D.R.O.P.S.
Critical Design Review

November 29th, 2021 ASEN
4018-012 Team 8

Company Customer:
TB2 Aerospace

Faculty Advisor:
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Presenters:
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Additional ***Team Members:***
Alex Karas, Sid Arora, Daniel Gutierrez Mendoza, Joshua Schmitz, Nate Kuczun

Presentation Overview

1. Project Purpose & Objectives — Cody Watson
2. Design Solution — Cody Watson
3. Critical Project Elements — Mia Abouhamad
4. Design Requirements — Mia A., Ian C., Dom D.
5. Project Risks — Rafael Figueroa
6. Verification and Validation — Caroline Dixon
7. Project Planning — Ben Capeloto

Project Purpose and Objectives

Background and Motivation

Background:

Autonomous drone delivery systems are being developed by and for large organizations

- *US Military*
- *Amazon Prime Air*
- *UPS Flight Forward*

However, **no standard exists** that allows **one cargo unit** to interface with different UAV types from different manufacturers

Motivation:

Effective: Current drone-to-pod attachment methods are non-standardized

Functionality: Current design solutions often hinder the overall performance of the drone's capabilities

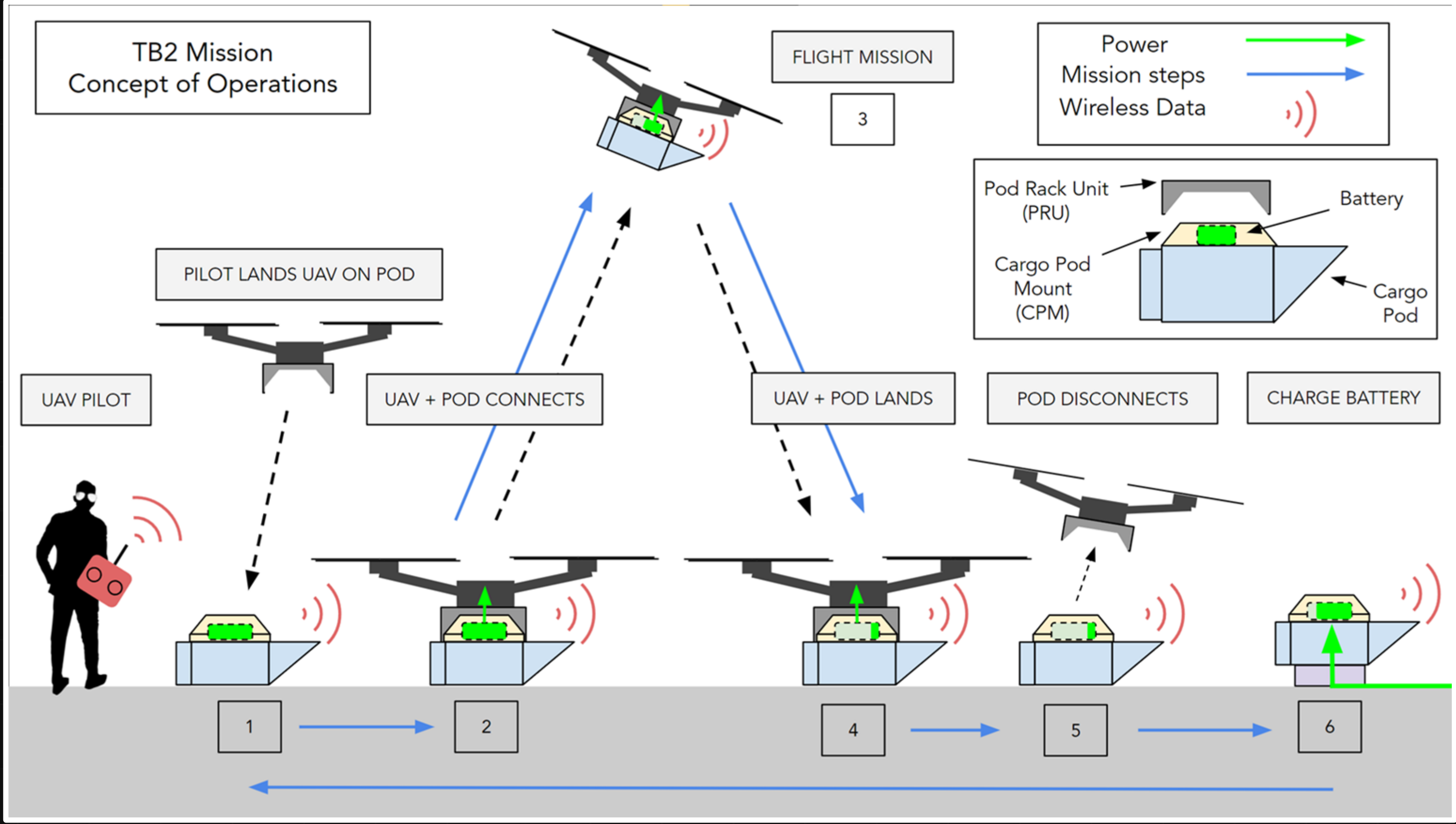
Safety: Current drone cargo delivery methods are often hazardous

- *Straps/Bags*
- *Different Source Components*

Mission Statement

The Drone Recharging Operational Payload System **(DROPS)** aims to standardize autonomous cargo delivery units for both **military and commercial applications**. Development of a docking system will permit **mechanical and electrical connection between class 2 UAVs** and powered cargo units **while increasing functional range**.

Concept of Operations

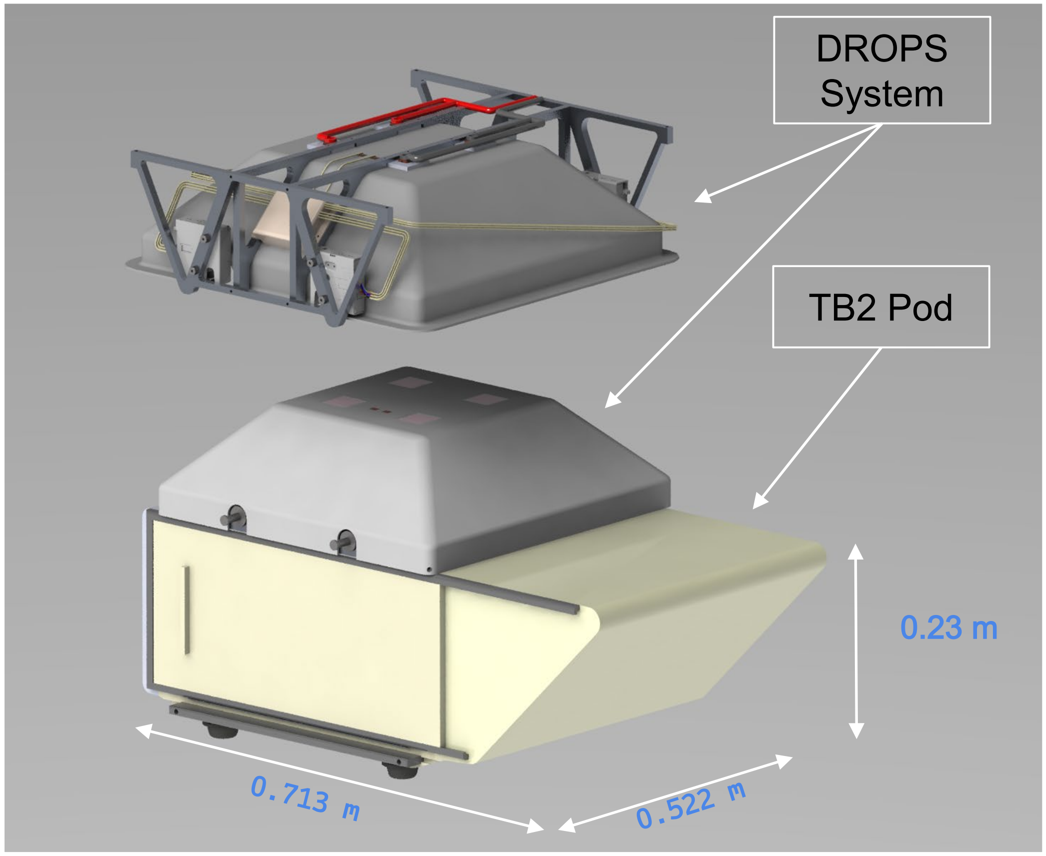


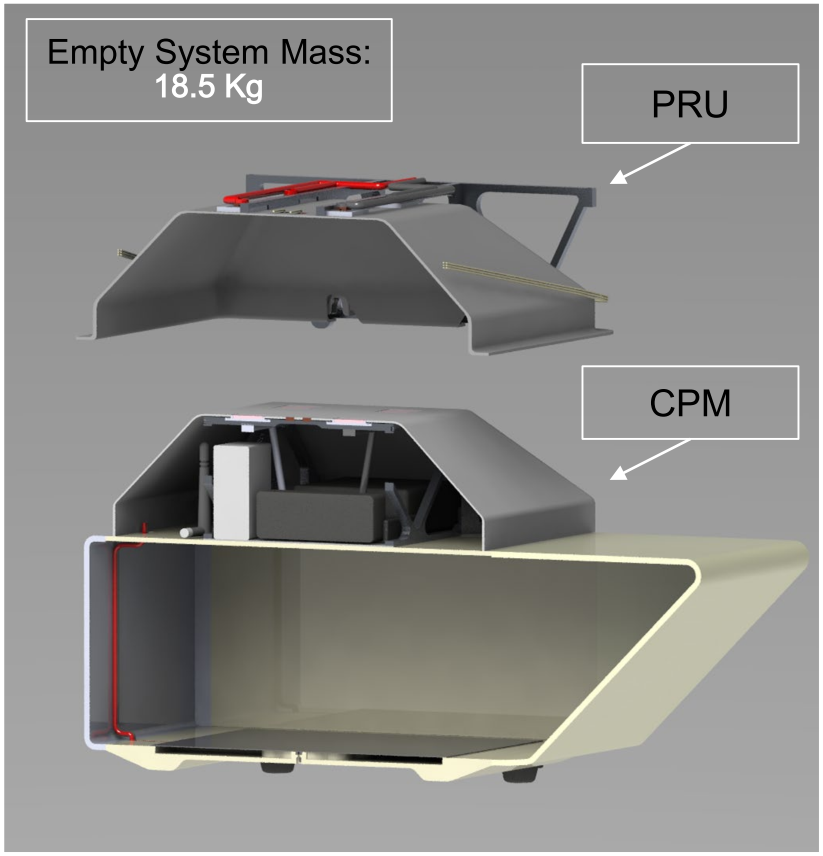
Primary Project Objectives

Structures	Demonstrate that the structure of the DROPS system will be able to withstand the forces on takeoff, in flight, and on landing with the Pod connected
Power Passthrough	Demonstrate power transfer capabilities from rechargeable batteries, through the DROPS system, to a UAV
Connection & Control	Demonstrate the ability to control the connection of the DROPS system after the alignment of UAV
Data Transmission	Demonstrate the ability to send telemetry between the DROPS system and an operator computer

Design Solution

System Overview: Baseline System Design





System Overview: Pod Rack Unit (PRU) Design

Key Features:

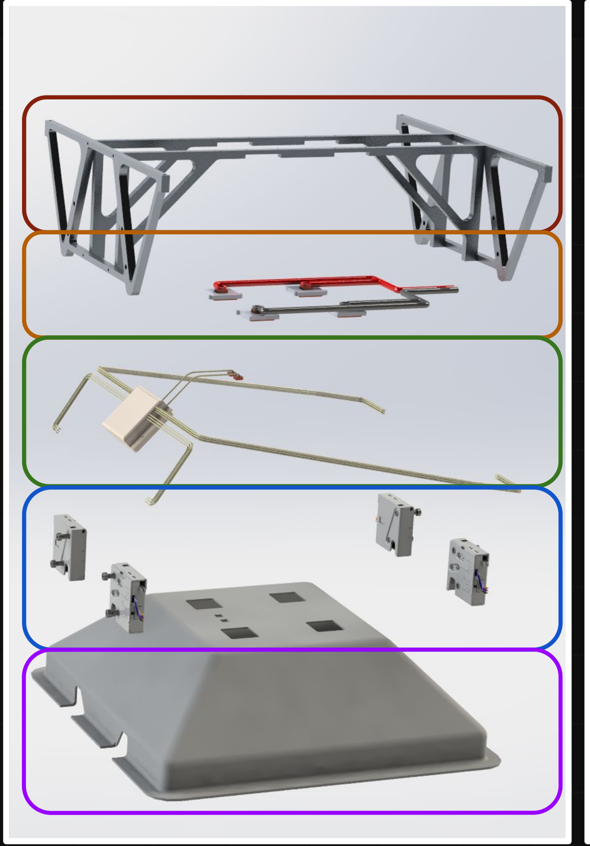
Interface : Attached to the UAV

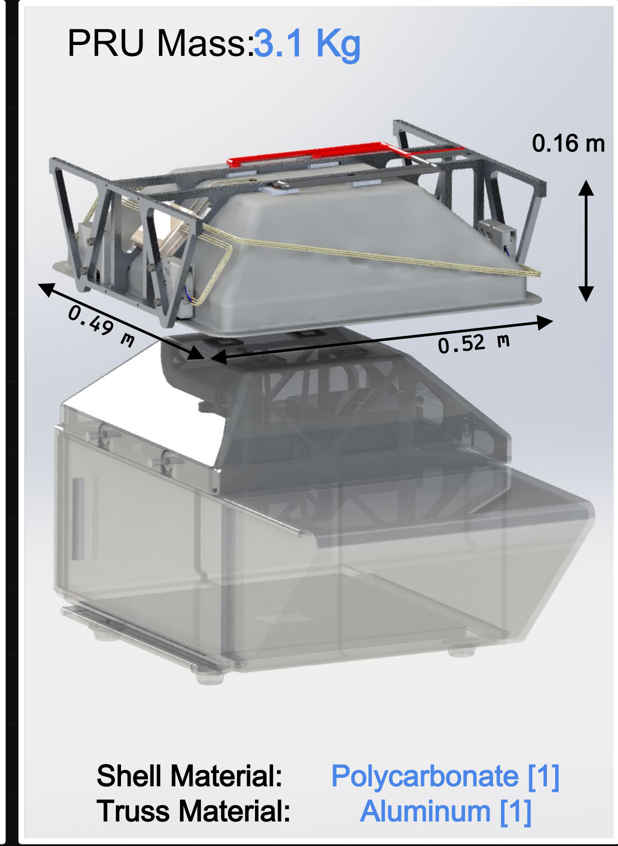
Power Contacts: Power to UAV

Electronics : Controls Latches

Connection: Connection to Pod

Slot Slopes : Alignment to Pod





System Overview: Cargo Pod Mount (CPM) Design

Key Features:

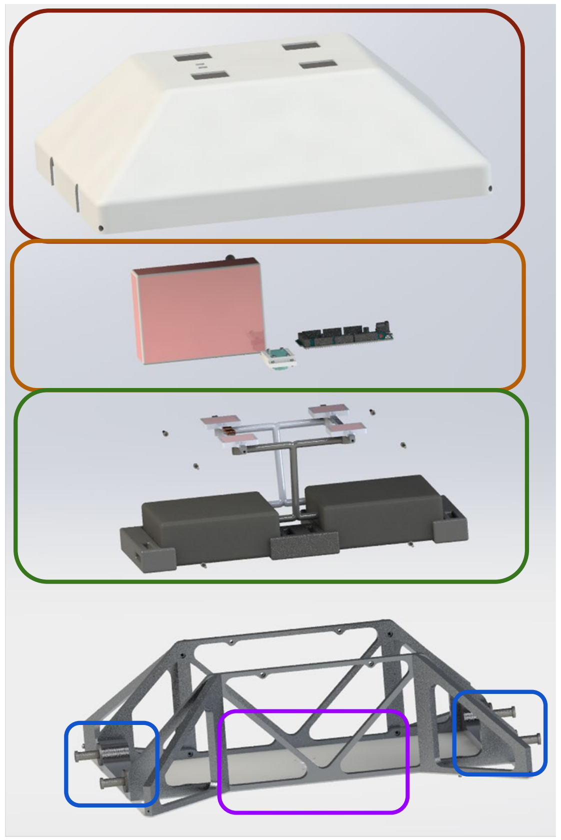
Slot Slopes: Alignment of UAV

Electronics: 2-Way Telemetry

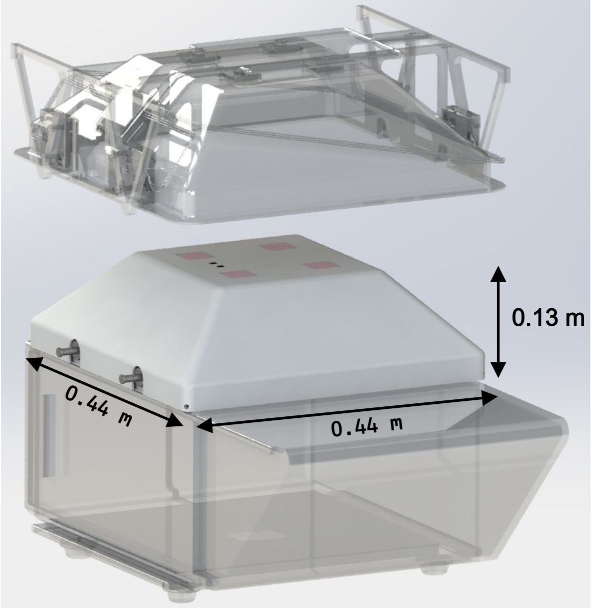
Power Contacts: Power to UAV

Connection: Connection to UAV

Interface: Attached to the Pod

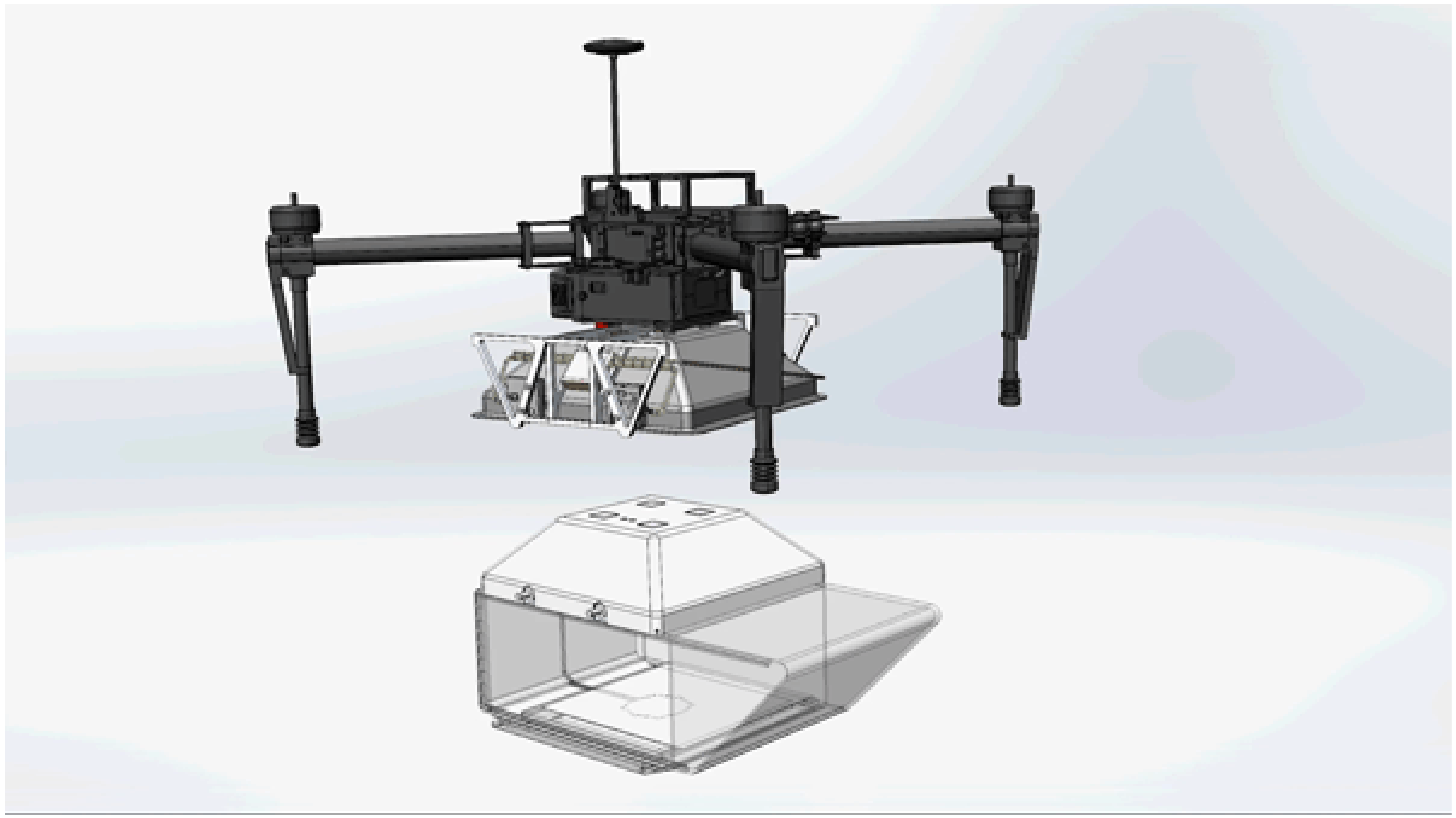


CPM Mass: 8.4 Kg

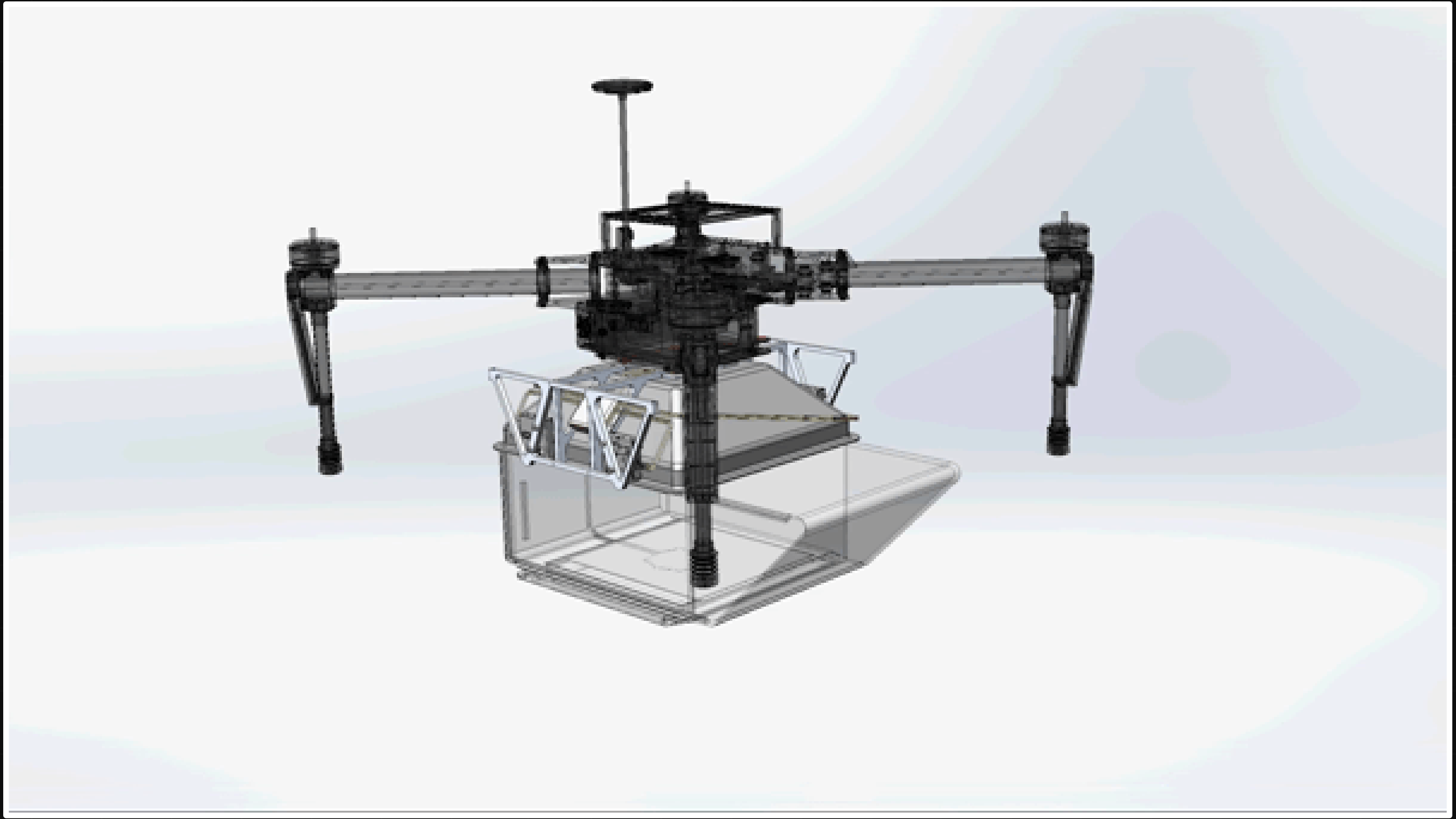


Shell Material: Polycarbonate [1]
Truss Material: Aluminum [1]

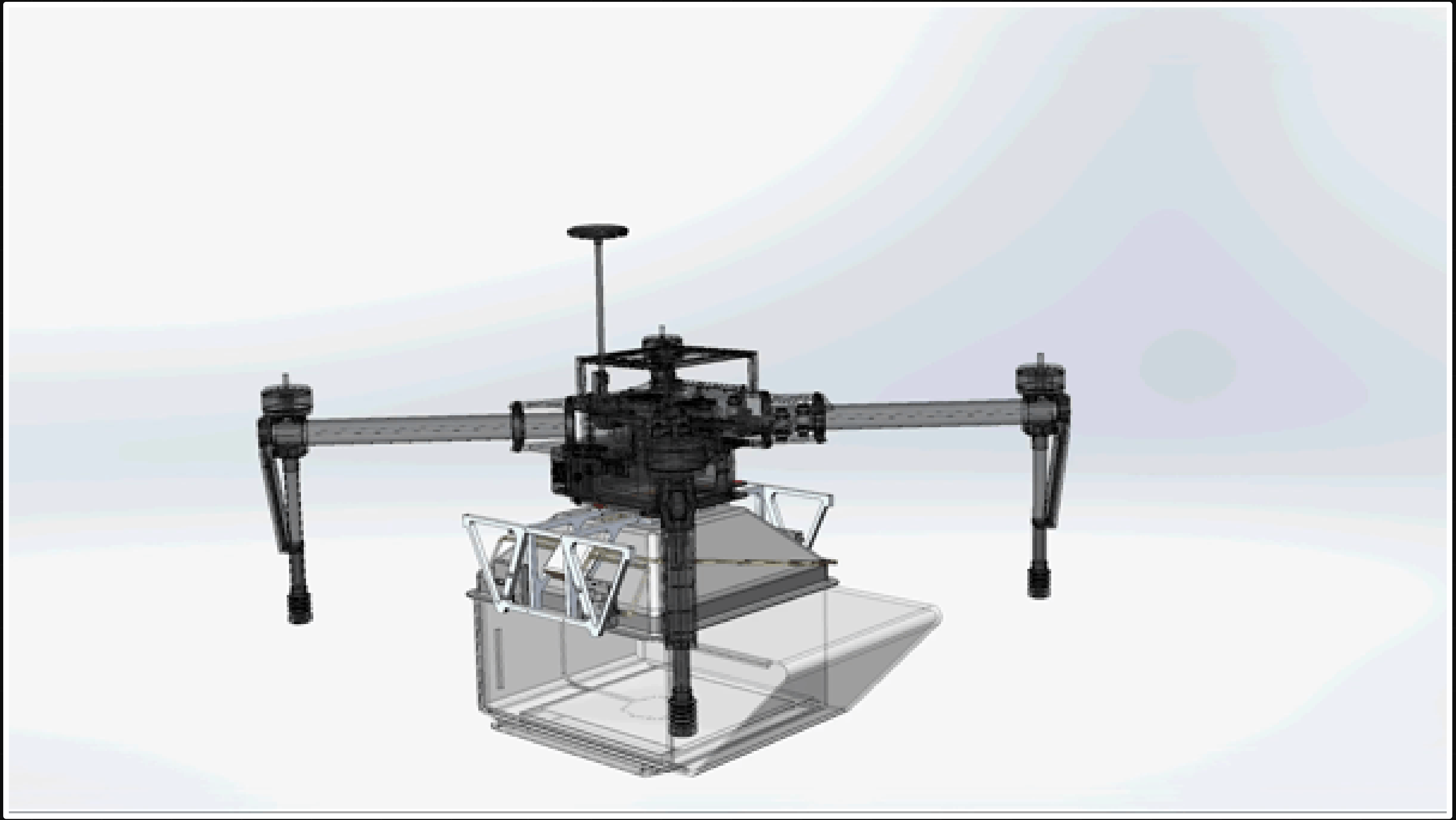
System Overview: Connection Animation



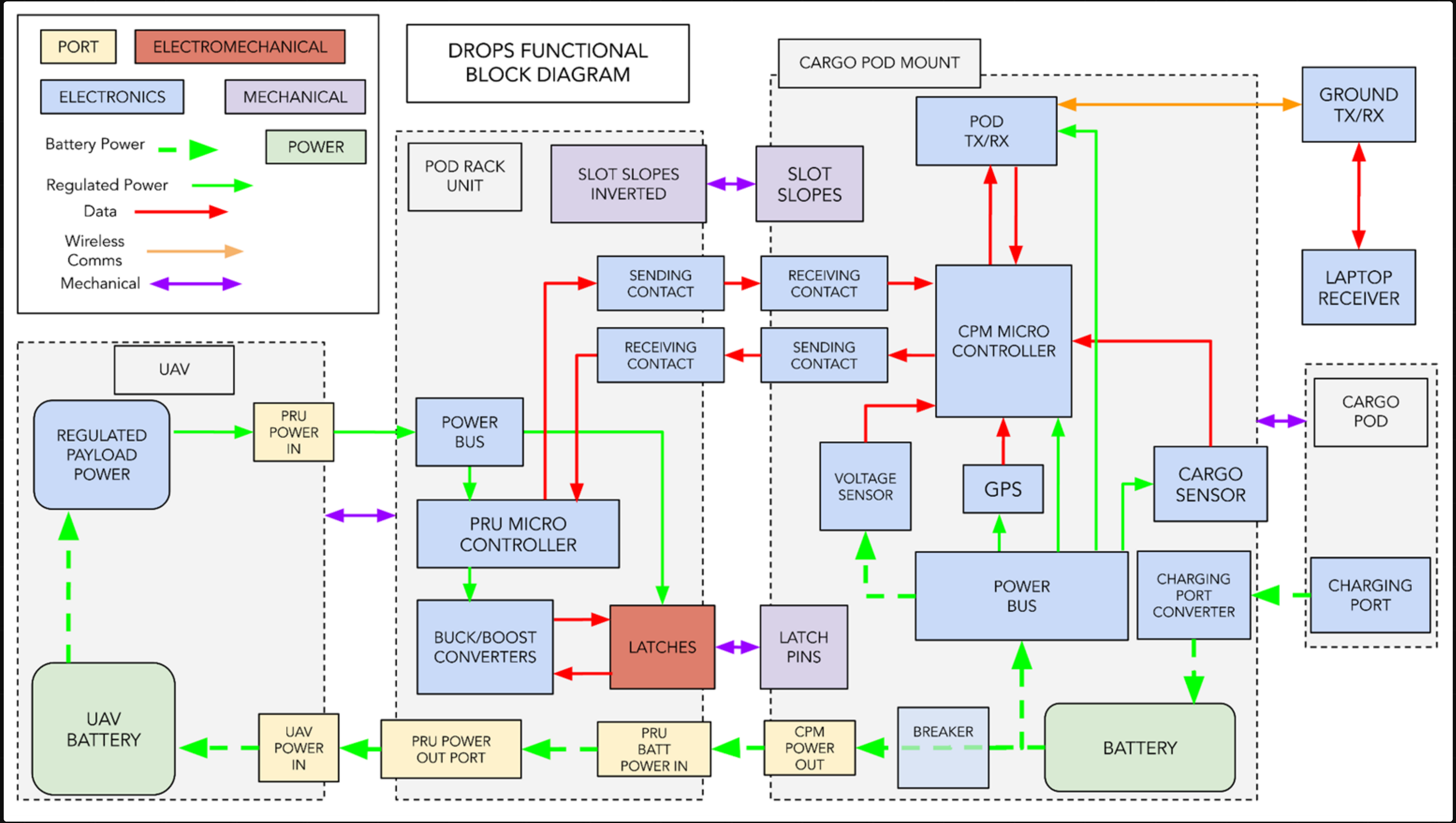
System Overview: Power Animation



System Overview: Charging Animation

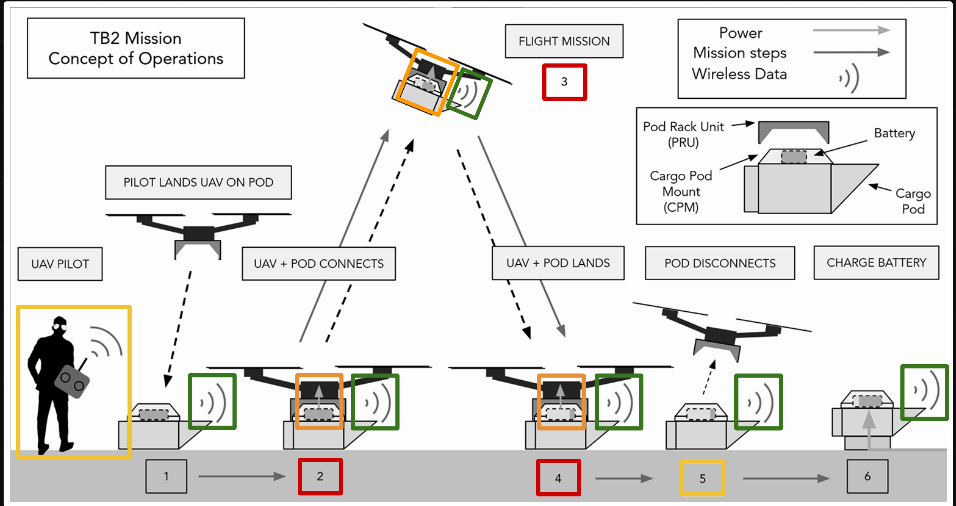


System Overview: Functional Block Diagram



Critical Project Elements

Critical Project Elements



CPE	Description	Functional Requirements	Justification
Structures	The PRU and CPM structure can withstand all forces throughout the mission	2	The DROPS system needs to be able to withstand all resultant forces of takeoff, landing, and in flight
Power	There shall be power available to the UAV through a passthrough from the CPM to the PRU	4	The customer would like that DROPS can demonstrate this proof of concept; supplying power to extend the drone's range via additional battery power
Connection & Control	Operators shall be able to send lock/unlock commands and receive the status of latches	3, 7	Sending commands to disconnect from the Pod and knowing latch status is required for Pod delivery
Data Transmission	The status of the Cargo Pod shall be transferred to the operator	7	The status of the batteries, cargo, latches, and Pod must be known for system monitoring and for future autonomous design goals

Design Requirements & Satisfaction

CPE 1: Structural Elements

Structures	The PRU and CPM structure can withstand all forces throughout the mission	FR 2

PR 2.3	The DROPS system can withstand vertical forces on takeoff due to accelerations of $25.4\ m/s^2$ with a FOS greater than 3
PR 2.3	The DROPS system can withstand vertical forces on landing due to accelerations of $25.4\ m/s^2$ with a FOS greater than 3
PR 2.3	The DROPS system can withstand lateral forces in flight due to accelerations of $7\ m/s^2$ with a FOS greater than 3

FR 2	The UAV shall connect to the Pod via the PRU

CPE 1: Critical Mission Elements Modeling

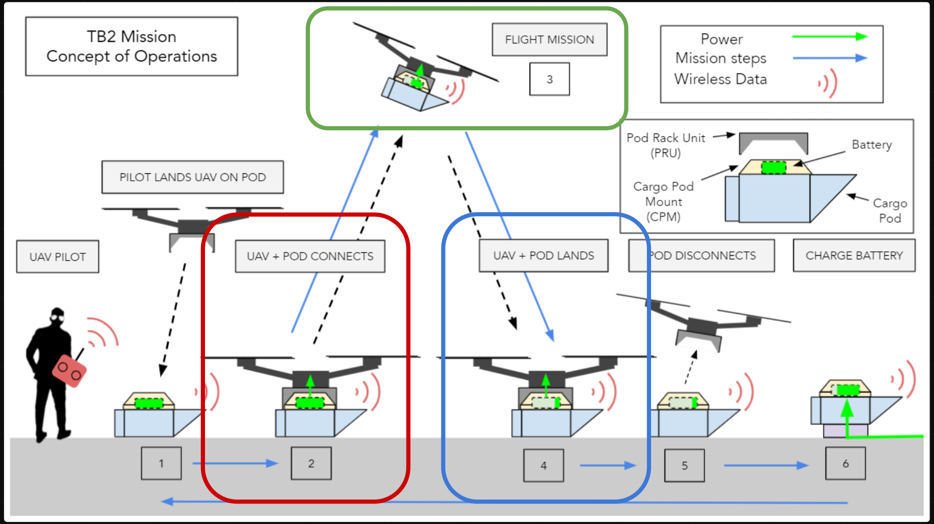
Structures	The PRU and CPM structure can withstand all forces throughout the mission

Will be analyzing three different phases of flight as they relate to this CPE

Forces on Takeoff

Forces during Mission

Forces on Landing

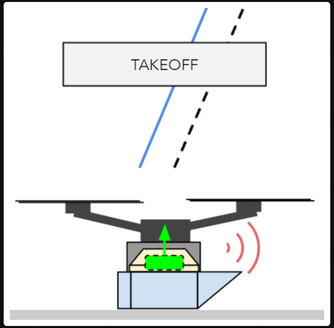


Forces from Periscope drone are modeled with assumed uniform distribution using Solidworks FEA

CPE 1: CPM Structure - Full Thrust Takeoff

PR 2.3	The DROPS system can withstand vertical forces on takeoff due to accelerations of 25.4 m/s^2 with a FOS greater than 3

Stage of Flight



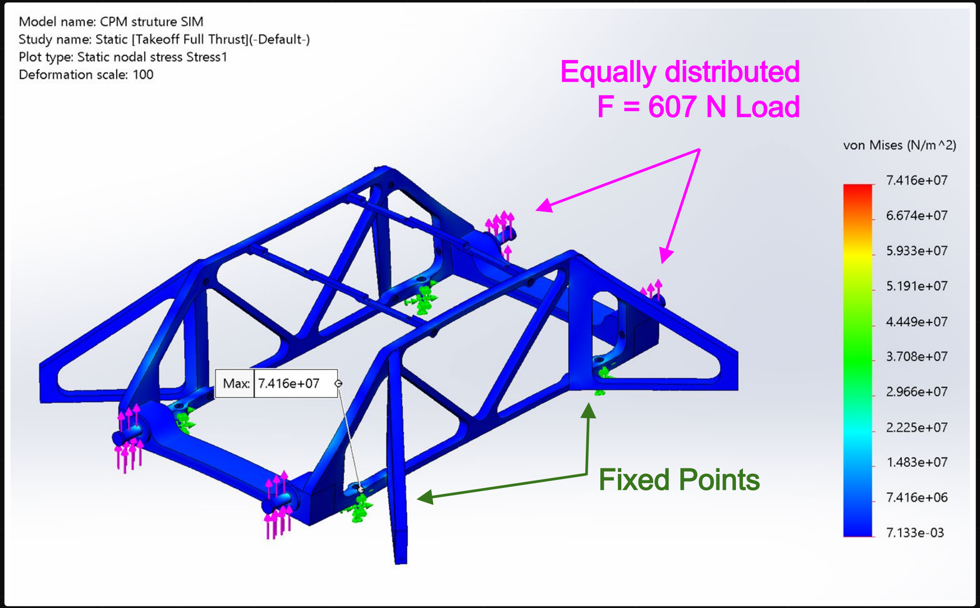
Component Details

Part	Material	Yield Str.
Truss	6061-T6	241 MPa
Latch Bolts	Alloy Steel	415 MPa

Factor of Safety Result

FOS_{MIN}	5.60

Finite Element Analysis



CPE 1: PRU Structure - Full Thrust Takeoff

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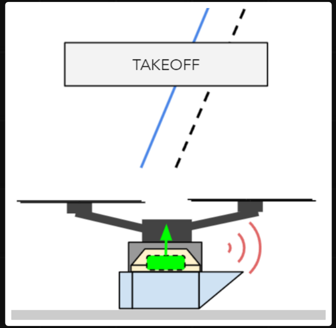


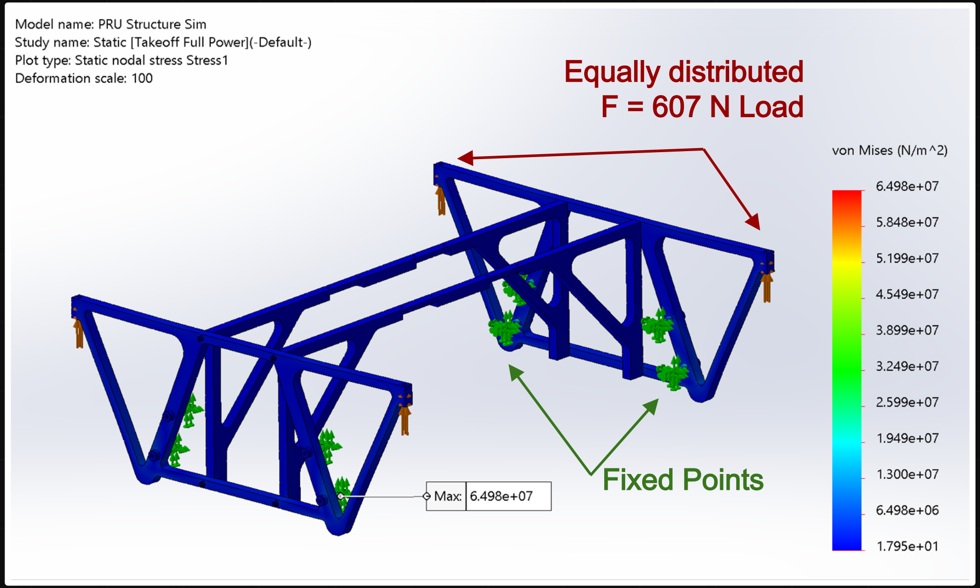
Component Details

Part	Material	Yield Str.
Truss	**6061-T6**	**241 MPa**
Latch Bolts	**Alloy Steel**	**415 MPa**

Factor of Safety Result

FOS_{MIN}	**6.34**

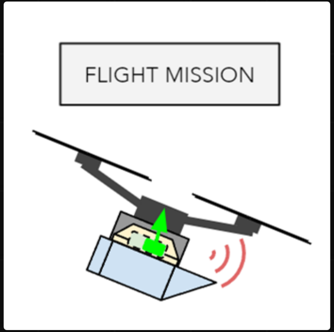
Finite Element Analysis



CPE 1: CPM Structure - Horizontal Accel. 7 m/s^2

PR 2.3	The DROPS system can withstand lateral forces in flight due to accelerations of 7 m/s^2 with a FOS greater than 3

Stage of Flight



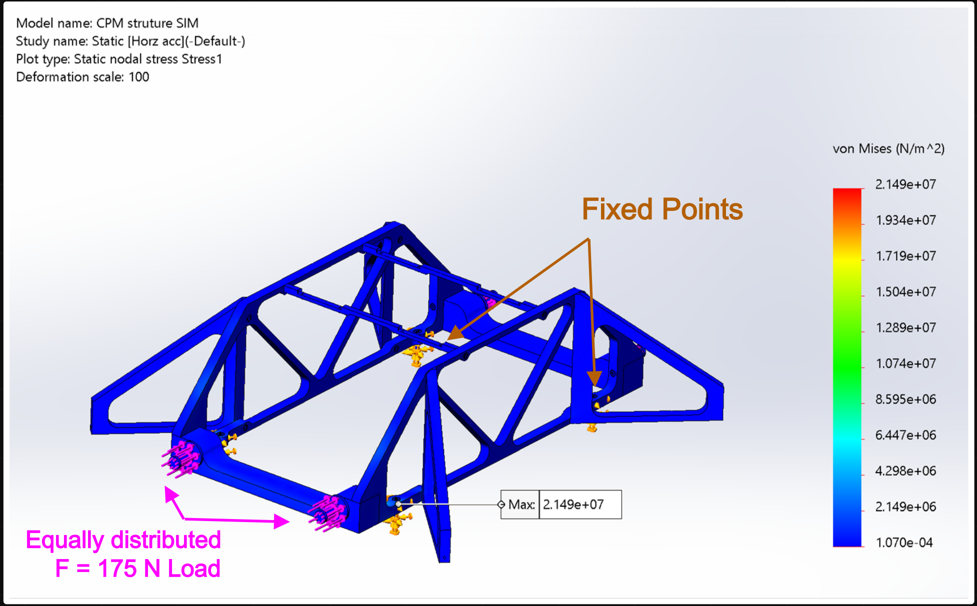
Component Details

Part	Material	Yield Str.
Truss	6061-T6	241 MPa
Latch Bolts	Alloy Steel	415 MPa

Factor of Safety Result

FOS_{MIN}	11.21

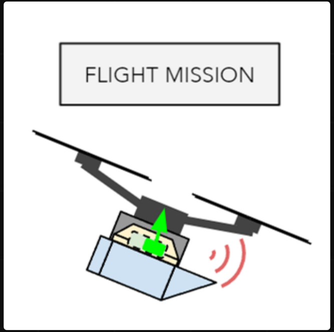
Finite Element Analysis



CPE 1: PRU Structure - Horizontal Accel. 7 m/s^2

PR 2.3	The DROPS system can withstand lateral forces in flight due to accelerations of 7 m/s^2 with a FOS greater than 3

Stage of Flight



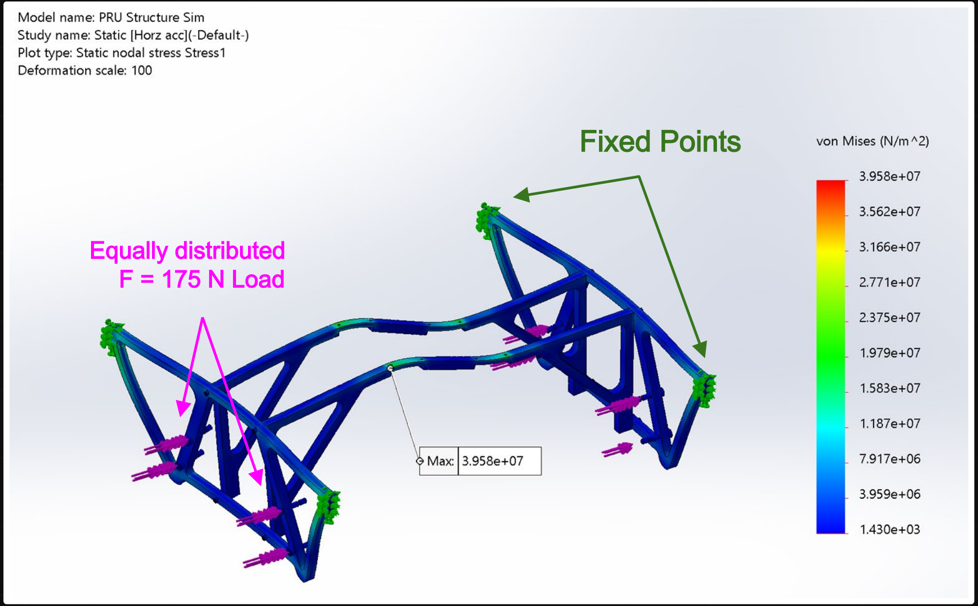
Component Details

Part	Material	Yield Str.
Truss	6061-T6	241 MPa
Latch Bolts	Alloy Steel	415 MPa

Factor of Safety Result

FOS_{MIN}	6.09

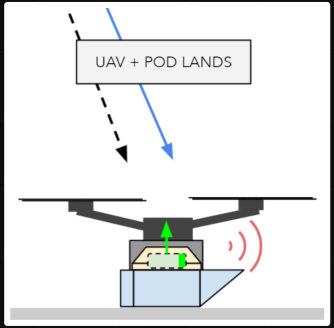
Finite Element Analysis



CPE 1: CPM Structure - Landing 0.5 m/s

PR 2.3	The DROPS system can withstand vertical forces on landing due to accelerations of 25.4 m/s^2 with a FOS greater than 3

Stage of Flight



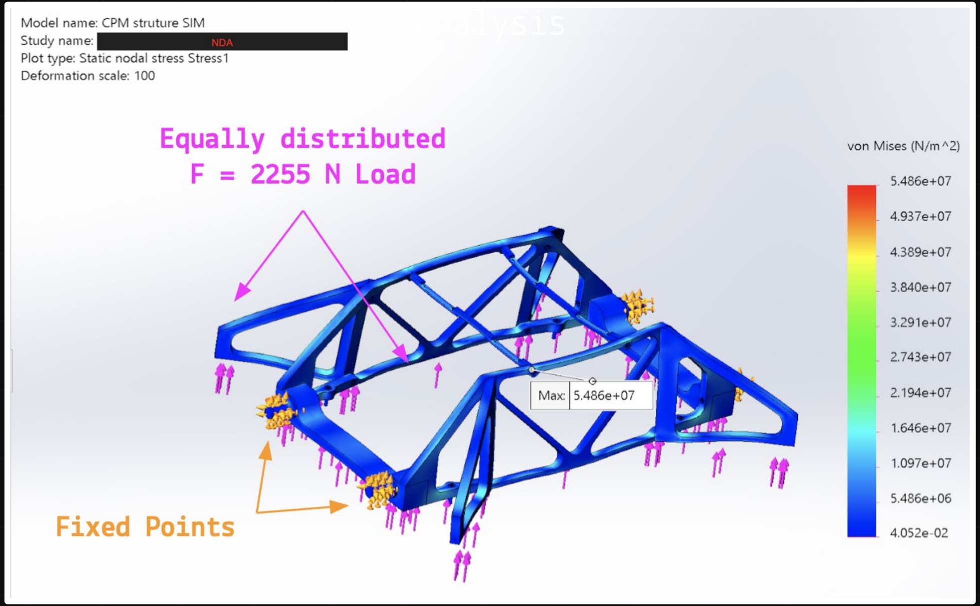
Component Details

Part	Material	Yield Str.
Truss	6061-T6	241 MPa
Latch Bolts	Alloy Steel	415 MPa

Factor of Safety Result

FOS_{MIN}	4.39

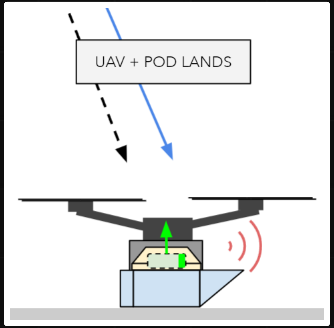
Finite Element Analysis



CPE 1: PRU Structure - Landing 0.5 m/s

PR 2.3	The DROPS system can withstand vertical forces on landing due to accelerations of 25.4 m/s^2 with a FOS greater than 3

Stage of Flight



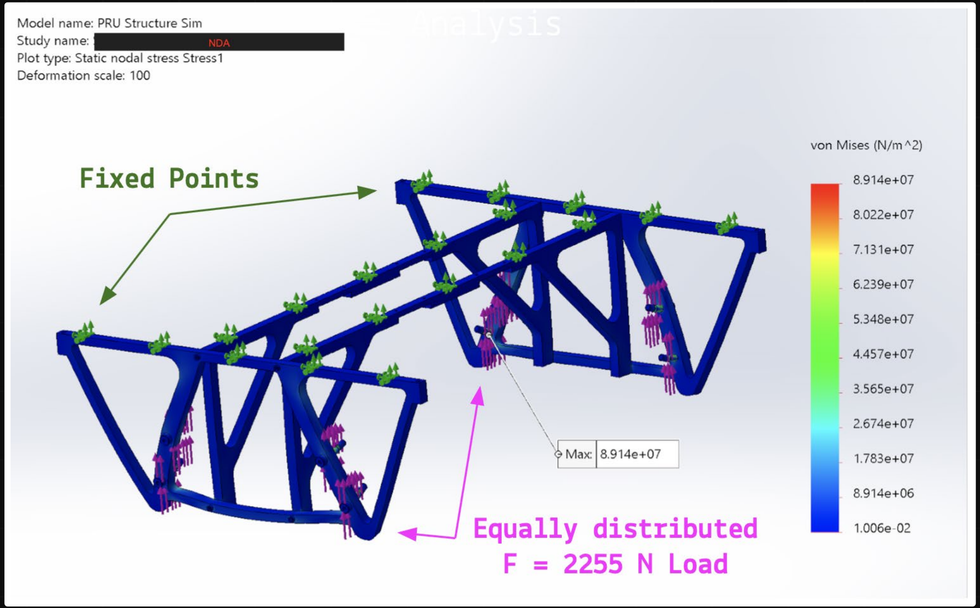
Component Details

Part	Material	Yield Str.
Truss	6061-T6	241 MPa
Latch Bolts	Alloy Steel	415 MPa

Factor of Safety Result

FOS_{MIN}	4.66

Finite Element Analysis



CPE 1: Structural Elements

Structures	The structural components of the PRU,CPM,and Pod structure can withstand all forces throughout the mission	FR 2

PR 2.3	The DROPS system can withstand vertical forces on takeoff due to accelerations of 25.4 m/s^2 with a FOS greater than 3
PR 2.3	The DROPS system can withstand vertical forces on landing due to accelerations of 25.4 m/s^2 with a FOS greater than 3
PR 2.3	The DROPS system can withstand lateral forces in flight due to accelerations of 7 m/s^2 with a FOS greater than 3

FR 2	The UAV shall connect to the Pod via the PRU

CPE 2: Power Passthrough

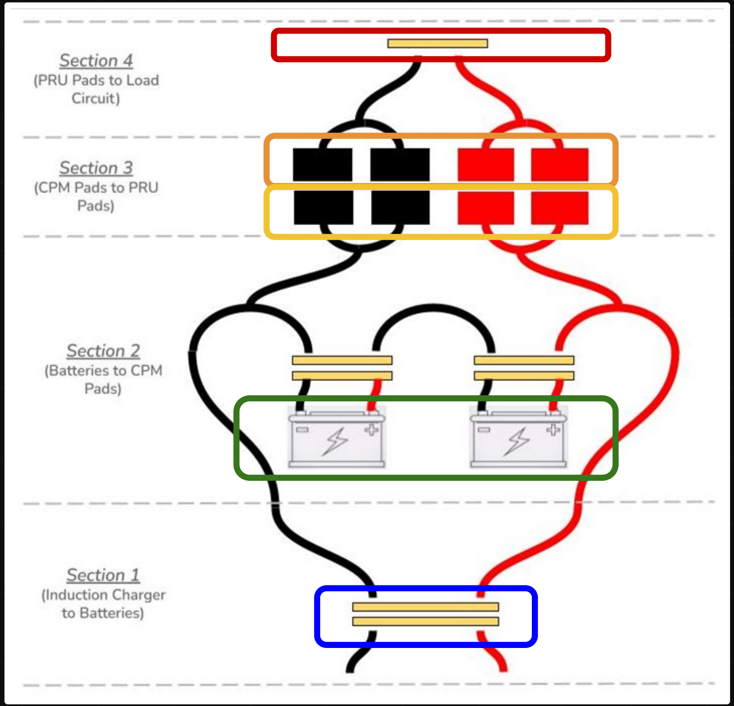
Power	There shall be power available to the UAV through a passthrough from the CPM to the PRU	FR 4

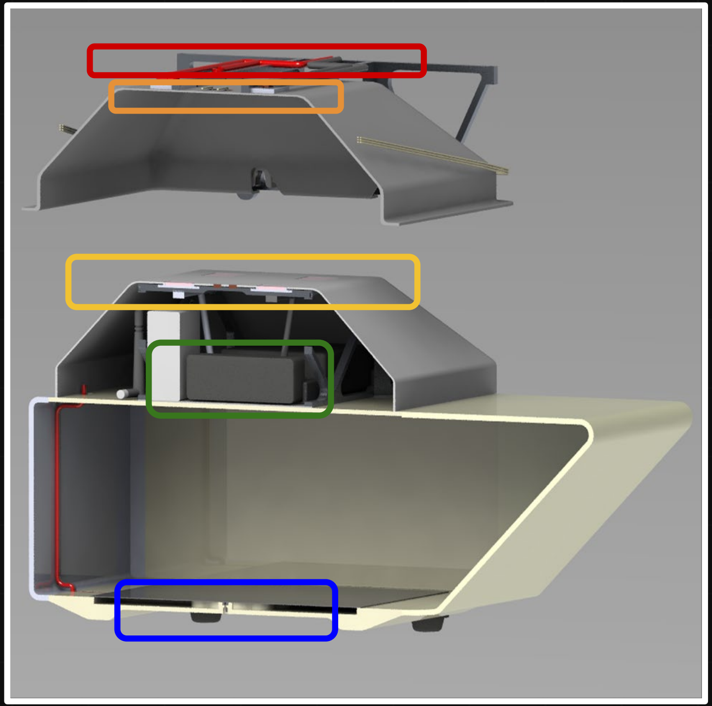
PR 4.2	There shall be unregulated, functioning power distribution cables between the CPM batteries and the PRU output that are designed to pass at most 100 Amps
PR 4.2	The contact pad connection system between the CPM and the PRU are designed to pass at most 100 Amps

FR4	There shall be power passthrough from the POD through the PRU outputs

CPE 2: High-Power Input/Output

Power	There shall be power available to the UAV through a passthrough from the CPM to the PRU	FR 4





CPE 2: High-Power Wire Specifications

PR 4.2	There shall be unregulated, functioning power distribution cables between the CPM batteries and the PRU output that are designed to pass at most 100 Amps

High-Current Details:

- Wires rated to 124A continuous current
- Testing to 20A

Gauge/Conductor:

Gauge	8 AWG
Material	Copper
Strand Config.	High-Strand Rope-Lay

	TurboFlex® Copper	
AWG	DC Resistance, Ohm/1000 ft	Max Current, Amps
16	4.55	36
14	2.85	54
12	1.85	68
10	1.16	90
8	0.72	124
6	0.46	165
4	0.30	220
2	0.19	293
1/0	0.12	399

CPE 2: Contact Pad Analysis

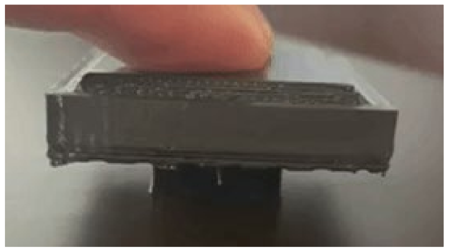
PR 4.2	The contact pad connection system between the CPM and the PRU are designed to pass at most 100 Amps

Pad Model Estimations:

Constant Voltage [V]	44.4
Constant Current Per Pad [A]	50

Copper 145 Alloy Specs [4]:

K [W/m*K]	386
ρ [Ohms]	$1.678 * 10^{-8}$



Pad Model Results:

Power Loss Per Pad [W]	$1.13 * 10^{-4}$
Temp. Increase Per Pad [K]	$7.88 * 10^{-7}$

Conclusion: Negligible temperature changes and power losses predicted per pad

CPE 2: Power Passthrough

Power	There shall be power available to the UAV through a passthrough from the CPM to the PRU	FR 4

PR 4.2	There shall be unregulated, functioning power distribution cables between the CPM batteries and the PRU output that are designed to pass at most 100 Amps
PR 4. 2	The contact pad connection system between the CPM and the PRU are designed to pass at most 100 Amps

FR4	There shall be power passthrough from the POD though the PRU outputs

CPE 3: Connection & Control

Connection & Control	Operators shall be able to send lock/unlock commands and receive the status of latches	FR 3, 7

PR 7.1	The PRU microcontroller must make serial connection with the CPM microcontroller
PR 7.1 & PR 3.2	The CPM microcontroller must send a trigger command to the PRU microcontroller which must receive & execute the command & return status of the latches to the CPM microcontroller

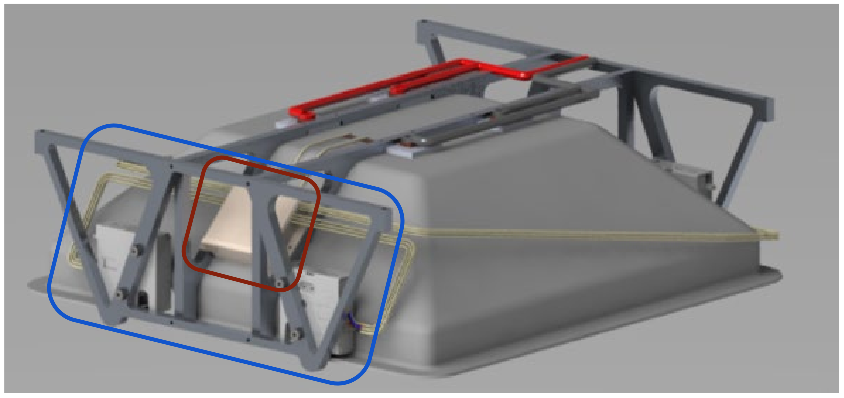
FR3	The UAV shall disconnect from the Pod via the PRU
FR7	There shall be data transfer between the PRU and the operator

CPE 3: PRU Full Circuit Diagram

Key Features:

Communication: Enables communication between PRU and CPM

Control & Cam Status: Provide control signal to latches and measure cam status



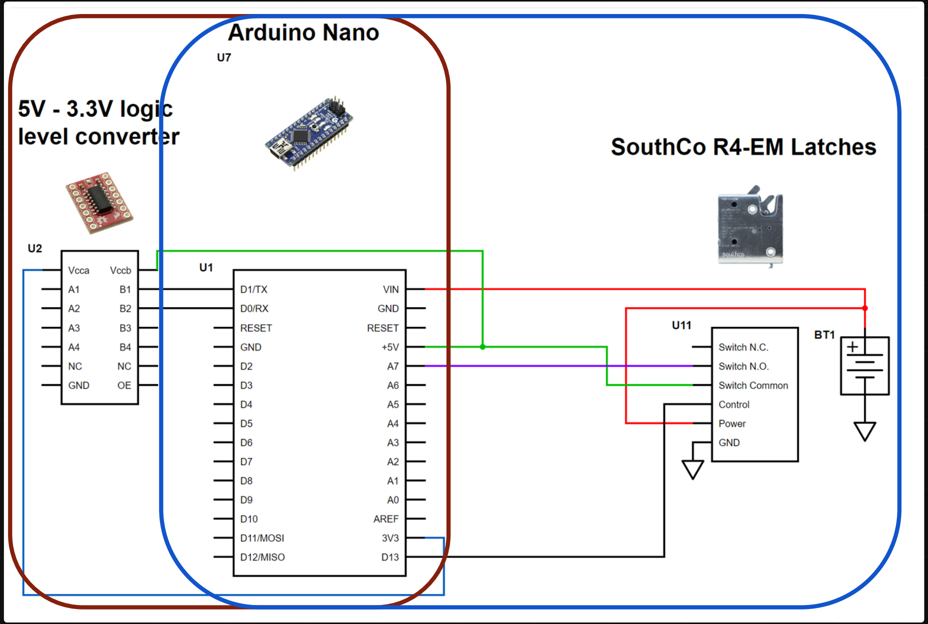
Latch Status

External power supply

5V line

DIO TX/RX line

3.3V line



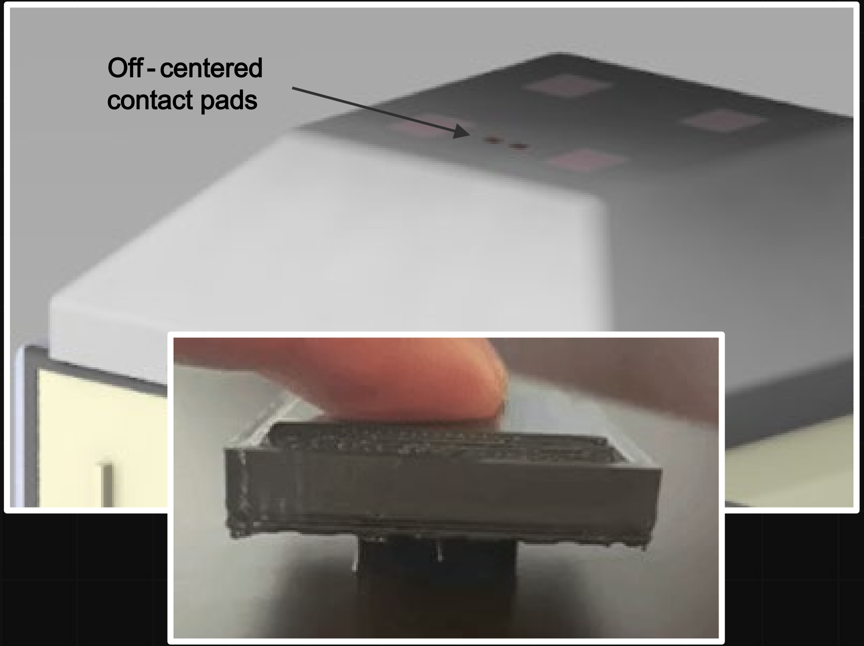
CPE 3: Data Passthrough Contact Pads

PR 7.1	The PRU microcontroller must make serial connection with the CPM microcontroller

2 smaller scale contact pads, similar to high power passthrough pads

Enables data and command pass through to and from user and PRU microcontroller

Off-centered to ensure serial **connection is not established when misaligned**



CPE 3: CPM/PRU Communication Solution

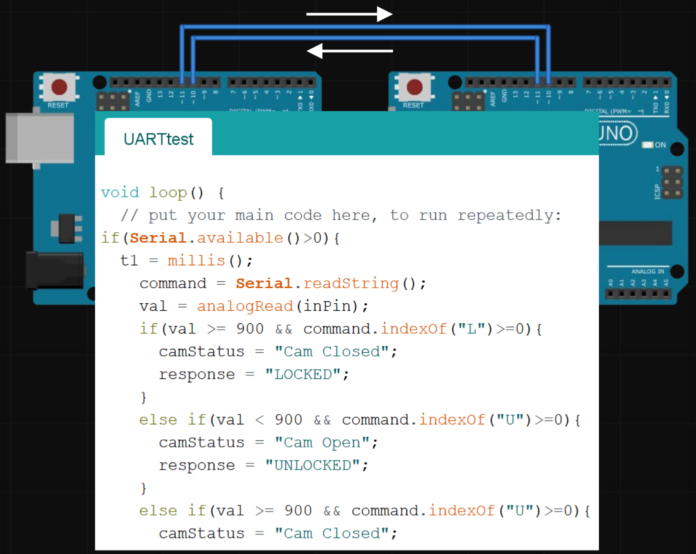
PR 7.1 & PR 3.2	The CPM microcontroller must send a trigger command to the PRU microcontroller which must receive & execute the command & return status of the latches to the CPM microcontroller

Serial UART communication [6] :

3 required connections : TX, RX, and ground

Common ground between MCU's will be routed through the high power passthrough ground contact pads

TX/RX routed through **off - centered contact pads**



Snippet of V&V code using Arduino Serial Library

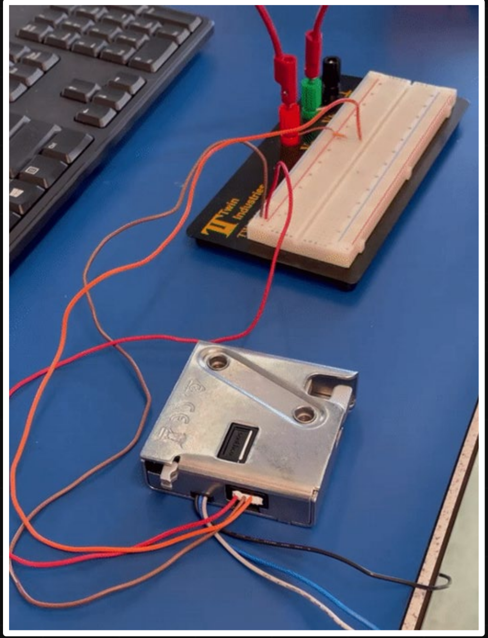
CPE 3: Latch Functionality

PR 7.1 & PR 3.2	The CPM microcontroller must send a trigger command to the PRU microcontroller which must receive & execute the command & return status of the latches to the CPM microcontroller

To Control SouthCo Latch :

"Provide 12V to 24V DC signal for a minimum of 50 ms to unlock"

Signal of 5V DC is sufficient (Compatible with Arduino outputs)



CPE 3: Cam Status

PR 7.1 & PR 3.2	The CPM microcontroller must send a trigger command to the PRU microcontroller which must receive & execute the command & return status of the latches to the CPM microcontroller

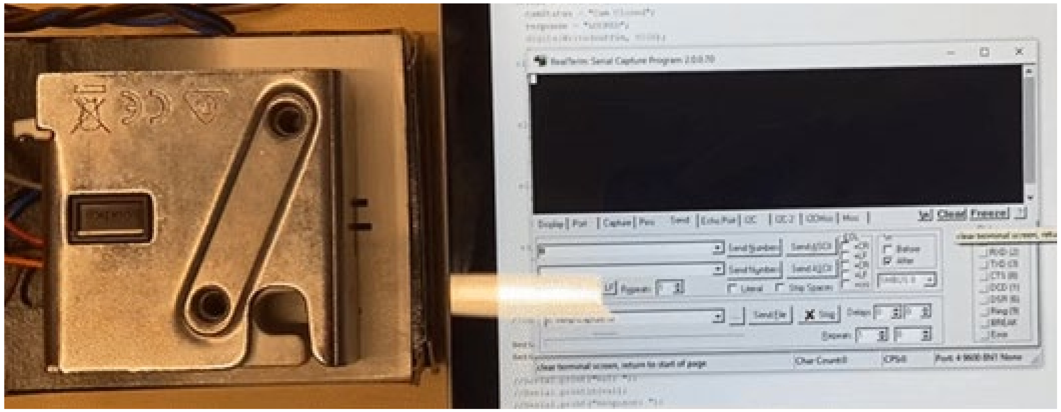
To Receive SouthCo Latch Signal :

1. **Provide 5VDC to switch common**
2. **The switch is closed when the cam is closed**

Black/Blue wire setup chosen :

Nano DIO pin will receive **high signal when cam is open** (open switch)

Nano DIO pin will receive **low signal when cam is closed** (closed switch)



Above Latch Status Demonstration

CPE 3: Connection & Control

Connection & Control	Operators shall be able to send lock/unlock commands and receive the status of latches	FR 3, 7

PR 7.1	The PRU microcontroller must make serial connection with the CPM microcontroller
PR 7.1 & PR 3.2	The CPM microcontroller must send a trigger command to the PRU microcontroller which must receive & execute the command & return status of the latches to the CPM microcontroller

FR3	The UAV shall disconnect from the Pod via the PRU.
FR7	There shall be data transfer between the PRU and the operator

CPE 4: Data Downlink

Data Transmission	The status of the Cargo Pod shall be transferred to the operator	FR 7

PR 7.1	All components selected must have the proper specifications to collect the required data at the proper resolutions
PR 7.1	All components selected must have the proper specifications to send the required data to the user at the proper data rates
PR 6.1	All components must be powered and integrated properly

FR7	There shall be data transfer between the PRU and the operator

CPE 4: Selected Sensor Resolution

PR 7.1	All components selected must have the proper specifications to collect the required data at the proper resolutions

Component	Component Name	Resolution	Desired Resolution	Satisfies Requirement?
GPS	NEO-6m	2.5 m	3 m	Yes
Voltage Divider	N/A	3.2 mV	0.5 V	Yes
Cargo Sensor	US-100	Binary Yes/No	Binary Yes/No	Yes

CPE 4: Component Selection- XBee Capability

PR 7.1	All components selected must have the proper specifications to send the required data to the user at the proper data rates

Required Specifications

Arduino Vout	3.3 VDC
Maximum Arduino Current Out	800 mA
Expected Telemetry Data Rate	0.64 kbs
Required Link Range	1 Mile Line of Sight

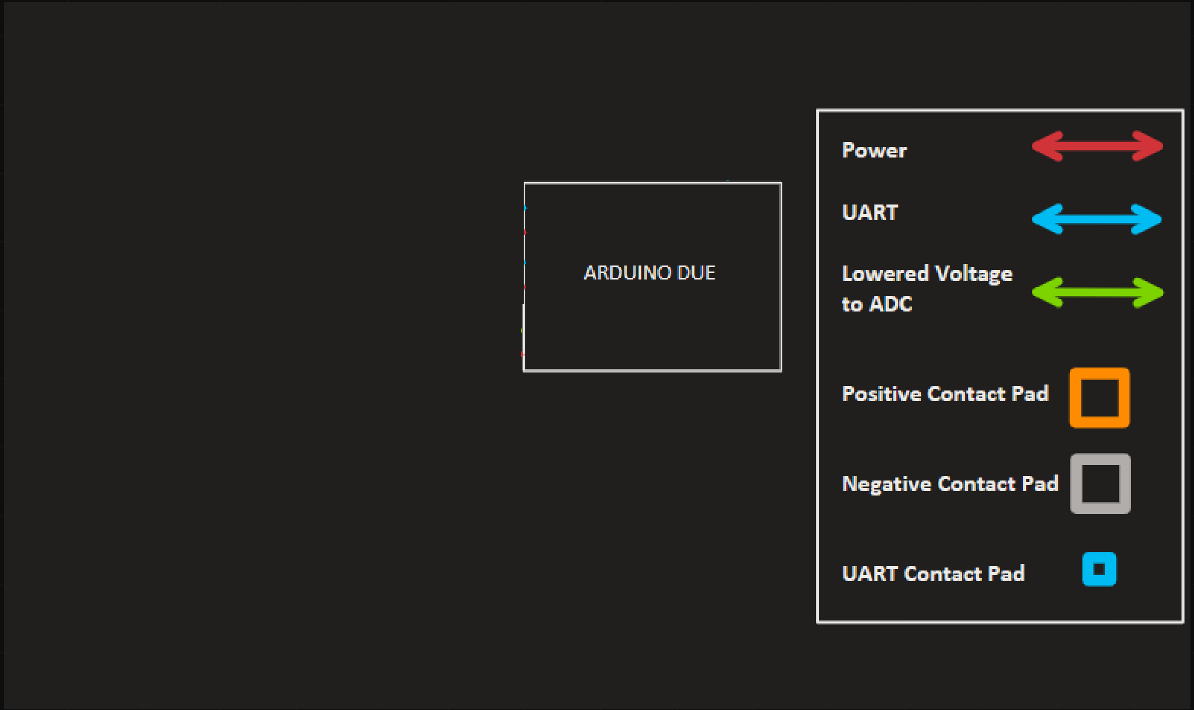
Performance Specs. of XBP9B-DPST-001

Vin Nominal	2.1-3.6 VDC
Maximum Current Draw	290 mA
Data Rate	10 kbs
Outdoor Line of Sight Range	Up to 9 miles

CPE 4: - Electronic Interface (CPM)

PR 6.1	All components must be powered and integrated properly

CPM Circuit Interface Diagram



CPE 4: Power Consumption of Components- CPM

PR 6.1	All components must be powered and integrated properly

Component	Operating Voltage	Max Current Draw	Max Power Consumption
XBee 3 Pro	3.3 V	290 mA	0.957 W
NEO-6M GPS Module	3.3 V	45 mA	0.1485 W
HC-SR04 Sonar Sensor	3.3 V	2 mA	0.0066 W
Arduino Due	12 V	200 mA	2.4 W
Total	N/A	537 mA	3.51 W

CPE 4: CPM Power Losses

PR 6.1	All components must be powered and integrated properly

Voltage Divider

Voltage Drop	38.4 V - 50.4 V
Resistance (Total)	16 kOhm
Power Loss	0.124 W

LTC3637 Converter [2]

Input Voltage	38.4 V - 50.4 V
Output Power	3.51 W
Efficiency	85%
Power Loss	0.28 W

Total Power Loss: 0.404 W

CPE 4: CPM Total Power

PR 6.1	All components must be powered and integrated properly

Total CPM Power Consumption
4.25 W

→

Battery Characteristics	Values
Operating Voltage	44.4 V
Capacity	16000 mAh
Watt hours at 44.4 V	710.4 Wh

→

Estimated CPM Run Time
167.15 h

CPE 4: CPM Takeaway

Data Transmission	The status of the Cargo Pod shall be transferred to the operator	FR 7

Due Max Current Out	800 mA	>	337 mA	Component Max Current Draw
Due Voltage Out	3.3 V	>	2.1-3.6 V	Component VCC range
Radio Data Rate	10 kbs	>	0.60 kbs	Expected Data Rate
Outdoor Line of Sight Range	Up to 9 miles	>	1 mile	Max Required Range

FR7	There shall be data transfer between the PRU and the operator

Project Risks

Risk Metrics

Risk Category	Description
Tolerable	Marginal Impact To Project Success
Serious	Considerable Impact To Project Success
Egregious	Detrimental Impact To Project Success

Categorized 43 project risks into the table on the right.

Tolerable	Serious	Egregious

	Minimal	Minor	Major	Hazardous	Catastrophic
Almost Certain					
Likely					
Possible					
Unlikely					
Improbable					

Risk Table

Tag	Risk	Mitigation
INDUC	Induction Charger and Metal Cargo Interaction	Only induction charge batteries when non metal cargo or no cargo exists in the cargo pod
SHOCK	CPM Pad Shock Danger	Implement electrical breaker to prevent high - power flow until required
COMMS	Communication To UAV Unavailable	Use weather rated antenna; maintain LOS if possible; increase gain if LOS not possible
TRUSS	Truss Support Structure Failure	Add rubber feet on bottom of Pod; mandate maximum descent speed of 0.5 m/s or less; implement landing pad
UCCOLL	UAV and CPM/Pod System Collision	Mandate slow approach speeds; operate in calm weather

Tolerable	Serious	Egregious

	Minimal	Minor	Major	Hazardous	Catastrophic
Almost Certain					
Likely					INDUC SHOCK
Possible					COMMS TRUSS INDUC UCCOL
Unlikely					COMMS TRUSS UCCOL
Improbable					SHOCK

Pre vs. Post Mitigation Risks

Pre-Mitigation Risks			
Subgroup	Tolerable	Serious	Egregious
Connection & Alignment	0	12	3
Power & Charging	3	9	4
Data & Electronics	1	3	1
Safety & Financials	0	3	4
Totals	**4**	**28**	**11**

Post-Mitigation Risks			
Subgroup	Tolerable	Serious	Egregious
Connection & Alignment	9	6	0
Power & Charging	10	5	1
Data & Electronics	3	2	0
Safety & Financials	4	3	0
Totals	**26**	**16**	**1**

Significant shift in the overall risk of the project post-mitigation

Verification and Validation

Testing Summary

Test Name	Relevant CPE	Relevant FR
Periscope Drone Test	Structures, Communication, and Control	3,6,7
High Power System Test	Power	4
IRISS Drone Test	Structures	1, 2
Data Downlink Radio Test	Data Transmission	7
Latch Command Test	Communication and Control	2
Induction Charging Test	Power	5
Manual Connection and Disconnection	Structures	1, 2

Test 1: Heavy Lift UAV Test - Model Details

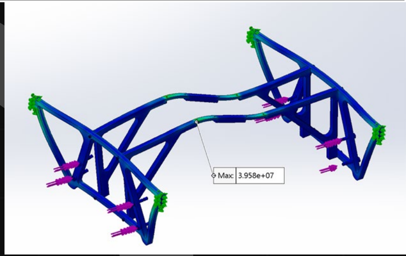
Periscope Thrust - to - Weight Ratio Specs

→

Expected forces/accelerations

→

FEA Modeling → Stress concentrations/deformation



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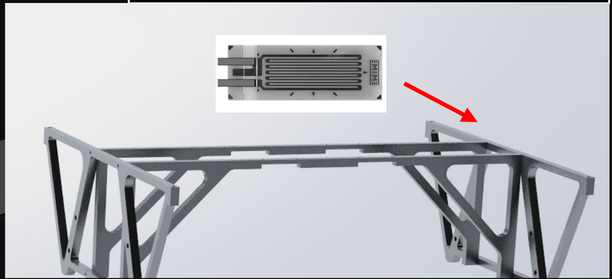
Strain Gauge Placement

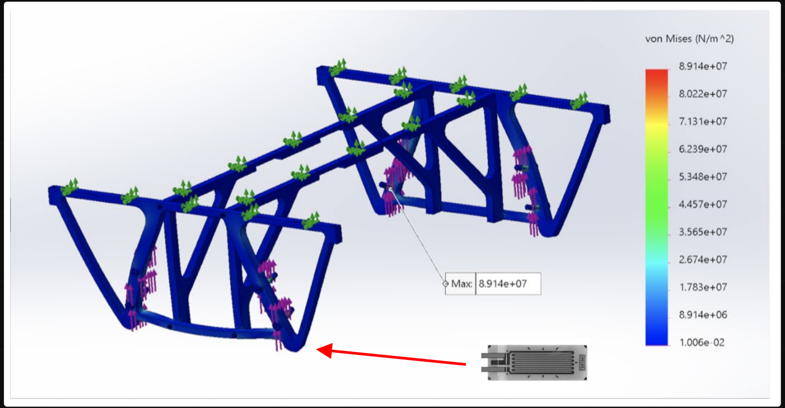


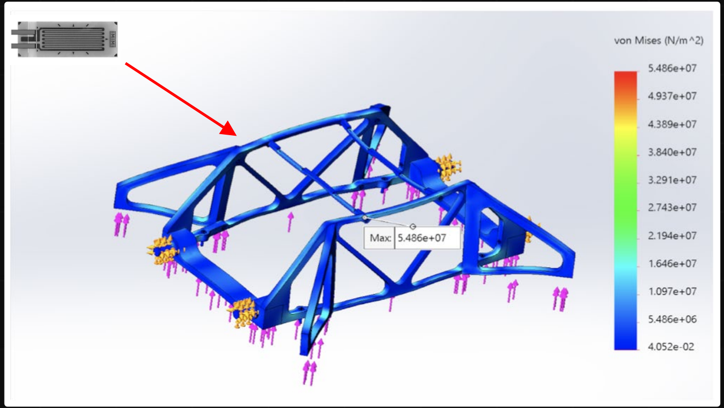
UAV Flight Test

Actual forces/deformation

Test 1: Heavy Lift UAV Test

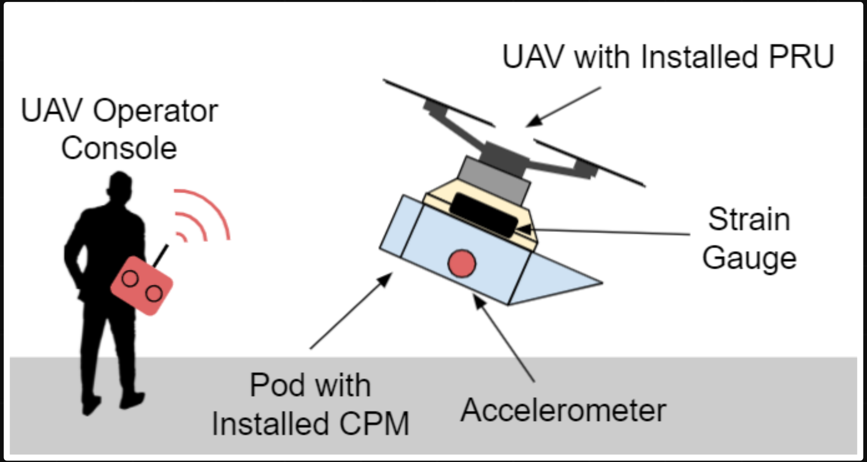
Goals	1. Fly the Pod with the drone and detach with remote operator 2. Dress rehearsal for Army event (AEWE)
Models verified	CPM FEA, PRU FEA (landing)
Data Collected	3 axis acceleration data Expected Values: < 25.4 m/s^2 vertical, 7 m/s^2 lateral Strain gauge data Expected Values at selected strain gauge location: 7.01 e - 2 mm (PRU), 1.35e-2 mm (CPM)





Test 1: Heavy Lift UAV Test

Facilities	Periscope facility
Steps	1. Pod manually connected to drone 2. Drone flys with Pod recording accel. and strain data 3. Drone lands 4. Pod remotely detached 5. Drone flies away
Requirements Closed	FR 4, level 2 and 3 performance requirements



Test 2: High Power System Test - Model Details

Copper 145 Alloy Specs:

K [W/m*K]	386
ρ [Ohms]	$1.678 * 10^{-8}$

Voltage and Current:

Constant Voltage [V]	44.4
Constant Current Per Pad [A]	50

Pad Model Results:

Power Loss Per Pad [W]	$1.13 * 10^{-4}$
Temp. Increase Per Pad [K]	$7.88 * 10^{-7}$

Pad Power Loss Equations:

$$R_{Pad} = \frac{\rho t}{wh}$$

$$V_{Drop} = I * R_{Pad}$$

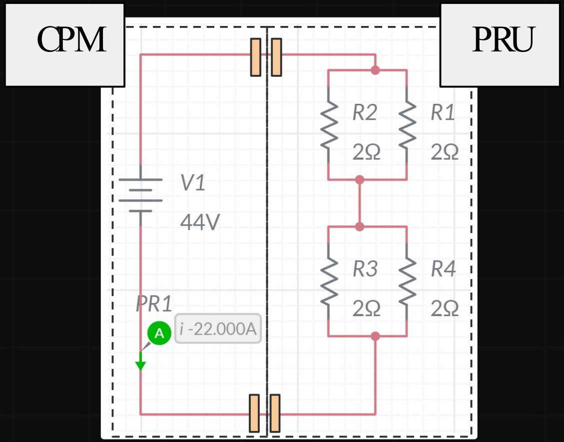
$$P_{Loss} = I * (44.4 - V_{Drop})$$

Pad Temperature Change Equation:

$$T_{Change} = P_{Loss} \frac{t}{whk}$$

Test 2: High Power System Test

Goal	Test the system can supply 22 Amps of current at the PRU terminal cables.
Models verified	1. Power pass through layout (Battery Input/Output and Pads) 2. Power and temperature losses with contact pads
Data Collected	Electrical Current through the High Power System (Expected: ~22 A) Voltage differential at PRU end (Expected: ~44 V) Copper PADs temperature (Expected: Room Temperature, Delta T << 1C)

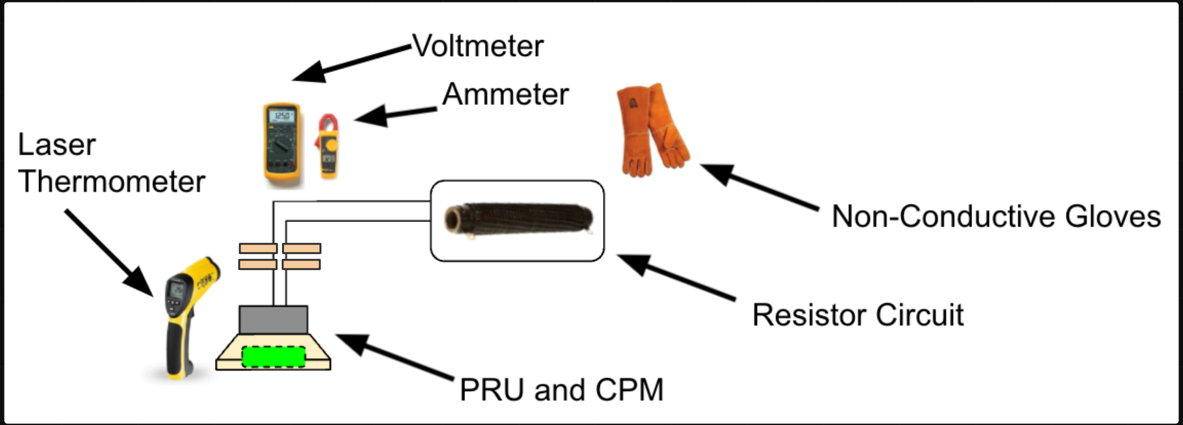


Test Circuit Modeling Results:

Est. Voltage at Input:	44 V
Test Current Desired:	20-25 A
Total Resistance Required:	2 Ohm
Resistor Power Rating:	300 W
Resistor Rating Tolerance:	5-10 %
Est. Dissipation Per Unit:	242 W
Safety Margin:	< 50 W / 20 %

Test 2: High Power System Test

Facilities	N200 Projects Space
Steps	1. Measure/Record PADS temperature 2. Connect testing circuit to PRU 3. Place PRU on CPM and turn power on 4. Measure/Record Current and Voltage 5. Turn power off, remove PRU 6. Measure/Record PADs temperature
Requirements	FR 4, performance level 2



Project Planning

Team Structure

Project Manager
Cody Watson

Customer
Hank Scott

Advisor
Dr. Jade Morton

Connection/Align Lead
Alex Karas

Systems Engineer
Nate Kuczun

Test Engineer
Caroline Dixon

Finance/Power Lead
Sid Arora

Downlink/Electronics Lead
Josh Schmitz

Internal Build Eng.
Dominic Dougherty

Manufacturing Eng.
Rafael Figueroa

Materials Engineer
Mia Abouhamad

Contact Engineer
Daniel Gutierrez

Charging Engineer
Ben Capeloto

Circuits/RF Engineer
Ian Chakraborty

Work Breakdown

Key

- Complete
- In Progress
- Future Work

DROPS

Deliverables
- PDD
- CDD
- PDR
- CDR
- Fall Report
- AIAA Paper
- TRR
- AEWE
- SFR
- Final Report

Systems
- Requirements
- Critical Project Elements
- Material Downselection
- Verification Methods
- Risk Analysis
- Subsystem Integration Plan
- AEWE Prototype

Connection & Alignment
- Requirements
- Design Concept
- Component Downselection
- Friction & Stress Estimates
- CAD
- Stress Analysis (FEA)
- Tolerance Modeling
- Assemble Truss Frames
- Integrate slopes & structure
- Connection mounting

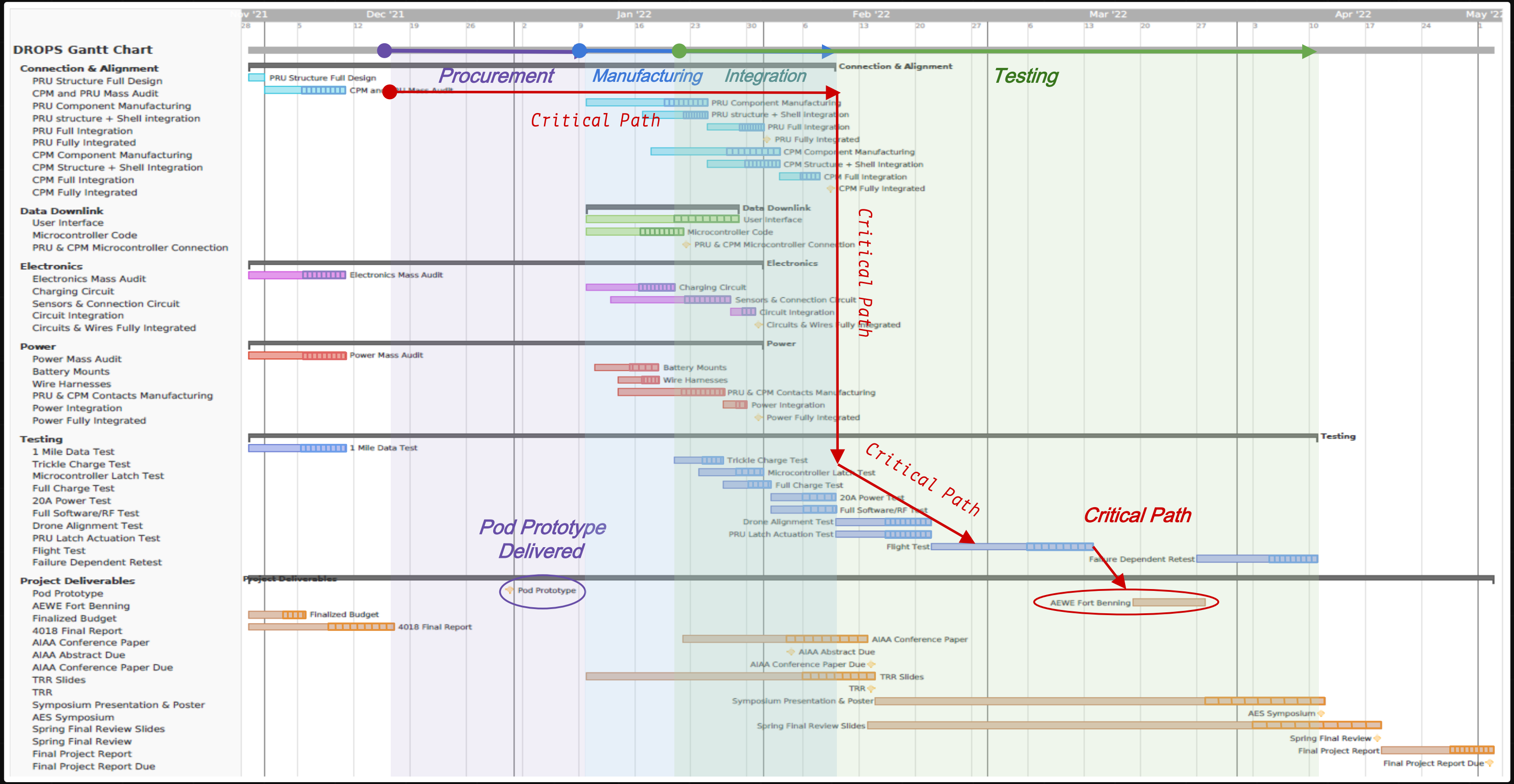
Data & Electronics
- Requirements
- Circuit Design
- Component Downselection
- Short Range Communication
- UI Design
- Latch Actuation
- Long Range Communication
- Sensor Integration

Power
- Requirements
- Battery System Design
- Component Downselection
- Load Circuit Design
- Contact Pad Design
- Material & Spring Selection
- Load Circuit Safety

Manufacturing
- Manufacturing Drawings
- Manufacturer Solicitations
- Shop Training
- Manufacturing Plan
- Manufacturer Selection
- Build Parts
- Assemble Structural Frame

Testing
- Test Plan
- Component Level Testing
- Data Downlink Testing
- Power Testing
- C&A Testing
- Full System Test
- Flight Test
- AEWE

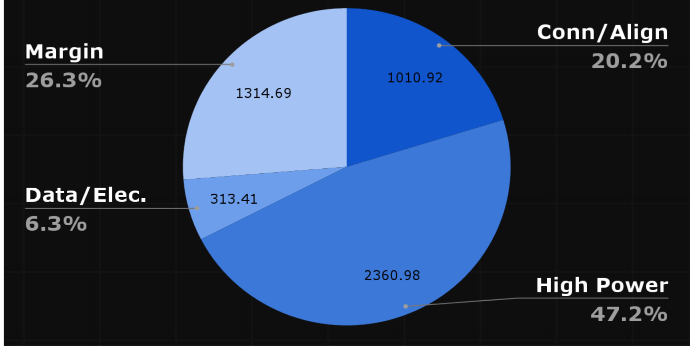
Spring 2022 Gantt Schedule

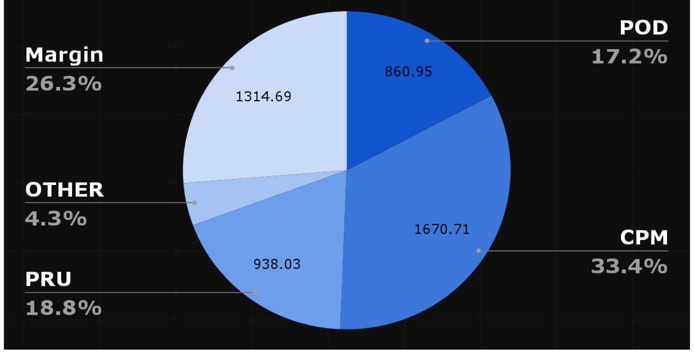


Major Test Details

Test Name	Scheduling		Risks & Resolution	
	Location	Anticipated Date	Hazards/Challenges	Resolution
High Power System Test	N200 Projects Space	1/30	Electrical Shock, Resistive Heating, Fire	Safety procedures, non-conductive gloves, resistor cages
Data Downlink Radio Test	US 36 Overlook	1/29	Antenna Range, High Noise in Data	Larger antenna option, shielded/twisted wiring, faraday cage, sensors close to Due
IRISS Drone Test	RECUV Indoor Flight Space	2/10	UAV Piloting Certifications, Logistical Delays, Weather	Part 107 Certification, file flight plan with CU, backup dates
Periscope Drone Test	Periscope Facility	2/20	Logistical Delays, UAV Availability	Backup UAV options

Financial Summary





Most Expensive Items Per Subteam:

Data/Electronics	
Item	Cost
Xbee Radios	103
Arduino Due	40
Xbee Dongle	26

Connection/Alignment	
Item	Cost
SouthCo Latches	360
Polycarbonate	250
Aluminum Spars	200

Power/Charging	
Item	Cost
Maxamps Batteries	1140
Wibotic Receiver	850
High- Power Resistors	75

Budget Uncertainties:

Potential Item	Cost
3D Printer for PRU/CPM	1300
PRU/CPM Material	400
Wibotic Induction Transmitter	1550

CURRENT PROJECT TOTAL
$3685.31

Acknowledgements

Customer & Faculty Advisor:

Hank Scott & Dr. Jade Morton

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CDR Reviewer:

Emma Markovitch

Thank You!

Questions?

Backup Slides

Citations

References

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Backup Slide Links

CPE Links

Alignment & Structures

Connection

Power

Electronics/Data

Risk Analysis

Verification and Validation

Project Planning

CPE's

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CPE backup links

CPE 1 & 2 Derivation

CPE 3 & 4 Derivation

System Mass Budget

Max Cg Offset

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CPE 1 Derivation

The PRU and CPM structure can withstand all forces throughout the mission

FR1	The UAV shall align itself with the Pod via the PRU.
FR2	The UAV shall connect to the Pod via the PRU.
FR3	The UAV shall disconnect from the Pod via the PRU.
FR8	The CPM shall be designed to enable stackable Pod unit.
FR9	The design of the PRU shall allow for the UAV to takeoff and land with the PRU without being connected to Pod

Mission critical activities above drive the design of structures to withstand resulting forces

CPE 2 Derivation

There shall be power available to the UAV through a passthrough from the CPM to the PRU

FR4	There shall be power passthrough from the POD though the PRU outputs

FR4 and FR6 drive the necessity for power passthrough in the entire system: some systems cannot operate without power being distributed.

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CPE 3 Derivation

Operators shall be able to send lock/unlock commands and receive the status of latches

FR3	The UAV shall disconnect from the Pod via the PRU.
FR7	There shall be data transfer between the PRU and the operator

Sending commands to connect/disconnect from the Pod is essential to mission success and must be relayed to operator

CPE 4 Derivation

The status of the Cargo Pod shall be transferred to the operator

FR7	There shall be data transfer between the PRU and the operator

FR7 is driven by the need for the user to know status of onboard batteries, location of Pod, cargo status, and latch status for monitoring of system and future autonomous design goals

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System Mass Budget

CPM	Mass (Kg)	QTY
Battery	1.99	2
Structure	1.73	1
Slope Cover	0.79	1
Electronics	0.54	1
Other	1.17	1
Total	8.21 Kg	

PRU	Mass (Kg)	QTY
Structure	1.53	1
Latches	1.16	4
Slot Slope Cover	1.12	1
Other	0.254	1
Total	4.06 Kg	

Of the 25 Kg UAV Payload → 12.73 Kg remaining for cargo + pod

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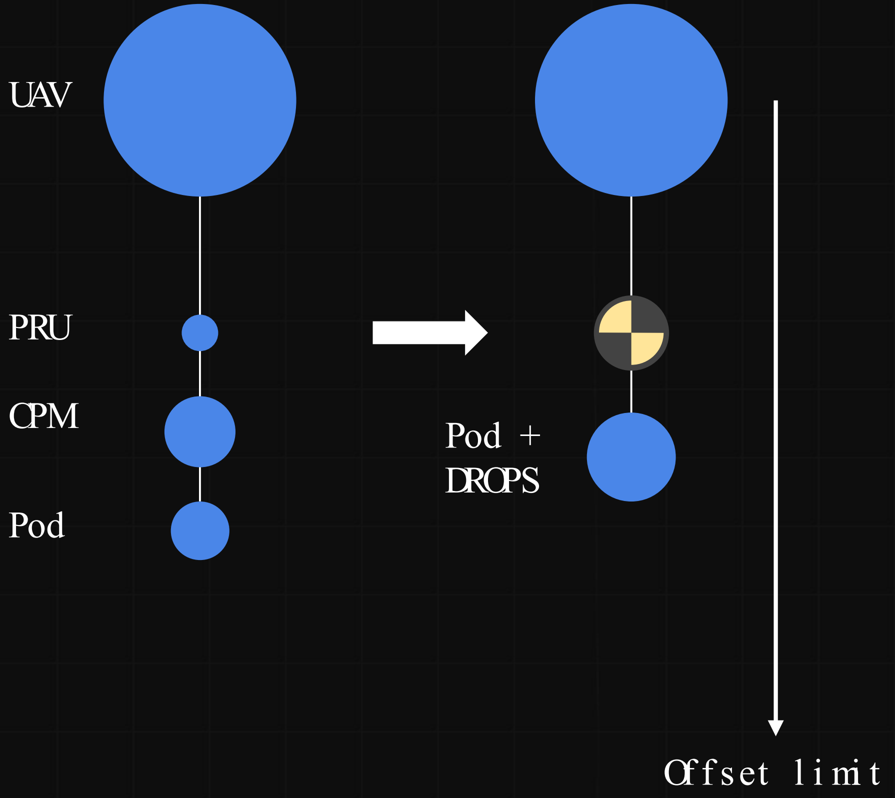
Max CG Offset



Information from Periscope:

- The combined CG of the PRU/CPM/Pod/Pod batteries can be a specified distance away from the original aircraft CG location based on current weight estimates and information provided by Periscope

- Currently, the bottom of the pod is 0.38 m away → Within tolerance

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Alignment & Structures

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Alignment backup links

Mission Elements Force Calcs

Bolt Mounting Calcs

CPM Structure - Resting Landing

PRU- Resting Landing

Striker bolt - Landing

Rubber feet

Proof of Concept

Surface Area Slot Slopes

Slot Slopes Material Study

Manufacturing Options

Feasibility: Slot Slopes

Alignment Review

Weatherproofing

CPM to Pod Bolt trade study

CPM to Pod Connection

CPM to Pod bolt analysis

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Critical Mission Elements - Force Calculations

The forces during these flights were calculated in the following ways:

Takeoff: $F_{thrust} - F_g = m_{sys} * a_{sys} \rightarrow F_{lift} = g * m_{sys} * (\frac{a_{sys}}{g} + 1)$

Landing: $F_{impact} = \frac{W_{sys} * V_{sys}^2}{2 * g * \Delta d}$ PRU + Drone $\longrightarrow$ 2255 N

The force upon landing with the full system is by far the largest, so this is what to use for the maximum force in FEA and other calculations.

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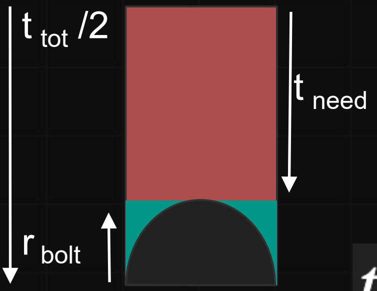
Striker Bolt Mounting

Striker bolt mounting calculations

$$\sigma_{tearout} = \frac{F}{A}$$

$$A = t_{need} * d_{bolt} + (r_{bolt} * d_{bolt} - \frac{1}{2} * \pi * r_{bolt}^{2})$$



$$F_{impact} = 2254.99\ N \qquad r_{bolt} = 2\ mm,\ d_{bolt} = 4\ mm$$

$$\sigma_{yield} = 8.03 * 10^{7} \xrightarrow{\text{For FOS = 3}} \sigma_{target} = 2.7676 * 10^{7}$$

$$t_{need} = 5.3\ mm \rightarrow t_{tot} = 14.6\ mm$$

E1	All structural components will be designed to withstand all forces throughout the mission without yielding to a reasonable FOS.

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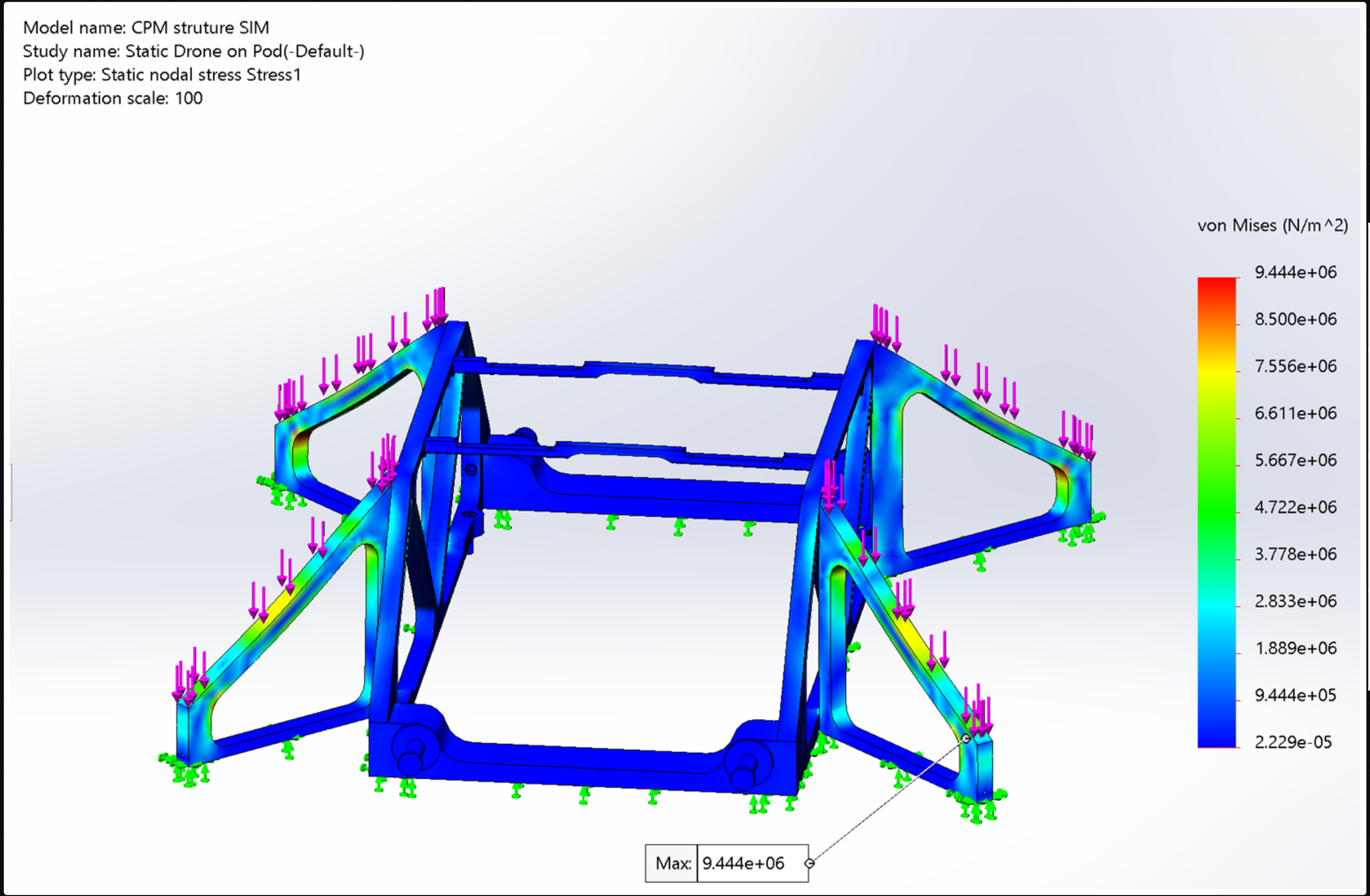
CPM Structure - Resting Landing Force



Total Load:	NDA
Truss:	6061-T6
Striker Bolts:	Alloy Steel
FOS_{MIN}	25.52

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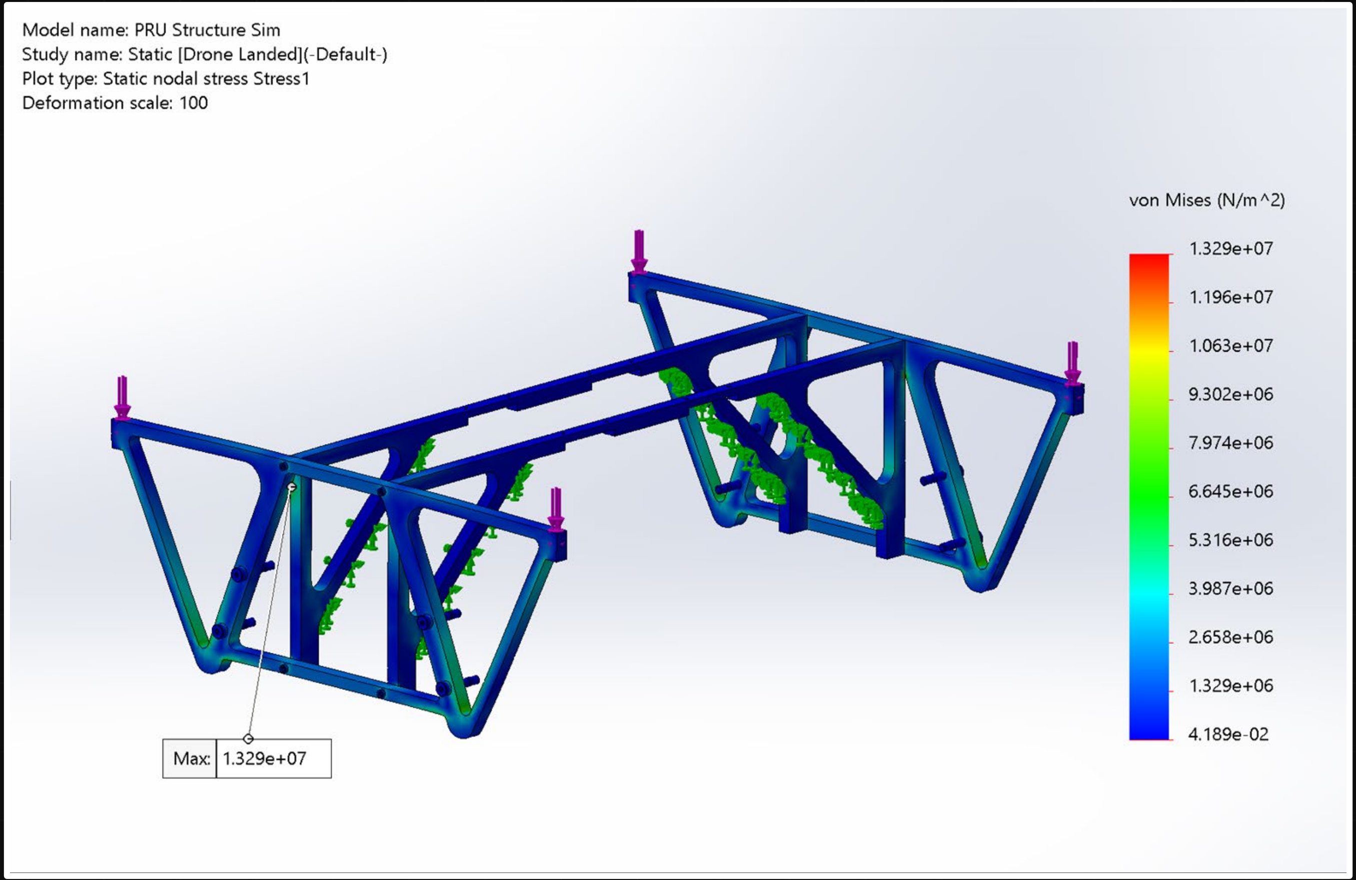
PRU Structure - Resting Landing Force



Total Load:	NDA
Truss:	6061-T6
Latch Bolts:	Alloy Steel
FOS_{MIN}	18.13

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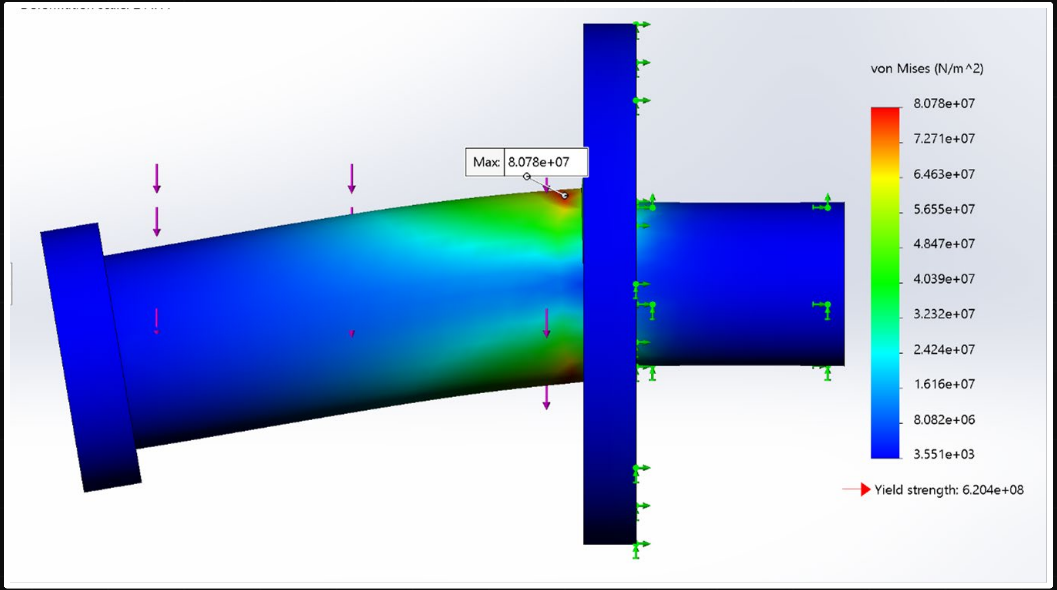
Striker Bolt FEA - Landing 0.5m/s d=5mm



Part	Material	Yield Strength
Latch Bolts	**Alloy Steel**	**415 MPa [8]**

FOS_{MIN}	7.68

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Landing Rubber Feet Analysis (Cody)

For reasons of protecting DROPS' Non - Disclosure Agreements,
we are unable to discuss details on the details on the
forces expected on the pod damping feet.

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Small Scale Proof of Concept

Connection & Control	Demonstrate the ability to control the connection of the DROPS system after the alignment of UAV

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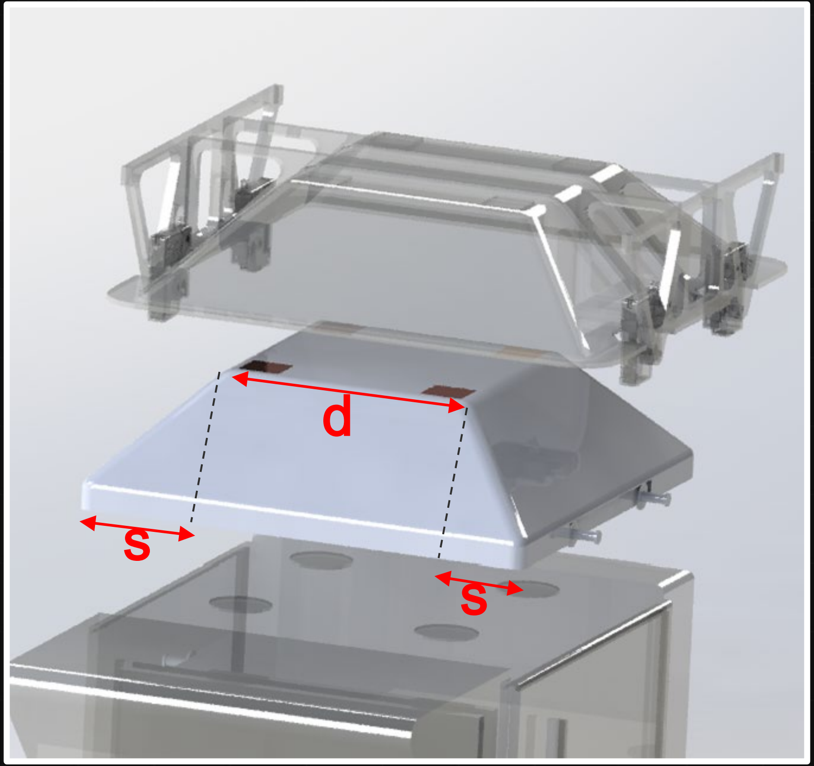
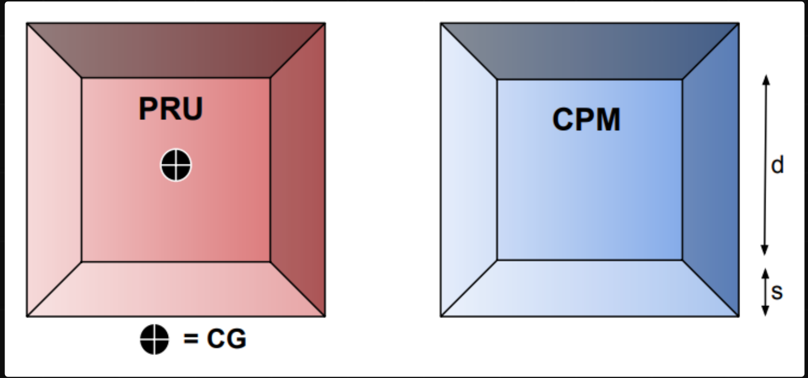
CPM/PRU Slot Slope Surface Area Analysis



S: Horizontal length of slope
(Defines accuracy requirement)

d: Length of top portion
(Defines stackability)



Top View

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Secondary Alignment/Autonomy Update

Autonomy will no longer be considered for the scope of our project, but will be considered in design decisions for future applications. Human operators and pilots will be utilized our demonstrations/tests.

Visual Alignment System: Planck Aerosystems

- Primary consideration for visual alignment system in combination with UAV control
- Alignment tolerance will be based on this system capability

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Slot Slopes Material Study

Alignment Decision Matrix

Categories	Manufacturability	Coefficient of Friction	Density (g/cm^3)	Interference with other subsystems	Lead Time	Scratch Hardness	
Weight	0.25	0.15	0.2	0.15	0.15	0.15	Total
PolyCarb	2.5	2	2.5	2.5	3	2	2.55
G10	2	2.5	2	2.5	2.5	2.5	2.4
Fiber Glass	1.5	2.5	2	2.5	2.5	2	2.2
Carbon Fiber	2.5	2	2.5	1	2.5	1.5	2.175
Acrylic	1.5	2	2.5	2	2.5	1	2
Aluminum 6061	1.5	1	1.5	1	3	2.5	1.8

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Manufacturing Options

Polycarbonate

Pros:

- 0.31 COF
- Modification Ability
- 3D Printing
- Impact Resistance (9500 psi)
- Minimal Attenuation

Cons:

- Possibility for material expansion
- Less scratch hardness
- Cost to manufacture in small quantities

Self - Manufacturing (G10/Hybrid)

Pros:

- 0.275 COF
- Access to sheets of material
- Tensile Strength
- Minimal Attenuation
- Less cost

Cons:

- More complex manufacturing for team
- Possibility of Fracturing
- Increased Weight
- Lower tolerances in alignment error

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Feasibility: Slot Slopes Material Study

Determine: Minimum slot slope angle θ for weight of PRU to overcome static friction force to passively align itself

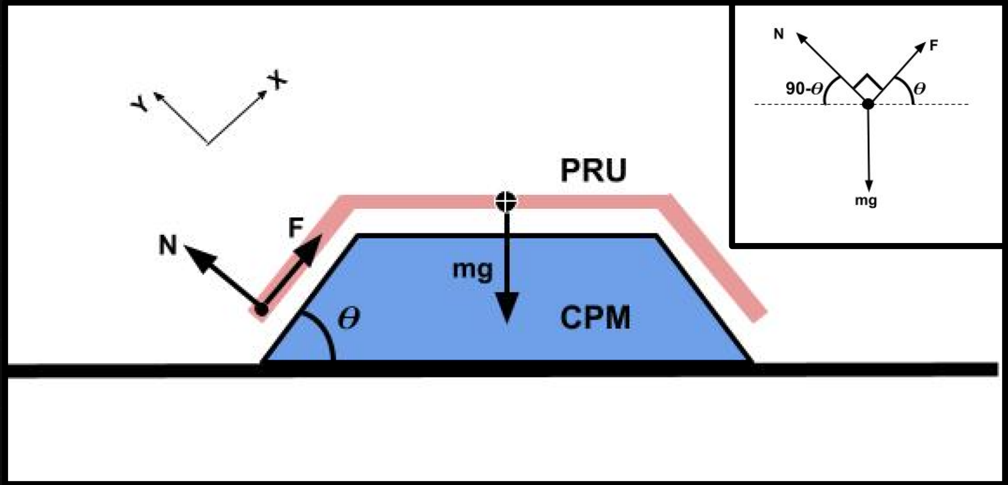
$$\Sigma F_y = N - mg\cos(\theta) = ma_y$$
$$\Sigma F_x = f - mg\sin(\theta) = ma_x$$

$$\Rightarrow \Sigma F_y = N - mg\cos(\theta) = 0$$
$$\Rightarrow \Sigma F_x = f - mg\sin(\theta) = 0$$

$$\Rightarrow N = mg\cos(\theta)$$
$$\Rightarrow f = mg\sin(\theta) = \mu N$$

$$\Rightarrow \mu mg\cos(\theta) = mg\sin(\theta)$$

$$\Rightarrow \boxed{\mu = \tan(\theta)}$$



For PC $\mu = 0.31$ | $\theta > 17$ degrees

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Alignment Review

Square Slotted Slopes Design

- Passive Alignment as UAV descends vertically
- Allows for centering offset of 10cm
- Allows for yaw offset of 20 degrees
- Provides sufficient space for electronics/power outside of Pod
- Stackable surface
- Truss structure for square slopes provides more rigidity

Friction Reevaluation

- Momentum of UAV/PRU system will allow for more significant tolerance within centering/yaw offset
- Overcoming the static friction models completed in PDR
- Professor advice about COF
    - The COF is just as important as the scratchability of the material which would cause friction to play more of a role

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Weatherproofing

CPM/Pod

- Electronics will be sealed by CPM slot slope design
- Any imperfections will be filled with epoxy for extra protection
- Planning for occasional human maintenance to ensure no foreign debris

PRU/UAV

- Currently, PRU system is more exposed than CPM system due to inverse design
- Working on design alongside with UAV mount to minimize weather effects
    - Solutions include layered cover/protection wrap
- Human maintenance is also encouraged in design

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CPM to Pod bolt trade study

Bolt Type	F max_T (N)	F max_shear (N)	FOS_t	FOS_s
M4	1980	1680	6.45	5.48
M5	3200	2730	10.43	8.90
M6	4520	3860	14.74	12.58

4x M6 bolts in square pattern bolted through CPM Spars, CPM bottom plate, into threaded aluminum on Pod

Loads:

- 5G vertical load
  - 55lbs = 25Kg*5*9.81 = 1227 N
- 5G shear load
  - 55lbs = 25Kg*5*9.81 = 1227 N * 3 FOS

Math:

FOS_t = F_max_T/(1227/4) = 1980/306.75, 3200/306.75, 4520/306.75 = 6.45, 10.43, 14.74 -> all feasible!

FOS_s = F_max_s/(1227/4) = 1680/306.75, 2730/306.75, 3860/306.75 = 5.48, 8.90, 12.58 -> all feasible!

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CPM to Pod connection

4x M6 bolts in square pattern bolted through CPM Spars, CPM bottom plate, into threaded aluminum on Pod

Loads:

- 5G vertical load
  - 55lbs = 25Kg*5*9.81 = 1227 N * 3 FOS = 3678.75 N / 4x bolts = 920 N/bolt < M6 4.6 class bolts proof load = 4520 N → feasible
- 5G shear load
  - 55lbs = 25Kg*5*9.81 = 1227 N * 3 FOS = 3678.75 N / 4x bolts = 920 N/bolt < M6 4.6 class bolts thread in shear = 3860 N → feasible

30 x 21.5 cm

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CPM to Pod Bolt Analysis/Decisions [tension/tearthrough]

Max force on bolts (from PDR,Cody's analysis): 10.5 kN

Modeled as ½ area of the M8 bolt pressing down into material: 1.25*10^-4 m^2

Total force: 251.297 MPa/bolt

POSSIBLE MATERIALS:	Yield Strength/3	Area necessary	Area minus minimum	Length necessary above the bolt fixture
Aluminum T6061-6	8.03E+07	2.81E-05	2.12E-05	5.30E-03
Easy-to-Machine 416 Stainless Steel	9.17E+07	2.46E-05	1.77E-05	4.43E-03

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Connection Backup Slides

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Connection Backup Links

Primary Project Objective - Structure

Connection & Control - Latches

How to Command Latches

Mounting Methods

Connection CONOPS

Power and Info Passthrough

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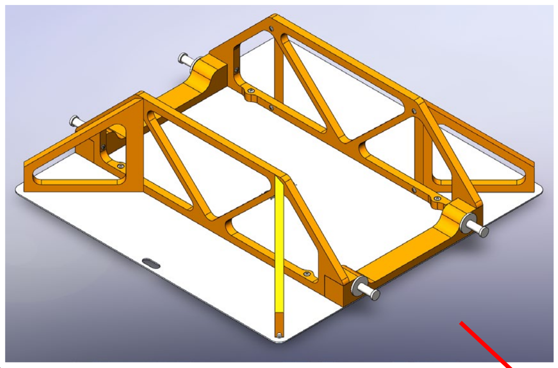
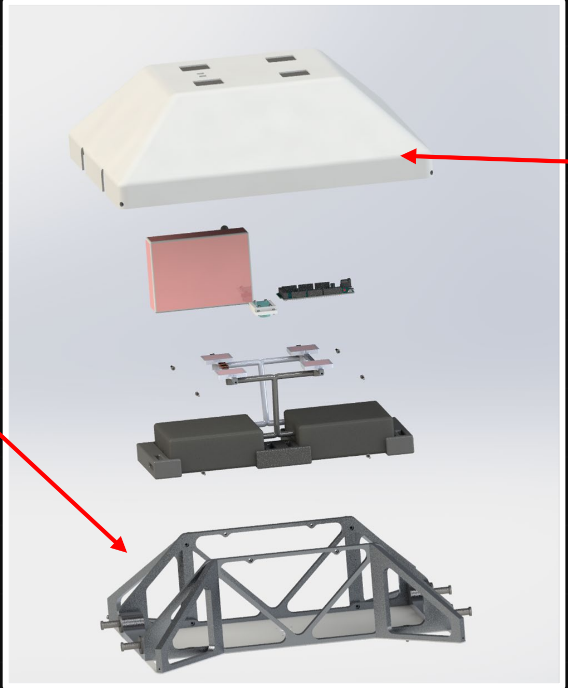
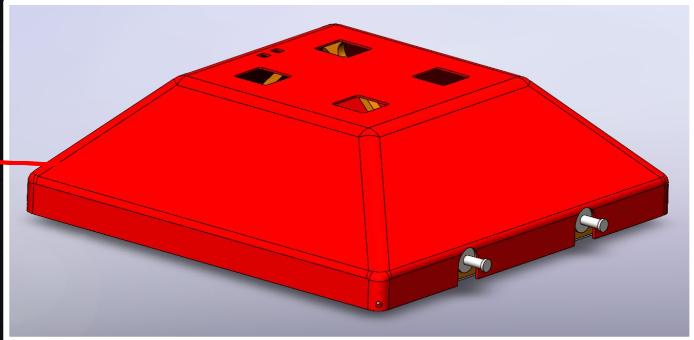
CPM Structures & Alignment Design

Structures	Demonstrate the structure of the DROPS system will be able to withstand forces in landing, alignment, flight, and takeoff







CPM Inner Truss Structure:

Supports weight of drone

Withstands forces during takeoff & landing

Manufactured with 1 cm thick aluminum material

Outer Sloped Structure:

Aids in alignment

Provides cover for internal components

Manufactured with polycarbonate material

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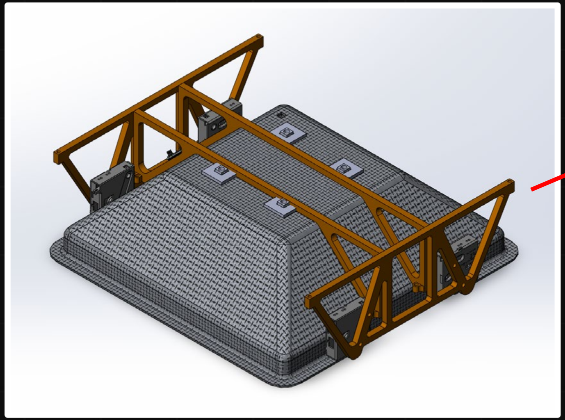
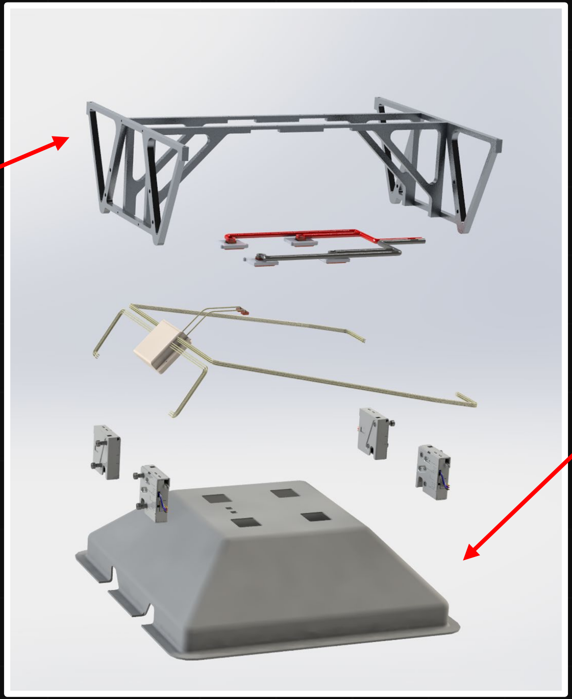
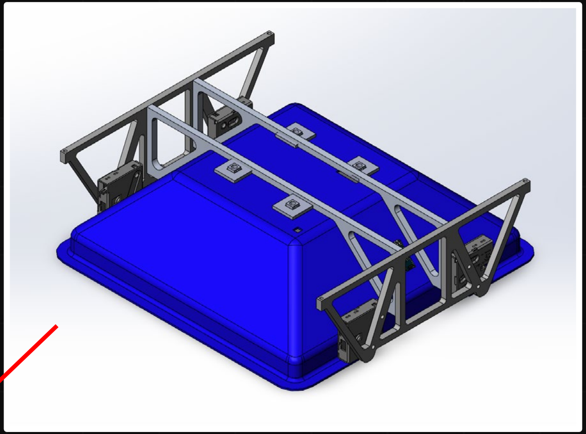
PRU Structures & Alignment Design

Structures	Demonstrate the structure of the DROPS system will be able to withstand forces in landing, alignment, flight, and takeoff







PRU Truss Structure:

Withstands forces during takeoff & landing

Manufactured with 1 cm thick aluminum material

Inverted Sloped Structure:

Aids in alignment

Provides space for internal components

Manufactured with polycarbonate material

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Connection & Control

SouthCo Electromechanical Rotary Latch [R4 - EM72- 161]

- Delayed Relock: Locked/Unlocked Control
- Latch Status Communication Protocol
- Sealed Electronics for Outdoor Applications

SouthCo Rotary Latch Striker Bolt [R4 - 90- 121- 10]

- Simple M8 Striker Bolt for Latch Attachment
- SouthCo Latch Compatible
- Sufficient Thread Length

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Latch Information

- Side- trigger easier to access but leaves wires exposed to damage, not as ideal as rear trigger … but in stock and quick responses of industry (lesson learned)
- Latch status only available; door status would require larger magnetic bolt
- No extrusion on latch means PRU is seated lower onto CPM
- Minimal force to close latch (4kg)
- Power draw of 12V, control draw of 5V (confirmed)

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How to Command Latches

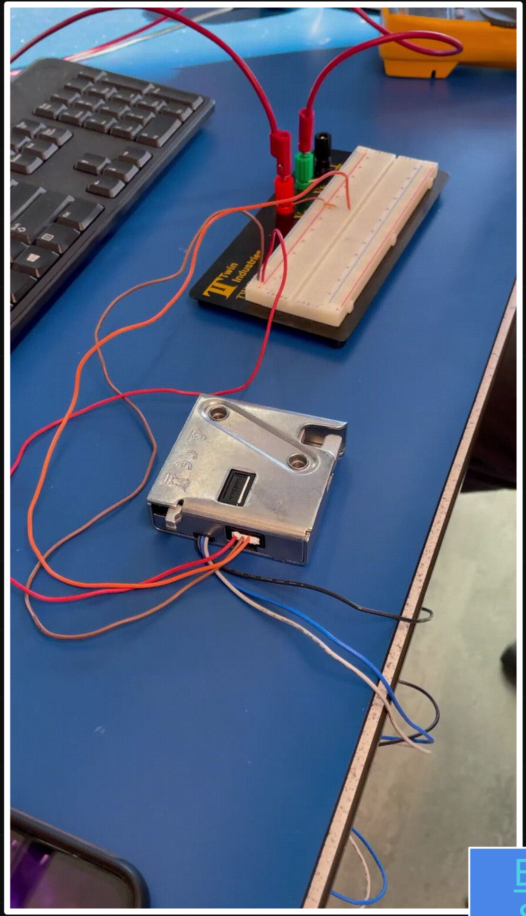
For SouthCo Delayed Relock model electronic latch:

1) Command sent to CPM from GUI

2) CPM Arduino Due communicates via UART to PRU Arduino Nano

3) Arduino Nano sends control signal to each latch

- Latches remain unlocked for as long as control signal is high (minimum 20 ms)
- Latches lock after control signal is low (minimum 50 ms)



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CPE 3: Communication Timing

PR 7.2	The CPM microcontroller must measure & return the status of all 4 latches to the Due within 1 second

Worst case scenario for timing:

Read either command + respond with an error message [3]

Determined via testing:

1. Reading a command takes **~400 µS + 5 mS** timeout [7]
2. Sending an error response takes **~500 µS**
3. Toggling a pin takes **4 µS**

Total time required: 5 mS + 0.4 mS + 0.5 mS ~= **6 mS << 1 second**

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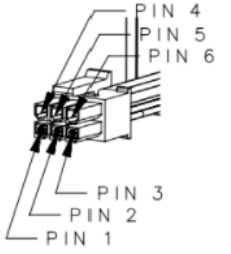
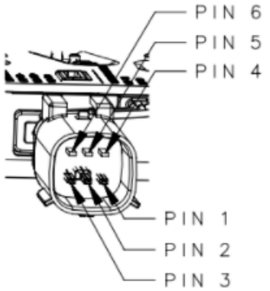
Latch Pin Layout and Control

CONNECTOR PINOUT		
PIN	WIRE COLOR	FUNCTION
1	BROWN	GROUND (-)
2	RED	POWER (+)
3	ORANGE	CONTROL SIGNAL
4	BLACK	SWITCH COMMON
5	BLUE	SWITCH N.O.
6	GREY	SWITCH N.C.



NON-SEALED CONNECTOR
PIN LOCATIONS



SEALED CONNECTOR
PIN LOCATIONS

- MOUN
- MOUN
- MAXI

I. MECHANI
THE LAT
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DEPTH I
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J. STRIKER
STRIKER

K. PACKAGE
EXAMPLE

ELECTRICAL HOOKUP (SWITCH CONTROL)

D. ELECTRICAL OPERATION:
TO UNLOCK OR RELEASE THE LATCH:
PROVIDE THE FOLLOWING CONTROL SIGNAL TO THE ORANGE WIRE OR CONNECTOR PIN 3
- PROVIDE 12 TO 24 VDC (CONTROL SIGNAL HIGH) FOR A MINIMUM OF 50 MILLISECONDS
- THE CONTROL SIGNAL CAN REMAIN HIGH INDEFINITELY
- THE LATCH WILL STAY UNLOCKED FOR A MINIMUM OF 20 MILLISECONDS OR AS LONG AS THE SIGNAL IS HIGH
TO LOCK THE LATCH:
PROVIDE THE FOLLOWING CONTROL SIGNAL TO THE ORANGE WIRE OR CONNECTOR PIN 3
- PROVIDE CONTROL SIGNAL LOW FOR 50 MILLISECONDS. POWER MUST BE AVAILABLE DURING TRANSIT TO LOCKE
NOTE:

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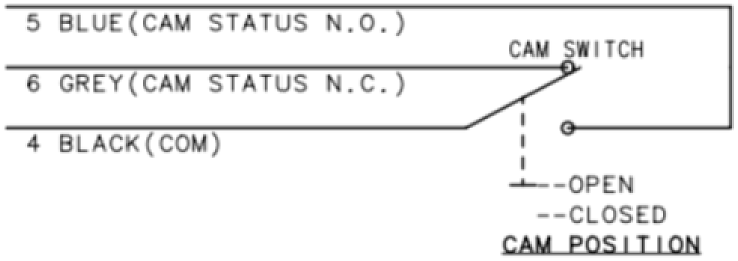
Latch - Cam Status Circuit

S=6 SINGLE SWITCH (CAM ONLY)

CAM STATUS INDICATOR CIRCUIT

	CAM POSITION	
	CAM OPEN	CAM CLOSED
BLACK/GREY WIRES	CLOSED CIRCUIT	OPEN CIRCUIT
BLACK/BLUE WIRES	OPEN CIRCUIT	CLOSED CIRCUIT



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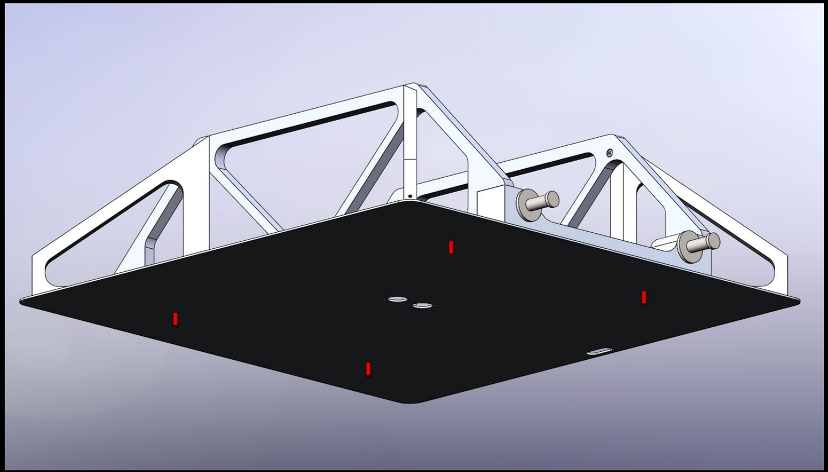
Mounting Methods

CPM to POD Mounting

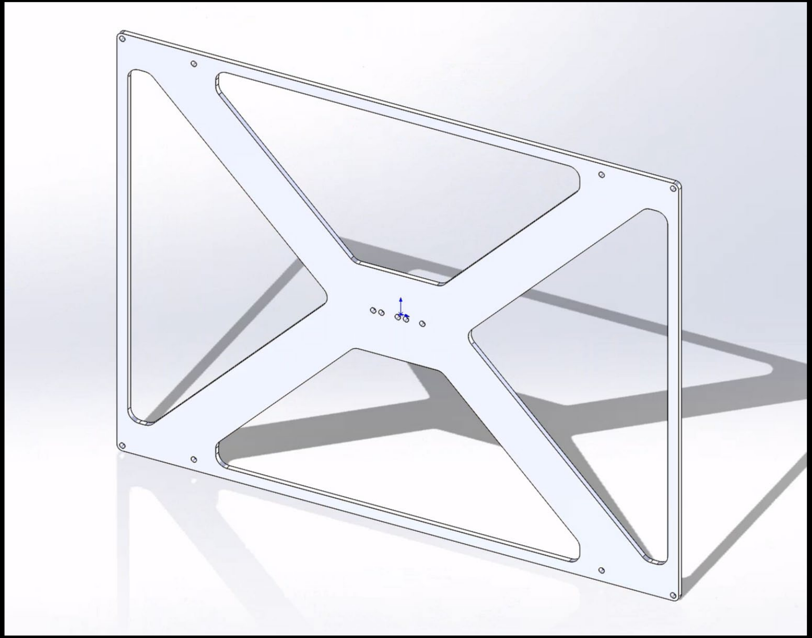


4 Fixed M4 Bolts Pattern from CPM to Pod in square pattern

920N (Max Experience Load)

< 4520N (Max Spec Load)

PRU to UAV Mounting



Adaptable Mounting Plate based on UAV Design with M4 Bolts

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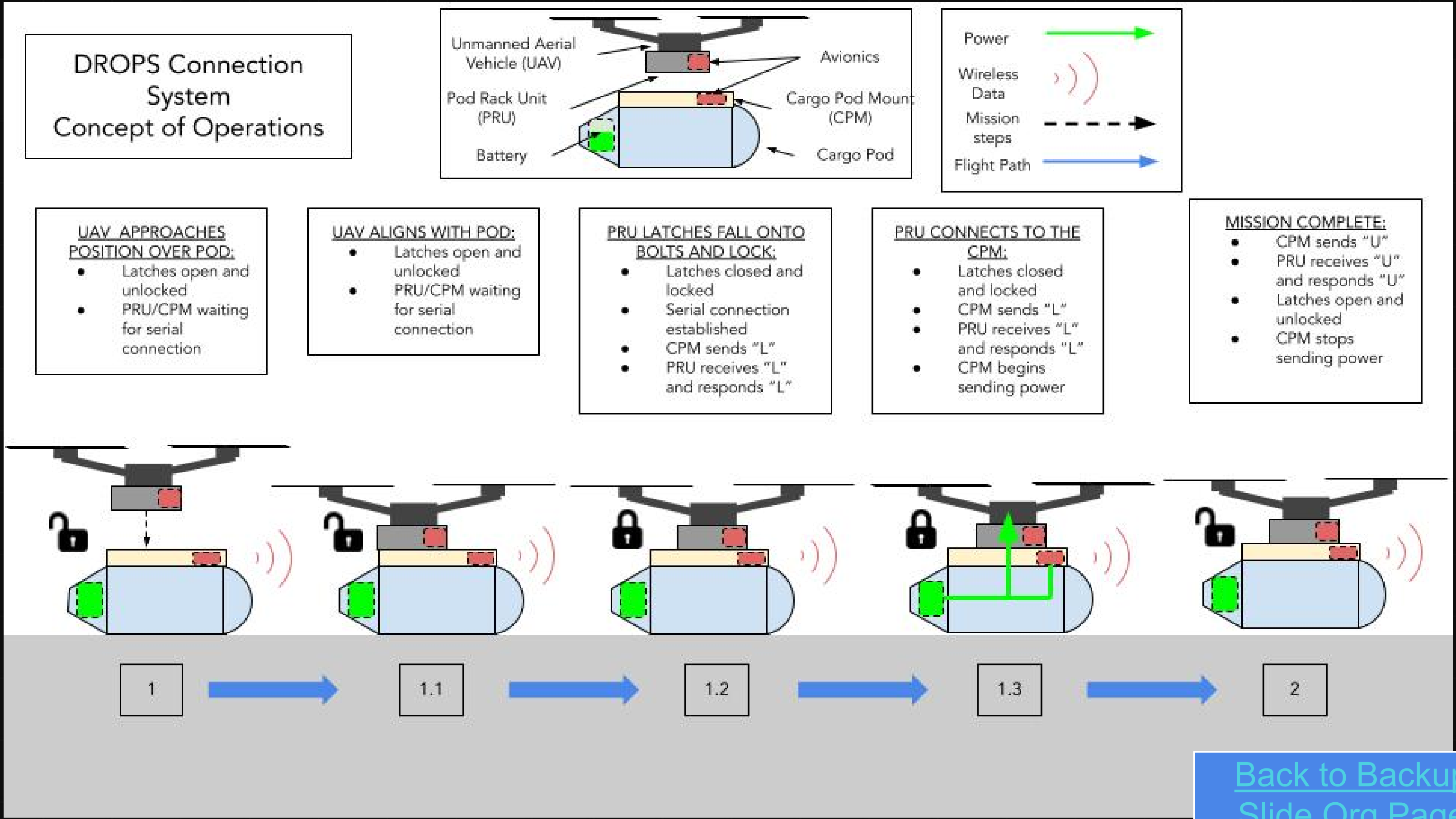
Connection CONOPS



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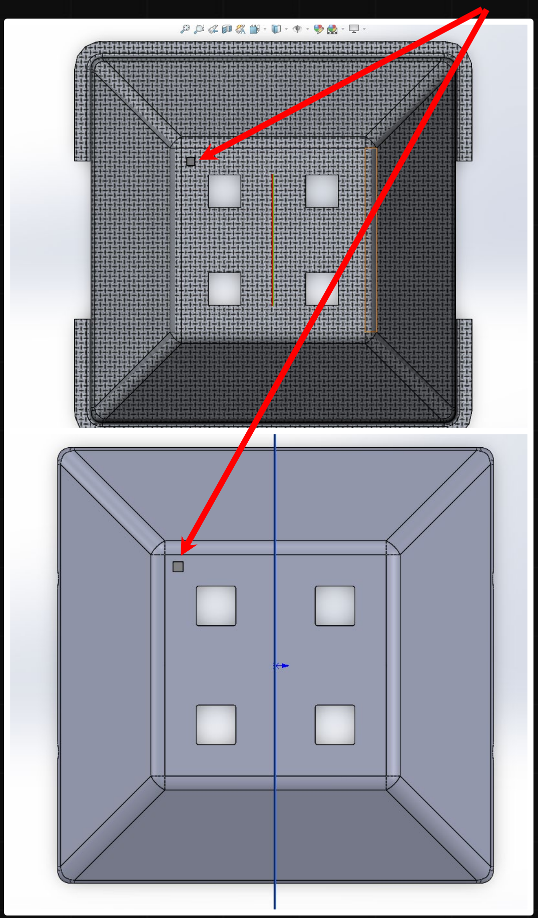
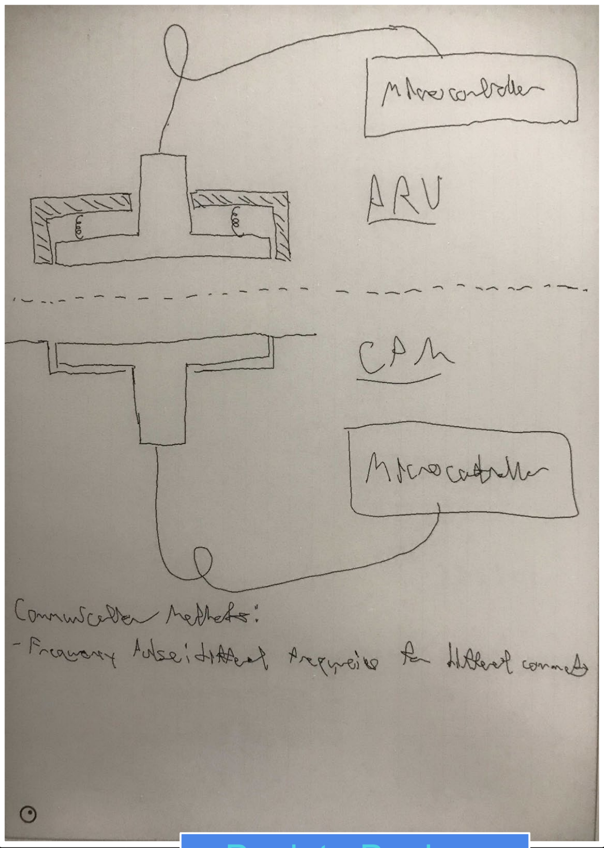
PWM & Information Passthrough (PIP)



- PRU to CPM passive connection for data transfer
- Uses PWM signals to communicate between two microcontrollers
- Used to check landing, latching, and activating power passthrough



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CPE 3: PRU to CPM Communication

PR 7.1 & PR 3.2	The CPM microcontroller must send a trigger command to the PRU microcontroller which must receive & execute the command & return status of the latches to the CPM microcontroller

Command:	Description:	Action:
"L"	Command that tells Nano to lock the cam	Sets control DIO pin high
"U"	Command that tells Nano to unlock the cam	Sets control DIO pin low

Response:	Description:	Action:
"L"	Response from Nano confirming ALL 4 latches are currently locked when commanded to be locked	Write string "L" to serial transmit port
"U"	Response from Nano confirming ALL 4 latches are currently unlocked when commanded to be unlocked	Write string "U" to serial transmit port
"LERR"	Response from Nano stating the one or more latches remain locked when commanded to be unlocked	Write string "LERR" to serial transmit port
"UERR"	Response from Nano stating the one or more latches remain unlocked when commanded to be locked	Write string "UERR" to serial transmit port

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PRU to CPM UART RS232 Communication

Full - duplex serial coms

- List of commands
  - "Latch"
    - Command sent from **GUI -> CPM -> PRU** to tell the Arduino Nano to send **high signal** to all 4 latches
  - "Unlatch"
    - Command sent from **GUI -> CPM -> PRU** to tell the Arduino Nano to send **low signal** to all 4 latches
- List of Status Replies
  - "Locked"
    - Signal sent from **PRU -> CPM -> GUI** to tell the user that the latches are all **closed and locked**
  - "Unlocked"
    - Signal sent from **PRU -> CPM -> GUI** to tell the user that the latches are all **open and unlocked**
  - "UERR"
    - There was an **error unlocking all latches** - one or more latches are still sending a "locked" signal
  - "LERR"
    - There was an **error locking all latches** - one or more latches are still sending an "unlocked" signal

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Power Backup Slides

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Power Backup Links

High Power Input/Output

Contact Mechanism

Copper Material Study

Induction Charging (117 - 120)

Induction Charging - Material Heating

Bottom of Pod Material Study

High power connector y - junction

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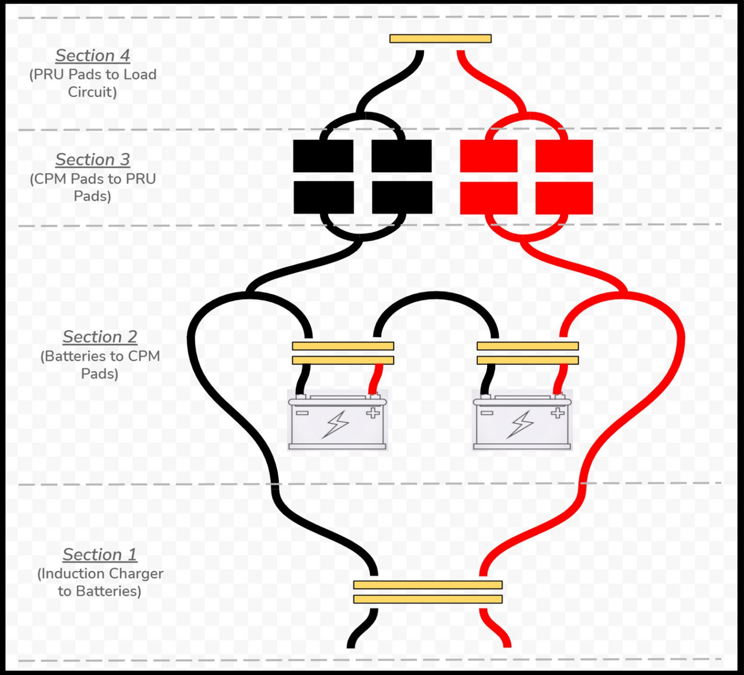
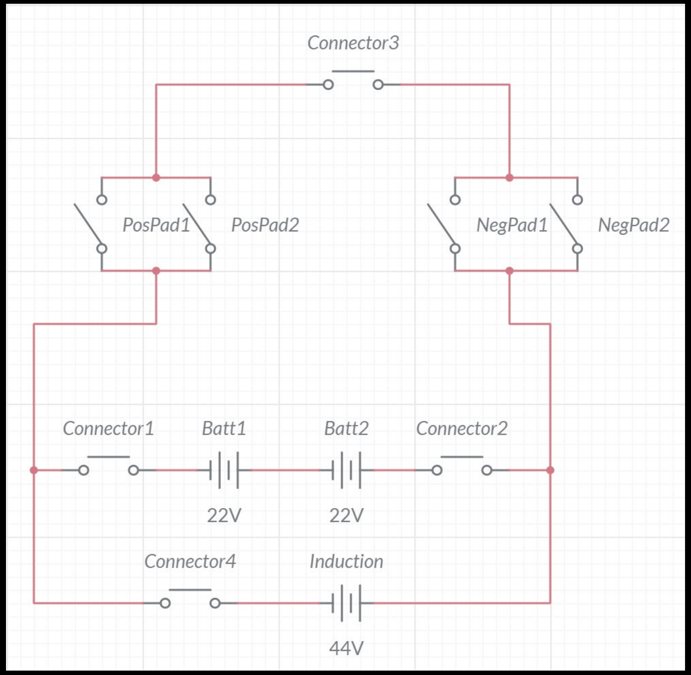
High- Power Input/Output



(High - Power Wiring Diagram)



(High - Power Circuit Diagram)

Important Note : ***Out of project scope*** *to* ***simultaneously*** *test battery induction charging and battery discharging to load circuit.*

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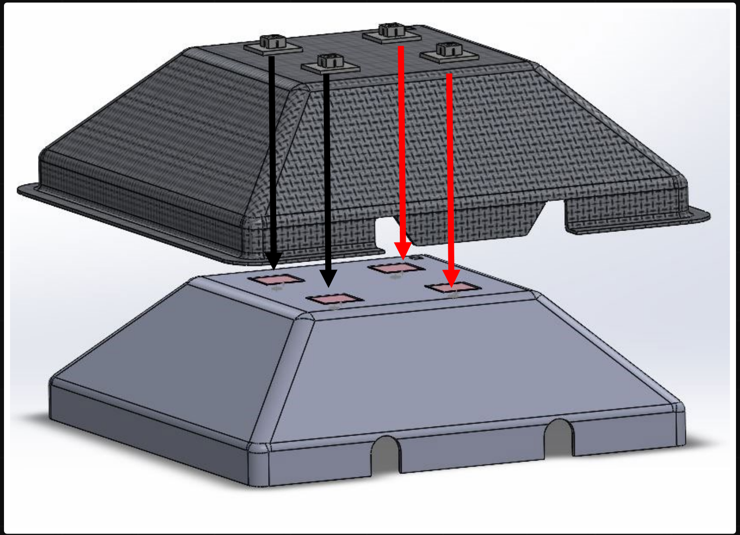
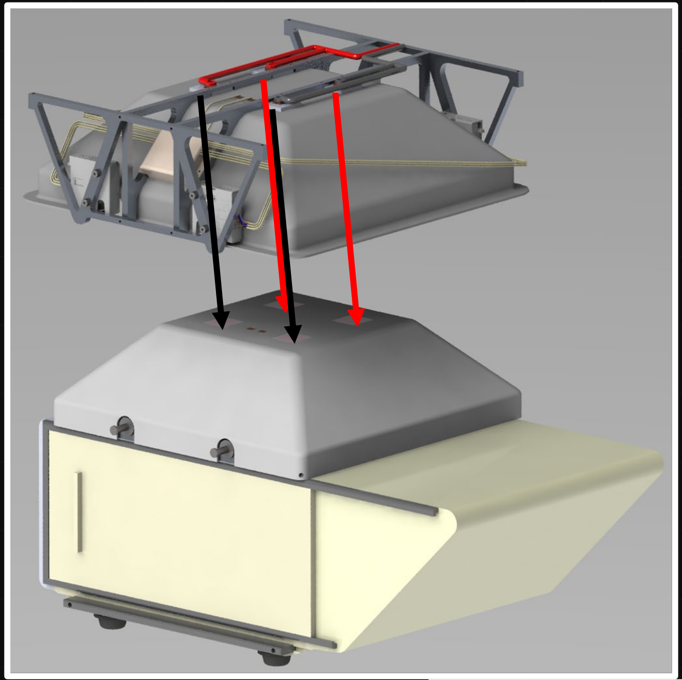
High- Power Contact Mechanism

Power Passthrough	Simulate power transfer from rechargeable batteries, through the DROPS system, to a UAV





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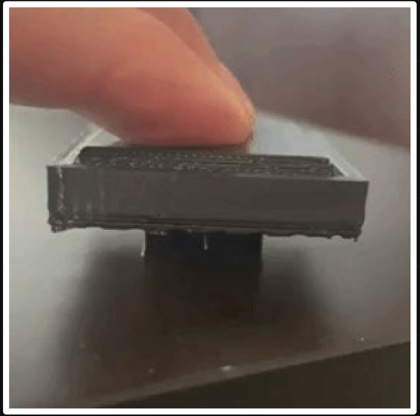
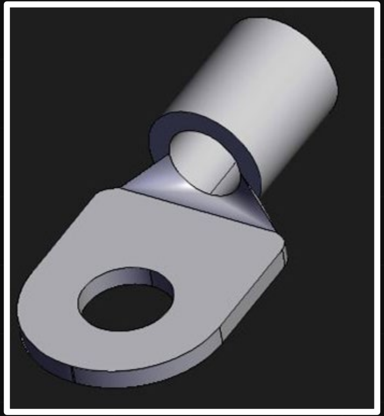
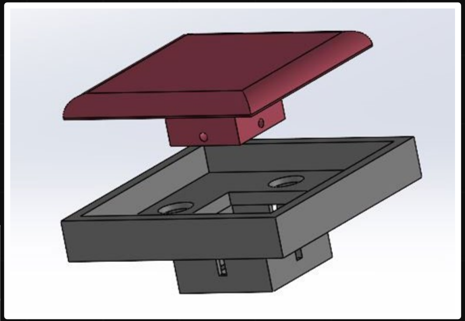
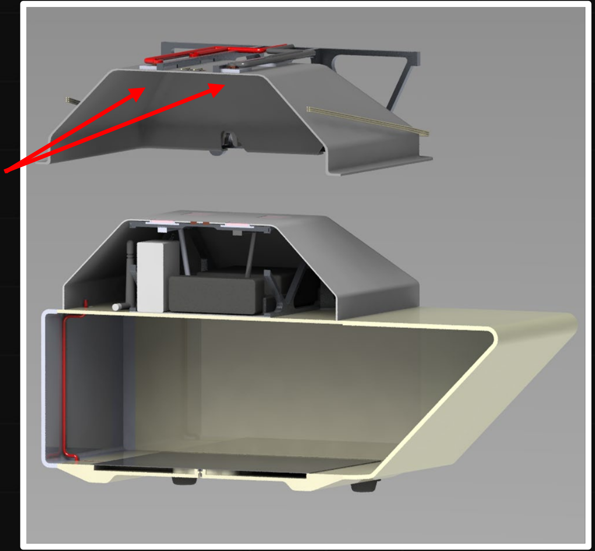
High- Power Contact Mechanism

Power Passthrough	Demonstrate power transfer from rechargeable batteries, through the DROPS system, to a UAV









Part	Material	Source/Manufacturing
PAD Mount	PLA Plastic	3D-Printed
Copper PAD	Copper Alloy	Machining
Ring Terminal	Copper Alloy	Commercially Available

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Copper Material Study

- Copper 145 (Machine Grade): Manu rating: 85, k: 355, elec con: 0.539
- Copper 17510 (Beryllium Cu): Manu rating: 80, k: 207, elec con: 0.281
- Copper Tungsten (Elkonite): Manu rating: 70, K: 260, elec con: 0.648

- After trading and consulting with Cameron (ITTL Engineer):

Copper 145 was decided due to ease of machining, weight constraints, and conductivity

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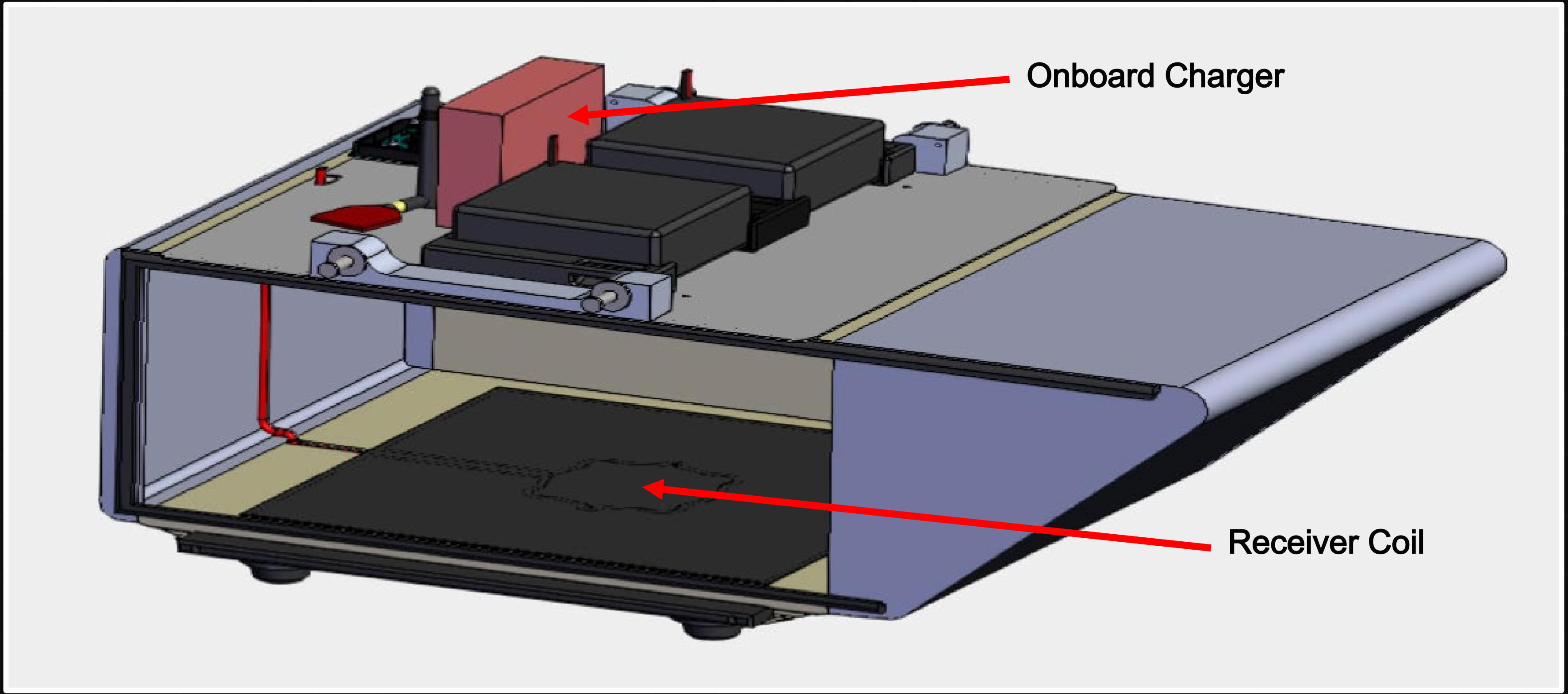
Induction Charging



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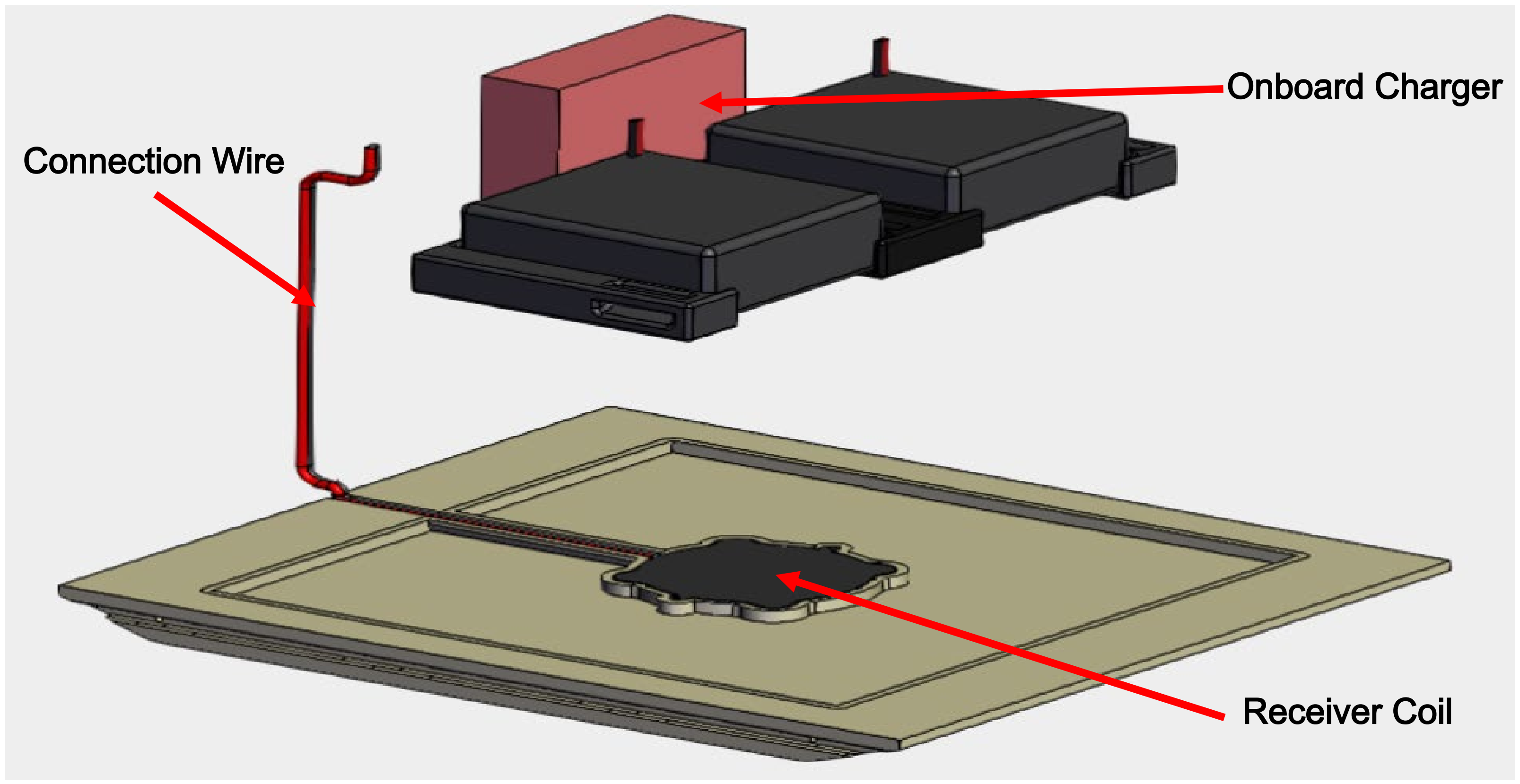
Induction Charging



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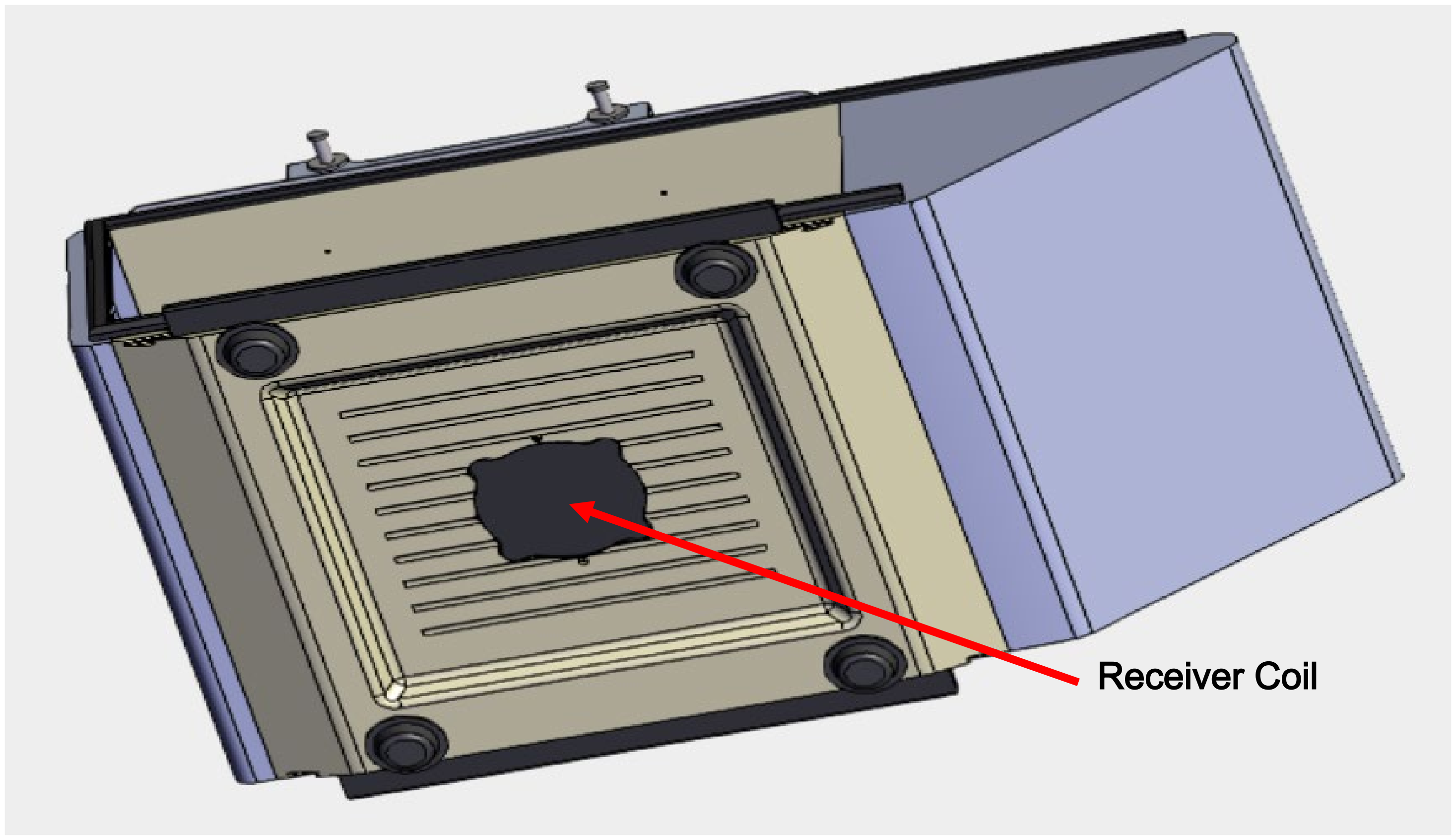
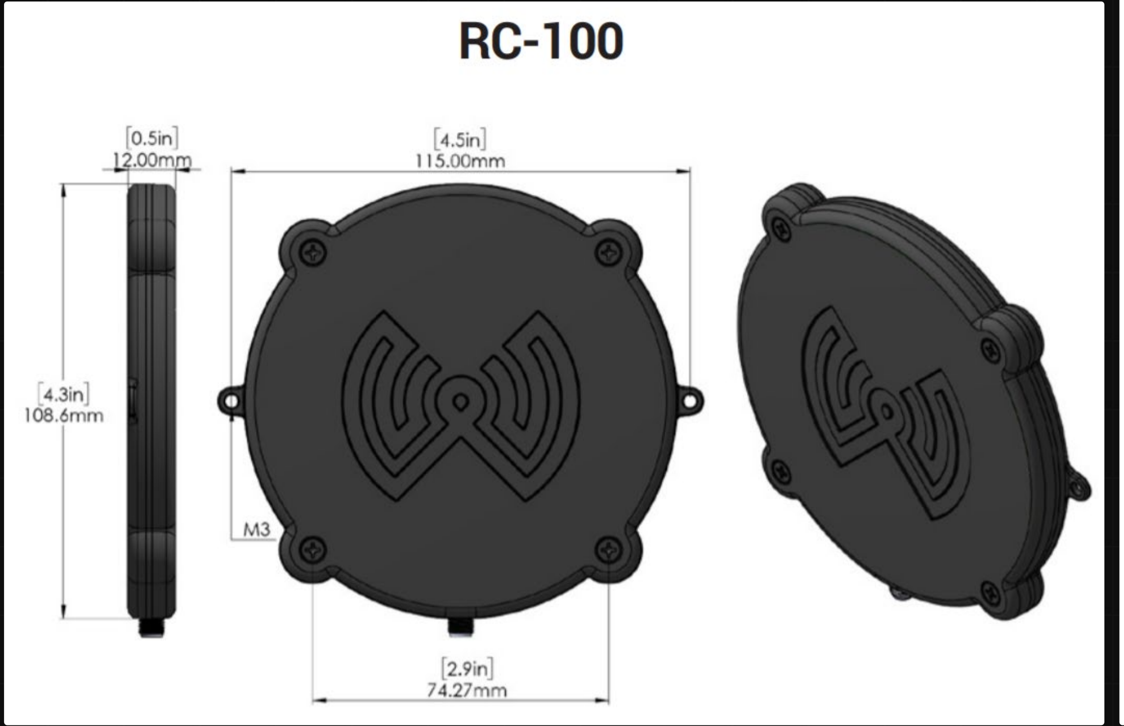
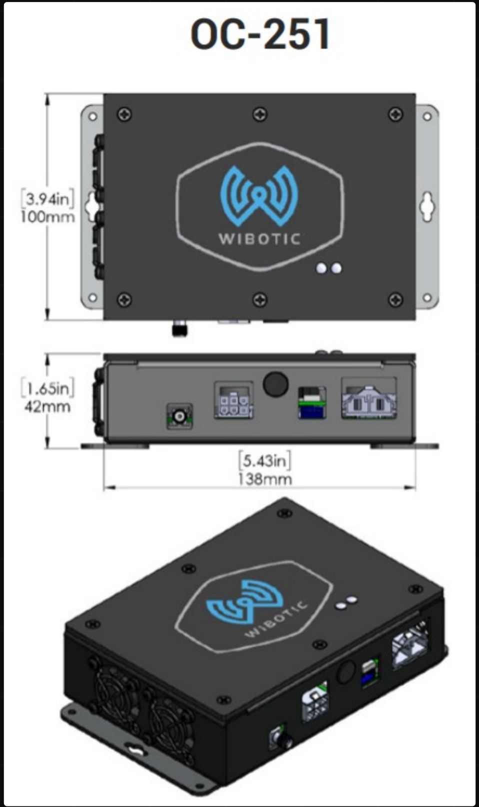
Induction Charging



Induction Charging





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Induction Charging

- Components
  - Receiver Coil
  - OC251 Charger
  - 12awg Cables
- Specs
  - Current - 6.5 Amps
  - Max Voltage - 58.4 Volts
  - Max Charge Power- 250 Watts
  - Weight - 362 grams

- High frequency fields induce AC charge in receiver coil that is passed through to the OC 251 Onboard Charger
- Charger rectifies and converts AC power to desired DC output
- Digital Board on charger communicates with transmitter to provide safe charging
- Charger outputs 38.4 - 50.4V at 6.5A with max power of 250W

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Induction Charging: Material Heating

Key Assumptions

1. Only eddy current power heating
2. Frequency of magnetic field approximately 6 MHz
3. Skin effect equation used for penetration depth
4. Simplified induced current

Power Heat Model:

$$H = P(t)t$$

$$H = I_{rms}^2 R t$$

Current Model:

I = Induced Current (A)
I_0 = Surface Current (A)
z = distance below surface (m)
δ = penetration depth (m)
ρ = resistivity (Ω m)
μ = Permeability (H/m)
F = frequency (Hz)

$$I = I_0 e^{\frac{-z}{\delta}}$$

$$\delta = \sqrt{\frac{\rho}{\pi \mu f}}$$

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Bottom of Pod Material Selection

Material	Density (g/cc)	Machinibility	Dielectric Strength (V/mil)	Cost ($/sq ft)	Young's modulus (psi)	Tensile Strength (psi)
Acrylic	1.39 - 1.43	Easy	431.8 - 672	28.26	17,000	11,030
High Density Polyethylene	0.963		500.38 (varies a lot)	18.59	318,000	4,000
Polycarbonate	1.19	Easy	378		340,000	9500
Noryl	1.09 - 1.11	Easy	500		370,000	9,600
G-10	1.8	Medium	350-450		2,400,000	38,000
GPO-3 Thermoset	1.7-2.5	Medium	400	Low	1,500,000	8,000 - 11,000
Polycarbonate 20% glass filled		Easy			800,000	16,000

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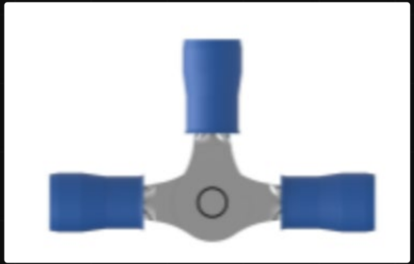
High- Power Connector/Y- Junction Specifications

Connectors:

- Rated for 6-12 Gauge
- 50A limit
- $12.99/pack of 4 pairs

Y- Junction:

- 3 ring terminals
- Crimp to each wire lead
- Bolt/nut attachment at junction
- Not purchasing 3-way wire splice (ring terminals can serve same purpose)



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Electronics/Data Backup Slides

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Electronics/Data backup links

Data Downlink FBD

Data Downlink Hardware

Data Acquisition Flowchart

Command Packet Flowchart

Serial Connection Flowchart

PRU Flowchart

UI

GUI Mockup

XBee API Packet Definition

PRU Component Integration

PRU Circuit Diagram

CPM Component Integration

CPM Circuit Diagram

Radio/Antenna Specs

Voltage Divider

Buck Converter

RF Protection

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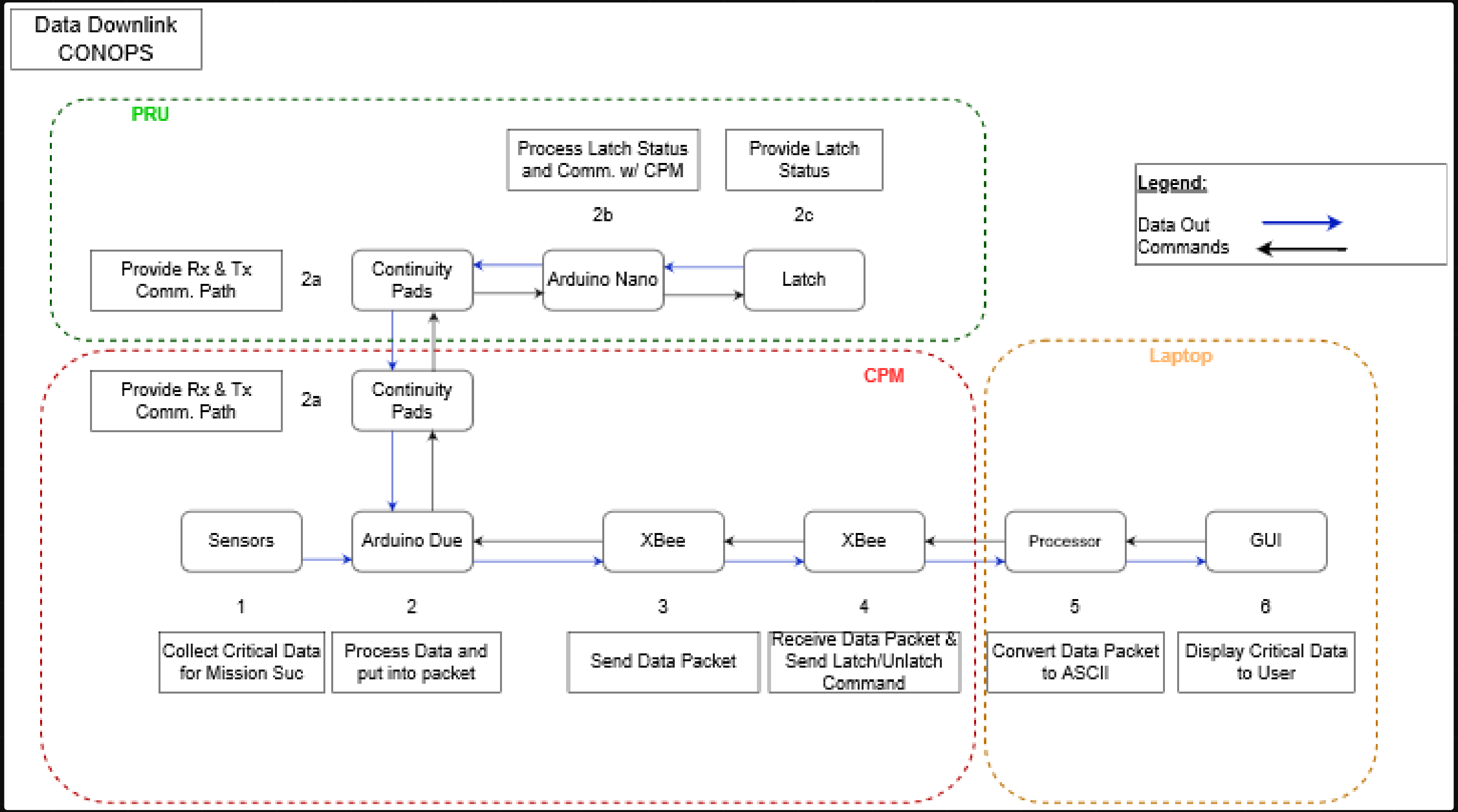
FBD- Data Downlink



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Hardware Details - Data Downlink

Hardware Component	Product Name	Mass (grams)
Cargo Bay Sensor	US - 100 Ultrasonic Distance Sensor	5
GPS	NEO-6P	9.8
Micro-controller (CPM)	Arduino Due	36
Micro-controller (PRU)	Arduino Nano	7
Radio	XBee S3B (900 MHz)	3

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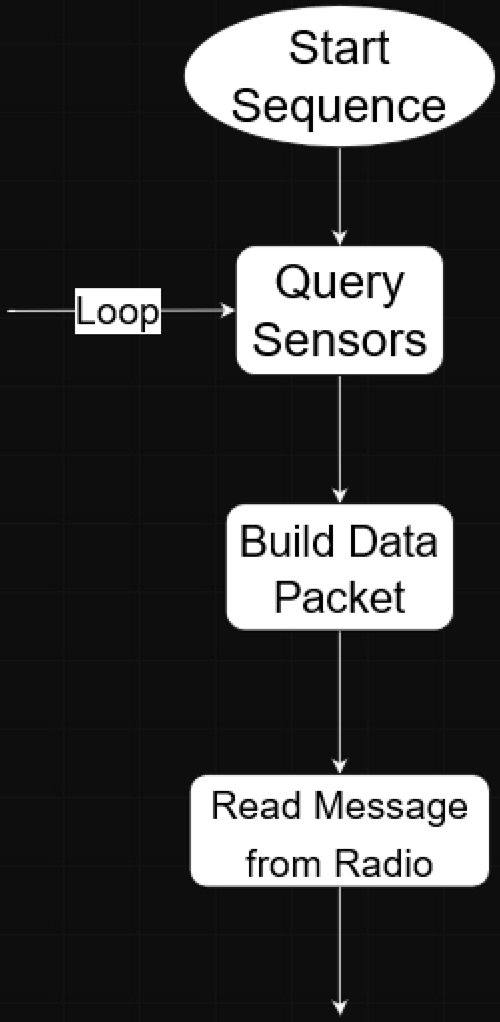
Part 1: Data Acquisition



- The Arduino will query the sensors at 1 Hz for the three sets of data that will be sent
  - Location, Battery Voltage, and Cargo Bay Status
- The Arduino Due will also be looking for a message from the ground station radio
  - This message will be to command the latches to open or close

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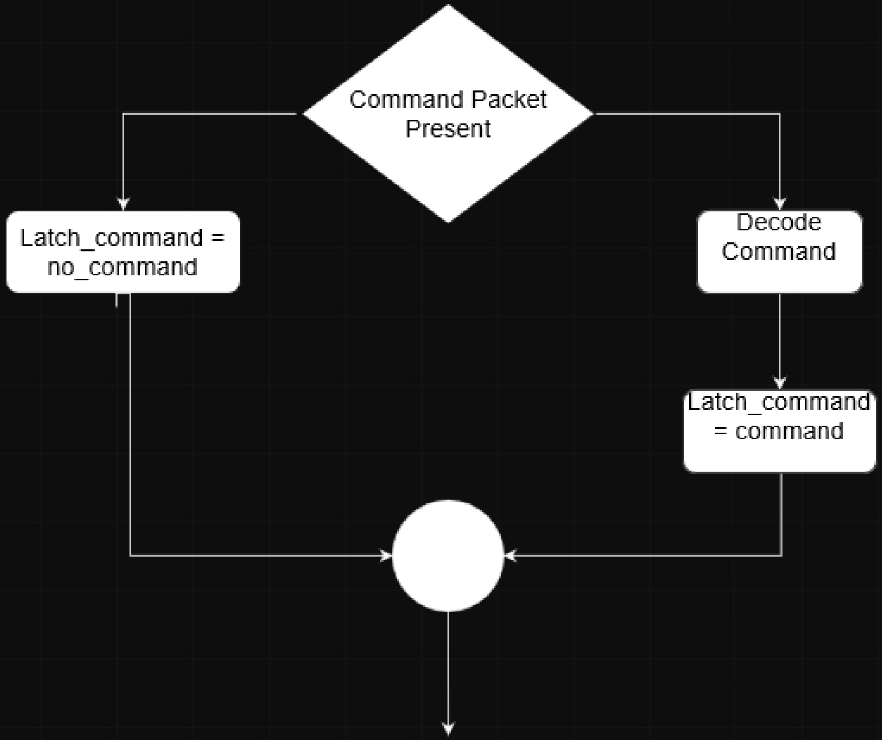
Part 2: Command Packet Present?



- The Arduino will be constantly looking for a command packet from the ground station radio
- There will be two situations, either there is a command or there isn't
  - If a command is present we will decode the packet determine what actions need to be taken

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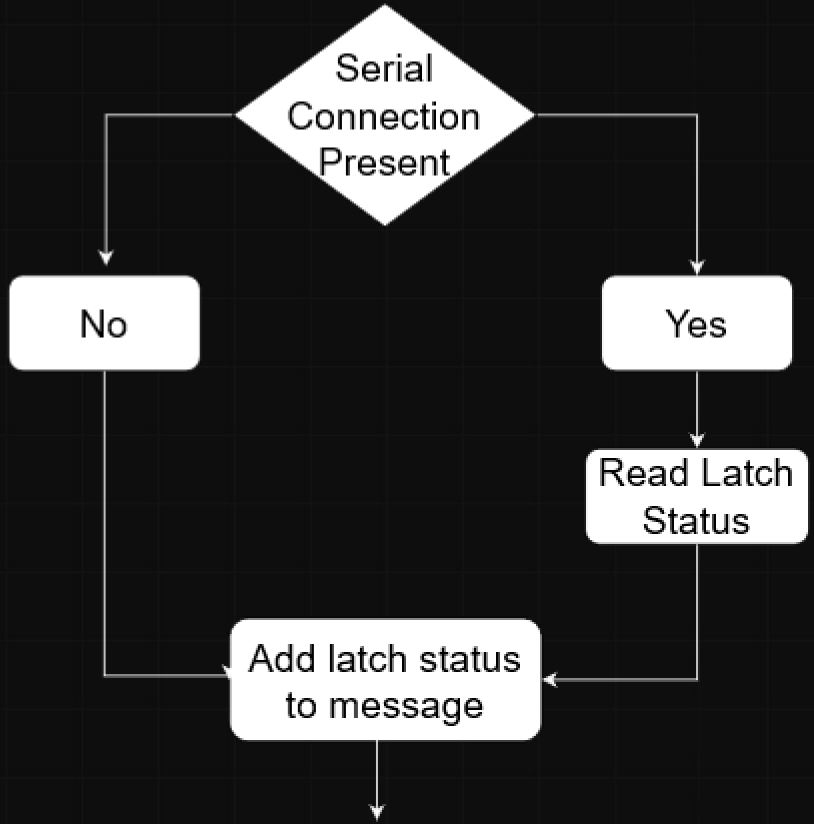
Part 3: Serial Connection Present?



- Electrical connection between the CPM Arduino and PRU Arduino is determined by checking serial connection
- If there is no serial connection, no communication between PRU and CPM occurs

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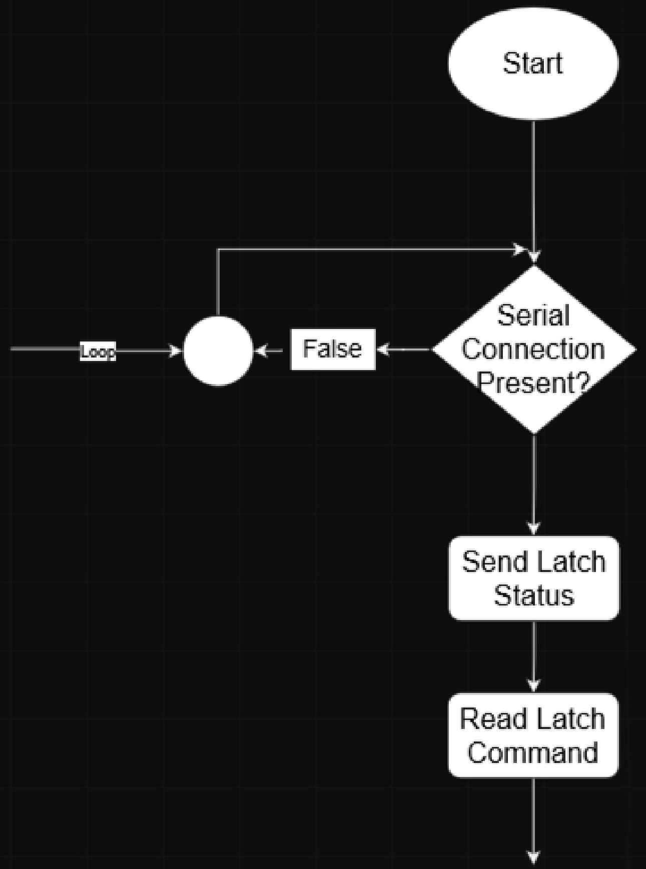
PRU FLowchart



- PRU Arduino will be waiting for serial connection to CPM Arduino
- After connection occurs, PRU Arduino will send latch status, and be able to receive the latch command from the CPM

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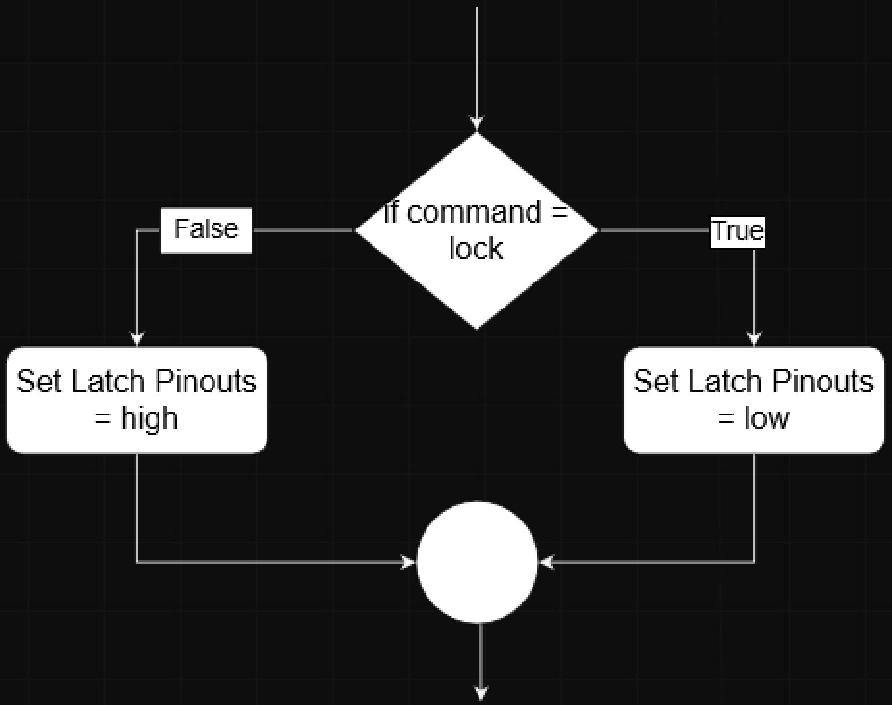
PRU FLowchart



- The PRU Arduino will read the command packet from the CPM
  - If the command is latch we will set the latch pins to low
  - If the command is unlatch we will set the latch pins to high

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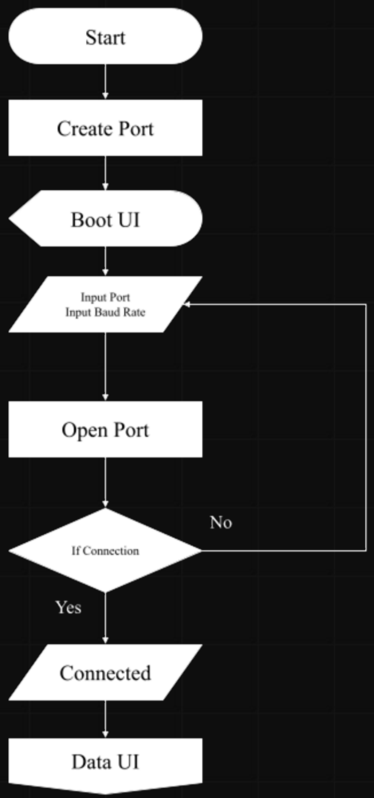
Serial Connection



Serial Connection:

- The PRU Arduino will read the command packet from the CPM
  - If the command is latch we will set the latch pins to low
  - If the command is unlatch we will set the latch pins to high
- Python Algorithms dictate serial connection, connect to local Xbee via user defined serial port and baud rate
  - Xbee is defined as 'Local' and API operating mode
- User inputs are taken from a boot GUI and the connection is tested before proceeding
  - Display if connection is achieved or loop back for new inputs

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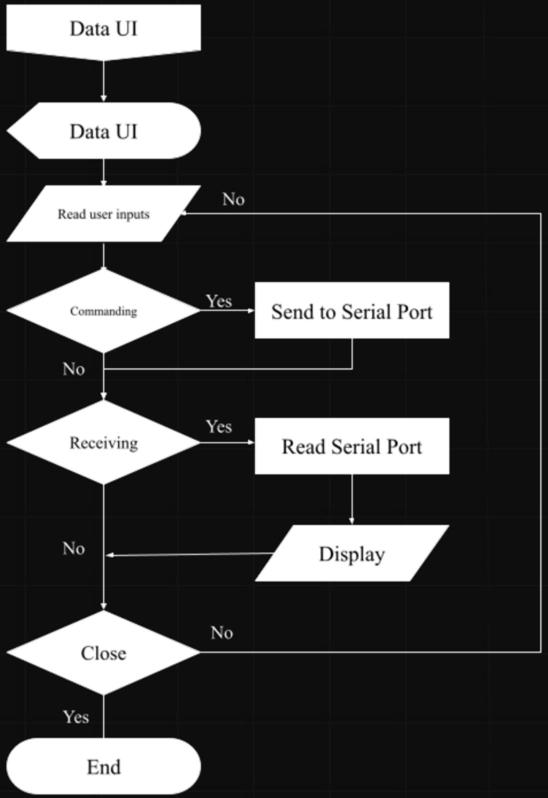
UI



- UI opens once serial connection is established, remains open with loop on a timer to check for user inputs
  - User has button to send latch command to serial port
  - If a command single is being sent to the serial port that is done before receiving data
- Data received is read from the serial port in API format
  - If checksum is not valid frame is not read
  - Otherwise start bit is found then data frame is accessed and read one byte at a time and passed to display functions that alter data format and print to GUI

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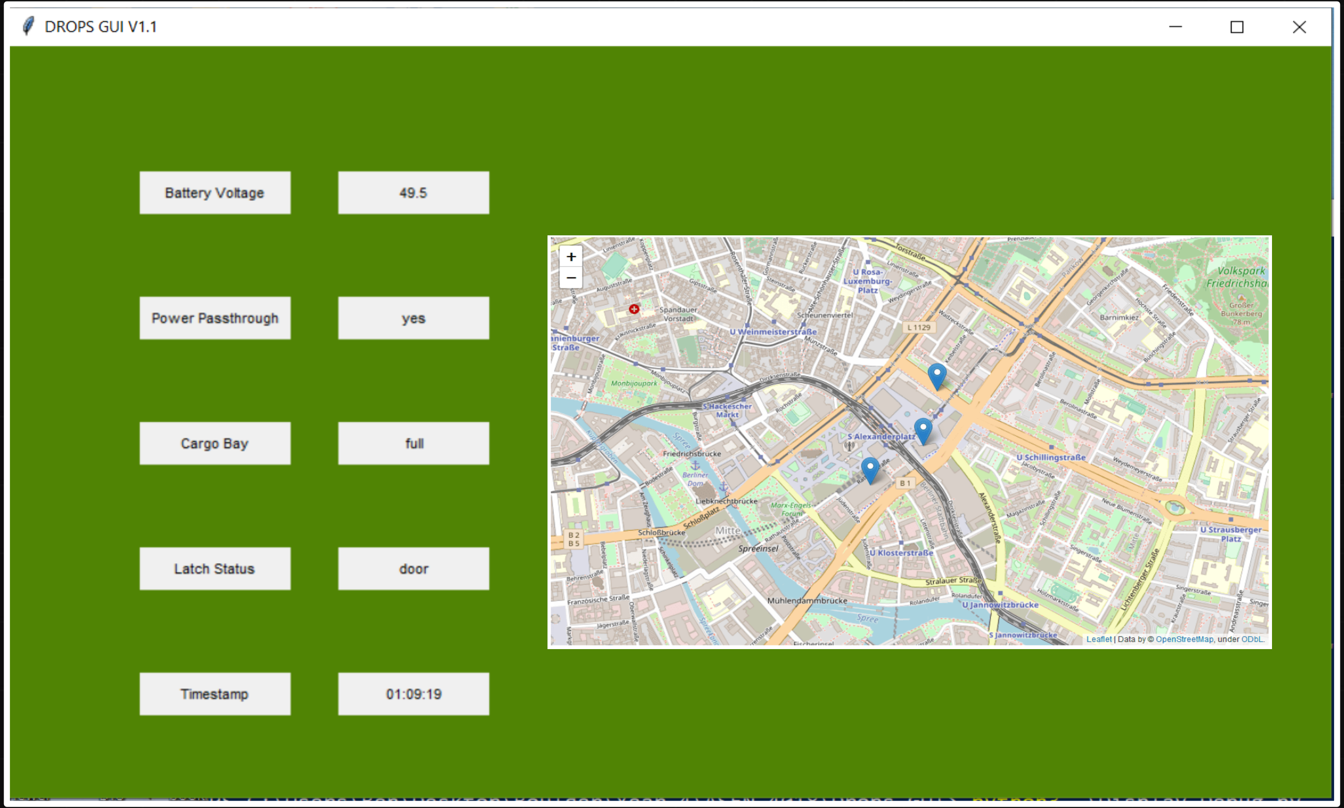
GUI Mockup



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XBee API Packet Definition

7E	Packet Length	Frame Type	Frame ID	Destination	Options	DATA	Checksum
	2B	1B	1B	8B	1B	65B	1B

DATA				
GPS Data	Battery Voltage	Connection Status	Cargo Status	Latch Status
50B	2B	4B	1B	8B

- Total Packet Size: 80B (640b)
- Minimum Packet Rate: 1Hz
- UART Default Data Rate: 9600 Baud

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PRU Component Integration - Dom

- Chosen MCU: Arduino Nano
- 4 latches
  - One 12V-24V @ <= 5mA line for control signal per latch (digital)
  - One 12V-24V @ negligible current for latch status signal per latch (digital)
- Each latch must have a boost converter between Nano and control signal line
- Each latch must have a buck converter between Nano and latch status line
- Use full duplex serial communication between PRU and CPM MCU's with TX/RX pins
- Power from done (hopefully)
  - 6-20V to Nano via micro-usb
  - 12-24V @ 1A max for each latch

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CPM Component Integration

- Chosen MCU: Arduino Due
- GPS: NEO-6M
  - Requires 3.3V
  - Communicates w/ UART
- Cargo Bay Sensor: HC-SR04 Sonar Sensor
  - Requires 3.3V
  - Communicates w/ UART
- Voltage Sensor: Voltage Divider
  - Using a pair of resistors, we will create a voltage output that can be taken in the Due's ADC

- Arduino Due will be powered by on board battery
  - One buck converter will be used to drop voltage to 12V

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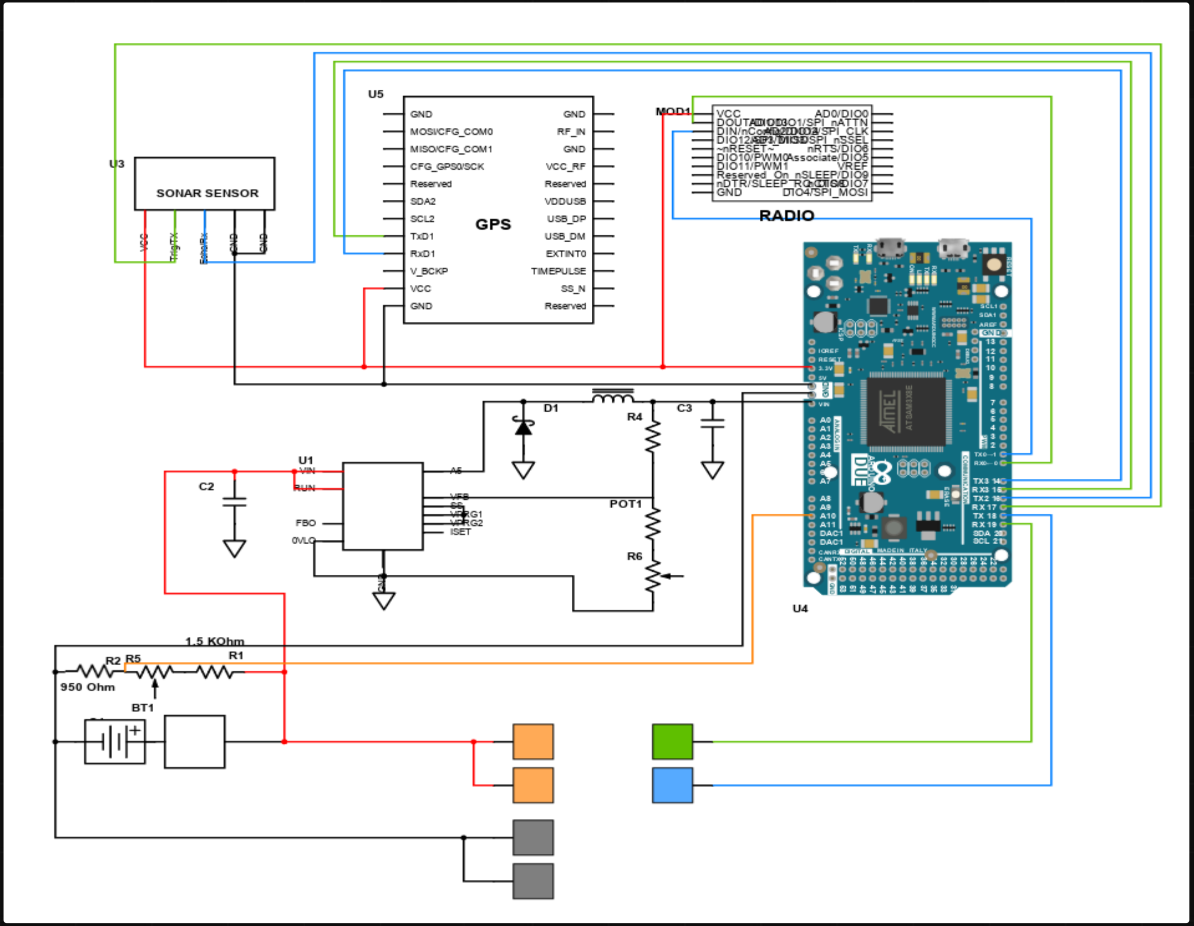
CPM Circuit Diagram



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Radio/Antenna Specs

Specification	Value
Ideal RF line-of-sight range	10 kb/s: up to 9 miles (15.5 km) 200 kb/s: up to 4 miles (6.5 km) (with 2.1 dB dipole antennas)
Transmit power output	24 dBm (250 mW) (software selectable)
RF data rate (high)	200 kb/s
RF data rate (low)	10 kb/s
Serial UART interface	Complementary metal–oxide–semiconductor (CMOS) Serial universal asynchronous receiver/transmitter (UART), baud rate stability of <1%
Serial interface data rate (software selectable)	9600-230400 baud
Receiver sensitivity (typical)	-101 dBm, high data rate -110 dBm, low data rate

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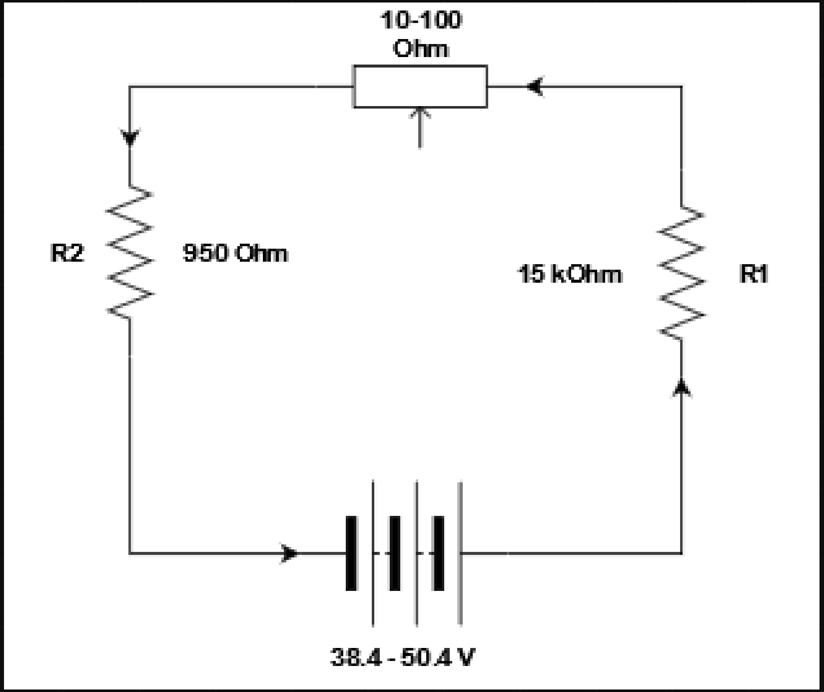
Voltage Divider

- 10 bit ADC with 0 - 3.3V range
  - 0.0032 V/bit

	R1	R2	R3
Power Dissipated (Watts)	0.1498	1E-4	0.0095
Resistor Value (Ohms)	15,000	10-150	950
Current (Amps)	0.0032	0.0032	0.0032



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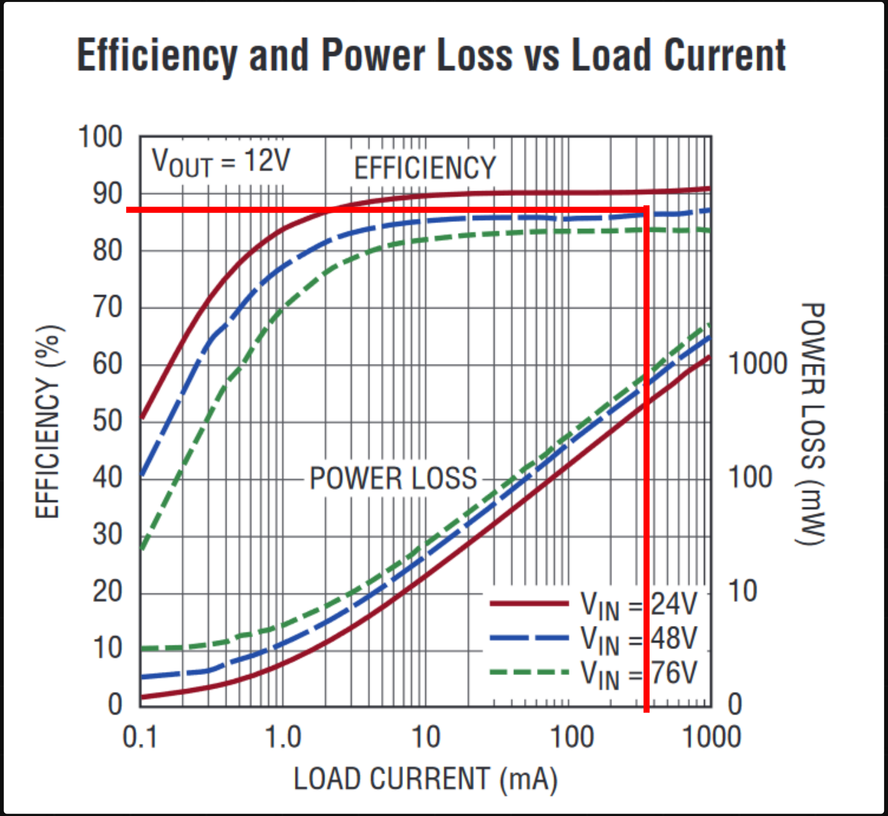
Buck Converter - LTC3637

- Voltage In: 44.4V
- Expected Efficiency: 85%



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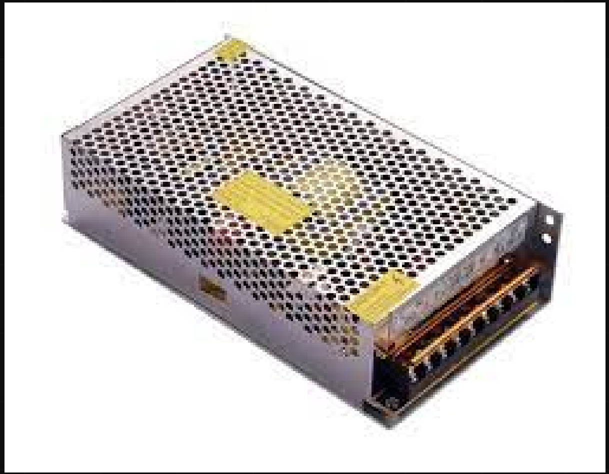
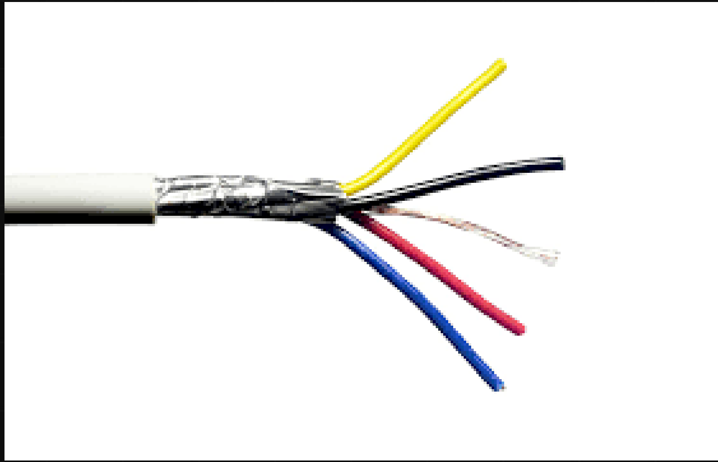
RF Protection

- Faraday Cage
  - Protect the Arduino Due from noise
- Twisted, Shielded Wire
  - Prevent noise emanating from voltage divider





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Risk Analysis Backup Slides

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Risk Analysis Backup Links

Risk Table - Egregious Stuff

Risk Analysis - Connection and Alignment

Risk Analysis - Power and Charging

Risk Analysis - Data and Electronics

Risk Analysis - Safety and Financials

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Risk Table

	Risk/Failure Statement	Estimated Likelihood (Before Mitigation)	Quantified Risk	Risk Level	Cause of Failure
Egregious	Metal cargo contents within 4cm of induction receiver	Likely	Catastrophic	20	Metal contents remain in Pod cargo bay while induction charger transmitter sending power to receiver located on the bottom of Pod
	Shock danger due to exposed/charged CPM pads	Likely	Catastrophic	20	CPM pads charged nd active - water/human/metal completed circuit and causes a high-power short
	Communication to UAV unavailable	Possible	Catastrophic	15	No clear LOS, antenuation issues, antenna damage/malfunction
	Truss support structures fail under forces	Possible	Catastrophic	15	Incorrect modeling or unexpected high forces. Manufacturing imperfections
	UAV system collides with CPM/POD system and crashes	Possible	Catastrophic	15	UAV operator error & weather conditions
Serious	Communication between CPM & PRU fails	Possible	Hazardous	12	Misallignment, spring in pads fail, substance obstruction
	Connection contact pads are misaligned	Possible	Hazardous	12	Misalignment or manufacturing imperfections

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Risk Analysis: Connection and Alignment

Risk/Failure Statement	Estimated Likelihood (Before Mitigation)	Quantified Risk	Risk Level	Cause of Failure
Accidental supply of control signal to latches from arduino in flight	Possible	Catastrophic	15	Malfunction by microcontroller or wiring
Truss support structures failiure under forces	Possible	Catastrophic	15	Incorrect modeling or unexpected high forces. Manufacturing imperfections
UAV system collides with CPM/POD system and crashes	Possible	Catastrophic	15	UAV operator error & weather conditions
Tolerances of slot slopes are not sufficient for alignment	Possible	Hazardous	12	Manufacturing imperfections
Connection contact pads are misaligned	Possible	Hazardous	12	Misalignment or manufacturing imperfections
Slot slopes fracture under pressure forces	Possible	Hazardous	12	Incorrect modeling or unexpected high forces
Derbis is lodged/located in latch cam, alignment surfaces, or other	Likely	Major	12	Environmental factors
Price for manufacturing exceeds budget limit	Likely	Major	12	Too expensive design choices or quoting
Drone is unable to carry entire weight of system	Likely	Hazardous	12	Utilizing a drone not capable of carrying weight or system is too heavy
Misalignment of UAV upon decent on slot slopes	Almost Certain	Minor	10	UAV operator error & weather conditions
CG offset of UAV/PRU system causes flight failure	Unlikely	Catastrophic	10	Incorrect modeling or incorrect drone specifications
1-4 of the latches do not fully fall onto striker bolts	Possible	Major	9	Failure in alignment or not enough tolerance for striker bolts
Power supply to latches fail to supply sufficient power	Possible	Major	9	Power fluctuations or failure from drone output
Latches do not lock/unlock when commanded	Possible	Major	9	Data transfer failure or latch communication failure
Lead time on latches exceeds scheudle	Possible	Major	9	Late ordering or short supply from SouthCo

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Risk Analysis Scoring: Connection and Alignment

Risk/Failure Statement	Estimated Likelihood (Before Mitigation)	Quantified Risk	Risk Level
Accidental supply of control signal to latches from arduino in flight	Possible	Catastrophic	15
Truss support structures failiure under forces	Possible	Catastrophic	15
UAV system collides with CPM/POD system and crashes	Possible	Catastrophic	15
Tolerances of slot slopes are not sufficient for alignment	Possible	Hazardous	12
Connection contact pads are misaligned	Possible	Hazardous	12
Slot slopes fracture under pressure forces	Possible	Hazardous	12
Derbis is lodged/located in latch cam, alignment surfaces, or other	Likely	Major	12
Price for manufacturing exceeds budget limit	Likely	Major	12
Drone is unable to carry entire weight of system	Likely	Hazardous	12
Misalignment of UAV upon decent on slot slopes	Almost Certain	Minor	10
CG offset of UAV/PRU system causes flight failure	Unlikely	Catastrophic	10
1-4 of the latches do not fully fall onto striker bolts	Possible	Major	9
Power supply to latches fail to supply sufficient power	Possible	Major	9
Latches do not lock/unlock when commanded	Possible	Major	9
Lead time on latches exceeds scheude	Possible	Major	9

Pre

Post

Risk/Failure Statement	Plan to Mitigate	Estimated Likelihood (After Mitigation)	New Risk Level
Accidental supply of control signal to latches from arduino in flight	Redudant safety on unlatching capability, impossing unlatch restriction while in flight	Unlikely	10
Truss support structures failiure under forces	Rubber feet on bottom of Pod. Require maximum decent speed of 0.5m/s. Landing pad?	Unlikely	10
UAV system collides with CPM/POD system and crashes	Operation in calm weather and slow speeds. Vertical decent of drone and escape plan	Unlikely	10
Tolerances of slot slopes are not sufficient for alignment	Depending on manufacturing option, do scaled testing on alignment and utilize more exact manufacturing methods	Unlikely	8
Connection contact pads are misaligned	Perform testing on connection pad alignment and ensure large enough connection pads	Unlikely	8
Slot slopes fracture under pressure forces	Choose strong material and limit decent speed of drone to 0.5m/s	Unlikely	8
Derbis is lodged/located in latch cam, alignment surfaces, or other	Frequent inspection of high contact surfaces and necessary cleaning	Unlikely	6
Price for manufacturing exceeds budget limit	Communication with sponsor and possible suppliers for budget	Unlikely	6
Drone is unable to carry entire weight of system	Research and communicate with drone companies about their capability. Keep weight budget accurate and optimized. If test drone can not carry, take out certain elements	Improbable	4
Misalignment of UAV upon decent on slot slopes	Operate in calm weather and have operator near system for visual aid	Possible	6
CG offset of UAV/PRU system causes flight failure	Communication with UAV suppliers and often CG analysis	Improbable	5
1-4 of the latches do not fully fall onto striker bolts	Ensure sufficient space for striker bolts to be lead into latch opening and strong alignment	Unlikely	6
Power supply to latches fail to supply sufficient power	Ensure lock safe mode and allow for manual override. Supply latches with slightly increased power to prepare for fluctuations	Unlikely	6
Latches do not lock/unlock when commanded	Have manual locking backup option and perfrom quantative testing	Improbable	3
Lead time on latches exceeds scheude	Allow for various types of latches to be used and obtain latches early	Improbable	3

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Risk Analysis: Power and Charging pt.1

Risk/Failure Statement	Estimated Likelihood (Before Mitigation)	Quantified Risk	Risk Level	Cause of Failure
Metal cargo contents within 4cm of induction receiver	Likely	Catastrophic	20	Metal contents remain in Pod cargo bay while induction charger transmitter sending power to receiver located on the bottom of Pod
Shock danger due to exposed/charged CPM pads	Likely	Catastrophic	20	CPM pads charged nd active - water/human/metal completed circuit and causes a high-power short
Induction Charger activated when pod lands but drone motors still pulling power (power pull/push conflict)	Likely	Hazardous	16	Battery power still being pulled from UAV motors while powering off while induction power being pushed into batteries simultaneously
Heat danger from high power resistor dissipation	Almost Certain	Major	15	High power resistors are safely rated to our dissipation needs, but heat dissipation can be dangers to team members
Lead time risk for high power resistors	Likely	Major	12	Shipping delays and not ordering early enough
Improper insulation pad/wire junctions	Possible	Hazardous	12	Improper shrinks/tape for ring terminal/pad joints - exposed and electrically charged metal
Improper insulation of Y junctions	Possible	Hazardous	12	Improper shrinks/tape for ring terminal/bolt joints - exposed and electrically charged metal
Lead time risk for high power wires (Glenair)	Possible	Hazardous	12	Glenair does not deliver wires at correct specs on time

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Risk Analysis Scoring: Power and Charging pt.1

Pre

Risk/Failure Statement	Estimated Likelihood (Before Mitigation)	Quantified Risk	Risk Level
Metal cargo contents within 4cm of induction receiver	Likely	Catastrophic	20
Shock danger due to exposed/charged CPM pads	Likely	Catastrophic	20
Induction Charger activated when pod lands but drone motors still pulling power (power pull/push conflict)	Likely	Hazardous	16
Heat danger from high power resistor dissipation	Almost Certain	Major	15
Lead time risk for high power resistors	Likely	Major	12
Improper insulation pad/wire junctions	Possible	Hazardous	12
Improper insulation of Y junctions	Possible	Hazardous	12
Lead time risk for high power wires (Glenair)	Possible	Hazardous	12

Post

Risk/Failure Statement	Plan to Mitigate	Estimated Likelihood (After Mitigation)	New Risk Level
Metal cargo contents within 4cm of induction receiver	Option 1: Wibotic sends some sort of shielding material to decrease 4cm minimum required distance | Option 2: Only induction charge batteries when non-metal cargo or no cargo exists in cargo pad	Possible	15
Shock danger due to exposed/charged CPM pads	Implement electrical breaker to prevent high - power flow until required	Improbable	5
Induction Charger activated when pod lands but drone motors still pulling power (power pull/push conflict)	UAV lands, pod detaches, then operator manually installs pod on top of induction power transmitter - Elecrical system to prevent induction power from initiating OUT OF SCOPE	Improbable	4
Heat danger from high power resistor dissipation	Dedicated test area on safe surface and ensure team members sufficnetly far away	Unlikely	6
Lead time risk for high power resistors	Consult multiple companies for similar products and find optimal lead time	Possible	9
Improper insulation pad/wire junctions	Thoroughly ensure that all surfaces are properly covered and use multiple shrinks/layers of insulation - ALSO purchase plastic covers and modify for our junctions at pads	Unlikely	8
Improper insulation of Y junctions	Thoroughly ensure that all surfaces are properly covered and use multiple shrinks/layers of insulation	Unlikely	8
Lead time risk for high power wires (Glenair)	Maintain constant communication with Glenair rep to ensure delivery date - worse case backup purchase generic 8 gauge wire on amazon	Unlikely	8

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Risk Analysis: Power and Charging pt. 2

Risk/Failure Statement	Estimated Likelihood (Before Mitigation)	Quantified Risk	Risk Level	Cause of Failure
Space between CPM/PRU contact pads - no solid contact	Possible	Major	9	Not enough spring pad displacement to fill the CPM/PRU empty space
Manufacturing risk of bending/warping thin copper pads	Possible	Major	9	Copper pads too thin and manufacturing/repeated use cases dents/ bending which reduces functionality
Ring terminal hardware cannot move through pad housing hole when pad is compressed	Possible	Major	9	Not enough space cut out from pad housing center hole for copper pad material block AND attached ring junction to pass through
Electrical arcing between contact pads when in close proximity	Unlikely	Hazardous	8	Overheating or overloaded circuit
50Amp chassis power connector failure	Unlikely	Hazardous	8	8 Gauge power connectros rated to 50 Amps but only 36 volts max. (project is passing 44 volts)
Spring contact pad jams when compression occurs	Possible	Minor	6	Not enough play/wiggle room between pads and spring housing
Copper pads corrode during testing/demos	Unlikely	Major	6	Corrosion/oxidation of copper with ambient air during testing/building time
High power resistor tolerance effects on battery current draw	Possible	Minor	6	Resistors possess their rating resistance value plus/minus certain tolerances that will vary the amount of current pulled from batteries when testing

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Risk Analysis Scoring: Power and Charging pt. 2

Pre

Risk/Failure Statement	Estimated Likelihood (Before Mitigation)	Quantified Risk	Risk Level
Space between CPM/PRU contact pads - no solid contact	Possible	Major	9
Manufacturing risk of bending/warping thin copper pads	Possible	Major	9
Ring terminal hardware cannot move through pad housing hole when pad is compressed	Possible	Major	9
Electrical arcing between contact pads when in close proximity	Unlikely	Hazardous	8
50Amp chassis power connector failure	Unlikely	Hazardous	8
Spring contact pad jams when compression occurs	Possible	Minor	6
Copper pads corrode during testing/demos	Unlikely	Major	6
High power resistor tolerance effects on battery current draw	Possible	Minor	6

Post

Risk/Failure Statement	Plan to Mitigate	Estimated Likelihood (After Mitigation)	New Risk Level
Space between CPM/PRU contact pads - no solid contact	Increase pad displacement capability and checking to make sure minimal space between CPM and PRU when landing	Unlikely	6
Manufacturing risk of bending/warping thin copper pads	Increase pad thickness	Unlikely	6
Ring terminal hardware cannot move through pad housing hole when pad is compressed	Expand housing hole in CAD design and estimate ring terminal size to ensure that smooth movement occurs	Unlikely	6
Electrical arcing between contact pads when in close proximity	Only pushing 20 Amps through pads for testing instead of 100+ | pad thermal analysis shows minimal change in temp and power dissipation	Improbable	4
50Amp chassis power connector failure	Original plan XT90's but those cannot accept 8 gauge wire - these connectors are mitigation plan	Improbable	4
Spring contact pad jams when compression occurs	Add additional space between pad and housing	Unlikely	4
Copper pads corrode during testing/demos	Clean pads thoroughly daily and avoid substances that will corrode more quickly	Improbable	3
High power resistor tolerance effects on battery current draw	Even with extreme - level tolerances experienced with resistor values, current draw does not pose a risk as wires and all electircal components can handle several times the 20Amp desired test current	Improbable	2

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Risk Analysis: Data and Electronics

Risk/Failure Statement	Estimated Likelihood (Before Mitigation)	Quantified Risk	Risk Level	Cause of Failure
Communication to UAV unavailable	Possible	Catastrophic	15	No clear LOS, antenuation issues, antenna damage/malfunction
Communication between CPM & PRU fails	Possible	Hazardous	12	Misallignment, spring in pads fail, substance obstruction
Error withing sending latch status	Possible	Major	9	Incorrect function looping, bad polling data
Power Bus gives wrong voltage	Unlikely	Hazardous	8	Circuit built incorrectly
Data package corrupted	Possible	Minor	6	Bad data from sensors or disconnected XBee

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Risk Analysis Scoring: Data and Electronics

Risk/Failure Statement	Estimated Likelihood (Before Mitigation)	Quantified Risk	Risk Level
Communication to UAV unavailable	Possible	Catastrophic	15
Communication between CPM & PRU fails	Possible	Hazardous	12
Error withing sending latch status	Possible	Major	9
Power Bus gives wrong voltage	Unlikely	Hazardous	8
Data package corrupted	Possible	Minor	6

Pre

Post

Risk/Failure Statement	Plan to Mitigate	Estimated Likelihood (After Mitigation)	New Risk Level
Communication to UAV unavailable	Weather rated antenna, maintain LOS if possible, increase gain if LOS not possible to compensate	Unlikely	10
Communication between CPM & PRU fails	Pads will be weather and damage resistent, PRU-CPM design will allow for constant alignment	Unlikely	8
Error withing sending latch status	Test polling code in multiple failure scenarios, build buffer into polling loop	Unlikely	6
Power Bus gives wrong voltage	Check diagrams with professors, test systems individually before integration	Improbable	4
Data package corrupted	Allow buffer between packet creation, have reconnect protocol for XBees	Unlikely	4

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Risk Analysis: Safety and Financials

Risk/Failure Statement	Estimated Likelihood (Before Mitigation)	Quantified Risk	Risk Level	Cause of Failure
Budget exceeds $5000	Almost certain	Major	15	High necessary component price point, increase pricing due to shortages, component replacement, contracting of outside manufacturing companies
Induction charging testing malfunctions	Possible	Catastrophic	15	Wiring failure, surrounding material melting, induction to nearby unintended surfaces, part failure
Landing testing malfuctions	Possible	Catastrophic	15	High landing speed, out of margin landing orientation
Data transmission testing malfunctions	Likely	Minor	8	Transmission obstruction, insufficient gain, hardware malfuction, software malfunction
Battery testing malfuctions	Possible	Hazardous	12	Wire shorting, cell damage, wiring connection failure
Latching/unlatching testing malfunctions	Likely	Minor	8	Latches jam, actuation software malfuctions, powering failure, insufficient tolerance
Pod stacking testing malfunctions	Unlikely	Hazardous	8	Pods tip over while unsupported, pods fail under stacked weight

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Risk Analysis Scoring: Safety and Financials

Risk/Failure Statement	Estimated Likelihood (Before Mitigation)	Quantified Risk	Risk Level
Budget exceeds $5000	Almost certain	Major	15
Induction charging testing malfunctions	Possible	Catastrophic	15
Landing testing malfuctions	Possible	Catastrophic	15
Data transmission testing malfunctions	Likely	Minor	8
Battery testing malfuctions	Possible	Hazardous	12
Latching/unlatching testing malfunctions	Likely	Minor	8
Pod stacking testing malfunctions	Unlikely	Hazardous	8

Pre

Post

Risk/Failure Statement	Plan to Mitigate	Estimated Likelihood (After Mitigation)	New Risk Level
Induction charging testing malfunctions	Surrounding pod material noncondictive with high dielectric strength, system tested before incorporated into pod, explain metal danger in instruction briefing	Unlikely	10
Landing testing malfuctions	Can limit landing speed of the drone (Periscope specs), testing rig can have a safety stop implemented for additional safety	Improbable	5
Budget exceeds $5000	Parts ordered ahead of time, most cost effective parts purchased, Hank and/or inverstors help subsidize cost, mitigate need for part replacements	Unlikely	6
Data transmission testing malfunctions	Maintain LOS, design gain to overcome LOS issues, test hardware and software seperately before integration	Possible	6
Battery testing malfuctions	Proper grouding and safety systems, testing in a controlled environment with Faculty assistance, safe battery storage location	Improbable	4
Latching/unlatching testing malfunctions	Test software in multiple scenarios of latch failure, examine play between latches and bolts to optimize	Unlikely	4
Pod stacking testing malfunctions	Impose stack limit in instuction briefing, incorperate margin of safety for weight	Improbable	4

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Verification and Validation Backup Slides

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Verification and Validation Links

4 Drones

Data Downlink Radio Test

Latch Command Test

IRISS Drone Test

Induction Charging Test

Connection and Disconnection Demo

High Power Test: Additional Info

Requirements

List of Predictive Models

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UAV TESTING AIRCRAFT

Periscope MK4 - Payload 27 kg

Freefly Alta X - Payload 16 kg

DJI M600 - Payload 6 kg

DJI S900 - Payload 3 kg

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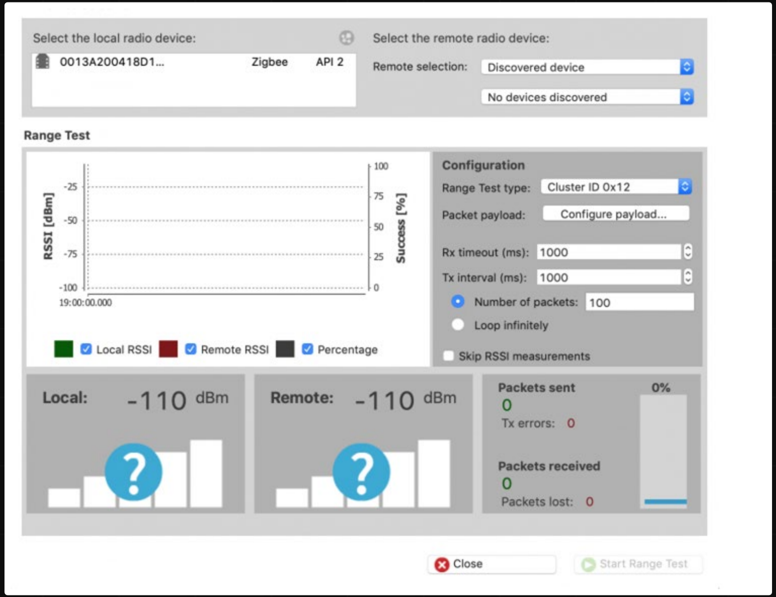
Additional Testing: Data Downlink Radio Test

Goal	Transmit data from CPM to the ground station at a range of at least 1 mile.
Models verified	Telemetry Range, Data Rate, Link Budget, Baud Rate Capabilities
Data Collected	Signal Power [dBm] at varying ranges Expected maximum value: XX dBm 9 miles



Specification	Value
Ideal RF line-of-sight range	10 kb/s: up to 9 miles (15.5 km) 200 kb/s: up to 4 miles (6.5 km) (with 2.1 dB dipole antennas)
Transmit power output	24 dBm (250 mW) (software selectable)
RF data rate (high)	200 kb/s
RF data rate (low)	10 kb/s
Serial UART interface	Complementary metal–oxide–semiconductor (CMOS) Serial universal asynchronous receiver/transmitter (UART), baud rate stability of <1%
Serial interface data rate (software selectable)	9600-230400 baud
Receiver sensitivity (typical)	-101 dBm, high data rate -110 dBm, low data rate

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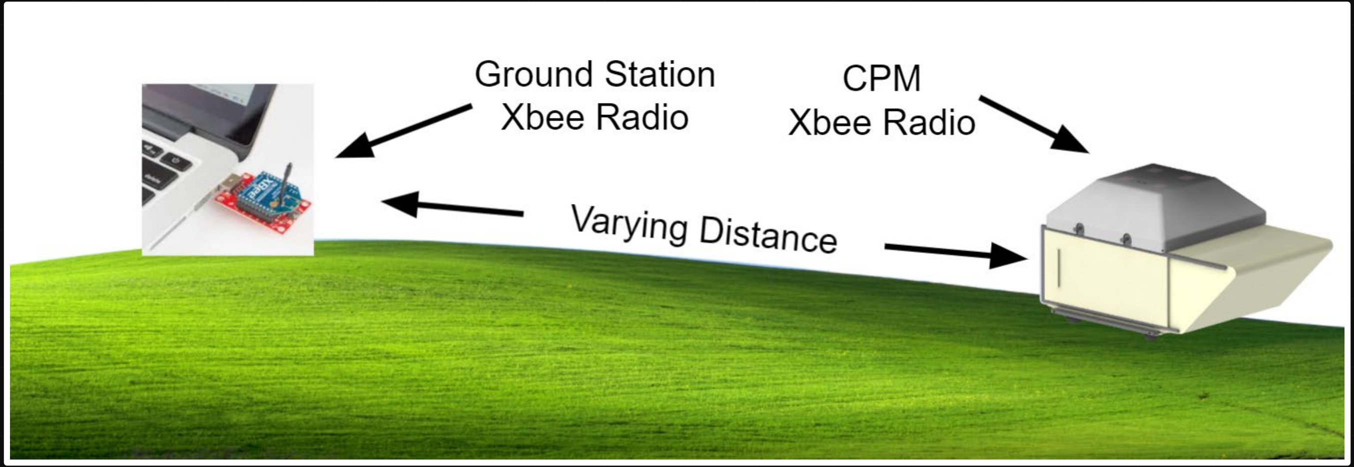
Additional Testing: Data Downlink Radio Test

Facilities	US 36 scenic overlook
Steps	1. Load a premade test file with packets to operator's device 2. Verify there is a distance of 1 mile between the two radios 3. Send data for 30 minutes at 1 Hz 4. Measure signal power and success percentage 5. Repeat for ranges up to 9 miles
Requirements Closed	FR 7, performance levels 1 and 2



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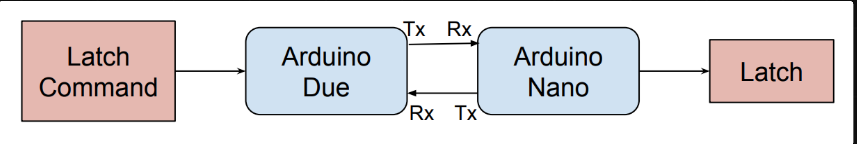
Additional Testing: Latch Command Test

Goal	Check that CPM can send latch command signal to the PRU
Models verified	PRU to CPM Data Passthrough Flowchart
Data Collected	Time to receive/send data
Facilities	Lab Benchtop
Steps	1. Create Rx and Tx connection between two Arduinos (Nano & Due) 2. Send latch command through CPM Microcontroller (Due) 3. Verify shackle on latch opens and closes
Requirements	FR 3, performance level 2



Test setup

Arduino	(2)
Latch	(1)
Breadboard	(1)
Jumper wires	(yes)

Test Equipment

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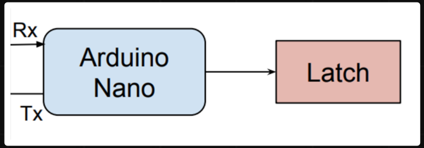
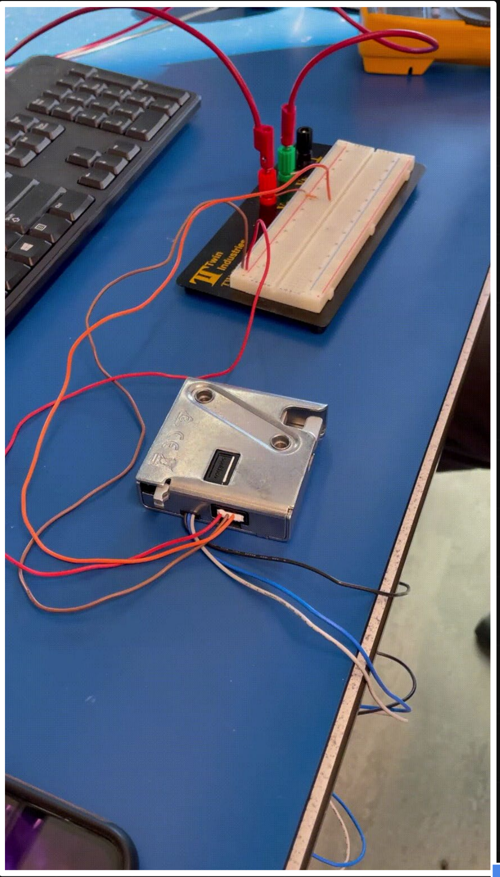
Additional Testing: Latch Command Test - Latch



Electronics lab power supply used to command latch as simulated Nano



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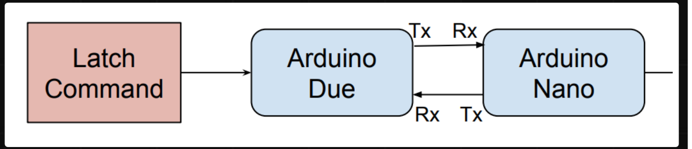
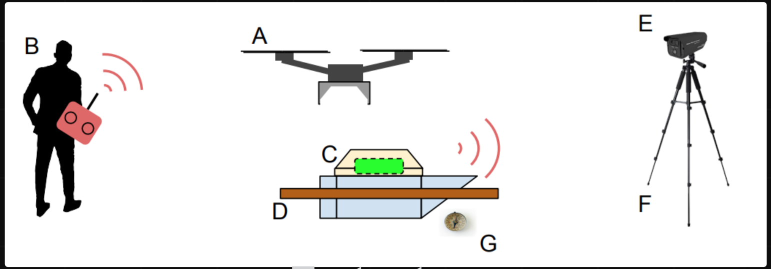
Additional Testing: Latch Command Test - Nano



- Simulated commands from Due sent via RealTerm software
- Measured time to execute
- Received command and response is displayed in RealTerm but not included in timing

Additional Testing: IRISS Drone Test

Goal	See if drone and pod can align, latch, and unlatch with a remote operator
Models verified	Alignment tolerances, materials selection, latch/bolt interference analysis
Data Collected	X, Y, and yaw alignment values Max expected x: 10 cm Max expected y: 10 cm Max expected yaw: 20 degrees
Facilities	Outdoor field
Steps	1. Drone piloted to Pod 2. Three alignment cases tested 3. Remote latching 4. Remote unlatching 5. Drone piloted away from Pod
Requirements Closed	FR 1, level 2 performance FR 6, level 1 performance



Test setup

A	UAV with installed PRU
B	UAV operator console
C	Pod with installed CPM
D	Meter stick (4)
E	Devices with photo and video (3)
F	Camera stands (3)
G	Compass

Test Equipment

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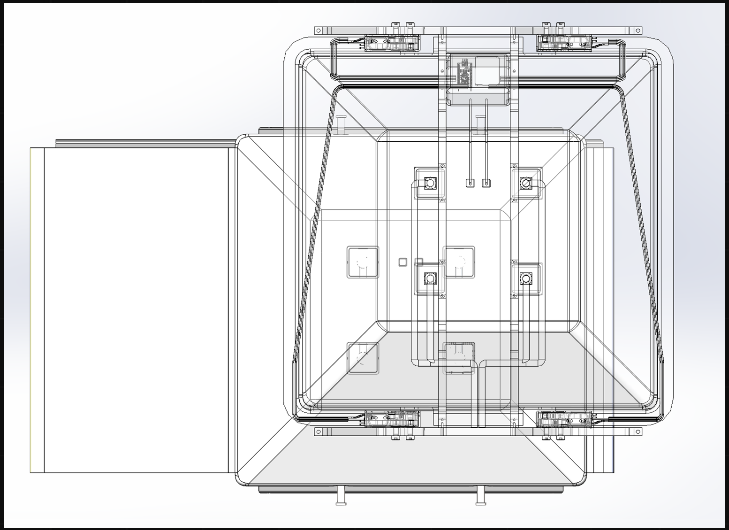
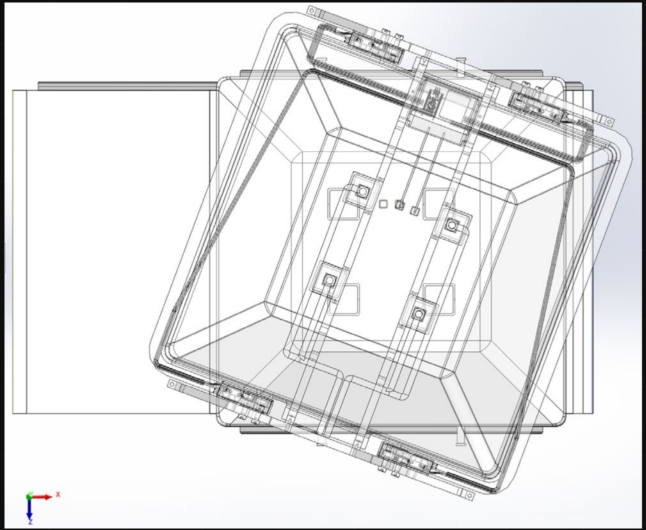
Additional Testing: IRISS Drone Test

Test cases:



10 cm offset in x and y



20 degree offset in yaw

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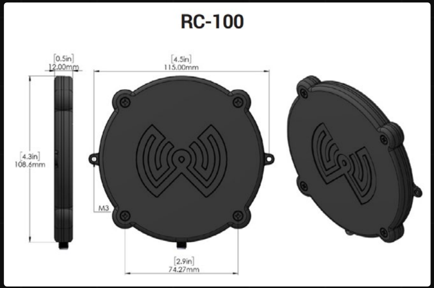
Additional Testing: Induction Charging Test

- **Goal:** Prove induction charging via induction
- **Steps:**
  - Set up WiBOTICS charging device
  - Place POD on top of transmitter antenna
  - Read Transmitter display
  - Measure/Record Voltage
  - Wait 1h
  - Measure/Record Voltage
  - Use analysis software to validate model
- **Models:**
  - Materials selection study for Pod bottom
  - Induction charging extrapolation model
- **Data Collected:**
  - Transmitter “Charging” display
  - First Voltage
  - Second Voltage
- **Location:** N200
- **Closed FR:**
  - Level 2 and 3 performance requirements of FR 5

A	WiBOTICS transmitter unit
B	WiBOTICS receiver unit
C	POD



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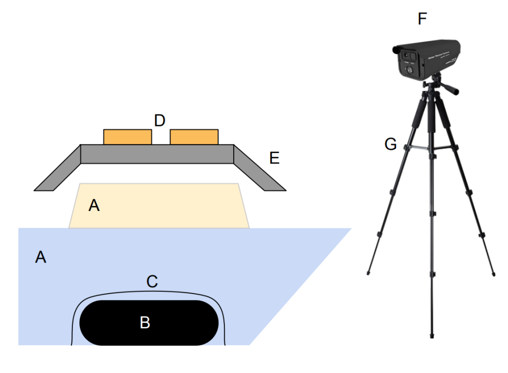
Additional Testing: Manual Connection and Disconnection Demo

- Goal: Make sure that latches connecting PRU to CPM work with physical operator input.
- Steps:
  - Operator places PRU on CPM
  - Operator closes latches
  - Operators pick up PRU, CPM, and Pod
  - Operator opens latches
- Data collected:
  - Photo and video
- Models verified:
  - Slot slope angle vs coefficient of friction
  - latch/bolt interference study
- Location: N200 projects space
- Closed FRs: 1, 2, 3, 8

A	Pod with installed CPM
B	Cargo simulation weights
C	Weight restraining device
G	Camera stand
D	Drone simulation device
E	PRU with installed SouthCO latches
F	Device with photo and video capability



Test setup

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High Power System Test: Safety

Concern	Fire
Rationale	Lithium Polymer batteries (LiPo's) are likely to start fires under not ideal operating conditions such as mishandling or shorts. LiPo batteries are self oxidizing so a LiPo fire cannot be put out with water.
Solution	There will be a bucket of sand in case of fire. LiPo's will be handled with extreme caution and the circuits will be verified prior to testing.

Concern	Resistive Heating
Rationale	Resistors will dissipate heat when pulling 20 amps through the system
Solution	Operators will follow specific procedures, use gloves, and cages will be installed around the resisters to avoid direct contact.

Concern	Electric shock
Rationale	44 V and a human electric resistance 1200 Ohm can result in a current of more than .03 Amps DC through the human body. 0.03 Amps or higher implies a risk of "human starting to not being able to let go"
Solution	Operators will use non conductive gloves during the test

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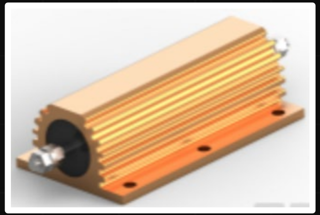
High Power System Test: Load Circuit Layout

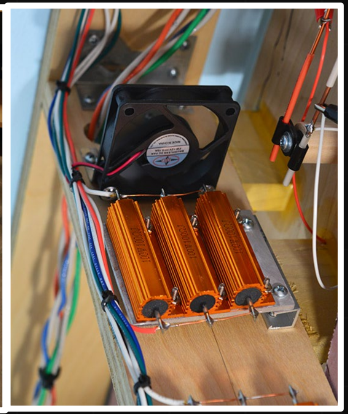
High-Power Resistors:

- TE vs. Digikey Models
- Same resistance and power dissipation
- 5% vs. 10% resistance tolerance
- Newer vs. older technology



Testing Set Up Notes:

- Vertical vs. horizontal mount
- Fan required
- Will install cage/cover similar to a space heater



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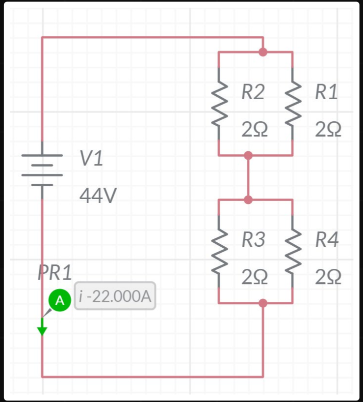
High Power System Test: Equipment

Ammeter


Gloves


Voltmeter



Resistor Circuit


Resistor


Laser Thermometer

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Requirements: Connection and Alignment

High-Level Functional Requirements	Performance - L1	Performance - L2	Performance - L3
FR 1. The UAV shall align itself with the Pod via the PRU	An operator present on scene shall align the UAV with an installed PRU onto the cargo Pod	A wireless operator shall pilot the UAV to align an installed PRU onto the Pod within a maximum yaw of +/- 20 degrees in the z direction and maximum centering offset of +/- 10 cm in the x and y directions.	-
FR 2. The UAV shall connect to the Pod via the PRU	The PRU shall connect to the Pod via physical operator input to the PRU	The UAV with an installed PRU shall mechanically connect with the Pod such that it can be lifted and translated by the UAV with vertical accelerations of 22.3 m/s^2 and lateral accelerations of 5 m/s^2	The capable vertical accelerations shall be increased to 25.4 m/s^2 and lateral accelerations to 7 m/s^2
FR 3. The UAV shall disconnect from the Pod via the PRU	The PRU shall disconnect from the Pod via physical operator input to the PRU	The PRU shall disconnect from the Pod via a wireless operator command	-

Verification Key:
- Requirement closed by demonstration
- Requirement closed by inspection
- Requirement closed by analysis
- Requirement closed by testing

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Requirements: Power Pass Through

FR 4. There shall be power passthrough from the POD though the PRU outputs	There are high-power cables present in the system that are designed to pass at least 100 Amps	There shall be unregulated, functioning power distribution cables between the CPM batteries and the PRU output that are designed to pass at least 100 Amps and are tested successfully to at least 20 Amps DC	-
FR 5. There shall be power passthrough from an induction charging system, through the bottom of the Pod, sending power to the CPM batteries	Induction charging reciever system is present in the bottom of the Pod with wired integration into CPM batteries	Instantaneous proof of power transfer exists from the induction system to CPM batteries when Pod is placed on the external induction transmitter	CPM batteries can be fully charged using the induction system within a 12 hour period.
FR 6. There shall be regulated power to operate the PRU and CPM components	CPM components can be successfully powered using regulated power form the CPM batteries. PRU components can be successfully powered using regulated power from the UAV batteries.	-	-

Verification Key:
- Requirement closed by demonstration
- Requirement closed by inspection
- Requirement closed by analysis
- Requirement closed by testing

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Requirements: Data Downlink

FR 7. There shall be data transfer between the PRU and the operator	The Cargo Pod Mount shall sucessfully transmit and recieve, at a range of 1 mile, a data packet containing the Pod's battery voltage and current, Pod connection status, cargo status, and location at a resolution of 0.5 V and 3m for the battery voltage and location.	The Cargo Pod Mount shall measure, at a range of 1 mile, the Pod's battery voltage and current, Pod connection status, cargo status, and location at a resolution of 0.5 V and 3m for the battery voltage and location. The data shall be sent at a rate of 1 Hz.	The battery voltage, connection status, cargo status, and location data transmission rates , at a range of 1 mile, shall be increasedto 5 Hz.

Verification Key:
- Requirement closed by demonstration
- Requirement closed by inspection
- Requirement closed by analysis
- Requirement closed by testing

Requirements: Design Constraints

FR 8. CPM shall be designed to enable stackable Pod unit	Two Pods shall have the ability to be stacked vertically on a flat surface without falling over	-	-
FR 9. The design of the PRU shall allow for the UAV to takeoff and land with the PRU without being connected to Pod	The PRU design shall support the UAV weight without a connected Pod	-	-

Verification Key:
- Requirement closed by demonstration
- Requirement closed by inspection
- Requirement closed by analysis
- Requirement closed by testing

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List of Predictive Models

Connection and alignment

- Slot slopes angle vs coefficient of friction
- Latch loading capabilities
- Materials selection study
- Alignment tolerances
- CPM to Pod bolt analysis
- Latch/bolt interference study

Data Downlink

- Component data output
  - Link budget
  - Baud rate capabilities (default 9600)
    - Max: 115200 (Arduino) & 921600 (Radio)
- Resolution frequency
- range/data rate

Power Subsystem

- Power loss modeling
  - High power path model background
- Power pass through layout (Battery Input/Output and Pads)
- Power and temperature losses with contact pads
- Materials selection study for pads
- Induction charging modeling
- High power load layout and circuit

Integrated System

- Surface area analysis: s and d determination
- Offset angle study
- Surface angle analysis
- Latch loading capabilities
- Minimum shaft diameter (flight)
- Minimum shaft diameter (impact)
  - Rubber feet dampers study
- Materials selection study
- CPM structure on landing (CAD FEA)
- CPM structure with maneuvering thrust (CAD FEA)
- CPM structure with resting landing force (CAD FEA)

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Project Planning Backup Slides

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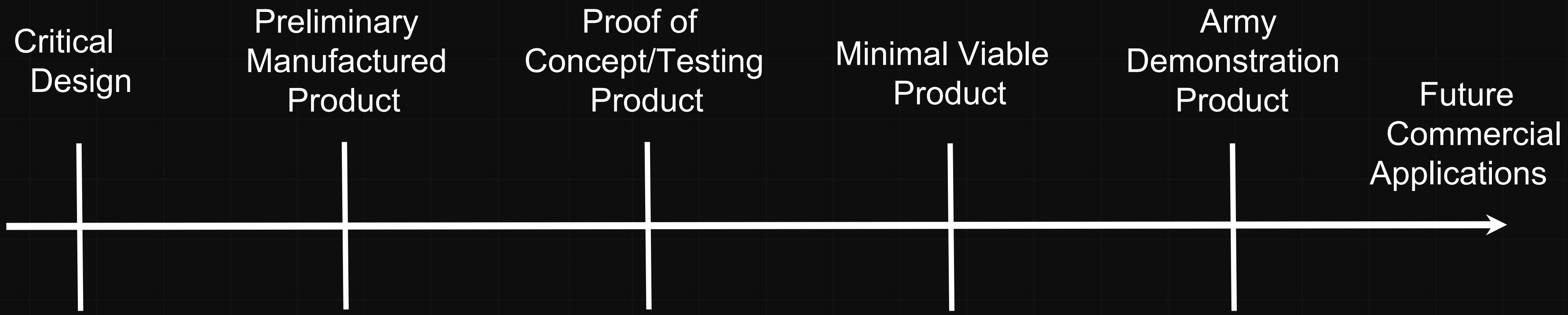
Progression of Product



Proof of Concept/Testing Product	Proven achievement and integration of primary project objectives & controlled testing environment
Minimal Viable Product/Army Demonstration	Completion of above and additional demonstration of requirements to CU and TB2
Future Commercial Applications	Consideration of team design to accommodate for future designs (autonomy, secondary alignment, etc)

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