Presenter: Chase

CRITICAL DESIGN REVIEW

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 10,000 ft IREC spec 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 an autonomous 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 2 seconds
3	The rover will be able to turn 360° (CCW or CW) in 3 seconds or less and move forward and backward
4	The rover will travel a minimum distance of 3.05 meters (10 feet) from the landing site in 15 sec maximum
5	The rover will have an altimeter to measure its altitude during its descent and that can determine when the rover is at rest within 5 seconds after landing
6	The rover will have an accelerometer that can determine when the rover is at rest within 5 seconds after landing
7	The maximum mass of the payload, sled, and capsule must be no more than 4.31 kilograms
8	The rover coupling will be able to hold at least 10 kg to secure the rover

DESIGN OVERVIEW

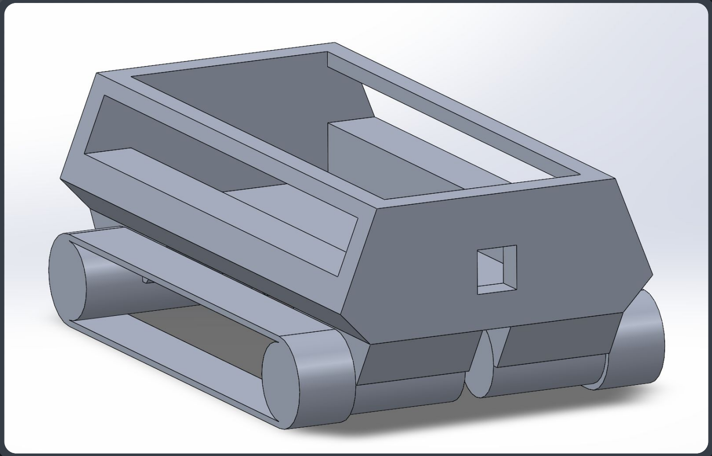
Presenter: Chase

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

Presenter: Chris

Rover

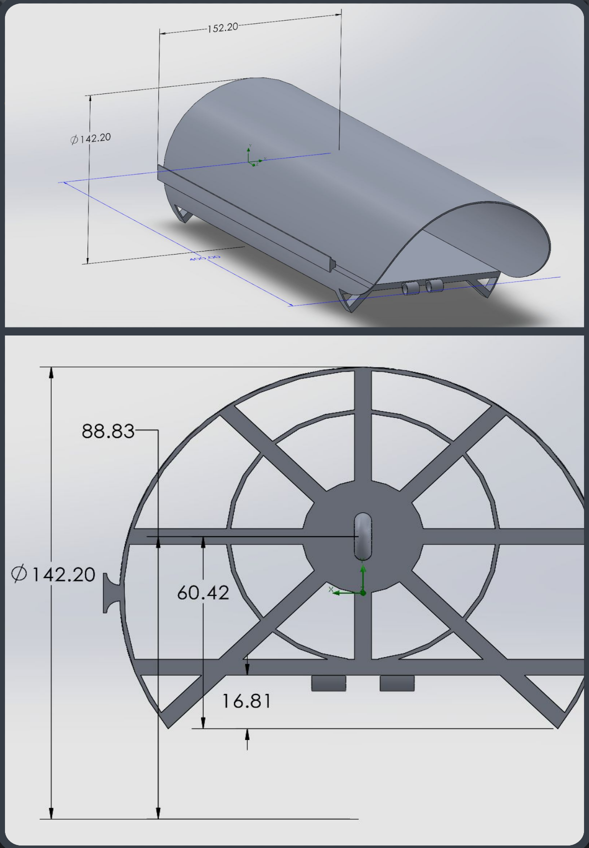
- The rover chassis will be a light aluminum frame that mounts the PCB, video camera, motors, and the power supply
- Rubber tires with aggressive treading will be used for the movement system to allow the rover to avoid terrain hazards
- The power supply for the rover chassis will power the PCB, camera,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



Presenter: Chris

Capsule

- 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



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

Presenter: Chris

Total System

- The capsule will be loaded into the rocket airframe with the rover inside
- The rover and capsule systems will be powered on and will be waiting to detect liftoff
- The rocket will liftoff (rover and capsule will detect this and start checking for landing) 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 and the rover will detect this, the rover will be released from its coupling to the capsule and drive itself out
- At the control station, it will be seen in the video reception that the rover is out of the capsule, and the rover will be piloted for a minimum of 10 ft to complete the mission

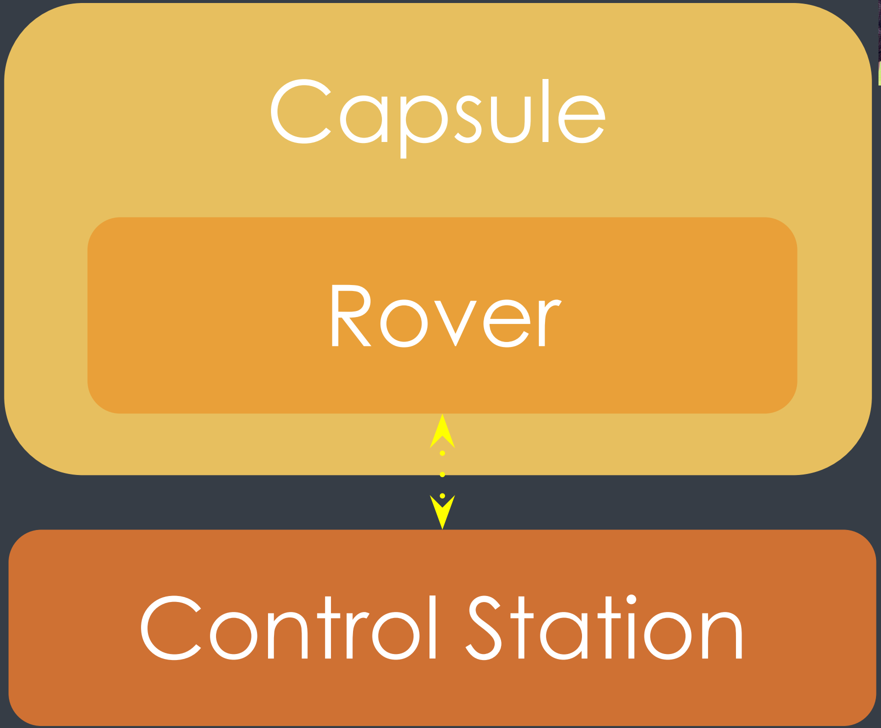
Presenter: Chris

MEMBER RESPONSIBILITIES

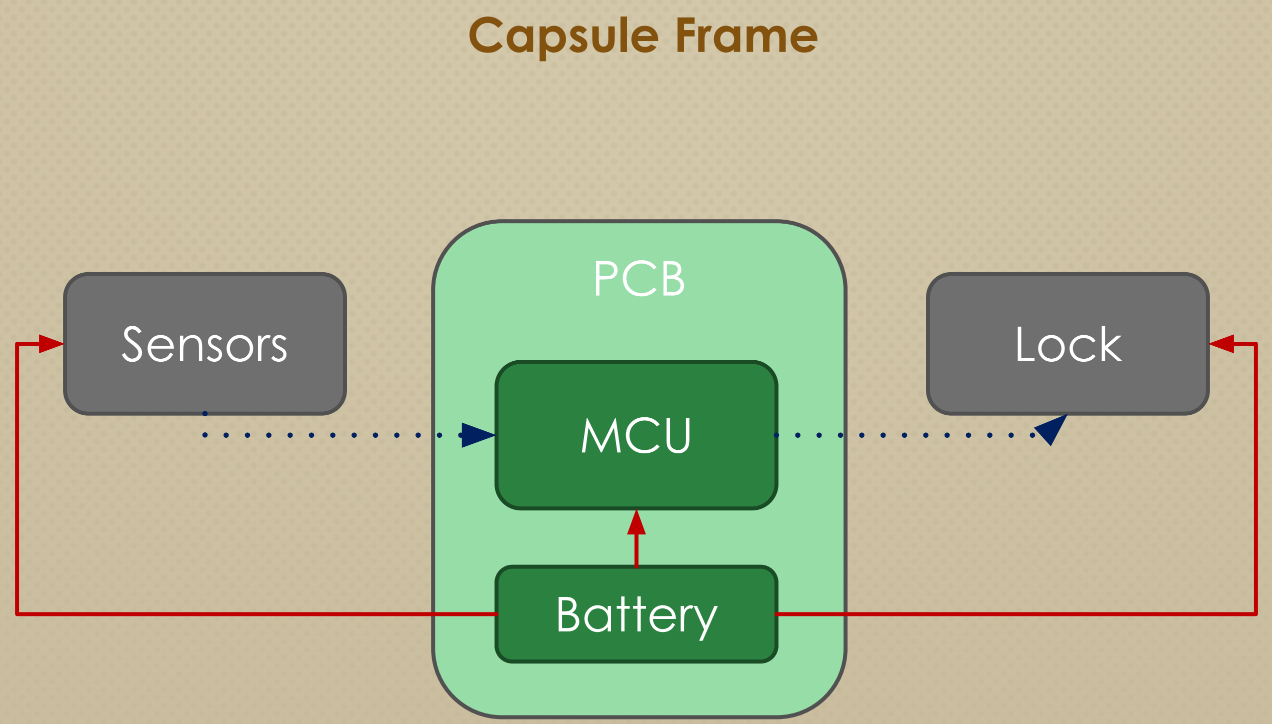
Name	Subsystems
Chris	Rover and capsule design and manufacturing
Joel	Video transmission System, PCB design
Anjali	Remote control system, PCB design
Chase	Power system, sensing systems, PCB design

OVERALL BLOCK DIAGRAM

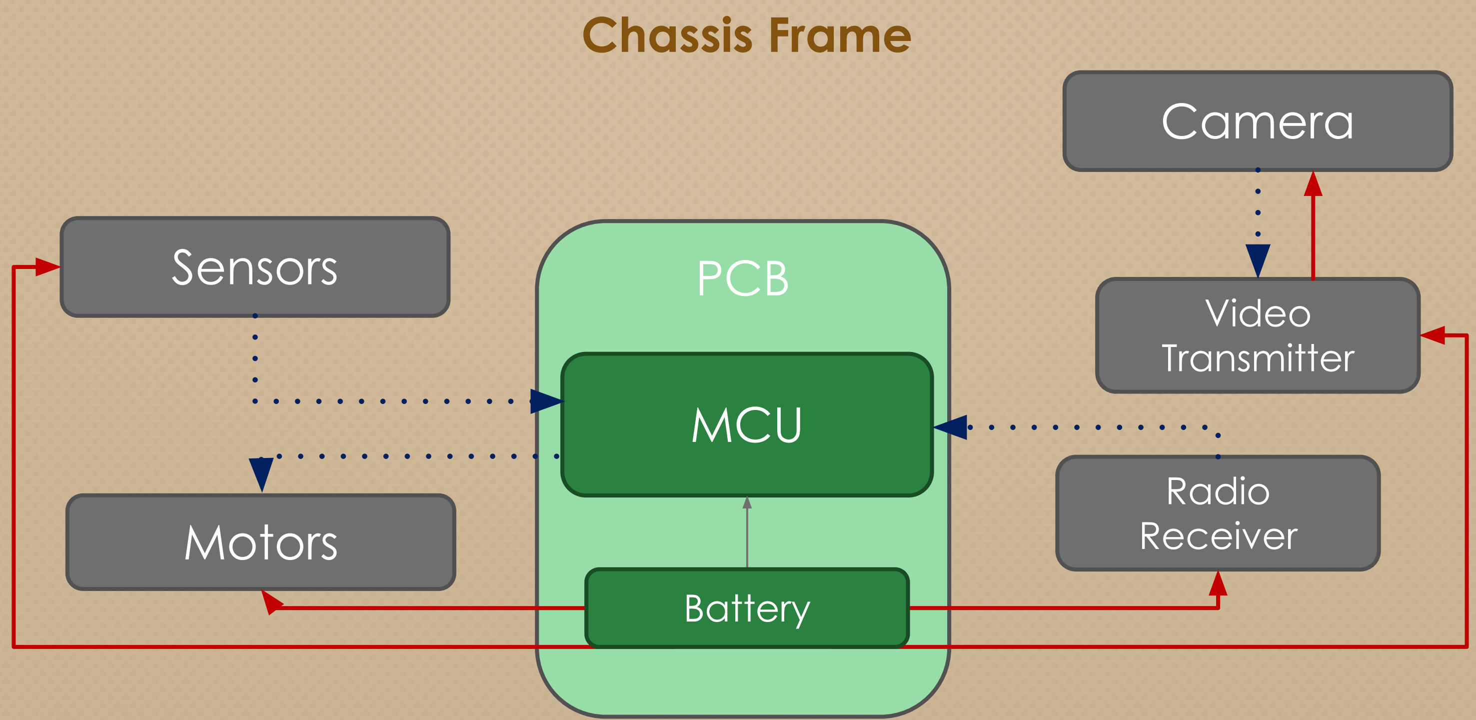
Presenter: Chris



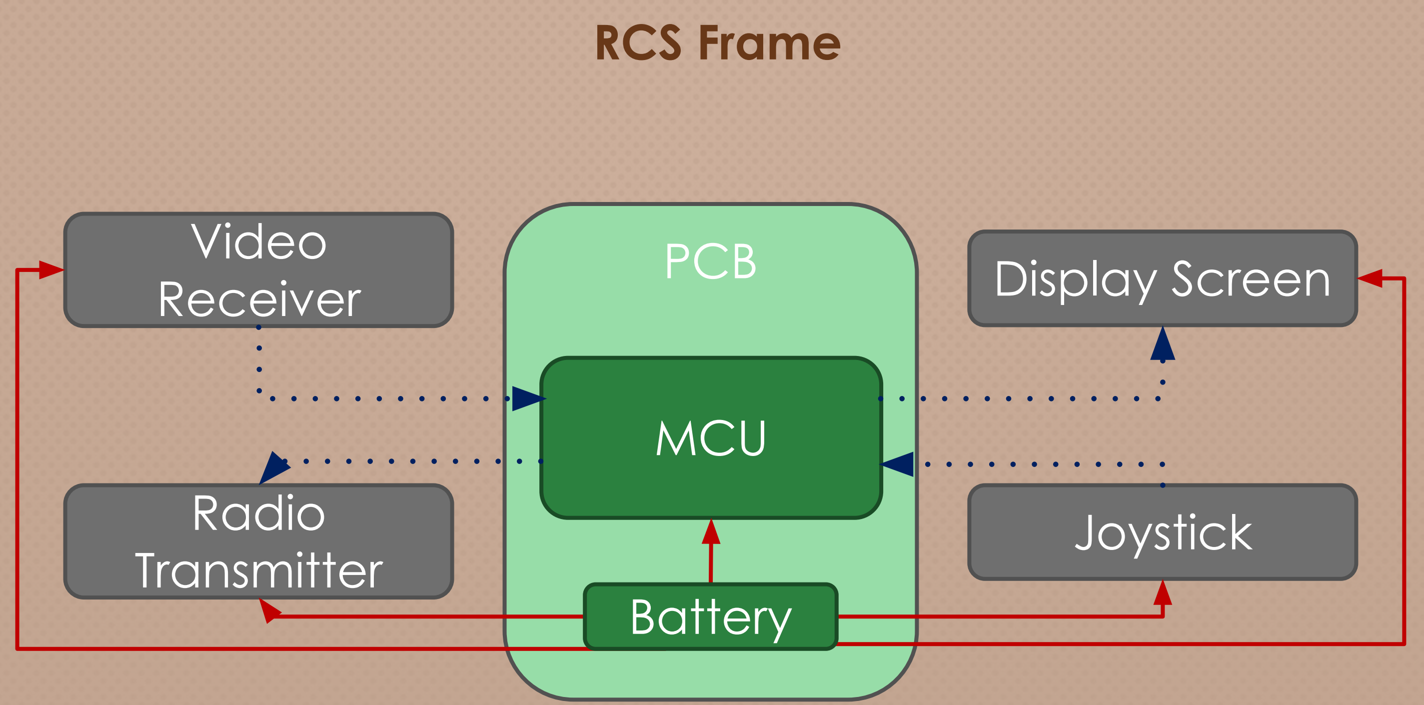
Presenter: Chris



CAPSULE BLOCK DIAGRAM



ROVER BLOCK DIAGRAM

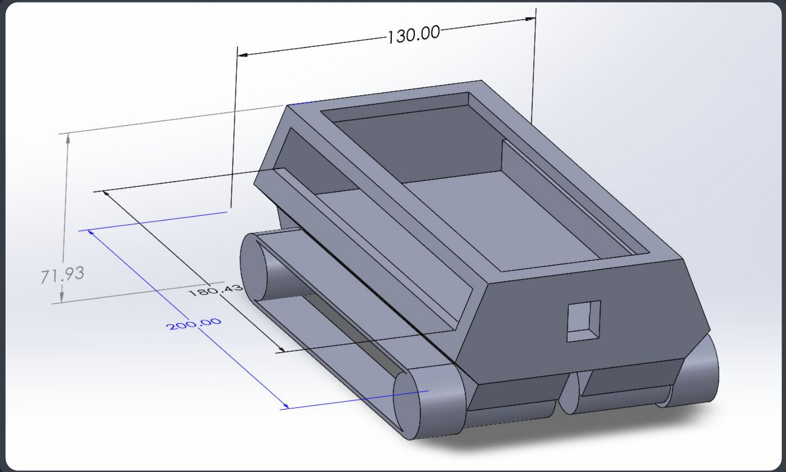


ROVER CONTROL STATION BLOCK DIAGRAM

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



Note: current CAD model of the rover is in progress, the model seen here is currently outdated

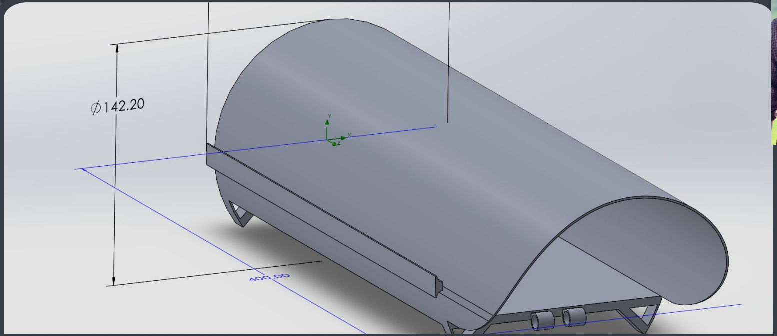
Presenter: Chris

ROVER CHASSIS MANUFACTURING

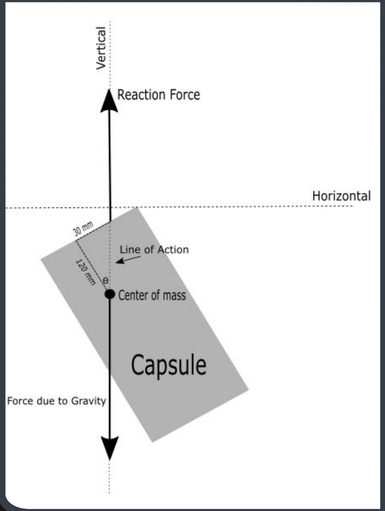
- 6063 - T5 Alloy Aluminum
- Cut aluminum pieces welded and fitted together
- Anchor points for electrical components
- Reinforced rubber housing for motors
- Required tools: plasma cutter, blow torch, power drill

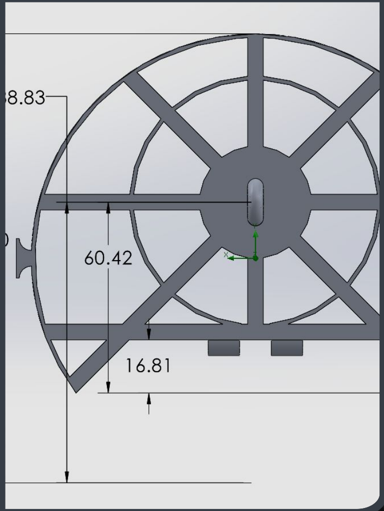
Presenter: Chris

CAPSULE STRUCTURAL DESIGN



- Capsule was designed with key geometry 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





Presenter: Chris

CAPSULE STRUCTURE MANUFACTURING

- 6063 - T5 Alloy Aluminum
- Cut aluminum pieces welded and fitted together
- Eyelet screw for parachute anchoring point
- Rubber C clamp for securing capsule door
- Capsule door hinge to be purchased and connected by fittings
- Railing and sled to be machined out of aluminum by manufacturing lab
- Required tools: Plasma cutter, blow torch, power drill

Presenter: Chase

VOLTAGE REGULATION

- Two voltages are needed in this project: 3.3V and 12V
- 3.7V LiPo batteries were chosen due to their high capacity and small form factors
  - Provide a voltage ranging from 3 - 4.2V depending on charge level
- 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 SUPPLY CALCULATIONS

Capsule Power

- Max draw: 400mA
- Idle draw: 100mA
- Target full power lifetime: 30s
- Allotted idle time: 8hr
- 1Ah battery
- 100mA * 8hr + 400mA * .00833hr = 803 mAh

Rover Power

- Max draw: 1750mA
- Idle draw: 350mA
- Target full power lifetime: 2hr
- Allotted idle time: 7hr
- 6Ah battery

$$\frac{6000mAh - 350mAh * 7hr}{1750mAh} = 2.03hr$$

RCS Power

- Constant draw: 600mA
- Target lifetime: 5hr
- 3Ah battery
- 600mAh * 5hr = 3000mAh

Presenter: Chase

POWER SUPPLY SELECTION

MIKROE-698

- 53.0mm x 35.0mm x 5.9mm
- 1Ah capacity
- Max discharge .5A
- $8.90

MIKROE-4474

- 63.0mm x 57.0mm x 8.1mm
- 3Ah capacity
- Max discharge 1.5A
- $14.50

MIKROE-4475

- 99.0mm x 67.0mm x 8.1mm
- 6Ah capacity
- Max discharge 3A
- $21.90

Presenter: Chase

Battery Charging System

- An out-of-the-box LiPo battery charger was chosen for this design
- The battery charging circuit uses a USB Micro-B for its power input due to its wide availability and convenience
- The circuit is on all three PCBs, and the user will move the battery from the PCB power input to the charging input, and then plugin the USB to a computer or wall wart for 5V input
- Charges at 1A

MCP73833-NVI/UN
3mm x 3mm
Vout: 4.35V
Iout: 1A
Vin: 3.75 - 6V
$1.13

Presenter: Chase

LANDING SENSING SYSTEM

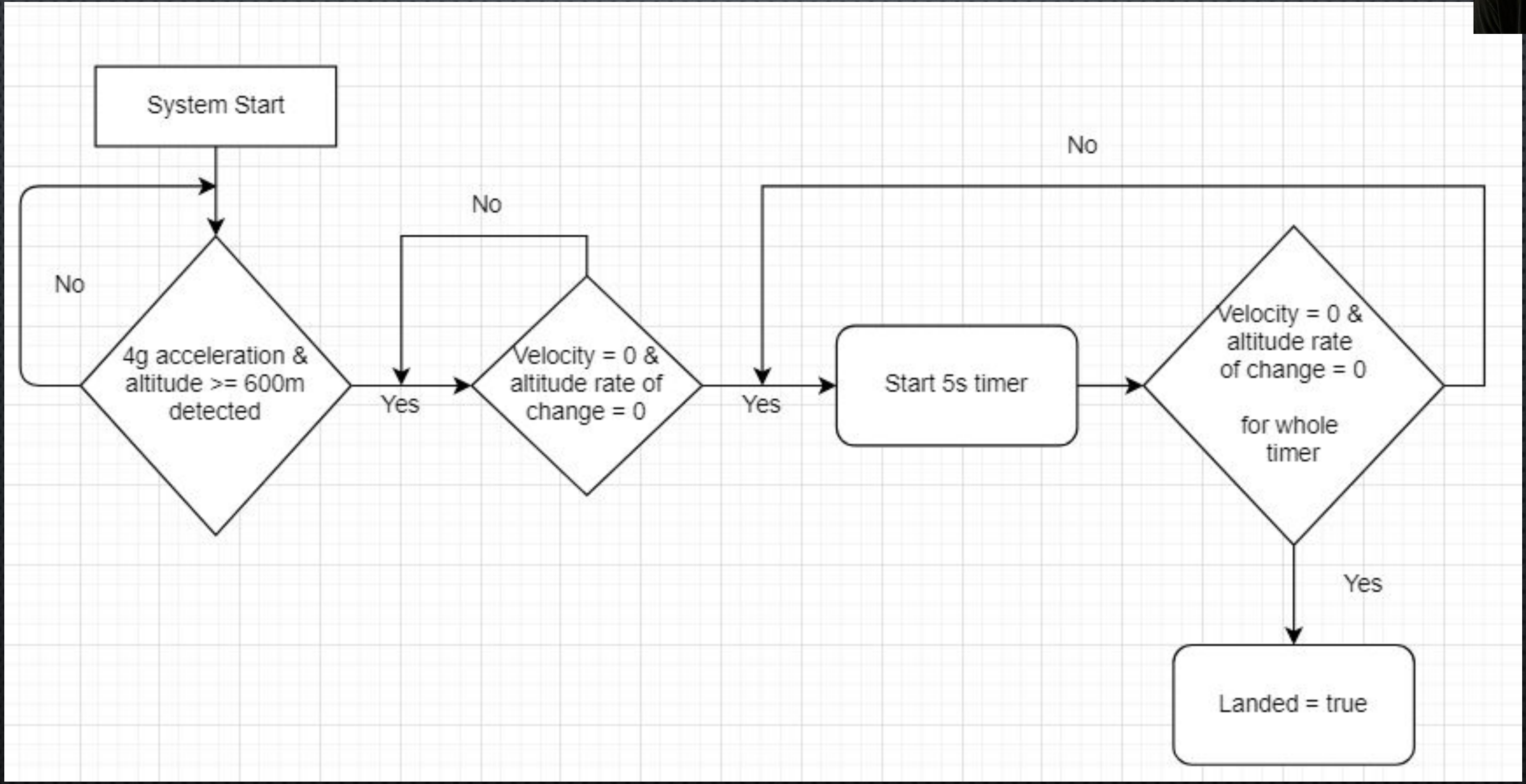
Both the rover and capsule use an altimeter and accelerometer that to detect liftoff and landing conditions

MCU checks each sensor for launch conditions based on acceleration and altitude

When launch is detected, landing criteria is consistently checked to find when the rover has had zero velocity and no change in altitude for a period of time

Presenter: Chase

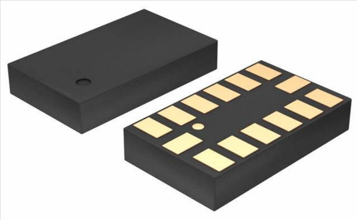
LANDING SENSING SYSTEM



Presenter: Chase

ACCELEROMETER AND ALTIMETER CHOICES

ADXL343 Accelerometer
3.3mm x 5.3mm
Capacitive Accelerometer
Up to 16g measurement at 10-bit precision
$3.49



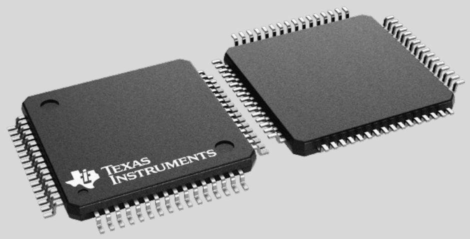
MS5607-02BA03 Barometric Pressure Sensor
3mm x 5mm
Provides built-in altitude output
± 20cm accuracy
Vin: 2 - 3.6V
$6.87

Presenter: Chase

MCU CHOICE

- 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
23 GPIO
$7.66



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
50mm x 30.2mm x 26.8mm
180g
12V, 100mA to unlock
150kg holding strength
$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

Vishay Siliconix SI1869DH-T1-E3
2mm x 2.1mm
On-resistance 200mΩ
Max current 1.2A
$0.62

Presenter: Chris

ROVER PROPULSION - MECHANICS

- Originally decided to use tank track system to traverse sandy, rocky soil expected from the launch location
- Design has changed to utilize an AWD (all wheel drive) drivetrain with aggressive off-road style tires
- Design was changed due to procurement issues and the mechanical complexity surrounding tank tracks

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

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 and 12V power rail will be bridged by one load switch per pair of motors (left side and right side)
  - Each load switch will be used to cut power to the motors when they are not supposed to be moving
  - This is done to avoid the mechanical stress and high power draw associated with forcing DC gear motors to stop moving

Presenter: Chase

ROVER AUTO-START

- Relies on the rovers landing sensing capabilities
- Combination of an altimeter, accelerometer, and MCU, allows the landing to be detected and the rover to be released by the capsule system
- Knowing it has landed, and having been released, will drive itself forward to push open the capsule door and exit
- It will then wait for user input to complete its mission

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 - 1023
- Resting point is (512,512)
- Coordinates will be classified in 4 levels:
  - Move Forward
  - Move Backward
  - Turn Right
  - Turn Left

Presenter: Anjali

ROVER REMOTE CONTROL - RADIO TX AND RX

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

Presenter: Anjali

ROVER REMOTE CONTROL - CONTROL SCHEMA

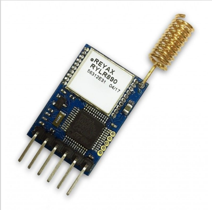
- Retrieve dominant X or Y component value in range 0 - 1023
  - If less than 511 (negative direction on joystick)
    - Set direction as backward or left rotation (based on input component)
  - If greater than 511 (positive direction on joystick)
    - Set direction as forward or right rotation (based on input component)
    - Subtract 511 from component
  - If 511 (joystick is in neutral position)
    - Set direction as no direction
    - Set speed value as 0
- Evaluate the resulting component value to translate the value to an integer between 0 and 10 and save that as the speed value for the motors

Presenter: Anjali

ROVER REMOTE CONTROL - PARTS

Reyax RYLR896 LoRa SX1276

- 42mm x 18mm x 6mm
- 3.3V, 16 – 45mA
- UART communication
- 15km range, 868 - 915 MHz
- $20



Analog Joystick

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

Presenter: Joel

Wireless Video - Capture

- Wireless video will be captured on the rover through an FPV camera.
- The FPV camera chosen is the RunCam Nano4 which has a 155° field of view.
- 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 Whip 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: Joel

WIRELESS VIDEO - PARTS

5” TFT LCD Screen

- 76mm x 102mm x 25mm
- 12 – 24V, 6W
- Dual RCA video input
- 800 x 480p
- $26

AKK TS832+RC832 5.8GHz Video Transmitter/Receiver

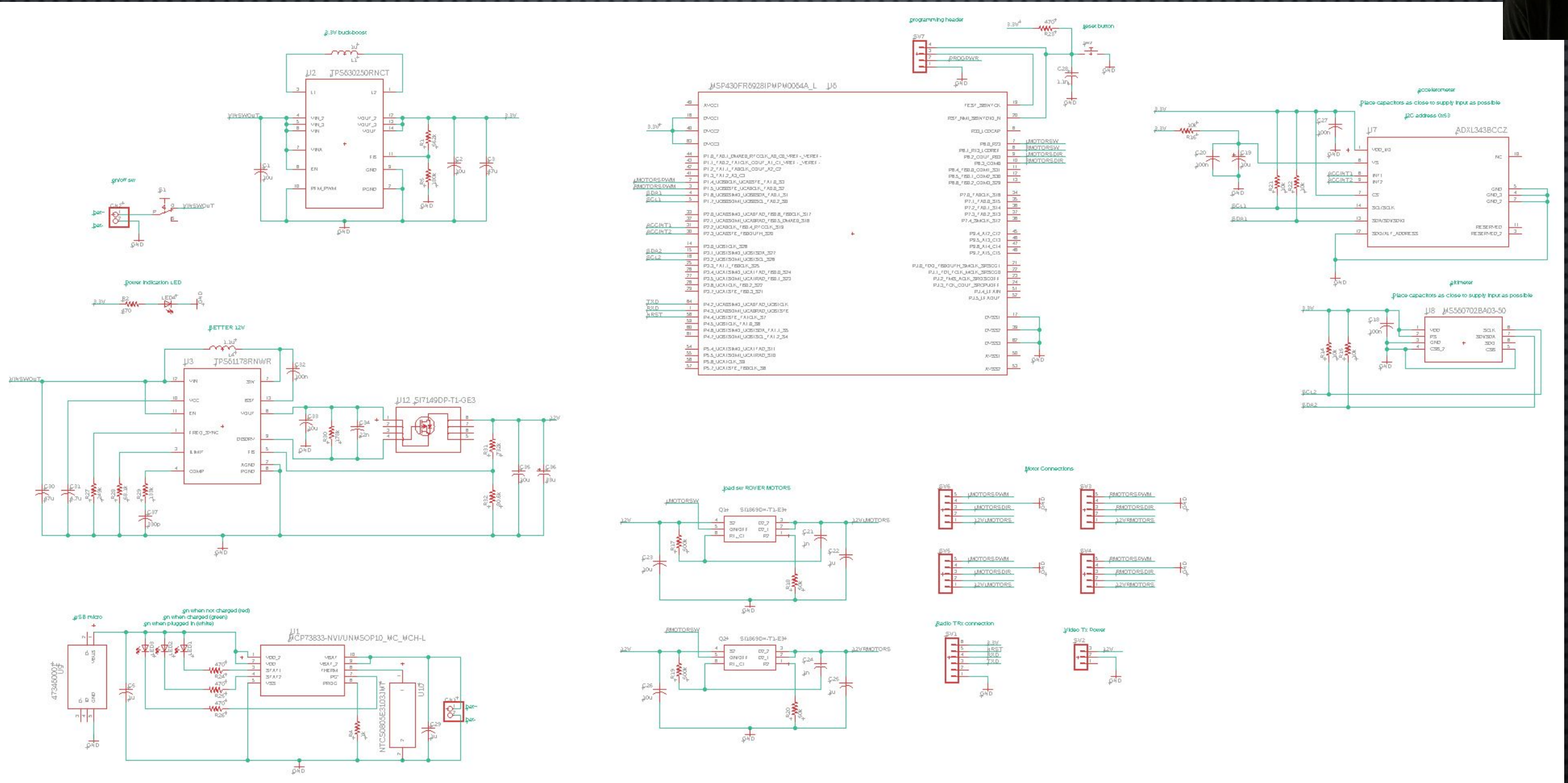
- Tx: 22g, 54mm x 32mm x 10mm
  Rx: 85g, 80mm x 65mm x 15mm
- 12V, 300mA each
- 5 bands, 8freqs, 37 channels
- Theoretical distance 3km
- $30

Runcam Nano 4 FPV Video Camera

- 2.9g, 14mm x 14mm x 14mm
- 2.1mm Lens
- 155 FOV
- 5V, 160mA
- $20

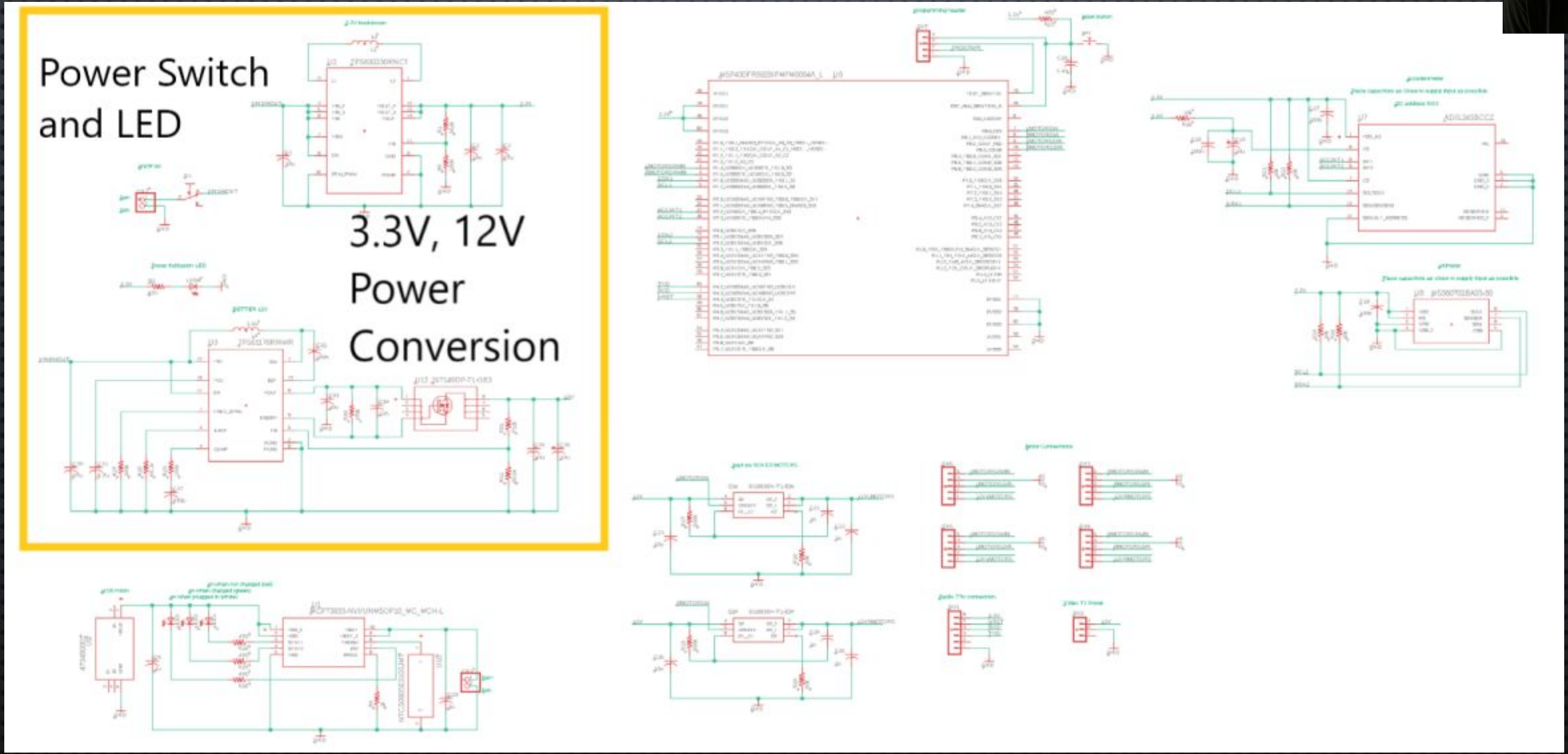
Presenter: Chase

ROVER PCB SCHEMATIC



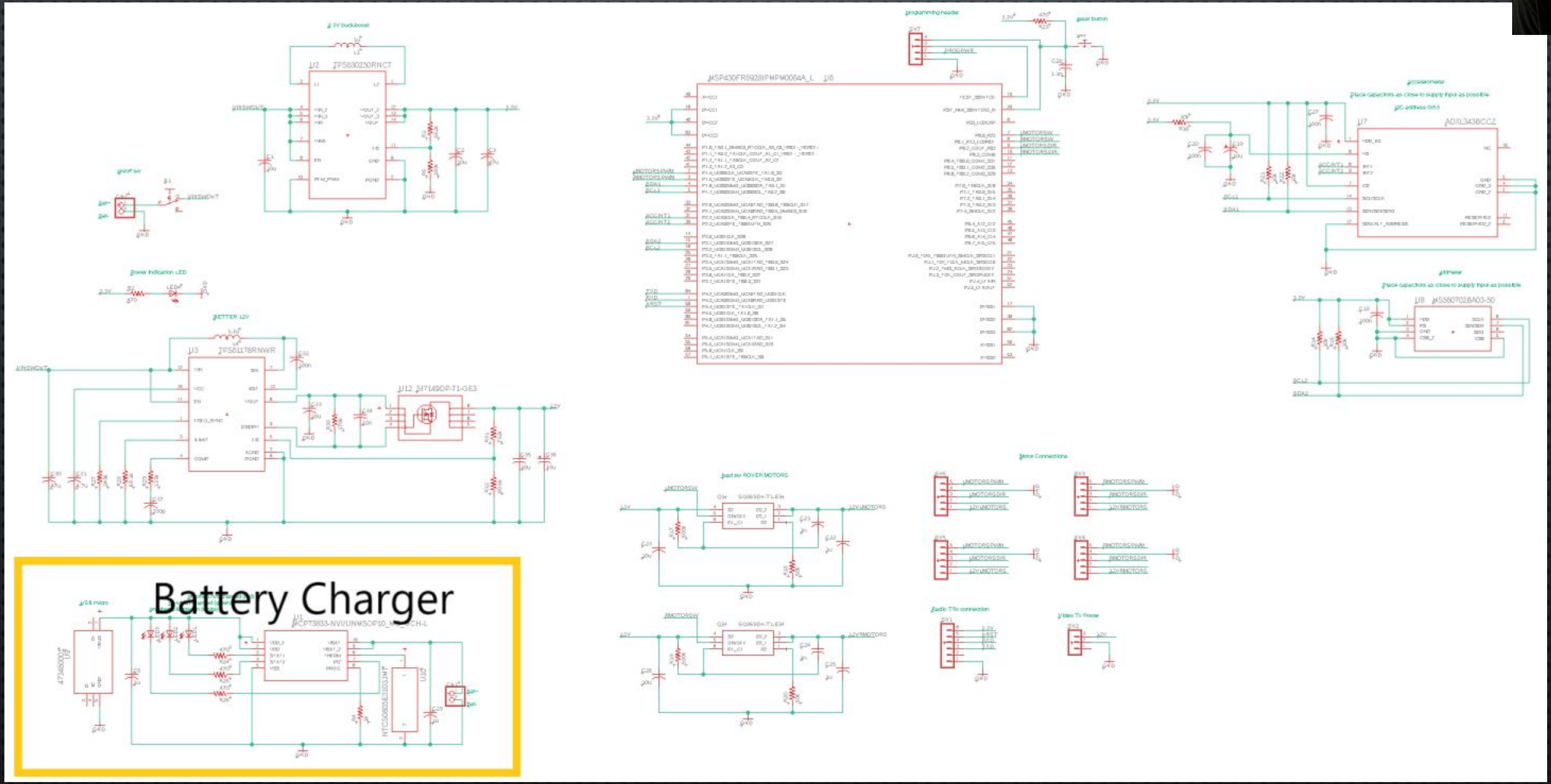
Presenter: Chase

ROVER PCB SCHEMATIC



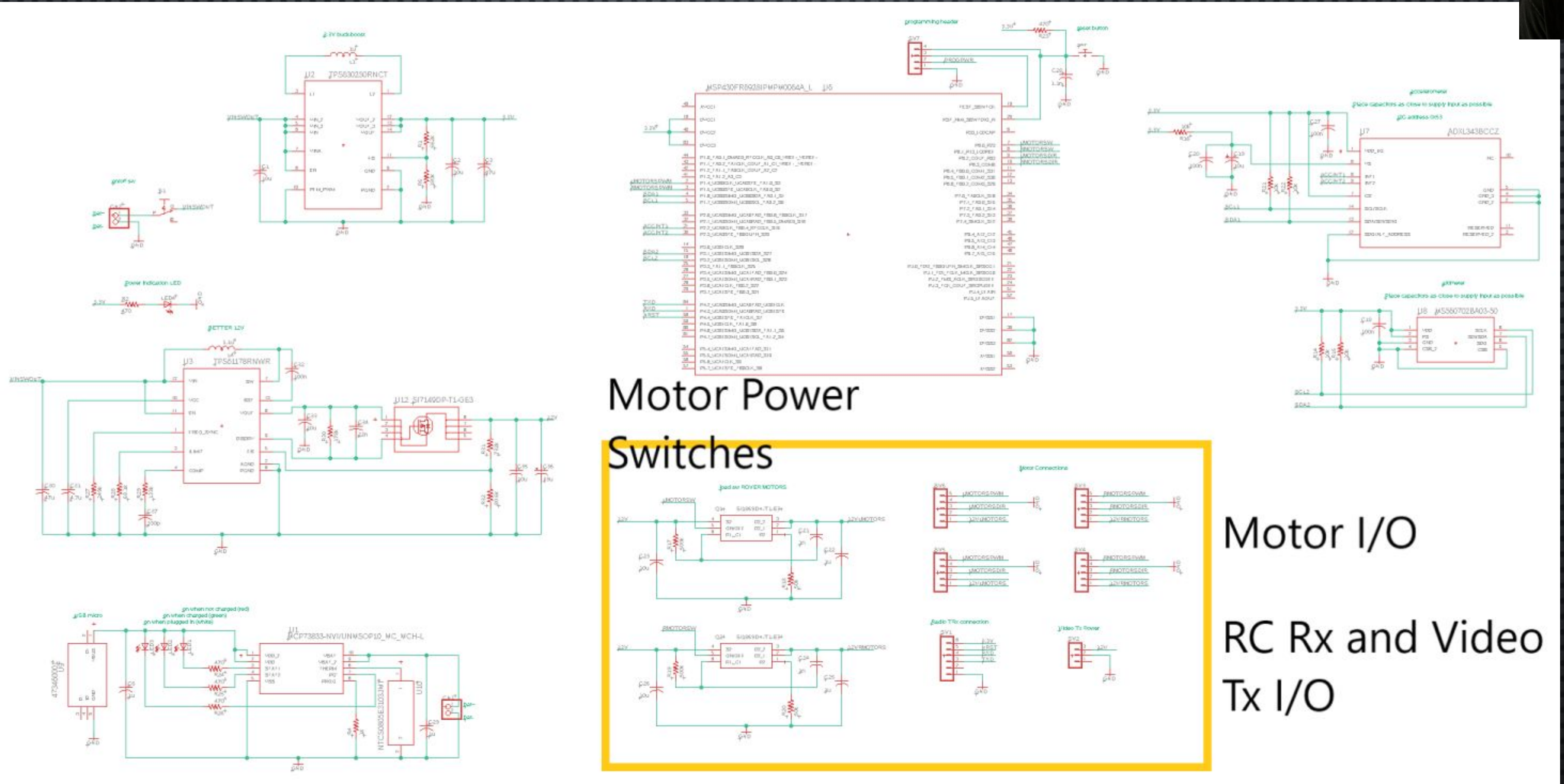
Presenter: Chase

ROVER PCB SCHEMATIC



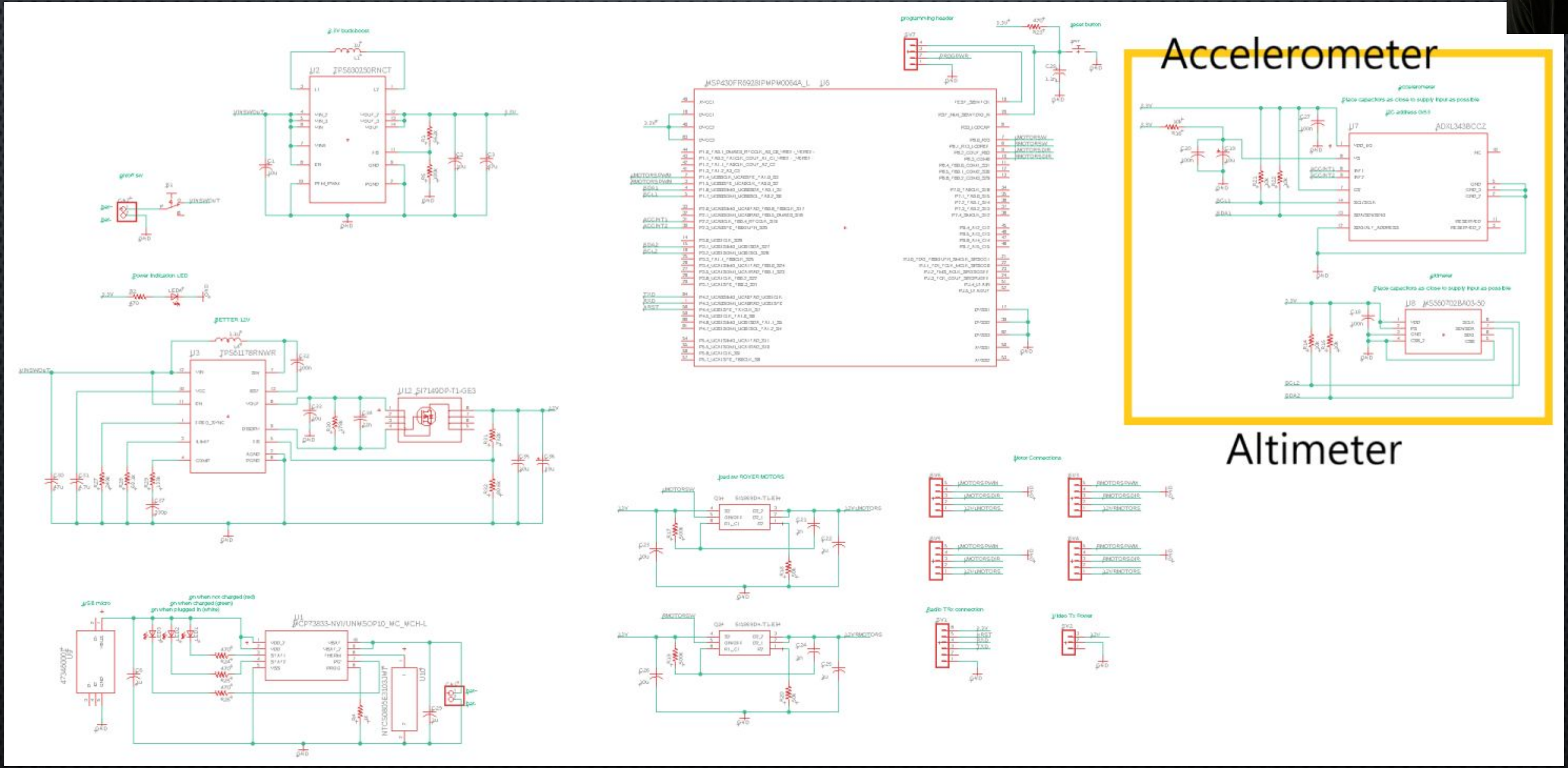
Presenter: Chase

ROVER PCB SCHEMATIC



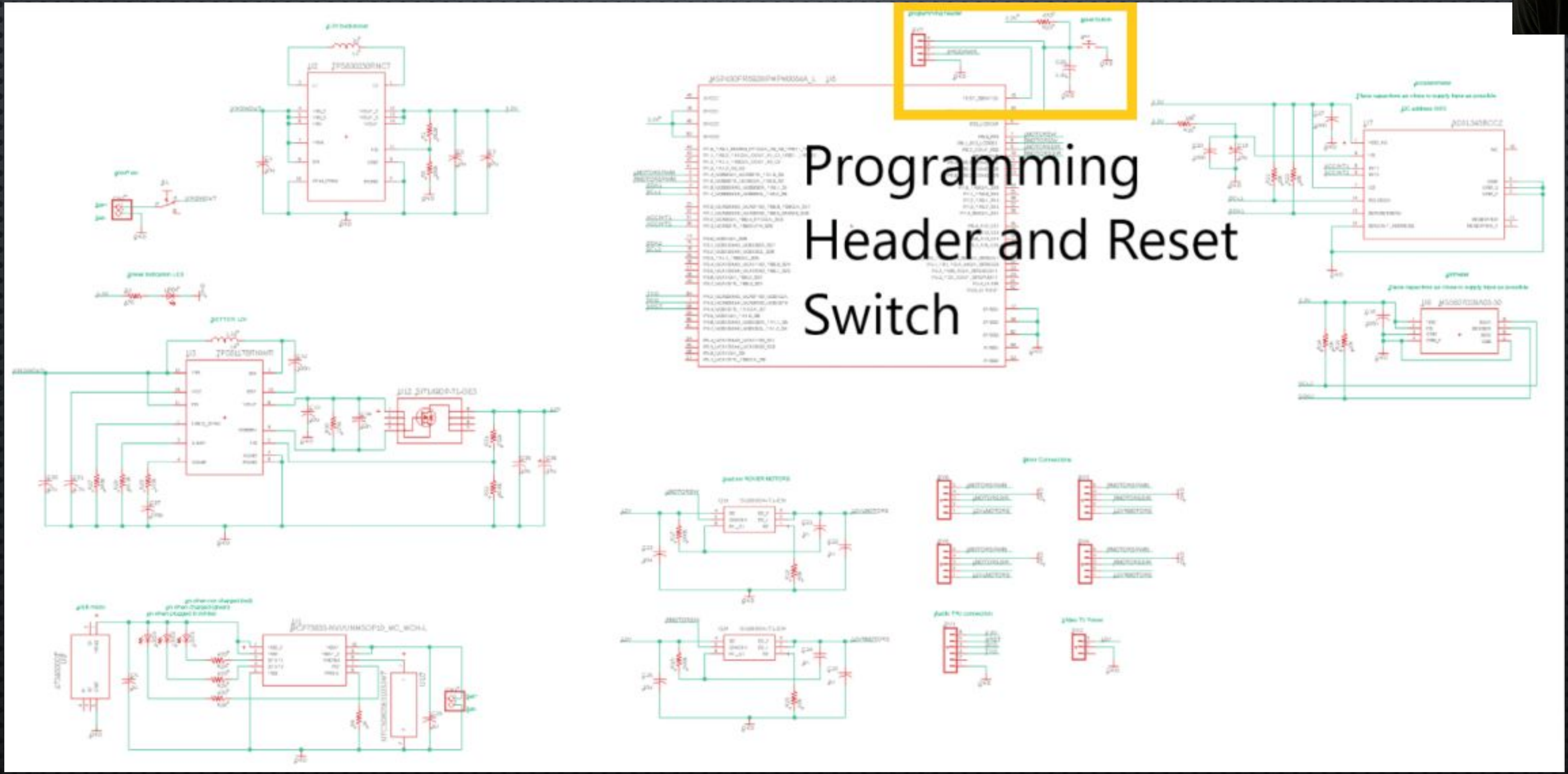
Presenter: Chase

ROVER PCB SCHEMATIC



Presenter: Chase

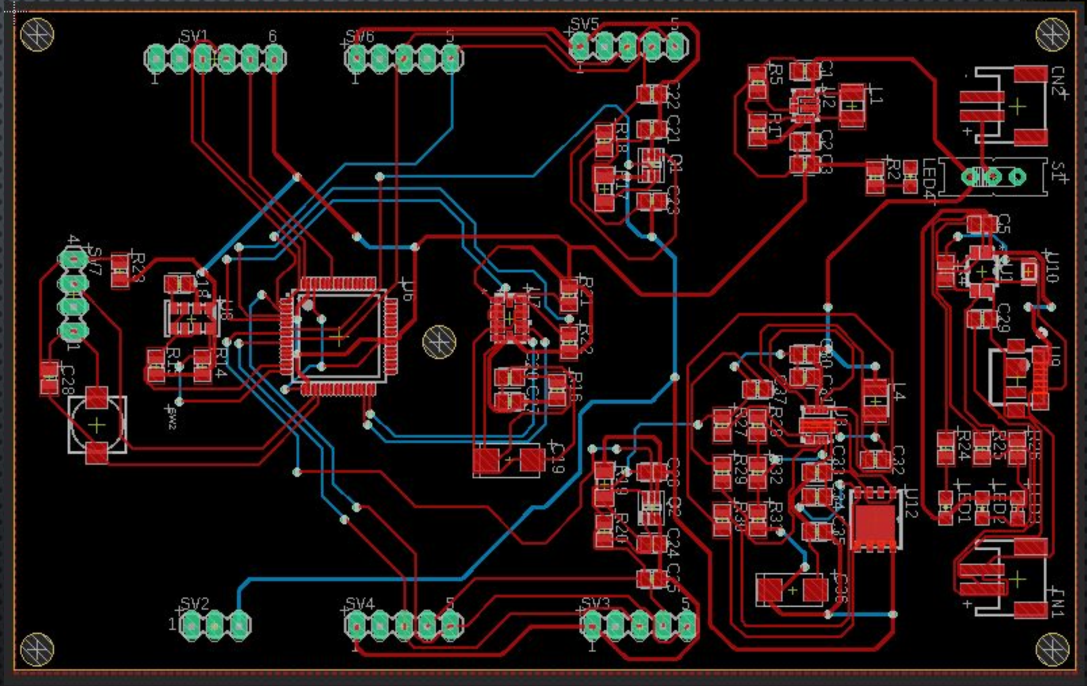
ROVER PCB SCHEMATIC



Presenter: Chase

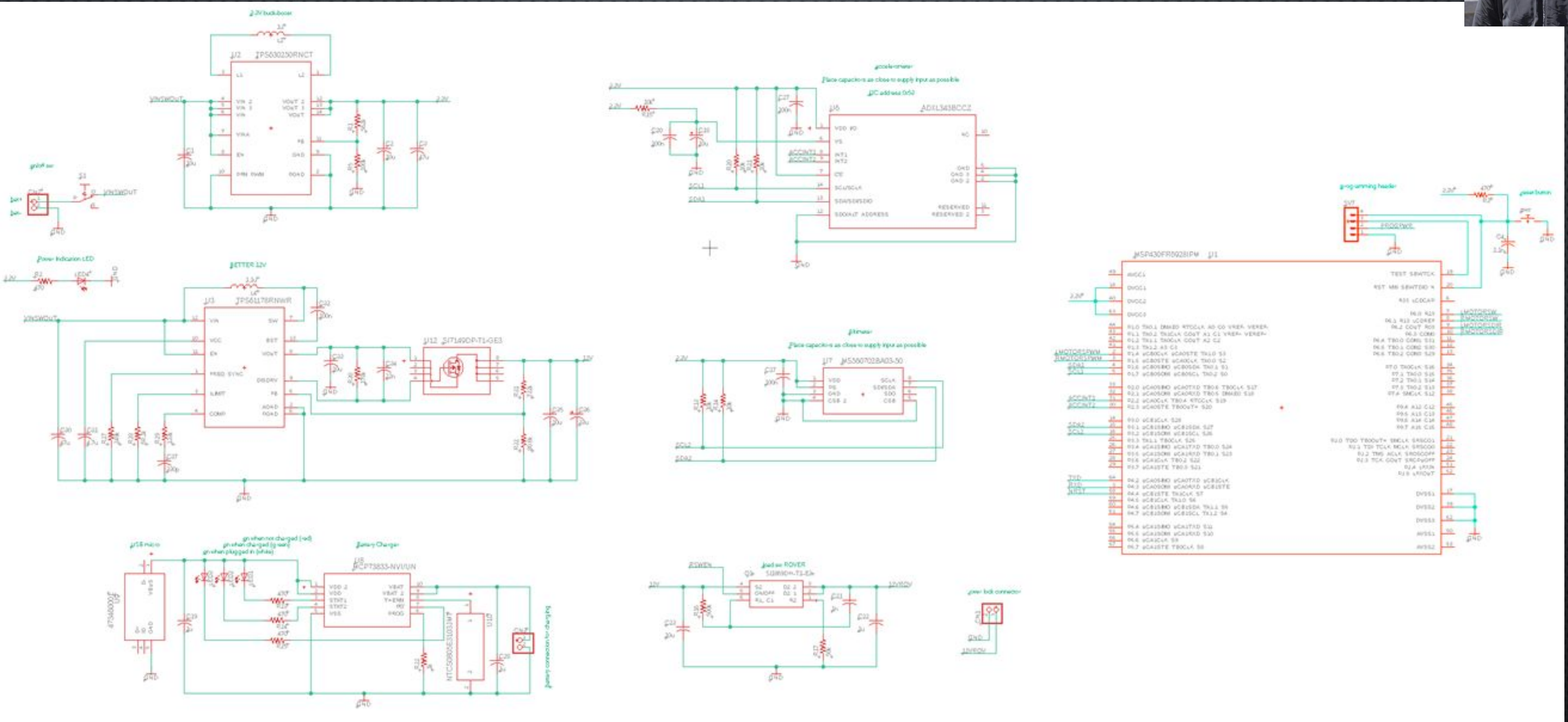
ROVER PCB LAYOUT

- 7.1 cm tall, 11.5 cm wide
- 5 M3 screw mounting holes
- Accelerometer near center of board/rover, and next to mounting hole for stability



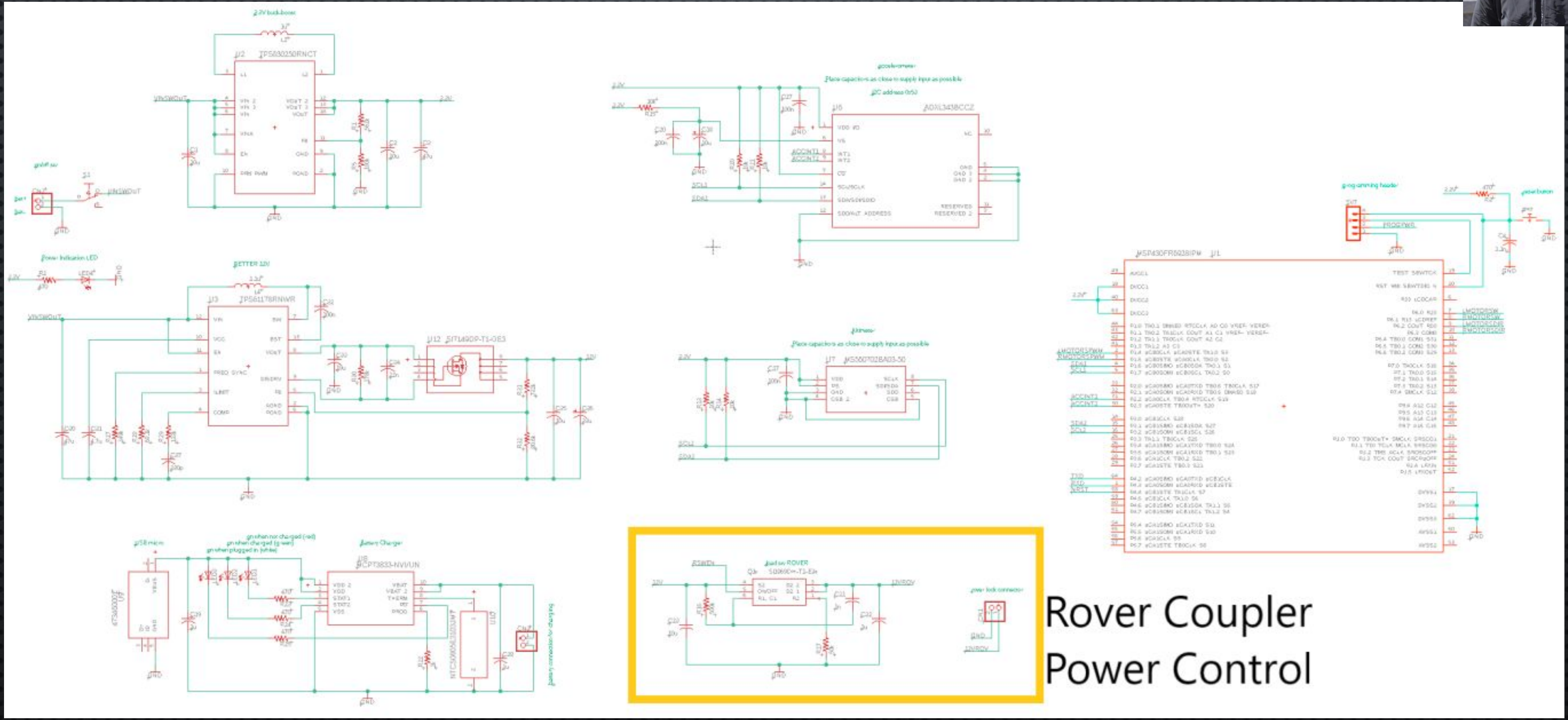
Presenter: Joel

CAPSULE PCB SCHEMATIC



Presenter: Joel

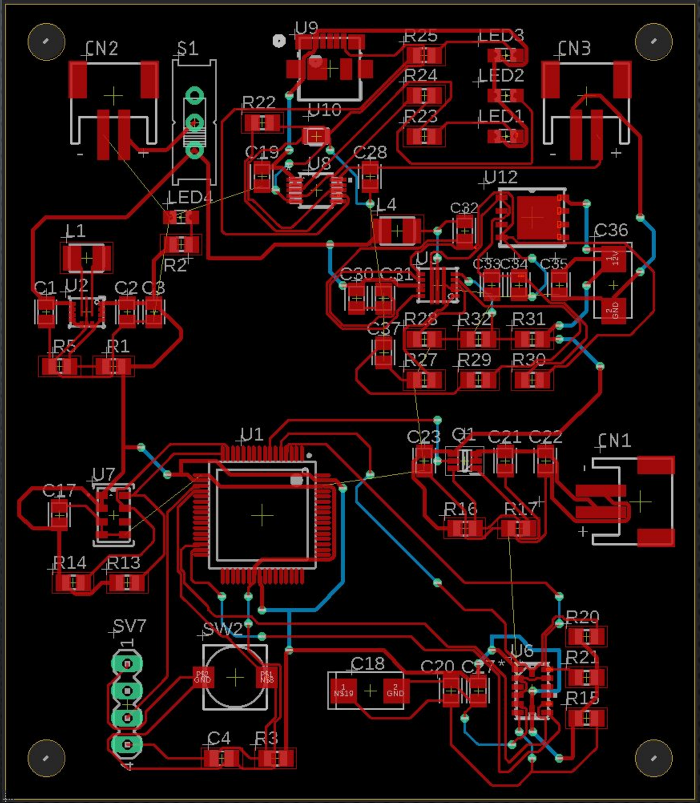
CAPSULE PCB SCHEMATIC



Presenter: Joel

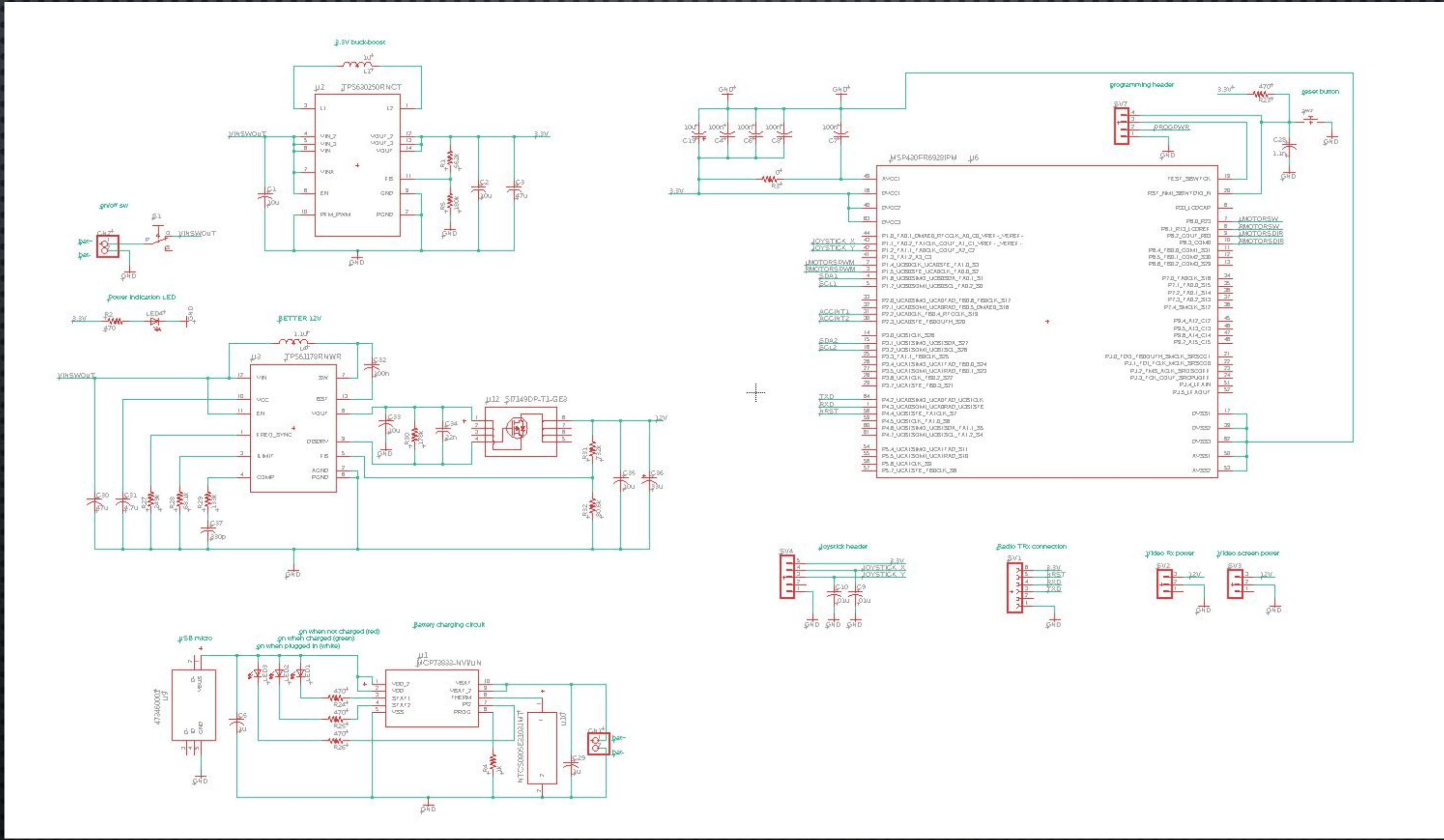
CAPSULE PCB LAYOUT

- 7.459 cm tall, 6.477 cm wide
- 4 M3 screw mounting holes
- Accelerometer is close to a mounting hole for stability (bottom right)



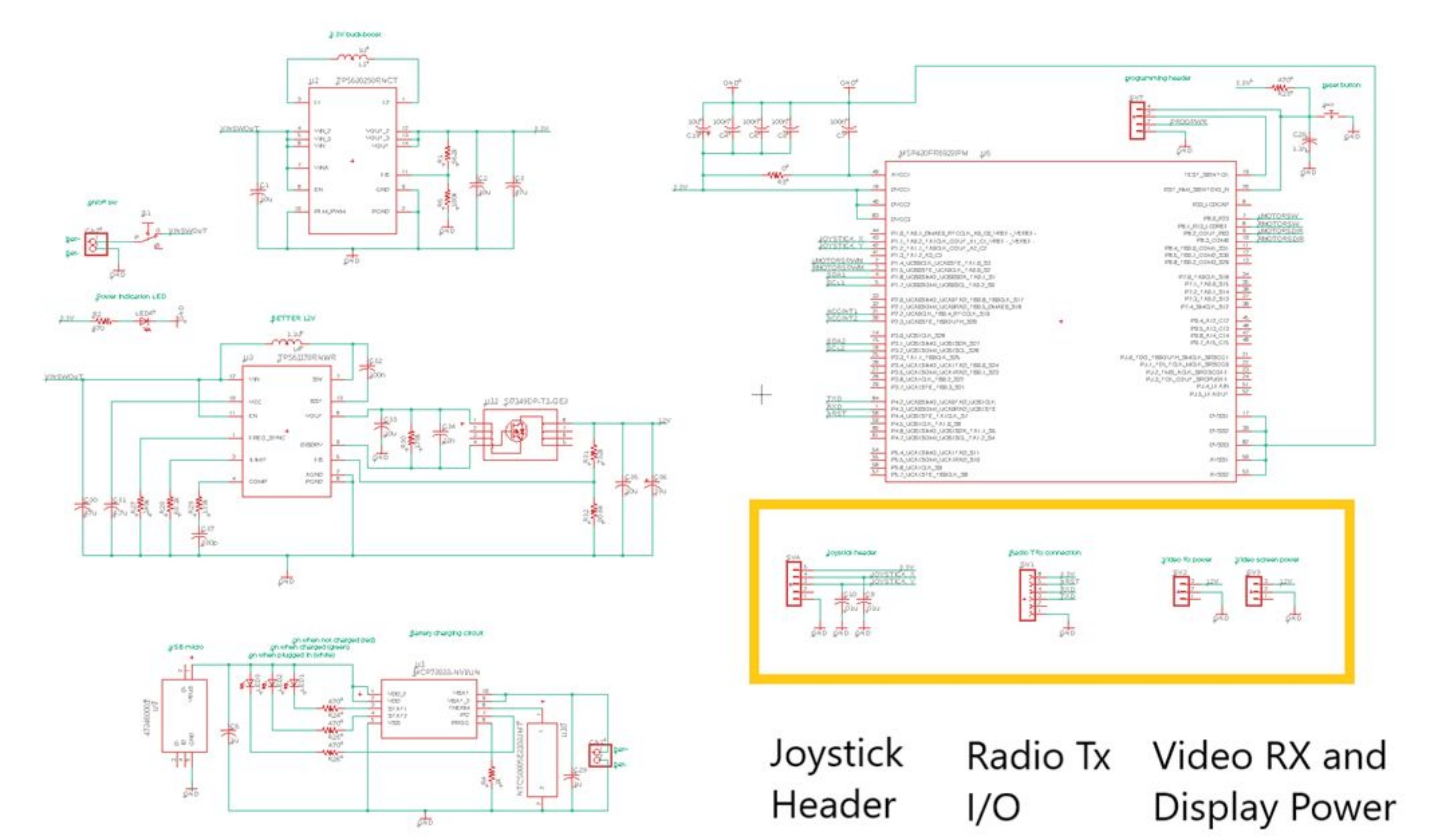
Presenter: Anjali

RCS PCB SCHEMATIC



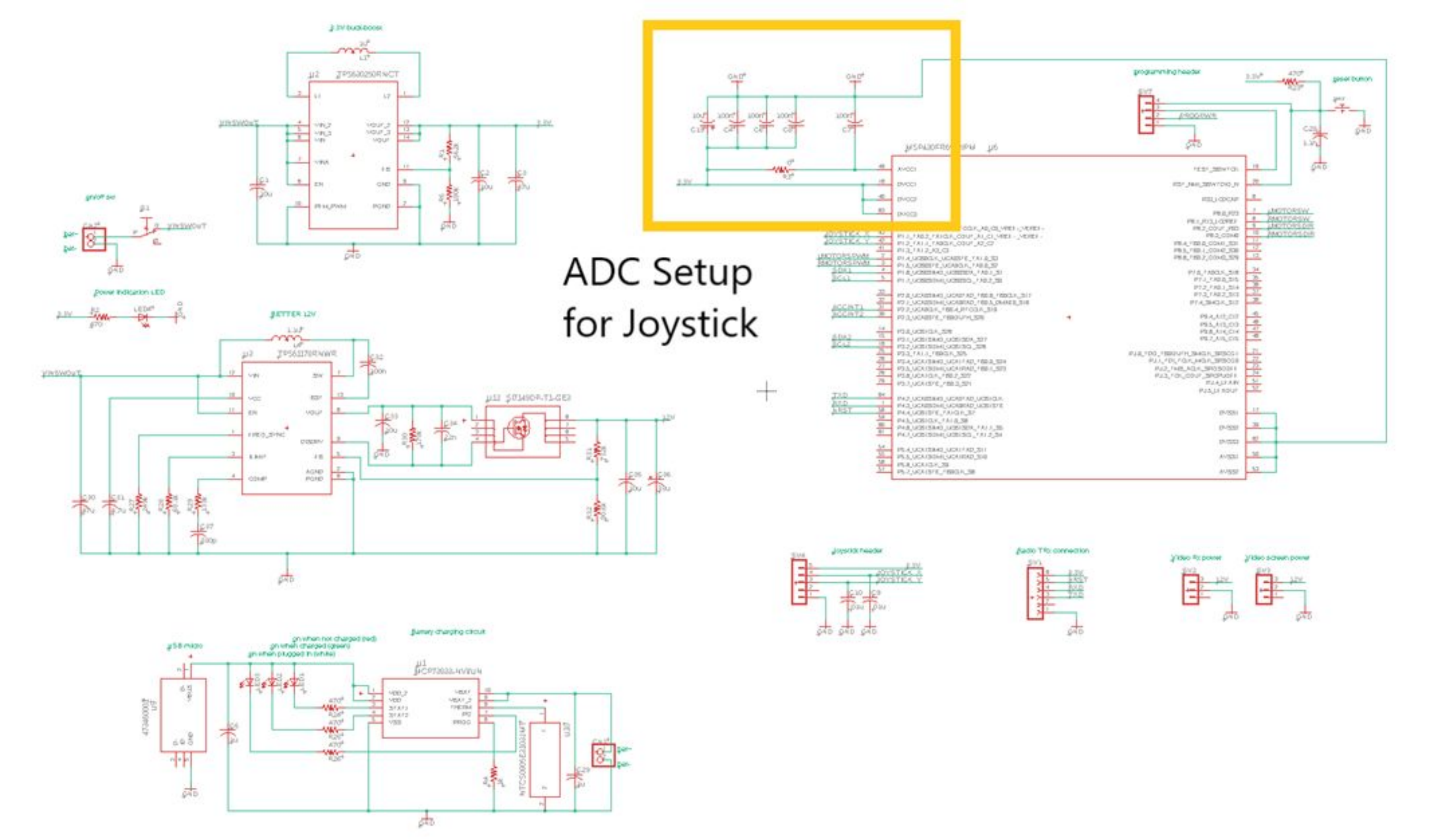
Presenter: Anjali

RCS PCB SCHEMATIC



Presenter: Anjali

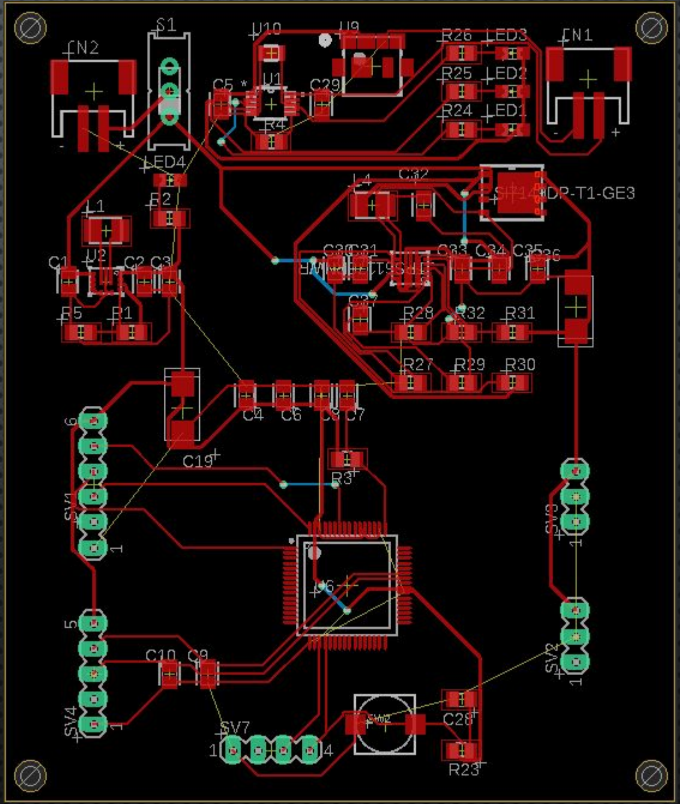
RCS PCB SCHEMATIC



Presenter: Anjali

RCS PCB Layout

- 8 cm tall, 6.7 cm wide
- 4 M3 mounting holes
- Connections for wireless video receiver and display screen on bottom right
- Connections for radio transmitter and joystick on bottom left



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

Presenter: Joel

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

- Code of Federal Regulations - Title 14 :
  - § 29.1303 Flight and Navigation Instruments
    - Altimeters used for precise navigation must be sufficiently sensitive for the application.
    - Therefore the team chose altimeters that were sensitive to +/- 20 cm to use for landing detection.
  - § 29.1325 Static Pressure and Pressure Altimeter Systems
    - To allow for accurate measurement, altimeters must be properly vented to the atmosphere during use.
    - The capsule design allows for this to be achieved due to its open and unsealed design.
- 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 STANDARDS

- 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

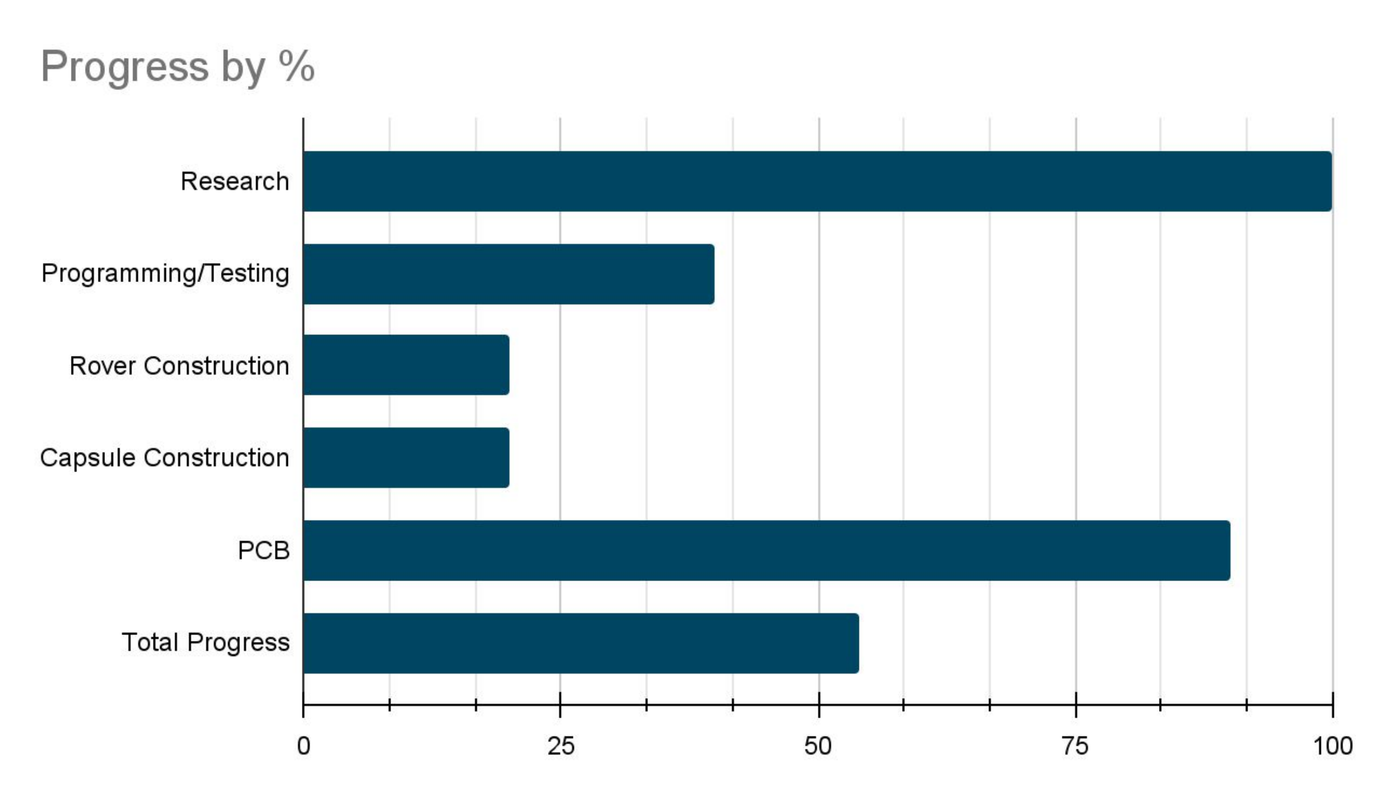
Presenter: Anjali

BUDGET AND FINANCING

Count	Part	Cost	Count	Part	Cost
4	Motors	79.60	3	Battery	45.30
18	Testing Parts	34.65	4	Altimeter	36.36
1	Coupler	30.06	4	Accelerometer	13.96
1	Screen	26	6	Battery Charger	6.78
2	Camera	20	6	MCU	42.45
1	Video Tx and Rx	30	NA	Linear parts and connectors	78
10	Load switch	5.45	3	PCBs	55
6	MOSFETs	9.78	12	Voltage regulators	46.68
2	Radio Transceiver	39	NA	Manufacturing	75
Sponsored Budget:		**500**	**Total Cost + Shipping:**		**760**

Presenter: Chase

CURRENT PROGRESS BY SUBSYSTEM



Presenter: Chase

DIFFICULTIES AND CONCERNS

- Parts shortage made parts acquisition challenging
- Parts shortage required multiple redesigns to choose new parts when previous parts were gone
- Inflation/Parts shortage made the project go over the sponsored budget
- Working with a separate team that also has design changes makes planning and manufacturing challenging
- Wireless video transmission over long distances may be hard to achieve on 5.8 GHz without line-of-sight
- Currently, the wireless video transmission system is non-functioning, and the issue has not yet been found, parts may be broken and need to be reordered

Presenter: Chase

PLAN FOR SUCCESS

Week(s)	Activity
1 - 2	PCB Assembly and Testing
1 - 2	Rover and Capsule Manufacturing
3 - 4	Full Assembly Testing
4 - 5	Integration Testing with Rocket Team
6 - 10	Final Testing and Code Improvements