Hephaestus

Preliminary Design Review

Oregon State University
November 2nd, 2016

Huy Nguyen	Sam Lundeen	Helena Bales	Michael Polander
Cole Morgan	Subret Aryal	Amber Horvath	Devin Wyckoff
Jonathan Hardman	Ian Finn	Michael Humphrey	Brett Moffatt

Michael Polander

Section 1:

Mission Overview

Mission Overview: Mission Statement

Michael Polander

The Oregon State University RockSat-X team will demonstrate that an autonomous robotic arm can locate predetermined targets around the payload under microgravity conditions by using precise movements. The technical actions performed by this demonstration will illustrate a proof of concept for creating assemblies, autonomous repairs, and performing experiments in space.

Mission Overview: Mission Objectives

Michael Polander

Minimum Success Criteria:

1. The arm assembly body shall deploy and a video sweep is successfully recorded.
2. The arm assembly body shall be fully retracted after data collection.

Maximum Success Criteria:

1. The arm assembly body shall deploy and a video sweep is successfully recorded.
2. The arm shall make contact with predetermined targets around the payload.
3. The camera shall record all instances of contact between the arm and the targets.
4. The arm assembly body shall be fully retracted after data collection.

Sam Lundeen

Mission Overview: Theory and Concepts

The idea is that if an autonomous arm can maneuver itself to reach each point, it would be able to do repairs, build assemblies, and perform experiments outside the spacecraft if it was equipped with the correct equipment.

The robot needs to:

- Determine where each point is in a range of target locations
- Perform the necessary motions to reach its target
- Record when it makes contact with a target point based on the force applied

The Canadarm is a somewhat similar idea to this, but it was not autonomous. It aided the Space Shuttle orbiters in working with payloads.

The United States Naval Academy Small Satellites Program is planning to develop a 3U CubeSat called RSAT. The CubeSat will have two remote manipulator arms that can perform experiments and investigations in space.

Ian Finn

Mission Overview: Expected Results

After the demonstration is performed and the payload returns to Earth, we expect to see data showing the arm made contact with each point and the force it experienced in reaching that point. Additionally, there will be a video recording of the arm while it is outside the craft, further proving the payload met mission success criteria.

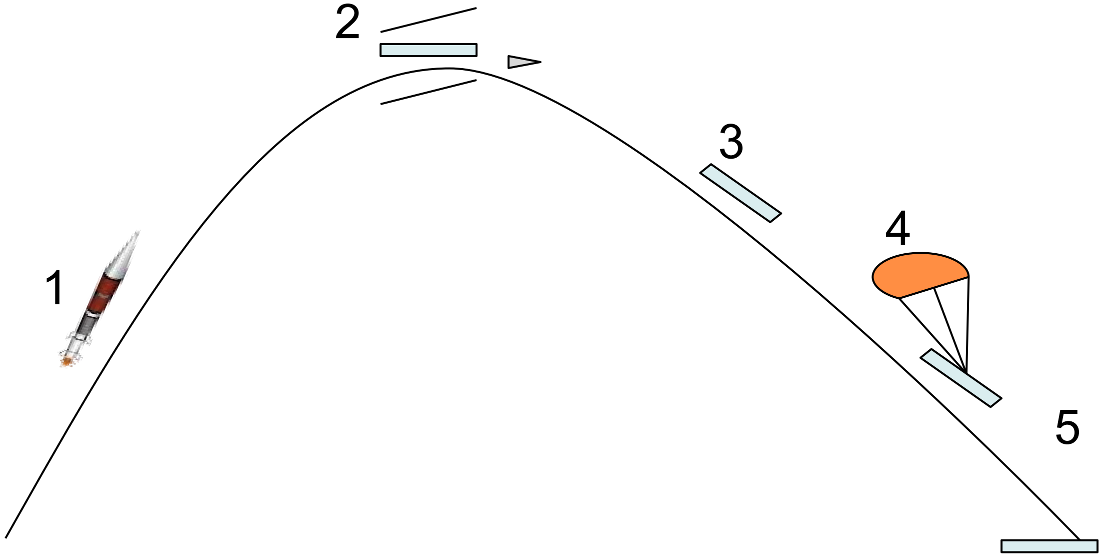
Mission Overview: Concept of Operations

Subret Aryal

1. **Launch**: The payload will stay dormant for launch and the journey to apogee
2. **Microgravity**: Once at Apogee, the arm assembly body will extend out of the rocket and perform its demonstration.
    a. After the arm assembly body is fully extended outwards, the arm will perform a camera sweep of the surrounding space.
    b. The arm will maneuver towards the target to make contact.
    c. Contact will be confirmed when a sensor registers an appropriate amount of force.
    d. Steps 2a-2c will be repeated until contact has been made with each target.
3. **Descent**: The arm assembly body will retract before descent begins and will stay retracted from then on out.

Sam Lundeen

Mission Overview: Concept of Operations



1. Launch
2. Apogee
   a. Record video of action
   b. Case extension
   c. Arm extension
   d. Arm rotates and touches targets on outside of rocket hull
   e. Record touches with sensor
   f. Case and Arm retract
3. Descent
4. Chute deploy
5. Landing
   a. Payloads recovered

Sam Lundeen

Section 2:

System Overview

Brett Moffatt

System Overview: Science Design

Instrumentation:

- **Camera**: To capture the demonstration on video
- **Rotary Encoders:** To provide information about the position of linkages
- **Sensors**: Track motion and capability of the arm's demonstration.
- **Microcontroller**: Store software and perform command and data handling

Brett Moffatt

System Overview: Engineering Design

Use of Scientific Design:

- The payload will be designed with an articulating arm situated on a moving base.
- The base will be situated on a mechanism to move the arm as a whole to be deployed external to the rocket.
- Once outside the rocket the encoders will be used to make precise movements with the arm to touch points on the outside of the rocket, using the sensors to track the arm's demonstration.
- A camera will be situated on the base to record the actions taken and confirm data recording and recovery.

System Overview: Engineering Design

Subsystems

- Structures
  - Materials: Withstands large stresses at extreme temperatures
  - Survivability: Managing heat and dampening vibrations to protect the robotic arm and electronics
- Robotics
  - Actuation and Performance: Determine arm motion and design
- Electronics
  - Power unit: Voltage Regulator, Power Controller
  - Control unit: AVR Microcontroller, Motor Drivers
- Software
  - Command and Data Handling

System Overview: Engineering Design

Heritage Elements

- Virginia Tech and Metropolitan State University both used deployables last year. We are looking at their methods for ideas to deploy our arm.
  - Were their deployments successful?

Devin Wyckoff

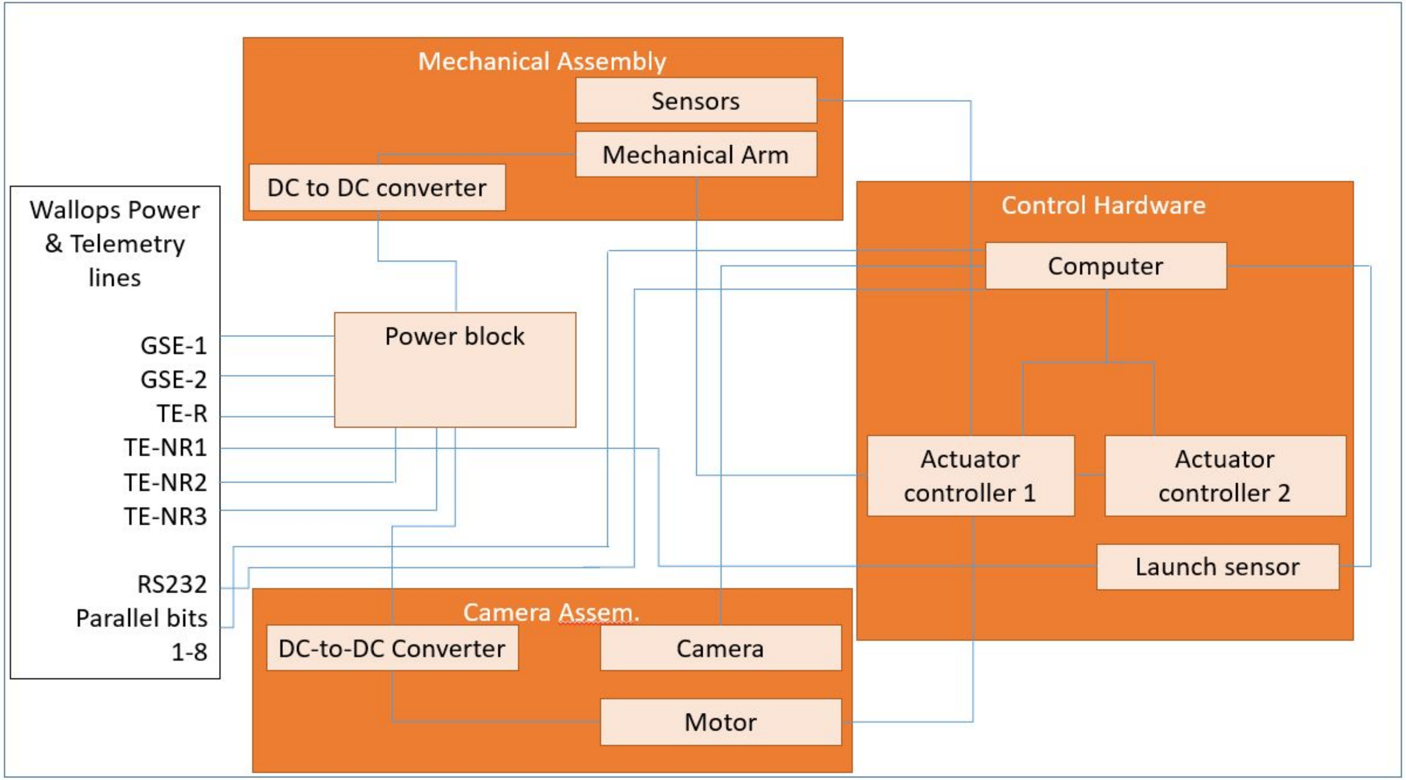
System Overview: Engineering Design

Technology Dependencies

- Highly dependent on the stepper motors that we would be utilizing to perform the actions we are looking at attempting.
- Dependent on the video recording provided by the camera on our payload used to visually confirm our actions.
- Dependent on sensors to acquire data to be transmitted to ground.
- Dependent on using RS-232 telemetry pin for air to ground communication

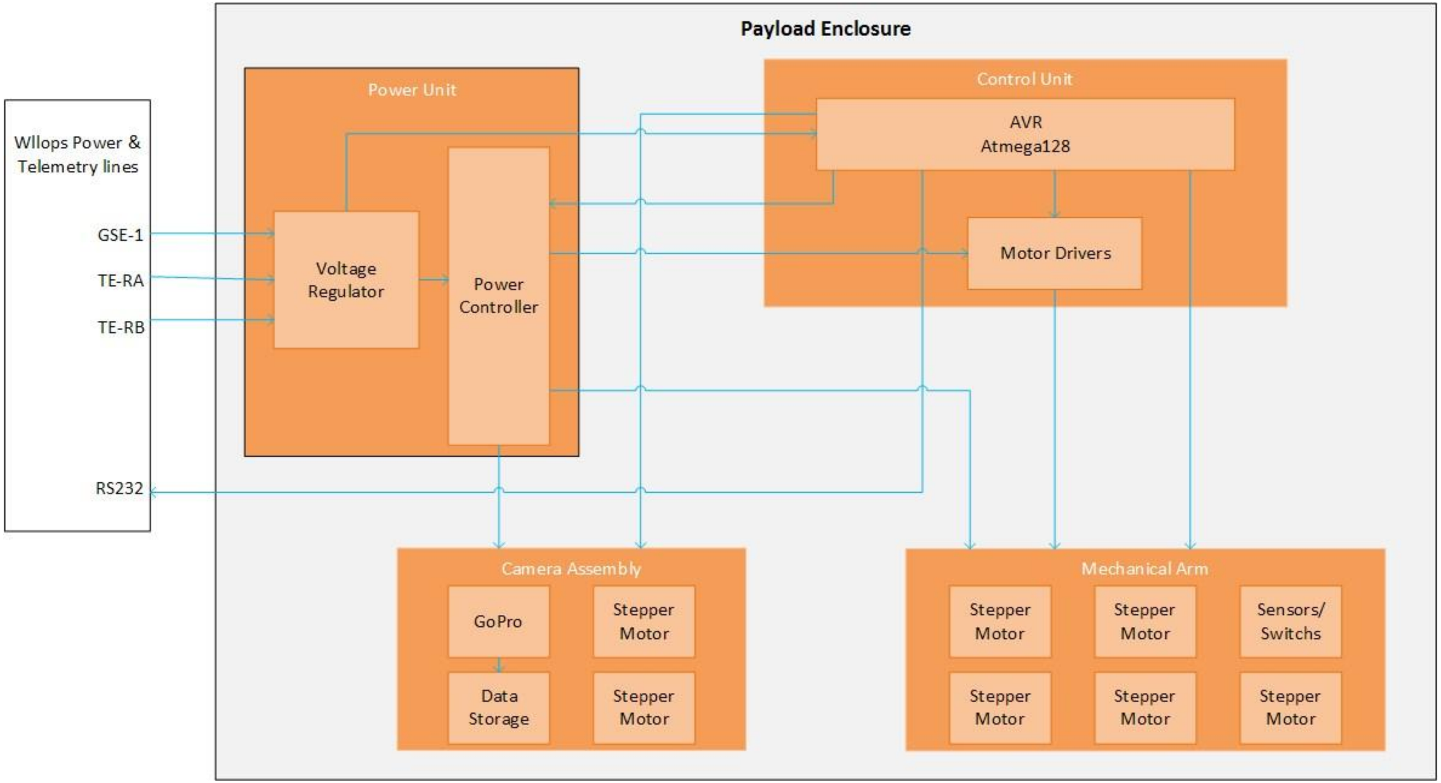
Huy Nguyen

System Overview: Functional Block Diagram - Old



Huy Nguyen

System Overview: Functional Block Diagram - New



Michael Polander

System Overview: Partnerships

AIAA - Providing Funding, Volunteers, and Work Space

Oregon Space Grant Consortium - Funding

OSU Robotics Club - Volunteers

System Overview: User Guide Compliance

Michael Polander

Requirement	*Status/Reason (if needed)*
Center of gravity in 1" plane of plate?	N/A
Weight 30.0+/- 1.0 (15.0 +/- 0.5) lbs?	N/A
Max Height < 10.75” (5.13”)	Yes
Bottom of deck has flush mount hardware?	Yes
Within Keep-Out Zone	Yes
Using < 10 A/D Lines	N/A
Using/Understand Parallel Line	No
Using/Understand Asynchronous Line	Yes
Using 1 GSE Line(s)	Yes
Using 1 Non-Redundant PWR Lines (TE-1, TE-2, TE-3)	Maybe
Using 1 Redundant Power Lines (TE-R)	Yes/TE-R
Using < 1 Ah	N/A
Using <= 28 V	N/A
Using RF (If yes, list frequency and TX Power)	No
Using deployable?	Yes
Whole team consists of US Persons	Yes
Using ITAR and/or Export Controlled hardware	N/A

Michael Polander

System Overview: Special Requests

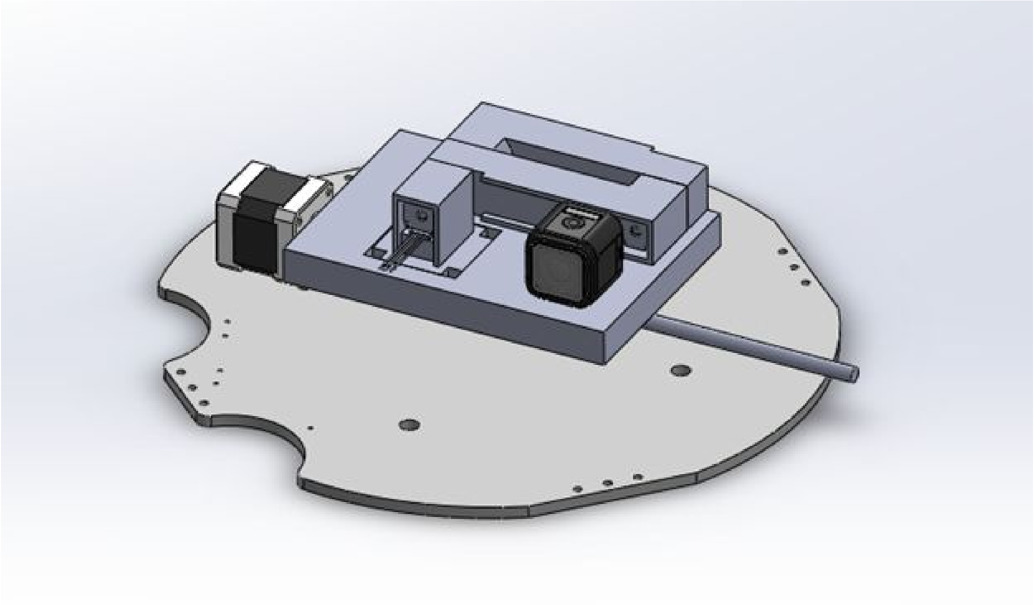
None at this time.

Michael Polander

Section 3:

Subsystem Design

Subsystem Design: Science (Robotics)

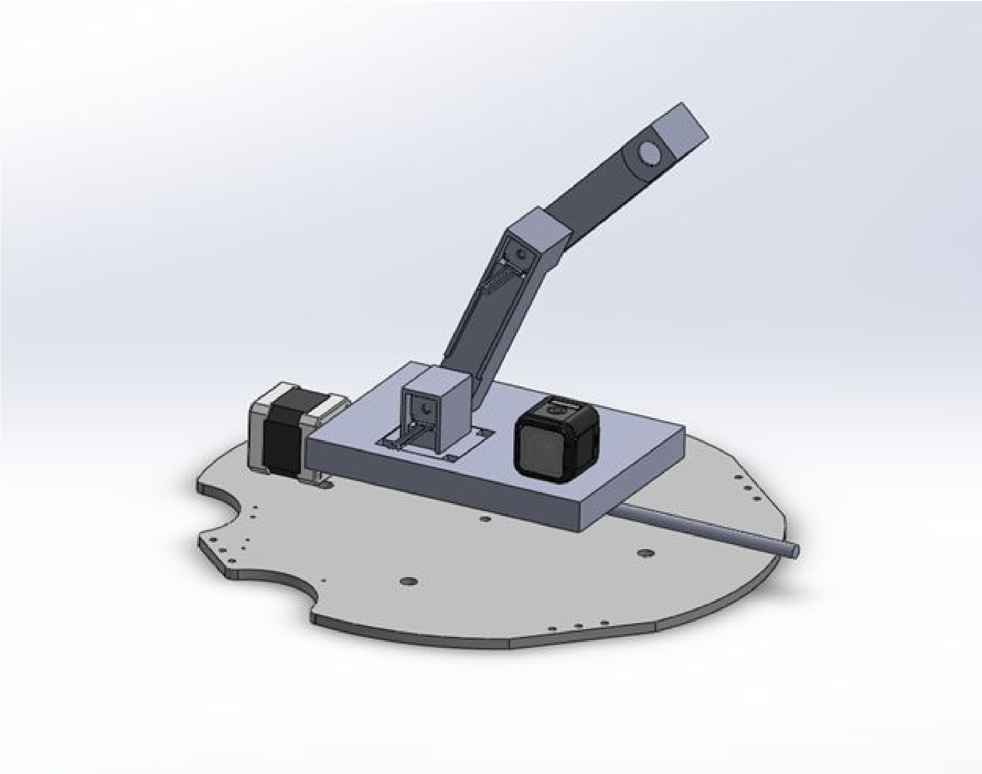


Arm in closed position.

GoPro Hero Session for test fitting space.

Devin Wyckoff

Subsystem Design: Science (Robotics)



Arm in open position, not deployed.

Shoulder and elbow design.

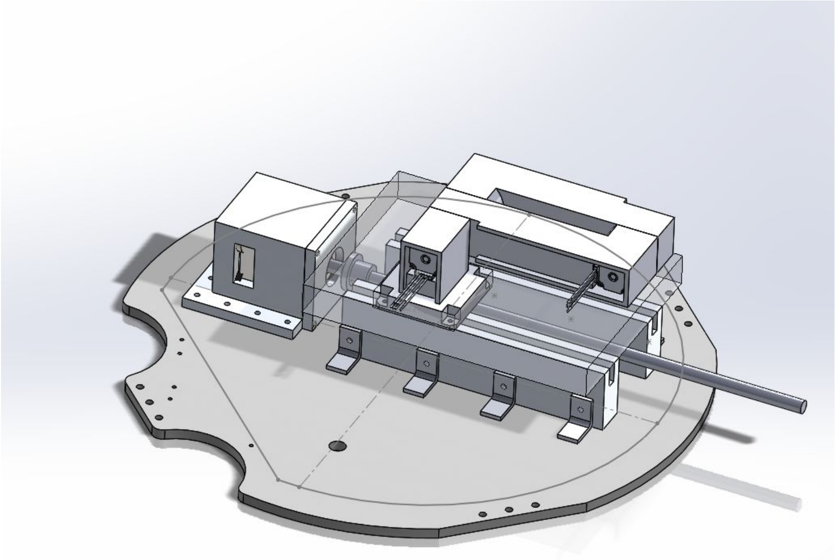
3 degrees of freedom at this time.

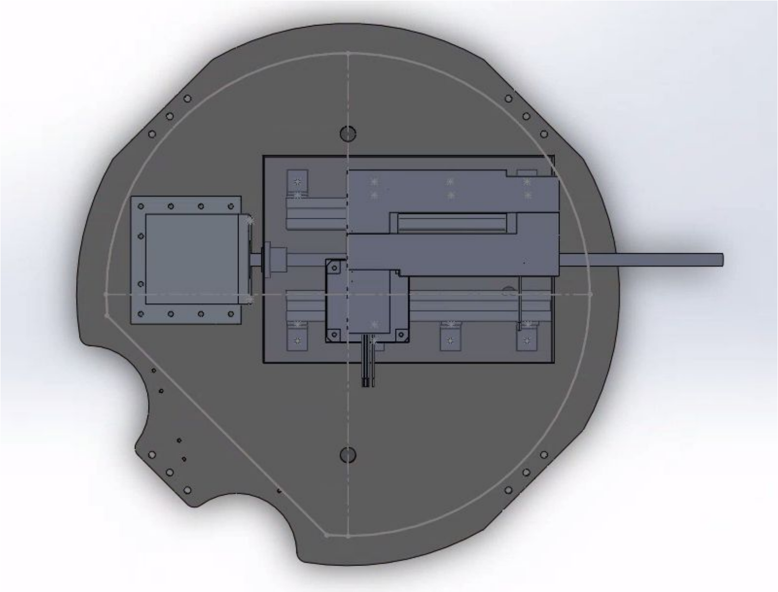
Intend to add additional degrees of freedom.

Question:
Who will be our neighbors on the flight?
We would like to coordinate to maximize operational range of the arm.

Subsystem Design: Structures

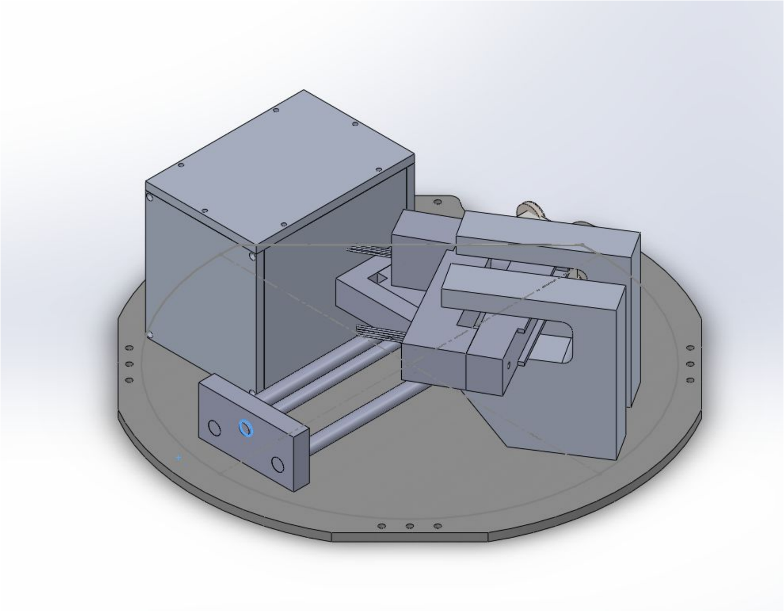
Subret Aryal





Subsystem Design: Structures

Sam Lundeen



Subsystem Design: Power

Cole Morgan

Voltage Regulator:

Input: 28 VDC with 6 Volt tolerance from GSE-1

28 Volts from TE-RA and TE-RB

Output: 18 Volts Maximum to Power controller

5 Volts to Power Controller and 5 Volts to Control Unit

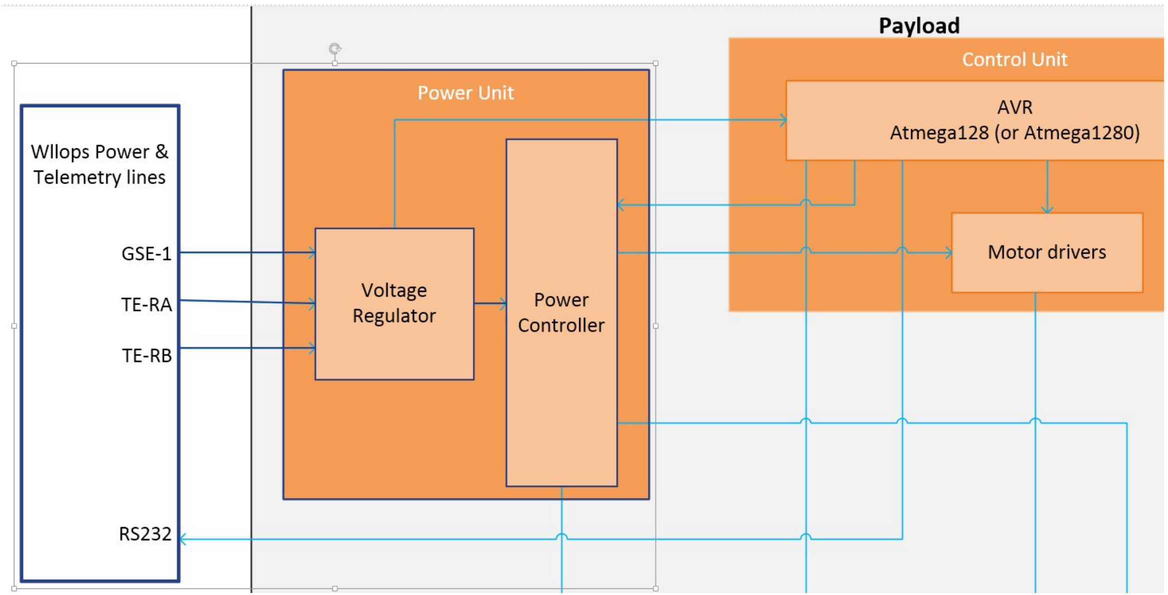
Power Controller:

Input: 2.5V - 5.5V Digital input

18V from Voltage Regulator

Output: 5 VDC to camera

18 VDC to motor drivers

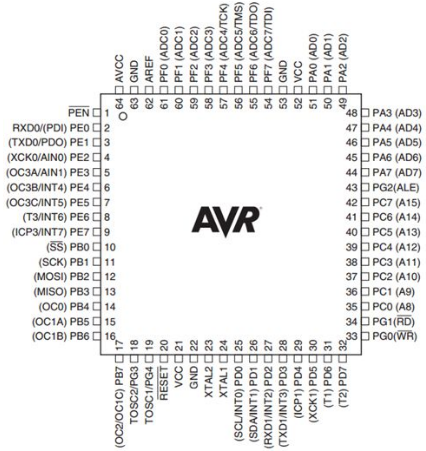


Jonathan Hardman

Subsystem Design: Control Unit

AVR ATmega128

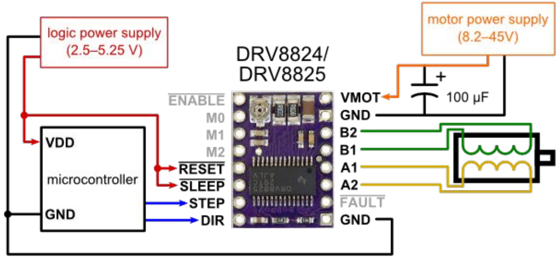
- PWM timer counters to send signals to the Motor Drivers
- Parallel digital signals to Power Controller to enable/disable electric systems
- Built-in UART serial transmitter to transmit 8-bit data to RS-232 port via MAX232 IC.
- GSE power line to keep the Control Unit on standby, and TE-R to trigger experiment.



ATmega128

Motor Drivers

- Uses signals from the AVR as input (steps and direction) to control the motors
- Interprets PWM signals as the amount of steps the motors need to move, and high/low logic for direction.



Motor Driver

Subsystem Design: Software

Functional Requirements:

- **Main Behavior:** The software shall control the movement of the arm assembly body to make contact with the outside of the rocket at locations generated by the Software.
- **Target generation**: The Software shall generate points in a full circle (0 - 359 degrees). These points shall be used as targets for the arm body.
- **Movement:** The Software shall control the movement of the arm body assembly. The Software shall rotate the arm body assembly in a full 360 degrees. The Software shall additionally control the movement the height of the arm body assembly. The arm should descend and touch the outside of the rocket at any rotation.
- **Modes:**
  - **Launch:** The Software shall remain idle during launch.
  - **Deployment:** The Software shall power on the arm assembly body and video camera. The Software shall begin saving the video feed from the camera to a persistent storage location. The Software shall generate target points.
  - **Science:** The Software shall collect data to serve as a proof-of-concept for construction of structures in flight.

Amber Horvath

Subsystem Design: Software

- **Safety:** The Software shall ensure that the arm assembly body can be fully retracted after completing the mission. The Software shall, in case of a failure, eject the arm to prevent the arm assembly body from being caught in the payload bay doors.
- **Observation:** The Software shall report all telemetry data to the ground station. The software should save a high quality video feed to a persistent storage location for review after the mission completes.
- **Off:** The Software shall remain idle.

- **Telemetry:** The Software shall report all telemetry data to the ground station. The Software shall report via telemetry all the target points it generates. The Software shall also report which code branch it takes to facilitate debugging and post-mortem analysis, if necessary. The Software should report highly compressed, low quality video feed from the video camera to verify mission success criteria in case the payload can't be recovered.

Amber Horvath

Subsystem Design: Software

Non Functional Requirements:

- **Performance:** The system shall perform efficiently. The maximum response service time should be long enough for the robotic arm to move from one target to another. The system should have a maximum throughput that allows for processing of input arguments about the arm's actions and processing for the telemetry data output. Resource usage should be limited to account for the storing of telemetry data. Power consumption must be limited to 28V.
- **Security:** The system shall be secure. Since it is a closed system, the device will be programmed such that it cannot be accessed remotely and will only output sanitized data.
- **Telemetry:** The system will perform telemetry. The data will be transmitted with a delay of up to 10 seconds.

Sam Lundeen

Section 4:

Risk Matrices

Risk Matrices: Overall

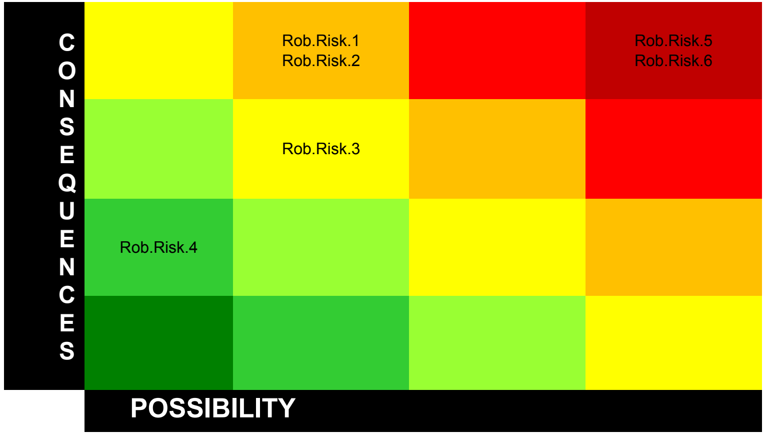
Sam Lundeen

CONSEQUENCES				
	Elct.Risk.3 CS.RSK.2	Rob.Risk.1 Rob.Risk.2 Str.Risk.3 Elct.Risk.1 CS.RSK.1		Rob.Risk.5 Rob.Risk.6
	Str.Risk.2 CS.RSK.4	Rob.Risk.3 Str.Risk.1 Elct.Risk.2	CS.RSK.3	
	Rob.Risk.4		Str.Risk.4	Elct.Risk.4

POSSIBILITY

Devin Wyckoff

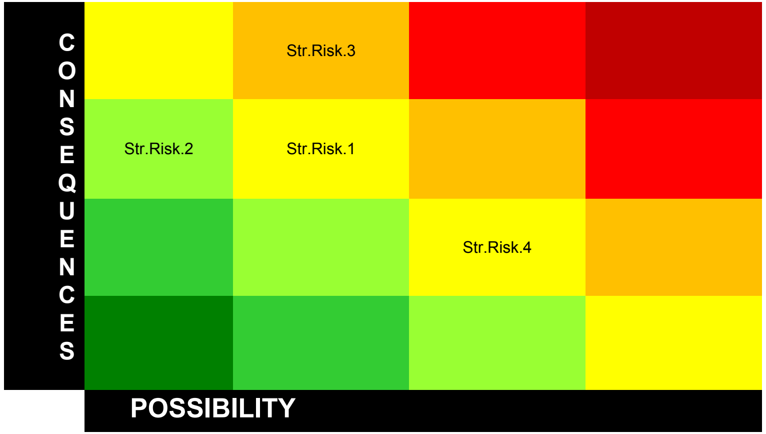
Risk Matrices: Robotics



Rob.Risk.1: All mission objectives aren’t met IF deployment motor fails.
Rob.Risk.2: Minimum mission objectives aren’t met IF either camera actuation motor fails.
Rob.Risk.3: Maximum mission objectives aren’t met IF 2 or more arm actuation motors fail.
Rob.Risk.4: Maximum mission objectives aren’t met if camera memory is not intact.
Rob.Risk.5: All mission objectives aren’t met IF motors do not survive launch conditions.
Rob.Risk.6: All mission objectives aren’t met IF motors do not survive orbit conditions.

Ian Finn

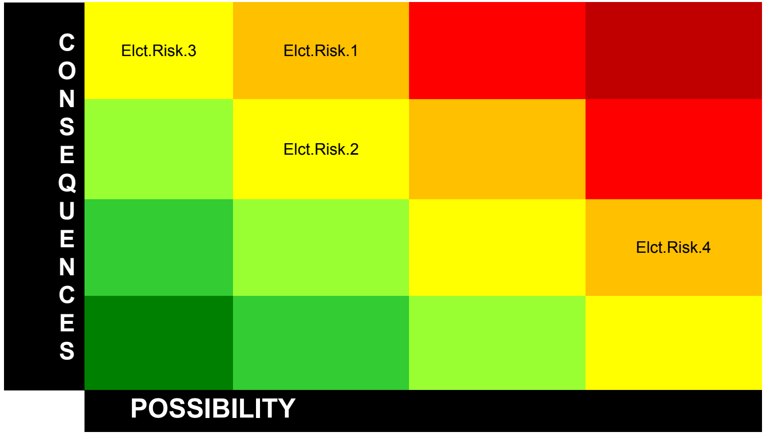
Risk Matrices: Structures



Str.Risk.1: Mission objectives are not met IF structures don’t withstand launch and reentry forces.
Str.Risk.2: Mission objectives are not met IF structures don’t withstand launch vibrations.
Str.Risk.3: Mission objectives are not met IF suitable insulation is not utilized.
Str.Risk.4: Mission objectives are not met IF water is allowed to damage data collected during the mission.

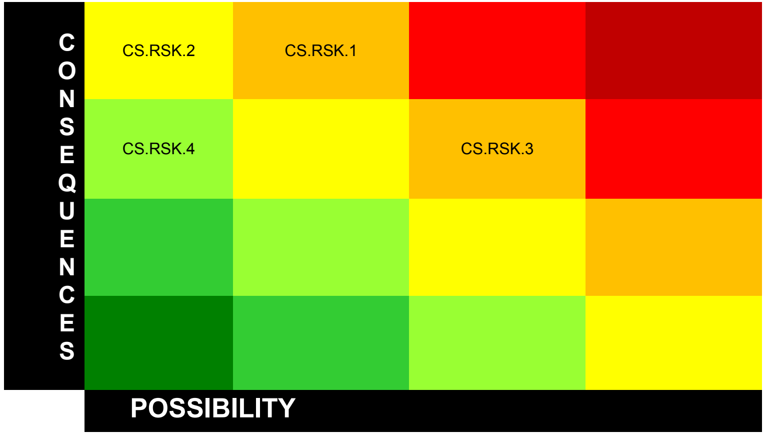
Jonathan Hardman

Risk Matrices: Electronics



Elct.Risk.1: All mission objectives aren't met IF microcontroller fails.
Elct.Risk.2: All mission objectives aren't met IF a suitable motor driver could fail when used at a high current for an extended time.
Elct.Risk.3: All mission objectives aren't met IF power unit not function properly prior to apogee.
Elct.Risk.4: Partial mission objectives aren't met IF the data storage can't be recovered or is damaged.

Risk Matrices: Software



CS.RSK.1: Mission objectives aren't met IF microcontroller (Atmega128) fails.
CS.RSK.2: Mission objectives aren't met IF the software fails to control the arm.
CS.RSK.3: Mission objectives aren't met IF the software fails to send telemetry data down to the base.
CS.RSK.4: Mission objectives aren't met IF the software fails to capture and store footage of the arms' performance.

Amber Horvath

Section 5:

Initial Test Plan

Initial Test Plan: Robotics

- Arm range of motion testing to confirm wiring and pathing.
- Cold testing to confirm operation at low temperatures.
- Hot testing to confirm operation after high temperature exposure.
- Operational testing to confirm intended path is followed and checkpoints are reached.
- Visual testing to confirm camera is tracking arm motion.

Subret Aryal

Initial Test Plan: Structures

- Shake table for sine and vibration testing
- Saltwater to test corrosion resistance
- FEA analysis of structures
- Heat resistance test for electronics and shielding (?)

Huy Nguyen

Initial Test Plan: Electronics

- Power Unit:
  - Voltage Regulator
    - Supply between 22 to 34VDC and check for nominal output voltages.
  - Power Controller
    - Manually apply 5VDC to each input control pin, and check for specific output voltages for each device.
- Control Unit:
  - AVR Microcontroller
    - Measure and record output port voltages for nominal I/O compatibility with other devices.
    - Run suite of unit tests to check for nominal operation of each required microcontroller function.
  - Motor Driver
    - Manually test varying control signals for motor driver and measure thermal and operating conditions.
- Camera Assembly
  - Camera/Data Storage
    - Send signal to turn on/off the camera and check for recorded video on data storage device.

Initial Test Plan: Software

- Arm control
  - Software can command 360 degree full range of rotational motion of the arm.
  - Software can command upward/downward motion of the arm and simulate contact with the rocket.
  - Software can generate a series of ten valid, random target locations.
  - Software can rotate the arm to each of the generated target locations and simulate contact with the rocket.
- Telemetry
  - Software can encode and transmit strings of data to the telemetry ports.
  - The ground station can successfully successfully decode the transmitted strings.
  - Software can share transmission of telemetry ports without corrupting its own data or an arbitrary second party's data.

Initial Test Plan: Overall

Full assembly run in freezing temperatures

Michael Polander

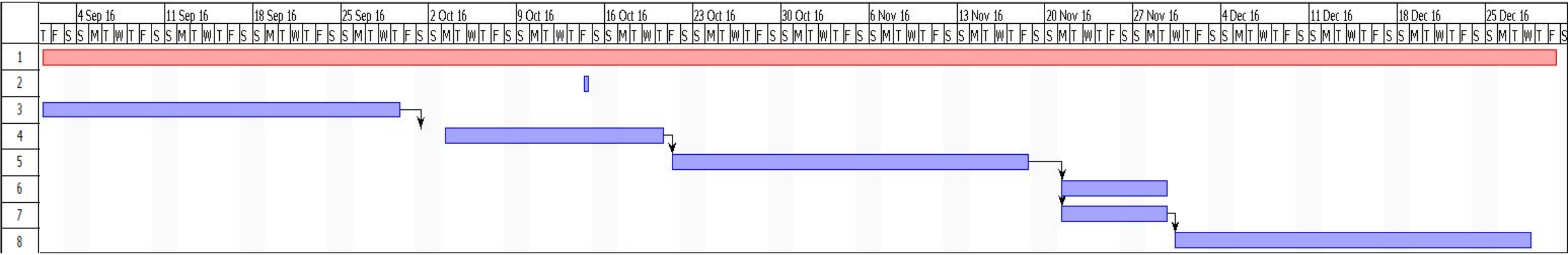
Section 6:

Project Management Plan

Devin Wyckoff

PMP: Schedule - Design Phase

		Name	Duration	Start	Finish	Predecessors
1		Design	87 days	9/1/16 8:00 AM	12/30/16 5:00 PM	
2		CoDR	1 day	10/14/16 8:00 AM	10/14/16 5:00 PM	
3		Design Direction	21 days	9/1/16 8:00 AM	9/29/16 5:00 PM	
4		Concept Design	14 days	10/1/16 8:00 AM	10/20/16 5:00 PM	3
5		Preliminary Design	21 days	10/21/16 8:00 AM	11/18/16 5:00 PM	4
6		Simulations	7 days	11/21/16 8:00 AM	11/29/16 5:00 PM	5
7		Prototype	7 days	11/21/16 8:00 AM	11/29/16 5:00 PM	5
8		Final Design	21 days	11/30/16 8:00 AM	12/28/16 5:00 PM	7



Brett Moffatt

PMP: Budget

Robotics	$2,850.00
Materials	$1,700.00
Electronics	$841.75
Software	$0.00
Deposit & Payments	$14,000.00
Travel	$15,910.00
Total	**$35,301.75**

PMP: Mentors

- Dr. Nancy Squires, MIME Capstone Instructor and Mechanical Engineering Instructor
- Dr. Bill Smart, MIME Robotics Professor

Michael Polander

PMP: Team Availability Matrix

Oregon State - Hephaestus

PDR RS-X Team Availability Matrix

PLEASE USE MOUNTAIN TIME ZONE TIMES

Oct 31-Nov 4	Monday	Tuesday	Wednesday	Thursday	Friday
7:00 AM	1	1	1	1	2
8:00 AM	1	1	1	1	2
9:00 AM		3		3	
10:00 AM		3		3	
11:00 AM	3	4	2	3	2
12:00 PM	2	2	2	2	2
1:00 PM		3		3	
2:00 PM		3		3	
3:00 PM		3		4	
4:00 PM	3	3	4	3	2
5:00 PM	2	4	2	4	1

Please Place priority levels for times you are availible. This is done by simply typing a 1,2,3, or 4 in each clear box. Hashed boxes an not availible

Example	1	2	3	4	

Michael Polander

PMP: Contact Matrix

Oregon State University Team							
Fall 2016 RS-X Contact Matrix							
Role	**Name**	**Day Phone**	**Cell Phone**	**Receive Texts?**	**Email**	**Citizenship**	**Add to mailing list?**
Project Manager	*Michael Polander*	*5036894119*	*5036894119*	*Yes*	polandem@oregonstate.edu	*U.S.*	Yes
ME Team Member	*Devin Wyckoff*	*5036216228*	*5036216228*	*Yes*	wyckoffd@oregonstate.edu	*U.S.*	Yes
ME Team Member	*Brett Moffatt*	*5415219505*	*5415219505*	*Yes*	moffatbr@oregonstate.edu	U.S.	Yes
ME Team Member	*Sam Lundeen*	5034375079	5034375079	*Yes*	lundeens@oregonstate.edu	U.S.	Yes
ME Team Member	*Subret Aryal*	5039290371	5039290371	*Yes*	aryals@oregonstate.edu	U.S.	Yes
ME Team Member	*Ian Finn*	5412311132	5412311132	*Yes*	finni@oregonstate.edu	U.S.	Yes
CS Team Member	*Helena Bales*	5034592253	5034592253	*Yes*	balesh@oregonstate.edu	U.S.	Yes
CS Team Member	*Amber Horvath*	5038845025	5038845025	*Yes*	horvatha@oregonstate.edu	U.S.	Yes
CS Team Member	*Michael Humphrey*	5412234594	5412234594	*Yes*	humphrmi@oregonstate.edu	U.S.	Yes
ECE Team Member	*Huy Nguyen*	5038888372	5038888372	*Yes*	nguyenh5@oregonstate.edu	**Green Card**	Yes
ECE Team Member	*Jonathan Hardman*	5038288739	5038288739	*Yes*	jonhman4@gmail.com	U.S.	Yes
ECE Team Member	*Cole Morgan*	5035455723	5035455723	*Yes*	Morgacol@oregonstate.edu	U.S.	Yes

Michael Polander

PMP: Team Organization Chart

CS Team:
Software

ME Team:
Robotics

Team Lead

Team Mentor

ECE Team:
Hardware

ME Team:
Structures

PMP: Status of Deposit

Complete

Risks/Worries:

The point of failure that has the greatest potential to limit mission success is the deployment of the arm assembly body. If the body failed to deploy, we would not be able to meet minimum success criteria.

This failure point is mitigated by the staged deployment of the arm assembly body. By first deploying a platform containing the arm assembly, we have the chance to meet minimum success by observing the platform deployment. The successful deployment and test of the arm would meet our maximum success criteria.

Conclusion

This mission provides a unique opportunity for proving the viability of flying a small arm to perform delicate on-orbit autonomous actions. This process could be extended to building structures or making repairs in a space environment. This project would additionally provide precedence for our university in pursuing more complex space missions.

In order to prepare for CDR, we must:

- Finalize full design of arm assembly body
- Simulate possible design concepts for stress, heat, and vibration
- Breadboard design of electronic systems
- Define software requirements
- UML design of software system