Space Lab Technologies, LLC

Ensuring Each Breath: *An Oxygen Compatible Flowmeter for the Exploration PLSS*

Adam Escobar

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Presentation Agenda

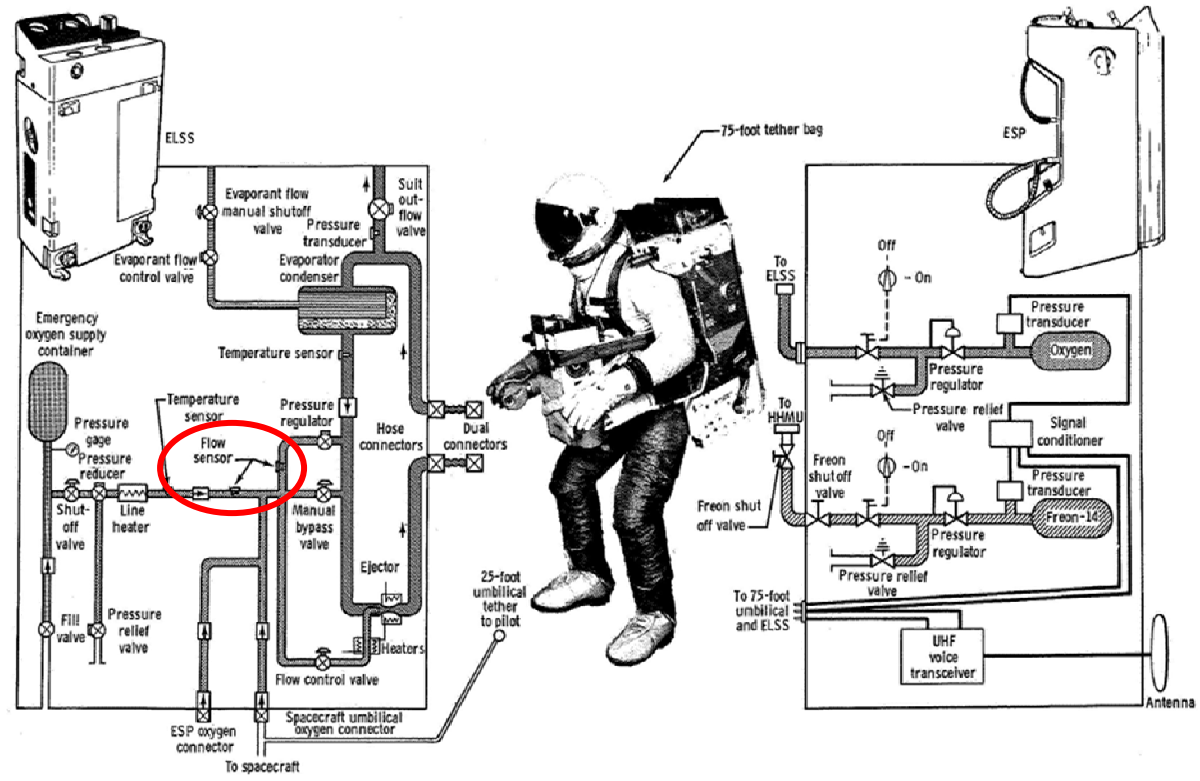
- **Portable Life Support System (PLSS) Flow Sensing History**
- **Space Lab's Innovation**
- **Phase I Results**
- **What We are Doing for Phase II**

PLSS FLOW SENSING HISTORY

Gemini ELSS

- **Nominal Pressure:**
  - 3.7 psia
- **Nominal Flow Rate:**
  - 5.1-7.8 lb/hr
- **Two flow sensors**
  - <u>Demand Flow Sensor</u>
  - → Flow sensed if chestpack is supplying oxygen (if suit pressure < 3.3 psia)
  - → If activated, triggers illumination of SUIT PRESS warning lamp & audio warning alarm
  - <u>Emergency Oxygen Flow Sensor</u>
  - → If inlet O2 pressure < 67 psia (nominally 90 psia) from the umbilical or external source, then sensor is triggered from this flow and energizes the EMERGENCY O2 Lamp & audio warning alarm
  - → Supplies O2 for 20-33 min.

<u>Extravehicular Life Support System (ELSS)</u>



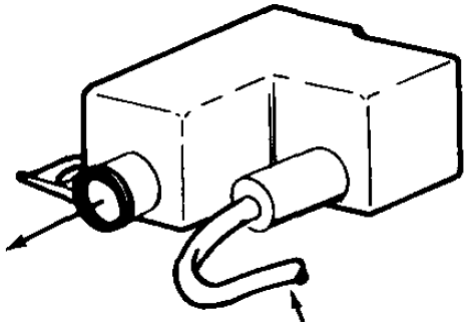
Machell, 1967

Apollo PLSS

- **Nominal Pressure**
  - 3.85 psia
- **Nominal Flow Rate**
  - > 5.5 acfm
- **Ventilation Flow Sensor**
  - Provide signal to alarm module and RCU warning indicators
    - When flow drops between 4.0-5.3 acfm
  - Initial approach included sensing
    - Rotational speed of fan
    - Differential pressure across fan

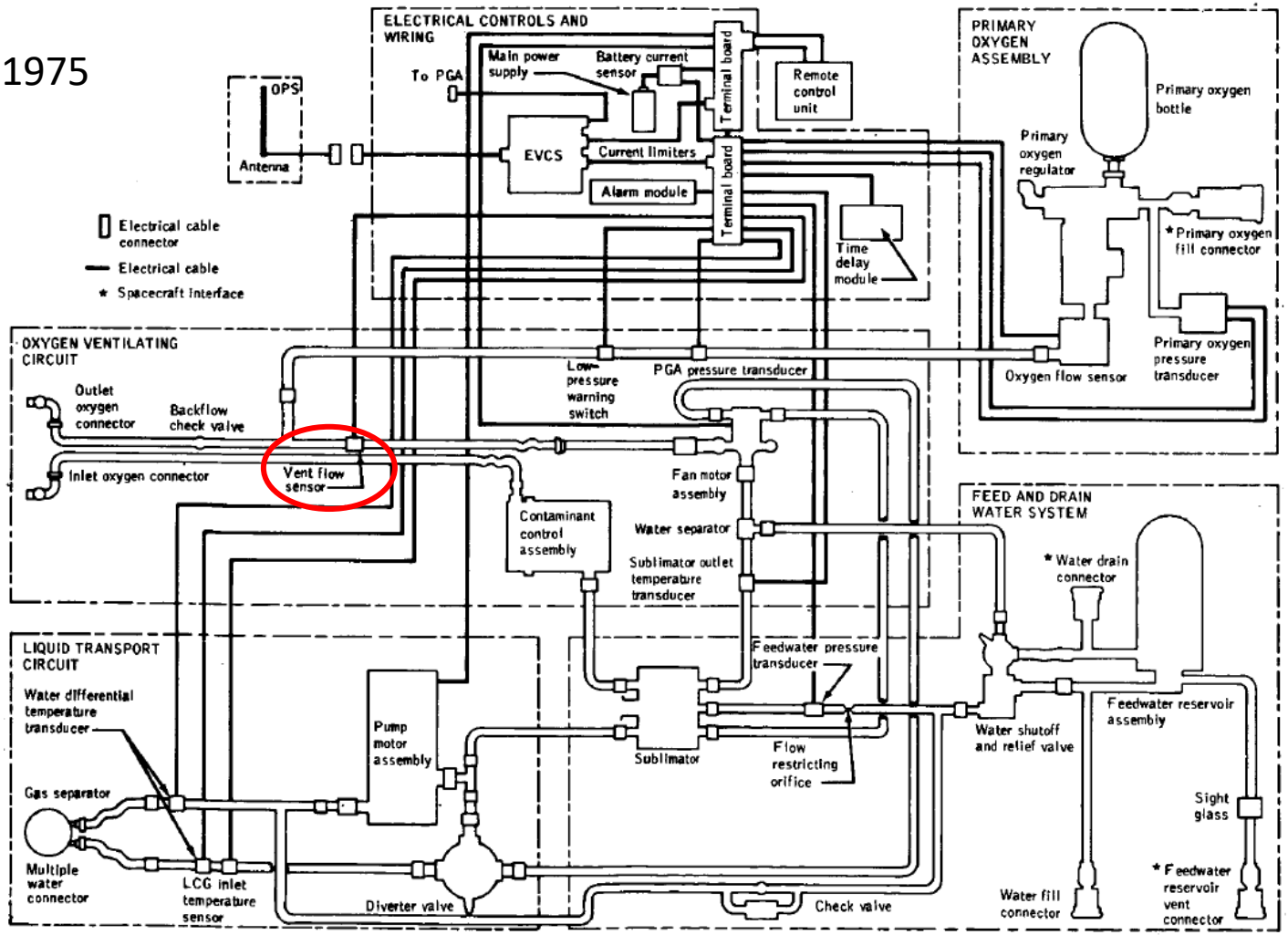
    --> Discontinued: due to undetectable blockage or disconnection
  - Low pressure drop venturi tube downstream from the fan outlet
    - Utilized a capacitive pressure transducer
    - Initial units were sensitive to ambient temperature changes (resolved)
    - Sensitivity to condensing moisture in capacitive pressure transducer
    - Problem was 'resolved' by adding T-VAC drying requirement

Lutz, 1975



Apollo PLSS Schematic

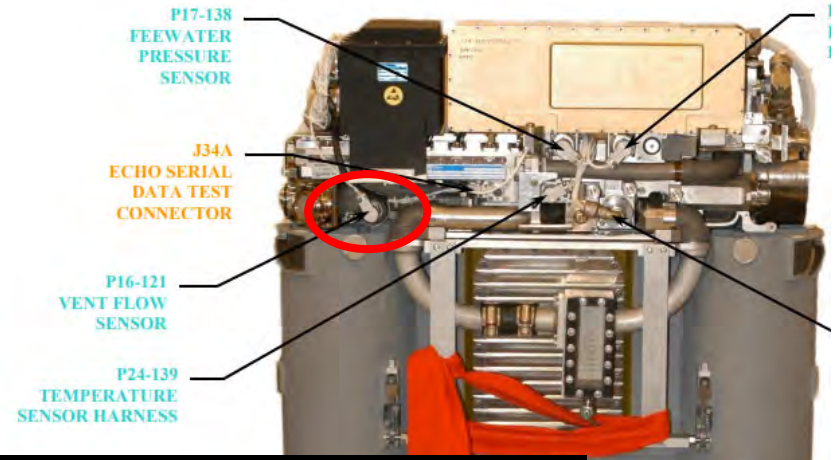
Lutz, 1975

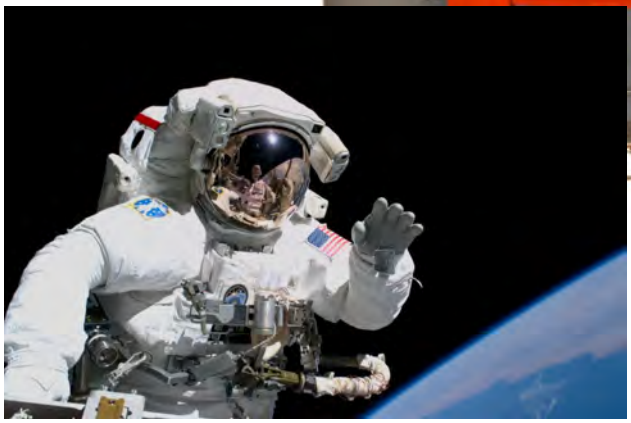


Shuttle / ISS PLSS

- **Nominal Pressure**
  - 4.3 psia
- **Adequate Flow Rate**
  - > 5.4 acfm
- **Ventilation Flow Sensor**
  - Check valve/flow sensor assembly
  - Pressure compensated
  - Bi-level readout
    - > 3.7 acfm minimum
    - < 5.4 acfm maximum

NASA EMU Data Book – Rev V., 2017

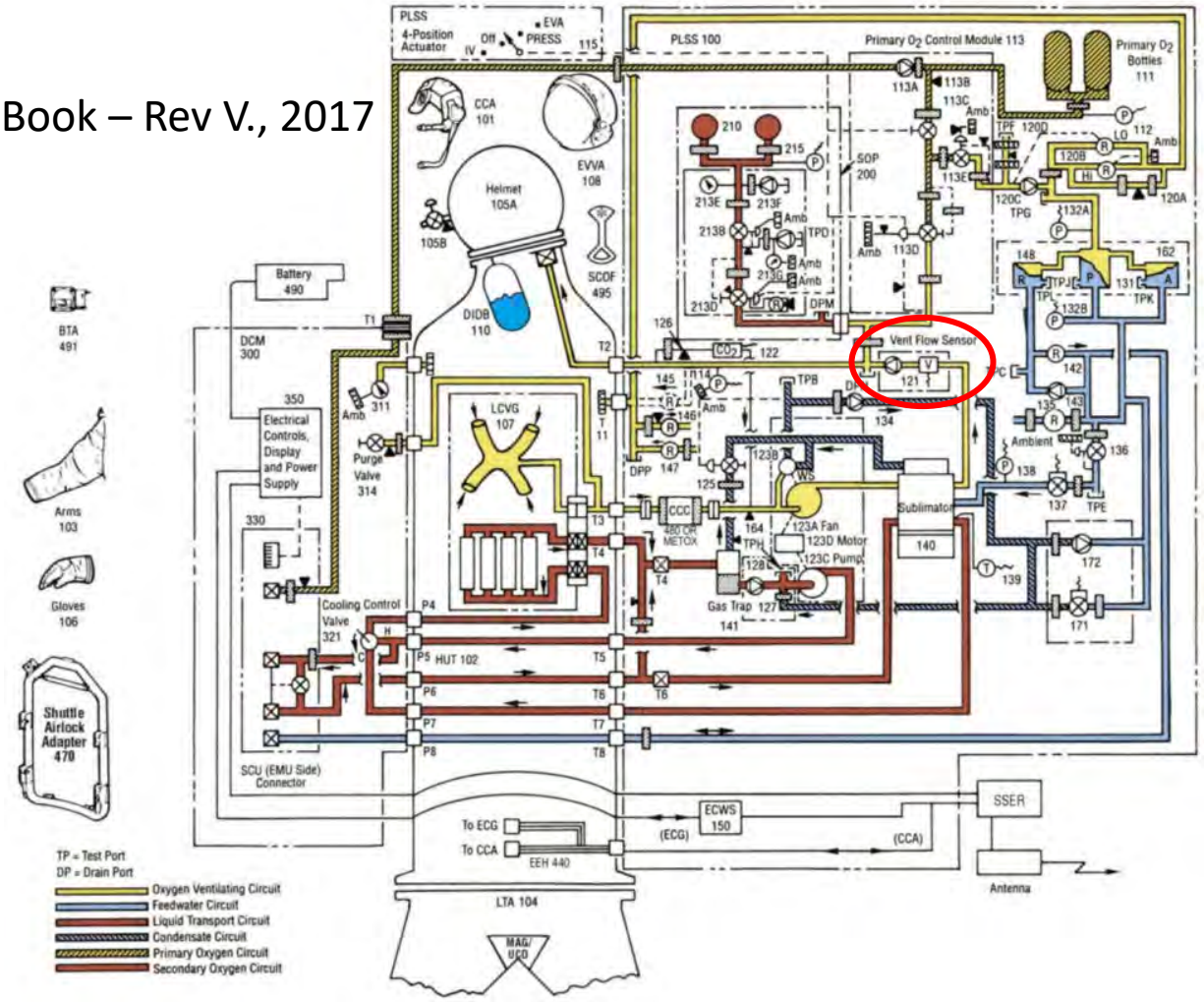




Credit: NASA, Joseph Tanner STS-115

Shuttle / ISS PLSS Schematic

NASA EMU Data Book – Rev V., 2017

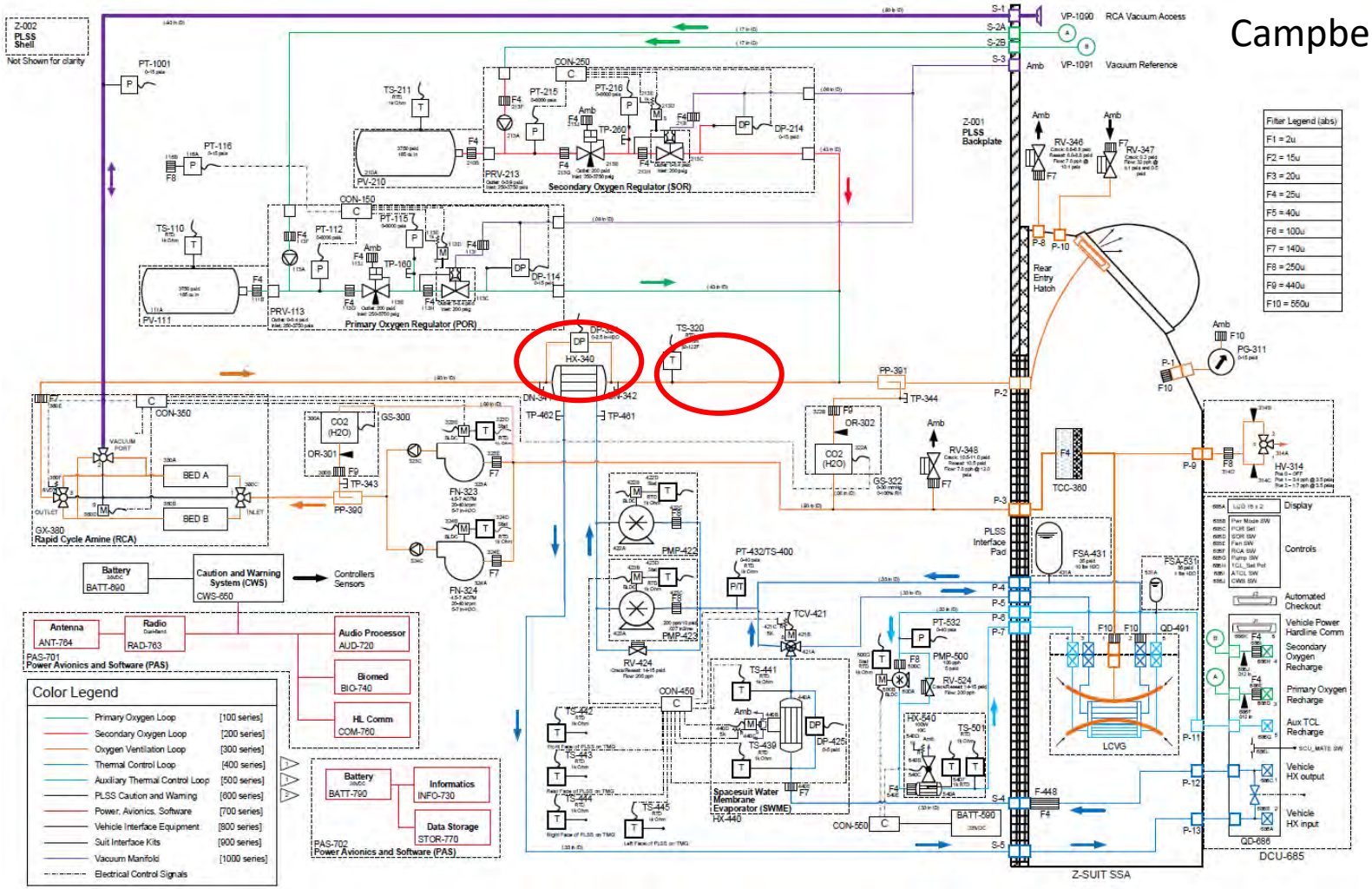


Exploration PLSS

- **Pressure Range**
  - 3.5 to 25 psia
- **Flow Rate Range**
  - 1 to 8 acfm
- **Two Redundant Flowmeters**
  - Differential pressure across the ventilation loop heat exchanger
  - Space Lab's innovation
- **Independent Technologies allow Increased Robustness**

Credit: NASA TV

Exploration PLSS Schematic

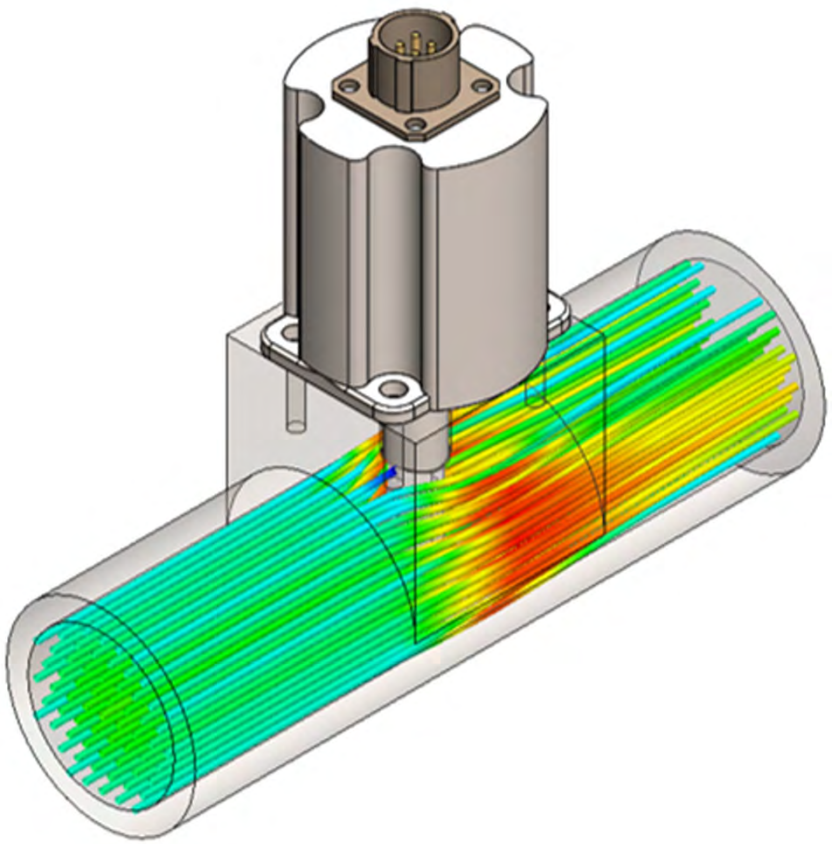


Campbell, 2015

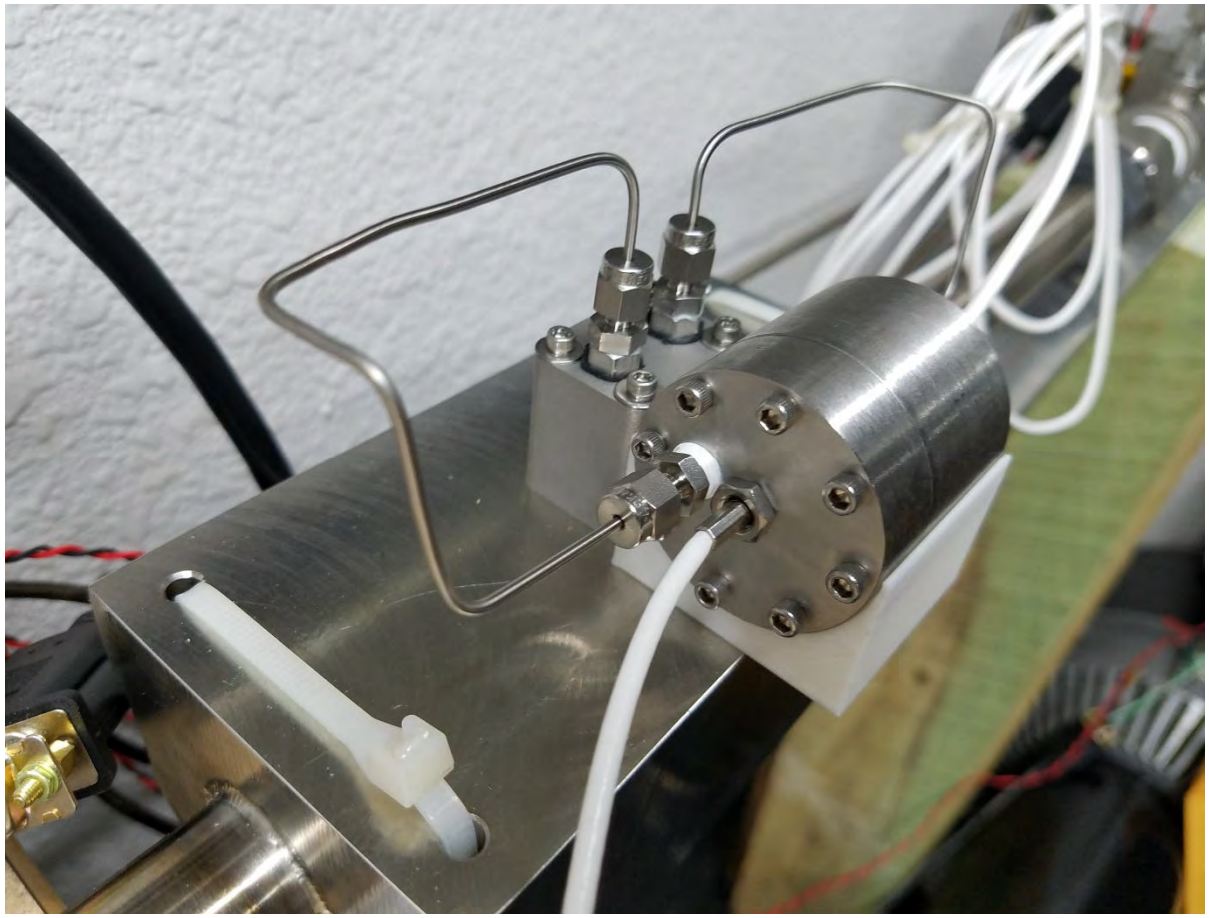
SPACE LAB'S INNOVATION

The Space Lab O=O Flow™

- **Low Pressure Drop**
  - < 0.04 inH2o drop @ 4.3 psia
- **100% Oxygen Compatible**
  - Wetted Materials:
    - Inconel 625
    - Nickel 200
    - Teflon® (PTFE)
    - Viton®
- **Accurate across Multi-flow Conditions (< 1.5% Uncertainty)**
  - Laminar, Transition, Turbulent
- **Compact Formfactor**
  - 3 × 2.5 × 1.5 inch envelope
- **Use of New Flow Field Relationships**



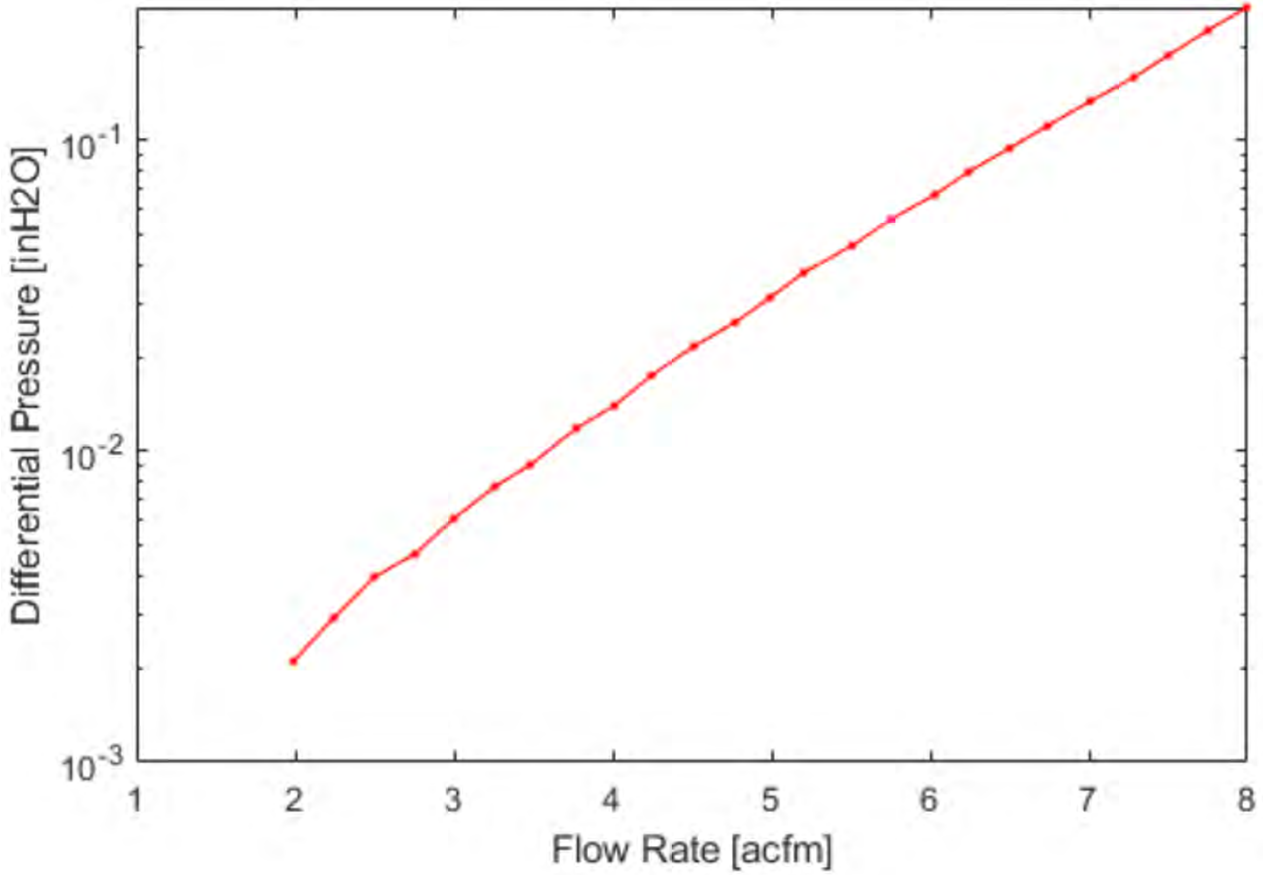
New Differential Pressure Transducer



High Turndown: Capable of measuring DP range of 0.001 to 10 inH2O

Phase I Results

APT Differential Pressure Output vs. Flow Rate
4.3 psia



WHAT WE ARE DOING FOR PHASE II

Phase II Deliverables to NASA

- **O=O Flowmeter™ EDU**
  - Engineering Demonstration Unit using commercial/industrial parts
  - 4-pin Mighty Mouse connector (6-4) interface
  - +5 Vdc input power (< 150 mW)
  - RS-485 data interface (flow rate, pressure, temperature)

- **O=O Flowmeter™ Test System**
  - Test system allows for immediate testing
  - Can be used for debug of EDU for operation in PLSS system

THANK YOU
TAKE A DEEP BREATH ;-)

BACKUP SLIDES

EVA from Gemini to the ISS and Beyond

Malik, 1968

Gemini Nov. 1961 – Nov. 1966

First U.S.A. EVA: Gemini IV – June 1965

Lutz, 1975

Apollo Nov. 1961 – Nov. 1966

First use of the complete EMU: Apollo 9 – March 1969

First on Lunar surface: Apollo 11 – July 1969

First two EVA periods: Apollo 12 – November 1969

First accompanied of the buddy secondary life-support system (BSLSS): Apollo 14 – Jan 1971

Commercialization

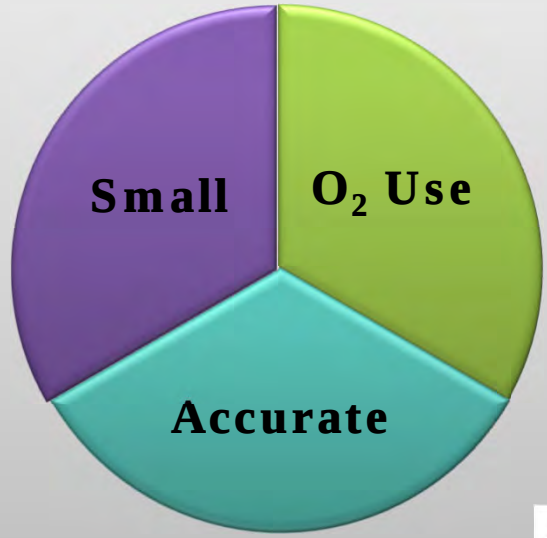
O=O Flowmeter™

EddySense™

Markets & Customers

- **NASA HEOMD AES – AEMU PLSS**
- **STMD - Small Spacecraft Thrusters**
- **Producers of Commercial O_2 Delivery Systems (priority order):**
  1. Commercial Space Suits
  2. Space Life Support Systems
  3. Military Breathing Equipment
  4. Satellite Propulsion Systems
  5. Commercial Harsh Environment Suits O_2
  6. Delivery Medical O_2 Therapy
  7. Industrial Process Monitoring

Value Proposition



Revenue Streams & Intellectual Property

- Years 3-5: Application specific units to beachhead customer (NASA) & markets 1-4
- 5+ Years: Sell standardized units to broader commercial markets 5-7
- 4 – 5 Patents Planned