Manufacturing Status Review

# RAVEN

## Rover and Air Visual Environment Navigation

**TEAM:** ROLF ANDRADA, RYAN BLAY, BRENDAN BOYD, CODY CHARLAND, RISHAB GANGOPADHYAY, TORFINN JOHNSRUD, NATHAN LEVIGNE, IAN LOEFGREN, NIKOLAS SETIAWAN, ALEXANDER SWINDELL, RYAN WALL

**CUSTOMER:** NISAR AHMED

**ADVISOR:** TORIN CLARK

# Agenda

# Project Purpose and Objectives



Mission Statement: RAVEN will develop a testbed that will collect image, position, and sensor data to be used by the customer for the verification of customer developed cooperative localization algorithms.

- Provide the customer with an **UAV and UGV** pair **testbed**
- Record **image, position, and sensor** data
- **Deliver** recorded information, including **collected GPS data,** and UAV/UGV pair to customer

# Specific Objectives



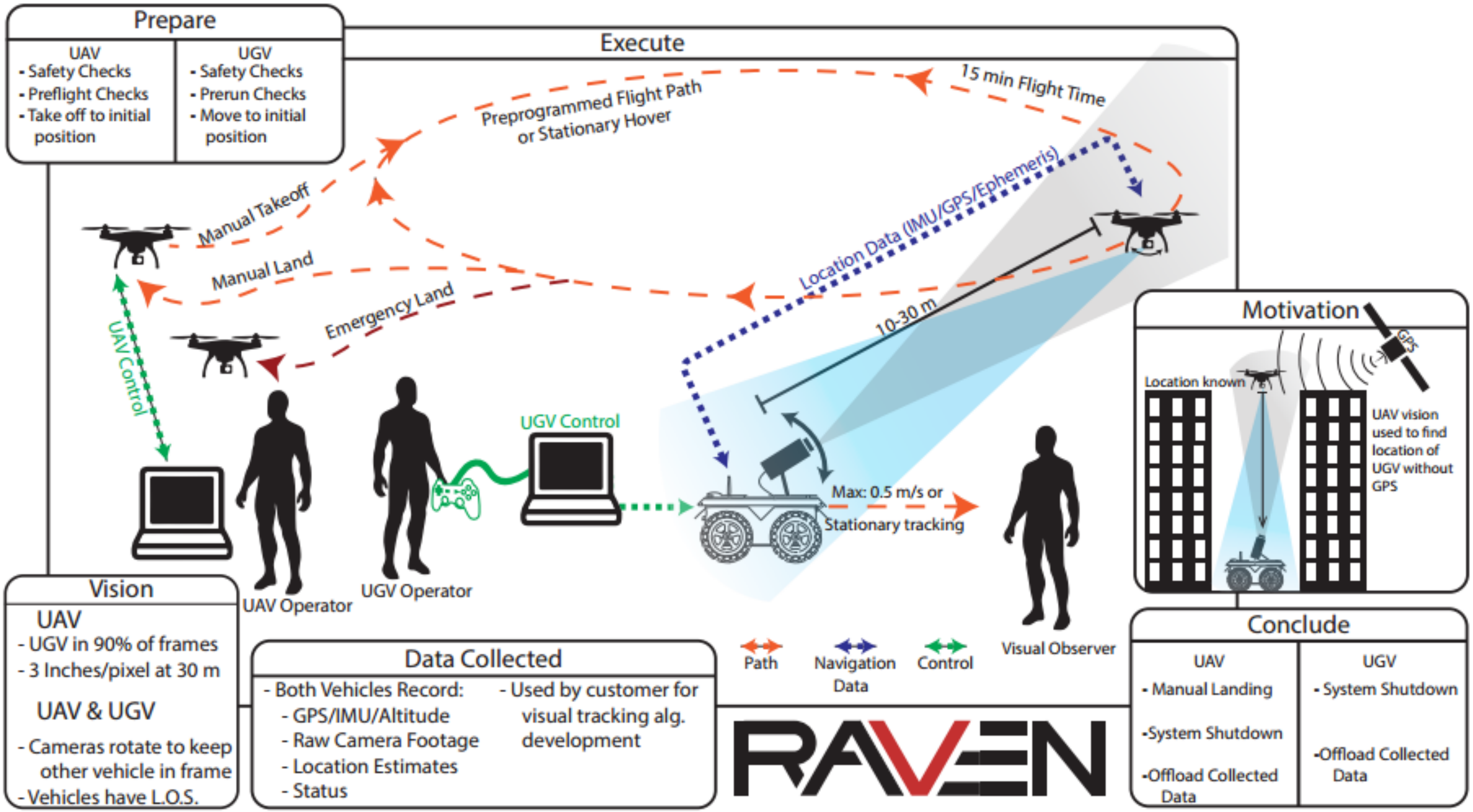
**Significant Level 3 Objectives:**

- **Vision: A moving UAV shall track the UGV at 10-30 m and be in 90 % of frames. A stationary UGV shall track the UAV at 10-30 m and be in 90 % of frames. Acquire target in less than 3 seconds.**
- **Captured Data: Store battery life estimate, package temperature, control input data, GPS/ephemeris data, IMU data, magnetometer data, and barometer data all in ROS bags w/ 20 GB storage margin.**
- **Controls: UAV will have emergency land switch. Control station displays map overlay of UAV/UGV positions as well as battery status, flight timer, and storage capacity.**
- **Comms: Vehicles shall share GPS data, visual tracking, and state data with the control stations.**
- **Electronics/Software: Vehicles shall have 15 min tracking endurance.**
- **Management: Project cost shall remain under budget.**

**<u>Currently on track to achieve Level 3 Objectives.</u>**

# Concept of Operations

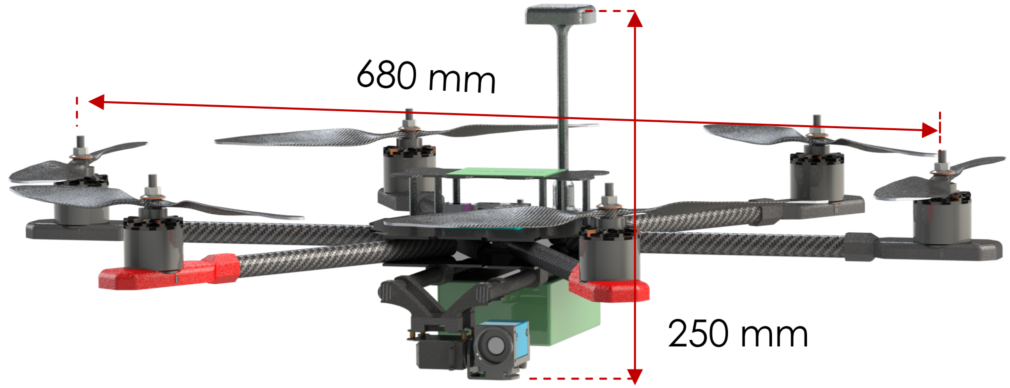




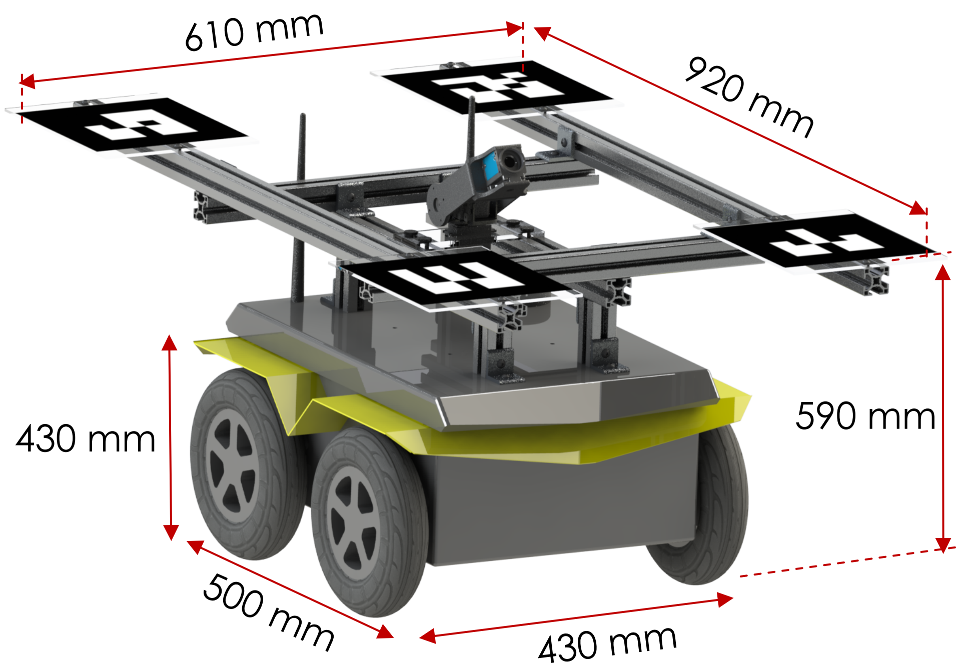
# Baseline Design



## UAV



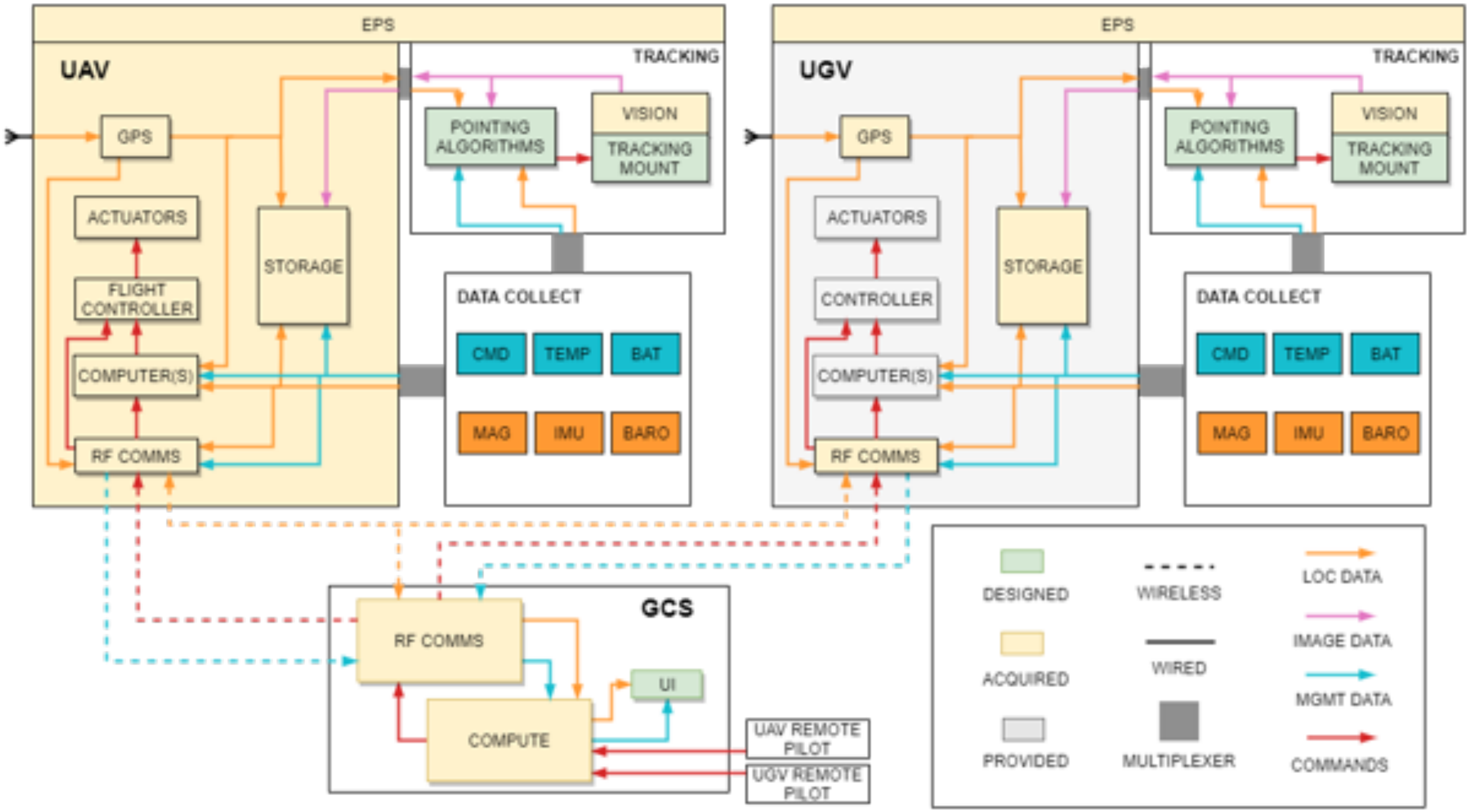

## UGV




## Ground Control Station

# Functional Block Diagram



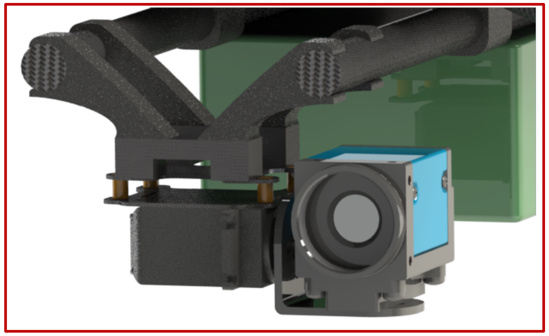


# Updates Since CDR



## UAV Gimbal:

- **Problem:**
  - **Requirement change** from customer post CDR
  - Unable to obtain true gimbal servo state
- **Solution:**
  - New **1D gimbal** using **feedback servo**
  - Addition of **Arduino Mini** for **servo control**

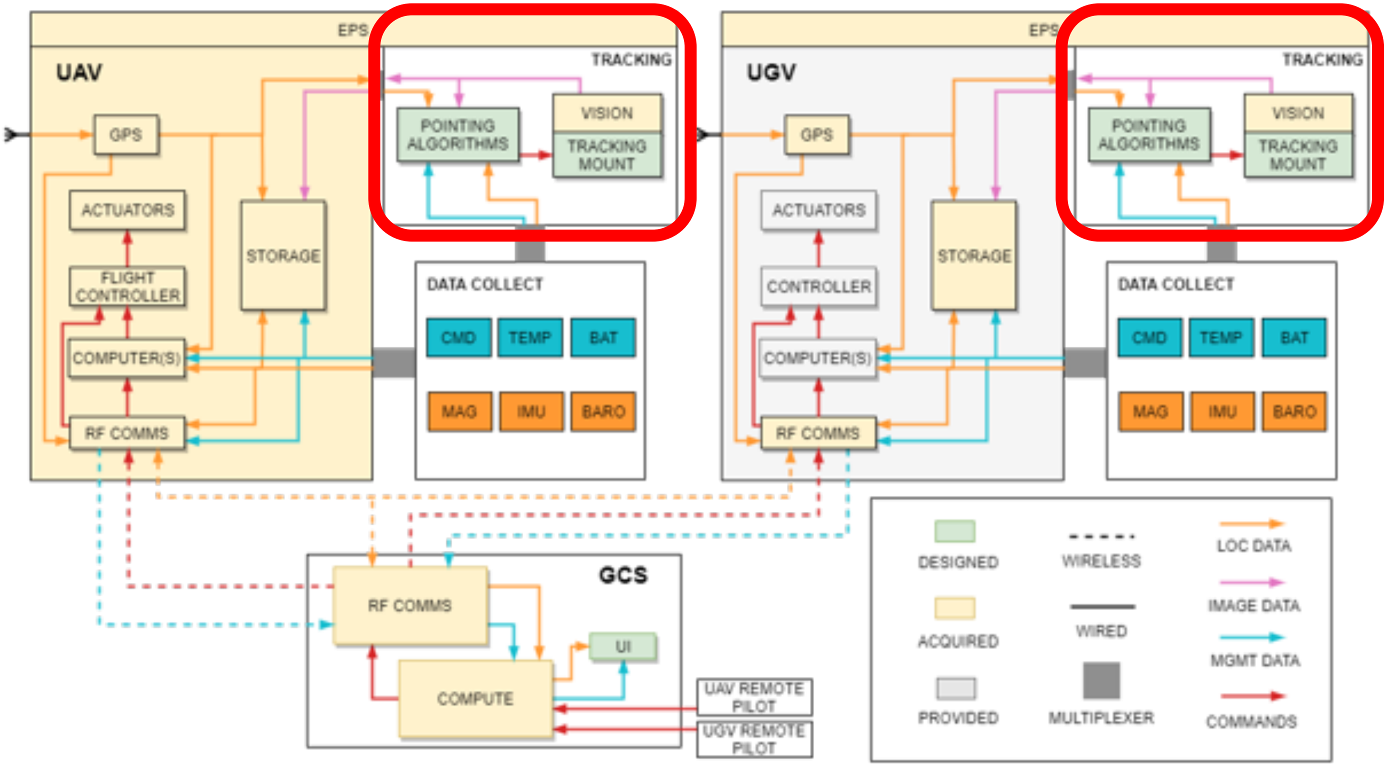


## UGV:

- Now using **acrylic** for **gimbal base plate**
- **Gimbal** and **AR plates** mounted on **8020**
- Manufacturing simplicity

# Critical Manufacturing Areas

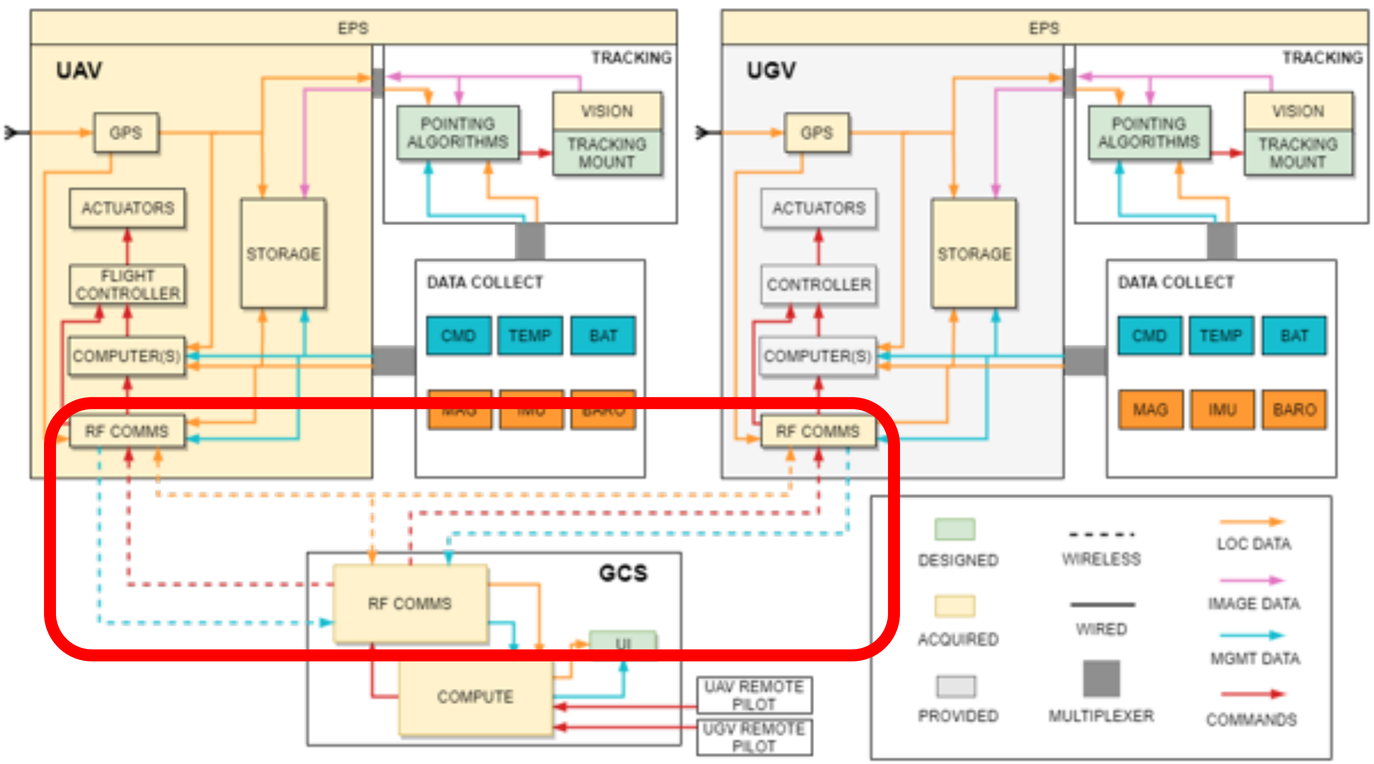





Tracking and Determination

# Critical Manufacturing Areas

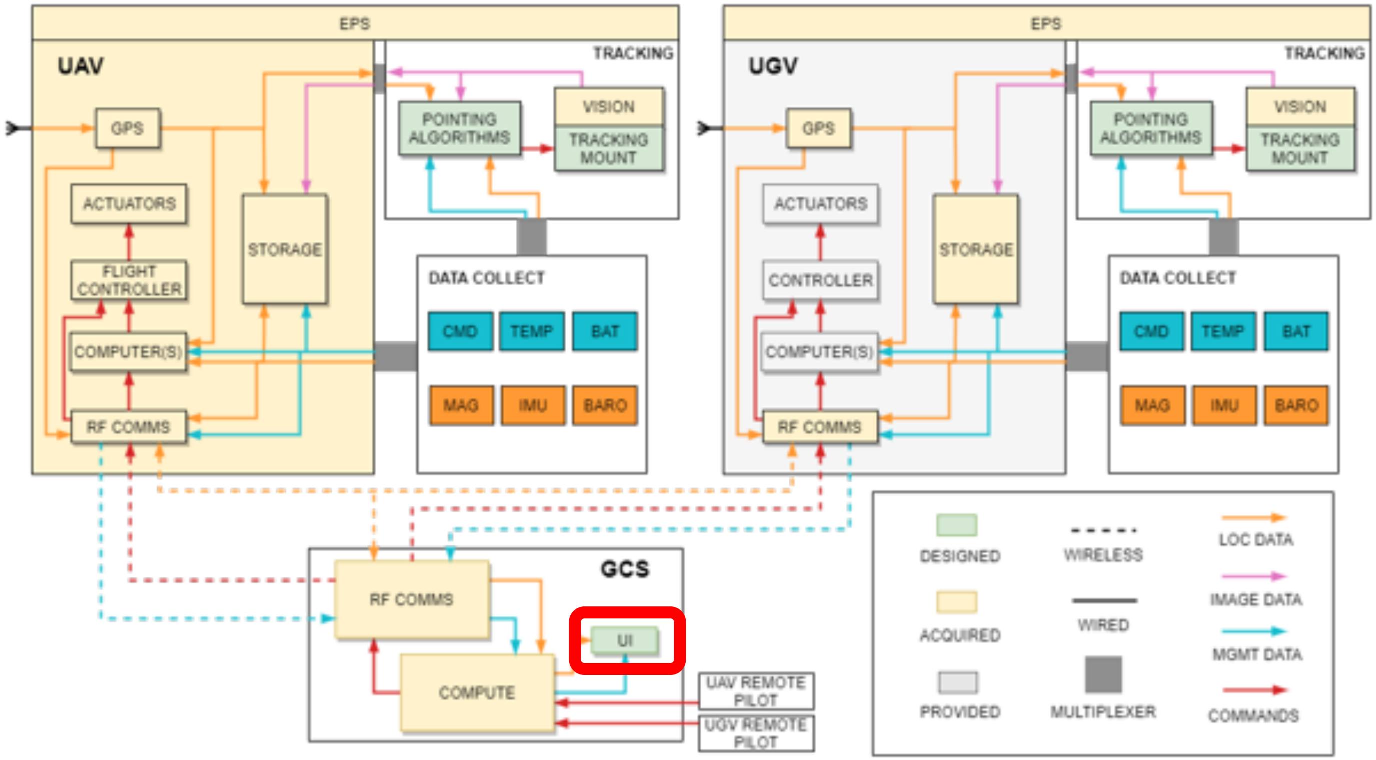





Communications and Watchdogs

# Critical Manufacturing Areas

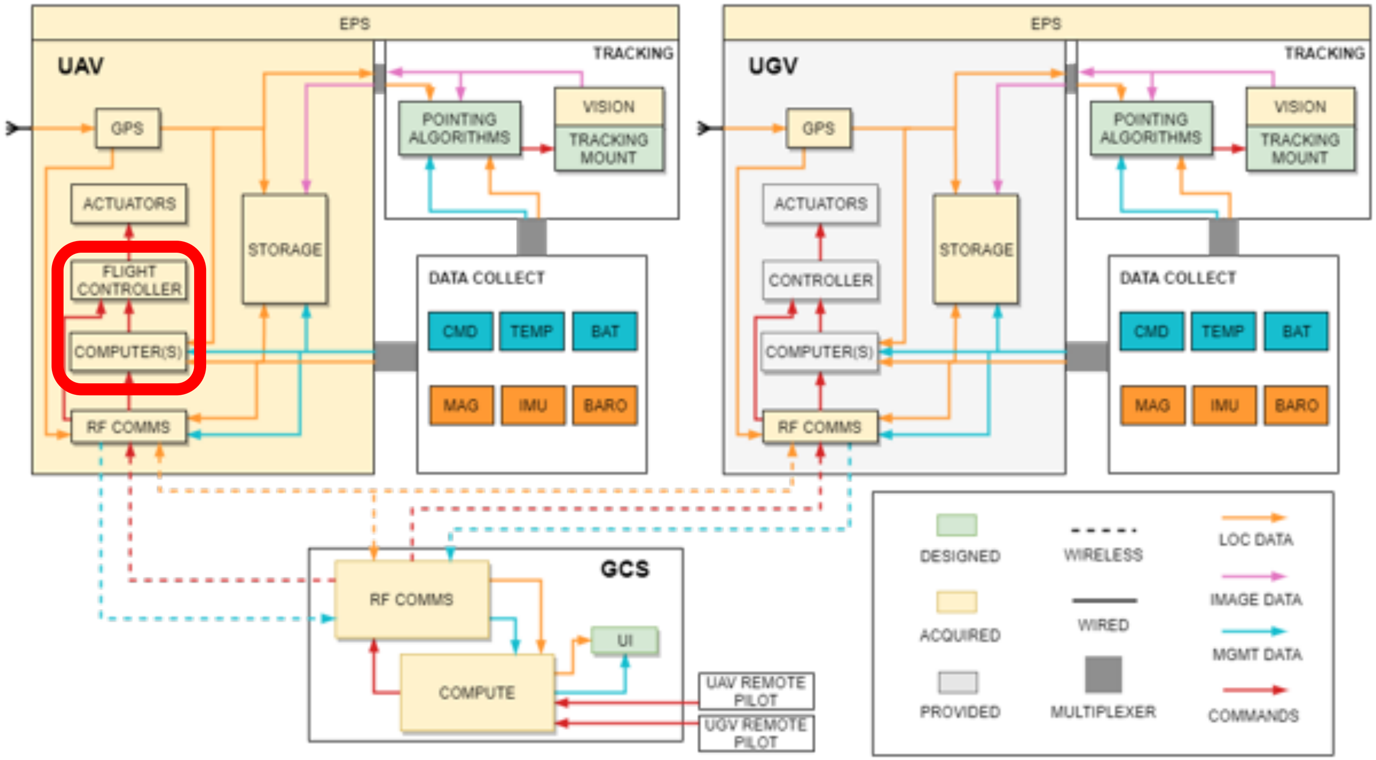





User Interface

# Critical Manufacturing Areas

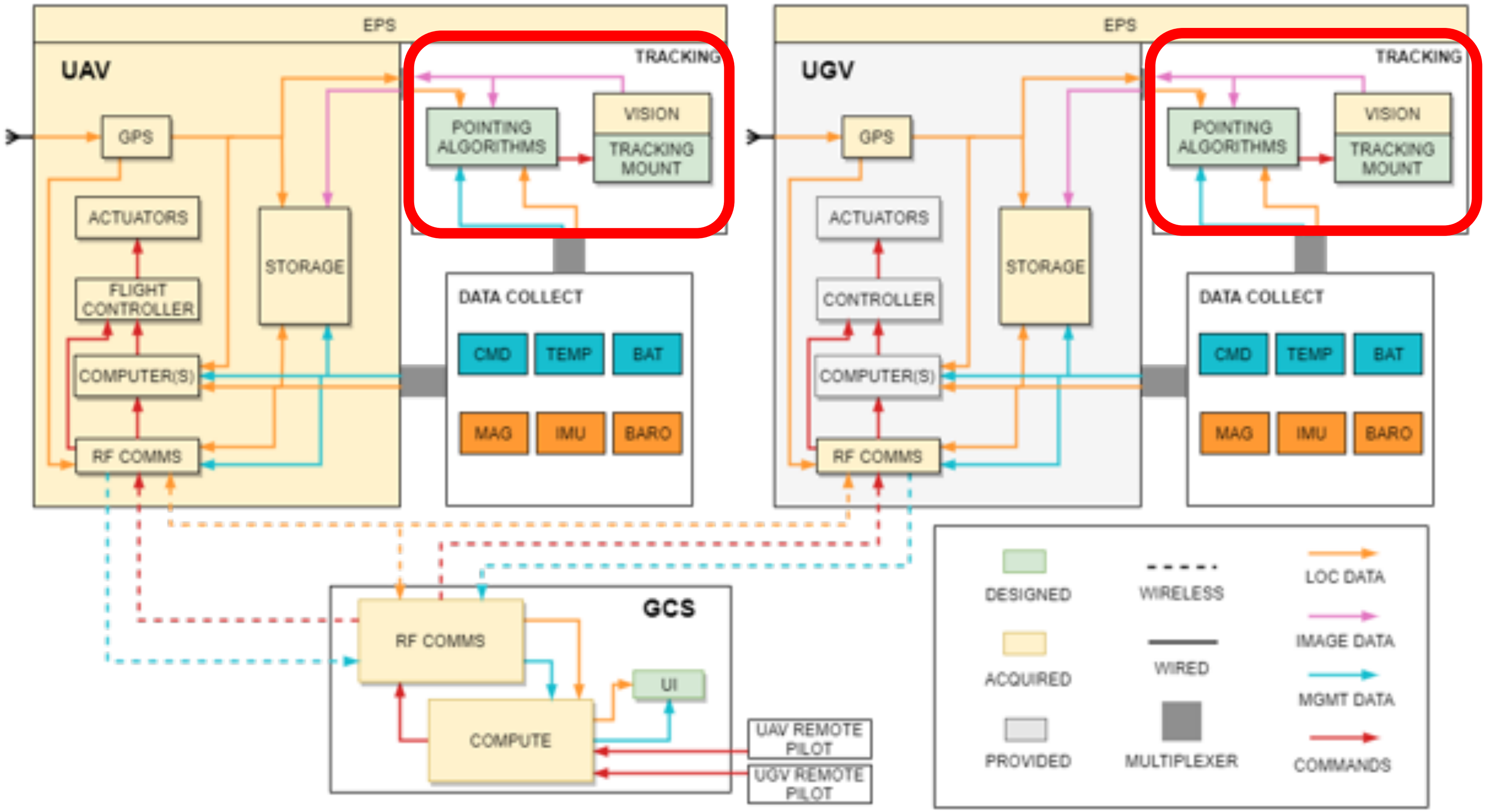




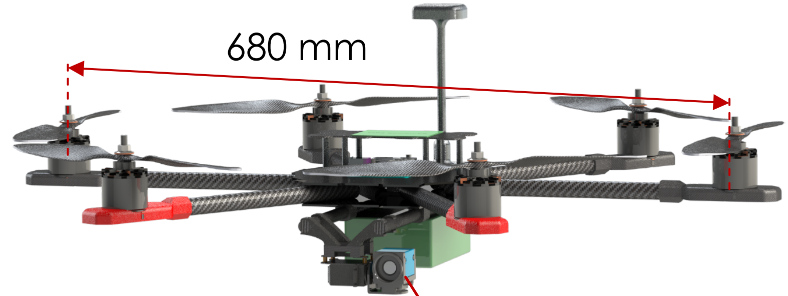

Interfacing Between Flight Controller and Flight Computer

# Tracking and Determination





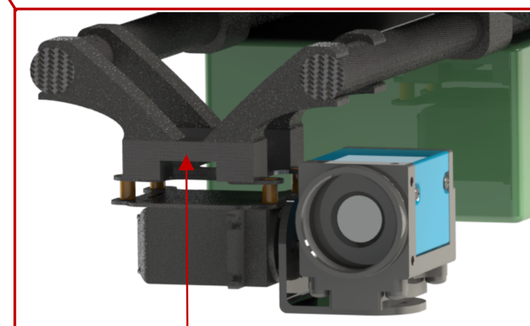
# UAV Tracking Hardware



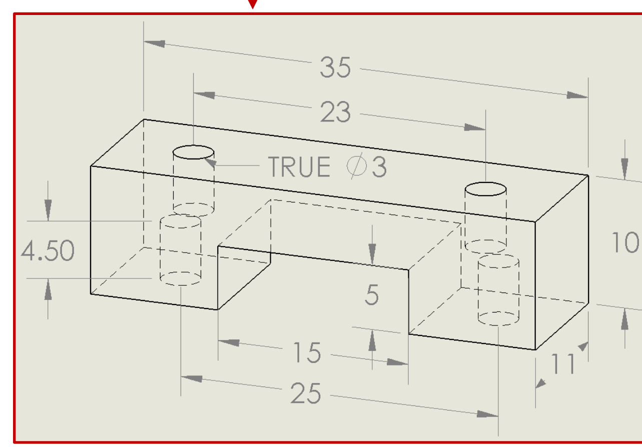

**Overview:**

- Majority of hardware purchased
- Only need to **manufacture gimbal hook adapter**
  - Hooks – 23 mm apart
  - Vibration dampener – 25 mm apart
- **Priority not a concern** due to ease of manufacturing

Tilt Gimbal



Hook Adapter (mm)




**Milestones:**

- Order hardware
- Assemble all electronics [4/10 hrs]
- Assemble tilt gimbal [0/1 hrs]
- 3D print hook adapter [0/2 hrs]
  - MarkForged carbon fiber printer

**Status:**

# UAV Build Status



**Overview:**

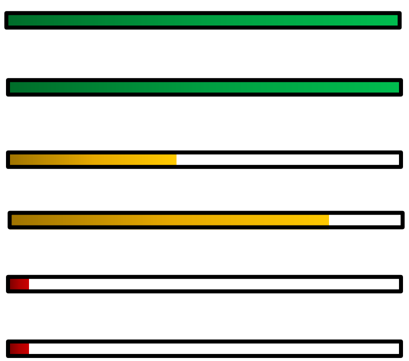
- Hardware received
- Major components assembled
- Flight test plan completed
- Indoor flight space secured

| | Projected | Updated |
|---|---|---|
| UAV Total Mass | 2.9 [kg] | 3.09 [kg] |
| UAV Motor Skew | 0 [deg] | 0.2 [deg] |
| UAV Endurance Estimate | 23.4 [min] | 21.7 [min] |

**Milestones:**

- Order hardware
- Assemble UAV frame [10/10 hrs]
- Assemble all electronics [4/10 hrs]
- Manufacture Proxy masses [8/10 hrs]
- Static Motor Test [0/5 hrs]
- First Flight [0/20 hrs]

**Status:**



**Unit Testing:**

- Manual Flight
- Automatic Indoor Flight
- Outdoor Flight

# UGV Tracking Hardware



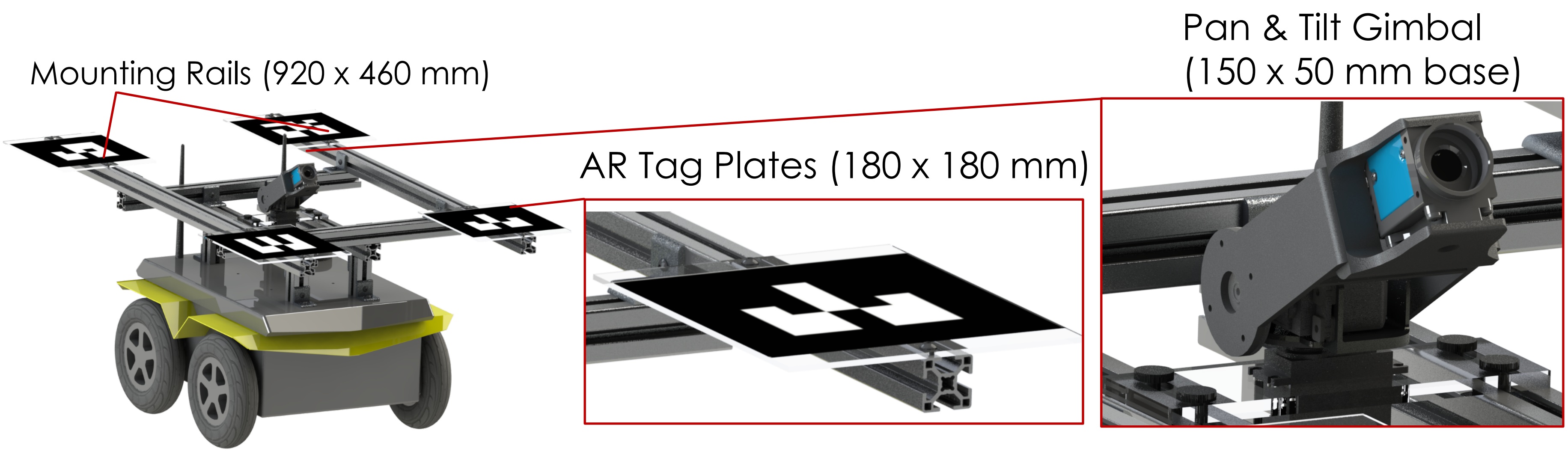
**Overview:**

- Majority of hardware purchased/provided
- Need **gimbal for acquisition** and **AR tags for verification**
- **Priority not a concern** due to **prototype from CDR**

**Milestones:**

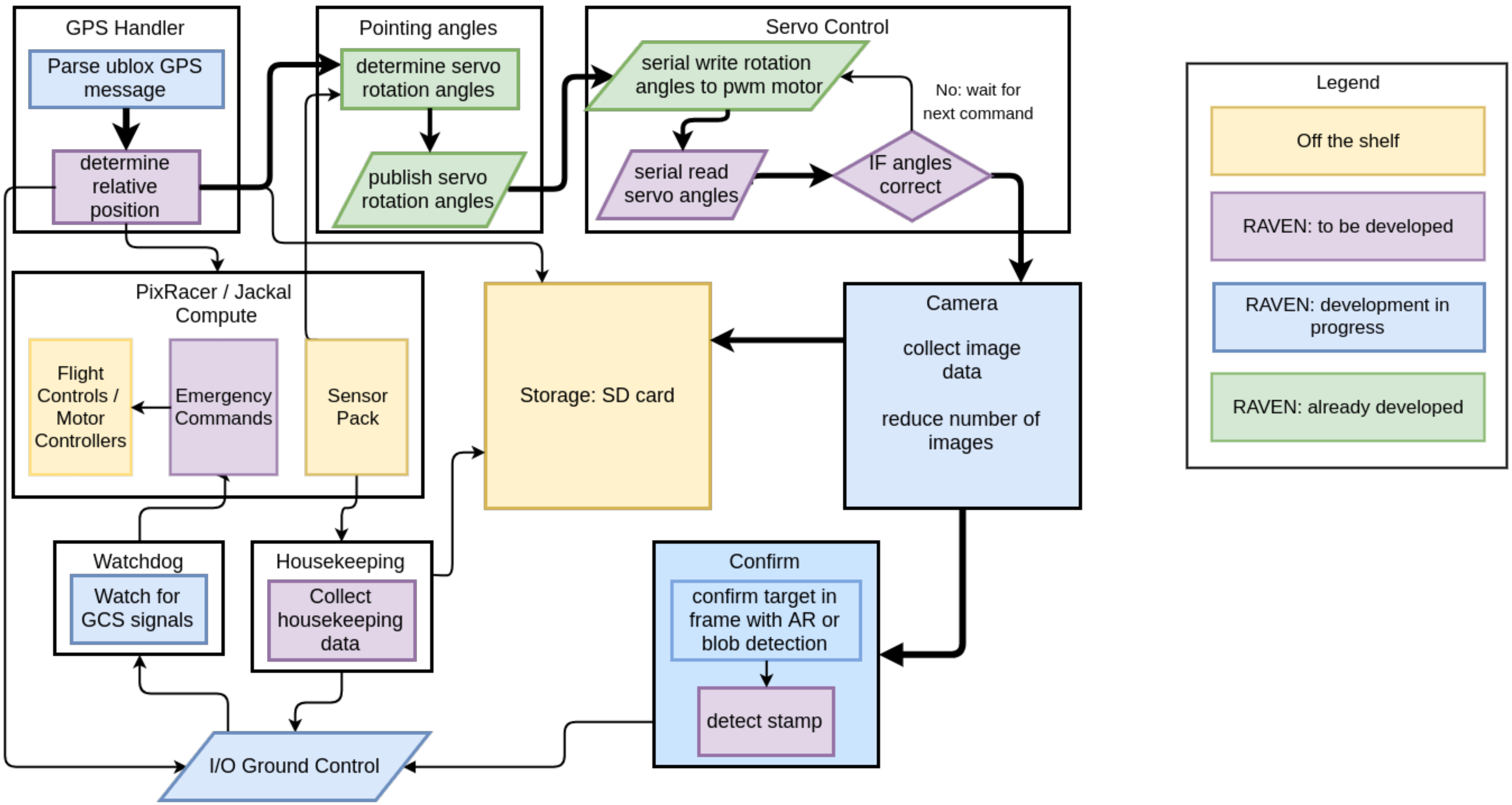
- Order hardware
- Assemble mounting rails [2/2 hrs]
- Cut AR tag plates and gimbal base [1/2 hrs]
  - Laser cutter
- Assemble pan & tilt gimbal [0/2 hrs)
- 3D print tilt arm [0/6 hrs]
  - Lulzbot PLA 3D printer

**Status:**



# Tracking and Determination Software Flowchart



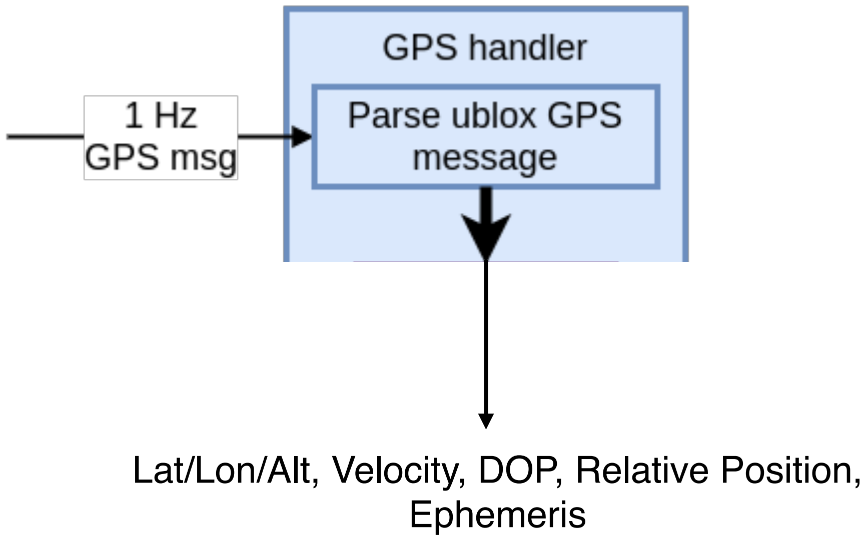


# GPS Parser



**Overview:**

- Parse GPS uBlox and NMEA messages to usable data for the Pixracer and determination software




**Inputs:**

- uBlox/NMEA messages from GPS receivers [1 Hz]

**Outputs:**

- Parsed lat/lon/alt, DOP, ephemeris, UTC time, relative NED UAV position, velocity in NED frame [1 Hz]

**Unit Testing:**

- Parse GPS data
- RTK accuracy analysis

**Milestones:**

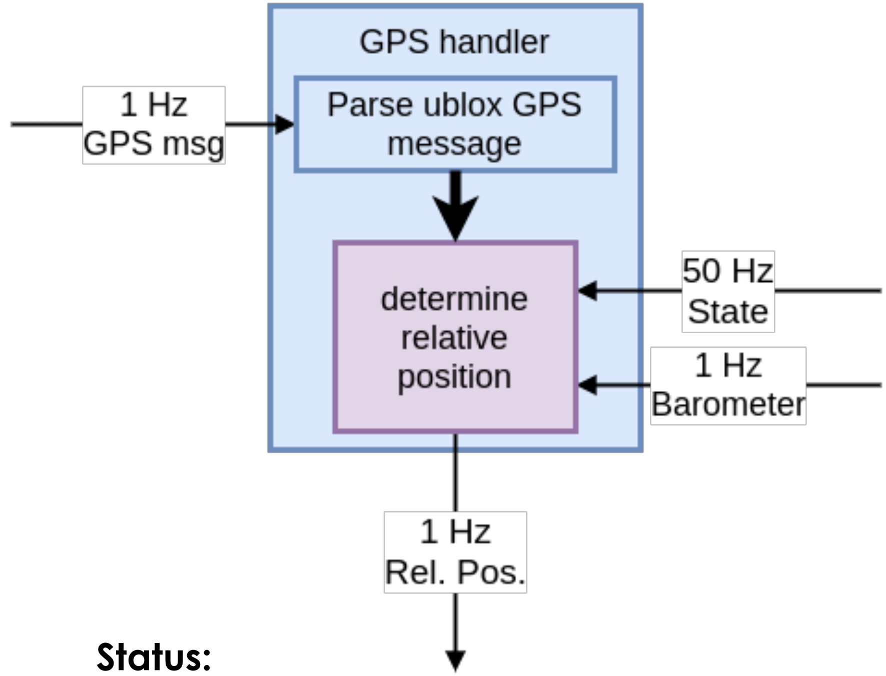
- MATLAB Parsing/Plotting Tools [5/5 hrs]
- Port to C++ Code [5/15 hrs]

**Status:**

# Determination Software



**Overview:** Determine relative position of each vehicle




**Inputs:** GPS Messages from uBlox [1 Hz], Vehicle State [50 Hz], Barometer Data [1 Hz]

**Outputs:** Relative Position [1 Hz]

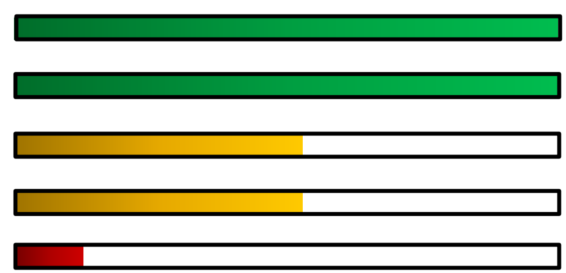
**Unit Testing:**

- Read in state data from Gazebo simulations

**Milestones:**

- Read state data from PixHawk [2/2 hrs]
- Read state data from Jackal [3/3 hrs]
- Parse GPS messages [10/20 hrs]
- Calculate Relative Position [2/5 hrs]
- Characterization of Peripheral Sensors [0/5 hrs]

**Status:**

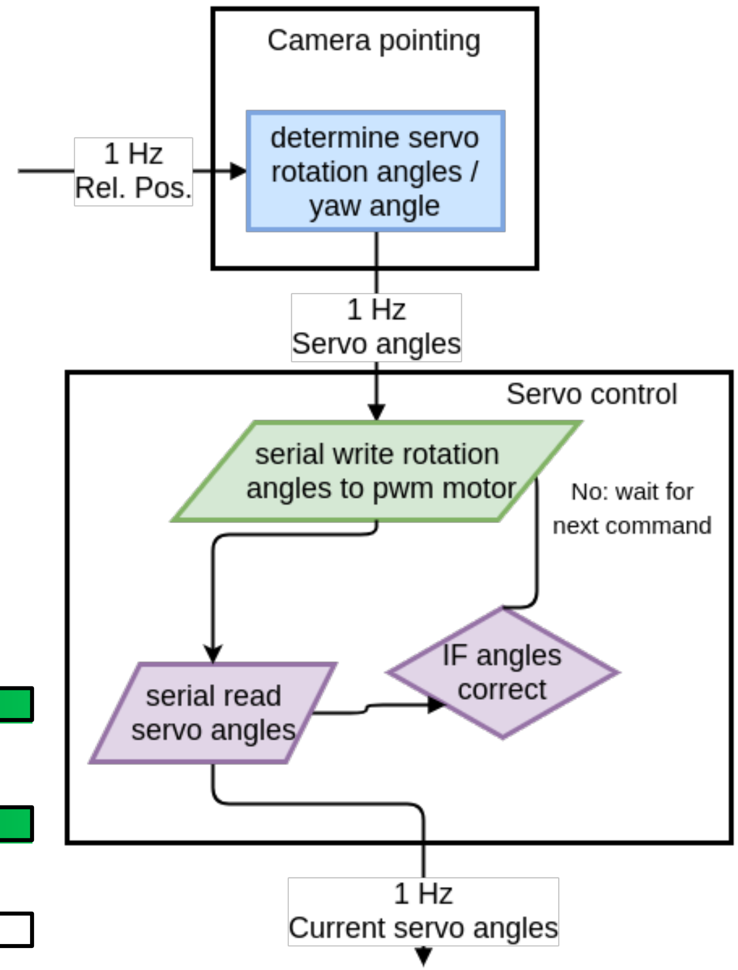


# Acquisition Software



**Overview:**

- Software that commands the servos to the requested angle
- The software runs on each vehicles microcontroller
- Integrates servo feedback to confirm that requested angle has been achieved




**Milestones:** **Status:**

- Control servos via PWM pins on microcontroller [2/2 hrs]
- Establish serial communication between computer and microcontroller [5/5 hrs]
- Integrate servo feedback [5/10 hrs]

# Camera Software Configuration



**Overview:**

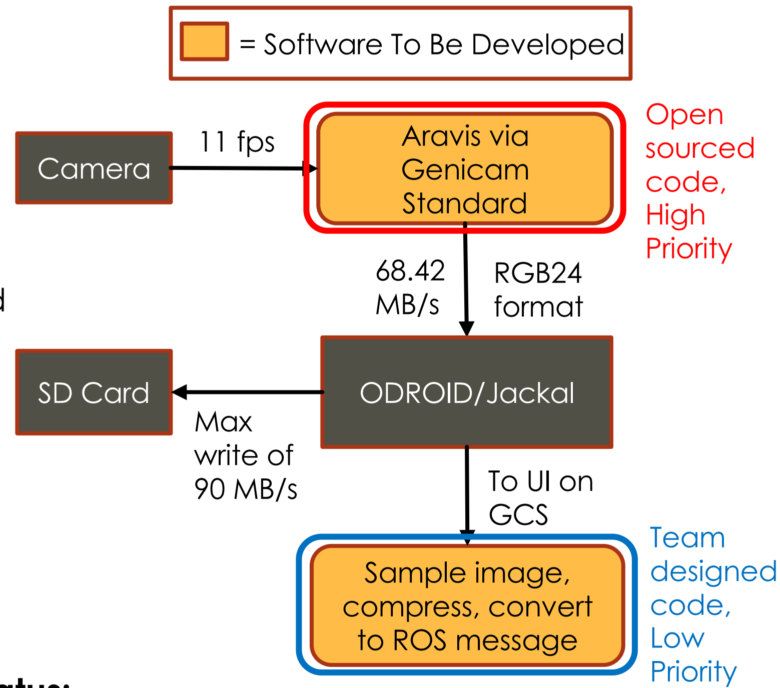
- Camera must interface with ODROID/Jackal
  - RGB24 color format
  - Aravis software package and Genicam standard used
- Images must be sampled, compressed, and converted to ROS message for UI

**Unit Testing:**

- Camera interface is tested via PC and ODROID
- UI sampling program tested via ODROID

**Milestones:**

- Integrate camera with PC and Linux [15/15 hrs]
- Write image data to file [4/10 hrs]
- Integrate camera with ODROID/Jackal [0/20 hrs]

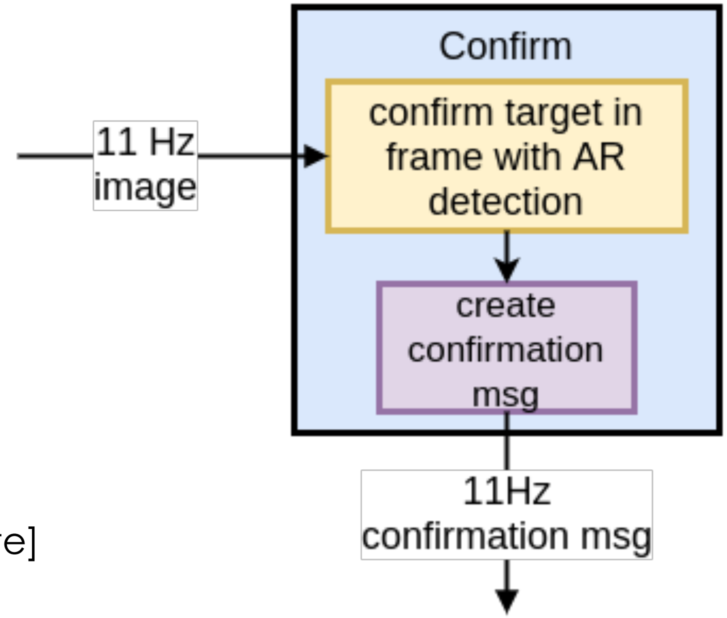



**Status:**

# UAV Image Confirmation Software



**Overview:** Confirm that the UGV is in frame of the UAVs camera by using AR tag detection ROS package: *AR_track_alvar*




**Inputs:** Camera image stream [11 Hz]

**Outputs:** Confirmation message [11 Hz] with image number stamp, Timestamp, Pos/Neg Confirmation

**Unit Testing:**

- Static Test of AR Tag Detection [Complete]
- Moving Test of AR Tag Detection

**Milestones:**

- Create tag bundle definition files [2/2 hrs]
- Create launch file to map inputs [2/2 hrs]
- Publishing of formatted topic [1/5 hrs]

**Status:**

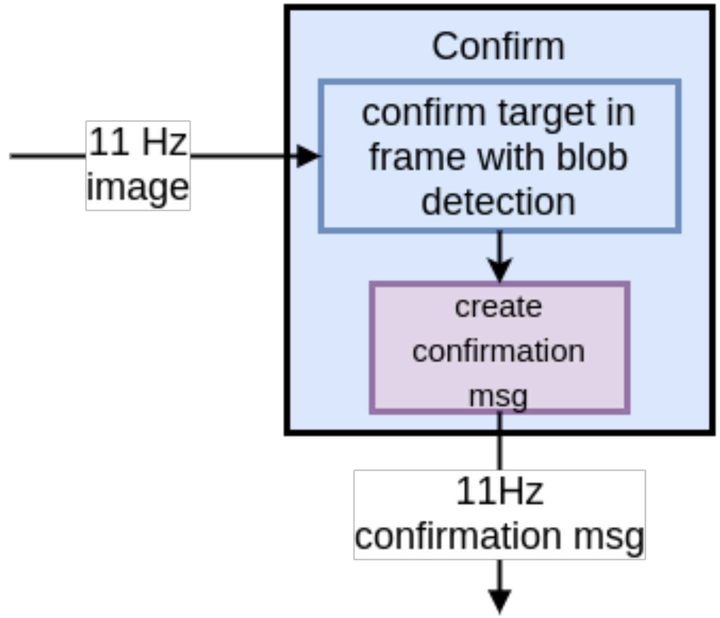
# UGV Image Confirmation Software



**Overview:** Confirm that the UAV is in frame of the UGV's camera by using OpenCV blob detection

**Inputs:** Camera Image Stream [11 Hz]

**Outputs:** Confirmation Message [11 Hz] with image number stamp, Timestamp, Pos/Neg Confirmation




**Unit Testing:**

- Static test of blob detection
- Moving test of Blob detection

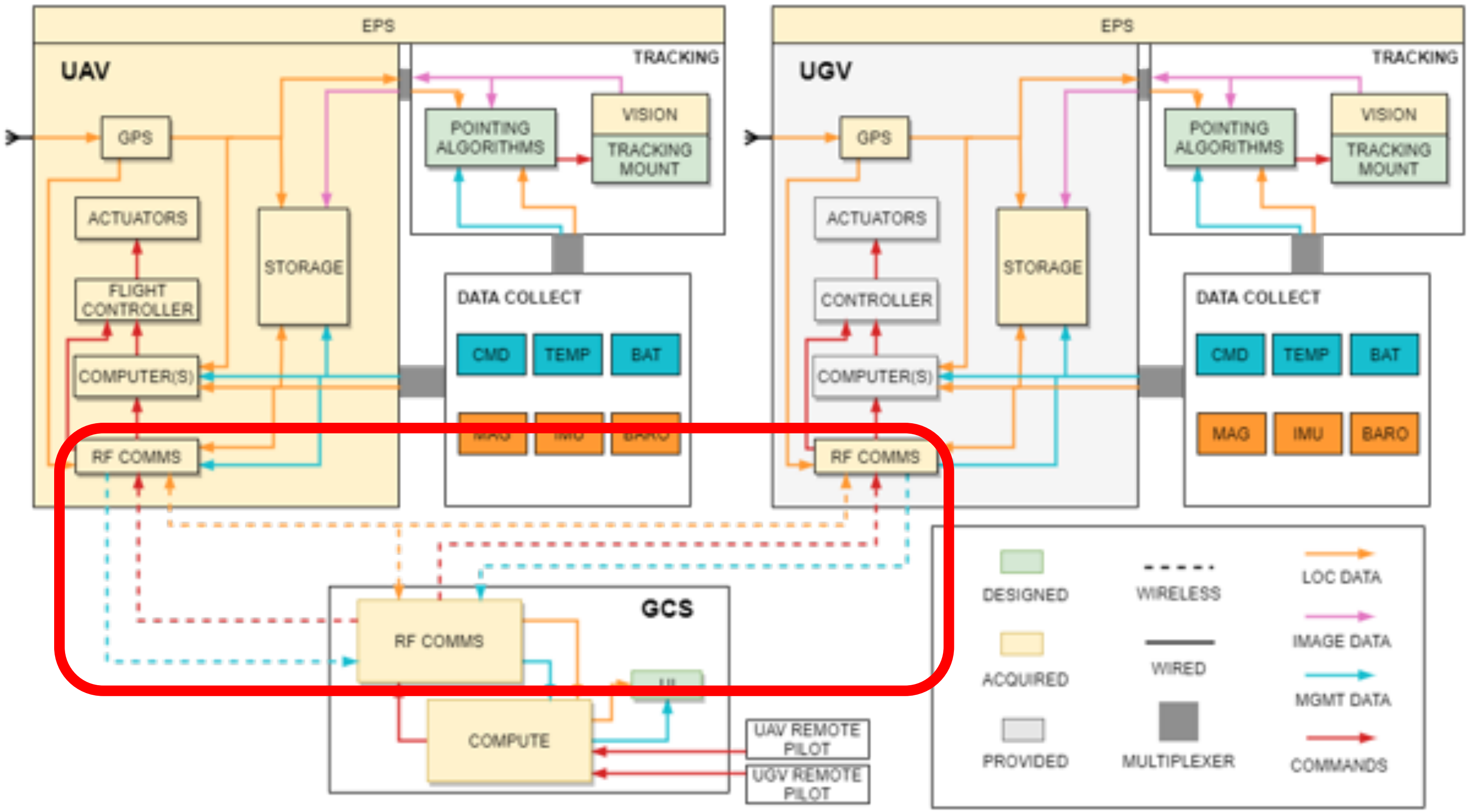
**Milestones:**

- Prototype Functionality in Python [2/2 hrs]
- Unit Test in Gazebo Simulation [2/2 hrs]
- Port to C++ for Speed [1/3 hrs]
- Parameter Tuning [0/5 hrs]

**Status:**

# Communications and Watchdogs

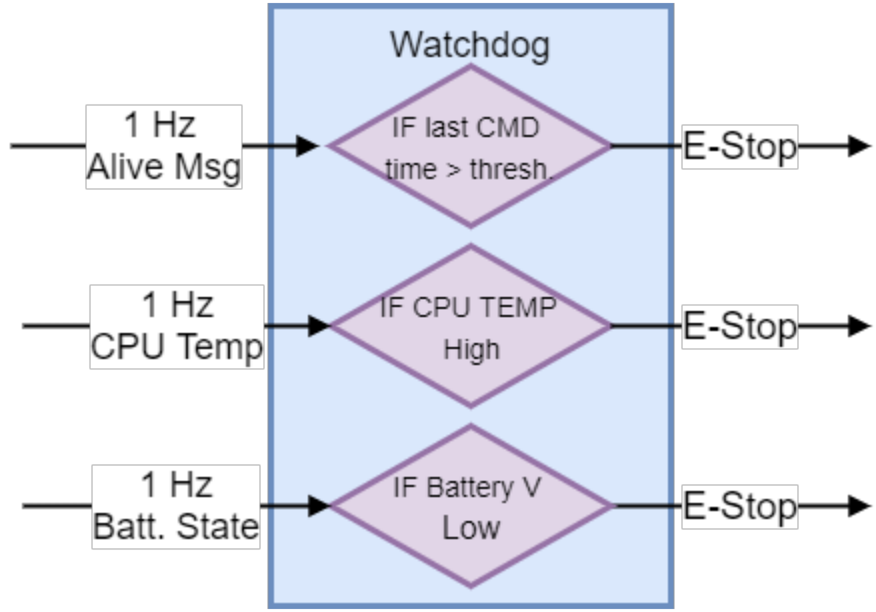




# Watchdogs



**Overview:** Routinely checking set of variables to ensure safe and effective operations




**Inputs:** Time of Last Command [1 Hz], CPU Temperatures [1 Hz], UAV/UGV Battery State [1 Hz]

**Outputs:** Emergency Stop [1 Hz]

**Unit Testing:**

- Envelope testing

**Milestones:**

- Determine CPU Temperatures [1/5 hrs]
- Determine Battery State [1/5 hrs]
- Write UAV Watchdog [0/5 hrs]
- Write UGV Watchdog [0/5 hrs]

**Status:**

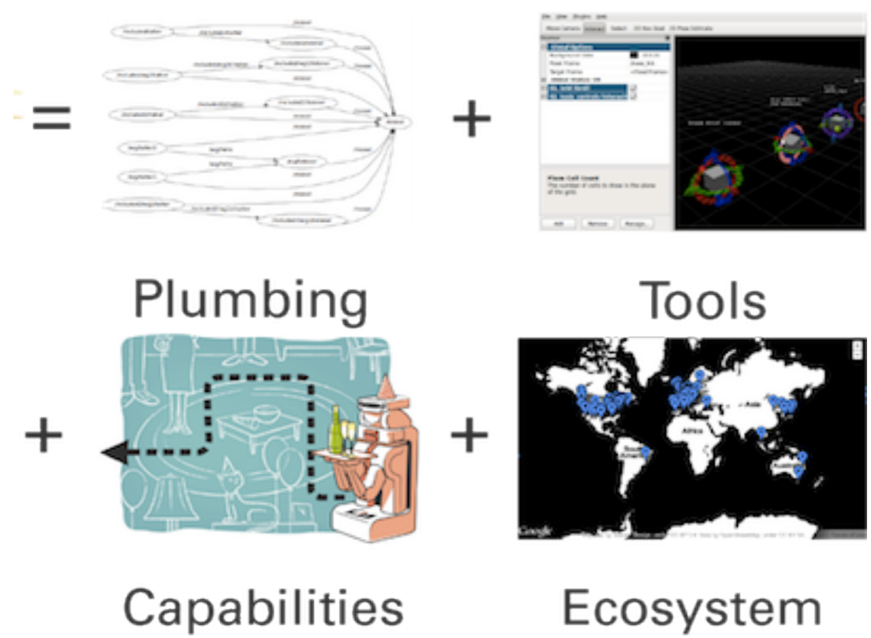
# Process Integration



**Overview:** Integrating of software in order to share data and information between code

**Solution:**

- Integration will be handled by ROS
- ROS serves as middleware
- **Off-the-shelf** tools for communication of data between processes on the same network
- Allows for unit testing of code




**Testing:**

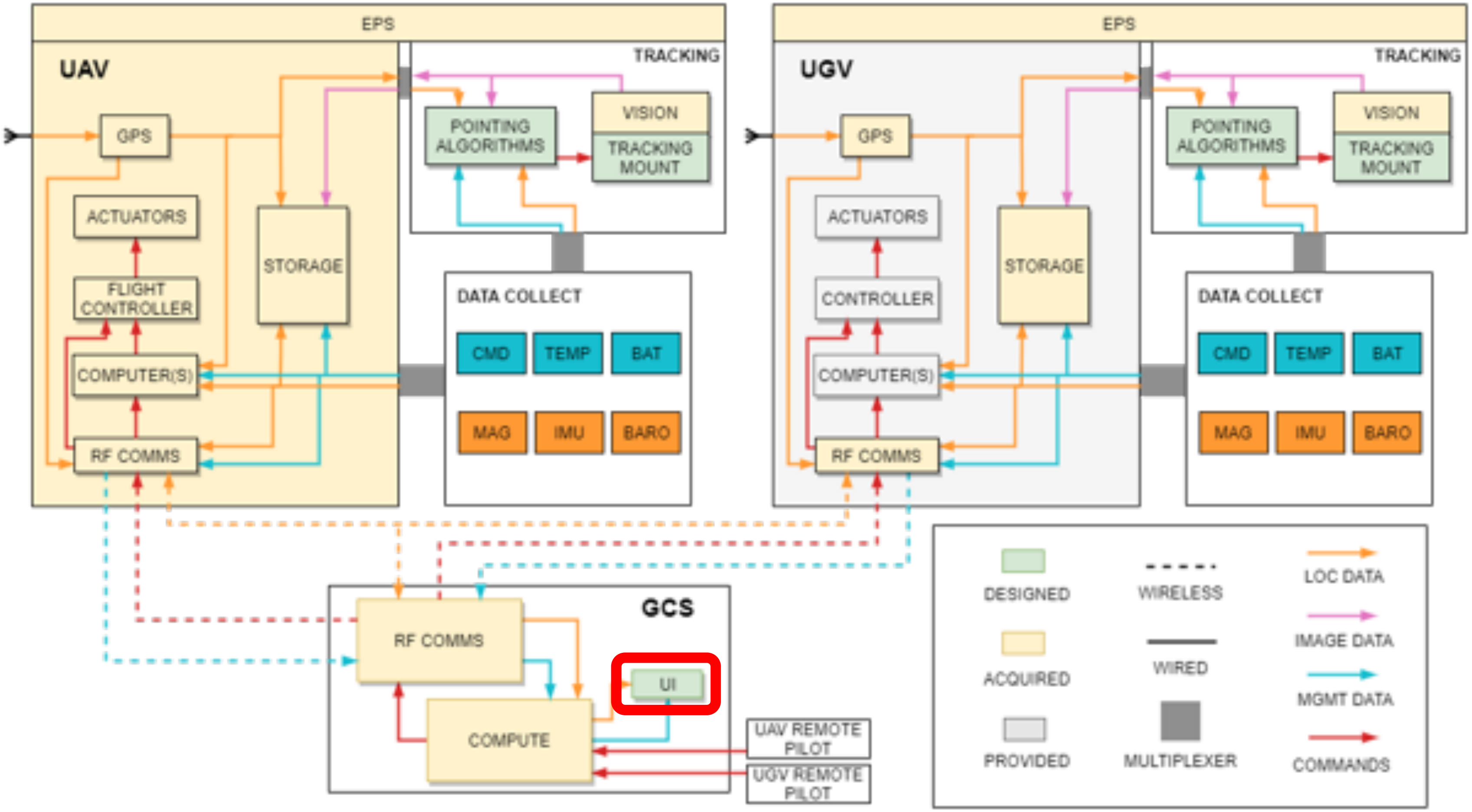
- Publishing input messages to environment
- View output topics using Linux Terminal
- Testing of Integration using Gazebo

**Milestones:**

- ROS Installation on ODROID [1/1 hrs]
- ROS Setup on Jackal [1/1 hrs]
- Nodes Communicating Data [15/15 hrs]
- Write UAV and UGV Launch Files [0/10 hrs]

**Status:**

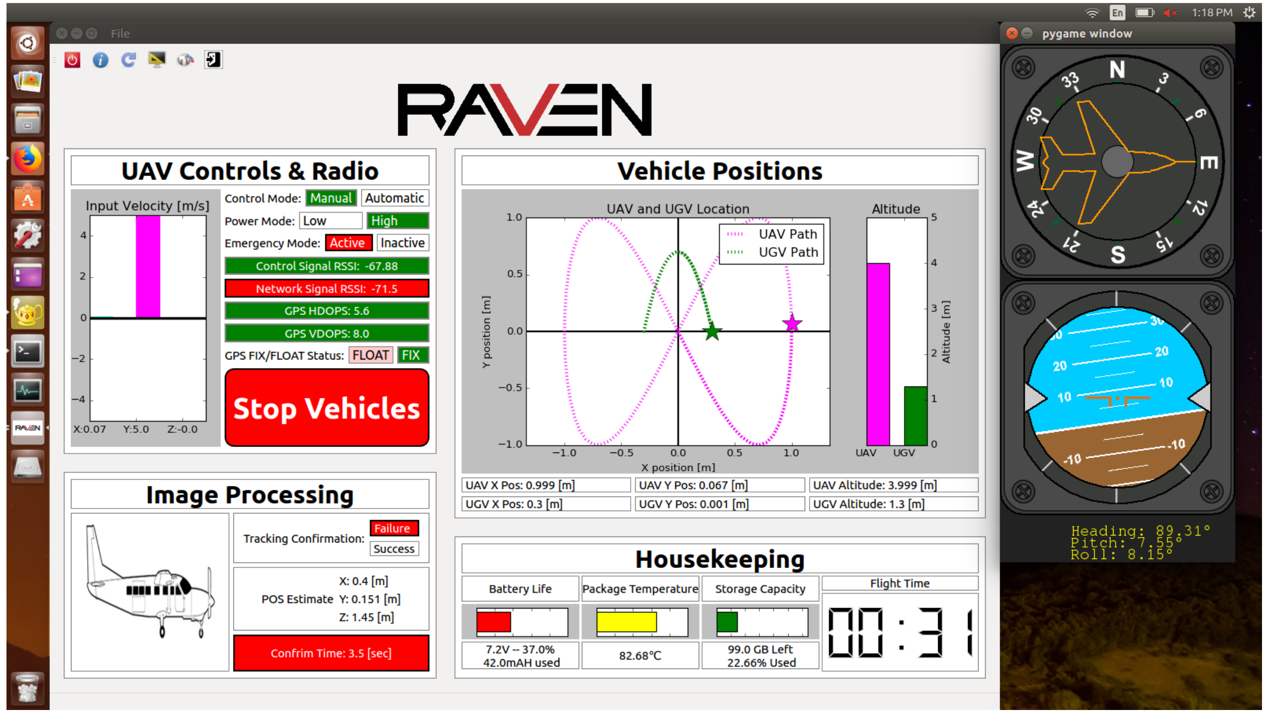
# User Interface



# User Interface Software



- **Overview:** Displays position, housekeeping, attitude, controls and imaging data to user
- **Inputs:** Preview Image [2 Hz], Vehicle Status [4 Hz], DGPS Position [1 Hz]
- **Outputs:** GUI, Emergency Signal, Test Initialization
- **Testing:**
  - Read in and update UI from dummy processes [Done]
  - Test all modules [Done]
  - Vehicle testing

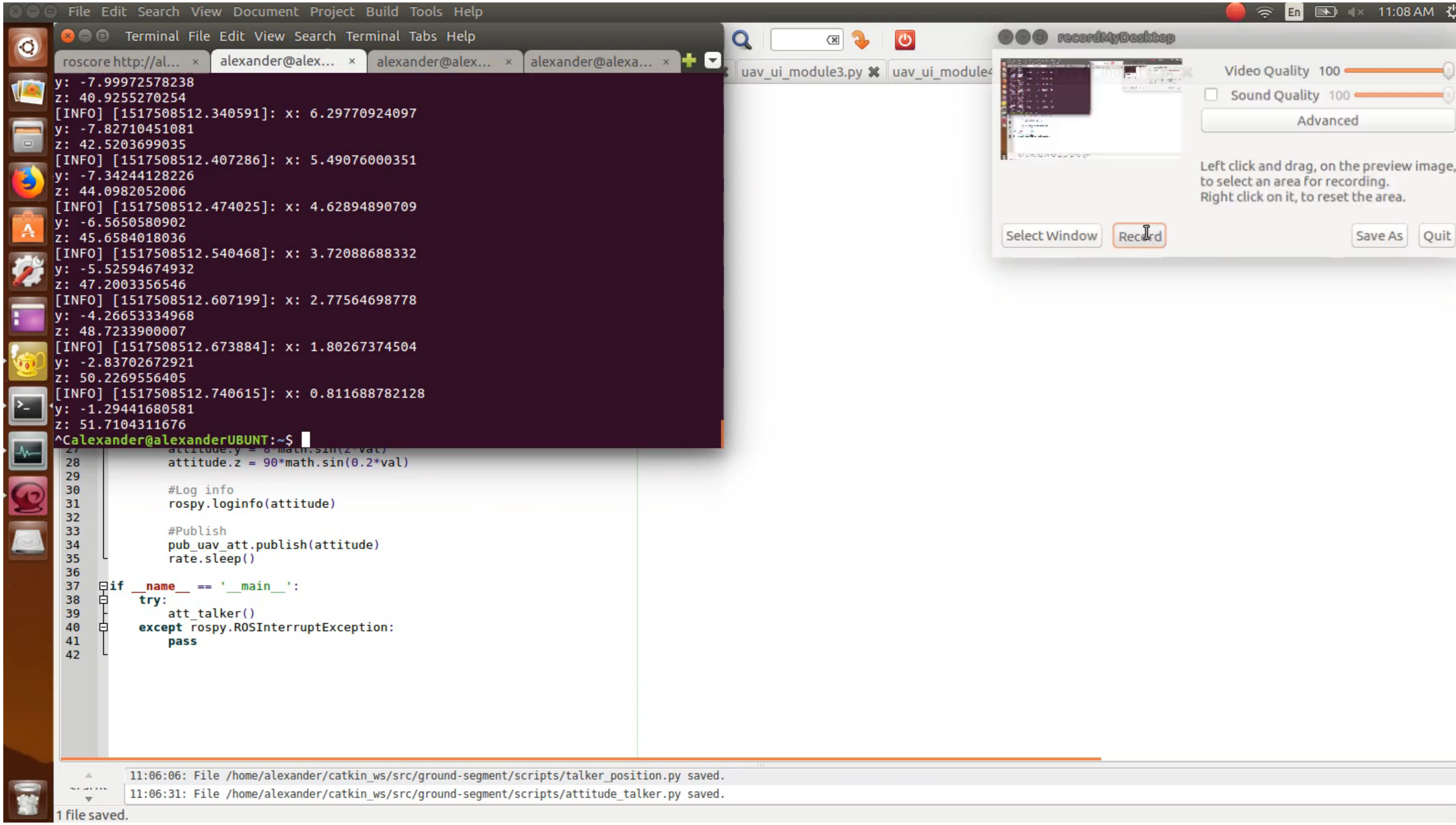



- **Milestones:**
  - Complete display modules [80/80 hrs]
  - Integrate data subscriptions [20/20 hrs]
  - Vehicle integration [5/25 hrs]
  - Data recording [0/10 hrs]

**Status:**

# UI Video




File Edit Search View Document Project Build Tools Help
11:08 AM
Terminal File Edit View Search Terminal Tabs Help
roscore http://al...
alexander@alex...
alexander@alex...
alexander@alexa...
y: -7.99972578238
z: 40.9255270254
[INFO] [1517508512.340591]: x: 6.29770924097
y: -7.82710451081
z: 42.5203699035
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y: -7.34244128226
z: 44.0982052006
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y: -6.5650580902
z: 45.6584018036
[INFO] [1517508512.540468]: x: 3.72088688332
y: -5.52594674932
z: 47.2003356546
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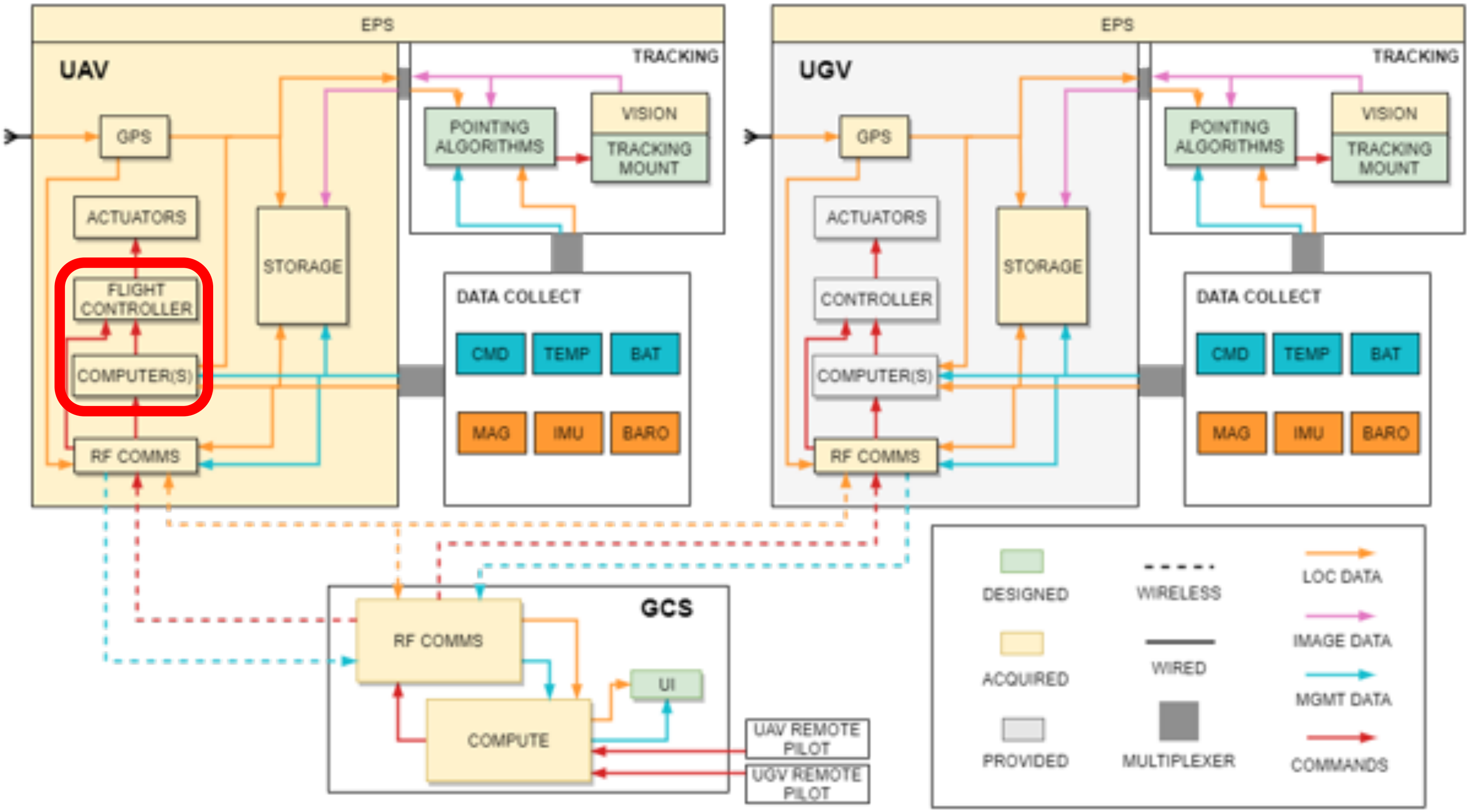
y: -4.26653334968
z: 48.7233900007
[INFO] [1517508512.673884]: x: 1.80267374504
y: -2.83702672921
z: 50.2269556405
[INFO] [1517508512.740615]: x: 0.811688782128
y: -1.29441680581
z: 51.7104311676
^Calexander@alexanderUBUNT:~$
uav_ui_module3.py
uav_ui_module4
recordMyDesktop
Video Quality 100
Sound Quality 100
Advanced
Left click and drag, on the preview image, to select an area for recording.
Right click on it, to reset the area.
Select Window
Record
Save As
Quit
attitude.z = 90*math.sin(0.2*val)
#Log info
rospy.loginfo(attitude)
#Publish
pub_uav_att.publish(attitude)
rate.sleep()
if __name__ == '__main__':
try:
att_talker()
except rospy.ROSInterruptException:
pass
11:06:06: File /home/alexander/catkin_ws/src/ground-segment/scripts/talker_position.py saved.
11:06:31: File /home/alexander/catkin_ws/src/ground-segment/scripts/attitude_talker.py saved.
1 file saved.

# Controller and Computer Interface



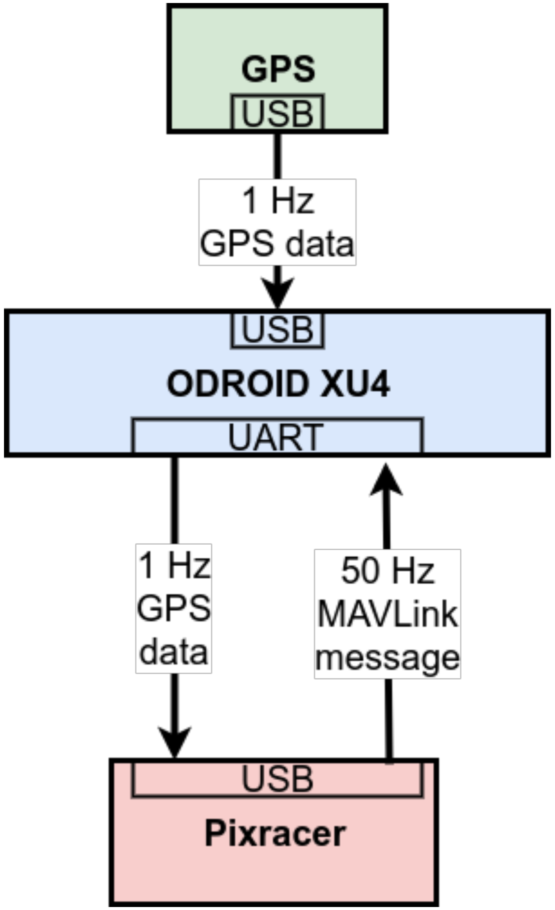


# ODROID/Pixracer/GPS Integration



**Overview:**

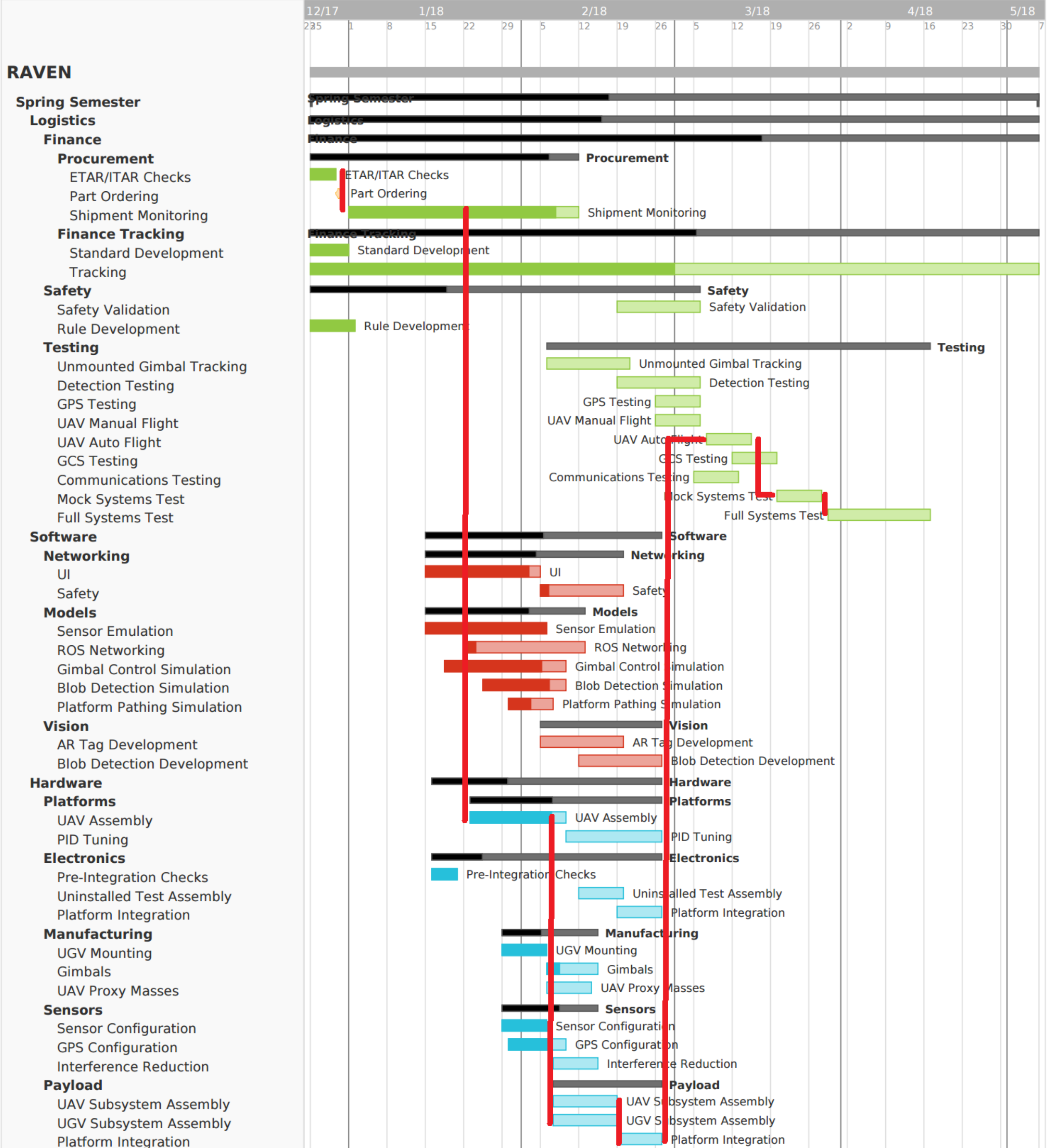
- ODROID and Pixracer connected via UART to USB
- ODROID and GPS connected via USB
- GPS will send relative position, global position, and ephemeris data to the ODROID
- Global position data will be sent to the Pixracer for navigation




**Milestones:** **Status:**

- Establish physical connections between ODROID and Pixracer [5/5 hrs]
- Send commands to the Pixracer [5/5 hrs]
- Send GPS data through ODROID to Pixracer. [5/10 hrs]
- Testing [0/20 hrs]

# Schedule




Multiple parallel tasks

Critical Path follows development of vehicles and payload integration

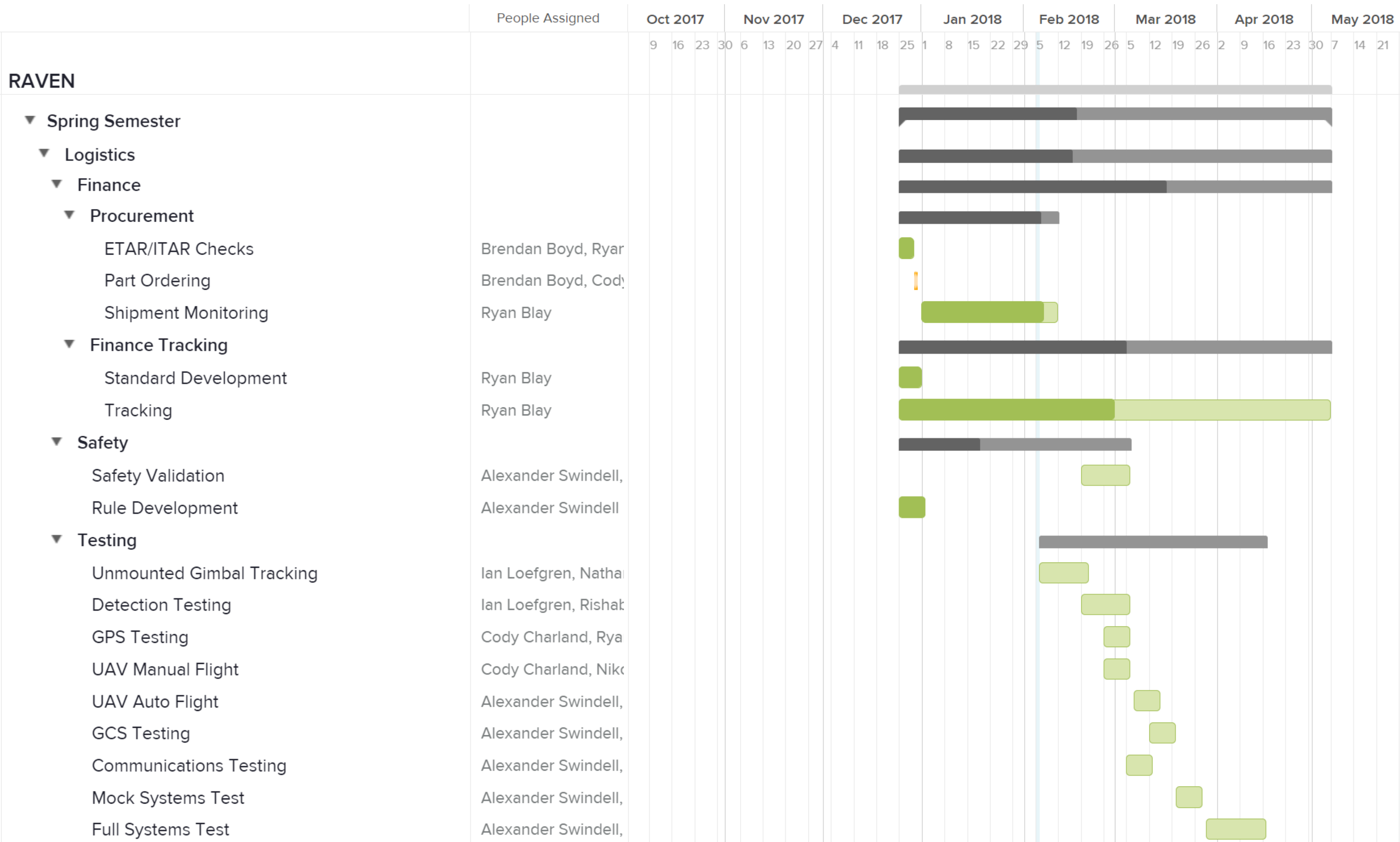
Culminates in tests that require integration

Buffer is built into each task giving a total buffer time of 1.5 weeks

3 days behind schedule however this is within the buffer

# Schedule – Logistics

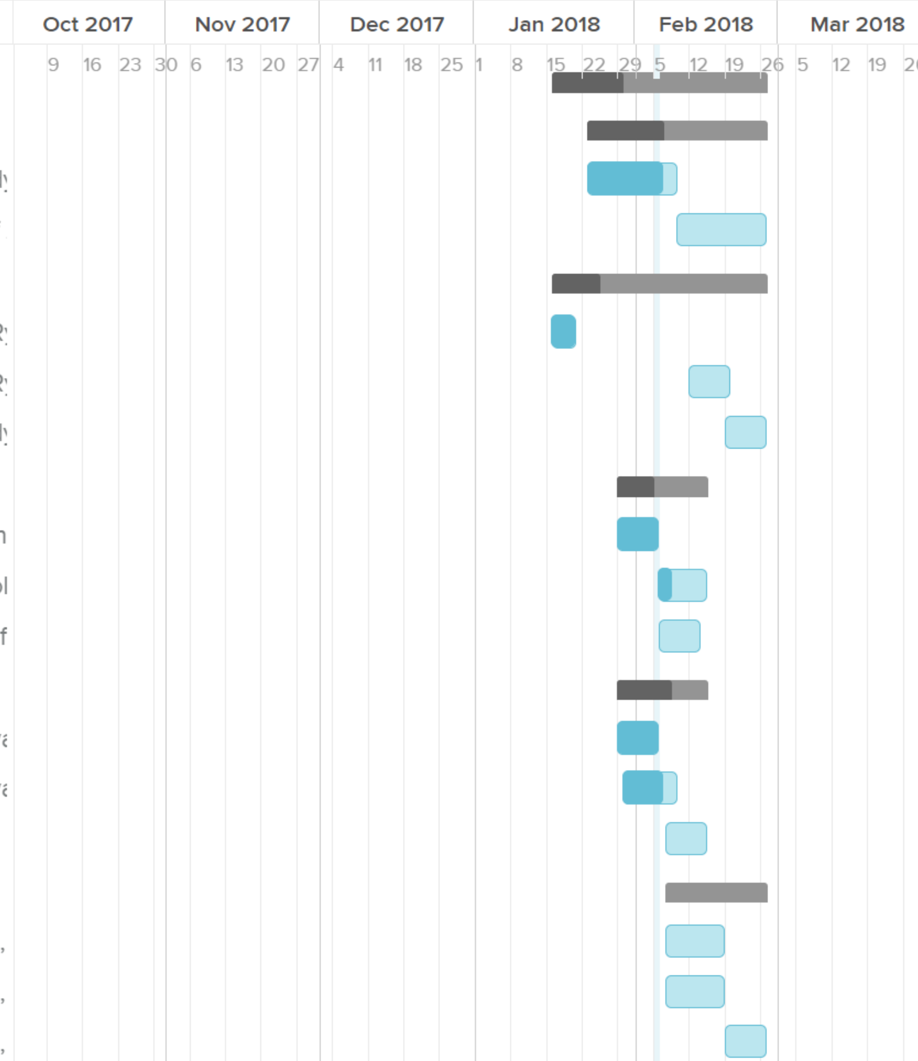




# Schedule - Hardware

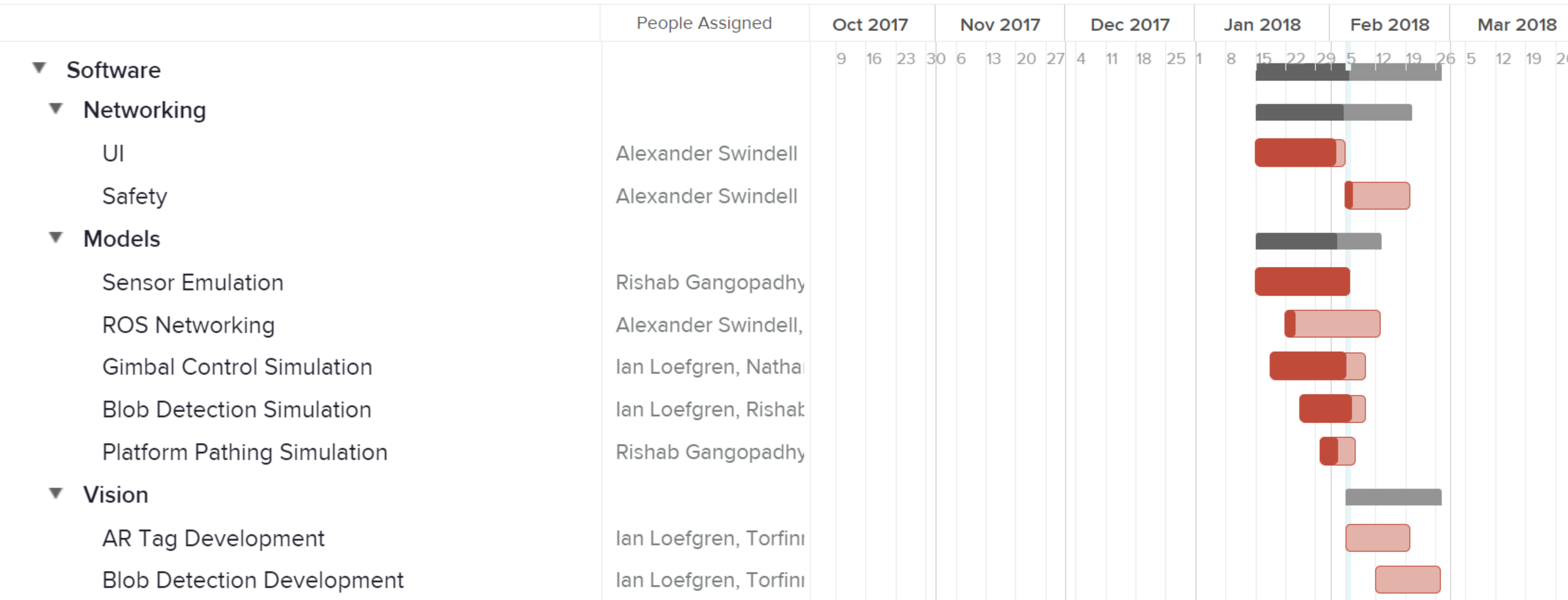


| | People Assigned |
|---|---|
| ▼ Hardware | |
| ▼ Platforms | |
| UAV Assembly | Brendan Boyd, Cody |
| PID Tuning | Brendan Boyd, Rolf |
| ▼ Electronics | |
| Pre-Integration Checks | Nikolas Setiawan, Ry |
| Uninstalled Test Assembly | Nikolas Setiawan, Ry |
| Platform Integration | Brendan Boyd, Cody |
| ▼ Manufacturing | |
| UGV Mounting | Rolf Andrada, Torfin |
| Gimbals | Nathan Levigne, Rol |
| UAV Proxy Masses | Cody Charland, Rolf |
| ▼ Sensors | |
| Sensor Configuration | Nathan Levigne, Rya |
| GPS Configuration | Nathan Levigne, Rya |
| Interference Reduction | Ryan Blay |
| ▼ Payload | |
| UAV Subsystem Assembly | Alexander Swindell, |
| UGV Subsystem Assembly | Alexander Swindell, |
| Platform Integration | Alexander Swindell, |



# Schedule - Software





# Budget

# Procurement Update



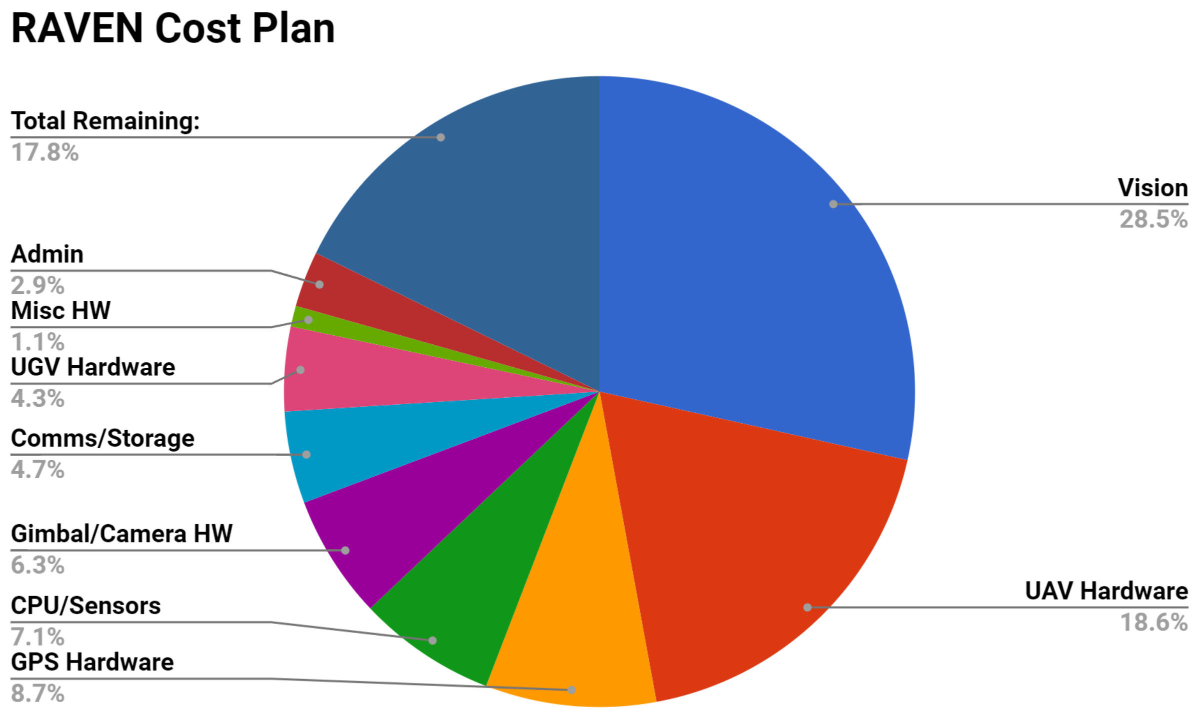
| Subsystem | Received | Purchased but not Received |
|---|---|---|
| Vision HW | Cameras, Lenses | |
| UAV HW | Frame, Motors, ESCs, Propellers, Batteries | |
| Sensor HW | GPS Receivers, GPS Antennas | Barometer |
| CPU HW | ODROID (CPU, eMMCs, Power), Flight Controller, PWM Board, Voltage Regulators | |
| Gimbal HW | Gimbal, Feedback Servos, Mounting HW | Servo Brackets, Bracket Bearing |
| Comms HW | Router, UAV Controller, micro SD cards, Telemetry Radios, Transceivers, Ethernet Cables | |
| UGV HW | 3030 Steel, Acrylic AR Mounts, Mounting HW | |
| Misc HW | Wires, Nuts, Bolts, Velcro, Cable Ties, Connectors, Mounting Tape | |

**Yet to be Purchased:** VICON Markers, Vinyl AR Tags, Misc. HW, Power Monitors, Administrative costs (Printing etc.)

# Cost Plan



| Subsystem | Cost |
|---|---|
| Vision HW | $ 1,994.00 |
| UAV HW | $ 1,303.55 |
| Sensor HW | $ 612.05 |
| CPU HW | $ 496.21 |
| Gimbal HW | $ 443.34 |
| Comms HW | $ 330.16 |
| UGV HW | $ 302.93 |
| Misc HW | $ 74.61 |
| Admin | $ 200.00 |
| **Money Spent** | **$ 5,756.85** |
| **Remaining Funds** | **$ 1,243.15** |
| **Total** | **$ 7,000.00** |




Uncertainties: Minor miscellaneous UAV/UGV Hardware.
Risks: UAV Crash, need money to replace.

# Conclusion



| Project Area | Hours Done/Total Hours |
| --- | --- |
| Tracking & Determination | 97/218 |
| Comms. & Watchdogs | 19/47 |
| User Interface | 105/135 |
| C & C Interfacing | 15/40 |
| **Total** | **236/440 (~50%)** |

- Currently 3 days behind schedule, but within our buffer of 1.5 weeks.
- Currently under budget with 17.8 % left.


Questions?

# Back up Slides

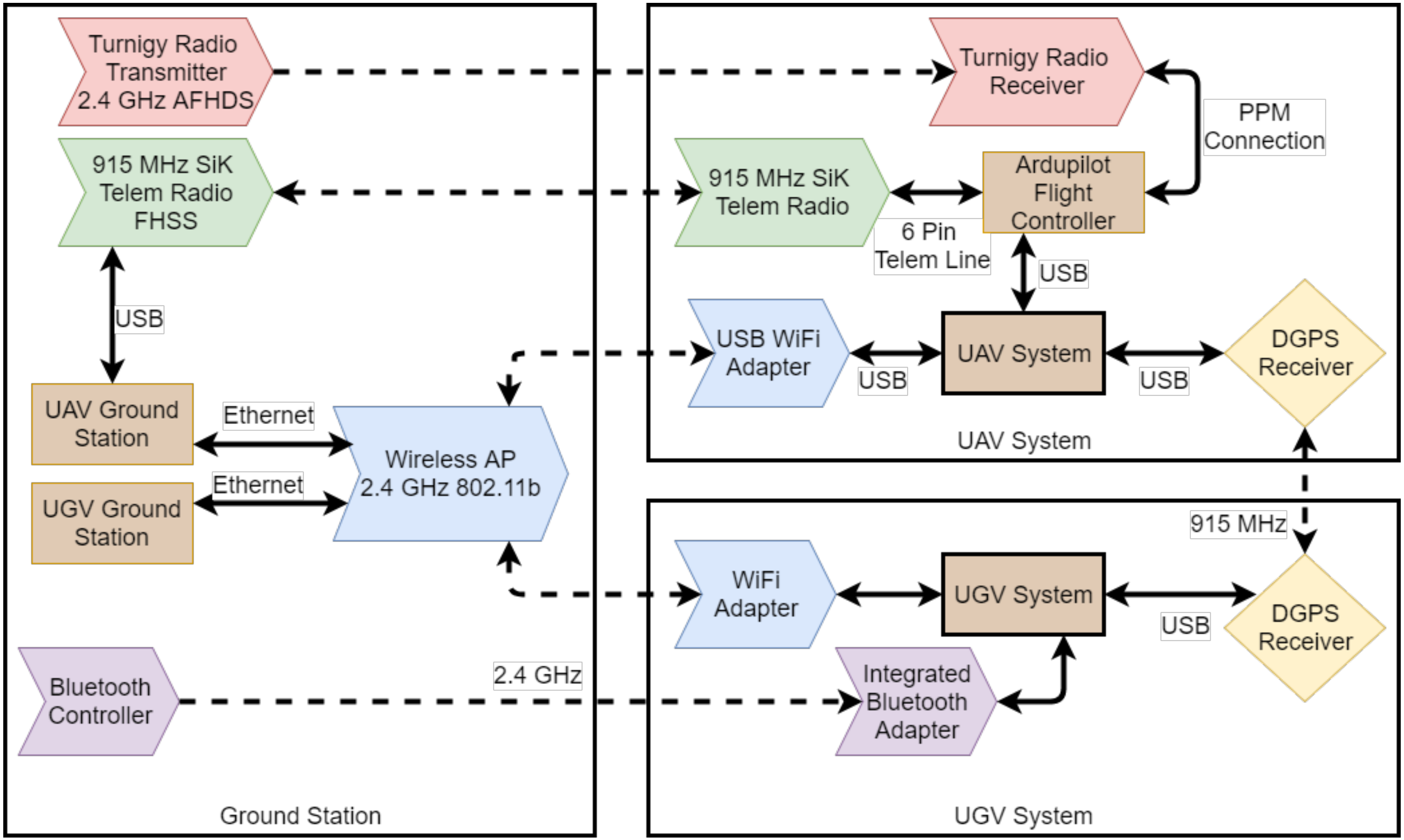
# Specific Objectives (All Level 3)



- **Vision: A moving UAV shall track the UGV at 10-30 m and be in 90 % of frames. A stationary UGV shall track the UAV at 10-30 m and be in 90 % of frames. Acquire target in less than 3 seconds.** Image resolution must be less than or equal to 3 in/pixel at 30 m.
- **Structure**: UAV < 50 lbs. UGV payload < 44 lbs. UAV and UGV are untethered. Batteries are field-accessible. Vision system shall be swappable and communicate over USB 3.0.
- **Captured Data**: Have at least 128 GB removable storage. **Store battery life estimate, package temperature, control input data, GPS/ephemeris data, IMU data, magnetometer data, and barometer data all in ROS bags w/ 20 GB storage margin.** Use lossless compression.
- **Controls**: **UAV will have emergency land switch.** Autonomous UAV tracking orbit with piloted takeoff and landing. UGV remotely piloted up to 0.5 m/s. Controls algorithms compatible with ROS. **Control station displays map overlay of UAV/UGV positions as well as battery status, flight timer, and storage capacity.**
- **Comms**: Vehicles shall communicate over ISM RF link. **Vehicles shall share GPS data, visual tracking, and state data with the control stations.**
- **Electronics/Software**: **Vehicles shall have 15 min tracking endurance.** GPS, IMU, Vision, magnetometer, and barometer shall be integrated. Shall be OpenCl 1.1 capable and have hardware floating point acceleration. Will be able to run cooperative localization algorithms on each vehicle with 50 % CPU overhead margin.
- **Management**: Adhere to UCB UAS FOM. Keep best safety practices. No DJI or prohibited components. **Project cost shall remain under budget.**

# Communications Layout





# UAV Gimbal Problem & Solution



- **Problem:** No way to tell where UAV gimbal was pointing.
- **Solution:** New 1D gimbal using feedback servo.

| Old Gimbal | New Gimbal |
|---|---|
| 167g | ~75g |
| 3-axis | 1-axis |
| No feedback | Analog feedback |

# Proxy Masses

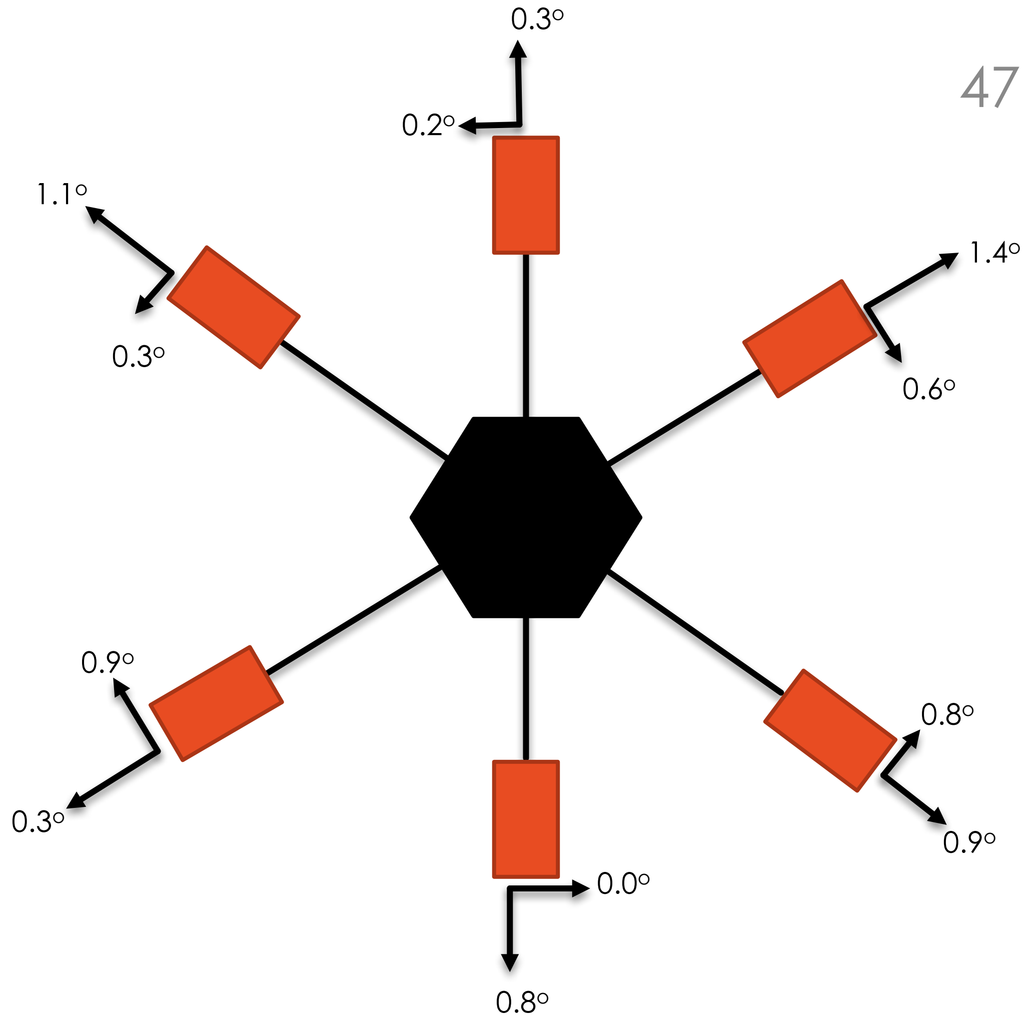


Proxy masses are needed for testing safety.

| Part | Mass | Dimensions |
|---|---|---|
| Camera & Lens | 116g | 74 x 29 x 29mm |
| Gimbal | 75g | 45 x 39 x 32mm |
| ODroid XU4 | 65g | 83 x 58 x 20mm |
| PixRacer | 11g | 36 x 36 x 20mm |
| GPS | 35g | 75 x 55 x 10mm |
| GPS Antenna | 100g | 30 x 30 x 100mm |
| Wiring | ~150g | |
| Wireless Comms | ~10g x3 | 10 x 10 x 10mm x3 |
| Additional testing masses | 10g x20 | 10 x 10 x 10mm x20 |

# UAV Build Status

| Milestone | Status |
|---|---|
| Receive Components | Done |
| Assemble Frame | Done |
| Assemble Motors | Done |
| Final Assembly | In Progress |
| ESC Programming | In Progress |
| First Flight | E.C.D. 2/9/18 |
| Automatic Flight | E.C.D. 2/20/18 |




Net Rotational Skew: 0.2°
Net thrust change: 0.04kg
Net loss in Endurance: ~3sec

# UAV Component Masses



| Component | Measured Mass | Qty | Total |
|---|---|---|---|
| Frame | 632g | 1 | 632g |
| Propeller | 24.5g | 6 | 147g |
| Motor | 88.2g | 6 | 529.2g |
| Batt | 954.5g | 1 | 954.5g |
| Camera+lens | 111g | 1 | 111g |
| Telemetry Radio | 16g | 1 | 16g |
| Gimbal | 76g | 1 | 76g |
| Vibration Isolator | 20g | 1 | 20g |
| GPS System | 123g | 1 | 123g |
| Wifi Receiver | 31g | 1 | 31g |
| RC Receiver | 15g | 1 | 15g |
| ESC | 31g | 6 | 186g |
| Odroid + Arduino | 120 g | 1 | 120g |
| Wiring [estimate] | 130g | 1 | 130g |
| Total | | | 3090g |

Expected Mass: 2.9 kg

# VICON motion capture



**Overview:** Motion capture system in RECUV indoor flight space. Allows for indoor vehicle flight tests. OTS ROS package solution: *vrpn_client_ros (virtual reality peripheral network)*

- VRPN:
  - **Inputs:** Data stream from VICON Tracker software [100Hz]
  - **Outputs:** Pose, linear and angular velocity, linear and angular acceleration of both vehicles [100Hz]
  - **Milestones:**
    - Attach motion capture markers and create VICON object for UAV and UGV [0/1]
    - Create launch file for *vrpn_client_ros* [0/1]
    - Integrate with UAV GPS collection process [0/5]
- "GPS" Handler
  - **Inputs:** Pose, linear and angular velocity, linear and angular acceleration of both vehicles
  - **Outputs:** Relative position and heading [1Hz]
  - **Milestones**:
    - Create handler [0/2]
    - Unit testing for integration [0/5]
    - Add noise to simulate sensor error [0/5]

# Housekeeping Data



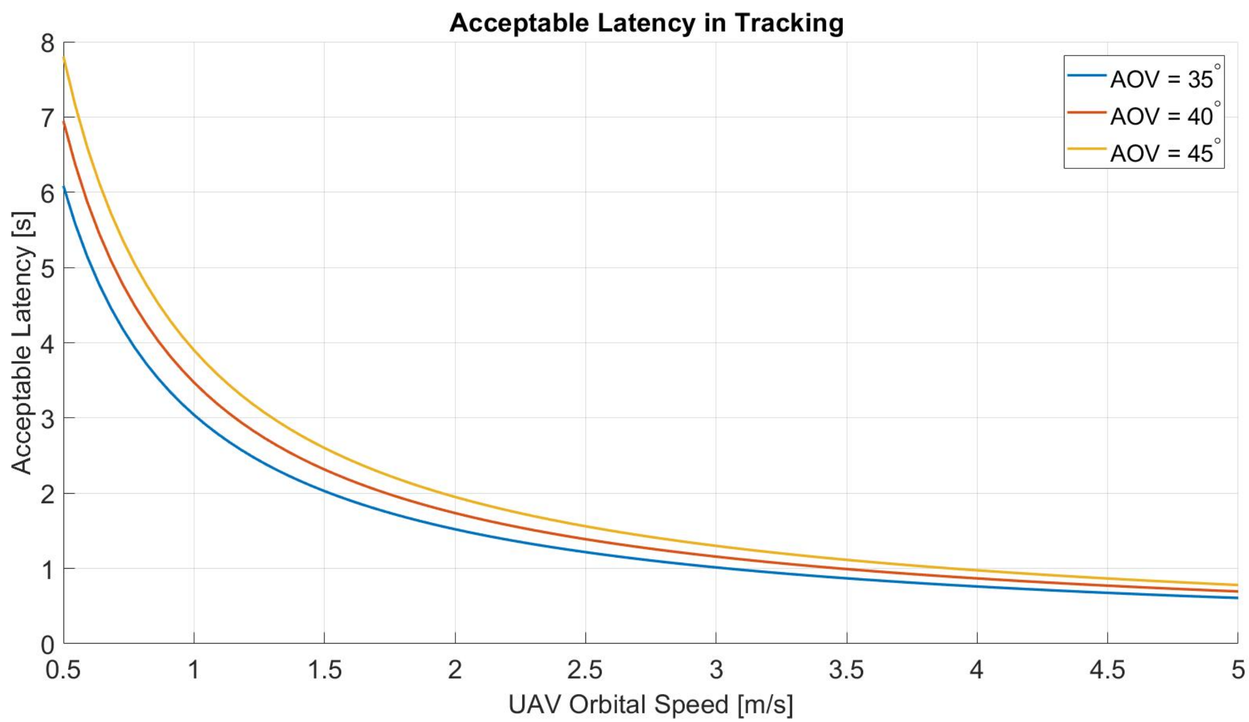
- UAV:
  - Pixracer outputs telemetry data when requested via mavROS message [50 Hz max]
  - Housekeeping process:
    - Create and send mavROS messages
    - Send data to SD storage and and package and send to GCS
- Milestones:
  - Create and send mavROS messages [0/5]
  - Package data and send to GCS [0/2]
  - Send data to SD storage [0/2]

- UGV:
  - Jackal software makes temperature, battery information, command, and IMU data available out of the box [50 Hz]
  - Housekeeping process:
    - Grab data and send to SD storage and package and send to GCS
- Milestones:
  - Find all ROS topics with pertinent data [0/2]
  - Package data and send to GCS [0/2]
  - Send data to SD storage [0/2]

# Latency Model

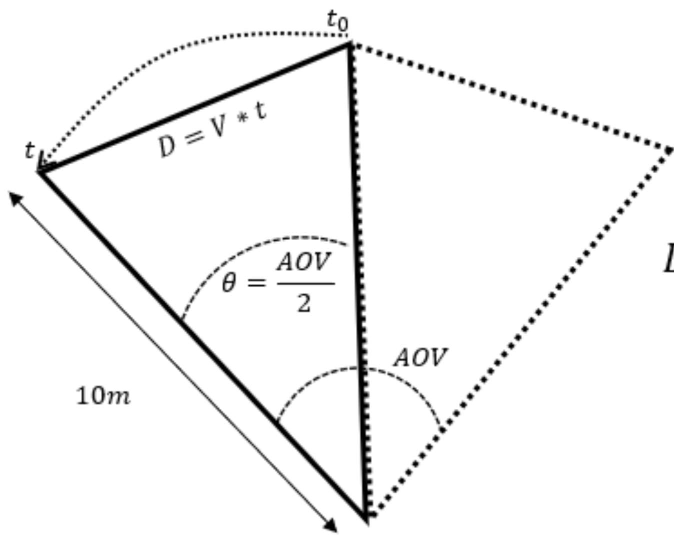


- Calculated Latency is time between pointing states
- Includes position transmission, processing, pointing commanding, and actuation



# Latency Model






$$t - t_0 = t_{lat}$$
$$D = V * t_{lat}$$
$$D = 2 * 10m * \sin\left(\frac{\theta}{2}\right) = 2 * 10m * \sin\left(\frac{AOV/_2}{2}\right)$$
$$V * t_{lat} = 2 * 10m * \sin\left(\frac{AOV/_2}{2}\right)$$
$$\boldsymbol{t_{lat} = \frac{2}{V} * 10m * sin\left(\frac{AOV/_2}{2}\right)}$$

# Mounting Rail

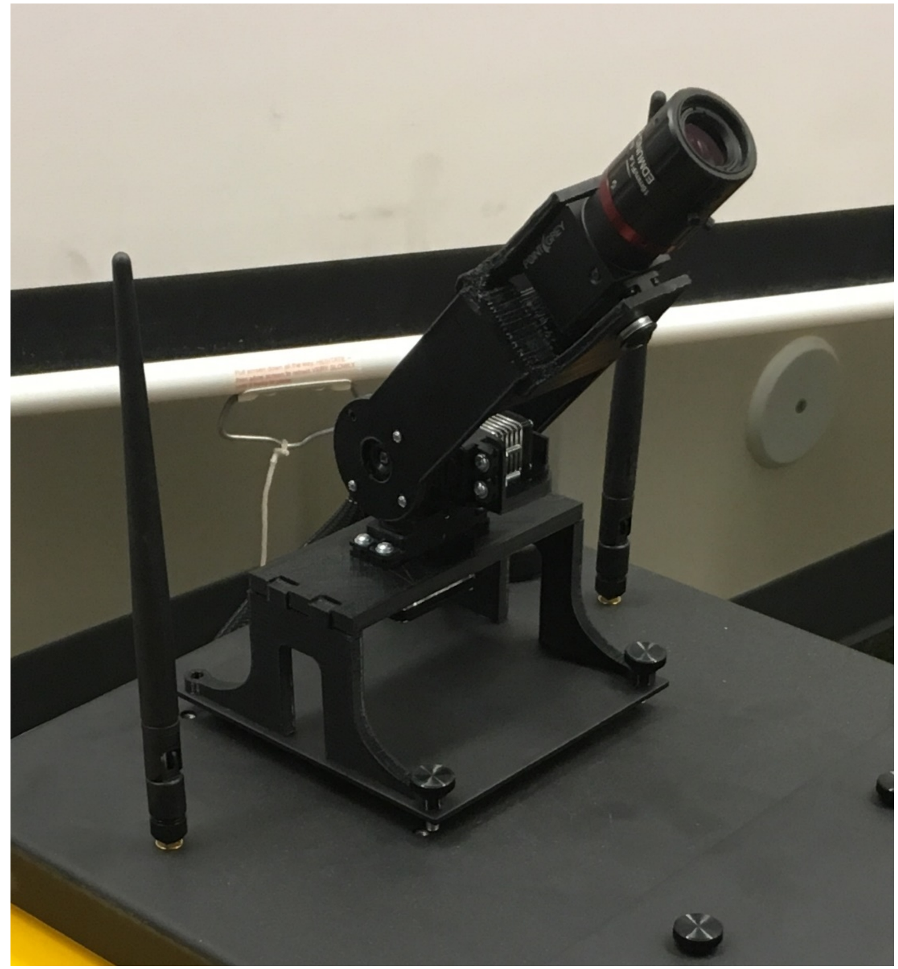


- Used to mount AR tag plates and gimbal
- 8020 – 3030
- M5 bolts for mounting onto UGV
- Weight not a concern

# UGB Gimbal



- Prototyped from CDR
- 3D printed PLA
- Tolerances sufficient (no necessity for accuracy)
- M5 bolts
- 2 x analog feedback servos
- Servo bearing on other side of tilt arm for smooth movement



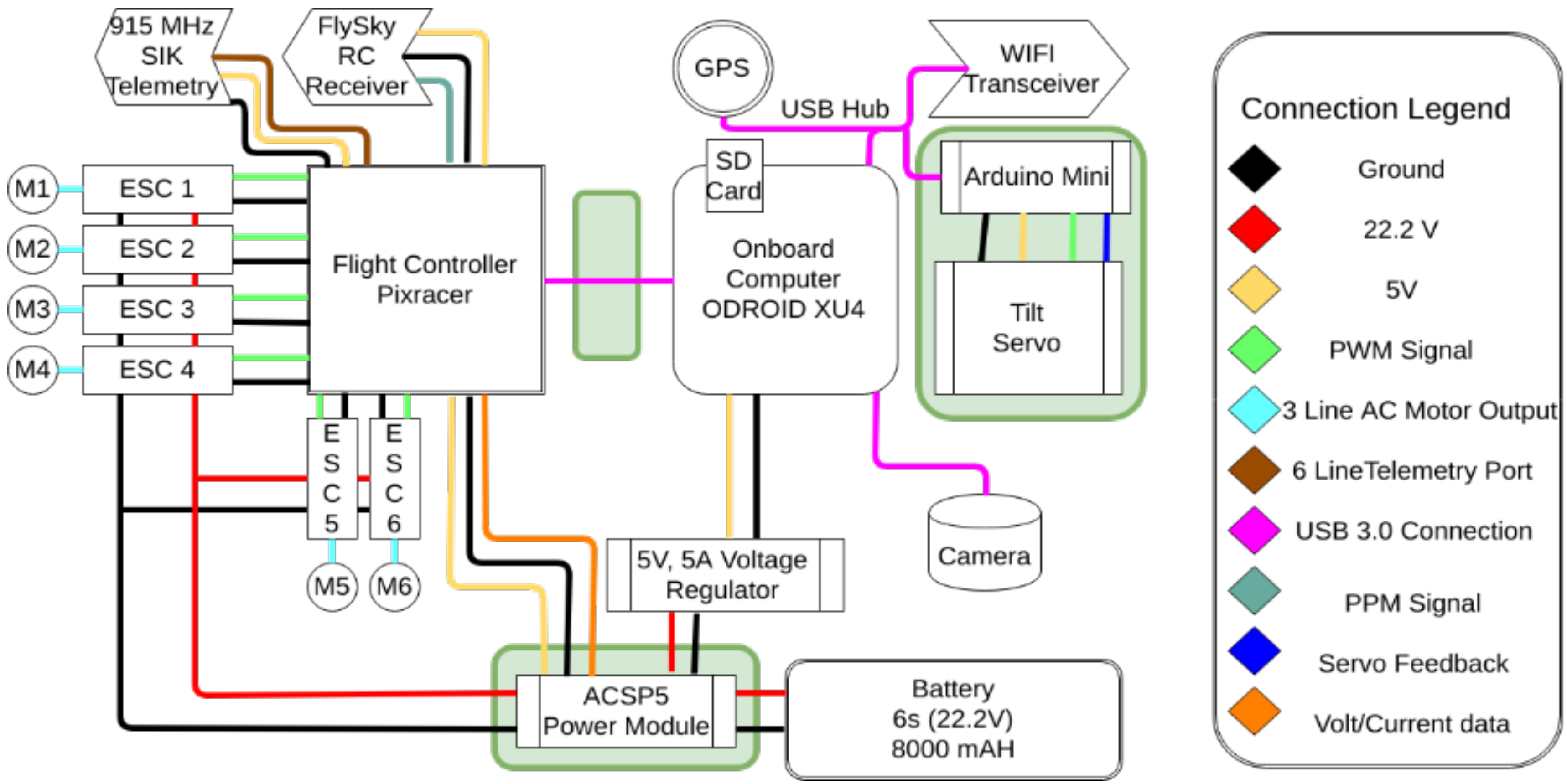
# GPS Configuration



- RTK Moving Baseline Mode (MB)
- Requires RTCM Messages:
  - 1077 (GPS Observations), 1087 (GLONASS Observations), 1230 (GLONASS Code-phase Biases), 4072 (uBlox Proprietary MB Message).
- Base will send RTCM messages at 19200 Baud, and Rover will receive RTCM messages at 19200 Baud.
- Both the Base and the Rover will be configured with 1 Hz navigation rate.
- Users will receive:
  - NAV-DOP, NAV-HPPOSECEF, NAV-TIMEUTC, NAV-VELNED, NAV-RELPOSNED, RXM-RAWX (Observations), RXM-SFRBX (Navigation Subframe)
  - NMEA-RMC (Recommended minimum NMEA message)

# Updated Electronics Connection Diagram





# Electronics Integration Status



Tested Working Connection:

- Pixracer - Odroid Connection
- Pixracer - RC Controller
- Pixracer - Telemetry Radio
- UGV - Bluetooth
- Wifi router setup
- ODROID - Arduino – Servo

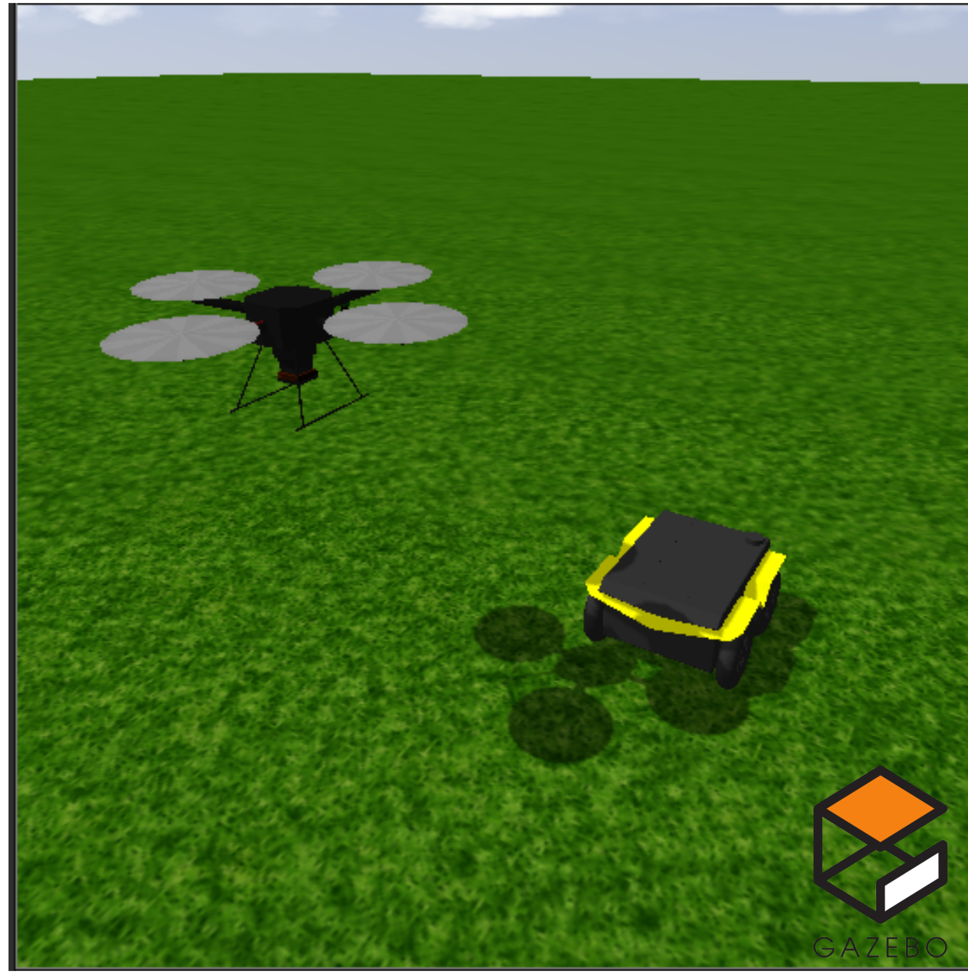
Untested Connection:

- Pixracer-ESC
- ODROID-Wifi
- ODROID-GPS
- ODROID-Camera
- UAV Power Distribution
- UGV Extra Sensors

# Gazebo Overview



- ROS Simulation Tool
- Provides 3D visualization of systems
- Allows sensor emulation
- Simulates reasonable approximations of dynamics
- **Allows prototyping of RAVEN network**



# Gazebo Assumptions

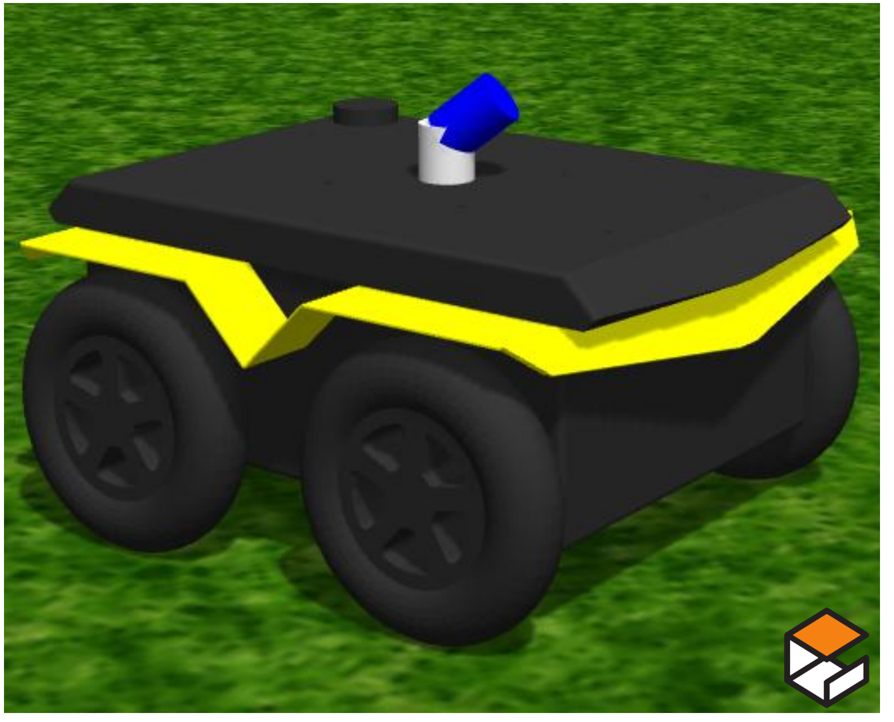


- Sensors are emulated
  - Sensor traits are not yet configured
  - Sensor data source will change
- Physical characteristics
  - Magnitude of losses are unknown
  - Can change with environment

# Simulated Camera and Mount



- Gazebo plugin for camera
  - Parameters
    - View distance
    - Resolution
    - Field of view
- Gazebo plugin for mount control
  - Modeled by two intersecting cylinders
  - Manually command pan and tilt joints to angles
  - Still to implement: mount tracks UAV by sharing GPS, more realistic model for camera and mount



# Gazebo Playback



- A ROS Bag records ROS messages for topics that the bag is subscribed to, as well as a time record of the message.
- Using ROS playback, tools these messages can be played back in real time.
- Utilizing the Gazebo model, and replaying all ROS messages, the test conditions and results can be played back.
  - There are some limitations, based on the time difference between when a topic was published to, and when the value was processed.

# UGV Gimbal Demonstration