Performance Characterization of the HYDROS™ Water Electrolysis Thruster

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HYDROS Overview

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- **Allows secondary payloads to launch with a *safe, storable, non-toxic* propellant: water**
- **Fuel cell electrolyzes water into oxygen and hydrogen on-orbit**
- **Modular design affords scalability to meet a wide range of mission and design imposed requirements**

HYDROS 1U Engineering Unit

HYDROS Overview

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- **High performance bipropellant thruster capable of providing up to 1 N of thrust at 300 seconds of specific impulse**
- **Current total propulsion system volume 1U, including control electronics**

Metric	Goal	Demo'ed To-Date
Thrust (Max)	1 N	0.8 N
Min. Bit Impulse	0.1 mN·s	< 0.75 mN·s
Specific Impulse	300 s	258 s
Power Required	0.5 -10W	0.5 -10W

HYDROS Performance Metrics

System Performance Estimates

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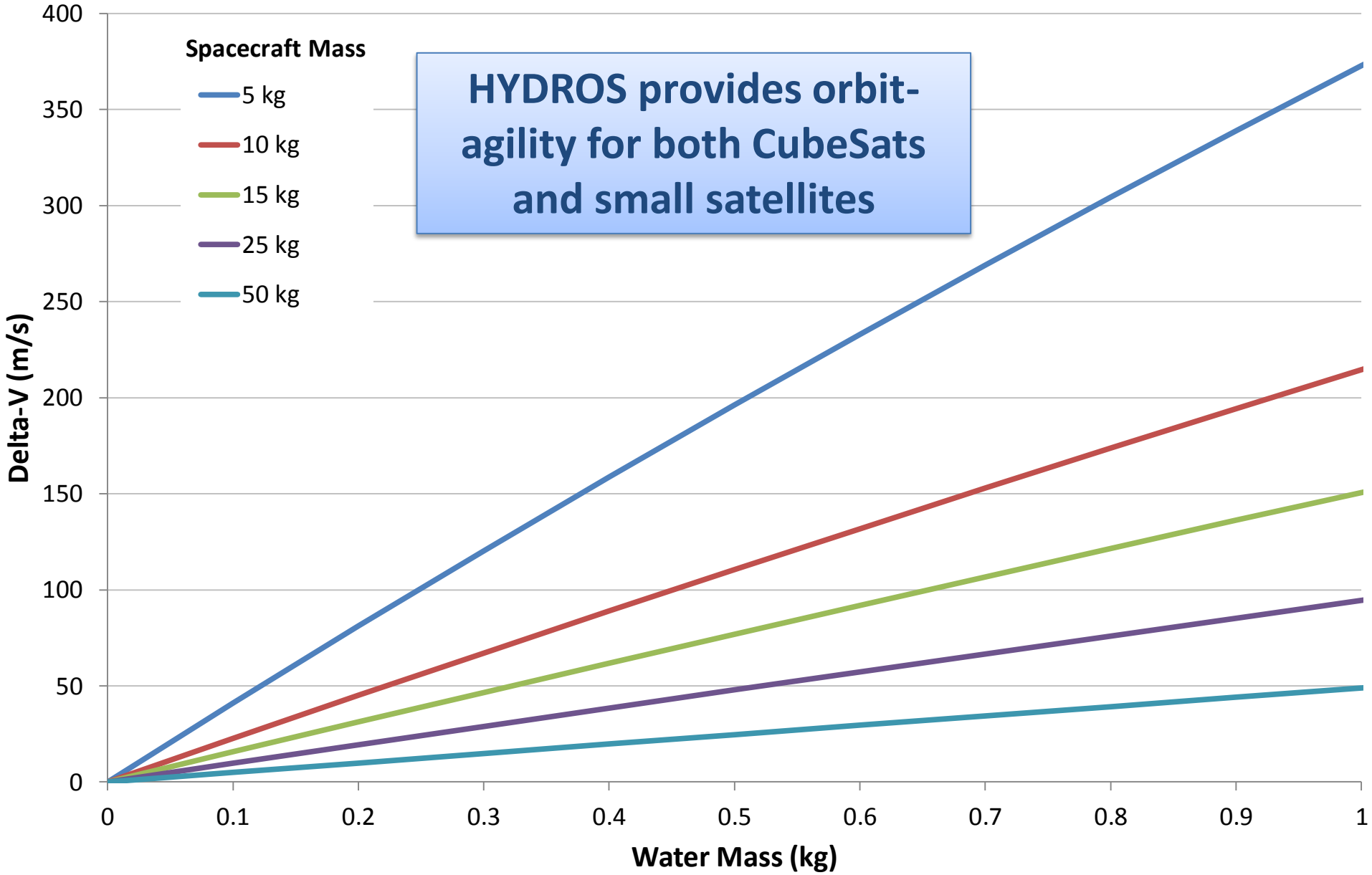

HYDROS provides orbit-agility for both CubeSats and small satellites

HYDROS System Architecture

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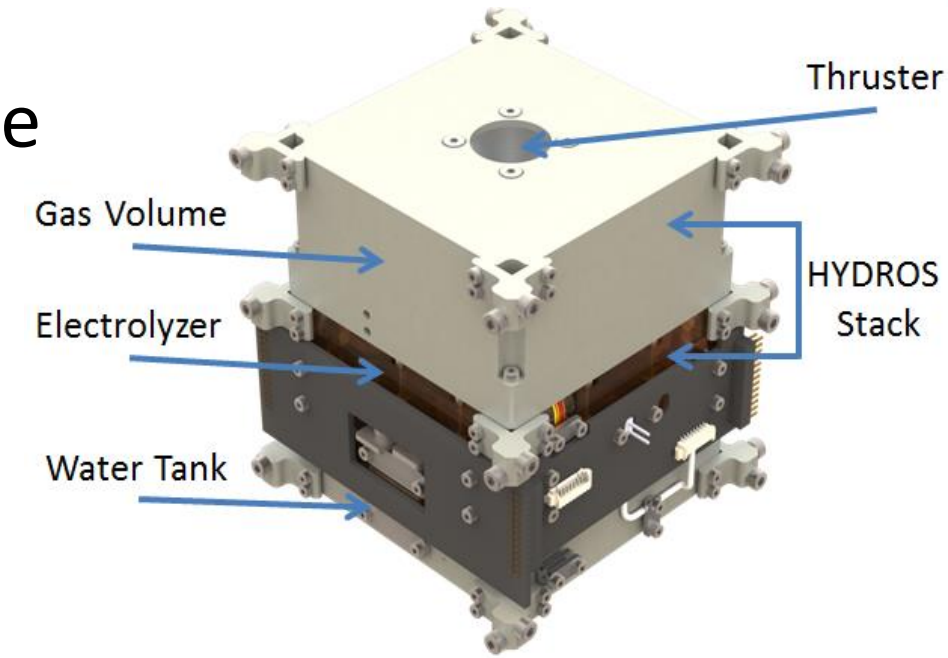
- **Electrolyzer**
  - Generates gaseous O2 and H2 on-orbit
- **Gas Volumes**
  - Store evolved gases for use in bipropellant thruster
- **Thruster**
  - Bipropellant 1N thruster capable of 300s I_{sp}
- **Water Tank**
  - Scalable to meet mission performance requirements

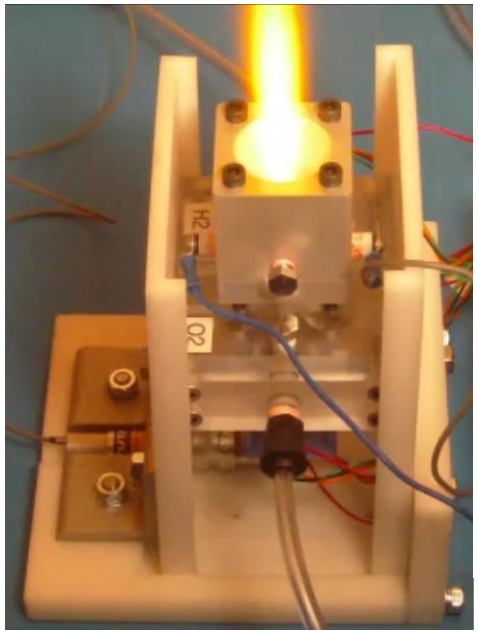


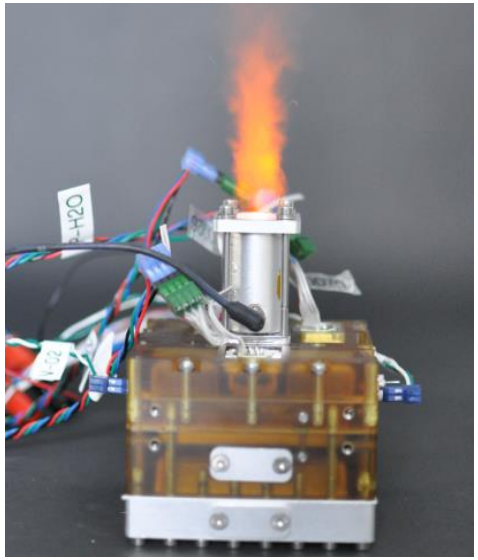
Current 1U HYDROS Architecture

Design History

- **Developed HYDROS thruster prototype under a NASA SBIR**
  - Phase I: Proof-of-Concept
  - Phase II: Technology Development

- **Electrolyzer and thruster developed in parallel efforts**
  - Extensive pre-integration test campaigns conducted for both sub-systems
  - Vacuum and gravity antagonistic testing used to validate design





HYDROS Thruster Test Efforts

Design History Cont.

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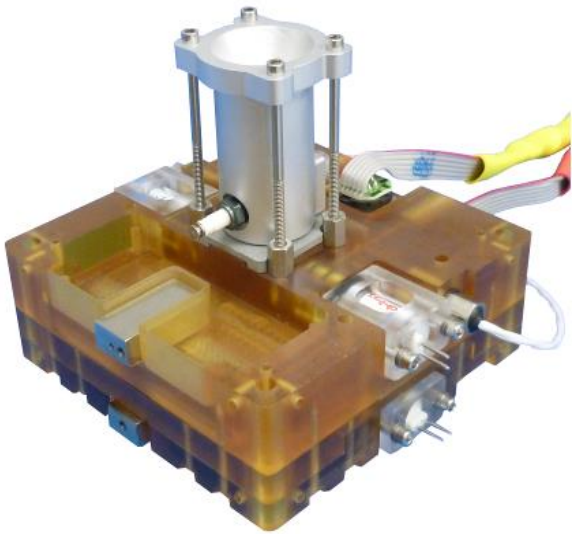
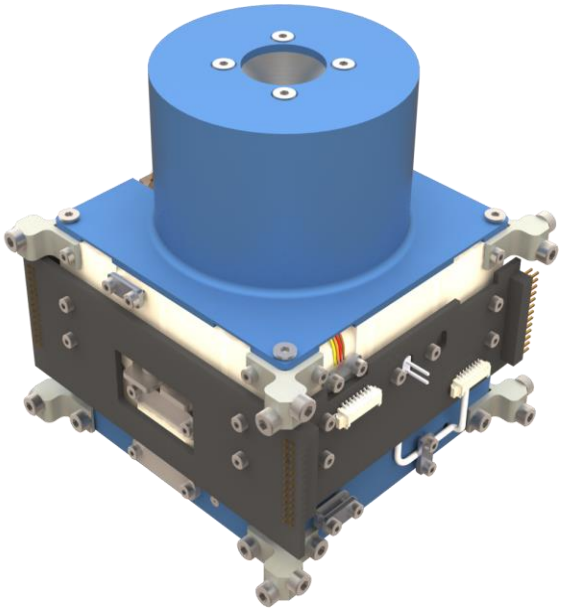
- **Initial integrated prototype designed for 0.5U footprint**
  - No avionics integration
  - Length constrained for 3U+ volume
- **Electrolyzer and thruster designs rev'd to improve performance**
  - Gas generation rate doubled
- **Improved system architecture incorporates improvements and provides expanded gas storage**
- **Engineering unit delivered to AFIT**
  - Testing by AFIT and TUI matures design to TRL 5



Initial HYDROS Prototype Unit



HYDROS ½ U+ Design

HYDROS Test Program

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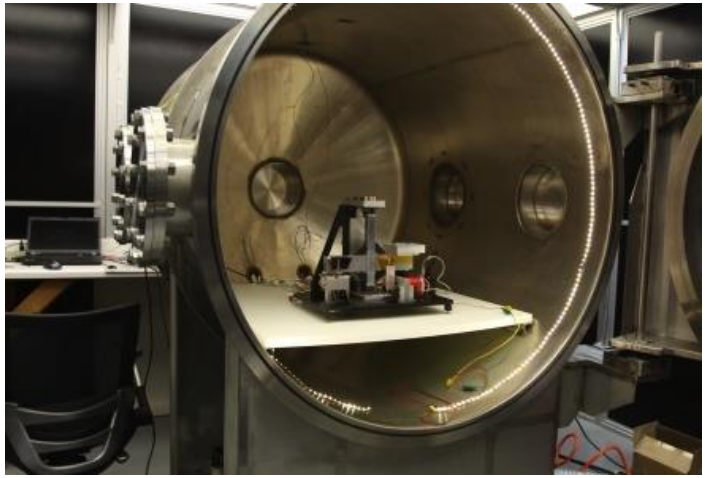
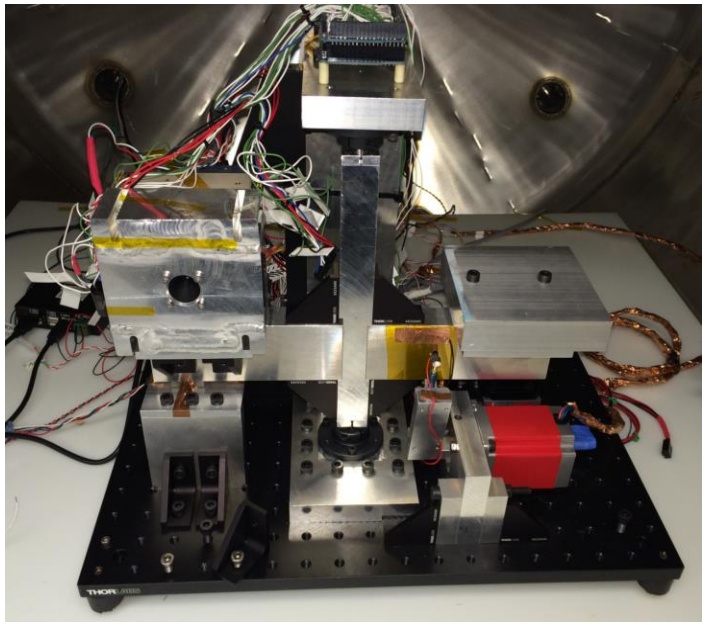
- **Testing conducted in-house utilizing TUI's vacuum chamber and thrust stand**
- **Vacuum Chamber**
  - Lifetime testing
  - Thruster/Electrolyzer characterization
- **Thrust Stand**
  - Torsion balance
    - Sub mN·s resolution
    - Measures thrust events up to 500 mN·s

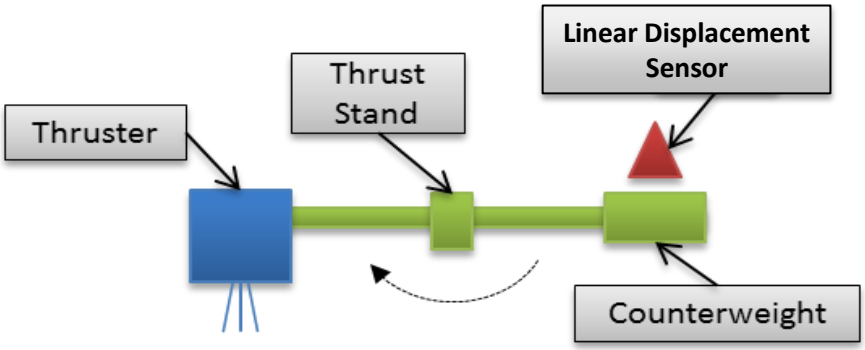




TUI's Vacuum Chamber and Thrust Stand

Test Configuration and Error

- **Thrust and Isp values are determined from impulse and pressure measurements**
- **Calibration**
  - Thrust stand and pressure transducers are calibrated prior to data collection
- **Error Analysis**
  - Calibration and measurement errors propagated to characterize total error
    - ~6% error with given test configuration



Top-Down View of the Torsional Thrust Stand

Electrolyzer Characterization

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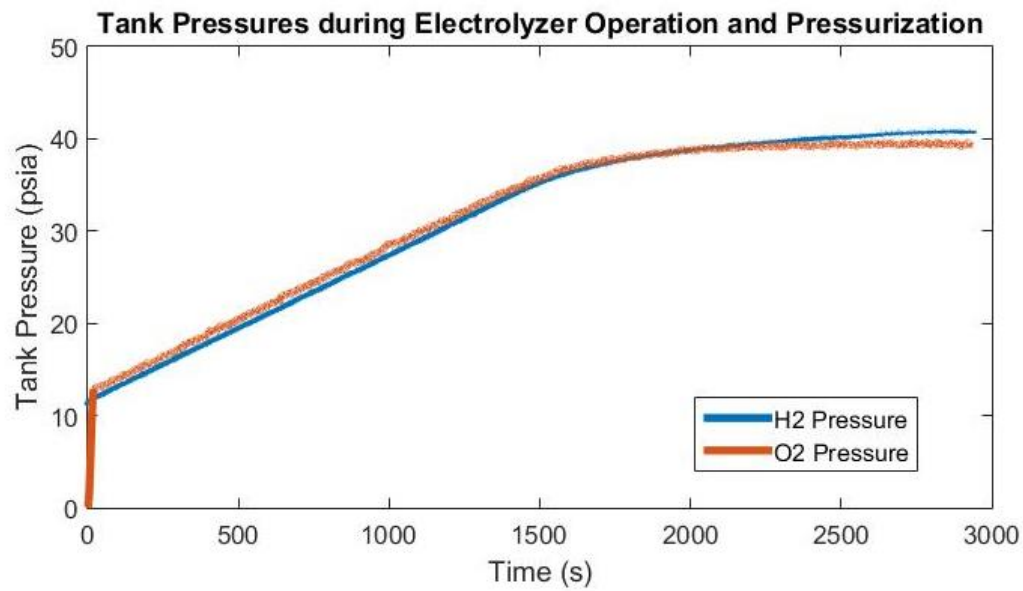
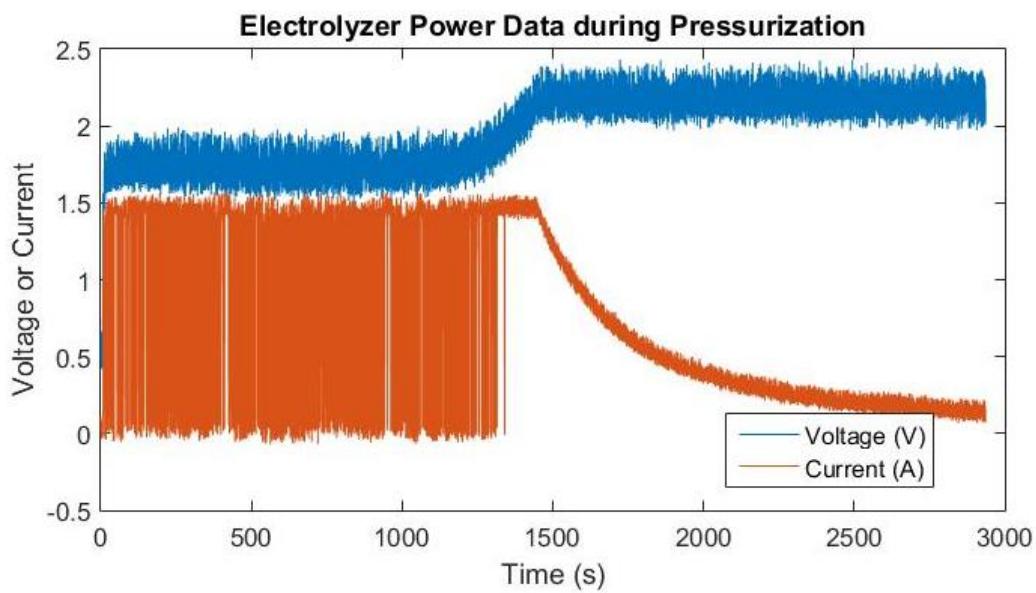
- **Verify analytical models of electrolyzer performance**
  - Time required to pressurize gas volumes
  - Current and power levels



- **Understand how power levels and wetting of the electrolyzer impact performance**



Electrolyzer Characterization

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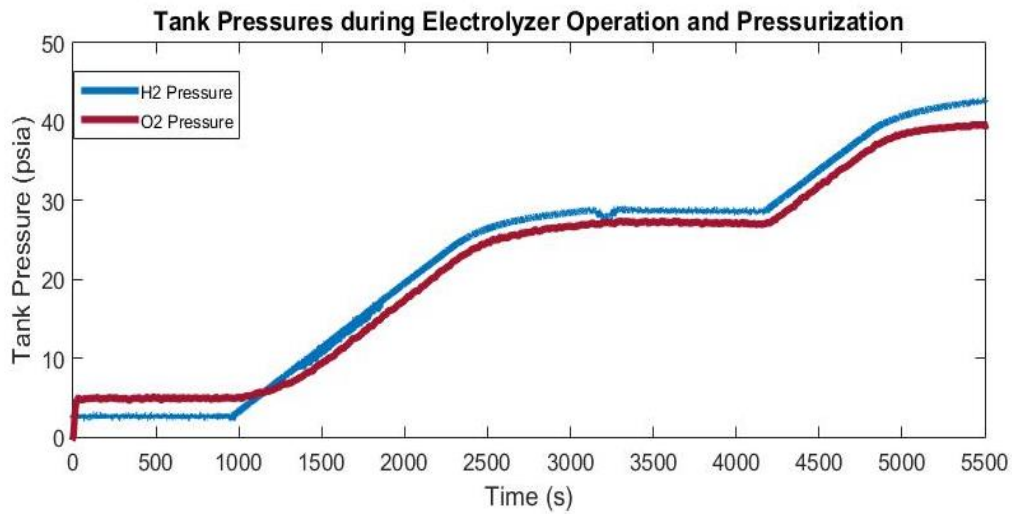
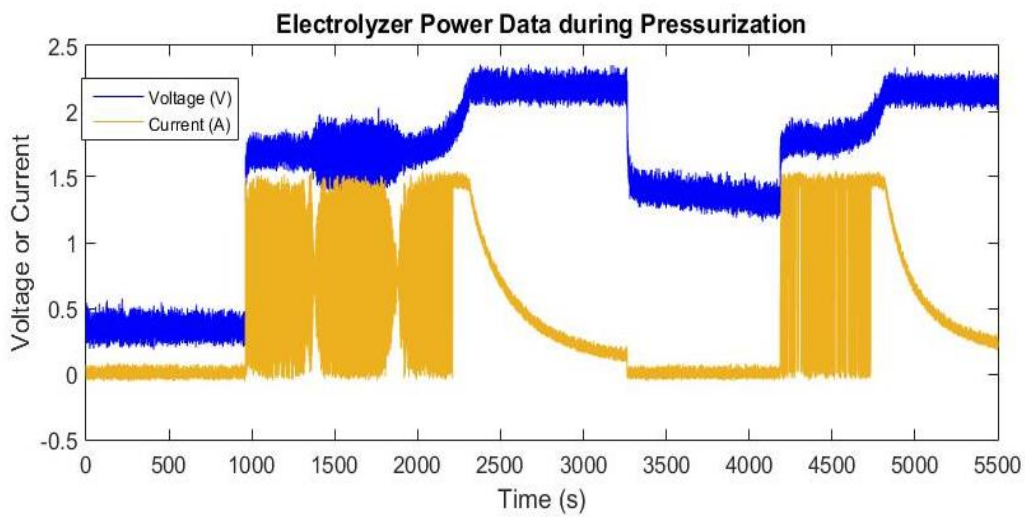
- **Understand driving properties of electrolyzer performance**
  - Maximum electrolyzer performance requires adequate wetting of Proton Exchange Membrane
  - Drop in current draw correlates to reduction in gas evolution rate and indicates inadequate wetting





Electrolyzer Characterization

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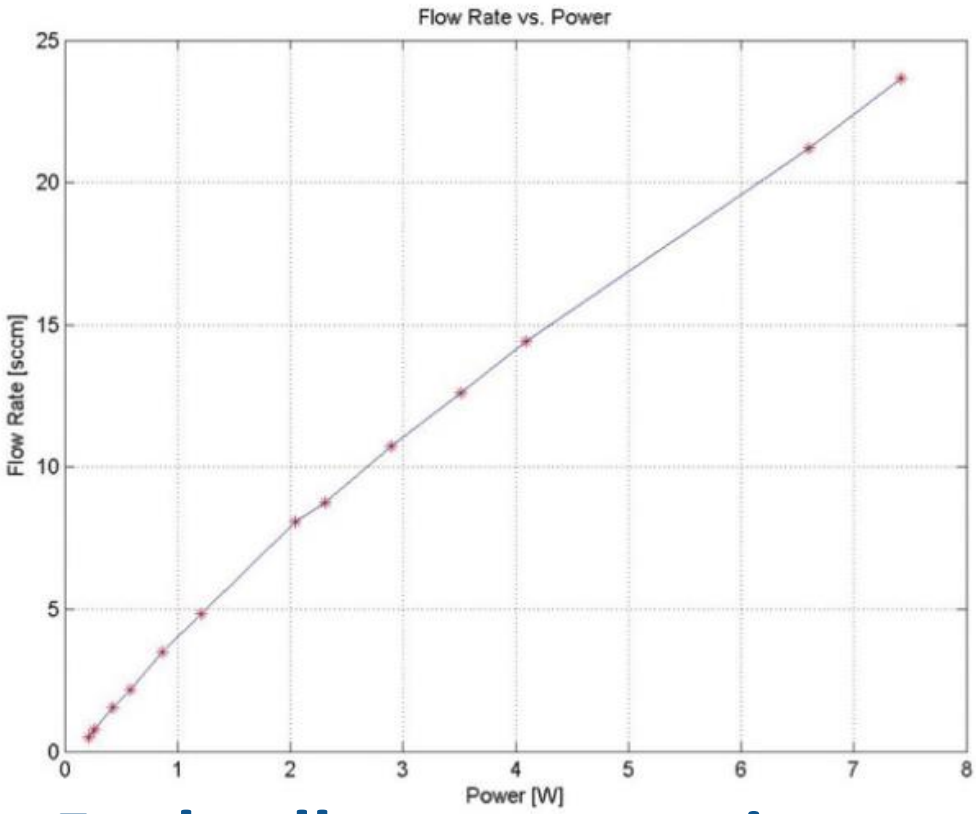
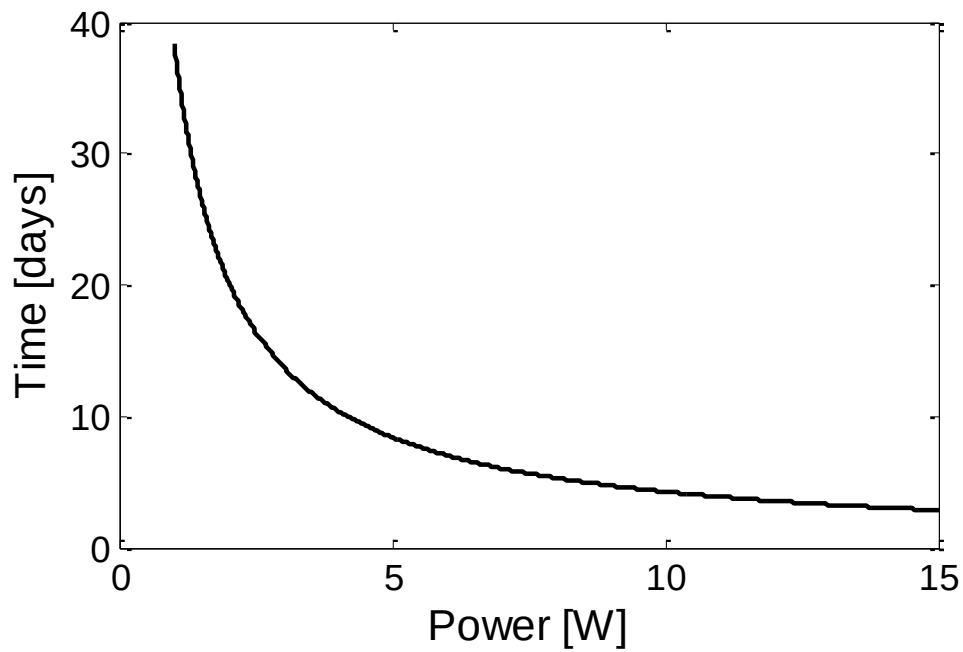
Power consumption testing:





Time to electrolyze 100ml of water

- **Fuel cell gas generation rate as a function of applied power**
  - Used to refine analytical models for system and mission design efforts

Thruster Performance

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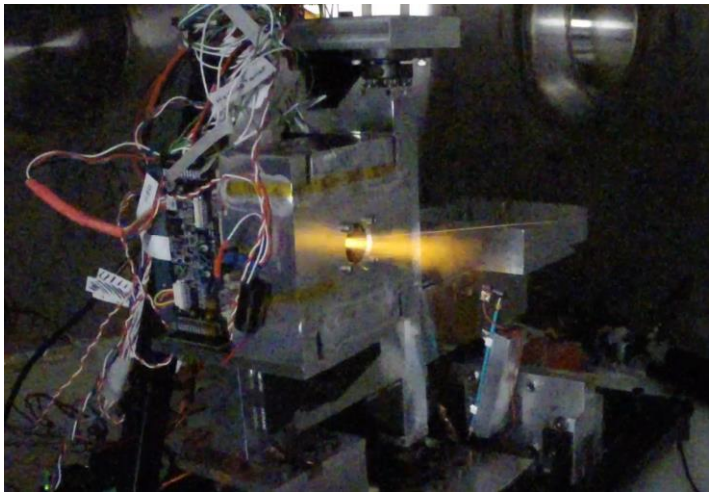
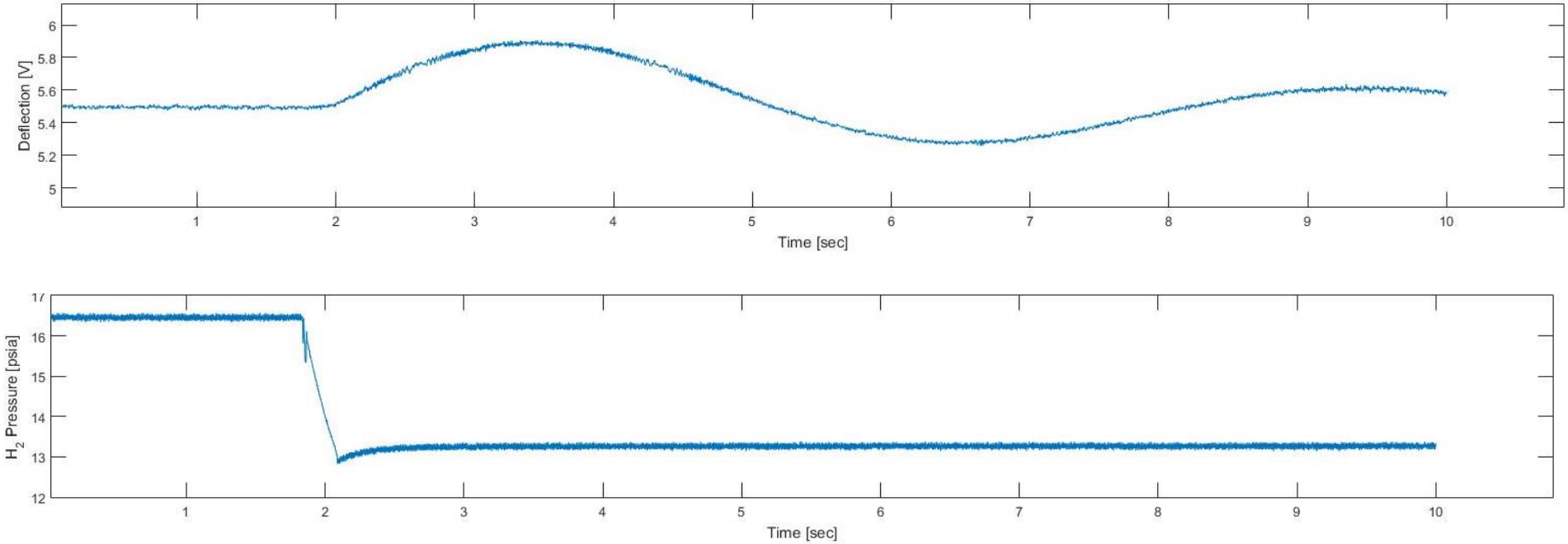
- **Initial characterization of the thruster has demonstrated:**
  - Avg Thrust: 0.6 N
  - Total Impulse: 150 mN·s
  - 250 ms pulse

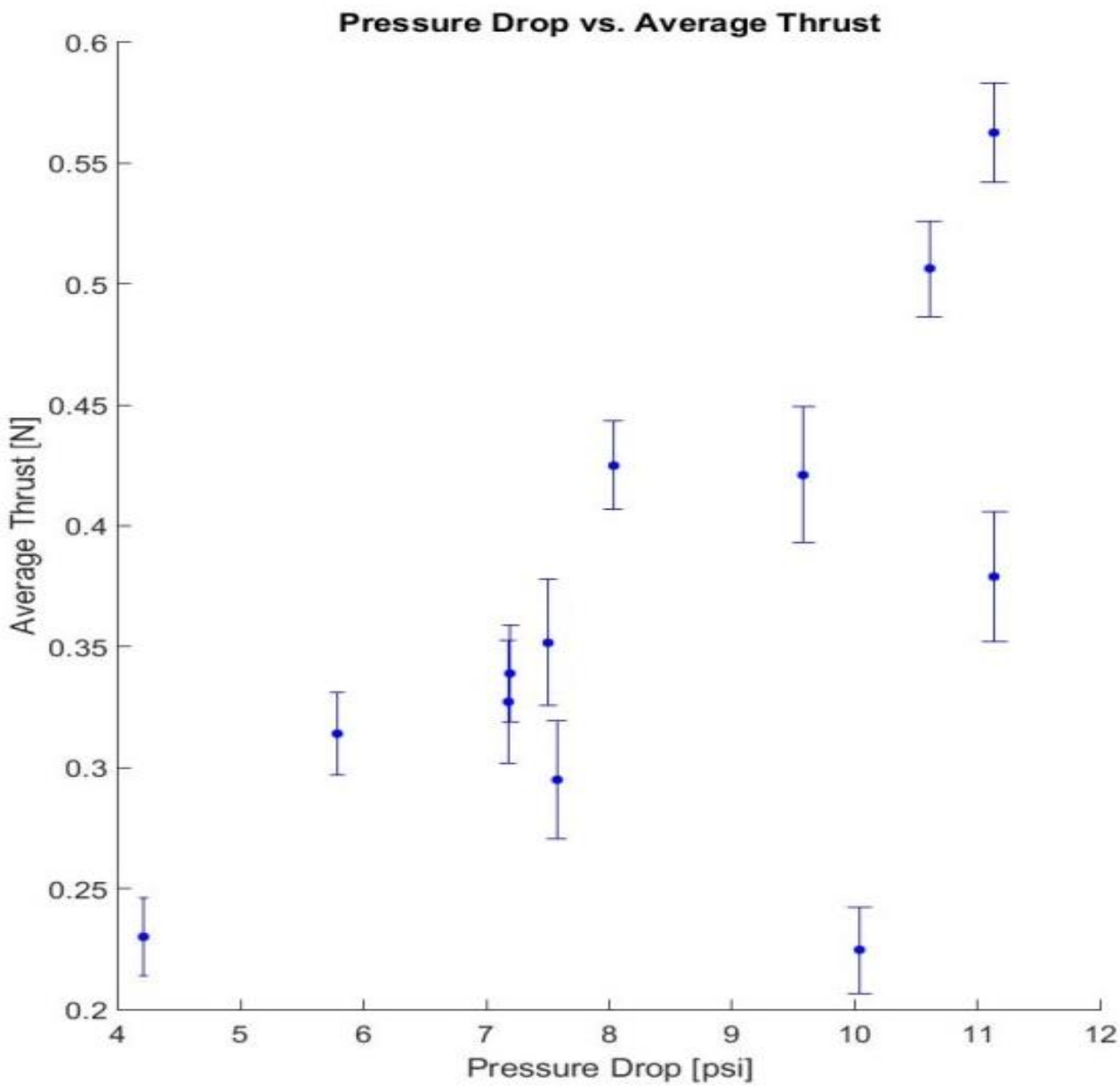


HYDROS Hotfire Testing



HYDROS Pressure Transducer and Thrust Stand Response

Thruster Performance



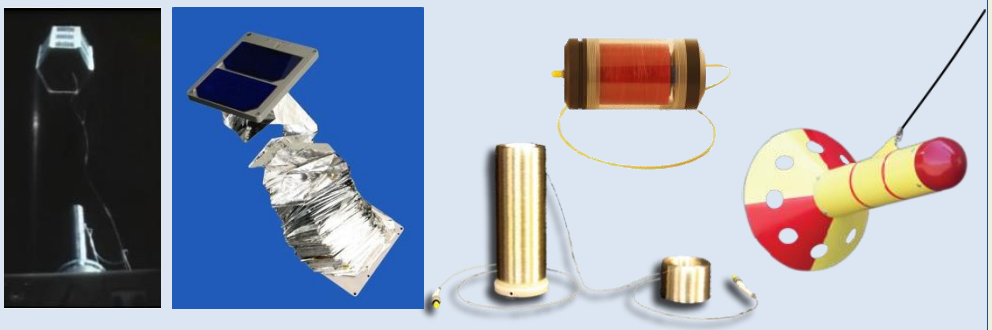
Tethers Unlimited, Inc.

Transformational Technologies for Space, Sea, Earth, & Air

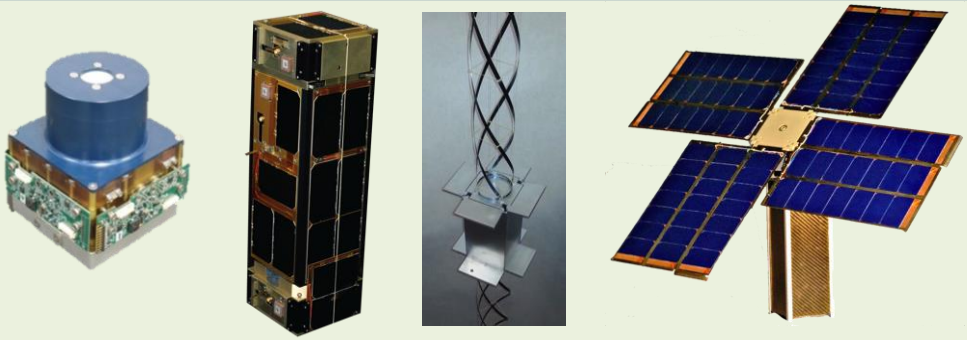
- TUI Develops Advanced Technologies for Space & Defense
- 20 years in operation, >80 contracts completed
- Clients: NASA, DARPA, Navy, Air Force, Army, & space primes
- Commercialized multiple SBIR technologies & supported multiple flight missions

Core Technology Areas

Tether Systems for Space and Defense



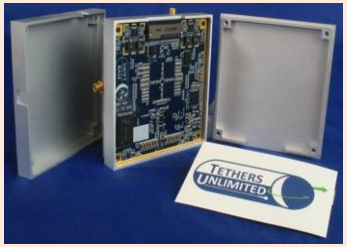
High-Performance SmallSat Components



SmallSat Software Defined Radios

SWIFT SDR

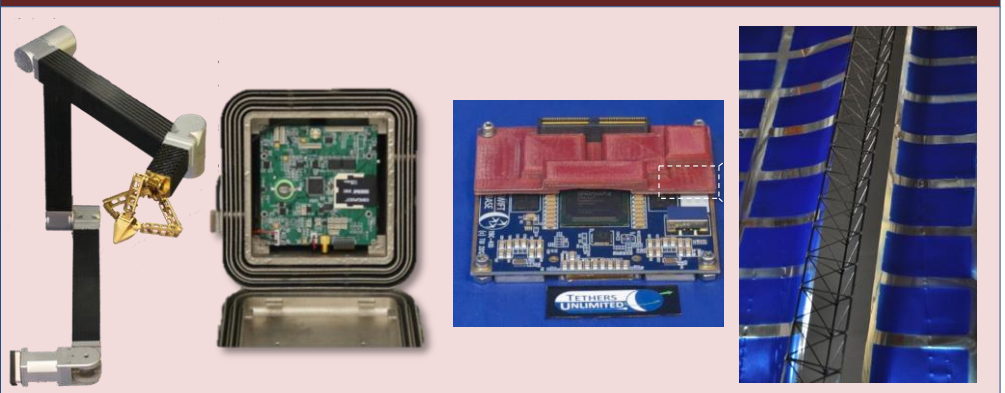
AFSCN/S-band



Wide-Band

UHF

Additive Manufacturing For- & In-Space



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