Advanced Capabilities
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HYDROS™

Development of a CubeSat Water Electrolysis Propulsion System

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Water Electrolysis Propulsion

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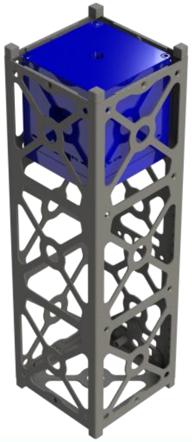
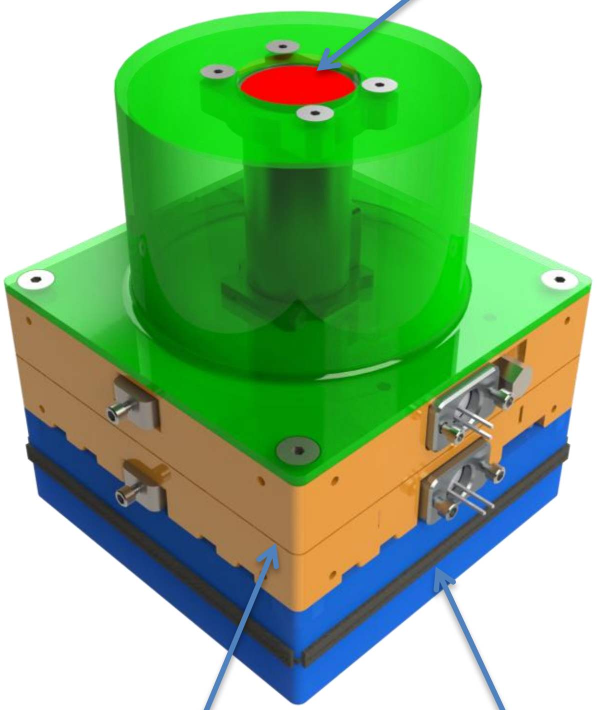
- **Allows CubeSats to launch with a *safe, storable, low-pressure, non-toxic* propellant: water**
- **Fuel cell electrolyzes water into oxygen and hydrogen once on-orbit**
- **High performance bipropellant thruster provides up to 1 N of thrust at 300 seconds of specific impulse for:**
  Orbit raising, plane changes, precision pointing, large delta-V maneuvers
- **Total propulsion system volume <1U, including electronics**
- **Available in two configurations, including one that utilizes the "tuna can" (3U+) volume**



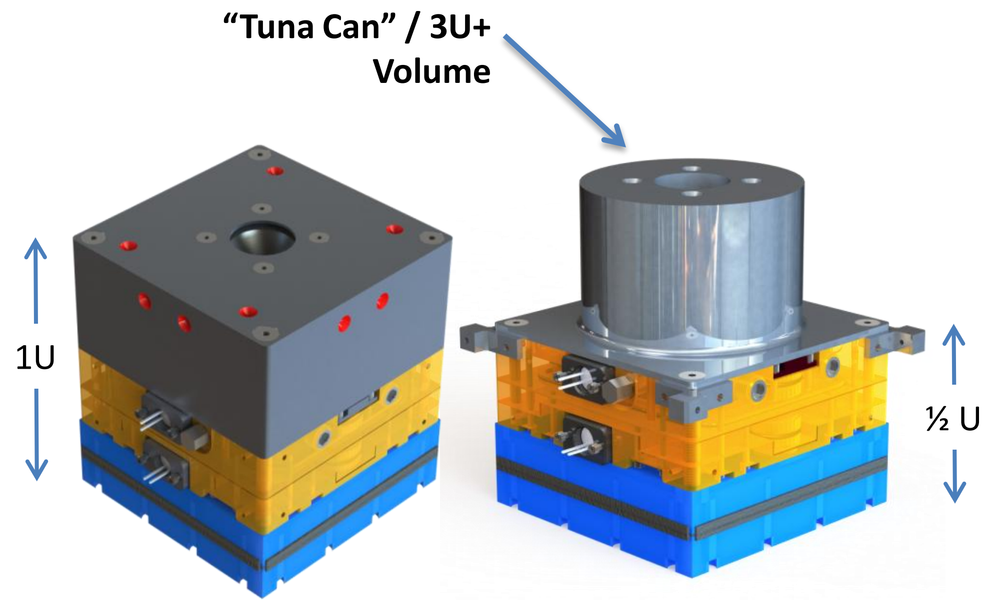
Current Status of Technology

- **TUI is developing water electrolysis propulsion under a NASA Phase II SBIR**
- **Fuel cell and thruster prototypes have been integrated and tested successfully**
  - TRL-4+ now; integrated prototype testing to TRL-5 by Jan 2014
- **Vacuum thruster testing has just been completed**
- **Flight hardware will be ready Dec 2013**



HYDROS Configurations

- **The HYDROS propulsion system is available in a standard 1U cubic configuration as well as a smaller “tuna can” (3U+) volume configuration that takes advantage of the extra space allowed within the P-POD deployer spring**
- **Both configurations are designed to easily integrate into any CubeSat bus, including Colony II, Pumpkin, and ISIS**



Standard Configuration **3U+ Configuration**

HYDROS with ACS Thrusters

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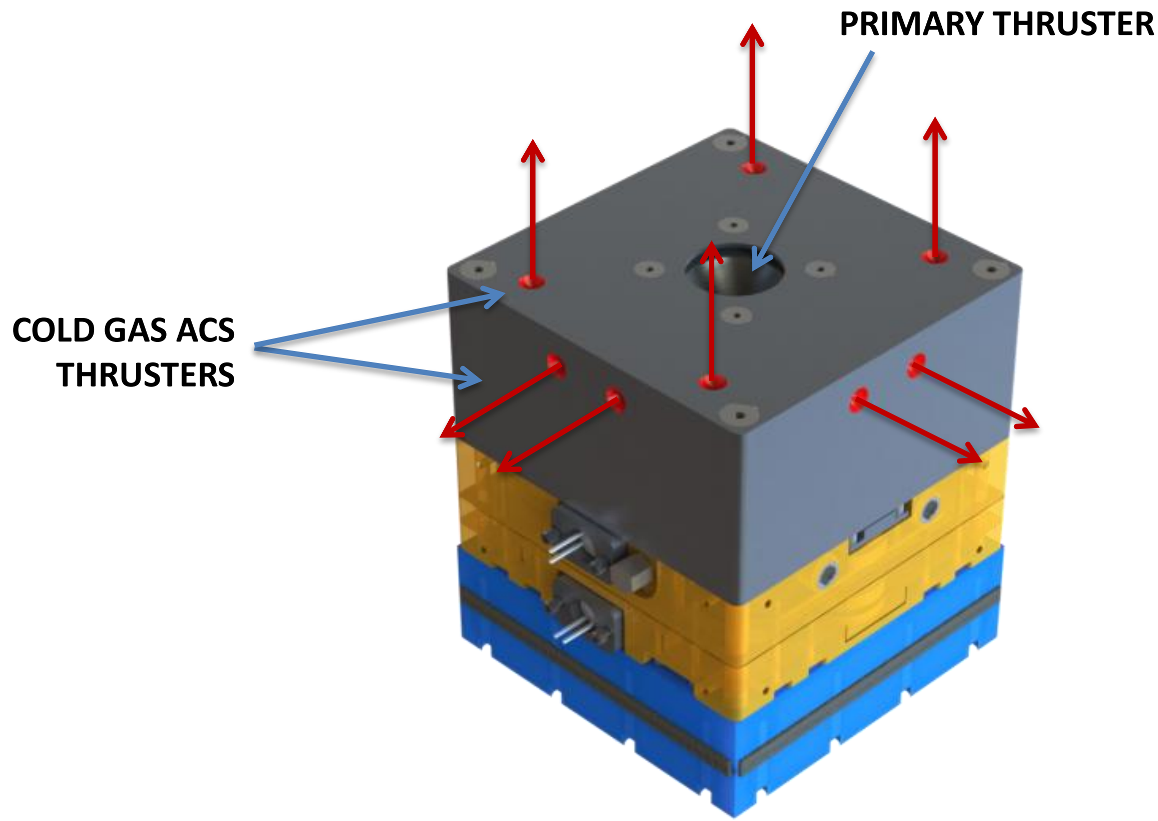
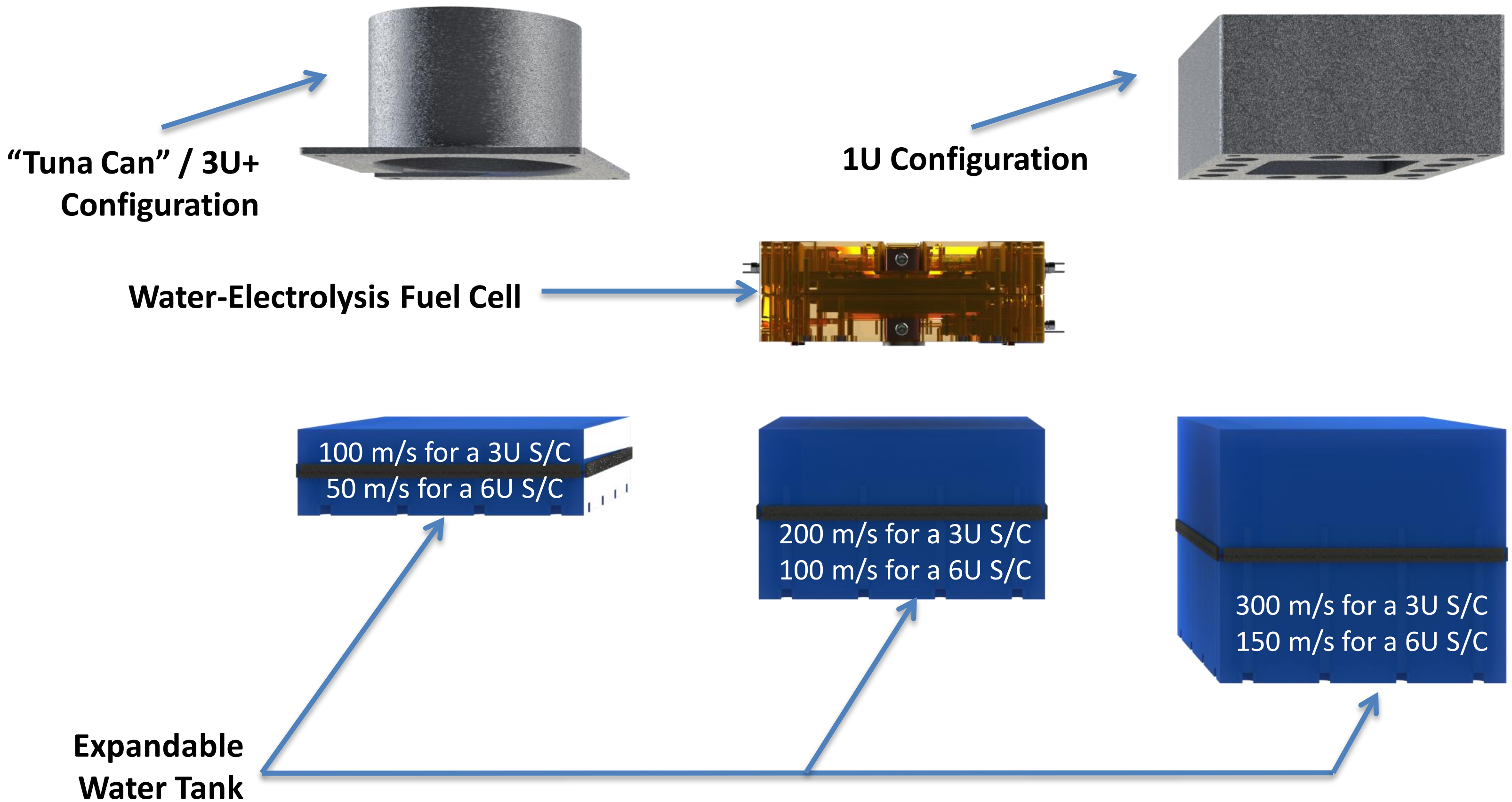
- **Future work will integrate cold-gas ACS thruster ports for attitude control**



HYDROS: A Modular Propulsion System

- Modular design allows HYDROS to fit within CubeSat form factors (1-12 U) as well as other small satellite platforms
- Water tank is easily scaled to provide the desired delta-V



Fuel Cell

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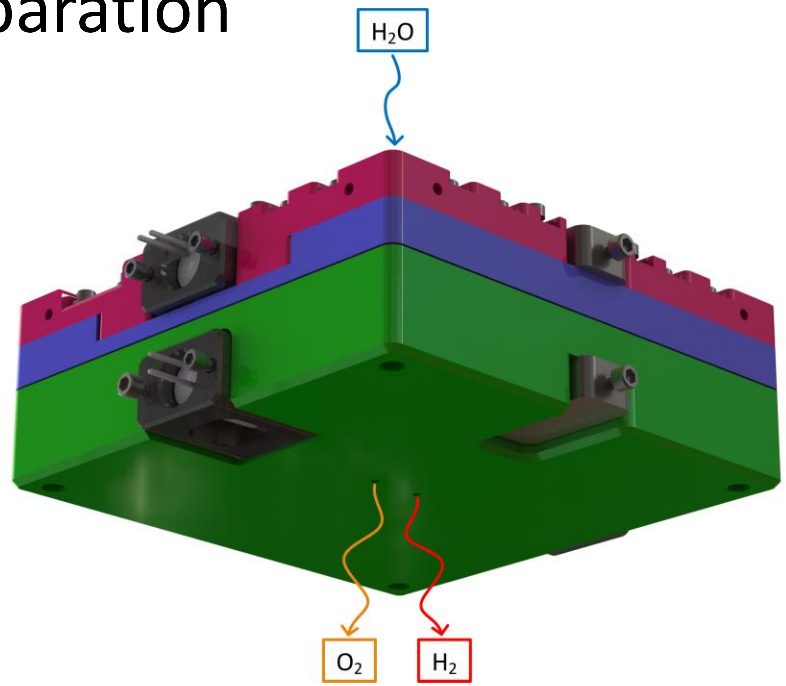
- **TUI's fuel cell is designed to generate and pressurize gaseous oxygen and hydrogen**
- **Designed for zero-g operation from the get-go**
  - No need for spacecraft spinning or other complex mechanics to enable gas separation
- **Fueled by deionized water**
- **Consumes 0.5 – 10 W depending on desired gas generation rate**
- **Produces gas at efficiencies up to 85%**



Thruster

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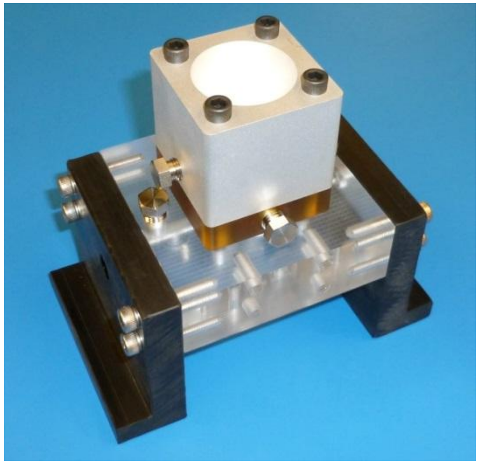
- Bipropellant microthruster designed for integration into CubeSats
- Gas flow is controlled via two lightweight , low power, and isolated propellant valves
- Features reliable and repeatable spark igniter design
- Can be easily optimized for desired mission parameters due to modular nozzle and injector design

Performance Metric	Goal	Demonstrated To-Date
Thrust (Max)	1 N	0.8 N
Minimum Bit Impulse	0.1 mN-s	< 0.75 mN-s
Specific Impulse	300 s	300 s

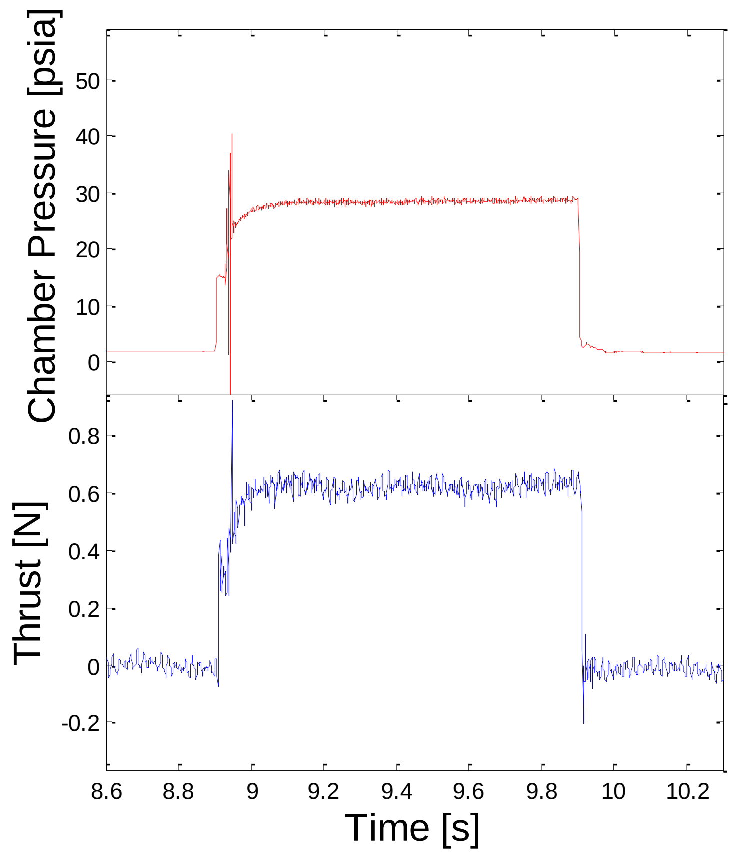


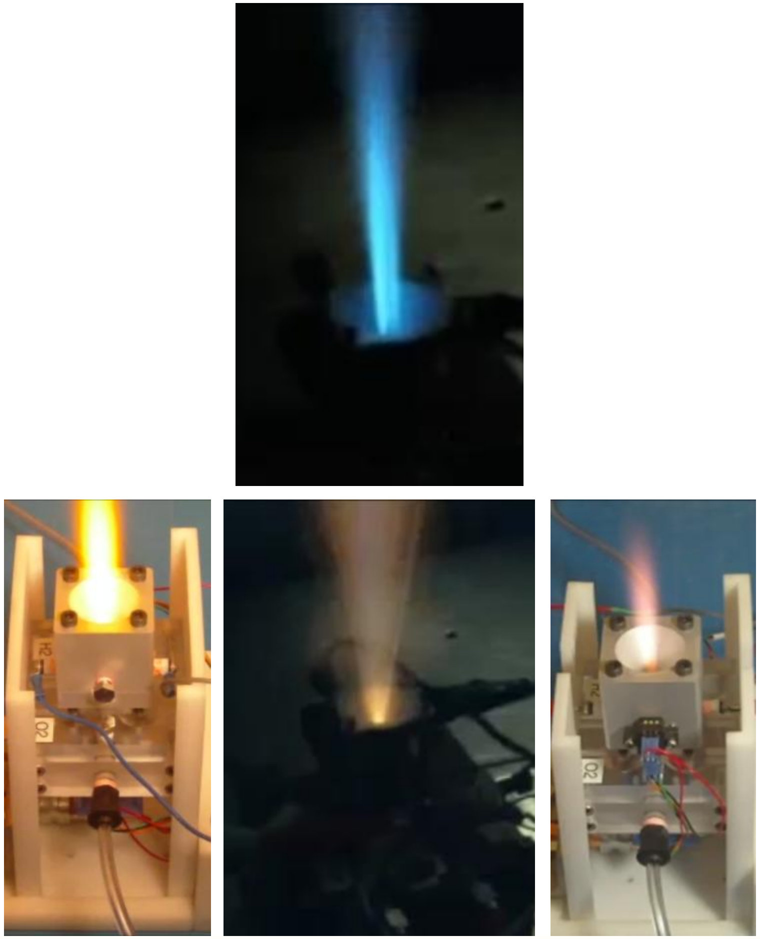
Developmental Prototype

Engineering Model

Hot Fire Test Results

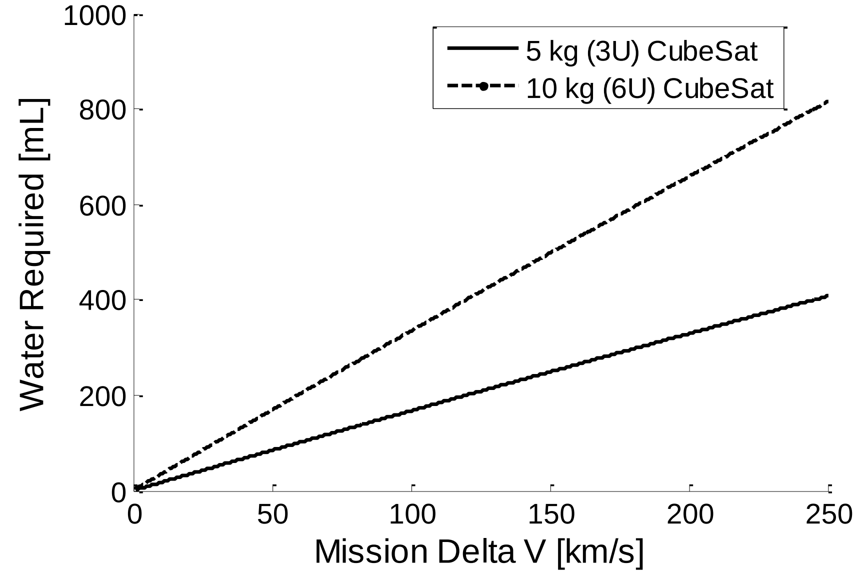
Hot fire testing of multiple prototypes under vacuum and ambient conditions has been completed





Water Propellant

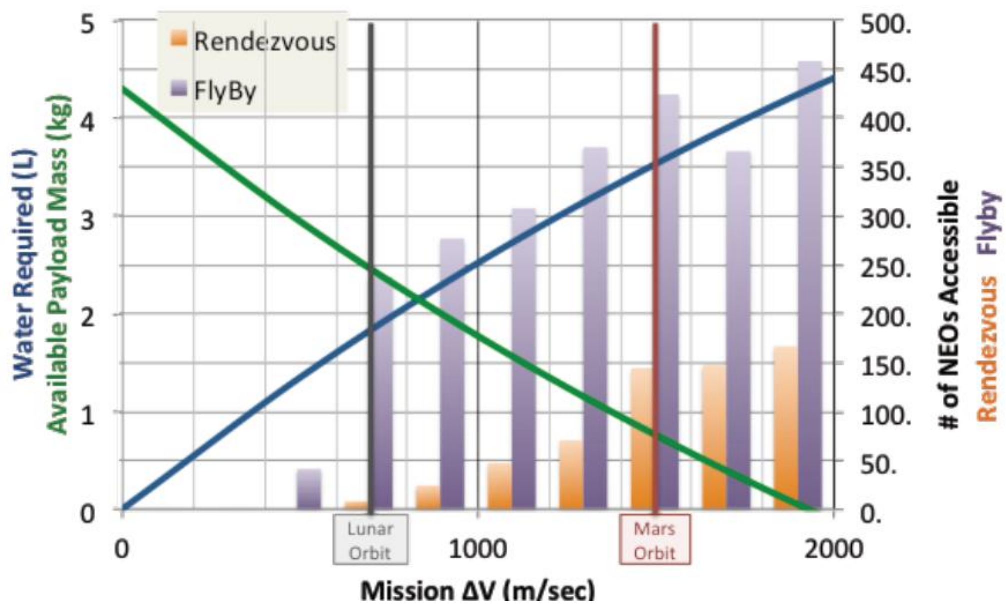
- **Reference mission requires just over 100 mL of water propellant to produce 100 m/s of ΔV**



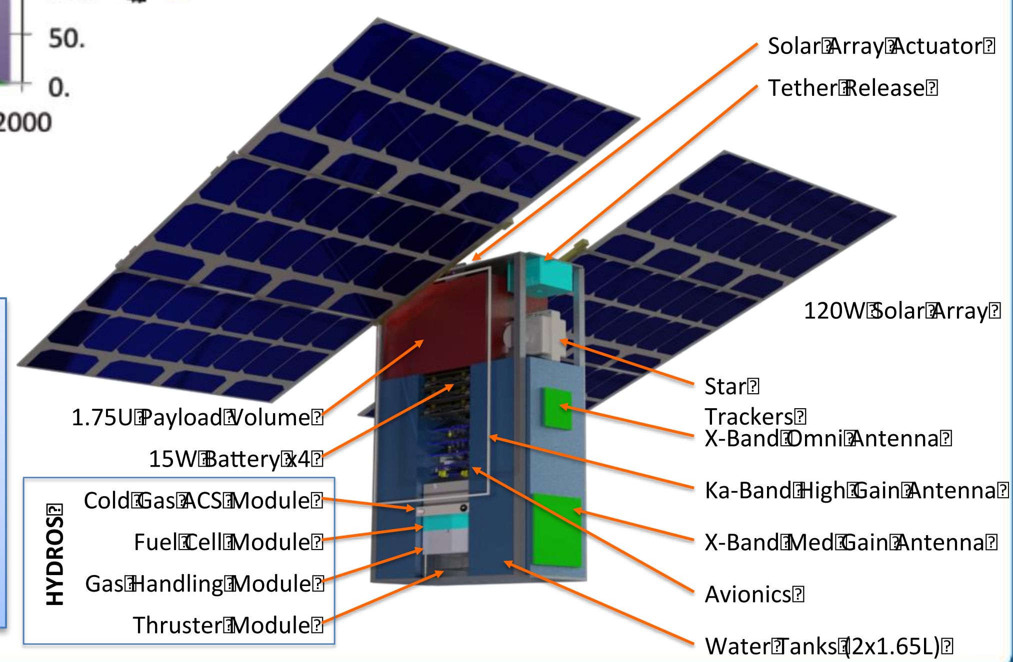
- **A 10 kg nanosat (eg. 6U CubeSat) will require just over 300 mL (1/3 U) of water for 100 m/s**
- **Water is stored in an elastic bladder that is pressurized with gas generated from the fuel cell, ensuring nearly complete propellant utilization**

Example Application: Asteroid Payload Express

- **6U CubeSat delivered to minimum-energy Earth-escape**



HYDROS enables small, affordable nanosats to deliver 1 kg payloads to ~100 known NEOs



PowerCube System

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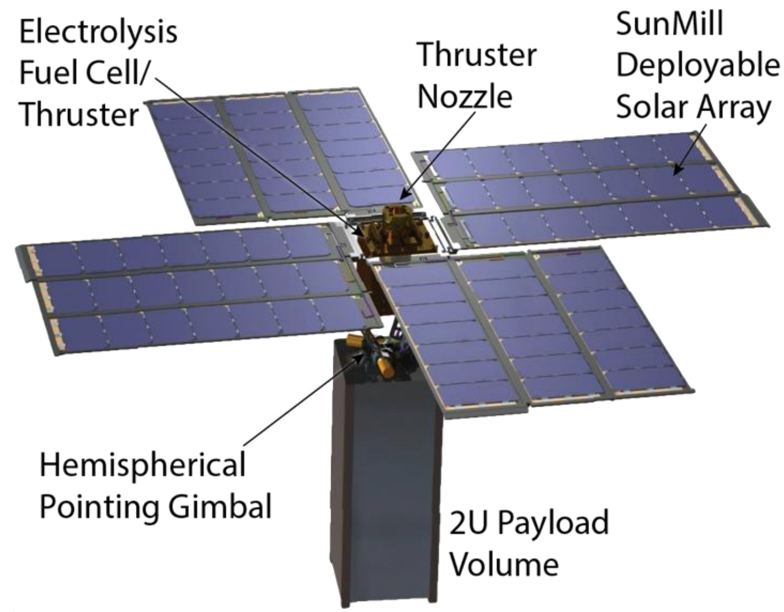
- **The PowerCube™ CubeSat module integrates HYDROS electrolysis propulsion with a deployable array and innovative COBRA™ gimbal**
- **Enable high performance, orbit agile CubeSat missions**
- **80 W Peak Power, 50 W OAP**
- **100 m/s ΔV, 5 m/s per orbit**
- **COBRA gimbal enables precise pointing of panel and payloads without momentum wheels**



About Tethers Unlimited, Inc.

TETHERS UNLIMITED
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- **Founded in 1994 by Robert L. Forward & Robert Hoyt**
- **NASA SBIR & NIAC funding fueled initial growth**
  - 2005 NASA SBIR "Success Story" Selection
- **Successfully completed >70 contracts for NASA, DARPA, Navy, AFRL, Army, & industry primes**
- **Designed, built, launched, & operated a 3-picosatellite space flight mission in 2007, for less than $1M**
- **7 Patents on space technologies**
- **Core Technologies:**
  - Tether Propulsion & De-Orbit Technologies
  - Software Defined Radio Comm. and Nav. Sensors
  - Deployable Apertures and Structures
  - Additive Manufacturing of Spacecraft Components
  - Space Robotics
  - Optical Fiber Tether Dispensers for Mobile Robots