TFAWS Active Thermal Paper Session

Spacesuit Water Membrane Evaporator; An Enhanced Evaporative Cooling Systems for the Advanced Extravehicular Mobility Unit Portable Life Support System

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THERMAL & FLUIDS ANALYSIS WORKSHOP
GRC · 2014

Overview

- SWME Design Criteria
- Previous Design
  - Pre - Gen. 4 design
  - SWME Gen. 4 early concepts
- Current Design
  - Housing Modification
  - End cap Modifications
  - Back Pressure Valve Modifications
- Thermal Control Valve (TCV)
- Sensor Selection

Scope and Background

- What is SWME?
  - Spacesuit Water Membrane Evaporator
  - Baseline heat rejection technology for the Portable Life Support System of the Advanced EMU
    - Replaces sublimator in the current EMU
    - Contamination insensitive
    - Can work with Lithium Chloride Absorber Radiator in Spacesuit Evaporator Absorber Radiator (SEAR) to reject heat and reuse evaporated water

Background

The Spacesuit Water Membrane Evaporator (SWME) is being developed to replace the sublimator for future generation spacesuits.

Current PLSS

...relies on a sublimator for LCVG and PLSS component cooling

- Sensitive to contaminants
- Only certified for 25 EVA's: Has failed before 25 EVAs (during EVA)
- Requires a separate feedwater loop
- Will not work on Mars due to increased atmospheric pressure

Advanced PLSS

Create a new, robust heat rejection device for future:

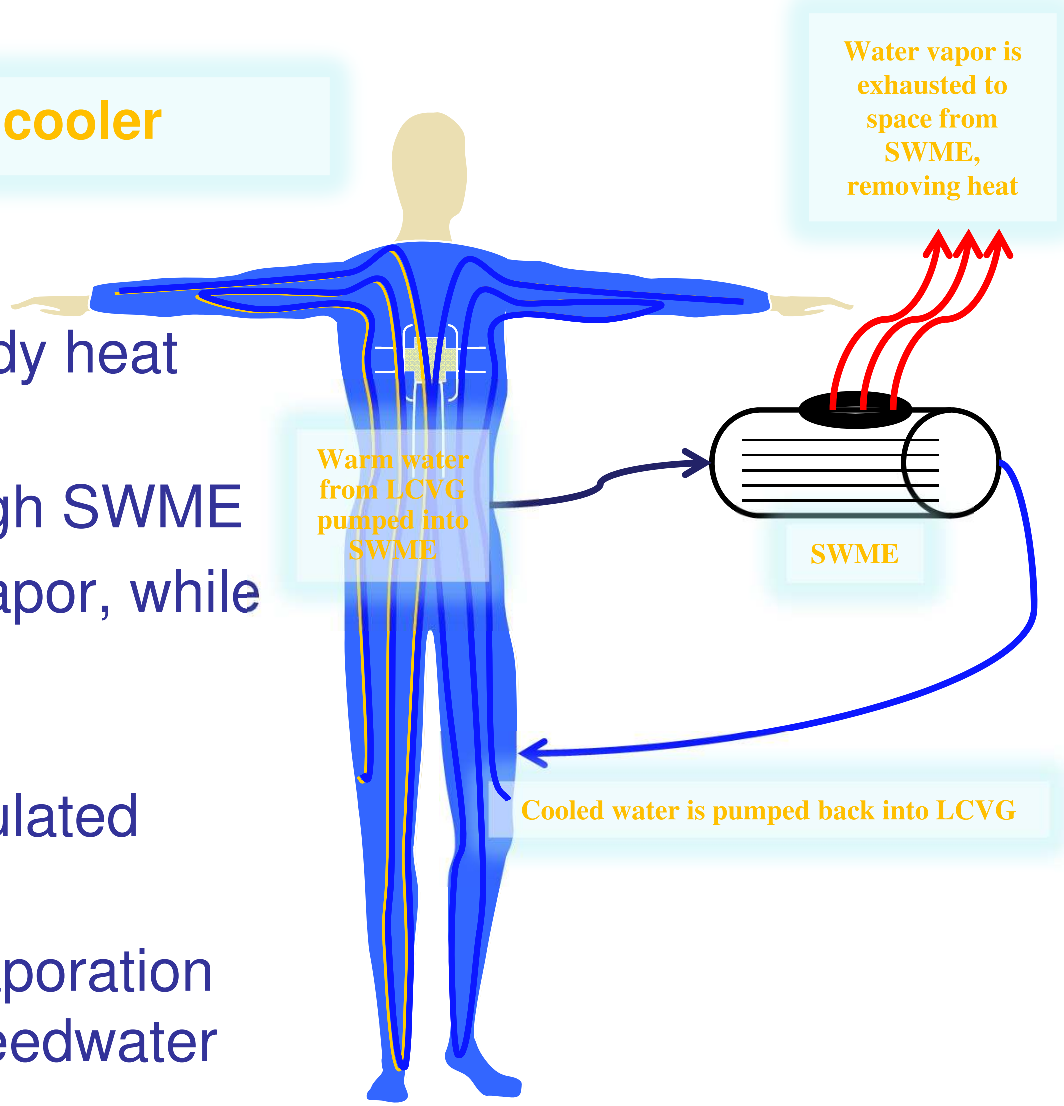
- Reject at least 807W at 10° C (50° F) outlet water temperature at EOL
- Operate for at least 100 8-hour EVA's
- Function in multiple EVA environments *(Lunar, Mars, Vehicle)*
- Resist contaminant fouling

SWME Overview

SWME is an evaporative cooler

Process

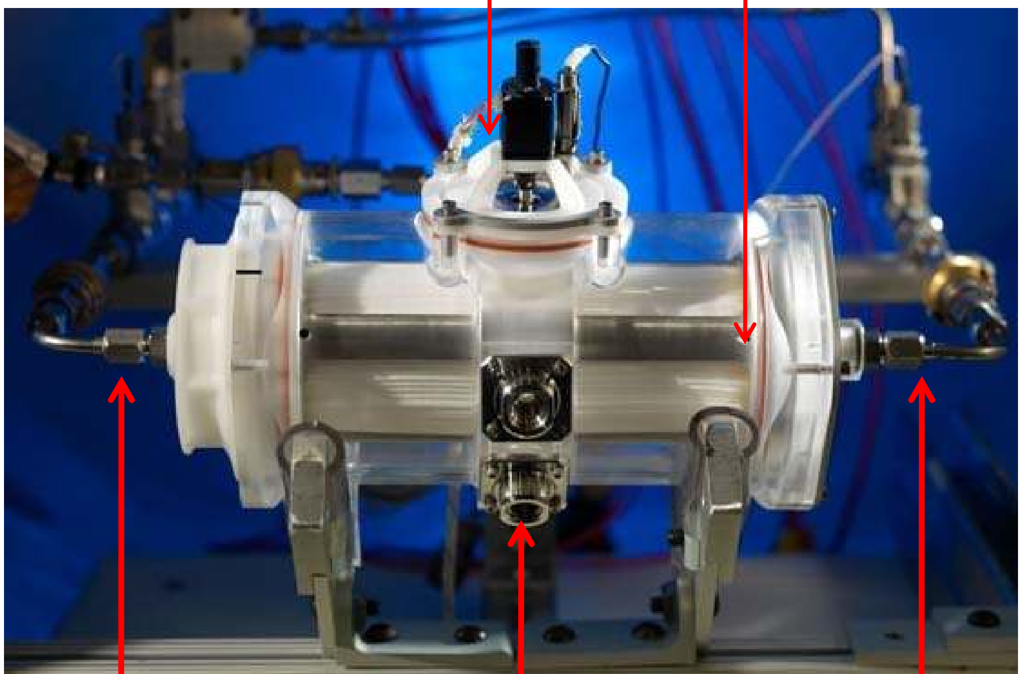
- Water in LCVG absorbs body heat while circulating
- Warm water pumped through SWME
- SWME evaporates water vapor, while maintaining liquid water
  - Cools water
- Cooled water is then recirculated through LCVG.
- LCVG water lost due to evaporation (cooling) is replaced from feedwater



SWME

Back Pressure Valve

Cage



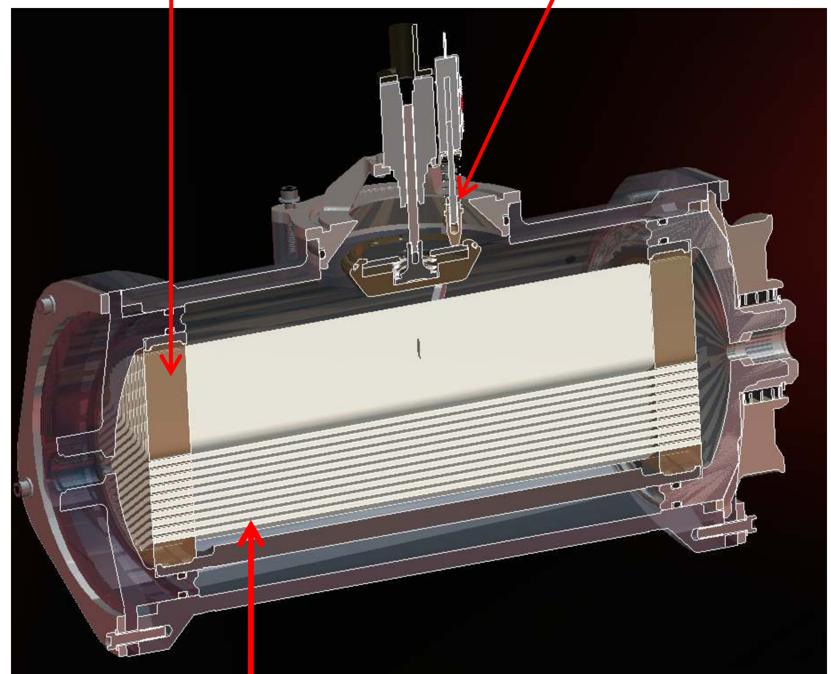
Water Inlet (warm water from LCVG)

Instrumentation Ports

Water Outlet (cool water to LCVG)

Polyurethane Plug

Valve Position Sensor

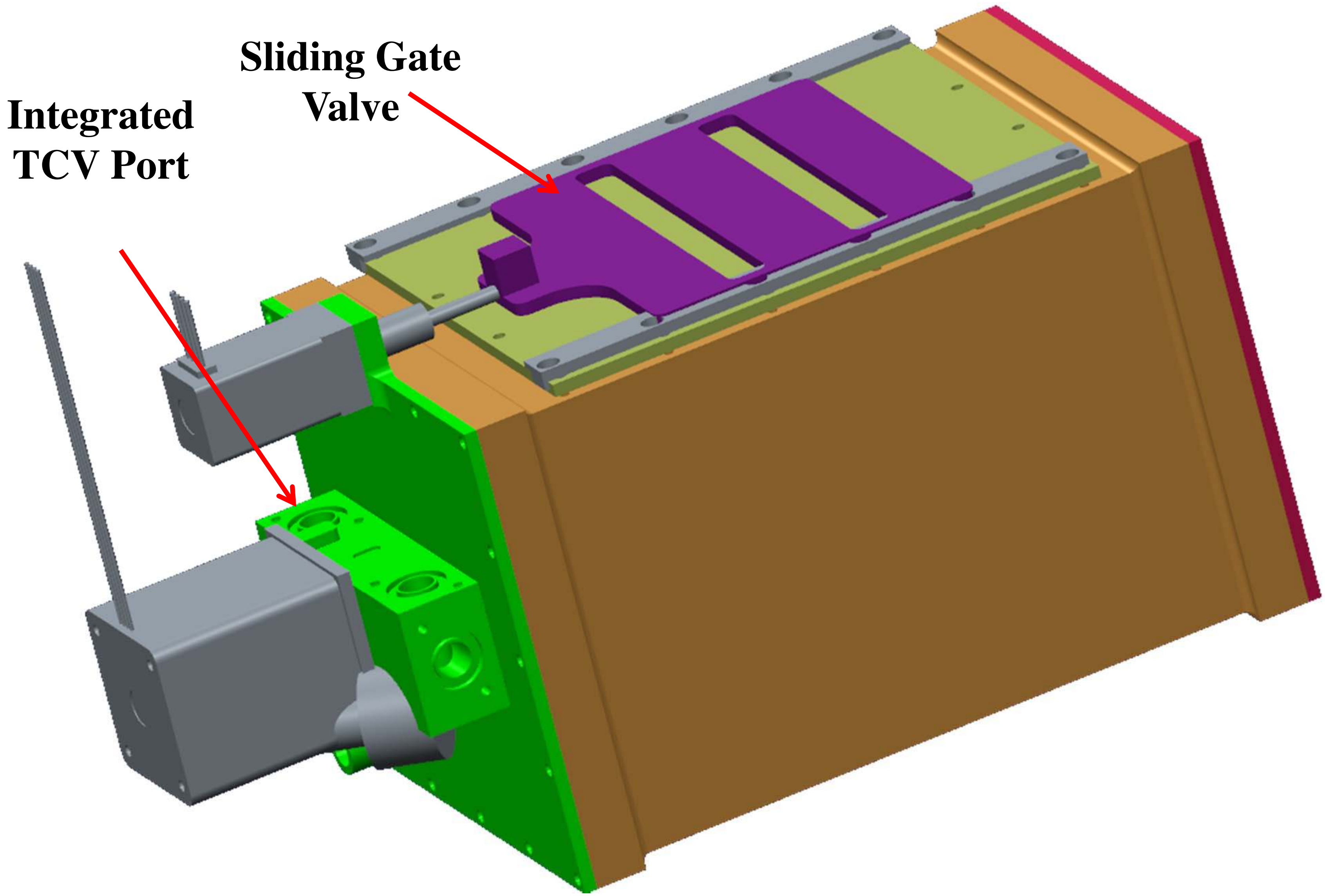


Hollow Fibers

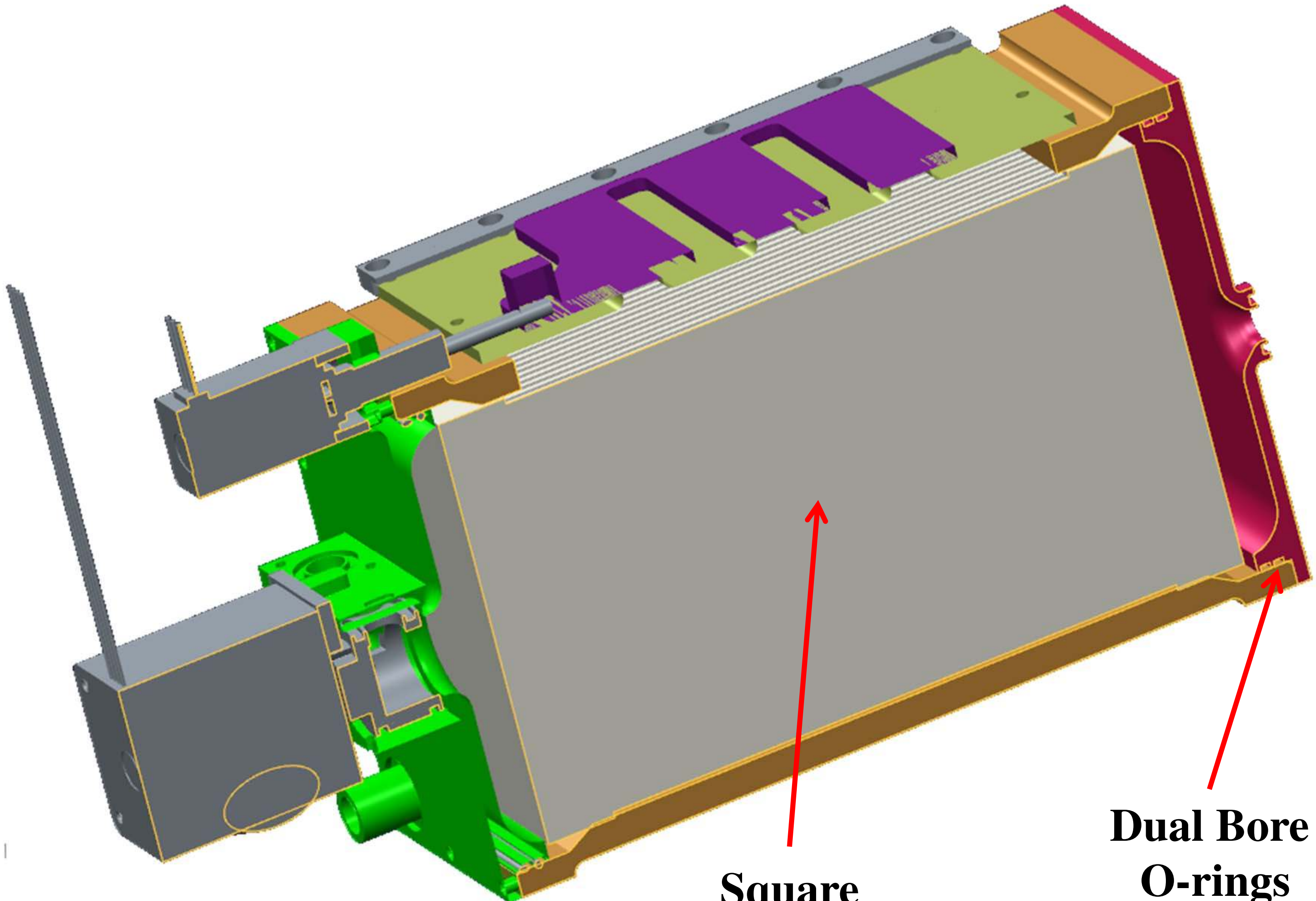
New Design Goals for Gen4 SWME

- Function
  - Meet or exceed earlier design requirements
  - 810 W heat rejection at end-of-life
  - Minimize or eliminate water vapor leak
  - Protect for over/under pressure conditions
  - Sense valve position
  - Maximize controllability over the lower metabolic range; to increase crewmember comfort.
- Form
  - Maximize packaging efficiency for incorporation into PLSS 2.5
    - Square profile
    - Minimize volume of SWME housing
    - Integrate the Thermal Control Valve (TCV), delta pressure, and temperature sensors into the SWME assembly

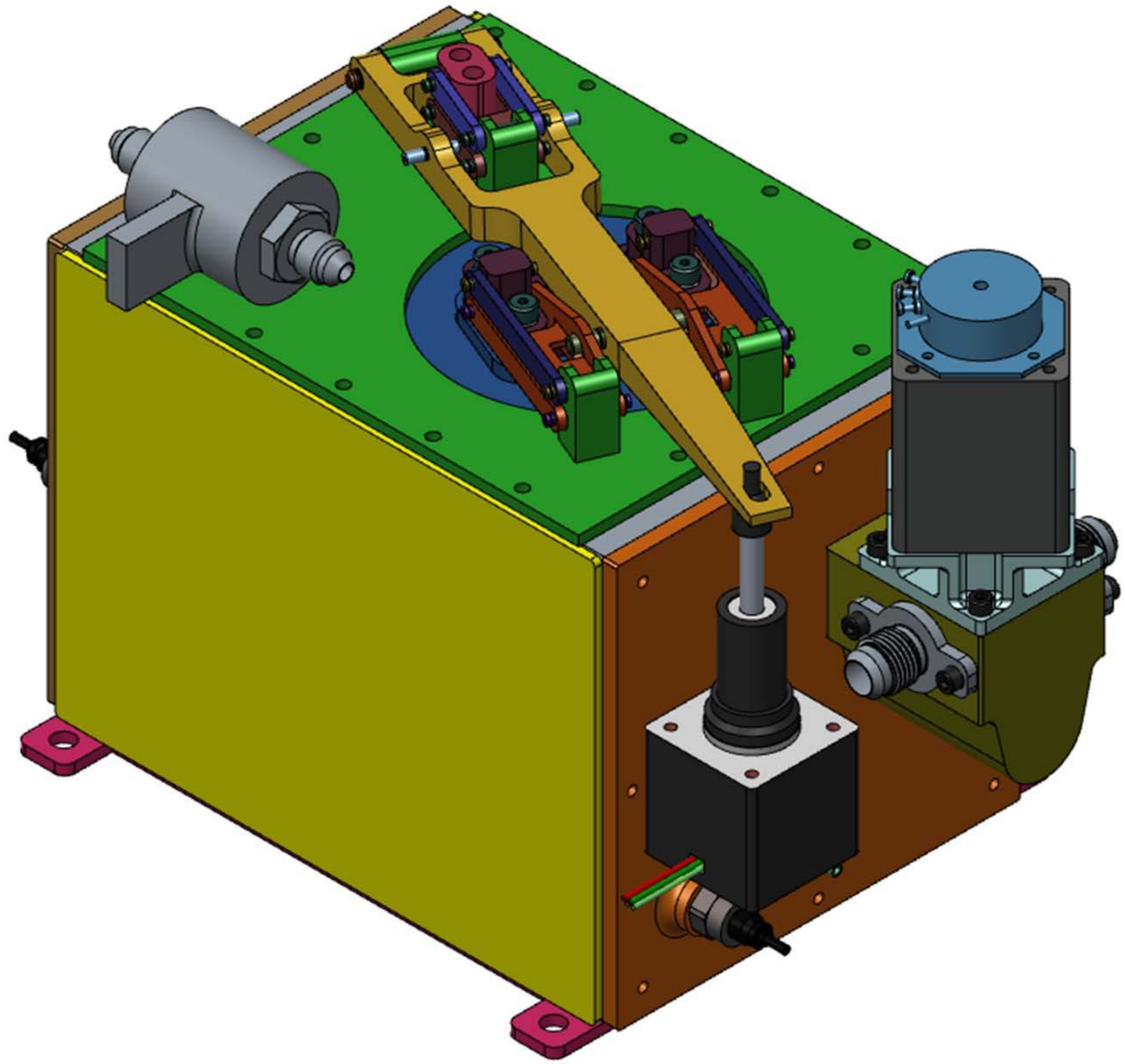
SWME Gen. 4 Early Concept



SWME Gen. 4 Early Concept

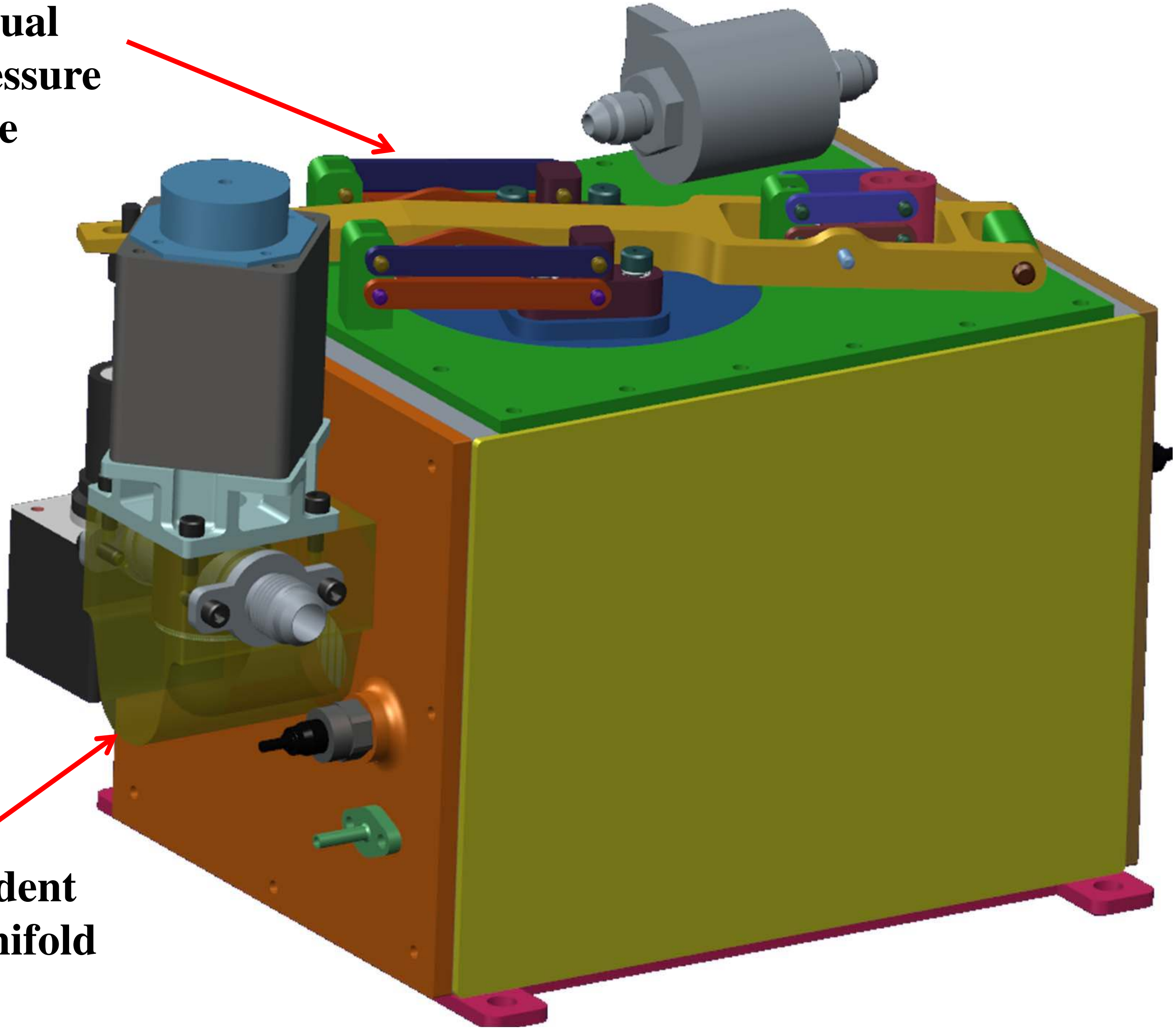


SWME Views (Cont.)



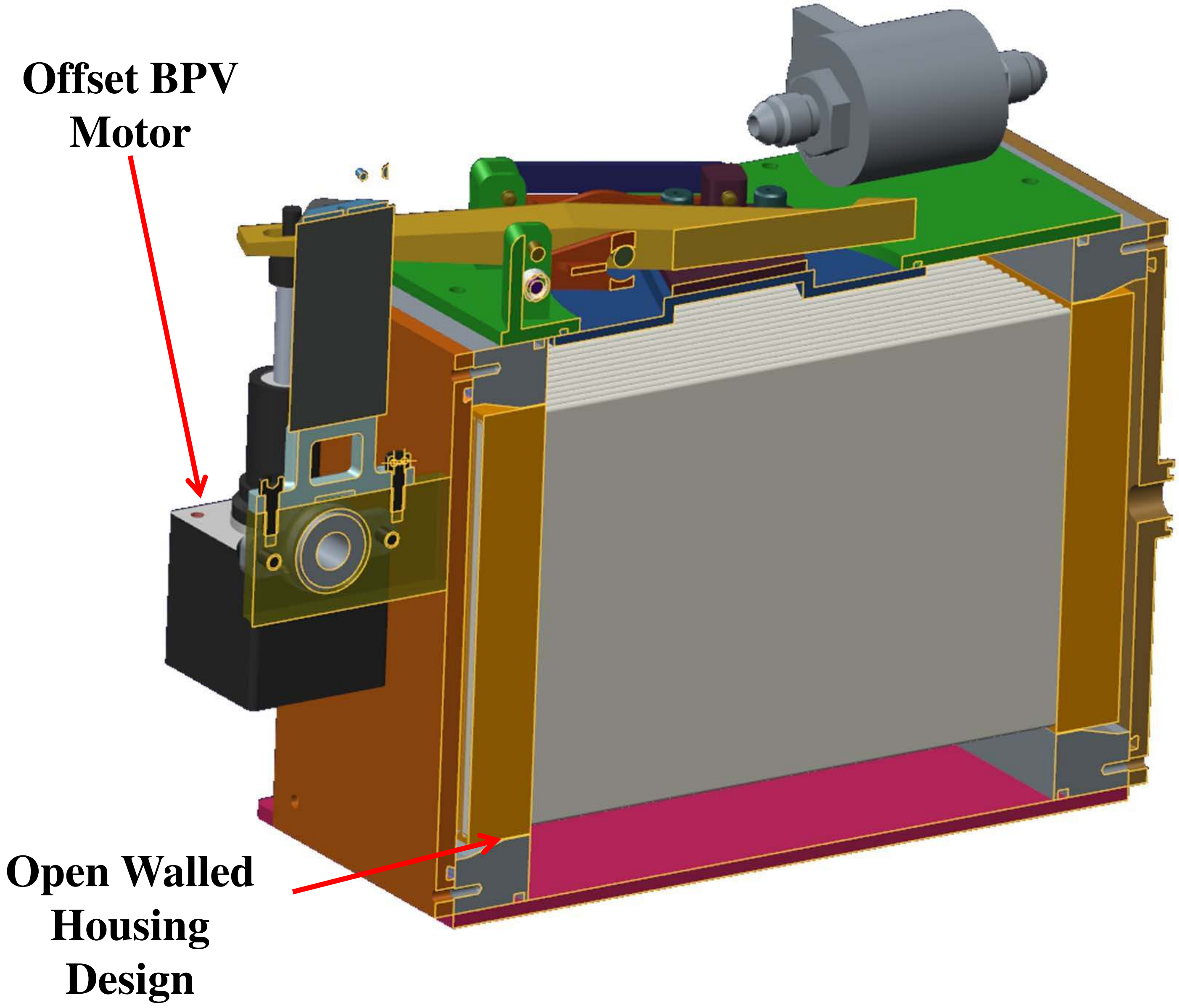
Current SWME Concept

New Dual Back Pressure Valve



Independent TCV Manifold

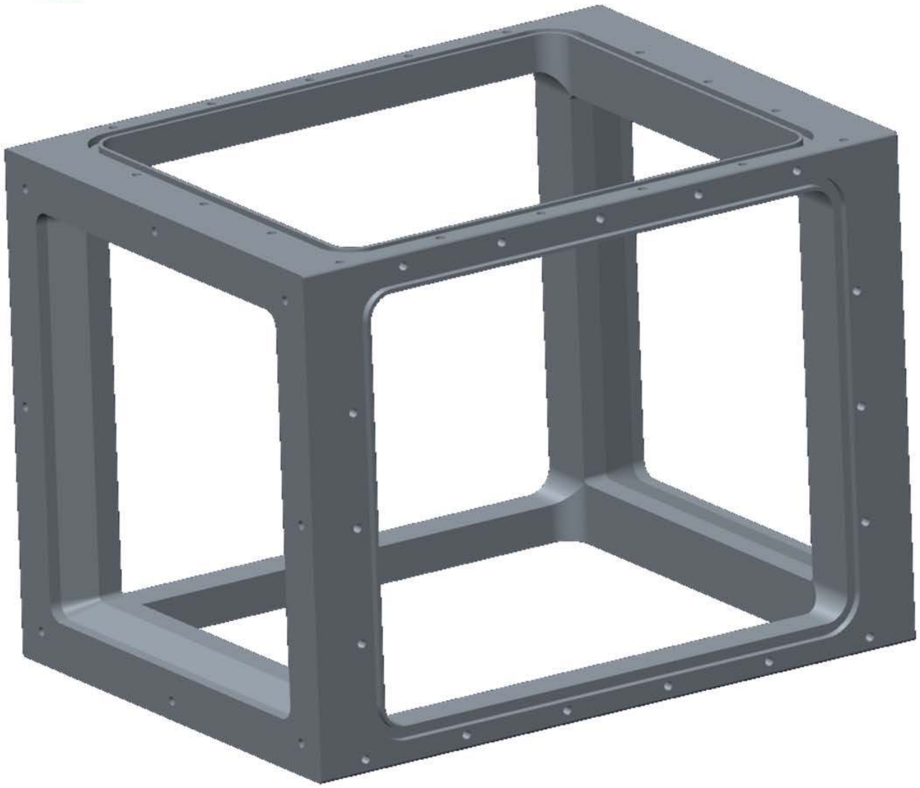
Current SWME Concept

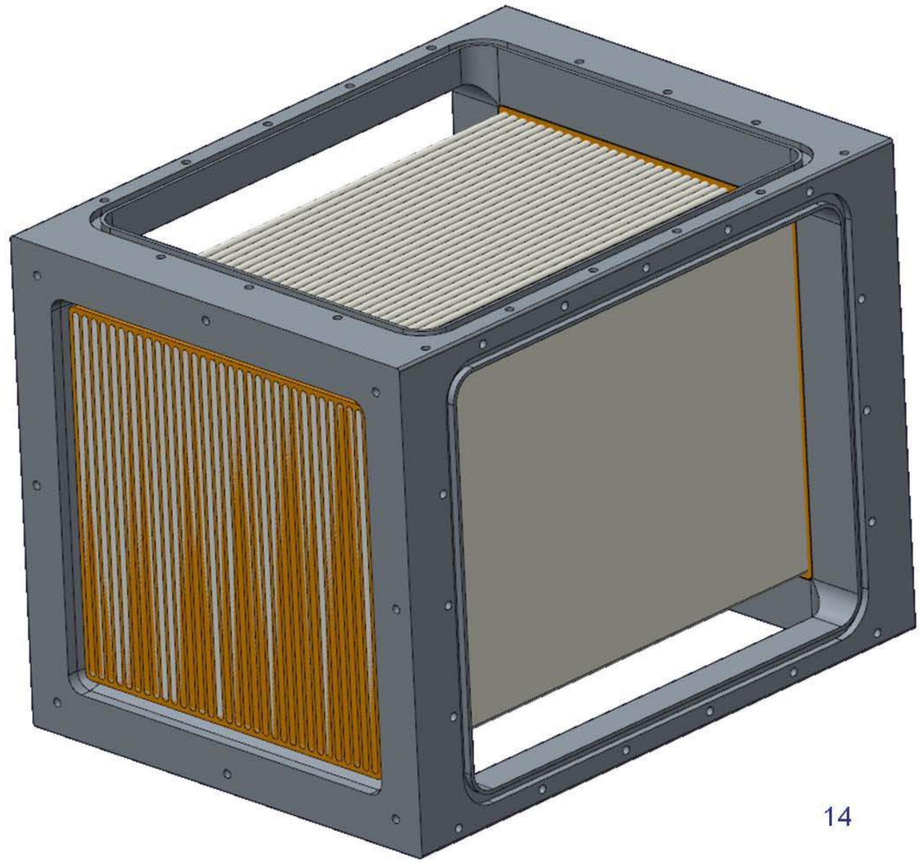


Design Modifications

- The Independent TCV Manifold reduces design complexity and manufacturing difficulty of the SWME End Cap.
- The offset motor for the new BPV reduces the volume profile of the SWME by laying the motor flat on the End Cap alongside the TCV.

New Housing Design

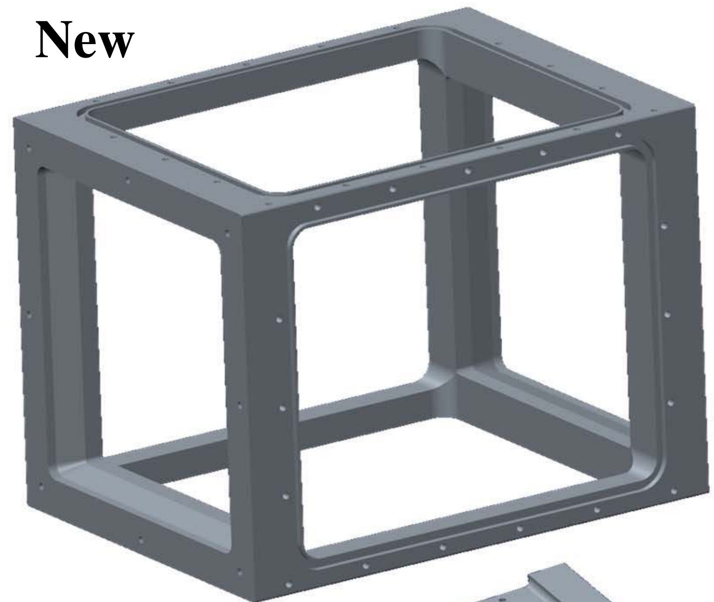




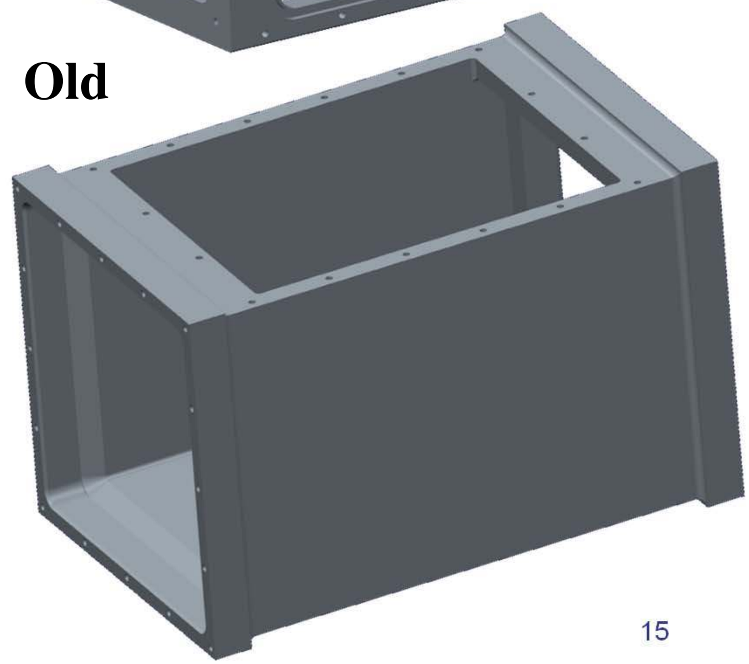
Housing Modification

- Side walls were opened up for:
  - Better access during assembly
    - A bead of polyurethane can be run on the inside of the cartridge now to prevent urethane leak during potting.
    - Easier leak identification and repair.
  - Ease of manufacturing
    - More generous tolerances
    - Standard and quicker machining methods can be used
  - Modularity of design
    - 4 open sides allow for more options such as relief valves to equalize pressure in an off-nominal repress/depress

New

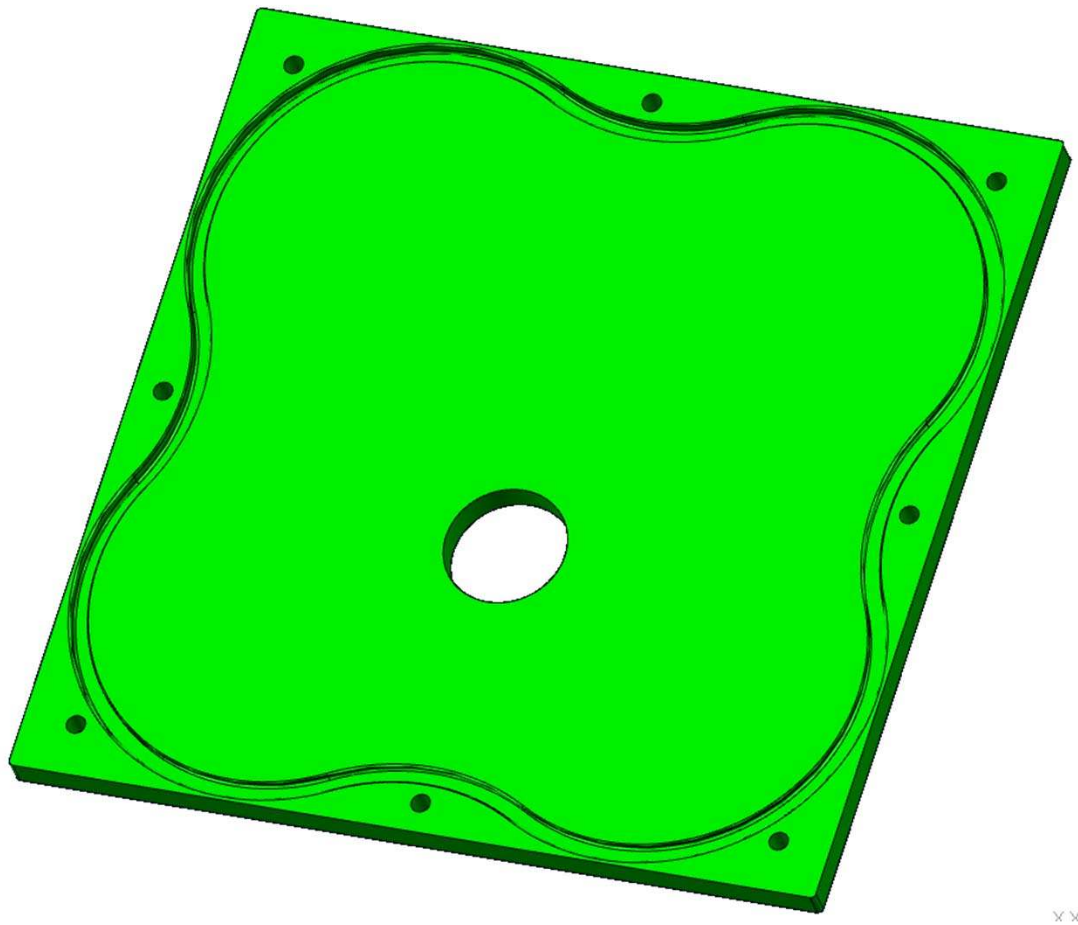


Old



End Cap

- Simplified End Cap with separation of TCV Manifold.
- Moved O-ring gland from bore O-ring on housing to face seal O-ring on End Cap.
  - Better Sealing Method
  - Serpentine pattern allows for generous bend radii on square cross section and COTS o-ring
- Increased surface area to allow for face seal



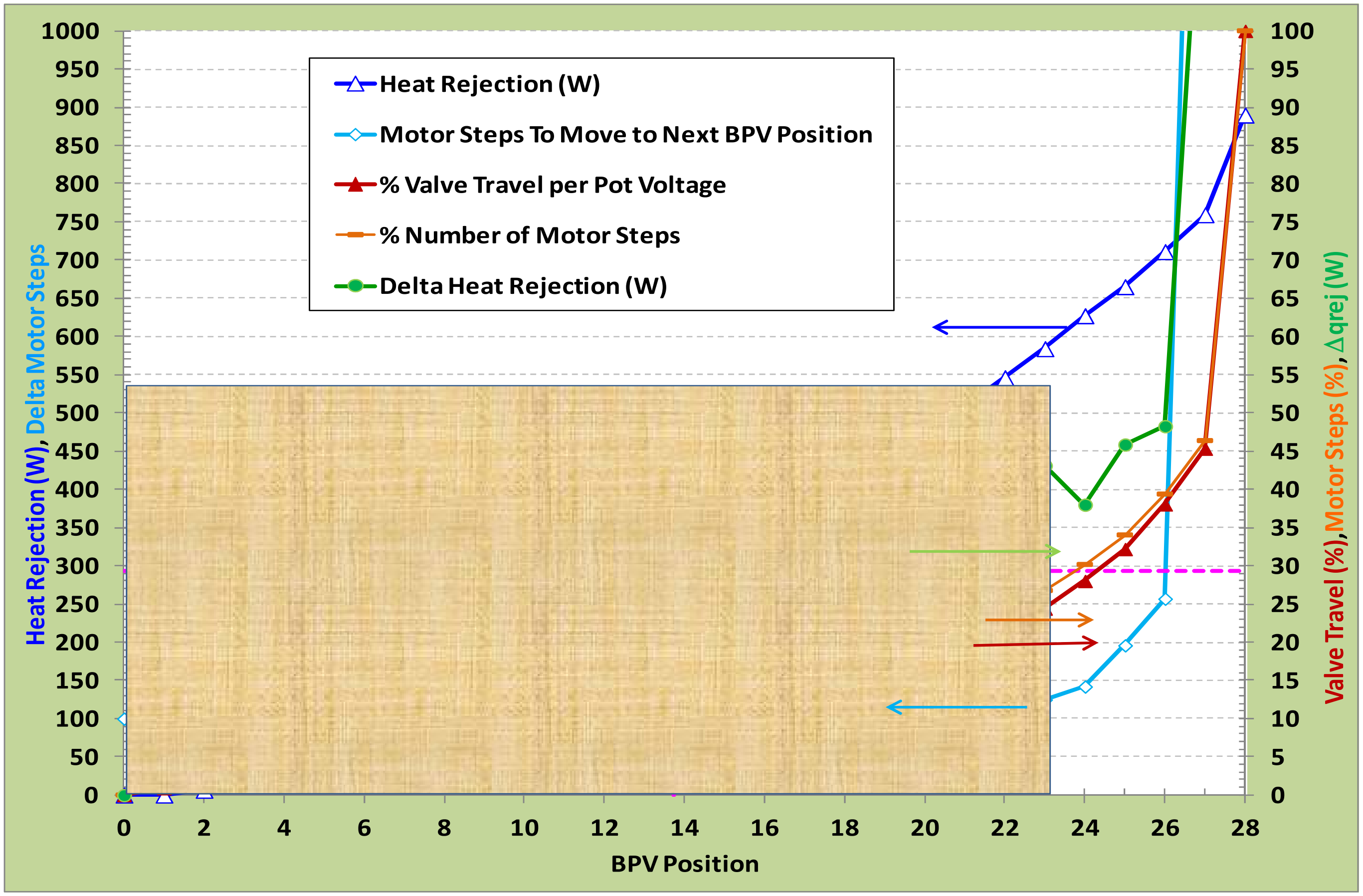
Note: Final design will have thicker edge distances on O-rings

Back Pressure Valve goals

- Reduce total SWME volume envelope through low profile
  - Facilitates PLSS packaging
- Allow for pressure differential equalization
- No heat leak during non-op periods
- Finer control at lower metabolic rates
- High cycle life capability
- 4 in^2 open area

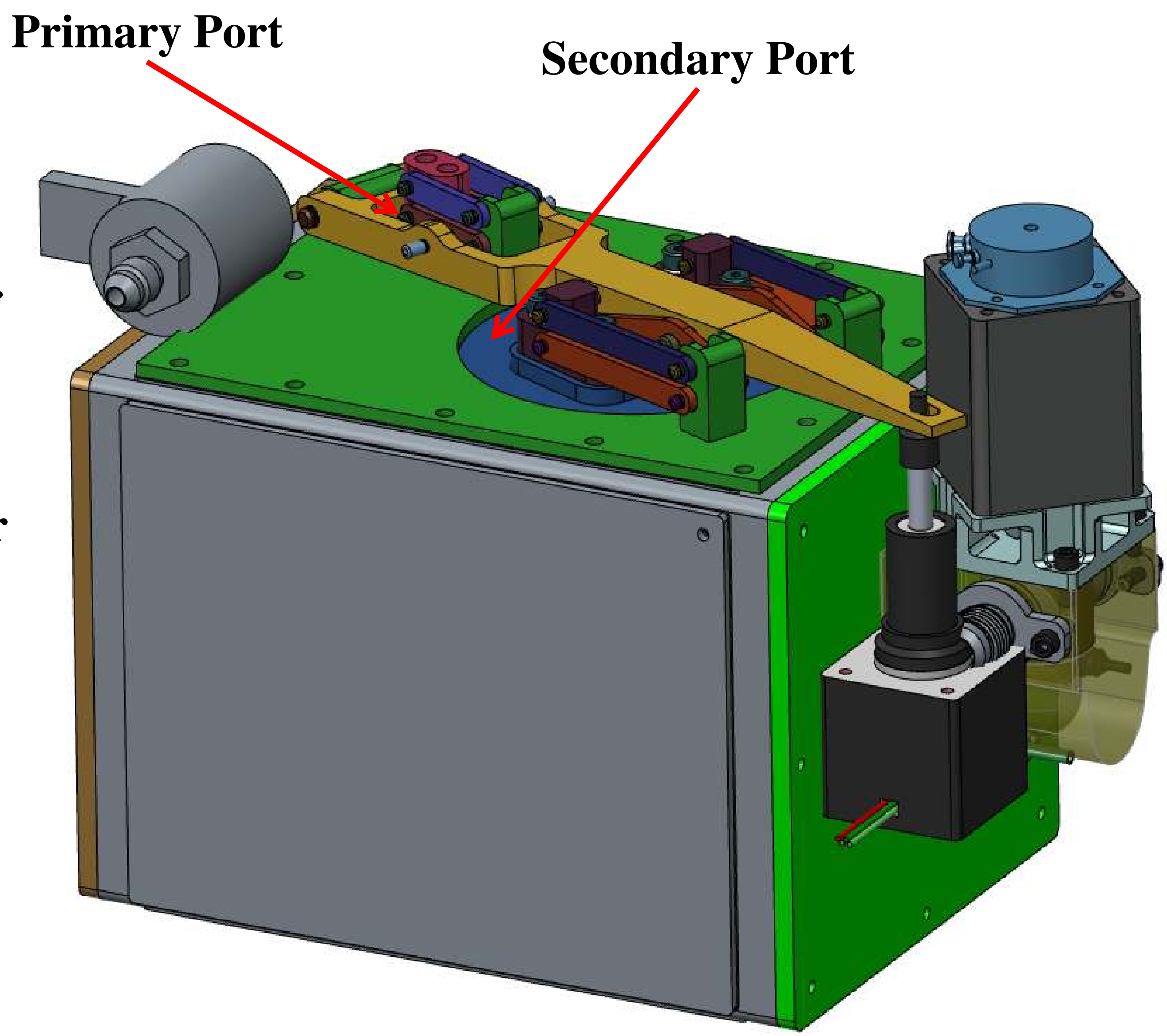
Gen2 SWME BPV Characterization

- Opening the valve 25% resulted in an SWME heat rejection of 66% of its full open BPV value
- The last 75% of valve poppet travel accounted for the final 34% of SWME heat- rejection capability.

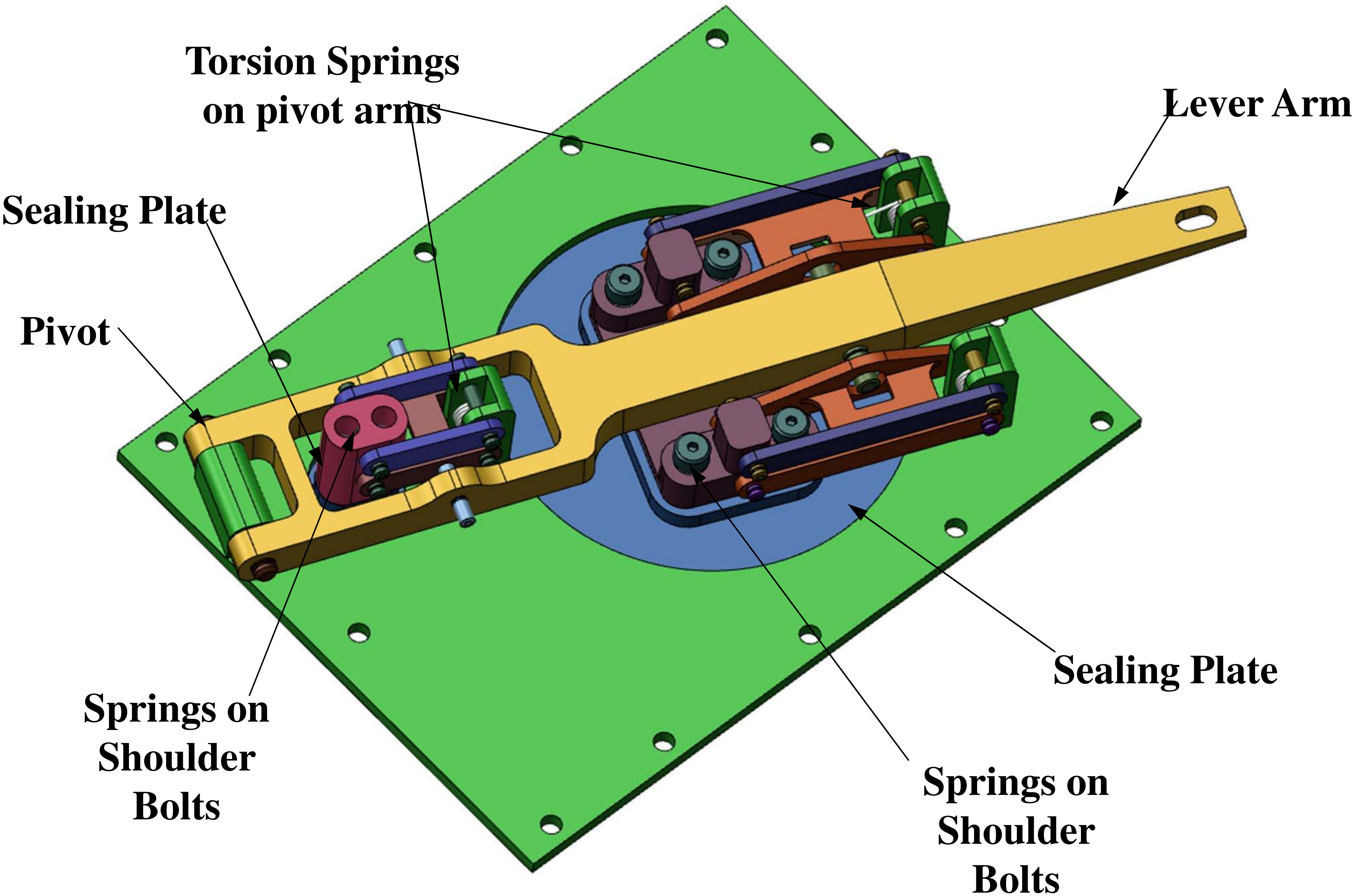


Back Pressure Valve

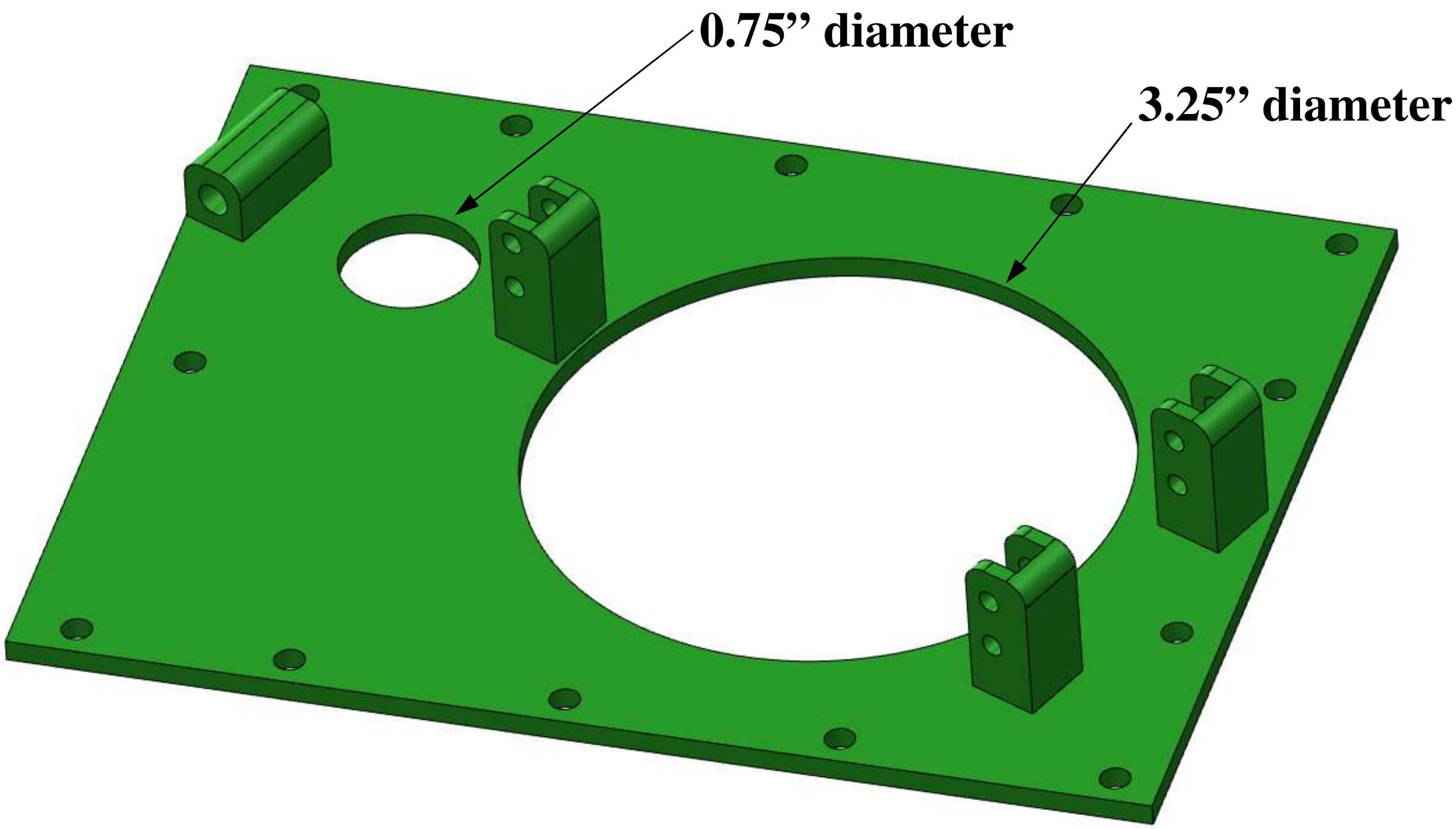
- Ports open sequentially.
- Smaller Primary port allows for finer control at lower metabolic rates.
- Larger Secondary port provides higher flow volumes when needed at higher metabolic rates.



Back Pressure Valve (Cont.)

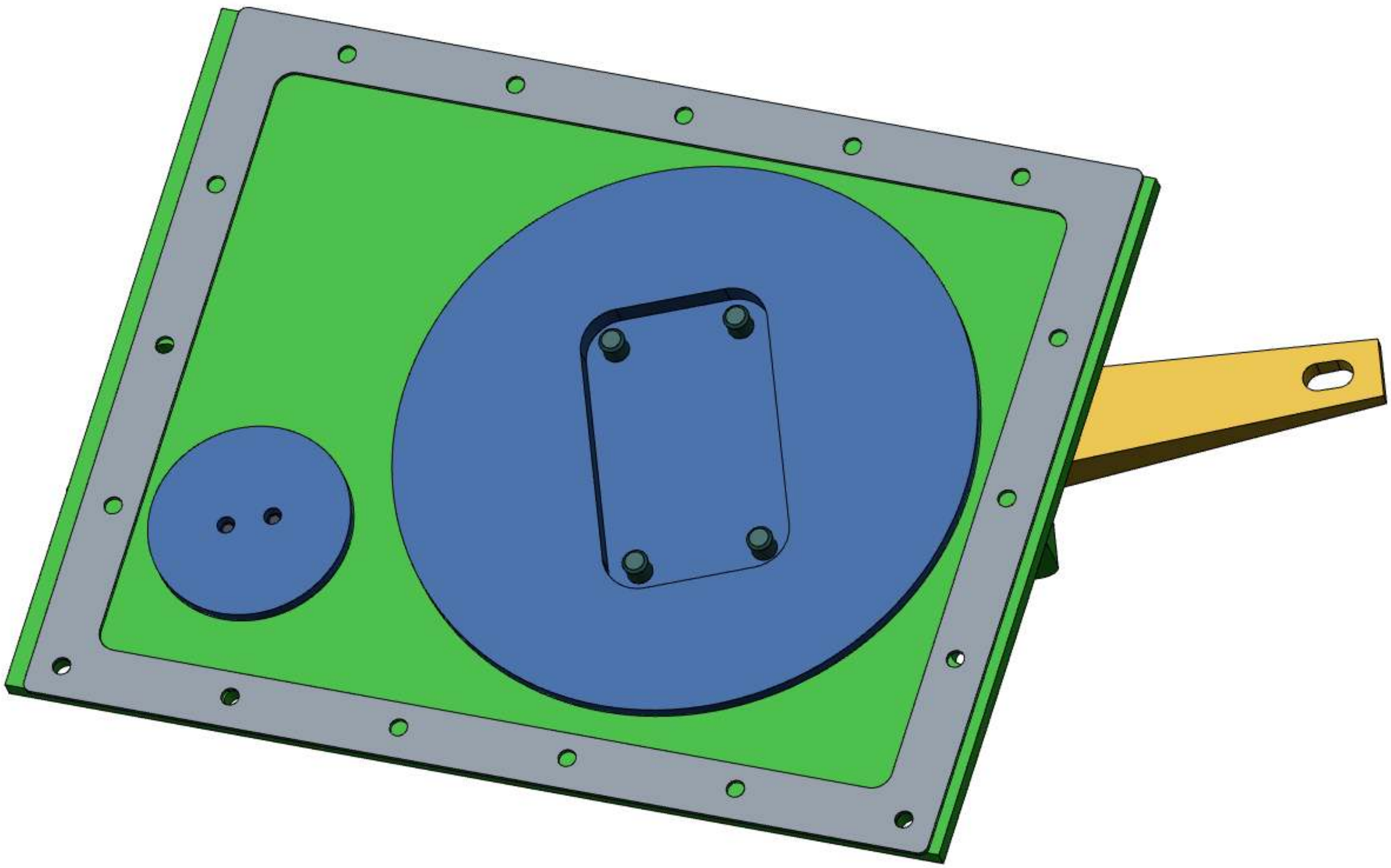


BPV Base Plate



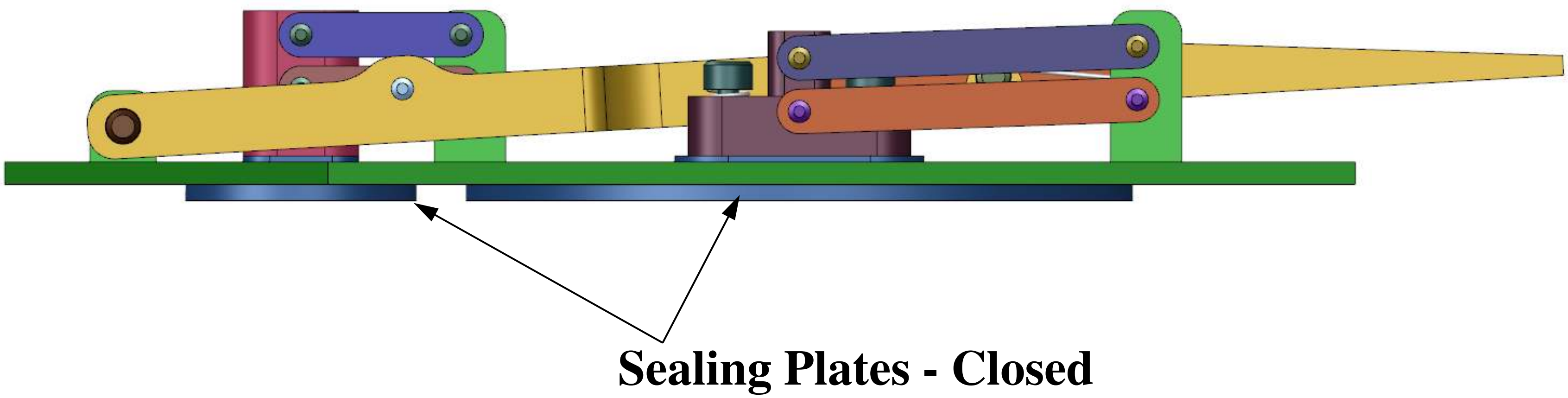
BPV Base Plate (Cont.)

View from inside

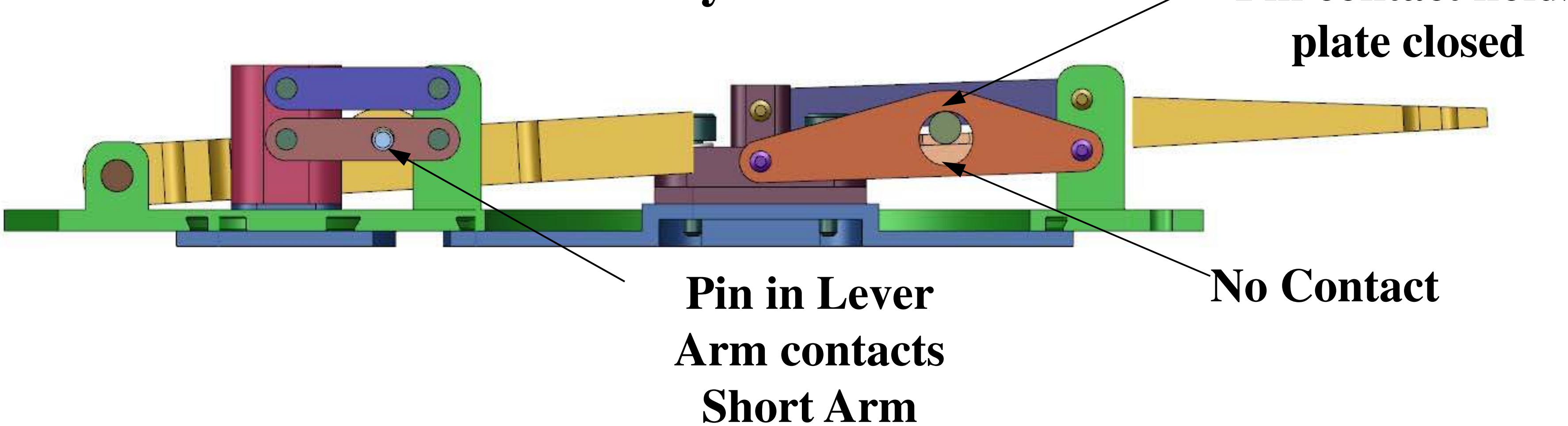


Valve Mechanism

Side View – Valves Closed

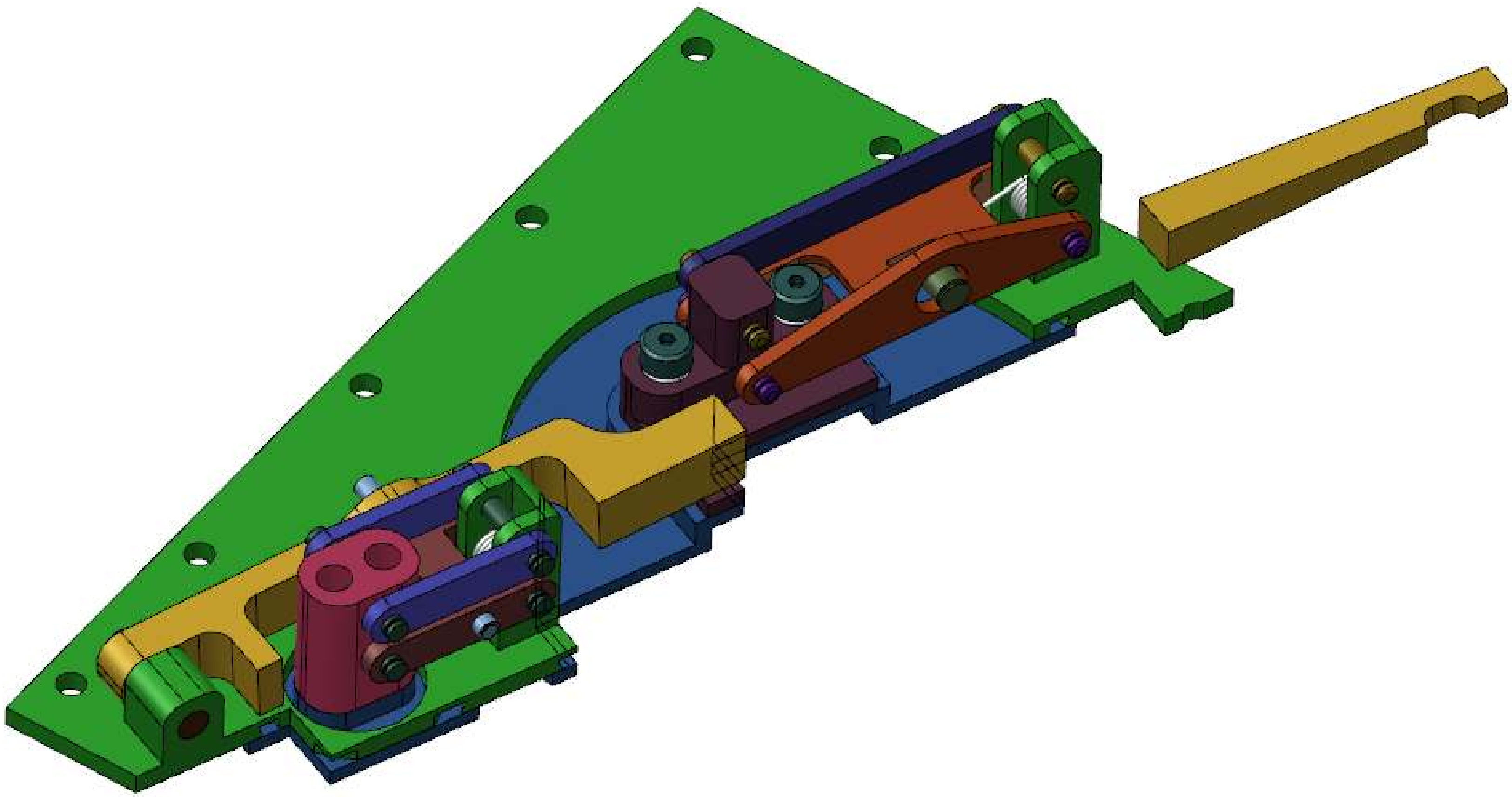


Cutaway View

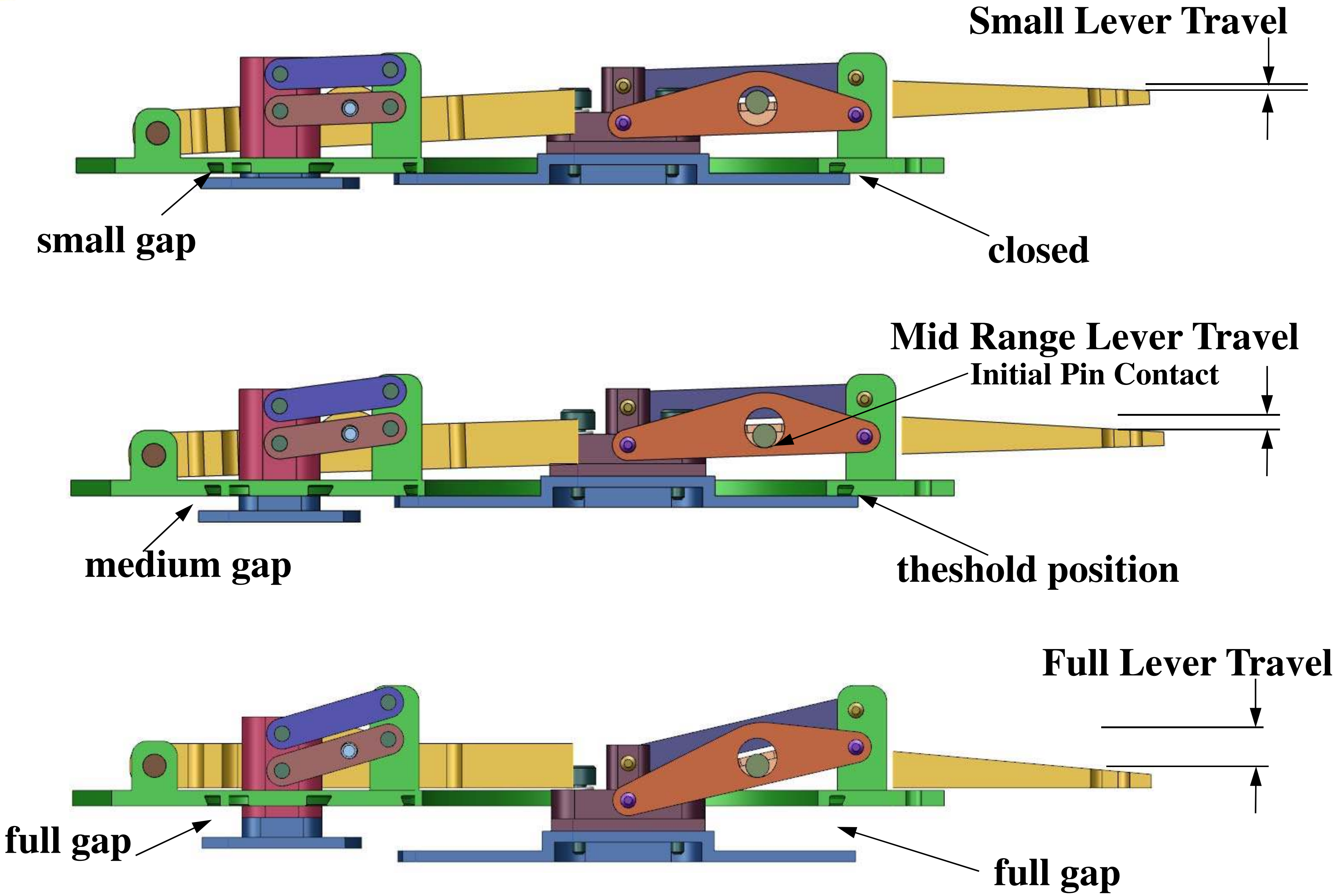


Valve Mechanism (Cont.)

Cutaway View



Valve Mechanism (Cont.)



BPV Pros and Cons

Pros:

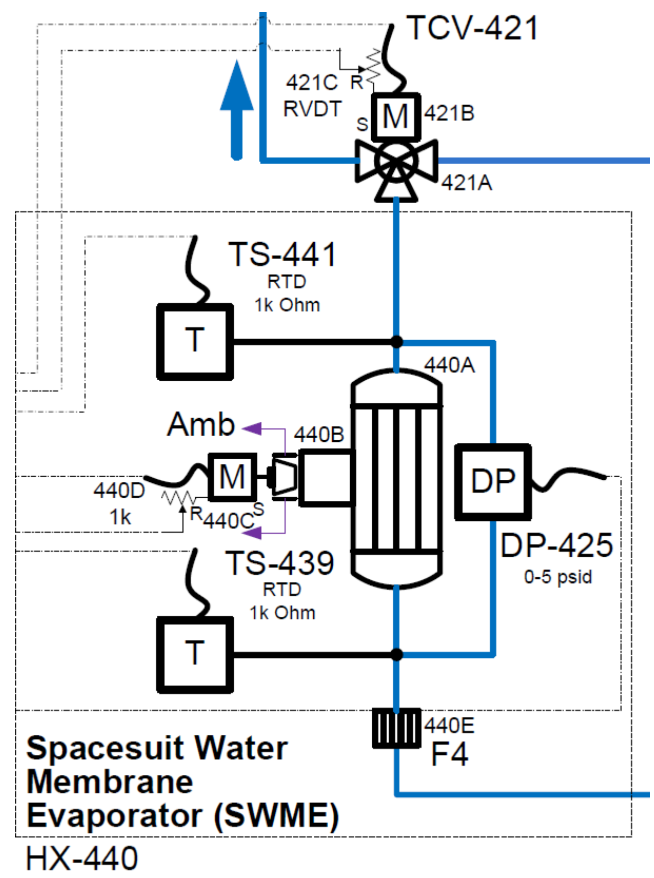
- **Smaller Primary port allows for finer control at lower operation rates.**
- **Larger Secondary port provides higher flow volumes when needed.**
- **Parallel linkages keep the sealing plates from tilting.**
- **Multiple linkages stop sliding motion on O-rings when compared to single linkage.**

Cons:

- **Multiple linkages increase part count and complexity**
- **Multiple pivots increase risk of valve "sticking"**

Integration - TCV

- Improved PLSS Packaging
  - Fewer tubing runs
  - Fewer retaining brackets
- Less instrumentation
  - Removal of redundant temperature sensors
- Closer proximity of thermal loop controller to components



Integration – TS 439, 441

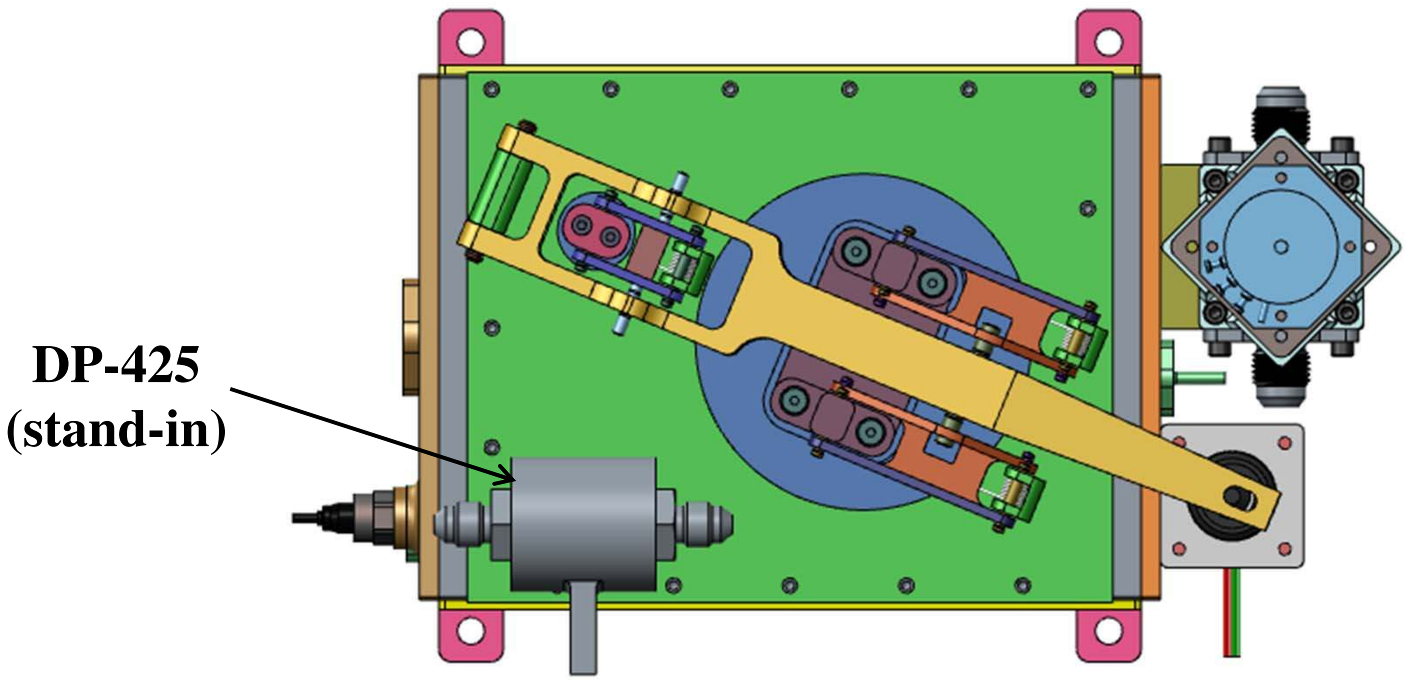
- Measure SWME inlet and outlet temps
  - TS-441 replaces TS-401 (TCV Inlet Temperature)
- COTS 1k RTDs
  - Standard temperature sensor for PLSS 2.5
  - O-ring Boss Port Interfaces

Integration – DP-425

- Measures dP across SWME
- Loss of flow triggers SWME safing
- Provides coarse thermal loop flow measurement
- 1/8 in tubing runs from inlet and outlet
- Sensor selection in-work

Integration – DP-425

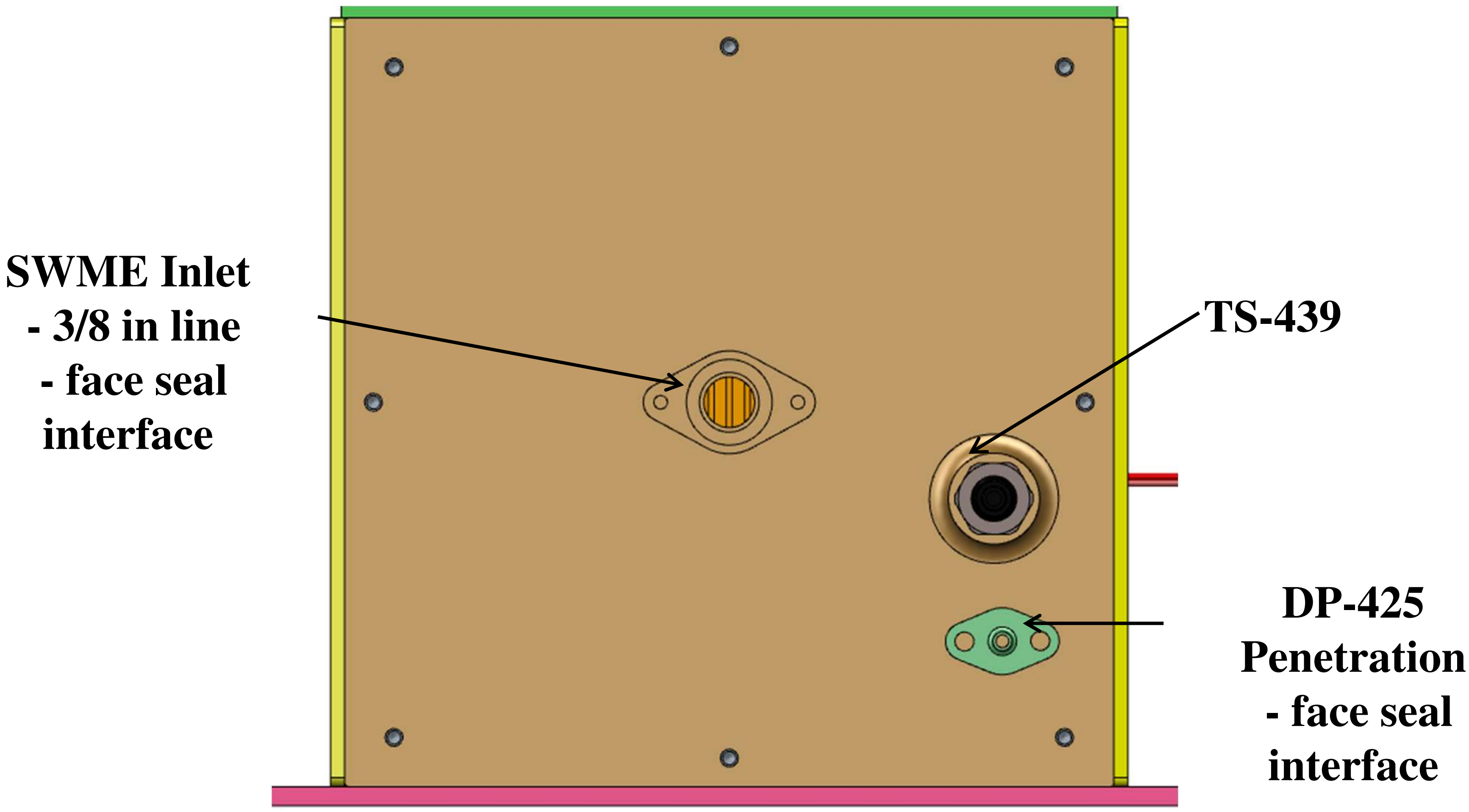
- Current volume constraints require sensor be placed on top of SWME



Integration - Endcaps

- Allow design of individual components in parallel with packaging and integration
- Reduced machining risk
  - Complexity of endcaps and risk of scrapping will not affect the entire SWME housing
- Pressure and temperature sensors can be placed anywhere
  - Allows optimal placement of SWME gate valve

Inlet Endcap

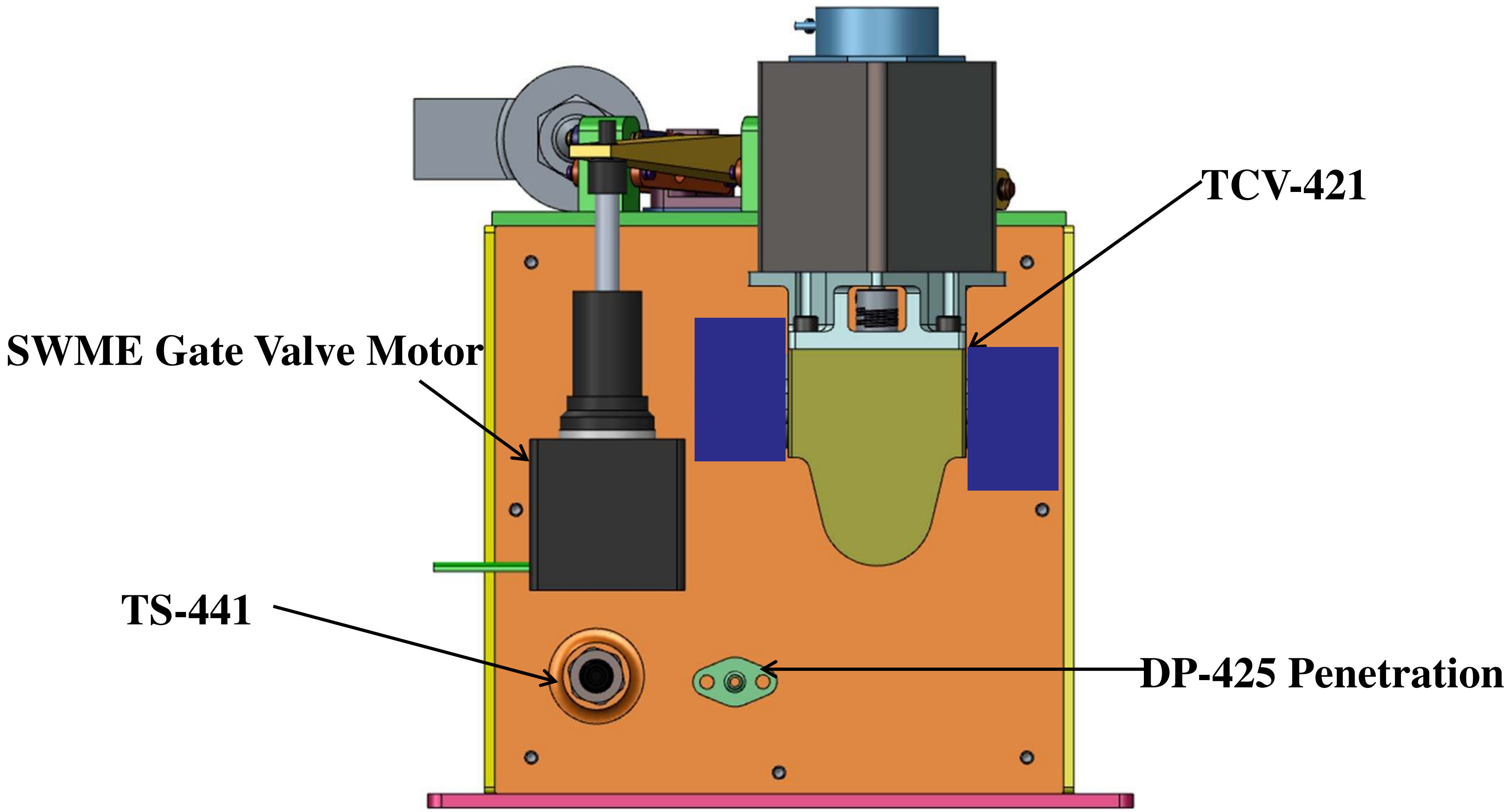


Inlet Endcap

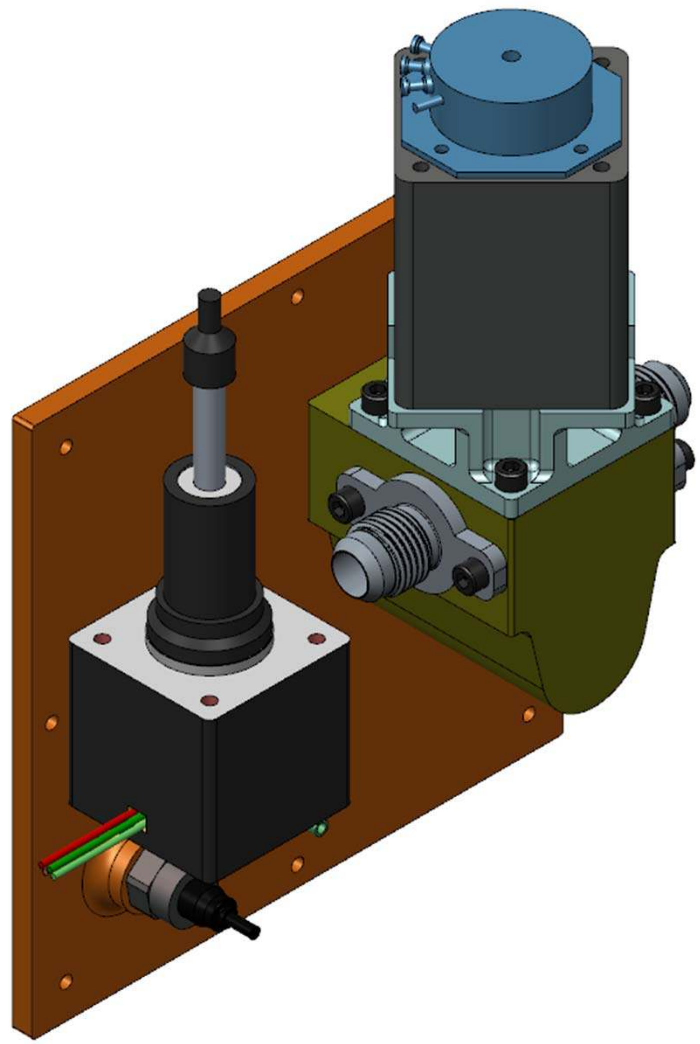
Outlet Endcap

- Currently, length is most packaging-critical dimension
- All large-volume components kept on one endcap to minimize swept volume
  - Valve Motor
  - TCV-421

Outlet Endcap



Outlet Endcap



Integration Forward Work

- Components still under development:
  - SWME Valve
  - SWME Fiber Count
    - FDTA testing
  - Mini-ME2
    - Will be based on lessons learned and data from Gen4
  - TCV-421
  - DP-425
- As these components continue to be developed and optimized, the integration concept will update as well