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
<table>
<thead>
<tr>
<th>Agenda</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Project Overview</strong></td>
<td>3 - 12</td>
</tr>
<tr>
<td>Tracking and Determination</td>
<td>13 - 23</td>
</tr>
<tr>
<td>Communications and Watchdogs</td>
<td>24 – 26</td>
</tr>
<tr>
<td>User Interface</td>
<td>27 – 29</td>
</tr>
<tr>
<td>Flight Controller and Computer Interfacing</td>
<td>30 - 31</td>
</tr>
<tr>
<td>Schedule and Budget</td>
<td>32 – 39</td>
</tr>
<tr>
<td>Conclusion</td>
<td>40</td>
</tr>
</tbody>
</table>
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.

Currently on track to achieve Level 3 Objectives.
Concept of Operations

**Prepare**
- UAV
  - Safety Checks
  - Preflight Checks
  - Take off to initial position
- UGV
  - Safety Checks
  - Prerun Checks
  - Move to initial position

**Execute**
- Preprogrammed Flight Path or Stationary Hover
- Location Data (IMU/GPS/Ephemeris)
- 15 min Flight Time
- Manual Takeoff
- Manual Land
- Emergency Land

**Vision**
- UAV & UGV
  - Cameras rotate to keep other vehicle in frame
  - Vehicles have L.O.S.
- UGV
  - UGV in 90% of frames
  - 3 Inches/pixel at 30 m

**Data Collected**
- Both Vehicles Record:
  - GPS/IMU/Altitude
  - Raw Camera Footage
  - Location Estimates
  - Status
- Used by customer for visual tracking alg. development

**RAVEN**

**Motivation**
- UAV vision used to find location of UGV without GPS

**Conclude**
- UAV
  - Manual Landing
  - System Shutdown
  - Offload Collected Data
- UGV
  - System Shutdown
  - Offload Collected Data
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

- Project Overview
- Tracking and Det.
- Comms. & Watchdogs
- User Interface
- C & C Interface
- Schedule and Budget
- Conclusion
Critical Manufacturing Areas

User Interface
Critical Manufacturing Areas

Interfacing Between Flight Controller and Flight Computer
Tracking and Determination

Project Overview

Tracking and Det.

Comms. & Watchdogs

User Interface

C & C Interface

Schedule and Budget

Conclusion
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

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

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:

<table>
<thead>
<tr>
<th>Projected</th>
<th>Updated</th>
</tr>
</thead>
<tbody>
<tr>
<td>UAV Total Mass</td>
<td>2.9 [kg]</td>
</tr>
<tr>
<td>UAV Motor Skew</td>
<td>0 [deg]</td>
</tr>
<tr>
<td>UAV Endurance Estimate</td>
<td>23.4 [min]</td>
</tr>
</tbody>
</table>

Unit Testing:
- Manual Flight
- Automatic Indoor Flight
- Outdoor Flight
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:
- Project Overview
  - Tracking and Det.
  - Comms. & Watchdogs
  - User Interface
  - C & C Interface
  - Schedule and Budget
  - Conclusion

Mounting Rails (920 x 460 mm)

Pan & Tilt Gimbal (150 x 50 mm base)

AR Tag Plates (180 x 180 mm)
Tracking and Determination Software Flowchart

Project Overview
Comms. & Watchdogs
User Interface
C & C Interface
Schedule and Budget
Conclusion

Legend
- Off the shelf
- RAVEN: to be developed
- RAVEN: development in progress
- RAVEN: already developed

GPS Handler
- Parse u-blox GPS message
- Determine relative position

Pointing angles
- Determine servo rotation angles
- Publish servo rotation angles

Servo Control
- Serial write rotation angles to PWM motor
- Serial read servo angles

Storage: SD card
- Collect image data
- Reduce number of images

Camera
- Confirm target in frame with AR or blob detection
- Detect stamp

Pixracer / Jackal Compute
- Flight Controls / Motor Controllers
- Emergency Commands

Sensor Pack
- Watchdog
- Watch for GCS signals
- Collect housekeeping data

Watchdog
- Housekeeping
- Collect housekeeping data

I/O Ground Control
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:

Project Overview
Tracking and Det.
Comms. & Watchdogs
User Interface
C & C Interface
Schedule and Budget
Conclusion
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 vehicle's microcontroller
- Integrates servo feedback to confirm that requested angle has been achieved

Milestones:

- 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]

Status:
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:
- Open sourced code, High Priority
- Team designed code, Low Priority

SD Card → Camera → Aravis via Genicam Standard → RGB24 format → ODROID/Jackal
- Sample image, compress, convert to ROS message
- To UI on GCS
- Max write of 90 MB/s
- 11 fps
- 68.42 MB/s
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:**

---

**Project Overview**

**Tracking and Det.**

**Comms. & Watchdogs**

**User Interface**

**C & C Interface**

**Schedule and Budget**

**Conclusion**
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]
Communications and Watchdogs

- Project Overview
- Tracking and Det.
- Comms. & Watchdogs
- User Interface
- C & C Interface
- Schedule and Budget
- Conclusion
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:**
- Complete

---

Project Overview  Tracking and Det.  Comms. & Watchdogs  User Interface  C & C Interface  Schedule and Budget  Conclusion
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]
UI Video

Project Overview
Tracking and Det. & Watchdogs
Comms. & Watchdogs
User Interface
C & C Interface
Schedule and Budget
Conclusion
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:
- 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

## RAVEN

### Spring Semester

#### Logistics

- **Finance**
  - **Procurement**
    - ETAR/ITAR Checks
    - Part Ordering
    - Shipment Monitoring
  - **Finance Tracking**
    - Standard Development
    - Tracking

#### Safety

- Safety Validation
- Rule Development

#### Testing

- Unmounted Gimbal Tracking
- Detection Testing
- GPS Testing
- UAV Manual Flight
- UAV Auto Flight
- GCS Testing
- Communications Testing
- Mock Systems Test
- Full Systems Test

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Brendan Boyd</td>
<td>9</td>
<td>16</td>
<td>23</td>
<td>30</td>
<td>6</td>
<td>13</td>
<td>20</td>
<td>27</td>
</tr>
<tr>
<td>Ryar</td>
<td>4</td>
<td>11</td>
<td>18</td>
<td>25</td>
<td>8</td>
<td>15</td>
<td>22</td>
<td>29</td>
</tr>
<tr>
<td>Cordy Charland</td>
<td>11</td>
<td>25</td>
<td>18</td>
<td>22</td>
<td>5</td>
<td>12</td>
<td>19</td>
<td>26</td>
</tr>
<tr>
<td>Ryan Blay</td>
<td>9</td>
<td>16</td>
<td>23</td>
<td>30</td>
<td>6</td>
<td>13</td>
<td>20</td>
<td>27</td>
</tr>
<tr>
<td>Alexander Swindell</td>
<td>9</td>
<td>16</td>
<td>23</td>
<td>30</td>
<td>6</td>
<td>13</td>
<td>20</td>
<td>27</td>
</tr>
</tbody>
</table>
## Schedule - Hardware

<table>
<thead>
<tr>
<th>Category</th>
<th>Task</th>
<th>Assigned By</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hardware</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Platforms</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UAV Assembly</td>
<td>Brendan Boyd, Cod.</td>
<td>8, 15, 22, 29, 5, 12, 19, 26</td>
</tr>
<tr>
<td>PID Tuning</td>
<td>Brendan Boyd, Rolf</td>
<td></td>
</tr>
<tr>
<td><strong>Electronics</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-Integration Checks</td>
<td>Nikolas Setiawan, Rolf</td>
<td></td>
</tr>
<tr>
<td>Uninstalled Test Assembly</td>
<td>Nikolas Setiawan, Rolf</td>
<td></td>
</tr>
<tr>
<td>Platform Integration</td>
<td>Brendan Boyd, Cod.</td>
<td></td>
</tr>
<tr>
<td><strong>Manufacturing</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UGV Mounting</td>
<td>Rolf Andrada, Torfin</td>
<td></td>
</tr>
<tr>
<td>Gimbals</td>
<td>Nathan Levigne, Rolf</td>
<td></td>
</tr>
<tr>
<td>UAV Proxy Masses</td>
<td>Cody Charland, Rolf</td>
<td></td>
</tr>
<tr>
<td><strong>Sensors</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sensor Configuration</td>
<td>Nathan Levigne, Ryan</td>
<td></td>
</tr>
<tr>
<td>GPS Configuration</td>
<td>Nathan Levigne, Ryan</td>
<td></td>
</tr>
<tr>
<td>Interference Reduction</td>
<td>Ryan Blay</td>
<td></td>
</tr>
<tr>
<td><strong>Payload</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UAV Subsystem Assembly</td>
<td>Alexander Swindell,</td>
<td></td>
</tr>
<tr>
<td>UGV Subsystem Assembly</td>
<td>Alexander Swindell,</td>
<td></td>
</tr>
<tr>
<td>Platform Integration</td>
<td>Alexander Swindell,</td>
<td></td>
</tr>
</tbody>
</table>
## Schedule - Software

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>9 16 23</td>
<td>30 6 13</td>
<td>20 27 4</td>
<td>11 18 25</td>
<td>1 5 12  19 26</td>
<td>5 12 19 26</td>
</tr>
</tbody>
</table>

### Software

- **Networking**
  - UI
  - Safety
  - Alexander Swindell
  - Alexander Swindell

- **Models**
  - Sensor Emulation
  - Rishab Gangopadhy
  - ROS Networking
  - Alexander Swindell, Ian Loefgren, Netha
  - Gimbal Control Simulation
  - Ian Loefgren, Rishak
  - Blob Detection Simulation
  - Ian Loefgren, Rishak
  - Platform Pathing Simulation
  - Rishab Gangopadhy

- **Vision**
  - AR Tag Development
  - Ian Loefgren, Torfin
  - Blob Detection Development
  - Ian Loefgren, Torfin
Budget
## Procurement Update

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

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

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vision HW</td>
<td>$1,994.00</td>
</tr>
<tr>
<td>UAV HW</td>
<td>$1,303.55</td>
</tr>
<tr>
<td>Sensor HW</td>
<td>$ 612.05</td>
</tr>
<tr>
<td>CPU HW</td>
<td>$ 496.21</td>
</tr>
<tr>
<td>Gimbal HW</td>
<td>$ 443.34</td>
</tr>
<tr>
<td>Comms HW</td>
<td>$ 330.16</td>
</tr>
<tr>
<td>UGV HW</td>
<td>$ 302.93</td>
</tr>
<tr>
<td>Misc HW</td>
<td>$  74.61</td>
</tr>
<tr>
<td>Admin</td>
<td>$ 200.00</td>
</tr>
<tr>
<td><strong>Money Spent</strong></td>
<td><strong>$5,756.85</strong></td>
</tr>
<tr>
<td><strong>Remaining Funds</strong></td>
<td><strong>$1,243.15</strong></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$7,000.00</strong></td>
</tr>
</tbody>
</table>

#### RAVEN Cost Plan

- **Total Remaining:** 17.8%
  - **Vision:** 28.5%
  - **UAV Hardware:** 18.6%
  - **UGV Hardware:** 6.3%
  - **Comms/Storage:** 4.7%
  - **CPU/Sensors:** 7.1%
  - **GPS Hardware:** 8.7%
  - **Misc HW:** 4.3%
  - **Gimbal/Camera HW:** 1.1%

**Uncertainties:** Minor miscellaneous UAV/UGV Hardware.

**Risks:** UAV Crash, need money to replace.
## Conclusion

<table>
<thead>
<tr>
<th>Project Area</th>
<th>Hours Done/Total Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tracking &amp; Determination</td>
<td>97/218</td>
</tr>
<tr>
<td>Comms. &amp; Watchdogs</td>
<td>19/47</td>
</tr>
<tr>
<td>User Interface</td>
<td>105/135</td>
</tr>
<tr>
<td>C &amp; C Interfacing</td>
<td>15/40</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>236/440 (~50%)</strong></td>
</tr>
</tbody>
</table>

- 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

Turnigy Radio Transmitter 2.4 GHz AFHDS

915 MHz SiK Telem Radio FHSS

USB

UAV Ground Station

UGV Ground Station

Bluetooth Controller

Ground Station

Wireless AP 2.4 GHz 802.11b

UGV System

2.4 GHz

Turnigy Radio Receiver

Ardupilot Flight Controller

USB WiFi Adapter

USB

UAV System

DGPS Receiver

6 Pin Telem Line

USB

USB

PPM Connection

UGV System

915 MHz

915 MHz SiK Telem Radio

UAV System

DGPS Receiver

915 MHz

Integrated Bluetooth Adapter

USB

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

<table>
<thead>
<tr>
<th>Old Gimbal</th>
<th>New Gimbal</th>
</tr>
</thead>
<tbody>
<tr>
<td>167g</td>
<td>~75g</td>
</tr>
<tr>
<td>3-axis</td>
<td>1-axis</td>
</tr>
<tr>
<td>No feedback</td>
<td>Analog feedback</td>
</tr>
</tbody>
</table>
Proxy Masses

Proxy masses are needed for testing safety.

<table>
<thead>
<tr>
<th>Part</th>
<th>Mass</th>
<th>Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Camera &amp; Lens</td>
<td>116g</td>
<td>74 x 29 x 29mm</td>
</tr>
<tr>
<td>Gimbal</td>
<td>75g</td>
<td>45 x 39 x 32mm</td>
</tr>
<tr>
<td>ODroid XU4</td>
<td>65g</td>
<td>83 x 58 x 20mm</td>
</tr>
<tr>
<td>PixRacer</td>
<td>11g</td>
<td>36 x 36 x 20mm</td>
</tr>
<tr>
<td>GPS</td>
<td>35g</td>
<td>75 x 55 x 10mm</td>
</tr>
<tr>
<td>GPS Antenna</td>
<td>100g</td>
<td>30 x 30 x 100mm</td>
</tr>
<tr>
<td>Wiring</td>
<td>~150g</td>
<td></td>
</tr>
<tr>
<td>Wireless Comms</td>
<td>~10g x3</td>
<td>10 x 10 x 10mm x3</td>
</tr>
<tr>
<td>Additional testing masses</td>
<td>10g x20</td>
<td>10 x 10 x 10mm x20</td>
</tr>
</tbody>
</table>
# UAV Build Status

<table>
<thead>
<tr>
<th>Milestone</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Receive Components</td>
<td>Done</td>
</tr>
<tr>
<td>Assemble Frame</td>
<td>Done</td>
</tr>
<tr>
<td>Assemble Motors</td>
<td>Done</td>
</tr>
<tr>
<td>Final Assembly</td>
<td>In Progress</td>
</tr>
<tr>
<td>ESC Programming</td>
<td>In Progress</td>
</tr>
<tr>
<td>First Flight</td>
<td>E.C.D. 2/9/18</td>
</tr>
<tr>
<td>Automatic Flight</td>
<td>E.C.D. 2/20/18</td>
</tr>
</tbody>
</table>

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

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

**Expected Mass: 2.9 kg**
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 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.

![Diagram: Acceptable Latency in Tracking](image)
Latency Model

\[ D = V \cdot t \]

\[ \theta = \frac{AOV}{2} \]

\[ 10m \]

\[ t_{\text{lat}} = \frac{2}{V} \cdot 10m \cdot \sin\left(\frac{\frac{AOV}{2}}{2}\right) \]

\[ V \cdot t_{\text{lat}} = 2 \cdot 10m \cdot \sin\left(\frac{\frac{AOV}{2}}{2}\right) \]

\[ D = 2 \cdot 10m \cdot \sin\left(\frac{\theta}{2}\right) = 2 \cdot 10m \cdot \sin\left(\frac{AOV}{2}\right) \]

\[ t - t_0 = t_{\text{lat}} \]

\[ D = V \cdot t_{\text{lat}} \]
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:

- 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

**Connection Legend**
- **Ground**
- **22.2 V**
- **5V**
- **PWM Signal**
- **3 Line AC Motor Output**
- **6 Line Telemetry Port**
- **USB 3.0 Connection**
- **PPM Signal**
- **Servo Feedback**
- **Volt/Current Data**
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
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