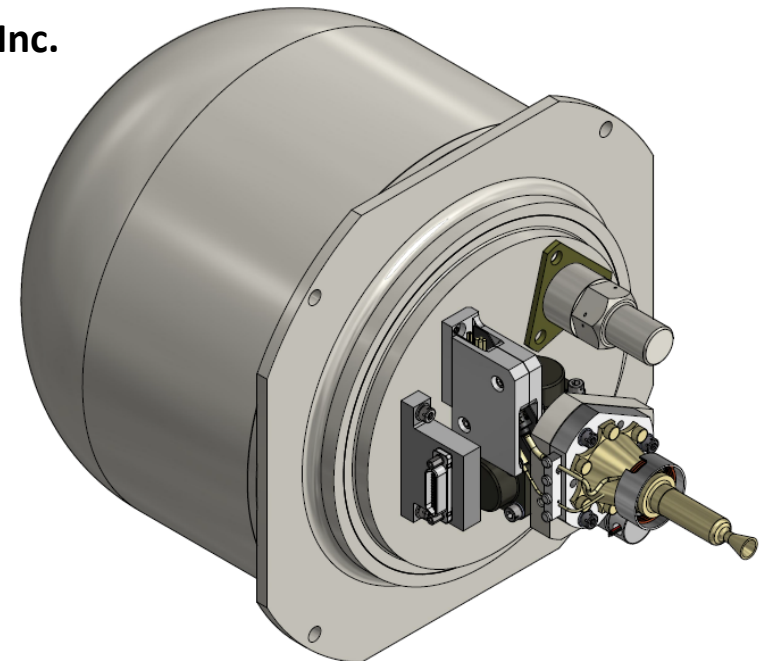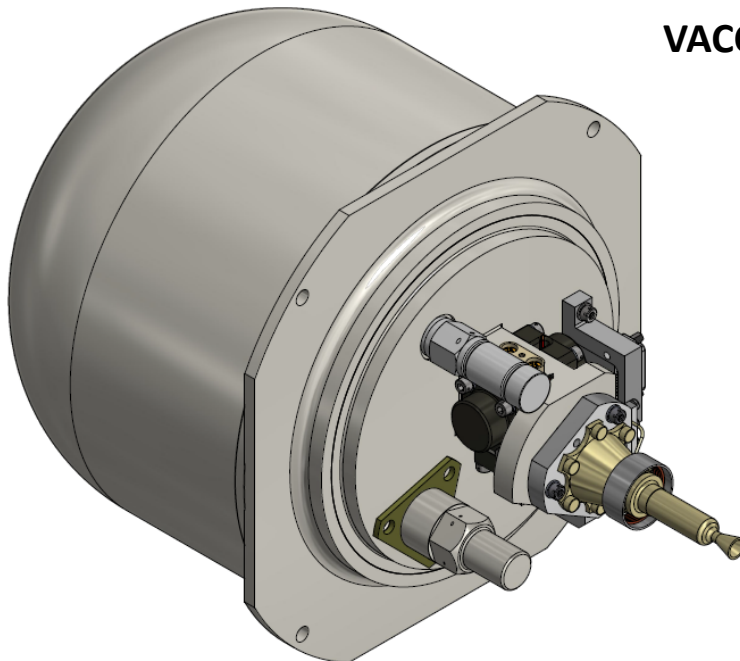# A High-Performance Delta-V Thrust Module for CubeSats and Small Satellites

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Chris Day, Lead Electrical Engineer

VACCO Industries, Inc.

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Thrust Modules are Simple

- Blow-down design eliminates the need for pressure control:
  - Maximum Design Pressure (MDP): 400 psia
  - 28V input
  - Standardized Manifold Assembly contains all the functional components
  - All-welded titanium construction
  - Features three normally-closed propellant valves directly operated by the user
- Single 1N Axial thruster:
  - Provides delta-V only
  - Flight proven: Eighty-two LMP-103S thrusters flown on twenty-one spacecraft
  - Initial thrust: 1N, final thrust: 150mN
  - Impulse Limit: >50,000N-sec
  - Minimum Impulse Bit: 50 mN-sec at 1N thrust
  - Primary and redundant eight-watt heaters included
  - Redundant thermocouples sense temperature
  - 30-minute pre-heat required before firing
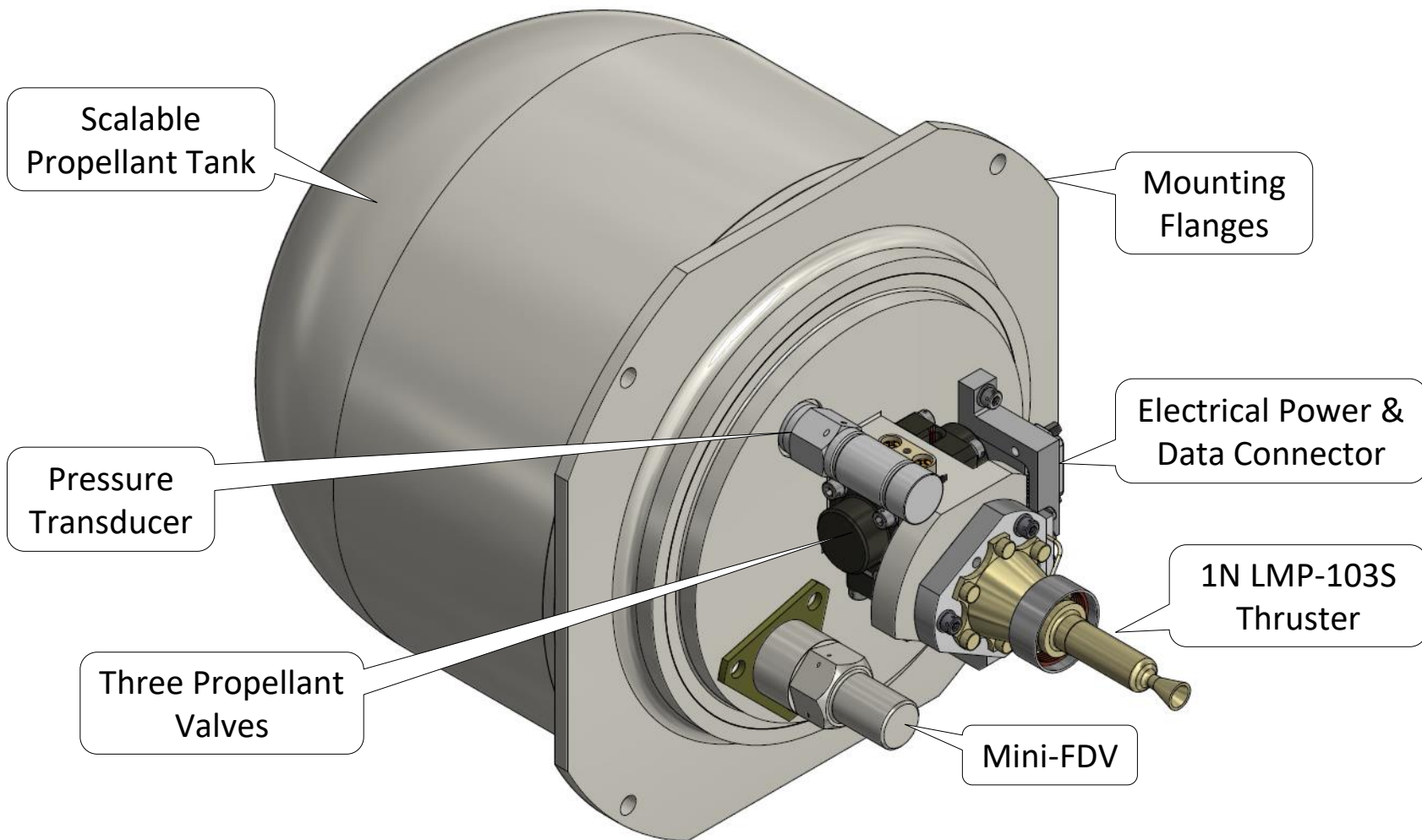- Flight-proven VACCO three seal Mini Fill & Drain valve

Thrust Modules are Simple

- Flight-proven Pressure Transducer provides fuel state
  - Output 0.1V to 4.9V proportional to pressure
  - Total error band 1.5% of full scale
- Range Safety Features:
  - Green, non-toxic LMP-103S Monopropellant:
    - Can be shipped via commercial aircraft (UN / US 1.4S)
    - Three Seals Against Leakage
  - Benign, flight proven GHe Pressurant
- Optional analog electronics assembly:
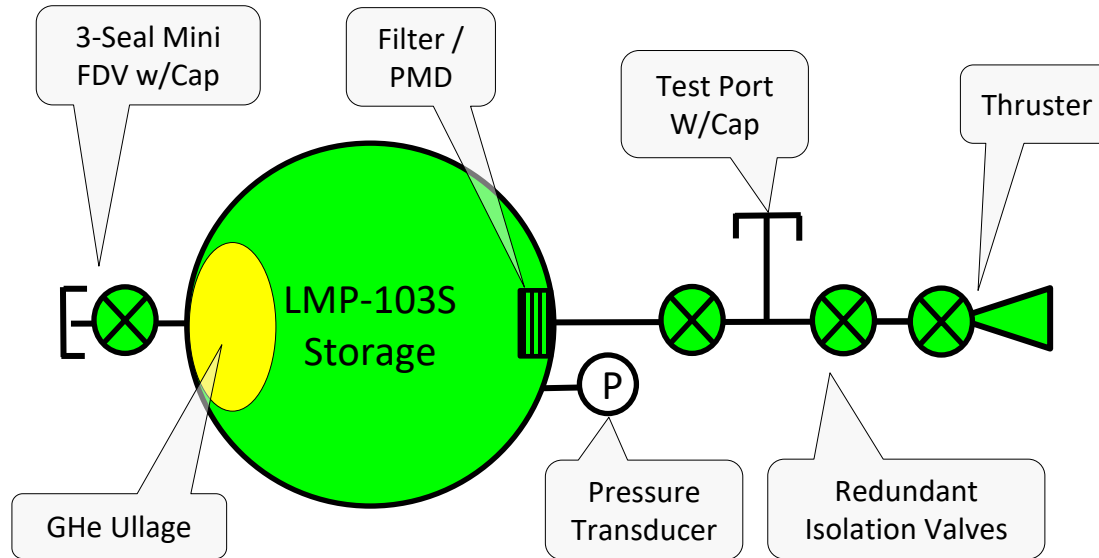 - Bolt-on subassembly

1N Thrust Module

Scalable Propellant Tank

Mounting Flanges

Electrical Power & Data Connector

Pressure Transducer

1N LMP-103S Thruster

Three Propellant Valves

Mini-FDV

1N Thruster and Manifold Assembly are Standardized, Tank is Sized as Required

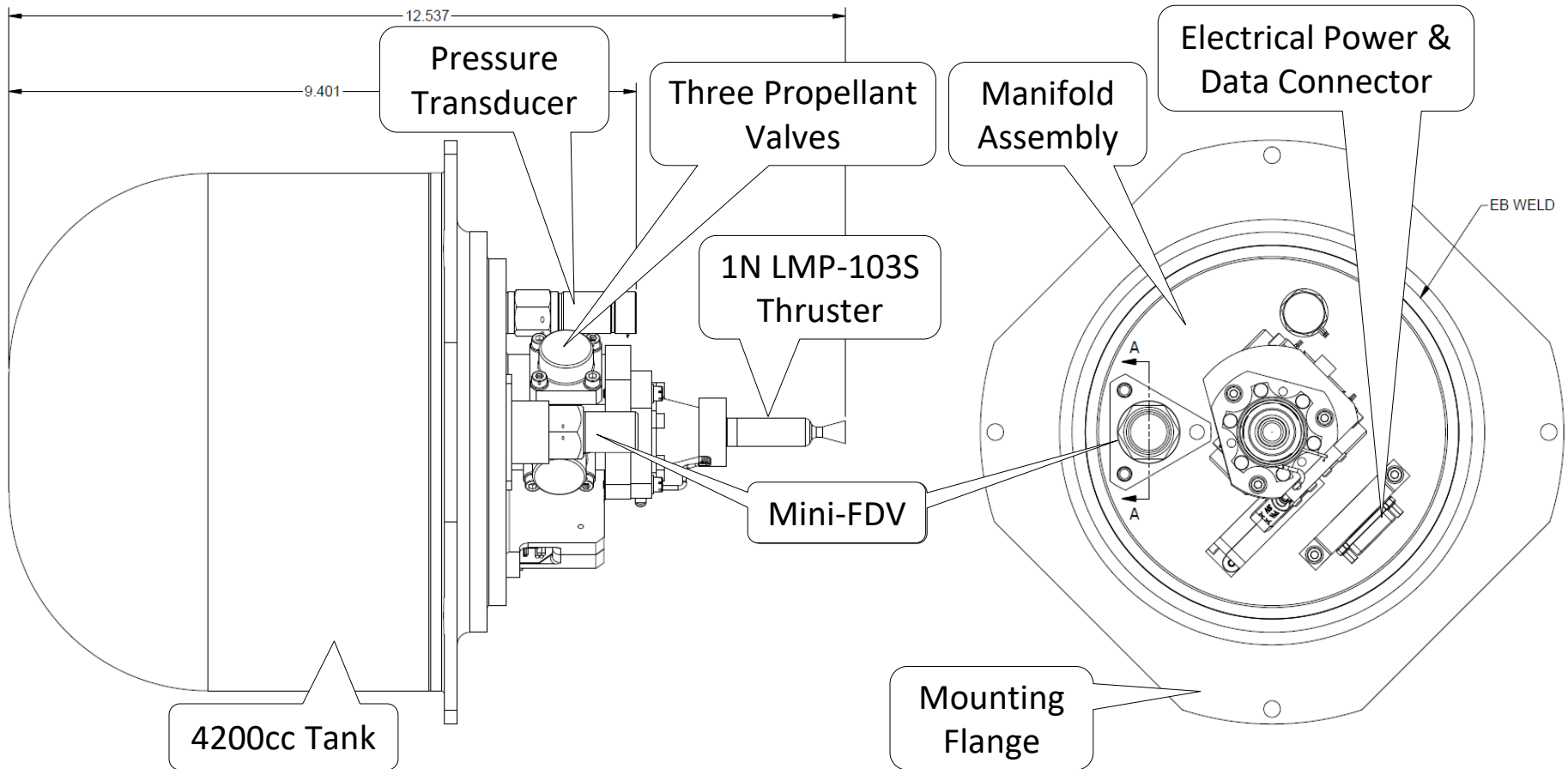# Thrust Module "Blow Down" Schematic & Performance

	Tank Vol. (cc)	Prop Vol. (cc)	Usable ADN Mass (g)	Avg. Isp (sec)	Total Impulse (N-Sec)	MiPS Dry Mass (Kg)	Initial Satellite Mass (Kg)	Delta-V (M/s)	Ghe Vol. (cc)	Initial Pressure (psia)
1N LMP Thruster	2000	1560	1774	218	3785	3.2	100	38	440	320
1N LMP Thruster	3300	2575	2973	218	6341	3.5	100	64	725	320
1N LMP Thruster	4200	3300	3872	218	8259	4.0	100	84	900	320

1Nx4200cc Thrust Module: Envelope

Pressure Transducer

Three Propellant Valves

1N LMP-103S Thruster

Manifold Assembly

Electrical Power & Data Connector

EB WELD

Mini-FDV

4200cc Tank

Mounting Flange

12.537

9.401

Key Component: 1N LMP-103S Thrusters

LMP-103S Monopropellant:

- ADN (Ammonium DiNitrimide) Based Propellant
- Non-Toxic, Non-Carcinogenic
- UN / US 1.4S (Commercial Aircraft Classification)
- Safe Fueling without SCAPE suits
- >6% Higher Specific Impulse vs. Hydrazine
- 24% Higher Propellant Density than Hydrazine
- Can be Stored for >20 Years
- Insensitive to Space Radiation
- Insensitive to Air and Humidity
- Broad Storage Temperature Range (-7° to +120°C)

1N High Performance Green Propellant Thrusters:

- Eighty-Two Thrusters Flown in Space
- Flight Proven for Ten Years
- Qualified for 60,000 Pulses
- Qualified for 1.5-hour Continuous Firing
- Broad Operating Temperature Range (-5°C to 60°C)
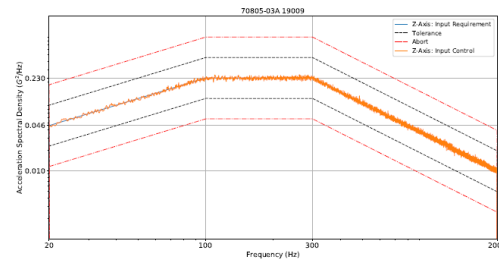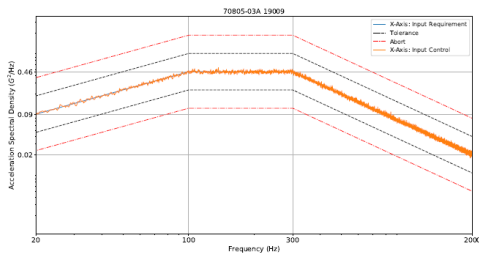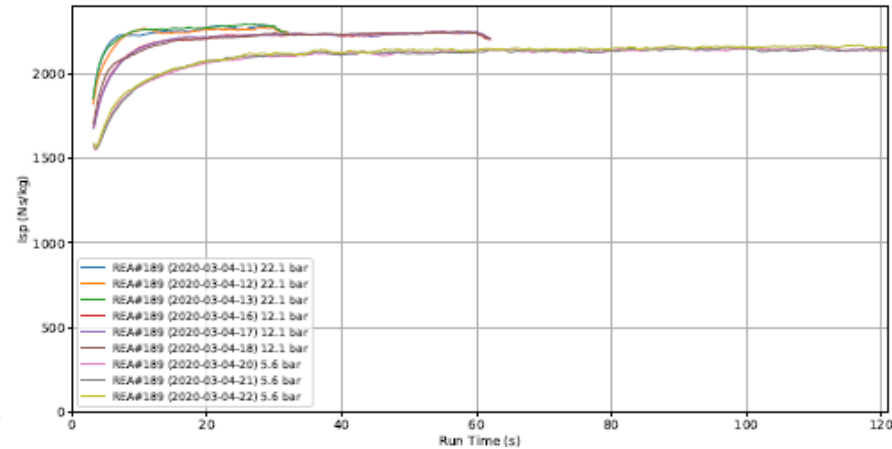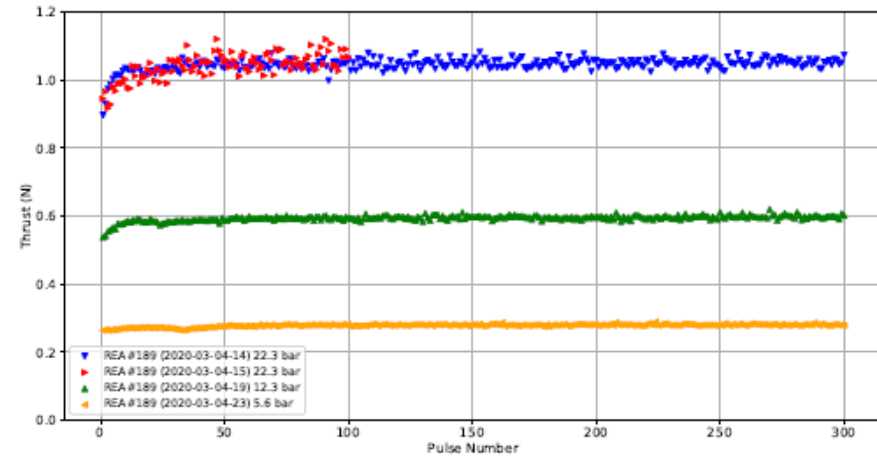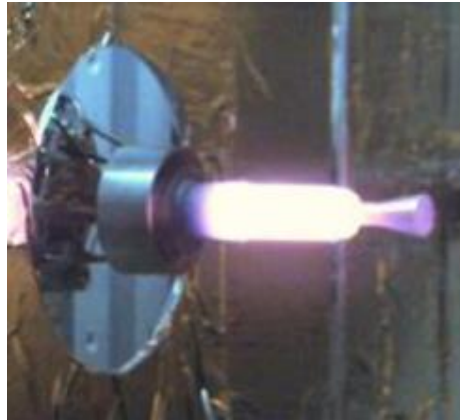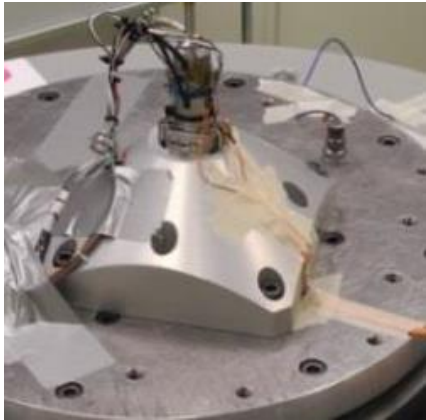- Non-corrosive Exhaust Gases (H_2O, N_2, H_2, CO, CO_2)
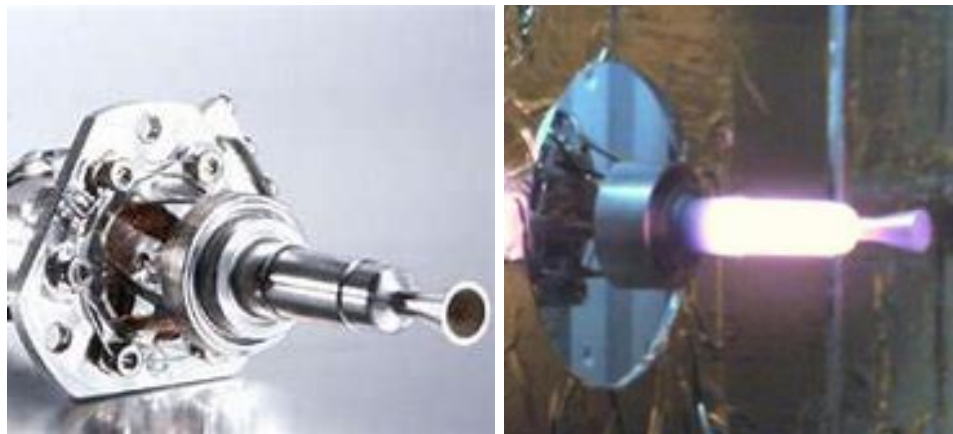
82 Thruster Flown with Hundreds of Units in Production or Waiting for Launch

1N Thrusters in Continuous Production

100% of 1N Thrusters are Hot-Fire Tested During ATP

Optional Analog Electronics Assembly (AEA)

- Provides independent control of valve driver
- Valves are controlled by digital logic signals
- Valve voltage stepdown is accomplished in the AEA
- Provides a single unified connector for electrical interface
- Simple & Robust system does not require a controller, processor or software
- Current will automatically drop to holding current after 50mS:
  - Reduces power consumption
  - Reduces valve self heating
- Back EMF is automatically blocked

VACCO Flight Controller

Conclusions

- VACCO has been designing and building small satellite propulsion systems since 2003:
  - Forty (40) propulsion systems of sixteen (16) different designs built to-date
  - Experience gained and lessons learned have improved the performance and reliability
- VACCO has designed a simple, high-performance green monopropellant propulsion module designed for shorter lead times and lower cost:
  - Self-contained propulsion assemblies that provide delta-V thrust
  - Green thruster, feed system and propellant storage in a bolt-on, plug-in assembly
  - Host CubeSat controller directly controls of the Thrust Module
  - System provides three seals against overboard loss of propellant
  - Propellant tank geometry can be customized for a total impulse >50,000N-sec
  - A flight-qualified pressure transducer accurately measures remaining propellant
  - A flight-qualified Fill & Drain Valve provides a propellant and Pressurant fluid interface
  - An optional analog electronics assembly provides valve driver circuits that suppress back-EMF and regulate voltage to minimize power consumption
- The initial Thrust Modules use flight-proven 1N LMP-103S green thrusters
- Thrust Module is compatible with other green propellants and larger thrust levels