CubeQuest CHALLENGE

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

Liz Hyde
Millennium Engineering and Integration
NASA Ames Research Center
SmallSat 2017– August 5, 2017

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

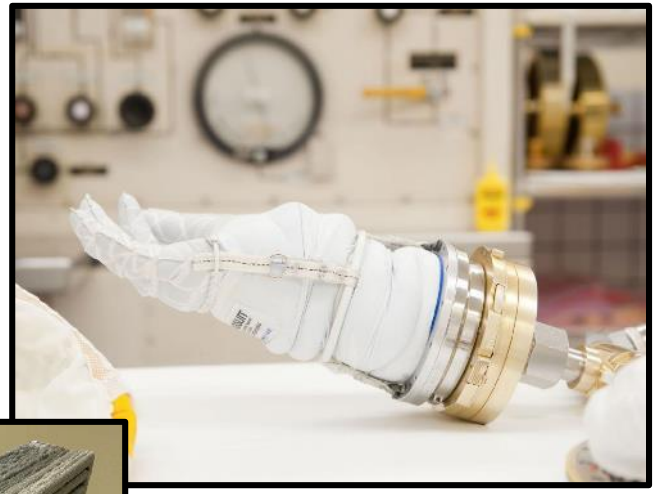
CubeQuest Challenge

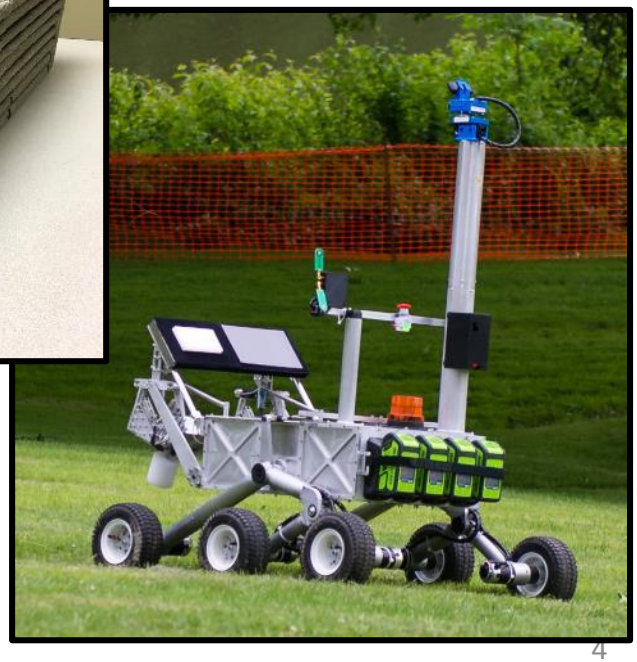
WHAT IS CUBEQUEST

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
Ground Tournament 2: March, 2016	
"PDR" Level	Top 5 - $30,000
Ground Tournament 3: October, 2016	
"CDR" Level	Top 5 - $30,000
Ground Tournament 4: June, 2017	
Between "CDR" and "SAR/FRR" Level	Top 3 - $20,000

CubeQuest is the first government challenge to take place in space!

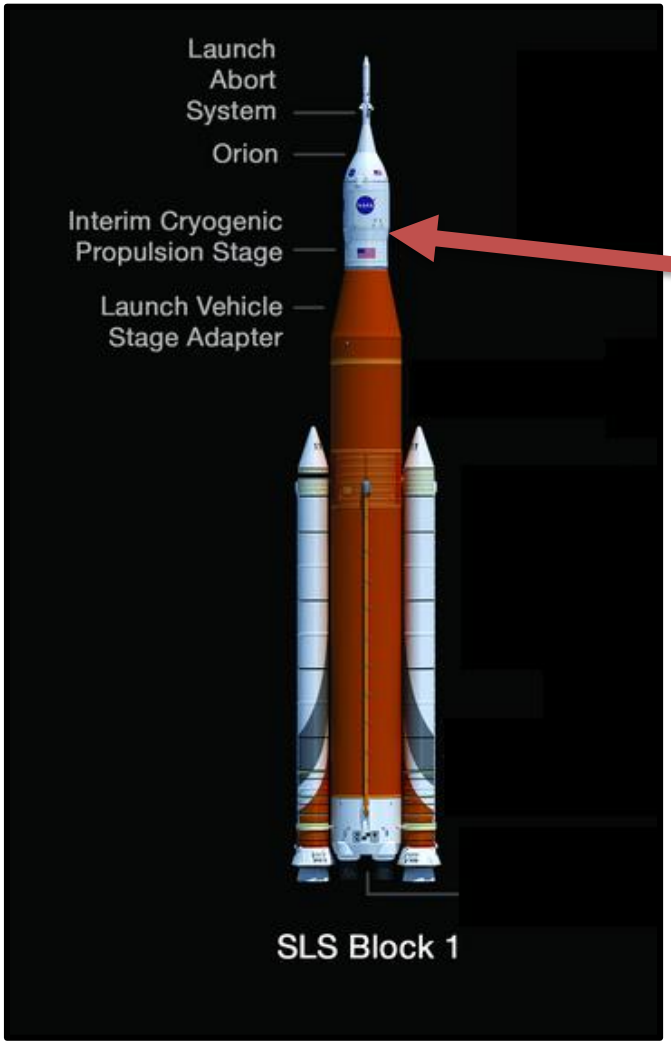
Lunar/Deep Space Derbies

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

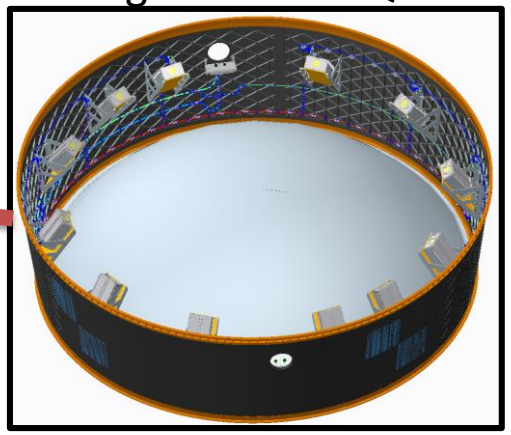
Deep Space Derby	
Farthest Communications Distance (>4m Km)	$250,000
Best Burst Data Rate	$250,000
Largest Aggregate Data Volume	$750,000
Spacecraft Longevity	$500,000

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

- 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)

Top 5 teams were awarded $20,000 and qualified for EM-1 launch opportunity

GT2 – 10 Teams

- 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)**

Top 5 teams were awarded $30,000 and qualified for EM-1 launch opportunity

GT3 – 7 Teams

- **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)

Top 5 teams were awarded $30,000

GT4 – 5 Teams

- 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)

Only 3 teams met the minimum scoring criteria

Top 3 teams were awarded $20,000 and continue with SLS launch safety reviews and manifesting on EM-1

The Teams – GT-4

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 TeamGroup of "citizen innovators" centered in Tampa, FL.
- Deep Space Derby
  - Farthest Comms Distance

CubeQuest Challenge

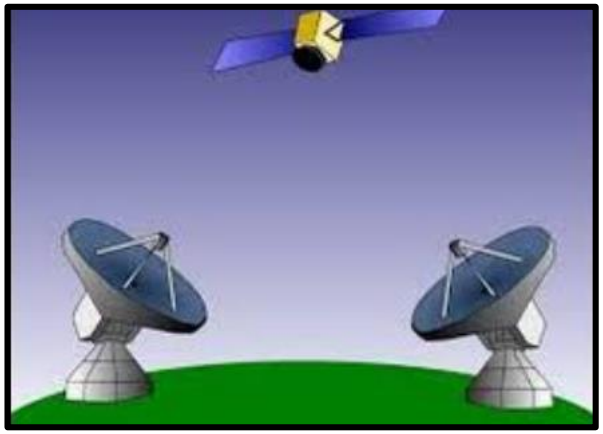
THE TECHNOLOGIES

The Technology

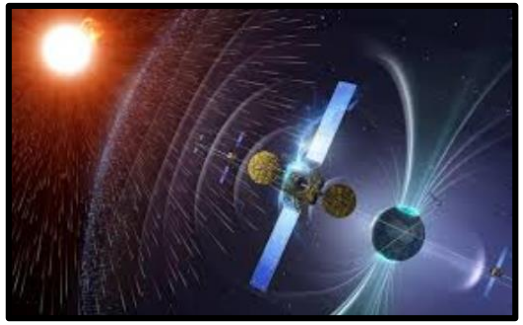
Technologies CubeQuest Teams need to succeed:

Propulsion

Communication



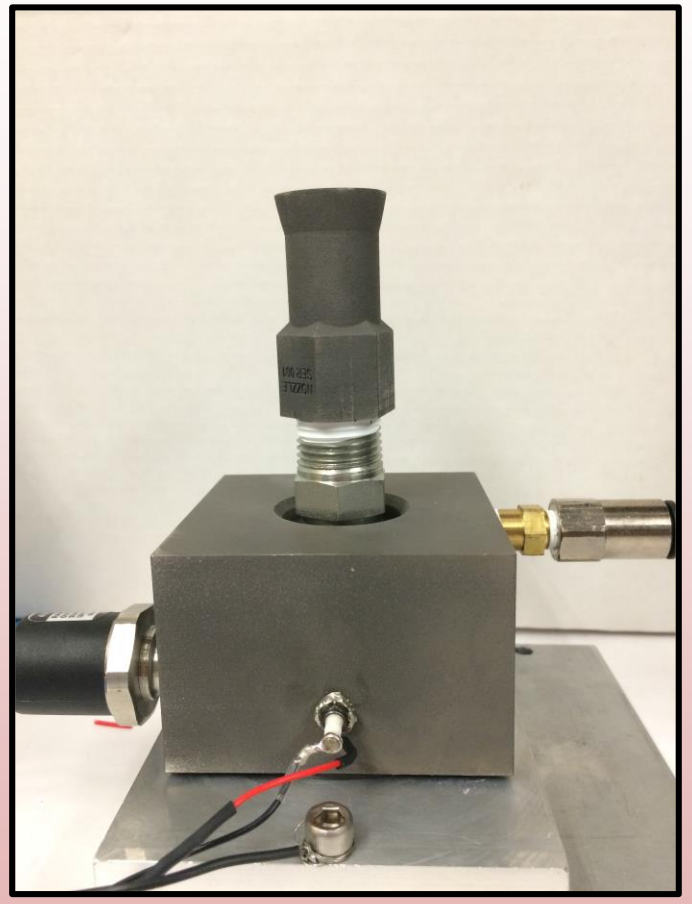
Deep Space Hardiness



The Technology

Propulsion – CisLunar Explorers

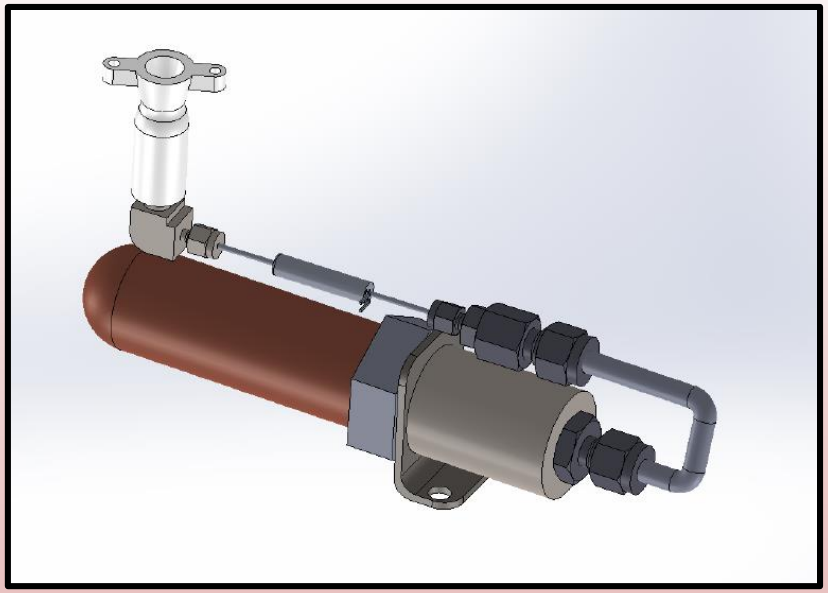
- In-house Water Electrolysis System
  - Inert, dense, simple operation, high ΔV
- Design ΔV: 417 m/s
- Holds 940 cc of propellent
- 3D-printed Ti Nozzle



The Technology

Propulsion (ADCS) – Cislunar Explorers

- In-house C02 system for reorientation operations.
- COTS Fuel tank, solenoid, nozzle and puncture device

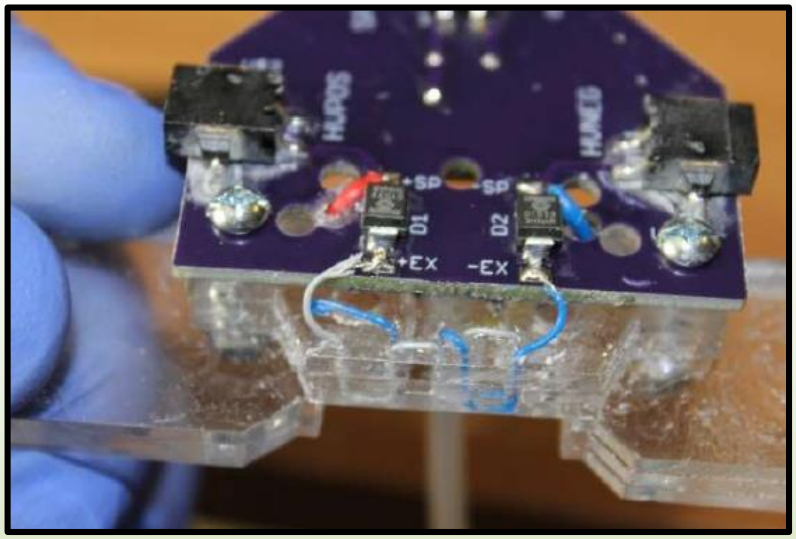


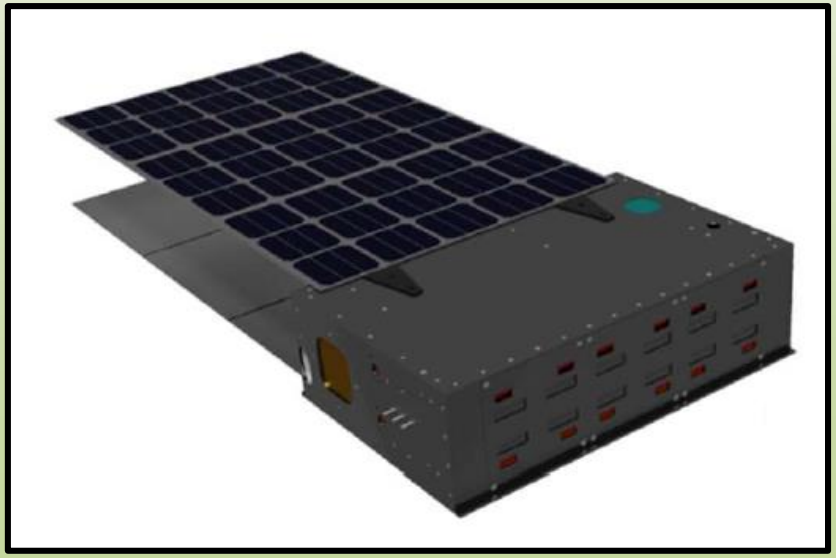
The Technology

Propulsion – Team Miles

ConstantQ plasma thrusters

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

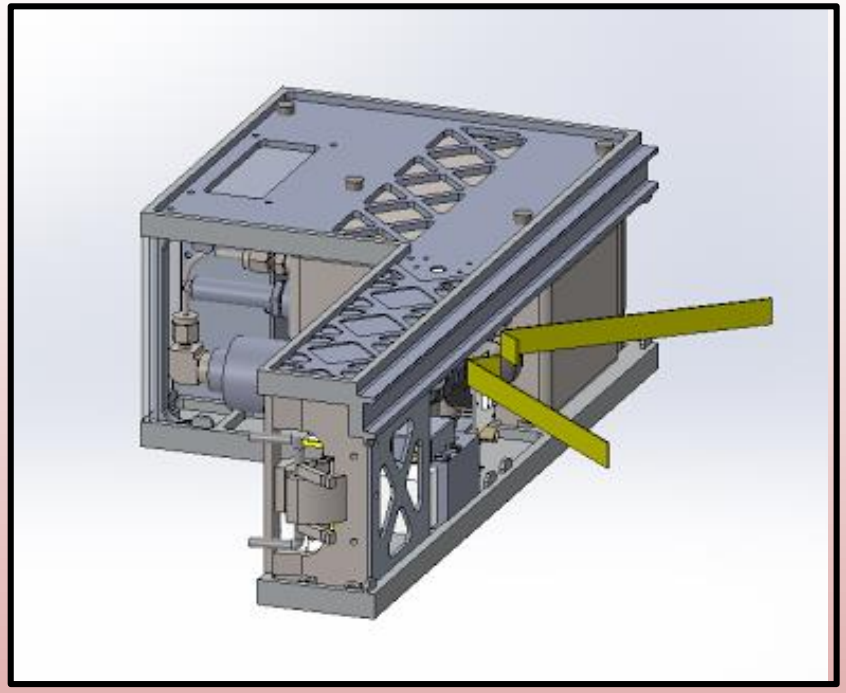


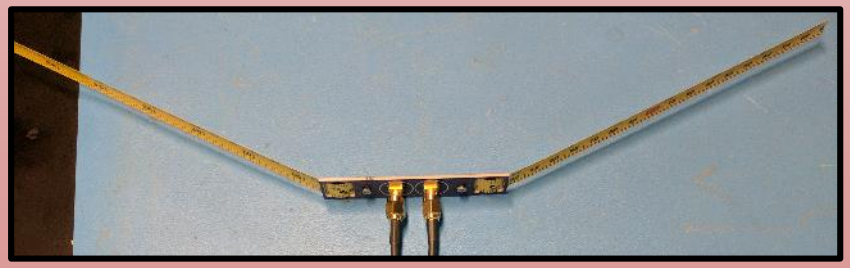


The Technology

Comunications (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





The Technology

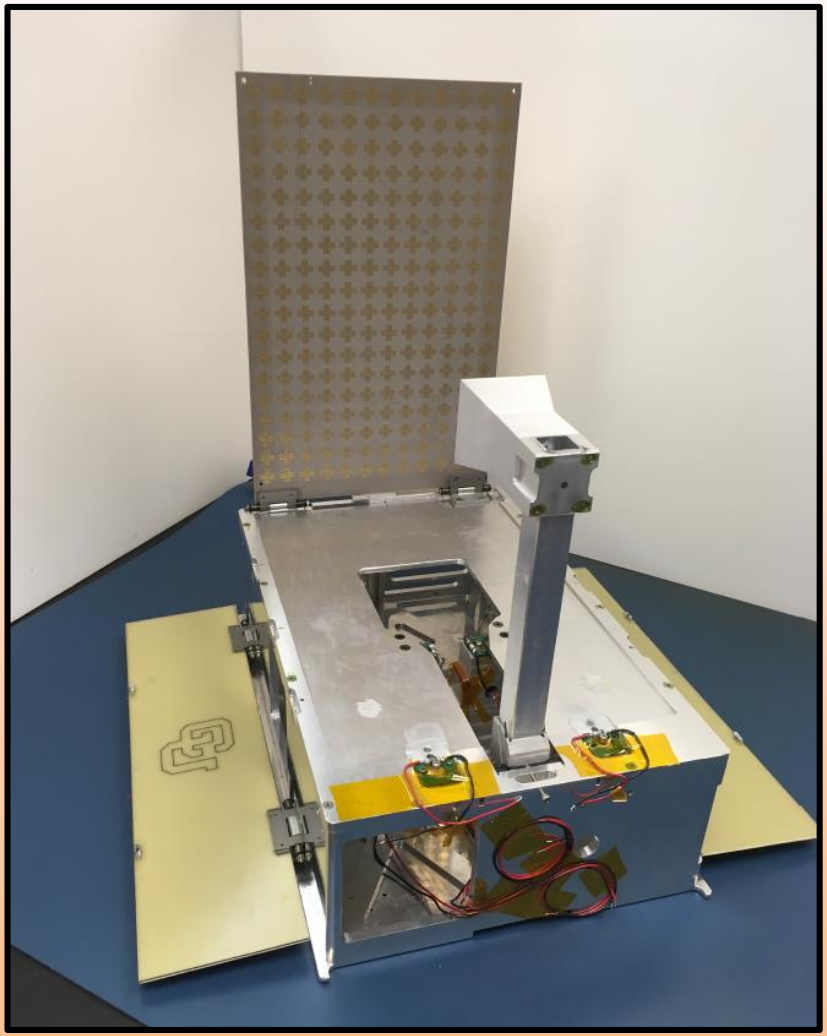
Communications (Ground Station) – Cislunar Explorer

- 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

The Technology

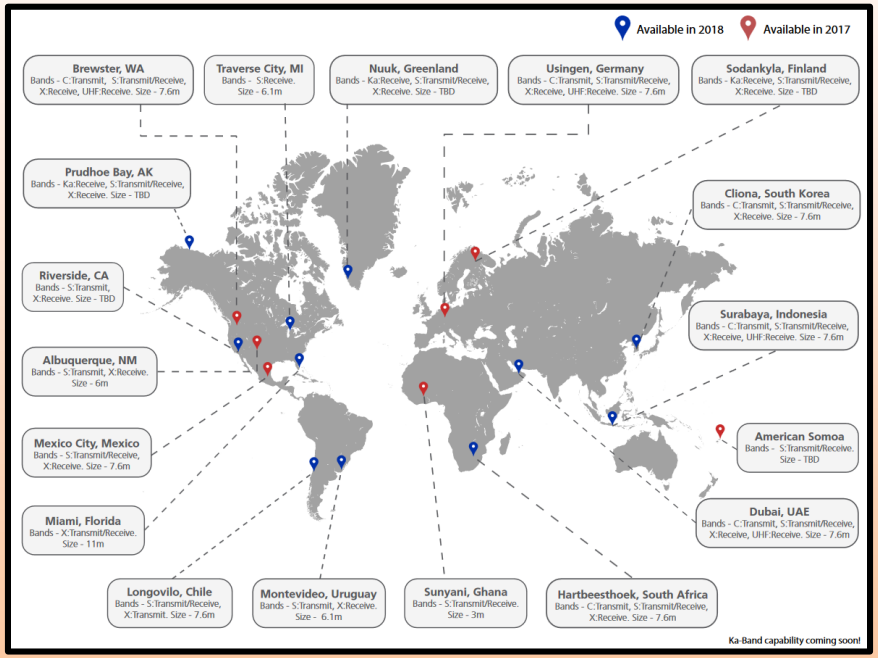
Communications (Radio) – CU-E3

- 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

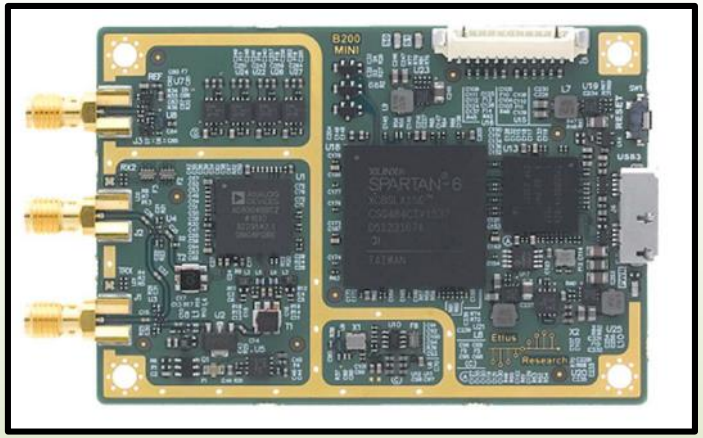
- ATLAS Ground Station
  - CU-E3 plans to use the ATLAS network for all satellite communications, including Telemetry, Command and Tracking

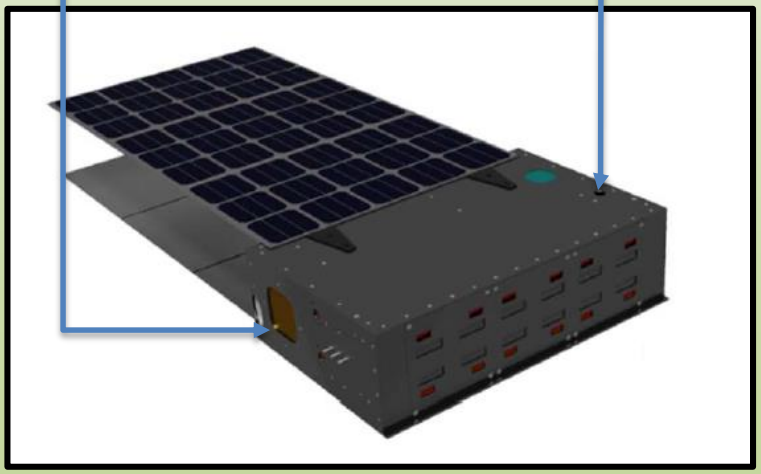


The Technology

Communications (Radio) – Team Miles

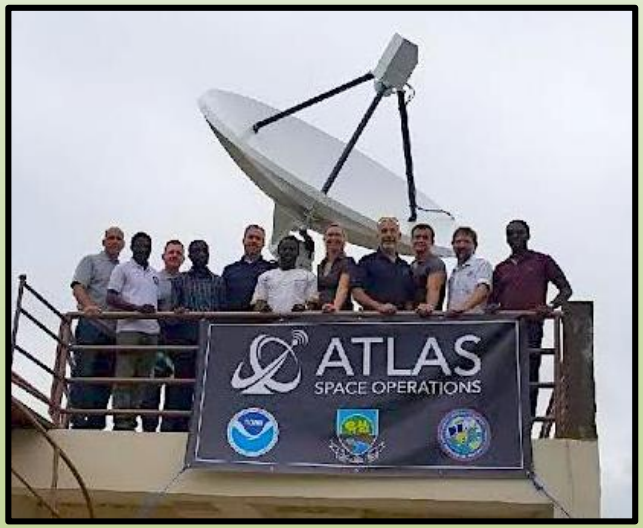
- S-band
  - Ettus USRP B200mini Software Defined Radio
- Dual Patch Antennas
  - 180° placement for full coverage of S/C
  - 4 hr/day coverage during operations phase





Communications (Ground Station) – Team Miles

- DSN
  - DSN currently plans to use DSN for S/C tracking
  - DSN has offered free tracking servies 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)

The Technology

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 Processer (RACP)
  - In-house designed flight computer
  - ARM processers 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