Individual Lab Report #3

Progress Review 4

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Team B

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1 Individual Progress

1.1 PCB Assignment

After taking over from my teammate Jet, I focused on completing the board design and tracing aspects of our PCB assignment. Building upon the foundation from schematic phase, I carefully translated the electrical connections into a physical board layout. First, I reviewed the existing schematic to understand the power requirements, component placement, and signal routing needs. With particular attention to the auxiliary battery system for hot-swapping capability, I strategically placed components to minimize trace lengths for critical signals while ensuring adequate separation for thermal management. I then executed the board layout, creating optimal trace routing that balanced electrical performance with manufacturing constraints. This included:

Designing proper copper pour zones for power and ground planes Implementing the correct trace widths based on current requirements Placing vias strategically to maintain signal integrity Ensuring appropriate clearances between high-voltage and signal traces Optimizing component placement for ease of assembly and maintenance

I also performed comprehensive design rule checks (DRC) to verify that the board layout met all manufacturing specifications and electrical requirements. After addressing any DRC issues, I generated the final Gerber files necessary for PCB fabrication. The completed board design successfully integrates all the components from the schematic, including the buck converter for 24V to 5V conversion, the diode system for the auxiliary battery, and all the connectors matching our existing hardware. The final design provides a reliable power distribution system that meets our drone's demanding requirements while maintaining compliance with DARPA's NDAA standards.

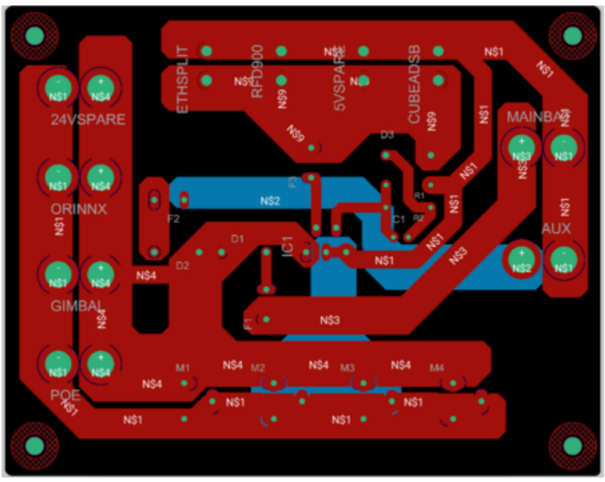

Figure 1: Board Design

1.2 MRSD Project

1.2.1 PX4 Autonomy System Development

The foundation of our aerial platform's capability rests on a robust autonomy stack that required significant debugging and enhancement efforts. A series of critical issues were addressed through systematic analysis and targeted solutions:

- **Sensor Fusion Troubleshooting:** Resolved persistent takeoff interruption issues by conducting in-depth analysis of Extended Kalman Filter (EKF) sensor data logs, which revealed both GPS instability patterns and mechanical failure points requiring hardware intervention.
- **Navigation System Enhancement:** Successfully corrected compass instability issues and implemented proper PX4 function usage, resulting in consistently stable autonomous takeoff capability under varied environmental conditions.
- **System Integration:** Implemented and optimized a comprehensive autonomy stack that integrated multiple subsystems:
  - Fixed bugs in the geofence mapping algorithm originally developed by Joshua Pen
  - Assisted with power management through drone battery monitoring system implementation
  - Supported Foxglove UI development for improved operator visibility
  - Initiated NDAA-compliant RTK integration to substantially improve GPS estimate accuracy and stability

1.2.2 Detection System Optimization

The detection capabilities of the platform underwent substantial improvement through focused optimization efforts:

- **Model Evaluation and Selection:** Conducted comprehensive testing of multiple detection models using flight test data collected during field operations.
- **Edge Computing Optimization:** Successfully deployed and debugged person detection model on resource-constrained edge device, achieving a significant **30**× improvement in inference speed without compromising detection accuracy.
- **Runtime Environment Configuration:** Optimized Docker configuration specifically for efficient PyTorch operation on edge computing platforms with limited computational resources.
- **Ongoing Development Initiatives:**
  - Advanced the gimbal lock functionality development for improved tracking of detected persons
  - Drafted intelligent autonomy pipeline architecture to enhance autonomous decision-making capabilities

1.2.3 Ground Control Implementation

The development of reliable ground control capabilities was essential for field operations:

- **Station Deployment:** Successfully adapted and deployed a complete ground control station (GCS) with appropriate modifications for our specific mission requirements.

- **Communication Pipeline:** Established robust bidirectional communication between the GCS and aerial platform, ensuring command reliability within the autonomy system architecture.
- **Middleware Troubleshooting:** Resolved complex ROS2 FastDDS middleware communication issues that were preventing reliable data exchange between detection and autonomy Docker containers.

1.2.4 Post-DARPA Workshop Contributions

Following the DARPA workshop, several advanced features were implemented to enhance system capabilities:

- **Hardware Design:**
  - Developed custom PCB board design (pcb.brd)
  - Manually traced PCB schematic provided by team member Jet to ensure manufacturing accuracy
- **Control System Integration:** Initiated ATAK integration as requested by Prof. Basti to implement enhanced drone control capabilities.
- **Computer Vision Enhancement:**
  - Labeled 500 frames of person detection data collected during DARPA workshop
  - Implemented various data augmentation techniques to expand the limited dataset to 3,000 frames
  - Fine-tuned detection model using specialized learning techniques to prevent overfitting on the relatively small dataset
- **Geospatial Functionality:**
  - Developed novel method to accurately estimate detected casualty's GPS coordinates
  - Implemented complete pipeline to send detected GPS data with bounding boxes in real-time to ground station

1.2.5 Additional Support Activities

Beyond core development work, operational support was provided during critical demonstration phases:

- **AirLab Industry Demo Day:** Provided comprehensive operational assistance for drone demonstrations and served as technical support to rapidly troubleshoot issues throughout the demonstration process.
- **Documentation and Usability:** Created the first version of the preflight checklist and drafted a one-line autonomy launching method to simplify field operations.

2 Challenges

2.1 PCB Assignment

For completing the drone's PCB design, I encountered several significant technical challenges.

2.1.1 Power Distribution Layout

Implementing the power system design while maintaining proper current capacity and thermal management.

Specific Issues:

- The auxiliary battery system components (diodes, protection circuits) required careful thermal consideration
- Buck converter components needed proximity for signal integrity but adequate separation for heat dissipation
- Multiple connector types with varying footprints needed strategic placement to allow for proper mechanical mounting

Solution: Grouped related components while optimizing for heat distribution, multiple placement iterations to find the optimal arrangement that minimized trace lengths, utilized both sides of the PCB to maximize available space while maintaining accessibility for connectors

2.1.2 Complex Power Trace Routing

Challenge: The power distribution network presented exceptional routing challenges due to varying current requirements across the board.

Specific Issues:

- High-current paths from batteries required significantly wider traces than signal lines
- The hot-swap functionality required carefully routed diode paths with minimal resistance
- Buck converter input/output paths needed proper sizing to handle current while minimizing voltage drop

Solution: Used varying trace widths based on calculated current requirements. Created copper pour zones strategically connected to power nets. Used multiple vias in parallel for high-current paths between layers. Implemented star-point grounding to prevent ground loops and interference

2.2 MRSD Project

There were two major obstacles to our MRSD project this time around - scattered software infrastructure, and hardware failure.

Hardware failure was the most present issue. During assembly, and during repeated testing, we noticed that occasionally, our video feed would go completely gray. After a while of debugging, we discovered that one of the wires within a data cable, corresponding to a USB signal according to the pinout document, had actually disconnected. Given the gimbal's price, and the criticality to our project, we opted to immediately repair it as soon as possible.

Figure 2: Broken data cable, under a soldering microscope.

Unfortunately, despite three hours of surgical effort, we were unable to reconnect the last wire together. Fortunately, a distributor of the gimbal was in Florida, and through shipping, we were able to receive a replacement almost immediately, allowing us to resume work on the gimbal's algorithms rapidly.

The next challenge faced was the distribution of software tasks, and the difficulty of integration between them. While we had three separate software engineers, and one additional software architect/designer, a differentiation in skill/approaches meant that our code largely wasn't standardized. While earlier on, we prioritized the completion of individual features, when integrating these features into a larger network, we found more and more problems that cropped up due to a failure of direct integrated work from the beginning, which definitely slowed down progress, as individual bugs on separate components could interrupt critical links, and with only one responsible person, would then cause delays that would interrupt the critical path that prevented other software components from being tested adequately.

To address this, we stepped in to unify ROS messages and ROS topics, as well as designing tests that did not have co-dependencies, and if they did, to have quick turnarounds that allowed us to continue understanding which parts need improvement, and which parts were deemed mission-ready. Thanks to our improvements, we have been able to start running continuous integration tests in March, just barely in time for the workshop.

3 Team Work

3.1 MRSD Project

Name	Contribution
Jet Situ	Represented the MRSD team at the DARPA Triage Workshop 2 event in Georgia, working alongside Lockheed Martin engineers to integrate their drone prior to competition data collection. Then worked to coordinate drone flight permissions and capability prior to the Team Chiron Demo Day event. Acted as safety pilot and speaker during the Industry Demo Day, and performed flight testing on the days prior for drone endurance and capability integration. Designed and submitted the PCB final draft creation materials.
Joshua Pen	Assisted in fully integrating and test Path Planner for searching the Geofence Zone and Local Search of Patient Planner with behavior tree (also integrate with Patient Detection), Design, integrate and test Triage Planner. Triage Data Collection from Test Flight. Design new mount for Rajant DX2 radio. Contribute to wire management. Contributed to project management and logistics. Helped Setup Industry Demo day, and create slides for Demo Day presentation. Helped construct presentation for PDR and PR3. Helped construct SVD and FVD one-page description.
Lance Liu	1. Autonomy: Resolved takeoff interruption issues through EKF sensor data analysis; Debugged compass instability; Assisted in drone battery monitoring module; Supported Foxglove UI development; Integrated improved geofence mapping algorithm; Initiated NDAA-compliant RTK integration; Refined overall autonomy system robustness. 2. Detection System Enhancements: Tested multiple detection models with flight recording; Optimized person detection model deployment (30x faster inference); Configured Docker for PyTorch on edge devices; Improved gimbal lock functionality for detected persons (in progress); Initiated intelligent autonomy pipeline (in progress); Enhanced thermal detection through data augmentation and model fine-tuning; Established real-time casualty GPS coordinate estimation and transmission pipeline. 3. Ground Control Implementation: Deployed ground control station with reliable drone communication; Ensured robust command execution; Resolved ROS2 FastDDS middleware issues between containers. 4. Additionals: one-line autonomy launching draft; preflight checklist draft; power distribution PCB board and tracing; Initiated ATAK integration; Provided technical support for the demonstration and workshop.
Gweneth Ge	Provided operational support including communication with airlab and media for the Industry Day demo, making slides for Jet presentation, and video review and editing of collecting data from various test flights and darpa workshop. In addition, I primarily contributed to the issue tracking and presentations required by MRSD project including SVD, FVD, project mangaments, and PR 1, 2, 3.
Yi Wu	Debugged the low latency issue of the people detection algorithm with Lance. Wrapped up the gimbal code for DARPA Workshop. Assist Lance with the thermal detection algorithm. Volunteered as the casualty in the AirLab Industry Demo Day.

4 Plans

4.1 MRSD Project

Name	Contribution
Jet Situ	Will work on robustness and cleaning procedures prior to SVD flight tests. Will coordinate and work on integrating gimbal software with Lockheed Martin and Lance. Will work with Wuyi and Lance on software reorganization and documentation prior to SVD. Will assist Josh on mechanical redesign of drone to increase performance.
Joshua Pen	Contributed to project management and logistics. Design new mount for all components on drone (to reorganize components and drone wiring). Help design the Inter-UAV De-conflict algorithm.
Lance Liu	1. PX4 Autonomy Enhancement: Complete NDAA-compliant RTK integration; Further refine autonomy system robustness through comprehensive testing; 2. Detection System Completion: Finalize person detection model optimization; Complete gimbal lock functionality for detected persons; Implement and test intelligent autonomy pipeline in field conditions; Explore ID&Re-ID capabilities beyond person detection. 3. System Integration: Complete ATAK integration for drone control; Finalize GPS coordinates estimation accuracy for detected casualties; Optimize real-time data transmission pipeline; Integrate all subsystems more cohesively. 4. Testing: Conduct extensive field testing
Gweneth Ge	I will continue working on overall project management and communication with airlab, potential media/sponsors as well as NREC/Mill19. In addition, I will help with Josh on reorganizing components and drone wiring, along with the inter-uav deconflict algorithm.
Yi Wu	Integrate the human pose detection algorithm in the perception module; upgrade the pose detection with known gimbal specs like intrinsic matrix. Working with Lance, check if AirLab has implemented the Re-ID algorithm; if not, review SOTA Re-ID algorithm and wrap it into ROS2 pkg.

Table 1: Team Members and Their Plans