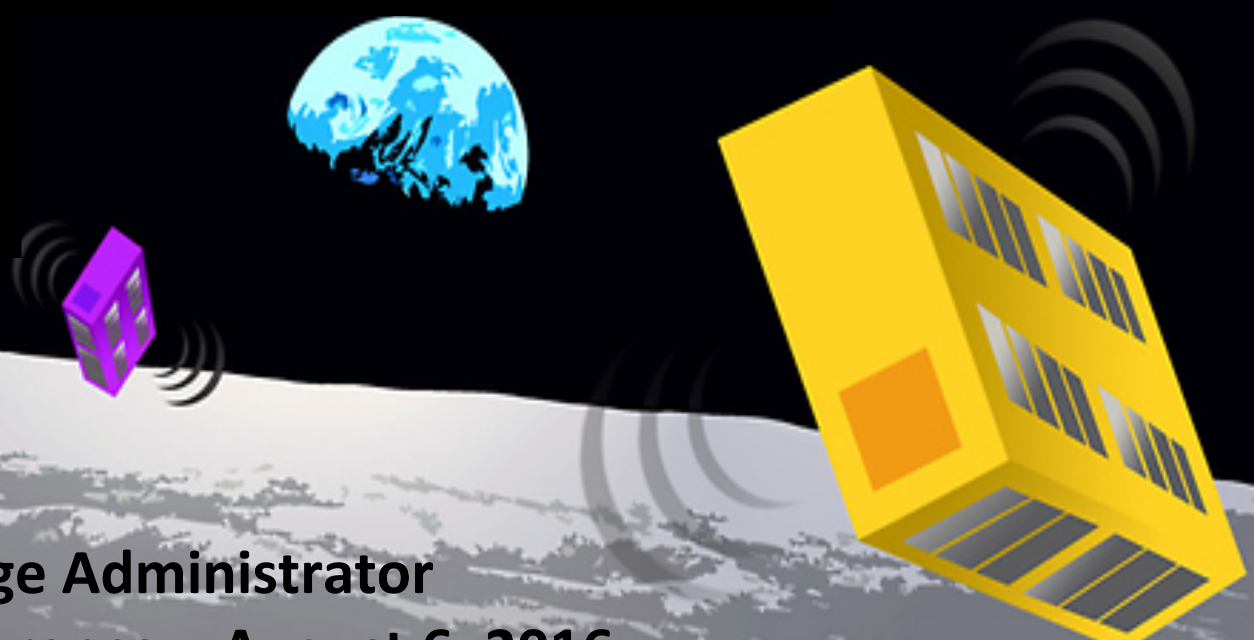
CubeQuest CHALLENGE

What's the Cube Quest Challenge?



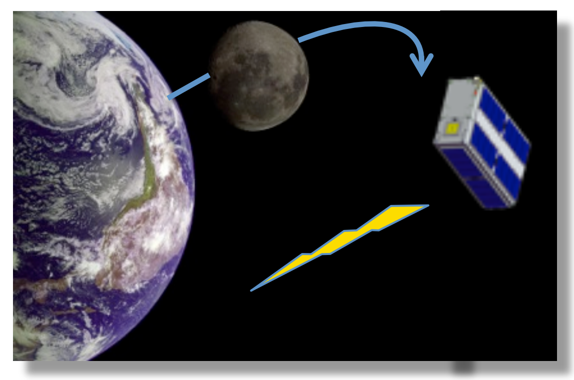
Jim Cockrell

Cube Quest Challenge Administrator

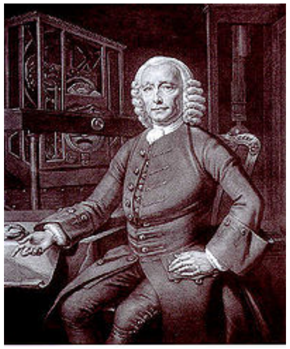
Small Satellite Conference – August 6, 2016

What's this Talk About?

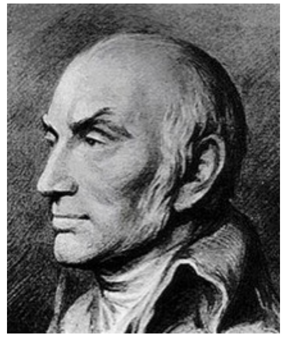
- What are Challenges?
- What is NASA's Centennial Challenges?
- Why a Cube Quest Challenge?
- What is Cube Quest? Who is Eligible?
- What is EM-1?
- How do they get on EM-1?
- What is the current status?



What are Challenges?



In 1761, John Harrison (clock maker) solved the British maritime navigation challenge



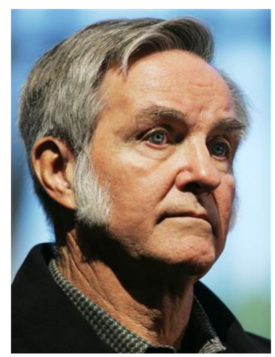
In 1809, Nicolas Appert (baker) solved the Napoleon challenge for food preservation

In 1901, Alberto Santos-Dumont (coffee plantation heir) won the French airship challenge

In 1910, Georges Chavez (pilot) won the Milan Committee challenge being the first to fly over the Alps

In 1927, Charles Lindbergh (mail pilot) won the Orteig Prize being the first to fly across the Atlantic Ocean

In 1977 & 1979, Paul MacCready (aeronautic engineer) won the Kremer Prizes for human-powered flight challenges



In 2004, Burt Rutan (aerospace engineer) won the X-Prize Ansari challenge being the first private entity to enter space twice within two weeks

In 2007, Peter Homer (unemployed engineer) won the NASA Astronaut Glove challenge by making a better glove

What is the Centennial Challenges Program?

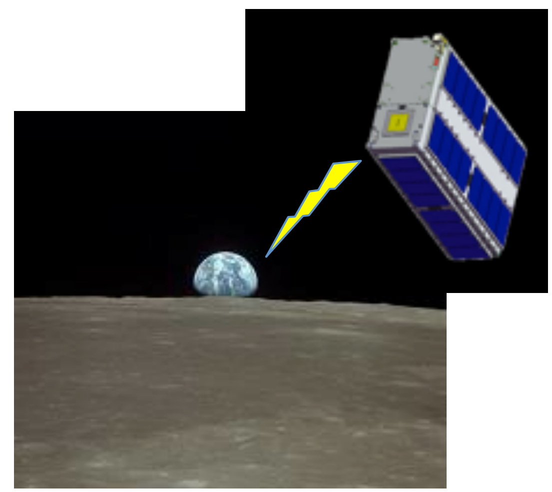
- NASA STMD's Centennial Challenges Program, initiated in 2005, named after Wright Brothers' Kitty Hawk flight
- Engages public in advanced technology development
- Prizes for solving problems of interest to NASA and the nation
- Competitors based in US; not supported by government funding.
- Since 2005, there have been eight challenge categories, resulting in more than 20 challenge events to date.
- More than $6 million in prize money has been awarded to more than 17 different teams
- Summer 2013, work began on Cube Quest Challenge

Current
Centennial Challenges:

- Sample Return Robot
- 3-D Printed Habitat
- Mars Ascent Vehicle
- Cube Quest

Why a Cube Quest Challenge?

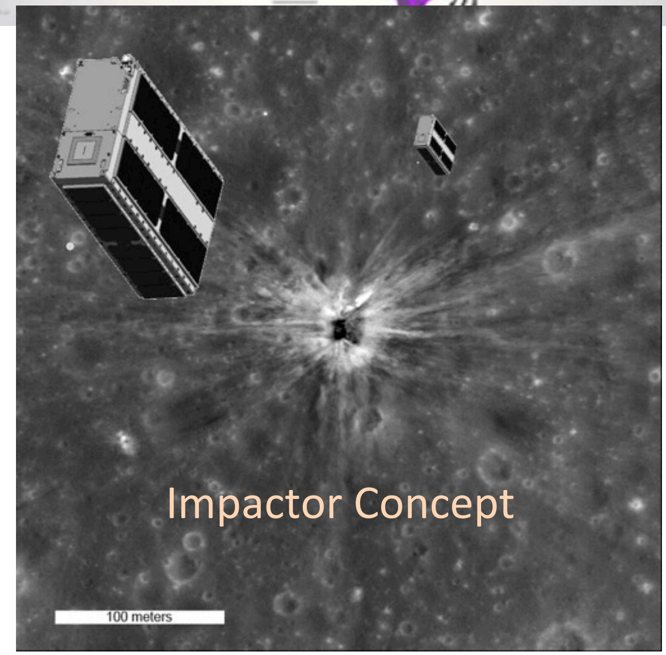
- CubeSats are smaller in: cost, mass, volume, risk
- Constellations of cooperative, little satellites > single, conventional satellites
- Cube Quest incentivizes progress of CubeSats for deep space:
  - Long distance, high bandwidth comm
  - Navigation and pointing - without GPS or Earth's magnetic reference
  - Thermal management outside Earth's albedo
  - Survival in radiation beyond LEO



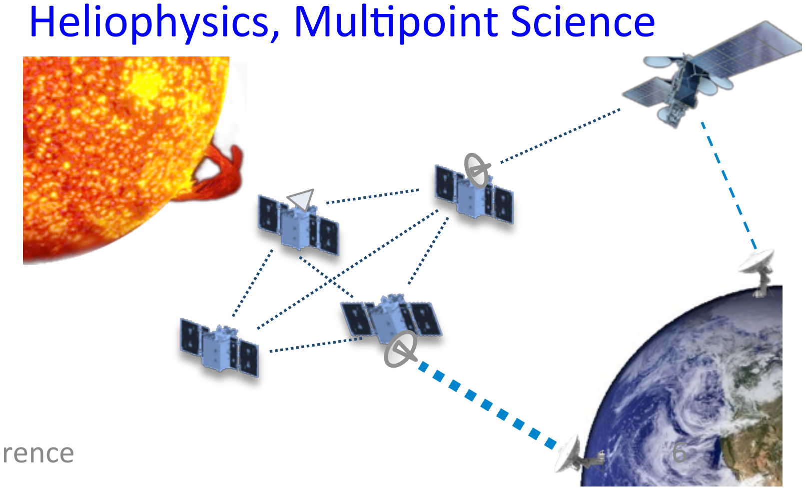
How Can CubeSats Enable Future Missions Faster and More Affordably?

Who Benefits from Advanced CubeSats?

- Astrophysics:
  - Distributed RF and Optical Arrays on affordable satellite constellation
  - Affordable, time-correlated (simultaneous) multi-point observations of NEOs (mass density, albedo, etc)
- Planetary Explorations:
  - Distributed measurements (Ex: surface seismographic; Mars "weather systems", multi-site impactors to detect lunar subsurface volatiles, etc.)
  - Co-ordinated assets (Ex: landers paired with orbiting relays)
- Heliophysics:
  - Global coverage
  - Multiple observations of transient events (Ex: radio occultation)
  - Geographically distributed time-correlated "space weather" measurements
- Earth Science
  - Global coverage (multiple)
  - Time correlated weather, oceanic observations
- DoD
  - Global coverage
  - Rapid response
  - System-level redundancy; high reliability



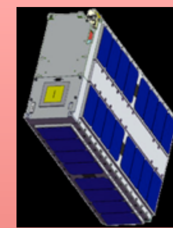
Heliophysics, Multipoint Science



What's the Cube Quest Challenge?

Get your CubeSat to the Moon
– or far beyond –
Work the best. Survive the longest. Win prizes.

Goal: to foster innovation in small spacecraft navigation, operations, and communications techniques for deep space



CubeSat limited to 6U and 14 kg

Qualify for EM-1 launch
- *or* –
get your own ride

Lunar Derby
While in lunar orbit

Achieve Lunar Orbit-
$1.5M/shared, $1M max per team

Error-free Communication
Burst Rate- $225k/25k
Total Volume- $675k/75k

Longevity
$450k/50k

Deep Space Derby
While range ≥4M km

Farthest Distance
$225k/25k

Error-free Communication
Burst Rate- $225k/25k
Total Volume- $675k/75k

Longevity
$225k/25k

Ground Tournaments (GT)

4 Rounds

Approx every 6 months

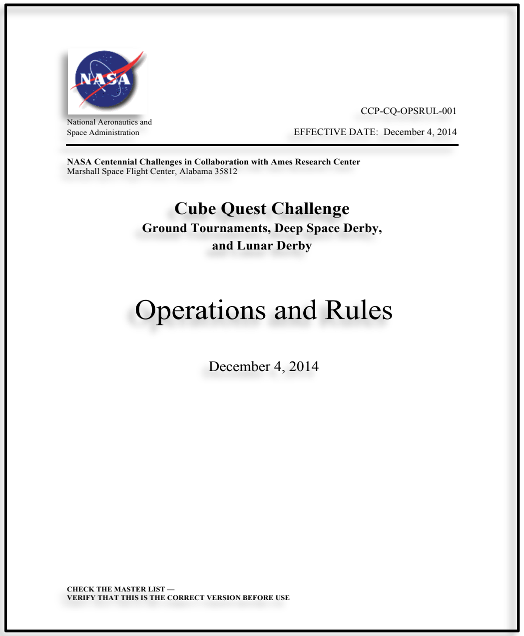
Top 5 teams receive incremental funding (max $100k per team)

Top 3 teams launch free on EM-1

$5.0M Prize Money

More info:
http://www.nasa.gov/cubequest/details

CubeQuest Operations and Rules


National Aeronautics and Space Administration

CCP-CQ-OPSRUL-001

EFFECTIVE DATE: December 4, 2014

NASA Centennial Challenges in Collaboration with Ames Research Center
Marshall Space Flight Center, Alabama 35812

Cube Quest Challenge
Ground Tournaments, Deep Space Derby, and Lunar Derby

Operations and Rules

December 4, 2014

CHECK THE MASTER LIST — VERIFY THAT THIS IS THE CORRECT VERSION BEFORE USE

SLS Safety and Interface Requirements

- SLS Payload Safety Reviews (to fly on EM-1)
- Or equivalent, for 3rd-party launches

Any allowable part of the spectrum

- subject to FCC public freq. alloc. and licensing regs

Comm data eligible for prizes

- May use NASA DSN – at your cost
- DSN tracks all trajectories; checks lunar orbit, 4M km range
- Comm data format per Rules, to qualify

Comply with Orbital Debris and Planetary Protection laws and regs

http://www.nasa.gov/cubequest/reference

Who Can Compete?

- US citizens, permanent residents, and US-based entities
- No federal employees, within their employment scope
- Register per rules
- Compete in any, or all, Ground Tournaments
- Your team can enter and win!

http://www.nasa.gov/cubequest/howtoenter

What is EM-1?

- NASA's first non-crewed lunar flyby mission of Orion from SLS
  - Launch in late 2018
- Capacity for thirteen 6U-sized CubeSats
- Secondary Payloads deploy after Orion departure into lunar flyby trajectory

SLS Configuration

Orion:
Carries astronauts into deep space

Stage Adapter:
The Orion MPCV Stage Adapter will be the first new SLS hardware to fly.

Interim Cryogenic Propulsion Stage:
Based on the Delta IV Heavy upper stage; the power to leave Earth

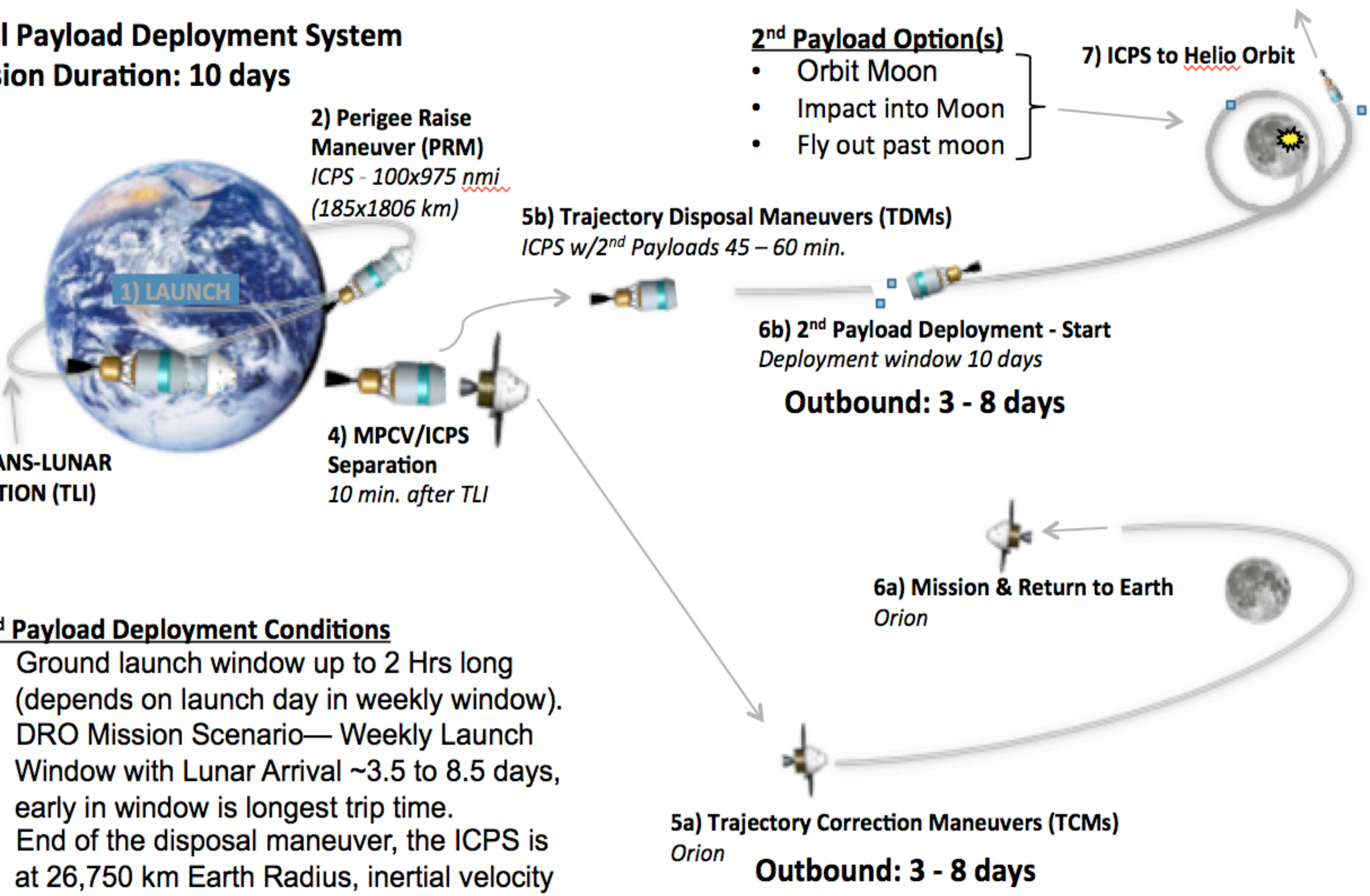
Core Stage:
Newly developed for SLS, the Core Stage towers more than 200 feet tall

Solid Rocket Boosters:
Built on Space Shuttle hardware; more powerful for a new era of exploration

RS-25 Engines:
Space Shuttle engines for the first four flights are already in inventory

What is EM-1?

Total Payload Deployment System
Mission Duration: 10 days



2nd Payload Deployment Conditions

- Ground launch window up to 2 Hrs long (depends on launch day in weekly window).
- DRO Mission Scenario— Weekly Launch Window with Lunar Arrival ~3.5 to 8.5 days, early in window is longest trip time.
- End of the disposal maneuver, the ICPS is at 26,750 km Earth Radius, inertial velocity of 5.279 km/s.

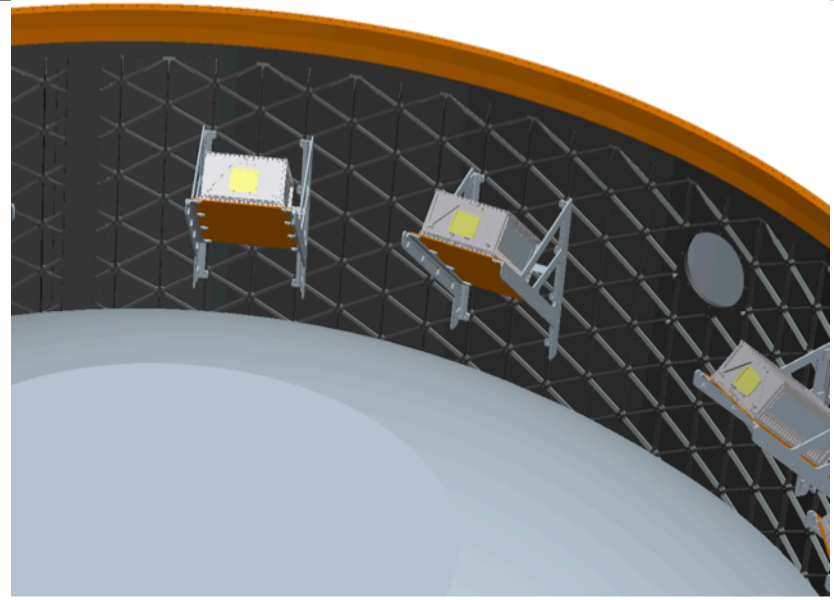
SLS Secondary Payload Accommodations

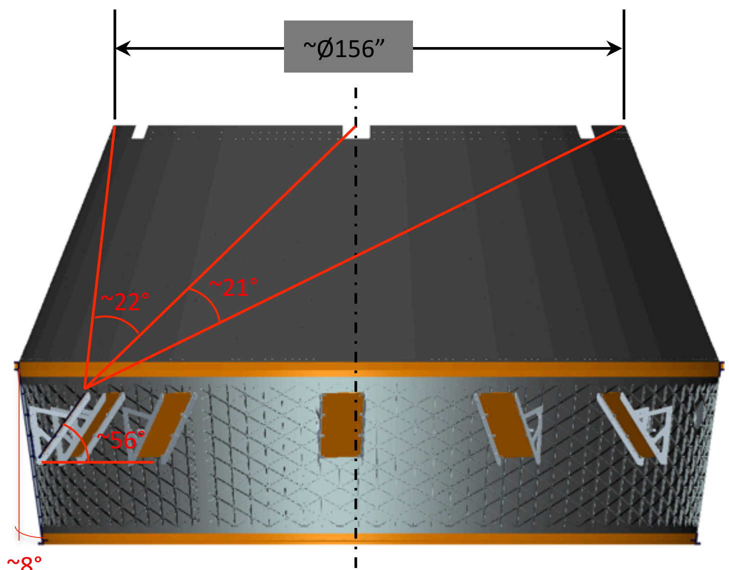
Eleven 6U/12U payload locations
6U volume/mass is the current standard (14 kg payload mass)

Payloads will be “powered off” from turnover through Orion separation and payload deployment

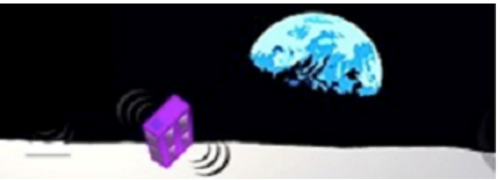
Payload Deployment System Sequencer; payload deployment will begin with pre-loaded sequence following MPCV separation and ICPS disposal burn

Payload requirements captured in Interface Definition and Requirements Document





How do I get on EM-1?



<u>Top 3 qualified GT-4 Winners offered free EM-1 launch</u>

  - Declare intent to fly EM-1
  - Be a top five winner in GT-1 and/or GT-2
  - Pass SLS payload safety reviews
  - Compete and win in GT-4

- Four Ground Tournaments (GTs)
  - GT-1 - Aug 2015 - $20k - winners announced!
  - GT-2 - Mar 2016 - $30k – winners announced!
  - GT-3 - Oct 2016 - $30k
  - GT-4 - Mar 2017 - $20k *and* chance to launch on EM-1

- Teams may compete in any or all four GTs
  - they get harder as they go!

How Ground Tournaments Work

Teams submit GT documents

5 Judge Panel

- 2 NASA
- 3 Non-NASA leaders
  - Industry
  - Academic
  - DoD

GT Winners:

Top 5 Teams

Scoring > 3.0/5.0

- Rules
- GT Workbook
- SLS IDRD
- SLS Safety Rqts (or equiv. launch provider rqts)

Team of technical SMEs

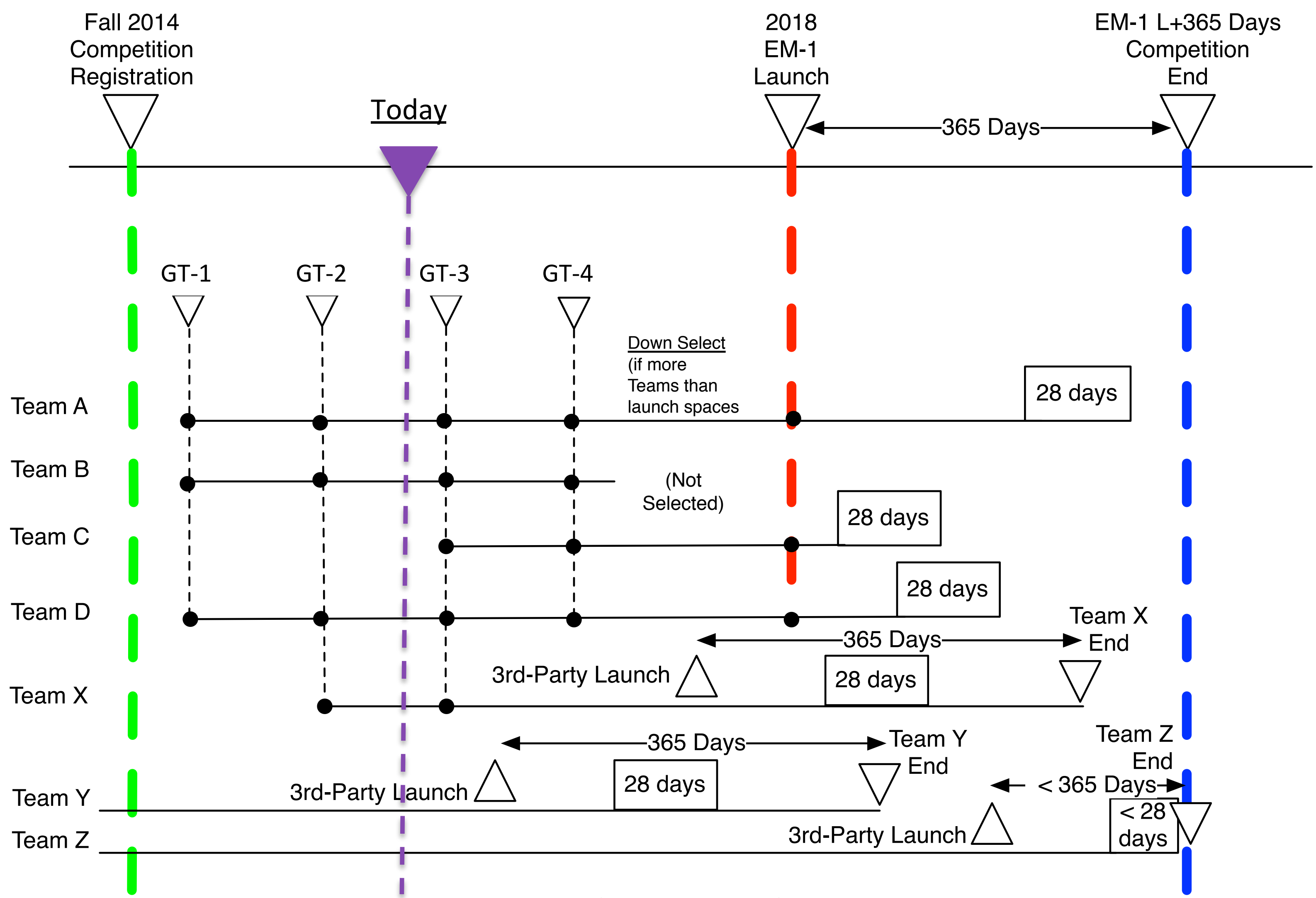
40% Likelihood of Mission Success

+

60% Compliance with Rules, SLS IDRD, SLS Saftey Rqts

Total GT Score

What's the Schedule?



GT-3 Competitors

* - indicates EM-1 Qualifier

Industry

Alpha CubeSat Xtraordinary
Innovative Space Partnerships, Inc.

***Heimdallr**
Ragnarok Industries, Inc

***Team Miles**
Fluid & Reason LLC

Academia

***Cislunar Explorers**
Cornell University

*** MIT KitCube**
Massachusetts Institute of Technology

*** SEDS UC San Diego**
University of California- San Diego

G.O.A.T.S.
Worchester Polytechnic Institute

*** CU-E3**
University of Colorado – Boulder

Lunar Derby | Deep Space Derby | Lunar & Deep Space Derby

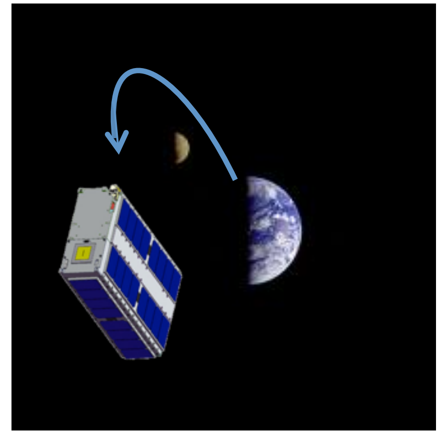
What's the Status?

- **Registration is Open for GT-3**
  - September 21, 2016
    - Registration Deadline and Submittals due date
  - Winners announced in October 2016

- **Final Ground Tournament**
  - In-Person at Ames Research Center in March 2017

http://www.nasa.gov/cubequest/howtoenter

Questions?



Jim Cockrell

Cube Quest Challenge Administrator

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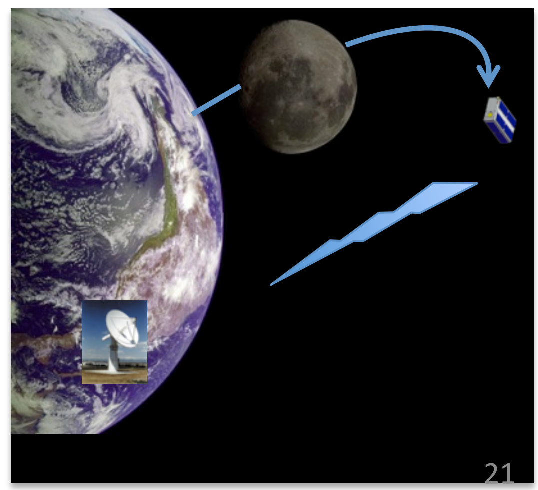
Good Luck and May the Best CubeSat Win!

Deep Space Communications

- Challenge:
  - *Farthest distance, largest volume, fastest rate - transmitted data*

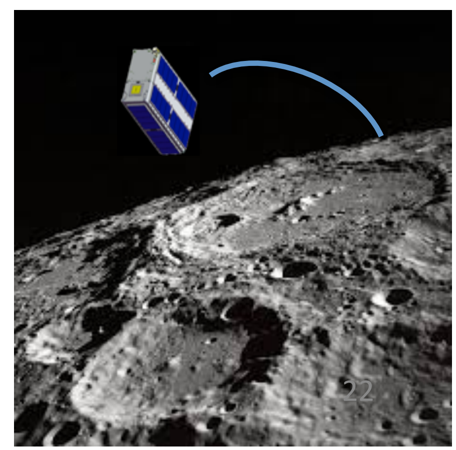
- Demonstrates:
  - Comm: award for farthest comm on certain date
  - Ground Stations: challengers can provide their own deep space ground stations, off-loading heavily subscribed DSN assets
  - Survival: award for farthest comm
  - Power: survival in cold environment
  - Pointing: aim directional antenna, camera
  - Propulsion, G&NC to point antennas

- Applications:
  - Planetary missions
  - NEO/NEA surveyor/precursor



Lunar Orbit

- Challenge:
  - *Achieve verifiable lunar orbit*
  -
- Demonstrates:
  - Propulsion: 700-900 m/s dV for Lunar Orbit Injection
  - Pointing: hi-gain antenna, articulated solar arrays
  - G&NC: navigate without benefit of GPS or Earth's magnetic references
  - Power: perform while coping with lunar and Earth eclipse periods
  - Survival: achieve orbits and survive longest
- Applications:
  - NEO missions
  - Earth Science
  - Pathfinders, In-situ resource surveyors
  - Heliophysics
  - Planetary science
  - Lunar Science



Longevity

- Challenge:
  - *Survive the longest in lunar orbit or 4M km range*
  -
- Demonstrates:
  - Rad tolerance in deep space (where CubeSats have not ventured before)
  - Power generation and management away from Earth
  - Thermal management in deep space
  - G&NC: point antennas without benefit of GPS or Earth's magnetic references
  - G&NC and propulsion: station keeping while in lunar orbit
  - Long distance communcaitons, command and control
  - Autonomy
- Applications:
  - NEO missions
  - Earth Science
  - Pathfinders, In-situ resource surveyors
  - Heliophysics
  - Planetary science
  - Lunar Science