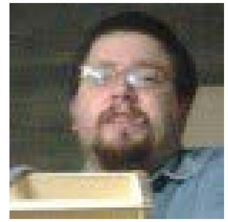
Ground Tournament 2
Face-2-Face Presentation

Alpha CubeSat

Don’t wait for the future, help us build it!

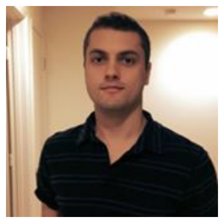
Introduction - Team Alpha CubeSat



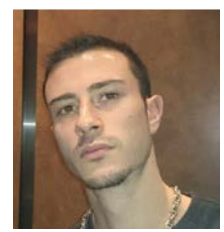


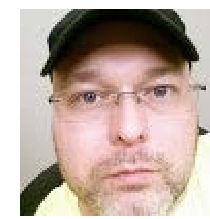


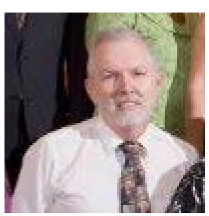


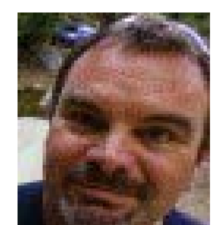










Introduction – Team Alpha CubeSat Roles (1 of 2)

Our team brings together an extraordinary combination of proven systems engineering talent, specialized discipline skills, and a shared commitment to build a mission of enduring value. We have made it to GT-2 as a team and are building a spacecraft!

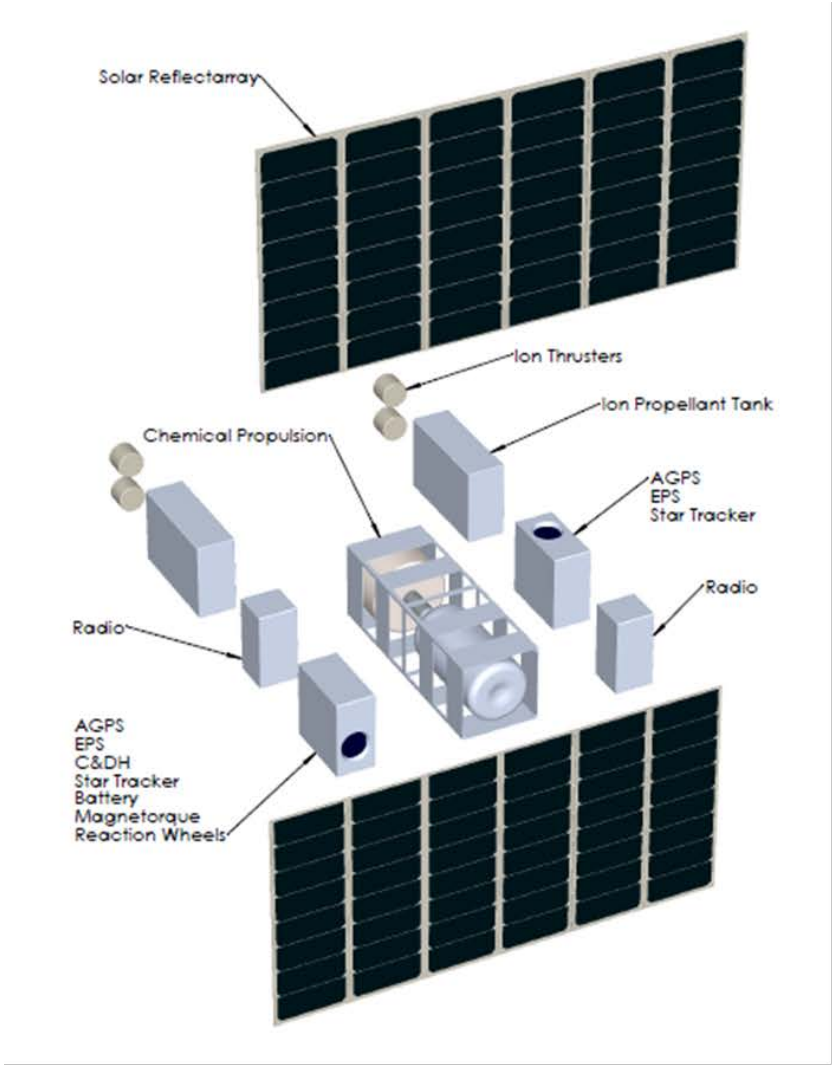
Team Member Name	Role
Gary Barnhard	Team Leader, CEO/Systems Engineering Lead
Ethan Shinen Chew	Propulsion System Lead, Systems Engineering Whip
Mike Doty	CAD/Systems Integration Lead
Anastasia Ford*	Structures & Mechanisms
Eric Gustafson	Thermal System Lead
Aaron Harper	Communications System Lead
Brian Martin	Guidance, Navigation & Control / ACS Lead
TJ McKinney	Radiation & Shielding, Scocial Media
Jamie Pulliam*	Multimedia Production
Joseph Rauscher	Contract Specialist/Documentation
Justin Siples	Web Design
John Tascione	Structures & Mechanisms

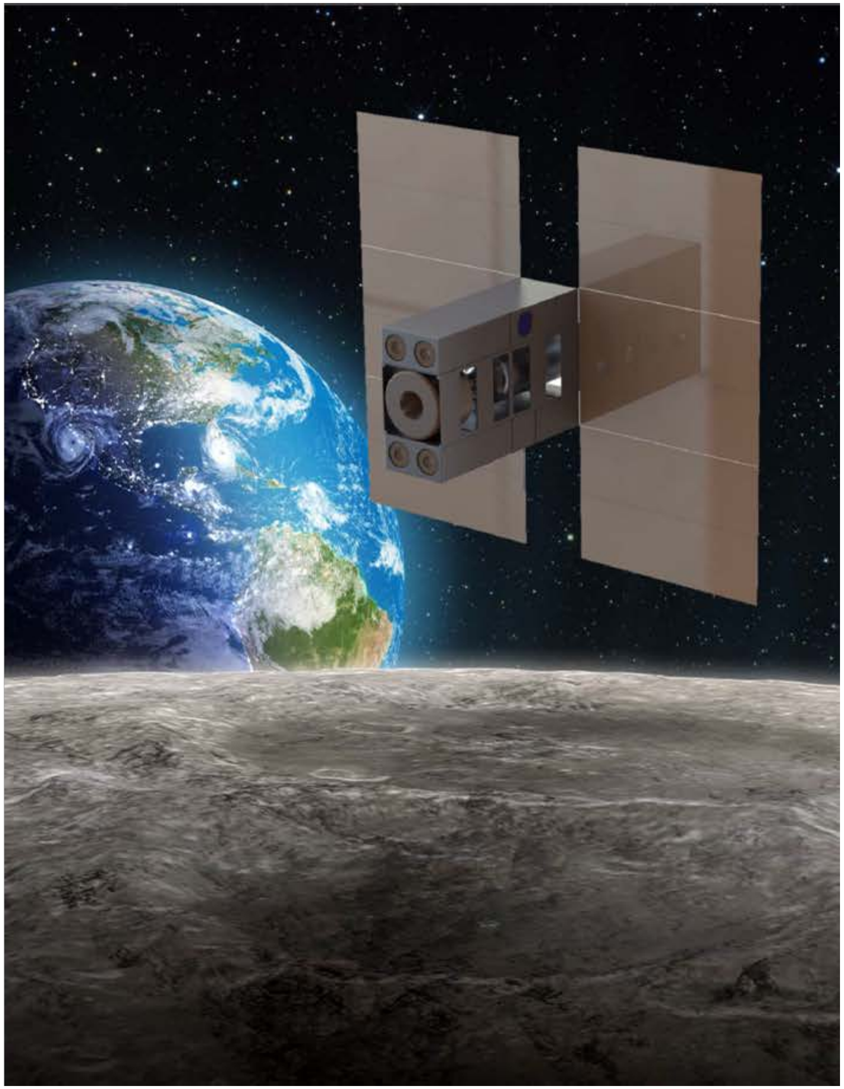
Introduction – Team Alpha CubeSat Roles (2 of 2)

Team Member Name	Role
Pat Barthelow	Communications systems Advisor
Edward Belbruno*	Trajectories Advisor
Chris Cassell	STK & Orbital Dynamics Advisor
Eric Dahlstrom	Astrophysics Advisor
James DiCorcia	Advisor – Mechanical Systems
David Dunlop	Advisor – Lunar Science
Craig Foulds	Advisor – Propulsion Systems
Matteo K. Borri	International Liaison – Attitude Control Systems
Issac DeSouza	International Liaison – Electrical Engineering
Daniel Faber	International Liaison – Systems Engineering
Joe Hatoum	International Liaison – Commercial Collaboration

* Addition or change in role

Winning Plans - ConOps Walk Through





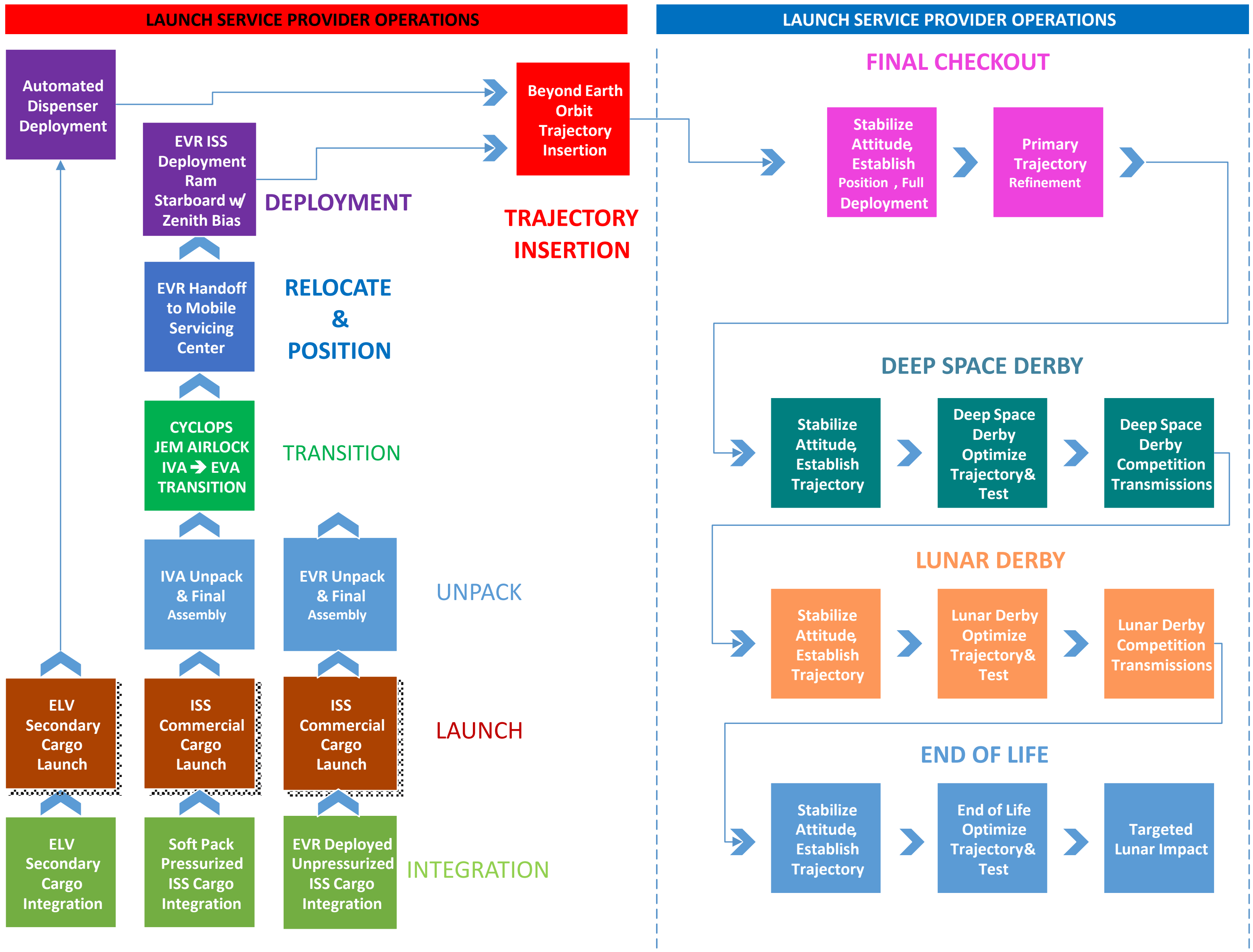
Winning Plans - ConOps Walk Through

- The Alpha CubeSat baseline is a commercial cargo launch to ISS with transportation to the deep space trajectory insertion point by a Launch Service Provider (LSP). Use of ELV deployment remains a mission alternate.
- Unpack, Transition, Relocate & Position operations are used where applicable
- Deployment is via release of robotic compatible interface at the desired alternate minimum energy deep space trajectory insertion point.
- Final Checkout operations are planned after Trajectory Insertion
- A combination of low thrust long duration, and high thrust short duration propulsion subsystems will be used to achieve trajectory insertion, and sequenced in-flight maneuvers.
- Initialization of Deep Space Derby operations begins with stablization of attitude and establishing actual trajectory, followed by optimizing trajectory & test of all systems. Competition transmissions will be initiated once navigation bits are verified.
- Initialization of Lunar Derby operations begins with stablization of attitude and establishing actual trajectory, followed by optimizing trajectory & test of all systems. Competition transmissions will be initiated once navigation bits are verified.
- Initialization of End 0f Life operations begins with stablization of attitude and establishing actual trajectory, followed by optimizing trajectory & test of all systems in support of targeted lunar impact.

Prizes Alpha CubeSat will complete for . . .

Deep Space Derby Prizes	Lunar Derby Prizes
Burst Rate	Lunar Orbit
Aggregate Data Volume	Burst Rate
Spacecraft Longevity	Aggregate Data Volume
Farthest Comm Distance	Spacecraft Longevity

Winning Plans - ConOps Walk Through



Winning Plans – Technologies and Strategies

Novel technologies/components/features of Alpha CubeSat and How they Relate to the Prizes:

Deep Space Derby - alternate launch options, propulsion options, minimum energy trajectories

- **Burst Rate:** Ka Band SDR, Available Power & CPU Cycles, NASA DSN
- **Aggregate Data Volume:** Ka Band SDR, Available Power & CPU Cycles, NASA DSN
- **Spacecraft Longevity:** Simplicity of design elements, redundancy, fault tolerance
- **Farthest Comm Distance:** Driven by return trajectory requirements (4 million km plus)

Lunar Derby - alternate launch options, propulsion options, minimum energy trajectories

- **Lunar Orbit:** minimum energy resonance orbits
- **Burst Rate:** Ka Band SDR, Available Power & CPU Cycles, NASA DSN
- **Aggregate Data Volume:** Ka Band SDR, Available Power & CPU Cycles, NASA DSN
- **Spacecraft Longevity:** Simplicity of design elements, redundancy, fault tolerance

Technical Development Plan – Design changes since GT-1

- ACS now has positive Volume, Mass, Power, Delta-V, and Communications Link budget margins as well as a second order trajectory calculation set which closes.
- ACS COMM now uses a software defined radio, Ka Band for downlink and X Band for uplink
- ACS EPS, DMS, and GN&C matured based on the use of the Blue Canyon XB1 System
- ACS S&Mech incorporates single axis array servos and structures are being optimized to anticipated loading
- ACS PROP has dropped Busek BIT-1 Ion Thrusters and is now baselining Phase 4 CAT (P4-50) Ambipolar Thruster (using Iodine).
- Use of Launch Service Provider (LSP) for delivery to Deep Space Trajectory Insertion Point baselined, a LSP Request For Proposal has been prepared, one Letter of Intent received
- Dr. Edward Belbruno is now a team advisor and his company has completed second order trajectory calculations which close with dramatically lower delta-V requirements
- Increased margins across the board allow for the consideration of secondary payloads
- Ground Systems using NASA DSN and the MCT/WARP Mission Control Technologies software suite being extended to accommodate near realtime state models are moving forward.

Technical Development Plan – Design changes since GT-1

- Candidate propulsion system concepts were compared against the requirements for delta-V, specific impulse, mass, and volume for both propellant and hardware. Performance was evaluated based on total impulse imparted, burn time required versus anticipated maximum system life, and trajectory leg periods.
- Communications system concepts were discussed in detail with NASA DSN representatives and it was determined that the only Ka Band uplink supported by the NASA DSN is currently carrier signal only. Accordingly, Ka Band uplink could not be considered an available DSN service. Further exploration of identified transceiver alternatives resulted in the selection of a Software Defined Radio solution which supports Ka Band downlink and X band uplink.
- Dr. Belbruno's revised trajectory calculations have reduced the delta-V requirement for the mission by an order of magnitude.
- Maturation of our requirements and available commercial products have resulted in the selection of the Clydespace 6 U reflectarrays.

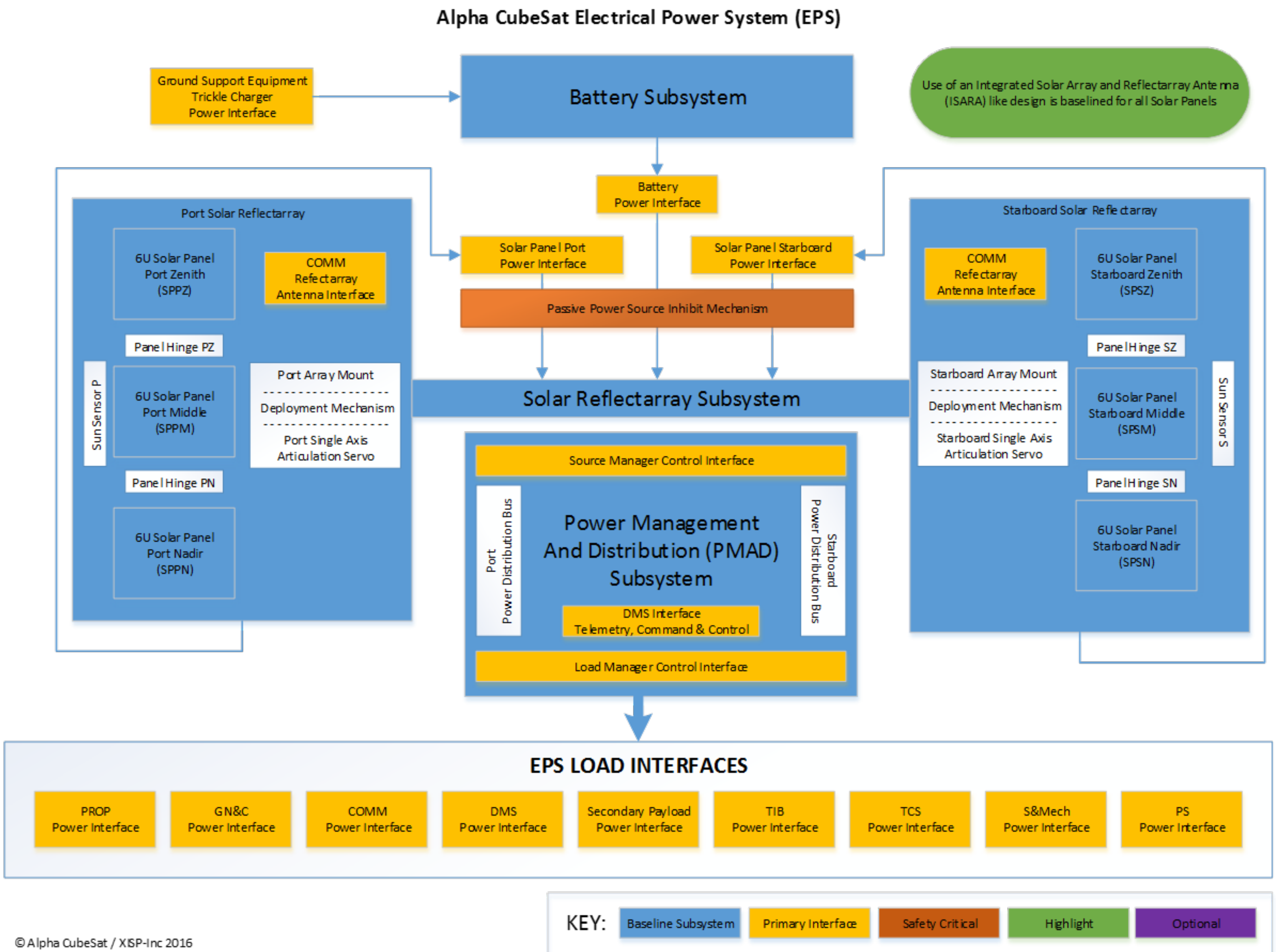
Technical Development Plan – Technical Maturity

Development Item	Current TRL	Plan to Raise TRL
COMM	5 7 9	5 => 7 transceiver is to be flown as a technology demonstrator of Software Defined Radio COTS X=>K band product is being upgraded by vendor to include Ka 7 => 9 Clydespace Reflectarray antennas are a new COTS product scheduled for this year DSN Ka Band Downlink and X Band Uplink are standard services using 34m BWG dishes
EPS	7 7 7	7 => 9 Blue Canyon battery is a COTS product with multiple flights scheduled for this year 7 => 9 Clydespace Reflectarray solar cells are a new COTS product scheduled for this year 7 => 9 Blue Canyon PMAD is a COTS product with multiple flights scheduled for this year
DMS	7	7 => 9 Blue Canyon XB-1 is a COTS product with multiple flights scheduled for this year
GN&C	7	7 => 9 Blue Canyon XB-1 is a COTS product with multiple flights scheduled for this year
S&Mech	7	7 => 7 components will be flown as a technology demonstrator
PROP	5 5	5 => 7 Hybrid Motor is to be flown as a technology demonstrator (if need is not obviated) multiple COTS vendor sources are being developed 5 => 7 Phase 4 CAT (P4-50) Ambipolar Thruster is to be flown as a technology demonstrator
TCS	5	5 => 7 components will be flown as a technology demonstrator
Ground Systems	5	5 => 7 control center will be a technology demonstrator web based console Leverage XISP-Inc Mission Control Technologies/WARP Extensions
Launch Service Provider	5	5 => 7 components will be flown as a technology demonstrator

Technical Development Plan – Verification & Validation Plan

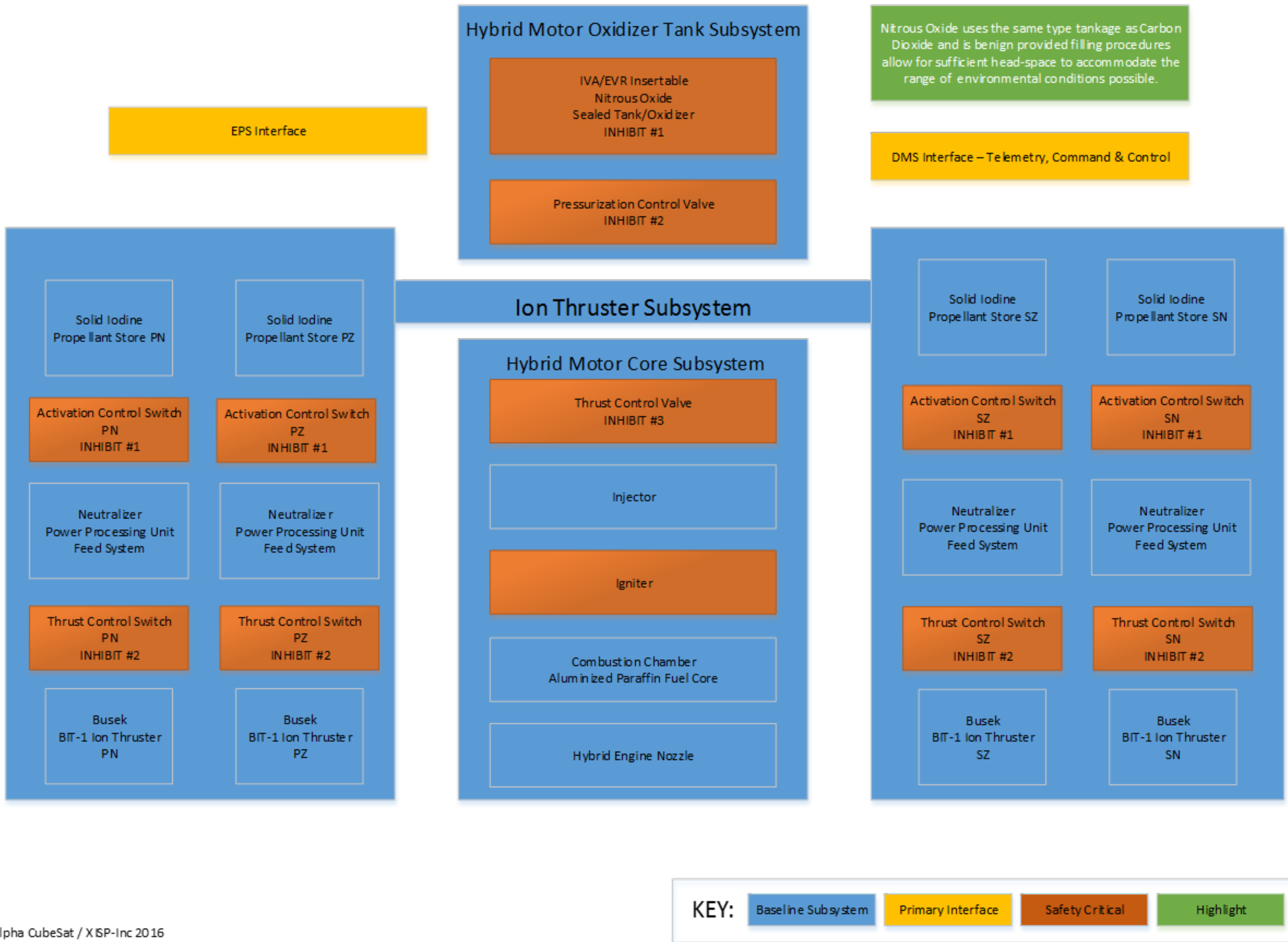
- **Overall Spacecraft:** Transition from simulation to mixed mode bench test Hardware/Software performance synchronization achieved with positive margins for all integrated systems, trajectories, and other identified design considerations will be used for verification and validation
- Prior to the Flight Readiness Review:
  - Environment Test (mechanical shock/ vibration, thermal, vacuum, solar irradiation for the overall spacecraft) will be performed along with
  - Failure Mode and Effects Analysis
  - Probabilistic Risk Assessment
  - Launch Service Provider Safety Analysis
  - Launch Service Provider Integration Assessment
- **System Level:** All defined interfaces will be assessed for convergence between simulated flows/performance and bench test measured flows/performance.
- **Subsystem Level:** Manufacturer’s testing will be used for verification and validation down to the subsystem level.

Technical Development Plan – Verification & Validation Plan

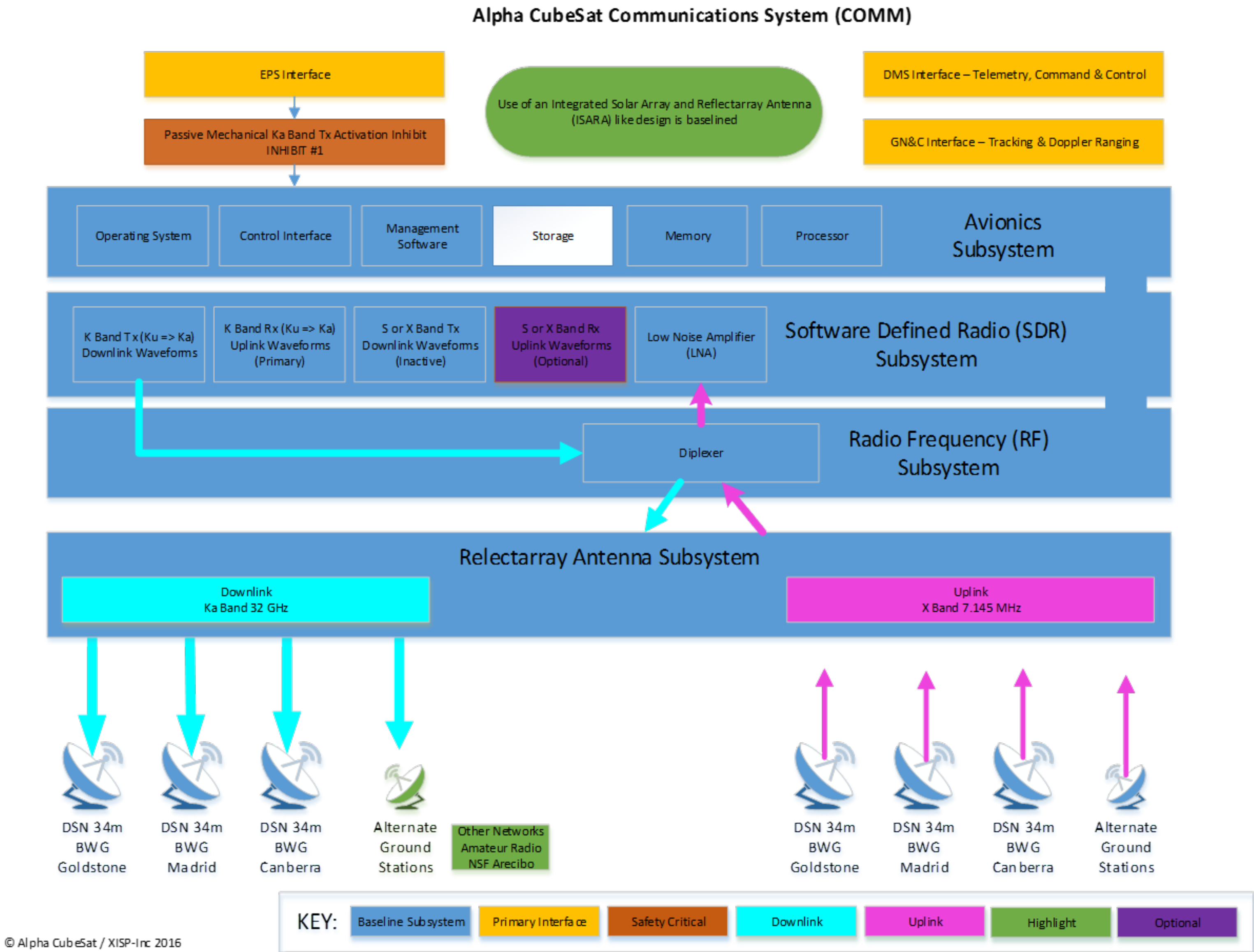


Technical Development Plan – ACS Propulsion

Alpha CubeSat Propulsion System (PROP)



Technical Development Plan – ACS Communications



Technical Development Plan – ACS Structures & Mechanisms

Use of 3D printed aluminum or titanium tanks/structural spars with interior cellular microtruss structure to maximize available space for propellant storage and optimize the overall structural chassis being evaluated.

DMS Interface
– Telemetry, Command & Control

GN&C Interface

TCS Interface

Alpha CubeSat Structures & Mechanisms

EPS Interface

TIB Interface

TIB Spacecraft Deployment Mechanism Attach Point

Passive Power Source Inhibit Mechanism

1U x 3U Ram/ Forward Plate Structure

Hybrid Motor Oxidizer Tank Subsystem

Mechanical Oxidizer Tank Seal

2U x 3U Core Structural Spars, Rails & Plate

Scar for Aft Plate + Hybrid Rocket + Oxidizer Tank Jettison

1U x 3U Aft Plate Structure

Ion Thruster Fuel Tank PZ

Ion Thruster Fuel Tank PN

Ion Thruster Fuel Tank SN

Ion Thruster Fuel Tank SZ

Use of an Integrated Solar Array and Reflectarray Antenna (ISARA) like design is baselined

COMM Interface
– Tracking & Doppler Ranging
– Telemetry, Command & Control

PROP Interface

Secondary Payload Subsystem (SPS)
- Memorial Spaceflight Canisters

Port Solar Reflectarray

6U Solar Panel Port Zenith (SPPZ)

COMM Refectarray Antenna Interface

Panel Hinge PZ

Sun Sensor P

6U Solar Panel Port Middle (SPPM)

Port Array Mount
Deployment Mechanism
Port Single Axis Articulation Servo

Panel Hinge PN

6U Solar Panel Port Nadir (SPPN)

Starboard Solar Reflectarray

COMM Refectarray Antenna Interface

6U Solar Panel Starboard Zenith (SPSZ)

Panel Hinge SZ

Starboard Array Mount
Deployment Mechanism
Starboard Single Axis Articulation Servo

6U Solar Panel Starboard Middle (SPSM)

Sun Sensor S

Panel Hinge SN

6U Solar Panel Port Nadir (SPSN)

KEY: Baseline Subsystem | Primary Interface | Safety Critical | Highlight | Optional

Programmatic Development Plan - Schedule

Major and Minor Milestones between GT-2 and Launch Date:

- GT3 - Critical Design Review Report & Presentation
- Flight Hardware/Software Integrated and All System Tests Initiated
- GT4 - Flight Readiness Review Report & Presentation
- Safety Review Final
- Flight System Delivery for Integration

Tasks Accomplished, Successes, Setbacks, Since Registration and GT-1:

- GT-1 Conceptual Design Review points identified Propulsion/Trajectory and Communications as major risk areas to be worked for PDR
- Refinement of the Trajectory Calculations by Dr. BelBruno has resulted in a dramatic lowering of the delta-V requirements.
- A reassessment of the Propulsion options has resulted in a new baseline line with built in flexibility to deal component availability issues.
- The Communications system has been refined to allow closure with substantial margin using NASA DSN standard services 34m BWG.

Programmatic Development Plan - Schedule

Tasks to be completed between GT-2 to GT-3:

- Finalize all System/Subsystem selections
- Prepare and implement acquisition/fabrication plan
- Define and implement required testing and integration plan
- Transition from simulation to bench test Hardware/Software performance synchronization achieved with positive margins for all integrated systems, trajectories, and other identified design considerations
- Flight safety review plan approved and implementation under way
- All areas of cost, schedule, and technical risk elements have been mitigated
- GT3 - Critical Design Review Report & Presentation

Delivery Schedule Margin:

- Delivery of the ACS spacecraft for commercial cargo integration is to be no later than three months before the intended launch date.
- All required testing must be completed to the satisfaction of the Commercial Cargo Carrier, NASA, and the Launch Service Provider prior to delivery for integration.

Milestones -- Payload Delivery to Launch:

- Complete command sequence edge case analysis
- Optimize command sequence to stable attitude and trajectory solution convergence
- Dry run entire mission simulation with anomalous event recovery

Programmatic Development Plan - Schedule

Team Alpha CubeSat Schedule as of February 5, 2016

Milestone	Date	Applicability	Status
Cube Quest Challenge Team Registration Opens	November 24, 2014	Yes	Challenge Announced
In-Space Competition; non-EM-1 launches	November 24, 2014	Yes	Competition Begins
Cube Quest Summit	January 7, 2015	Yes	Attended
Notice of Intent to Form Team Alpha CubeSat	January 1, 2015	Yes	Submitted & Confirmed
Formal Registration Acceptence	March 2, 2015	Yes	Confirmed
Notice of Intent of Team Alpha Cubesat to Compete	March 2, 2015	Yes	Submitted & Confirmed
Mission Concept Registration Data Package	April 30, 2015	Yes	Submitted
Monthly Report Team Inception through March 2015	April 30, 2015	Yes	Submitted
Monthly Report - April 2015	May 7, 2015	Yes	Submitted
Monthly Report - May 2015	June 7, 2015	Yes	Submitted
Cube Quest Challenge Townhall	June 11, 2015	Yes	Attended
Monthly Report - June 2015	July 7, 2015	Yes	Submitted
Alpha CubeSat Conceptual Design Review Process			
GT1 Data Submission	July 3, 2015	Yes	Submitted
GT1 Tournament	August 3, 2015	Yes	Submitted
Monthly Report - July 2015	August 7, 2015	Yes	Submitted
ACS Conceptual Design Review	August - October	Yes	Team agreed press to PDR
Cube Quest Summit II	October 21, 2015	Yes	Attended
Cumulative Monthly Report - January 2015 - January 2016	February 2, 2016	Yes	Submitted
Alpha CubeSat Preliminary Design Review Process			
GT2 Data Submission	February 5, 2016	Yes	Pending
GT2 Tournament	March 1, 2016	Yes	Pending
ACS Preliminary Design Review (PDR)	March - April	Yes	Team Vote
Alpha CubeSat Critical Design Review Process			
GT3 Data Submission	August 5, 2016	Yes	Future Event
GT3 Tournament	September 7, 2016	Yes	Future Event
ACS Critical Design Review (CDR)	September - October	Yes	Team+LSP+NASA Vote
Alpha CubeSat Flight Readiness Review Process			
GT4 Data Submission	February 3, 2017	Yes	Future Event
GT4 Tournament	March 1, 2017	Yes	Future Event
ACS Flight Readiness Review (FRR)	March - December	Yes	Team+LSP+NASA Vote
ACS Delivery to Launch Service Provider (LSP)	FRR Complete + 1 month	Yes	Future Event
ACS Delivery to Deep Space Trajectory Insertion Point	FRR Complete + 3/6 months	Yes	Future Event
In-Space Competition; EM-1 scheduled launch date	EM-1 Launch (early 2018)	Reference	Sliped to Late 2018
End of Competition	EM-1 Launch + 365 days	Yes	Future Event

Programmatic Development Plan - Programmatic Risks

Programmatic Risks:

- Goodwill: Availability of technical resources, materials, and equipment is predicated on maintaining goodwill between Team Members and Teammates/Sponsors, actualization of perceived mission value, integrity, and formalization of business relationships.
- Margins: The necessary design robustness, margins, integrated risk review process, and technical interest to warrant the in-kind hardware/software investments needed must be defined and maintained to obtain and sustain sponsorships.
- Commercial Value: Link to commercial world and perceived value of mission products drives down many elements of schedule risk, technical risk, and cost risk but will increase team critical path workload by driving out any available slack time/schedule margin.
- Skill Mix: Team is growing and evolving with the work, but as the stakes and level of the work increases skill gaps & volunteer time limits are becoming apparent.

Alpha CubeSat Programmatic Risk Matrix

Likelihood of Occurrence	Highest	5			Skill Mix		
		4				Goodwill	
		3					
		2		Margins		Commercial Value	
	Lowest	1					
			1	2	3	4	5
			Lowest				Highest
			Consequences of Occurrence				

Programmatic Development Plan - Programmatic Risks

Programmatic Risk Mitigation Strategies:

- Goodwill: We have to conduct business in a transparent, straight forward manner, formalize our business relationships to accommodate growth, deliver what we promise, and never promise more than we can deliver.
- Margins: We will clearly define and document all trades, implement our integrated risk review process, and share our margin analysis with our sponsors on an ongoing basis.
- Commercial Value: Alternate launch option will be maintained, slack time/schedule margin claims must be mitigated by fungible resource/cash infusion/other recognized exchange of value.
- Skill Mix: internal education program has been defined, subject matter experts have been hired where needed, treat volunteers as a managed resource, schedules have been adjusted to meet volunteer availability.

Programmatic Development Plan - Cost Factors

Planned CubeSat Costs (including materials, labor, tests, test facilities):

- Burn Rate Actuals Start-to-GT2 ~2844 hours, ~1.56 FTE / ~$367,000 In-kind & Cash Expenses
- Burn Rate Projected Start-to-End ~ 8 FTE, ~ $1,000,000 Unmitigatable Labor & Other Running Costs
- Value of donated hardware/software/tests/test facilities/tools/services projected to be between $1,000,000 to $5,000,000. Budget closure pending completion of design trades and buyoff by sponsors on the value of a participation in a technology development and demonstration mission.
- Use of the NASA DSN ground stations, aperture time, ground support equipment, data pass through, ground data systems, operations facilities, and labor is included in the above estimates. Low end costs assume parsimonious use of "just-right" sized DSN services and in general tag along, time available access to resources. Access on demand will drive costs towards the higher end.

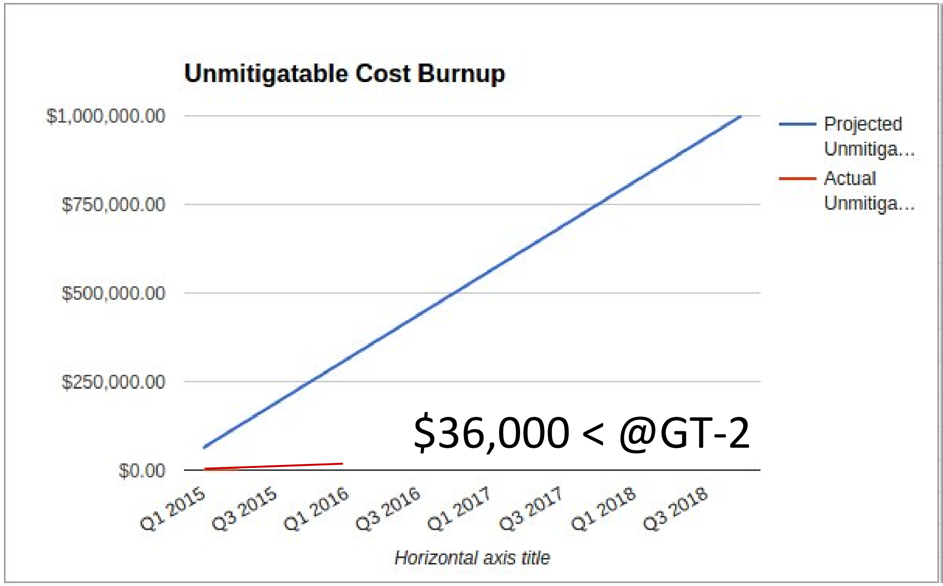
How costs are phased, by quarter, from registration date until competition end and CubeSat disposal:

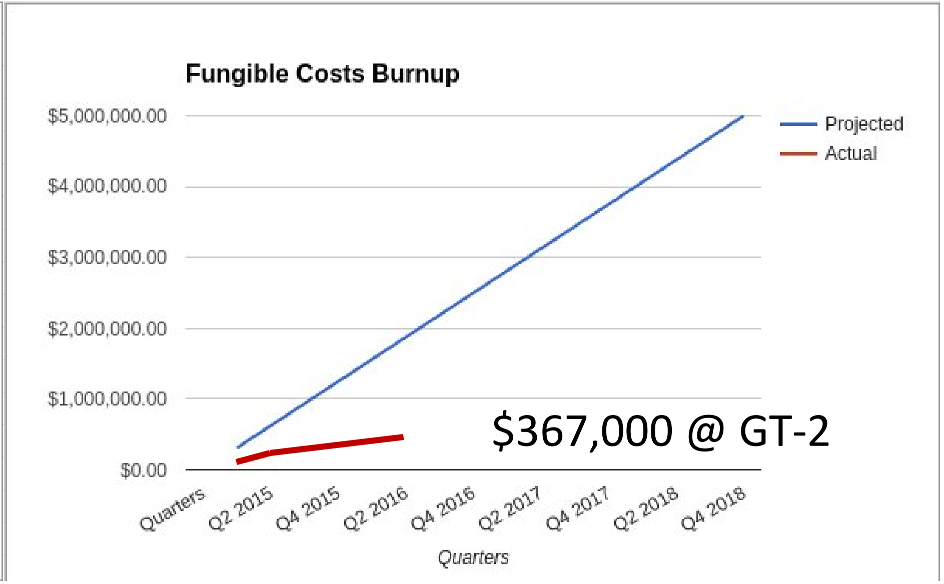
- Running costs ~$125,000 1st QTR 2015 - 1st QTR 2017, ~$18,000 QTR thereafter until EOL

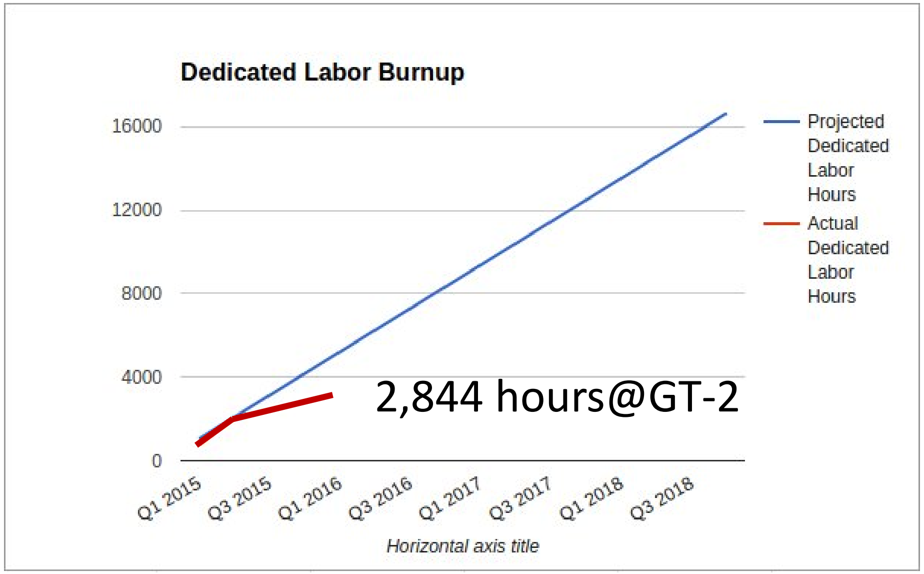
Plans to Cover Costs & Account for Uncertainties in Costs.

- Press to GT-2/Preliminary Design Review to achieve viable technical mission/spacecraft design
- Prepare mission sponsorship marketing campaign
  - Plan, brochure, video, mission "sponsors", system "partners", social media "supporters"
- ACS is a "Technology Development and Demonstration Mission," we have a growing list of sponsors, partners, supporters, and payloads!
- ACS is leveraging all available relationships to create a web of resources which enables both the successful flight of the CubeQuest mission payload and foster the development of a range of commercial products.

Programmatic Development Plan - Cost Factors







Programmatic Development Plan - Technical Risks

Identified Technical Risks:

- Ka Radio: Timely availability of suitable Ka Band Transceiver
- Volume: Loss of volume margin due to system trade results
- Heat: Thermal disconnect under competition loading
- Radiation: Due to changes in trajectory radiation environment is materially increased
- Trajectory: Trajectory/Propulsion optimization is required to restore mass, volume, and delta V margins

Technical Risks Mitigation Strategies:

- KA Radio: We have found a suitable Ka Band transceiver that fits our schedule.
- Volume: Advances in trajectory have mitigated this risk and substantially reduced propulsion requirements.
- Heat: All available thermal management tools will be traded to provide thermal margin under loading.
- Radiation: Advances in trajectory have mitigated the Van Allen radiation belt risk. The deep space radiation environment impact is being traded with propulsion, shielding, and other systems.
- Trajectory: Advances in trajectory and maturation of the propulsion system options analysis have resulted in clearly defined solutions with margin.

Programmatic Development Plan - Technical Risks

Alpha CubeSat Technical Risk Matrix

Likelihood of Occurrence	Highest	5					
		4					
		3			Thermal		
		2			Volume Radiation		Ka Radio
	Lowest	1					Trajectory
			1	2	3	4	5
			Lowest				Highest
			Consequences of Occurrence				

Judge Questions to Teams

Thank you for your consideration

Questions can be directed to our team lead
gary.barnhard@xisp-inc.com

Additional resources can be found via our website www.alphacubesat.com

Team Alpha CubeSat is not waiting for the future we are building it!

Ground Tournament 2 Team Presentation

Good Luck and May the Best CubeSat Win!