MANUFACTURING STATUS REVIEW

INFERNO

INtegrated Flight-Enabled Rover For Natural disaster Observation

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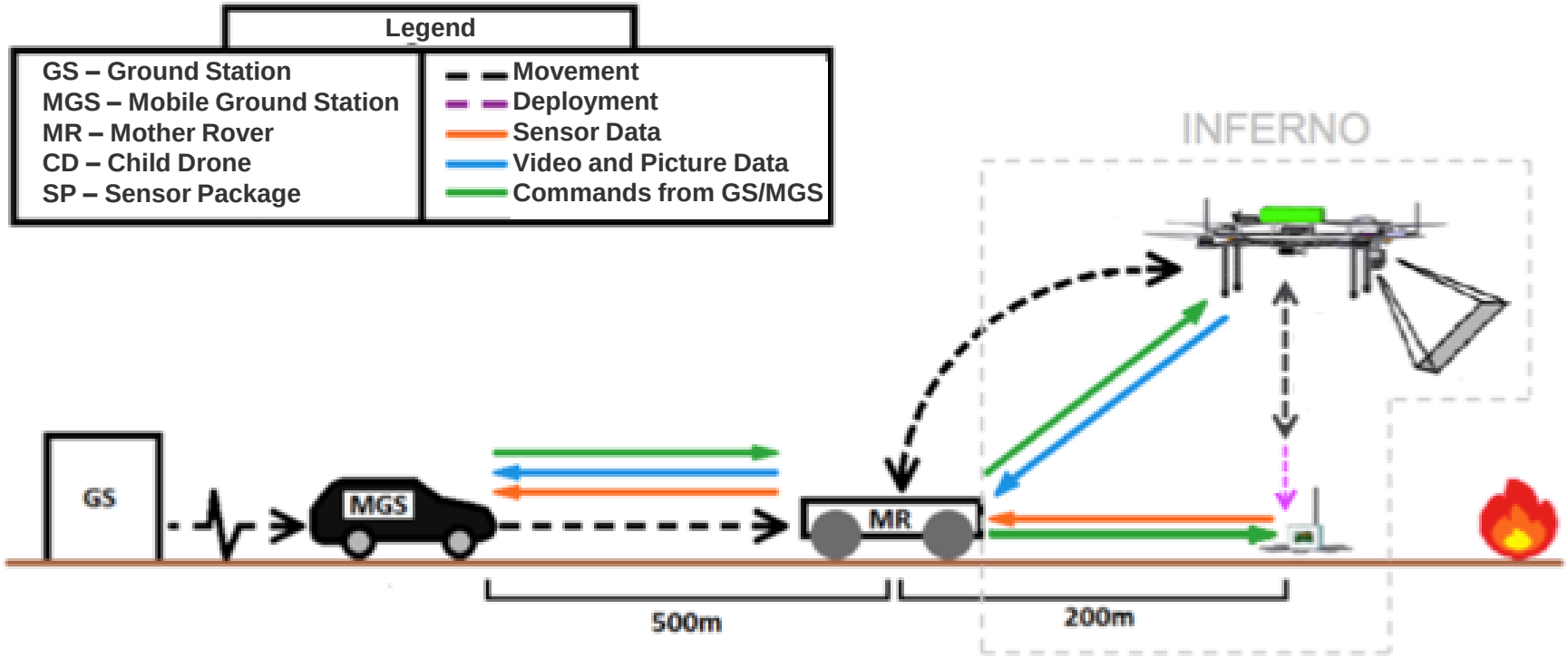
JPL
Jet Propulsion Laboratory

PRESENTATION OUTLINE

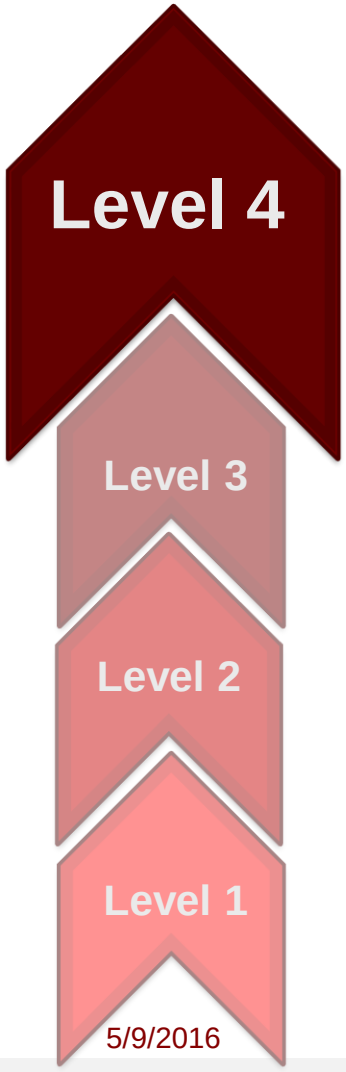
- Project Purpose and Objectives
- Baseline Design
- Critical Project Elements
- Spring Schedule
- Manufacturing Status
  - Child Drone
  - Imaging System
  - Sensor Package Deployment Mechanism
  - Sensor Package
  - GSMRS
- Financial Status

PROJECT OVERVIEW

CONCEPT OF OPERATIONS



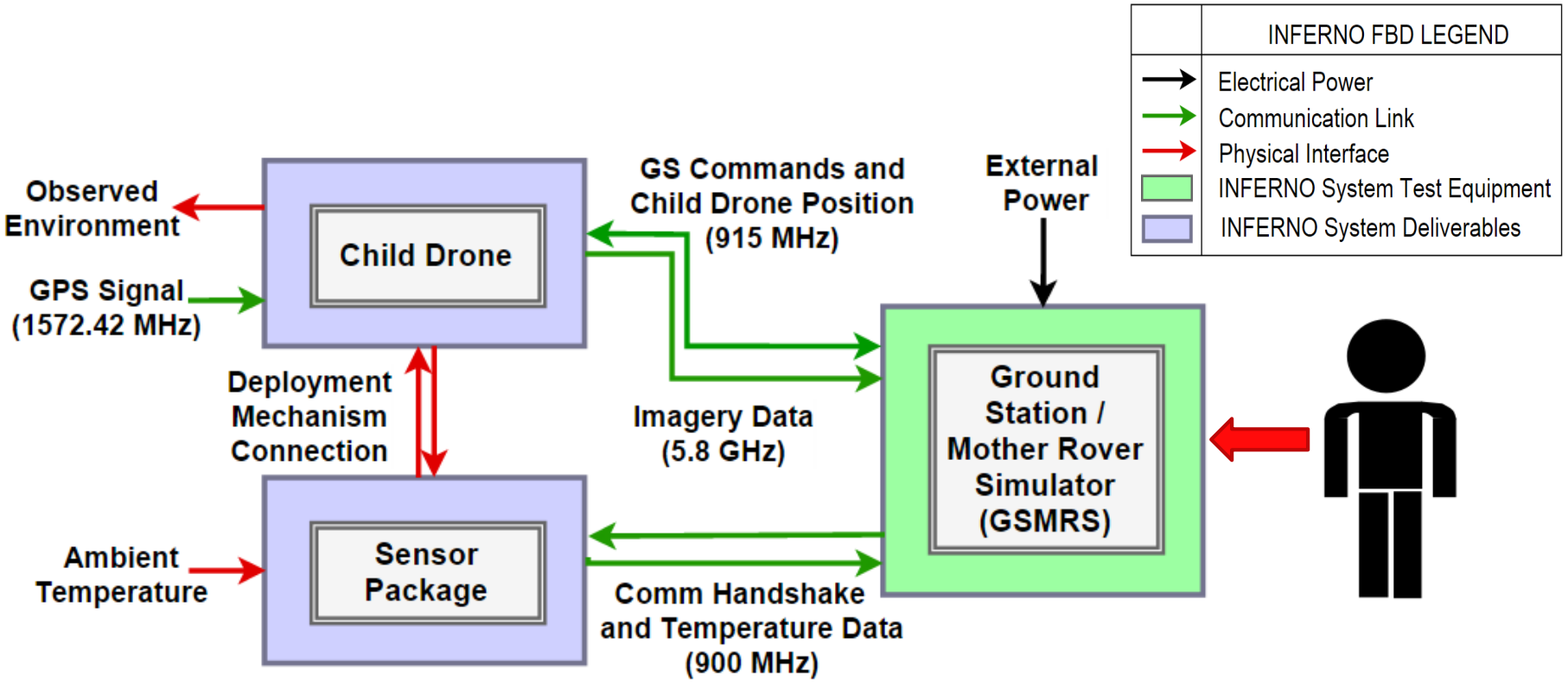
LEVELS OF SUCCESS



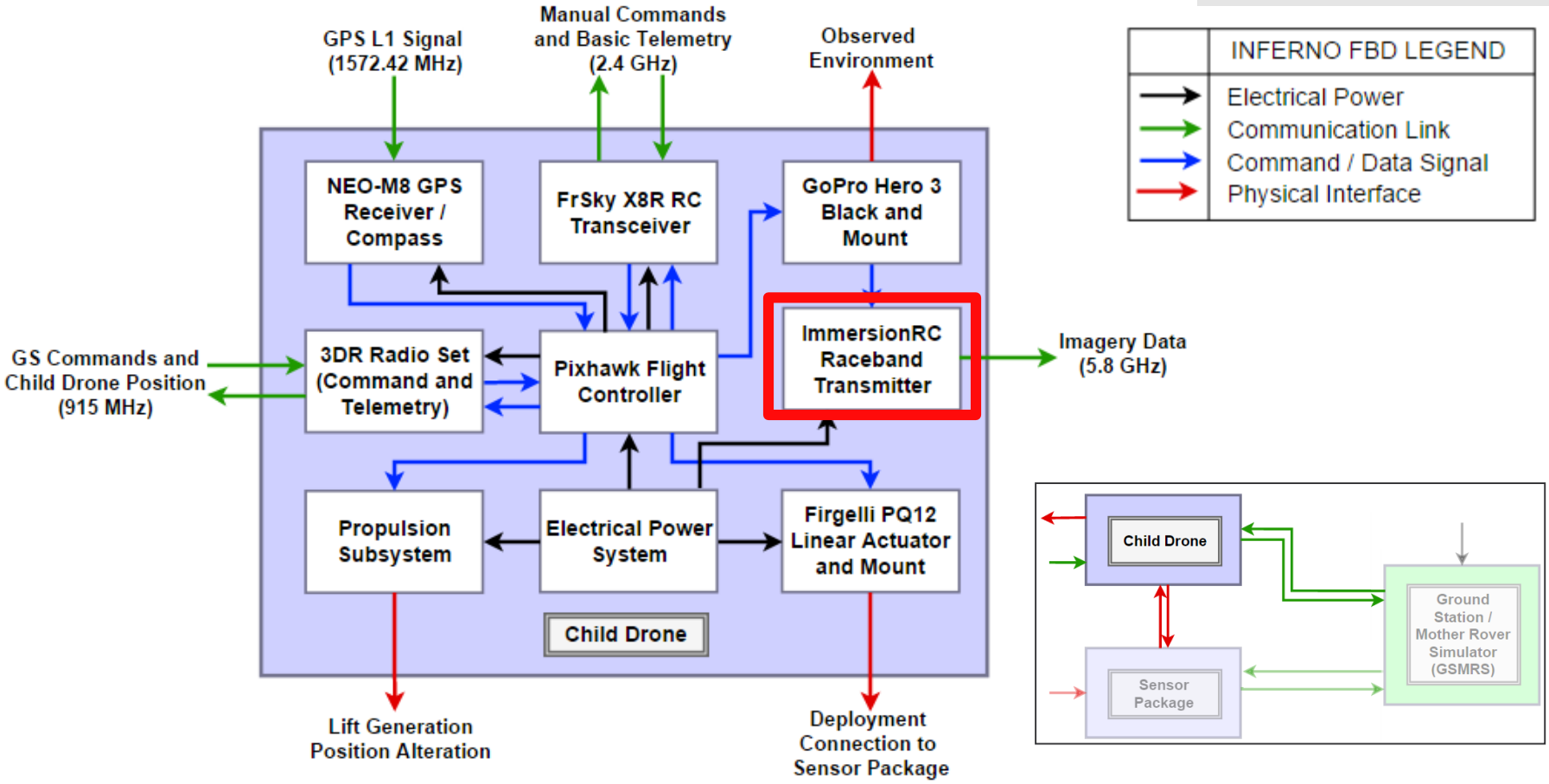
- 10 m/s translational flight
- Landing and deployment within 5 m of LOI on command
- Fully autonomous flight except during takeoff and landing
- Time stamped video transmitted at 720 p 30 fps
- >90% wireless data transmission from SP to GSMRS at 200 m
- Data retransmission possible
- Data transmission and reception GUI on GSMRS

Levels of Success Status:
Currently on track to meet Level 4 Success

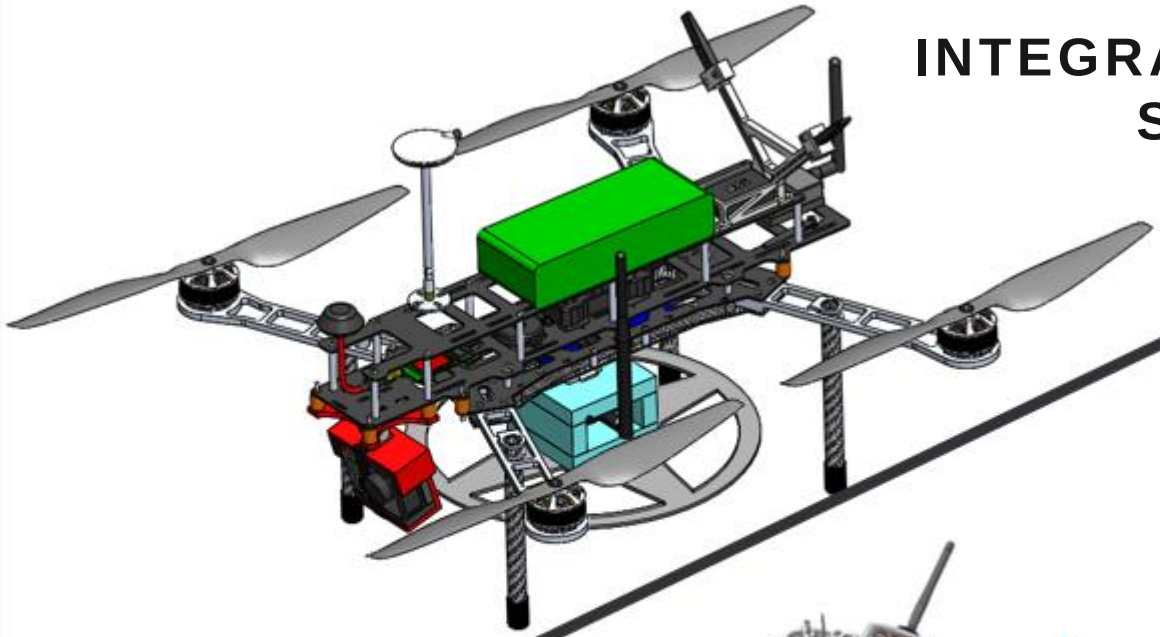
FUNCTION BLOCK DIAGRAM: SYSTEM LEVEL



FUNCTION BLOCK DIAGRAM: CHILD DRONE



BASELINE DESIGN - SYSTEM



INTEGRATED INFERNO SYSTEM

GSMRS

CRITICAL ELEMENTS

Critical Element	Mission Influence
Communications	Subsystems must be able to send and receive commands and data to ensure mission success and safety.
Software Integration	Responsible for command and execution of all systems.
Subsystem Integration	Full mission success is unachievable without compatible integration.
Power Limitations	Subsystems must be able to function for mission duration on limited power supplies.

SCHEDULE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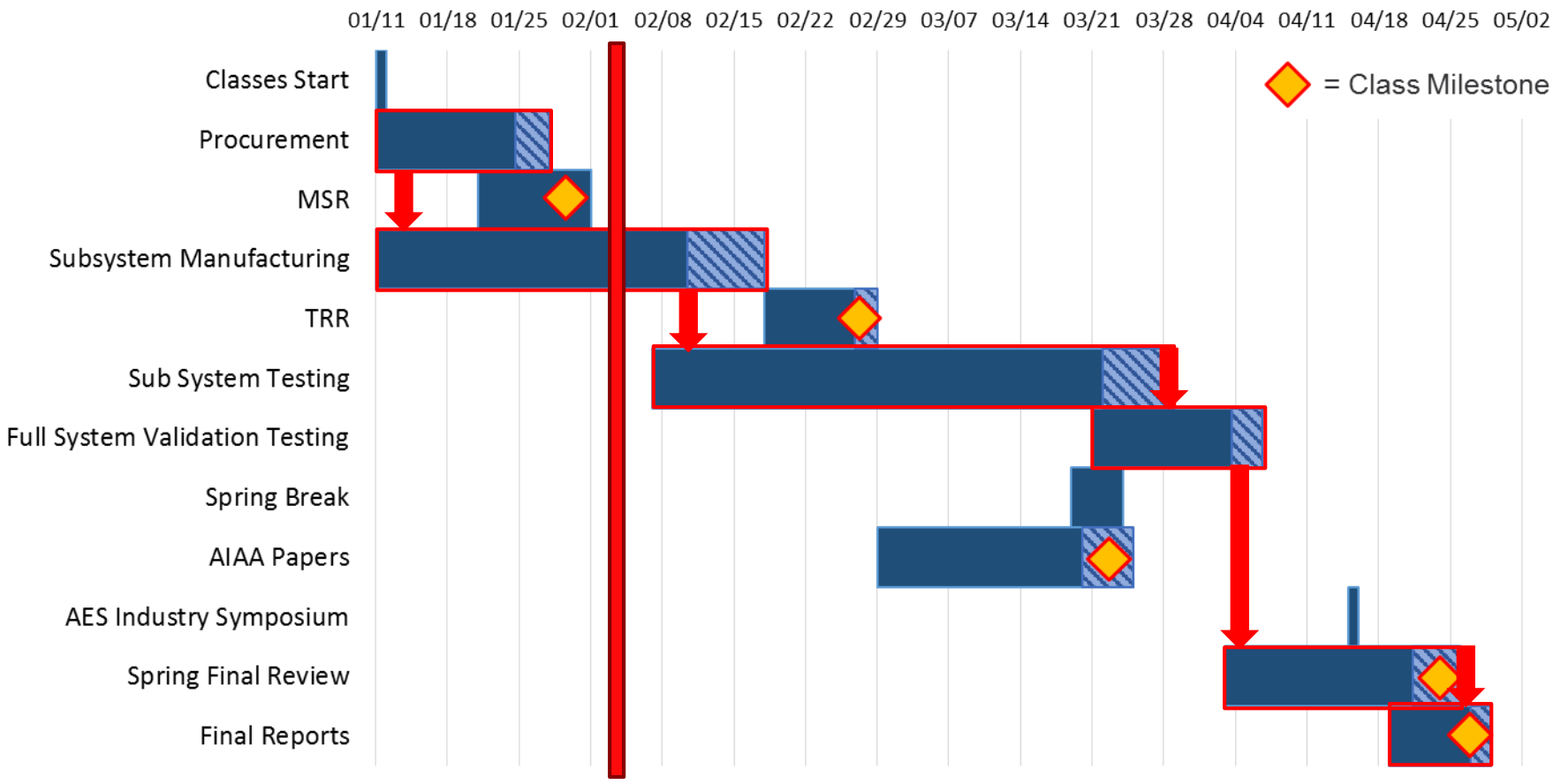
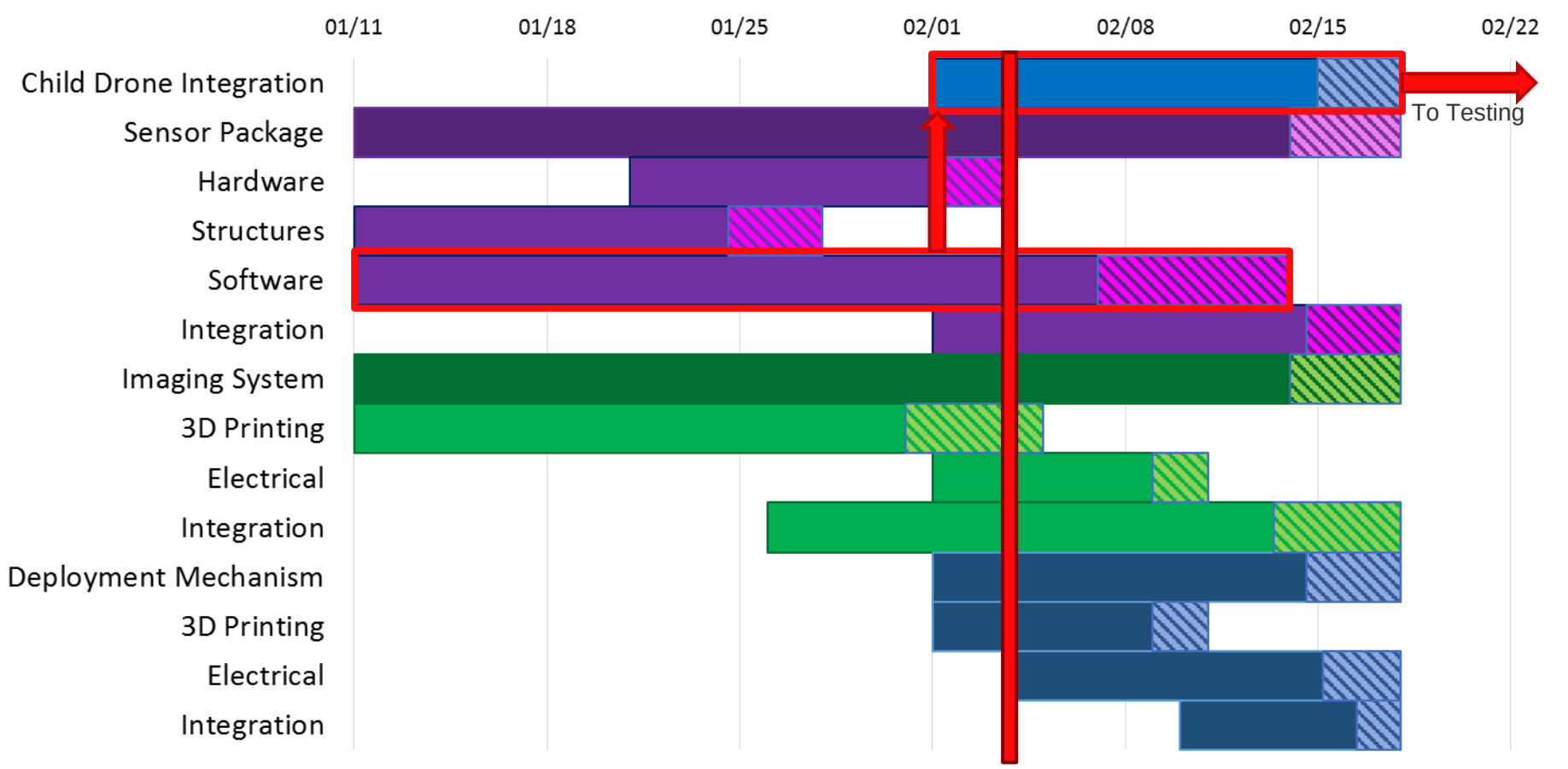
SCHEDULE OVERVIEW

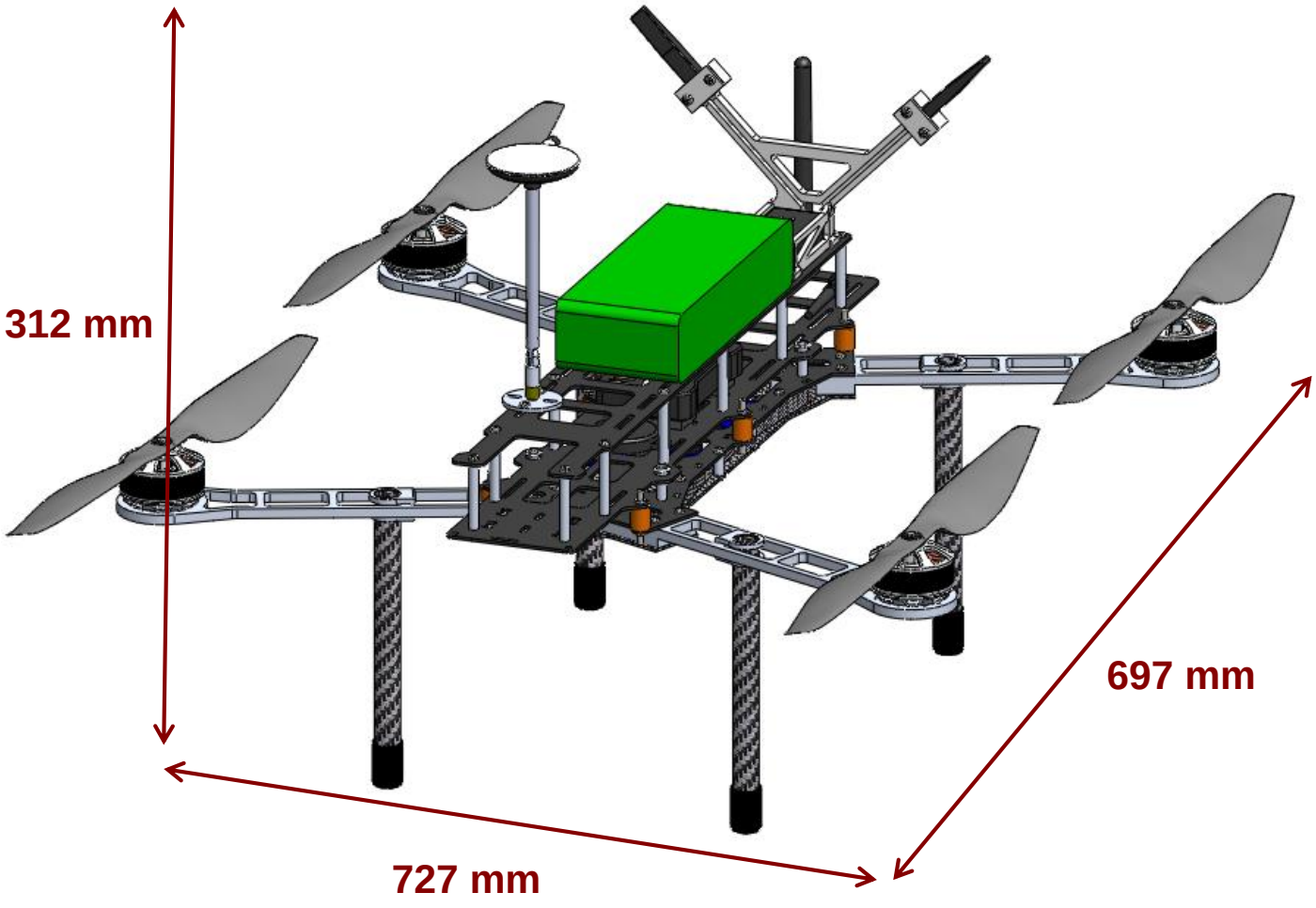


SCHEDULE MANUFACTURING



MANUFACTURING STATUS

CHILD DRONE



CHILD DRONE: OVERVIEW

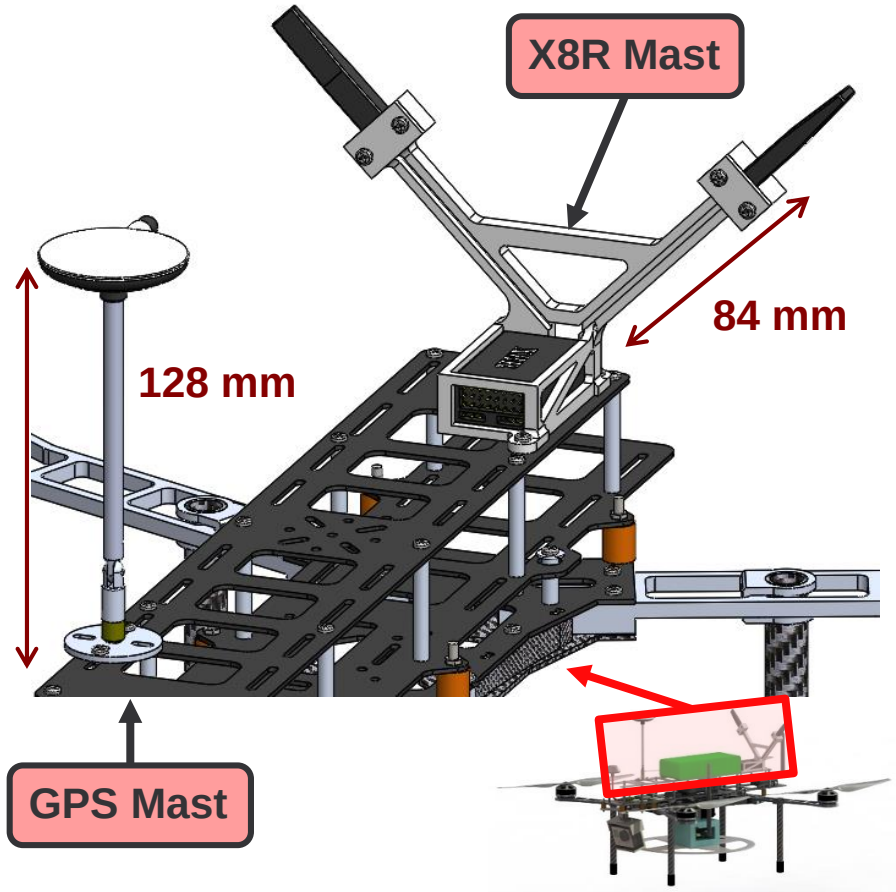
	Progress	Remaining Hours	Completion Date	On Schedule?
3D Printed Antenna Mast Manufacturing	90%	1-2	Feb 9	✓
Child Drone Structure/ Electronic Assembly	50%	18-25	Feb 10	✓
Pixhawk Configuration	20%	8-12	Feb 17	✓

- Antenna Mast fully designed and interfaced through CAD
  - Ready for printing
- Child Drone Assembly procedure finished and reviewed
  - Ready to begin assembly
- Pixhawk Configuration procedure currently being written
  - To be completed prior to Assembly completion
  - In contact with RECUV for indoor flight testing

CHILD DRONE: STRUCTURE

Changes to CD Structure

- 3D-printed antenna mast for X8R receiver
  - Provide proper orientation for diverse antennas
  - 22g weight increase
  - $15-$20 to print
- COTS aluminum mast added for GPS
  - Preemptive measure to reduce EMI
  - Provided with GPS unit
  - 14g weight increase



CHILD DRONE: ASSEMBLY

	Progress	Remaining Hours	Completion Date	On Schedule?
Assembly Procedure	100%	---	Complete	✓
Test Power Distribution Board (PDB)	0%	2-4	Feb 2	✓
Install and Test Motors, Propellers, and Voltage Regulator	0%	12-15	Feb 8	✓
Install/Wire Electronics	0%	2-3	Feb 10	✓
Assemble Structure	0%	2-3	Feb 10	✓

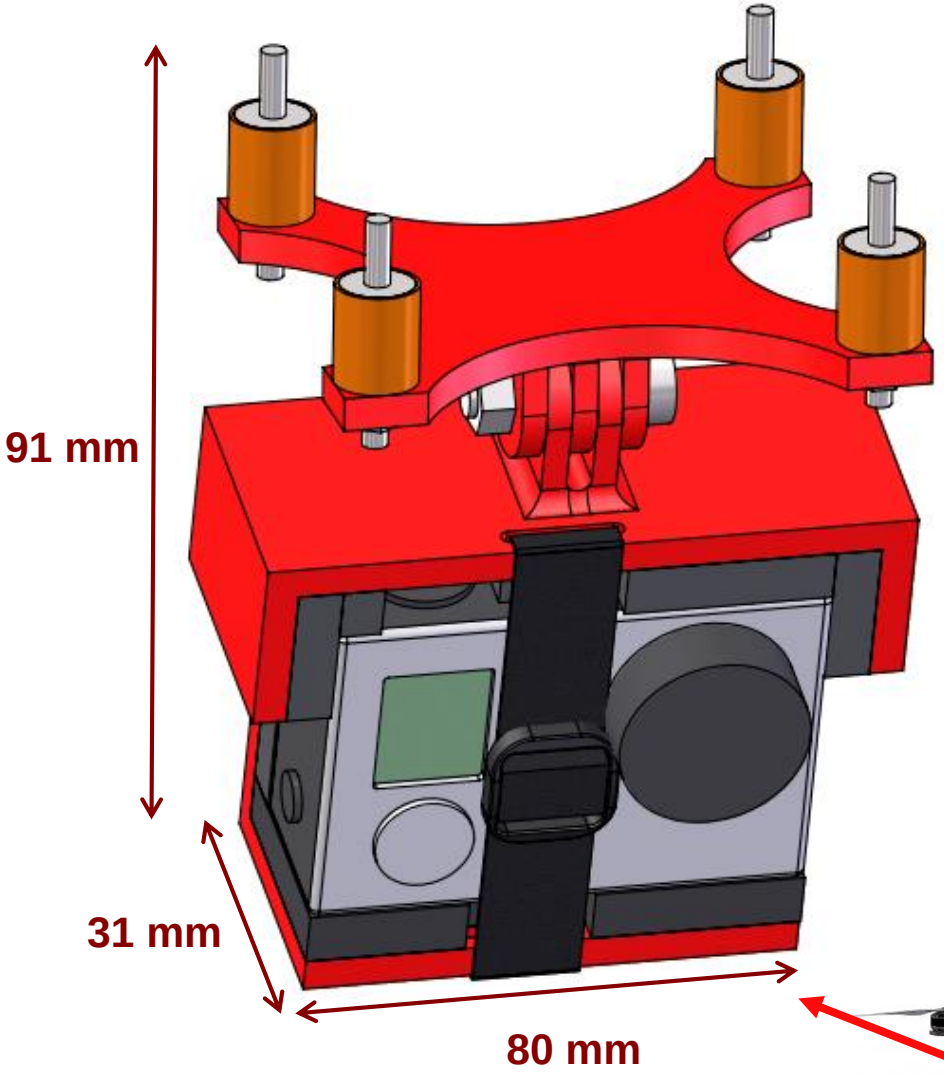
- PDB must be tested for proper input/output
- Multiple solders/cable modifications required for propulsion
- Propulsion to be tested for PWM input and motor output

CHILD DRONE: PIXHAWK CONFIGURATION

	Progress	Remaining Hours	Completion Date	On Schedule?
Pixhawk Configuration Procedure	75%	2-3	Feb 5	✓
Initial Electronics Setup (Accelerometers/ Compass/Radio)	0%	3-4	Feb 12	✓
Control Gains Tuning	0%	3-5	Feb 17	✓

- Configuration procedure to be completed prior to completion of Assembly
- Gain Tuning will be done in the RECUV indoor flight facility
  - Most crucial aspect to make the CD flight-ready
- Setup will be done by the INFERNO team in-house

IMAGING SYSTEM



IMAGING SYSTEM: OVERVIEW

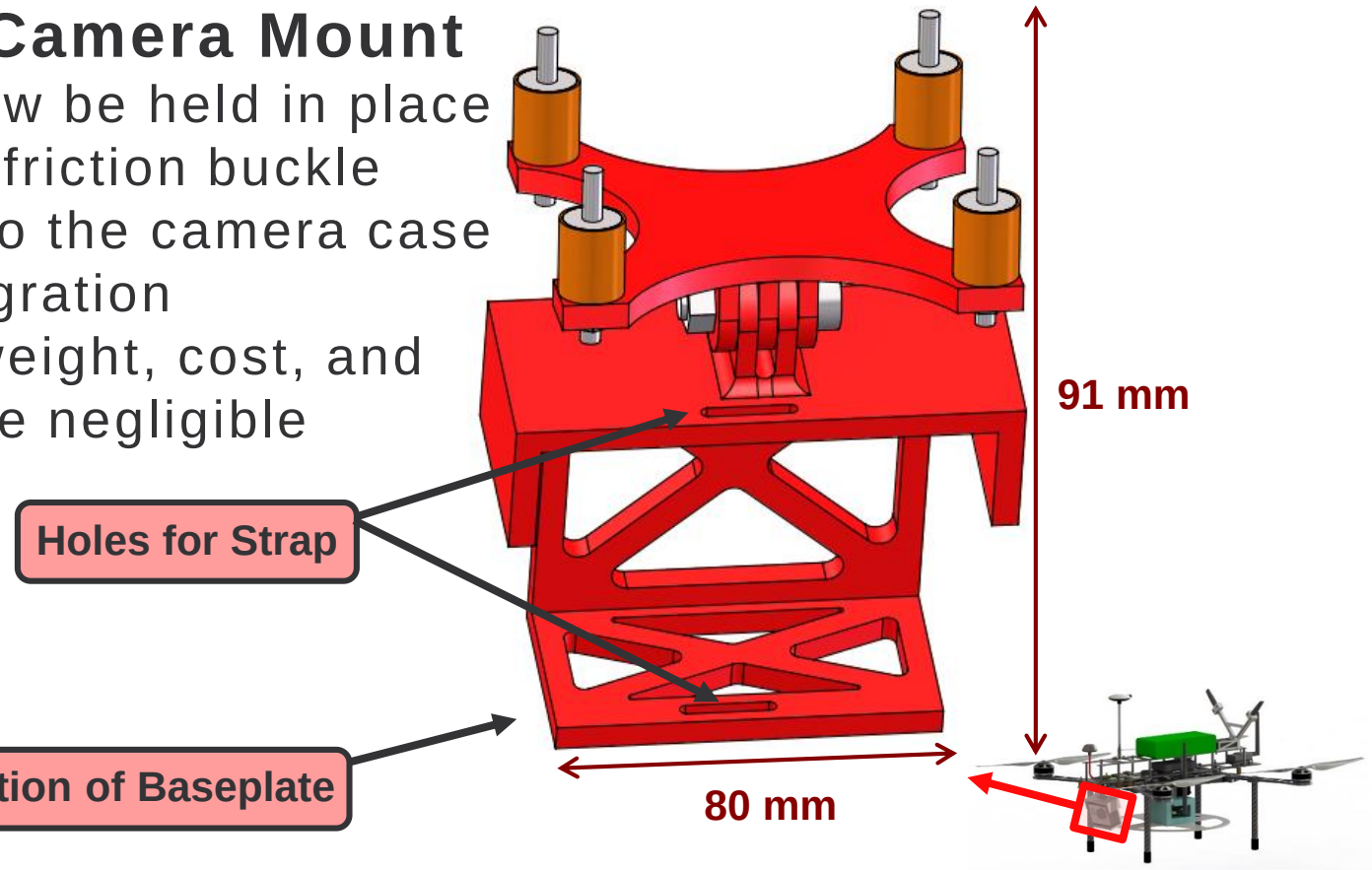
	Progress	Remaining Hours	Completion Date	On Schedule?
Camera Mount Manufacturing/Assembly	90%	5	Feb 13	✓
GoPro Power Circuit Assembly	20%	3	Feb 25	✓
Video Transmitter Assembly	0%	5-8	Feb 29	✓

- Camera Mount has been prototyped and all issues have been addressed
  - Ready for final print of the camera mount
- GoPro power circuit has been prototyped
  - Safety procedures for altering the GoPro need to be addressed before final assembly and test

IMAGING SYSTEM: STRUCTURE

Changes to Camera Mount

- GoPro will now be held in place by strap with friction buckle
- Base added to the camera case for strap integration
- Changes to weight, cost, and schedule were negligible



IMAGING SYSTEM: STRUCTURE

Camera Vibrations

- Conduct a vibration table test on the GoPro while mounted to the camera mount
  - Relate frequency to RPM of motors and sweep the amplitude
- Use accelerometers mounted on the GoPro and visual inspection of video by professional pilot

Future Work:

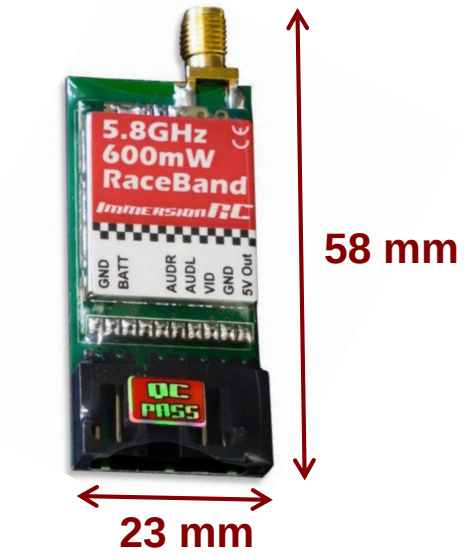
- Create test procedure for vibration test (Feb 8-15)
- Conduct test and analyze quality (Feb 22-29)

IMAGING SYSTEM: ELECTRICAL

Video Transmitter Change

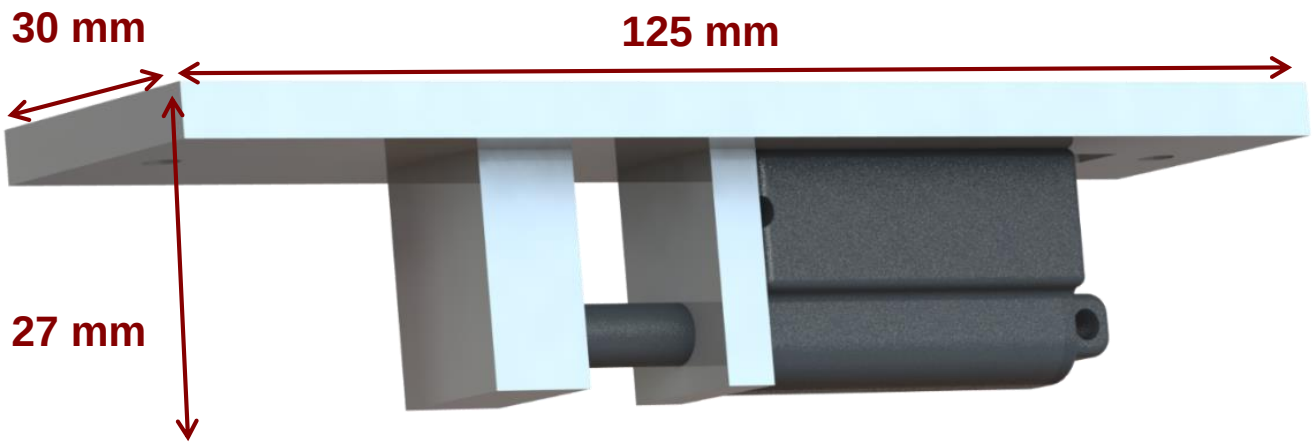
- 3DR Video Set has been discontinued
- ImmersionRC 600mW 5.8GHz Transmitter will be used instead
- No effect on the schedule

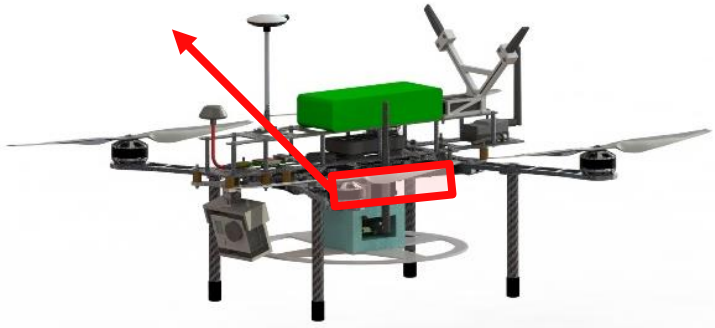
	3DR	ImmersionRC
Cost	$211	$240
Power	200 mW	600 mW
Frequency	5.8 GHz	5.8 GHz
Link Margin	31 dB	38 dB
Power Budget	175 mAh	51 mAh



Project Context | Baseline Design | Critical Elements | Schedule | Financial | Manufacturing Status

SENSOR PACKAGE DEPLOYMENT MECHANISM



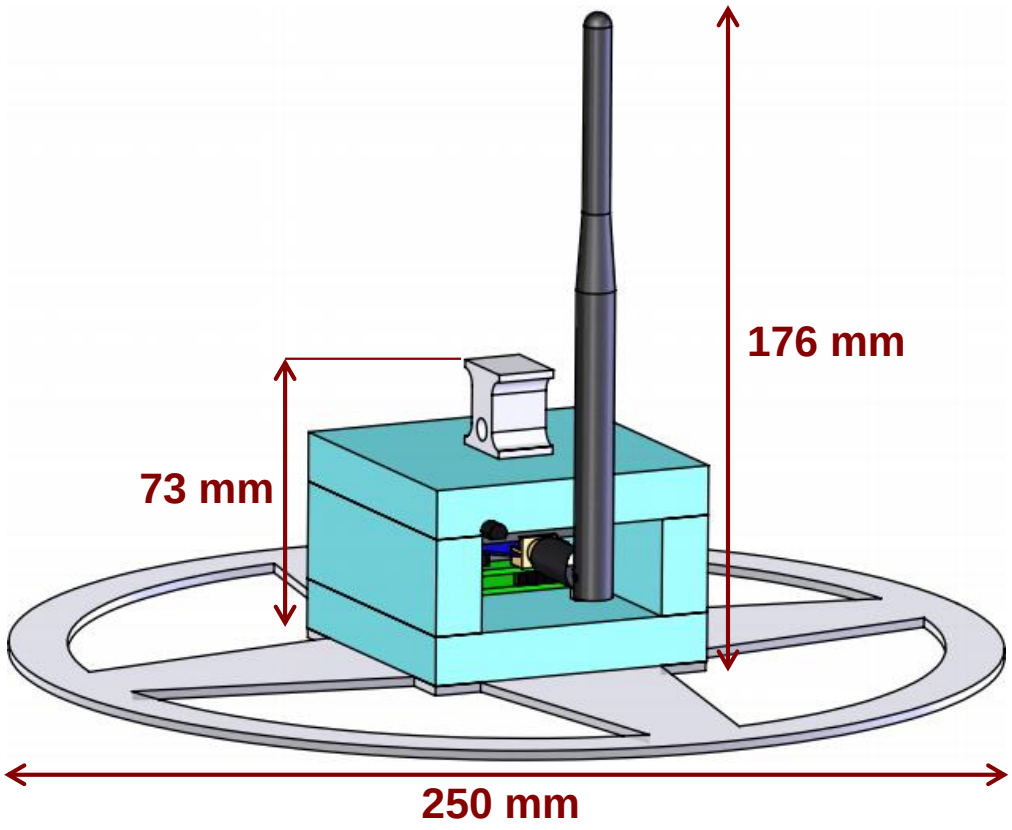


DEPLOYMENT MECHANISM: OVERVIEW

	Progress	Remaining Hours	Completion Date	On Schedule?
Deployment Mechanism Manufacturing/Assembly	30%	6	Feb 13	✓
Linear Actuator Power Circuit Assembly	40%	4	Feb 13	✓

- 3D integration plate ready for printing
  - Updated tolerances based off of camera mount prototyping results
- H-Bridge Power Circuit has been prototyped
  - Final soldering to perf-board still needs to be completed

SENSOR PACKAGE

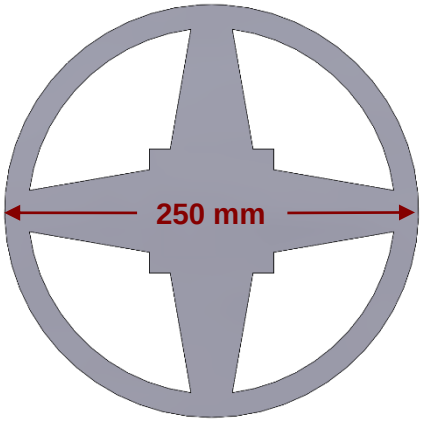


SENSOR PACKAGE: STRUCTURE OVERVIEW

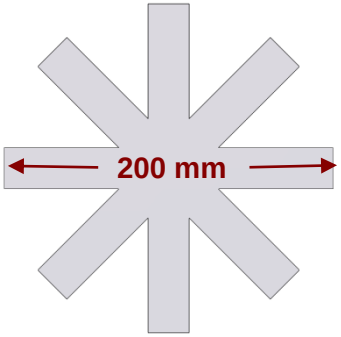
	Progress	Remaining Hours	Completion Date	On Schedule?
Baseplate Manufacturing	100%	--	Complete	✓
Foam Housing Assembly	100%	--	Complete	✓
Altimeter Board Standoff Assembly	50%	2	Feb 5	✓
3D Print CD Attachment	0%	1	Feb 5	✓

- Baseplate and Foam Housing have been manufactured
  - PCB mounting standoffs need to be secured to foam
- XBee interface PCB has been ordered
- 3D printed CD attachment is ready to print

SENSOR PACKAGE: BASEPLATE CHANGE



New



Old

Design Issues Addressed	
Issues	Design Adjustment
Brittle Material	Switch from Acrylic to Polycarbonate
Possible Flipping Due to Downdraft	Increased Radius and Added Outer Ring

Manufacturing Complete

- Switch to polycarbonate requires more complex machining
  - No additional cost
  - Approximate doubling in man hours required

SENSOR PACKAGE: SOFTWARE/ELECTRONICS

Sensor Package Software				
	Progress	Remaining Hours	Completion Date	On Schedule
XBee Transmission Subroutine	90%	2-3	Feb 29	2 Weeks
Temperature Collection Subroutine	100%	--	Complete	✓
EEPROM Read/Write Subroutine	90%	15	Feb 29	2 Weeks
Transmission Error Subroutine	80%	5	Feb 29	2 Weeks

- Primary time sink is a bug in the EEPROM subroutine

Sensor Package Electrical				
	Progress	Remaining Hours	Completion Date	On Schedule
PCB Designed/Ordered	100%	--	Complete	✓
PCB Verification	0%	1	Feb 10	✓
Solder Components	0%	3	Feb 12	✓

GROUND STATION MOTHER ROVER SIMULATOR

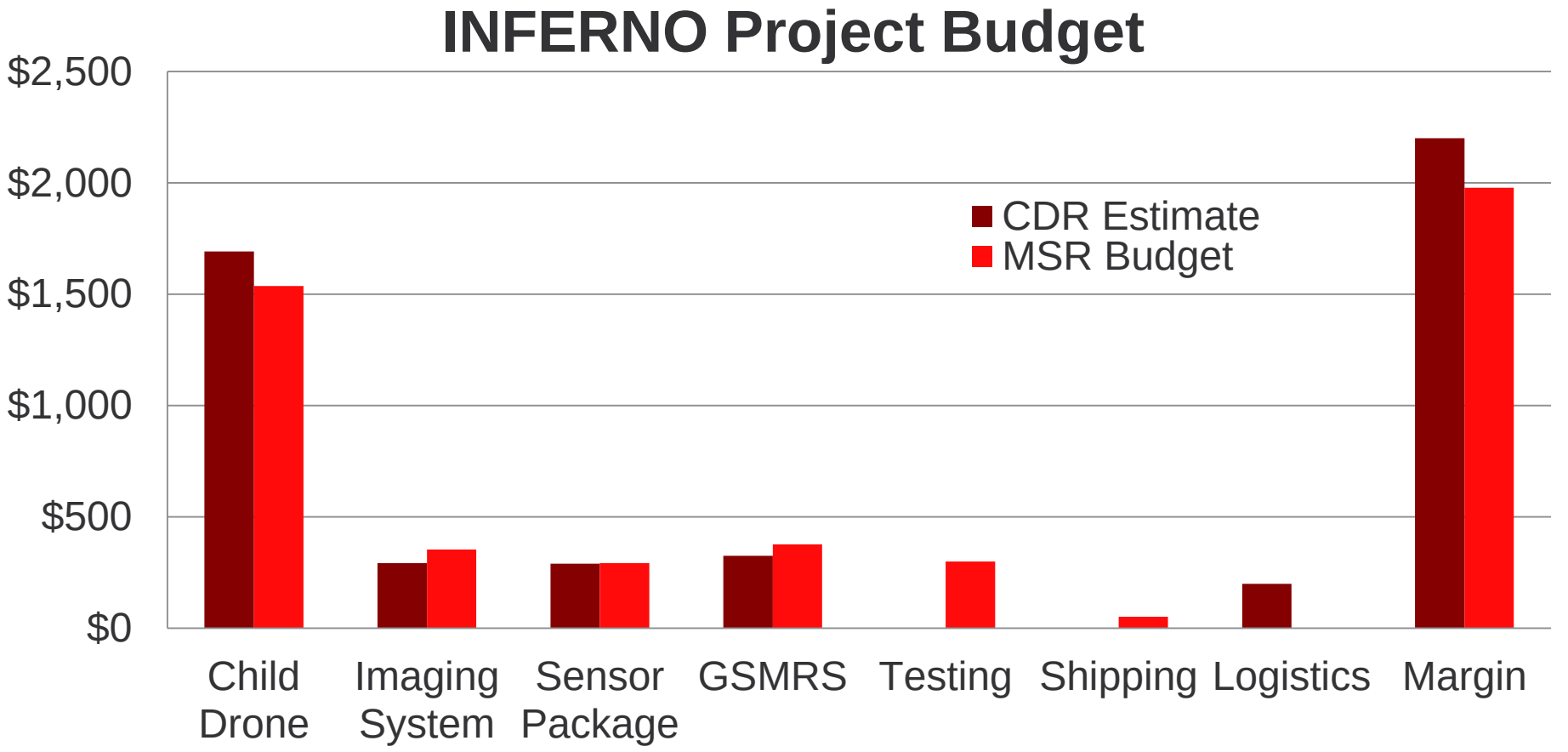
GSMRS SOFTWARE

	Progress	Remaining Hours	Completion Date	On Schedule?
Data Reception and Transmission	90%	2-3	Feb 5	✓
Plotting Capabilities	100%	--	Complete	✓
GUI Interface	25%	25-30	Feb 12	✓

- Plotting, data reception and data transmission are operational
  - 10% remaining is testing with functional SP
  - Ready for integration with GUI interface
- GUI interface needs to be completed
  - Prototype and design concepts completed

FINANCIAL STATUS

FINANCIAL STATUS: BUDGET



FINANCIAL STATUS: PROCUREMENT

PROCURED (As of 2/1/2016)

CHILD DRONE

- Airframe (arms, landing legs, baseplate)
- Propulsion Subsystem (motors, speed controllers, propellers)
- Power Distribution and Battery
- Flight Controller, GPS Unit
- Communication Hardware (X8R, ImmersionRC Transmitter, 3DR Radio Set)
- Imaging Mount Manufacturing and GoPro
- Linear Actuator

GSMRS

- Communication Links (Taranis, ImmersionRC Uno Receiver, 3DR Radio Set)
- ImmersionRC Uno Battery
- MissionPlanner GS Software

SENSOR PACKAGE

- Communication Hardware (Xbee Pro)
- Temperature Sensors
- Structural Materials (Polycarbonate, Foam)
- PCB Mounting Standoffs
- Xbee Antenna

FINANCIAL STATUS: PROCUREMENT NEXT STEPS

Procurement Item	Procurement Plan	Total Cost	Estimated Completion Date
FAA Flight Physical (2)	Research certified doctors Select two team members	$300.00	Mid to Late Feburary
Printed Circuit Board	Ordered from Advanced Circuits on 1/29/16	$33.00	Estimated Delivery within Upcoming Week
Sensor Package Battery	Order from Power Stream following testing	$7.59	End of February

Margin Allocation

- Purchase of additional Child Drone batteries and propellers (~$180)
- Replacement GoPro as necessary
- Incidental test equipment
- Replacement components in case of CD crash or testing failure
- Future logistic costs (printing, report binding, etc.)

QUESTIONS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BACKUP SLIDES

BACKUP SLIDES CONTENT

- Levels of Success
- CONOPS
- Functional Block Diagrams
- Baseline Design
- CD Structures
- SP Stability Post Deployment
- CD Electrical
- SP Power
- Imaging Structure
- Imaging Electrical
- SP Structures
- SP Electronics
- AI&T

LEVELS OF SUCCESS

Level 1

- Manually controlled CD flight with simulated payload
- Simulated deployment
- Time-stamped video at 420 p at 30 fps
- 8 MP still images taken on command
- Wired communications (SP, Imaging, CD, GSMRS)
- Time stamped temp data at 1 Hz, 8 bit resolution

Level 2

- 10 minute fully loaded flight duration
- Landing and deployment on command
- Wireless communications (SP, Imaging, CD, GSMRS)
- Time-stamped video at 720 p at 30 fps
- SP-GSMRS handshake at 200 m
- SP storage of 1 hour of temperature data

LEVELS OF SUCCESS

Level 3

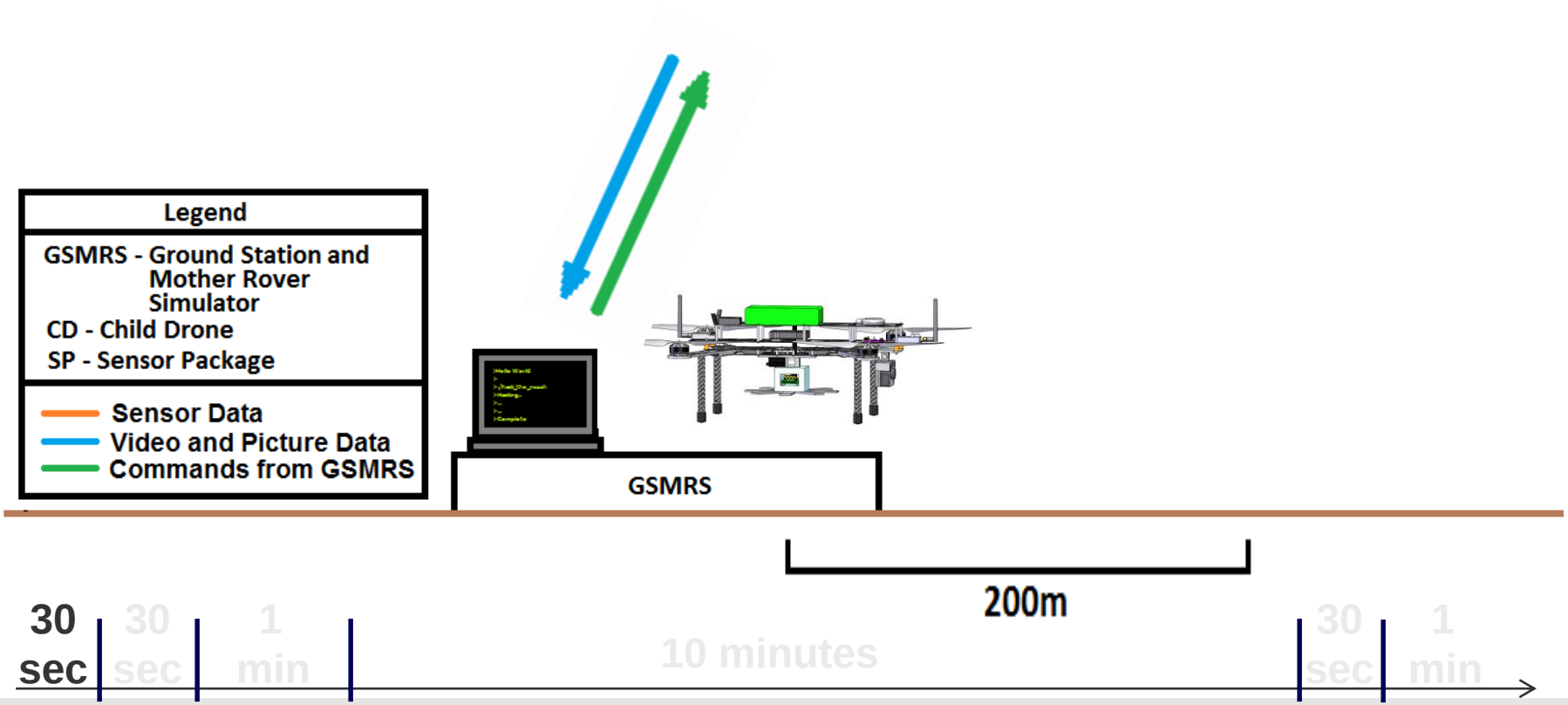
- 15 minute fully loaded flight duration
- 5 m/s translational flight
- Landing and deployment within 10 m of LOI on command
- Time stamped video recorded at 1080 p at 30 fps
- >50% wireless data transmission from SP to GSMRS at 200 m

Level 4

- 10 m/s translational flight
- Landing and deployment within 5 m of LOI on command
- Fully autonomous flight except during final landing
- Time stamped video transmitted at 720 p 30 fps
- >90% wireless data transmission from SP to GSMRS at 200 m
- Data retransmission possible
- Data transmission and reception GUI on GSMRS

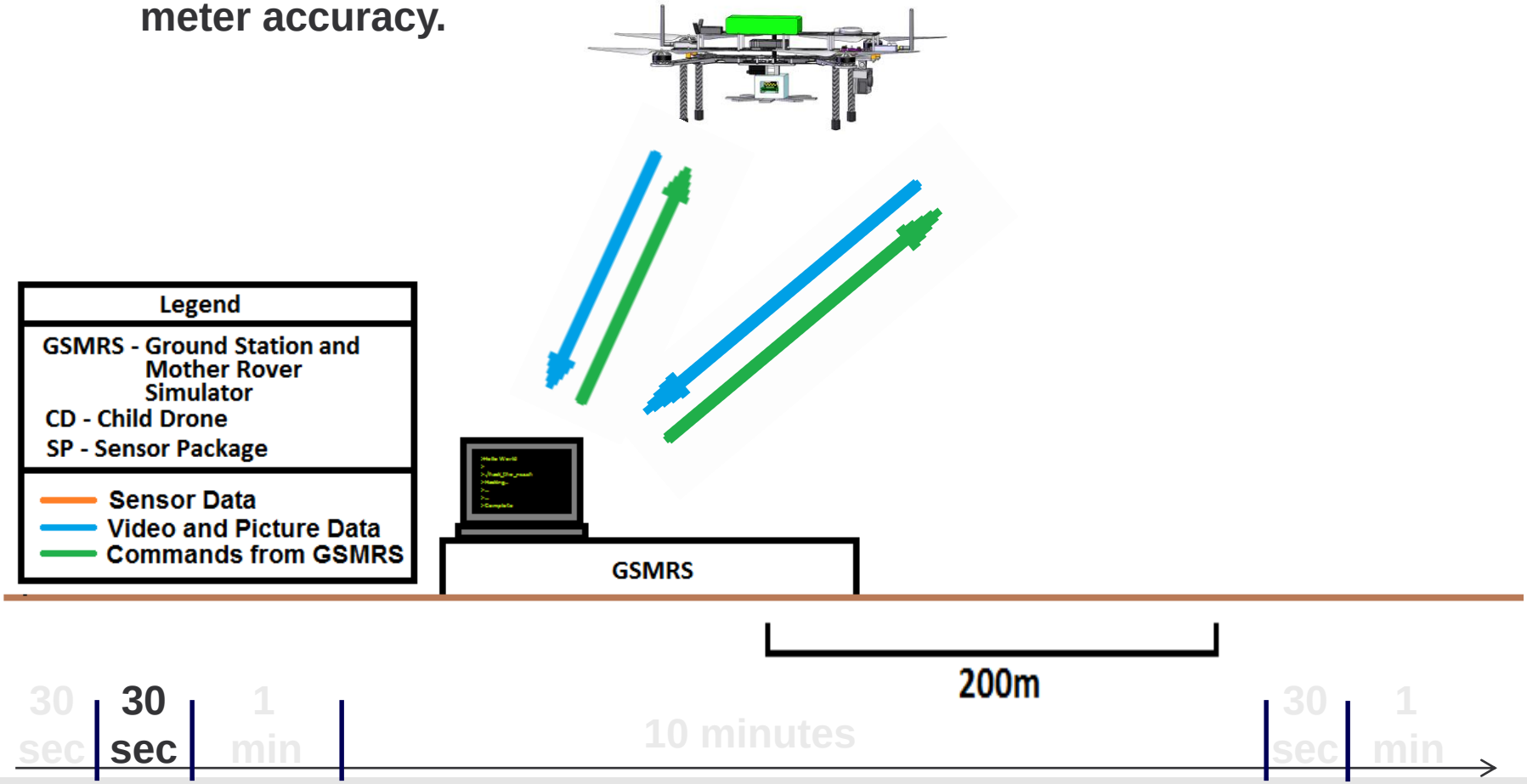
INFERNO SCOPE: CONCEPT OF OPERATIONS

The CD takes off from the GSMRS using autopilot.



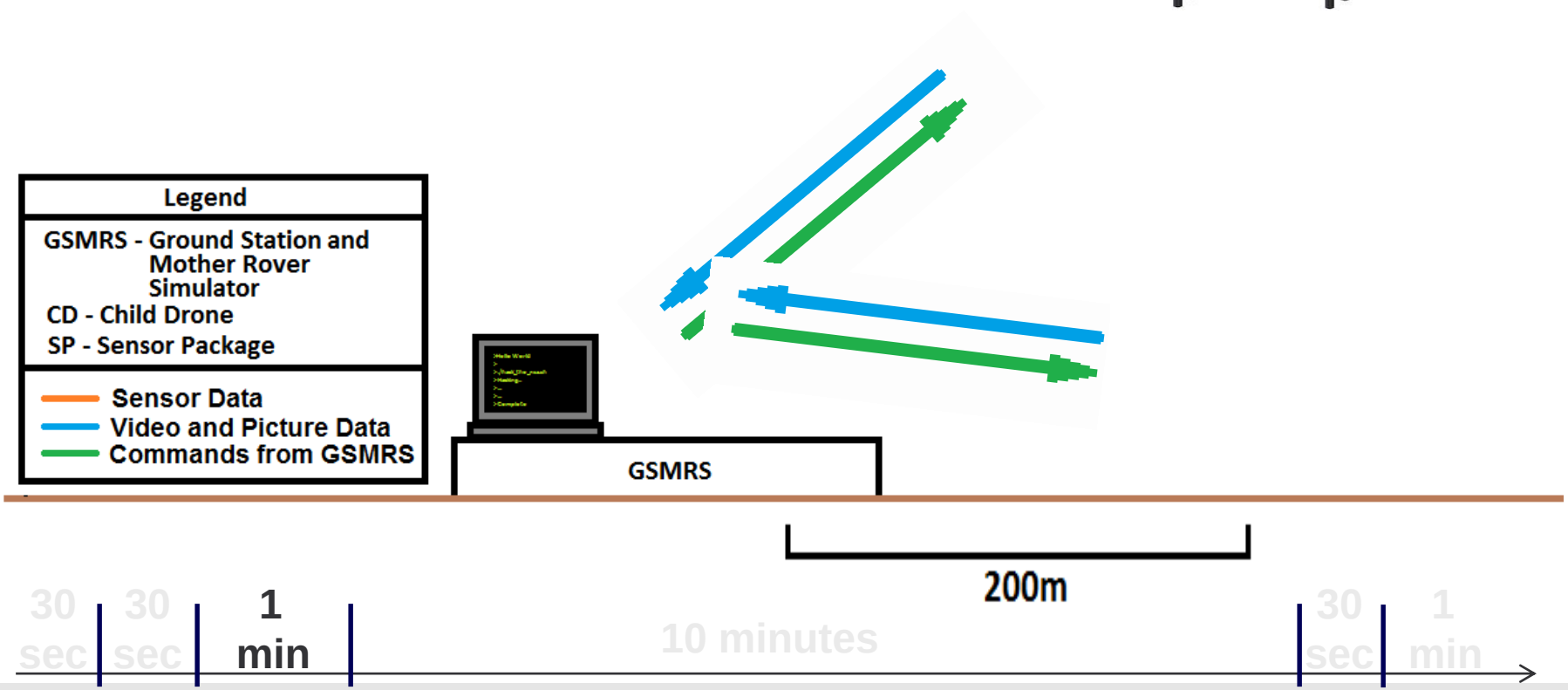
INFERNO SCOPE: CONCEPT OF OPERATIONS

The CD flies to a GPS waypoint up to 200 meters away using autopilot. The CD then maintains its commanded position to 5 meter accuracy.



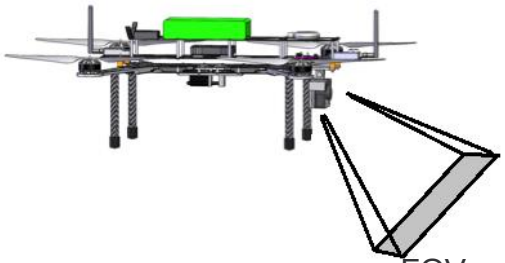
INFERNO SCOPE: CONCEPT OF OPERATIONS

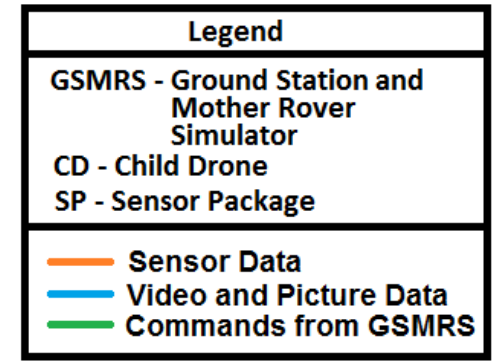
Using autopilot, the CD lands and deploys the SP which begins collecting and storing 1 hour of data.

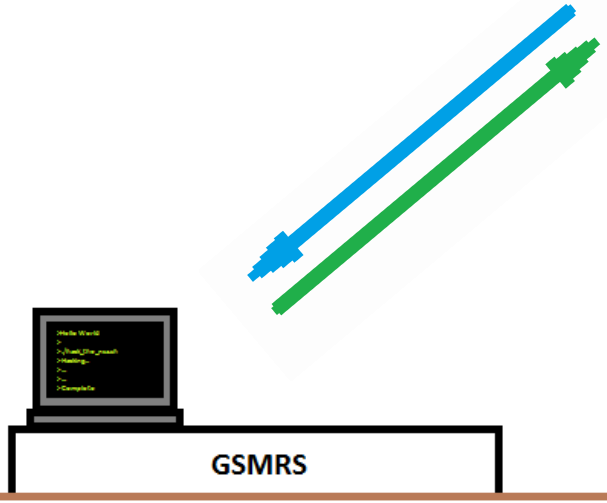


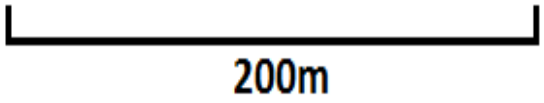
INFERNO SCOPE: CONCEPT OF OPERATIONS

The CD returns to hover using autopilot. It may be commanded to capture video and/or still images at any time. This data is transmitted to the GSMRS.



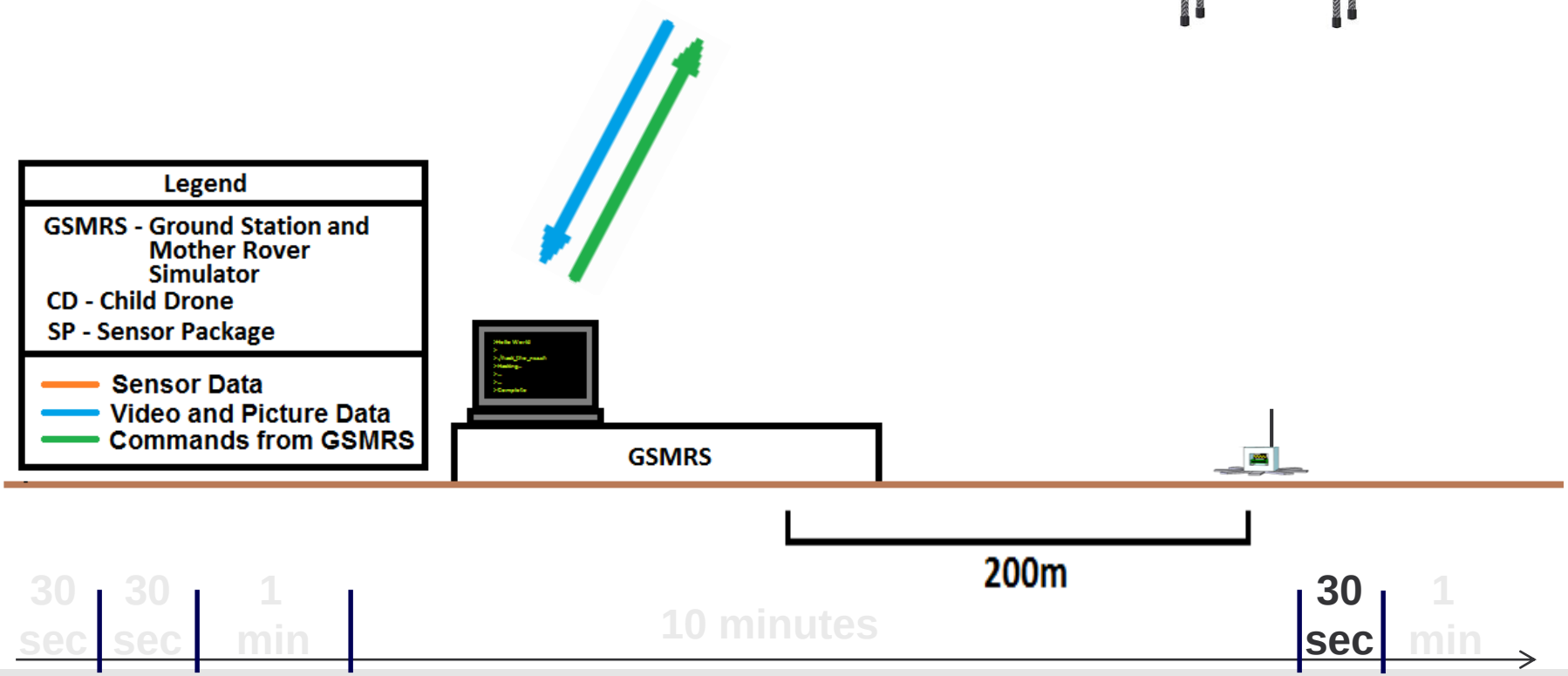






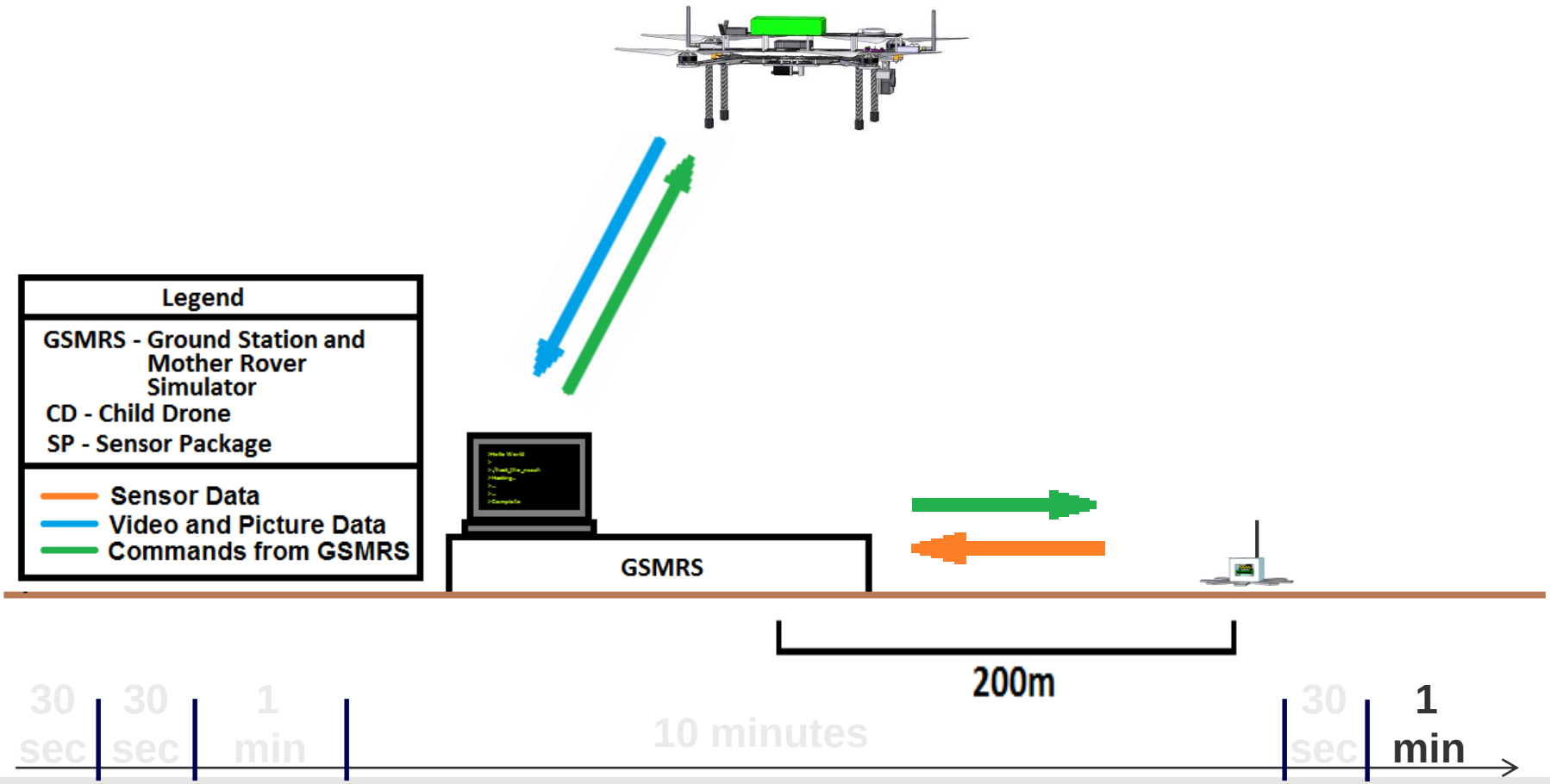
INFERNO SCOPE: CONCEPT OF OPERATIONS

The CD returns to the GSMRS after a 15 minute maximum flight duration using autopilot.

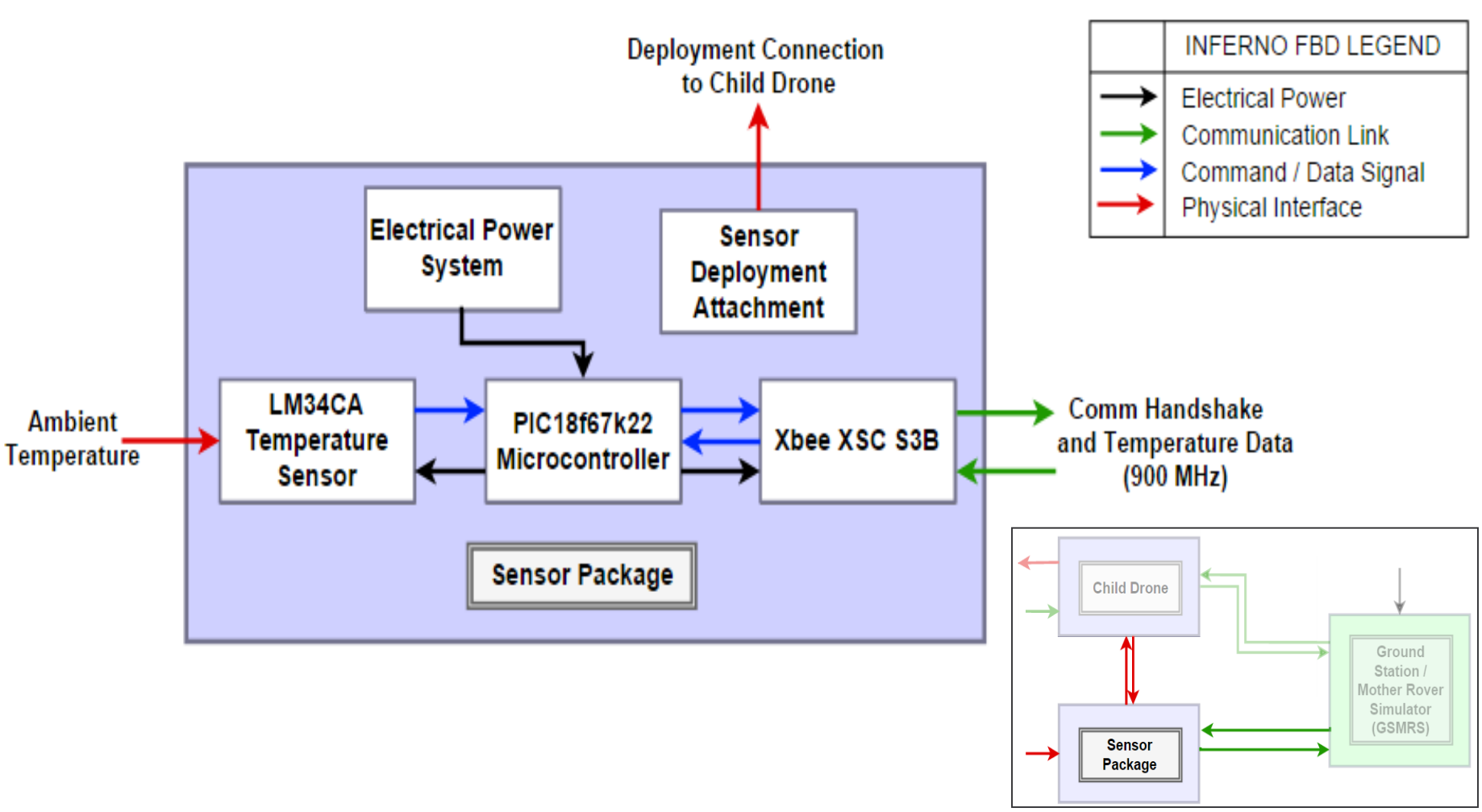


INFERNO SCOPE: CONCEPT OF OPERATIONS

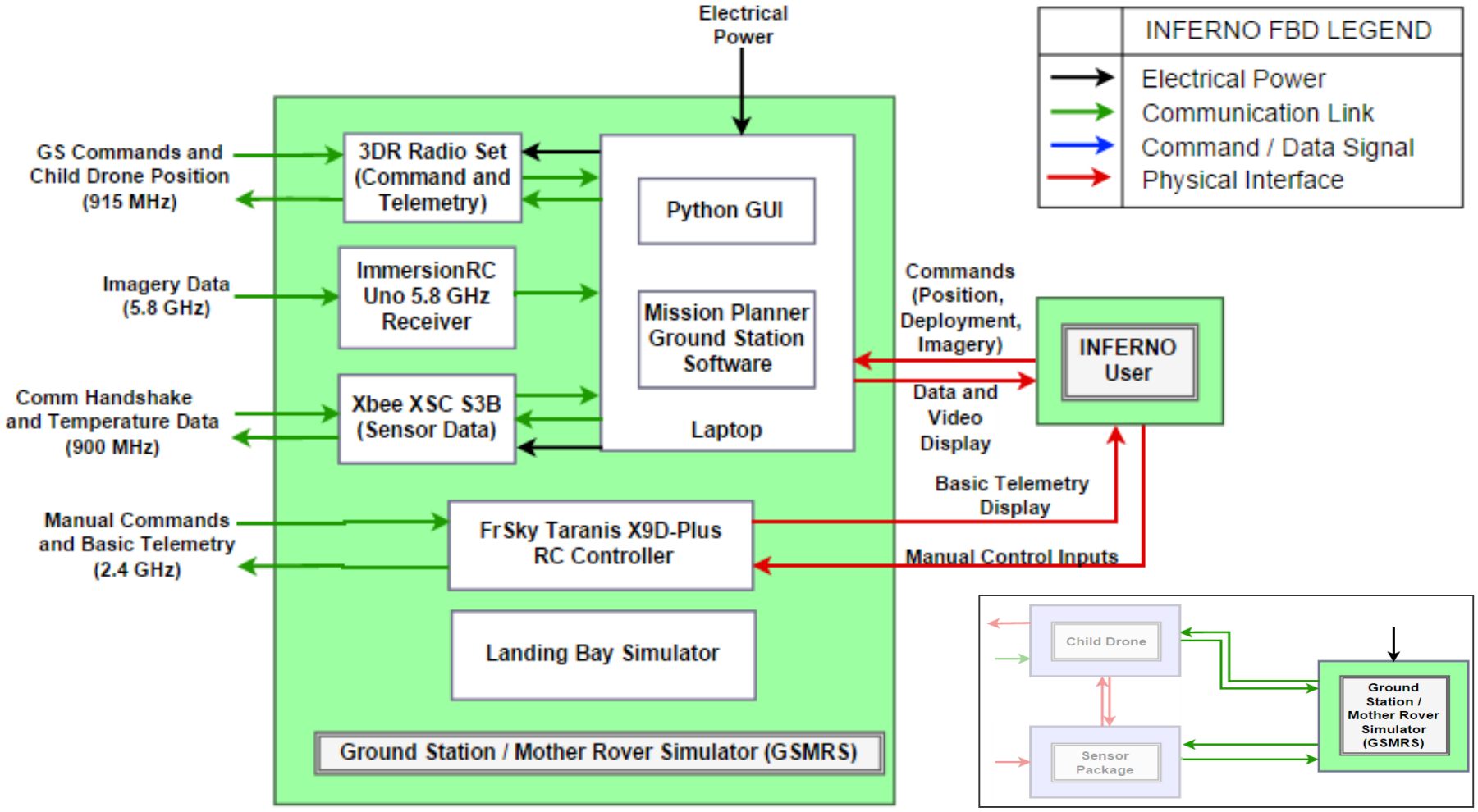
The CD lands on the GSMRS under pilot control and the SP begins transmitting to the GSMRS.



FUNCTION BLOCK DIAGRAM: SENSOR PACKAGE

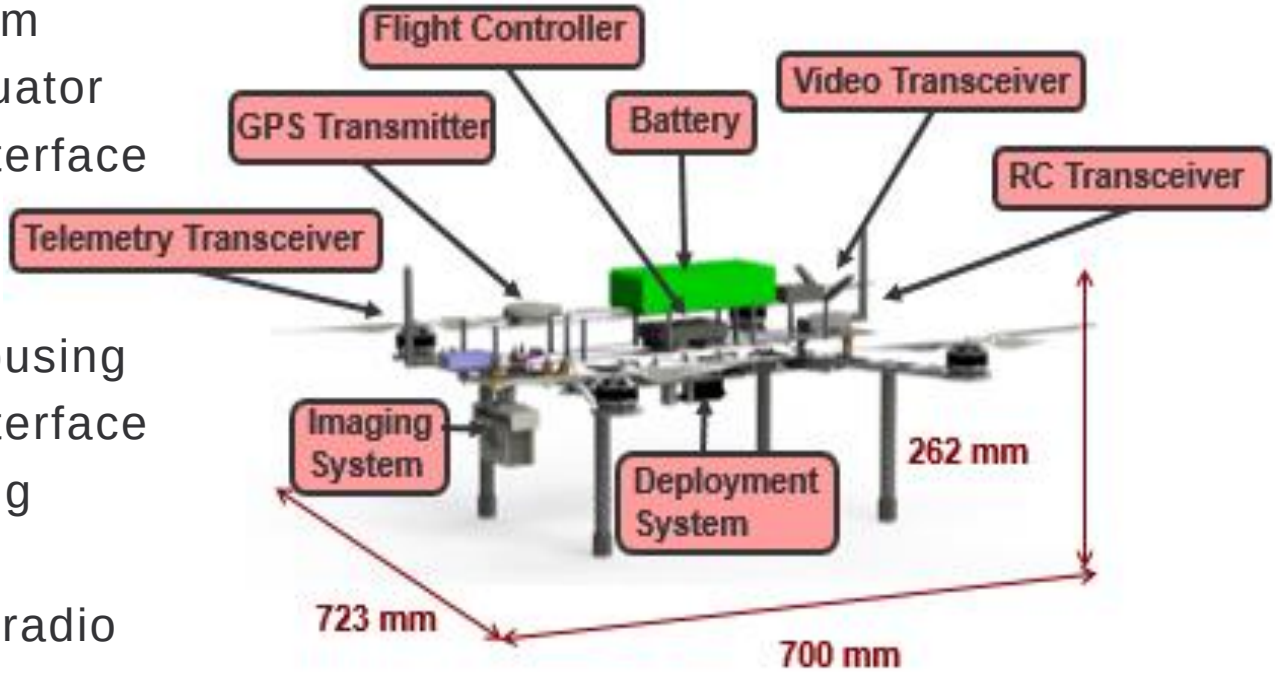


FUNCTION BLOCK DIAGRAM: GSMRS



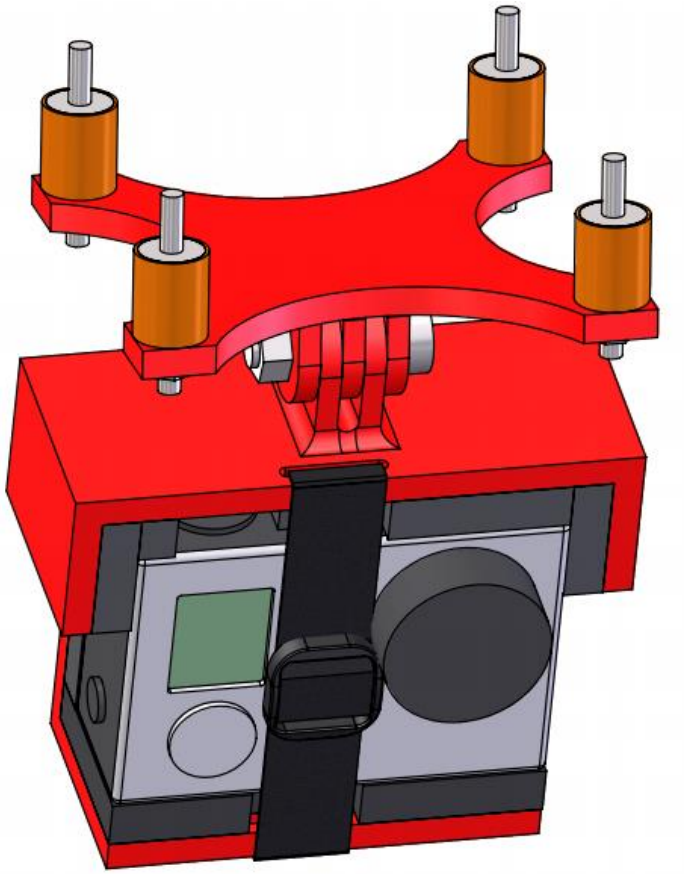
BASELINE DESIGN – CD

- Deployment System
  - COTS linear actuator
  - Manufactured interface
- Imaging System
  - COTS GoPro
  - Manufactured housing
  - Manufactured interface
  - Vibration damping
- Communications
  - COTS telemetry radio
  - COTS video radio
  - COTS R/C Transceiver
  - Custom software



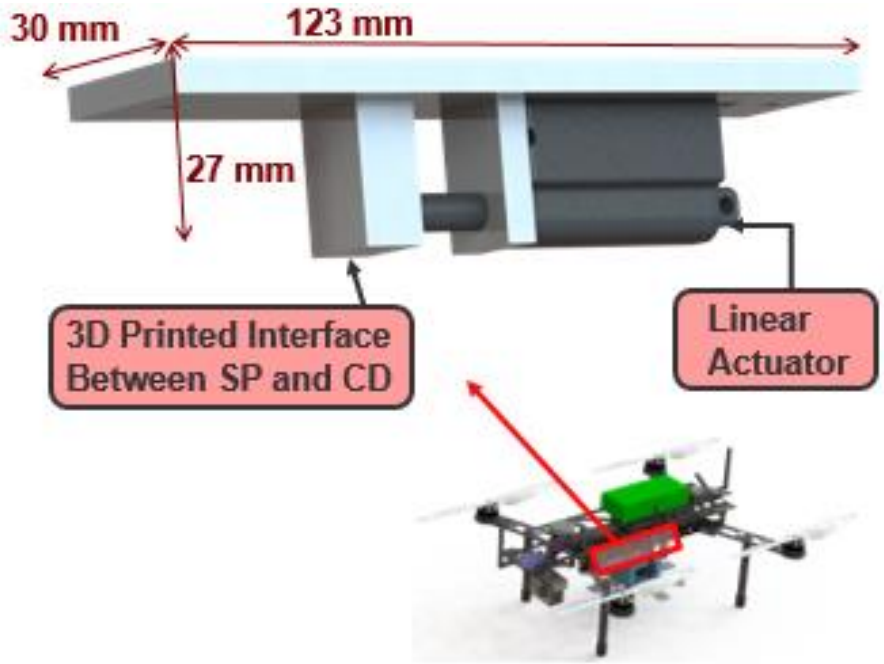
BASELINE DESIGN – IMAGING

- Isolation Plate
  - Manufactured interface
  - Vibration damping with silicon bobbins
  - Interfaces with baseplate of airframe
- Camera Mount
  - Manufactured housing
  - Camera securement strap
  - Friction locking integration
- Imaging
  - COTS GoPro
  - Custom circuit for operation



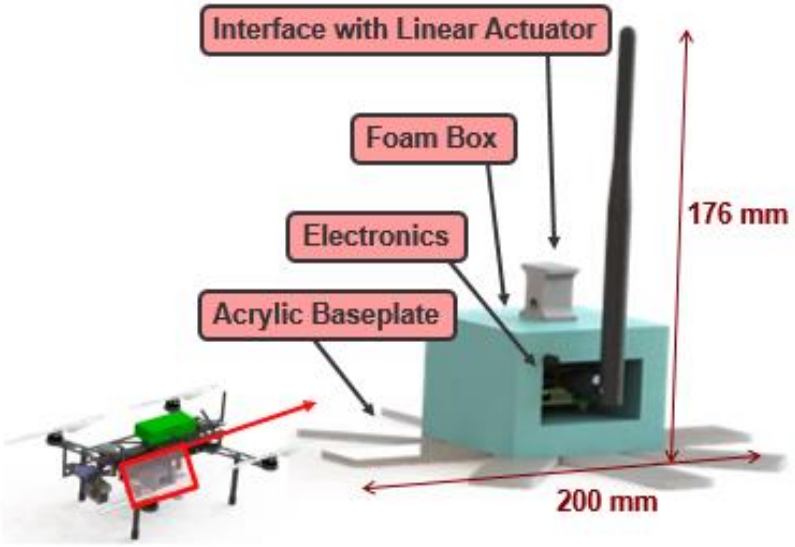
BASELINE DESIGN – DEPLOYMENT

- Integration Plate
  - Manufactured interface
  - Attaches to airframe baseplate
  - Holds linear actuator
- Linear Actuator
  - COTS Firgelli PQ-12
  - Holds sensor package
  - Custom circuit for power



BASELINE DESIGN – SP

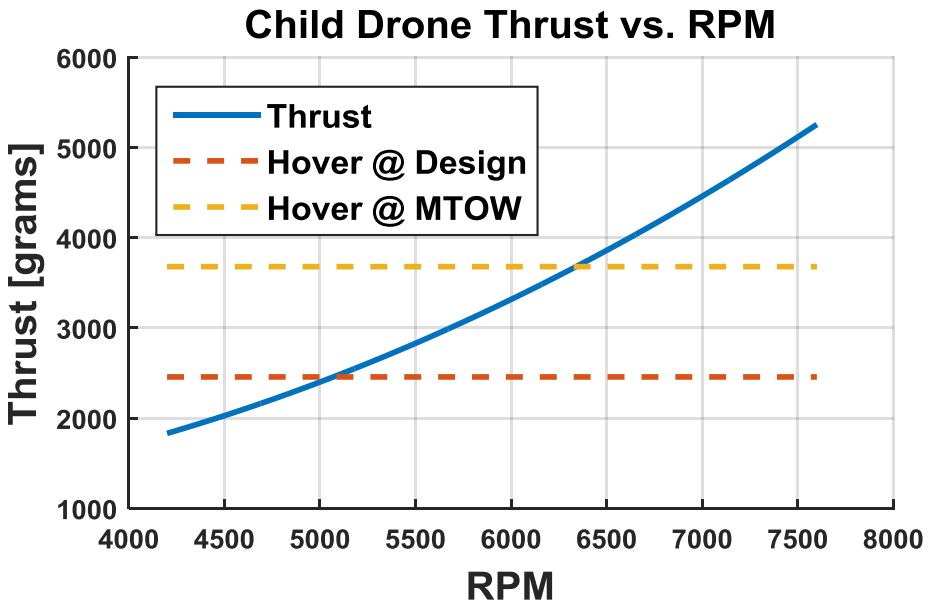
- Interface
  - Manufactured interface with linear actuator
- Baseplate
  - Manufactured polycarbonate baseplate for stability
- Foam Box
  - Manufactured housing for electronics
- Electronics
  - COTS XBee transceiver
  - Repurposed altimeter board



CHILD DRONE: MASS BUDGET

Component	Mass [g]	Change [g]
Child Drone Bus	2070	+29
Imaging System and Transmitter	218	-18
Deployment System	40	+1
Sensor Package	150	+16

Total Mass	2478	+28
Max Takeoff Weight	3677	---
Margin vs. MTOW	1194	-28
Margin vs. Max Thrust	2770	-28

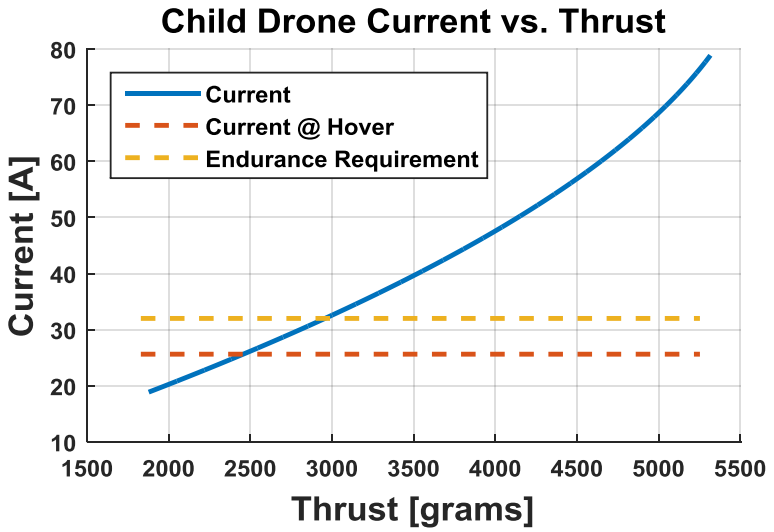


Conclusions:

- System mass increased by 28 g since CDR
- MTOW remains ~33%
- Max thrust margin remains ~50%

CHILD DRONE: POWER BUDGET

Component	Current [A]	Charge Used [mAh]	Change [mAh]
Propulsion @ Hover	25	6,250	+60
Pixhawk/Radios	0.2	45	---
Video Transmitter	0.2	51	-125
Deployment System	0.1	~0	---
Total	**25.5**	**6,345**	**-65**
Endurance	**32.0**	**8,000**	**---**

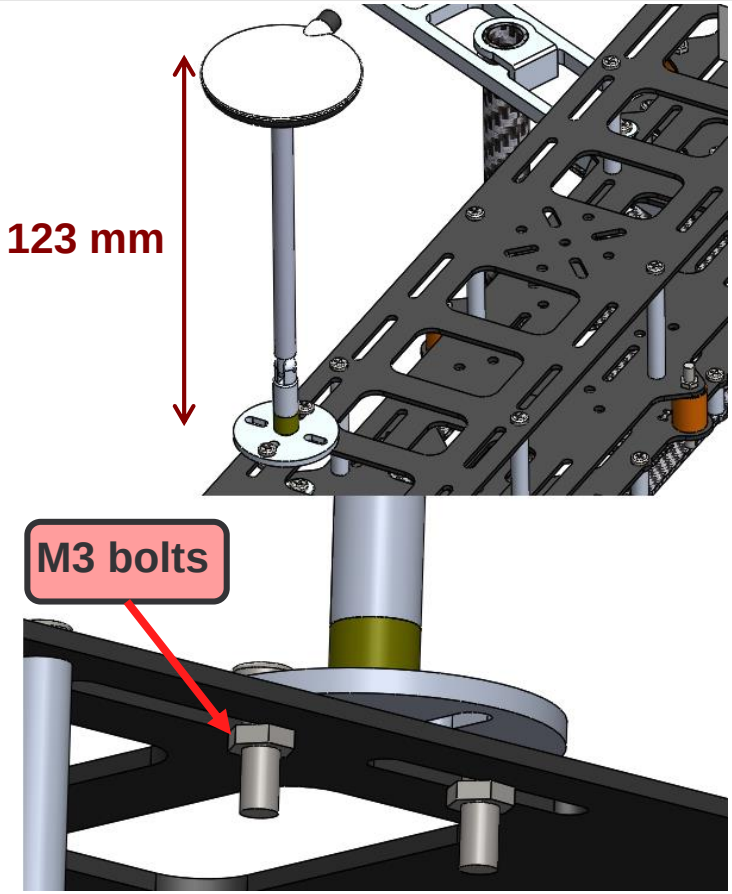


Conclusions:

- System charge requirements reduced by 65 mAh
- System retains 20% charge margin @ 15 minute mission

CHILD DRONE: GPS MAST

- Aluminum GPS mast procured to increase standoff from potential EMI
- Will mate to existing slots in airframe
- FOS = 119 @ 2g load
  - Limited by compressive stress on airframe

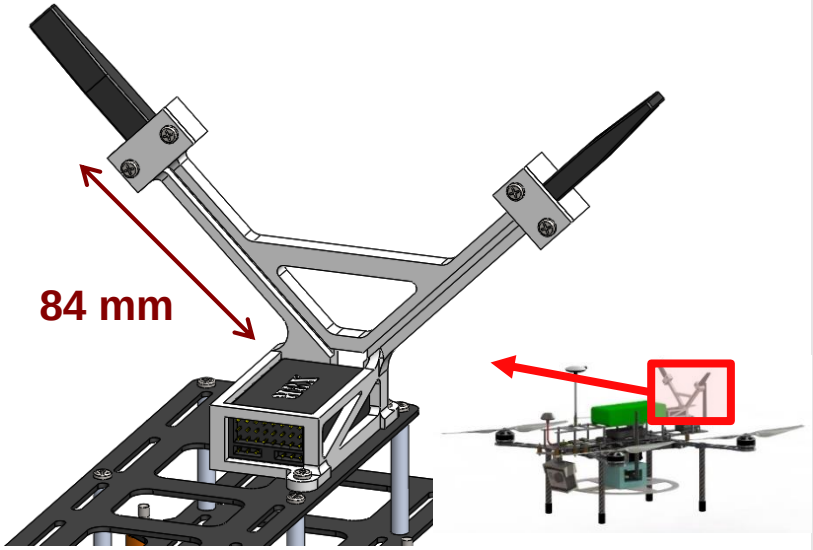


Conclusions:
- Requires no manufacturing or airframe modification
- Acceptable stress for nominal loads

CHILD DRONE: ANTENNA MAST

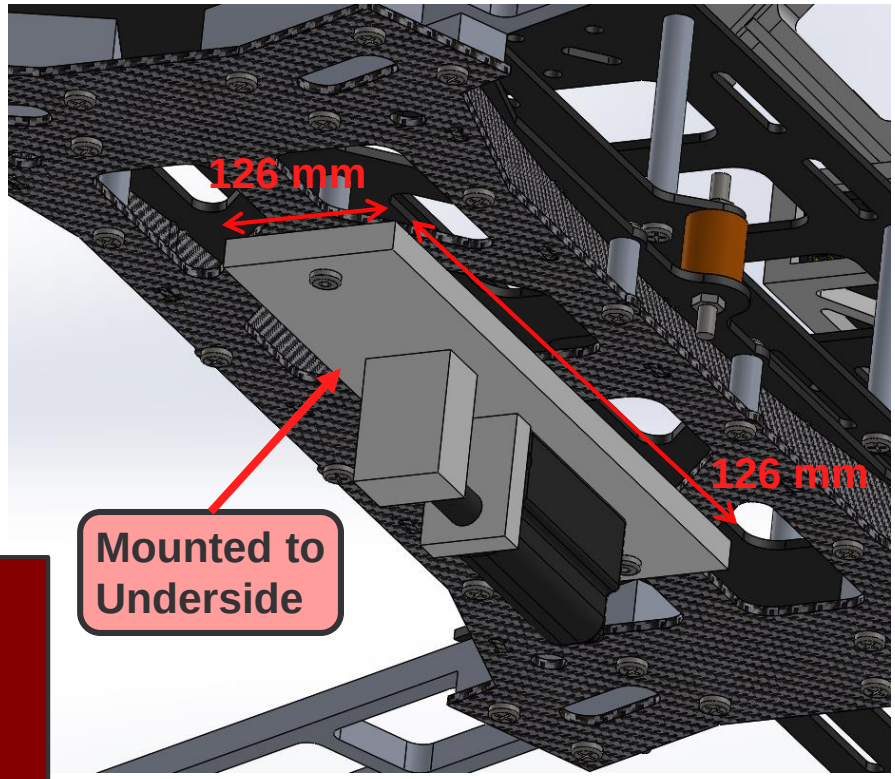
	Progress	Remaining Hours	Completion Date	On Schedule?
CAD Design and Interfacing	100%	--	Completed	✓
3D Printing	0%	1-2	Feb 4-5	✓
Installation on CD	0%	0.25	Feb 5-6	✓

- 3D-printed (ABS P430) case/antenna masts for X8R
- Provides sturdy, diverse orientation for antennas
- CAD model interfaced with existing slots in airframe
- FOS = 39 @ 2g load
  - Limited by compressive stress on airframe
  - Max deflection at break 4.5 mm



CHILD DRONE: STRUCTURE

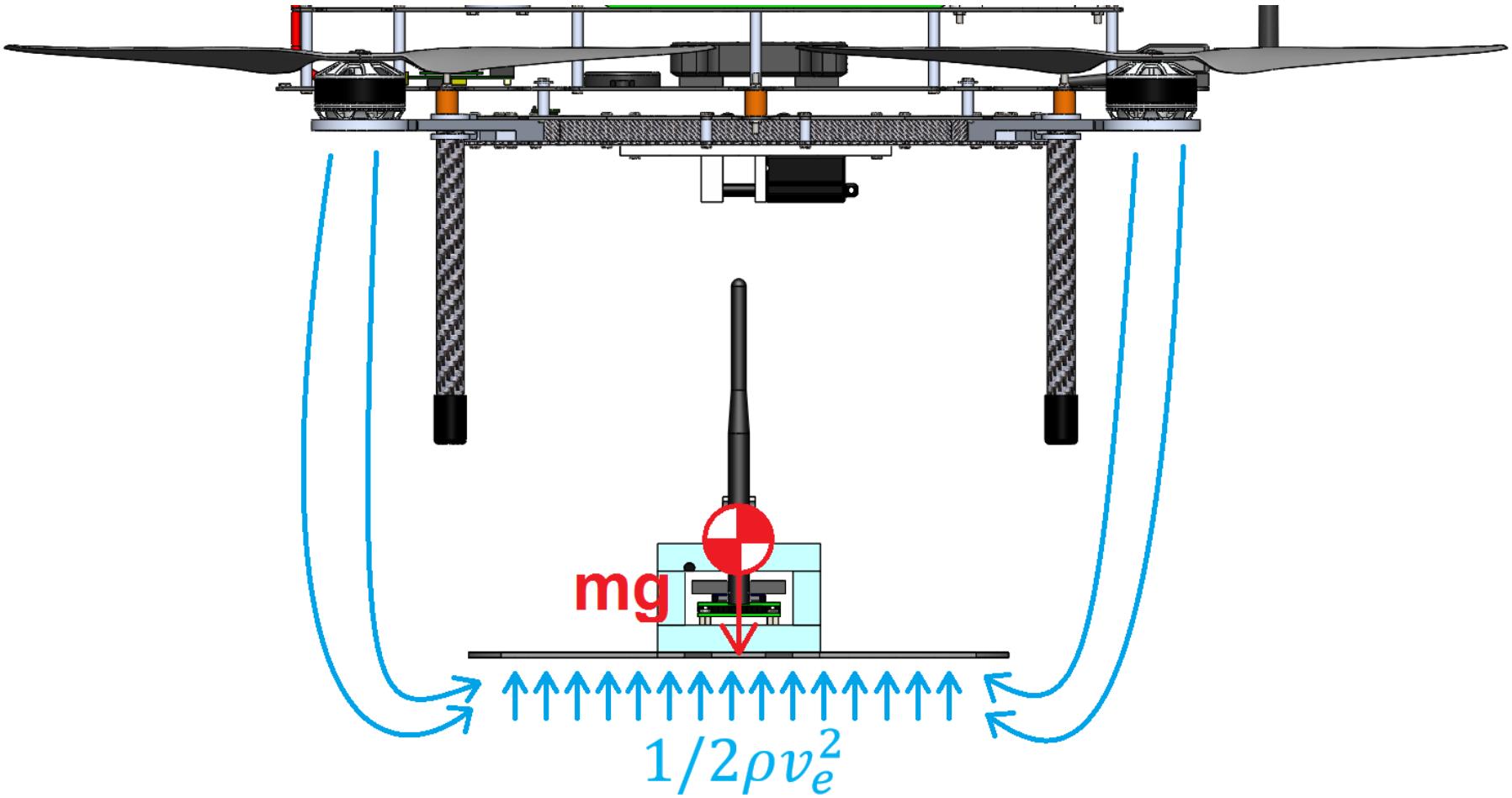
- 3D-printed (ABS P430) interface for deployment
- CAD model interfaced with airframe and actuator
- Mated to existing slots in airframe
- FOS = 24 @ 2g load
  - Limited by bending stress on plate



Conclusion:

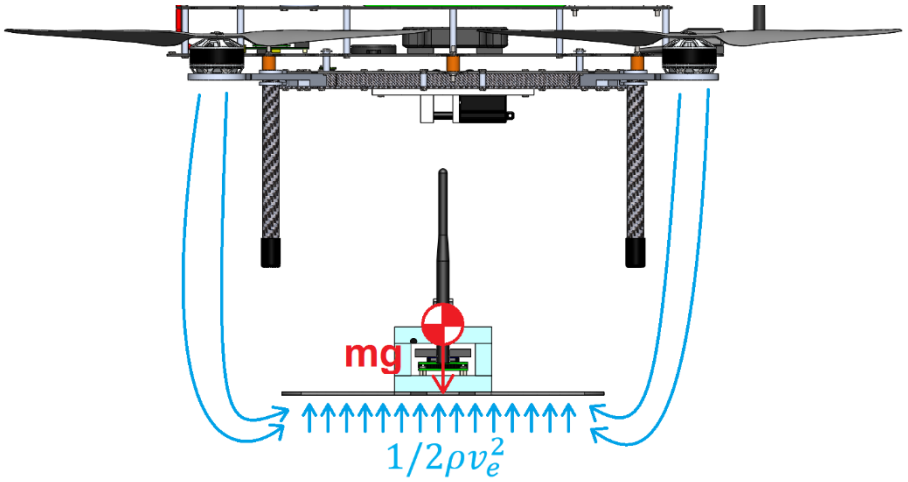
- Acceptable stress under expected loads
- Ready for printing

SP STABILITY
EXHAUST ANALYSIS



SP STABILITY
EXHAUST ANALYSIS

- Exhaust velocity $V_e = \sqrt{\frac{2F_{prop}}{\rho A_{prop}}}$
- Lift force $F = \frac{1}{2}\rho v_e^2 A_{SP}$
  - Baseplate area $A_{SP} = 0.0274\ \mathrm{m}^2$
- SP weight $mg = 1.45\ \mathrm{N}$

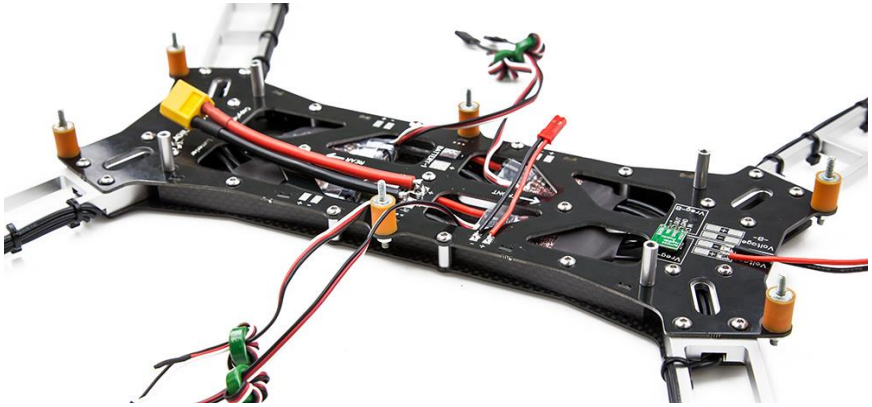


Throttle	Exhaust Velocity [m/s]	Dynamic Pressure [Pa]	Lift Force [N]
50%	12.0	75.6	**2.07**
70%	14.2	106	**2.90**
100%	16.9	150	**4.10**

CHILD DRONE: ELECTRICAL

Soldering	
Battery pigtail to Power Distribution Board	
Electronic Speed Controllers to Power Distribution Board	
Voltage regulator to Power Distribution Board	

Modifications	
Speed controllers wires shortened	
Motor cables shortened to fit airframe	
Change power module connector from xt60 to xt90	
Cut straight pin assembly	



Future Work:

- Begin assembly and soldering (2/1-2/8)

CHILD DRONE: ELECTRICAL

Child Drone Electrical				
	Progress	Remaining Hours	Completion Date	On Schedule
Solder battery pigtail to Power Distribution Board	0%	1	2/1-2/8	
Solder electronic Speed Controllers to Power Distribution Board	0%	1	2/1-2/8	
Solder voltage regulator to Power Distribution Board	0%	.5	2/1-2/8	
Speed controllers wires shortened	0%	1	2/1-2/8	
Motor cables shortened to fit airframe	0%	2	2/1-2/8	
Change power module connector from xt60 to xt90	0%	1.5	2/1-2/8	
Cut straight pin assembly	0%	.5	2/1-2/8	

SENSOR PACKAGE: POWER MODEL

Component	Current Draw [mA]	Time in use [hour]	Voltage [V]	Power [J]
PIC18F67K22	8	1	3.7	108
LM34CA	0.075	1	5	1.4
XBee (Sleep)	0.045	0.96	3.3	0.5
XBee (Idle)	23	0.035	3.3	9.7
XBee (Transmitting)	190	0.0023	3.3	5.4

Results:

- Total power draw for 1 hour: ~125 J
- Battery power: 5994 J
- Margin: 5869 J → Could run for ~40 hours longer

IMAGING SYSTEM: STRUCTURE

Camera Mount Prototyping

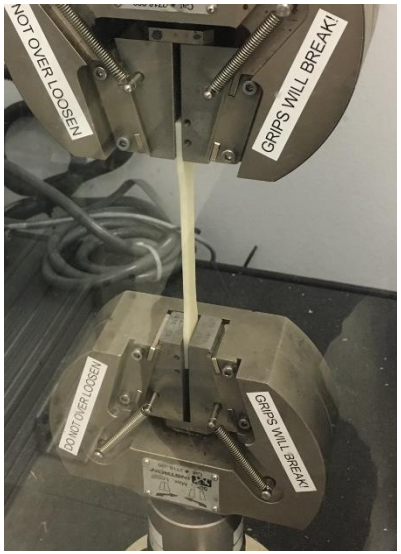
Discovered Issues		
Issues	Fixes	
Horizontal movement of GoPro	Horizontal dimensions of case reduced by 1 mm Sides of case extended by 5 mm	✓
Bobbin holes don't line up with airframe	Model modified to match airframe dimensions	✓

IMAGING SYSTEM: STRUCTURE

Tensile Strength Testing

- Instron machine used to determine Young's Modulus and failure stress
- ASTM D638 Standard with Type 1 specimen used for tests

	Failure Stress (MPa)	Young's Modulus (GPa)
Tested	12.87	1.82
Specified	33	2.2



GIMBAL OFF-RAMP: MASS/POWER BUDGETS

Component	New Mass [g]	Change [g]
Imaging System and Transmitter	270	+52
Total Mass	2530	+52
Margin vs. MTOW	**1142**	**-52**
Margin vs. Max Thrust	**2718**	**-52**

Component	Current [A]	Charge Used [mAh]	Change [mAh]
Propulsion @ Hover	25.7	6,420	+170
Gimbal	0.5	125	+125
Total	**26.0**	**6,640**	**+295**
Endurance	**32.0**	**8,000**	**---**

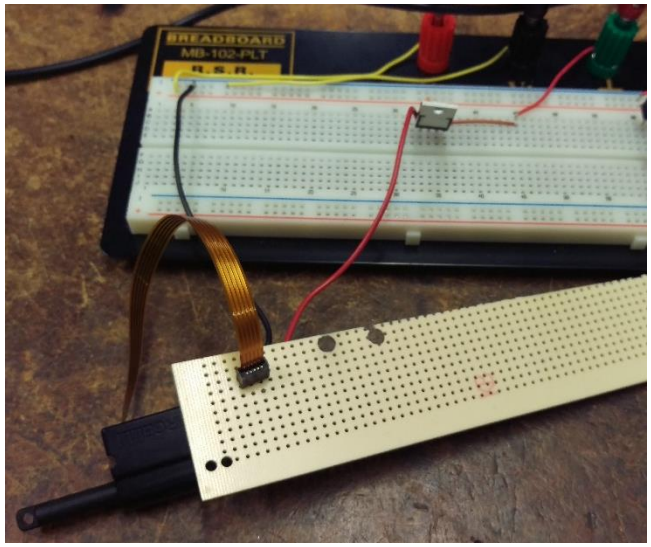
- Tarot T-2D
  - Cost: $190
  - Mass: 200g
  - Power: 200-500 mA @ 12 V
  - Accuracy: 0.1°

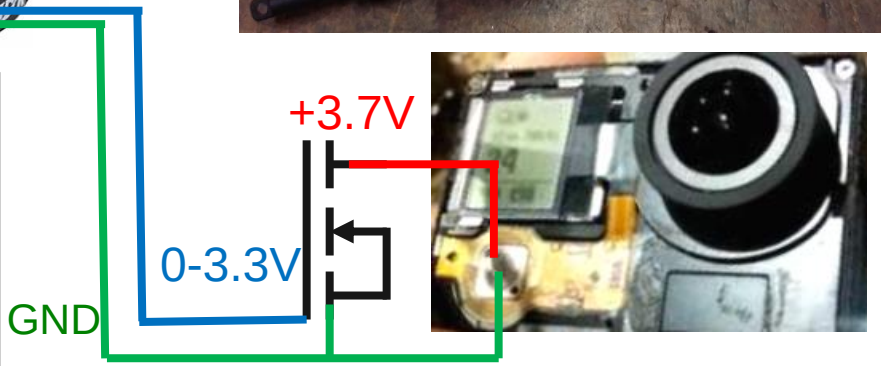
Conclusions:
- Cost manageable within project margin
- Margin vs MTOW reduced to 31%
- Charge margin reduced to 17%
- Additional Pixhawk/EPS integration

IMAGING SYSTEM: ELECTRICAL

GoPro Circuit Power Switch

- Initial prototyping completed for circuit
  - Linear actuator was used in place of GoPro until permission is obtained to modify GoPro



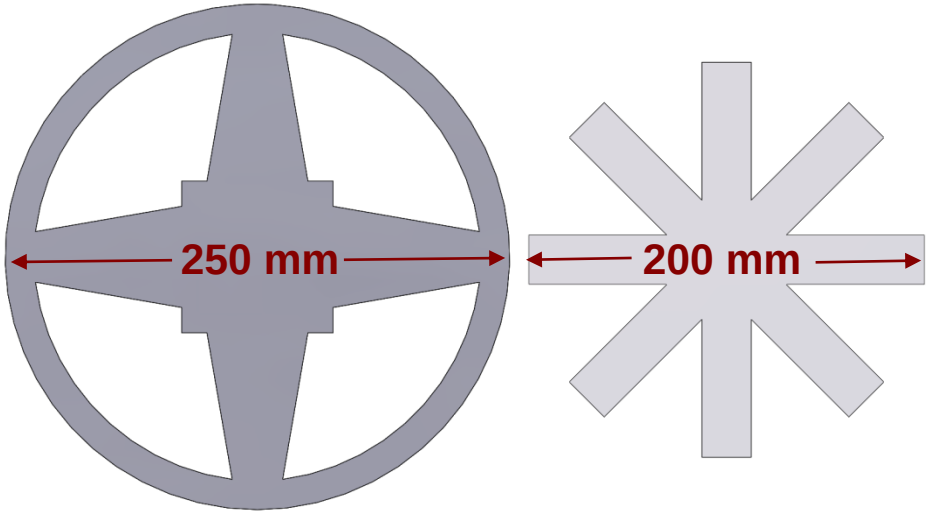


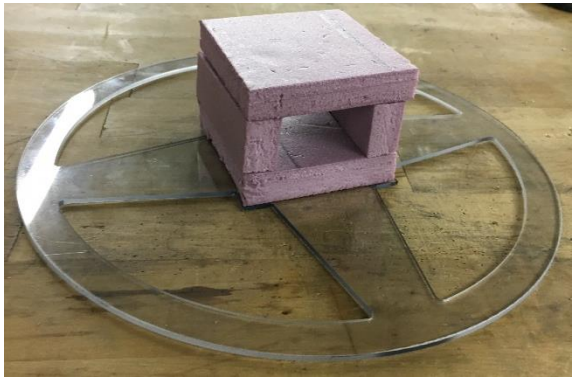
Future Work:

- Create Assembly/Test Procedure (2/20)
- Test GoPro & Pixhawk with Power Switch Circuit (2/22-2/29)

SENSOR PACKAGE: BASEPLATE CHANGE

Design Issues Addressed	
Issues	Design Adjustment
Brittle Material	Switch from Acrylic to Polycarbonate
Possible Flipping Due to Downdraft	Increased Radius and Added Outer Ring



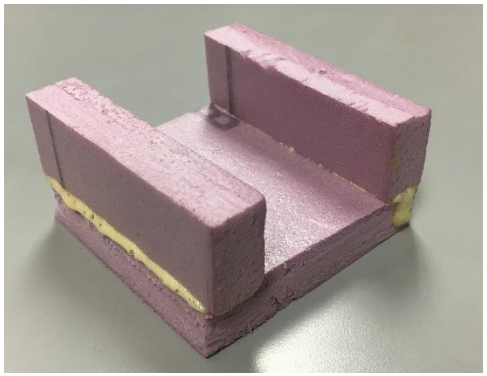


	New		Old
Material	Polycarbonate		Acrylic
Radius	125 mm	+ 25%	100 mm
Surface Area	27,574 mm^2	+ 63%	16,982 mm^2
Mass	78.8 g	+ 24%	63.6 g

SENSOR PACKAGE: STRUCTURE – HOUSING

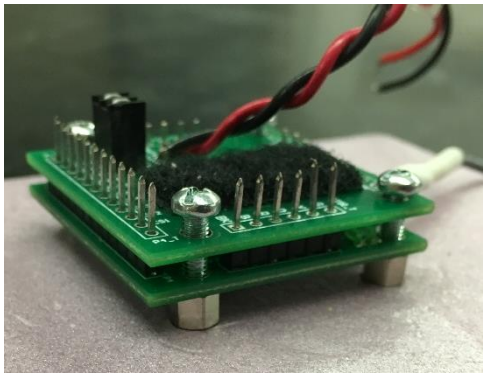
Permanently Joined Foam Housing

✓ **Manufactured**



PCB Mounting

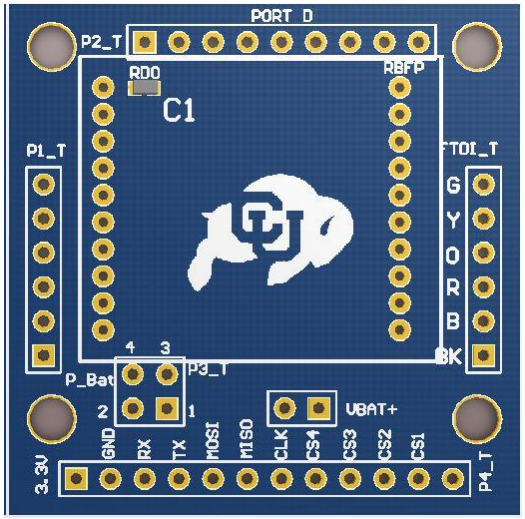
Prototyped

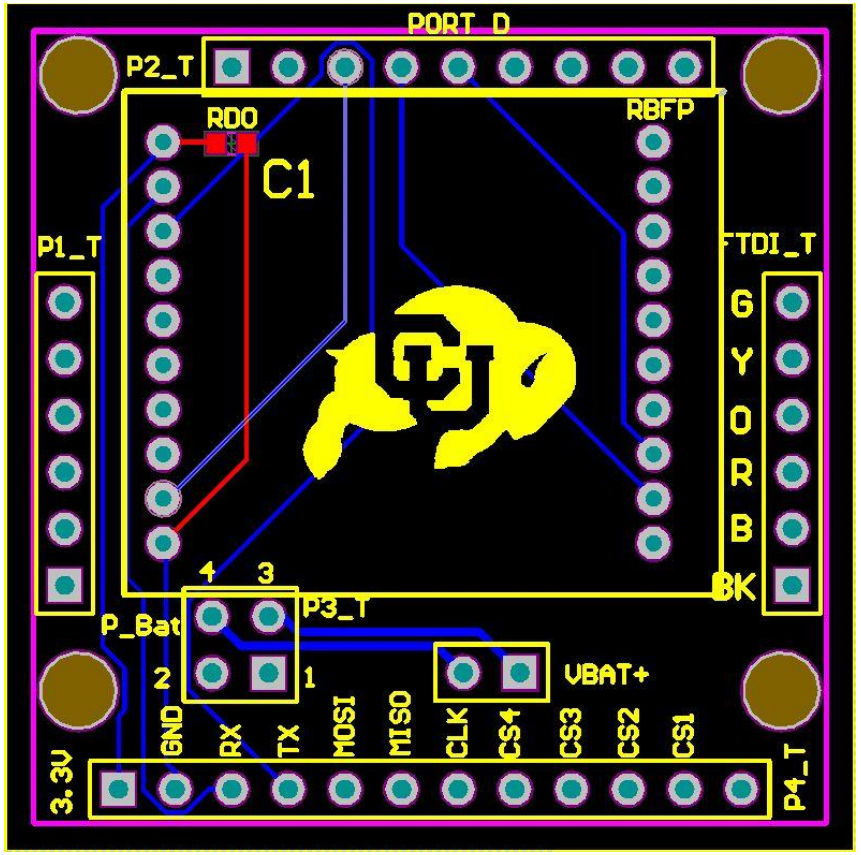


Foam - Standoff - Screw Interface

SENSOR PACKAGE: ELECTRONICS

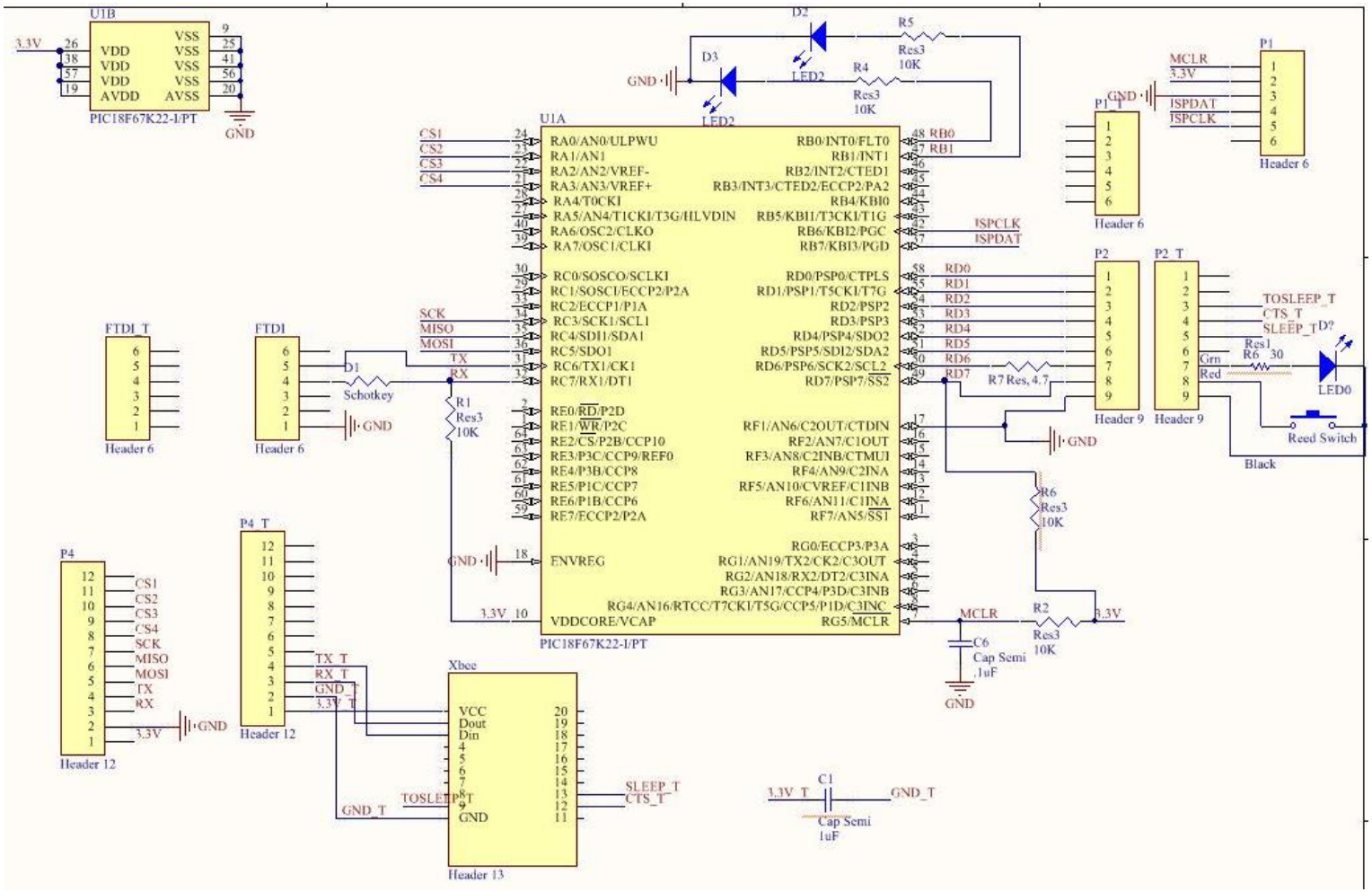
- Expected delivery of 2/8-2/10
- Reprint will take 12 days if necessary



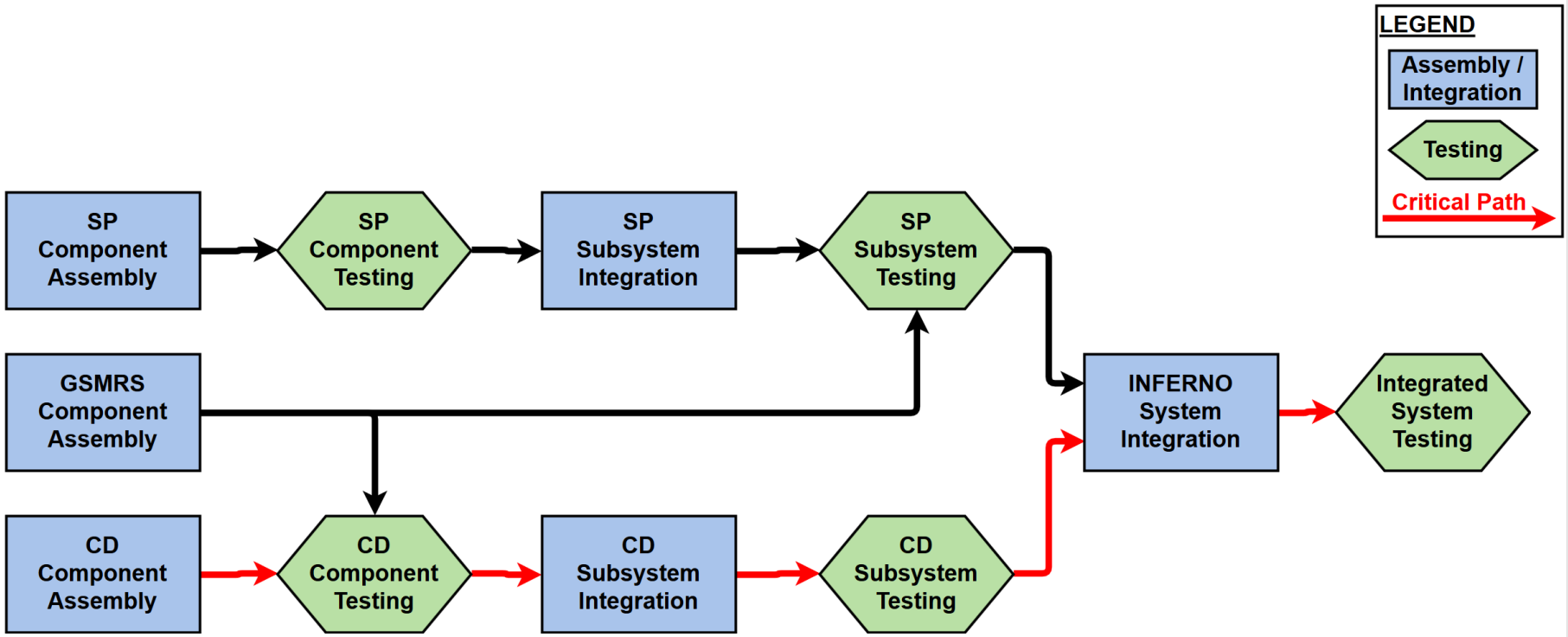


Future Work:
- Test printed board (2/10-2/11)

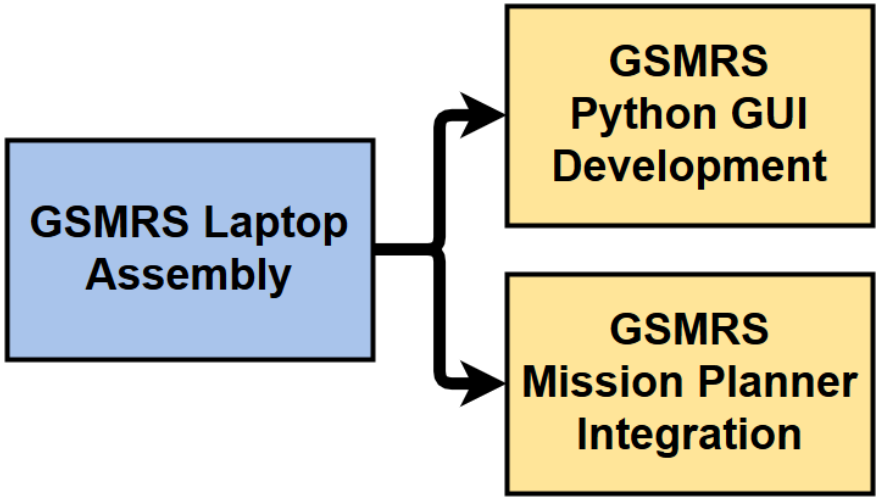
SENSOR PACKAGE: FULL ELECTRONICS

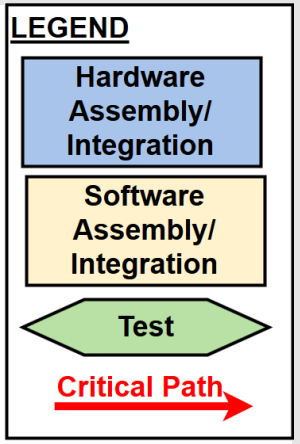


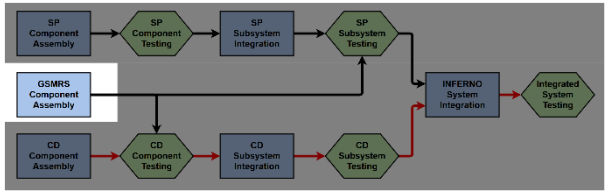
ASSEMBLY, INTEGRATION & TEST (AI&T) PLAN



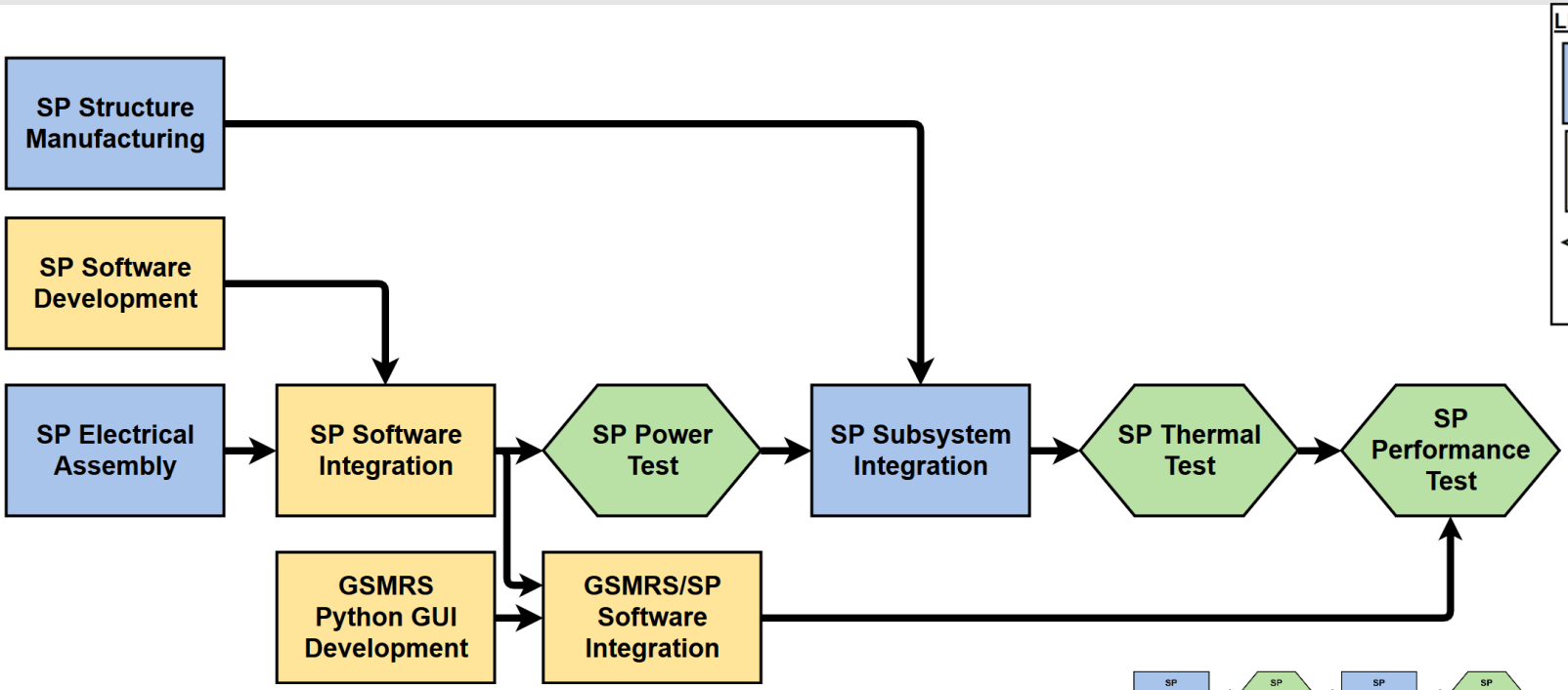
AI&T PLAN: GSMRS

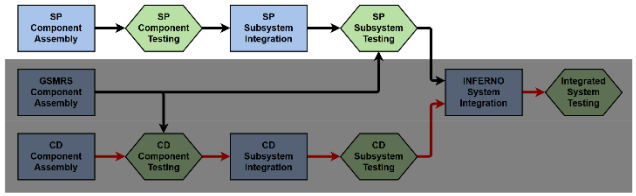




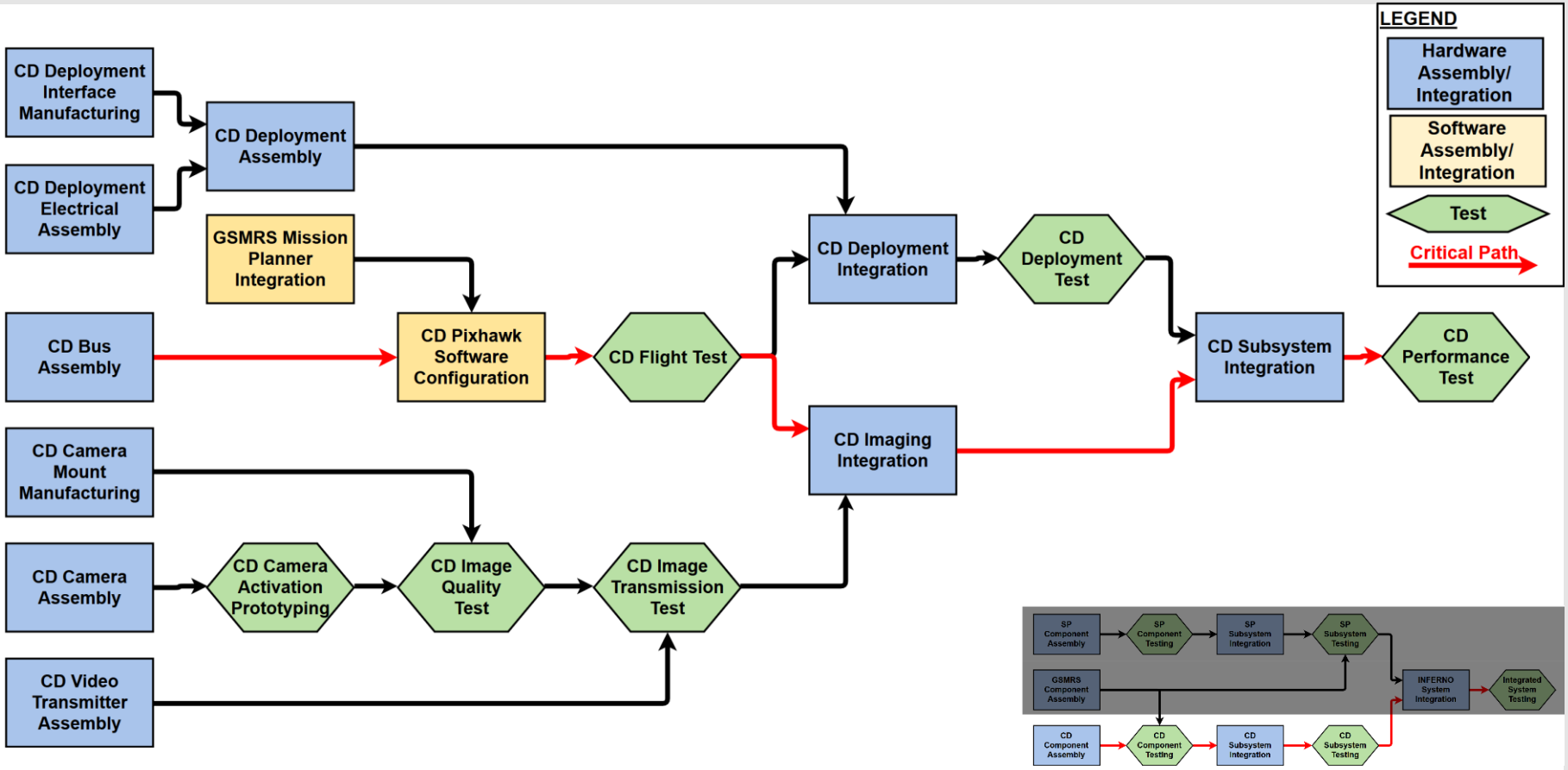


AI&T PLAN: SENSOR PACKAGE

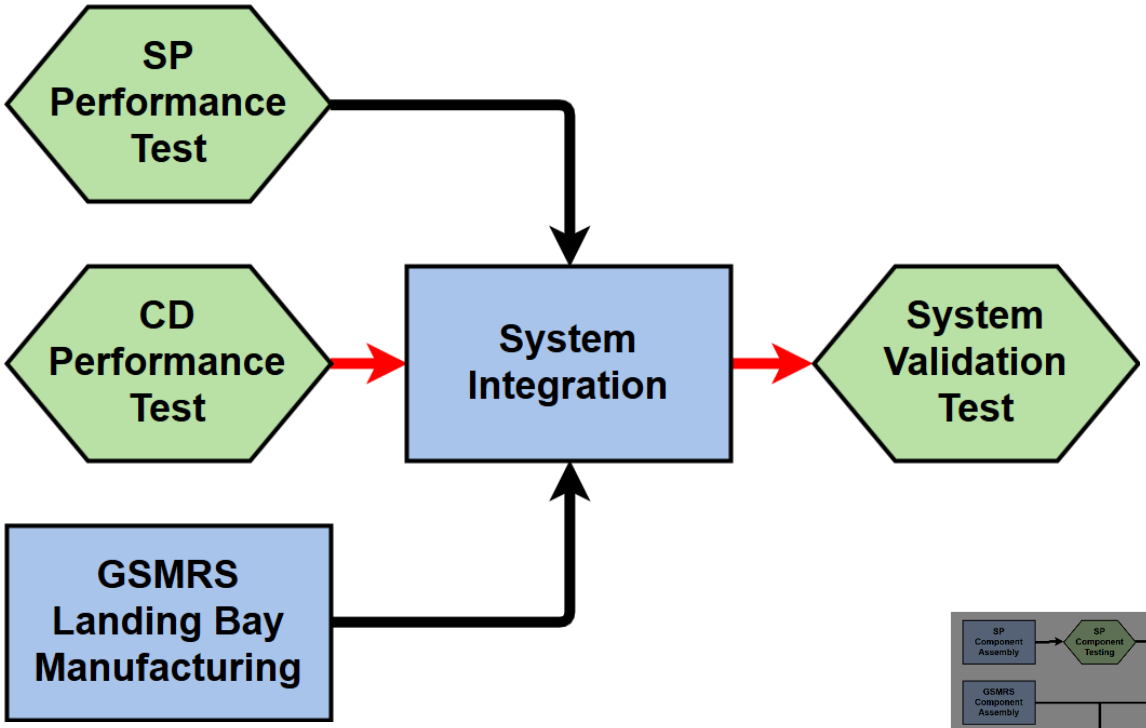


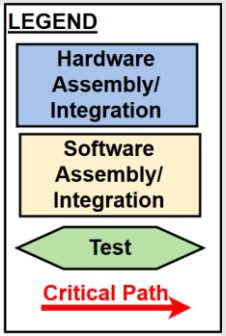


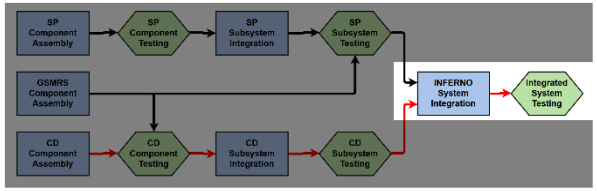
AI&T PLAN: CHILD DRONE



AI&T PLAN: SYSTEM







THE END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