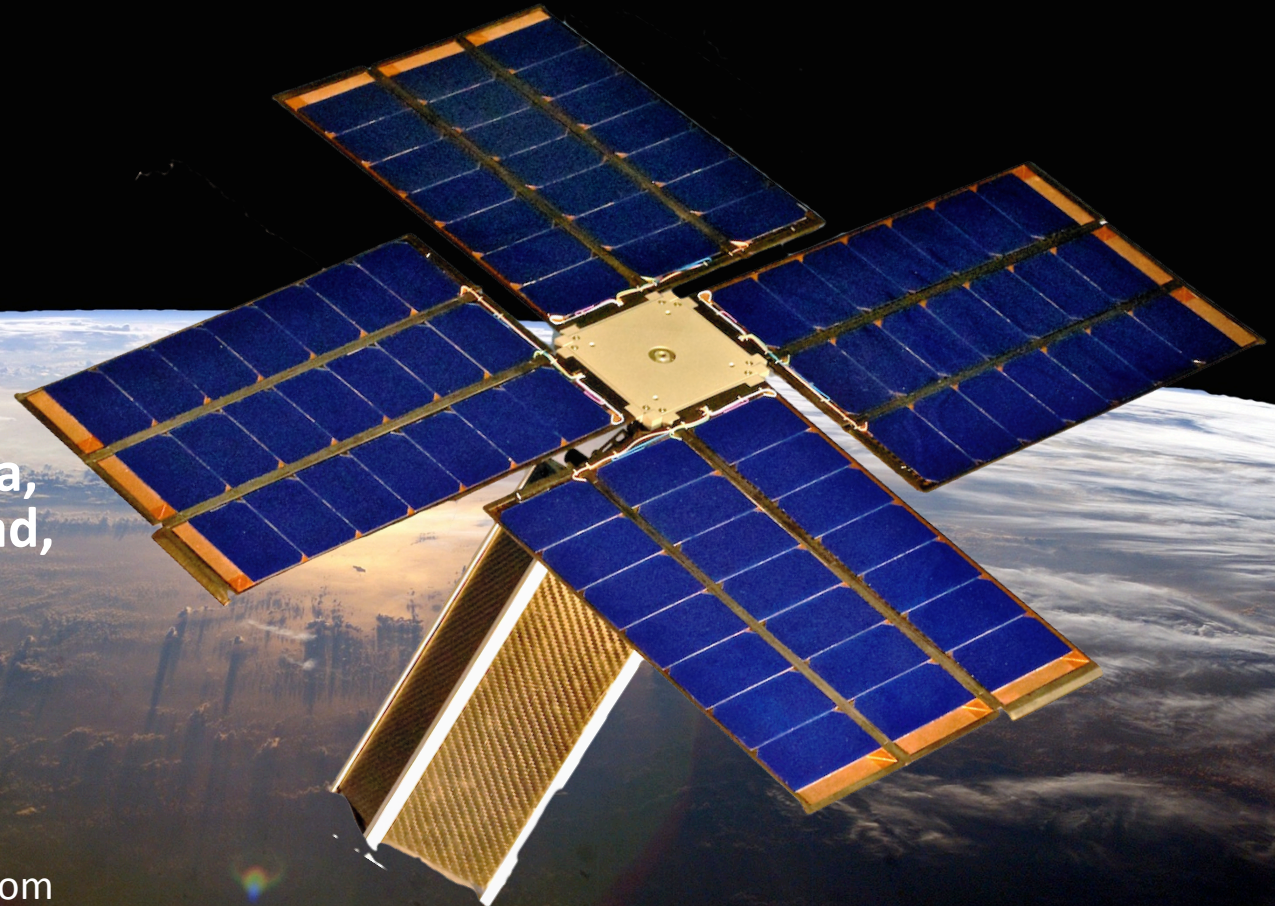




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# *High Power Panels to Enable High-Performance CubeSat Missions*



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# High Performance CubeSats

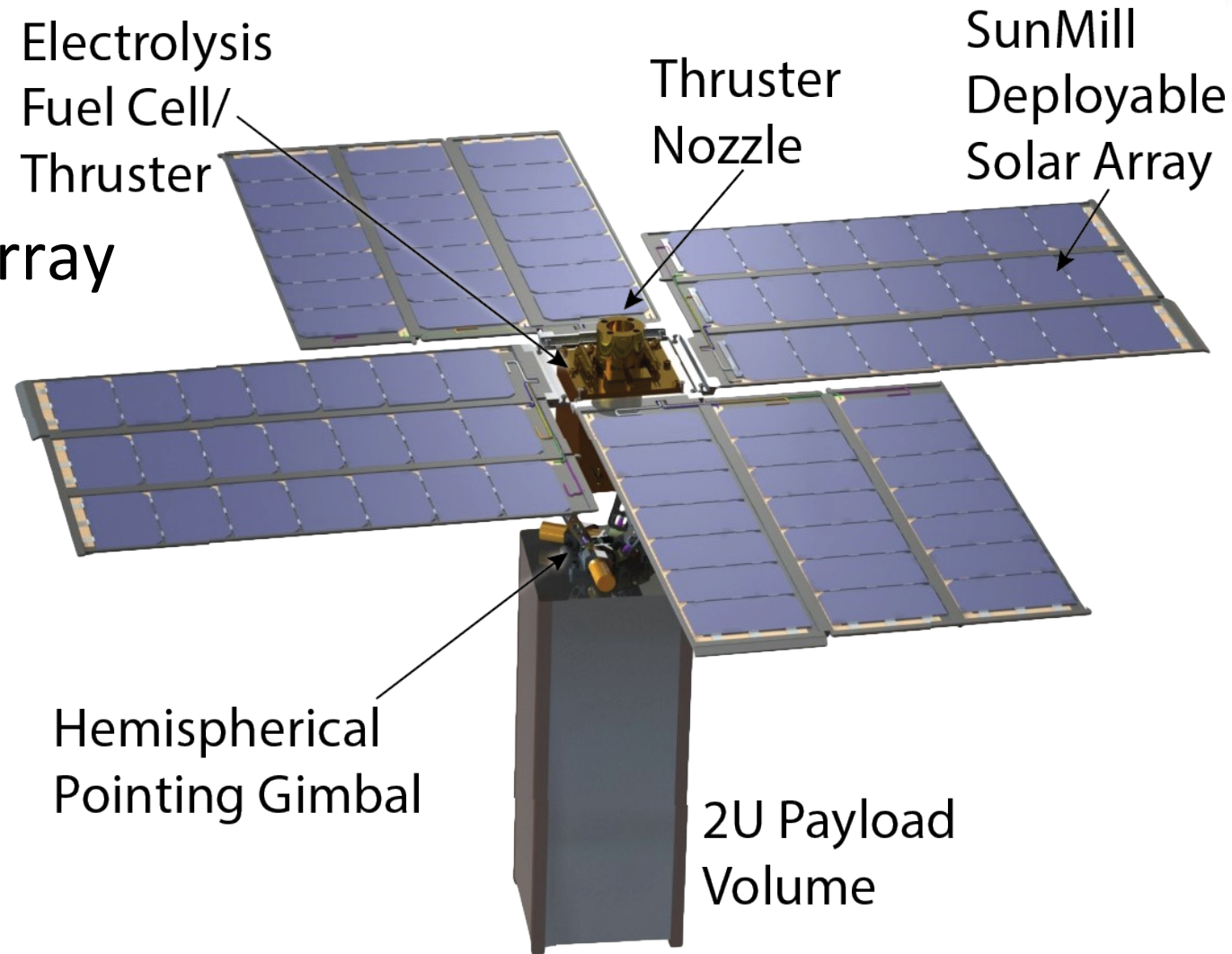
## Outline

- **New Systems**

- Deployable Array
- Gimbal
- Propulsion
- Comm.

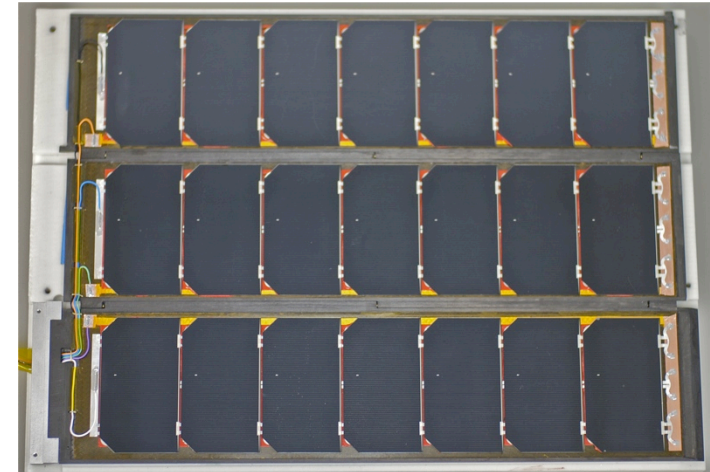
- **Lessons Learned**

- **New Mission Capabilities**

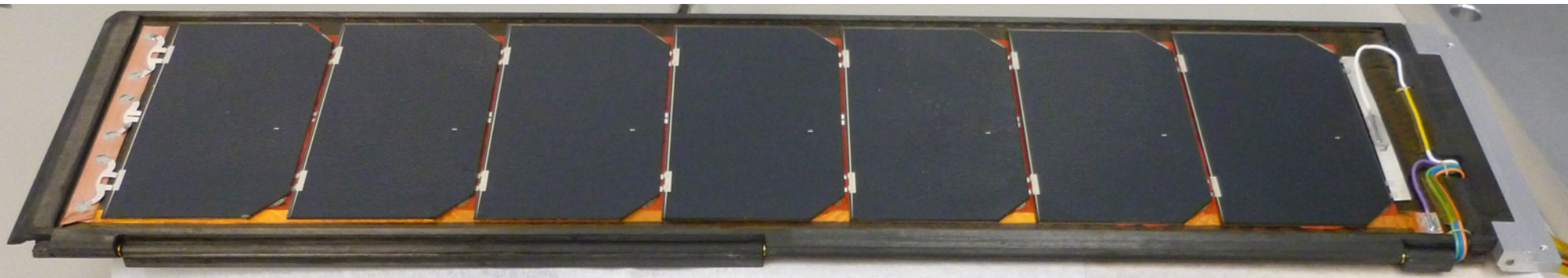


# Deployable Array Overview

- **Power System Goals:**
  - Low volume
  - High reliability/low risk
  - Simplified operation
- **12x 2mm thick composite panels**
  - 3 panels per side of the CubeSat
- **80W peak and 49W OAP delivered from PPU**
- **Full hemispherical pointing achieved by the Gimbal mechanism**
- **Developed via the Army SBIR program**



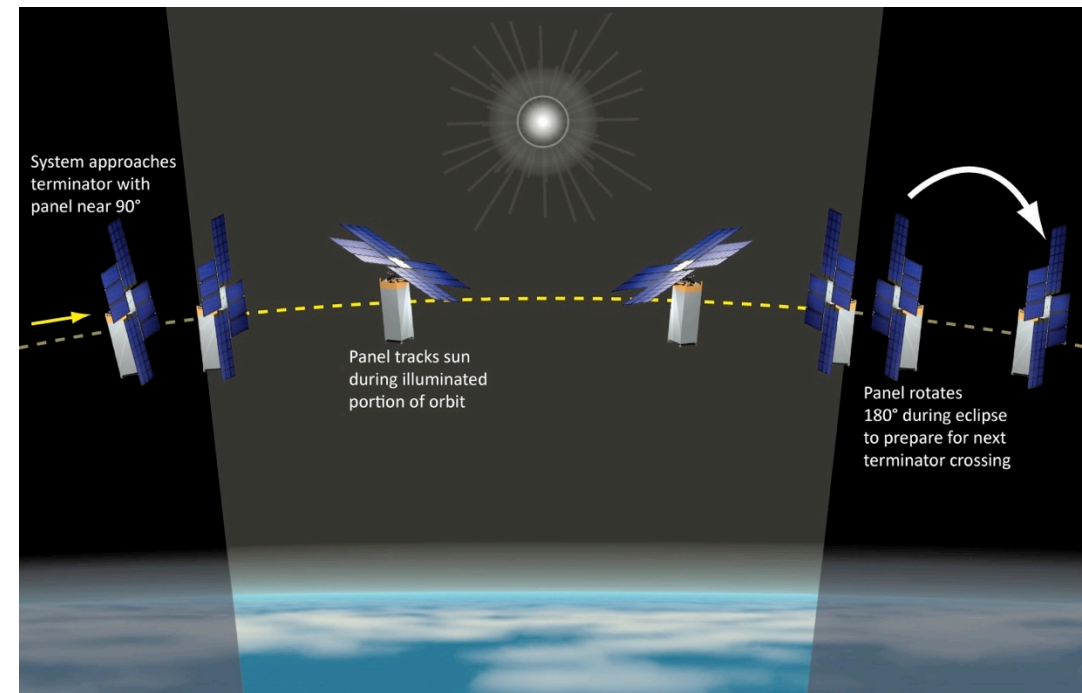
# Composite Solar Panels



- **Carbon fiber structure composed of unidirectional and woven fibers strategically placed for stiffness profile**
- **Each panel 1 mm thick plus 1 mm rails around cells**
- **Embedded Cu tape reduces need for wiring on panels**
- **Built-in hinge features reduce part count and increase manufacturing reliability**
- **Outer panels' cells face away from body providing the option for pre-deployment power**

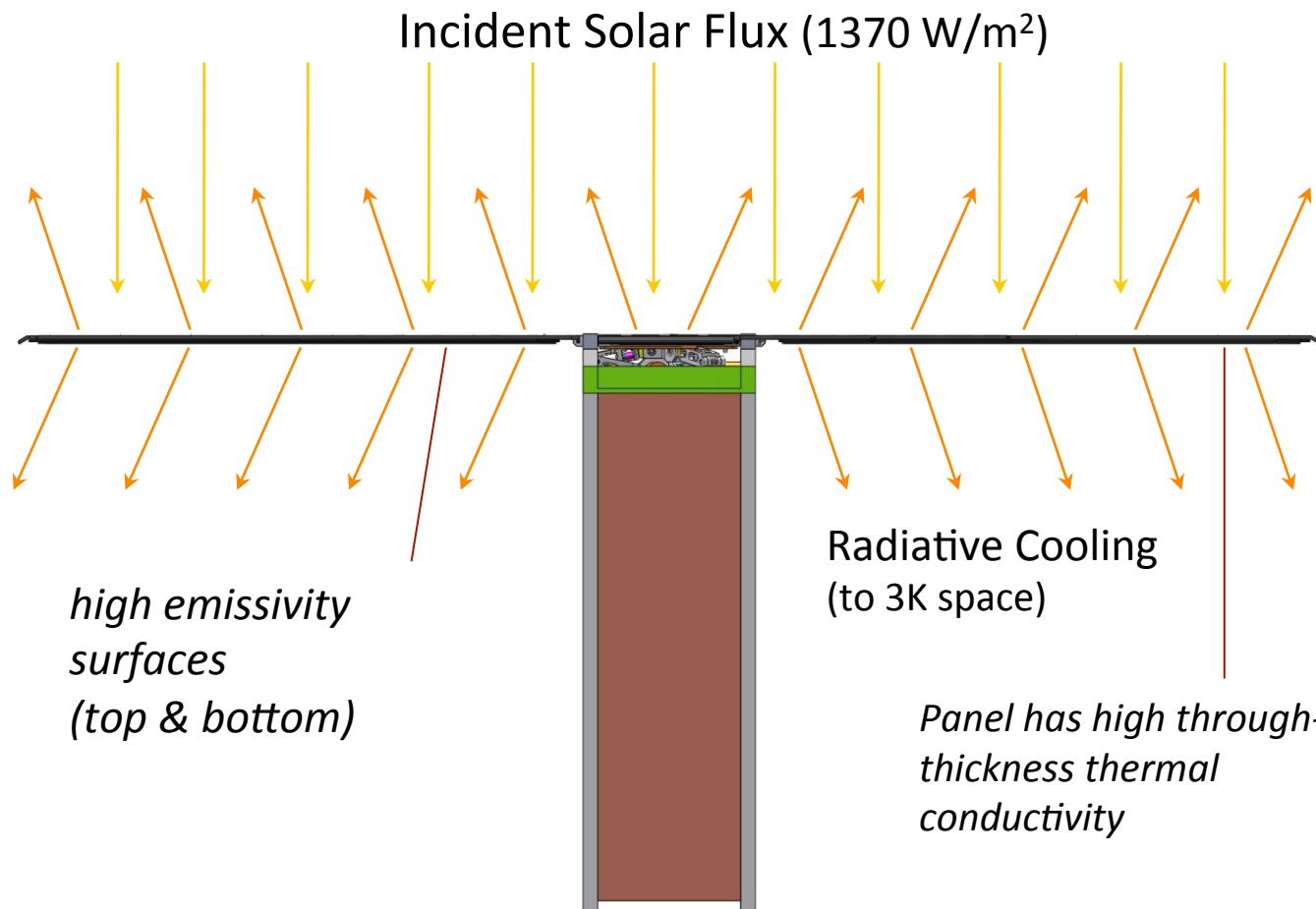
# Deployable Array CONOPS

- **Discrete movement of the panels**
  - Gimbal can move panel  $2.5^\circ$  ahead of incidence angle and then power down until panels fall  $2.5^\circ$  behind incidence angle
- **This operation scheme allows for power savings by powering down the motors and relying on the detent torque through the gearhead to hold the panels in place.**



# Steady State Temp Thermal Analysis

- Carbon fiber panels will be 78% covered by solar cells
- Due to panel thinness, good thermal conduction to the back side allows comparable radiative cooling to Al

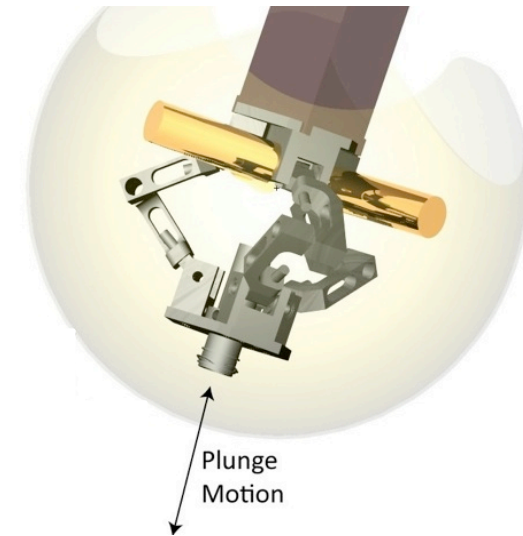


Configuration	Panel Temp
Al Panels	64 C
<b>CF Panels</b>	<b>65 C</b>
PCB Panels	71 C
Body Mount	124 C

Panel Design Maximizes Cell Efficiency and Shades CubeSat Body

# “Carpal-Wrist” Gimbal

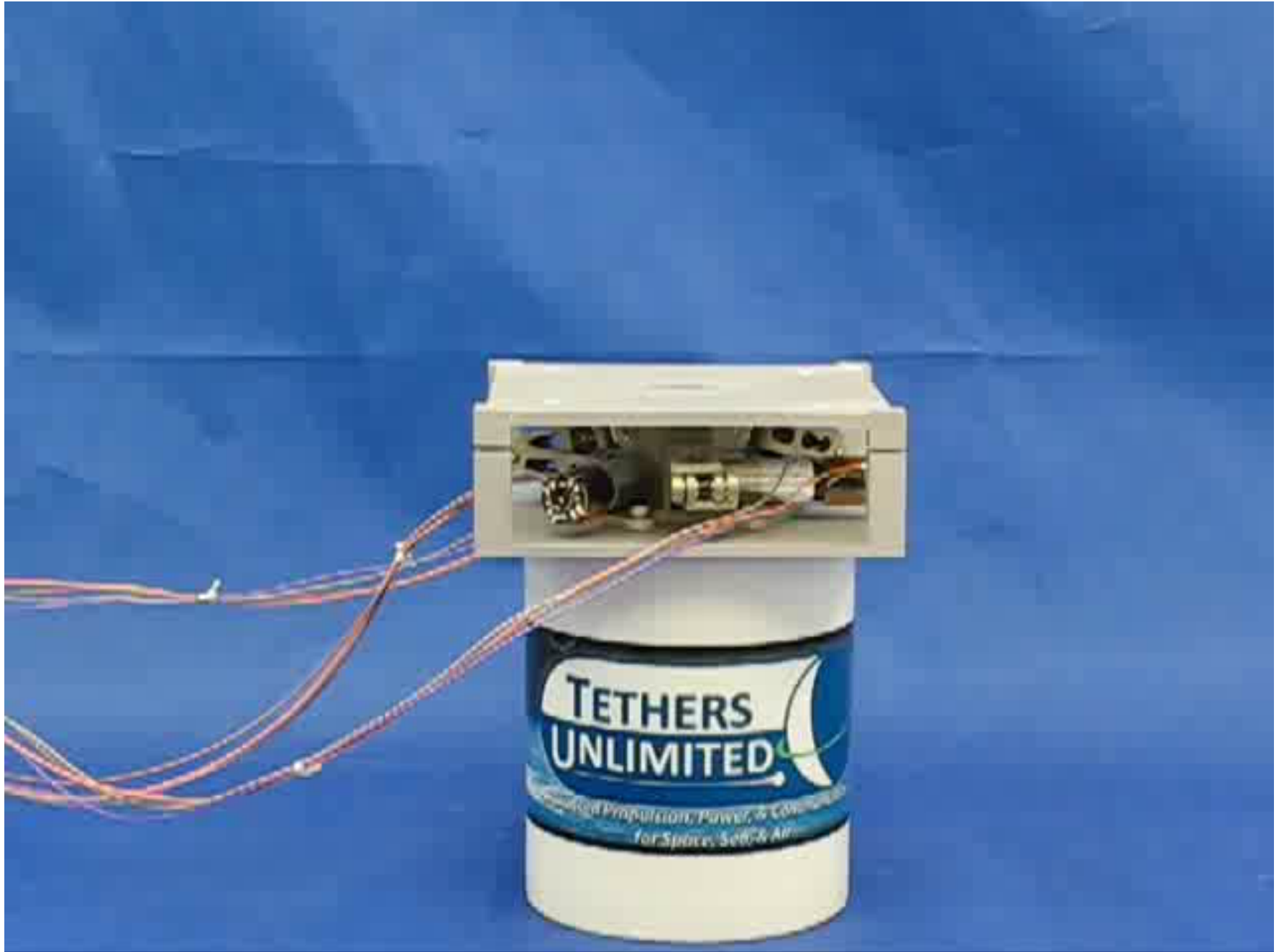
- **3 stepper motors achieve 3 DOF**
  - Hemispherical pointing on nearly any radius
- **Gimbal motivates panel deployment**
  - No added actuators needed
- **Mechanism designed for accuracy over an extended lifetime**
  - Simulated 3 years of orbital motion and maintained accuracy to remain within 1% of peak power
- **No cable windup**
  - Gimbal mechanism does not twist, allowing cables to easily pass through mechanism
- **Qualified to CDSv12 requirements**



# Gimbal Video



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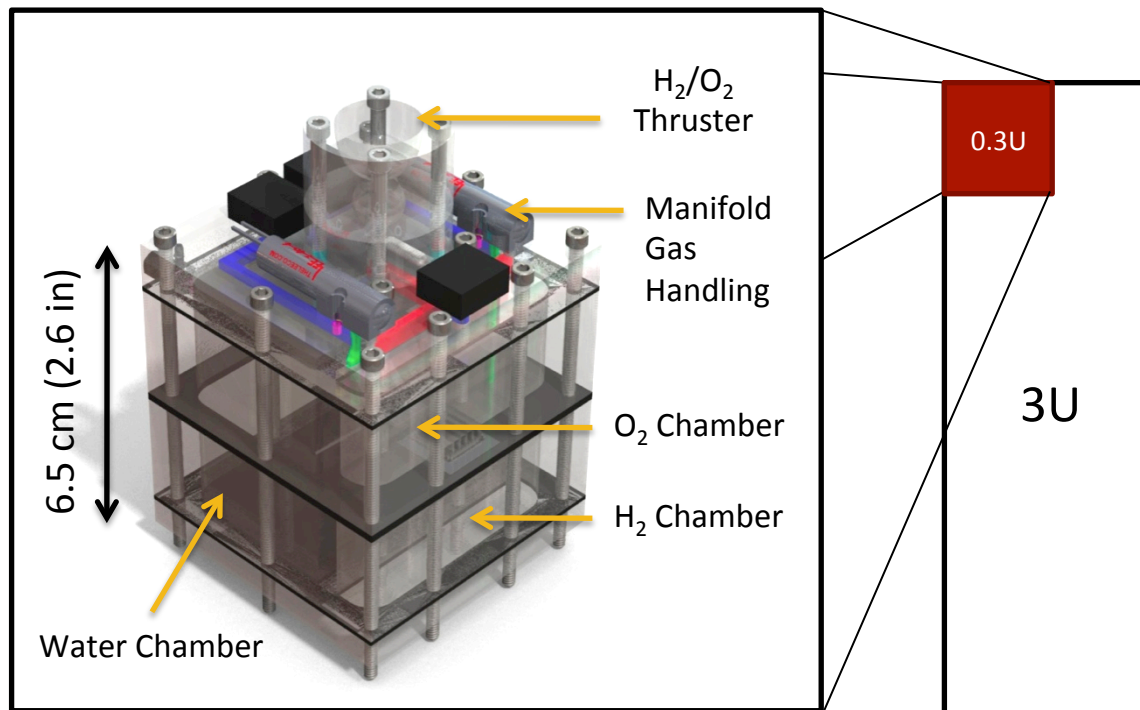


# Power-Enabled Propulsion

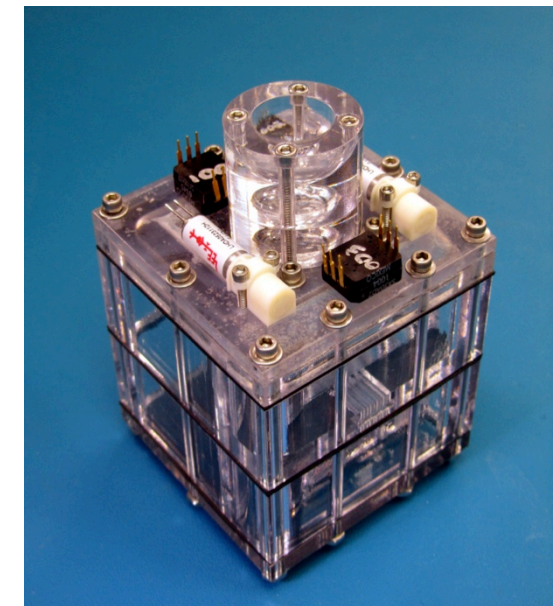
## Water Electrolysis Thruster (WET) Propulsion

- On-orbit electrolysis of water into  $gO_2$  and  $gH_2$  enables high- $I_{sp}$  propulsion while avoiding stored energy on launch to conform to P-POD requirements
- High-thrust rates: up to 6 m/s of  $\Delta v$ -per-orbit for a 3 kg CubeSat
- 500  $\mu N$ -s bit-impulse, appropriate for attitude control and station keeping
- Modular, stand-alone propulsion module

Design



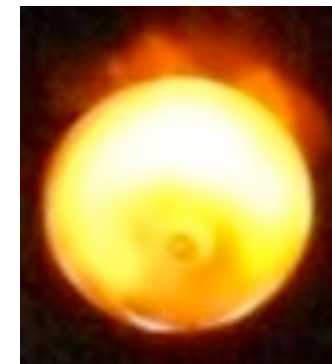
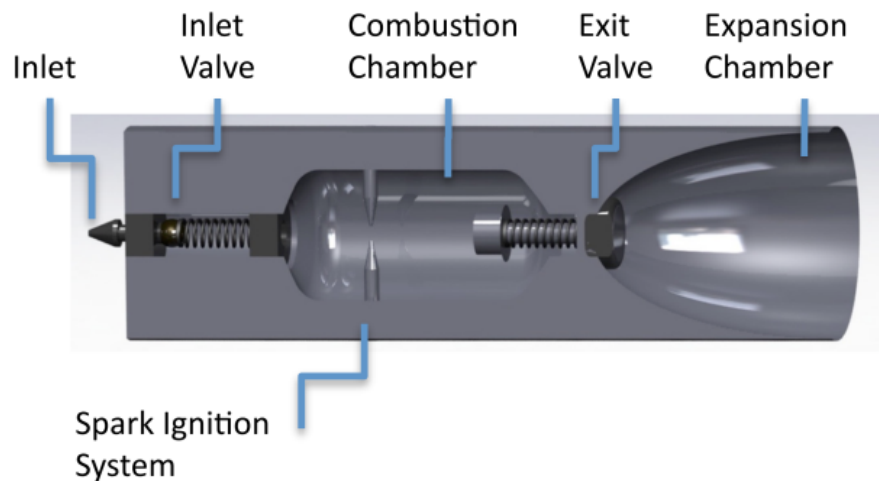
Prototype



# Power-Enabled Propulsion

## Scalable Propulsion

- The WET propulsion unit is highly deformable and can be easily scaled to a desired total impulse or interior volume form factor
- Favorable scaling: 300 Ns per 100g of water (100 m/s  $\Delta v$  for a 3 kg CubeSat)
- The thruster can be designed to fit in the interior volume of the PPOD pusher-plate spring, freeing the 3U volume
- Completely green propulsion system, using de-ionized water
- The advantage over similar-scale electric propulsion approaches is the higher  $\Delta v$  available per orbit and the cleaner exhaust plume of the  $H_2/O_2$  rocket.



Test Firing

- **More power enhances CubeSat communications**
  - More power → higher EIRP (radiated power)
  - Higher EIRP → faster data rates
  - Higher EIRP → more link margin
  - More sophisticated processing w/ SDRs
    - Lower bit error rates
    - Spectrally efficient waveforms → faster data rates
    - Improved filtering for spectral mask compliance
    - Digital predistortion maintains spectral efficiency over system lifetime

# SWIFT-SDR™ CubeSat Radios



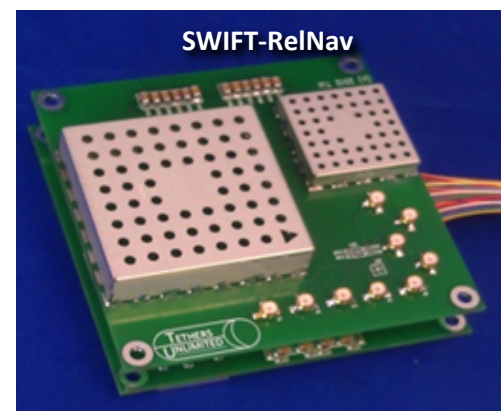
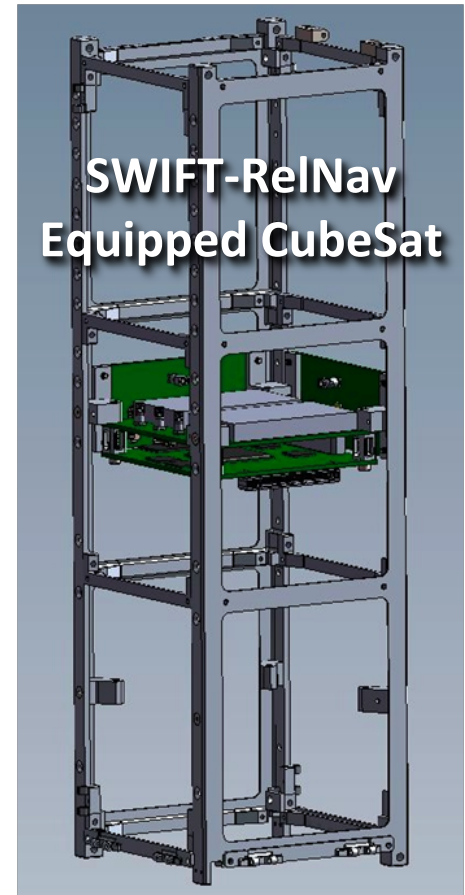
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- **Unprecedented capabilities for CubeSat applications**
- **Programmable**
  - FPGA-based w/ lots of RAM and Flash
- **Flexible**
  - Multiple RF frontends to support different bands
  - Flexible host spacecraft interfaces
  - 100% runtime programmable
- **Compatible**
  - 82mm square for Colony-II bus
  - Type-1 encryption ready
- **High performance**
  - >100 MHz bandwidth
  - 100% phase coherent
- **Reliable and fault tolerant**
  - Latchup detection and protection
  - Thermal and power monitoring





- **Cluster navigation, communication, and timing**
- **Performance**
  - $< 0.1$  m ranging precision ( $1-\sigma$ )
  - $< 1^\circ$  attitude precision ( $1-\sigma$ )
  - Crosslink data rate  $> 15$  Mbps
  - Timing synchronized to  $< 20$  ns ( $1-\sigma$ )
  - No sensor pointing required
  - No external references (i.e. GPS) required
  - Scalable to large number of spacecraft
  - Specified performance up to 10 km
- **SWaP**
  - 82 x 82 x 25 mm
  - 0.4 kg
  - 3.2 W RX
  - 6.9 W peak TX

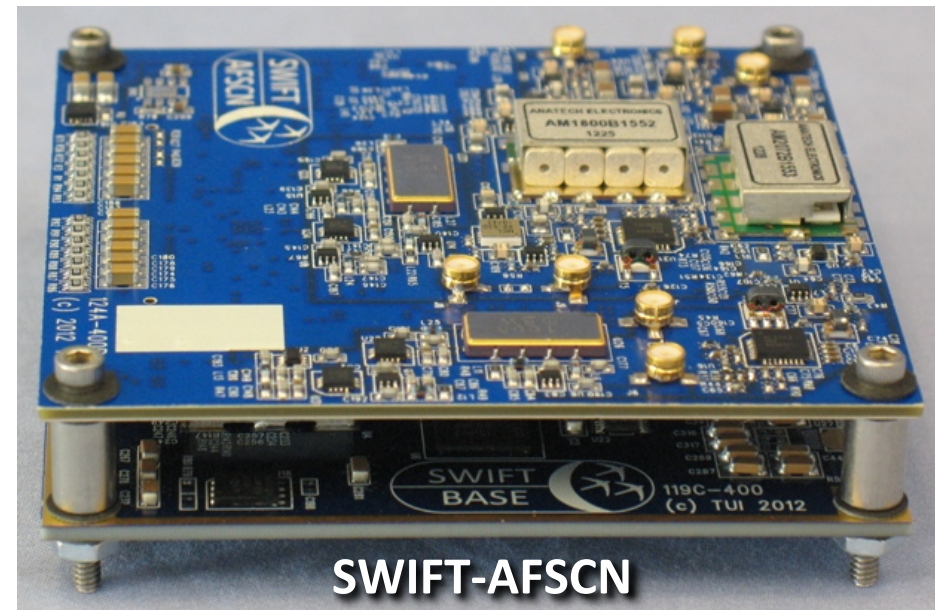


# SWIFT-AFSCN™ Specifications



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- **Simultaneous dual-band receiver**
  - SGLS: 1760-1840 MHz
  - USB: 2025-2100 MHz
- **>1W transmitter**
  - S-band: 2200-2300 MHz, > 30 MHz BW
- **Encryption ready**
  - Integrated AES-256 encryption
  - Compatible w/ Type-1 encryption
- **100% runtime programmable**
- **Coherent turn-around ranging**
- **SWaP**
  - 82 x 82 x 25 mm
  - < 0.4 kg
  - 3.2 W RX
  - 6.9 W peak TX



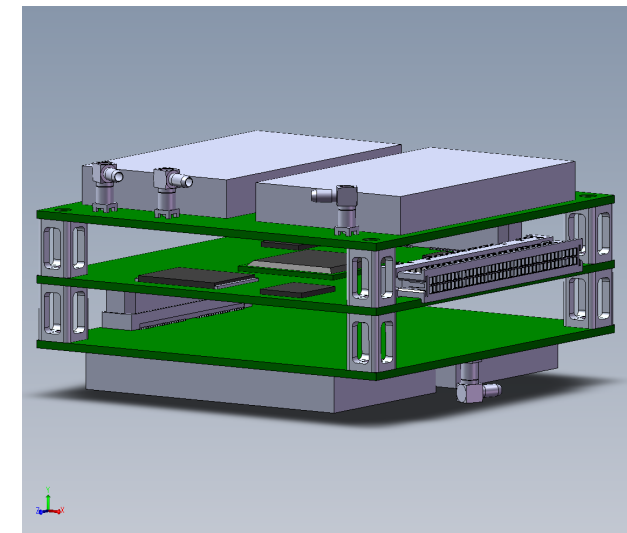
SWIFT-AFSCN

# SWIFT-TacSatComm™



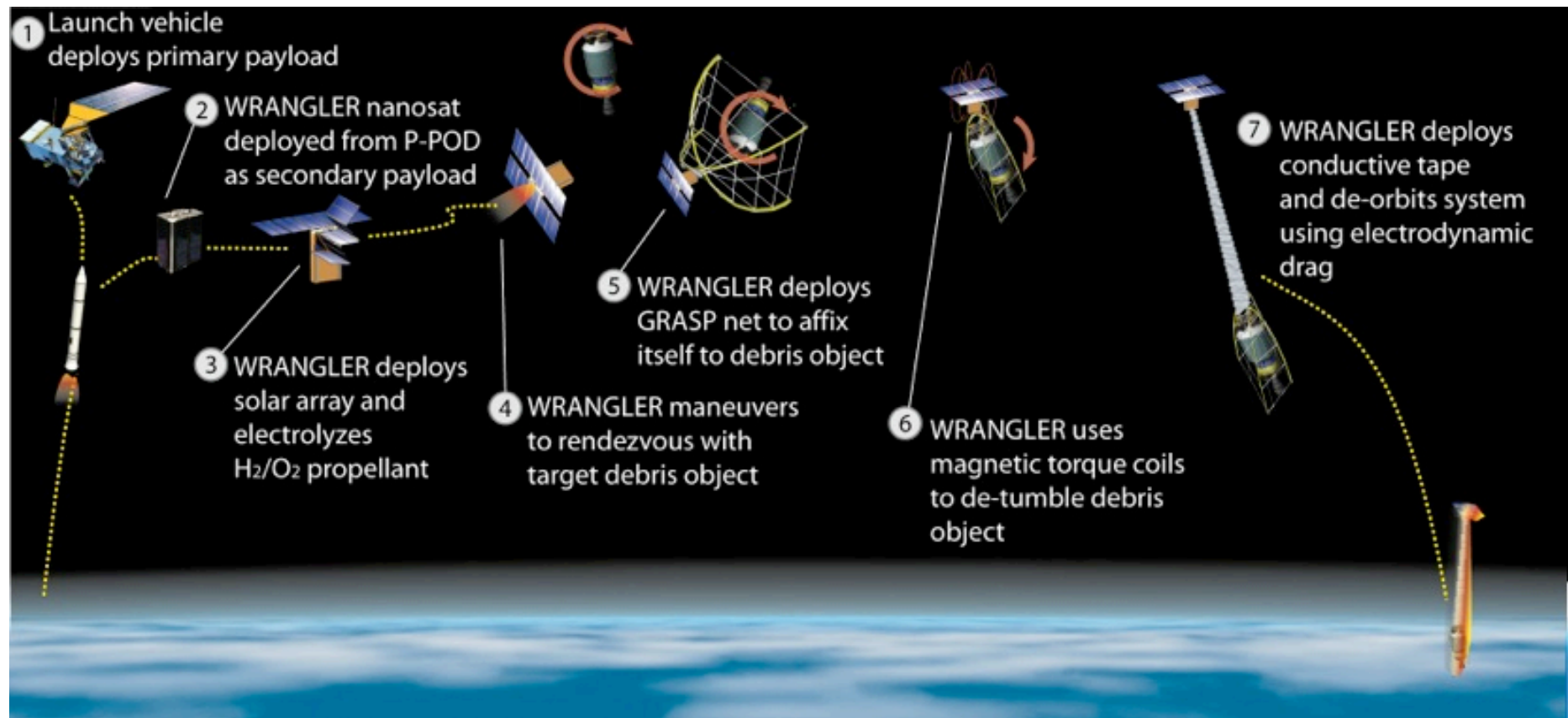
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- **System to communicate w/ standard Army issue handheld radio**
- **Dual-band transceiver**
  - UHF @ 56 kbps
    - > 4 W transmit power, with EIRP > 10 W
  - S-band backhaul link
  - Encryption, FEC, Doppler compensation
- **High gain antenna**
  - Deployable
  - Steerable w/ gimbal
- **SWaP**
  - Size: 0.5-1U
  - Power: < 14.7 Watts



# New Mission Capabilities

- Orbit Agility for Reconfigurable CubeSat Constellations
- Cis-Lunar CubeSat missions
- Orbital Debris Remediation using CubeSats







# TETHERS UNLIMITED.

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