A Propulsion System Tailored to Cubesat Applications

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Overview

- Micro Aerospace Solutions (MAS) has be developing a series of microthruster systems for nano and pico sat applications
- We have now developed a propulsion module suited for cubesat applications
- Propellants are hydrogen peroxide and hydrazine as well as possibly ADN and cold gas
- Thrust Levels 0.05N to 0.1N

Cubesat Propulsion Options

- The cubesat standard defines a cubesat as a 10 cm cube with a mass of no more than 1 kg
- Most cubesats that have flown have had limited or no propulsive capability
- Mass and power are severely limited

Design Objectives

- Thrust level 0.050N to 0.1N
- A positive expulsion propellant tank capable of operation in microgravity
- Microthruster operation with fast-acting solenoid valves
- Power requirements are 0.5 watts and the voltage requirement is 12 volts.

Design Objectives (cont)

- Pulse-mode operation
- Minimum impulse bits ~1×10^{-4} N-s
- Lifetime of at least 250,000 pulses (90 day lifetime with one pulse every 30 seconds)
- Limiting factor is small tank size available

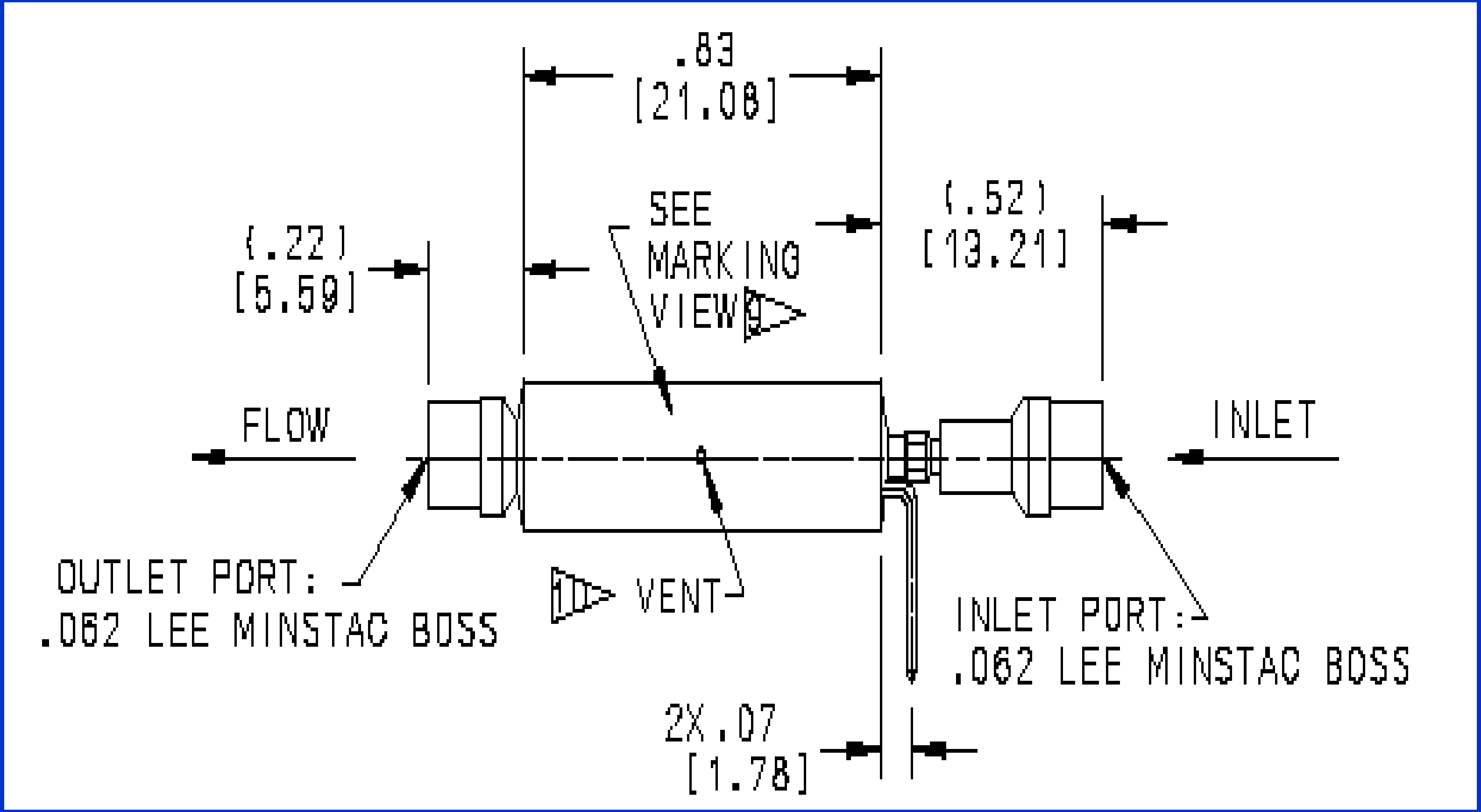
Thruster Design

- Small-scale microthrusters have issues with viscous boundary layer losses
- Divergence angle needs to be wider than conventional nozzles
- Chamber needs to withstand hydrogen peroxide decomposition temperatures of as much as 750 degrees C
- Hydrogen peroxide is preferred propellant for university cubesats

Valves

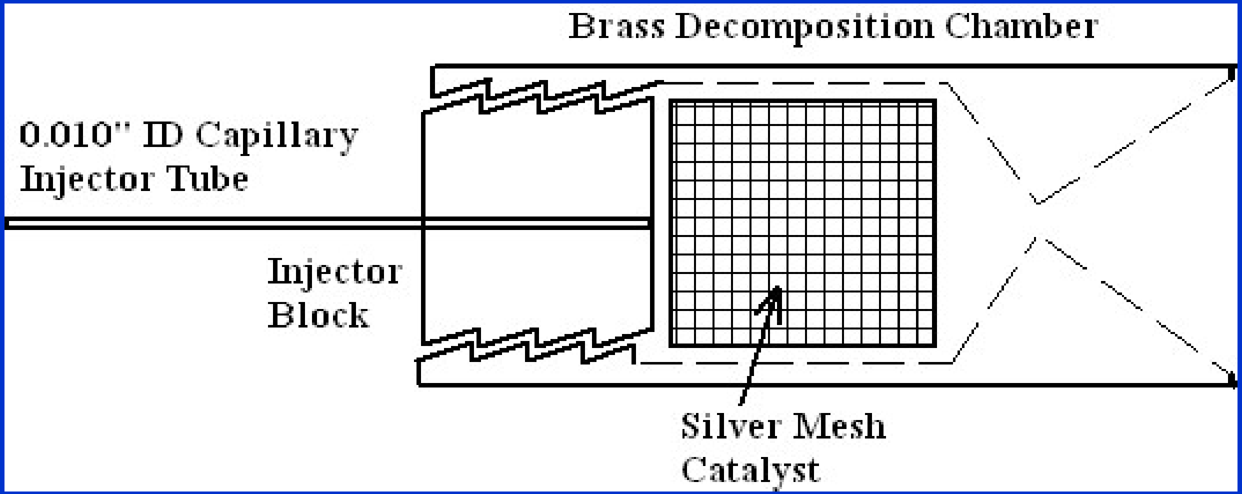
- Microsolenoid valves from Lee company
- Compatible with hydrogen peroxide
- Power 0.5 watts, 12 volts
- Pulses as short as 1 msec (300 microsecond pulses have been demonstrated)

Valve


.83
[21.08]
(.22)
[5.59]
SEE
MARKING
VIEW 9
(.52)
[13.21]
FLOW
INLET
OUTLET PORT:
.062 LEE MINSTAC BOSS
10 VENT
INLET PORT:
.062 LEE MINSTAC BOSS
2X .07
[1.78]

Microthruster

- Microthrusters machined from brass
- Catalyst is silver mesh
- Capillary tube injector

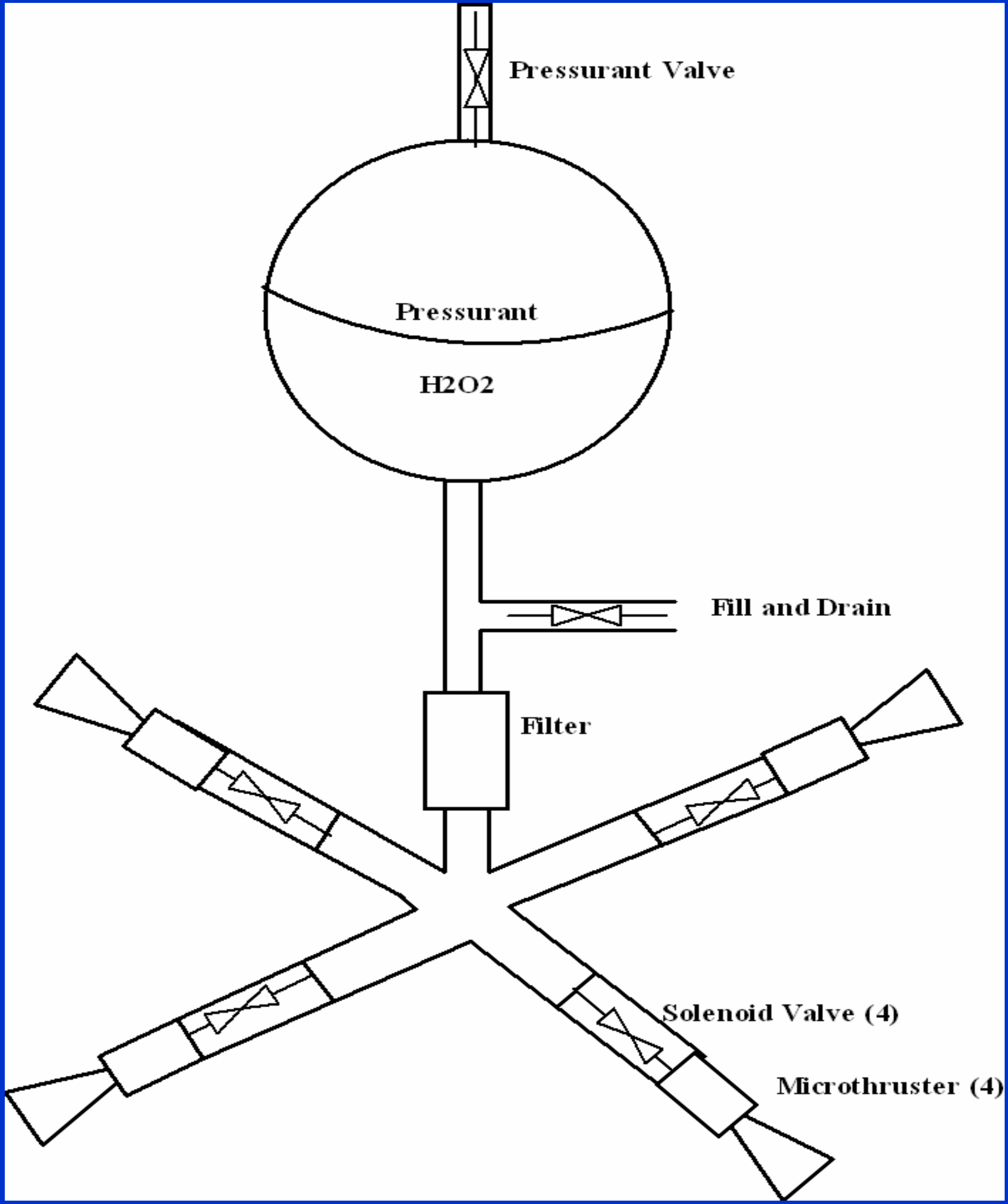


Catalyst

- Extensive testing has been done with high concentration hydrogen peroxide (90% propulsion grade from FMC)
- Exhibits excellent decomposition in thrusters down to 0.050N thrust (clear exhaust)
- 1 million pulses with 0.050N HTP thruster and Lee microdispense valve

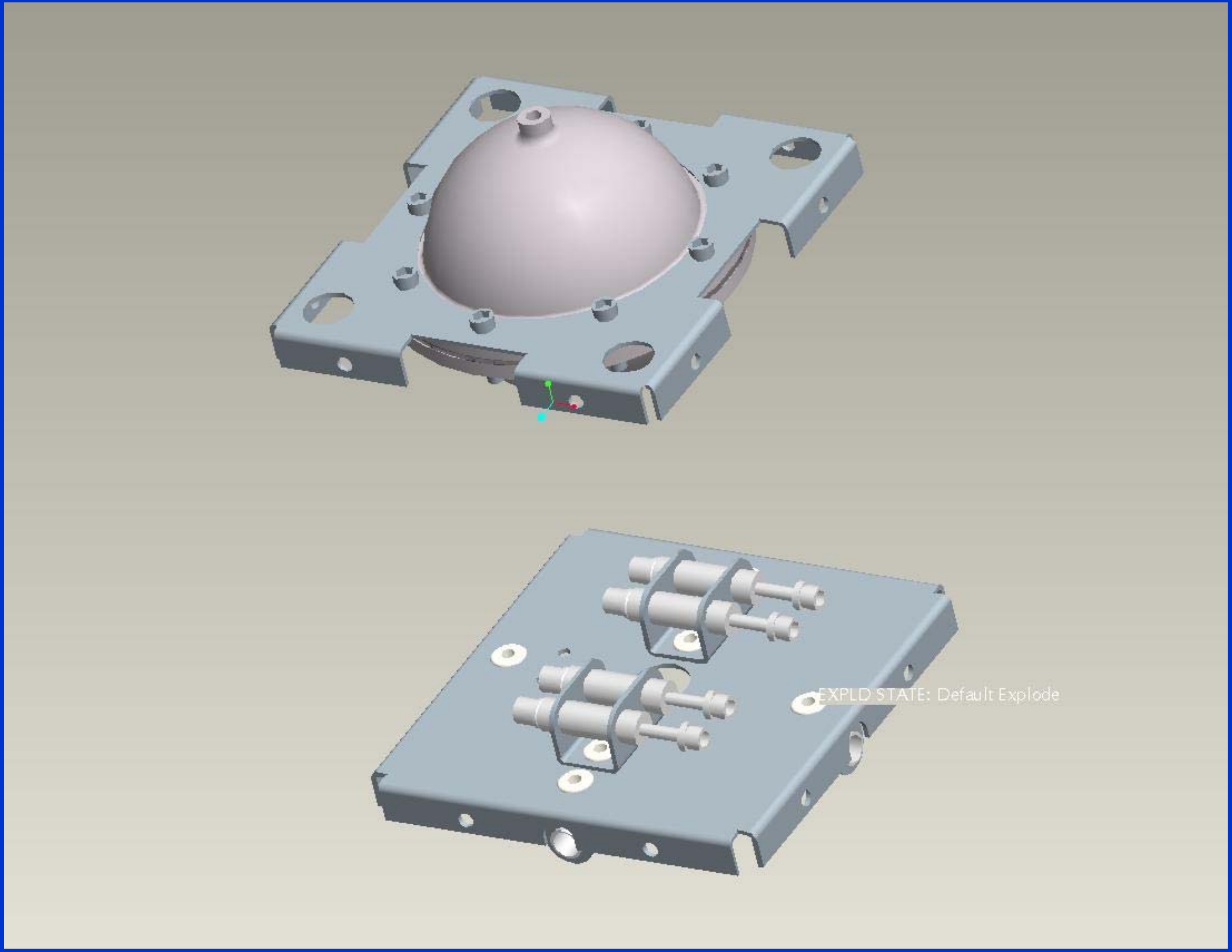
Prototype Module

- Design prototype built in conjunction with Florida Institute of Technology's FUNSAT development program
- A CAD model of a 4 thruster system was developed
- Incorporated a 2" positive expulsion tank
- From drawings an actual module was built and tested

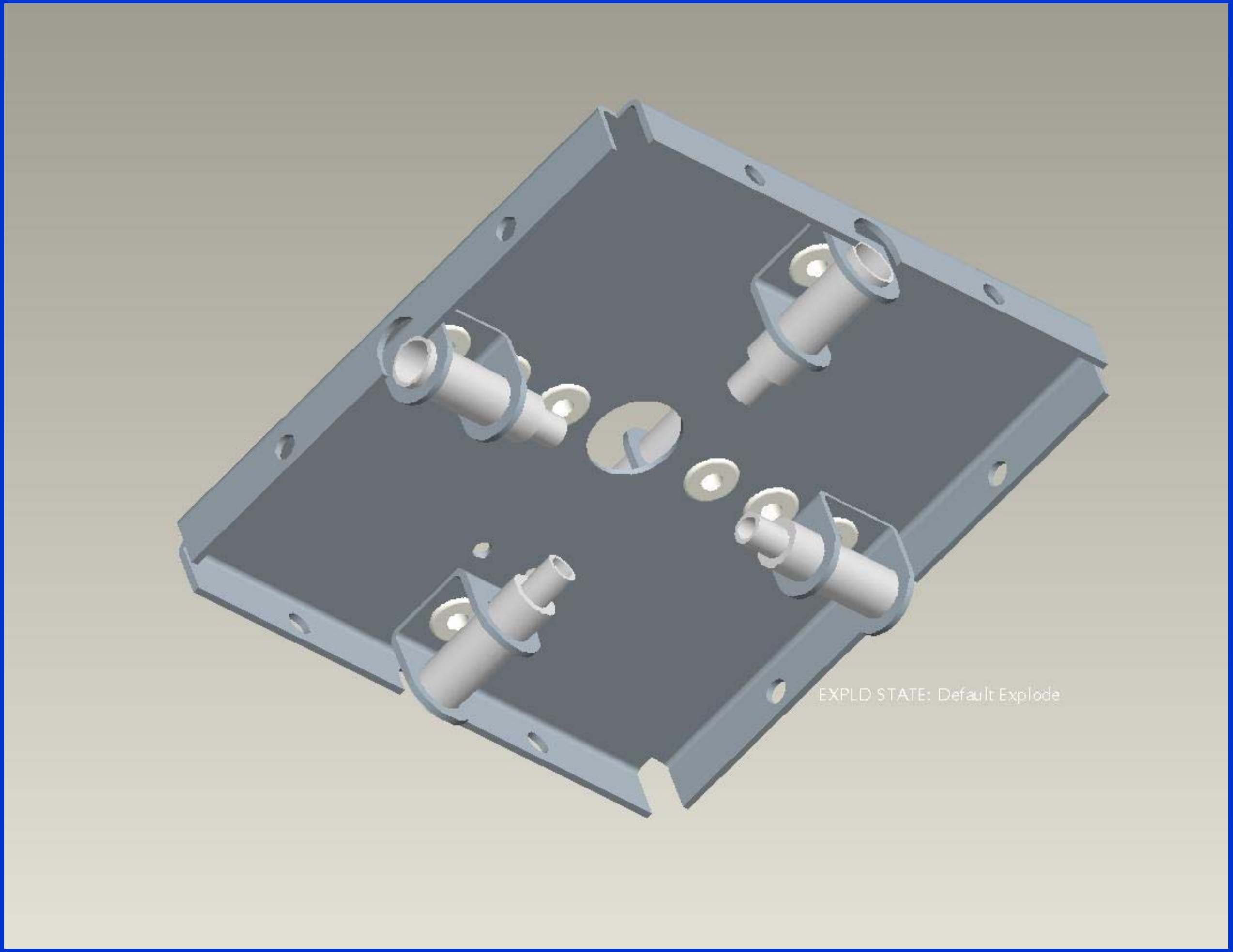


Pressurant Valve
Pressurant
H2O2
Fill and Drain
Filter
Solenoid Valve (4)
Microthruster (4)

3-D model



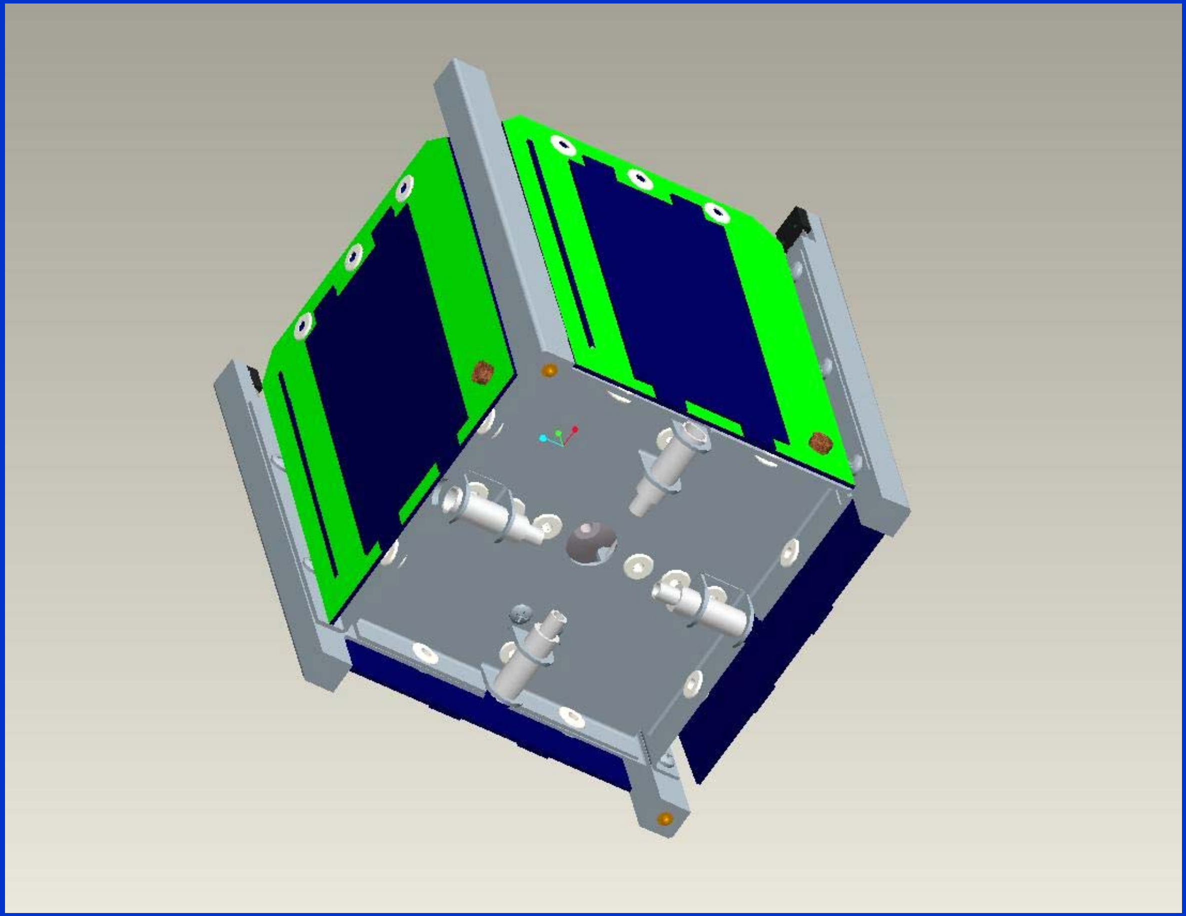
3-D model (cont)



Electronics Module

- Micro Aerospace Solutions developed an electronics control module
- The board capable of controlling 4 microthrusters measures about 1.5” by 1.3”
- Can interface with C&DH system by serial or USB interface

Cubesat with Propulsion Module



Mass Summary

Part	Material	Density (gm/cm^3)	Volume(cm^3)	Unit Mass (gms)	Qty:	Mass(gm)
Tank(2.54 cm radius)	Aluminum 6061-T6	2.685	7.79		1	20.92
Fuel	H2O2@90%	1.4	60.85		1	85.19
Thruster w/ valve	Aluminum 6061-T6	2.685		4.9	4	19.60
4-way Hypodermic tubing Conn	SS	7.85	0.15		1	1.18
Tubing ID .045 (10 ')	Teflon	60.62	0.07		4	16.97
					Total:	143.87

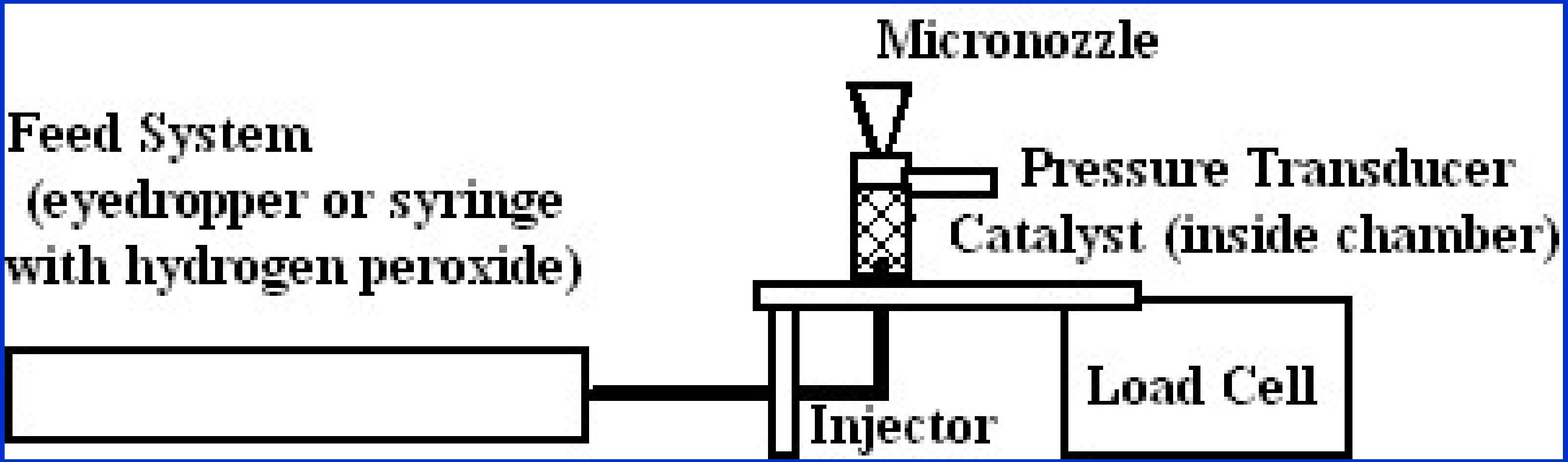
Propellant Alternatives

- We have demonstrated our microthrusters with hydrogen peroxide and hydrazine monoprops
- Also test fired tridyne (gas combination of O2, H2, N2)
- Studying the possibility of using Ammonium Dinitramide (ADN) in conjunction with Swedish Space Corporation
- ADN has higher performance and is safer than hydrazine making it an interesting cubesat propulsion alternative

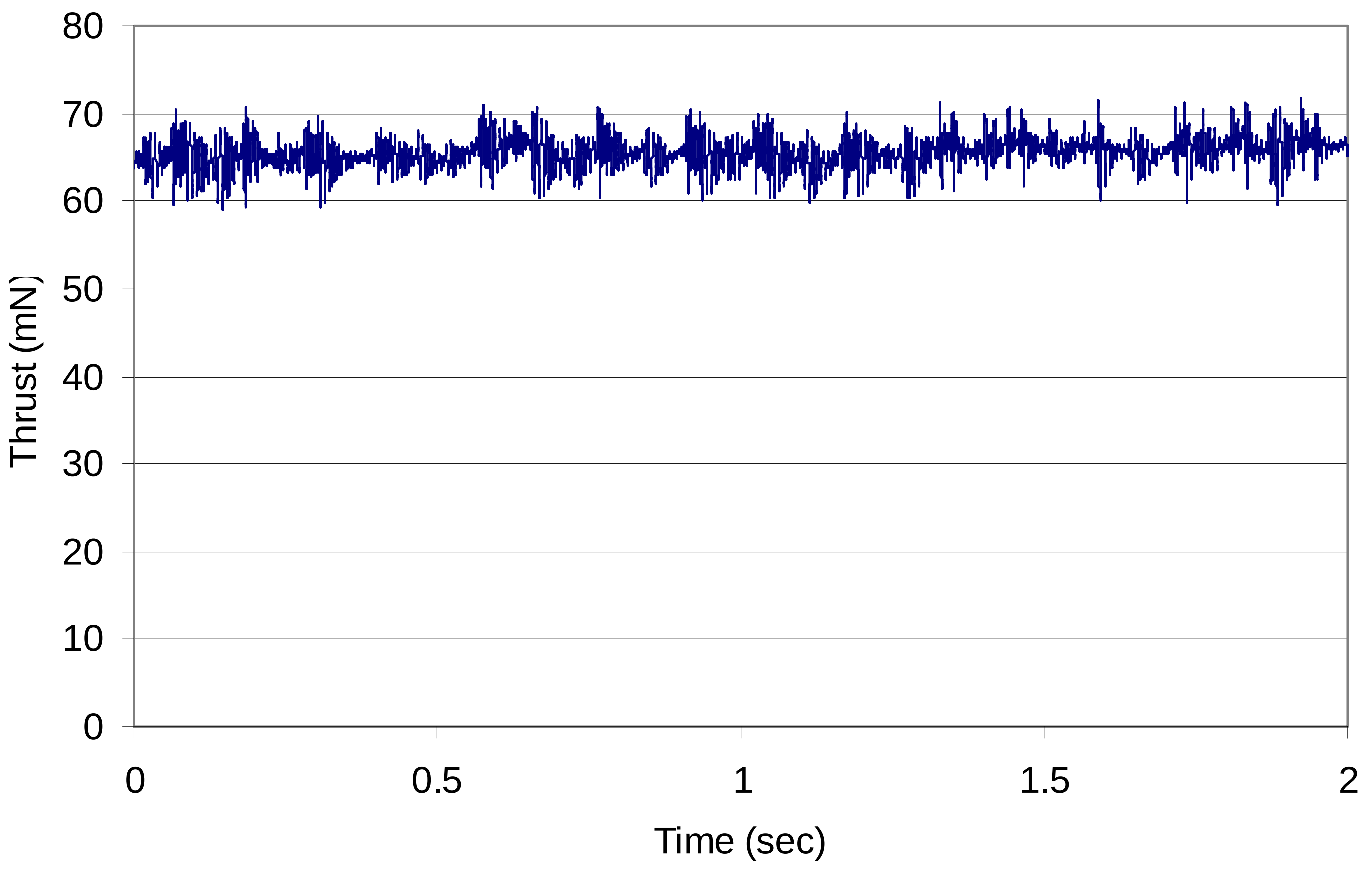
Microthruster Test Stand

- A simple test stand was developed
- Feed system is a syringe (could be a syringe pump)
- 25 gram load cell used for thrust measurements
- Accuracy about 1 mN
- For pulse mode, incorporated tank,valve and cantilever beam system

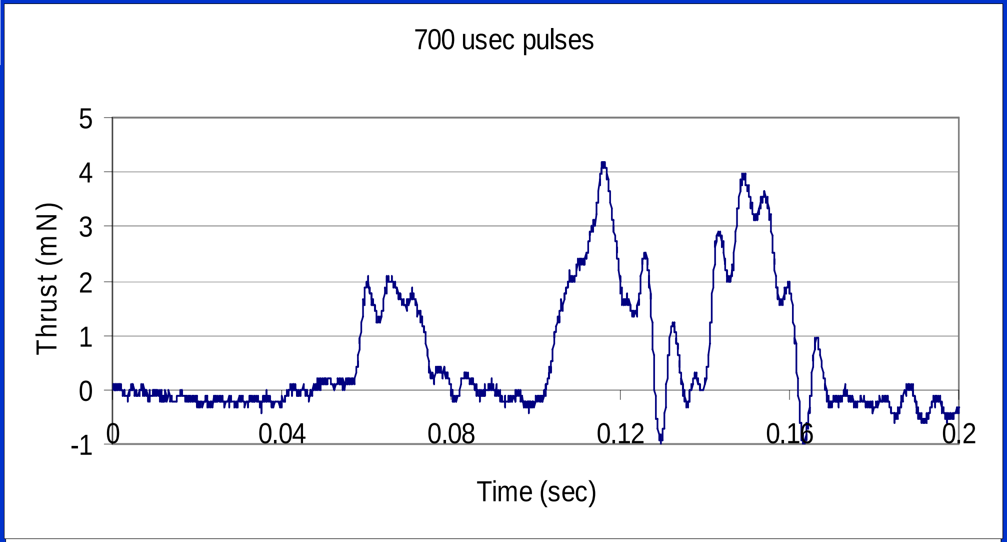
Microthruster Test Stand

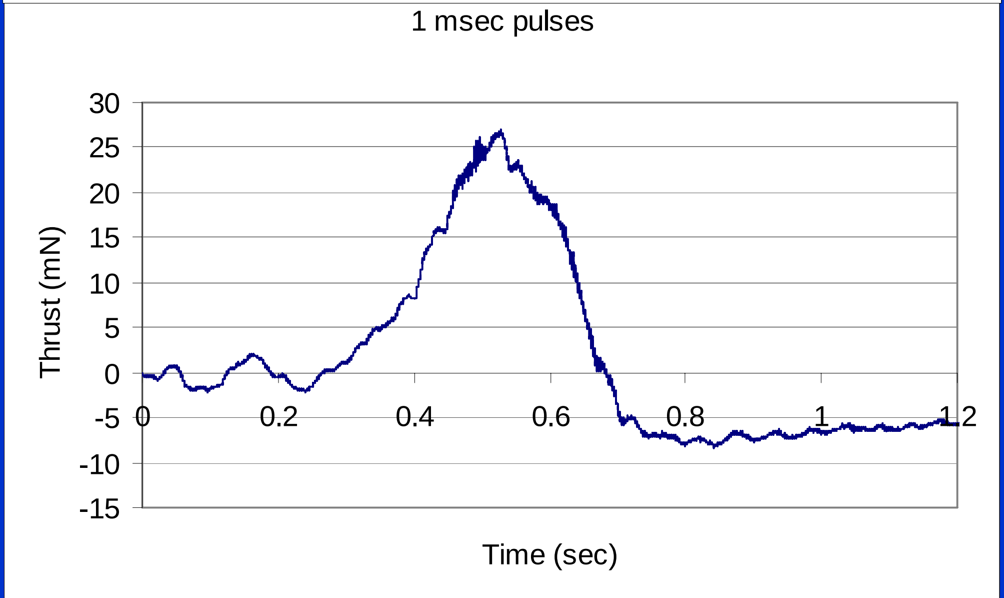


Steady State Thrust Measurements



Pulse Measurements

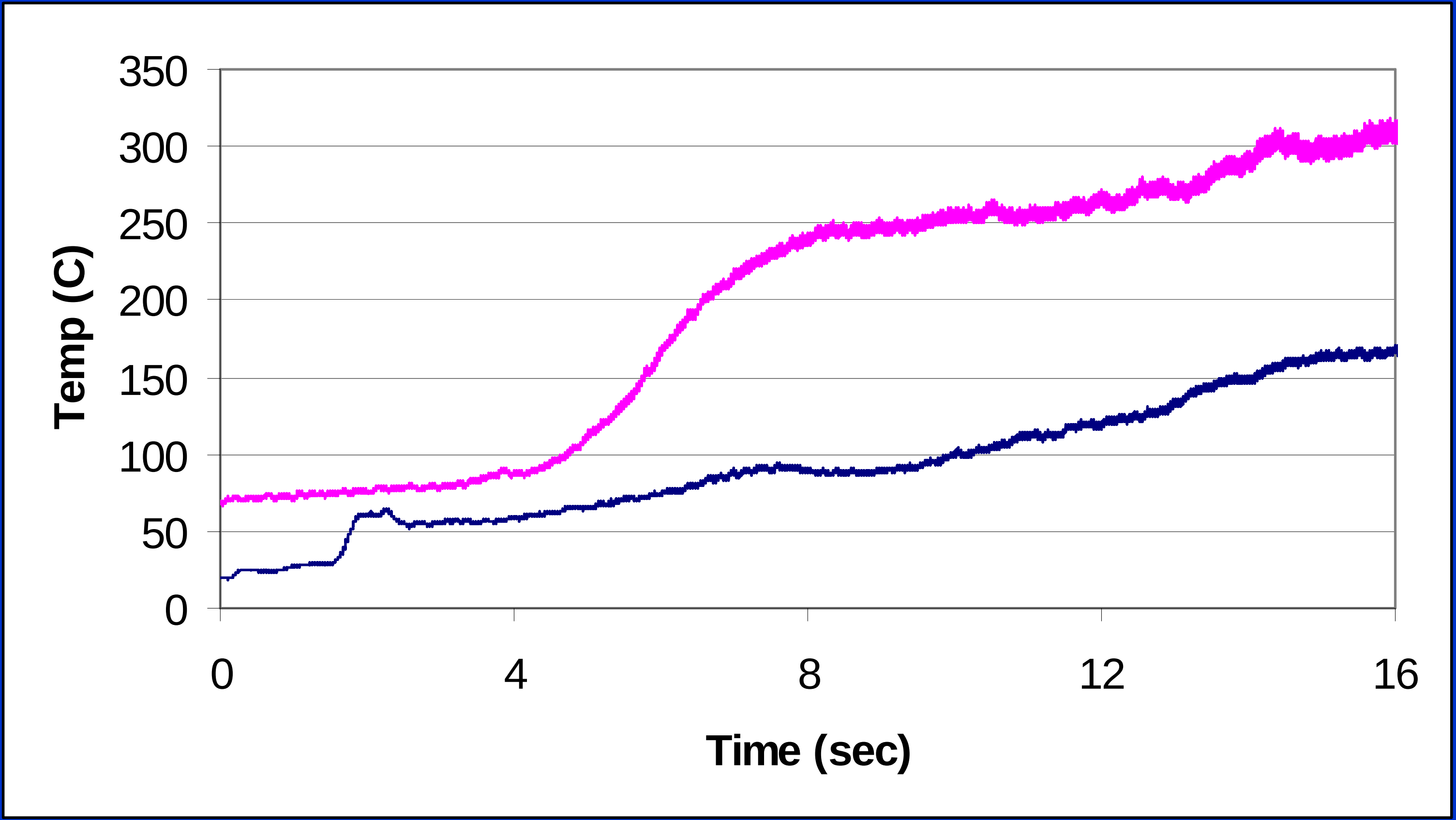




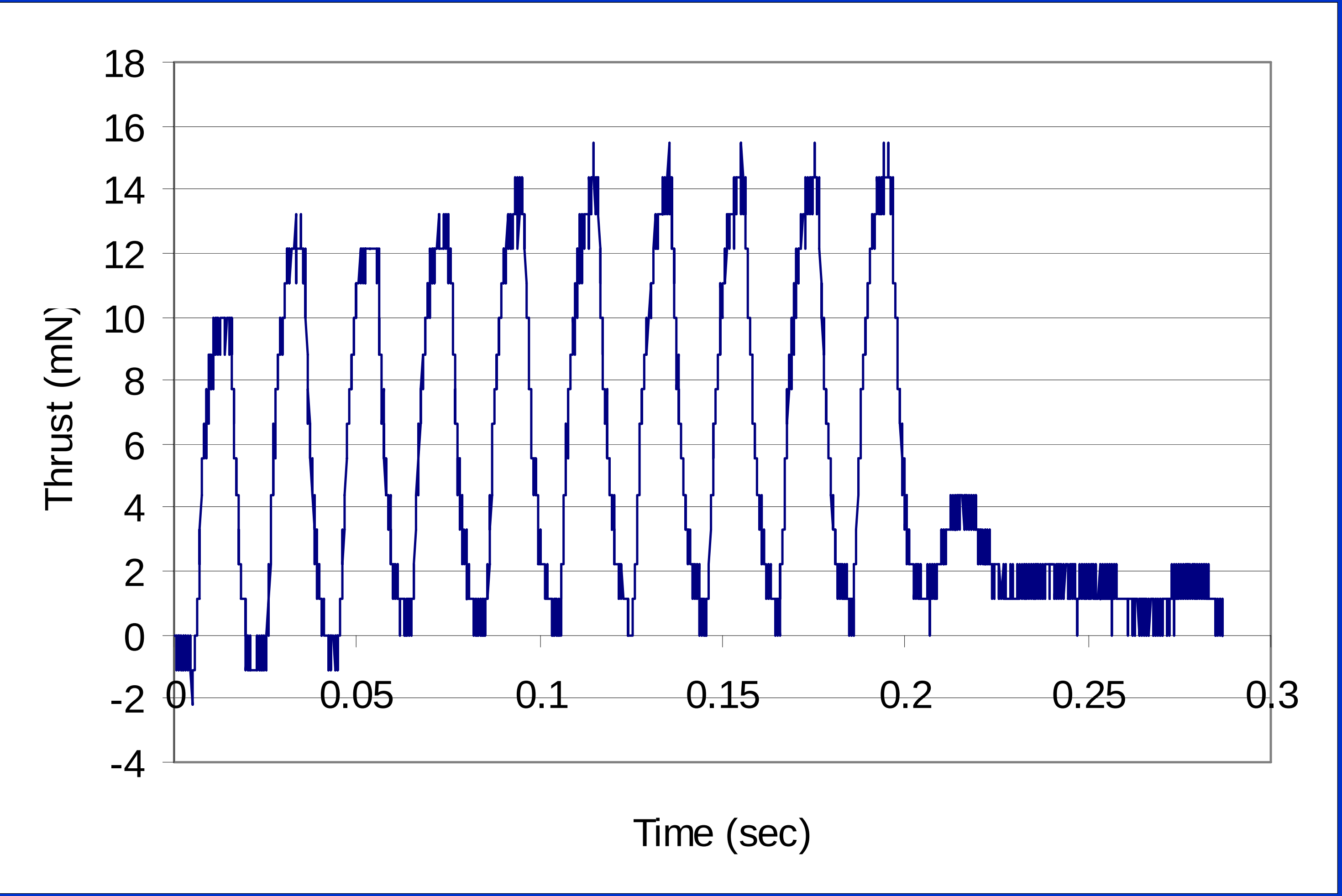
Pulse Thrust Measurements

- Measured thrust from pulses from 300 microseconds to 2 milliseconds
- Minimum impulse bit ~1.5×10^{-4} N-s
- Measured catalyst temperatures as well
- Also conducted pulse measurements with hydrazine and tridyne microthrusters

Temperature Measurements (20 C and 60 C initial)



Tridyne Pulse Measurements



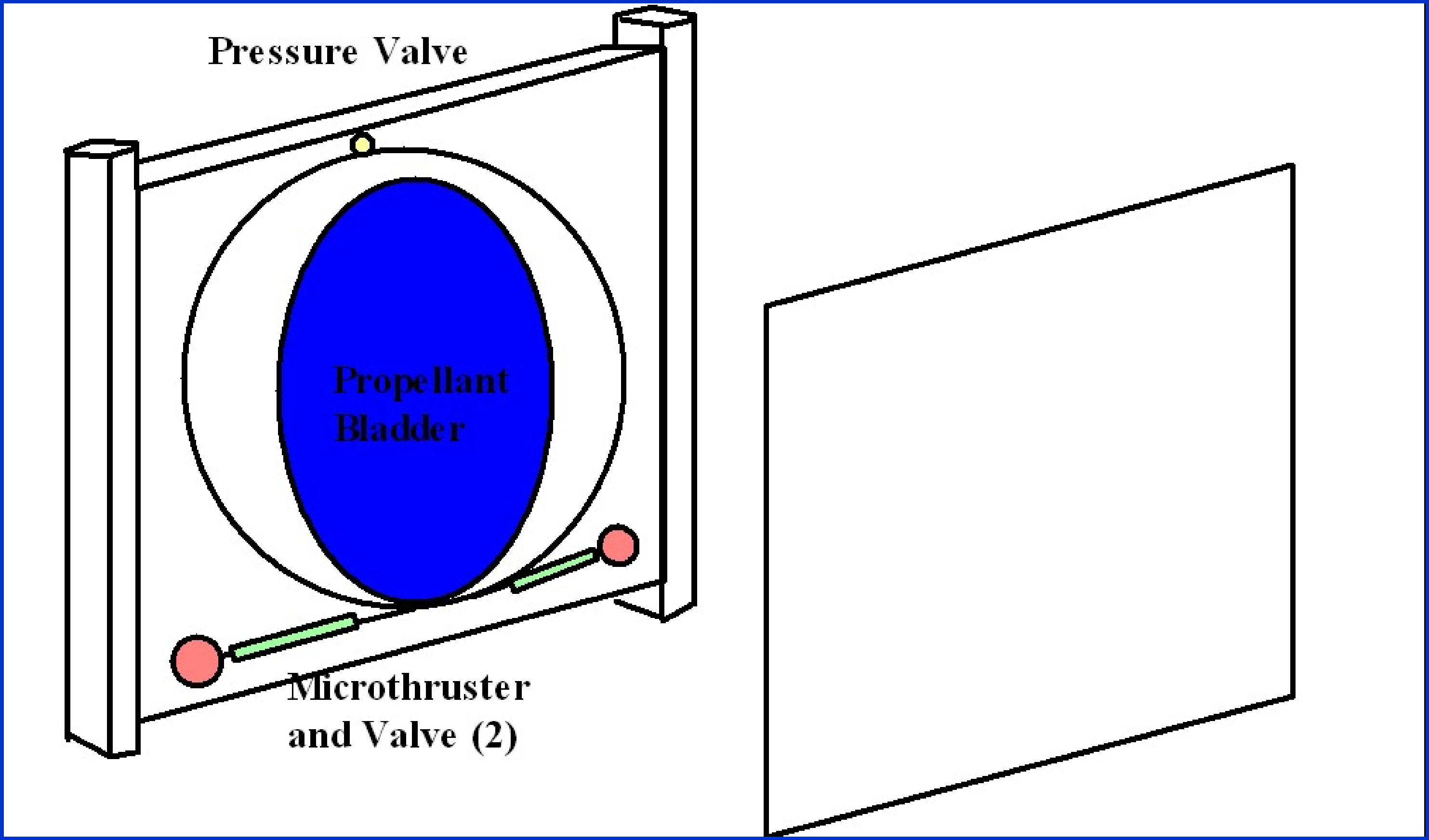
Multi-Functional Structures

- **Volume must be optimized and used to the maximum that is possible or at least practical in any nanosat.**
- **Spherical pressure vessels do not make the most practical use of space in a cubesat.**
- **Need to make maximum use of structural elements and make components and elements multi-use - Multi-Functional Structures .**

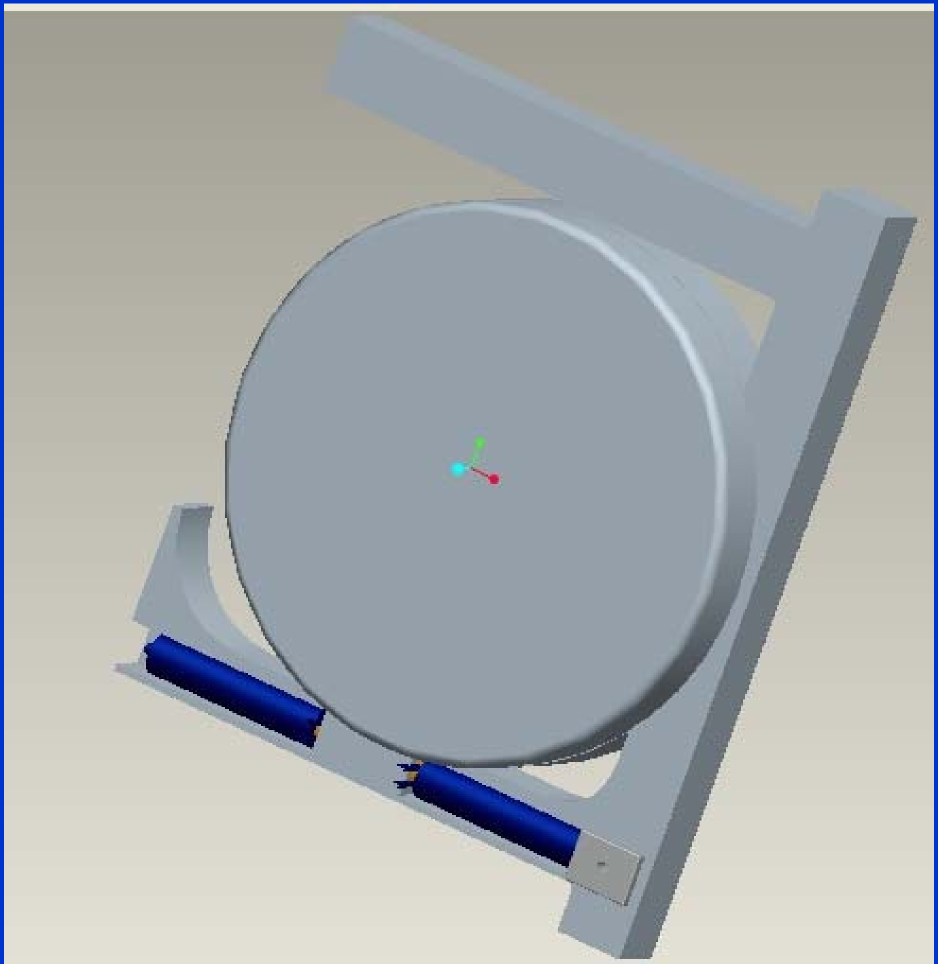
Advanced Tank Concept

- We looked at how a propulsion system could be integrated into the structure of a cubesat
- Structural wall could be made from aluminum with a circular pressurized area.
- A propellant bladder could then be placed inside this circular area.

Advanced Tank Concept



Integrated Tank Structure Model



Conclusion

- We have developed a propulsion module ready for cubesat use
- Can use a variety of propellants – hydrogen peroxide, hydrazine, tridyne, cold gas
- Built and tested system
- Measured thrust in <50 mN range, impulse bit ~1 x10^{-4} N-s