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

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What is CubeQuest?
• NASA Centennial Challenges
• The CubeQuest Challenge
  o Challenge Structure
  o Prizes!
  o SLS Integration

The Teams
• GT1-3 Winners/Prizes
• GT4 Winners

The Technologies
• Propulsion
• Communications
• Other Tech

Next Steps
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
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
## Competitions & Prizes

### Ground Tournaments

<table>
<thead>
<tr>
<th>Ground Tournament</th>
<th>Date</th>
<th>Level</th>
<th>Top N - Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>1: August, 2015</td>
<td>“MCR/SRR” Level</td>
<td>Top 5 - $20,000</td>
<td></td>
</tr>
<tr>
<td>2: March, 2016</td>
<td>“PDR” Level</td>
<td>Top 5 - $30,000</td>
<td></td>
</tr>
<tr>
<td>3: October, 2016</td>
<td>“CDR” Level</td>
<td>Top 5 - $30,000</td>
<td></td>
</tr>
<tr>
<td>4: June, 2017</td>
<td>Between “CDR” and “SAR/FRR” Level</td>
<td>Top 3 - $20,000</td>
<td></td>
</tr>
</tbody>
</table>

### Lunar/Deep Space Derbies

<table>
<thead>
<tr>
<th>Lunar Derby</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Achieve Lunar Orbit</td>
<td>$1.5 M (shared)</td>
</tr>
<tr>
<td>Best Burst Data Rate</td>
<td>$250,000</td>
</tr>
<tr>
<td>Largest Aggregate Data Volume</td>
<td>$750,000</td>
</tr>
<tr>
<td>Spacecraft Longevity</td>
<td>$500,000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Deep Space Derby</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farthest Communications Distance (&gt;4m Km)</td>
<td>$250,000</td>
</tr>
<tr>
<td>Best Burst Data Rate</td>
<td>$250,000</td>
</tr>
<tr>
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</table>

CubeQuest is the first government challenge to take place in space!
SLS EM-1 Launch Opportunity

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

<table>
<thead>
<tr>
<th>EM1 Secondary Payload Manifest</th>
</tr>
</thead>
<tbody>
<tr>
<td>BioSentinel</td>
</tr>
<tr>
<td>NEA Scout</td>
</tr>
<tr>
<td>Lunar Flashlight</td>
</tr>
<tr>
<td>Lunar IceCube</td>
</tr>
<tr>
<td>SkyFire</td>
</tr>
<tr>
<td>CuSP</td>
</tr>
<tr>
<td>LunaH-Map</td>
</tr>
<tr>
<td>EQUULEUS</td>
</tr>
<tr>
<td>OMOTENASHI</td>
</tr>
<tr>
<td>ArgoMoon</td>
</tr>
<tr>
<td>CisLunar Explorers</td>
</tr>
<tr>
<td>CU-E3</td>
</tr>
<tr>
<td>Team Miles</td>
</tr>
</tbody>
</table>
CubeQuest Challenge

THE TEAMS
### 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 (Atacadero, 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)
- MIT KitCube, Massachusetts Institute of Technology (Cambridge, MA)
- Goddard Orbital and Atmospheric Testing Satellite (GOATS), Worcester Polytechnic Institute (Worcester, MA)
- Lunar CubeQuestador, Missouri University of Science & Technology (Rolla, MO)
- 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 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)

**Top 5 teams were awarded $30,000**

**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**

5/11/2017
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
Technologies CubeQuest Teams need to succeed:

- **Propulsion**
- **Communication**
- **Deep Space Hardiness**
Propulsion – CisLunar Explorers

• In-house Water Electrolysis System
  – Inert, dense, simple operation, high $\Delta V$
• Design $\Delta V$: 417 m/s
• Holds 940 cc of propellant
• 3D-printed Ti Nozzle
Propulsion (ADCS) – Cislunar Explorers

- In-house C02 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
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
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
• 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
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