INTRODUCTION:

This proposed MSD project involves the design of a CubeSat avionics system, built upon already existing components. These components will be at a high level (microcontrollers, communications, and memory systems) due to the severely reduced likelihood of NASA picking up RIT's CubeSat proposal with a custom manufactured avionics system. The challenge for the MSD team will be to balance the demanding functionality of the subsystem with the high cost of these components, the goal being to meet all of the customer and engineering constraints and as many requirements as possible for the least cost.

ADMINISTRATIVE INFORMATION:

- Project Name (tentative): RIT SPEX Avionics System Evaluation and Selection
- Project Number, if known: N/A
- Preferred Start/End Semester in Senior Design:
  ☒ Fall/Spring ☐ Spring/Fall
- Faculty Champion:

Name	Dept.	Email	Phone

- Other Support, if known:

Name	Dept.	Email	Phone
Anthony Henning	MECE	aih2400@rit.edu	804-691-7186

- Project "Guide" if known: *N/A*
- Primary Customer, if known (name, phone, email):
  RIT Space Exploration (SPEX) Team
  POC: Anthony Hennig [*aih2400@rit.edu*]
- Sponsor(s):

Name/Organization	Contact Info.	Type & Amount of Support Committed

PROJECT OVERVIEW:

Currently, the Rochester Institute of Technology is doing cutting edge research in a variety of different fields ranging from sustainability to biomedical sciences and everything in between. Since the launch of the first satellites, space has become an ever growing field of interest for research and experimentation. However, RIT currently does not have a presence in space. The goal of the RIT Space Exploration (or SPEX) team is to create an organization that supports students and their research of space systems engineering such that RIT can have a presence in space in the future.

Currently the most common and inexpensive way to test different space system technology is through the use of CubeSats. CubeSats are a class of miniaturized research satellites called nanosatellites which are usually no larger than a loaf of bread [1]. While they are not inexpensive to develop and launch, they are significantly cheaper than their full sized counterparts which have the potential to be the size of a school bus [2]. This makes CubeSats a great tool for research [1]. Currently, CubeSats have attracted interest for both universities and industry. For example, a few of the many organizations invested in CubeSats include NASA, Planet Labs, and Los Alamos Laboratories [3].

For their first CubeSat the SPEX team hopes to develop and test a LASER Uplink Experiment (LUX). Communication is an area of concern with CubeSats and LASER communication is growing area of research in satellites due to low power requirements and minimal addition of interference [4]. to be tested and integrated into future spacecraft and other technology.

The RIT SPEX group has accumulated a lot of momentum in the short timespan since it started. Unfortunately, despite the rather strong start, the SPEX team is faced with difficulty in choosing which direction they need to go to maintain their success. RIT SPEX has requested the help of several MSD teams to help research, evaluate, and select potential “out-of-the-box” subsystems. Because of the “one-shot” nature of CubeSat launches, NASA expects only one experimental system being tested on each CubeSat. In RIT SPEX’s case this is the LUX system, and the rest of the subsystems need to be commercial, proven options to ensure SPEX gets funding from NASA.

The goal of this MSD team is to perform the research and evaluation required to select an avionics system that will act as the main “brain” for the CubeSat. This system will need to perform functions such as logging sensor data, tracking orbital location, communicating with NASA’s system via standard radios, and providing input to control systems of various other functions (deployable solar panels, attitude control, etc).

[1] "CubeSat Launch initiative (CSLI)." NASA, n.d. Web. 6 Feb. 2015.
[2] "What Is a Satellite?." NASA, n.d. Web. 6 Feb. 2015.
[3] P. M. Swartwout, "CubeSat Database," St. Louis University. [Online]. [Accessed 7 February 2015].
[4] Mission Design Division Staff Ames, "Small Spacecraft Technology State of the Art," 2014.

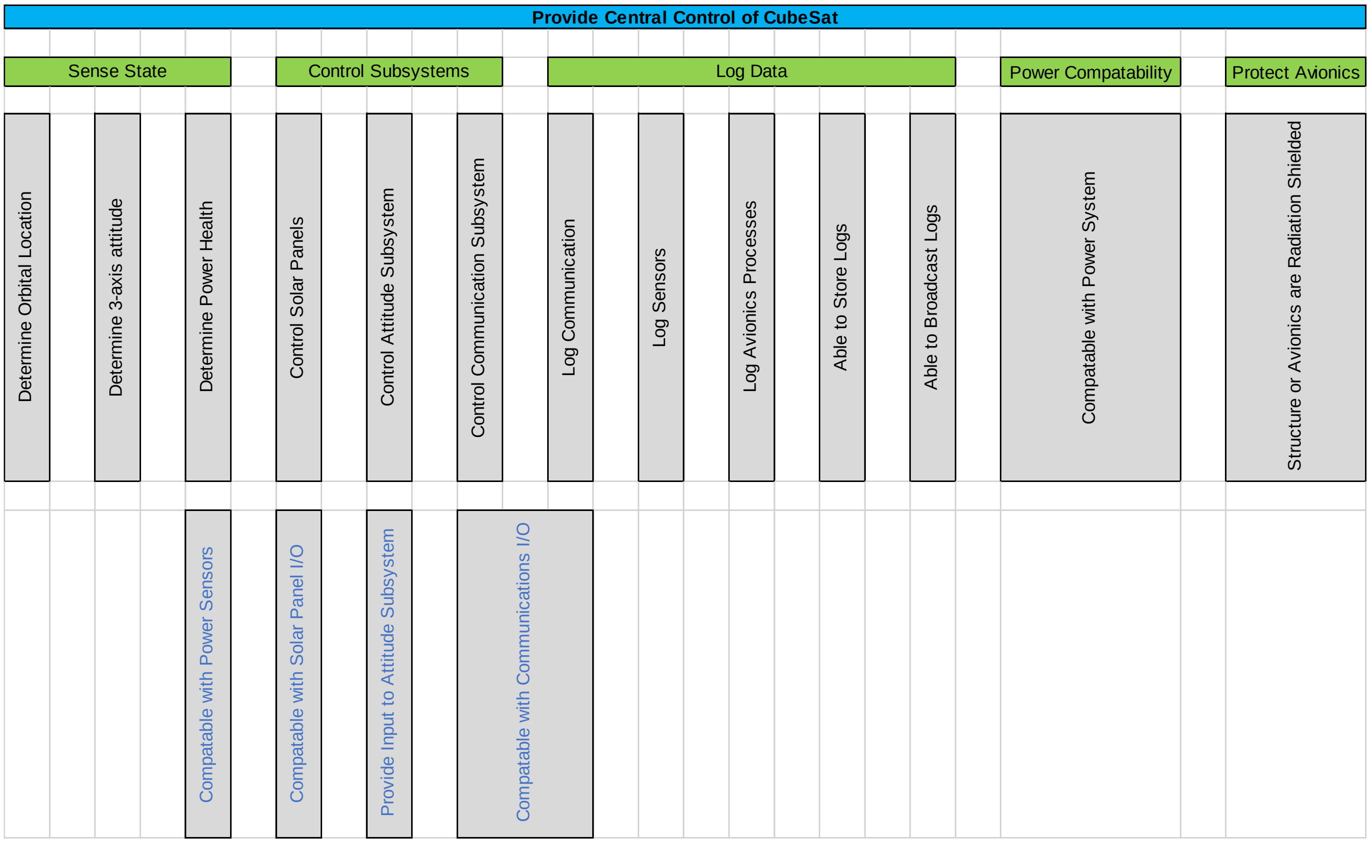
DETAILED PROJECT DESCRIPTION:

- Customer Needs and Objectives:

Customer Requirements		
Objective Number	**Importance**	**Description**
CR01	3	Compatability with NASA Communication System
CR02	1	Components are housed in a single unit structure
CR05	3	3-axis attitude control and sensing
CR08	3	Functional Flight Software
CR19	3	All components need to be cost effective and cheaper than existing solutions
CR28	3	Able to determine orbital location
CR29	2	Able to log all operational status, location, communication, and sensor data for entire duration of flight
CR36	3	CubeSat's electrical componets have a system to protect from effects of radiation in orbit

Legend	
Importance	**Number**
Critical	3
Important	2
Desired	1

- Functional Decomposition:



- Potential Components:

	Space Micro ProtonX-Box	http://www.spacemicro.com/assets/datasheets/digital/ProtonX.pdf
	AAC Microtec Mass Memory Unit	http://www.aacmicrotec.com/index.php?option=com_content&view=article&id=82&Itemid=201
	TI's MSP430F1612 for CubeSat	http://www.cubesatkit.com/docs/datasheet/DS_CSK_PPM_A1_710-00485-B.pdf

- Specifications (or Engineering/Functional Requirements):

ER Number	CR Number	Function	Engineering Requirements	Unit	Marginal	Ideal	Test to Verify Performance
ER17	CR28	Determine Orbital Location	Determine Location via GPS/GNSS at given rate	[m], [Hz]	[5], [0.2]	[1], [1]	GPS diagnostics, ground testing with known position
ER18	CR05	Determine Attitude	Determine Attitude via Gyroscope or AHRS at given rate	[deg], [Hz]	[0.5],[1]	[0.1],[5]	Check for accuracy and precession via rotation testbed
ER20	CR29, CR08	Determine Power Health	Compatable with Power Sensors	[Boolean]	Yes	Yes	Verify protocol compatability
ER25	CR29, CR08	Control Solar Panels and Determine Health	Compatable with Solar Panel I/O	[Boolean]	Yes	Yes	Verify protocol compatability
ER54	CR05, CR08	Provide Input to Attitude Control System	Compatable with Attitude Control I/O	[Boolean]	Yes	Yes	Verify protocol compatability
ER16	CR01, CR08	Control Communications Subsystem Log Communications Able to Broadcast Logs	Compatable with Communication I/O	[Boolean]	Yes	Yes	Verify protocol compatability
ER19	CR29	Able to Store Logs	HDD/SDD Capacity to store logs for duration of flight	[days]	730	1000	Test data storage rate, mathematically evaluate storage capacity
ER19	CR29	Able to Log Avionics Health	Avionics functionality to log status	[Boolean]	Yes	Yes	Check manufacturer specifications and check functionality
ER19	CR29	Able to Log Subsystem Health	Compatable with subsystem sensors or subcontrols	[Boolean]	Yes	Yes	Verify protocol compatability
ER20	CR08	Compatable with Power System	Avionics are within voltage specifications and current capacities	[Boolean]	Yes	Yes	Compare against Power MSD designed specifications
ER10	CR36	Protect Avionics	CubeSat is shielded or Avionics have radiation shielding	[Boolean]	Yes	Yes	Shielding MSD project results OR shielding specifications
ER14	CR02	Fit in Structure	Fit inside MSD designed structure	[Boolean]	Yes	Yes	Verify final volume
ER55	CR08	Dissipate Head	Provide temperature margin from max operational temp.	[Deg C Delta]	10	15	Thermal model evaluation

- Constraints:
    - Avionics subsystem components need to be “off-the-shelf” to ensure risk-minimization
    - Must be able to fit in space allotted by RIT SPEX inside the frame

- Project Deliverables:

It is expected that the MSD team will research several potential “off-the-shelf” products and design a set of components that constitute the Avionics subsystem. Considerations should be taken to ensure that for the cheapest price possible that all functions are covered reliably while also minimizing space usage. After identifying several candidate subsystems (combinations of components) the team will ideally procure samples for in-person testing.

- Budget Estimate:

Costs will be highly variable due to the dependence on the manufactures of these avionics components for if they will even rent the systems for testing, and if so how much the cost will be.

Item	Cost
Equipment Rentals	$1000 - $10000
Testing Equipment	$0 - $500
Total:	$1000- $10500

- Intellectual Property (IP) considerations:

The performance of certain subsystems may be proprietary for each product, and care should be taken to not publish these specifications at the manufacturer’s request. Protocol information as well as certain subsystem choices and design are proprietary to the RIT SPEX team and should not be released with consulting the customer.

- Other Information:

Customer Requirements	Customer Weights	Engineering Metrics: Determine Location via GPS/GNSS at given rate	Determine Attitude via Gyroscope or AHRS at given rate	Compatable with Power Sensors	Compatable with Solar Panel I/O	Compatable with Attitude Control I/O	Compatable with Communication I/O	HDD/SDD Capacity to store logs for duration of flight	Avionics functionality to log status	Compatable with subsystem sensors or subcontrols	Avionics are within voltage specifications and current capacities	CubeSat is shielded or Avionics have radiation shielding	Fit inside MSD designed structure	Provide temperature margin from max operational temp.	Customer Perception: 1 Worse	2	3	4	5 Better
Compatability with NASA Communication System	3						15			15									+
Components are housed in a single unit structure	1												10	15	+				
3-axis attitude control and sensing	3		15																+
Functional Flight Software	3	15	15	15	15	15	15	5	10	10	15			10					+
All components need to be cost effective and cheaper than existing solutions	3	10	10					5	5	10									+
Able to determine orbital location	3	15	15			15													+
Able to log all operational status, location, communication, and sensor data for entire duration of flight	2	15	15	15	15	15	15	10	15	15							+		
CubeSat's electrical componets have a system to protect from effects of radiation in orbit	3											15	10						+
Technical Targets (Specifications)		[1 m], [1 Hz]	[0.1 deg],[5 Hz]	Yes	Yes	Yes	Yes	1000 days	Yes	Yes	Yes	Yes	Yes	[15 C]					
Technical Benchmarking (*Better* 5 … *Worse* 1)		4 (+)	4 (+)	5 (+)	5 (+)	5 (+)	5 (+)	3 (+)	5 (+)	5 (+)	5 (+)	5 (+)	5 (+)	5 (+)					
	Raw Score	150	195	75	75	120	120	50	75	135	45	45	40	45					
	Relative Weight	13%	17%	6%	6%	10%	10%	4%	6%	12%	4%	4%	3%	4%					

Risk	Likelihood	Impact	Importance	Method of Mitigation
Unable to procure samples	3	1	3	Communicate early with suppliers Prepare to do data-sheet evaluation
Specified Protocol Unknown	2	2	4	Available protocols become constraints for other projects
Not enough funding to procure samples	3	1	3	Communicate early with suppliers Communicate early with sponsors Prepare to do data-sheet evaluation
Trial sample gets damaged	1	3	3	Establish safety methods to preserve rented or loaned systems
Specifications are not available or incorrect	2	2	4	Communicate directly with mfg. Pursue alternate options

- Continuation Project Information, if appropriate:

Academic Year	Team A	Team B
2015 - 2016	Structure	-
2016 - 2017	Power Acquisition	Attitude Control
2017 - 2018	Communication	Radiation Protection
2018 - 2019	Avionics	-
2019 - 2020	Vibration Mitigation	-

** Table of proposed timeline for all the PRPs related to developing a CubeSat. The structure of the CubeSat must be developed prior to any other system. After developing the outer structure of the CubeSat, internal subsystems can begin development. It's expected that the power acquisition and attitude control systems can be developed concurrently. Likewise, it's expected that the communication and radiation protection systems can be developed simultaneously Then, the overall avionics of the CubeSat can be developed to ensure proper functionality between all subsystems. Lastly, vibration mitigation must be considered in the final PRP to ensure that the completed CubeSat will survive launch and possibly re-entry.*

STUDENT STAFFING:

- Skills Checklist:

Skills are ranked for most important to least important.

Mechanical Engineering

	3D CAD		Aerodynamics
3	MATLAB programming		CFD
	Machining (basic)		Biomaterials
	Stress analysis (2D)		Vibrations
	Statics/dynamic analysis (2D)		Combustion engines
	Thermodynamics		GD&T (geometric dimensioning & tolerancing)
	Fluid dynamics (CV)		Linear controls
5	LabView (data acquisition, etc.)		Composites
1	Statistics		DFM
			Robotics (motion control)
	FEA		Composites
2	Heat transfer		Other:
	Modeling of electromechanical & fluid systems		Other:
	Fatigue & static failure criteria (DME)	4	Other: System Dynamics
	Specifying machine elements		

Reviewed by (ME faculty): ______________________________

Industrial & Systems Engineering

2	Statistical analysis of data – regression		Shop floor IE – methods, time study
	Materials science		Programming (C++)
	Materials processing – machining lab		
	Facilities planning – layout, material handling		DOE
	Production systems design – lean, process improvement	3	Systems design – product/process design
	Ergonomics – interface of people & equipment (procedures, training, maintenance)	4	Data analysis, data mining
6	Math modeling – linear programming), simulation		Manufacturing engr.
1	Project management		DFx -- Manuf., environment, sustainability
5	Engineering economy – ROI		Other:
7	Quality tools – SPC		Other:
	Production control – scheduling		Other:

Reviewed by (ISE faculty): ______________________________

Electrical Engineering

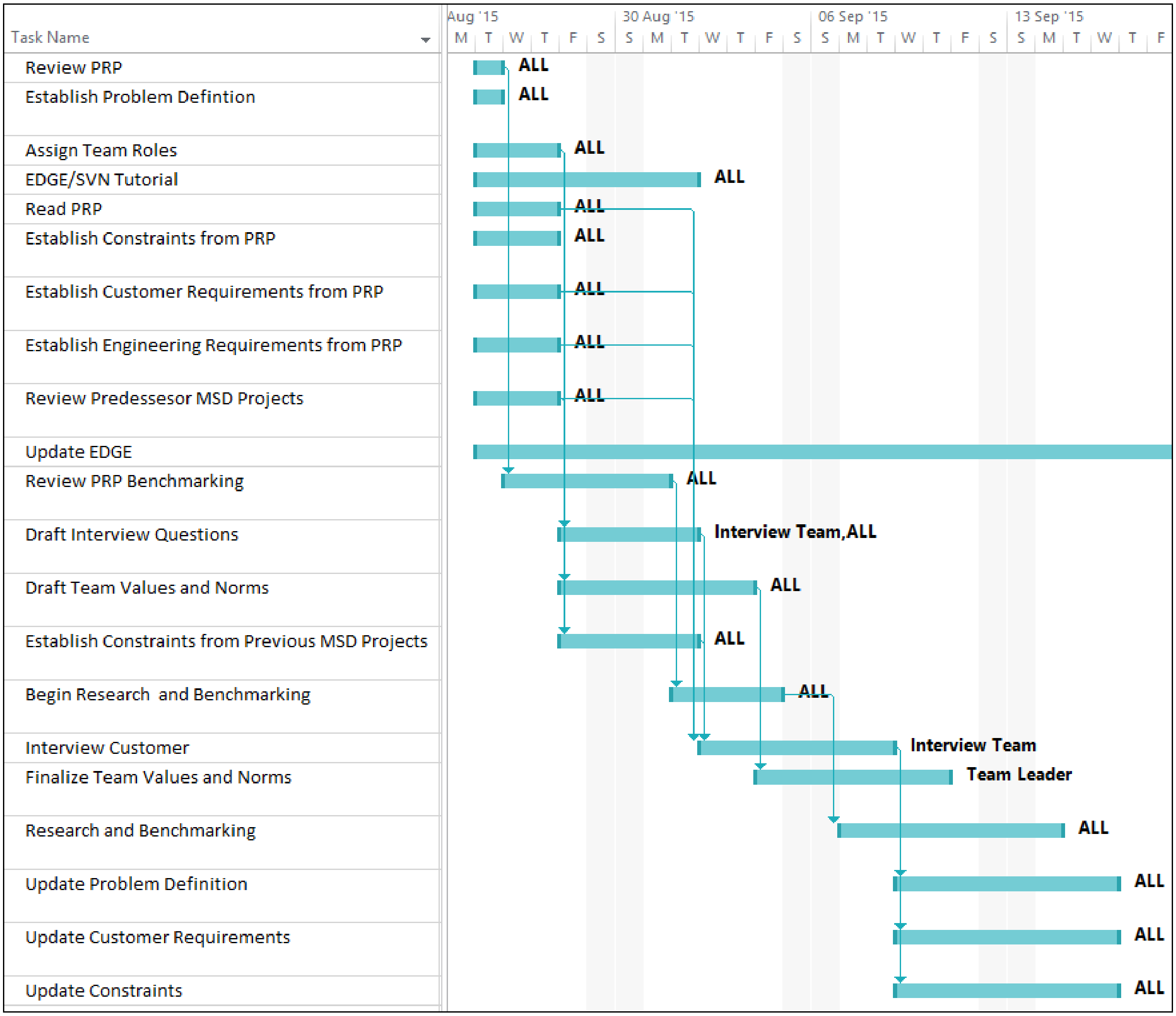
	Circuit design: AC/DC converters, regulators, amplifier ckts, analog filter design, FPGA Logic design, sensor bias/support circuitry		Digital filter design and implementation, DSP
4	Power systems: selection, analysis, power budget determination		Microcontroller selection/application
3	System analysis: frequency analysis (Fourier, Laplace), stability, PID controllers, modulation schemes, VCO's & mixers, ADC selection		Wireless protocol, component selection
	Circuit build, test, debug (scopes, DMM, function generators)		Antenna selection (simple design)
	Board layout		Communication system front end design
5	MATLAB		Algorithm design/simulation
	PSpice		Embedded software design/ implementation
	Programming: C, Assembly		Other:
6	Electromagnetics (shielding, interference)	2	Other: System Design
		1	Other: Statistics

Reviewed by (EE faculty): ______________________________

- Anticipated Staffing Levels by Discipline:

Discipline	How Many?	Work Breakdown
EE	2-3	Interpretation of Electrical Specifications Manage Power Subsystem Compatibility System Analysis
		Manage Subsystem I/O Protocols System Analysis
ME	1-2	Volume and Mounting Considerations Design Heat Dissipation System System Analysis
ISE	1-2	Team Leadership and Management Engineering Economy Considerations Budgetary Management System Analysis

- 3 Week Plan


Task Name
Aug '15
30 Aug '15
06 Sep '15
13 Sep '15
Review PRP
Establish Problem Defintion
Assign Team Roles
EDGE/SVN Tutorial
Read PRP
Establish Constraints from PRP
Establish Customer Requirements from PRP
Establish Engineering Requirements from PRP
Review Predessesor MSD Projects
Update EDGE
Review PRP Benchmarking
Draft Interview Questions
Draft Team Values and Norms
Establish Constraints from Previous MSD Projects
Begin Research and Benchmarking
Interview Customer
Finalize Team Values and Norms
Research and Benchmarking
Update Problem Definition
Update Customer Requirements
Update Constraints
ALL
Interview Team,ALL
Interview Team
Team Leader

OTHER RESOURCES ANTICIPATED:

Category	Description	Resource Available?
Faculty		☐
		☐
		☐
Environment	**Systems Laboratory (or similar)**	☒
		☐
		☐
Equipment	**Sample Avionics for Trail-Testing**	☐
	Oscilloscope	☒
	Digital Multimeter	☒
Materials	**Sample Avionics Package**	☐
		☐
		☐
Other	**MATLAB**	☒
	LabView	☒
		☐

Prepared by: Eric Reese Date: 16 May 2015