Presenter: Chase

Final Presentation

Aerojet Rocketdyne Remote Controlled Rover Payload

Advisor: Dr. Felix A. Soto Toro
Group 21

Christopher Keefer - Mechanical Engineering

Joel Marquez - Computer Engineering

Anjali Padmanaban - Electrical Engineering

Chase Walker - Computer Engineering

Presenter: Chase

MOTIVATION

- Project Sponsor Aerojet Rocketdyne wanted to fund students to make a project for entry to the FAR rocket competition
- The competition consists of a rocket and payload that will work together to reach the competition goal
- The reconnaissance vehicle payload - a remote controlled rover that transmits live video - was chosen due to the teams interest in the wireless communication and control implementation

Presenter: Chase

GOALS AND OBJECTIVES

1

Create a payload that will mate with a rocket and deliver a rover to the ground

2

Create a rover that will operate via remote control and will transmit wireless video to the launch station

3

Create a rover and capsule mating system for security

4

Design all systems for battery power for unhindered mobility

Presenter: Chase

REQUIREMENTS

Number	Description
1	The live video will transmit at a minimum of 480p 24 fps during its mission
2	The rover will respond to controller input within 10 seconds
3	The rover will be able to turn 360° (CCW or CW) in 5 seconds, move forward, and backward
4	The rover will travel a minimum distance of 3.05 meters (10 feet) in 15 seconds
5	The rover will have an accelerometer to measure its orientation
6	The maximum mass of the payload, and capsule must be no more than 4.31 kilograms
7	The rover coupling must hold 20kg and will be secure until landing is detected
8	The coupling will only unlock after the payload has been horizontal for 5 seconds

Presenter: Chase

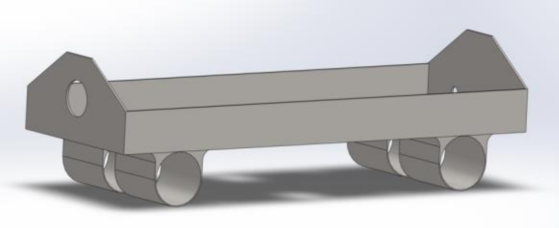
DESIGN OVERVIEW

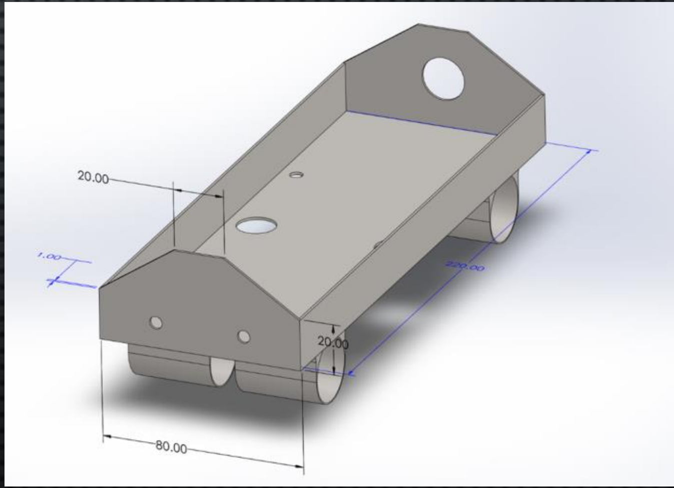
- Rover
- Capsule
- Rover Control Station (RCS)
- Total System

Presenter: Chris

Rover

- The rover chassis will be a light steel frame that mounts the PCB, video camera, motors, and the power supply
- Rubber tires with aggressive treading will be used for the movement system to allow the rover to avoid terrain hazards
- A LiPo battery cell will be used to power the PCB, camera, and receiver
- A rechargeable 11.1V battery will power the motors and transmitter
- The PCB will control all the remote-control reception and translation operations, the video transmission, and the rover auto-start system

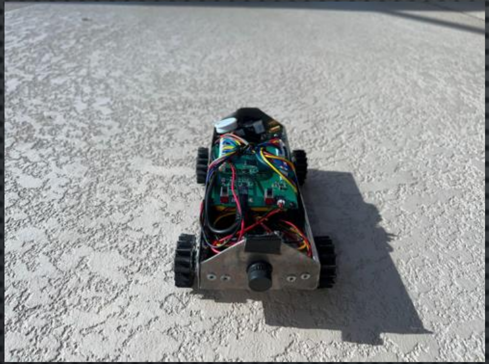


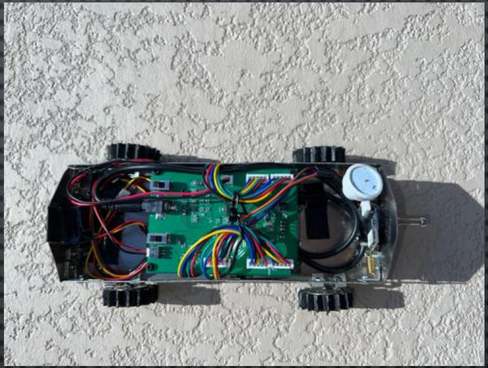


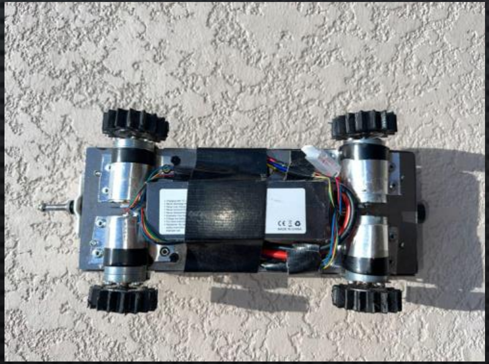
*Dimensions in mm

Presenter: Chris

Rover Manufactured



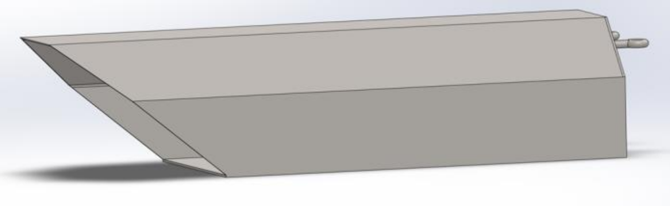


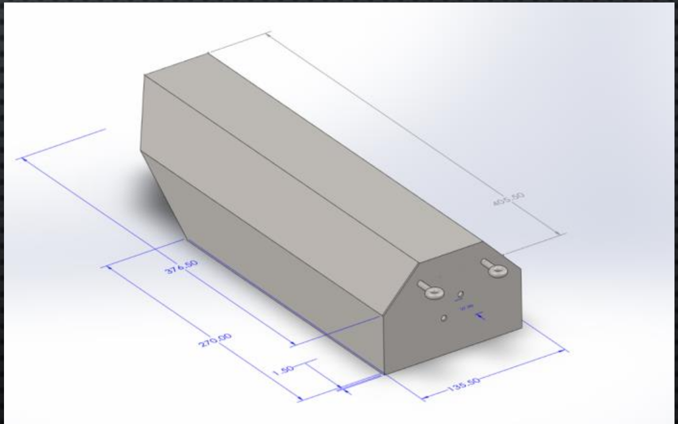


Presenter: Chris

Capsule

- The capsule and rover are to be mated using an electromagnetic coupler
- The PCB will be responsible for sensing when the capsule has landed and for releasing the coupler to allow the rover to begin its mission
- It will have its own battery and will be electronically disconnected from the rover

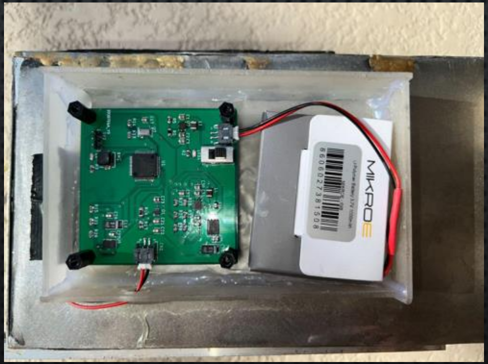




*Dimensions in mm

Presenter: Chris

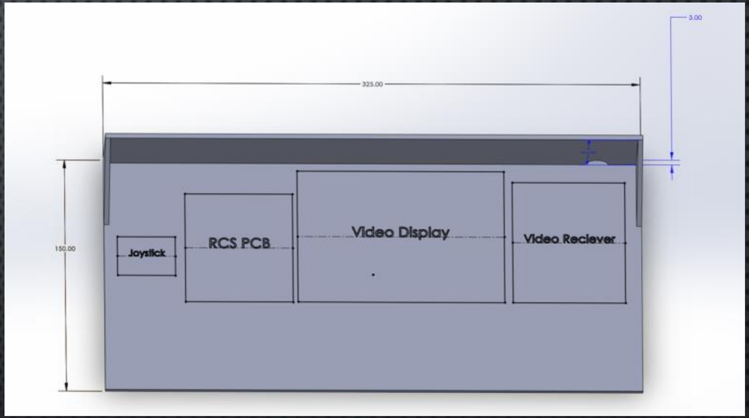
Capsule Manufactured



Presenter: Chris

Rover Control Station (RCS)

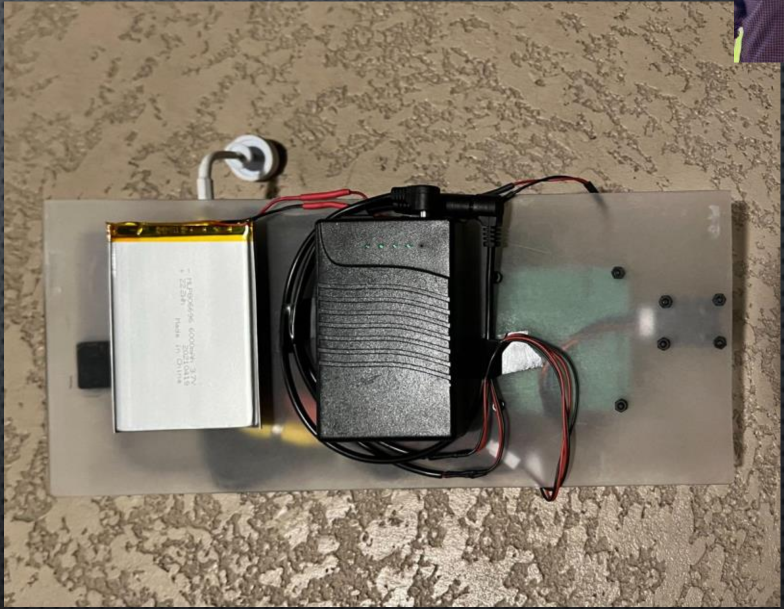
- This controller and video receiver unit will be free standing from the rover
- It will have its own rechargeable power source to allow it to be moved freely
- It will receive and display the wireless video signal from the rover in 480p
- It will have a joystick used to control the movement of the rover via radio transmission



*Dimensions in mm

Presenter: Chris

RCS Manufactured



Presenter: Chris

Total System

- The capsule will be loaded into the rocket airframe with the rover inside
- The capsule system will be powered on and will be waiting to detect liftoff
- The rocket will lift off and the rocket will reach 10,000ft before descending
- The capsule will be ejected from the rocket via parachute at 1,000 ft
- When the capsule lands, it will detect landing and the rover will be released from its coupling and will be able to drive out
- At the control station, it will be seen in the video reception that the rover has landed with the capsule, and the rover will be piloted for a minimum of 10 ft to complete the mission

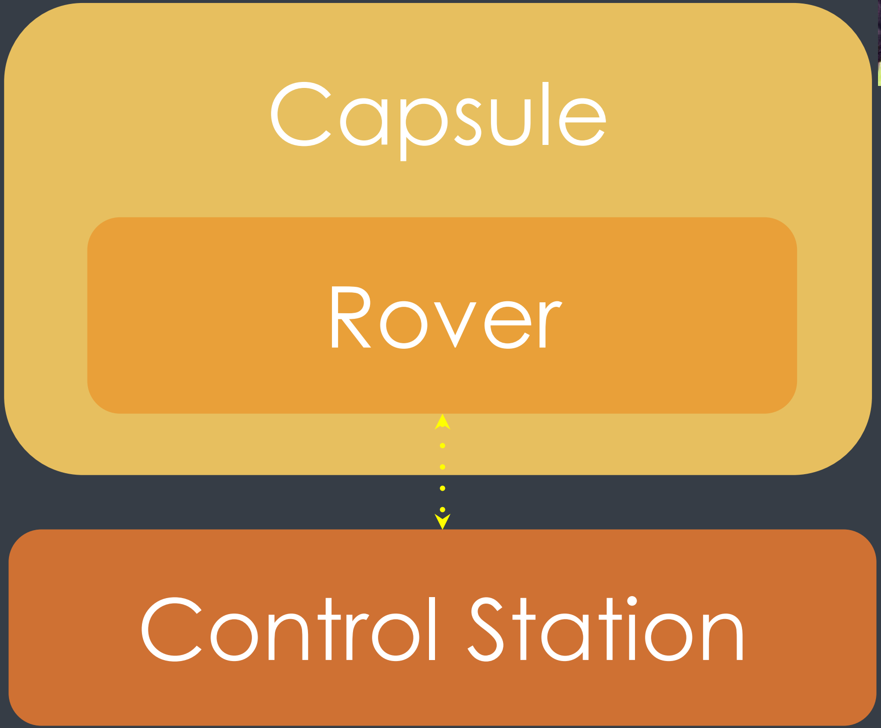
Presenter: Chris

MEMBER RESPONSIBILITIES

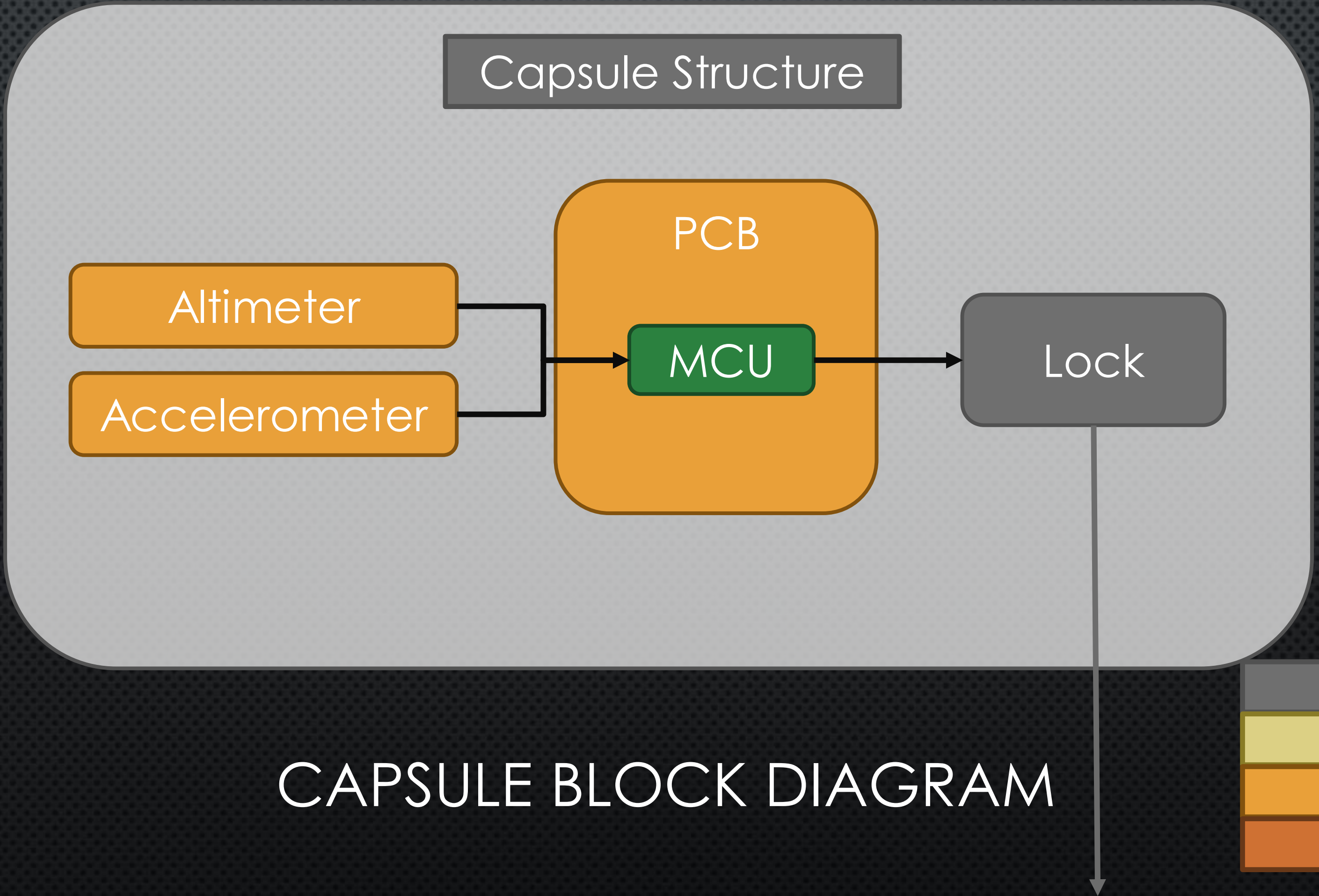
Name	Subsystems
Chris	Rover and capsule design and manufacturing
Joel	Video transmission System, PCB design
Anjali	Remote control system, PCB design
Chase	Power system, sensing systems, PCB design

OVERALL BLOCK DIAGRAM

Presenter: Chris

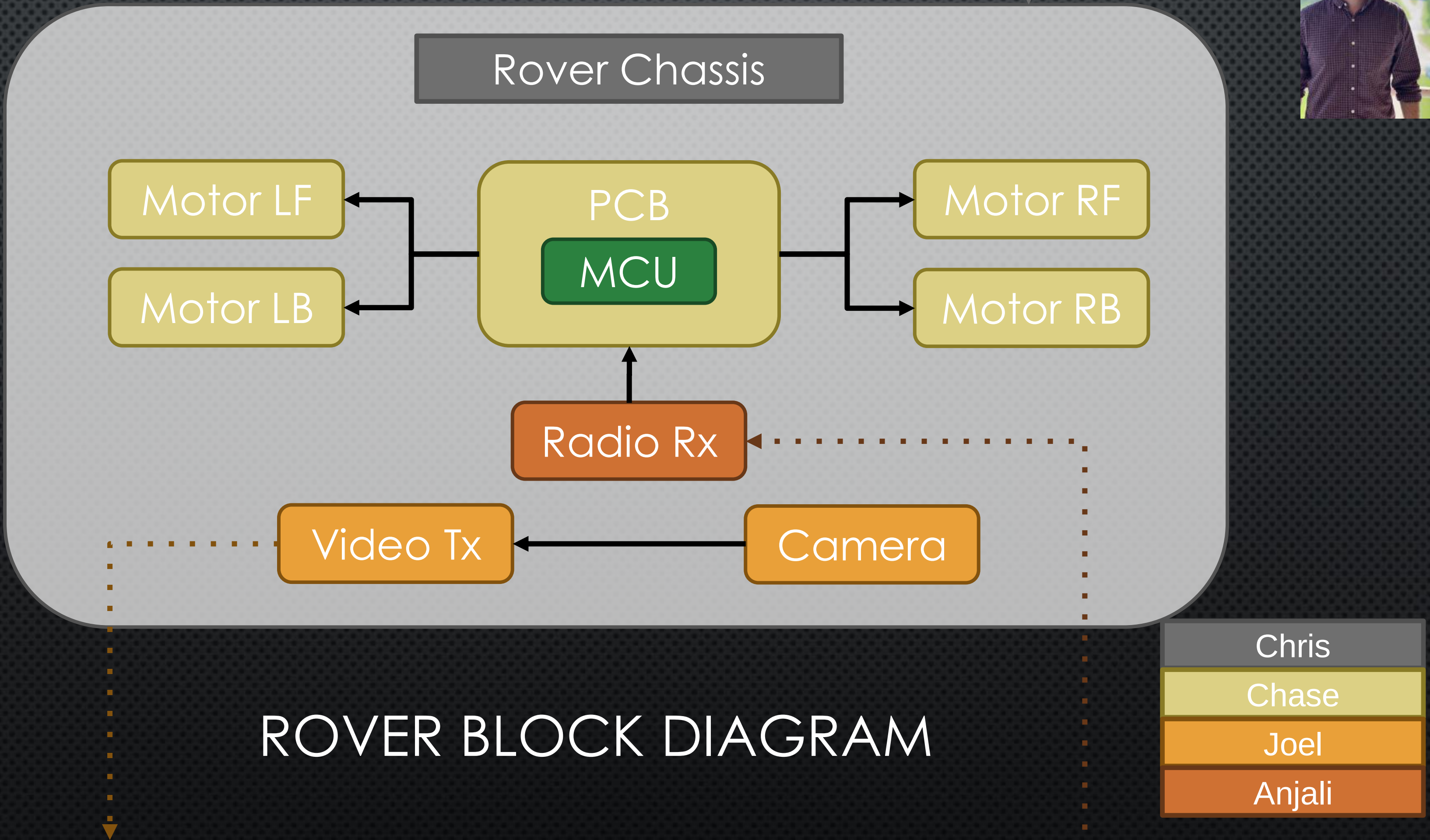


Presenter: Chris



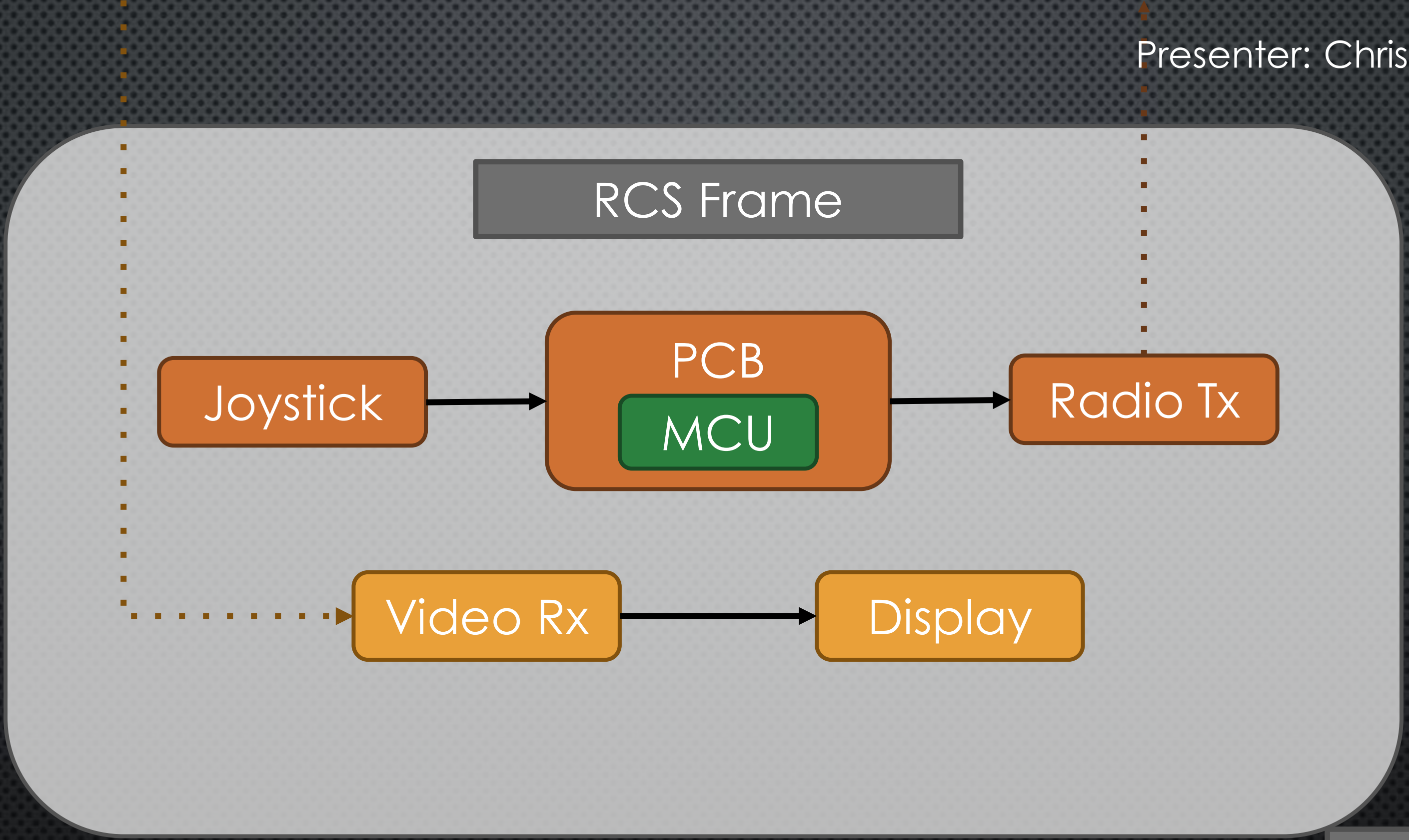
CAPSULE BLOCK DIAGRAM

Presenter: Chris



ROVER BLOCK DIAGRAM

Presenter: Chris



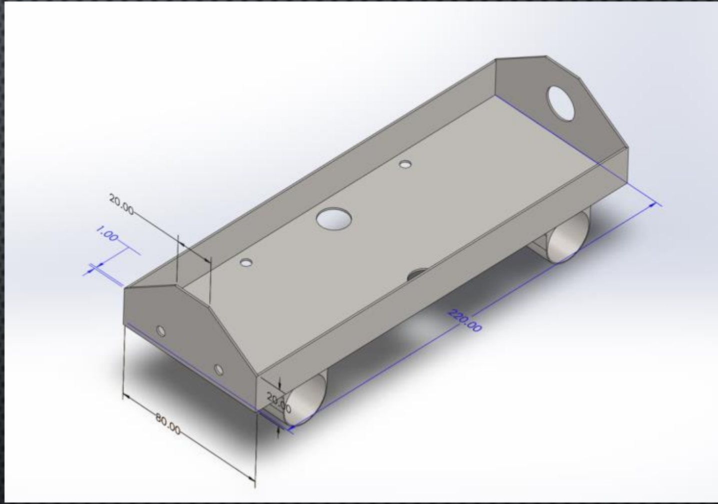
Chris
Chase
Joel
Anjali

ROVER CONTROL STATION BLOCK DIAGRAM

Presenter: Chris

ROVER CHASSIS DESIGN

- Designed to be fit within a diameter of approximately 14.5 cm in order to fit within the capsule and rocket payload bay
- Designed to fit largest electrical components
- Small cut-out on the front of the rover to house the video camera



*Dimensions in mm

Presenter: Chris

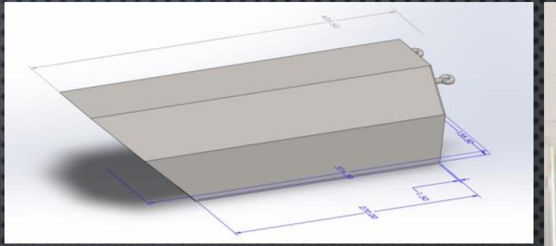
ROVER CHASSIS MANUFACTURING

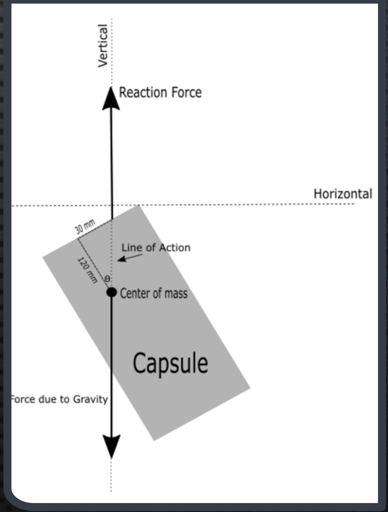
- AISI 1060 Steel
- Cut steel pieces riveted together
- Anchor points for electrical components
- Custom aluminum housing for motors
- Custom wheels fashioned from gears
- Required tools: jigsaw, rivet gun, power drill

Presenter: Chris

CAPSULE STRUCTURAL DESIGN

- Capsule was designed with key geometric features that allow for successful upright landings
- Scoop feature on the front of the capsule guides the capsule to land on its landing gear after initial contact with the ground
- Planned force balance within the payload will induce an angle of attack with the purpose of landing the capsule in the proper orientation





*Dimensions in mm

Presenter: Chris

CAPSULE STRUCTURE MANUFACTURING

- AISI 1060 Steel
- Cut steel pieces welded and riveted together
- Two eyelet screws for parachute anchoring
- Railing and sled were custom manufactured out of aluminum and plastic
- Required tools: jigsaw, welder, rivet tool, power drill

Presenter: Chase

VOLTAGE REGULATION

- Two voltages are needed in this project: 3.3V and 12V
- Two power circuits were designed using the TI WEBENCH software
  - Both circuits have an input range of 3 - 4.2V
  - The 3.3V circuit uses a buck-boost topology to provide a maximum current of .75A
  - The 12V circuit uses a boost topology to provide a maximum current of 1.75A
  - Current outputs were determined from max currents across the three PCBs plus 250mA of overhead
  - Schematics will be shown later

Presenter: Chase

POWER SUPPLIES

- A mix of 11.1V and 3.7V LiPo batteries were chosen due to their high capacity and small form factors
  - 11.1V provides a voltage ranging from 9 - 12.6V depending on charge level
  - 3.7V provides a voltage ranging from 3 - 4.2V depending on charge level
- Each system has one 3.7V battery for the 3.3V ranges needed for the ICs and MCUs, the capsule board uses the 12V boost circuit on this battery
- The rover and RCS each have a 11.1V battery on top of their 3.7V batteries to support high-current parts that cannot use the boost circuit
  - The rover requires this battery to power its motors and video transmitter
  - The RCS requires this battery to power the video receiver and video screen

Presenter: Chase

ROVER POWER SUPPLY 1 - 3.7V

- AVERAGE DRAW: 150MA
- TARGET LIFETIME: 12HR
- 150MA * 12HR = 1800MAH

MIKROE-4474
3000mAh, 3.7V
1C max discharge
63.0 x 57.0 x 8.1mm
$14.50

MIKROE-1120
2000mAh, 3.7V
1C max discharge
63.5 x 44.2 x 7.0
$12.50

Presenter: Chase

ROVER POWER SUPPLY 2 - 11.1V

- Idle draw: 250mA
- Average Draw: 650mA
- Max draw: 1550mA
- Target idle time: 2hr
- Target avg time: 3hr
- 250mA * 2hr + 650mA * 3hr = 2200mA

Ovonic 3S Lipo Battery 50C 2200mAh
2200mAh, 11.1V
50C max discharge
105 x 33 x 14mm
$22.20

YOWOO 2200mAh LiPo Battery 11.1V 50C 3S
2200mAh, 11.1V
50C max discharge
105 x 34 x 24mm
$23.99

Presenter: Chase

CAPSULE POWER SUPPLY

- Max draw: 200mA
- Average draw: 50mA
- Target full power time: 3hr
- Target avg time: 7hr
- 50mA * 7hr + 200mA * 3hr = 950mAh

MIKROE-698	MIKROE-4473
1000mAh, 3.7V	1500mAh, 3.7V
1C max discharge	1C max discharge
53.0 x 35.0 x 5.9mm	63.0 x 39.5 x 6.1mm
$8.90	$10.90
	

Presenter: Chase

RCS POWER SUPPLY 1 - 3.7V

- Average draw: 150mA
- Target lifetime: 12hr
- 150mA * 12hr = 1800mAh

* The group had already purchased a 6000mAh battery for another use before deciding to make this a 2 battery system, therefore the battery seen to the right was used regardless of other options since it was suitable

MIKROE-4475

6000mAh, 3.7V

1C max discharge

99.0 x 67.0 x 8.1mm

$21.90

Presenter: Chase

RCS POWER SUPPLY 2 - 11.1V

- AVERAGE DRAW: 500MA
- TARGET LIFETIME: 6HR
- 500MA * 6HR = 3000MA

*THESE MORE UNCONVENTIONAL BATTERIES WERE CHOSEN FOR THEIR QUICK SHIPPING TIME AND EASY ADAPTATION COMPARED TO OPTIONS SEEN FOR THE ROVER BATTERY

TalentCell Rechargeable 12V 3000mAh	**TalentCell Rechargeable 12V 6000mAh**
3000mAh, 11.1V	6000mAh, 11.1V
1C max discharge	.5A max discharge
105 x 65 x 25mm	145 x 85 x 28mm
$28.99	$39.99
	

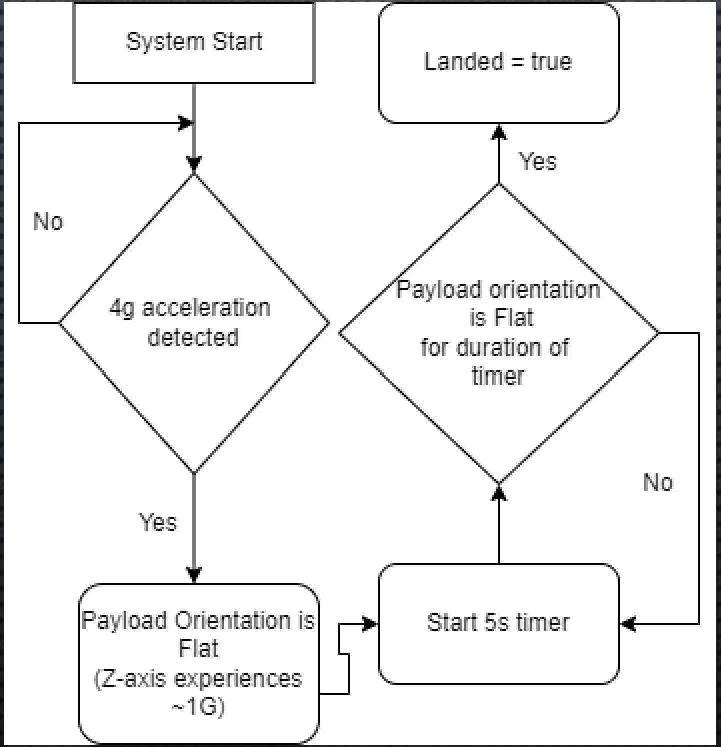
Presenter: Chase

LANDING SENSING SYSTEM

- User may not have line of sight on capsule during landing, so an automatic release system of the coupler must be used
- Both the rover and capsule use an accelerometer to detect landing
- MCU checks the sensor for landing condition based on orientation

Presenter: Chase

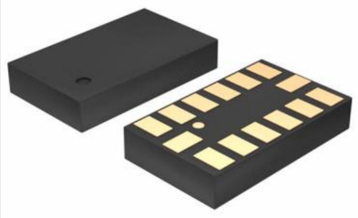
LANDING SENSING SYSTEM



Presenter: Chase

ACCELEROMETER CHOICES

Analog Devices ADXL343	Memsic MXC4005XC	Memsic MC3419
3.3mm x 5.3mm	1.7mm x 1.18mm	Unknown Dimensions
Capacitive Accelerometer	Thermal Accelerometer	Capacitive Accelerometer
Measures 16G at 10-bit precision	Measures 8G at 12-bit precision	Measures 16G at 16-bit precision
$3.42	$1.72	$1.96
Breakout board availability		

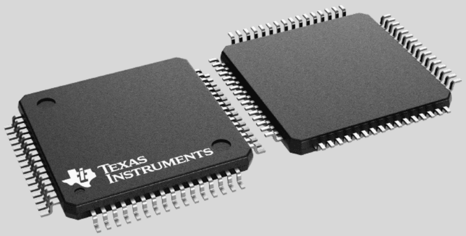


Presenter: Chase

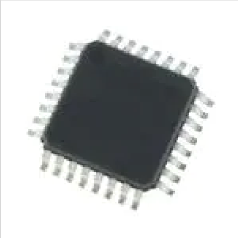
MCU CHOICES

- The TI MSP430FR6928IPM was chosen for use in this project on all three PCBs
- The main draw was its familiarity to the team members, and its ability to easily be programmed via an MSP430 launchpad
- This MCU provides enough PWM and GPIO pins for the needs of the project
- It provides two I2C lines which is handy for the accelerometer and altimeter implementations to not have to share a communication line

MSP430FR6928 IPM
16-bit, 16MHz
12, 12-bit ADCs
2 I2Cs
63 GPIO
$7.08



MC9S08PB8MTG
8-bit, 20MHz
12, 12-bit ADCs
1 I2Cs
18 GPIO
$8.14



Presenter: Chris

ROVER AND CAPSULE COUPLING

- TO PREVENT THE ROVER FROM MOVING INSIDE OF THE CAPSULE DURING FLIGHT, A COUPLING MECHANISM WAS NEEDED
- AN ELECTROMAGNETIC LOCK WAS CHOSEN DUE TO ITS FORM FACTOR AND HIGH STRENGTH
- WHEN LANDING IS DETECTED BY THE CAPSULE, THE LOAD SWITCH CONNECTED BETWEEN THE POWER SOURCE AND COUPLER WILL BE OPENED TO ALLOW THE ROVER TO DRIVE AWAY

MATEE DC12V Electromagnetic Lock	ATOPLEE Electromagnetic Solenoid Lock
50mm x 30.2mm x 26.8mm	27mm x 29mm x 18mm
180g	140g ea.
12V, 100mA to unlock	12V, 350mA to unlock
50kg holding strength	50kg holding strength
$30.06	$30.06
	

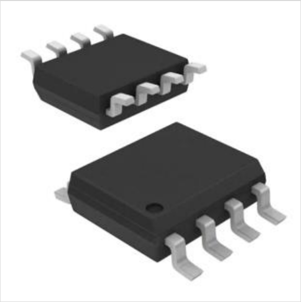
Presenter: Chase

LOAD SWITCH PART DETAILS

- The IC load switches used for capsule-rover coupler control and motor control act as physical throw switches that can be controlled by a MCU GPIO pin
- They use a series of MOSFETs to control current flow on demand
- Two switches are being used for the motors to abide by the max current of the chosen switch

Vishay Siliconix SI1869DH-T1-E3
2mm x 2.1mm
Input voltage 1.8 - 20V
Max current 1.5A
$0.53

Diodes Incorporated AP2401MP-13
2mm x 2.1mm
Input voltage 2.7 - 5.5V
Max current 2A
$0.89



Presenter: Chris

ROVER PROPULSION - MECHANICS

- DIFFERENTIAL STEERING: REQUIRES FOUR MOTORS
- EACH MOTOR MUST HAVE A MINIMUM OF 0.45 KG.CM OF TORQUE
- EACH MOTOR MUST HAVE A MINIMUM OF 97 RPM TO MEET REQUIREMENT OF 10 FEET IN 20 SECONDS (4 CM WHEEL DIAMETER)

DFROBOT FIT0441
12V, 300mA
159RPM
2.4kg*cm of torque
70g
$19.90

25SG-2418BL-20
12V, 450mA
108RPM
0.55 kg*cm of torque
Unspecified Mass
$13.95

Presenter: Chase

ROVER PROPULSION - ELECTRONICS

- The motors speed and direction will be controlled by the onboard MCU using PWM and GPIO respectively
  - Each pair of motors (left side and right side) will share both direction and speed signals
- The motors are on the 12V power rail of the rover board

Presenter: Anjali

ROVER REMOTE CONTROL - JOYSTICK

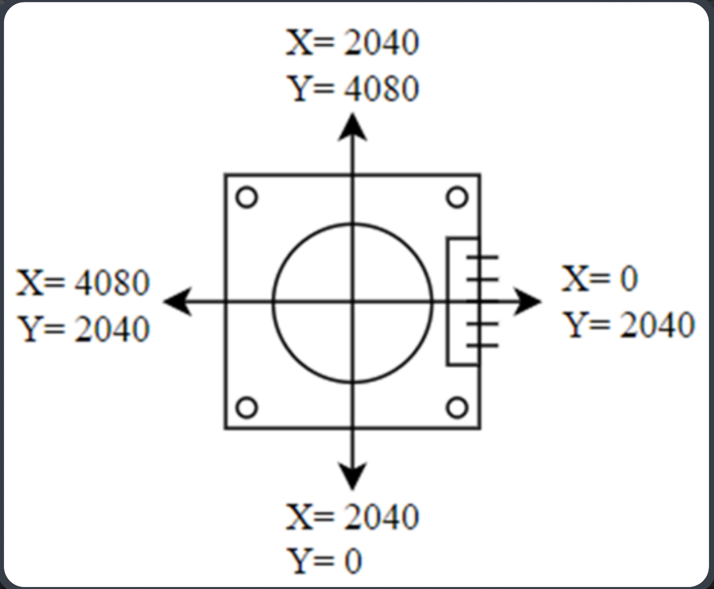
Adafruit 2-Axis Analog Joystick
38mm x 38mm x 32mm
3.3V
ADC reading
X, Y, click outputs
$6 (had before project)

Adafruit Tactile Buttons
6mm x 6mm x 5mm
1 - 50 mA
Digital reading
4 buttons total (1 per control)
$2.50 (had before project)

Presenter: Anjali

ROVER REMOTE CONTROL - JOYSTICK READING

- The 2-axis Analog Joystick works by providing coordinate points of the joystick's position
- Values range from 0 - 4080
- Resting point is (2040,2040)
- Coordinates will be classified in 4 levels:
  - Move Forward
  - Move Backward
  - Turn Right
  - Turn Left



Presenter: Anjali

ROVER REMOTE CONTROL - RADIO TRANSCEIVER

Reyax RYLR896 LoRa SX1276	Reyax RYLR406 LoRa SX1278
42mm x 18mm x 6mm	42mm x 18mm x 6mm
3.3V, 16 – 45mA	3.3V, 16 – 45mA
UART communication	UART communication
15km range, 868 / 915 MHz	15km range, 433 / 470 MHz
$20	$20
	

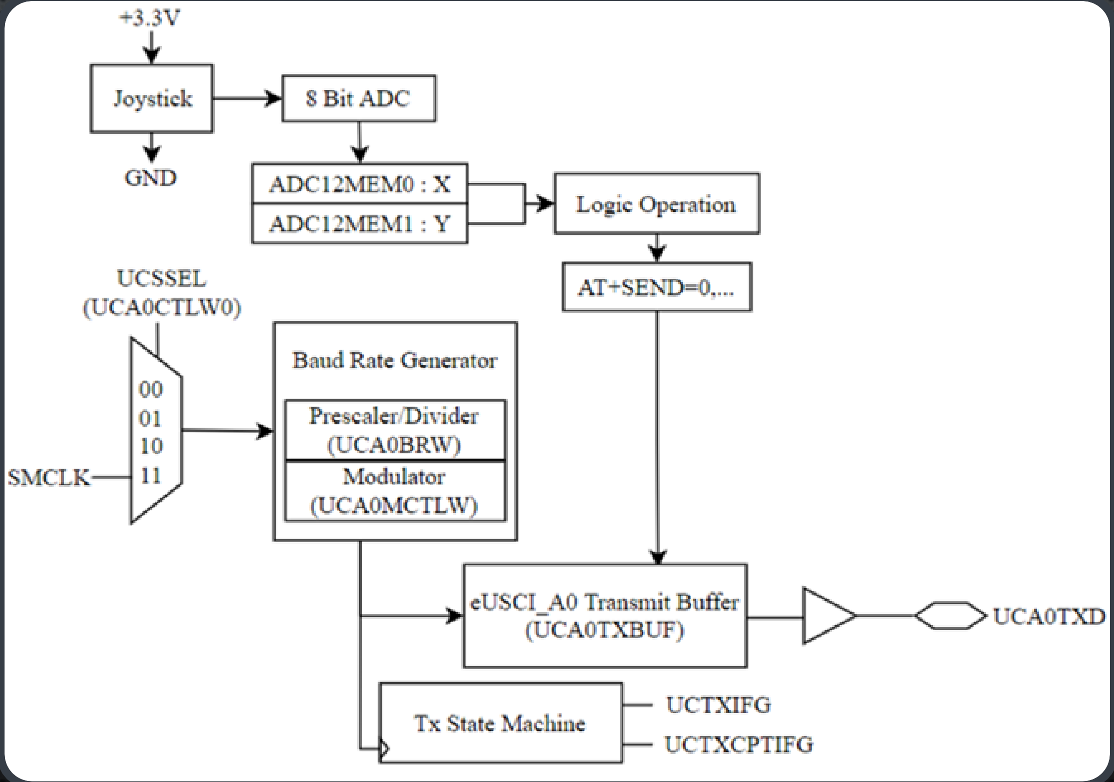
Presenter: Anjali

ROVER REMOTE CONTROL - RADIO TRANSMISSION

- Data from the joystick is transmitted through the radio transmitter
- Transmitter/Receiver work in 868 MHz / 915 MHz
- Use AT Commands
- Must transmit over a distance of 2km
- Receiver on the rover will relay the information to the motors

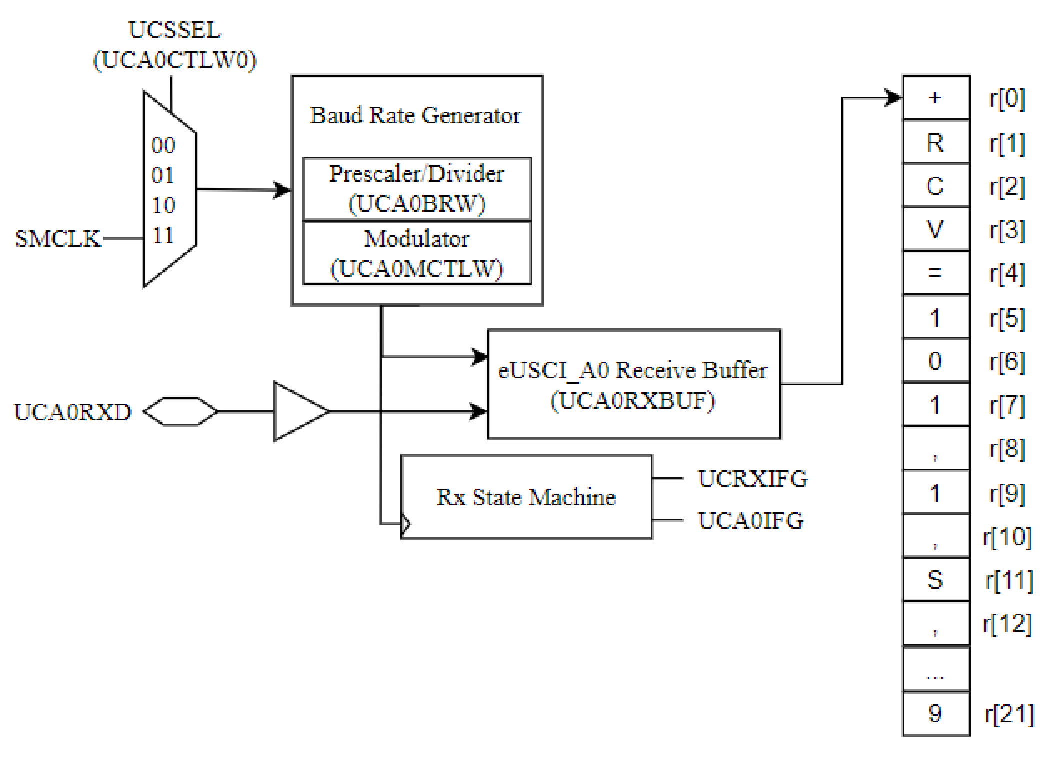
Presenter: Anjali

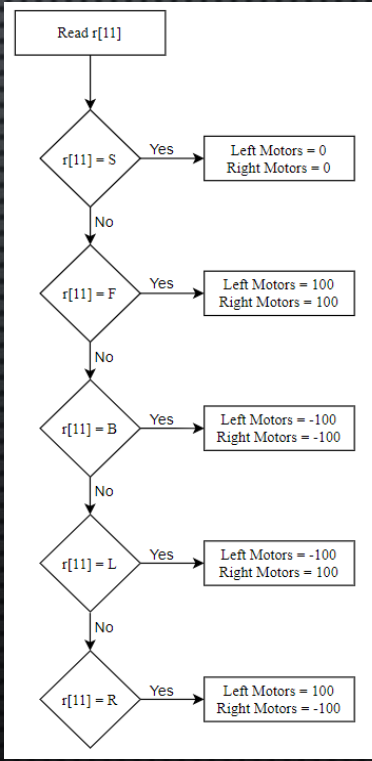
ROVER REMOTE CONTROL - RADIO TRANSMITTER



Presenter: Anjali

ROVER REMOTE CONTROL - RADIO RECEIVER





Presenter: Joel

VIDEO CAMERA CHOICES

Runcam Nano 4 FPV Video Camera
2.9g, 14mm x 14mm x 14mm
2.1mm Lens
155 FOV
5V, 160mA
$20

Wolfwhoop FC21 FPV Camera 2.8mm
2.9g, 26mm x 26mm x 28mm
2.8mm Lens
12V, 70mA
$11

Presenter: Joel

WIRELESS VIDEO TRANSMISSION CHOICES

AKK TS832+RC832 5.8GHz Video Transmitter/Receiver
Tx: 22g, 54mm x 32mm x 10mm Rx: 85g, 80mm x 65mm x 15mm
12V, 300mA each
5 bands, 8freqs, 37 channels
Theoretical distance 3km
$30

Boscam 5.8GHz TS835 Transmitter+RX5808 5.8GHz Video Receiver
Tx: 22g, 54mm x 32mm x 10mm Rx: 85g, 28mm x 23mm x 3mm
Tx:12V, 600mA Rx: 3.5V, 170mA
4 bands, 8freqs, 32 channels
Theoretical distance 3km
Tx: $16, Rx: $17

Presenter: Joel

VIDEO SCREEN CHOICES

5" TFT LCD Screen	7" Lychee Digital HD Car TFT Color Screen
76mm x 102mm x 25mm	N/A
12 – 24V, 6W	12 – 24V, 6W
Dual RCA video input	Dual RCA video input
800 x 480p	800 x 480p
$26	$38

Presenter: Joel

WIRELESS VIDEO - CAPTURE

- Video will be captured by the rover through an FPV camera
- The FPV camera chosen is the Wolfwhoop FC21 FPV Camera
- It captures at a horizontal resolution of 700TVL or 976 by 582 pixels
- This data out wire from the camera will be directly fed into the video transmitter
- Video data is fed out in NTSC format

Presenter: Joel

Wireless Video - Transmission and Reception

- Upon receiving the video signal from the camera, the transmitter will send out the video signal along one of the 40 different 5.8 GHz bands the transmitter can select from
- The signal will be transmitted from the Pagoda antenna attached to the transmitter
- On the receiving end of the transmitter, the receiver will retrieve the 5.8GHz signal from the transmitter and output it to the display via an AV(Audio Video) wire

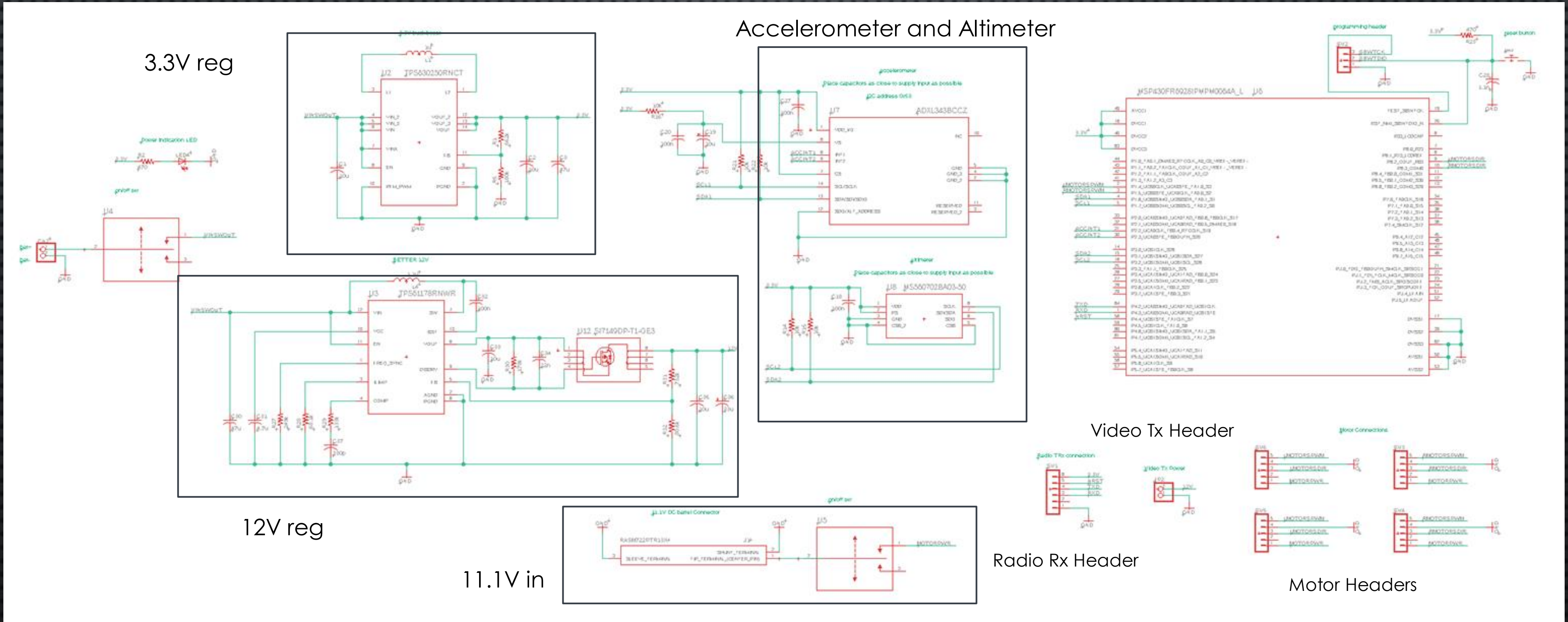
Presenter: Joel

WIRELESS VIDEO - DISPLAY

- The 800x480 pixel monitor will get the video feed from the 5.8GHz receiver
- The monitor which will be attached to the RCS(Rover Control Station) the live video feed to the rover operator

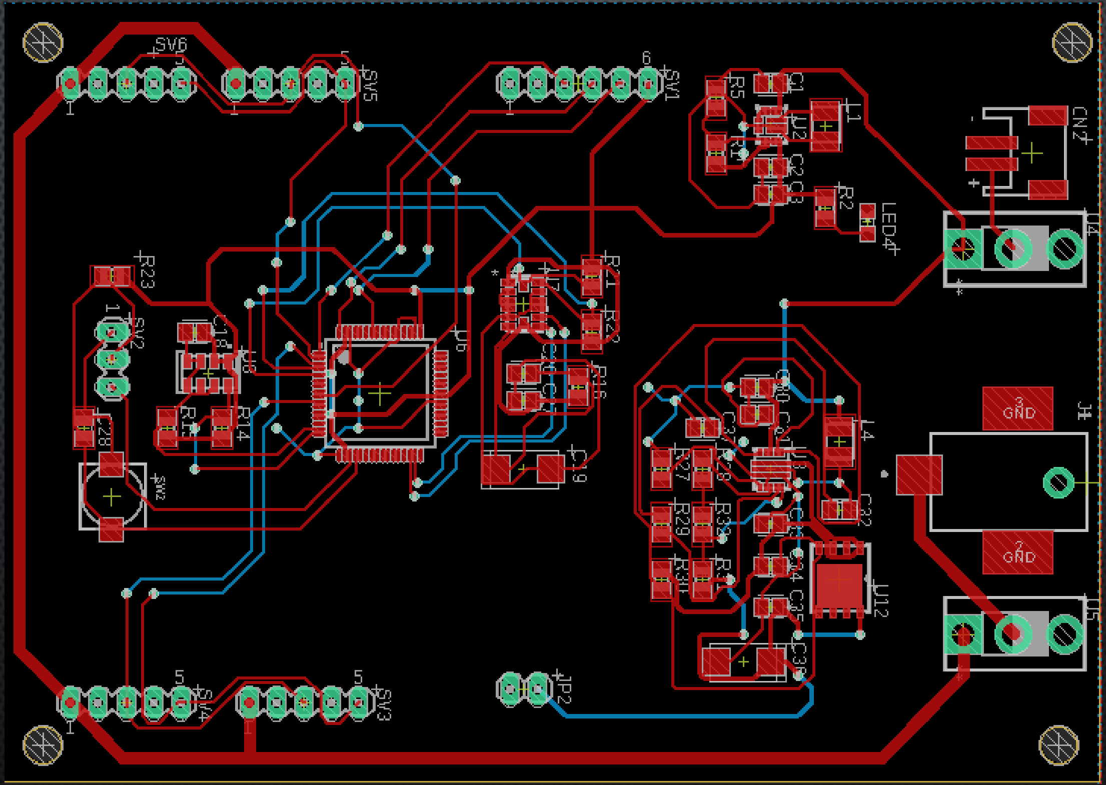
Presenter: Chase

ROVER PCB SCHEMATIC



Presenter: Chase

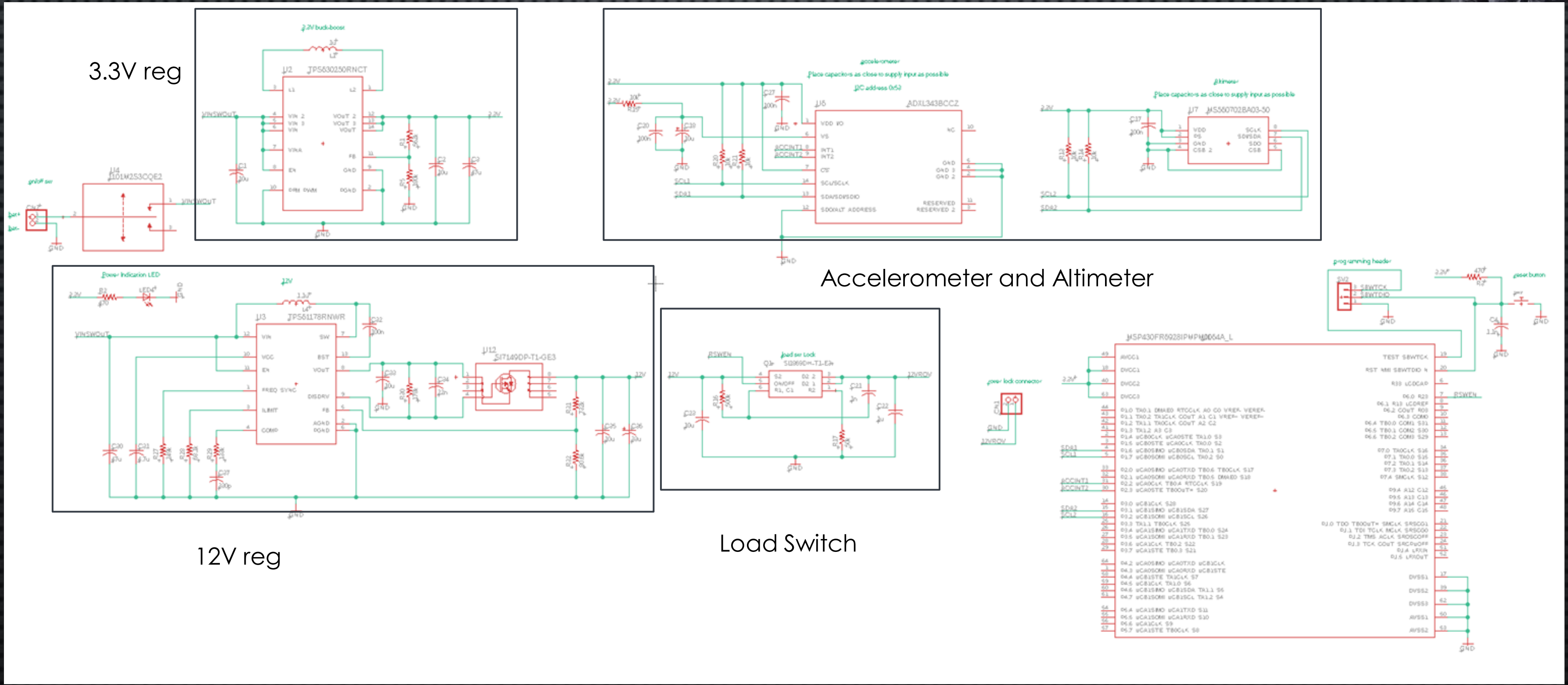
ROVER PCB LAYOUT



7.239 CM TALL, 10 CM WIDE

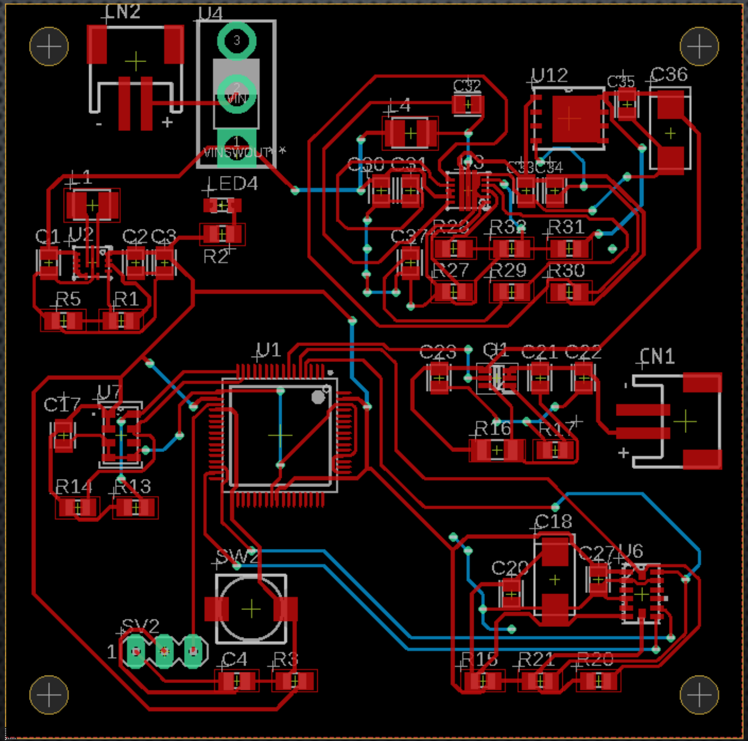
Presenter: Joel

CAPSULE PCB SCHEMATIC



Presenter: Joel

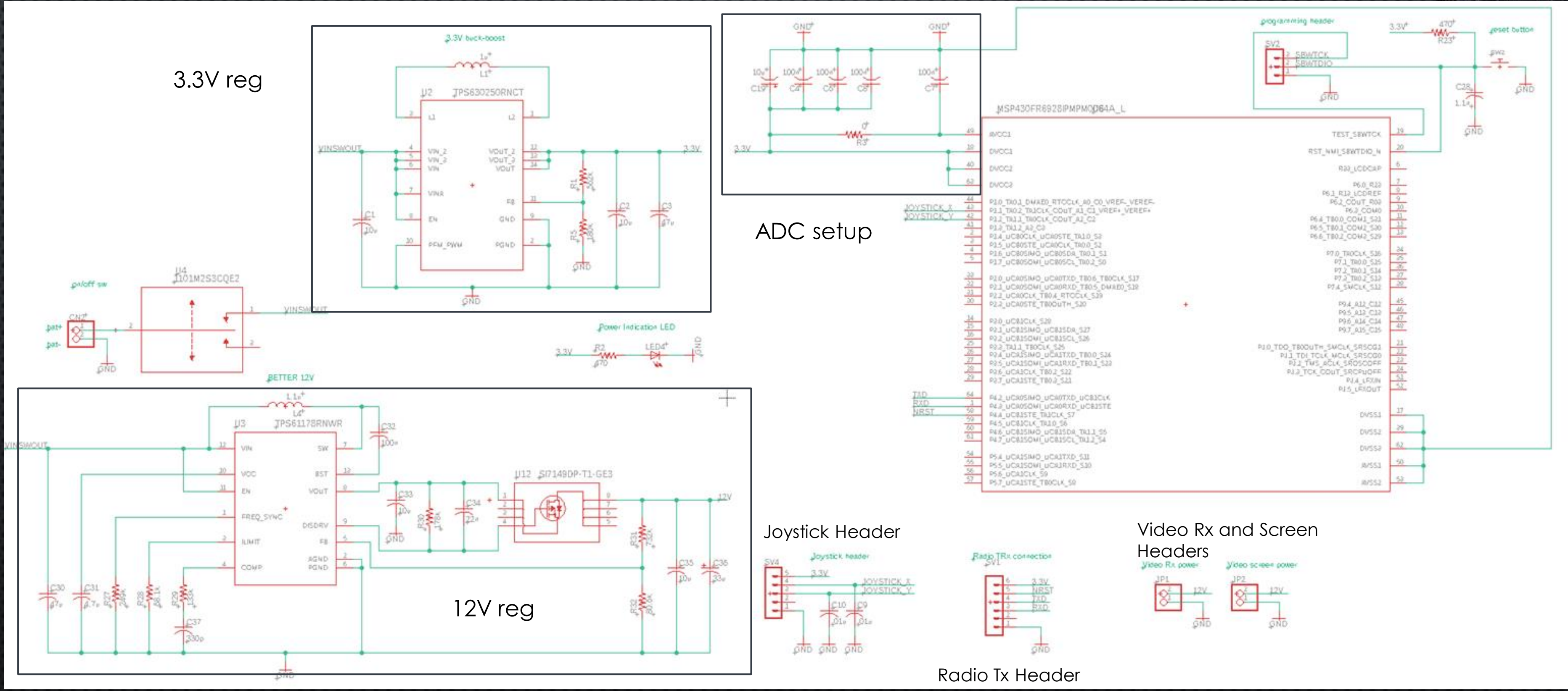
CAPSULE PCB LAYOUT



6.5 CM TALL, 6.5 CM WIDE

Presenter: Anjali

RCS PCB SCHEMATIC



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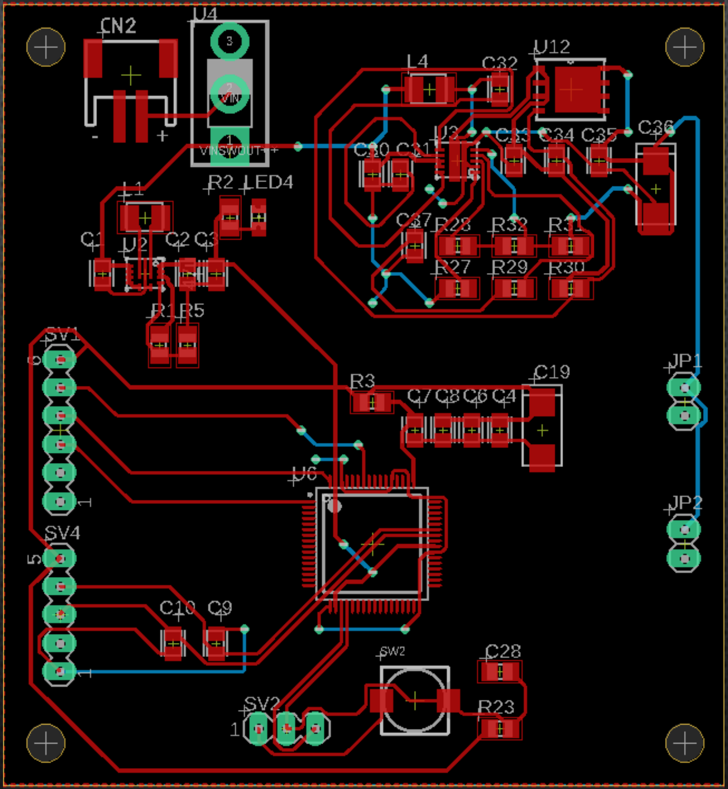
RCS PCB LAYOUT



7 CM TALL, 6.35 CM

ENGINEERING CONSTRAINTS

Number	Description
1	Payload capsule and payload must be able to handle impact speed of 3 m/s
2	The rover must be able to traverse desert terrain including sand and rocks
3	The radio band of 420 MHz - 450 MHz is reserved for the rocket avionics
4	Payload capsule and payload must be able to withstand up to 8 g when the drogue parachute deploys and during launch acceleration
5	The payload, sled, and capsule assembly must weigh less than or equal to 4.31 kg
6	The payload must be unaffected by operation in the radio frequency ranges of 420 MHz - 450 MHz and 1 GHz - 2 GHz
7	Payload sled must take up no more than 1.27 cm on either side of the payload
8	Payload dimensions must be less than 14.5 cm in diameter and 40.64 cm in length

Presenter: Chris

Presenter: Chris

ENVIRONMENTAL AND SUSTAINABILITY CONSTRAINTS

- LITTER AND WASTE PROTECTIONS
  - PROJECT WAS DESIGNED IN A WAY THAT IT WILL NOT CREATE LITTER AND ALL PARTS USED WILL BE HARVESTED AFTER THE MISSION
  - RECHARGEABLE BATTERIES WERE CHOSEN TO REDUCE WASTE AND ONE-TIME-USE TECHNOLOGIES WERE AVOIDED
- ENVIRONMENTAL OPERATION CONSTRAINTS
  - CONSIDERATION WAS MADE FOR THE WAY THE SANDY TERRAIN OF THE TARGET OPERATION ENVIRONMENT COULD IMPACT THE ROVER

Presenter: Chris

MANUFACTURING CONSTRAINTS

- DUE TO POTENTIALLY HARMFUL SIDE EFFECTS OF THE MANUFACTURING TECHNIQUES USED IN THIS PROJECT (SOLDERING, TORCH WELDING, PLASMA CUTTING), SPECIAL CARE AND SAFETY MEASURES WILL BE TAKEN TO PREVENT BODILY HARM
- THE SILICON SHORTAGE PLACED EXTREME PRESSURE ON BOTH THE TEAM'S ABILITY TO SOURCE PARTS AND THEIR BUDGET
- THE INCREASE IN PRICES OF THE SHORTAGE ALONG WITH INFLATION CAUSED THE TEAM TO GO OVER BUDGET WITH PRICES OF MULTIPLE COMPONENTS INCREASING BY 200% SINCE FALL 2021

Presenter: Chris

ETHICAL CONSTRAINTS

- The team explored ethical considerations when creating the design of the system to make sure no harm is done to the public
- The conclusion the team reached was to keep the operation of the rover restricted to group members so the electronics aren't used without regard for typical ethical considerations
- It was concluded that there will be hardly any impact on humans because this project will not be used commercially, and will be used in a regulated environment
- The team still maintained the ethical considerations regarding the environment mentioned in a previous slide

SAFETY CONSTRAINTS

- ROCKET SAFETY IS CRITICAL DUE TO THE VOLATILE NATURE
- THIS TEAM IS NOT IN CONTROL OF THE ROCKET, BUT WILL AVOID INTERFERENCE WITH THE ROCKET
  - MANAGE INTERFERENCE WITH ROCKET ELECTRONICS AND COMMUNICATION SYSTEMS
  - DESIGN TO NOT HINDER OR DAMAGE ROCKET STRUCTURE
- LIPO BATTERIES CAN BE VOLATILE, AND THE USE OF THESE BATTERIES WAS CONFIRMED TO BE ACCEPTABLE BY THE ROCKET TEAMS
- PROPER DISTANCE FROM LAUNCH SITE WILL BE SAFELY MAINTAINED AND REGULATED

Presenter: Joel

SENSOR STANDARDS

- ASTM F811:
  - An accelerometer must be firmly attached to the chassis of its vehicle, for accurate acceleration measurement.
  - As seen in the schematic, accelerometers were placed near the mounting points of both PCBs to reduce the measurement of vibrations

Presenter: Joel

Wireless Transmission Regulations and Testing Standards

- FCC 03-11A01 document outlines acceptable uses for 5GHz frequency
  - 5.725 GHz - 5.825 GHz is allowed for individual use if operating in a total spectrum of 300 MHz
  - When operating within 5.47 - 5.725 GHz, transmitting power cannot exceed over 250 mW
  - Video Transmitter and Receiver will operate at 5.8 GHz, and the rules will be followed
- ASTM E2854/E2854M
  - Provides criteria for testing to determine if robot is still effective and responsive at certain distances
  - The team will either borrow these testing procedures or derive their own from the knowledge provided by the standard

Presenter: Joel

PROGRAMMING LANGUAGE STANDARD

- Embedded C
  - This language will be used for all three separate systems
  - Michael Barr's *Embedded C Coding Standard* is a free to use online standard book that will be used to maintain clarity and organization in this projects code

Presenter: Anjali

DISPLAY STANDARDS

- For video encoding the camera is using the NTSC format
- The RCA (Radio Corporation of America) Phono Connector is the display connector being used to route the composite audio video signal

Presenter: Anjali

ELECTRONIC COMMUNICATION AND CONTROL STANDARD

- I2C or TWI
  - Used for altimeter and accelerometer communication with the MCU
- PWM
  - Used to control the speed and response of the motors for rover locomotion
- UART
  - Used to handle communication of transmitters and receivers with their respective MCUs

Presenter: Anjali

CONNECTION/INTERFACE STANDARDS

- USB 2.0 - USB Micro-B
  - Used for the 5V input into the battery charging circuits on each PCB
- JST
  - Used for battery, camera, and coupling mechanism connections. Provides strong physical latching connection resistant to vibration
- 2.54mm pitch pin headers or PCB connection holes
  - Used for motor connections, programming pins, and power connections for video transmitter, receiver, and display
  - Provide easy soldering, and are a standard pitch for male and female headers used in prototyping

Presenter: Anjali

BUDGET AND FINANCING

Count	Part	Cost	Count	Part	Cost
4	Motors	79.60	5	Battery	125.30
18	Testing Parts	34.65	4	Altimeter	36.36
2	Coupler	60	4	Accelerometer	13.96
1	Screen	26	6	Battery Charger	6.78
3	Camera	60	6	MCU	42.45
1	Video Tx and Rx	30	NA	Linear parts and connectors	120
10	Load switch	5.45	3	PCBs	110
6	MOSFETs	9.78	12	Voltage regulators	46.68
2	Radio Transceiver	39	NA	Manufacturing	150
Sponsored Budget:		**500**	**Total Cost + Shipping:**		**956**

Presenter: Chase

Difficulties and Concerns

- Inflation/Parts shortage made the project go over the sponsored budget
- PCB design
  - Parts shortage made design challenging
  - Lack of incoming knowledge caused bad designs to be created
- Capsule/Rover
  - Working within the tolerances of a rocket
- RCS/Rover
  - Setting up remote control was a process that was not well documented for our use case
  - Video Transmission was difficult to choose, we would have made a different choice with more funding
- Working with a separate team that also has design changes makes planning and manufacturing challenging

Presenter: Chase

SKILLS GAINED

- PCB design
- Metal work - cutting, grinding, welding, and riveting
- Manufacturing Techniques - measuring, material selection, and workshop safety
- Configuring and debugging embedded systems
- Parsing documentation
- Creating technical documentation