National Aeronautics and
Space Administration

NASA

Centennial Challenges Program
Space Technology Mission Directorate

CubeSat Lunar and Deep Space Challenges

2014 Small Satellite Conference

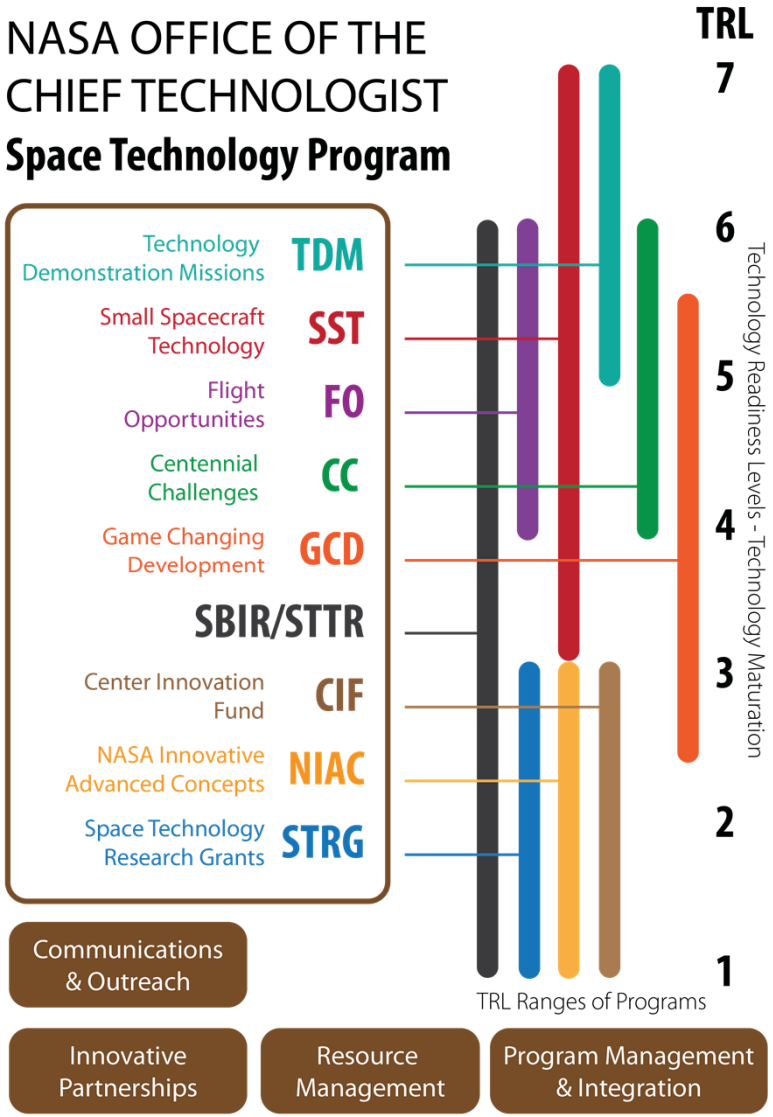
08/03/2014

www.nasa.gov/spacetech

Centennial Challenges

- Centennial Challenges Program is unique in Space Technology Program
  - Stimulates innovative development using cash prize competitions
  - Targets technical solutions in areas of interest to NASA
  - Serves to competitors
    - US citizens, permanent residents, or US entities only
    - Primarily TRL 4-6 development
    - Intellectual Property rights
    - Minimal reporting and government oversight
- Reaching solutions beyond the typical government solicitations and methods

We Need You!



Prize Competitions

- **Stimulates innovation in ways unlike contracts or grants**
  - Reward achievement, not effort
  - **Competitors are not paid until goals are achieved**
- **Achieves returns that outweigh investment**
  - High ratio of private investment to prize value **at a fraction of the cost of traditional procurement.**
  - Almost all funds go to prize purses
- **Reaches new sources of innovation and talent**
  - Multiple teams
  - Multiple approaches to same problem
- **Stimulates new commercial ventures**
  - New startups
  - New partners
  - More commercial competition
- **Educate, inspire, and motivate the public**
  - Train the future workforce; Inclusion, not exclusion
  - Increase awareness of science & engineering

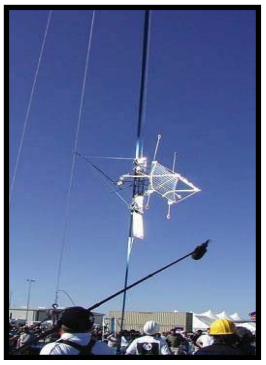
Previous Centennial Challenges

Since 2005, 24 competitions held in 9 Challenges
~$6.0M in prizes awarded to 16 different teams

Regolith Excavation – $750K

Lunar Lander – $2M

Astronaut Glove – $550K



Power Beaming - $900K

Personal Air Vehicle - $250K

Green Flight – $1470K

Sample Return Robot Challenge

managed by Worcester Polytechnic Institute

Incentivize advancement in robotic navigation and sample manipulation technologies.

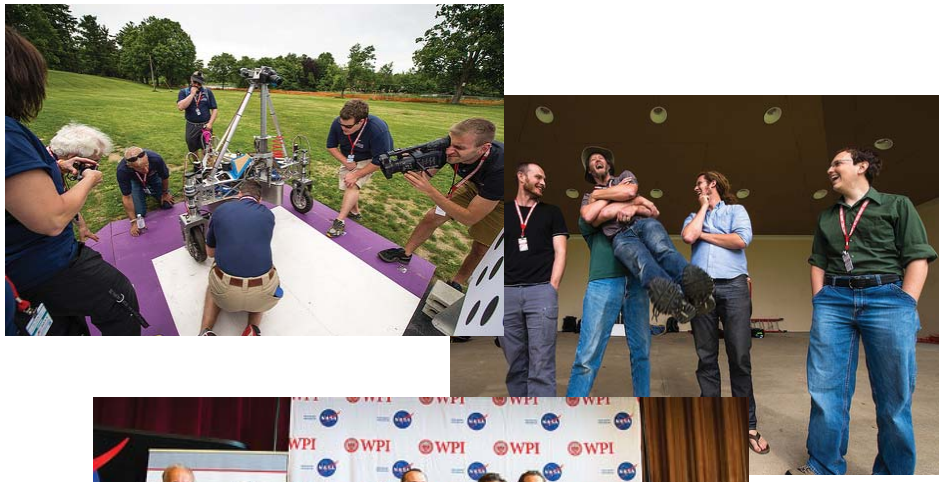
Goal: Demonstrate a fully autonomous robot that can locate and retrieve several identified samples with no use of GPS or other terrestrial navigation aids.

PRIZE PURSE: $1.49 Million

Status

- 10 teams competed June 5-6, 2013
- 18 teams competed June 11-14, 2014
- Level I Winners
  - ✓ Team Survey (2013)
  - ✓ West Virginia University (2014)
- Competitors Include
  - ❑ Universities and High School Students
  - ❑ Amateur Designers
  - ❑ Industrial Teams

SRR Level I Winners



Team Survey

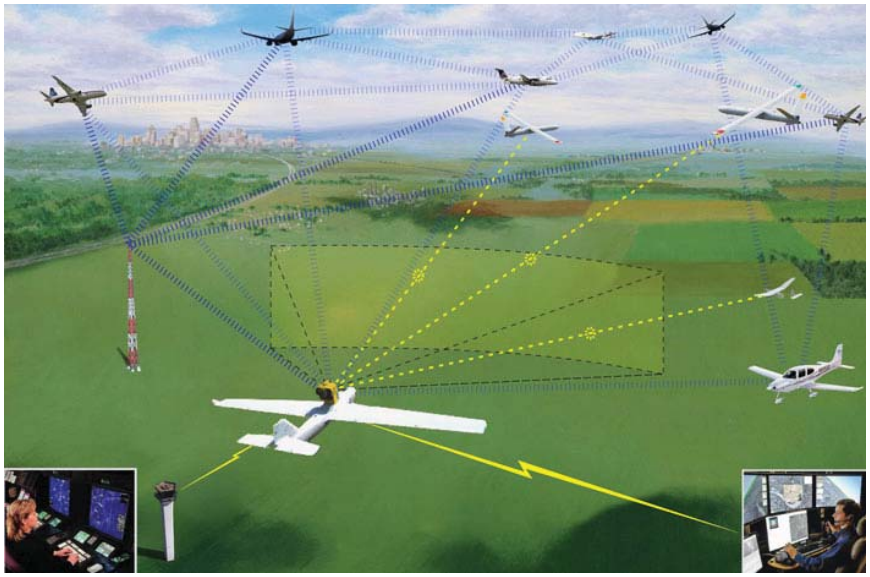
West Virginia University

UAS AOC Challenge

managed by NASA & DPI

Incentivize advancement in avionic capabilities for operation in the Next Generation (NextGen) Airspace concept.

- Phase 1 Competition ($500K)
  - Fly 4-Dimensional Trajectories (4DT)
  - Employ ADS-B IN
  - Maintain safe separation from cooperative air traffic
  - Operate safely in a number of contingency situations
- Phase 2 Competition ($1M) (Planned) -
  - Maintain safe separation from uncooperative air traffic
  - Employ ADS-B IN and OUT
  - Have onboard systems capable of communicating verbally with the Air Traffic Control (ATC) system



Detect, Sense & Avoid for Separation Assurance

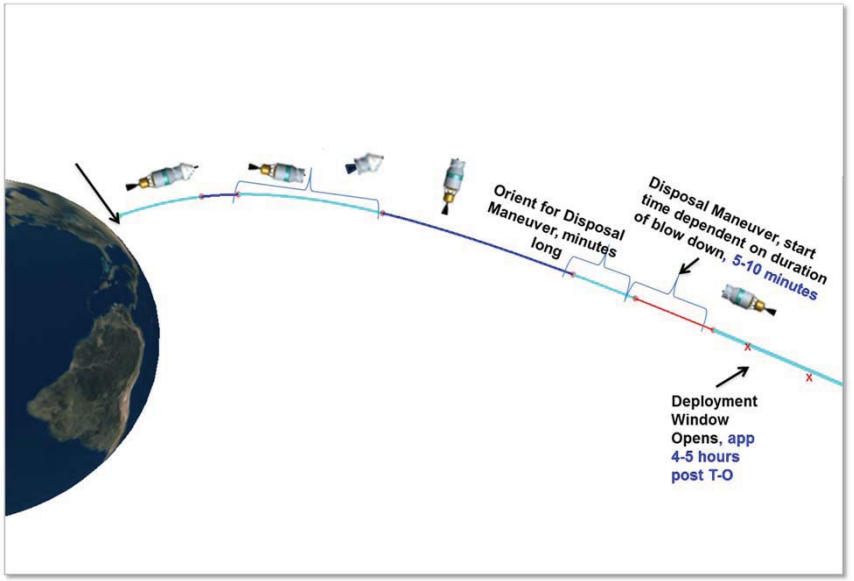
- **Status**
  - Development Systems, Inc of Dayton Ohio selected as Allied Organization and Space Act executed on May 6.
  - Registration open
  - Phase 1 Competition Fall 2014. Phase 2 will be one year after Phase 1 success.

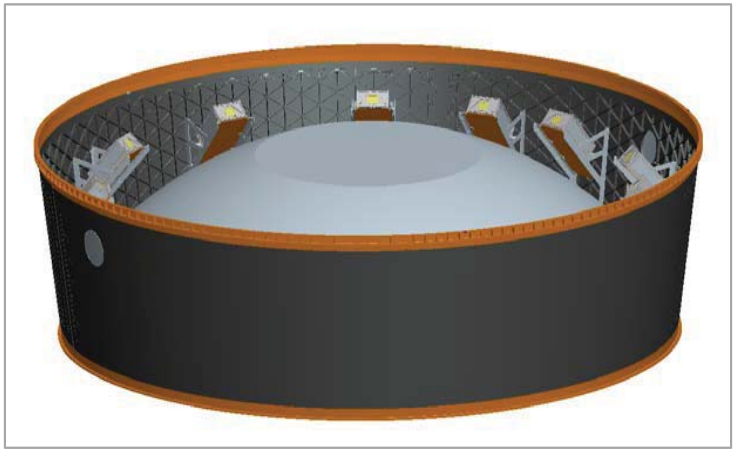
http://go.usa.gov/YHmA

UAS AOC – Unmanned Aircraft System Air Operations Challenge

New Challenges

- Centennial Challenge Program is pleased to announce two new challenges to kick off this Fall
  - The CubeSat Deep Space Communications Challenge
  - The CubeSat Lunar Propulsion and Communications Challenge
- Qualified Teams will launch on board NASA's Exploration Mission EM-1 at no cost
  - EM-1 is the first uncrewed lunar flyby of Orion
  - Secondary Payloads will deploy during trans lunar orbit





Why a Deep-Space CubeSat?

- CubeSat Form Factor
  - Advantages include
    - Low cost
    - Small size, mass, and power
    - Easier launch vehicle integration
  - Current limitations include
    - Short-term operations, in Low Earth Orbit (LEO)
    - Communications subsystems
      - Low-bandwidth data rates
      - Low transmit power
      - Low-gain
      - Unique protocols, or amateur radio wavelengths
    - No in-space propulsion (with limited exceptions)
    - No deep space navigation
- Future Applications include
  - Astrophysics
  - Planetary Exploration
  - Heliophysics
  - Earth Science
  - DoD Applications
  - Near Earth Object Exploration
- Successful teams will demonstrate sustained spacecraft and ground-segment capabilities necessary for deep-space exploration.

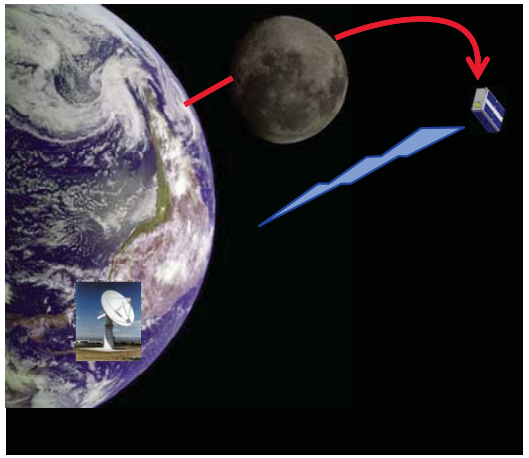
Goal: Incentivize small spacecraft deep space operations capabilities development, leading to the economic achievement of NASA, other government agencies, academia, and industry objectives.

Challenge Firsts

- First opportunity for non-government entities to develop spacecraft, and compete to operate at the moon and beyond
- Challenges incentivize alternate solutions to
  - Deep Space Communications
    - Ground station networks
    - Deployable CubeSat antennas
    - Improved transmitters
    - Game-changing high bandwidth optical
  - In-Space Propulsion
    - CubeSat market poised to offer a variety of propulsion systems
    - To date, only NanoSail-D has demonstrated propulsion in LEO
    - Three propulsion types allowed
      - Solar sail
      - Solar electric
      - Chemical (subject to SLS approval)
  - Longevity in Deep Space:
    - New approaches to rad hardening
    - Thermal and power management
    - Advanced CubeSat GN&C to achieve lunar orbit and steer antennas
- First ever in-space Centennial Challenge

Challenge Structure

- Concurrent In-space Challenges
  - Lunar CubeSat Propulsion and Communications Challenge
    - Achieve Lunar Orbit
    - Downlink the largest volume of error-free data
      - 30-minute burst
      - 28-day aggregate
    - Survive the longest
      - Transmit the last data packet heard within the challenge timeframe
  - CubeSat Deep Space Communications Challenge (> 4 million km)
    - Farthest data transmission distance
    - Largest volume of error-free data
      - 30-minute burst
      - 28-day aggregate
    - Longest duration of operability
      - Transmit the last data packet heard within the challenge timeframe



- Five Ground Qualification Competitions (GQC) Milestones
  - Purposes:
    - Gain insight into competitor's mission designs
    - Provide feedback to teams
    - Award intermediate prizes
  - Judging based on technical maturity, compliance with Challenge Rules and with SLS requirements
  - GQCs culminate in down-select for EM-1 integration and launch
  - GQCs not required of teams that elect to procure 3rd-party launches

Prize Structure

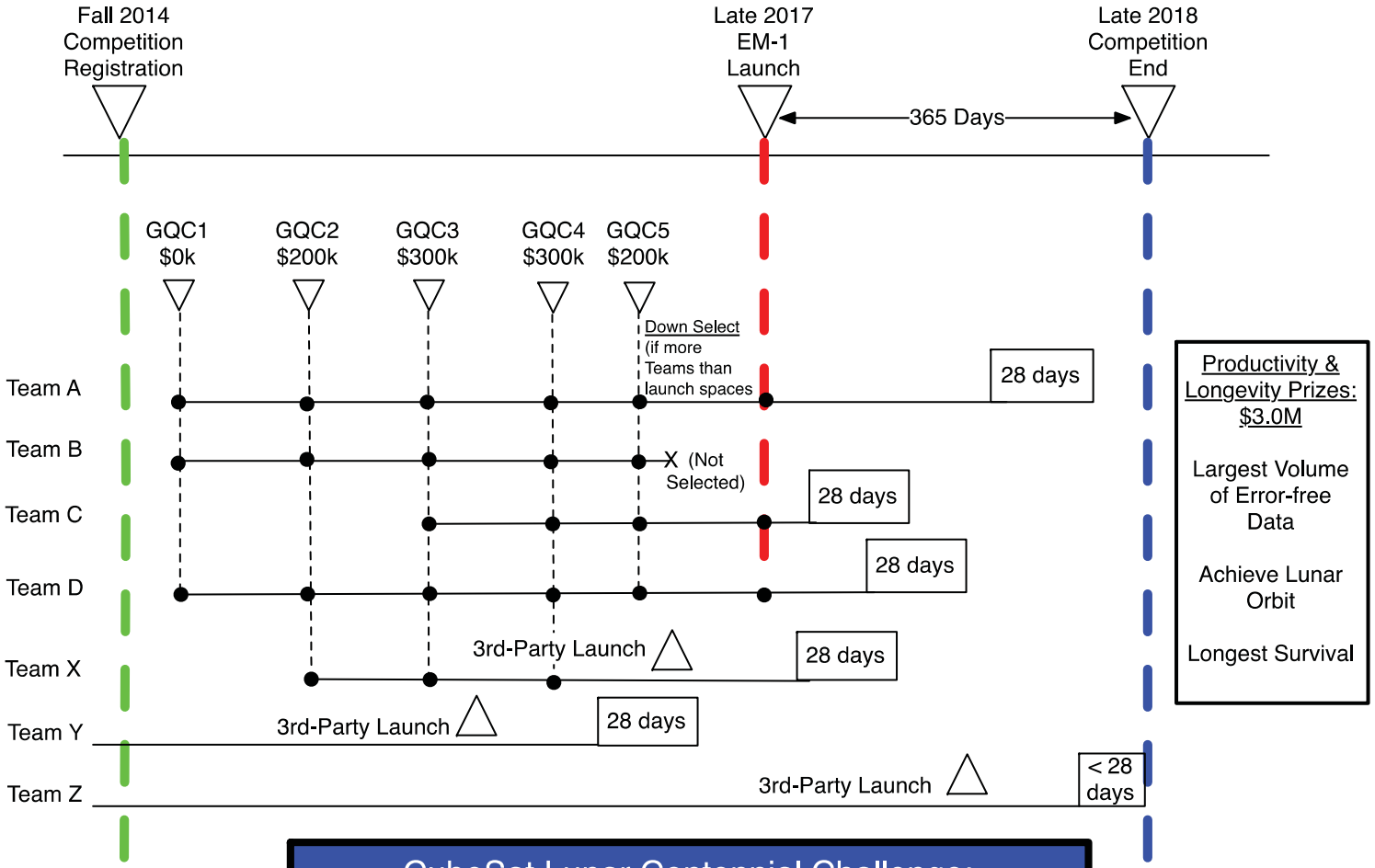
- Lunar Challenge Will Award — Up To $3M
  - Achieve Lunar Orbit — $1.5M *(shared)*
  - Error Free Communication — $1.0M
  - Longevity *(Orbit maintenance)* — $500k
- Deep Space Communication Challenge Will Award — Up To $1.5M
  - Error Free Communication — $1.0M
  - Longevity *(No maintenance needed)* — $250k
  - Distance — $250k
- Ground Qualification Competition (GQC) Will Award Up To $1.0M
- Challenges End Date is 365 Days After NASA-provided Launch Date
- Winner(s) Determined by Submitted Results At The End of Competition Period
- Teams Competing In More Than One Challenge
  - Must Use A Single Spacecraft
  - Must Meet All Respective Challenge Rules To Qualify for Prize

$5.5M Allocation of Prize Money

Versatility of Rules

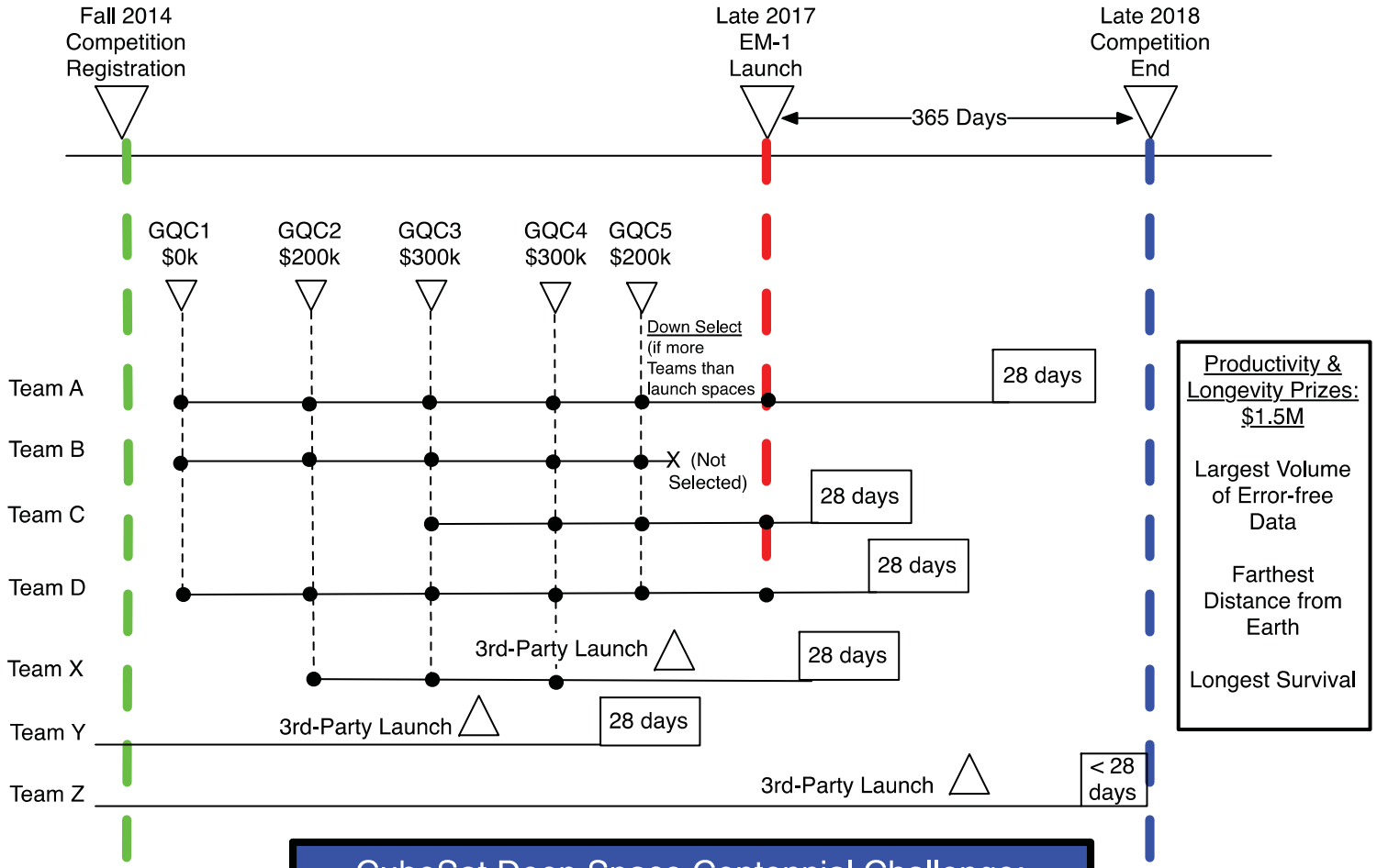
- Challenges are structured to cover a variety of scenarios:
  - EM-1 or other launcher
    - Teams may choose to qualify for EM-1, or obtain their own launch (at their expense)
  - Propulsion or no propulsion
    - Deep Space Challenge does not require propulsion
    - 365-day time rule should allow exotic trajectories to lunar orbit
  - With/Without NASA-provided Space Communication and Navigation (NEN, DSN)
    - Competitors may elect to use Deep Space Network (DSN) at their cost or procure own ground station
    - Third party methods must provide NASA specified evidence for authenticating transmission origin
- Rules avoid "hard coding" certain TBD constraints at this time:
  - EM-1 launch date
  - Final number of secondary payload slots

Lunar Challenge Time Line



CubeSat Lunar Centennial Challenge:
Can your team achieve lunar orbit,
return the most data, and last the longest?

Deep Space Challenge Time Line



CubeSat Deep Space Centennial Challenge:
Can your team go well beyond lunar orbit,
return the most data, and last the longest?

Summary

- New Challenges Starting
  - CubeSat Deep Space Communications
  - CubeSat Lunar Propulsion and Communications
- Favorable Responses To Request for Information
  - 29 Respondents on First
  - 20 Respondents on Second (7 Repeats)
  - 42 Total Respondents
- Challenge Information
  - Registration to Begin Fall 2014
  - Kickoff Summit Will Be Held
  - For More Information Go To NASA Centennial Challenges Website

www.nasa.gov/challenges

BACKUP

Challenge Rules Team

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