\EC

Agenda

- Architectural Overview
- PLSS Evolution
- Current xPLSS Design Overview
- Product Break-down Structure
- Component Overview
- Development Approach
- Risk Items

PLSS Architecture

| Function	Method
Primary pressurization	High pressure gaseous oxygen with regulation
Ventilation Circulation	Fan turbomachine
Ventilation Loop CO_2 Removal	Amine Pressure Swing Adsorption Swingbed
Ventilation Loop H_2O Removal	Amine Pressure Swing Adsorption Swingbed
Trace Contaminant Control	Activated charcoal with phosphoric acid
Crew waste heat rejection	Liquid cooling and ventilation garment with cooling water circulation and latent heat rejection
System waste heat rejection	Hollow-fiber membrane evaporator
Short duration - Secondary pressurization, ventilation, CO_2/H_2O removal, trace contaminant control, and cooling	High pressure gaseous oxygen with regulation and purge valves setting high open loop flow
60 min long duration - Secondary pressurization, ventilation, CO_2/H_2O removal, trace contaminant control, and cooling	High pressure gaseous oxygen with regulation and purge valves setting low open loop flow Core torso liquid cooling garment with 1/3 size hollow-fiber membrane evaporator

PLSS Evolution/History

COMPLETE ✔	COMPLETE ✔	FY18/FY19	FY22/23
PLSS 1.0 (Breadboard)	**PLSS 2.0 (Packaged GN2)**	**PLSS 2.5 -302 (DVT)**	**PLSS 3.0 (Qual)**

- Schematic validation with models
- Component pneumo-hydraulic integration
- Prototype: RCA, Fan, SWME, POR, SOR
- Balance COTS/Instruments
- 8 simulated EVA transient profiles
- 397 hrs of full PLSS operation
- 595 hrs of SWME/thermal loop operation
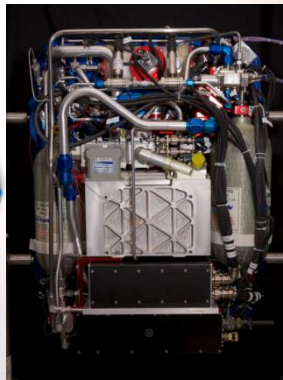
- Packaged lab unit
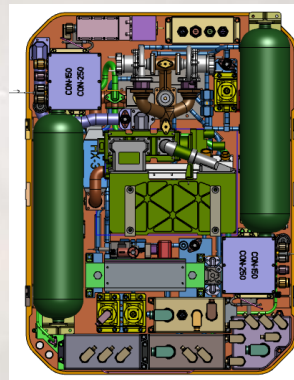- 2nd gen prototypes: POR, SOR, RCA, SWME
- 1st gen prototypes: remainder
- Pre-Installation Acceptance (PIA) test against system spec
- 19 psia air human-in-the-loop testing with the Mark III spacesuit (19 x 2hr EVAs)
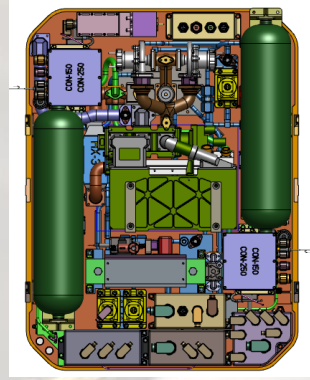- 25 EVAs, failure simulations, integration tests

- Flight design GN2/Air only
- Pre-Installation Acceptance (PIA) test against system spec
- 25-100 unmanned EVAs in vacuum
- Unmanned thermal vacuum testing
- Pressurized launch vibe testing at ESTA
- SSP EMI Testing
- Static Magnetics Testing

- Flight design GN2, Air, O2
- Pre-Installation Acceptance (PIA)
- Full qualification test
- 25-100 unmanned EVAs in vacuum
- Unmanned thermal vacuum testing
- Pressurized launch vibe testing at ESTA
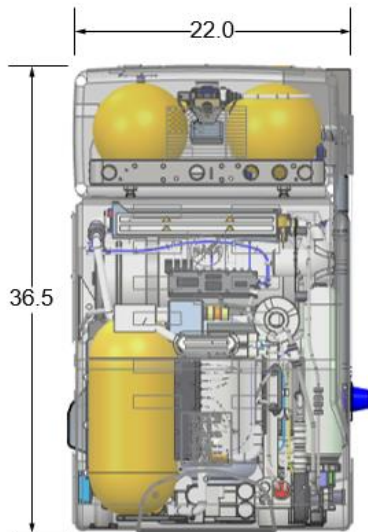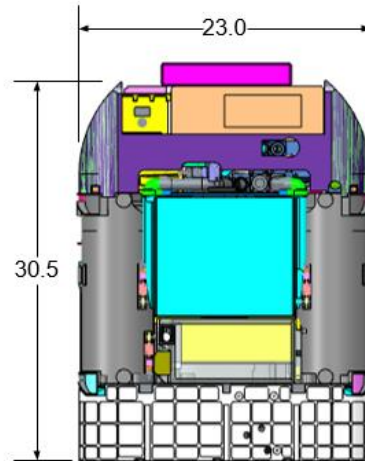- SSP EMI Testing
- Static Magnetics Testing
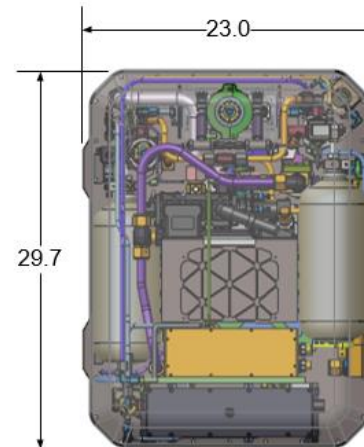- Manned vacuum integration testing
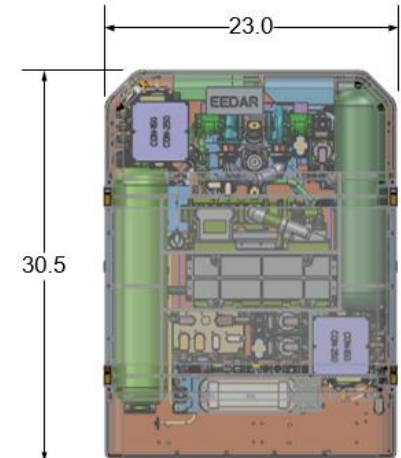- Manned thermal vacuum testing

	Apollo EMU	Shuttle/ISS EMU	xEMU PLSS 2.0	xEMU PLSS 2.5 -301 Live Loads Assy
Volume	7750 in3	4300 in3	6800 in3	5400 in3
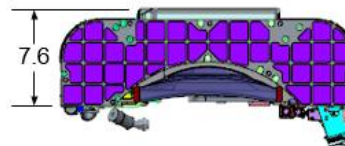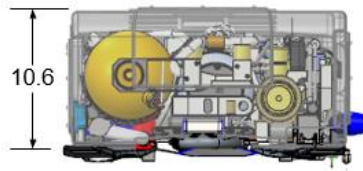
Design Paradigm Shift

- Longer mission and much higher EVA count
- Carried sparing
- Very limited up/down logistics train
- Extensive In-Flight Maintenance

- Brief missions and limited number of EVAs
- Carried sparing
- Altered sparing for mission critical scenarios (e.g. Hubble, etc)
- Limited In-Flight Maintenance

Exploration EMU

ISS EMU

- Longer mission duration and higher EVA count
- Carried sparing
- Available up/down logistics train
- Extensive In-Flight Maintenance

Shuttle EMU

Apollo EMU

Number of EVAs

Mission Duration (days)

Design Paradigm Shift

- xEMU design is not within current experience base or paradigm
  - Higher EVA count on longer duration missions further from ground supplies places a much higher premium on system robustness and inherent redundancy
- Ways to attack this
  - Design in redundancy not seen on Apollo/Shuttle/ISS EMU
    - Current ISS EMU has NCRs for insufficient fault tolerance per current ISS requirements
    - xEMU will also have NCRs but will have fewer as the design will provide more redundancy
  - Rely on commonality to reduce logistical burden and lower development costs
    - Enables fewer spares to cover more potential faults
    - Reduced development cost can be reinvested in more extensive development testing on the ground
  - Include enhanced system health sensing and logic to enable enhanced fault isolation and real-time decision making
  - Classic single unit DVT and Qual with scatter factor and qual margins still assumes a single tolerance stack-up and single process run
    - Examine novel ways in development to test less expensive components to failure examining both margin and failure causes similar to how industry readies a product for market
  - Gain experience with system usage incrementally prior to departing LEO
    - Implementation of the xPLSS Thermal Loop for long term microgravity operational water quality testing as part of the SWME EXPRESS Rack Flight Experiment (SERFE) project provides risk reduction
    - ISS Demonstration of xEMU system is critical as unknown long term issues can be seen during demonstration deployment and addressed before long term deployment
      - ISS EMU water quality is an example of this type of lesson

PLSS Development Philosophy

- Take advantage of the 35+years of operational/failure/lessons learned data from the STS/ISS EMU Program*
  - Corporate knowledge from team experience
  - EMU Requirements Evolutions
  - Assured EMU Availability (AEA) Reports
  - PRACA FIAR summaries
- At the system level, simplify as much as possible
 - Remove components if the function can be achieved with new technologies and fewer components

| Shuttle/ISS EMU CEI	Description
113E	Primary Pressure Control Module, Feewater Pressure Regulator
120	Dual mode relief valve
123B	Fan/Pump/Separator - Water Separator
125	Pitot Actuated Valve
127/128	Pump inlet filter and check-valve
132A	Feedwater supply pressure sensor, gas side
134	Condensate water relief valve
135	Feedwater relief valve
136	Feedwater pressure regulator
137	Feedwater shut-off valve
142	Feedwater relief valve
143	Feedwater check valve
171/172	Coolant loop isolation valve

Components Removed from ISS EMU to xEMU PLSS 2.5

*Reference ICES-2015-327 for additional information

PLSS Development Philosophy

ISS EMU

xPLSS 2.5 -301

- Use FMEA and analysis of ISS EMU failure history to guide addition of redundancy to PLSS
  - There is insufficient vol/mass available to simply double/triple the component functions in order to provide 3 controls to a catastrophic hazard
  - Examples of added redundancy
    - Cold spare thermal loop pump
    - Cold spare ventilation fan
    - Two-stage regulators (primary and secondary)
    - Dual multi-gas sensors
    - Redundant sensors with fail-over correction algorithms in CWS
    - Multi-string distributed battery
    - Distributed controllers with independent control from the Display and Control Unit
- Margin/redundancy result from new technologies and system choices
  - Examples
    - SWME
      - No break-through due to thermal load, single pass degassing, apparent margin on contamination
    - Separation of F/P/S => centrifugal fan and positive displacement pump
      - Ability to add cold spares
      - Loss of both fans results in low purge mode with full thermal loop cooling and abort
      - Loss of both pumps results in low purge mode with auxiliary thermal loop cooling and abort
    - FSA within ventilation loop
      - Loss of primary supply or I-113E Feedwater Pressure Reg on EMU causes loss of thermal loop function
      - Loss of primary supply on xEMU results in secondary supply operation with full thermal loop capability
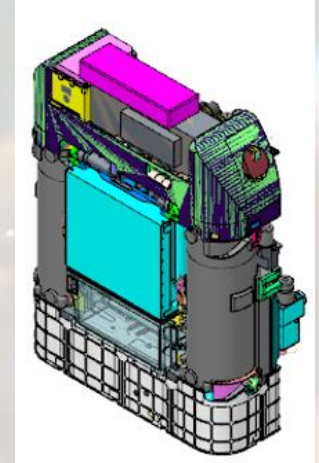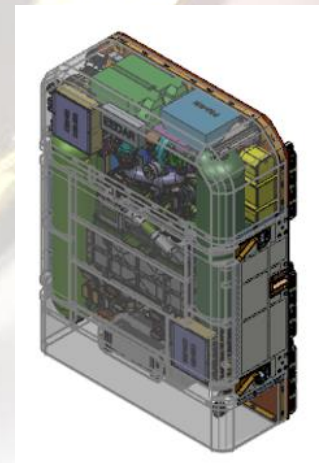
PLSS Development Philosophy

- If the component has operated well for the ISS EMU, then consider reuse
  - Examples
    - Primary O2 tanks from Arde' use cryo-formed 301 that has now been demonstrated in both Apollo and STS/ISS EMU as a long term, highly reliable approach
      - COPVs do not offer significant mass savings at the POV/SOV wetted volumes but do offer stress rupture failure modes as well as modeling/inspection challenges
    - Secondary Oxygen Pack second stage regulator
      - This is the basis for the second stage regulator in the POR/SOR but with extended bellows/actuator to provide increased functionality

- For components that have exhibited reliability issues or cannot meet needed functional requirements, then look for new technology or redesign it address the short comings
- Extensively test and analyze at the component level and sub-system level to mature

ISS EMU SOP Regulator
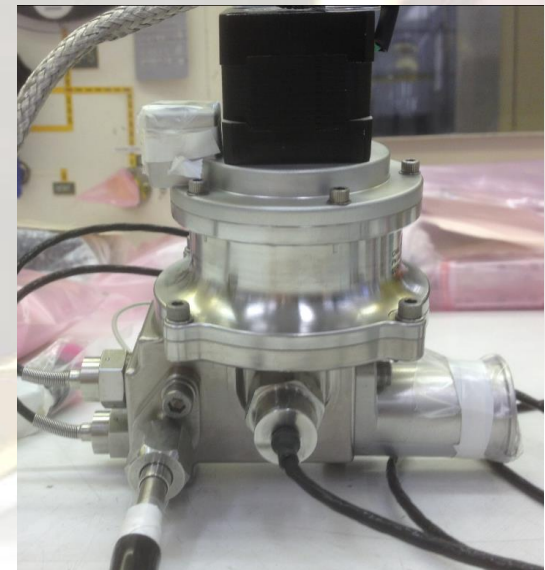
POR 2.0

PLSS 1.0 Overview

- Table shows initial key prototypes, other components were COTS equivalents of items in the schematics

Accomplished

- 397 hrs of full PLSS operation
- 595 hrs of SWME/thermal loop operation
- Schematic validation with models
- 8 simulated EVA transient profiles
- Steady state profiles
- Failure modes simulations
- Closed loop to open loop purge transitions

| Components	Provider
Rapid Cycle Amine 1.0	UTAS
Fan 1.0	UTAS
Spacesuit Water Membrane Evaporator (SWME) Gen 2	EC/JETS
Primary Oxygen Regulator (POR) 1.0	Cobham
Secondary Oxygen Regulator (SOR) 1.0	Cobham

PLSS 2.0 Overview

Accomplished

- Packaged lab unit
- Pre-Installation Acceptance (PIA) test against system spec
- 19 psia air human-in-the-loop testing with the Mark III spacesuit (19 x 2hr EVAs)
- 25 EVAs
- Test to failure and/or failure simulations
- Integration tests for ISS/exploration vehicle interfaces

| Components	Provider
Rapid Cycle Amine 2.0	UTAS
Fan 1.0	UTAS
Spacesuit Water Membrane Evaporator (SWME) RVP	NASA/JSC
Primary Oxygen Regulator (POR) 2.0	Cobham
Secondary Oxygen Regulator (SOR) 2.0	Cobham
Ventilation Heat Exchanger 1.0	UTAS
Primary Thermal Loop Pump 2.0	UTAS
Multi-gas Sensors (CO2/H2O/O2) – APLSS 2.0	Vista Photonics
Mini-Membrane Evaporator (Mini-ME) 1.0	NASA/JSC
Thermal Control Valve 2.0	EC
Vent Flow Sensor and Check Valve 1.0	NASA/JSC
Feedwater Supply Assembly 1.0	OSS
Auxiliary Feedwater Supply Assembly 1.0	OSS
Avionics Coldplate 1.0	OSS/Paragon
EMU LCVG Dual Loop LCVG	ISS EMU OSS
Positive Pressure Relief Valve (PPRV)	OSS/Airlock
Caution Warning and Control System (CWCS)	NASA/GRC
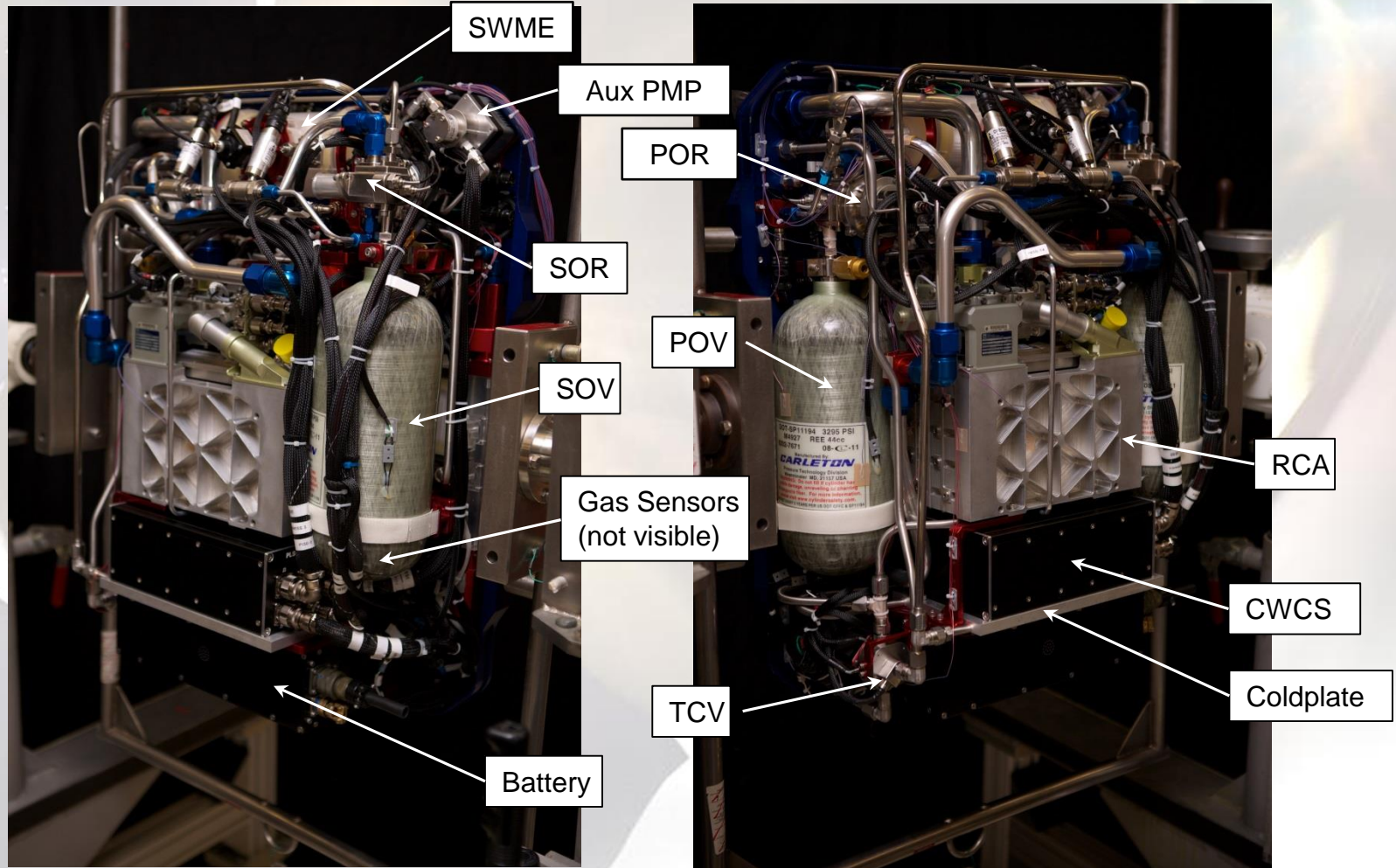
PLSS 2.0
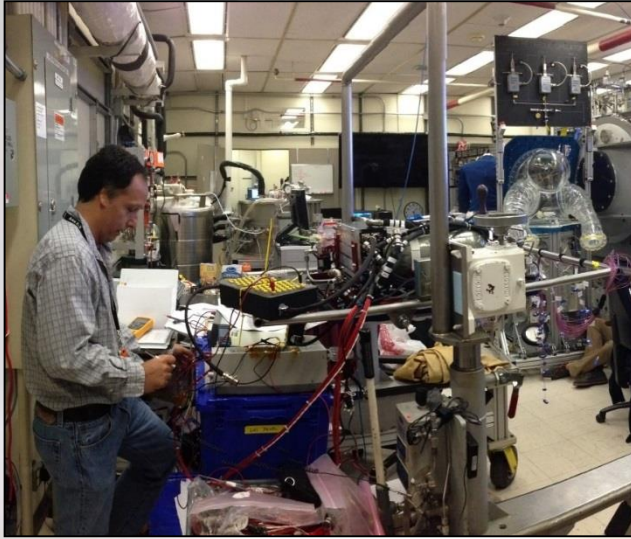
PLSS 2.0 PIA Testing
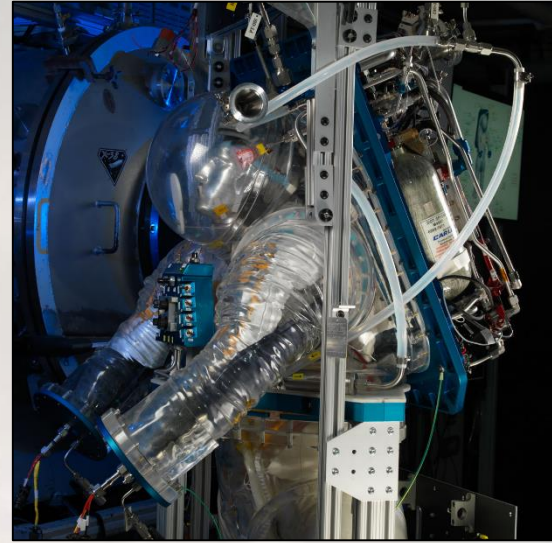
Simulated On-back Testing
With Space Suit Assembly Simulator (SSAS)
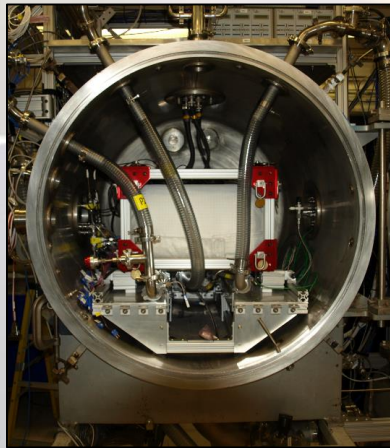
25 EVA Vacuum Chamber Testing

Human-In-The-Loop (HITL) Testing

Planning to complete

- Verification of PLSS communications specification

- Integrated electrical testing considering communications, analog inputs, digital inputs, power quality

- Power switching, current limiting

- Simulated electrical interfaces via Power Supply Assembly (PSA) Simulator

Components	Provider
Rapid Cycle Amine 3.0	UTAS
Fan 2.0	UTAS
Spacesuit Water Membrane Evaporator (SWME) Simulator (actuator/sensors)	NASA/JSC
Primary Oxygen Regulator (POR) 3.0	Cobham
Secondary Oxygen Regulator (SOR) 3.0	Cobham
Ventilation Heat Exchanger 2.0	NASA/JSC
Primary/Auxiliary Thermal Loop Pump 3.0	UTAS
Mini-Membrane Evaporator (Mini-ME) 2.0 Simulator (actuator/sensors)	NASA/JSC
Thermal Control Valve 3.0	NASA/JSC
Pressure Transducers	GP:50
CON-450, Thermal Loop Controller	OSS
CON-550, Auxiliary Thermal Loop Controller	NASA/JSC
Caution and Warning System (CWS-650)	NASA/JSC
Primary/Auxiliary/Accessory Battery Assemblies	NASA/GRC NASA/JSC

PLSS 2.5 -301
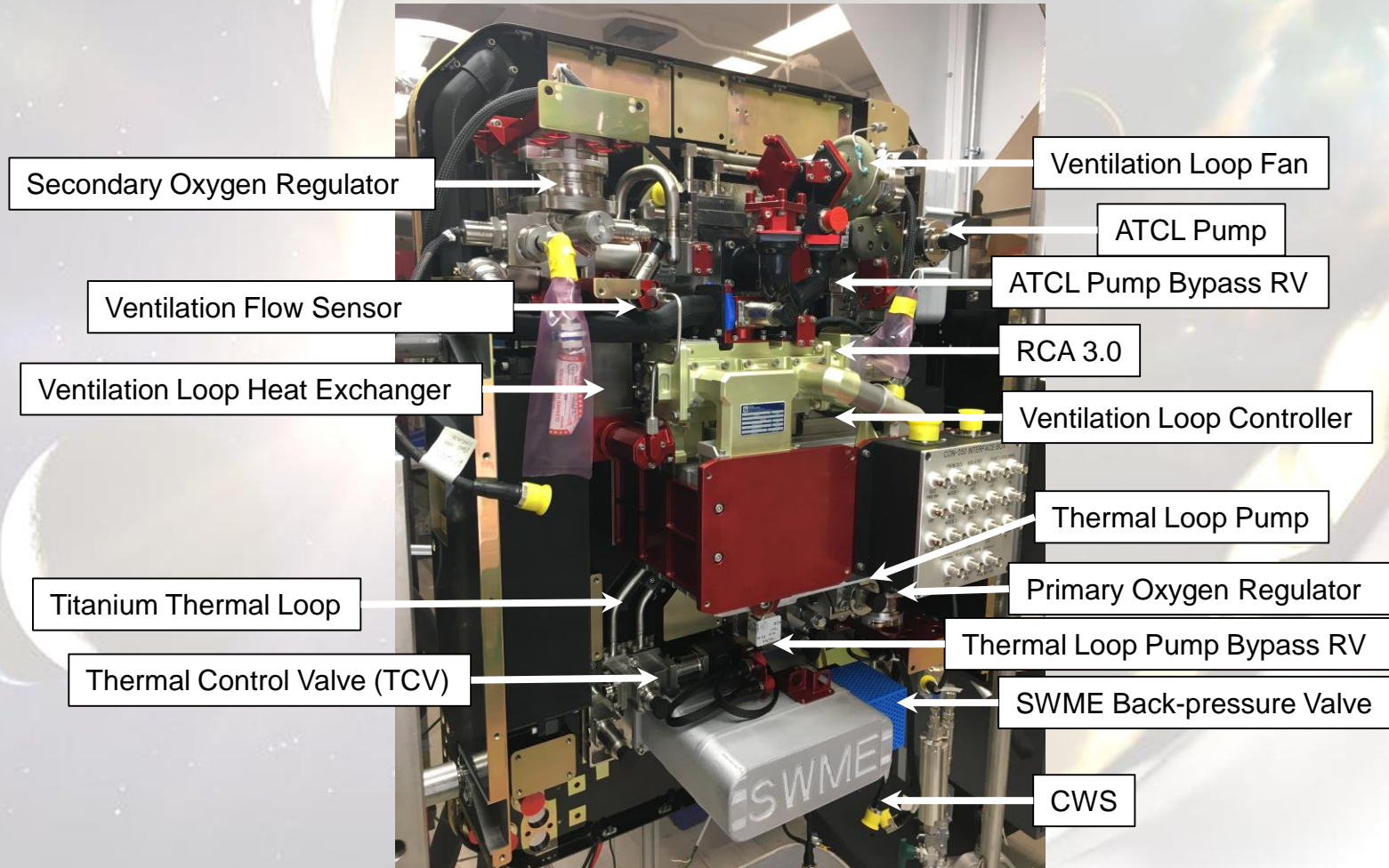
PLSS 2.5 -301 Live Loads Testing

PLSS 2.5 Distributed Battery
Bread-board

PLSS 2.5 Ventilation/Thermal Loop
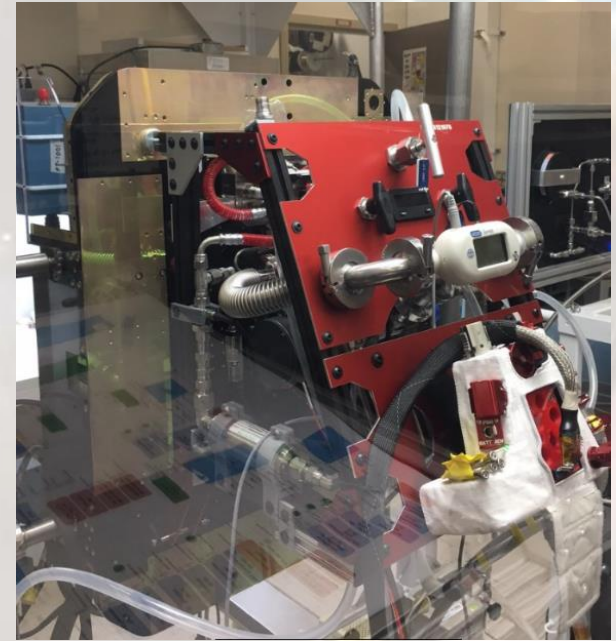Jumper Assembly

PLSS 2.5 -302 DVT Unit

Planning to complete

- Integrated electrical loads testing
- Pre Installation Acceptance (PIA)
- 25-100 EVAs in lab neutral thermal environment
- Integration tests for ISS/exploration vehicle interfaces
- PLSS-level thermal vacuum testing
- Conducted/Radiated EMC
- Static magnetic field testing
- Operating vibration testing
- Launch vibration testing
- Failure simulations

Components	Provider
Rapid Cycle Amine 3.0	UTAS
Fan 2.0	UTAS
Spacesuit Water Membrane Evaporator (SWME) 4th Gen	NASA/JSC
Primary Oxygen Regulator (POR) 3.0	Cobham
Secondary Oxygen Regulator (SOR) 3.0	Cobham
Primary Oxygen and Secondary Oxygen Vessels	Arde'
Ventilation Heat Exchanger 2.0	Creare NASA/JSC
Primary/Auxiliary Thermal Loop Pump 3.0	UTAS
Multi-gas Sensors (CO2/H2O/O2) – APLSS 3.0	Vista Photonics JPL UTAS
Mini-Membrane Evaporator (Mini-ME) 2.0	NASA/JSC
Thermal Control Valve 3.0	NASA/JSC
Pressure Transducers	GP:50
CON-150, Primary Oxygen Regulator Controller	OSS
CON-250, Secondary Oxygen Regulator Controller	OSS
CON-350, Ventilation Loop Controller	OSS
CON-450, Thermal Loop Controller	OSS
CON-550, Auxiliary Thermal Loop Controller	NASA/JSC
Caution and Warning System (CWS-650)	NASA/JSC
Primary/Auxiliary/Accessory Battery Assemblies	NASA/JSC

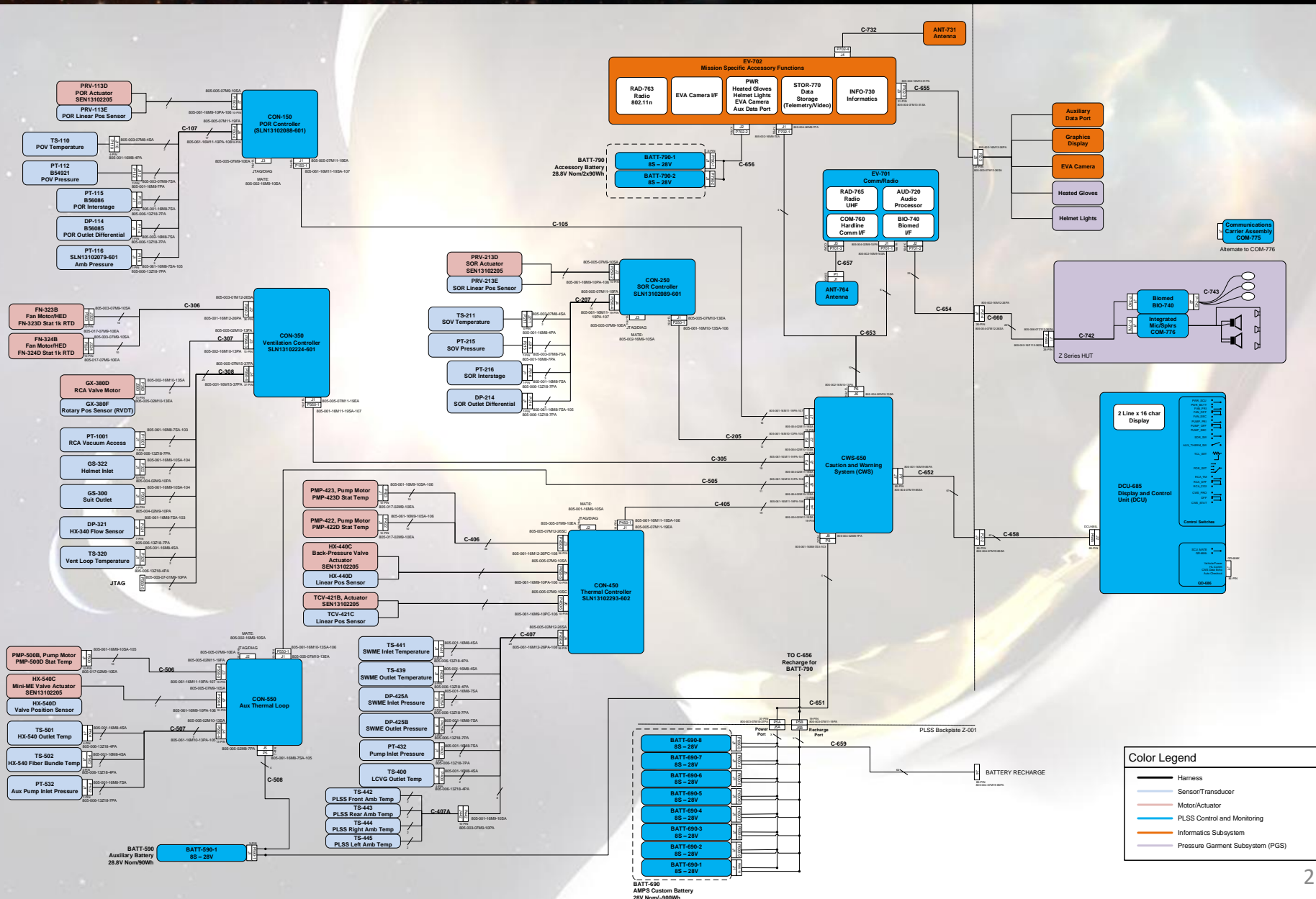## CWS-650
Caution and Warning System (CWS)

MASTER

LVDS Half-Duplex Twisted Shielded Pair 3ft max 24AWG

LVDS Half-Duplex Twisted Shielded Pair 3ft max 24AWG

LVDS Half-Duplex Twisted Shielded Pair 3ft max 24AWG

LVDS Half-Duplex Twisted Shielded Pair 3ft max 24AWG

LVDS Half-Duplex Twisted Shielded Pair 3ft max 24AWG

CON-150 POR Controller
SLAVE

CON-250 SOR Controller
SLAVE

CON-350 Ventilation Controller
SLAVE
MASTER

CON-450 Thermal Controller
SLAVE

CON-550 Aux Thermal Loop
SLAVE

RS-485 Full-Duplex Twisted Shielded Pair 2ft max 24AWG

GS-322 SLAVE

GS-300 SLAVE

CWS-650
Caution and Warning System (CWS)

SLAVE *MASTER* *MASTER*

LVDS Full Duplex Twisted Shield Pairs 3ft max 24AWG

LVDS Full Duplex Isolated Twisted Shield Pairs 3ft max 24AWG

RS-485 Simplex Twisted Shielded Pair 4ft 24AWG

EV-701 Radio

MASTER

| RAD-765 Radio UHF | AUD-720 Audio Processor |
| COM-760 Hardline Comm I/F | BIO-740 Biomed I/F |

EV-702 Informatics Mission Specific Accessory Functions

SLAVE

| STOR-770 Data Storage (Telemetry/Video) | INFO-730 Informatics |
| PWR Heated Gloves Helmet Lights Aux Data Port | Radio 802.11n |

CWS Diagnostic Pass-Through ISOLATED

DCU-685 Display and Control Unit (DCU)
SLAVE

RS-485 Simplex Twisted Shielded Pair 30ft max 24AWG

CHK-850 Auto Checkout

GROUND TEST INTERFACE

VEHICLE DATA INTERFACE

FN-324 Secondary Fan

CKV-326 Secondary Fan Check Valve

GS-322, Suit Inlet Gas Sensor (top)
GS-300, Suit Outlet Gas Sensor (bottom)

CON-250, SOR Controller

PRV-213, Secondary Oxygen Regulator

BATT-690 x8 Module

DP-321, Ventilation Flow Sensor

EV-701, Space to Space AEMU Radio (UHF)

HX-340, Ventilation Loop Heat Exchanger

CON-450, Thermal Loop Controller

PV-210, Secondary Oxygen Tank

TCV-421, Thermal Control Valve

TS-441, SWME Outlet Temperature Sensor

PT-425B, SWME Outlet Pressure Sensor

HX-440, Spacesuit Water Membrane Evaporator

Battery Modules x3 to be removed

TS-400, Pump Inlet Temperature Sensor

BATT-590 x1 Module

BATT-790 x2 Module

CON-550 Auxiliary Thermal Loop Controller

FN-323 Primary Fan

CKV-325 Primary Fan Check Valve

TS-501, Mini-ME Outlet Temperature Sensor

PMP-500, Auxiliary Thermal Loop Pump

HX-540, Auxiliary Thermal Loop Evaporator

RV-348, Secondary Positive Pressure Relief Valve

CON-350, Ventilation Loop Controller

GX-380, Rapid Cycle Amine Swingbed

EV-702, Informatics Processor/Wi-Fi

PV-111, Primary Oxygen Tank

PRV-113, Primary Oxygen Regulator

CON-150, POR Controller

PMP-423, Primary Pump

PMP-422, Secondary Pump

TS-439, SWME Inlet Temperature Sensor

DP-425A, SWME Inlet Pressure Sensor

CWS-650, Caution and Warning System

PT-432, Pump Inlet Pressure Sensor

RV-424, Pump Bypass Relief Valve

CON-150
CON-250

CON-150
CON-250

*Package updates to optimize front to back dimension with Z-HUT in process

- Of course the goal is to design a system that requires no maintenance and never fails but just in-case...

- ORU-able Items are outlined in red-boxes

- Each of the ORUs includes captive fasteners, pneumatic or hydraulic interfaces with redundant seals, alignment guides, and scoop-proof connectors

- Interfaces between major components involve comm and high level power rail enabling increased modularity for both maintenance and future upgrade
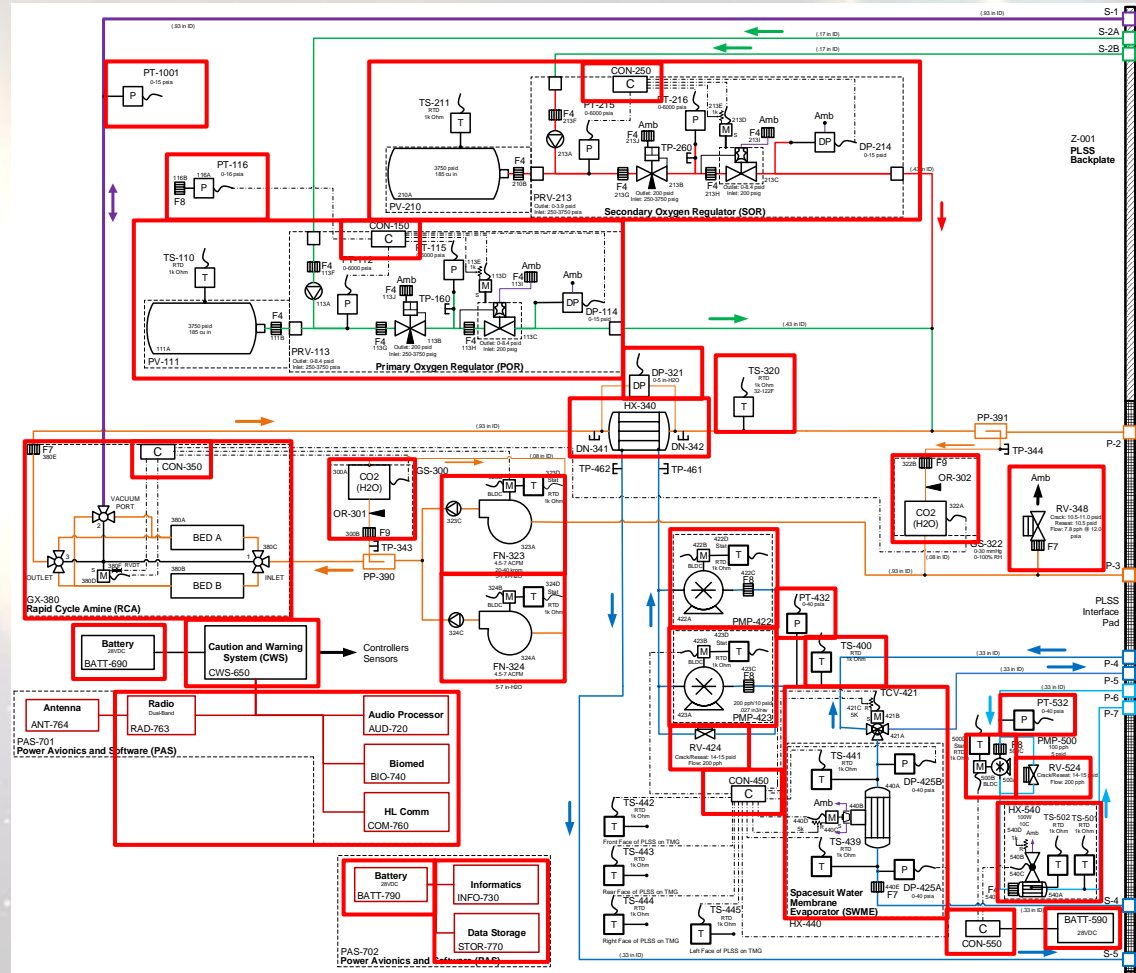
Maintainability/Modularity

- PLSS 2.5 backplate incorporates embedded hydraulic lines (like a printed circuit board)

- Enables modular packages that mate to flat manifolds with face-seals and captive fasteners

- Electrical harnessing/connectors face normal and outboard from backplate for ease of access

- Nearly all components may be replaced directly without removal of collateral components

Pump

Pump Manifold

Pump

Bracket

Captive Screws

Outlet Port (Face Seal)

Inlet Port (Axial Seal)
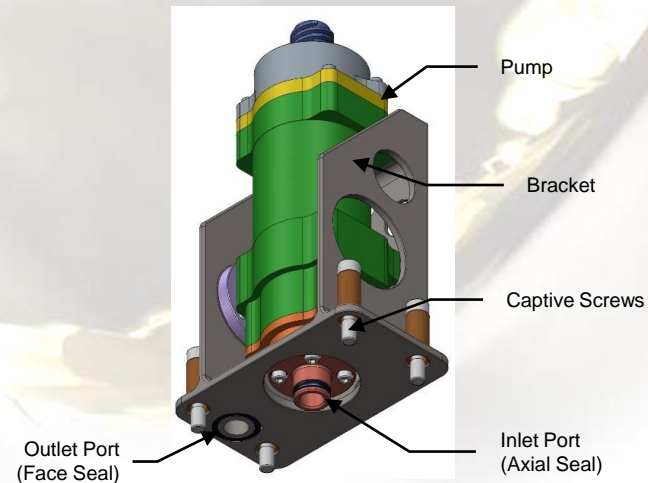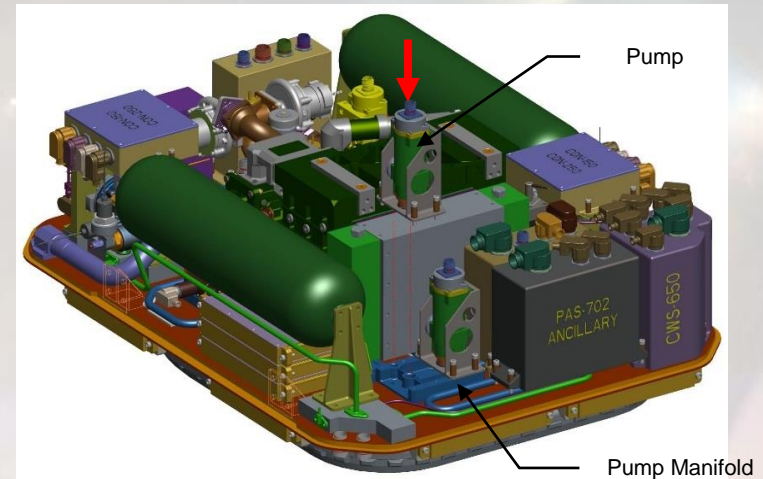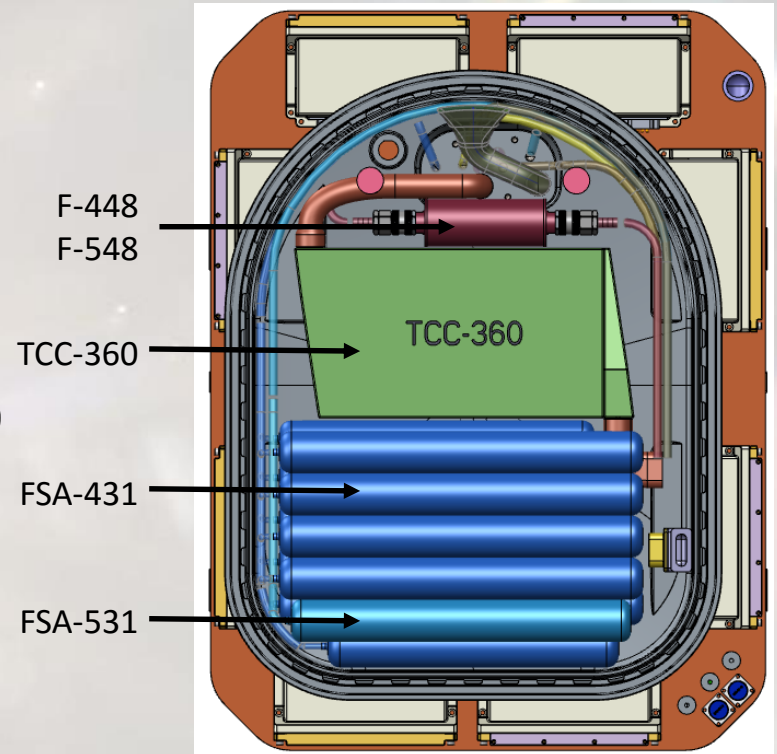
PLSS Logistical Items

- Shape is based on Z-2 model
  - New hatch/cage shape and package in-work for xHUT
- Provides mounting location for speakers
- Acts as a secondary containment to mitigate the hazard of FSA rupture during charge
- While containing free water, must permit gas exchange to prevent hatch from becoming a pressure vessel
  - Gas Permeability requirement based on depress/repress rates
- Structural Load vs Deflection
  - Must tolerate crew loading without exhibiting excessive deflection

Quarter-Turn Fastener
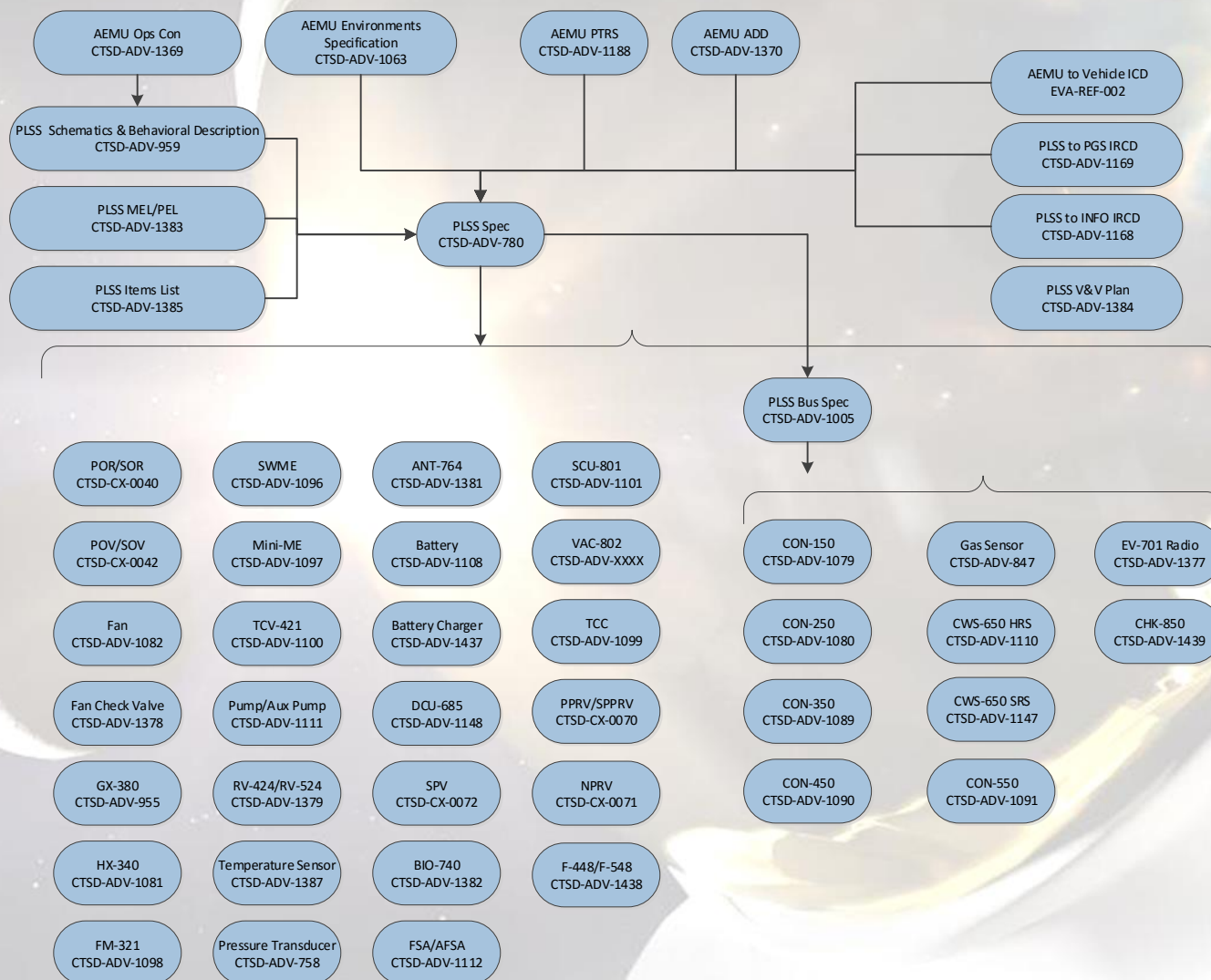
Integrated Speakers

Hatch Cover
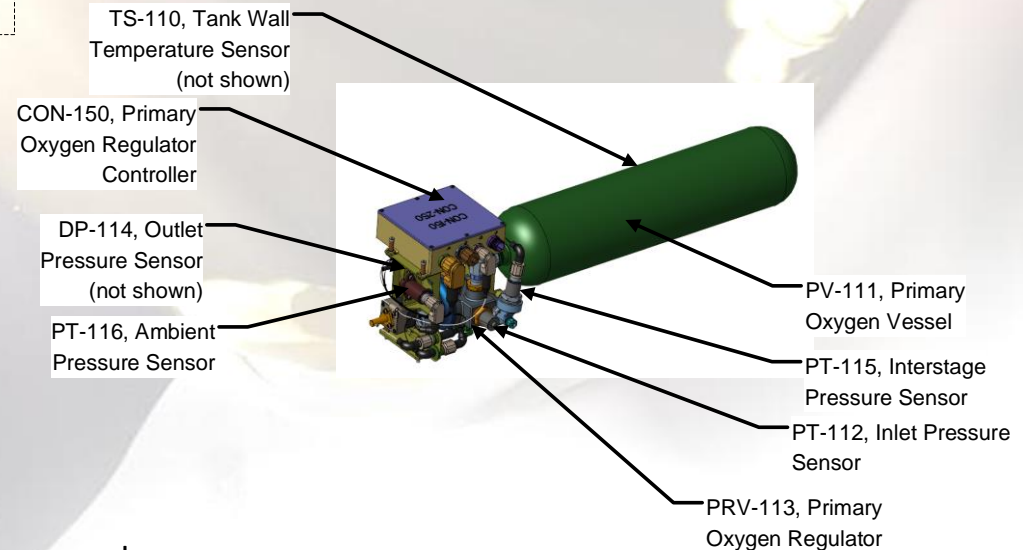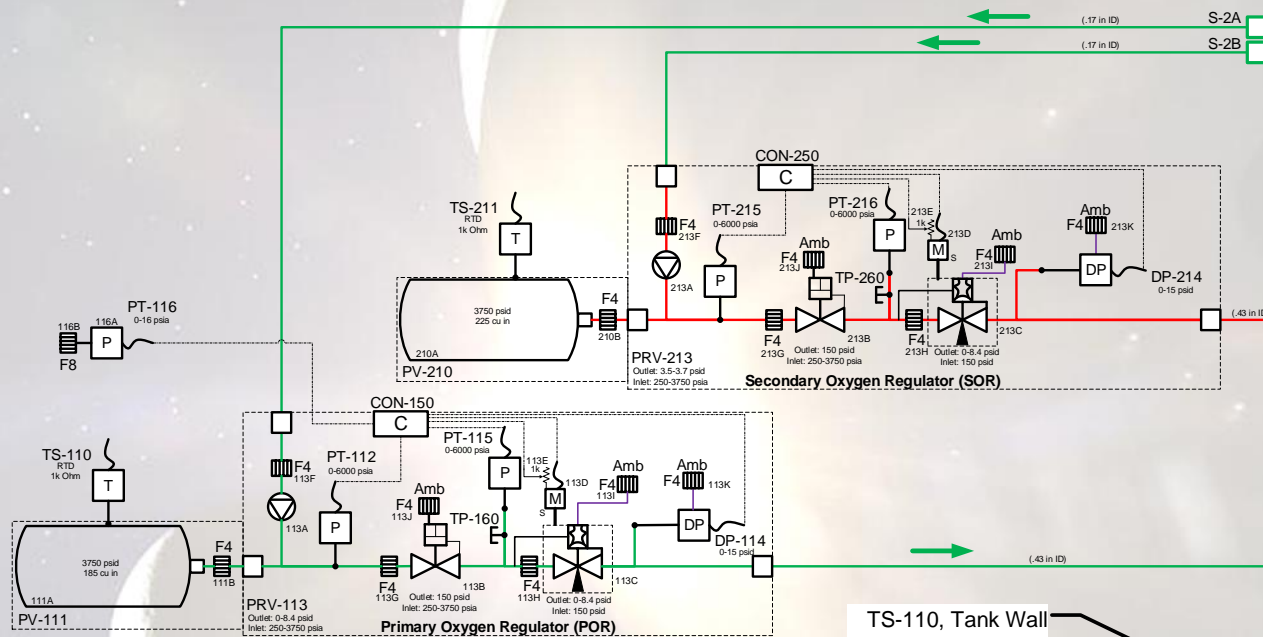
Vents
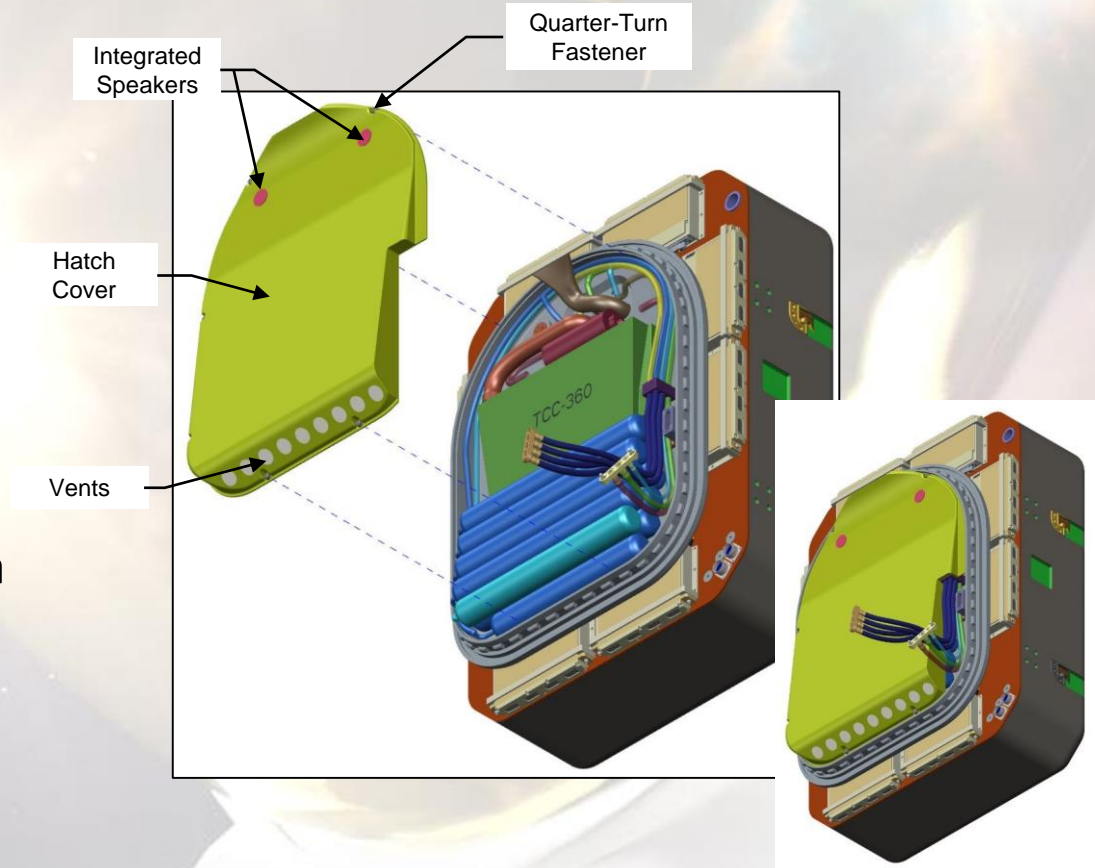
PLSS Logistical Items

- Consumables located in hatch to enable inspection/change-out between EVAs without removal/opening PLSS
  - Trace Contaminant Control (TCC-360)
  - Thermal Loop Filters (F-448/F-548)
    - 25micron
    - Finest filter in respective thermal loops
  - Feedwater Supply Assemblies (FSA-431/FSA-531)
    - Primary/Auxiliary feedwater supply
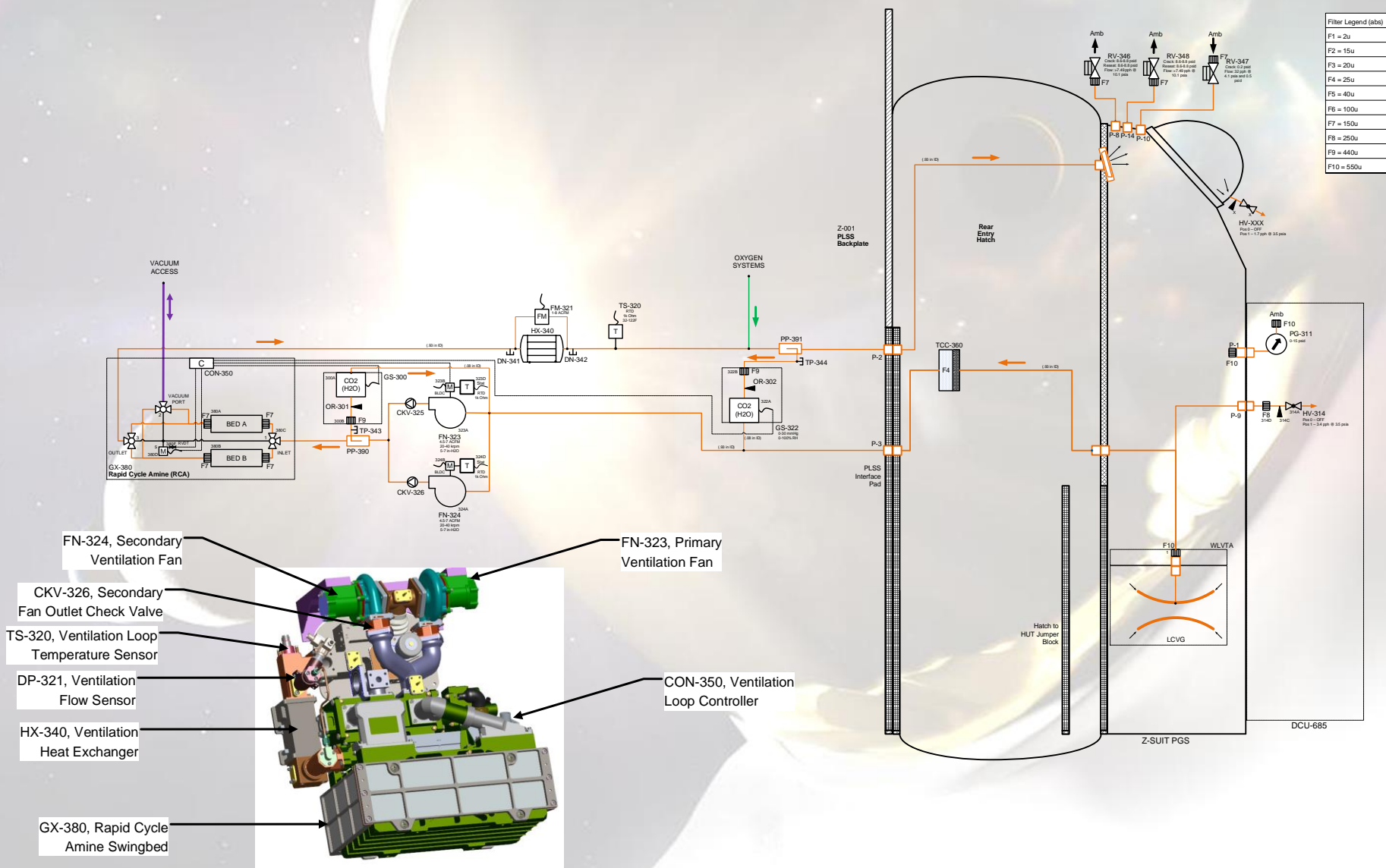- Cover sequesters any free-water within the hatch

F-448
F-548

TCC-360

FSA-431

FSA-531

TS-110, Tank Wall Temperature Sensor (not shown)

CON-150, Primary Oxygen Regulator Controller

DP-114, Outlet Pressure Sensor (not shown)

PT-116, Ambient Pressure Sensor

PV-111, Primary Oxygen Vessel

PT-115, Interstage Pressure Sensor

PT-112, Inlet Pressure Sensor

PRV-113, Primary Oxygen Regulator

*SOA is the same with exception of PT-116 removal

FN-324, Secondary Ventilation Fan

FN-323, Primary Ventilation Fan

CKV-326, Secondary Fan Outlet Check Valve

TS-320, Ventilation Loop Temperature Sensor

DP-321, Ventilation Flow Sensor

HX-340, Ventilation Heat Exchanger

CON-350, Ventilation Loop Controller

GX-380, Rapid Cycle Amine Swingbed

*GS-322/GS-300 not shown

- PLSS Power
  - 28VDC from vehicle or internal battery power switched by CWS via commanding at the DCU
  - Current limiting and monitoring for each attached load is provided by the CWS
  - A common battery module (8S) is used to build-up all battery assemblies

| Battery	Description	Nominal Voltage (VDC)	Location	Configuration	Capacity[1] (Wh)	Load Criticality
BATT-590	Auxiliary Thermal Control Loop Battery	29.1	Inside PLSS volume	8S – 1P	95	Crit 1S
BATT-690	Primary PLSS Battery	29.1	Underside of PLSS backplate and PLSS volume	8S – 8P	756	Crit 1R
BATT-790	Accessory Battery	29.1	Inside PLSS volume	8S – 2P	189	Crit 3
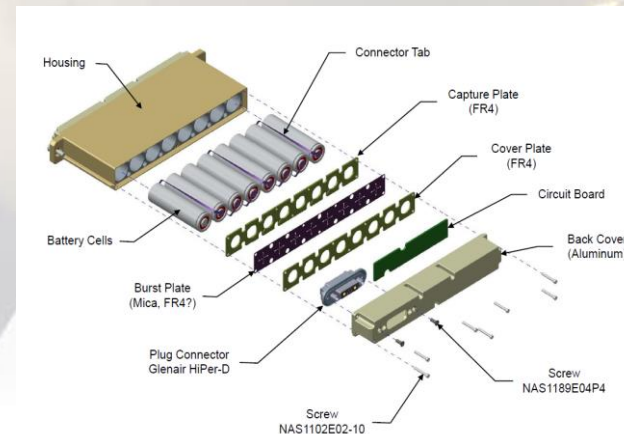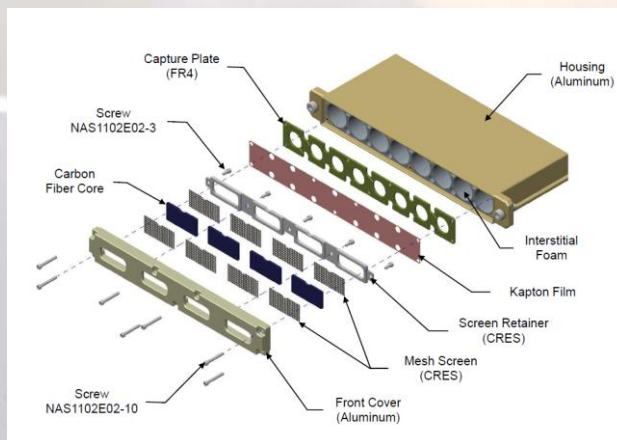
- Crewmember Interface
  - The Display and Control Unit (DCU-685) provides switching for all critical functions by direct access via gloved hands
  - Commands for radio string, comm vol, CWS vol, and comm frequency are soft-menu items set via the CWS_SW
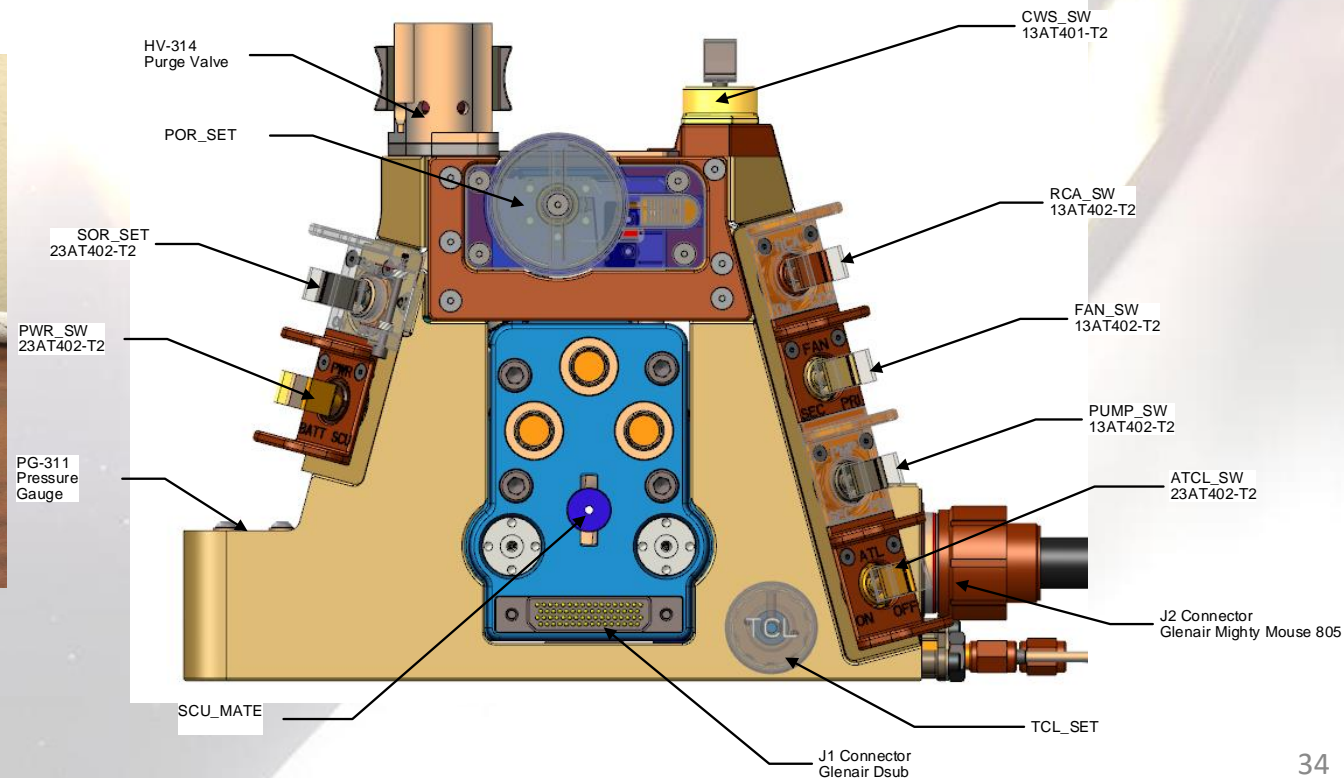
xPLSS – Control

- Control of PLSS functions is performed via five independent, modular controllers that are independently tied to the respective switch inputs on the DCU

  - CON-150: Primary Oxygen Regulator Controller
    - Accepts command input from POR_SET on DCU to set Primary Oxygen Regulator pressure to a limited range of predefined set-pressures (OFF, 0.4, 0.9, 4.3, 6.2, 8.2 psid)
    - When a pressure set-point is changed, the controller enables the actuator, moves the actuator counting steps and verifying against an integrated position sensor checking for faults
    - Local feedback is acquired from attached sensors
    - Telemetry is packaged and transmitted to the CWS over an LVDS link

  - CON-250: Secondary Oxygen Regulator Controller
    - Accepts command input from SOR_SET on DCU to set Secondary Oxygen Regulator to either ON/OFF which sets an output pressure of 3.5-3.7 psid or OFF
    - When a pressure set-point is changed, the controller enables the actuator, moves the actuator counting steps and verifying against an integrated position sensor checking for faults
    - Local feedback is acquired from attached sensors
    - Telemetry is packaged and transmitted to the CWS over an LVDS link
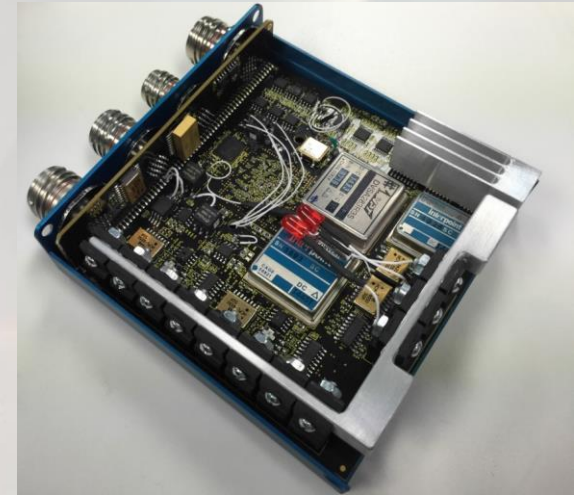
xPLSS – Control

- CON-350: Ventilation Loop Controller
  - Accepts command input from FAN_SW and RCA_SW on DCU to set Fan to PRI/OFF/SEC or set RCA to TM/OFF/CO2 respectively
  - When FAN_SW is changed, the controller enables and commutates the BLDC fan motor selected at a fixed speed with HED feed-back
  - When RCA_SW is changed, the controller enables the stepper actuator on the RCA valve and drives the valve, counting steps to the next bed position checking against the integrated RVDT as position error checking
  - Local feedback is acquired from attached sensors
  - Telemetry is packaged and transmitted to the CWS over an LVDS link

- CON-450: Thermal Loop Controller
    - Accepts command input from PUMP_SW, TCL_SET, and SCU_MATE to set Pump to PRI/OFF/SEC or set TCV-421 to a particular throttled position or set the controller mode based on the presence of the SCU respectively
    - When PUMP_SW is changed, the controller enables and commutates the BLDC pump motor selected at a fixed speed with HED feed-back
    - When TCL_SET is changed, the CON-450 responds by either directly changing the TCV position or engages Auto Cooling Control to automatically position the TCV
    - When the SCU_MATE detects the SCU presence, the CON-450 sets the SWME back-pressure valve to 10% open to enable degassing but no longer attempts to control the SWME outlet temperature as the vehicle heat exchanger is controlling the loop water temperature
    - Local feedback is acquired from attached sensors
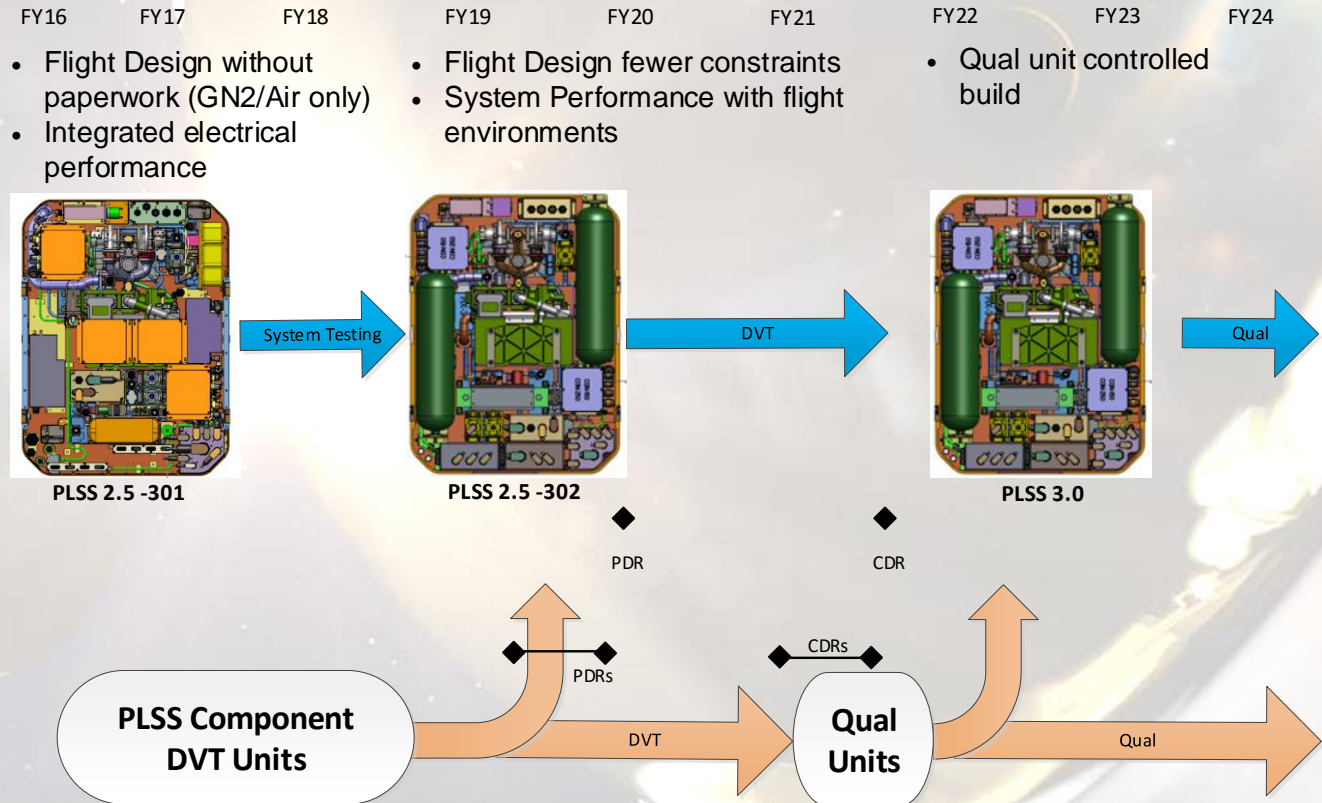   - Telemetry is packaged and transmitted to the CWS over an LVDS link

xPLSS – Control

- CON-550: Auxiliary Thermal Loop Controller
  - Accepts command input from ATCL_SW to set Pump to ON/OFF and set back-pressure valve on the HX-540 OPEN/CLOSED
  - When ATCL_SW is taken to "ON", the CON-550 enables and commutates the PMP-500 BLDC motor at a fixed speed and takes the back-pressure valve on the HX-540 to full open
  - CON-550 has direct power input from BATT-590 which enables it to operate with the loss of the primary power rail from BATT-690
    - PMP-500 and HX-540 input power to the half-bridges and h-bridges are derived directly from BATT-590
  - Local feedback is acquired from attached sensors
  - Telemetry is packaged and transmitted to the CWS over an LVDS link but only while main power is present

Development Approach

PLSS Development

FY16   FY17   FY18   FY19   FY20   FY21   FY22   FY23   FY24

- Flight Design without paperwork (GN2/Air only)
- Integrated electrical performance

- Flight Design fewer constraints
- System Performance with flight environments

- Qual unit controlled build

PLSS 2.5 -301 → System Testing → **PLSS 2.5 -302** → DVT → **PLSS 3.0** → Qual

PDR   CDR

PLSS Component DVT Units → PDRs → DVT → **Qual Units** → CDRs → Qual

Risk Items

- Component maturation
  - FM-321
    - Mass flow sensor not yet prototyped
  - CON-150/CON-250/CON-350
    - Controllers not yet prototyped with new architecture
  - HX-440/HX-540 (SWME and Mini-ME)
    - Bonding of polypropylene, cyclic loading, permissible pressure schedule, lot to lot materials and performance properties, sensitivity to contaminants
  - QD-686/886 (water and 3000 psi O2 QD)
    - Keeping mating loads manageable
    - Addressing contamination prevention or tolerance moving towards exploration
  - DCU-685 (and detail components)
    - Design is extremely compact with constraining functional requirements and several detailed custom components that need to be prototyped
  - EV-701 (UHF radio)
    - Design is complex and has not been fully prototyped in a packaged form
  - CWS-650 (Caution and Warnings)
    - Bread-board operating but a packaged prototype has not been developed
  - RV-346 (PPRV)
    - Prototypes have been fielded but presented stiction issues at dwell durations well short of the existing Item 146 on EMU Program
    - Need prototypes that can meet quiescent periods required for exploration 2-4 years
  - CKV-325/CKV-326 (fan outlet check valves)
    - In order to keep the pressure drop down the design is very constrained and needs to be prototyped and tested
  - GS-322/GS-300 (Multi-gas sensor)
    - The ISS EMU CO2 sensor replacement project is addressing this need presently to mitigate expiration of the current Item 122 CO2 sensor on the ISS EMU
  - BATT-690/BATT-590/BATT-790 and CHGR-840
    - Packaged prototypes for the battery modules demonstrating thermal runaway performance needs to be completed
    - Battery charger concept generated by AES/AMPS but need to develop a packaged unit that performs all of the required safety functions/tests
- Water quality for long term operations and quiescent periods
  - This has been a problem for long term systems such as the current ISS EMU requiring consistent maintenance attention to mitigate
  - The xEMU will face the same challenges but potentially with reduced maintenance access