JSC/EC5 U.S. Spacesuit Knowledge Capture (KC) Series Synopsis

All KC events will be approved for public using NASA Form 1676.

This synopsis provides information about the Knowledge Capture event below.

Topic: PLSS 101

Date: March 31, 2011 **Time:** unknown **Location:** JSC/B5S/R3204

DAA 1676 Form #: 29670

A PDF of the presentation is also attached to the DAA 1676 and this is a link to all lecture material and video: \\js-ea-fs-01\pd01\EC\Knowledge-Capture\FY11 Knowledge Capture\20110331 G. Thomas_PLSS 101\For 1676 Review & Public Release

*A copy of the video will be provided to NASA Center for AeroSpace Information (CASI) via the Agency's Large File Transfer (LFT), or by DVD using the USPS when the DAA 1676 review is complete.

Assessment of Export Control Applicability:

This Knowledge Capture event has been reviewed by the EC5 Spacesuit Knowledge Capture Manager in collaboration with the author and is assessed to not contain any technical content that is export controlled. It is requested to be publicly released to the JSC Engineering Academy, as well as to CASI for distribution through NTRS or NA&SD (public or non-public) and with video through DVD request or YouTube viewing with download of any presentation material.

* This PDF is also attached to this 1676 and will be used for distribution.

For 1676 review use_Synopsis_Thomas_PLSS 101_3-31-2011.pdf

Presenter: Gretchen A. Thomas

Synopsis: This presentation reviewed basic interfaces and considerations necessary for prototype suit hardware integration from an advanced spacesuit engineer perspective during the early design and test phases. The discussion included such topics such as the human interface, suit pass-throughs, keep-out zones, hardware form factors, subjective feedback from suit tests, and electricity in the suit.

Biography: Gretchen Thomas has worked for NASA for more than 20 years in PLSS technology development and integration. She has served as the PLSS architecture and integrated testing lead for EVA technology development. Her specialty areas have included carbon dioxide removal systems, thermal control systems, and system integration and analysis. Thomas earned a bachelor of science in mechanical engineering from the University of Houston, and in 2000, she received a master of science in space studies from the University of North Dakota.

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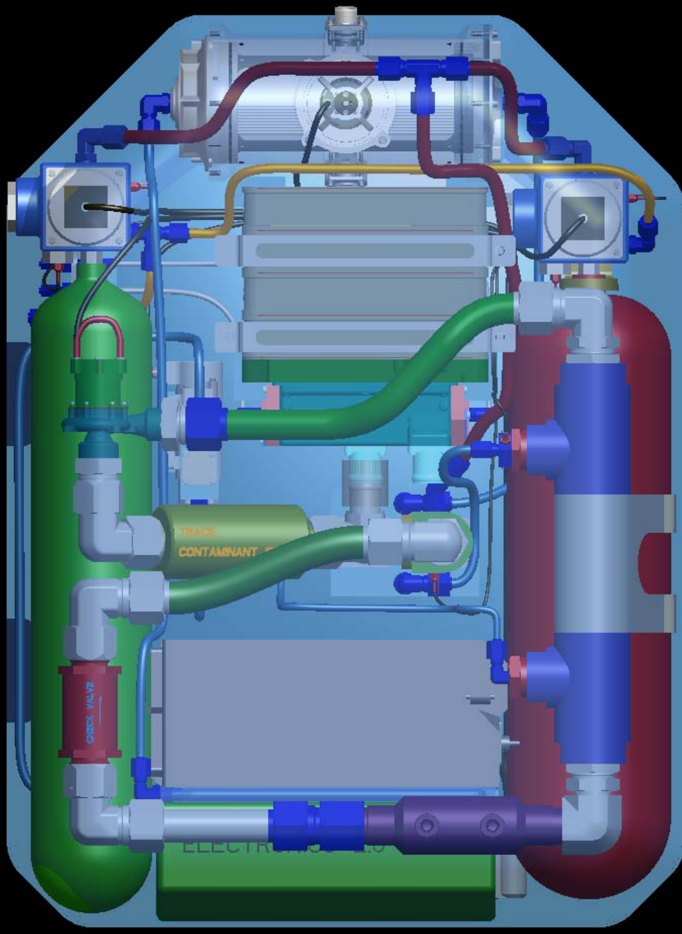


Portable Life Support System
PLSS 101

EC5 / Gretchen A. Thomas

March 31, 2011

The Space Suit Vehicle

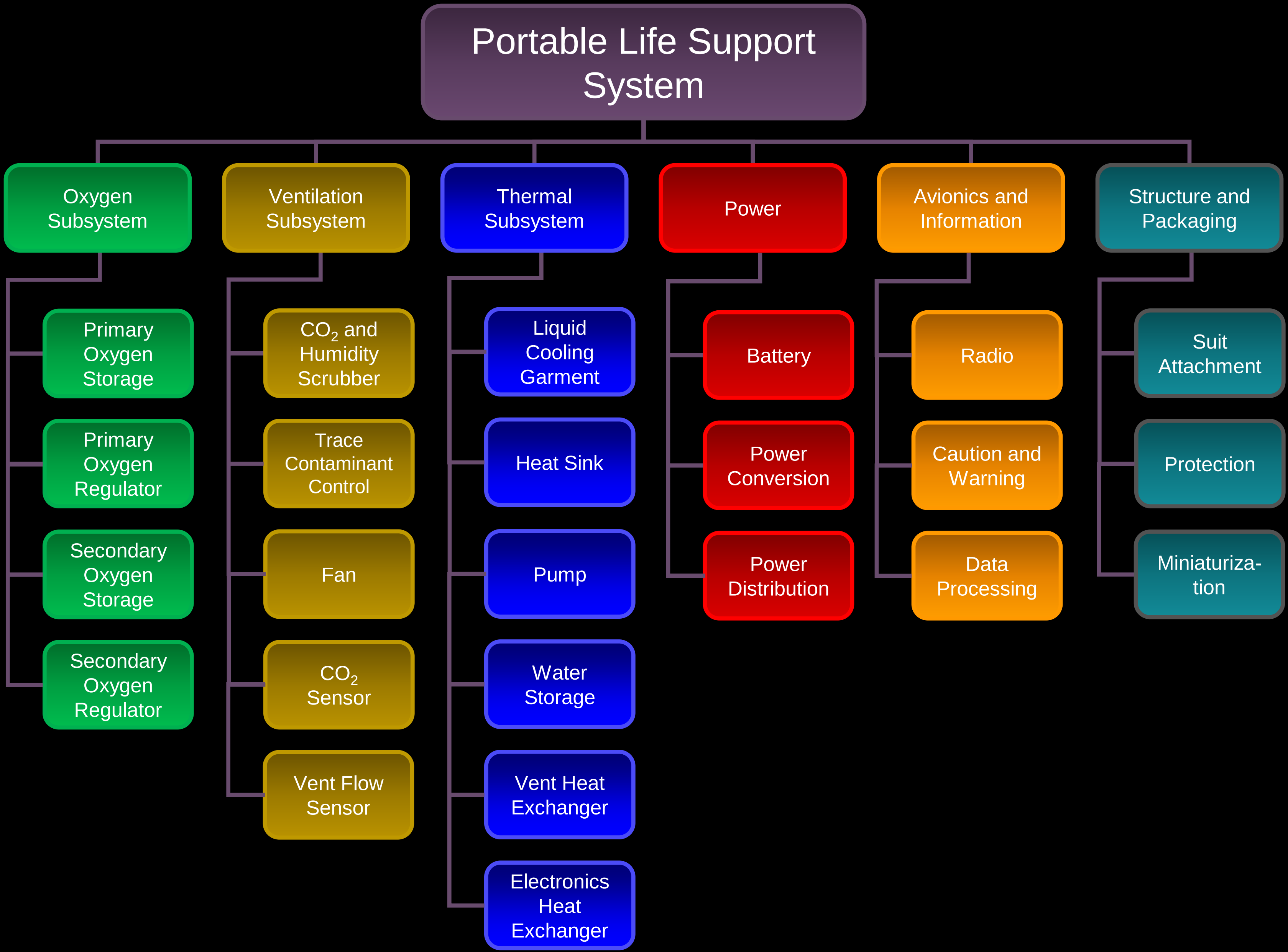
- A Space Suit is a miniature one-person sized vehicle
- All of the functions of a larger space vehicle must be provided in a highly integrated system that is:
  - Independent
  - Mobile
  - Portable
  - Reliable
  - Compact
  - Lightweight

Life Support Functions of a PLSS

- Regulate suit pressure
- Provide oxygen for breathing, using 100% O_2
  - allows operation at lower suit pressures
  - increases mobility and comfort
  - easier to manage than an air mixture
- Remove metabolic by-products
  - Carbon dioxide
  - Humidity
  - Waste heat
  - Trace gases / odors
  - Particulates

Other Functions of a PLSS

- A PLSS also provides other vehicle support functions:
  - System control
  - System monitoring (for safety and alarming)
  - Power
  - Communication


Portable Life Support System
Oxygen Subsystem
Primary Oxygen Storage
Primary Oxygen Regulator
Secondary Oxygen Storage
Secondary Oxygen Regulator
Ventilation Subsystem
CO_2 and Humidity Scrubber
Trace Contaminant Control
Fan
CO_2 Sensor
Vent Flow Sensor
Thermal Subsystem
Liquid Cooling Garment
Heat Sink
Pump
Water Storage
Vent Heat Exchanger
Electronics Heat Exchanger
Power
Battery
Power Conversion
Power Distribution
Avionics and Information
Radio
Caution and Warning
Data Processing
Structure and Packaging
Suit Attachment
Protection
Miniaturiza-tion

Space Suit Architecture

Existing NASA Space Suit architecture is over 30 years old (1977) and has evolved from Apollo, Skylab and Shuttle technology and operations.

All current Space Suits are only compatible with low earth orbit zero-G activities and require regular ground based maintenance, resupply and monitoring.

Exploration Objectives

NASA desires exploration to destinations beyond LEO, long-duration Lunar, and Mars

Beyond-LEO

Near Term Demonstration

- 0-gravity
- Regenerable
- Short Mission Duration
- Low Crew Overhead
- Very Cold Environment
- High Radiation Environment

Lunar

Long Term Demonstration

- Planetary EVA
- Regenerable/ISRU
- Lightweight
- Low Crew Overhead
- On-orbit Maintainable
- Dust
- Fall Protection

Mars

Autonomous Operation

- Planetary EVA
- CO_2 Atmosphere
- Regenerable/ISRU
- Long Term Use
- Ultra-lightweight
- Low Crew Overhead
- Highly Reliable
- On-orbit Maintainable
- Dust
- Fall Protection

Historical PLSS Comparison

	Apollo EMU	Shuttle/ISS EMU	Lunar (CxP) EMU
Overall	~115 lbm dry	~158 lbm LiOH dry	Mass goal wet < ~108 lbm
Thermal Control	▪ Sublimator ▪ De-ionized water ▪ Centrifugal pump ▪ Manual temperature control ▪ No prebreathe ▪ Minimum flow to sublimator needed to prevent freezing	▪ Sublimator ▪ De-ionized water ▪ Centrifugal pump ▪ Manual temperature control ▪ Lengthy prebreathe ▪ Minimum flow to sublimator needed to prevent freezing	▪ Water Evaporator (SWME) ▪ Potable water ▪ Positive Displacement Pump ▪ Manual temperature control ▪ Less prebreathe than EMU ▪ No minimum flow required
Feedwater	▪ 15 psid O_2 regulator to provide backpressure for feedwater tanks	▪ 15 psid O_2 regulator to provide backpressure for feedwater tanks	▪ Uses suit pressure to provide tank backpressure (eliminates regulator)

Historical PLSS Comparison

	Apollo EMU	Shuttle/ISS EMU	Lunar (CxP) EMU
CO_2 Control	▪ LiOH canister (6.4 lbm) ▪ LiOH increases thermal load on PLSS thermal control unit ▪ 8-hour EVA	▪ LiOH canister ▪ Metox -regenerable (14 hr & 100W & 32lbm) ▪ Both LiOH and Metox increase thermal load on thermal control unit ▪ 8-hour EVA	▪ Cycling Amine (RCA) regenerates during EVA ▪ RCA – no recharging or replacement after EVA & vents CO_2 and H_2O to vacuum ▪ Dual bed allows for transfer of heat back and forth – practically no cooling required
Heat Exchanger	▪ Condensing heat exchanger integrated with sublimator	▪ Condensing heat exchanger integrated with sublimator	▪ Non-condensing heat exchanger
O_2	▪ Primary O_2 = 1420 psia ▪ Secondary O_2 = 5800 psia ▪ Primary O_2 mass = 1.8 lbm ▪ Secondary O_2 mass = 5.8 lbm ▪ Mechanical regulators	▪ Primary O_2 = 900 psia ▪ Secondary O_2 = 6000 psia ▪ Primary O_2 mass = 1.2 lbm ▪ Secondary O_2 mass = 2.6 lbm ▪ Mechanical regulators ▪ Two primary regulator set-points	▪ Primary O_2 = 3000 psia ▪ Secondary O_2 = 3000 psia ▪ Primary O_2 mass = 1.6 lbm ▪ Secondary O_2 mass = 2.6 lbm ▪ Electronic regulators ▪ Infinite set-points
Buddy Capability	▪ Cooling water only	▪ No Buddy Capability	▪ Cooling water and ventilation capability (deleted in current activity)

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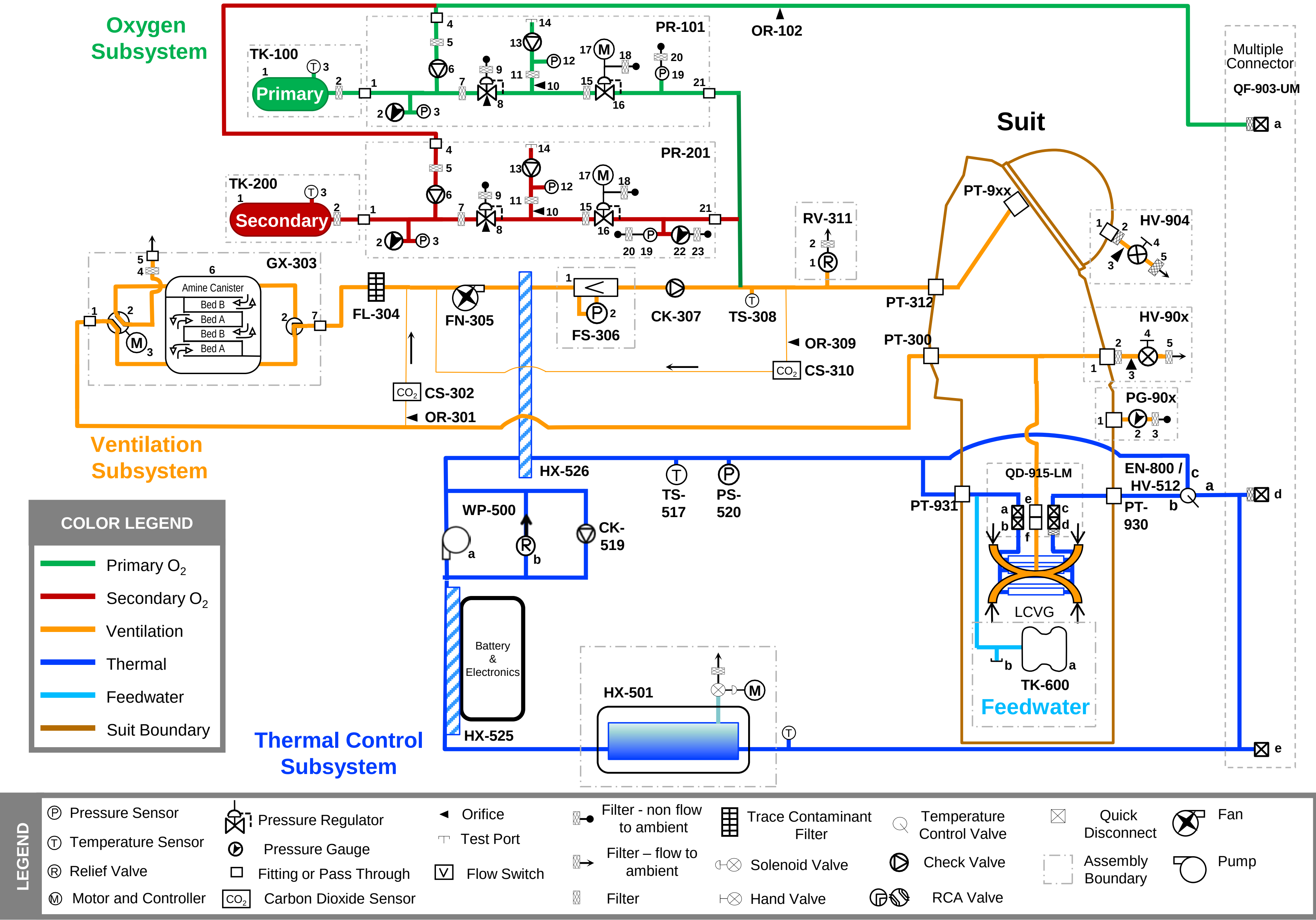
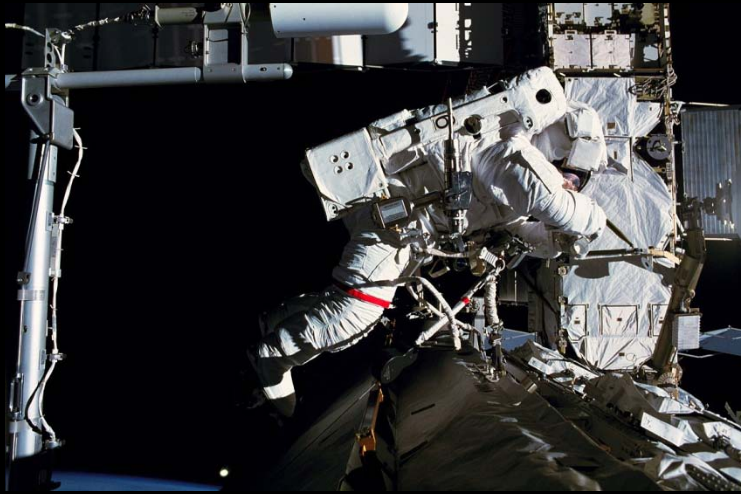
Portable Life Support System (PLSS)



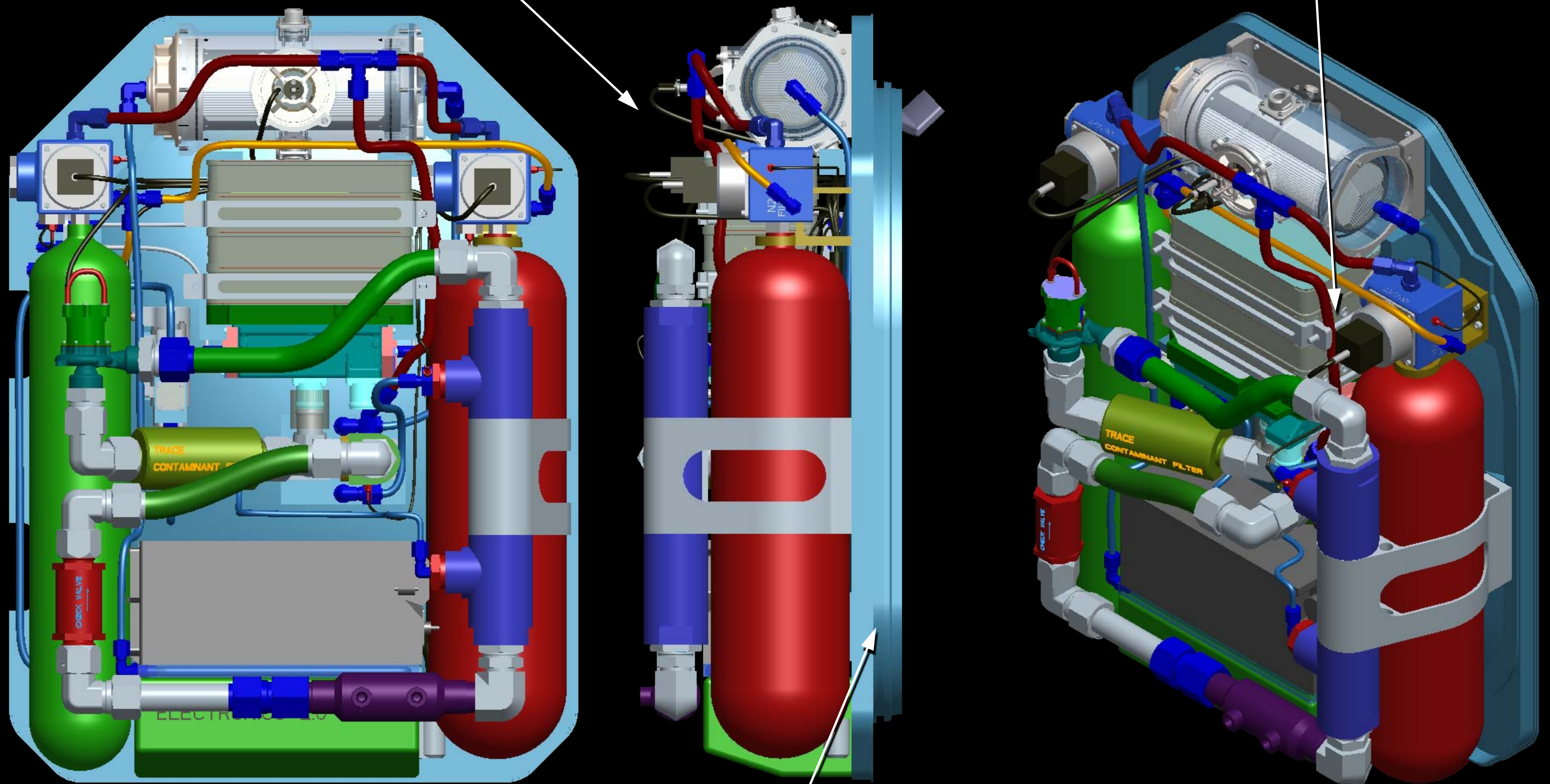
PLSS Architecture Driving Requirements

- On-back Recharge
- IVA Removable
- EVA Removable
- Buddy Mode
- Environments
  - Thermal
  - Gravity
  - Atmosphere
- Suit Constraints
  - Waist Entry vs. Rear hatch
  - Work Envelope / Reach
  - Visibility
- Vehicle Constraints
  - Resources
  - Volume
  - Up-mass



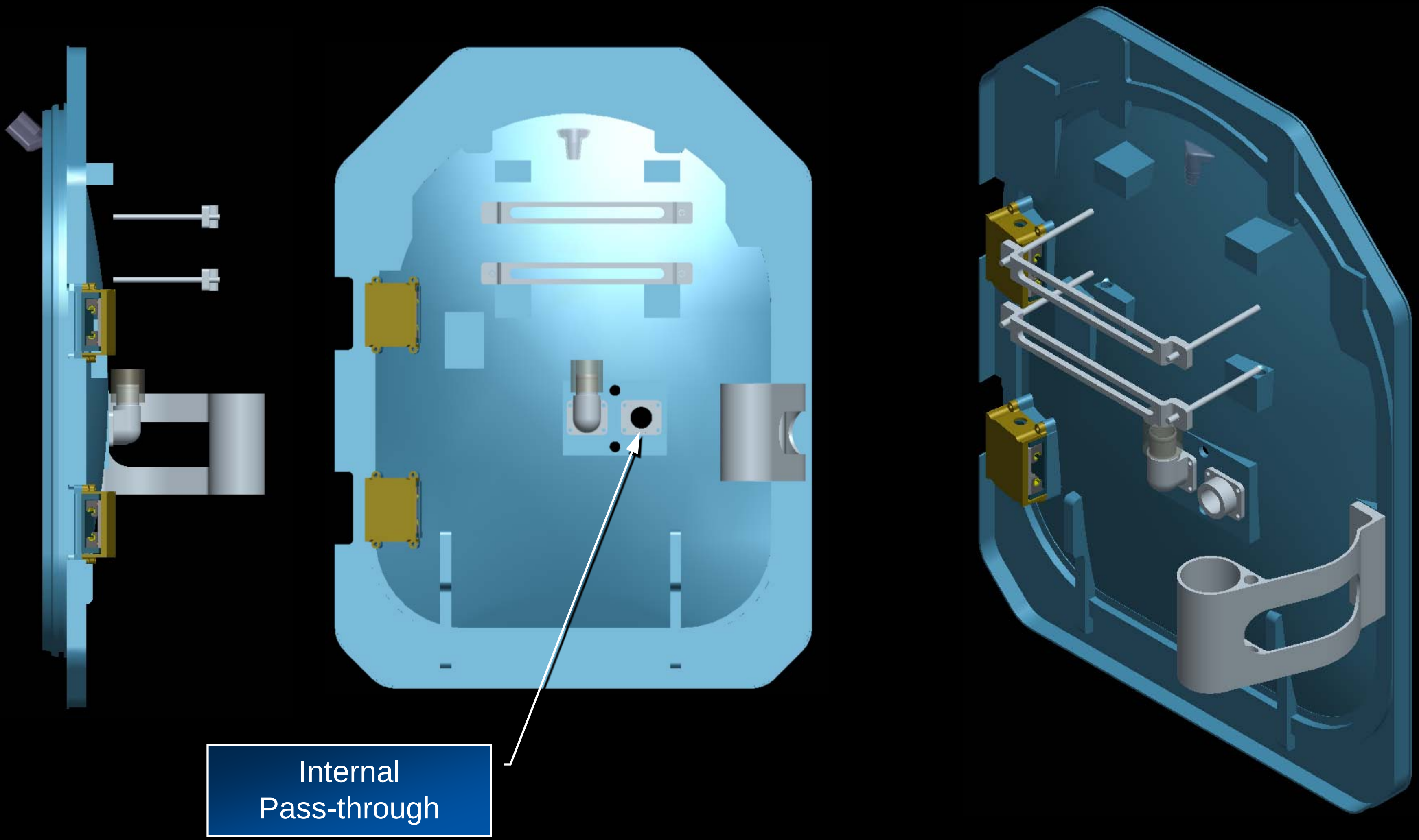
Packaging Concept

Suit Port / ISS Constraints

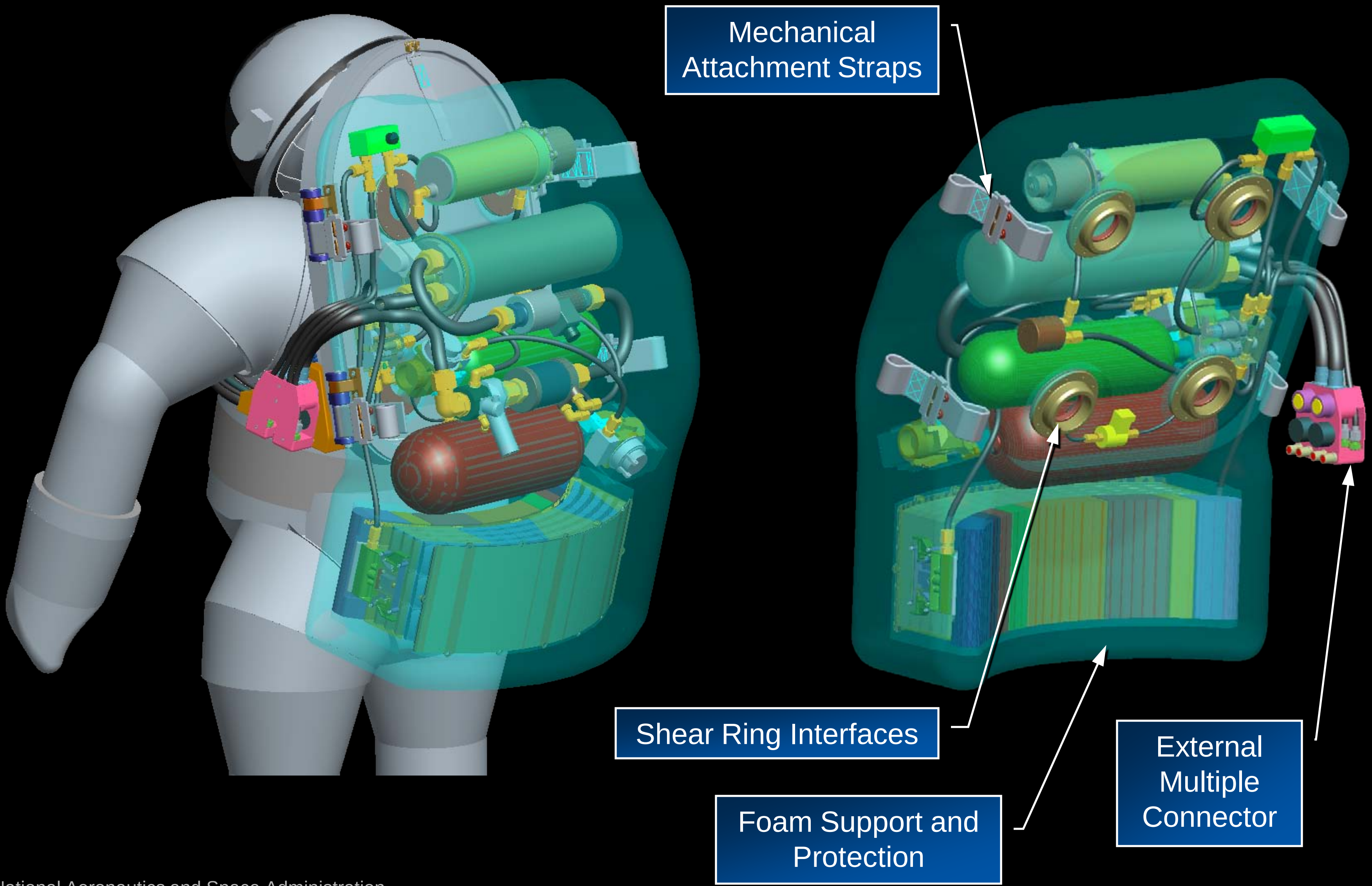


PLSS to Suit Interface Concept

Mk III Hatch Constraints

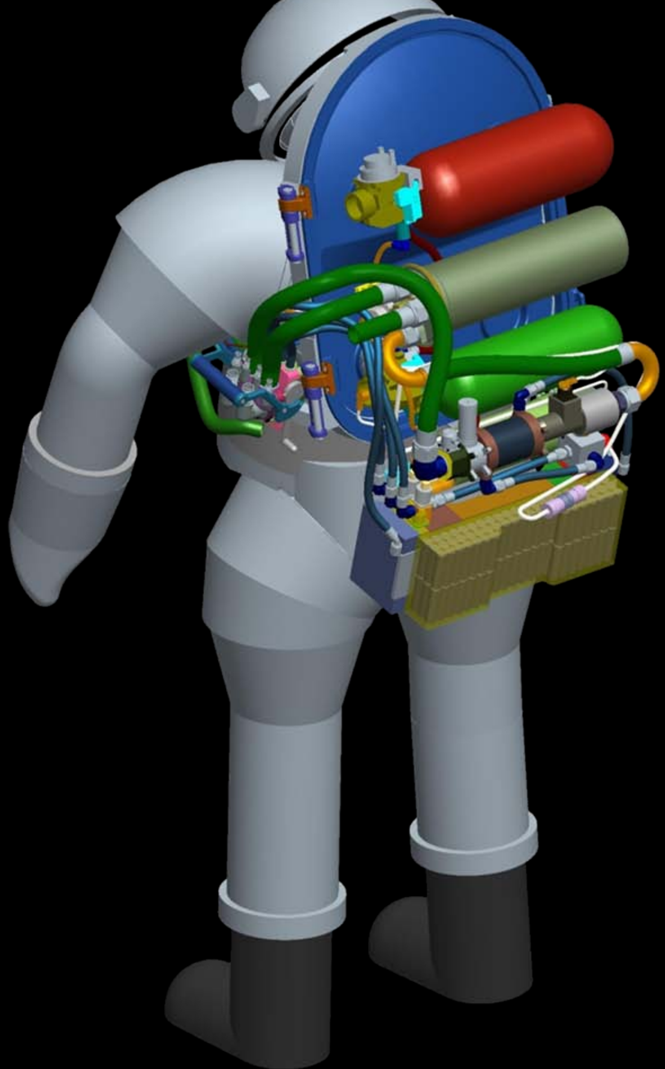


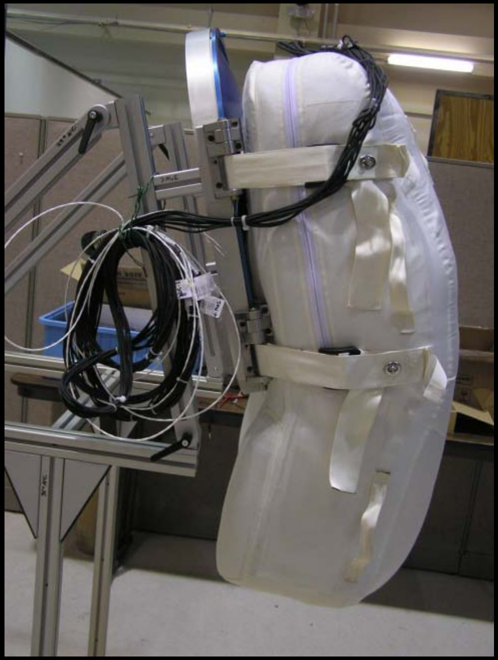
Packaging Concept
Mass, Maintainability, and Impact Constraints

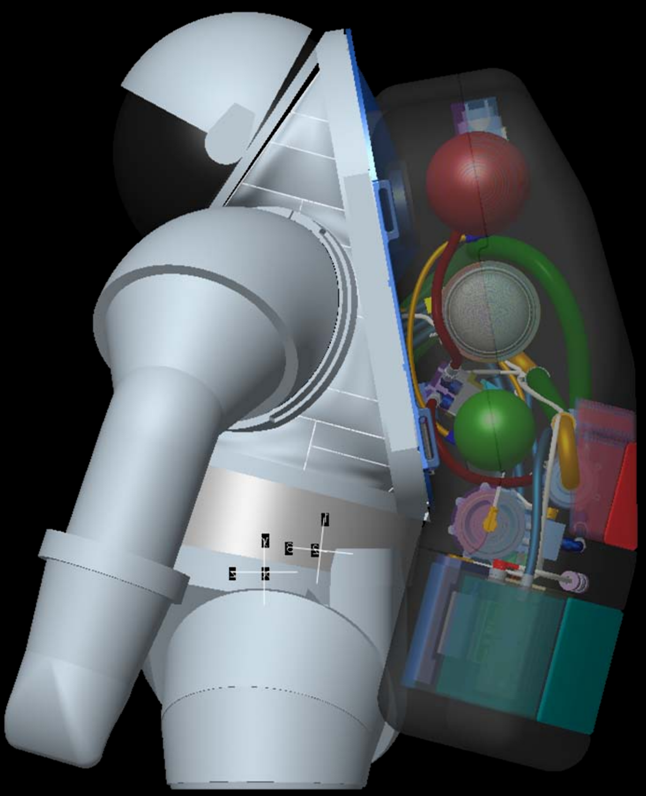


Packaging Concept

Vacuum-Removable and CG Constraints







Technology Development Timeline

A Little History

1980s Space Station Freedom

Non-venting
Resource Conservation
Up-mass Constrained

Thermal
- Auto Cooling Control 1
- Vapor Compression Heat Pump
- Ice Pack Heat Sink
- Wax PCM-Radiator-Thermal Electric Heat Pump
- Metal Hydride Heat Pump-Radiator

System Integration
- Integrated Energy Mgmt System

CO_2/Humidity Removal
- Solid Amine Absorber
- Pumped Liquid Membrane Contactor
- Metal Oxide Absorber 1

Ventilation
- Air Bearing Fan

Power
- Fuel Cell

Information
- Helmet Mounted Display
- Voice Recognition

Technology Development Timeline

A Little History

1990s Exploration Technology

Size constrained
Mass constrained
Long Mission Duration

Thermal
- •Auto Cooling Control 2
- •Venting Metal Hydride Cooler
- •Gas-Gap Radiator
- •Freezable Radiator
- •Composite Radiator
- •SWME 1
- •Segmented LCG
- •Piezoelectric Water Pump
- •Magnetostrictive Water Pump

Oxygen
- •Liquid Crystal Polymer LOX Storage
- •Magnetic LOX Acquisition

CO_2/Humidity Removal
- •Metal Oxide Absorber 2 & 3
- •Metal Oxide Flight System
- •Cycling Amine
- •Cycling Molecular Sieve
- •Thin Film Composite Membrane
- •Immobilized Liquid Membrane

Power
- •Fuel Cell 2

System Integration
- •Multiple Schematics (C, M, S-PLSS)
- •Multiple Packaging Concepts

Technology Development Timeline

A Little History

2000s **Exploration + Constellation Program**

Mass constrained
Increased Capability
Maintainable
Long Mission Duration

Thermal
- SWME 2
- Aerogel Insulation
- Liquid Cooling and Warming Garment
- Piezoelectric Pump 2

Oxygen
- Electronic Regulators

System Integration
- Constellation Schematic
- Packaging
  - Lightweight
  - Evolvable
  - Maintainable

CO_2/Humidity Removal
- Bioenzyme membrane
- Cryogenic Freeze-out
- Temperature Swing Cycling Scrubber
- Photoionization/Laser Decomposition

Power
- Zirconia Cell Electrolysis
- PEM Fuel Cell

Information
- Time Modulated Ultra-Wideband Radio
- Electronic Cuff Checklist

Technology Development Timeline

A Little History

2010s **Technology Development**

Increased Capability
Cost Constrained
ISS / Suit Port Compatible

Thermal
- SWME 3
- Robust Pump

Oxygen
- Electronic Regulators 2

System Integration
- ISS Compatible Schematic
- Integrated Breadboard
- Packaging
  - Suit Port
  - Mk III

CO_2/Humidity Removal
- Cycling Amine 2

Ventilation
- Compact Fan

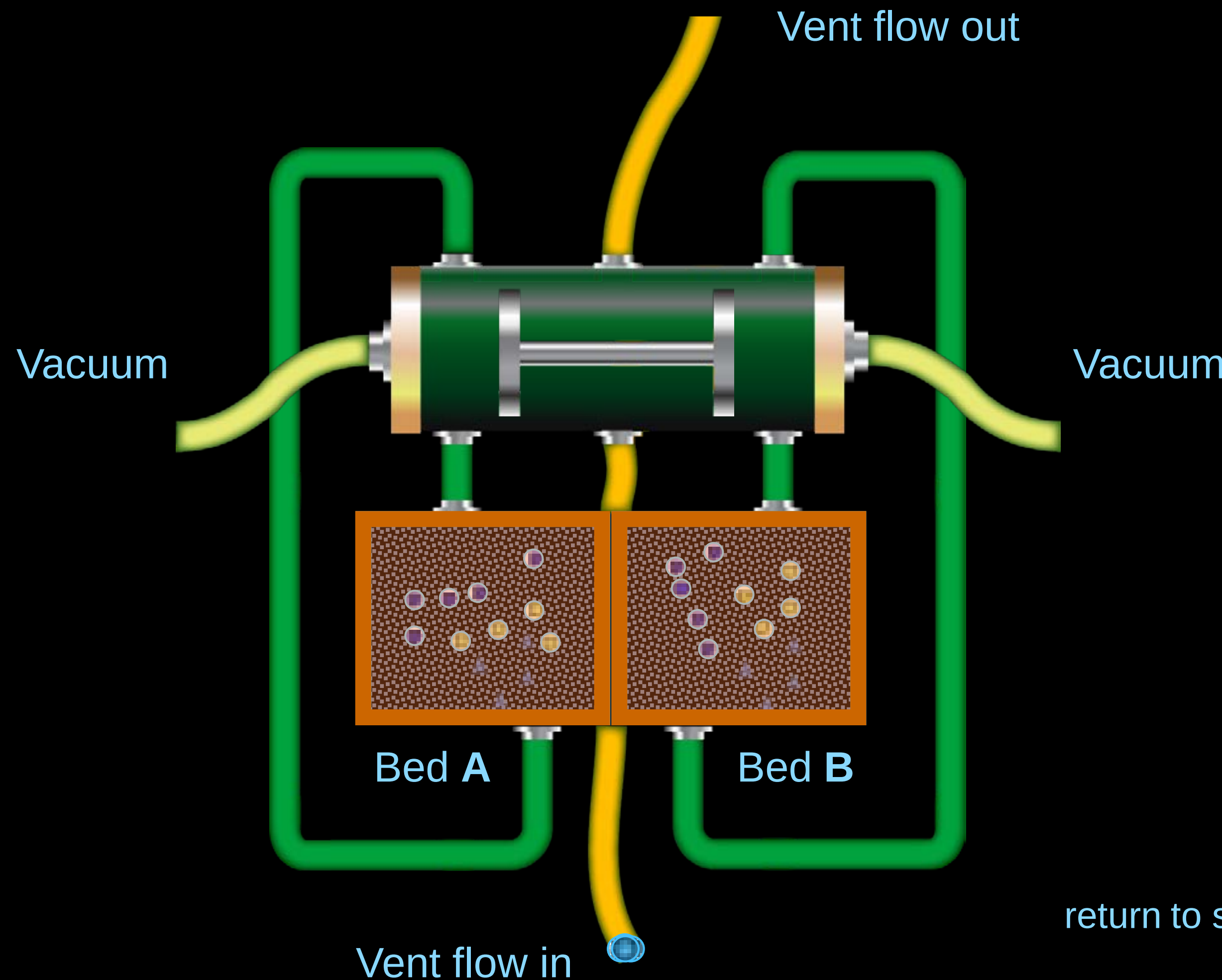
Power
- High Density Battery

Information
- Heads Up Display

NASA

RCA

Rapid Cycling Amine



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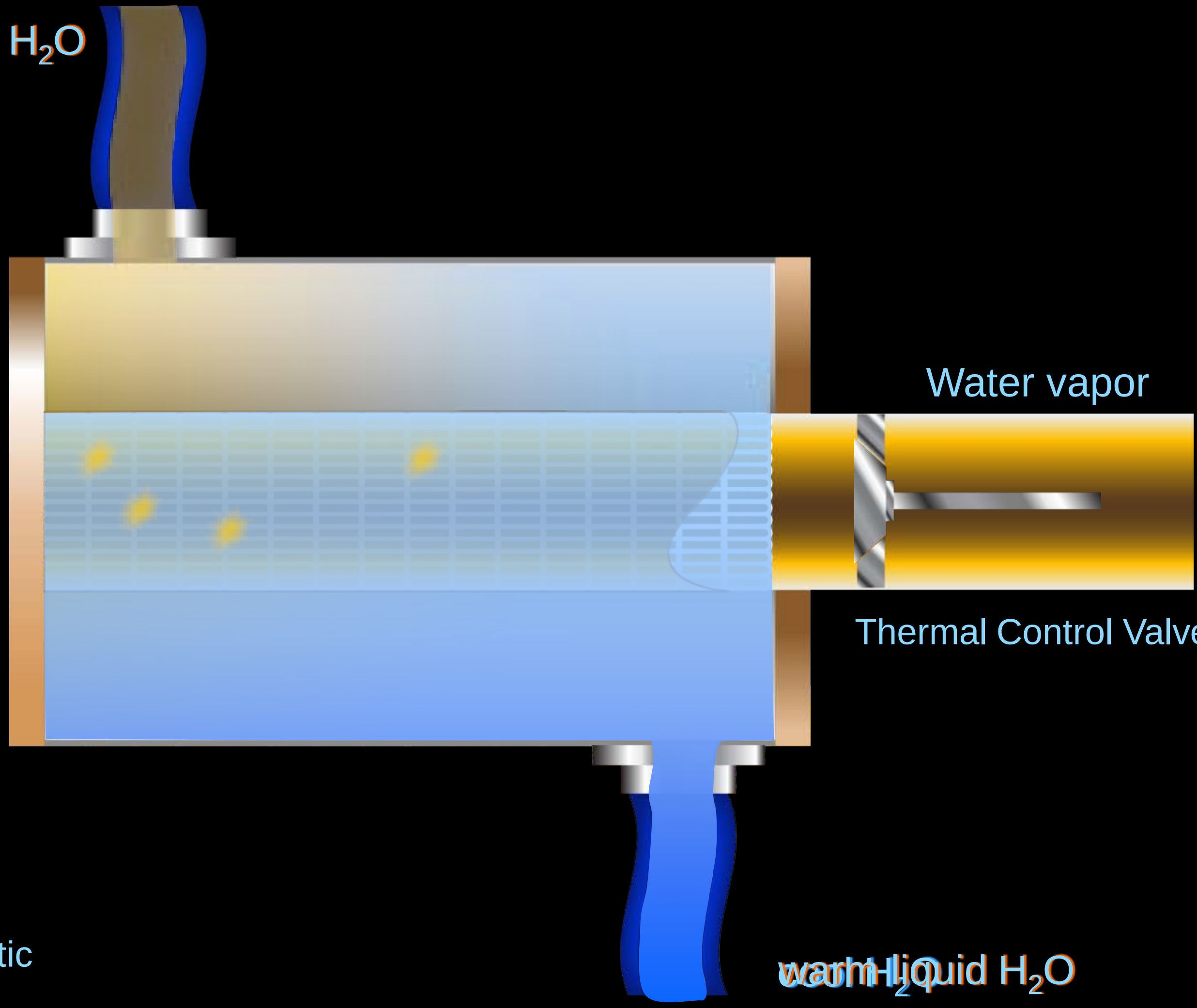
SWME

Space Suit Water Membrane Evaporator



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