Flight Qualification of a Water Electrolysis Propulsion System

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Outline

HYDROS® is a ***water*** propulsion system that uses ***electrolysis*** to self-generate hydrogen and oxygen for use in its ***bipropellant thruster***.

This presentation includes:

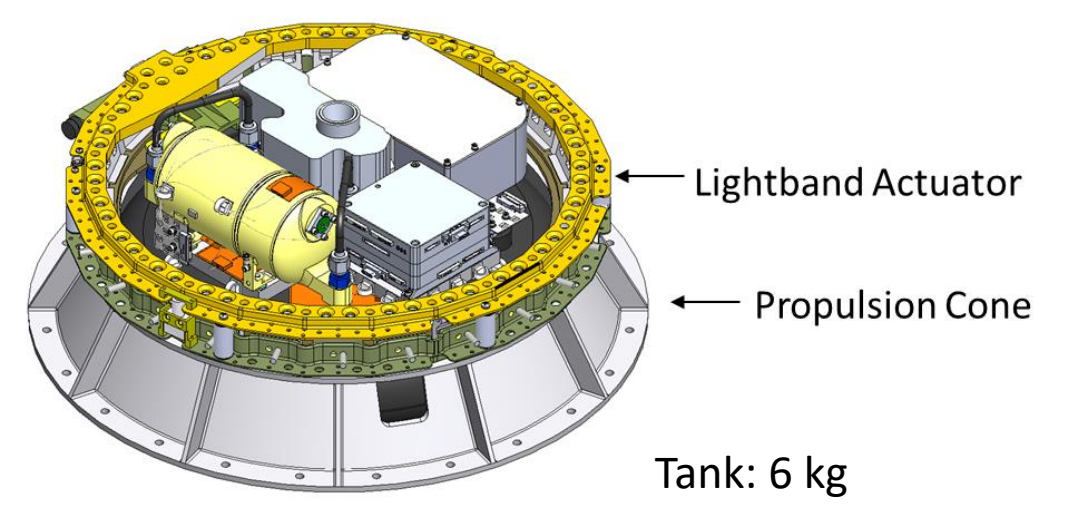
- Overview of HYDROS-C design
- Ground testing of the protoflight unit
  - Characterized performance over range of operational points
- On-orbit mission demonstration
  - Performance correlates with ground data

HYDROS on PTD-1 is the first ever on-orbit operation of a water electrolysis thruster

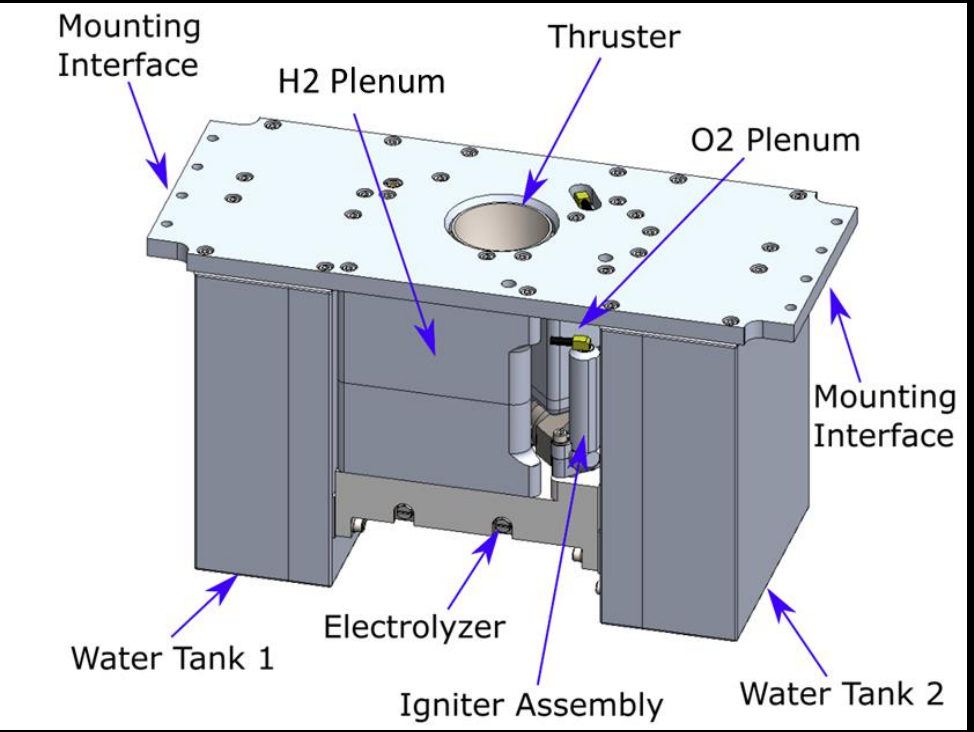
PTD-1 with HYDROS-C being loaded into the CubeSat deployer during launch integration

Image Credit: Lisa Middlebrook, Spaceflight

HYDROS® Architecture



MicroSat: HYDROS-M



CubeSat: HYDROS-C

HYDROS = Water tank(s)

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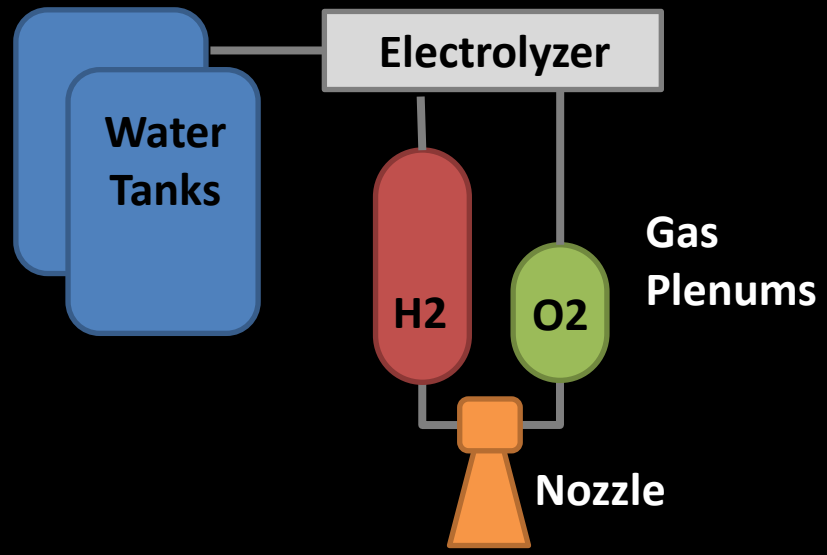
Core
- Electrolyzer
- H2 and O2 gas plenums
- Thruster nozzle
- Avionics controller

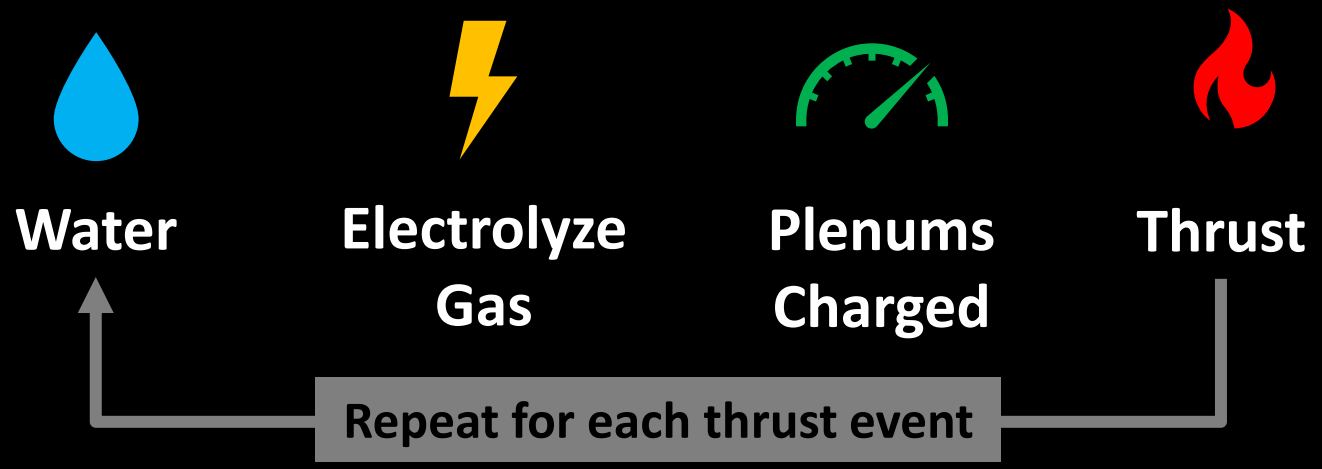
Size	Overall	Water Capacity
HYDROS-M	Ø15” (38 cm)	6 kg
HYDROS-C	2U x 1U x 1U	500 g

Conops Overview

Launch condition:

- Water stored as a liquid
  - Not considered to be a pressure vessel
  - Non-toxic so safe for ground handling
- Until on-orbit commissioning
  - Freeze tolerant
  - Unpowered





On-orbit operation:

- Electrolyzer generates gas proportional to current draw
- Fill plenums to chosen target pressure
- Thrust event releases stored gases that are combusted and expelled out the nozzle
  - Blowdown from plenum charge pressure to the pressure baseline
  - Combustion produces higher thrust with higher Isp than unburned water vapor

Ground Testing

Environmental Testing

Heritage: HYDROS-M

- Shock
- TVAC
- EMI/EMC

Unit: HYDROS-C only

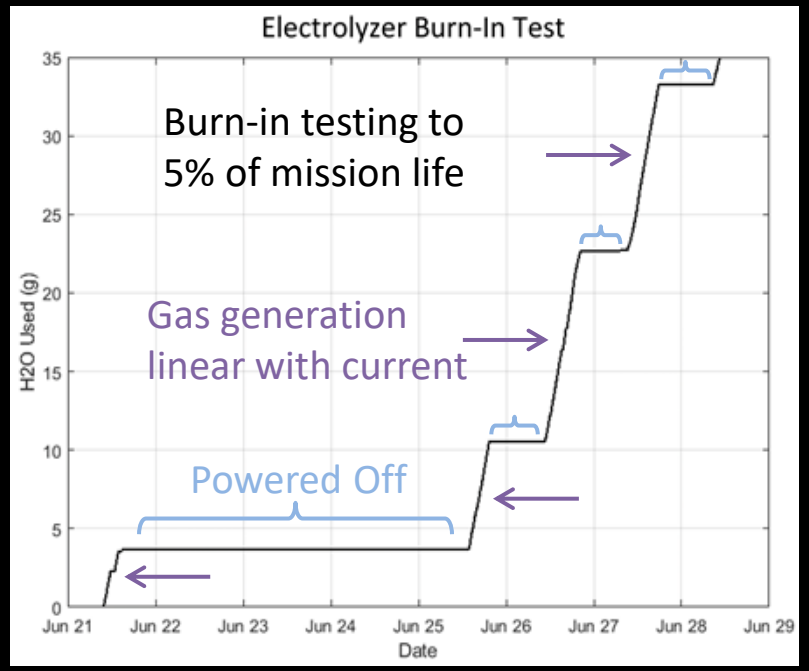
- Vibration
- Ambient thermal

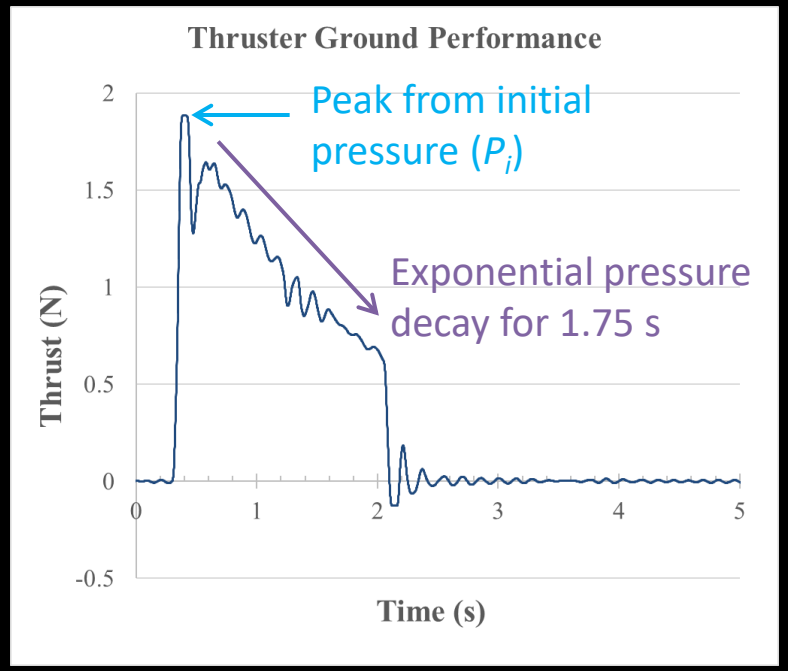
Spacecraft: PTD-1 & HYDROS-C

- Vibration
- TVAC

Thruster performance dependent on plenum pressure as a tunable operational parameter

Performance Testing



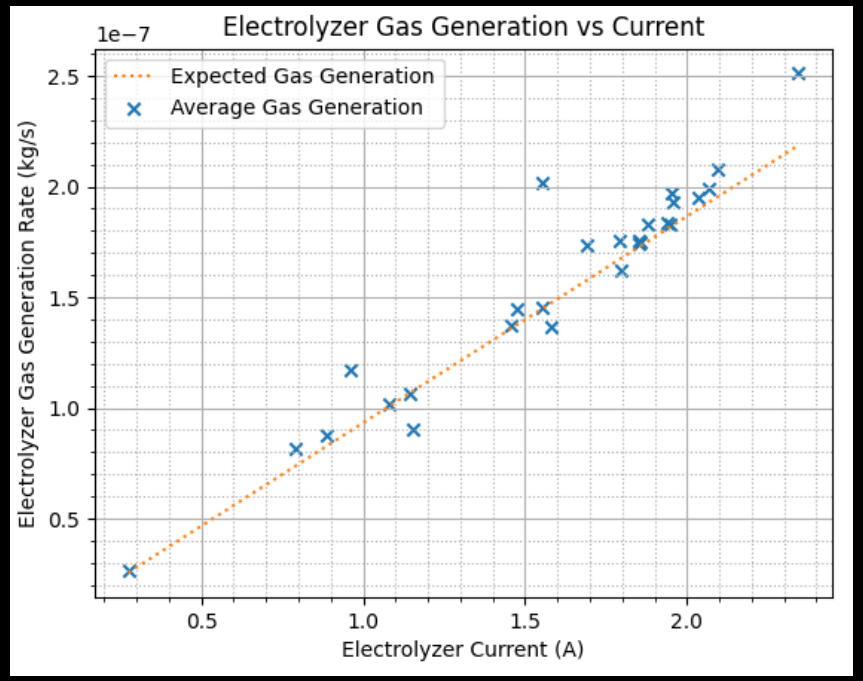


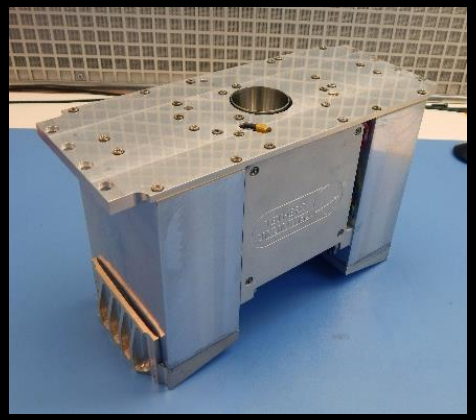
Trial	Avg P_i (psi)	Avg ΔP (psi)	I (Ns)	Isp (s)
1	198	111	1.96	**309**
2	113	63	0.99	269
3	51	27	0.15	91

Flight Data:
$P_i \approx 95$ psi
Isp ≈ 230 s

PTD-1 Mission Demonstration

Launched via rideshare in January 2021 on SpaceX Transporter-1



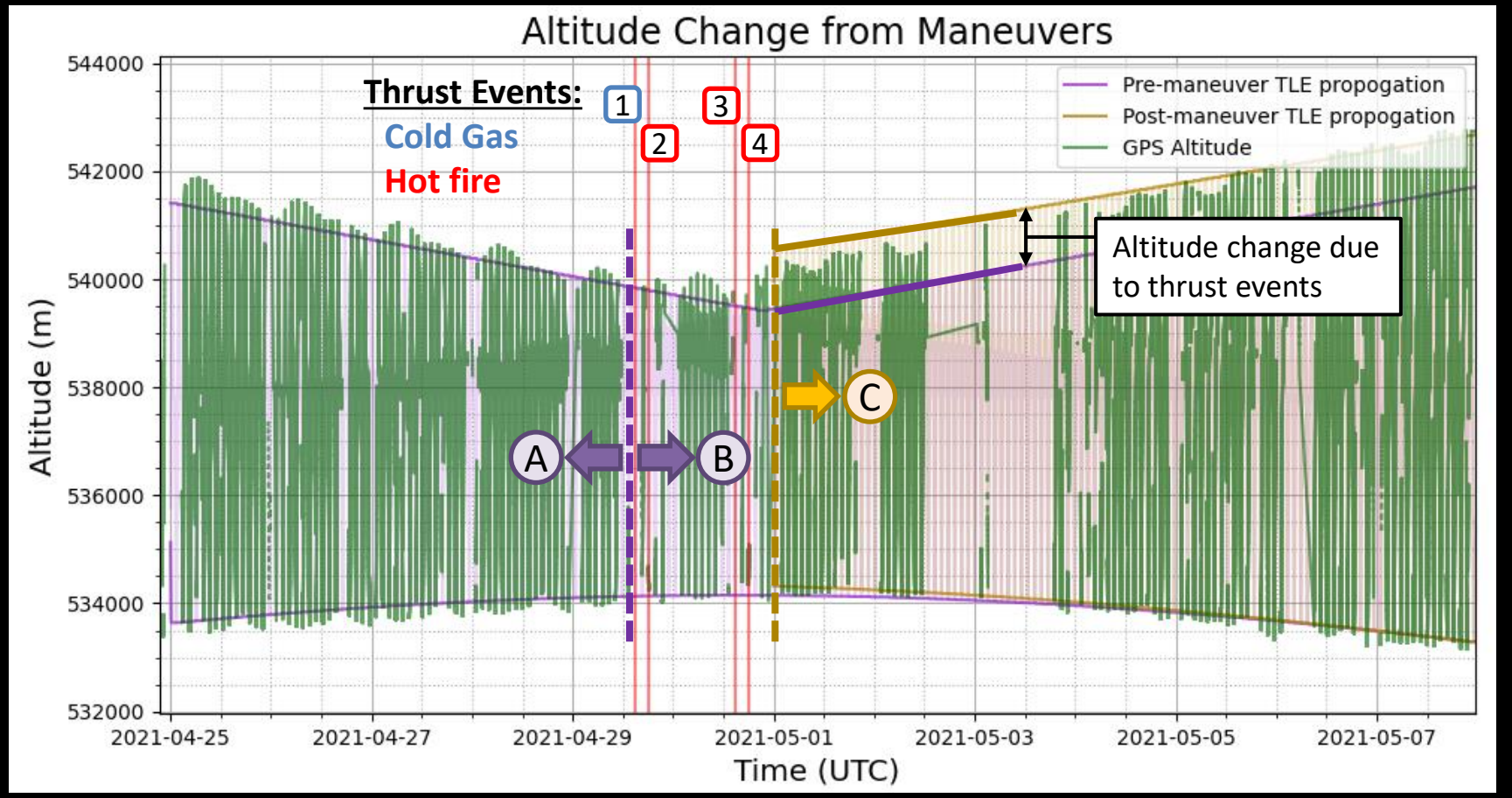


HYDROS-C flight unit prior to integration

On-orbit Electrolysis Performance

- Rate calculated from rise in plenum pressure from floor to target during each electrolysis cycle
- On-orbit data matches well with expected gas generation based on electrochemical reaction

PTD-1 Mission Demonstration



Region A: Propagate NORAD TLE back to compare against GPS during 'no-thrust' time

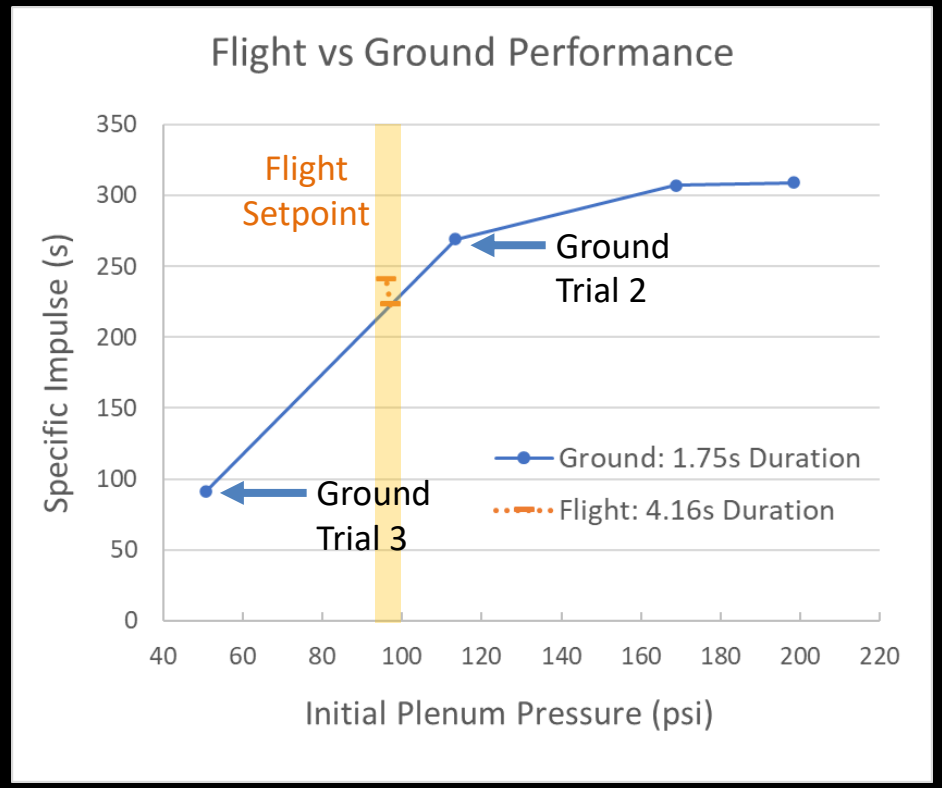
Region B: Propagate NORAD TLE forward as 'no-thrust' predict

Region C: Propagate NORAD TLE forward as new 'post-thrust' orbit

Orbit change due to thruster performance

- No on-board sensors to measure acceleration from thrust events
- Rely on orbit changes to back out thruster performance

Comparison of Flight vs Ground



Preliminary Performance Based on Orbit Change

Description	NORAD TLE	GPS
Pre-maneuver perigee (m)	533318	
Pre-maneuver apogee (m)	541670	
Post-maneuver perigee (m)	533314	533339
Post-maneuver apogee (m)	542640	542721
Total maneuver impulse (N-s)	3.12	3.38
Specific impulse, Isp (s)	223	241

Refinement of orbit determination is still on-going

Flight Operation Differences Compared to Ground Testing

- Lower target plenum charging pressure
- Longer thrust duration

On-orbit performance validates the ground testing correlation between plenum charge pressure and specific impulse

Forward Work & Closing Remarks

Summary of On-orbit Performance

- Electrolyzer design validated
- Thruster performance matches ground testing trend data

TRL 8

Image Credit: SwRI

What's next for HYDROS?

- PTD-1 mission data processing
- More commercial flights coming up
- Maturing advanced mission concepts such as on-orbit refueling and applications beyond Earth orbit

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