Rover and Air Visual Environment Navigation

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Customer: Nisar Ahmed

Advisor: Torin Clark
# Agenda

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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
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
- 15 min Flight Time
- Location Data (IMU/GPS/Ephemeris)
- 10-30 m
- Max: 0.5 m/s or Stationary tracking

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

UGV Control
- UGV Operator
- UGV Control

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

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

Conclude
- UAV: Manual Landing, System Shutdown, Offload Collected Data
- UGV: System Shutdown, Offload Collected Data
- RAVEN
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.
System Level Functional Block Diagram

UAV
- GPS
- Actuators
- Flight controller
- Computer(s)
- RF COMMS

VG
- GPS
- Actuators
- Storage
- Computer(s)
- RF COMMS

ECS
- Pointing algorithms
- Vision
- Tracking

Data Collect
- Baro
- Bat
- CMD
- Temp
- Mag
- IMU
- State

GCS
- RF COMMS
- Compute
- UI

- UAV Remote Pilot
- UGV Remote Pilot

Legend:
- Designed
- Wireless
- Image Data
- MGMT Data
- Wired
- Provided
- Multiplexer
- Commands
Schedule

Unit Testing

1. 1/15
2. 1/22
3. 1/29
4. 2/05
5. 2/12
6. 2/19
7. 2/26
8. 3/05
9. 3/12
10. 3/19

Subsystem Testing

11. Spring Break
12. AIAA Paper
13. Sym. Paper Poster
14. SFR
15. Project Final Report
16. 4/30

System Testing

1. MSR
2. TRR

17. 4/02
18. 4/09
19. 4/16
20. 4/23
21. 4/30
Schedule – UAV Critical Path

Where we are

Where we want to be


1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

UAV Built MSR Manual Flight Test Power Model Test Auto Flight Test System Integration TRR Indoor Mock Test Outdoor Mock Test Spring Break Full System Test

Behind schedule by 1 week
• Mitigate by crashing integration week
Schedule – Payload Systems Critical Path

1/15
1/22
1/29
2/05
2/12
2/19
2/26
3/05
3/12
3/19
3/26
4/02
4/09
4/16
4/23
4/30

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16

Gimbal Integration
MSR
Gimbal Point Test
TRR
Indoor Mock Test
Outdoor Mock Test
Spring Break
Full System Test
SFR
Project Final Report

Currently on schedule


Spring Break

Gimbal Integration
MSR
Gimbal Point Test
TRR
Indoor Mock Test
Outdoor Mock Test
Spring Break
Full System Test
SFR
Project Final Report

Currently on schedule
Testing Flow Chart

Payload
- Gimbal Control
- Gimbal Pointing
- Camera Pointing
- UGV Tracking
- Blob Detection
- GPS Accuracy
- GPS Decoding

Platform
- Payload Install
- UAV Manual Flight
- UAV Autonomous Flight
- UAV Endurance
- UGV Control
- UGV Failsafe

System
- Mock Systems Test
- Full System Comms
- Ground Segment
- Demonstration/Delivery
- Full System Test: Scenario #1
- Full System Test: Scenario #2

Critical Path
- Flight Test
- UAV Test
- UGV Test
- System Test
- Complete
Unit Testing
GPS Accuracy Verification

Reasoning: To determine the accuracy of the RTK GPS units. This will ensure that it will be sufficient enough for the tracking requirements and validate our model.

Testing Prerequisites:
• MATLAB parsing tools developed.

Equipment and Facilities:
• C94-M8P GPS units w/Antennas
• 2 Laptops
• Business Field

Recorded Data:
• Position Data (Lat, Lon, Alt) [1 Hz]
• Velocity Data in NED Frame [1 Hz]
• Relative Position Vector from UGV to UAV [1 Hz]

Success Criteria:
• Standard Deviation < 0.973 m
• Handles data throughput of all necessary messages
GPS Accuracy Verification - Results

Test Completed
• Dynamic test, where both units move along parallel lines was conducted.
  • Relative distance kept close to constant.

Accuracy
• UGV average deviation from line: 14 cm
  • Std Dev: 11 cm
• UAV average deviation from line: 11 cm
  • Std Dev: 8 cm

Issues:
• By collecting ephemeris data, message throughput was too high for 1 Hz update rate.

Solution:
• Have UGV collect ephemeris and UAV send relative position vector (1 Hz) to UGV for gimbal pointing.
  • Second test planned

Success Criteria:
• Standard Deviation < 0.973 m: PASS
• Handles data throughput of all necessary messages: FAIL
Completed Subsystem Testing
Manual Flight

Reasoning: Determine flight characteristics of UAV platform. Ensure UAV is flyable and stable during manual flight operations using proxy masses for payload simulation.

Testing Prerequisites:
- UAV Built
- Proxy Masses
- Pixracer Unit Testing

Equipment and Facilities:
- VICON space (RECUV Fleming Lab)
- VICON markers
- UAV Transmitter
- Stopwatch

Risks:
- UAV crash/damage
- LiPo battery damage
- Damage to VICON space

Recorded Data:
- Flight Time
- VICON data

Success Criteria:
- UAV flight for >18.15 minutes
- UAV stable in flight
Manual Flight - Results

Two tests completed:
• Test 1
  • Flight Length: 15:03
  • VICON data collected
• Test 2
  • Flight Length: 18:36
  • VICON data collected

Results:
• No major damage to UAV
• Safety hoop needed to be refitted
• Testing concluded after impact
• Automatic landing successful

Success Criteria:
• UAV flight for >18.15 minutes: PASS
• UAV stable in flight: PASS
Power Model Verification

Reasoning: UAV flight to validate the accuracy of the power model developed in the previous semester. Two flights for each battery pack.

Testing Prerequisites:
• Manual Flight

Equipment and Facilities:
• VICON space (RECUV Fleming Lab)
• VICON markers
• UAV Transmitter
• Stopwatch

Risks:
• UAV crash/damage
• LiPo battery damage
• Damage to VICON space

Recorded Data:
• Amperage [100 Hz]
• Voltage [100 Hz]
• Throttle input [100 Hz]

Success Criteria:
• UAV flight for >18.15 minutes
• Data recorded for flight duration and offloaded between flights
• Flight time
• UAV flight mass 3.3 [kg]
Power Model Verification - Results

Flights 1 and 2 Current Draw (Amps)

Flight 1
- Current Draw: 0.83 A
- Total Typical Error: 1.056 A
- Environmental Error (0.06 A)
- Mass Measurement Error (0.017 A)
- UAV Angle Dissipation (0.13 A)
- Pilot Input Error (0.323 A)
- Power Module Measurement Error (0.5 A)

Flight 2
- Current Draw: 1.02 A
- Typical Data Point @ 17.5 A

Flight 1 σ: 0.83 A
Flight 2 σ: 1.02 A
Success Criteria:

• UAV flight for >18.15 minutes: PASS
• Data recorded for flight duration and offloaded between flights: PASS

1177 mAh reserve (17% of useable battery life)

5.56 A continuous payload draw allowable

At 18.5 minutes: 1.03% deviation from model

1.75 A typical draw
Upcoming Tests

Gimbal Control → Gimbal Pointing → Camera Pointing → UGV Tracking → Blob Detection

GPS Accuracy

GPS Decoding

Payload Platform

Payload Install

UGV Control

UGV Failsafe

UGV Autonomous Flight → UAV Endurance

UAV Manual Flight

System

Mock Systems Test

Full System Test: Scenario #1

Full System Test: Scenario #2

Ground Segment

Full System Comms

Demonstration/Delivery

Flight Test

UAV Test

UGV Test

System Test

Critical Path

Complete
Automatic Flight

Reasoning: Verify operation of the pixracer’s automatic flight system and waypoint positioning system.

Testing Prerequisites:
- Manual Flight
- Safety Systems

Equipment and Facilities:
- VICON space (RECUV Fleming Lab)
- VICON markers
- UAV Transmitter
- Stopwatch

Risks:
- UAV crash/damage
- LiPo battery damage
- Damage to VICON space

Recorded Data:
- Flight time
- VICON data
- Control Inputs

Major Obstacles:
- VICON data to fake GPS
- Publishing VICON data to onboard CPU
- Onboard CPU to flight controller comms.

Success Criteria:
- UAV flight for >18.15 minutes
- UAV stable in flight
Gimbal Pointing Test

Reasoning: Verify that the gimbal pointing software and hardware works to desired specifications. Characterize pointing error in gimbal mechanism. Validate Gazebo models.

Testing Prerequisites:
• Gimbal unit test
• GPS unit test
• Odroid unit test
• Camera unit test

Equipment and Facilities:
• VICON space (RECUV Fleming Lab)
• UGV
• UAV

Risks:
• Damage to camera.
• Damage to gimbal
• Damage to GPS units

Recorded Data:
• Images [7 Hz]
• GPS [1 Hz]
• Pointing angles [1 Hz]

Major Obstacles:
• Servo Jitter
• Relative angle determination

Success Criteria:
• Gimbal keeps vehicle in 90% of frames
System Testing

Starting the week of 3/12
Indoor Mock System Test

Reasoning: Verify that the integrated system is ready to move on to final testing steps.

Testing Prerequisites:
• Automatic Flight
• Gimbal Pointing Test
• Integration
• Watchdogs

Equipment and Facilities:
• VICON space (RECUV Fleming Lab)
• Integrated UGV
• Integrated UAV
• GCS with UI

Risks:
• Schedule slippage
• Integration Failure
• Damage to VICON space

Recorded Data:
• RAW image data [7 Hz]
• Ephemeris data [1 Hz]
• Vehicle position and orientation [100 Hz]
• Gimbal state [1 Hz]
• Vehicle command [50 Hz]
• Housekeeping data [10 Hz]

Success Criteria:
• Mission duration > 18.15 minutes
• Data is saved in the correct format

Major Obstacles:
• UAV heading determination
• Camera integration
Outdoor Mock System Test

**Reasoning:** Verify GPS integration works in the full system.

**Testing Prerequisites:**
- Indoor Mock System Test

**Equipment and Facilities:**
- South Boulder Campus
- Integrated UGV
- Integrated UAV
- GCS
- Wifi router

**Risks:**
- Schedule slippage
- Integration Failure

**Recorded Data:**
- RAW image data [7 Hz]
- Ephemeris data [1 Hz]
- Vehicle position and orientation [1 Hz]
- Gimbal state [1 Hz]
- Vehicle command [50 Hz]
- Housekeeping data [10 Hz]

**Success Criteria:**
- Mission duration > 18.15 minutes
- Data is saved in the correct format

**Major Obstacles:**
- Switching to GPS from VICON data
Full System Test

**Reasoning:** Validate the completed RAVEN design.

**Testing Prerequisites:**
- Outdoor Mock System Test
- Detection Testing

**Equipment and Facilities:**
- South Boulder Campus
- Integrated UGV
- Integrated UAV
- GCS
- Wifi router

**Recorded Data:**
- RAW image data [7 Hz]
- Ephemeris data [1 Hz]
- Vehicle position and orientation [1 Hz]
- Gimbal state [1 Hz]
- Vehicle command [50 Hz]
- Housekeeping data [10 Hz]

**Success Criteria:**
- Mission duration > 18.15 minutes
- Data is saved in the correct
- All data is usable by the customer

**Major Obstacles:**
- Completion of mock systems testing
- Determination
### Procurement Update

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<th>Subsystem</th>
<th>Received</th>
<th>Purchased but not Received</th>
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<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, Barometer</td>
<td>GPS Mount</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, Servo Brackets, Bracket Bearing</td>
<td></td>
</tr>
<tr>
<td>Comms HW</td>
<td>Router, UAV Controller, micro SD cards, Telemetry Radios, Transceivers, Ethernet Cables, WiFi Module</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, Battery Charger, Power Module</td>
<td></td>
</tr>
</tbody>
</table>

**Yet to be Purchased:** Continuous Rotation Servos, Misc. HW, Administrative costs (Printing etc.)
## Cost Plan

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Cost</th>
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<tbody>
<tr>
<td>Vision HW</td>
<td>$1,994.00</td>
</tr>
<tr>
<td>UAV HW</td>
<td>$1,364.45</td>
</tr>
<tr>
<td>Sensor HW</td>
<td>$632.39</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>$342.03</td>
</tr>
<tr>
<td>UGV HW</td>
<td>$302.93</td>
</tr>
<tr>
<td>Misc HW</td>
<td>$86.30</td>
</tr>
<tr>
<td>Admin</td>
<td>$200.00</td>
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<tr>
<td>Money Spent</td>
<td>$5,861.55</td>
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<tr>
<td>Remaining Funds</td>
<td>$1,138.45</td>
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<tr>
<td>Total</td>
<td>$7,000.00</td>
</tr>
</tbody>
</table>

**RAVEN Cost Plan**

Uncertainties: Minor miscellaneous UAV/UGV Hardware.

Risks: UAV Crash, need money to replace.
Conclusion

• Behind schedule by one week
  • Mitigating delay by increasing testing time and crashing schedule
• Next large step is integration and mock system testing
• Have 1 week of buffer left for error during testing
• Under budget by $1,138.45
Questions?
Back up Slides
GPS Error (Backup)

Maximum allowable error:

\[
\tan\left(\frac{AOV}{2}\right) = \frac{2\delta_{err}}{10m}
\]

\[
\delta_{err} = \frac{10m}{2}\tan\left(\frac{28\text{ deg}}{2}\right) = 1.2466m
\]

Z-score for 90% of frames is 1.281551.

\[
\sigma = \frac{1.246640014m}{1.281551} = 0.9728m
\]

Therefore, the GPS error must have a standard of deviation less than or equal to 0.973 m in order to meet requirement.
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.

<table>
<thead>
<tr>
<th>Old Gimbal</th>
<th>New Gimbal</th>
</tr>
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<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>
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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 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>
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<tr>
<td>Gimbal</td>
<td>76g</td>
<td>1</td>
<td>76g</td>
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<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>
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<tr>
<td>Wifi Receiver</td>
<td>31g</td>
<td>1</td>
<td>31g</td>
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<tr>
<td>RC Receiver</td>
<td>15g</td>
<td>1</td>
<td>15g</td>
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<tr>
<td>ESC</td>
<td>31g</td>
<td>6</td>
<td>186g</td>
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<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>
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</table>

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 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

\[ D = V \cdot t \]

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

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

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

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

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

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