Final Presentation

Target Acquired

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Requirements and Deliverables

Need statement: The ASE Design Team and Austin Fire Department need a software able to recognize targets of interest, discern between critical/non-critical targets, and deliver accurate GPS coordinates within a generated map.

- Guaranteed Deliverables
    - Image recognition software able to recognize and classify TOI’s
    - Targets of Interests’ GPS location & classification (CAT/CRT)
    - Generated map of area of interest
- Stretch Goals
    - An interactive map with that is paired with the respective GPS coordinates

(Rohan)

Decision Matrix

Technology Differentiation

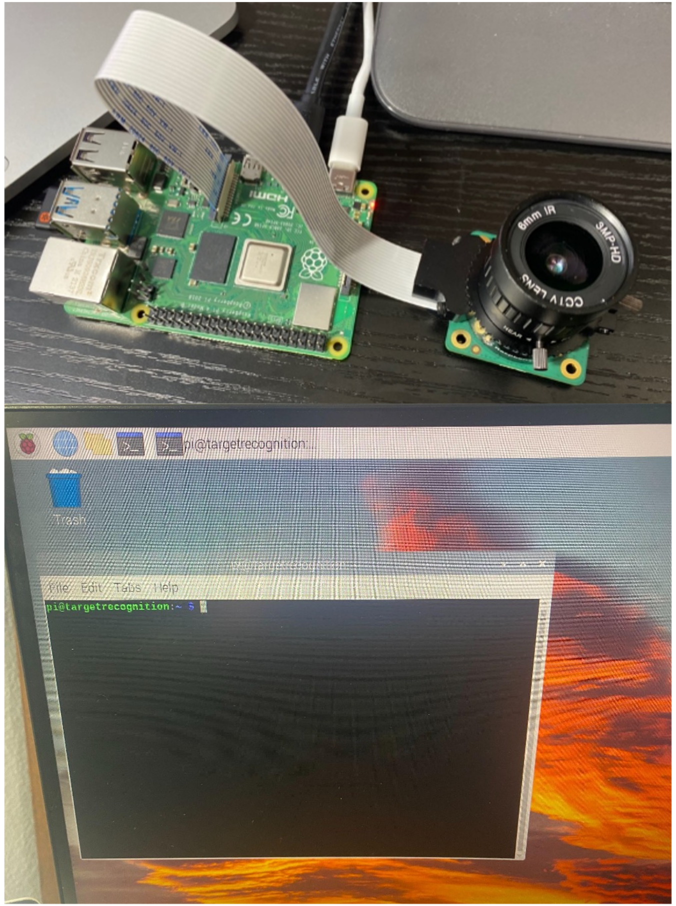
Customer Satisfaction

	Easy to do	Hard to do
Needs	1) Collect video feed of AOI and GPS coordinates (Successful during simulation run) 2) Generate map of field given classifications and GPS locations (Successful during simulation run) 3) Transmit generated map to contractor(Not Implemented)	1) Refine GPS coordinates to get more accurate target and tarp locations (Successful during simulation run) 2) Classify TOI's as critical and non-critical (Successful during simulation run)
Wants	1) Identify static/simple features from AOI (ex: trees, grass, changes in elevation, etc.) (Not Implemented) 2) Incorporate interactive elements into generated map (Not Implemented)	1) Pair GPS coordinates with image frames from video feed (Successful during simulation run) 2) Design more "efficient" target recognition algorithm that improves detection accuracy and/or optimizes runtime (Successful during simulation run) 3) Identify human faces/emotions in addition to identified TOI's (Not Implemented)

(Justin)

Final Design Plan

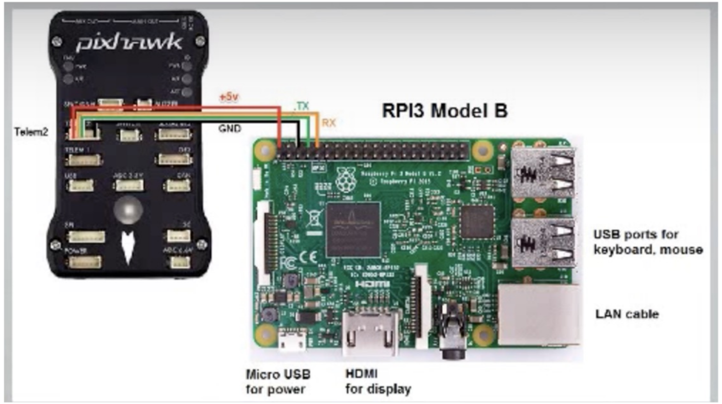
Assembly and Set-up of Imaging System



- Debian Linux OS was flashed from user guide to SD card and inserted into SD card port
- Power supplied to Raspberry Pi using USB-C interface
- Micro HDMI to HDMI cable connected for display of Raspberry Pi computer to connected device
- Peripheral devices (mouse and keyboard) connected through USB port
- CSI interface used to connect the Raspberry Pi High Quality Camera (HQC)

(Nicholas)

Hardware Overview for the Mission



- Camera and Raspberry Pi working outside of the plane, next they must be integrated into the plane
- The camera was mounted on the bottom of the plane, while the Pi needed to be near the Pixhawk
- Through the pinout to the left, the Pi both received power from the Pixhawk and could send and receive messages from the Pixhawk
- To support this hardware interface, software settings on the Pi also had to be configured, such as enabling serial communication and designating which port would be used for communication with the Pixhawk.

(Nicholas)

Software Overview for the Mission

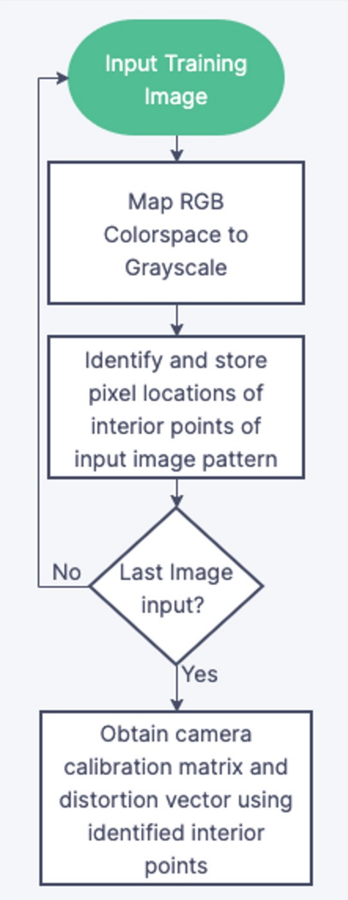
Iterate During Search Phase

- Pull Frame & Lat/Lon
- Undistort & Resize
- RGB Thresholding
- SIFT & FLANN
- Make Decision: Smiley/Frowny/Tarp
- Calculate GPS Location
- Check Distance to Closest Target
- Target Refinement
- Map Generation & Overlay

ATR Model

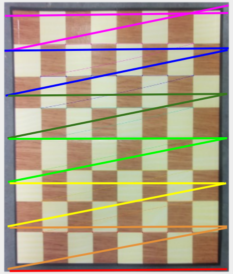
Pass off to ADP Team

Procedure for Camera Calibration Algorithm

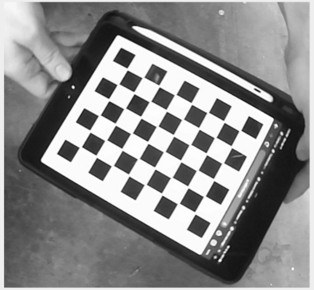


Camera Calibration Flowchart

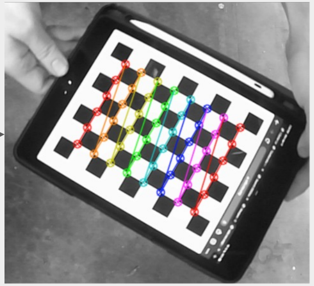
Distorted Hard-copy Chessboard



Undistorted Hard-Copy Chessboard



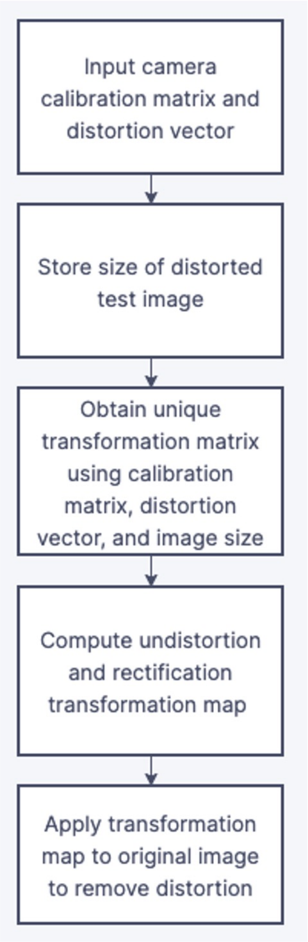
Distorted Digital Chessboard



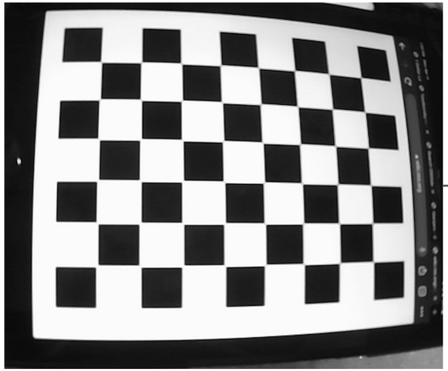
Distorted Digital Chessboard with Interior Points Identified

(Justin)

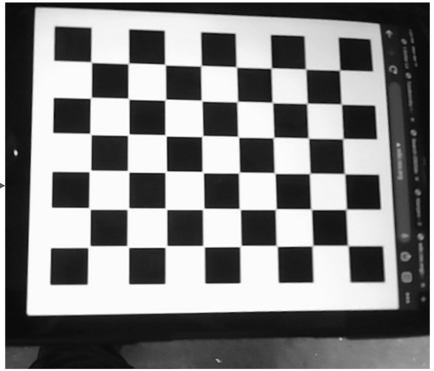
Procedure for Undistortion Algorithm



Flowchart for Undistortion Algorithm



Training image with radial distortion



Undistorted training image after application of transformation map

(Justin)

Map Generation Algorithm

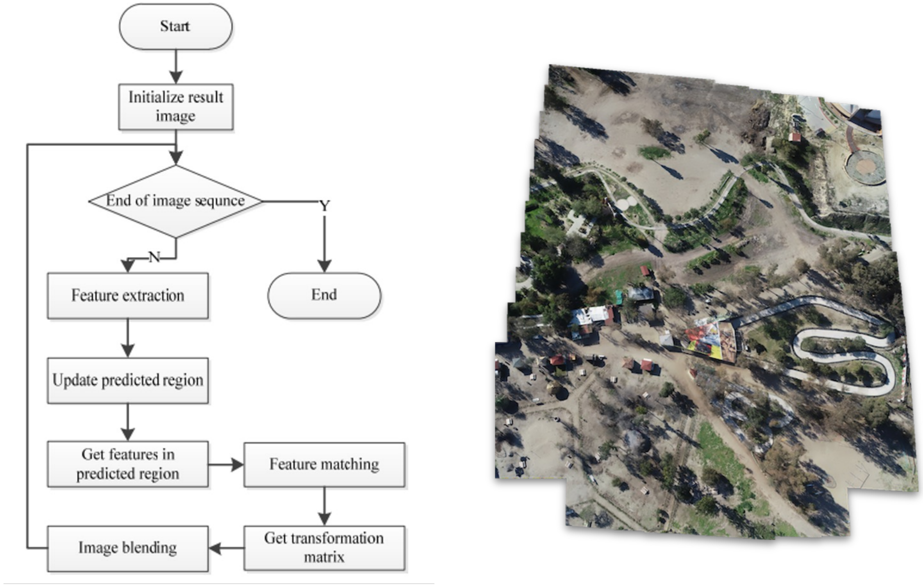


Figure: Flow Chart/Block Diagram for our Aerial Image Stitching algorithm and example output

What type of map generation did we ultimately settle upon?

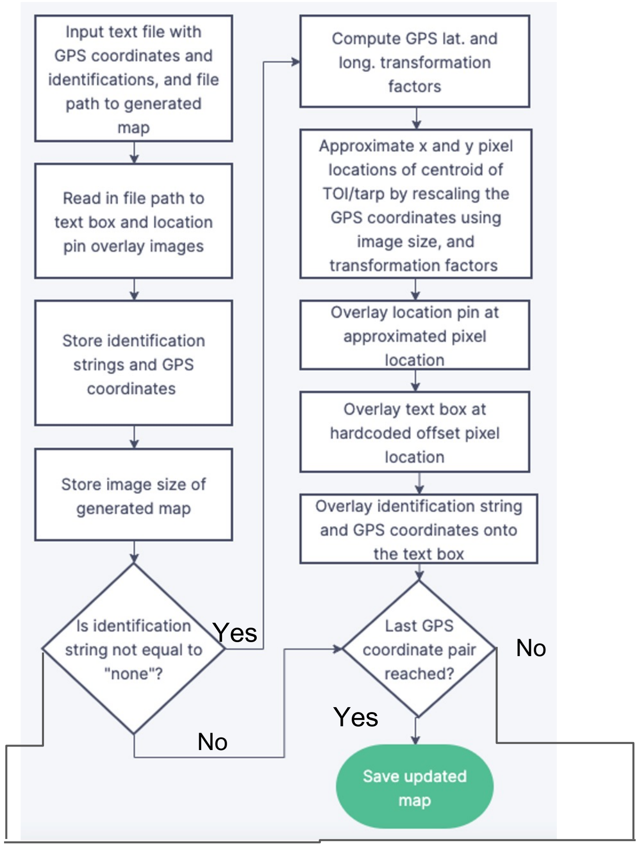
- We chose to use an aerial image stitching algorithm that utilizes:
  - SIFT feature detection and FLANN feature matching
  - Homography transformation to match the images
  - RANSAC to remove outliers

What kind of input does this algorithm require?

- For the best results, our algorithm requires images to:
  - Be undistorted
  - Have decently high overlap between images (60-70%+)
  - Fairly vertical as to not cause too much perspective warping

(Ryan)

Identification and GPS Coordinate Overlay Algorithm



(Justin)

Camera Calibration Results

$$\begin{bmatrix} f_x & 0 & c_x \\ 0 & f_y & c_y \\ 0 & 0 & 1 \end{bmatrix}$$

Camera Calibration
Matrix Definition

$$\begin{matrix} 3910.01 & 0 & 2021.48 \\ 0 & 3896.32 & 1417.29 \\ 0 & 0 & 1 \end{matrix}$$

Calibration Matrix from Hard-copy Chessboard Images

$$\begin{matrix} 587.394 & 0 & 329.668 \\ 0 & 590.266 & 265.307 \\ 0 & 0 & 1 \end{matrix}$$

Calibration Matrix from Digital Chessboard Images

- Using images of a hardcopy chessboard with inconsistencies in glare and unlevel surface produced a matrix with severe limitations in undistortion and accuracy of map generation

- A refined batch of images of a digital chessboard produced a matrix whose undistortion was much more effective

(Justin)

Mission Results

Sources of Error in Mission Performance

Forced pivot in connection with Pixhawk

Lack of sufficient testing of the entire program together

No testing environment for ATR together with flight data

Realistically only had 3 flights to test ATR together with waypoint-driven flight

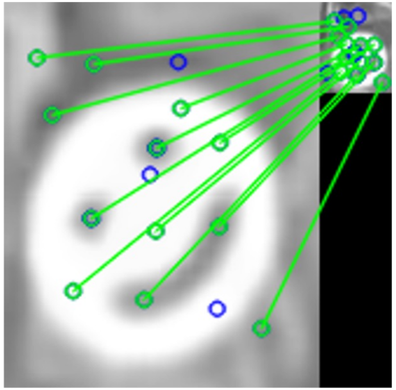
Lack of a robust logging scheme meant less info during flights

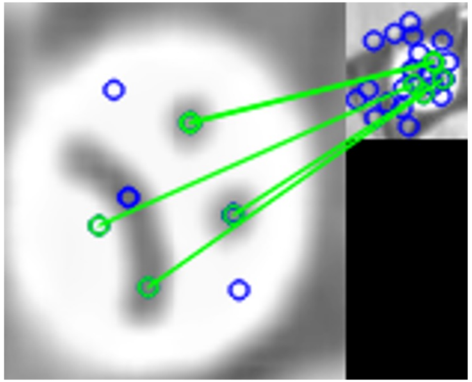
(Nicholas)

Simulated Results

Results from Target Recognition

Type of Target	Search Phase Identifications	Refinement
Tarp	265	4
Smiley Face	261	1
Frowny Face	54	2

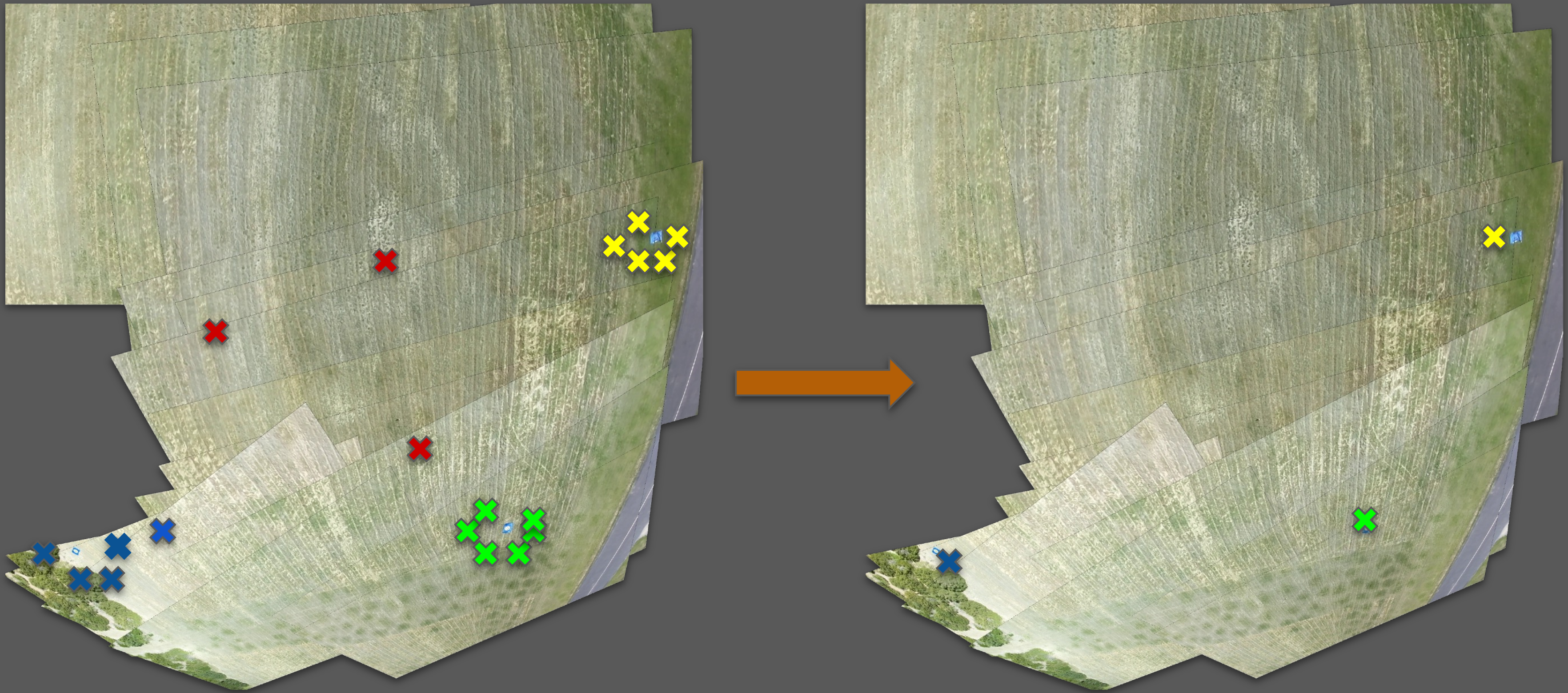




*GPS coordinates were randomly generated during the simulation for each frame of the video that was analyzed

(Preston)

Target Proximity and GPS Refinement



(Preston)

Results from Map Generation

- Although we were ultimately not able to receive images of the field during our fly off, we were still able to stitch together a map using a video from a previous flyout.

- The following two maps are stitched together from frames of two different passes of the field, as such they display slightly different views of the field.

- The second map (bottom) displays all five candidate targets (3 tarps, 1 Smiley, 1 Frowny)

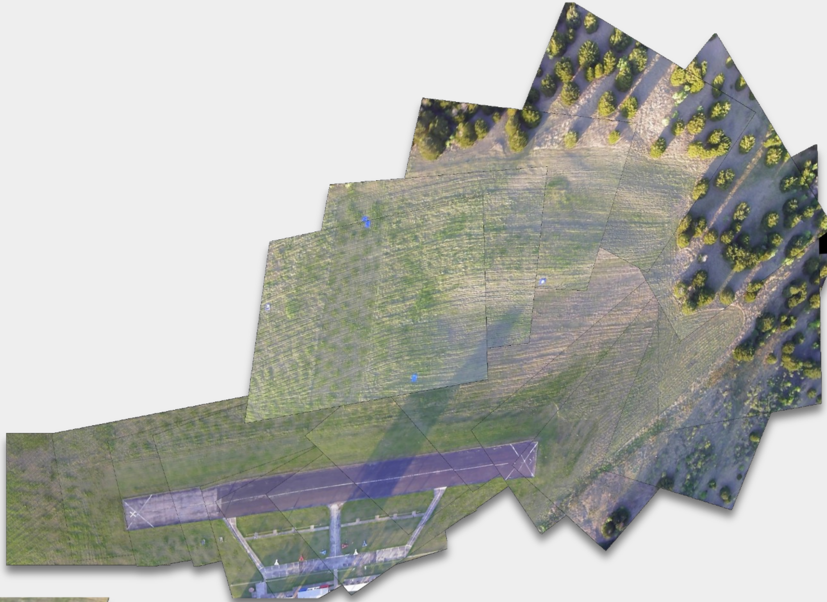


Figure: Map #1 generated from our test video

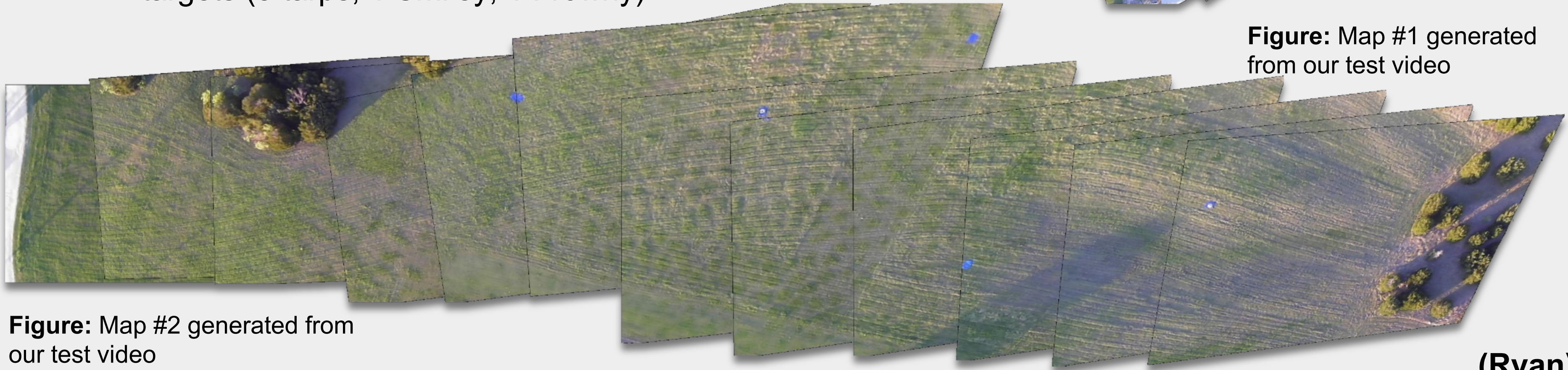
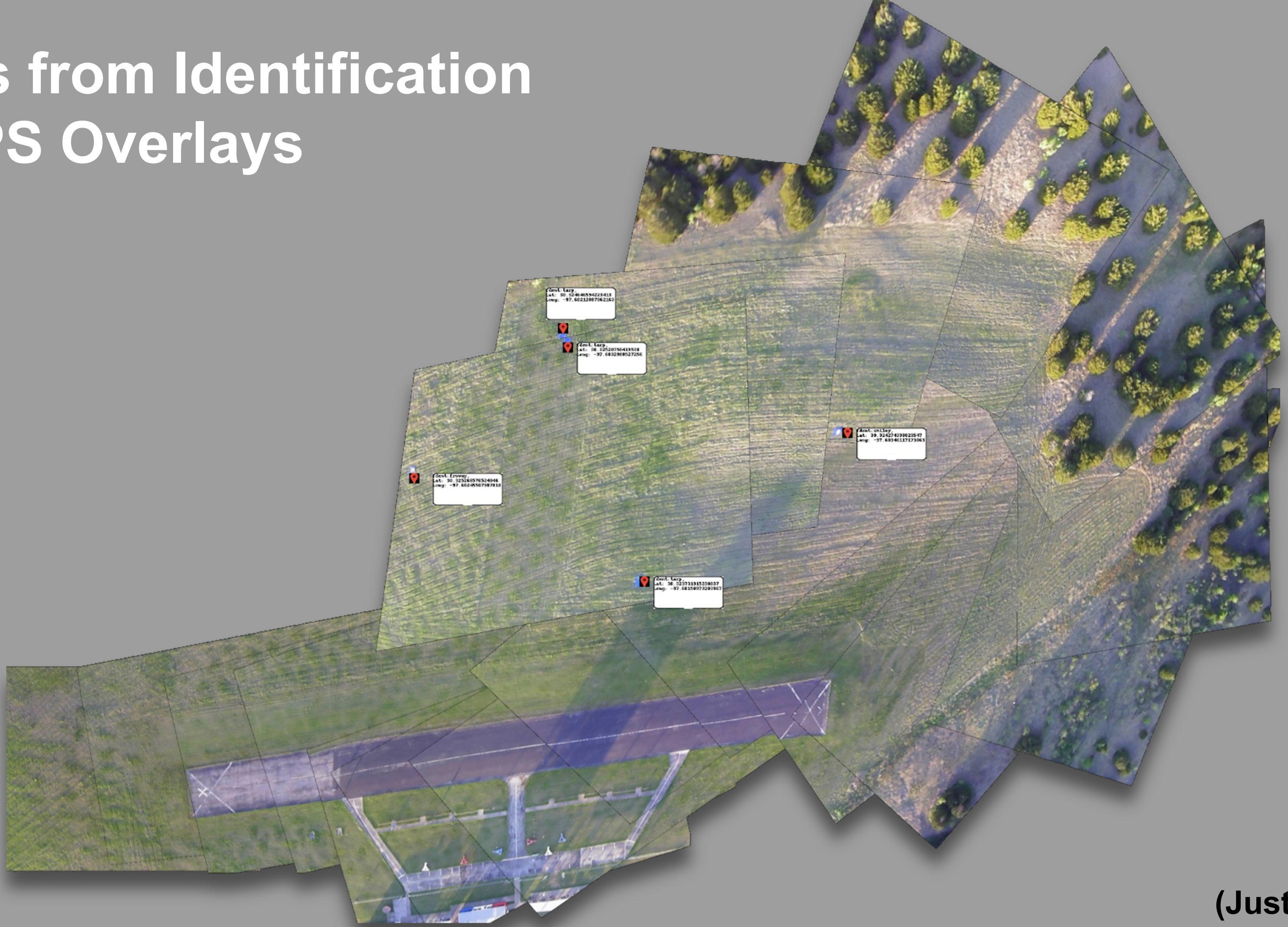


Figure: Map #2 generated from our test video

(Ryan)

Results from Identification and GPS Overlays



(Justin)

Limitations and Shortcomings of Simulated Results

- GPS coordinates were randomly generated
- Overlay of map had to be hardcoded
- Full mission process could not be simulated
- Map generation had to be done separately
- Grouping of targets & refinement is uncorrelated with the video

(Preston)

Project Outlook & Impact

What We Learned?

Functioning code on local machine != functioning code on Pi in the sky

Needed a more robust logging scheme

More integrated testing with Pixhawk & Mission Planner

Needed a flight day purely for testing ATR software

(Nicholas)

Conclusions and Future Work

Deliverable	Success in Practice Flights?	Success in Simulation?
ATR Algorithm	✓	✓
Map Generation	✓	✓
GPS Coord Identification	✗	✗

To explore:

Hardware:

- Successfully integrate all hardware into the plane
- Set up reliable live communication between Pixhawk and Raspberry Pi

Software:

- Generate and transmit an interactive map
- Train ATR code to identify other properties (such as human faces, changes in elevation, environmental features)
- Parallelize code to optimize runtime and refine map generation to maximize stitching accuracy

(Rohan)

Global, Environmental, and Societal Impact

- Global:
    - Semi-autonomous vehicles are already used in search and rescue missions on areas affected by natural disasters
    - Fully autonomous vehicles can improve the search and rescue process
    - ATR and Map Generation scripts are not uncommon
- Societal:
    - Effective usage of UAVs are safer for AFD
    - Easier to deliver supplies to stranded people
- Environmental:
    - UAVs are energy efficient
    - Able to generate a map of an area greatly affected by natural disaster

(Rohan)