



JPL



# CHIMERA

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CHild drone deployment MEchanism and Retrieval Apparatus

## Manufacturing Status Review

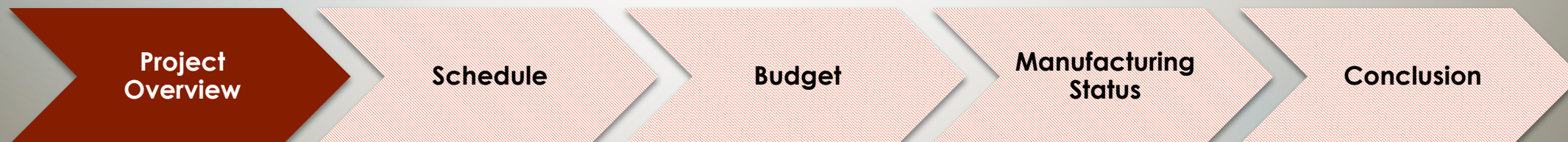
**Team:** Adam St. Amand, Christopher Chamberlain, Griffin Esposito, Shannon Floyd, Justice Mack, Azalee Rafii, Christopher Rouw, Mitchell Smith, Amanda Turk, Alexander Walker

**Customer:** Barbara Streiffert, Jet Propulsion Laboratory

**Advisor:** Jelliffe Jackson

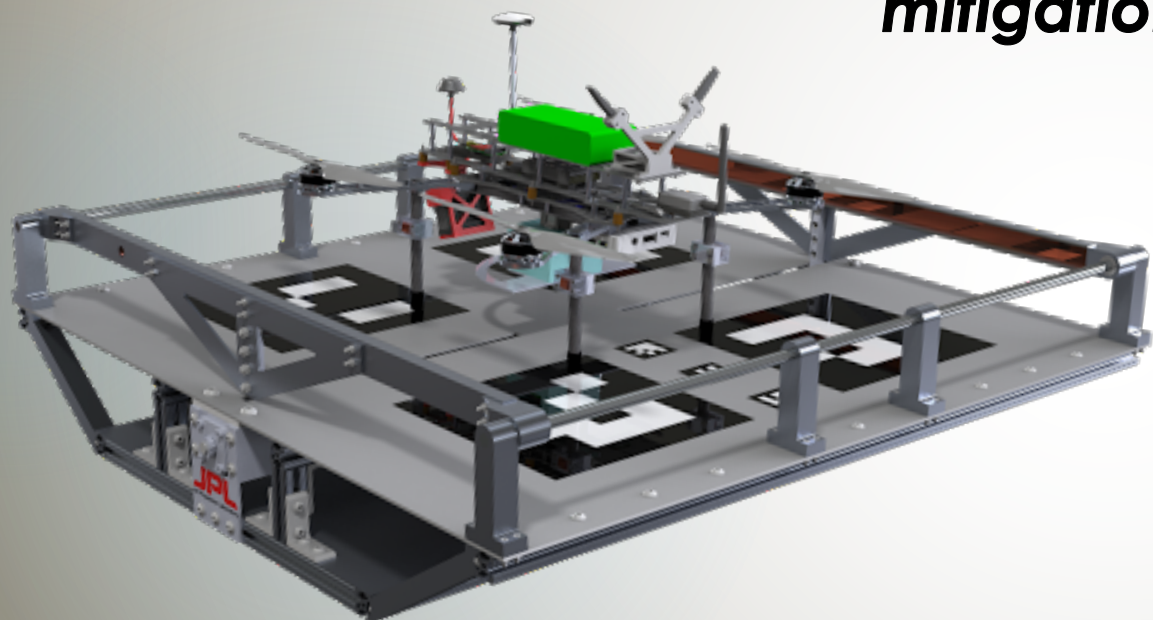
# Agenda

- ▶ Project Overview
- ▶ System Design
- ▶ Schedule
- ▶ Budget
- ▶ Manufacturing & Status Update
  - ▶ Image Recognition System
  - ▶ Platform Hardware
  - ▶ INFERNO Hardware
  - ▶ Electronics
- ▶ Conclusion



# Mission Statement

***CHIMERA (CHild drone deployment MEchanism and REtrieval Apparatus) will support the autonomous deployment, landing, and securing of the INFERNO unmanned aerial system and act as a communications relay to assist firefighters in the monitoring and mitigation of wildfires.***



Project  
Overview

Schedule

Budget

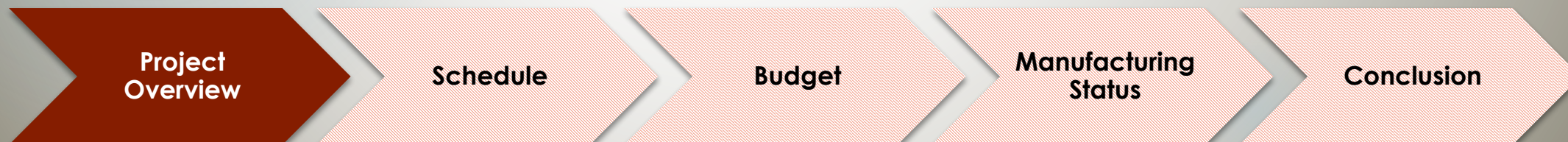
Manufacturing  
Status

Conclusion

# Mission Objectives



- ▶ Contribute to the overall Fire Tracker mission by designing and building a child drone platform capable of **integration** with a future mother rover.
- ▶ Modify the child drone built by last year's INFERNO senior design team to **autonomously land** on the platform.
- ▶ Design a platform capable of **securing** and **charging** a child drone after autonomous landing.
- ▶ Design a **communication system** that facilitates communication between the child drone, the platform and a ground station.



## ▶ **Autonomous Landing** of Child Drone

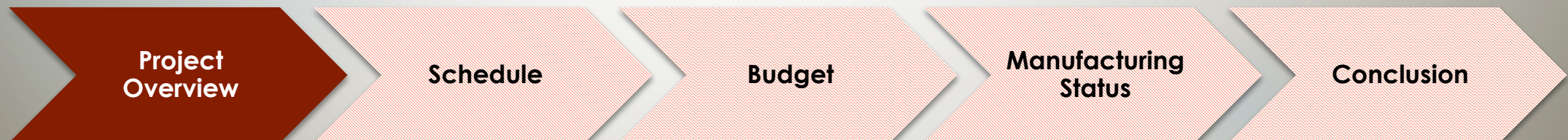
- ▶ Implements image recognition software for command and control of child drone to land on platform
- ▶ **RISK:** Commanding the Pixhawk

## ▶ **Automatic** Child Drone **Recharging**

- ▶ Utilizes conductive contacts to transfer power from platform battery bank to child drone for extended mission duration
- ▶ **RISK:** Open copper contacts, complex circuitry

## ▶ **Securing** of Child Drone

- ▶ Platform shall capture the child drone and restrict movement over rough terrain
- ▶ **RISK:** Complex mechanical hardware



# Levels of Success

## Level 4

- CDS **autonomously lands on Platform** upon command in **correct orientation**
- Charging system **autonomously charges CDS** battery **upon command**
- Securing system prevents CDS from tipping and **positions CDS for charging**
- COM system transmits/receives **video** at 720p and 30 fps according to CONST 1.3
- COM systems transmits/receives **telemetry/SPS** data according to CONST 1.3

## Level 3

- CDS **autonomously lands on Platform** upon command
- Charging system **charges CDS** battery with human in-the-loop
- COM system transmits/receives **video** across a minimum of 200 m
- COM system **functions** across a minimum of 200 m

**Currently on track to achieve Level 4 Objectives**

## Level 2

- CDS **autonomously lands** upon command
- Charging system **demonstrates charging capability** by illuminating LED on platform
- COM system transmits/receives **telemetry and SPS data**

## Level 1

- CDS IRS **recognizes** platform and initiates landing sequence upon command
- COM system transmits/receives **telemetry**
- Securing system **engages** upon command

Project  
Overview

Schedule

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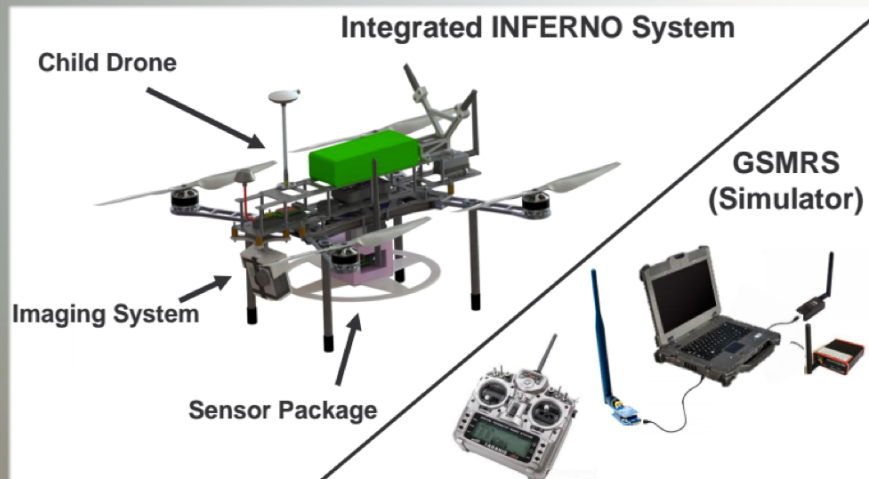
# Inherited Project

## INFERNO



### INtegrated Flight Enabled Rover for Natural disaster Observation<sup>2</sup>

- ▶ 2015-2016 JPL sponsored senior design project
- ▶ Semi-autonomous drone capable of delivering temperature-sensing package to wildfire area of interest
- ▶ **CHIMERA** will utilize existing **INFERNO** hardware



Project Overview

Schedule

Budget

Manufacturing Status

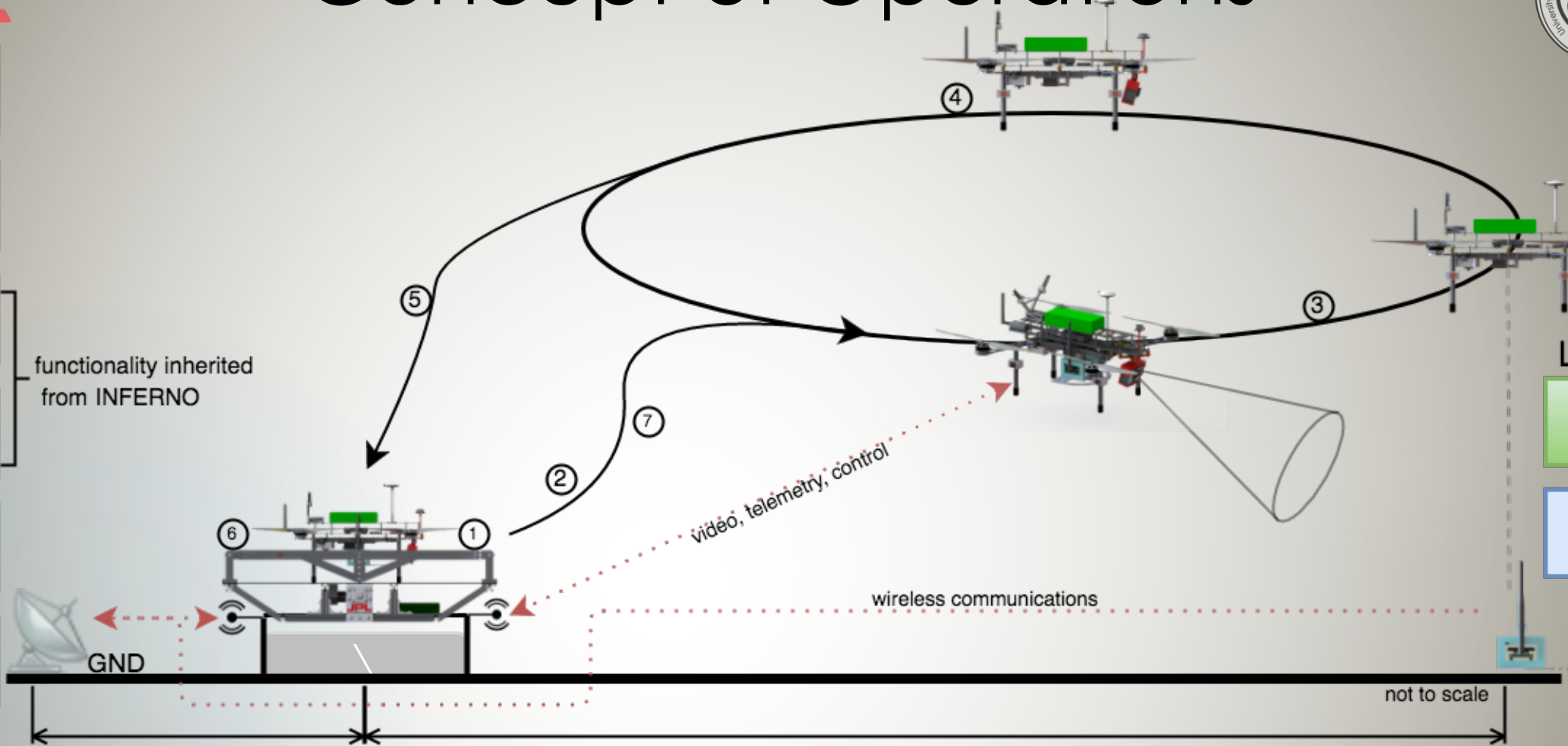
Conclusion

# Concept of Operations



- ① Securing Over Sample Environment
- ② Deploy CDS (Takeoff)
- ③ CDS Mission (13.5 Minutes)
- ④ CDS Return
- ⑤ CDS Autonomous Landing
- ⑥ CDS Recharge
- ⑦ CDS Redeploy

functionality inherited from INFERNO



## LEGEND

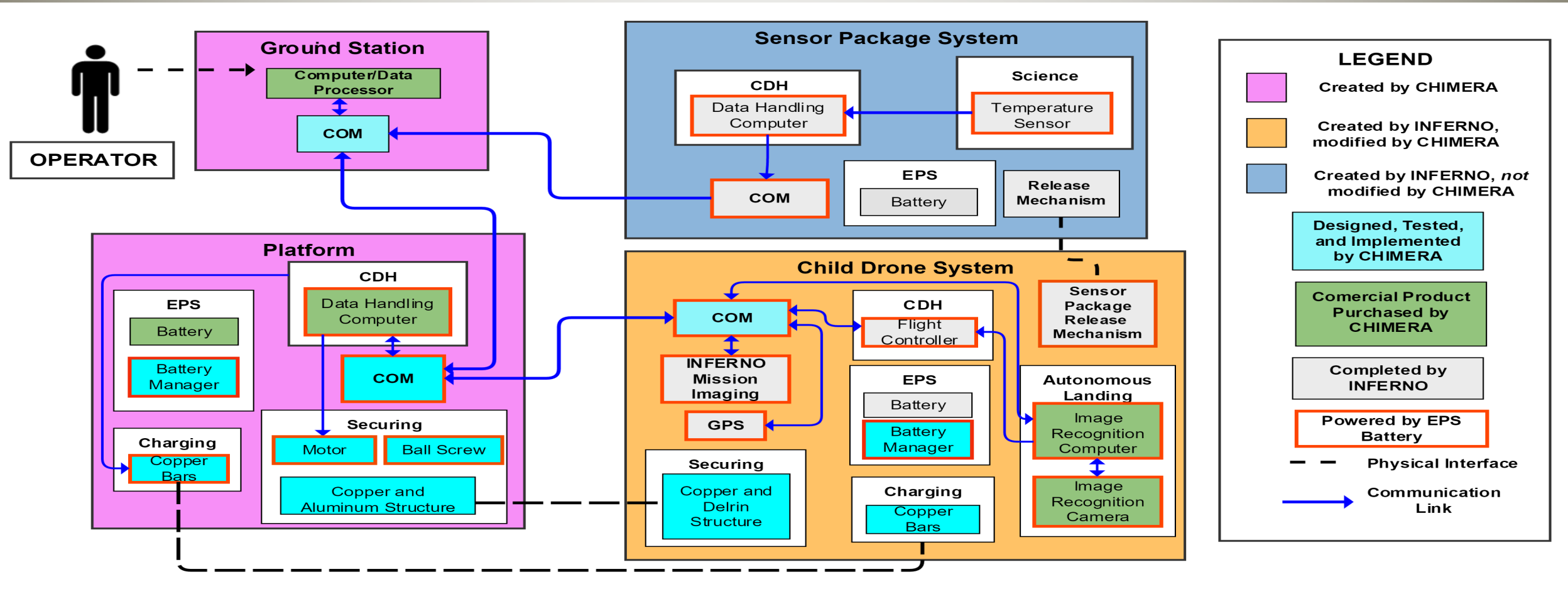
CHIMERA Mission

INFERNO Mission

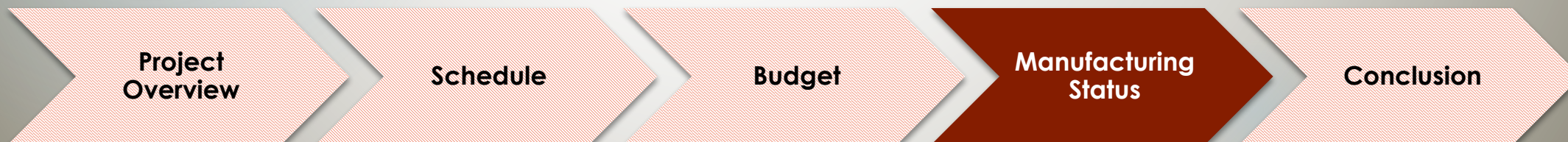
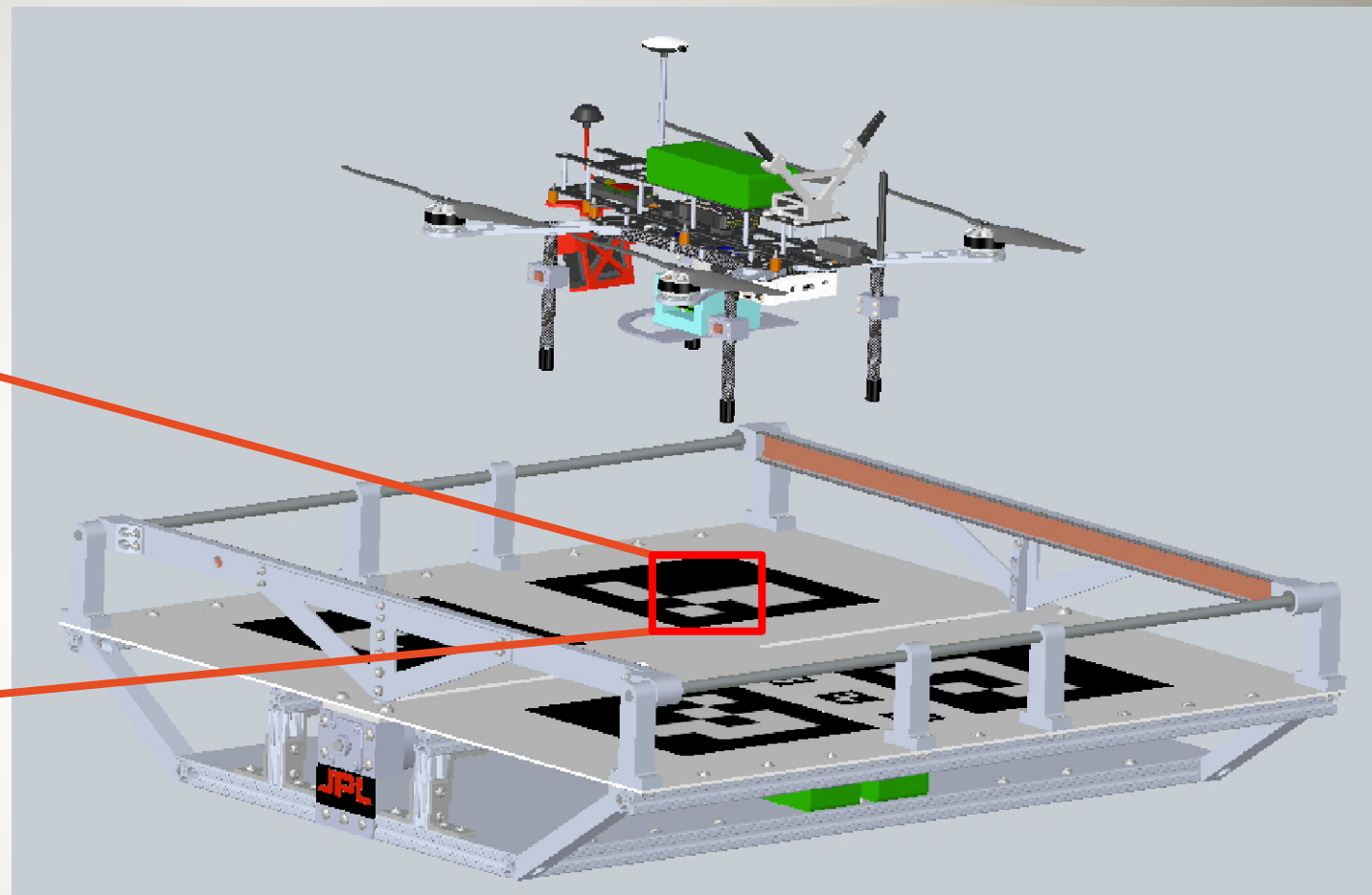
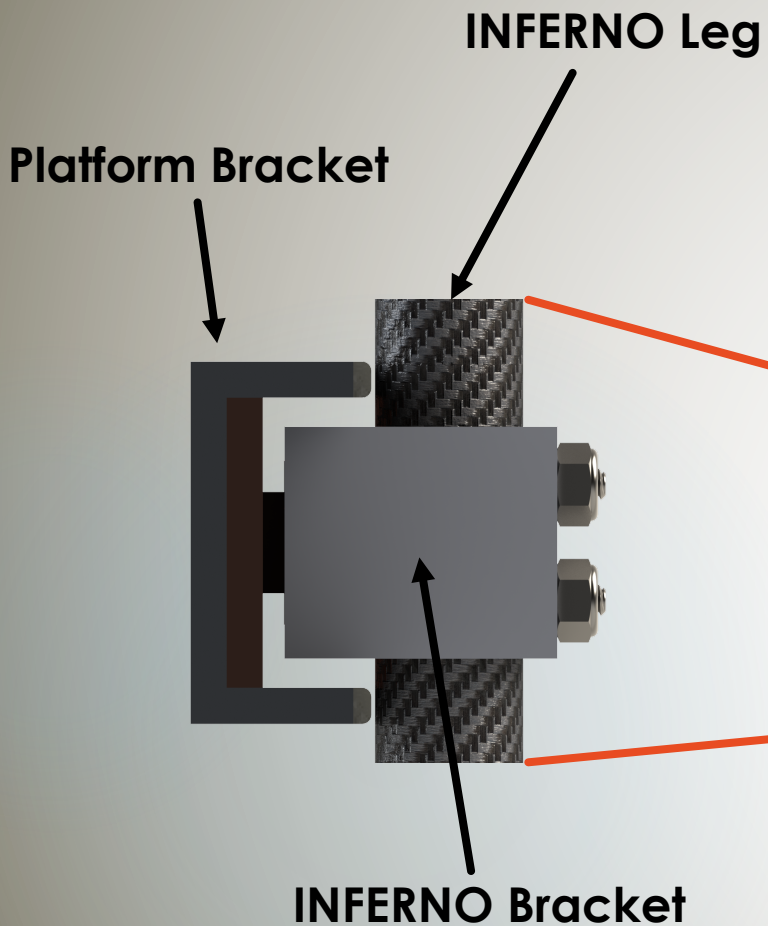




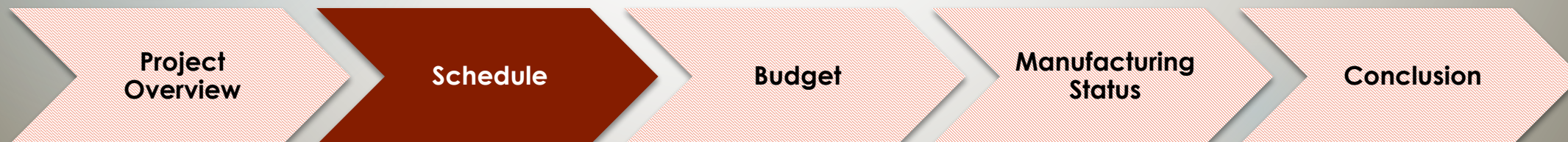
# Functional Block Diagram: System Level



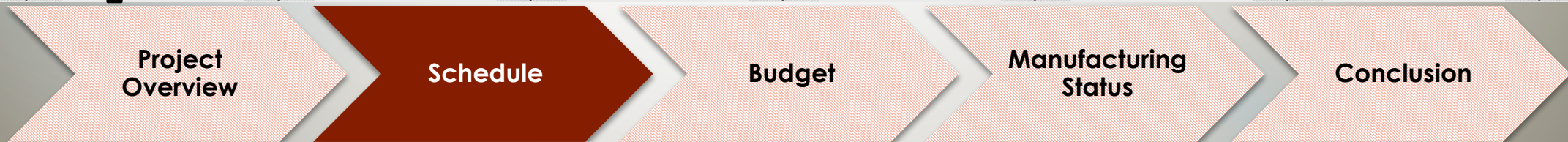
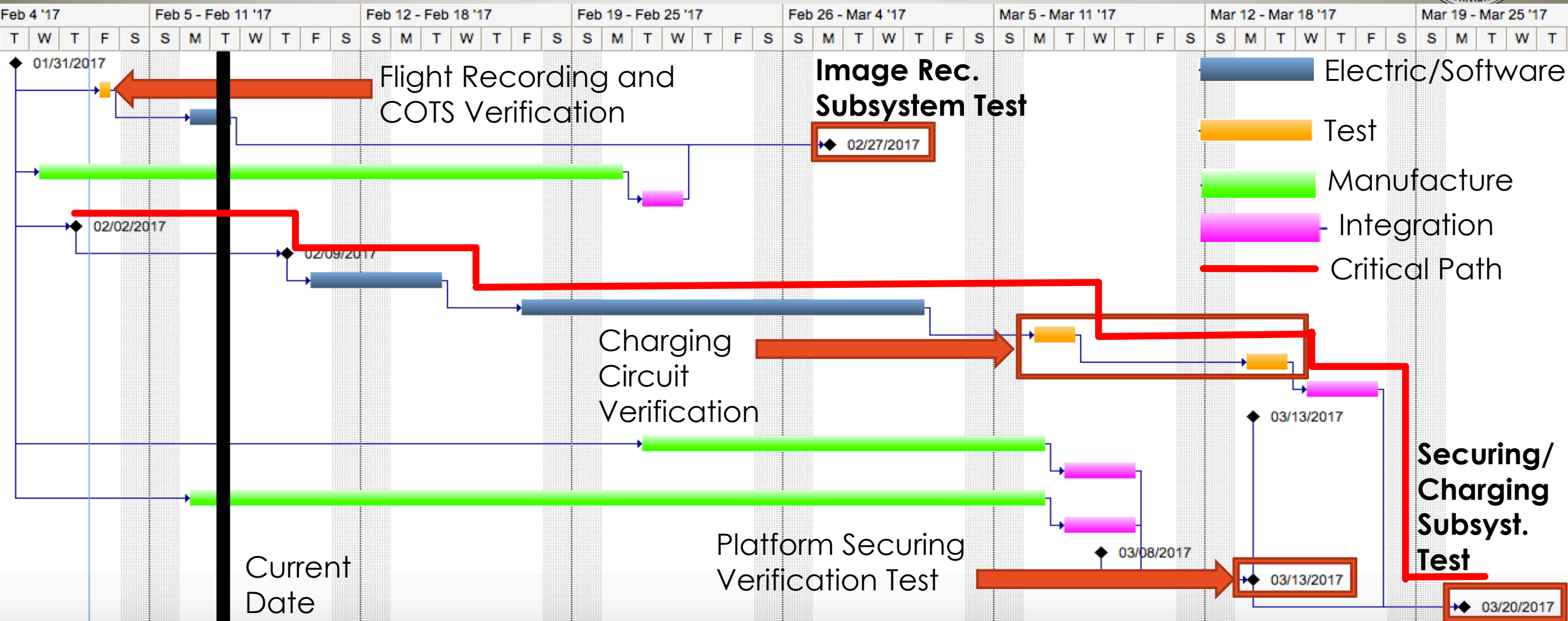
# System Design



# Schedule Breakdown

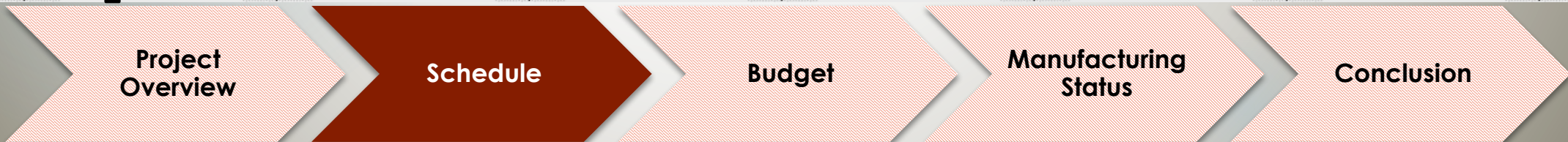
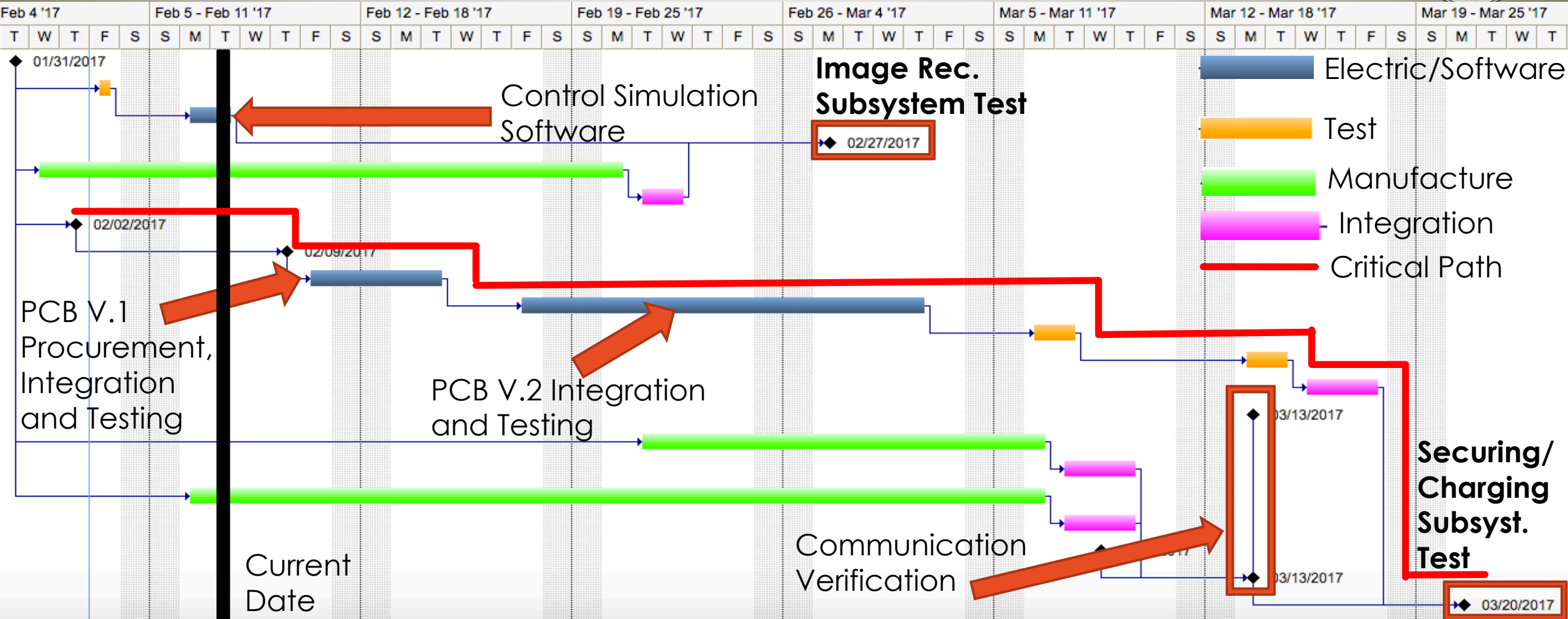


# Testing Schedule Highlight



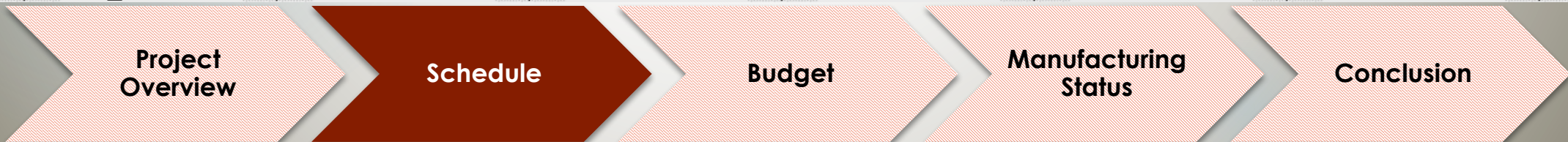
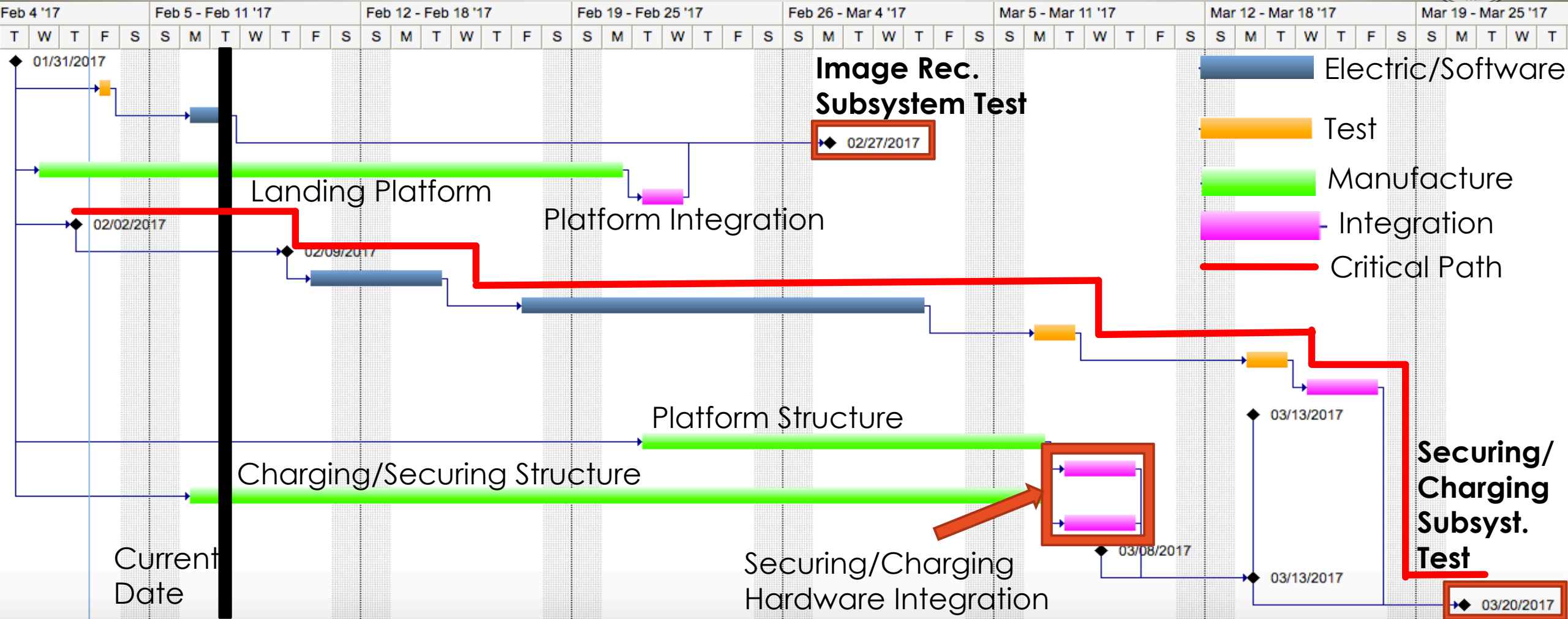


# Electrical/Software Schedule Highlight

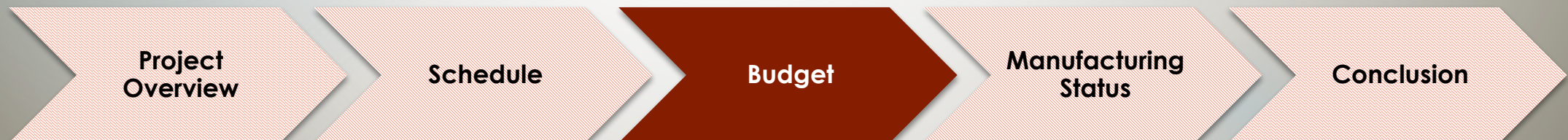




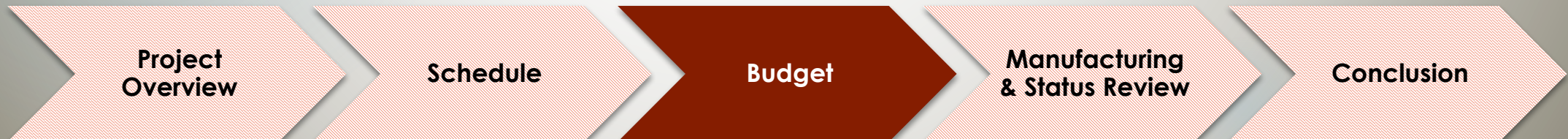
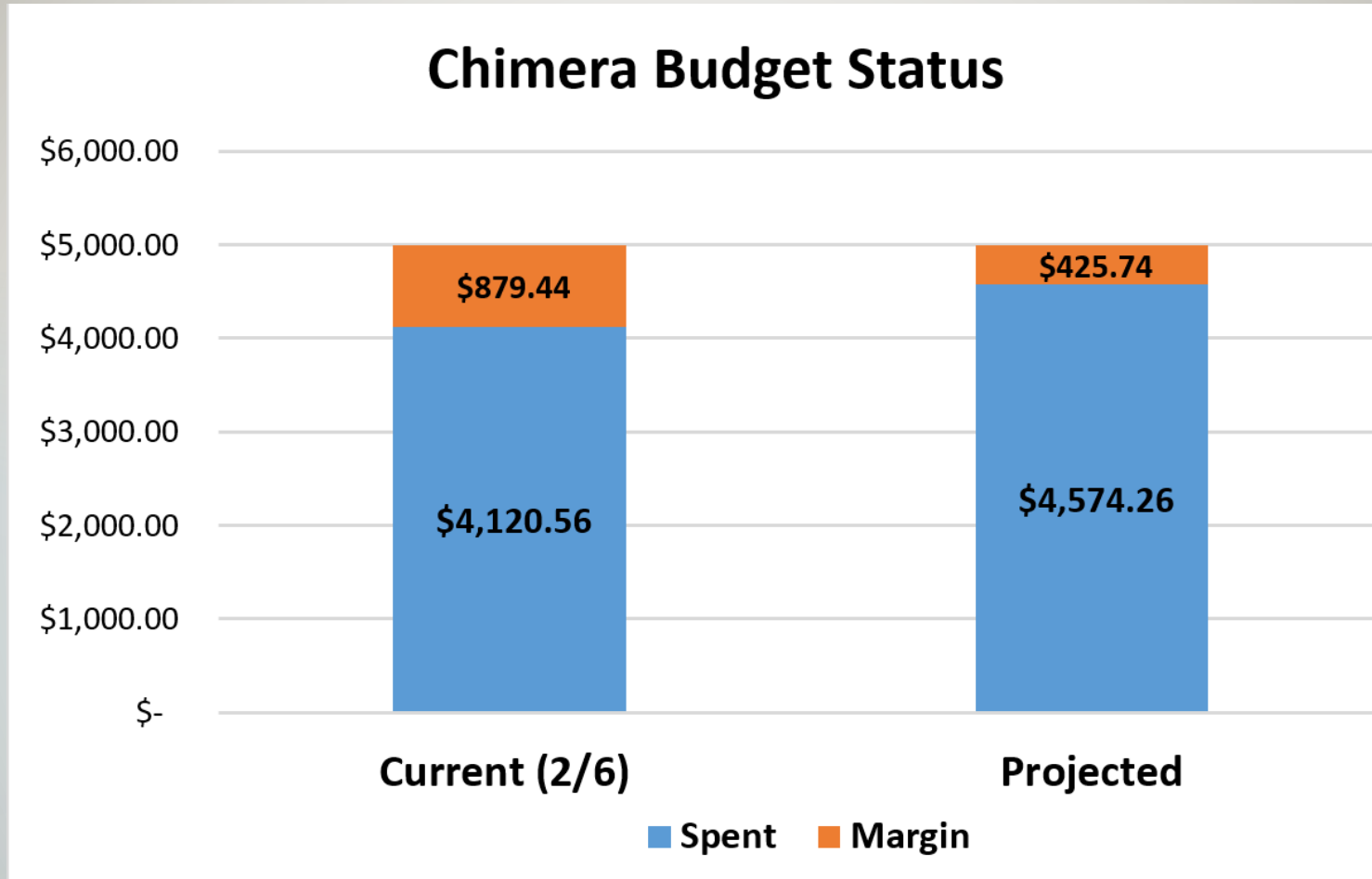
# Manufacturing Schedule Update



# Budget Status Update



# Budget Status





# Purchasing Status

## ARRIVED:

- Raw materials for platform
- Ball screw
- PCB electronic components
- Communication components
- Electronic hardware
- Platform motor

## PURCHASED, NOT ARRIVED:

- Platform and child drone PCBs
- Additional PCB components
- LiPo batteries for platform and child drone

## NOT PURCHASED:

- Worm gear
- Anodizing of aluminum
- Spare INFERNO components
- Presentation and report printing

## LEGEND

Schedule risk

Budget risk

Critical component

Project Overview

Schedule

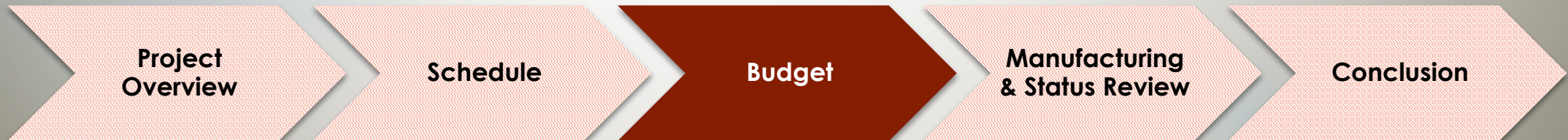
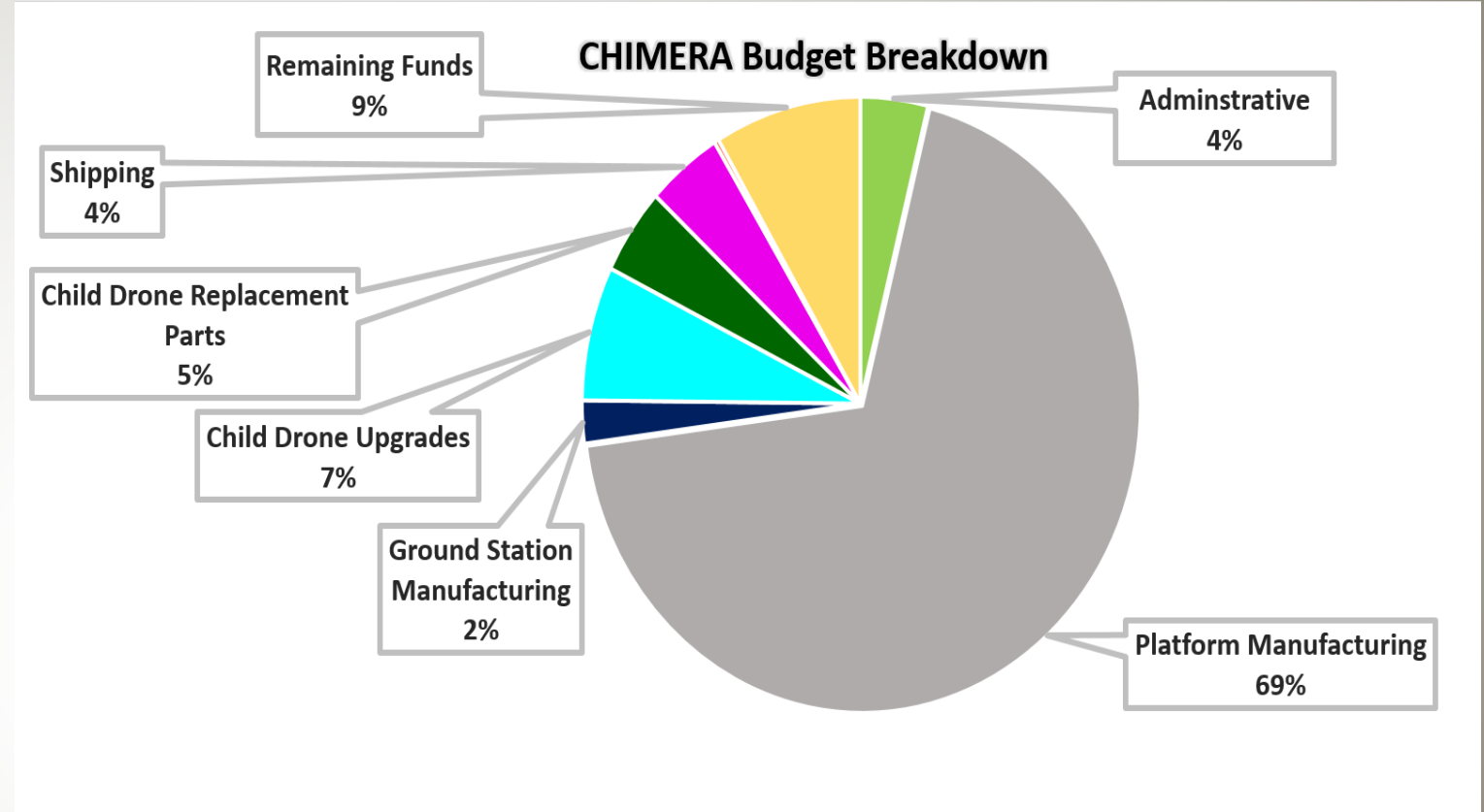
Budget

Manufacturing & Status Review

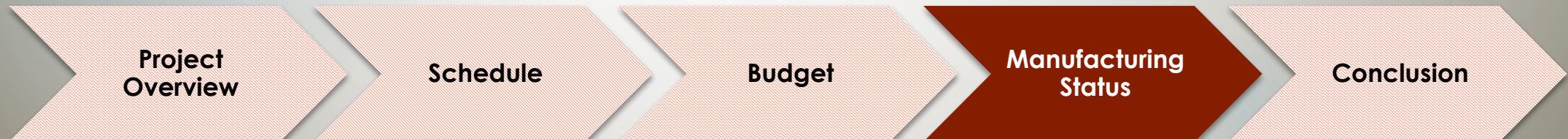
Conclusion

# System Cost Breakdown

SUMMARY	
System	Cost
Adminstrative	\$ 195.50
Platform Manufacturing	\$ 3,550.14
Ground Station Manufacturing	\$ 112.85
Child Drone Upgrades	\$ 354.65
Child Drone Replacement Parts	\$228.78
Shipping	\$ 219.24
Testing and Safety	\$ 13.10
<b>Remaining Funds</b>	<b>\$ 325.74</b>
<b>Budget</b>	<b>\$ 5,000.00</b>



# Manufacturing Status Update



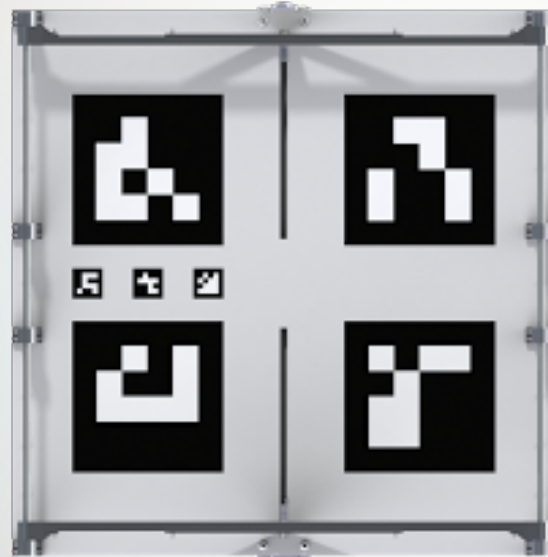
# Image Recognition Software

**CPE 1:** Autonomous Landing of Child Drone

# Software Image Recognition

## Image Recognition Objective:

Transform an image into a **velocity vector** and **yaw rotation** that can be used to navigate the child drone to a landing platform



## Solution:

- ▶ Robust lighting variation immunity, i.e. does not get washed out in sunlight
- ▶ Infinite Combinations
- ▶ Lock only requires one target

Project  
Overview

Schedule

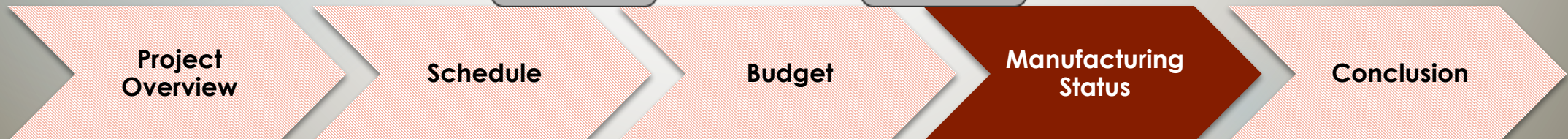
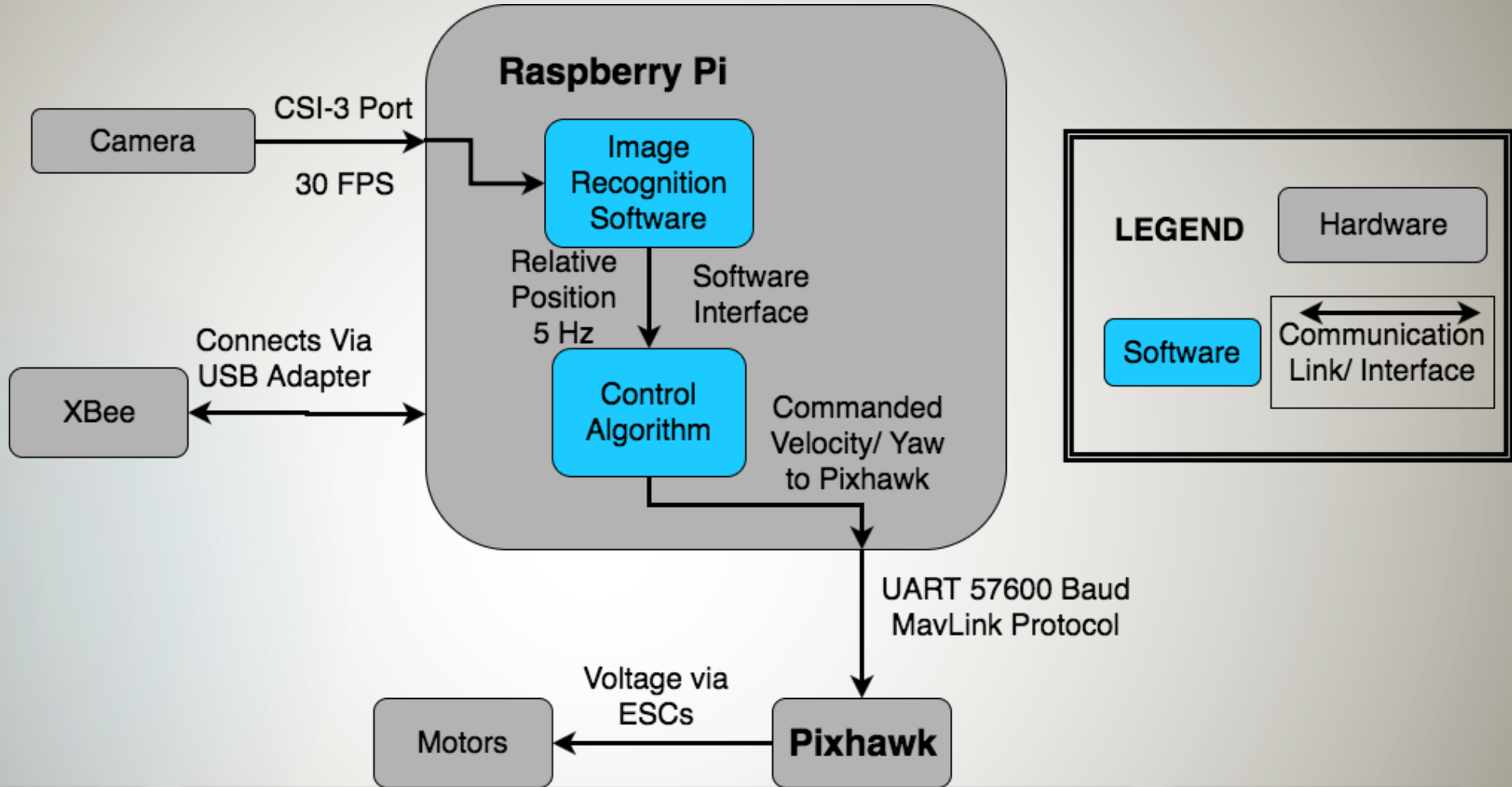
Budget

Manufacturing  
Status

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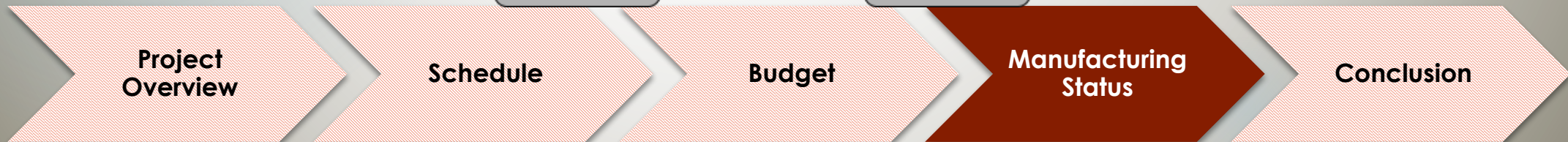
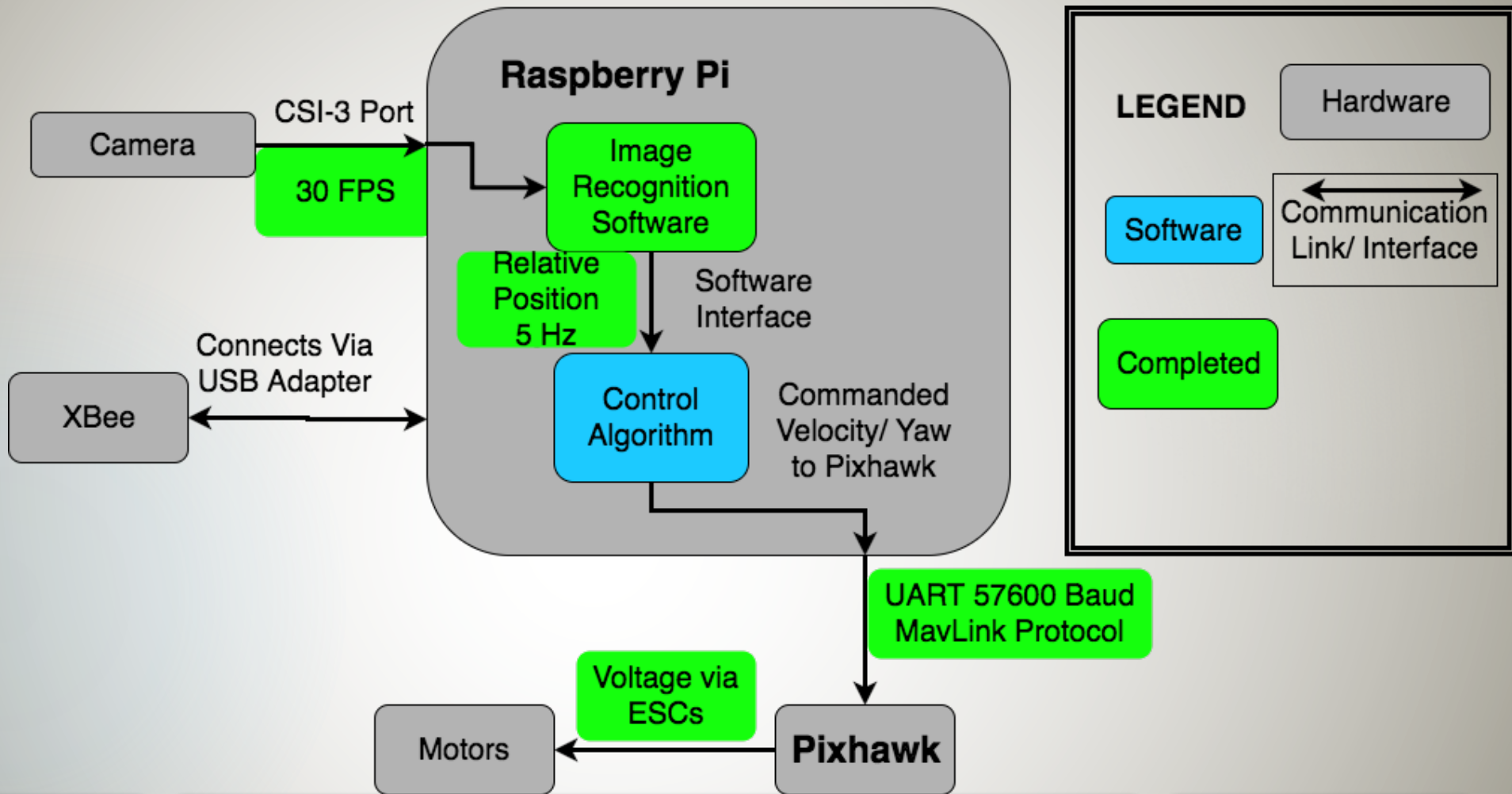
# Software

## Image Recognition Flowchart



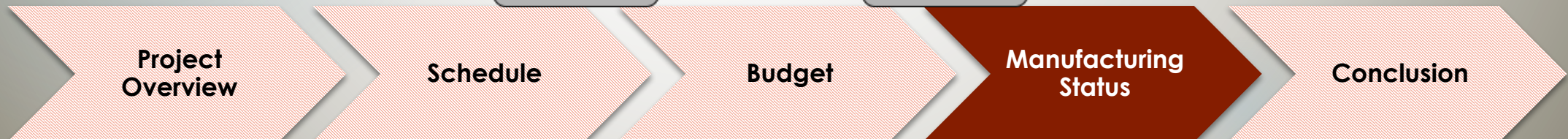
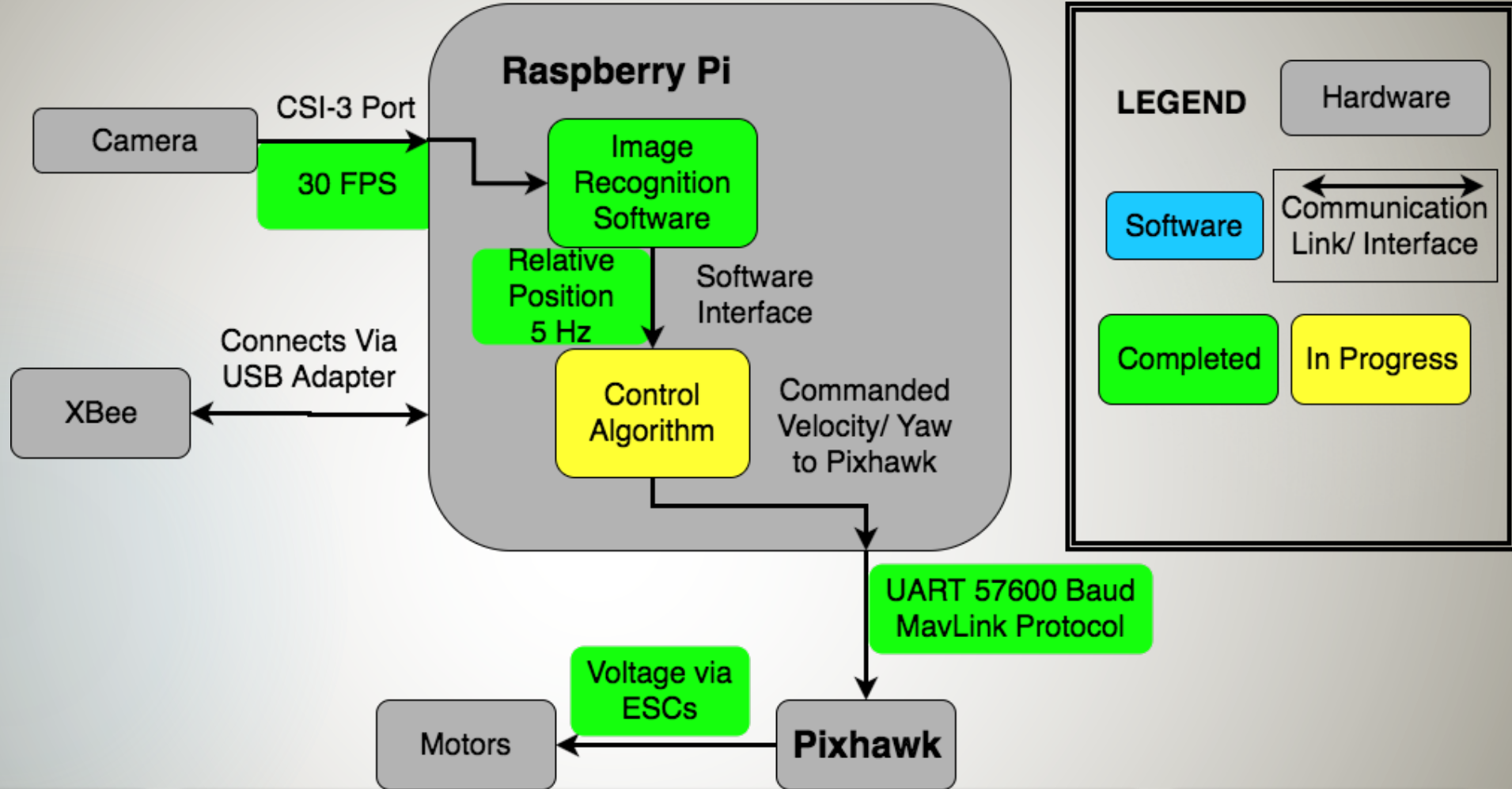
# Software

## Image Recognition Flowchart



# Software

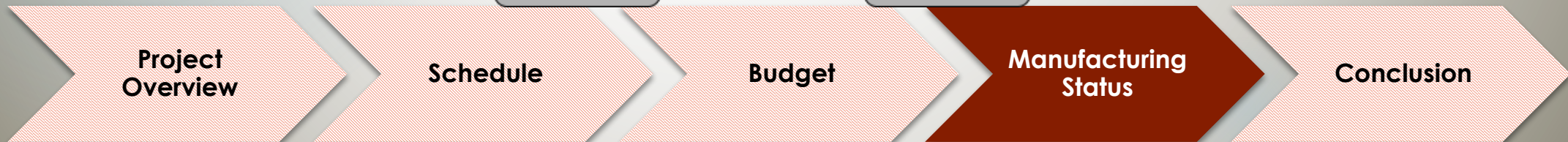
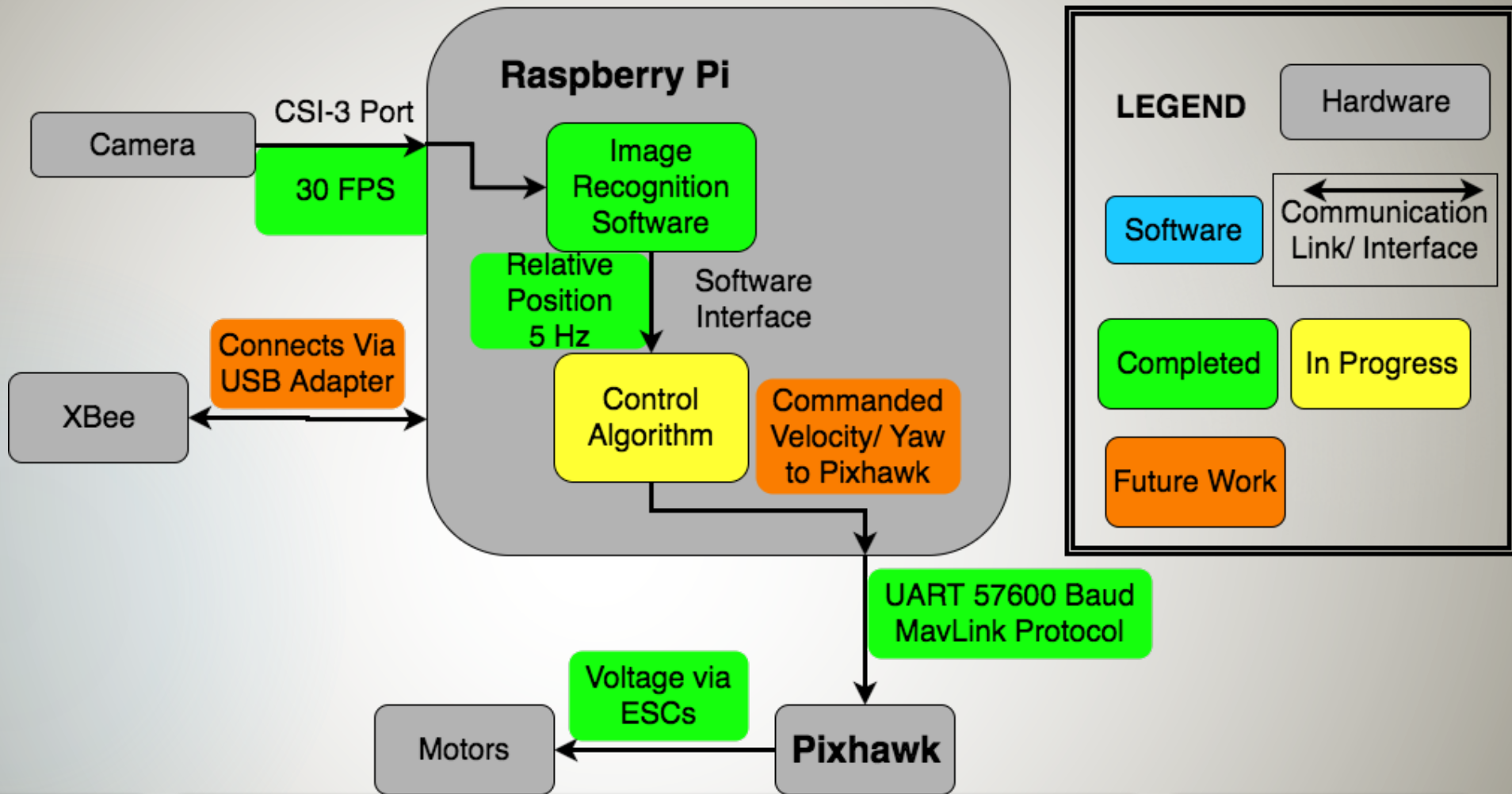
## Image Recognition Flowchart





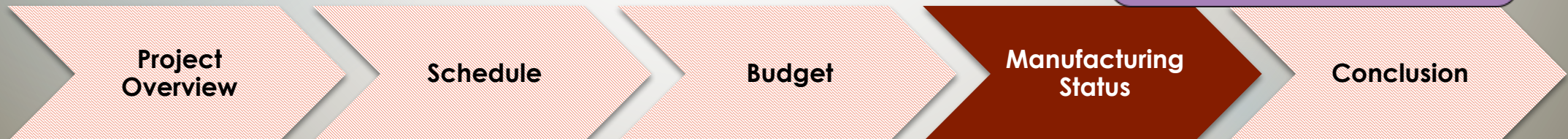
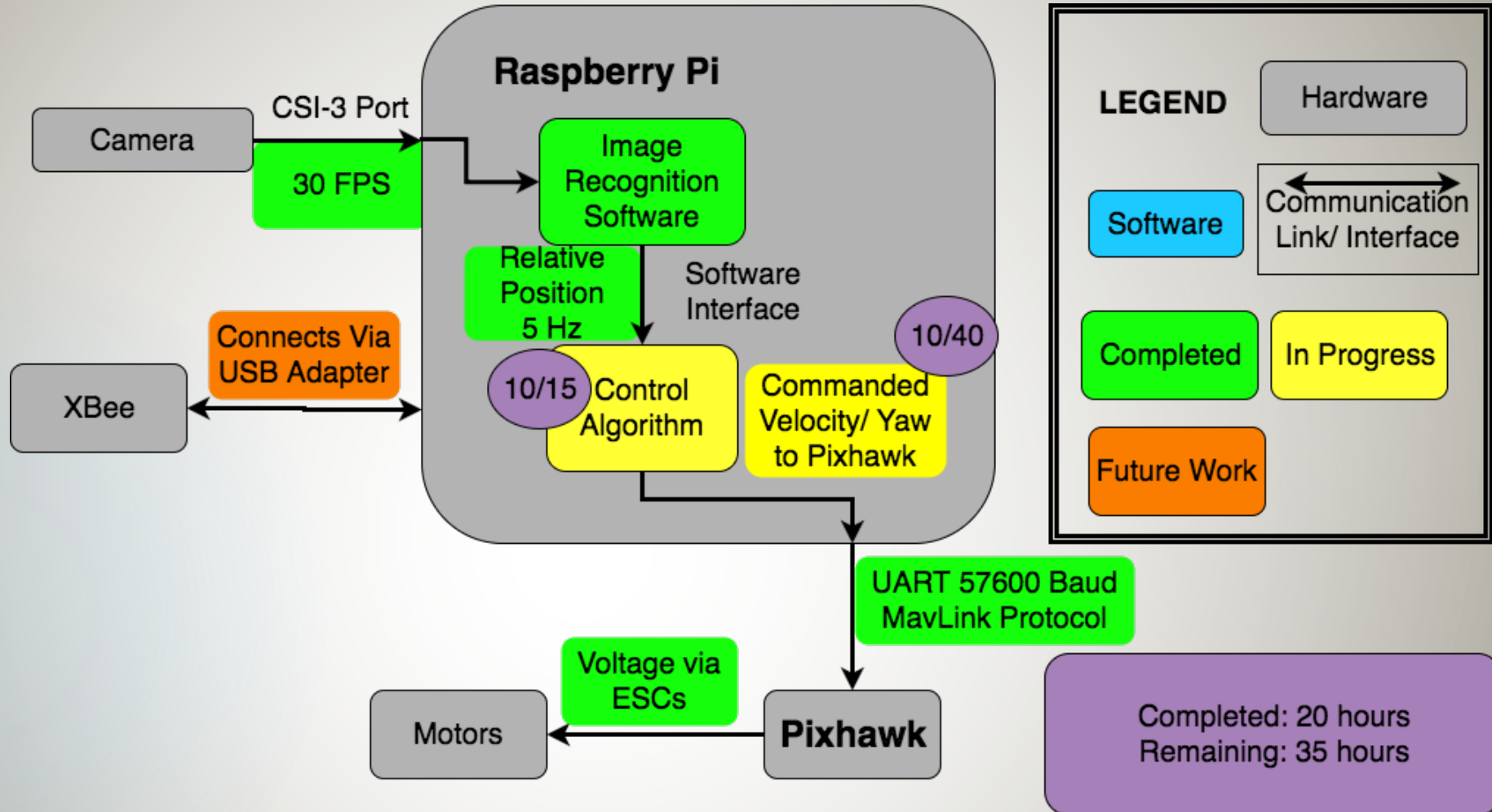
# Software

## Image Recognition Flowchart



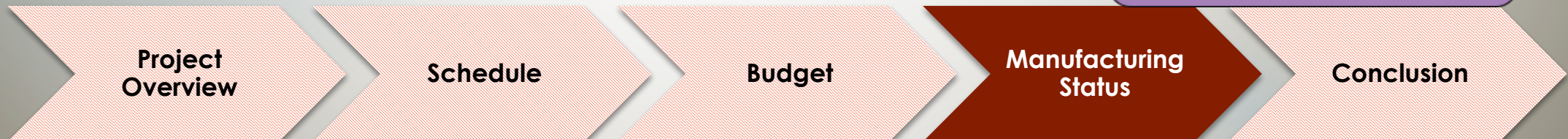
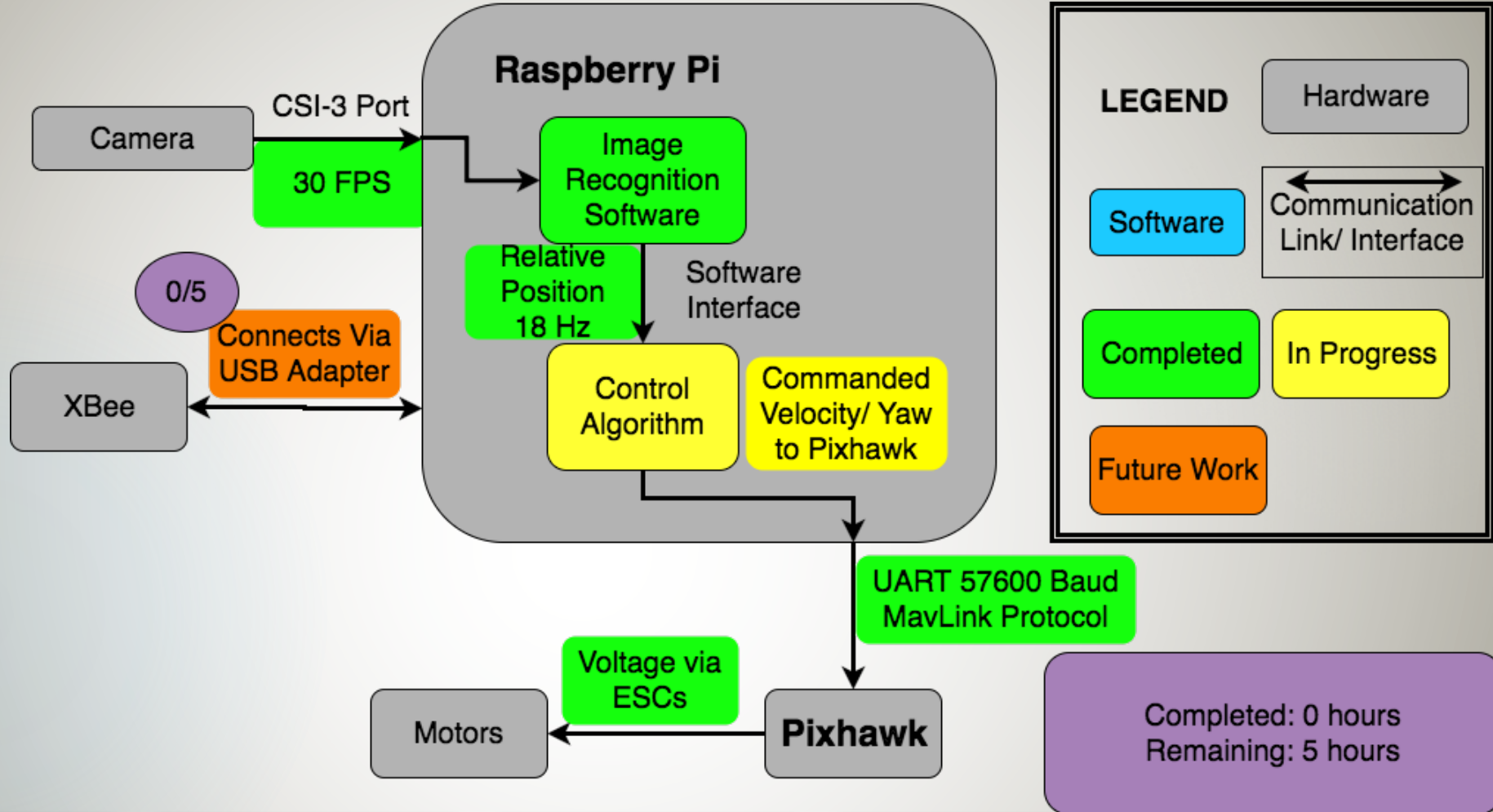
# Software

## Image Recognition Flowchart



# Software

## Image Recognition Flowchart



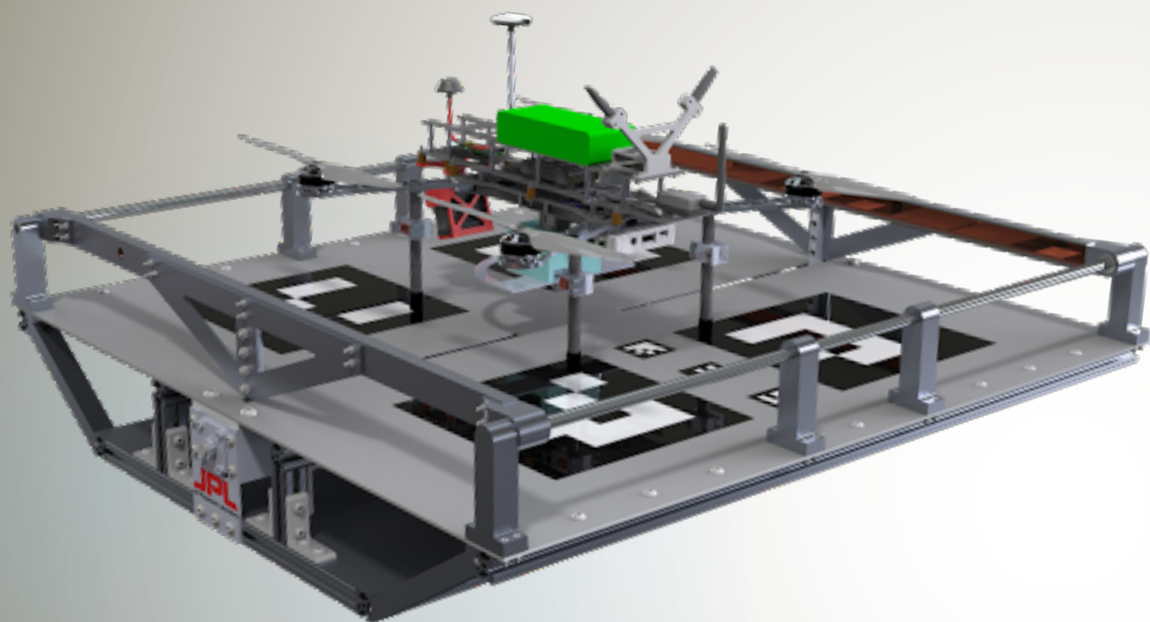
# Hardware Manufacturing Update

**CPE 1:** Autonomous Landing of Child Drone

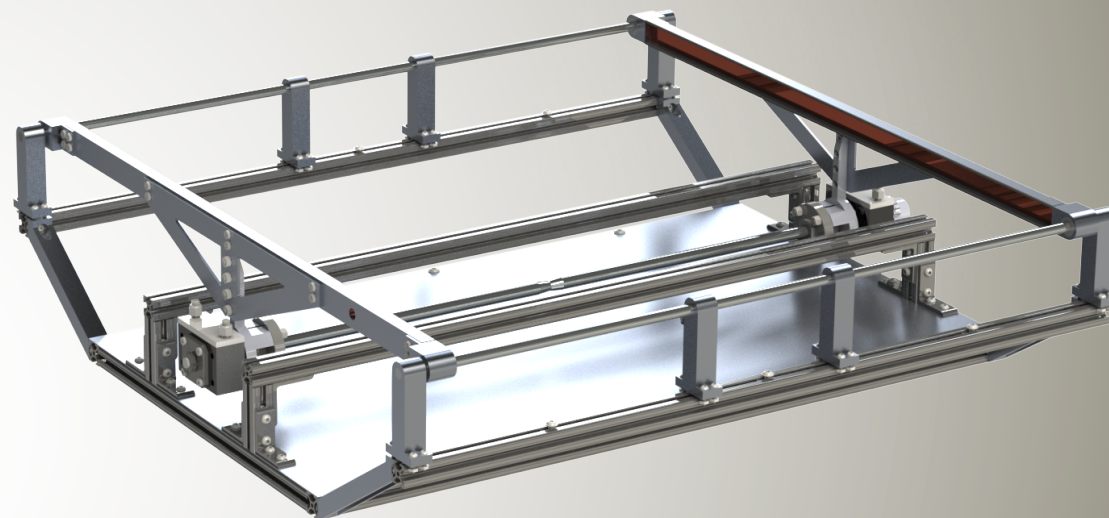
**CPE 2:** Charging Child Drone

**CPE 3:** Securing Child Drone

# Platform Hardware



Fully integrated structure



Structure with the landing platform removed

Project Overview

Schedule

Budget

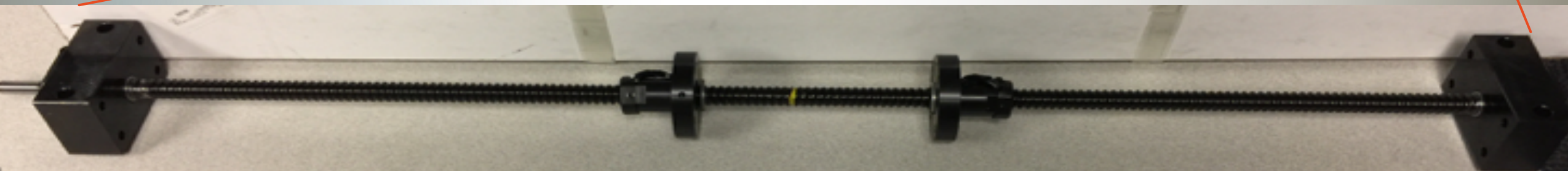
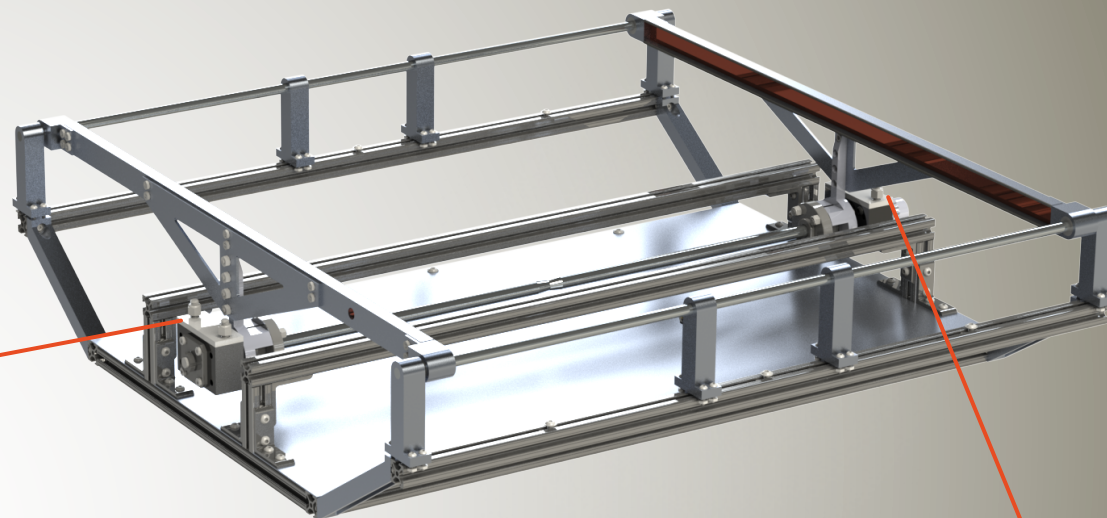
Manufacturing Status

Conclusion

# Platform Hardware

## Ball Screw System

- ▶ Material: Varied
- ▶ Procured
- ▶ Quantity: 1
- ▶ Date Received: 01/31



Project  
Overview

Schedule

Budget

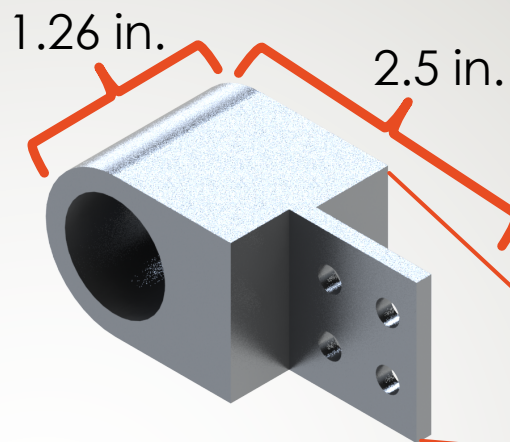
Manufacturing  
Status

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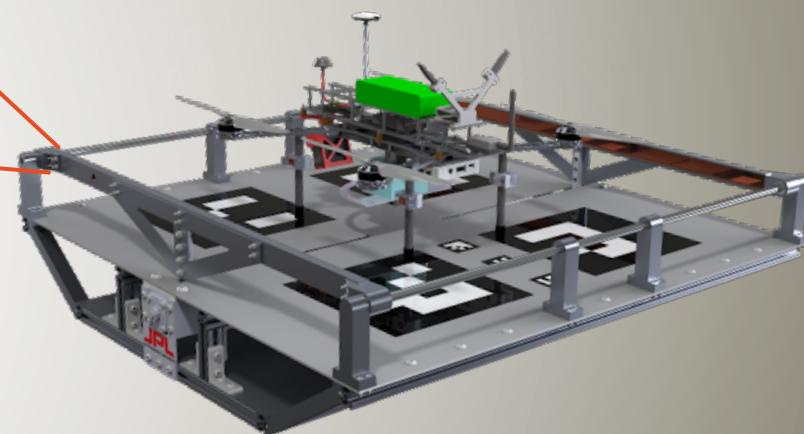
# Platform Hardware

## Guide Rail Bearing Bracket

- ▶ Material: Aluminum 6061
- ▶ Machine: CNC/lathe
- ▶ Quantity: 4
- ▶ Due Date: 03/05
- ▶ Press fit bearing



0/20  
Hrs.



Material Procured

Stock Squared

Machined

Integrated

Finalized

Project  
Overview

Schedule

Budget

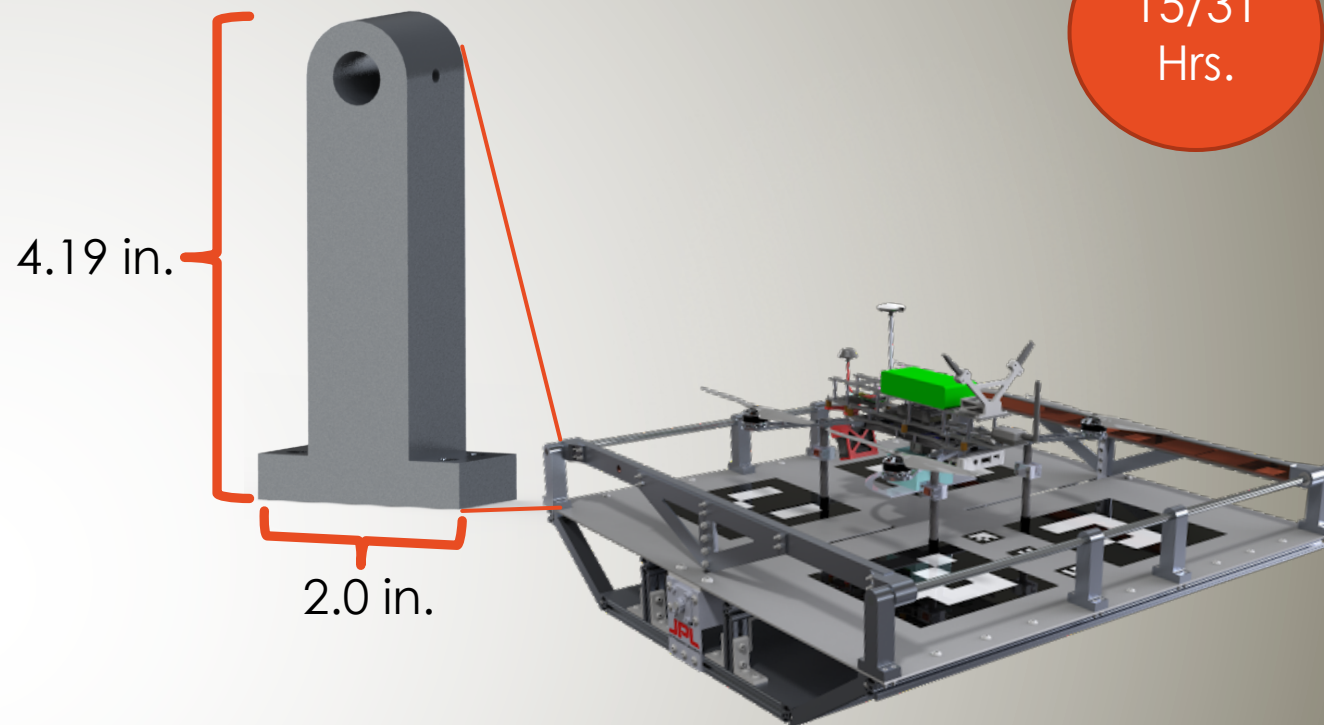
Manufacturing  
Status

Conclusion

# Platform Hardware

## Guide Rail Support Bracket

- ▶ Material: Aluminum 6061
- ▶ Machine: Mill
- ▶ Quantity: 8
- ▶ Due Date: 03/05



15/31  
Hrs.

Material Procured

Stock Squared

Machined

Integrated

Finalized

Project  
Overview

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Manufacturing  
Status

Conclusion

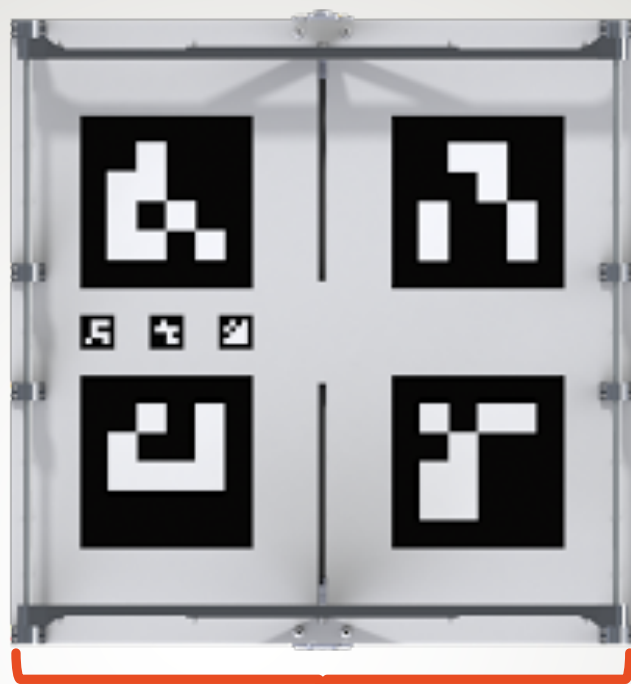


# Platform Hardware

## Landing Platform

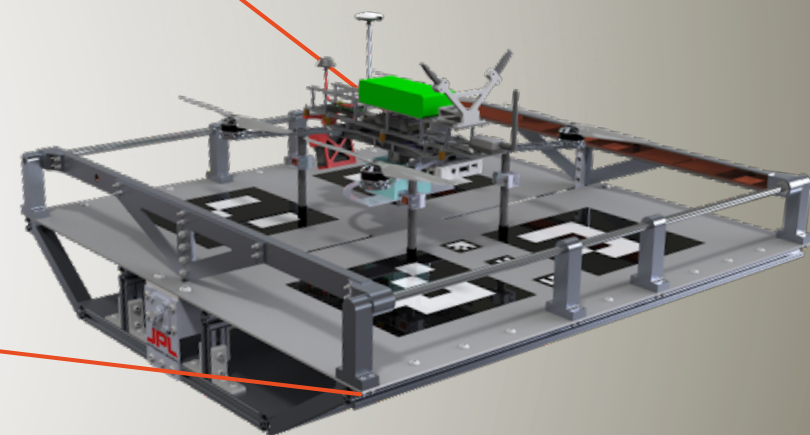
- ▶ Material: Aluminum 6061
- ▶ Machine: Mill
- ▶ Quantity: 1
- ▶ Due Date: 02/27

0/12  
Hrs.



36.0 in.

36.0 in.



Material Procured

Stock Squared

Machined

Integrated

Finalized

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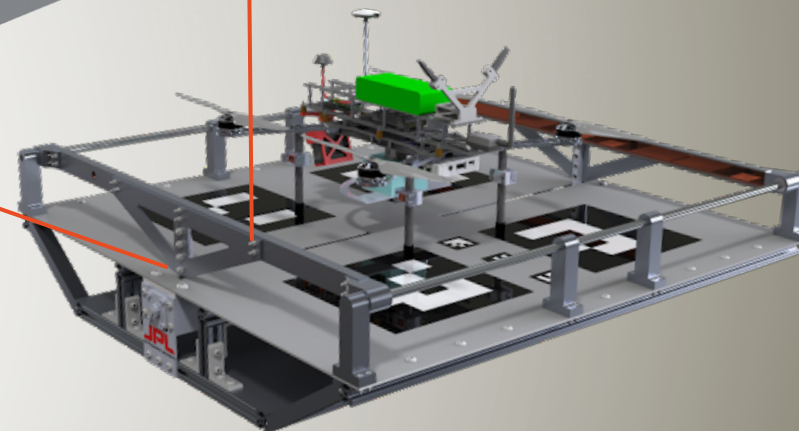
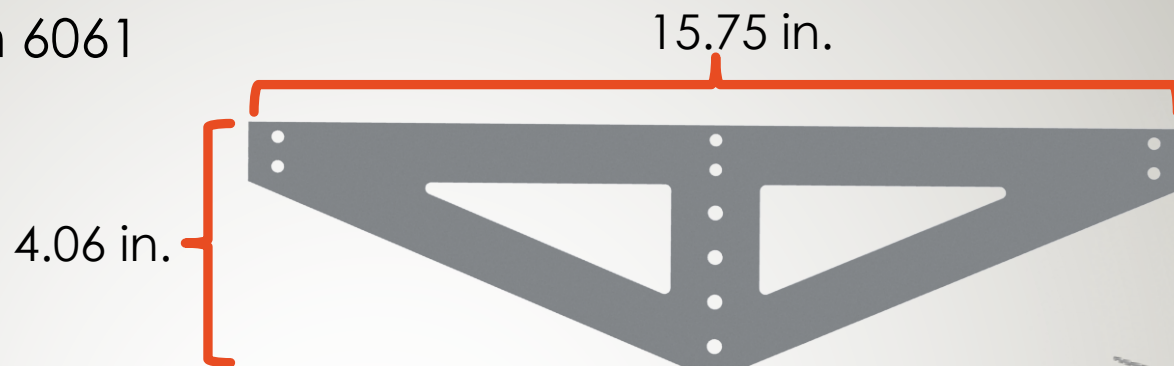
Conclusion

# Platform Hardware

## Charge Bracket

0/12  
Hrs.

- ▶ Material: Aluminum 6061
- ▶ Machine: CNC/Mill
- ▶ Quantity: 2
- ▶ Due Date: 03/05



Material Procured

Stock Squared

Machined

Integrated

Finalized

Project  
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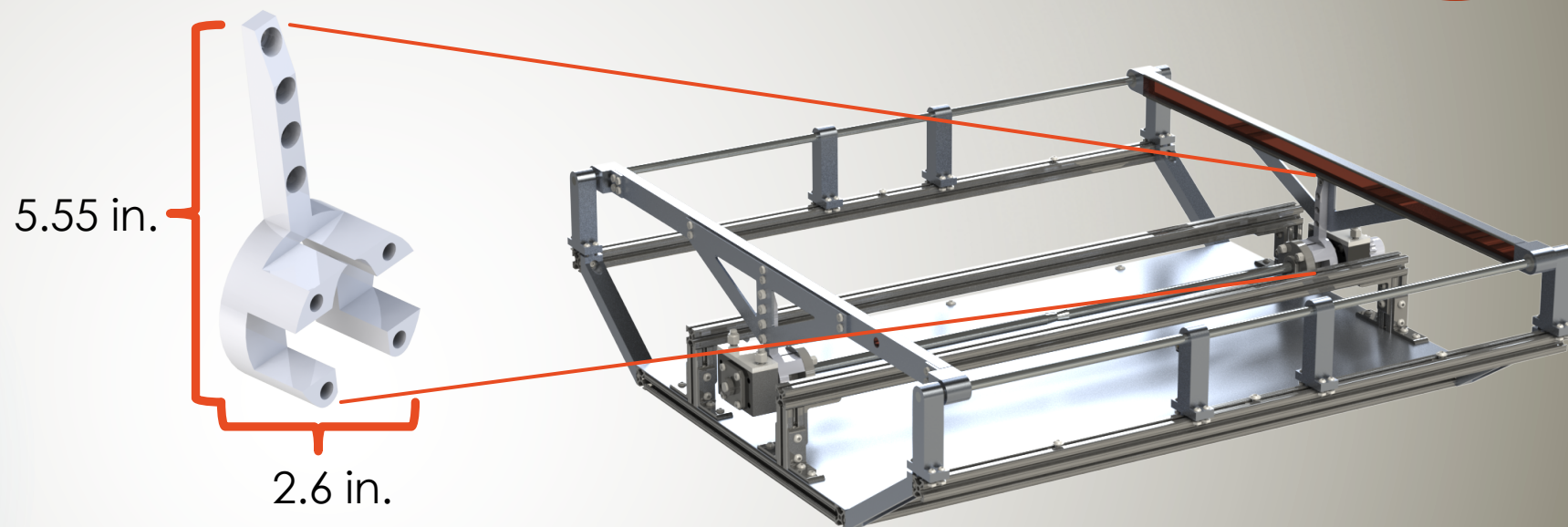
Conclusion

# Platform Hardware

## Ball Screw Extension

0/20  
Hrs.

- ▶ Material: Aluminum 6061
- ▶ Machine: CNC/Mill
- ▶ Quantity: 2
- ▶ Due Date: 03/05



Material Procured

Stock Squared

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Finalized

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Status

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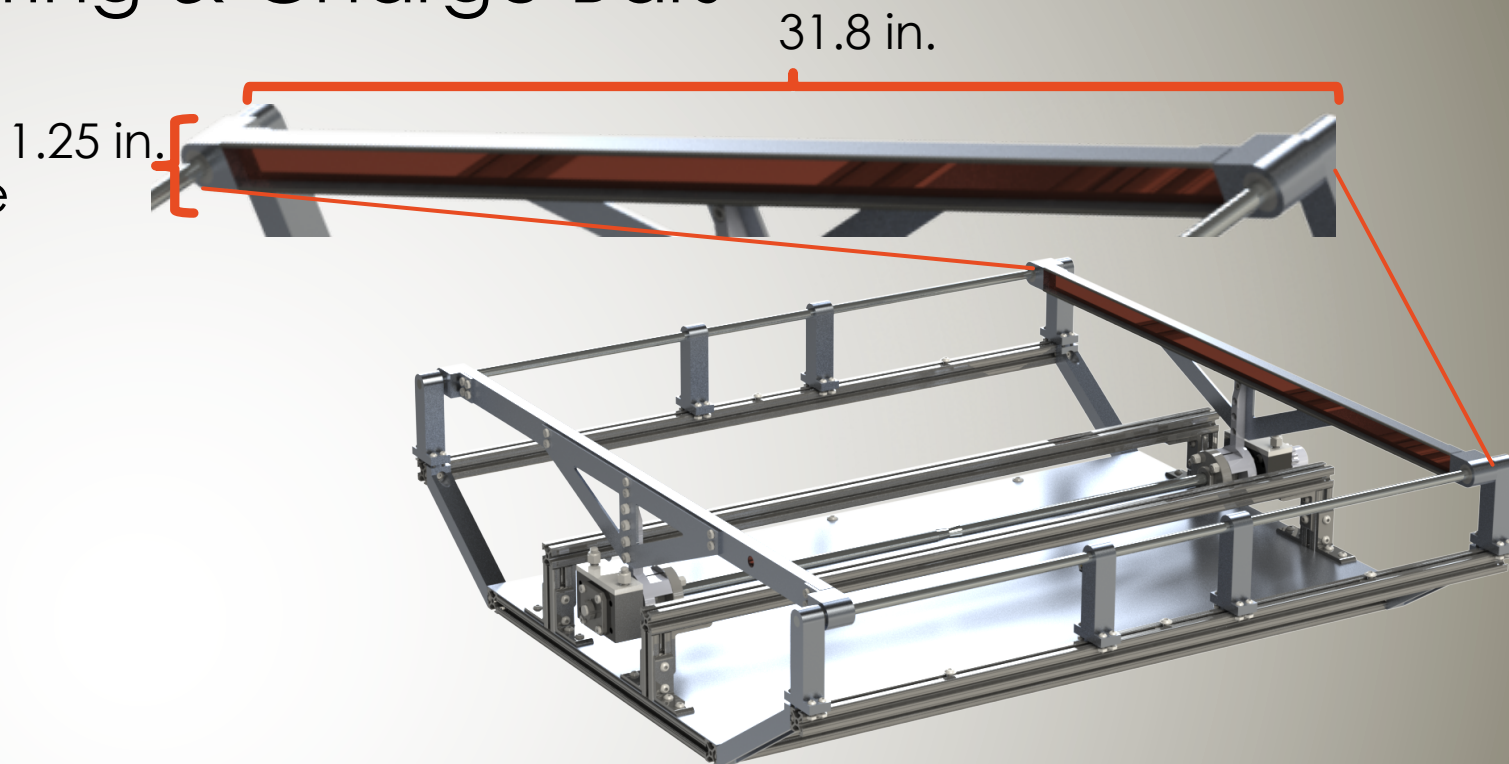
# Platform Hardware

## Securing & Charge Bars

6/14  
Hrs.



- ▶ Material: Aluminum 6061
- ▶ Machine: CNC/Mill/Anodize
- ▶ Quantity: 2
- ▶ Due Date: 03/05



Material Procured

Stock Squared

Machined

Integrated

Finalized

Project  
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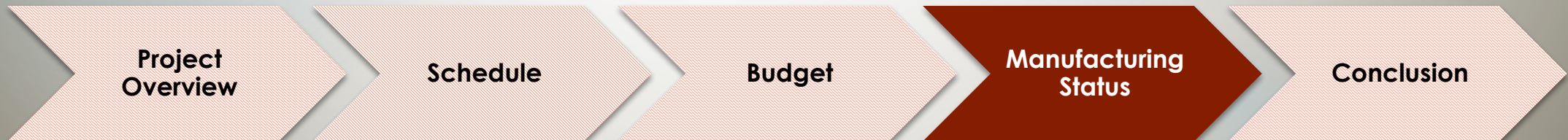
Budget

Manufacturing  
Status

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# Hardware Manufacturing Overview

	Procured	Stock Squared	Machined	Integrated	Finalized
Guide Rail Bearing Bracket	0/20	✓ On Track			03/05
Guide Rail Support Bracket	15/31	✓ On Track			03/05
Landing Platform	0/12	✓ On Track			02/27
Charge Bracket	0/12	✓ On Track			03/05
Ball Screw Extension	0/20	✓ On Track			03/05
Securing & Charge Bars	6/14	✓ On Track			03/05
	<b>Hrs.</b>				<b>Date</b>



# Hardware Manufacturing Overview

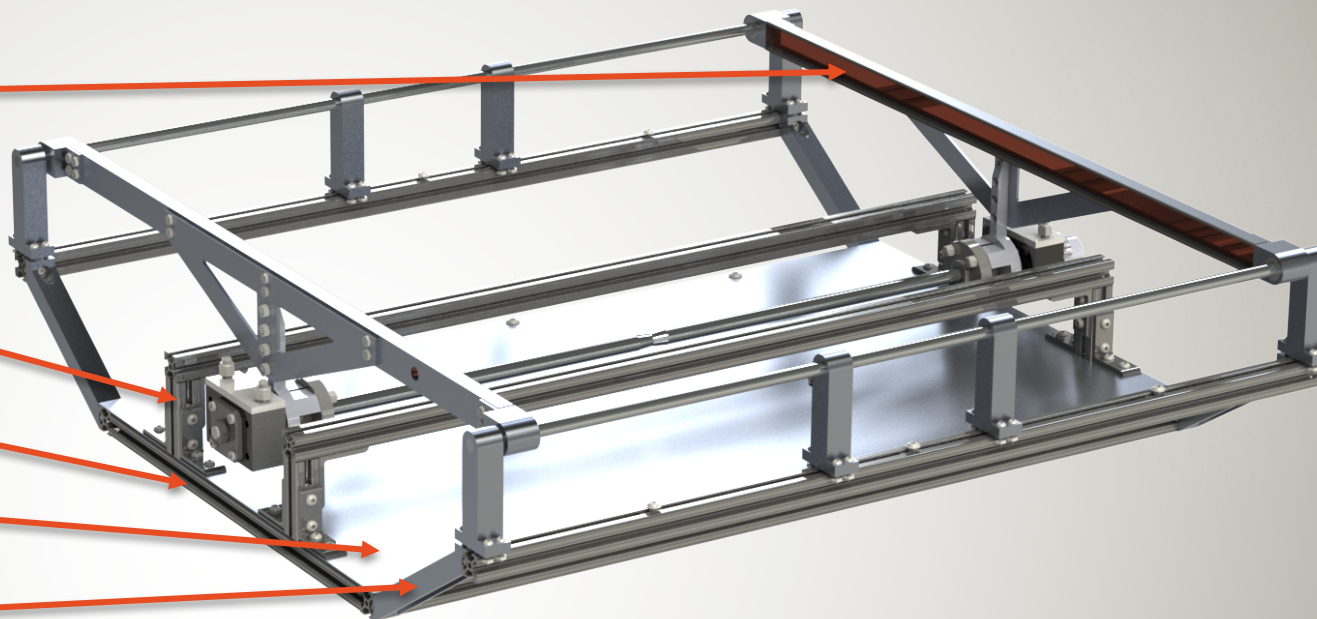
Copper Charge Plate

3 inch Framing

19 inch Framing

Lower Platform

Landing Platform Supports



Project Overview

Schedule

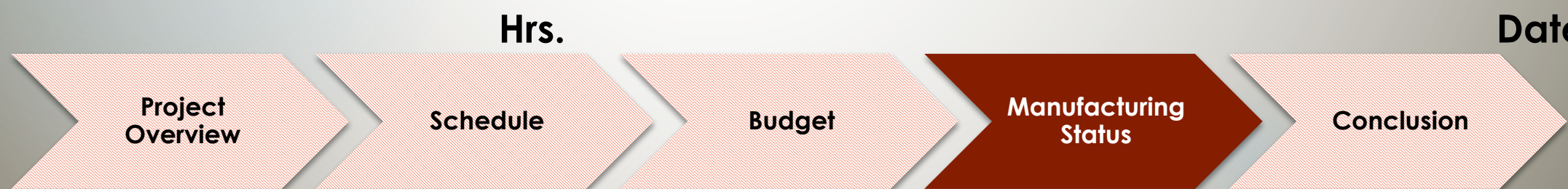
Budget

Manufacturing Status

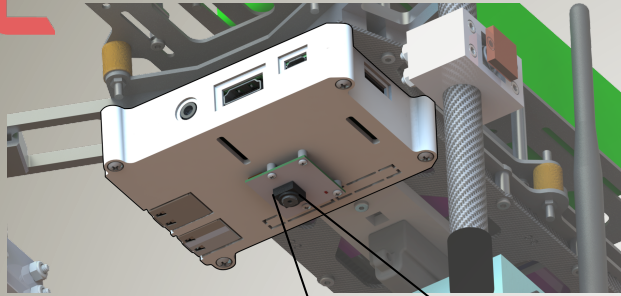
Conclusion

# Hardware Manufacturing Overview

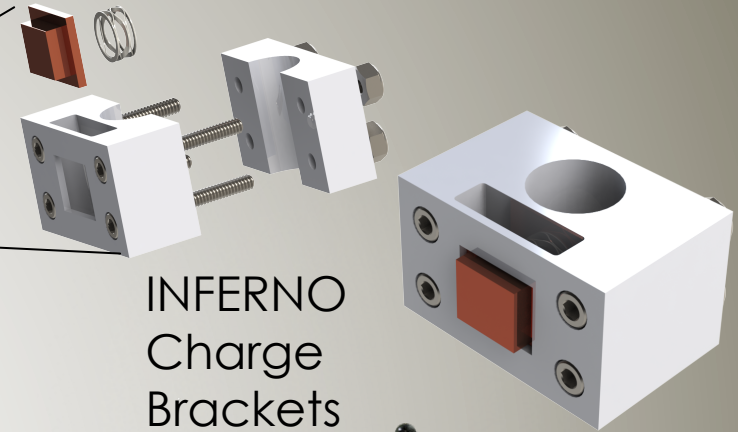
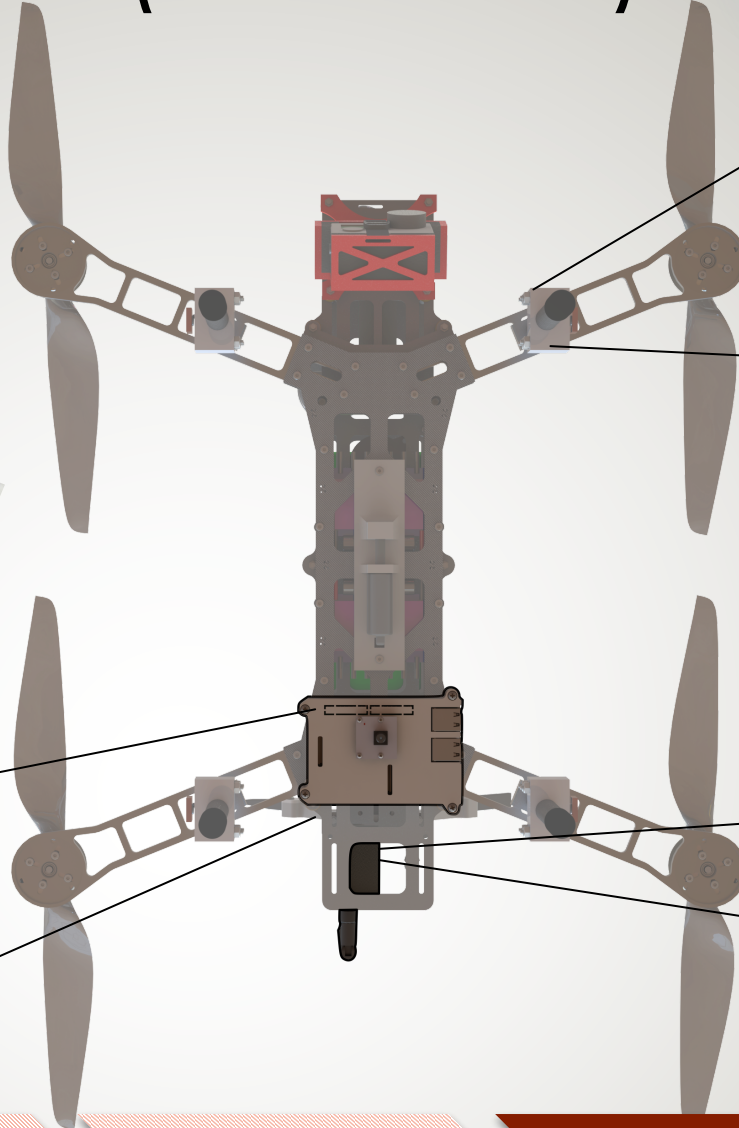
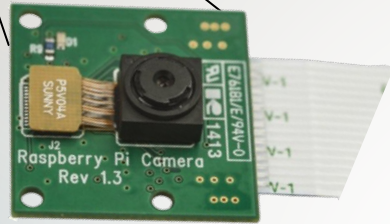
	Procured	Stock Squared	Machined	Integrated	Finalized
Copper Charge Plate	1/2	✓ On Track			03/05
3 inch Framing	1/1	✓ On Track			03/20
19 inch Framing	1/1	✓ On Track			03/20
Lower Platform	1/3	✓ On Track			03/20
Landing Platform Supports	2/22	✓ On Track			03/20



# Child Drone (INFERNO) Hardware

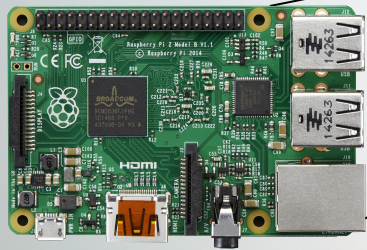


Raspberry Pi 5MP  
Camera Board  
Module

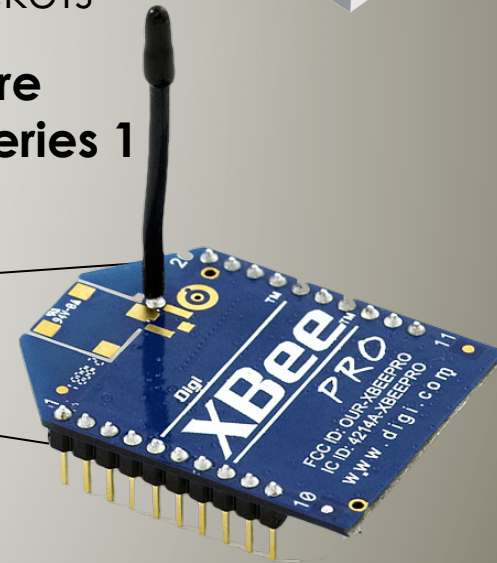


INFERNO  
Charge  
Brackets

XBee Pro Wire  
Antenna - Series 1  
2.4 GHz



Raspberry Pi 2  
Model B



Project  
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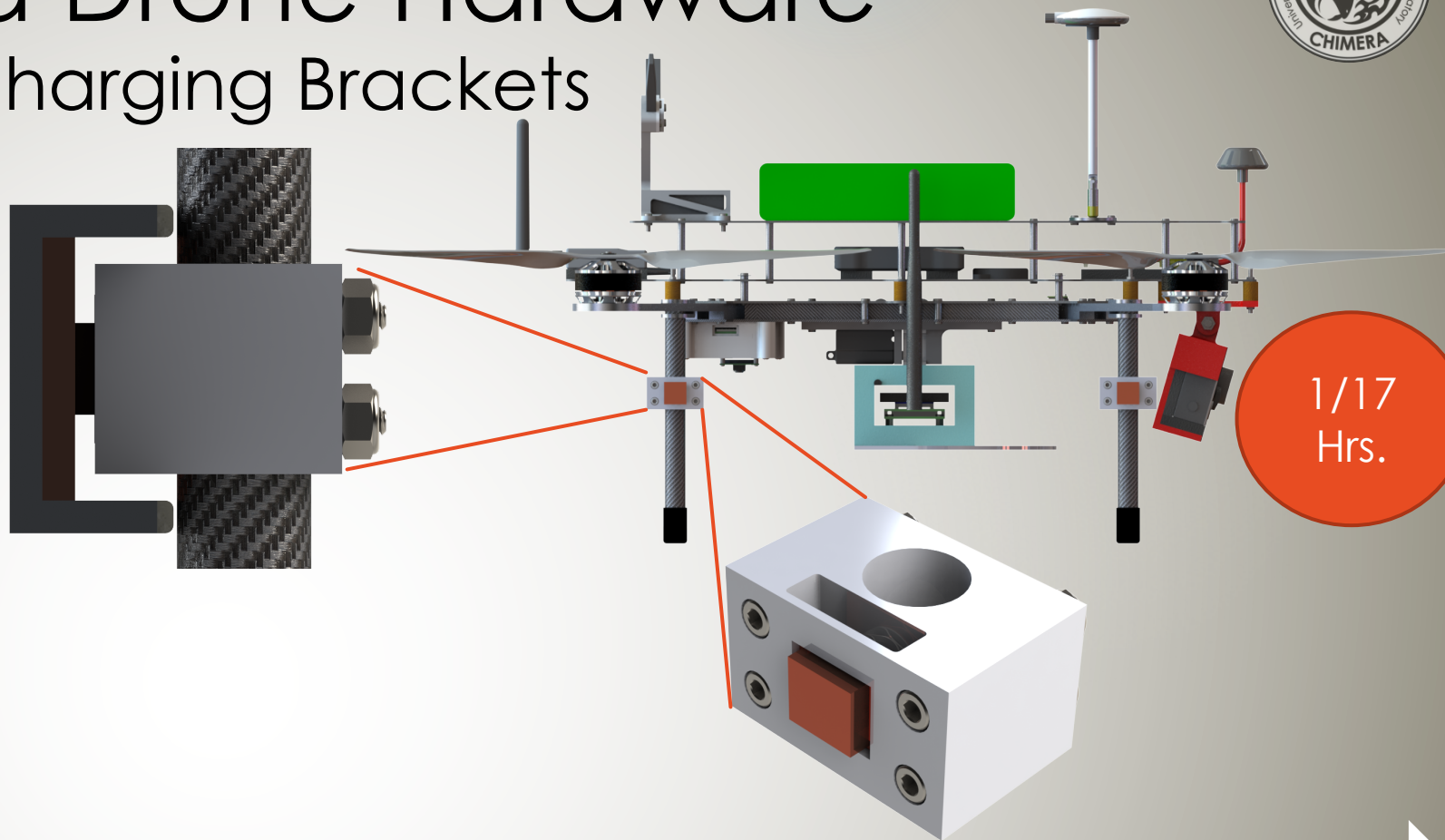
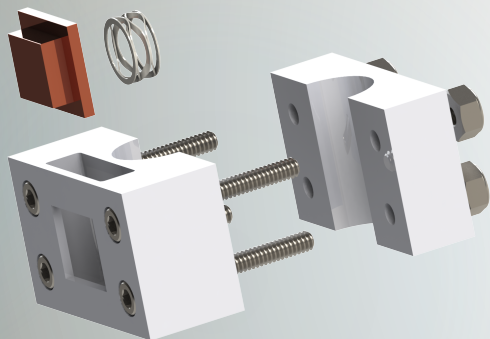
Conclusion



# Child Drone Hardware

## Charging Brackets

- ▶ Material: Delrin, Copper
- ▶ Machine: CNC/Mill
- ▶ Quantity: 4
- ▶ Due Date: 03/05



Material Procured

Stock Squared

Machined

Integrated

Finalized

Project  
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Schedule

Budget

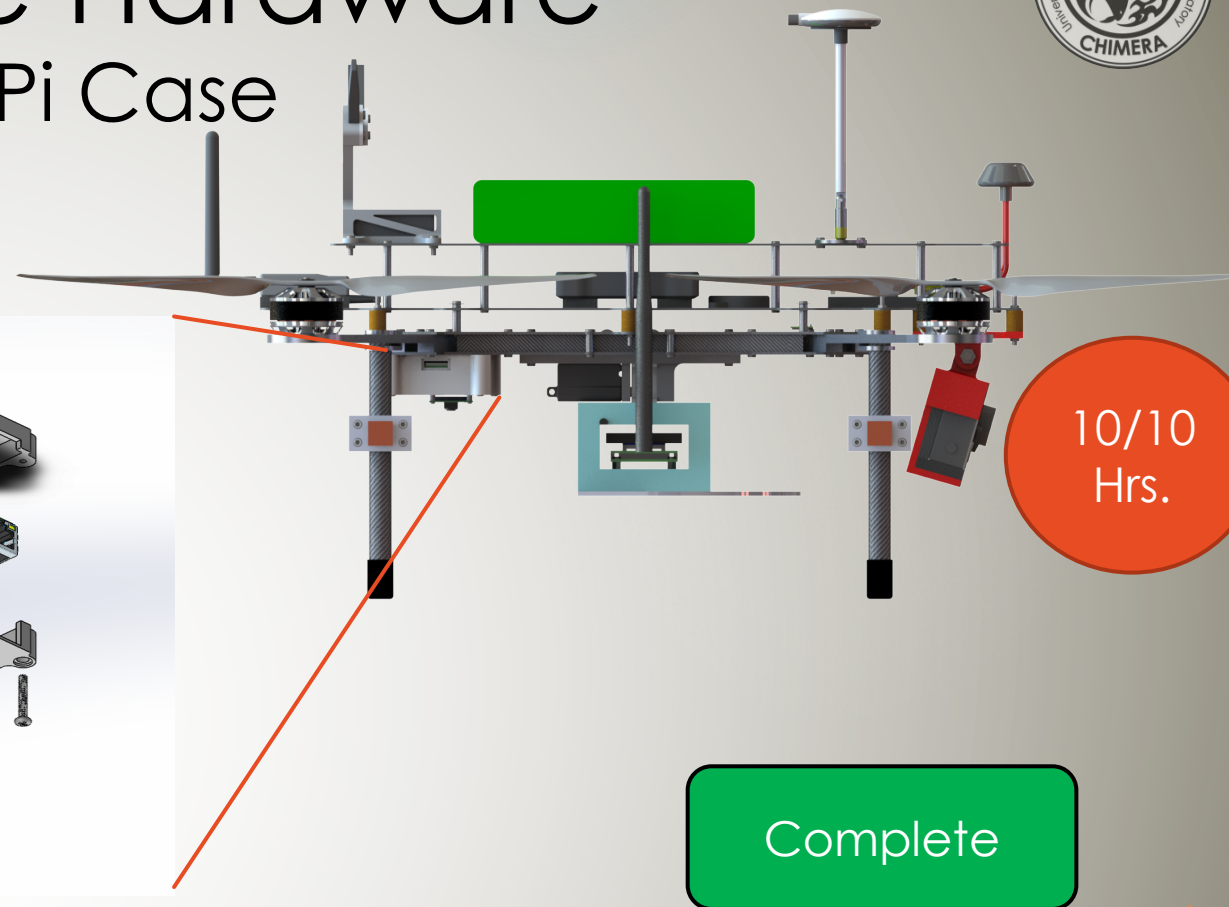
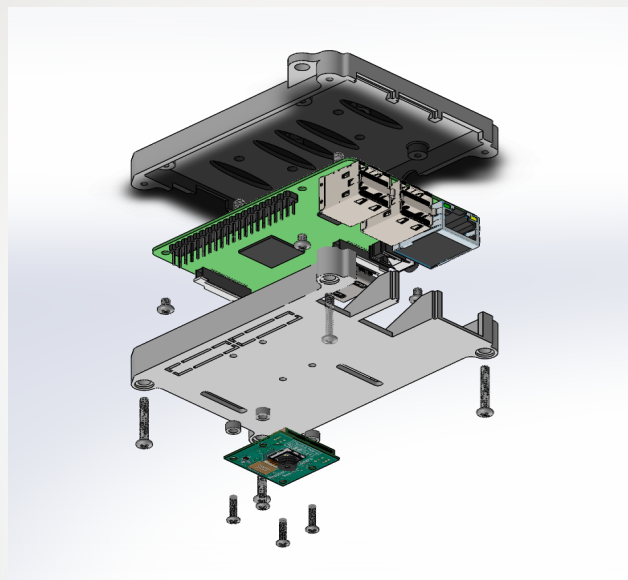
Manufacturing  
Status

Conclusion

# Child Drone Hardware

## Raspberry Pi Case

- ▶ Material: ABS
- ▶ Machine: Electronics Lab 3D Printer
- ▶ Quantity: 1
- ▶ Due Date: 02/03



Material Procured

Case Top Printed

Case Bottom Printed

Pi Integration

INFERNO Installation

Project Overview

Schedule

Budget

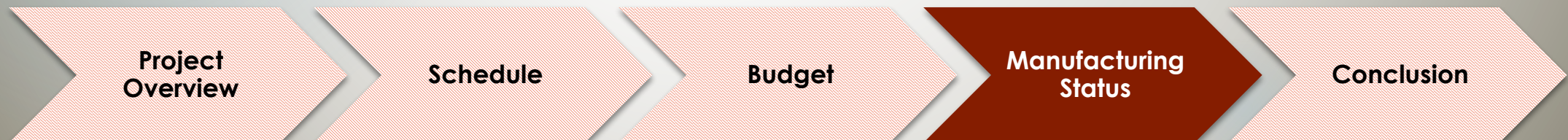
Manufacturing Status

Conclusion

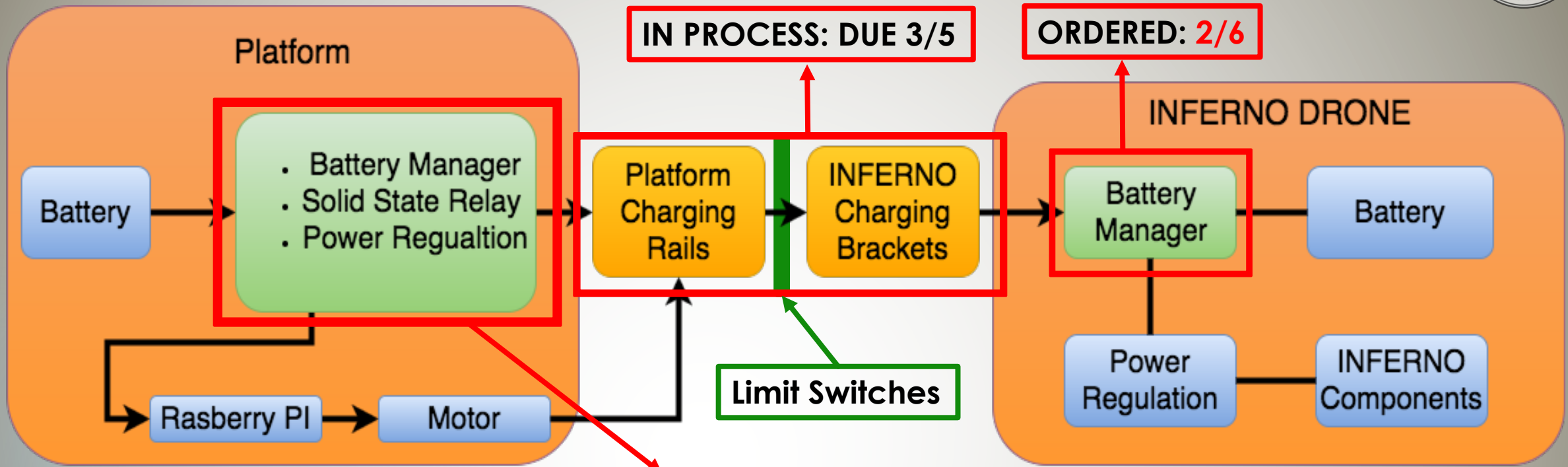
# Child Drone Hardware Manufacturing

## Overview

	Procured	Stock Squared	Machined	Integrated	Finalized
Charging Bracket (housing)	1/14	✓ On Track			03/05
Charging Bracket (copper)	1/3	✓ On Track			03/05
Raspberry Pi Case	10/10				02/03
	<b>Hrs.</b>				<b>Date</b>



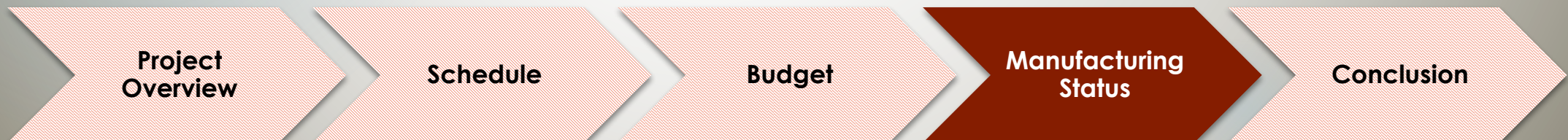
# Electronic Status Update



## Legend

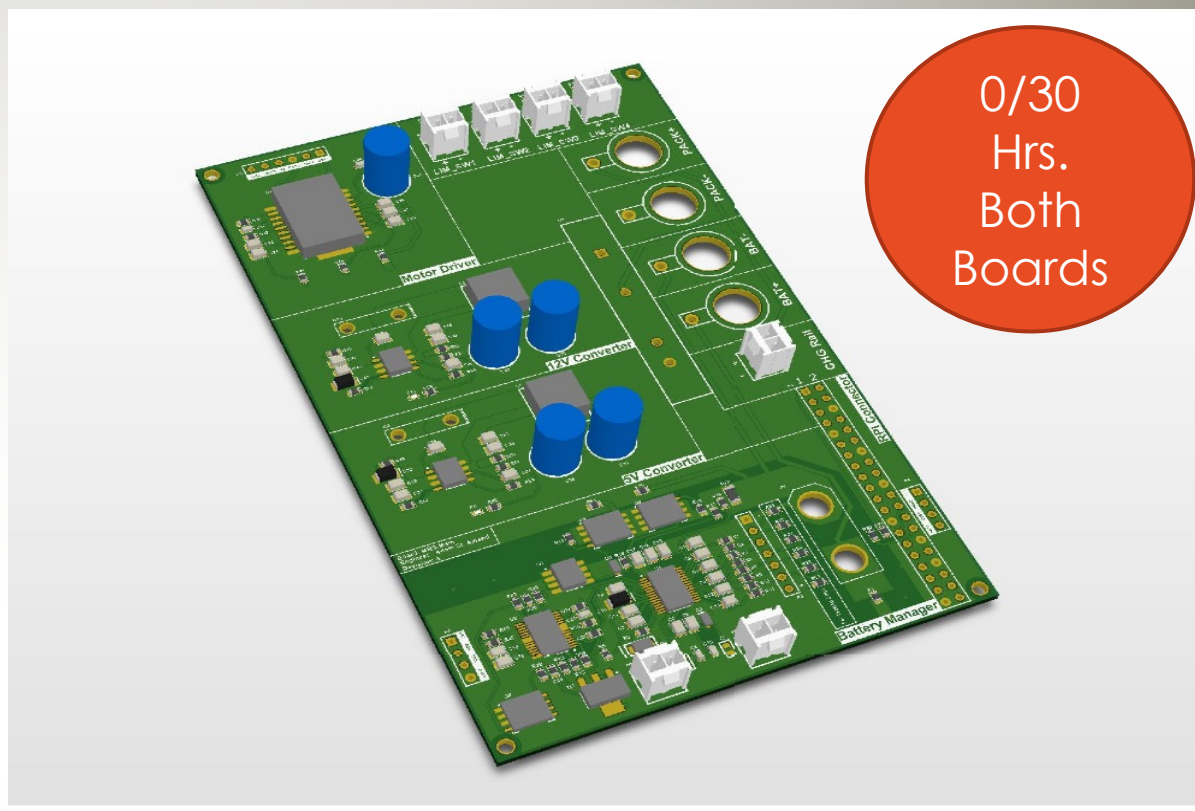


**\*All COTS parts accounted for as of 2/1**



# Electronic Status Update

- ▶ PCB for Platform and INFERNO are being fabricated
- ▶ Need to populate boards prior to testing
- ▶ Margin for another PCB Revision
- ▶ Behind schedule by 4 days but built in margin can absorb difference



Platform PCB with all components integrated

PCB Designed

PCB Fabricated

PCB Populated

Pi Integration

INFERNO/Platform Installation

Project Overview

Schedule

Budget

Manufacturing Status

Conclusion

# Conclusion

- ▶ Changes from CDR: Motor mount for ball screw system
- ▶ Schedule
  - ▶ PCB fabrication has been delayed a week
    - ▶ Can make up time in populating the board
- ▶ Budget
  - ▶ Unforeseen cost due to necessary design changes
    - ▶ Bevel Gear to Worm Gear
  - ▶ \$400 remaining funds
    - ▶ Not necessary for external funding

Project  
Overview

Schedule

Budget

Manufacturing  
Status

Conclusion

Questions?



# Backup



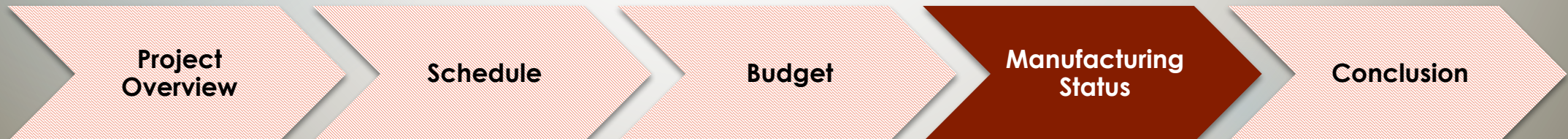




# Communications Backup Update



- ▶ All Communication COTS Procured
- ▶ All but one Antenna has arrived (Crosshair Receiver Expected 02/06)
- ▶ Component communication testing will occur (02/10)



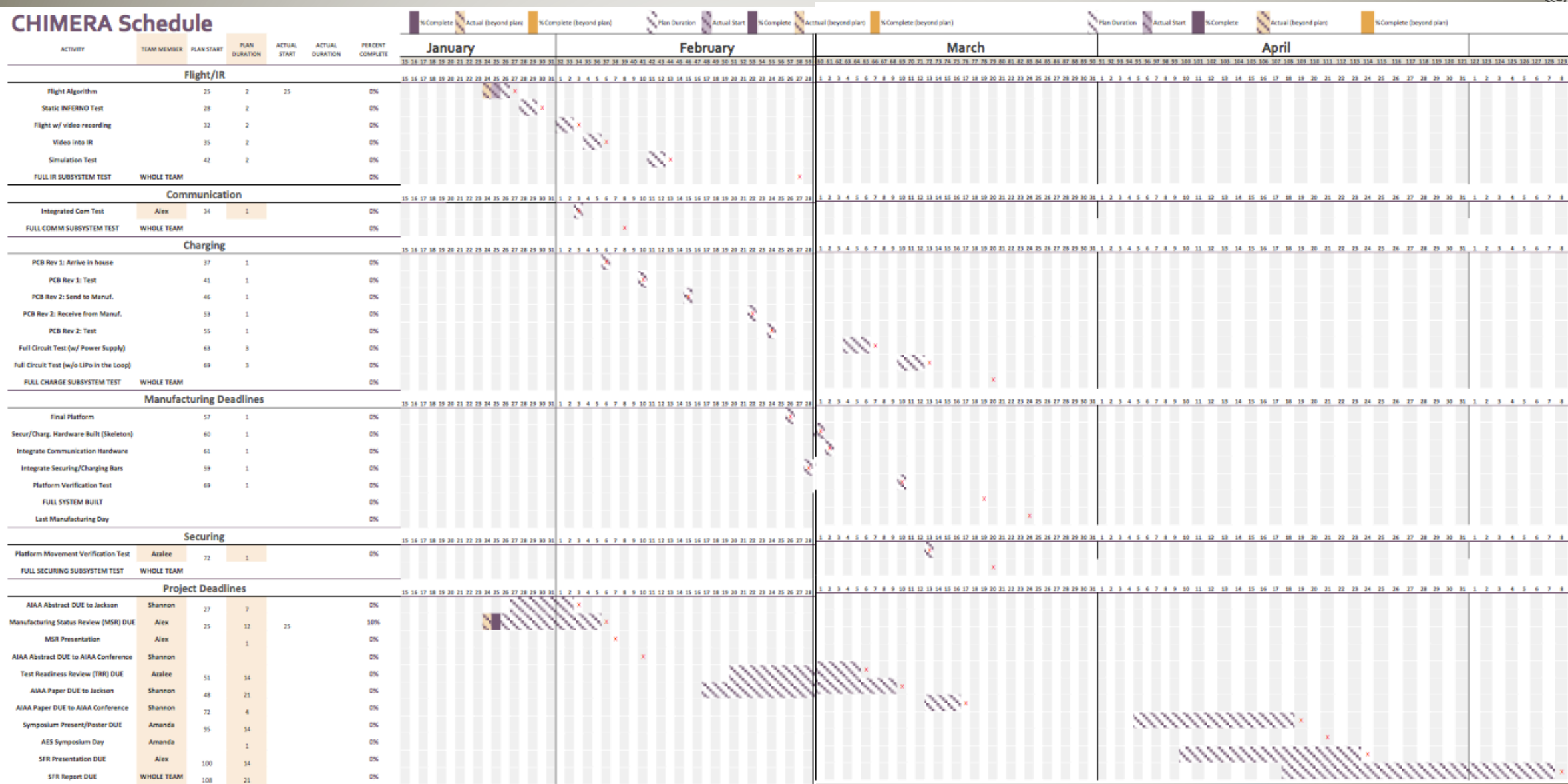


# Schedule Backup





# Schedule Backup







# Budget- Back Up



# Purchasing- Risk and Margin

Part	Cost Margin
Ball screw	PURCHASED AND ARRIVED <b>Final cost \$1521.39</b>
LiPo batteries	PURCHASED <b>Final cost \$338.99</b>
Worm gear	\$150, unexpectedly needed after the arrival of the ball screw
Aluminum anodizing	\$100, still weighing options with cost vs. quality

Part	Schedule Margin
PCBs	PURCHASED <b>1 week margin available</b>
LiPo batteries	PURCHASED <b>1 week margin available</b>



# Shipping and Procurement



Purchasing and Shipping						
Company	Purchased	Received	Description	Shipping Cost	Parts Cost	Total Cost
McMaster Carr	22-Dec	17-Jan	Raw Materials for INFERNO mods and the Platform	\$ 61.12	\$865.06	\$ 926.18
Jameco Electronics	16-Jan	24-Jan	Motor for Platform	\$ -	\$39.53	\$ 39.53
Mouser Electronics (2)	18-Jan	24-Jan	Battery Manager and a spare	\$ 7.99	\$13.10	\$ 21.09
Thomson Linear	20-Jan	30-Jan	Guide rails and bearings	\$ 15.21	\$161.51	\$ 176.72
SparkFun	26-Jan	3-Feb	Comm parts- Xbees	\$ -	\$151.80	\$ 151.80
DigiKey (2)	26-Jan	30-Jan	Comm Parts- Xbee adapters	\$ 7.40	\$99.80	\$ 107.20
Nook Industries	23-Dec	31-Jan	Ball screw system for platform	\$ 26.39	\$1,495.00	\$ 1,521.39
HobbyKing	3-Feb		Batteries for platform and CDS	\$ 42.87	\$296.12	\$ 338.99
Mouser Electronics	21-Dec	17-Jan	Electronics for Custom PCB	\$ 7.99	\$126.97	\$ 134.96
Advanced Circuits	2-Feb		PCBs, rev 1	\$ 10.00	\$132.00	\$ 142.00
McMaster Carr (2)	27-Jan	31-Jan	Forgotten spacers	\$ 6.30	\$1.05	\$ 7.35
McMaster Carr (3)	30-Jan	31-Jan	Misc nuts and bolts	\$ 13.44	\$56.54	\$ 69.98
McMaster Carr (4)	3-Feb		Spacers AGAIN	\$ 6.18	\$1.05	\$ 7.23
Get FPV	1-Jan		Comm antenna, spare INFERNO parts	\$ -	\$98.96	\$ 98.96
DigiKey (3)	3-Feb		Electronics for Custom PCB	\$ 7.40	\$26.15	\$ 33.55
Newark	3-Feb		Electronics for Custom PCB		\$31.57	
Arrow (2)	3-Jan		PCB Components	\$ -	\$80.54	\$ 80.54
Ready made RC			Spare INFERNO propellers			\$ -
DigiKey	5-Jan	17-Jan	Electronics for Custom PCB	\$ 6.95	\$12.57	\$ 19.52
Arrow	21-Dec	17-Jan	Electronics for Custom PCB	\$ -	\$16.14	\$ 16.14
Amazon	25-Jan	30-Jan	Raspbery Pis and camera, XT90 connectors, PURCHASED BY JOANIE	\$ -	\$119.93	\$ 119.93
ITLL	24-Jan	N/A	3D Printing plastic	\$ -	\$12.00	\$ 12.00
CU Bookstore	12-Dec	N/A	FFR Flashdrives	\$ -	\$13.98	\$ 13.98
InkSpot atCU	12-Dec	N/A	FFR Printing	\$ -	\$81.52	\$ 81.52
<b>Total Spent</b>						<b>\$ 4,120.56</b>
<b>Shipping Costs Total</b>				<b>\$ 219.24</b>		-
					Total Budget Remaining	\$ 879.44



# Hardware Backup

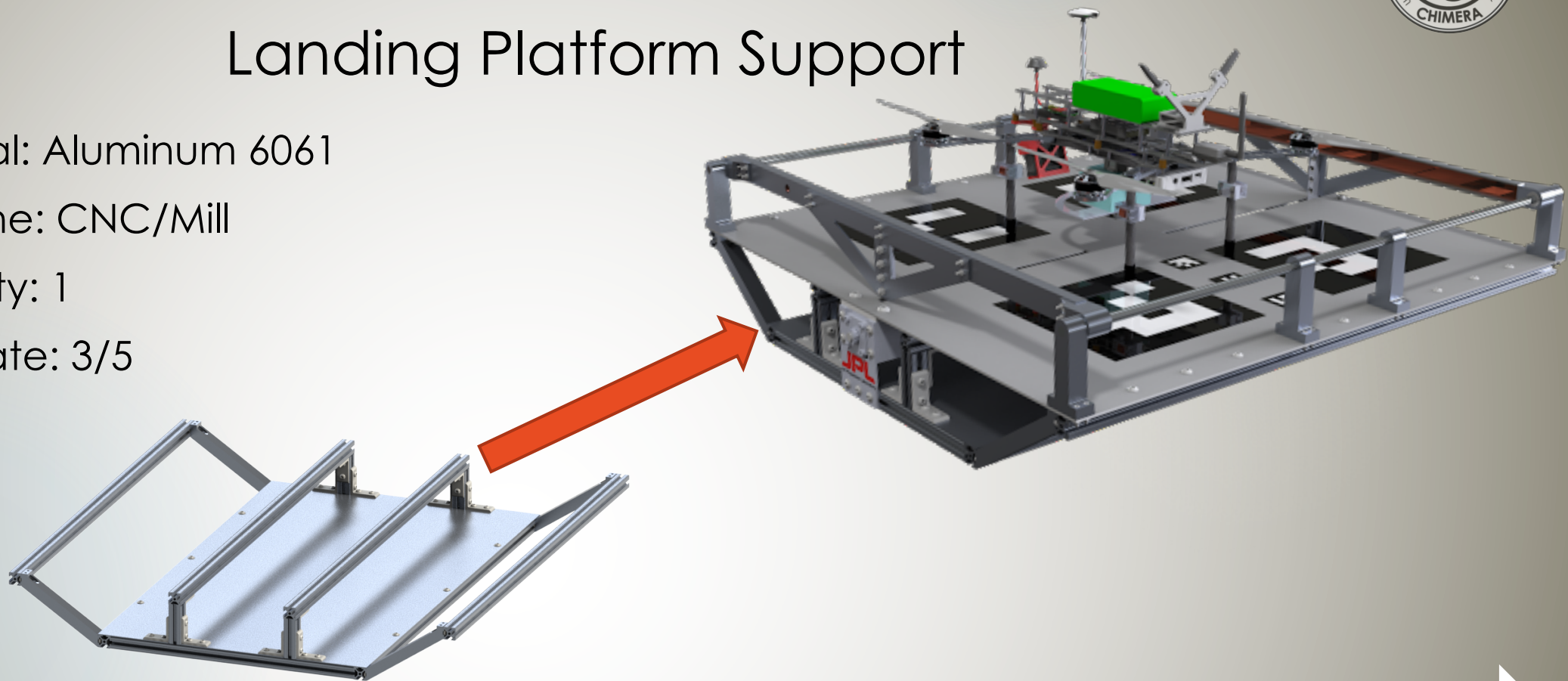




# Platform Hardware

## Landing Platform Support

- ▶ Material: Aluminum 6061
- ▶ Machine: CNC/Mill
- ▶ Quantity: 1
- ▶ Due Date: 3/5



Material Procured

Material Cut to Size

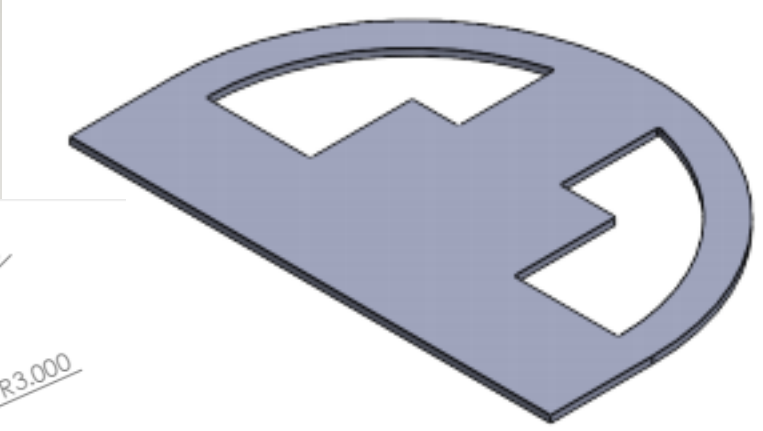
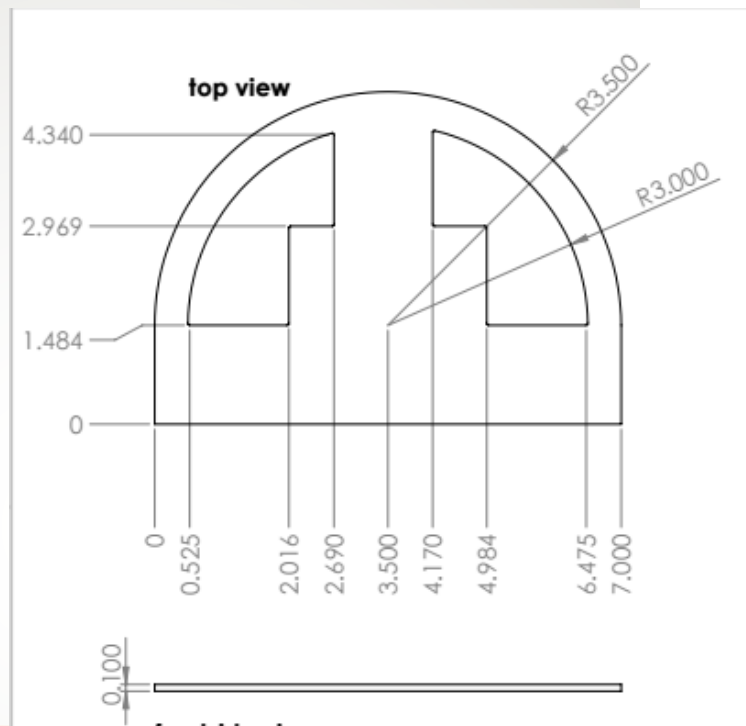
Components Assembled

Final Assembly

# Child Drone Hardware

## Sensor Package Base

- ▶ Material: Acrylic
- ▶ Machine: ITLL Laser Cutter
- ▶ Quantity: 1
- ▶ Due Date: March 20<sup>th</sup>



Material Procured

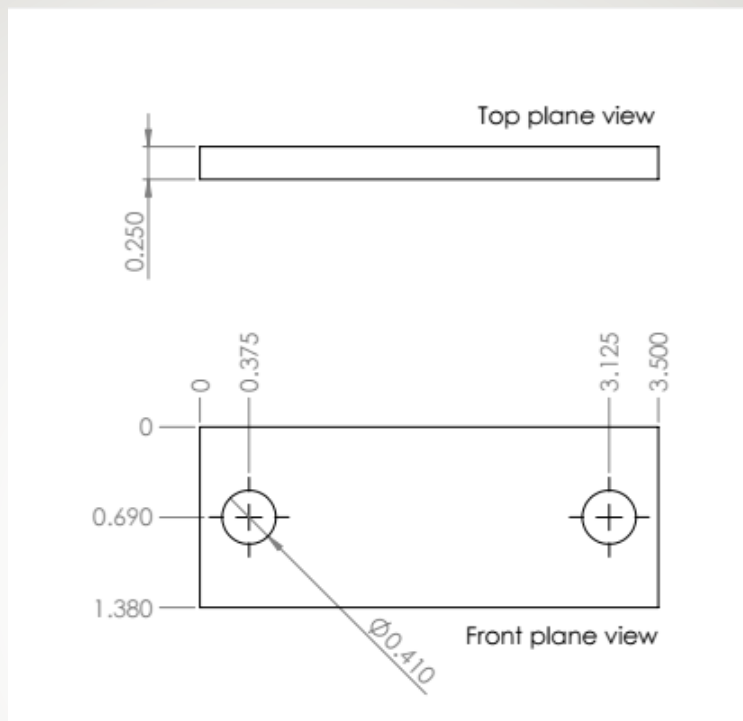
Part cut from stock

Sensor Package Integration

# Platform Hardware

## Bearing Spacer

- ▶ Material: Delrin
- ▶ Machine: Mill
- ▶ Quantity: 2



Material Procured

Brackets Machined

Copper Milled

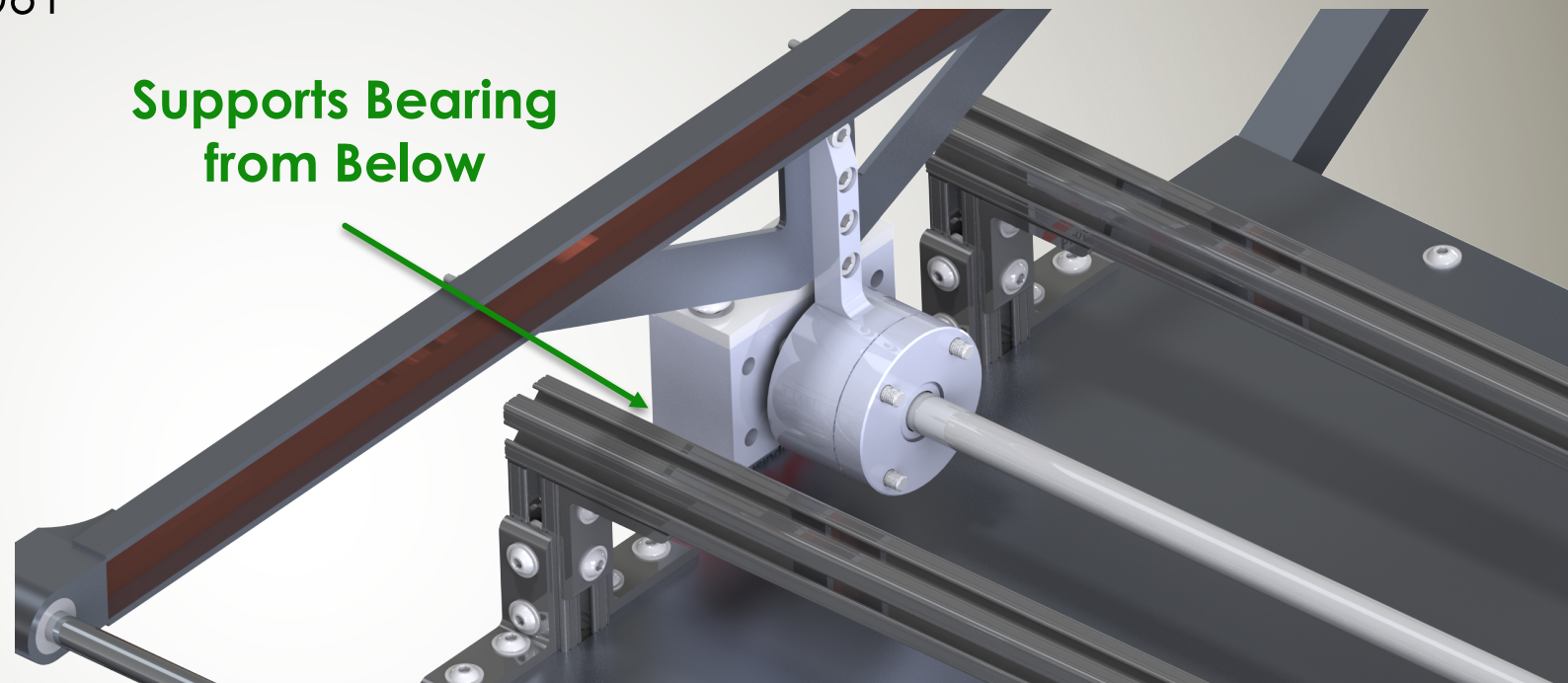
Copper/Bracket  
Integration

Platform Integration

# Platform Hardware

## Bearing Support Brackets

- ▶ Material: Aluminum 6061
- ▶ Machine: Mill
- ▶ Quantity: 2
- ▶ Due Date: 3/5



Material Procured

Brackets Machined

Copper Milled

Copper/Bracket  
Integration

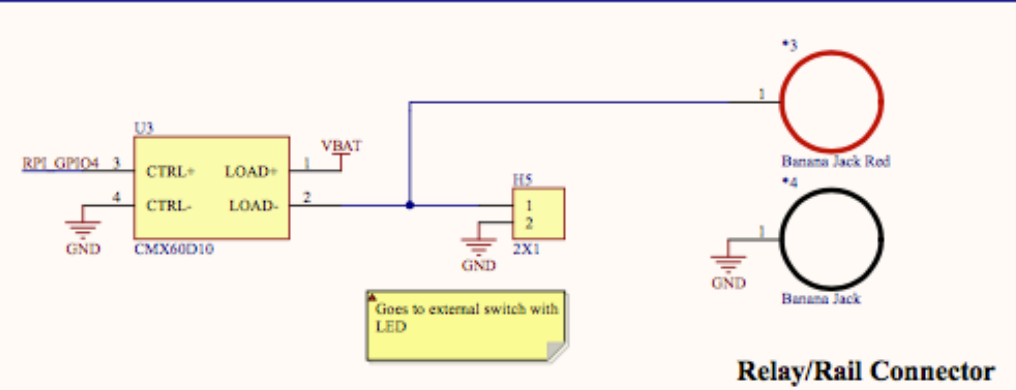
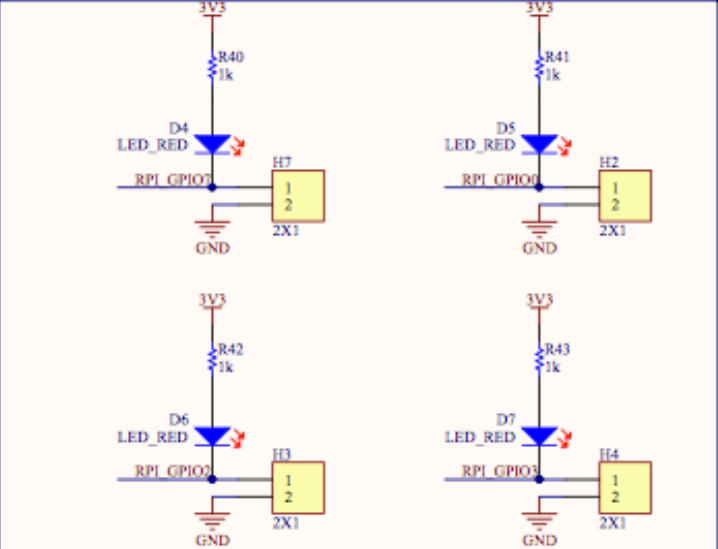
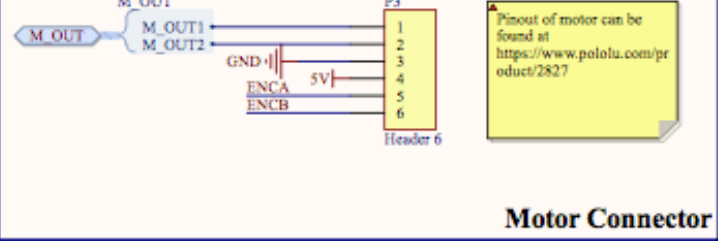
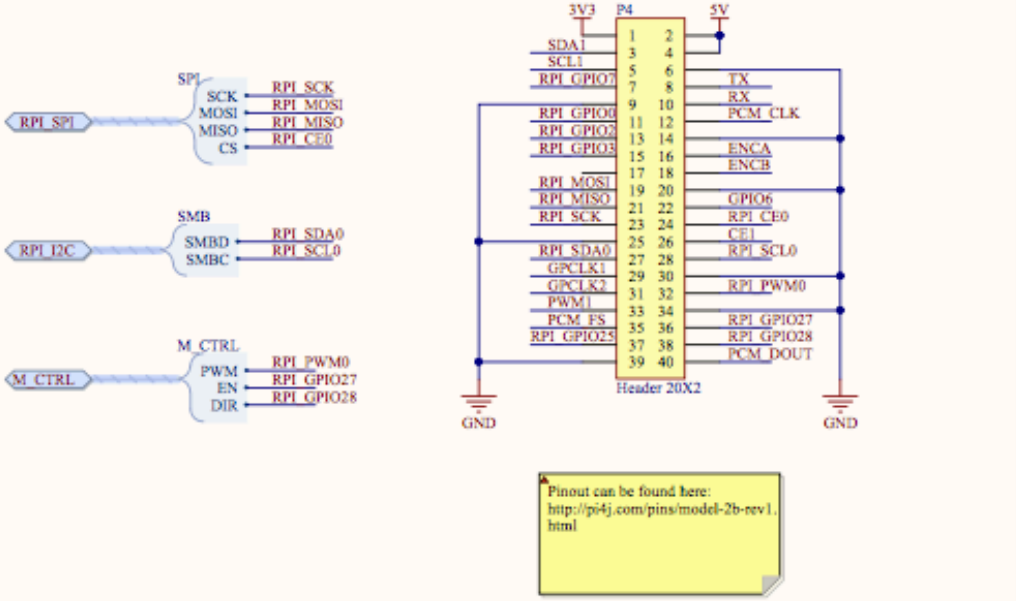
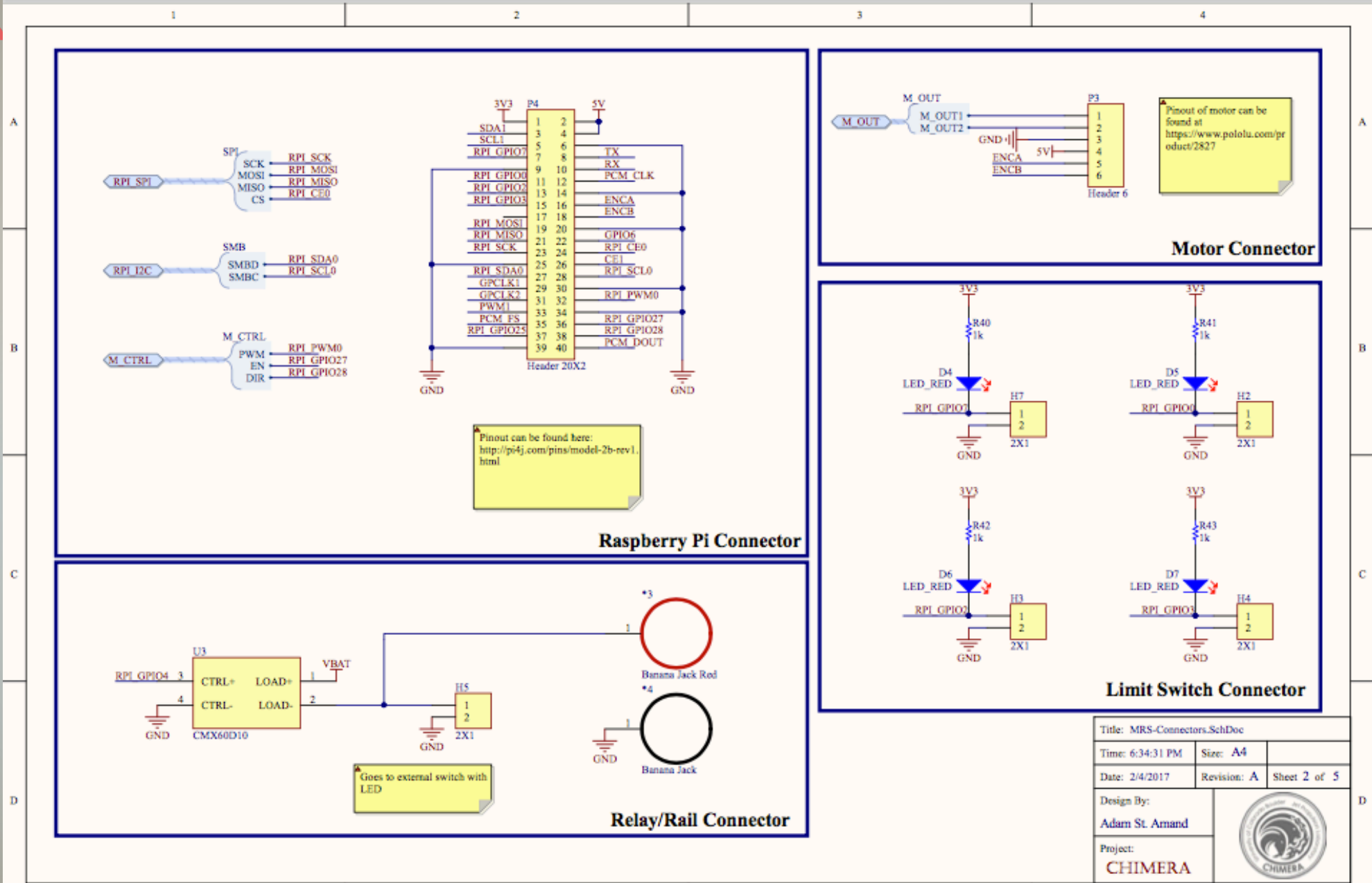
Platform Integration



# Electronics Backup

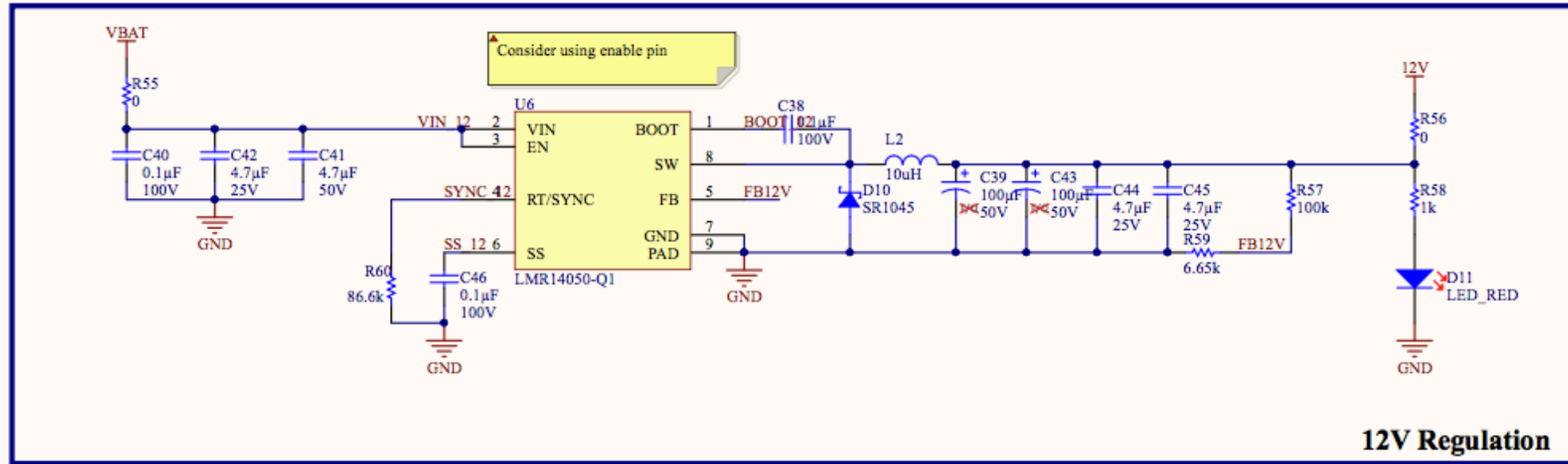
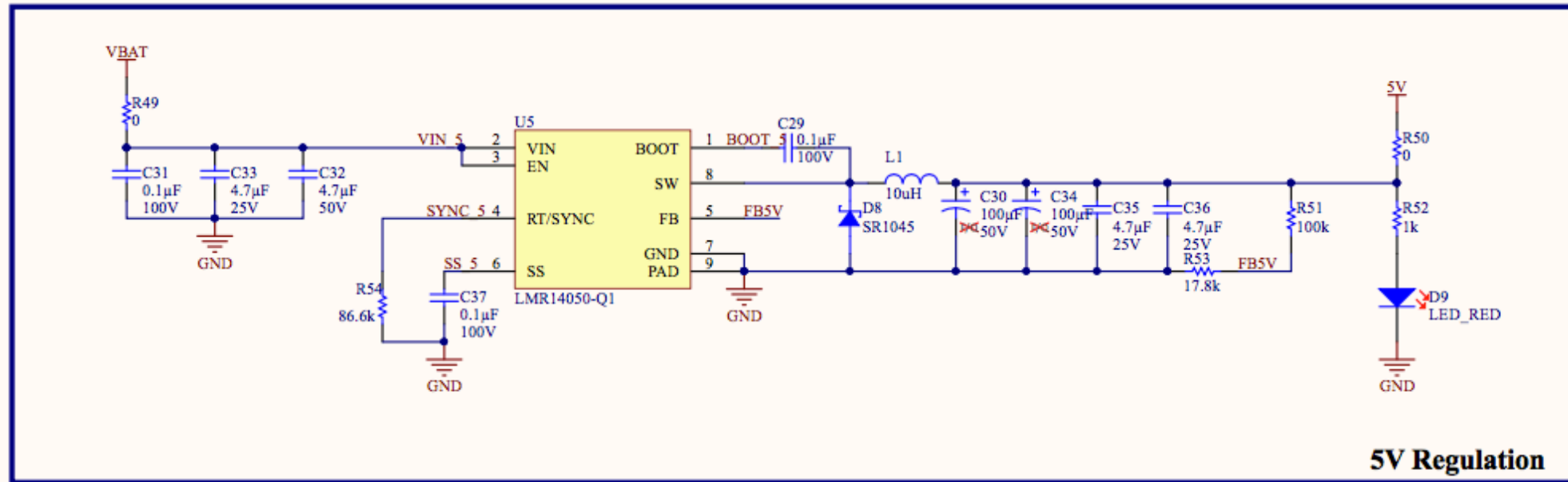


# Electronics Platform Schematic

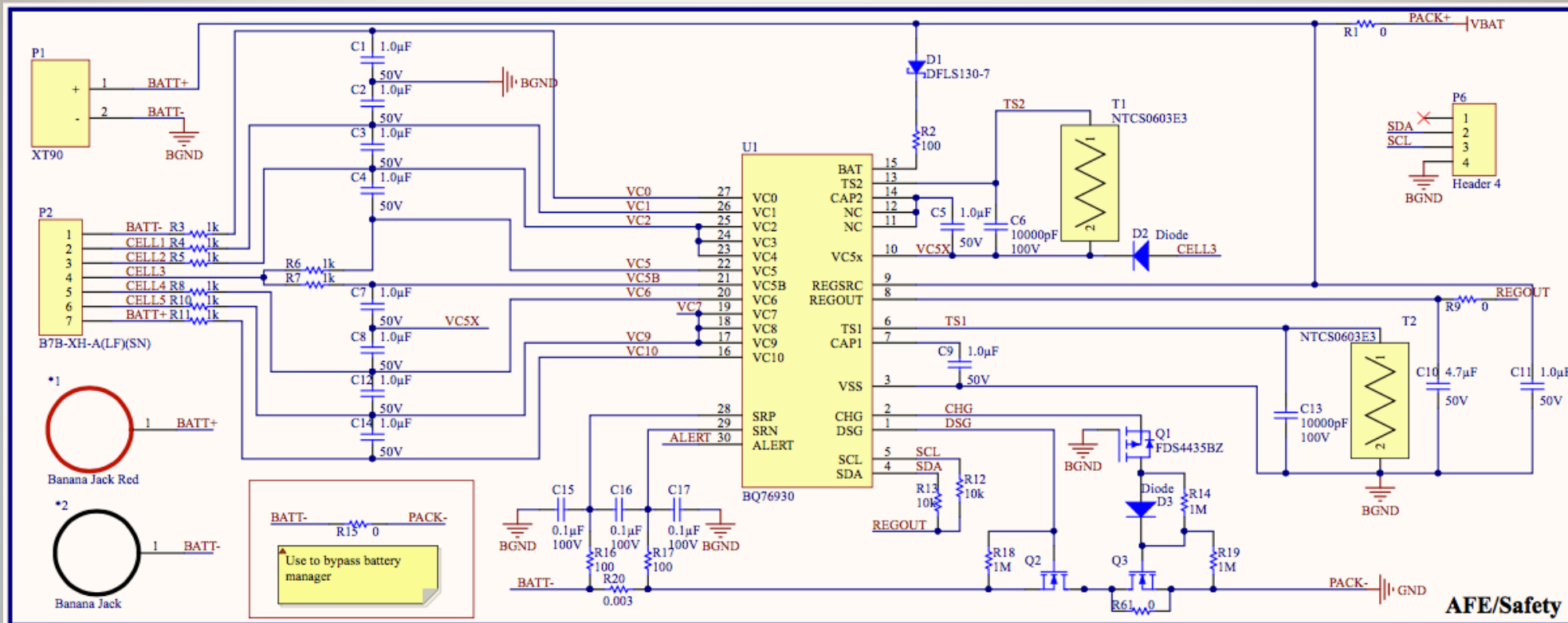


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Time: 6:34:31 PM	Size: A4	
Date: 2/4/2017	Revision: A	Sheet 2 of 5
Design By: Adam St. Armand		
Project: CHIMERA		

# Electronics Platform Schematic

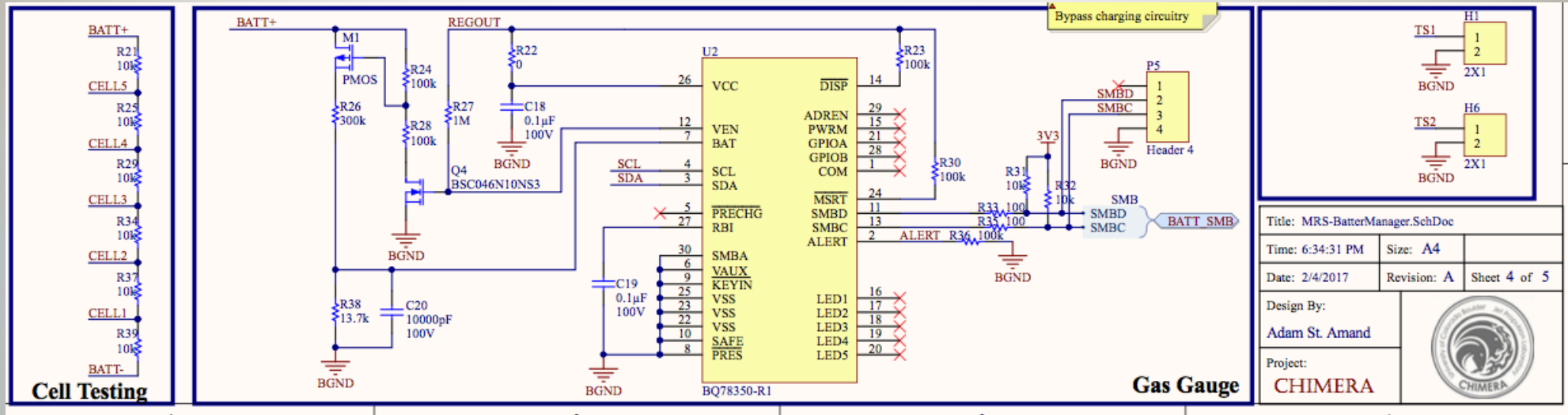


# Electronics Platform Schematic

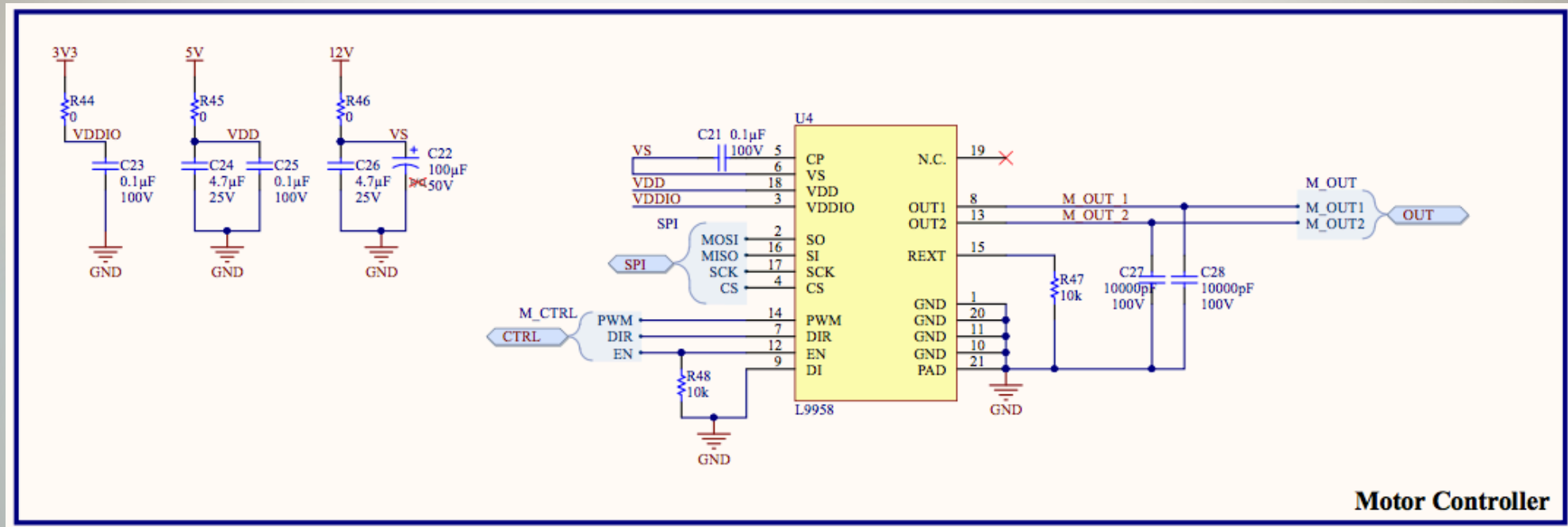




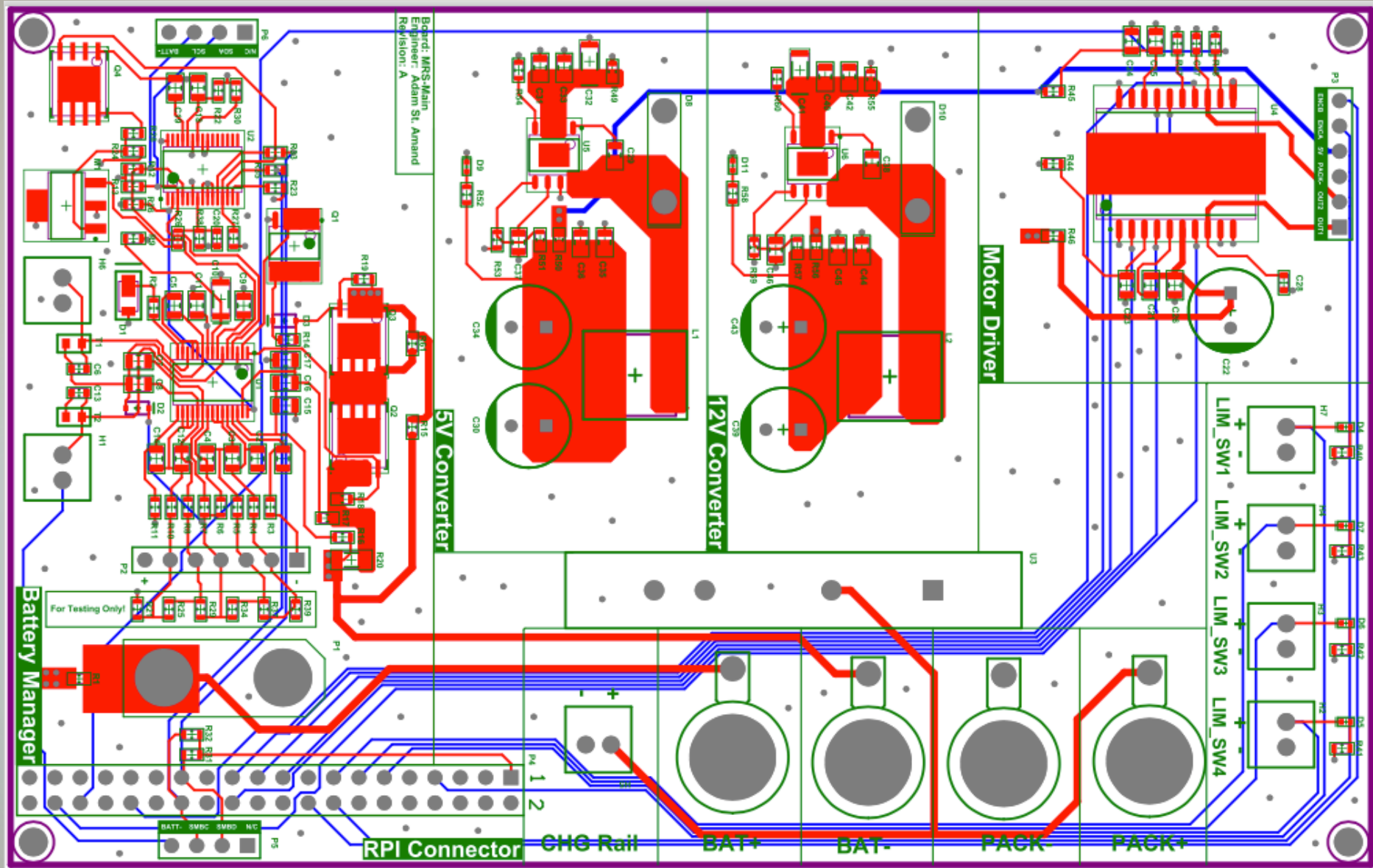
# Electronics Platform Schematic



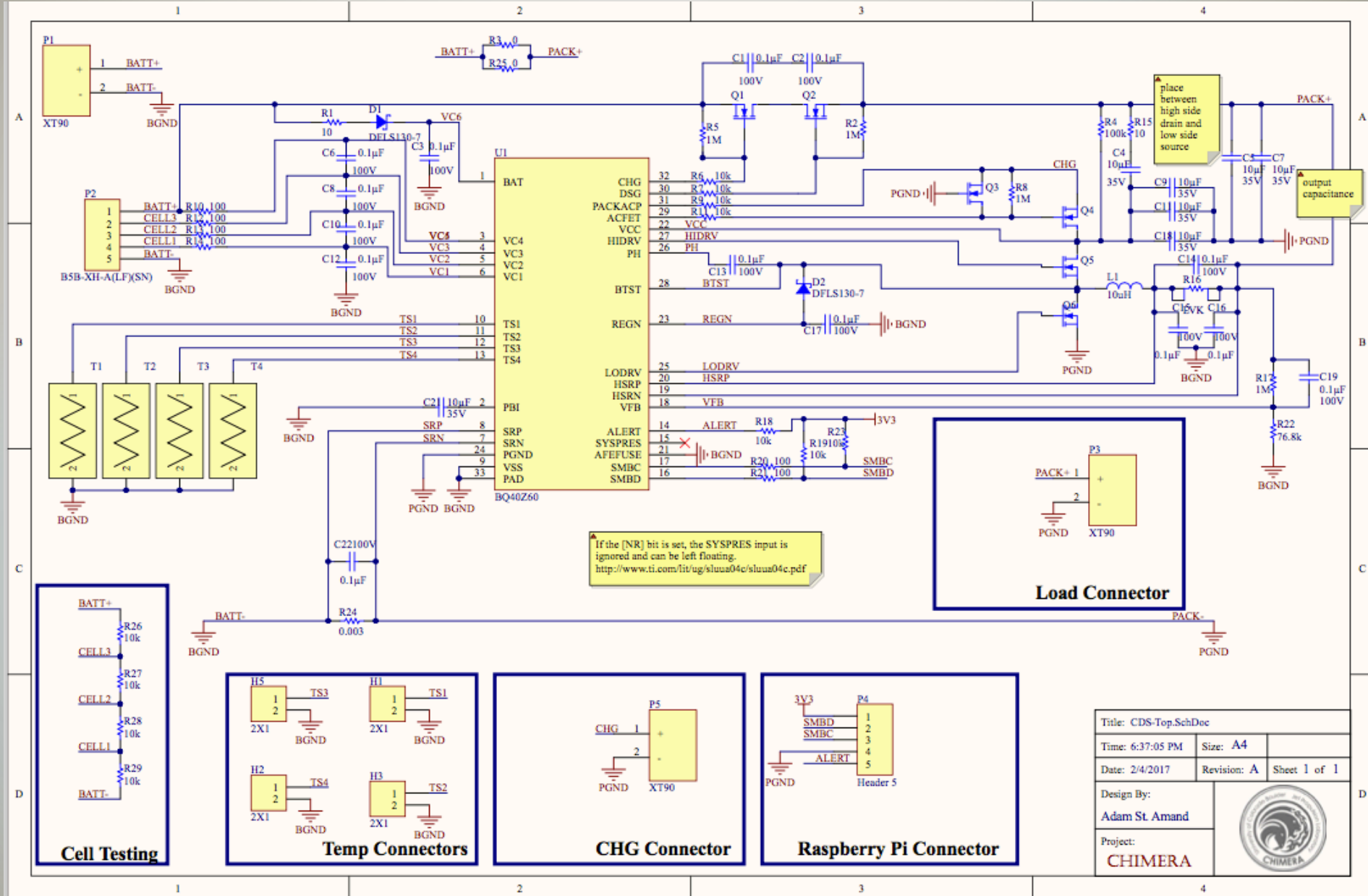
# Electronics Platform Schematic



# Electronics Platform Schematic



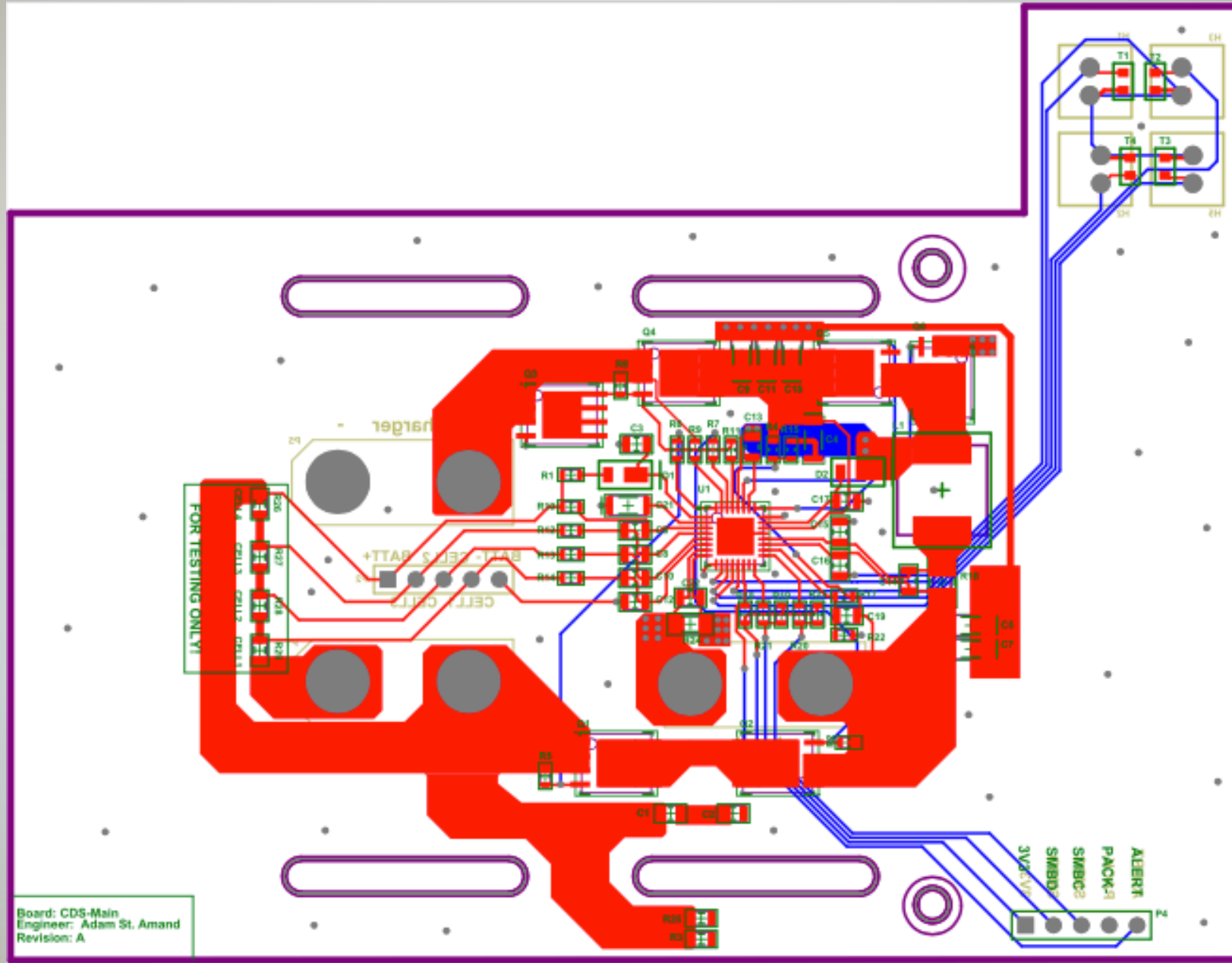
# Electronics INFERNO Schematic



Title: CDS-Top.SchDoc	
Time: 6:37:05 PM	Size: A4
Date: 2/4/2017	Revision: A
Sheet 1 of 1	
Design By: Adam St. Amand	
Project: CHIMERA	



# Electronics INFERNO Schematic



# INFERNO PCB

