



CubeQuest CHALLENGE

NASA's CubeQuest Challenge: Ground Tournament 4 Results and Technology

Liz Hyde

Millennium Engineering and Integration

NASA Ames Research Center

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Agenda

What is CubeQuest?

- NASA Centennial Challenges
- The CubeQuest Challenge
 - Challenge Structure
 - Prizes!
 - SLS Integration

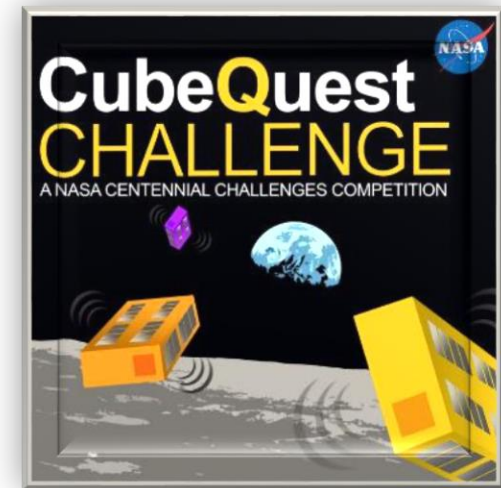
The Teams

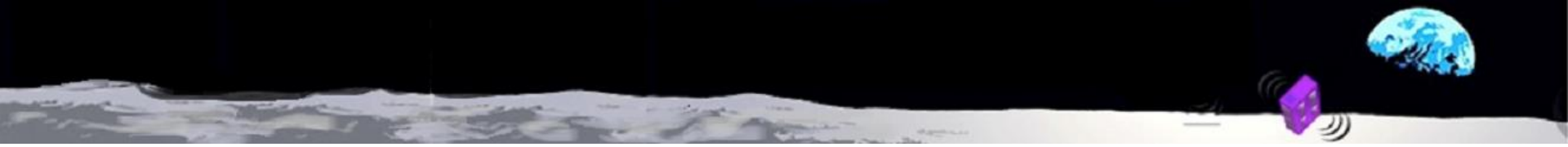
- GT1-3 Winners/Prizes
- GT4 Winners

The Technologies

- Propulsion
- Communications
- Other Tech

Next Steps





CubeQuest Challenge

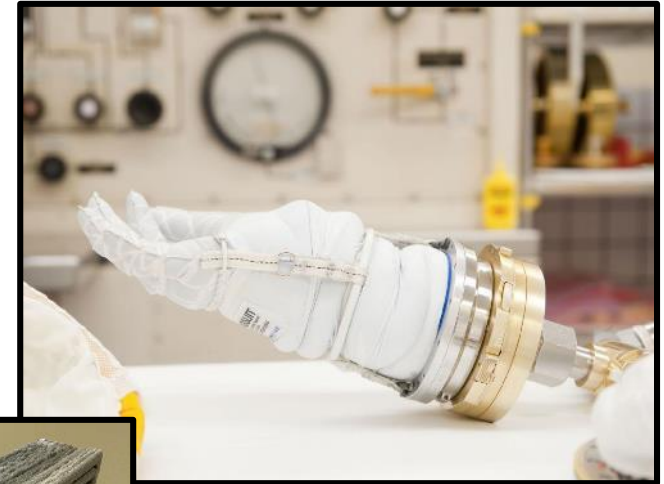
WHAT IS CUBEQUEST

What is CubeQuest?



NASA Centennial Challenges

- Space Technology Mission Directorate created Centennial Challenges in 2005
- Since 2005, over \$6m has been given out as prizes
- Past Challenge include Sample Return Robots, Astronaut Gloves, Strong Tethers, and Green Flight
- Current Challenges: 3D-Printed Habitat, Space Robotics, Vascular Tissue, and CubeQuest

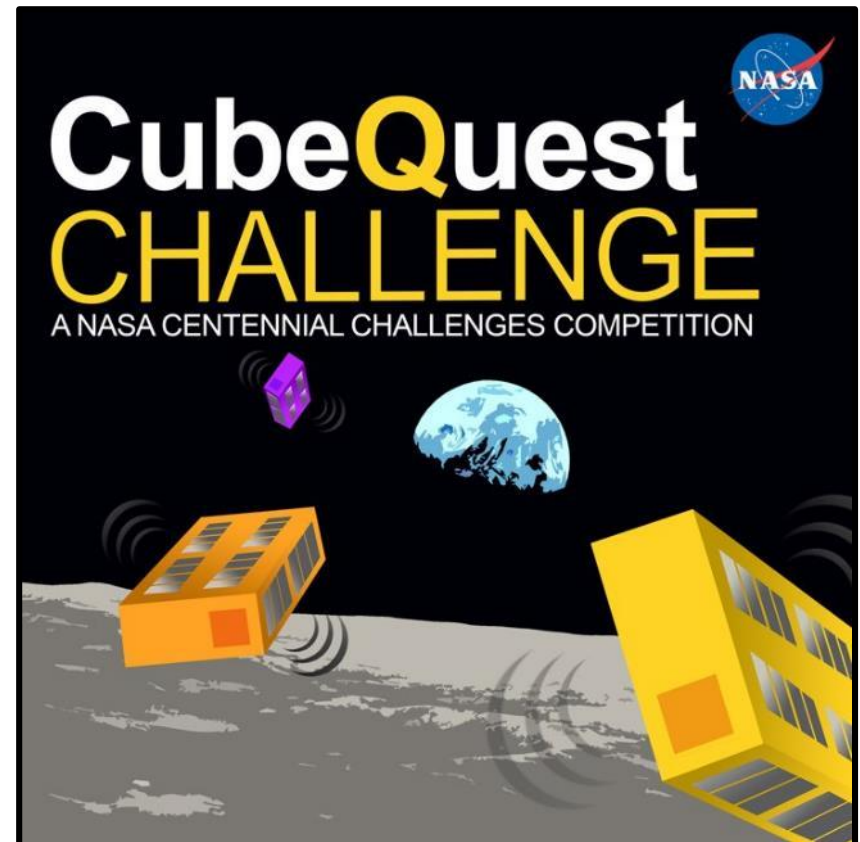


What is CubeQuest?



The Cube Quest Challenge

- Designed in 2013
- Official “Kick-Off” in January 2015
- \$5m in total prize money
 - Plus SLS Launch Opportunity
- Non-government, US entities eligible
- Both Ground and In-Space competitions
 - 4 “Ground Tournaments”
 - 2 in-space “Derbies”, with multiple prizes per Derby



What is CubeQuest?



Competitions & Prizes

Ground Tournaments

Ground Tournament 1: August, 2015

“MCR/SRR” Level	Top 5 - \$20,000
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Ground Tournament 2: March, 2016

“PDR” Level	Top 5 - \$30,000
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Ground Tournament 3: October, 2016

“CDR” Level	Top 5 - \$30,000
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Ground Tournament 4: June, 2017

Between “CDR” and “SAR/FRR” Level	Top 3 - \$20,000
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CubeQuest is the first government challenge to take place in space!

Lunar/Deep Space Derbies

Lunar Derby

Achieve Lunar Orbit	\$1.5 M (shared)
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Best Burst Data Rate	\$250,000
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Largest Aggregate Data Volume	\$750,000
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Spacecraft Longevity	\$500,000
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Deep Space Derby

Farthest Communications Distance (>4m Km)	\$250,000
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Best Burst Data Rate	\$250,000
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Largest Aggregate Data Volume	\$750,000
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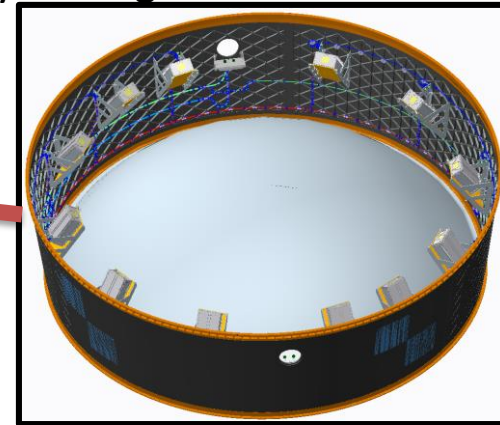
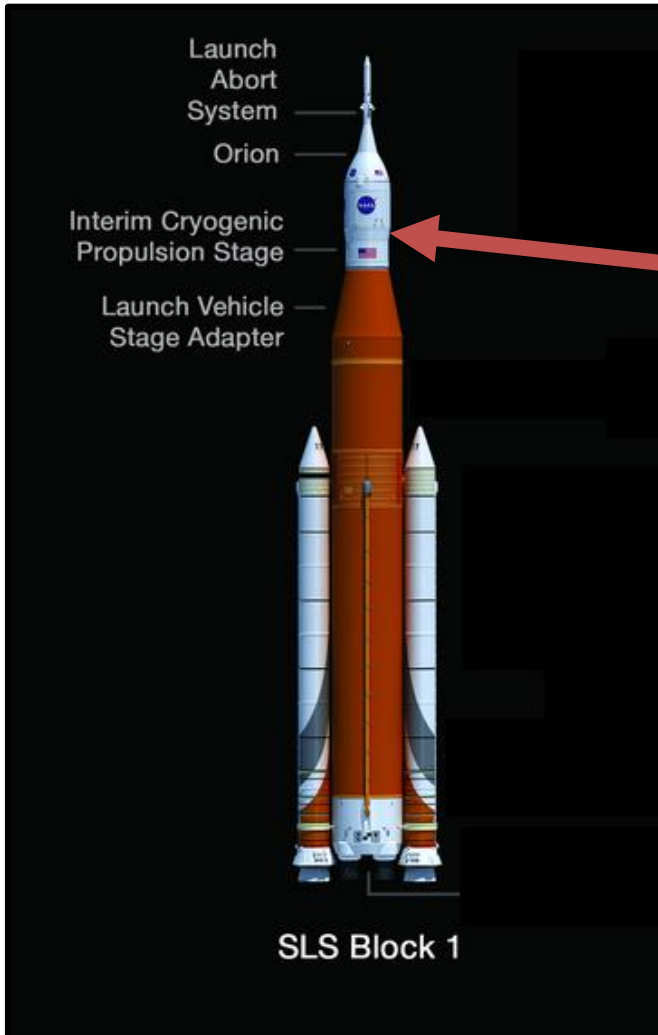
Spacecraft Longevity	\$500,000
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What is CubeQuest?



SLS EM-1 Launch Opportunity

3 of the 13 secondary payloads on SLS EM-1 will qualify through the CubeQuest Challenge



What is CubeQuest?



The Path to EM-1

CubeQuest EM-1 Launch Checklist:

- Top 5 finisher in either GT-1 or GT-2
- Top 3 finisher in GT-4
 - Score >3.0 in GT-4
- Complete/Pass all SLS Safety Reviews
- ✓ Get manifested!



EM1 Secondary Payload Manifest

BioSentinel	AES
NEA Scout	AES
Lunar Flashlight	AES
Lunar IceCube	AES
SkyFire	SMD
CuSP	SMD
LunaH-Map	SMD
EQUULEUS	JAXA
OMOTENASHI	JAXA
ArgoMoon	ASI
CisLunar Explorers	STMD
CU-E3	STMD
Team Miles	STMD



CubeQuest Challenge

THE TEAMS

Ground Tournaments Lead to EM-1 Launch

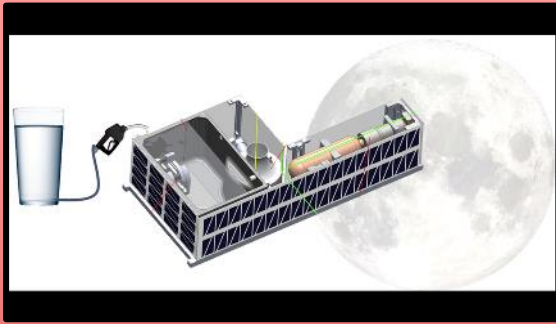


GT1 – 13 Teams	GT2 – 10 Teams	GT3 – 7 Teams	GT4 – 5 Teams
<ul style="list-style-type: none"> • Alpha Cubesat - Xtraordinary Innovative Space Partnerships, Inc (Cabin John, MD) • Cislunar Explorers - Cornell University (Ithaca, NY) • HuskySat - University of Washington (Seattle, WA) • Lunar CubeQuestador - Missouri University of Science and Technology (Rolla, MO) • MIT KitCube - Massachusetts Institute of Technology (Cambridge, MA) • Novel Engineering - Novel Engineering Inc. (Cocoa Beach, FL) • OpenOrbiter Lunar I - University of North Dakota (Grand Forks, ND) • ERAU Eagles - Embry-Riddle Aeronautical University (Daytona Beach, FL) • Project Selene - Flintridge Preparatory School (La Cañada Flintridge, CA) • Heimdallr- Ragnarok Industries, Inc. (Wilmington, DE) • SEDS - University of California - San Diego (San Diego, CA) • Team Miles - Fluid & Reason LLC (Tampa, FL) • True Vision Robotics - Isakson Engineering (Atacsadero, CA) <p style="text-align: center;">Top 5 teams were awarded \$20,000 and qualified for EM-1 launch opportunity</p>	<ul style="list-style-type: none"> • Alpha CubeQuest, XISP Inc (Cabin John, MD) • Cislunar Explorers, Cornell University (Ithaca, NY) • Eagles-Quest, Embry-Riddle Aeronautical University (Daytona Beach, FL) • Earth Escape Explorer (CU-E3), University of Colorado, Boulder (Boulder, CO) • Goddard Orbital and Atmospheric Testing Satellite (GOATS), Worcester Polytechnic Institute (Worcester, MA) • Lunar CubeQuestador, Missouri University of Science & Technology (Rolla, MO) • MIT KitCube, Massachusetts Institute of Technology (Cambridge, MA) • Heimdallr, Ragnarok Industries Inc. (Wilmington, DE) • SEDS Triteia, SEDS University of San Diego (San Diego, CA) • Team Miles, Fluid & Reason LLC (Tampa, FL) <p style="text-align: center;">Top 5 teams were awarded \$30,000 and qualified for EM-1 launch opportunity</p>	<ul style="list-style-type: none"> • Team Miles Fluid & Reason (Tampa, FL) • Cislunar Explorers - Cornell University (Ithaca, NY) • CU-E3- University of Colorado, Boulder (Boulder, CO) • KitCube - Massachusetts Institute of Technology, (Cambridge, MA) • SEDS Triteia - University of California, San Diego (San Diego, CA) • Heimdallr, Ragnarok Industries Inc. (Wilmington, DE) • Goddard Orbital and Atmospheric Testing Satellite (GOATS), Worcester Polytechnic Institute (Worcester, MA) <p style="text-align: center;">Top 5 teams were awarded \$30,000</p>	<ul style="list-style-type: none"> • Team Miles Fluid & Reason (Tampa, FL) • Cislunar Explorers - Cornell University (Ithaca, NY) • CU-E3- University of Colorado, Boulder (Boulder, CO) • SEDS Triteia - University of California, San Diego (San Diego, CA) • Heimdallr, Ragnarok Industries Inc. (Wilmington, DE) <p style="text-align: center;">Only 3 teams met the minimum scoring criteria</p> <p style="text-align: center;">Top 3 teams were awarded \$20,000 and continue with SLS launch safety reviews and manifesting on EM-1</p>



Ground Tournament 4 Winners

CisLunar Explorers



- Academic Team - Cornell University
- Lunar Derby
 - Achieve Lunar Orbit
 - S/C Longevity

CU-E3



- Academic Team - University of Colorado at Boulder
- Deep Space Derby
 - Best Burst Data Rate
 - Largest Data Volume
 - Farthest Comms Distance
 - S/C Longevity

Team Miles



- Industry Team Group of “citizen innovators” centered in Tampa, FL.
- Deep Space Derby
 - Farthest Comms Distance



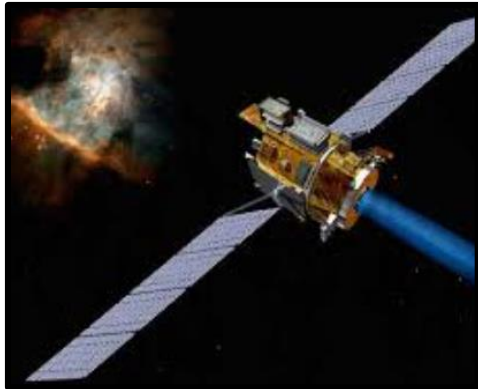
CubeQuest Challenge

THE TECHNOLOGIES

The Technology

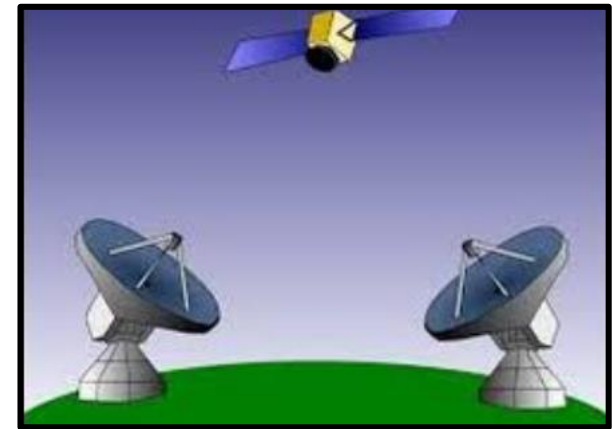


Technologies CubeQuest Teams need to succeed:

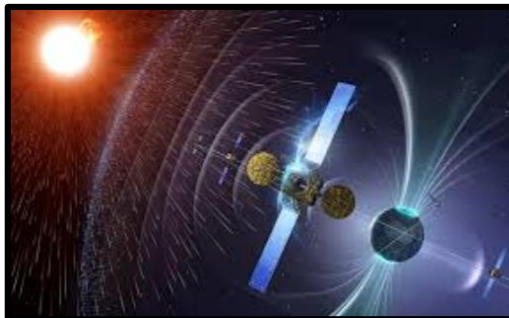


Propulsion

Communication



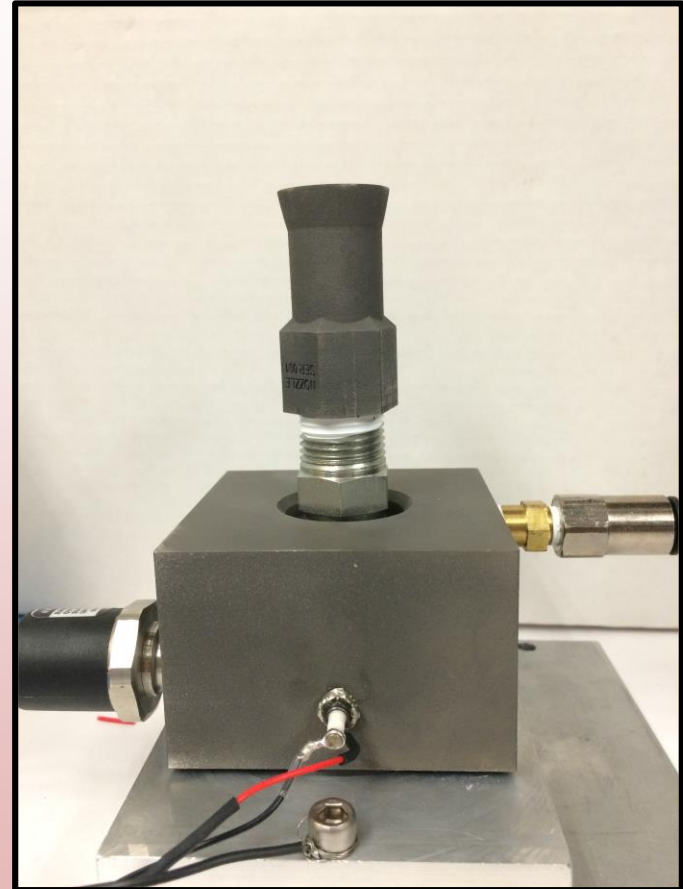
Deep Space Hardiness





Propulsion – CisLunar Explorers

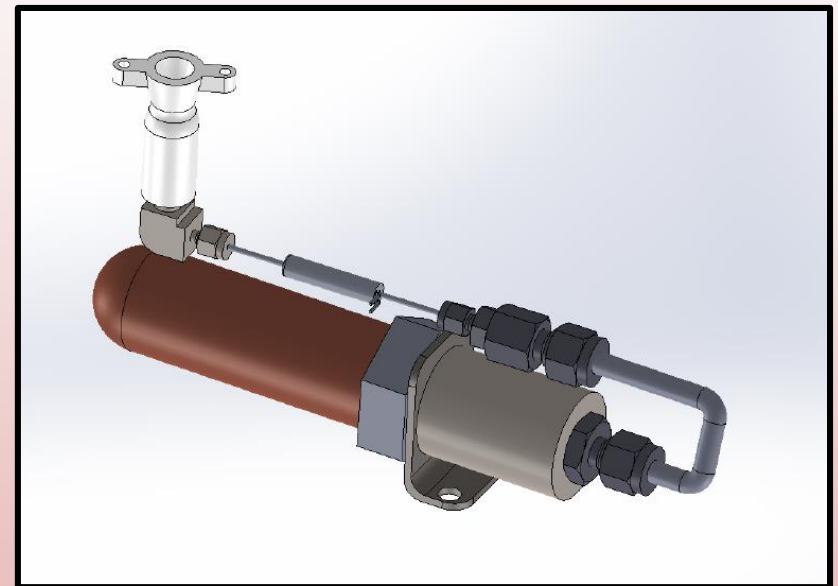
- In-house Water Electrolysis System
 - Inert, dense, simple operation, high ΔV
- Design ΔV : 417 m/s
- Holds 940 cc of propellant
- 3D-printed Ti Nozzle





Propulsion (ADCS) – Cislunar Explorers

- In-house CO₂ system for reorientation operations.
- COTS Fuel tank, solenoid, nozzle and puncture device

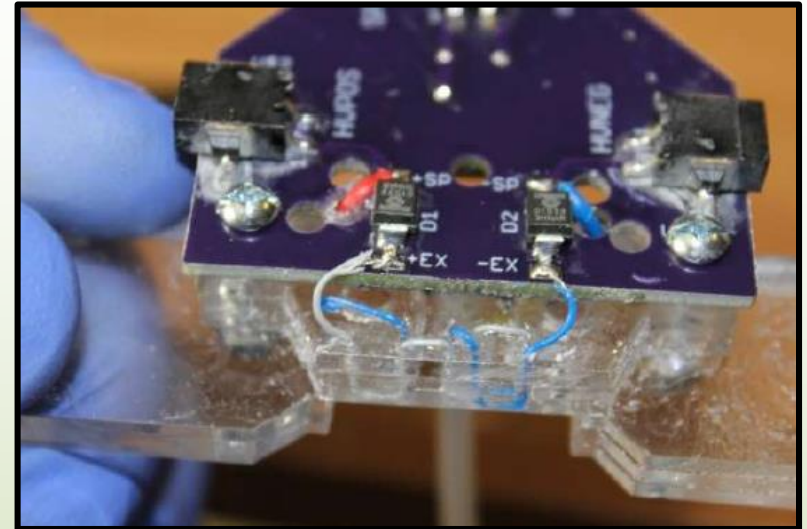




Propulsion – Team Miles

ConstantQ plasma thrusters

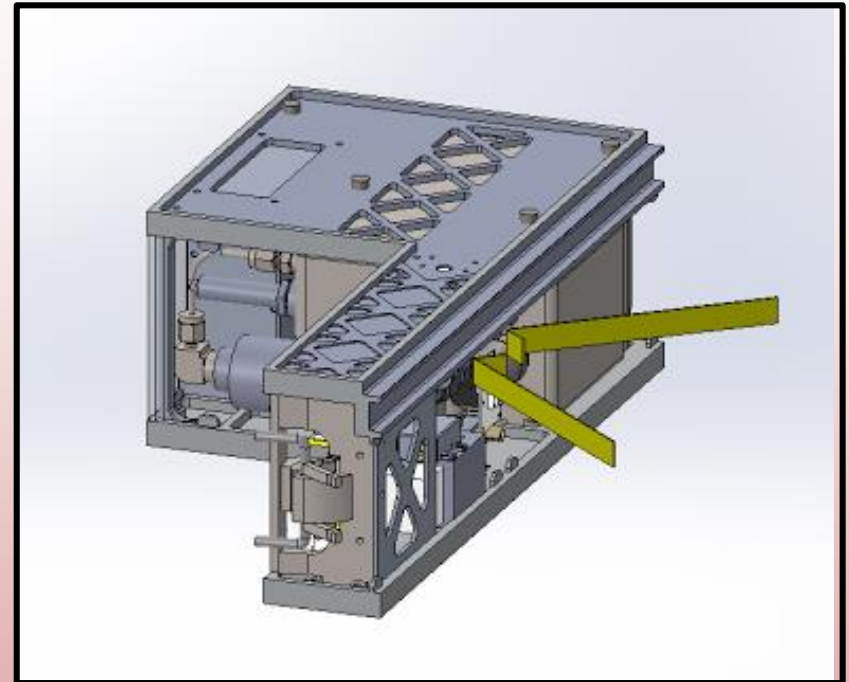
- Iodine propellant
- 12 total thruster units
- Thrusters are canted, used for both primary prop and RCS





Communications (Radio) – Cislunar Explorer

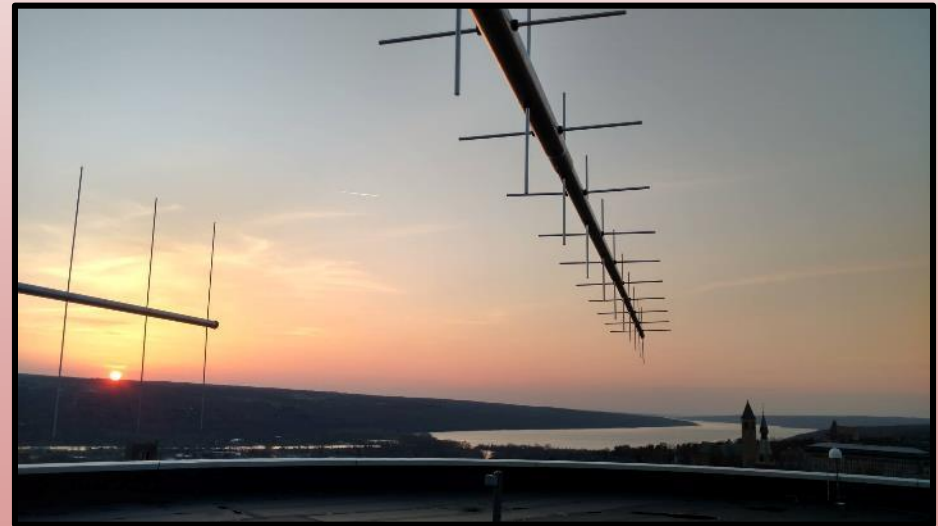
- UHF (70cm band)
- Deployable tape measure half-wave dipole antenna
- AX5043 AXSEM/ON Semi Transceiver
- In-house RF power amplifier
- Raspberry Pi Flight Computer





Communications (Ground Station) – Cislunar Explorer

- Main Ground Station on campus at Cornell
 - Ability for 8hr/day access
- 60ft antenna at WFF for tracking
- S/C Tx even when not LOS to GS – Amateur Radio operators can receive transmissions





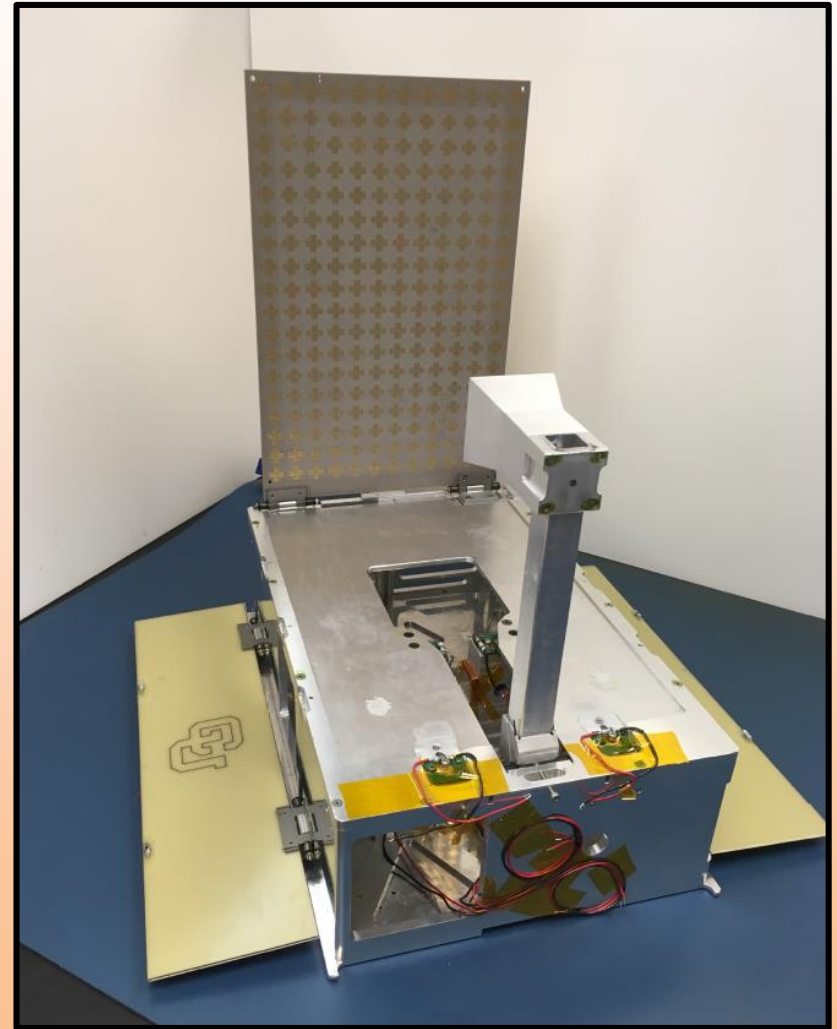
Communications (Radio) – CU-E3

X-band Tx

- In-house Transmitter
- In-house deployable Reflectarray with Feed Horn

C-band Rx

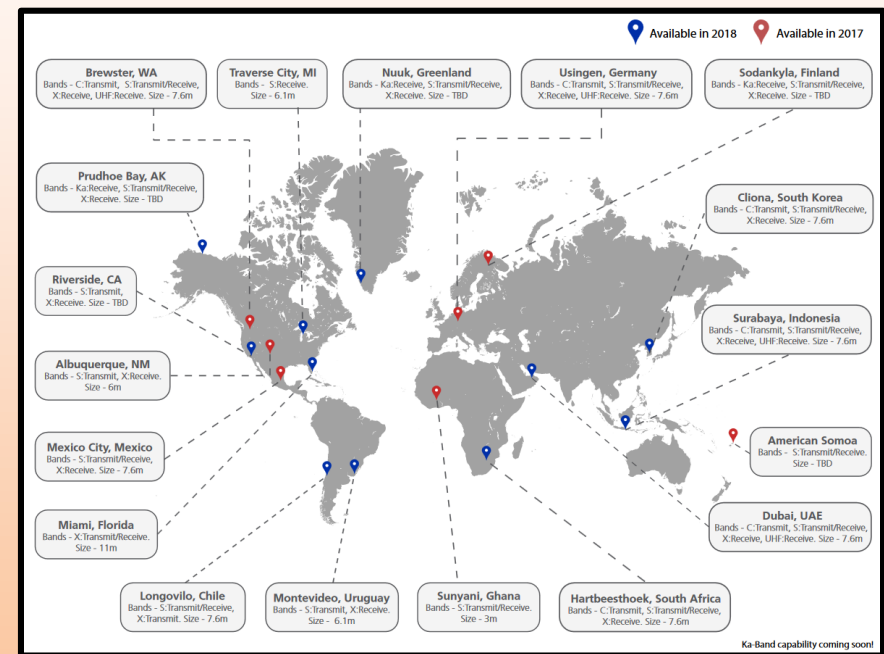
- C-band converted to UHF
- AstroDev Li-1 UHF radio
- 1 C-band patch antenna array





Communication (Ground Station) – CU-E3

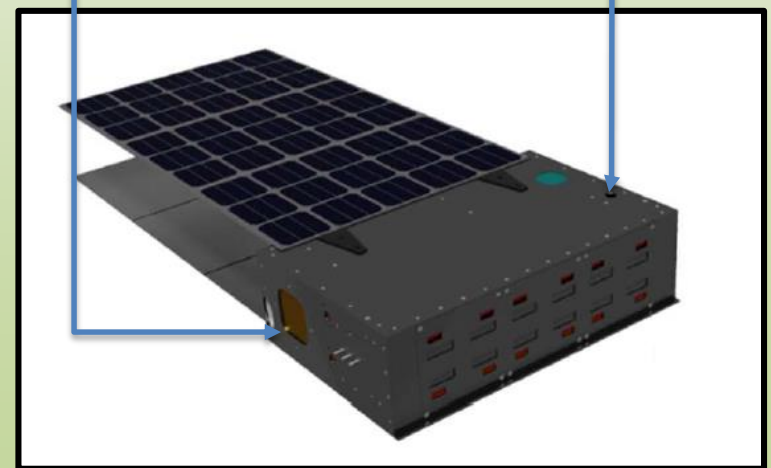
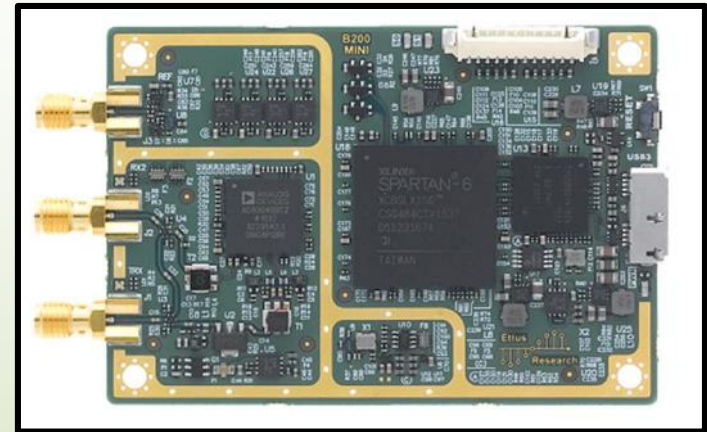
- ATLAS Ground Station
 - CU-E3 plans to use the ATLAS network for all satellite communications, including Telemetry, Command and Tracking





Communications (Radio) – Team Miles

- S-band
 - Ettus USRP B200mini Software Defined Radio
- Dual Patch Antennas
 - 180° placement for full coverage of S/C
 - 4 hr/day coverage during operations phase





Communications (Ground Station) – Team Miles

- DSN
 - DSN currently plans to use DSN for S/C tracking
 - DSN has offered free tracking services for the CubeQuest EM-1 payloads
 - Team Miles may also contract with DSN for Tx/Rx if necessary
- ATLAS
 - Team Miles has contracted with ATLAS to provide S/C Tx/Rx if necessary





Additional Technology Paths to Mission Success – CU-E3

Non-propulsive Deep Space ADCS

- CU-E3 does not carry any propulsion, and is outside the Earth's magnetic field
- Modified BCT ADCS solution
 - Reaction wheel saturation will be avoided by maneuvering the S/C in such a way to utilize Solar Radiation Pressure to aid in rotation (counter-torques)



Additional Technology Paths to Mission Success – Team Miles

Radiation

- Team Miles has TID tested prototypes of all major circuit boards
 - Including the In-House designed flight computer (RACP)
- Testing provides confidence in S/C's ability to survive >4M km away from Earth (goal: 7.7M km)

Resilient Affordable CubeSat Processor (RACP)

- In-house designed flight computer
- ARM processors mixed with rad-tol microcontrollers to provide fault tolerance

Next Steps



- SLS is scheduled to launch in 2019
- In-space Competitions end 365 days after SLS Launch
- Teams with 3rd party launches have one year from launch to achieve mission and prize objectives or SLS Launch T+365 days, whichever is sooner

The End – Until Next Time

