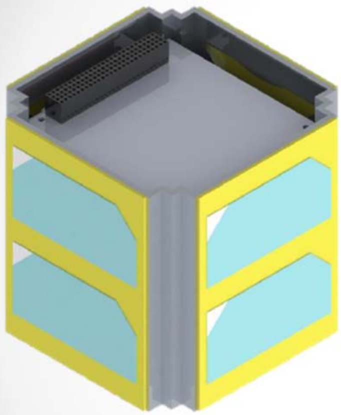


Thomas Jefferson High School

NASA CubeSat Launch Initiative (CSLI) Feasibility Review

11 November 2016

Principal Investigator: Michael Piccione
Energy Systems Lab Director
Thomas Jefferson High School for Science and Technology

EMERGENT Space Technologies

RAGNAROK INDUSTRIES NANO SATELLITE COMPANY

1

Logistics

Bathrooms: Out the back door and on the right
Fire exit: Exit through the main office and out through the dome

2

Agenda

Topic	Presenter	Time (TBD)
Tour and Lunch		12:00 - 1:00
Introduction, Project Goals and Goals of the Review	Emma	1:00 – 1:10
Management Team and Organization Chart	Justin	1:10 – 1:15
Mission Concept	Justin	1:15 – 1:25
System Requirements	Justin	1:25 – 2:15
Break		*2:15 – 2:30*
Technical Implementation – Preliminary CubeSat Design	SC, AS, SM, AZ, LD, SS, MK	2:30 – 3:45
Launch Services Requirements Compliance	AS, SS, DZ	3:45 – 3:55
Break		*3:55 – 4:05*
Risks	Diana (DZ)	4:05 – 4:15
Schedule and Cost	Michael, Thomas	4:15 – 4:30
Q&A		4:30 – 5:00

Introductions

- Mentors:
  - Mr. Luigi Balarinni, Ragnarok Industries, CEO
  - Dr. Sun Hur-Diaz, Emergent Space Technologies
- Reviewers:
  - Ms. Hannah Goldberg, Planetary Resources
  - Mr. John Rotter, Retired Space Systems Engineer, US Air Force
  - Mr. Nantel Suzuki, NASA HQ
  - Dr. Jeff King, US Naval Academy, Aerospace Engineering Instructor

Mission of TJHSST

The mission of Thomas Jefferson High School for Science and Technology (TJHSST) is to provide students with a challenging learning environment focused on math, science, and technology, to inspire joy at the prospect of discovery, and to foster a culture of innovation based on ethical behavior and the shared interests of humanity.

5

Education Goals and Minimum Success Criteria

Goals	Success Criteria
Train students in building of a 1U CubeSat	1U CubeSat is built and tested by students to NASA CSLI requirements
Develop and document the processes needed	Project website is populated with process documents, lessons learned, and educational material
Engage in STEM outreach to the public and local students	• Ground stations at other schools are set up for communication with the CubeSat • CubeSat build/test lessons • Hands-on activities for kids • News and social media report progress
Operate the 1U CubeSat in orbit	• Activities and lessons developed from data

6

Project Goals and Success Criteria

Goals	Success Criteria
Design Cubesat while staying within budget: Power, Volume, Mass, Cost	• Power budget: Battery bank stays charged above 20% • All components fit within 1U frame and maintain clearance • All components are under 1.3Kg • Cost for cubesat launch materials < $60,000
Assess feasibility of cubesat design	• Committee deems project is feasible or gives guideline to achieve feasibility
Assess Risk Factors	• Committee deems project is within acceptable risk or gives guideline to achieve acceptable risk
Apply for and be selected as a NASA CSLI candidate with the **Education** focus area	• Merit Review results in improved education plan for NASA Educational goals • Feasibility Review results in improved technical design • Proposal is submitted by 11-22-16; TJ is selected
Build, launch, and operate the 1U CubeSat in orbit	• Ground communicates with the CubeSat • Useful payload data is received

7

Goals of the Feasibility Review (1/2)

- Assess the proposed mission's
  - Technical implementation
  - Feasibility (technical difficulty, schedule, cost, etc.)
  - Resiliency
  - Probability of success
- Management team roles, experience, expertise, organizational structure
- Technical development risk of the overall mission
- Assess critical technology development required
  - Determining critical technology
  - Plans for completing the critical technology development

8

Goals of the Feasibility Review (2/2)

- Probability of successful development of the CubeSat for flight
- Compliance with the Launch Services requirements and any potential waivers
- Reasonableness of the schedule for remaining CubeSat development that supports a launch in 2017-2020
- Strengths and weaknesses of the proposed design
- Provide constructive feedback for improvement

9

Summary of Merit Review

- How proposed mission meets NASA educational goals
    - Within TJ CubeSat engineering teams
    - Outreach
        - Partner schools
        - Local disadvantaged K-12 students
- Major Concerns
    - Team spread too thin
    - More details on proposed payload

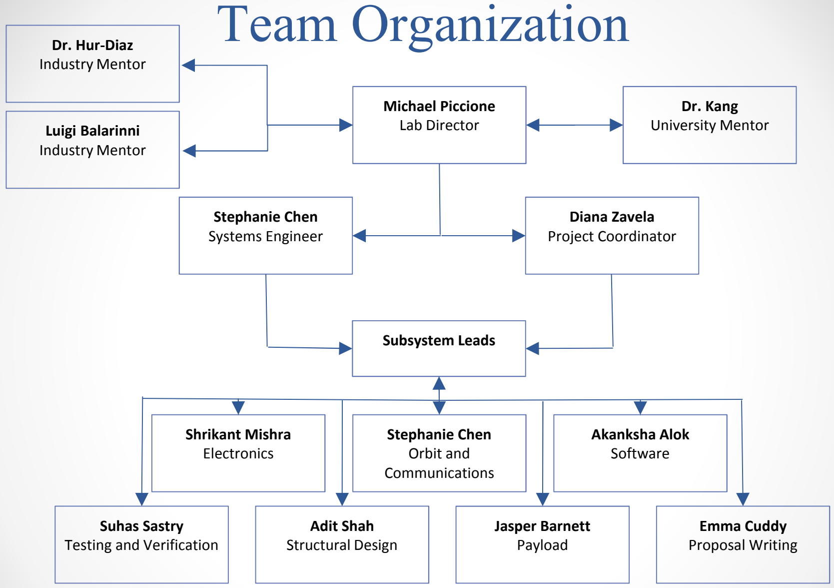
10

Management Team

Role	Name	Title: Affiliation	Expertise / Experience
Principal Investigator	Mr. Michael Piccione	Energy Systems Lab Director: TJHSST	15 years HS instructor. Topics include: engineering design, CAD, electronics, prototyping
Industry Mentor	Dr. Sun Hur-Diaz	Chief Engineer: Emergent Space Technologies	VP of Research and Development, received her PhD and MS at Stanford in Aerospace Engineering her expertise is in Guidance, Navigation, and Control and Flight Dynamics.
Industry Mentor	Mr. Luigi Balarinni	CEO: Ragnarok Industries	Ragnarok is one of the 6 finalists teams in NASA's Lunar CubeSat Challenge, Previously he worked on the 6U CubeSat Dellingr in 2014 at NASA Goddard Space Flight Center.
University Mentor	Dr. Jin Kang	Assistant Professor: US Naval Academy, Aerospace Engineering	Director of USNA Small Satellite Program and 11 years teaching experience

11

Team Organization



12

1U Project Details

- The current mission is a joint operation between:
  - Thomas Jefferson High School for Science and Technology
  - Ragnarok Industries
  - Emergent Space Technologies
- Train students in the basic parts of a 1U cubesat
- Develop and document the processes needed for cubesat design
- Apply for a NASA CSLI launch under "Educational Merit"
- Design, launch, and test the "Research and Education Vehicle for Evaluating Radio Broadcasts"(REVERB) Cubesat which will be used to evaluate the effectiveness and ease of use of at least 2 onboard radio systems in a deployed cubesat and determine the feasibility of at least 2 methods of ground communication

13

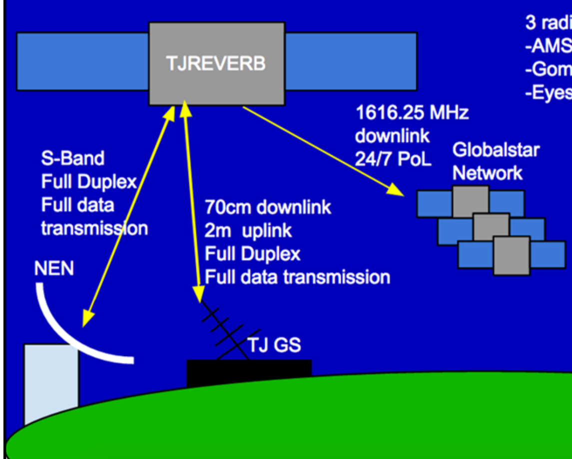
System Requirements

No.	Requirement Statement
1	TJREVERB shall operate in-orbit for at least 90 days
2	TJREVERB shall be capable of being deployed from an ELANA Rocket
3	TJREVERB shall be capable of being deployed from the ISS (Typical ISS Orbit: 400 km altitude, 51.65 deg incl, 93 minute orbit)
4	TJREVERB shall carry at least two radios for educational use
5	The two radios shall be capable of receiving uplink commands
6	The two radios shall be capable of broadcasting data for telemetry and verification of educational testing goals
7	TJREVERB shall comply with P-POD CubeSat deployment dispenser requirements
8	TJREVERB shall wait 30 minutes after spacecraft deployment before any comms deployments / 45 mins for RF Comms
9	TJREVERB shall survive the LEO environment.

14

Break

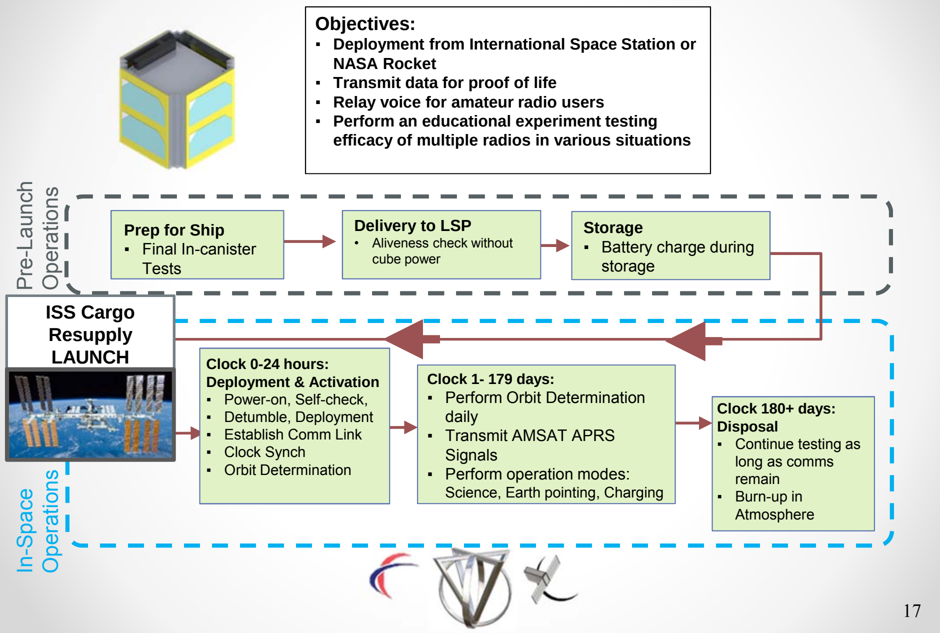
TJREVERB Mission



3 radios:
-AMSAT UHF Down/VHF Up Transceiver
-Gomspace NanoCom S100 Transceiver
-Eyestar S-3 Simplex Radio

Rational and Notes
-2m(VHF) is more effective at penetrating the atmosphere and ionosphere, and will have a higher receive fidelity by the cubesat resulting in faster transmission, while TJGS can amplify and filter 70cm(UHF) received data more extensively than the cubesat can
-Full duplex saves space and power
-Simplex transmitter can be used as 24/7 Proof of Life (PoL)
-S-Band transceiver can be used for full data relay to compare communications testing between NASA's Near Earth Network and TJ's amateur radio ground station

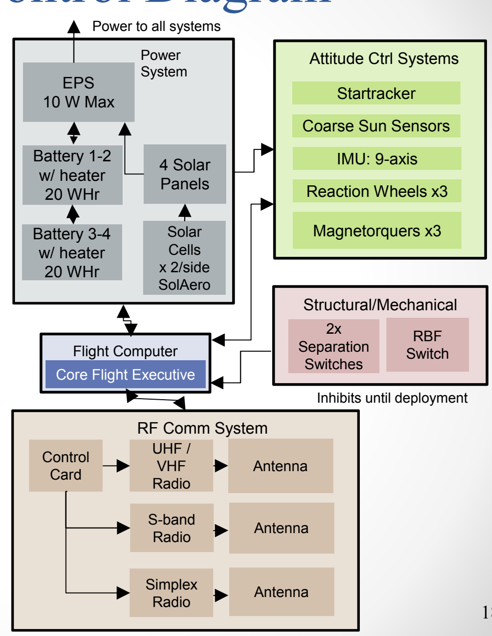
TJREVERB Mission Concept



17

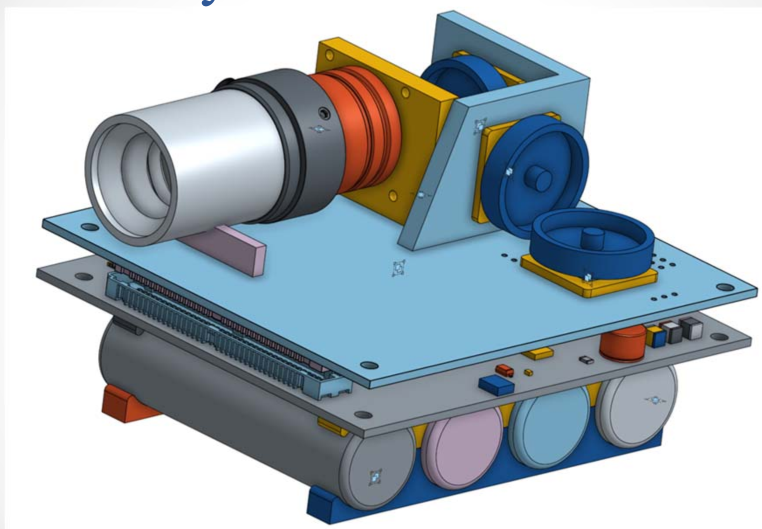
Systems Control Diagram

The separation switches and remove before flight switch inhibit communication deployment and radio frequency emission per NASA's requirements.
The Power system will be charged from the solar panels and power the all systems. The ACS, and Comms system will be controlled by the flight computer.



18

Subsystems CAD Model



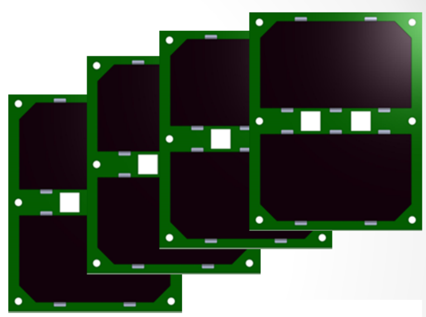
19

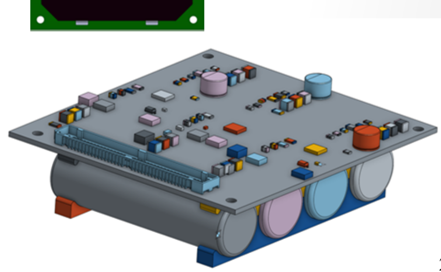
Power Subsystem

Solar Cells:
- Photovoltaic energy → electrical energy

Li-Ion Batteries:
- Charging while illuminated
- Discharging while eclipse

Electrical Power System (EPS):
- Management of all available power to systems





20

Power Subsystem

Requirements	Trades, options, and analysis (if any)	Verification and Validation
Supply necessary power and voltage to all components from batteries	Power limited by solar panels	Will test in lab under mission conditions
Store charge from solar cells so batteries remain over 20% charged	Option to use deployable cells if current configuration is deemed ineffective	EPS will monitor voltage generation in lab tests More testing needs to occur to determine necessity.
Use a two cell by two bank 18650 battery configuration	Use large flat battery pack from NSL kit	Will test in lab under mission conditions
Change to charged cells when current cells reach 20% charge		Will test in lab under mission conditions

21

Power Subsystem

Hardware	Mass (g)	Total Watts (W)	Vendor	TRL	QTY	Cost
Electrical Power Supply Board	100	-	Ragnarok	6	1	Donated
18650 2 Battery Set X2, 96g each	192	5.9	Ragnarok	6	4	Donated
Solar Panel Boards, PCB/FR-4, 29g/each; 2 ZTJ 29.5% per Board, 2.4 grams each	116	4.4	SolAero	9	4	Donated
Deployable Cells (optional)	>135	>4.4	NSL	9	4	$3600/side

22

Payload Subsystem

- 3 radios to be tested, we will measure power usage during broadcast and standby, bps data transfer rate and bit loss in various orientations
  - EyeStar-S3 Satellite Simplex Radio
  - NanoCom S100: Full duplex or simplex S-Band
  - Amsat Radio: Full duplex UHF/VHF
    - Primary Communications Radio

23

Communications Payload

Requirements	Trades, options, and analysis (if any)	Verification and Validation
Full data transmission with Near Earth Network (NEN)	NEN uses X-band, S-Band, VHF, and Ka-band. The majority of NEN ground stations have S-Band capabilities vs. VHF which was only used for voice communication with ISS.	Test S-Band radio in lab under mission conditions.
Continuous proof of life	Duplex UHF/VHF could be used as redundancy. Two redundant RX and TX options will be available and accessible by both NEN and TJGS, but Eyestar is more compact and has better coverage.	Test Eyestar simplex radio on the ground with a cable. Potentially build a ground eyestar simplex radio and test it with a balloon.
Full data transmission with TJ ground station	Considered VHF, UHF, UHF/VHF, and S-Band. Same frequency duplex is nearly impossible because of interference. VHF up is more effective at penetrating the atmosphere, while TJGS can amplify UHF down which is faster due to greater bandwidth. S-Band set-up is difficult and not amateur radio.	Test in lab under mission conditions. Make sure frequencies don't interfere in ground testing.

24

Communications Payload Hardware

Component	Idle Power (W)	Tx Power (W)	bps	Frequency (MHz)	Vendor	TRL	Cost	Mass (g)
Simplex Radio w/ Antenna	~0.2	~2.75	72	1616.25 Tx	NSL	8	$5K	50
Duplex S-Band w/ Antenna	TBD	<=2.0	1.5k- 25M	2025-2110 Rx, 2200–2290 Tx	Gom Space	9	$32K	100
Full Duplex VHF/UHF w/ Antenna	0	~.5	9600	144-148 Rx, 420-450 Tx	AMSAT	9	donat ed	80

Attitude Determination & Control Subsystem (ADCS)

Requirements	Trades, options, and analysis (if any)	Verification and Validation
Determine location using onboard systems	Startracker and sun sensor	Reference data from camera to last known telemetry data
Control cubesat with 3 Axis pointing to .1 degree error for comms test	Startracker: Pitch / Yaw: 1 arc-minute (0.0167 degs) Roll: 30 arc-minute Reaction Wheels x3 Torque: 0.15 mN*meter	Use onboard IMU and other sensors to determine accuracy
Control cubesat with 1 axis control for charging or Comm Rx	Startracker: Pitch / Yaw: 1 arc-minute (0.0167 degs) Roll: 30 arc-minute Reaction Wheels x1 Torque: 0.15 mN*meter	Use onboard IMU and other sensors to determine accuracy
Dump momentum through embedded magnetorquers	3 magnetorquers for 3 axis 1 Magnetorquer for 1 axis	Use onboard IMU and other sensors to determine accuracy

Guidance, Navigation, & Control Sys

Component	Power (mW)	Power Used per Avg Orbit (mW)	Mass (g)
Star Tracker	20	100	170
SunSensor: S5106,	1	10	10
Magnetorquer X, Y, Z	60	300	60
IMU: MPU-9250	92	100	0.005
Reaction Wheel A, B, C	60	400	90
Flight Computer	50	500	150

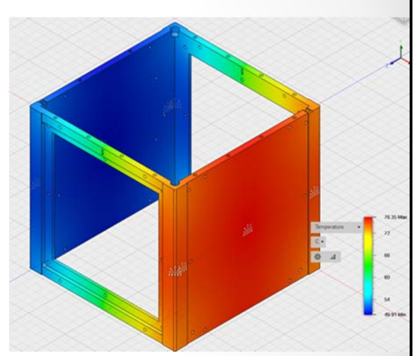
27

Thermal Subsystem and Simulation

For all simulations:
- Use Autodesk Fusion 360

Part simulations:
- Stress analysis of frame
- Thermal analysis of electronics

Full system simulations:
- Stress analysis
- Thermal analysis



28

Thermal Subsystem (cont.)

- Passive thermal system design
- Active elements, Kapton thin-film heaters located between batteries, preventing them from dropping below 0 °C

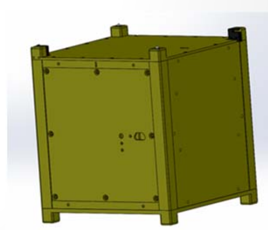
Component	Thermal Tolerance
Batteries	0 °C to 40 °C
EPS	-40 °C to 85 °C
Magnetorquer	-35 °C to 75 °C
IMU	-40 °C to 125 °C
Startracker	-40 °C to 85 °C
S-Band Radio	-40 °C to 85 °C
Simplex Radio	-50 °C to 85 °C

29

Structure & Mechanism Subsystem

Specifications	
TRL (Electronics)	9
TRL (Structure)	9
Mass	150g
Dimensions	10.3 cm x 10.3 cm x 13.5 cm
Mechanical Specifications: Cooling	Thermal radiator shield
Flight Test: Temperature	Passive Heat Sink/ Radiator EPS: -40 to +85℃

Flight Heritage (Low-Earth Orbit)	Rocket, Altitude
TSAT (2U - April 18, 2014)	SpaceX Launch, 325 km, ELaNa 5
GEARRS1 (3U - July 13, 2015) Collaboration: AFRL	Cygnus CRS-2 Launch, 410 km, ISS
GEARRS2 (3U - May 20, 2015)	Atlas 5 (501) Launch, 700 km

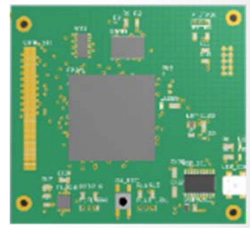


*Frame will be purchased off-the-shelf

30

Command & Data Handling (C&DH) and Flight Software Subsystem

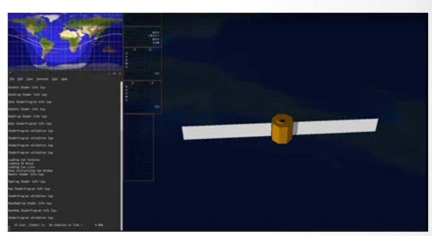
	Ragnarok Flight Computer
TRL Level	4
Processor	Microsemi Igloo2
Interfaces	SPI I2C RS232 CSS
Additional	Integrated MPU-9250 IMU
Power Consumption, Estimated	525 mW
Memory Budget	512 mb internal memory + large flash memory storage
Backplane	None
Development Board & Existing Libraries	Yes RTEMS / Core Flight Executive
Radiation Tolerance	SEL watchdog timer SEU Immune



31

Software

- Onboard and on the ground
- Goddard's Core Flight Software System
  - Core Flight Executive
  - Delegates and controls internal tasks
- Goddard's *42* Software
  - Orbital simulation software
- GNURadio
  - Manages SDR component of data transmission



32

Flight Dynamics Subsystem

- ≥ 1440 orbits assuming ≥ 90 days operation
- Mission life from 1/1/18-8/6/19 ~1 year 8 months in ISS orbit
- Satellite is in sunlight ≥ 59% of the time; maximum total eclipse ~38 min/orbit (92.69min) simulation max: 36.664 min
- TJREVERB is projected to weigh 1183g, (TLE)
- A waiver can be applied for exceeding 1333g

33

Total Power and Mass Budget

Power systems will prevent greater than 80% Depth of Discharge of battery capacity

- Panasonic 18650B are depleted to 80% DoD. 3.2V @ 3500 mAH = 11.2 W*Hr
- 80% DoD Capacity available of 11.2 W*Hr = 8.96 W*Hr
- Ragnarok Battery Pack is made of 2 batteries (17.92 W*Hr capacity)

Total Mass is below 1330g

Subsystem	Component	Voltage	Power (W)	Orbit Length (hrs)	Science Mode		Earth-Pointing Mode		Sun-Safe / Charging Mode		
					Duty Cycle	Whrs Used / Orbit	Duty Cycle	Whrs Used / Orbit	Duty Cycle	Whrs Used / Orbit	mass
GNC	Star Tracker	5	0.200	1.500	0.2	-0.04	0.2	-0.04	0.0	0.00	170.00
	CSS: S5106, QTY:6	3.3	0.001	1.500	1.0	0.00	1.0	0.00	1.0	0.00	10.00
	Magnetorquer X	5	0.200	1.500	0.25	-0.05	0.25	-0.05	0.25	-0.05	20.00
	Magnetorquer Y	5	0.200	1.500	0.25	-0.05	0.25	-0.05	0.25	-0.05	20.00
	Magnetorquer Z	5	0.200	1.500	0.25	-0.05	0.25	-0.05	0.25	-0.05	20.00
	IMU: MPU-9250	5	0.092	1.500	1.0	-0.09	1.0	-0.09	0.0	0.00	0.01
	RXN Wheel A	5	0.200	1.500	1.0	-0.20	1.0	-0.20	0.0	0.00	30.00
	RXN Wheel B	5	0.200	1.500	1.0	-0.20	1.0	-0.20	0.0	0.00	30.00
	RXN Wheel C	5	0.200	1.500	1.0	-0.20	1.0	-0.20	0.0	0.00	30.00
	Flight Computer	5	0.525	1.500	1.0	-0.53	1.0	-0.53	1.0	-0.53	150.00
Comm	AMSAT, Tx	5	1.00	1.500	0.1	-0.10	0.1	-0.10	0.1	-0.10	80.00
	AMSAT, Rx	5	0.00	1.500	1.0	0.00	1.0	0.00	1.0	0.00	0.00
	Antenna	5	0.00	1.500	1.0	0.00	1.0	0.00	1.0	0.00	20.00
	Simplex	12	2.5	1.5	0.2	-0.75	0.0	0.00	0.0	0.00	50.00
	Sband	5	2	1.5	0.2	-0.60	0.0	0.00	0.0	0.00	100.00
Power	EPS	5V / 3.3V	0.10	1.500	1.0	-0.10	1.0	-0.10	1.0	-0.10	100.00
	Solar Panels	5V	1.06	1.500	1.0	1.06	1.0	1.06	1.0	2.14	150.00
Batteries	Battery	3.2	17.92	1.500	1.0	17.92	1.0	17.92	1.0	17.92	192.00
Heaters	Battery Heater, 0.25W	3.2/cell	0.25	1.500	0.1	-0.05	0.1	0.00	0.1	0.00	10.00
Total Consumption						-3.00		-1.61		-0.88	1182.01
Total Consumption (Including EPS Losses)						-3.18		-1.70		-0.93	
Total Consumption (Including EPS and Battery Losses)						-3.34		-1.79		-0.97	
Worst Case Energy Generation (Beta=0, Orbit Avg x Orbit Length)						1.06		1.06		2.14	
Worst Case Energy Generation (including EPS Losses)						1.00		1.00		2.02	
Worst Case Energy Generation (including EPS & Battery Losses)						0.95		0.95		1.92	
Net Whrs Per Orbit (Production + Battery Capacity - Consumption)						-2.39		-0.84		0.95	
# Orbits typical Day						5.00		7.00		4.00	
Net Whrs on a day (Net Whrs per Orbit x # of Orbits)						-11.97		-5.87		3.79	
Net Whrs on a day Total					3.88						

34

Ground System and Operations at TJ

Requirements	Trades, options, and analysis (if any)	Verification and Validation
Antenna rotor to point the yagi antenna	Yaesu antenna or student build antenna from SATNOG	Test if we can track Fox-1 CubeSat
Transceiver to send and receive communications	USRP B100 is cheaper, but USRP B210 is faster.	Test for communication capabilities with current CubeSats.
Computer system to interface with the motor control and send and receive signals.		Test for motor control before launch and test communication with current CubeSats.

35

Ground System and Operations at TJ

- Motorized Azimuth/Elevation Control of UHF / VHF
- Amateur frequency bands: 2m and 70cm
- VHF and UHF hi-gain yagi antenna 15dBi

- USRP B210 transceiver: 70MHz-6GHz
- Windows 10 (or Linux) development board to run system
- Current ham operator: Gavin Saul (plan to certify others)

36

Launch Services / Deployment Interface

- Will follow the Launch Service Requirements detailed in "Launch Service Program, Program Level Dispenser and CubeSat Requirements Document"
- Rocket based CubeSat Dispenser (P-POD)
  - Less than 1.33kg
  - Center of gravity less than 2 cm from the geometric center
  - All rails and standoff will be made from hard anodized aluminum
- Interface with ISS Cubesat deployment

37

Safety & Mission Assurance

- Technical Verification & Validation
- Subject the PCB and CubeSat to environmental testing
  - EMI/EMC
  - Vibration
  - Thermal cycling (cold case and hot case)
  - Thermal Vacuum (cold and hot and outgassing)
- CubeSats that comply with the ISS ballistic coefficient requirements (less than 100 kg/m^2) should always decay faster than (and be below) the ISS
  - $\beta = m/(C_d*A) = 45.45\ kg/m^2$ (for TJREVERB), with m = mass, C_d = drag coefficient, and A = cross-sectional area

38

Safety Assurance

- Classified Sub Class-D Mission
- Deployed from the ISS and an ELANA Rocket
  - Comply with P-POD CubeSat deployment dispenser requirements

Mission Assurance

- Minimum success criteria - Training
  - Train students in building of a 1U CubeSat
  - 1U CubeSat is built and tested by students to NASA CSLI requirements
  - Develop and document the processes needed
- Minimum success criteria - Outreach
  - Project website is populated with process documents, lessons learned, and educational material
  - Engage in STEM outreach to the public and local students
  - Ground stations at other schools are set up for communication with the CubeSat
- Minimum success criteria - Mission Operation
  - Operate the 1U CubeSat in orbit
  - Ground communicates with the CubeSat
  - Useful payload data is received

Break

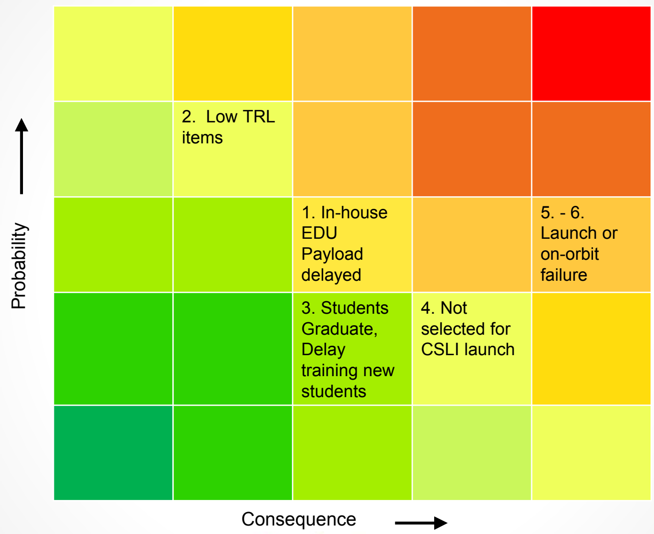
41

Risk Management

Risk Statement					Risk Treatment
Likelihood (0-5)	Consequence (0-5)				
	Safety	Performance	Schedule	Cost	
#1 - I&T or payload development requires additional time					Mitigation - Add time buffer in schedule to allow for delays, reduce scope of project but still meet objectives.
3	0	0	2	0	
#2 - Low TRL of subsystems, especially electronics,					Mitigation - Extensive testing of payload and electronics subsystems, build redundancy for high-risk systems.
4	0	2	3	0	
#3 - Students graduate, delays training new students					Mitigation - Underclassmen shadow current juniors and seniors and after 1-2 years they will work on the CubeSat.
2	0	2	3	0	
#4 - Not selected for CSLI grant					Mitigation - Reach out to industry and universities for assistance on the Merit Review and Feasibility review, as well as for project development. If risk comes true, apply for CSLI at a later date.
2	0	0	5	5	
#5 - On-orbit failure					Mitigation - Extensive testing to lower likelihood of failure in space.
3	0	4	3	3	
#6 - Launch failure					Mitigation - Plan 3U mission with Vector Space Systems
3	0	5	5	5	

42

Risk Management



43

Accomplishments

- Organized a team of 41 high school seniors into subsystem engineering teams
  - Leading underclassmen directives
- Internships with partner company
- Completed background research on individual subsystems
- Students visited and learned about satellite programs at Goddard Space Flight Center and US Naval Academy
- Lab director attended 2015 SmallSat Conference
- Mentors from the Naval Academy
- Mentorship with students from University of Michigan
- Established contacts and guest speakers from industry
- Partnership with George Mason University on the 3U

44

Strengths of Proposed Mission

- Easily measurable participant outcomes
  - Degree choices that support national education and workforce needs
- Educational goals grounded in good practice or research
- Successful history of student managed complex projects
- Much of the selected hardware has flight heritage
  - NSL Fast Bus 1U kit (TRL 7-9)
- Robust mentor network
  - College students, companies, and engineers

45

Why Launch TJ?

- Prospect of launch motivates project progress
- Orbiting satellite required to create partnerships for ground stations
- Educational outreach
  - Materials posted online more accurate
  - Greater credence for elementary and middle school outreach
- Impacts for successive team members
  - Monitor payload data
  - Develop future CubeSat projects

46

Formulation Timeline

			2016				
Tasks	Pre-fall 2016	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
Project Formulation							
Mission concept and design developed							
Development of educational goals and Merit review							
System requirements developed							
Mission /system definition stage							
Feasibility Review (1 Day)							
Proposal submittal							
Preliminary design developed							

47

Project Timeline

							2017								
Tasks	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
Project Implementation															
Subsystem design Implementation															
Critical design established															
Systems integration and testing															
Operational readiness stage and review															
Flight readiness review (one day)															
Pre-Ship review (one day)															
Delivery and launch															

48

Mission Timeline

			2018				
Tasks	Feb.	Mar.	Apr.	June	Jun.	Jul.	Aug.
Mission Implementation							
Post launch assessment							
Mission operation and sustainment							
Decommission, deorbit, and closeout							

49

Summary

- Presented system and subsystem requirements
- Presented preliminary design of all subsystems
- Presented verification and validation plan
- Showed schedule and cost are achievable
- Identified risks and their mitigation plans
- Next steps

50

Thank You!

Feedback and Questions

51