SmallSat Propulsion Systems: Development Challenges

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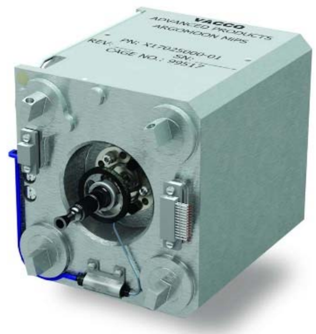
Overview

- **The purpose of this discussion is to highlight some of the design and development challenges that SmallSat Propulsion System Technologist are facing.**

Propellant Tanks

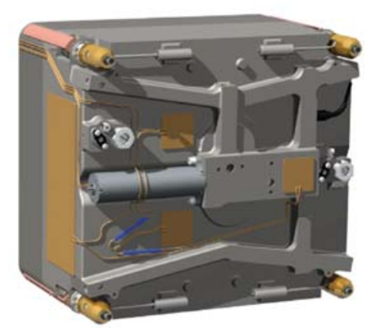
- **Ideal propellant storage tank is a conformal tank**
  - Volumetrically efficient for various SmallSat missions
  - Maximizes propellant load to accommodate high Δv missions
- **Key drawbacks to this design:**
  - Not suitable for high pressures
    - Maximum Expected Operating Pressure (MEOP) around 100 psig
    - Corners can be rounded and thickened to reduce stress concentrations. This increases tank mass
  - Propellant expulsion methods in early development.
    - VACCO will fly diaphragm in conformal tank
    - PMDs research for conformal tanks in early stages.
      - Used in Aerojet and VACCO systems.
      - Independent PMD research being conducted by Emily Beckman (NASA Fellow) at Purdue University.
    - Microgear pump in development under several NASA & AF SBIRs



VACCO
ArgoMoon
Green Prop MiPS

VACCO
Lunar Flashlight
Green Prop MiPS

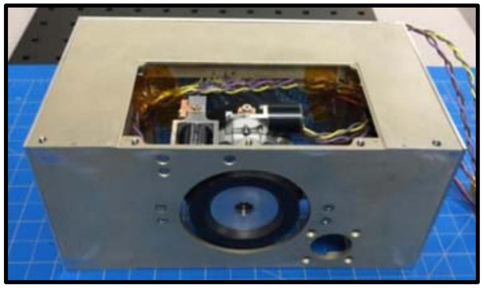
VACCO
MarCO Cold Gas MiPS



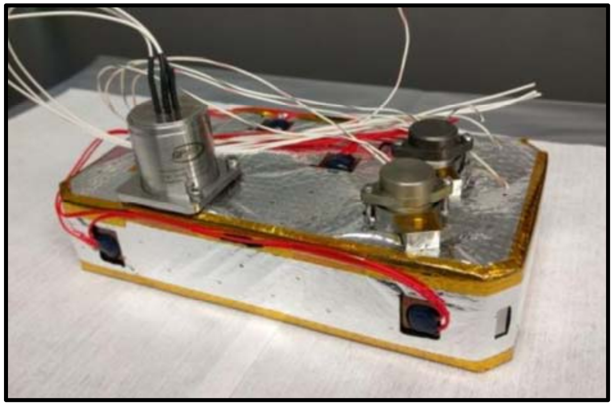
Aerojet
MPS-135

Propellant Tanks

- **Conformal tank demonstrated in lab for BIT-3 RF Ion system**
  - Iodine (propellant) can be stored as a solid.
  - Tank is heated to sublimate iodine vapor
  - Tank is materially compatible with iodine.



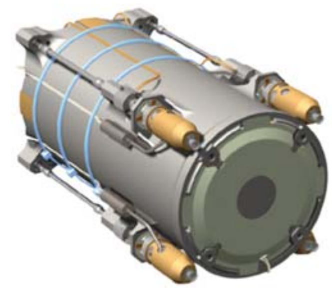
Busek
BIT-3 RF Ion
Iodine EP Sys.



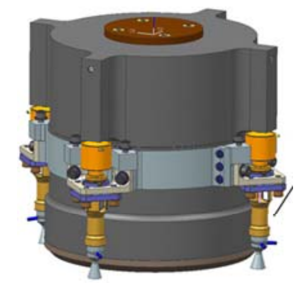
Busek
BIT-3 Iodine
Conformal Tank

Propellant Tanks

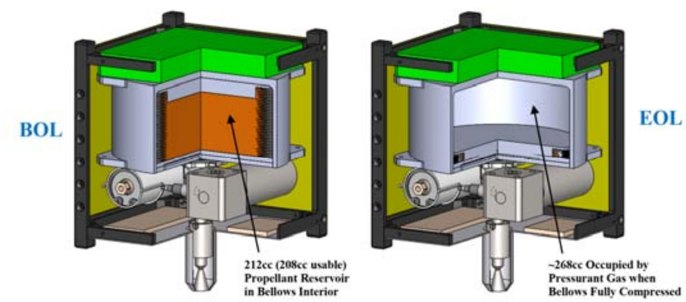
- **Cylindrical tanks with pistons or bellows are another option in early development:**
  - Piston
    - Aerojet offers this type for < 6U S/C.
    - To maintain packaging advantages and optimal thruster performance use with some type of post-launch pressurization system (PLPS).
    - Balance internal surface finish and piston length needed to prevent cocking.
    - Reduced available liquid volume depending on piston volume, as compared to a diaphragm tank.
    - Requires higher than standard MEOP to overcome piston friction. This pressure differential can be found via analysis and test.
    - Can result in higher design costs as compared to diaphragm tanks.
  - Bellows
    - Busek used this type on their proposed Advanced Monoprop Application for CubeSats (AMAC) system.
    - To maintain packaging advantages and optimal thruster performance use with some type of post-launch pressurization system (PLPS).
    - Provides steady pressure.
    - Reduced cocking issue.
    - Completely sealed
    - Increased mass and complexity as compared to diaphragm or conformal tanks.
    - Reduced volume as compared to diaphragm, PMD, or conformal tanks



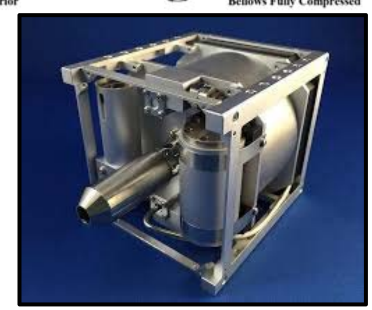
Aerojet
MPS-130-2U



Aerojet
MPS-130-1U

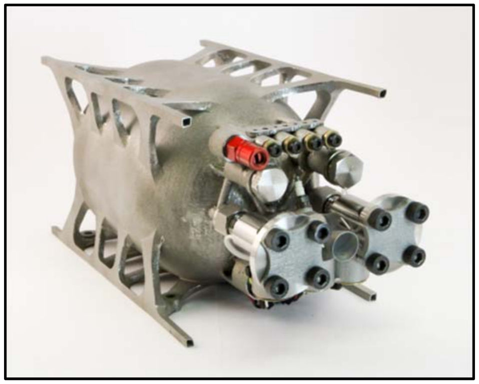


Busek
AMAC



Propellant Tanks

- **Standard dome cylinder and spherical tanks are high TRL options:**
  - Standard propellant expulsion devices (e.g., diaphragm and PMD) made by various vendors
  - Some repurposed from military use
- **Even though used in many electric SmallSat propulsion systems, starting to see dome cylinder tanks in integrated chemical SmallSat propulsion systems.**
- **These tanks limit system capability as compared to conformal tanks**
  - Volumetrically inefficient
  - Reduced propellant load



Hyperion
Green Bi-Prop

Bradford
Green System for SkySat

Flow Control Components

- **Most small valves that can be used in small satellites were developed for EP systems or repurposed from missile systems**
  - This is good for EP systems used on ESPA class spacecraft.
  - For chemical systems:
    - Need to consider propellant compatibility of soft goods (i.e., seals) and metals.
    - TRL for use in chemical system would drop to 5 to account for any redesign and requalification needed.

Electronics

- **Components for chemical and electric propulsion have seen improvement in this area over the years.**
- **Things to consider:**
  - Radiation Tolerant:
    - Total Ionizing Dose (TID): 100 kRad
    - Single Event Effects (SEE): 37 MeV
  - Class “S” electronics
  - Operation at 12 Vdc bus voltage
- **Rad Tol or Class “S” parts increases cost of component.**

Thrusters

- **Chemical Thruster Development Challenges**
  - – Handling thermal loads caused by reactions used to produce thrust. Mismanaged heat leads subcomponent failure.
  - – Complete reaction (catalytic or hypergolic) reduces plume contaminates
- **Electric Thruster Development Challenges**
  - – Grid erosion
    - Standard concern with all EP systems
  - – Propellant compatibility
    - Iodine is optimal due to volume efficiency. But is highly corrosive.

Final Words

- **Many issues and challenges to solve**
- **Good work is being done by commercial and academic organizations to solve these challenges.**
- **Goal is to facilitate development of optimal chemical and electric SmallSat Propulsion systems.**