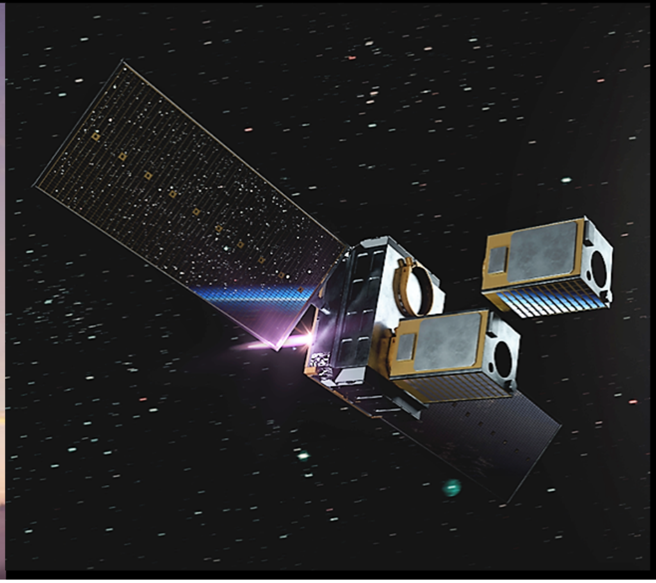
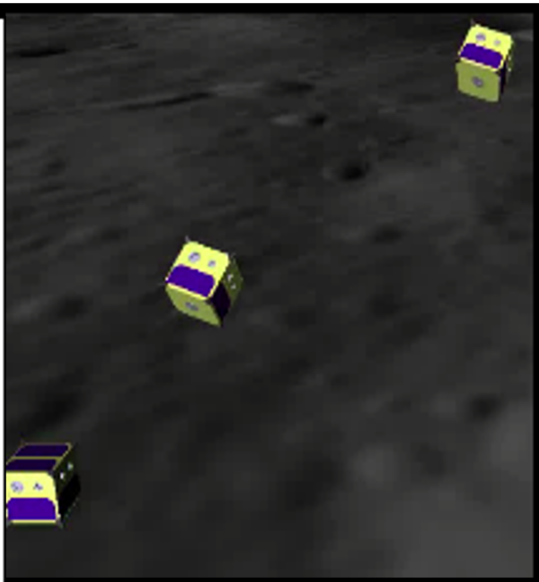
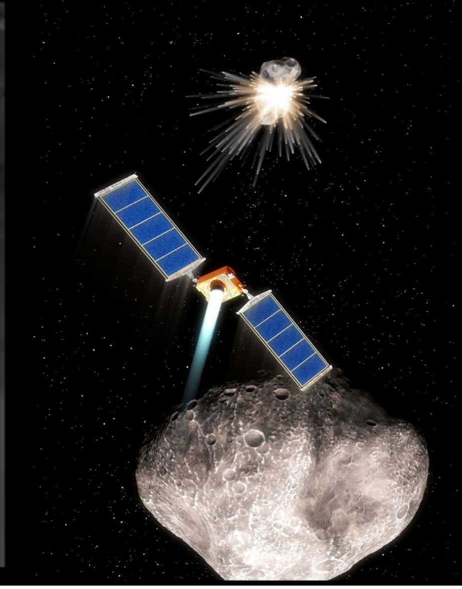
Partner

ASTEROIDS SpaceTREx

Design for a CubeSat Propulsion System Using Polymer Electrolyte Membrane Electrolyzers

Maanyaa Kapur, Avery Stockdale
Mentor: Dr. Greg Ogden
Department of Chemical & Environmental Engineering, University of Arizona

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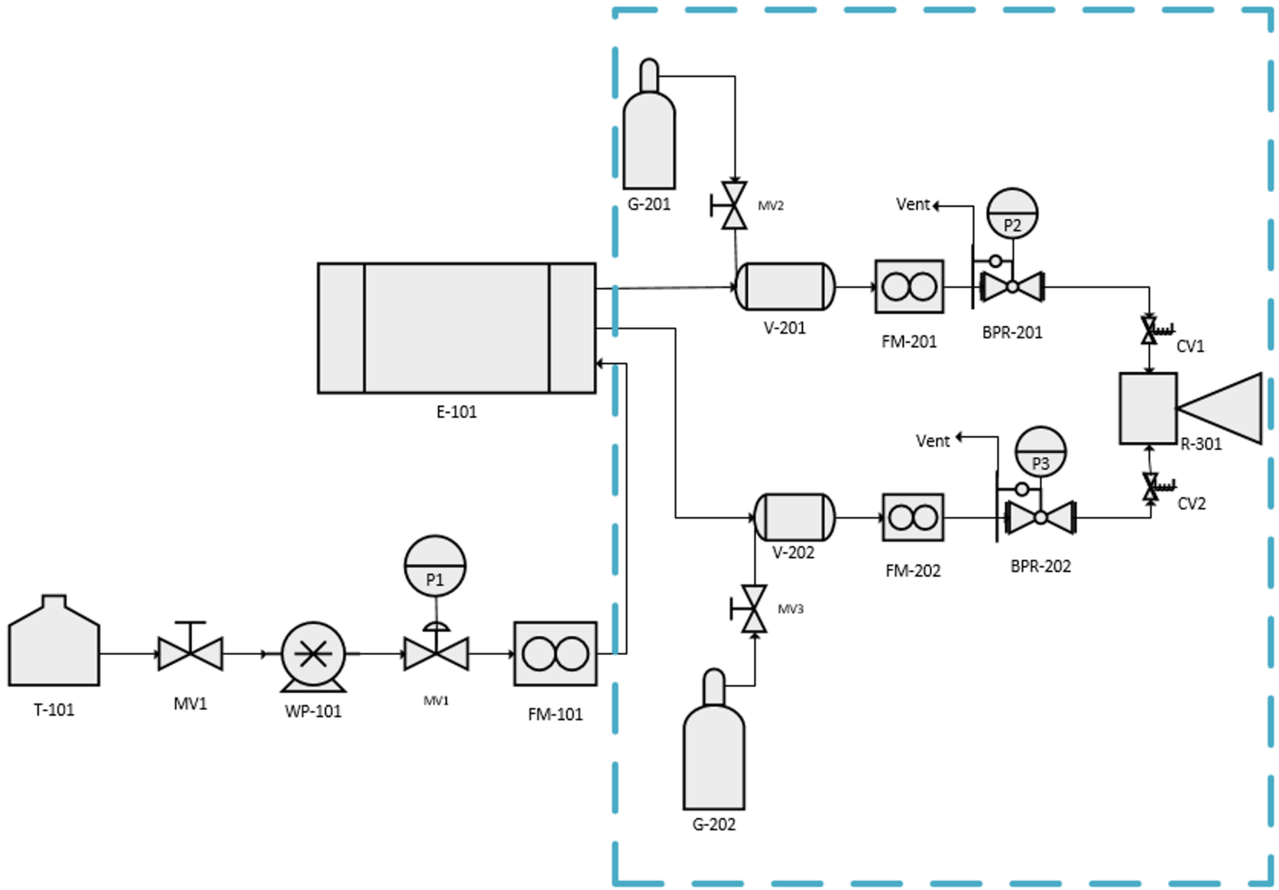
Presentation Outline

- Big Picture
- Objective
- Challenges
- Experiment Progress
  - PFD and CEA
- System Design
- Analysis
- Discussion

Big Picture

T-101	WP-101	E-101	FM-101	G-201	G-202	V-201	V-201	BPR-201	BPR-202	FM-201	FM-202	R-301
Water Tank	Pressurization Pump	PEM Electrolyzer	Flow Meter	Hydrogen Cylinder	Oxygen Cylinder	Hydrogen Tank	Oxygen Tank	Hydrogen Back Pressure Regulator	Oxygen Back Pressure Regulator	Flow Meter	Flow Meter	Rocket Engine

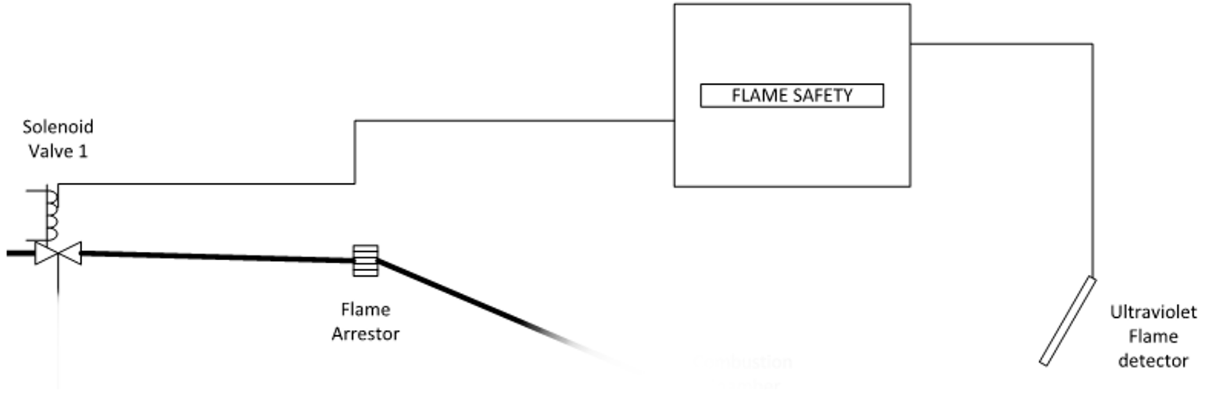


Objectives

- Determine volumetric flow rates necessary to produce the required thrust
- Develop Flame Safety System
- Test the system at different pressures to optimize flame stability
- Design a nozzle within mass budget constraints

Challenges

- Flame safety system setup (to prevent backward flow of hydrogen)
- Getting a stable flame at relatively low pressures
- Viewing the hydrogen and oxygen flames
- Integrating nitrogen in our system design
- Setting up and testing the system with limited resources and time constraints

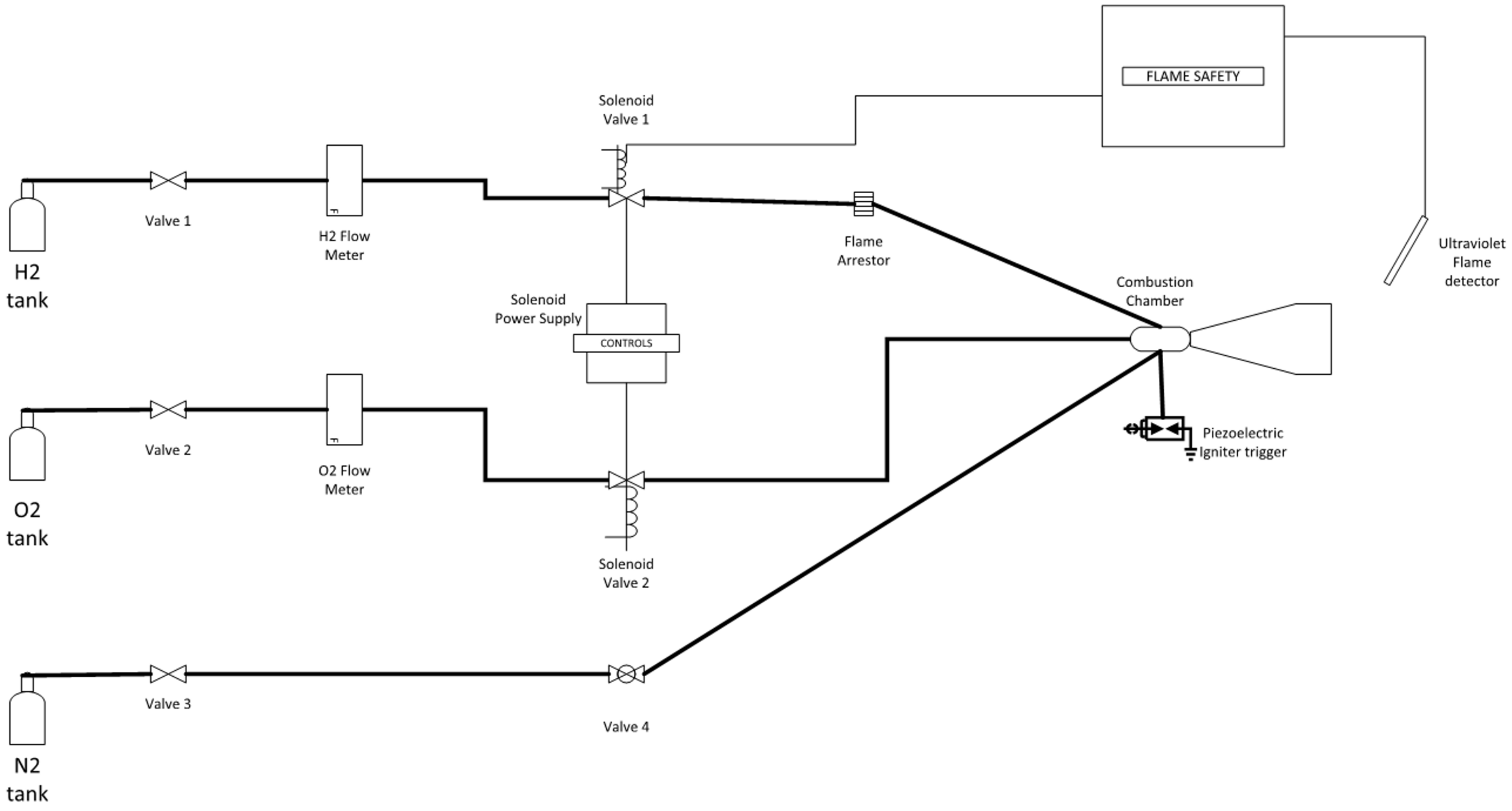


Experiment Progress

- System design and PFD is complete
- Flame detection device wired into the flame safety system
- CEA code used to determine flow rates needed for 2N thrust
- Volumetric flow rates calculated
- Developed preliminary design nozzle that fits within the CubeSat mass and volume constraints

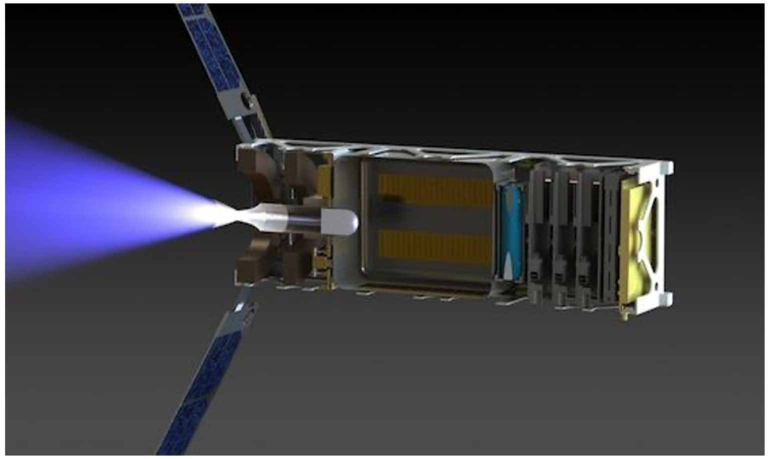
Combustion Experiment PFD

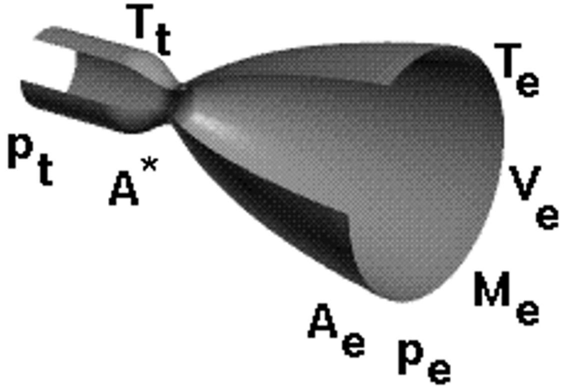
- PFD key features:
  - Solenoid valves
  - Flame arrestor
  - Nitrogen injection into combustion chamber



System Design Considerations

- Nozzle design
  - Designing ejecting nozzle for generating 2N nominal thrust
- Volumetric flow rates
  - CEA code
  - Important to determine gas nozzle sizes





Volumetric Flow Rates

- Used CEA code and

$$ISP = \frac{F}{\dot{m} g}$$

- Based on 8:1 O/F
- Given mass flow rates, estimated volumetric flows based on gas densities at pressure
- These flow rates are important for sizing nozzle ejectors through which our gases flow into the combustion chamber and burn

Flow Rates Required at Each Pressure

Pressure (Pa)	Gas	Flow Rate (ml/min)
200000	H_2	23220
	O_2	13200
300000	H_2	15480
	O_2	8820
400000	H_2	11640
	O_2	6600

Sample Nozzle Design

- Nozzle design
  - In addition to stabilizing pressure in and out of fuel cell, need further pressurization (done through the nozzle)
  - Smaller expansion ratio required to meet mass-volume budget constraints and design specifications
  - More area for fuel tank

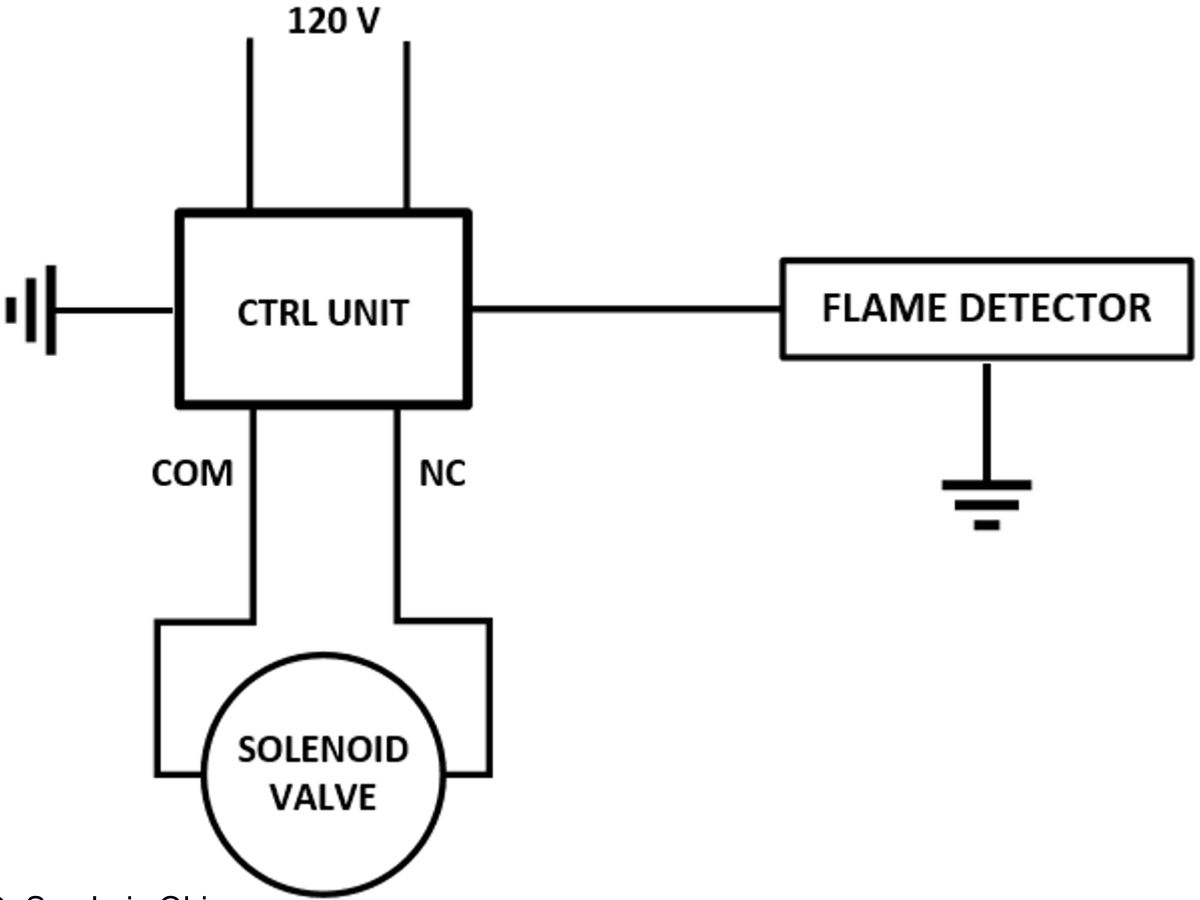
$\epsilon = 55$

$\epsilon = 22$

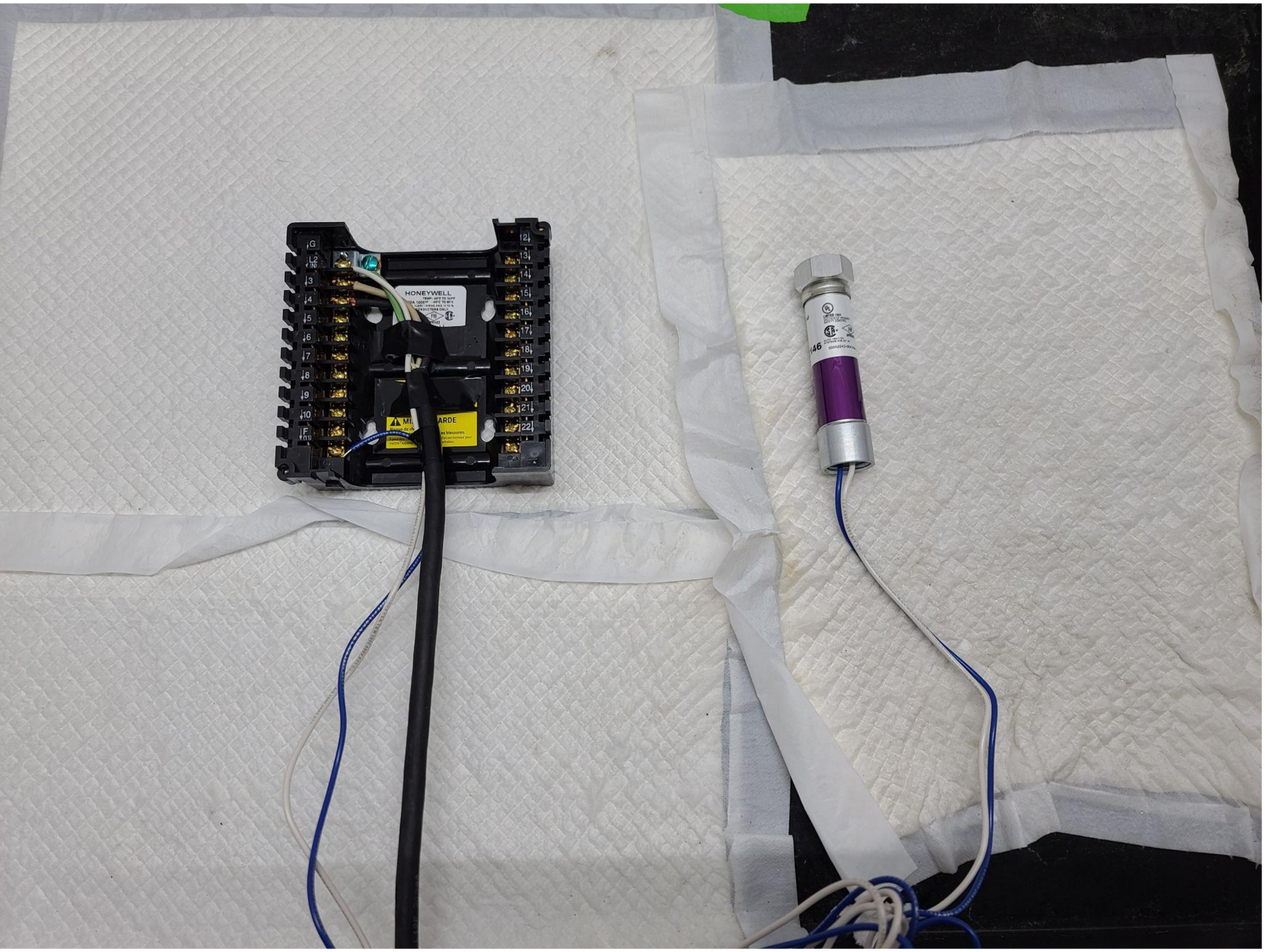
Two possible design considerations (both within the CubeSat and not protruding outside).
<u>Fact:</u> Choosing the nozzle with an expansion ratio of 22 over the one with the 55 ratio will increase the fuel tank by 64%

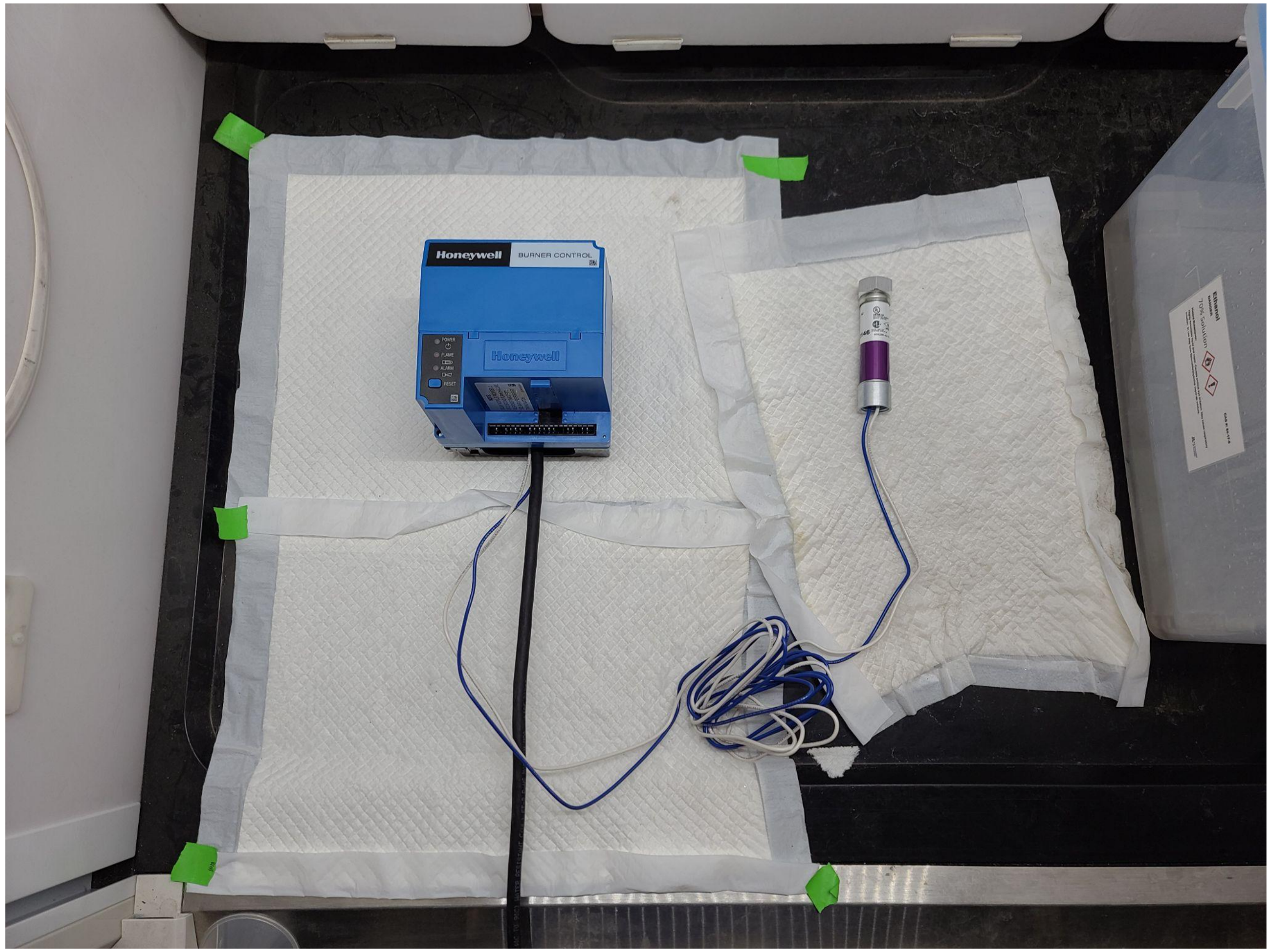
Flame Safety System Design

- Ultraviolet light detection system
  - Prevents uncontrolled release of flammable gases in the fume hood
  - Flame detector signals the solenoid shut off valve in absence of a flame

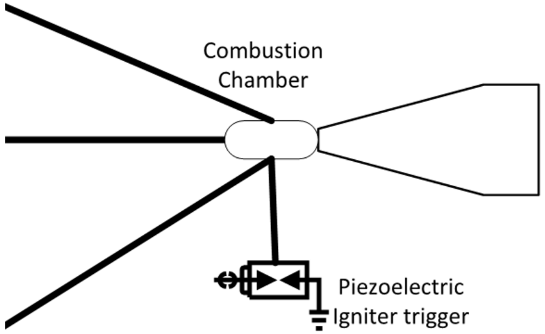


Flame Detector Wiring





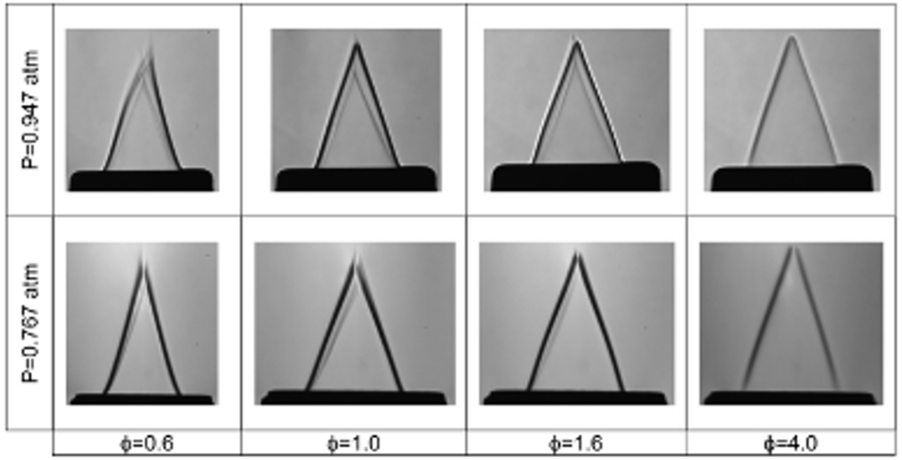
Analysis



- Testing to get a stable flame
  - First at the pressure that the gases flow out at
  - Then at different pressures (different nozzles) until a stable flame is obtained.
- Inert Setup (flushing nitrogen in the combustion chamber)
  - Ensures Hydrogen burns in presence of oxygen produced by fuel cell
  - Adjustments can be made to balance the oxygen flowing out and aiding in combustion.

Discussion

- CubeSat Propulsion System: Overview
  - CEA analysis performed
  - Hydroproofed PEM units
  - Tested electrolyzer gas production under different pressures
  - Flame Safety setup
  - Combustion experiment setup



g. 8 – Instantaneous Schlieren photographs of H_2/air flames at different pressures and various equivalence ratios.

- Next steps:
  - Test flame stability
  - Integrate within electrolyzer
  - Run entire system tests

Sources

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