ALIS

Aerial Land Inspection System

May 1617
Sponsored by Vermeer Corporation

Introduction
Planning
Design
Testing
Conclusion

Problem Statement

- Decline of skilled operators for agricultural equipment
- Increased interest in remote controlled machinery
- View the environment prior to arrival
- Automate the capture process

Project Deliverables

- Map the terrain of a future work site
- Generate a quadcopter flight path based on user input
- Autonomously fly the quadcopter and capture images
- Create a VR-compatible 3D model from the images

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Functional Requirements

- Sustained flight in adverse weather
- At least 20 minutes of flight time
- Fly up to ½ mile away from controller
- Take images with more than 50% overlap
- Model generated in less than 6 hours
- Model is viewable in a virtual reality platform

Non-Functional Requirements

- Generate sharp, accurate model
- Terrain agnostic
- System contains safety measures

Risks and Considerations

- FAA Regulations
  - Quadcopter registration
  - System altitude limit
- Battery Life
  - Flight pattern
  - Testing area
- Winter
  - Limited testing period

Market Research - Quadcopters

- Lumenier QVA250 Kit with OpenPilot
- Parrot Bebop
- DJI Matrice 100
- DJI Phantom 3 Advanced

Photogrammetry

Transform 2D pictures into a 3D model

1. Align Images
2. Generate Point Cloud
3. Apply Texture
4. Export Model

Photogrammetry Challenges

- Generation time
  - CPU / GPU dependent
  - Software Dependent
- Polygon limit
  - Unity Game Engine
  - Model decimation

Market Research - Photogrammetry

- VisualSFM + CMP-MVS
  - Long generation time
  - No longer supported
- Pix4D
  - Expensive
- RealityCapture
  - Fast generation time

Prototype Costs

- Powerful Windows PC - Already Available
- DJI Phantom 3 Advanced - $1000
- Android 4.2+ Device - $100
- Capturing Reality License - $112

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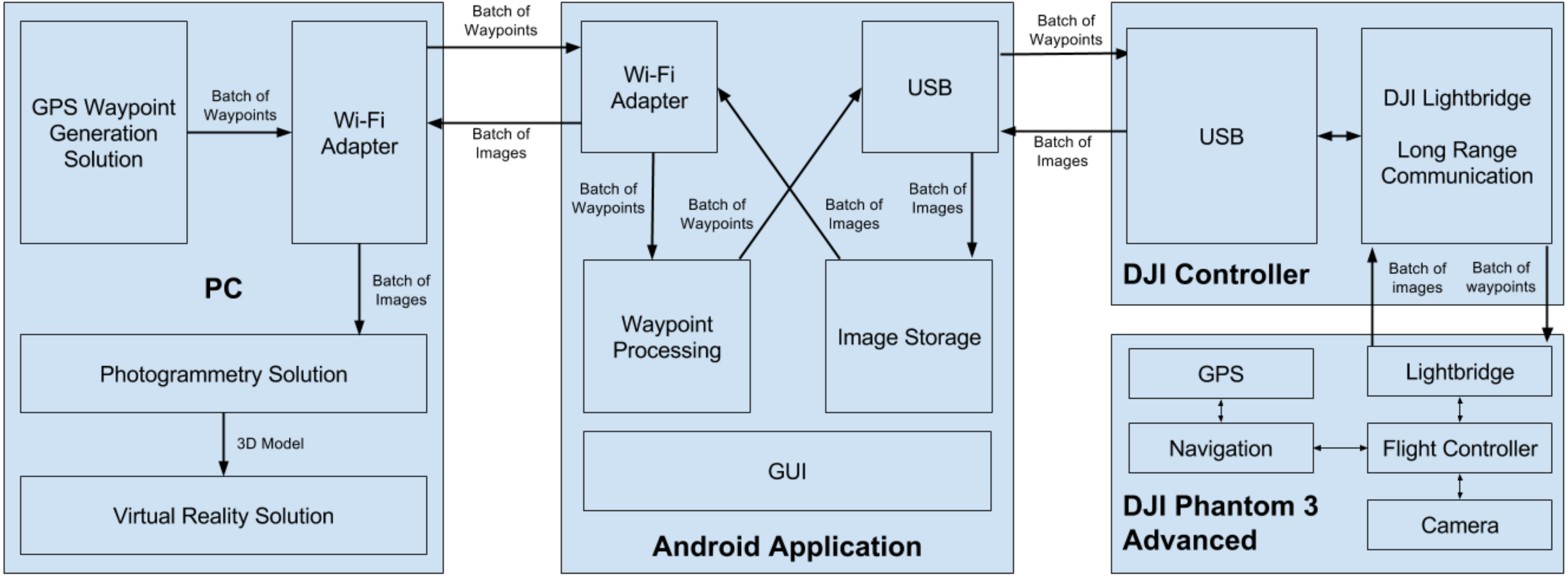
Design Challenges

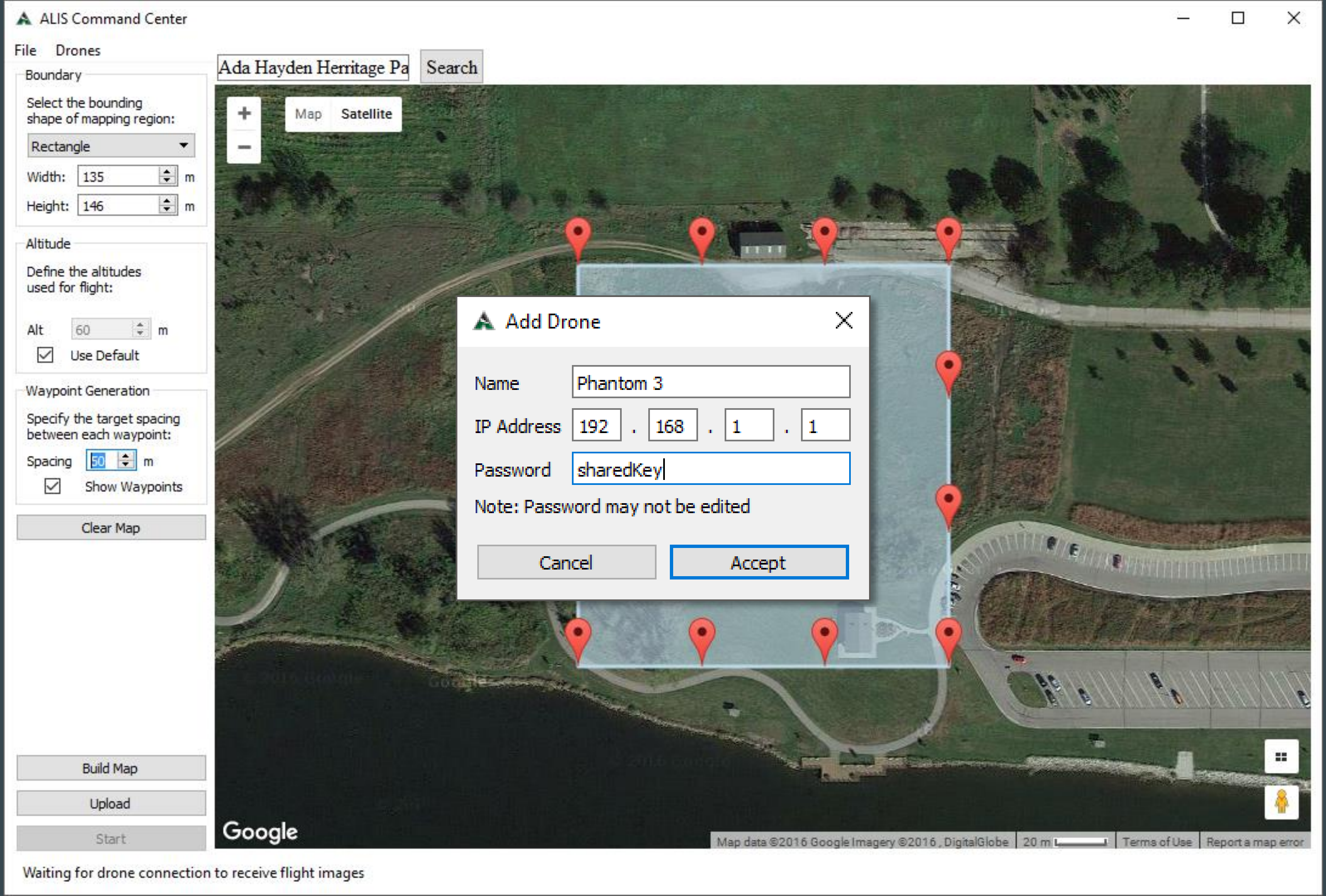
- Quadcopter agnostic
  - Other systems may be used
  - Modular system
- DJI Mobile SDK
  - Android / iOS Only
  - Update to Version 3.0
  - Documentation



GPS Waypoint Generation Solution
Batch of Waypoints
Wi-Fi Adapter
Batch of Images
PC
Photogrammetry Solution
3D Model
Virtual Reality Solution
Batch of Waypoints
Batch of Images
Wi-Fi Adapter
USB
Batch of Waypoints
Batch of Waypoints
Batch of Images
Batch of Images
Waypoint Processing
Image Storage
GUI
Android Application
Batch of Waypoints
Batch of Images
USB
DJI Lightbridge
Long Range Communication
DJI Controller
Batch of images
Batch of waypoints
GPS
Lightbridge
Navigation
Flight Controller
Camera
DJI Phantom 3 Advanced

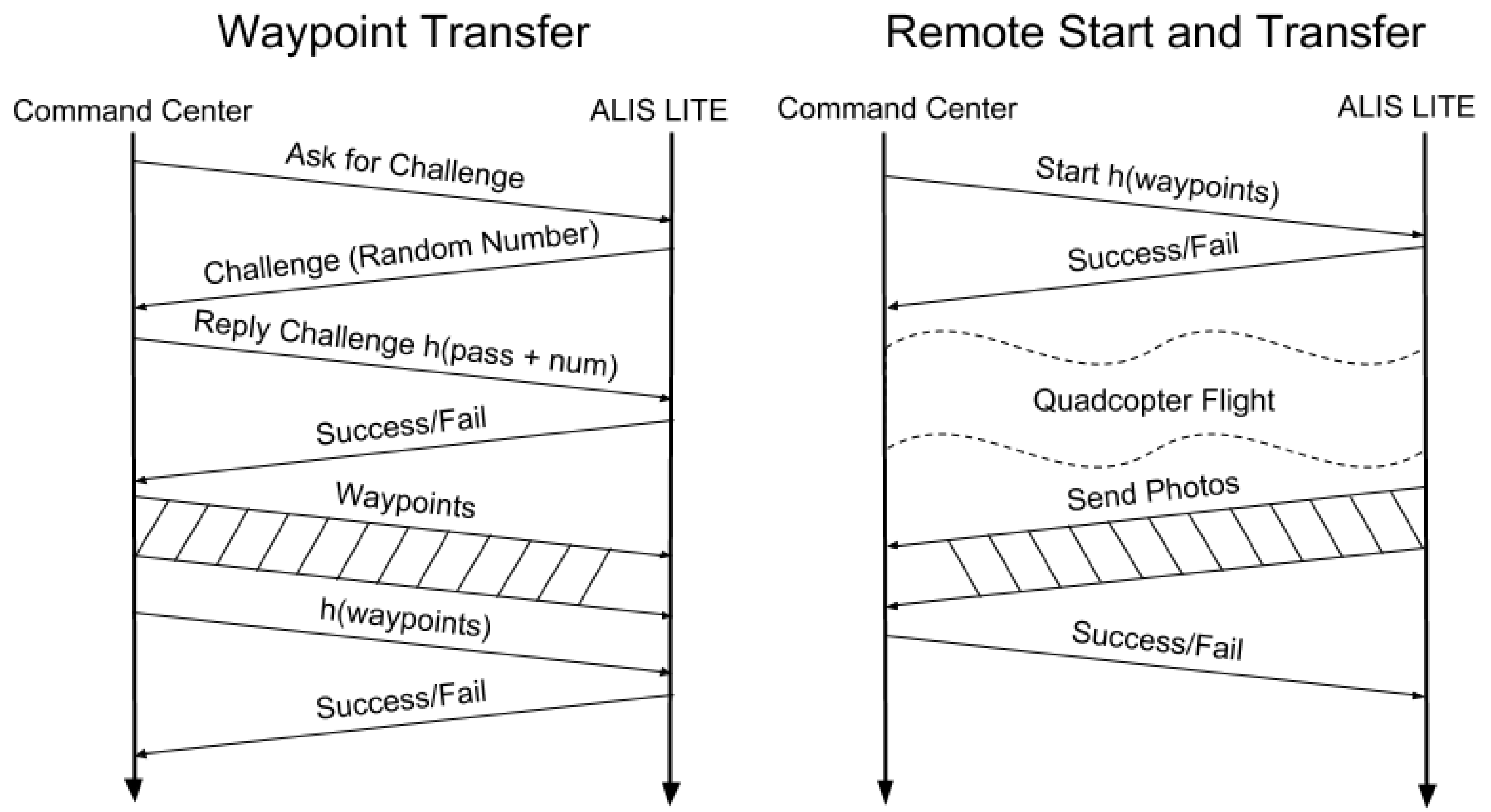
ALIS Command Center

- Built with Qt GUI framework using C++
- Google Maps integration
  - JavaScript to C++ Messages
- Automatic route generation
- Network communication to Android device


ALIS Command Center
File
Drones
Ada Hayden Herritage Pa
Search
Boundary
Select the bounding shape of mapping region:
Rectangle
Width: 135 m
Height: 146 m
Altitude
Define the altitudes used for flight:
Alt 60 m
Use Default
Waypoint Generation
Specify the target spacing between each waypoint:
Spacing 50 m
Show Waypoints
Clear Map
Build Map
Upload
Start
Waiting for drone connection to receive flight images
Map
Satellite
Add Drone
Name Phantom 3
IP Address 192 . 168 . 1 . 1
Password sharedKey
Note: Password may not be edited
Cancel
Accept
Google
Map data ©2016 Google Imagery ©2016 , DigitalGlobe
20 m
Terms of Use
Report a map error

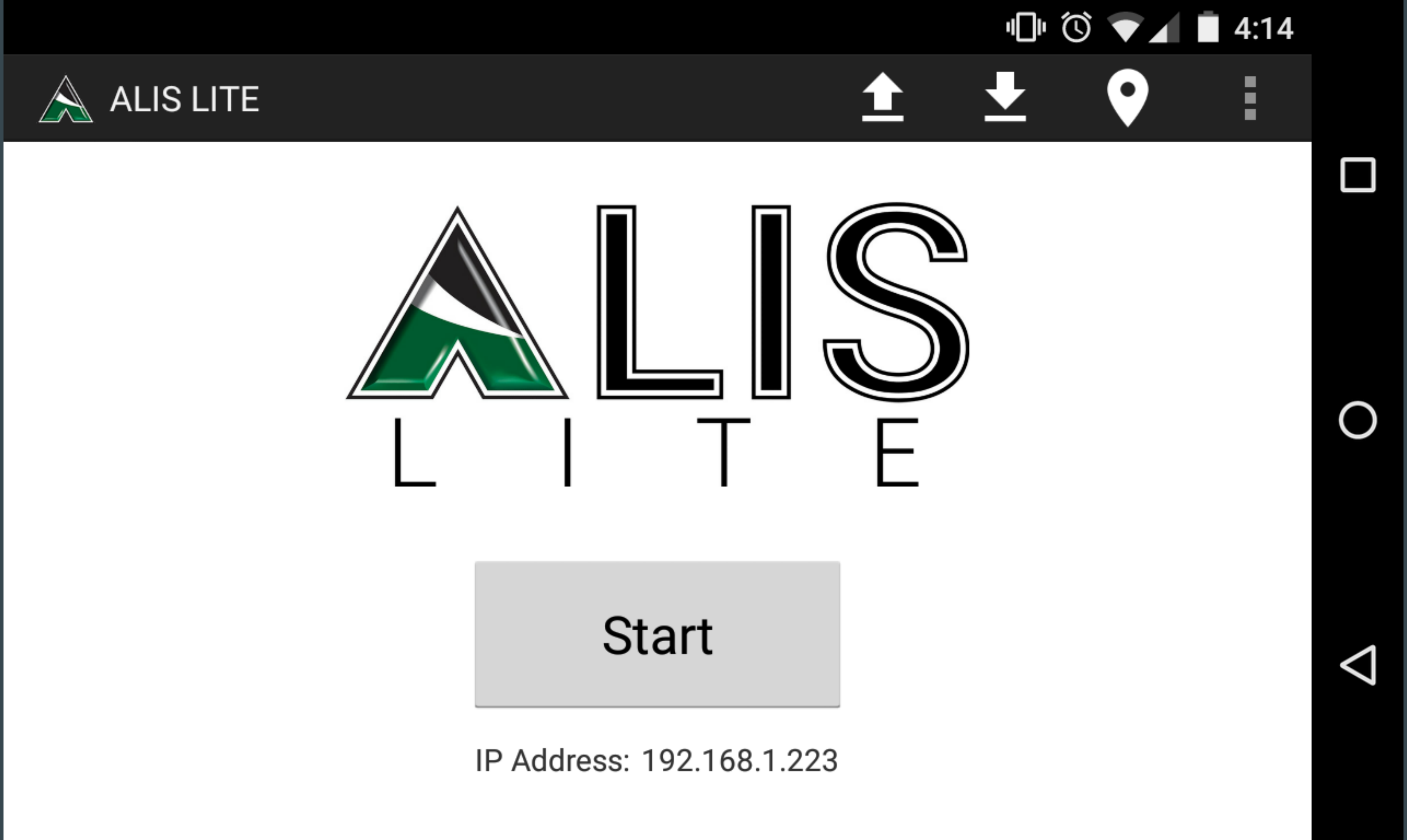
Networking Protocol

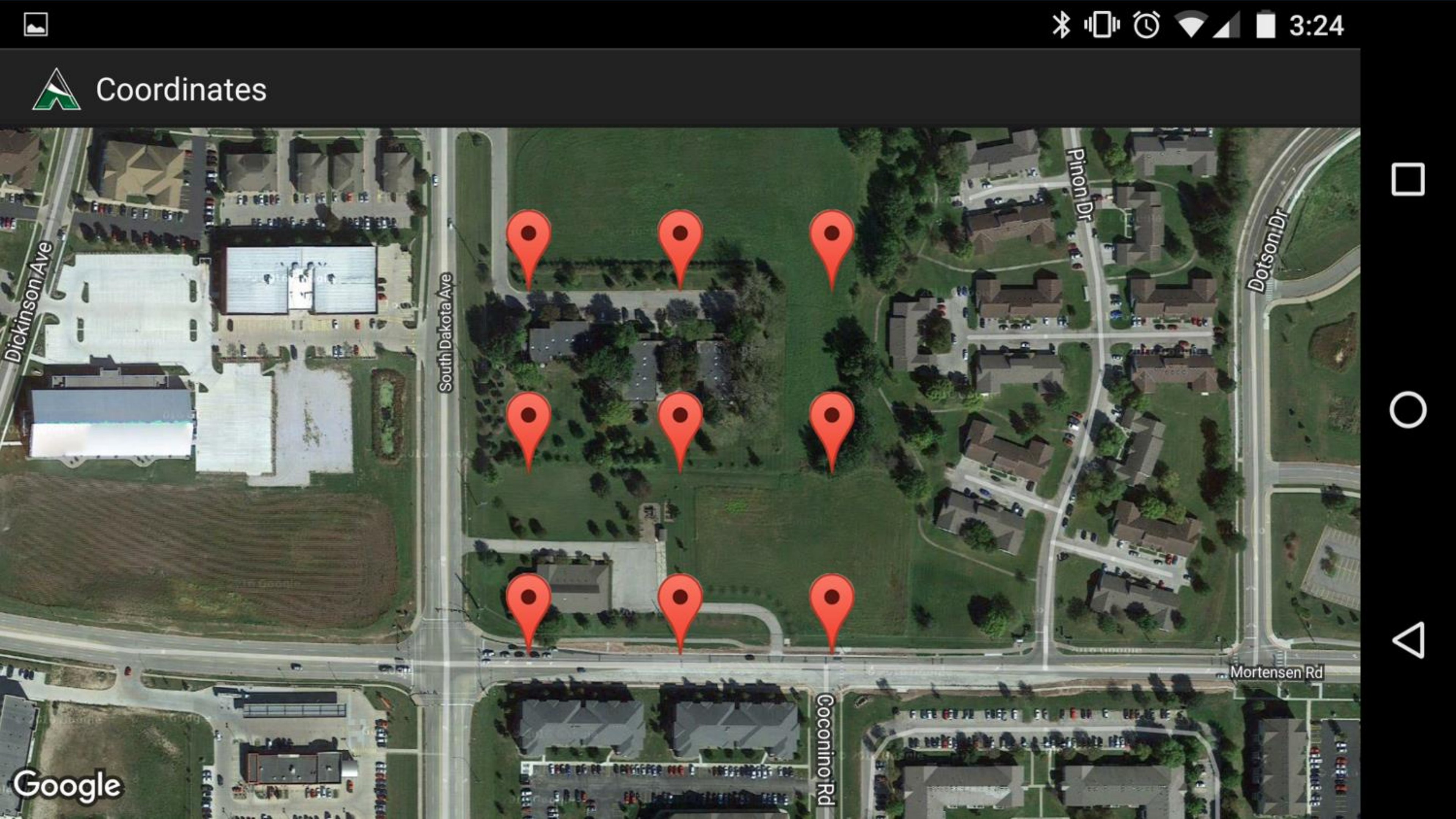
- Verify and Authorize Drone and PC
- Send Waypoints
- Remote Starting of Drone
- Retrieve Photos from Drone
- Fault Tolerant

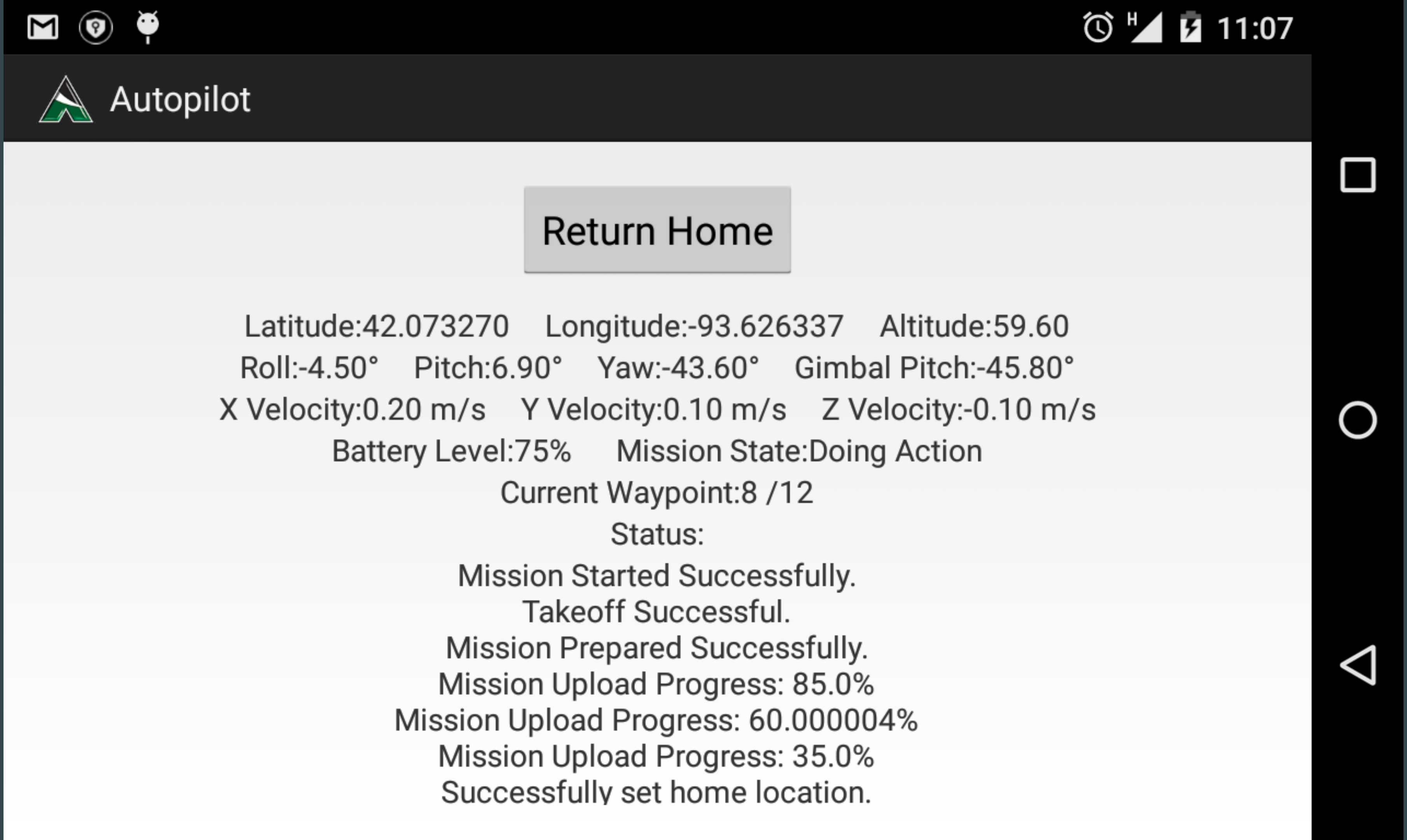

Waypoint Transfer
Command Center
ALIS LITE
Ask for Challenge
Challenge (Random Number)
Reply Challenge h(pass + num)
Success/Fail
Waypoints
h(waypoints)
Success/Fail
Remote Start and Transfer
Command Center
ALIS LITE
Start h(waypoints)
Success/Fail
Quadcopter Flight
Send Photos
Success/Fail

ALIS LITE

- Android Thin Client: acts as a bridge between PC and Quadcopter
  - See the state of the quadcopter
  - Map the coordinates
  - Force it to land
  - Photo transfer
- Uses DJI Mobile SDK 3.0.1 for quadcopter control
  - SDK is asynchronous, need to watch for race conditions
  - Challenge: SDK is also poorly documented


4:14
ALIS LITE
ALIS
LITE
Start
IP Address: 192.168.1.223


3:24
Coordinates
Dickinson Ave
South Dakota Ave
Pinon Dr
Dotson Dr
Mortensen Rd
Coconino Rd
Google


11:07
Autopilot
Return Home
Latitude:42.073270 Longitude:-93.626337 Altitude:59.60
Roll:-4.50° Pitch:6.90° Yaw:-43.60° Gimbal Pitch:-45.80°
X Velocity:0.20 m/s Y Velocity:0.10 m/s Z Velocity:-0.10 m/s
Battery Level:75% Mission State:Doing Action
Current Waypoint:8 /12
Status:
Mission Started Successfully.
Takeoff Successful.
Mission Prepared Successfully.
Mission Upload Progress: 85.0%
Mission Upload Progress: 60.000004%
Mission Upload Progress: 35.0%
Successfully set home location.

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Unit Testing

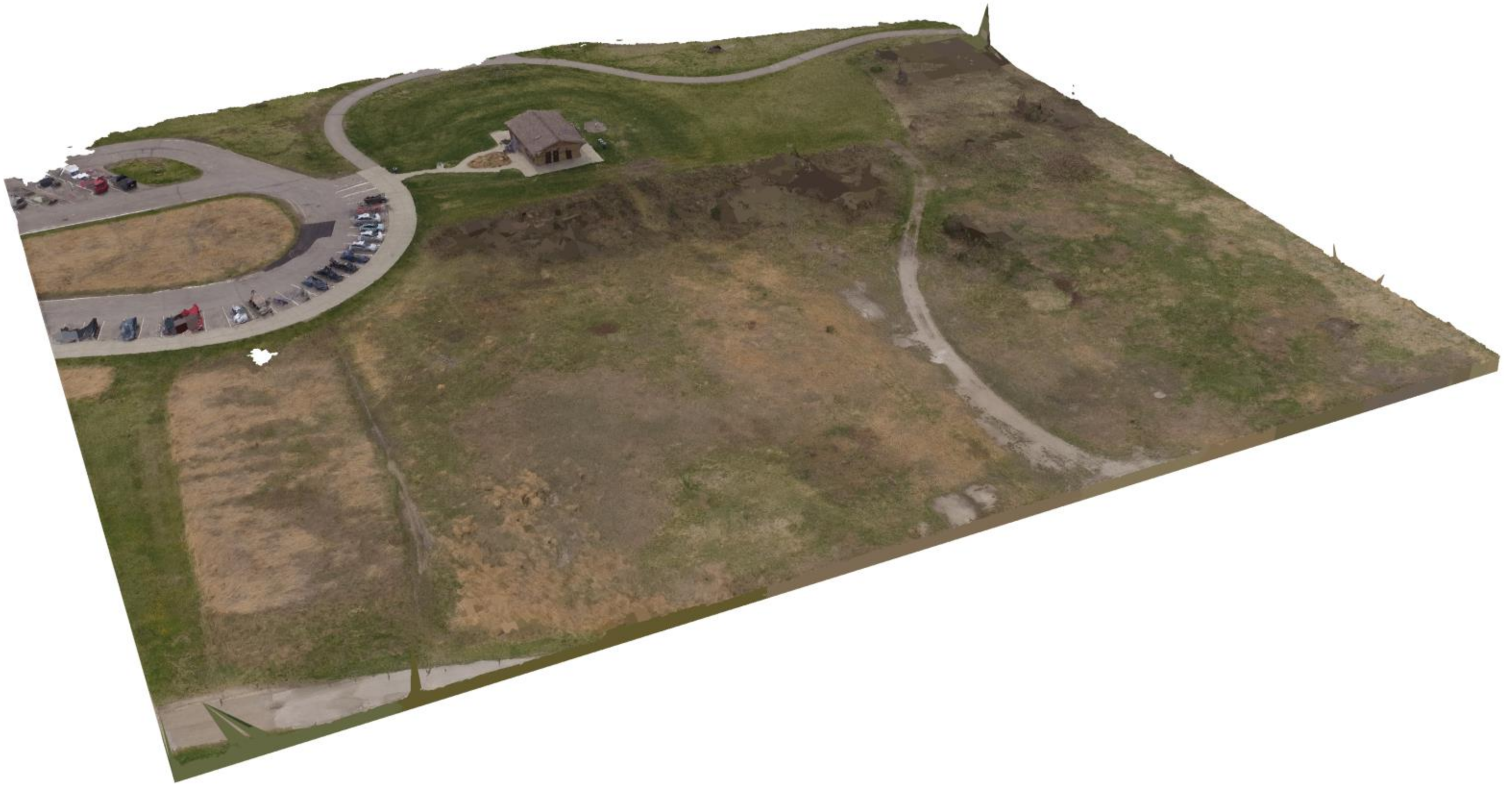
- Windows
  - Generates correct waypoints
  - UI usability testing
- Android
  - Receive mock waypoints and generate flight mission
  - Hard to test control of quadcopter

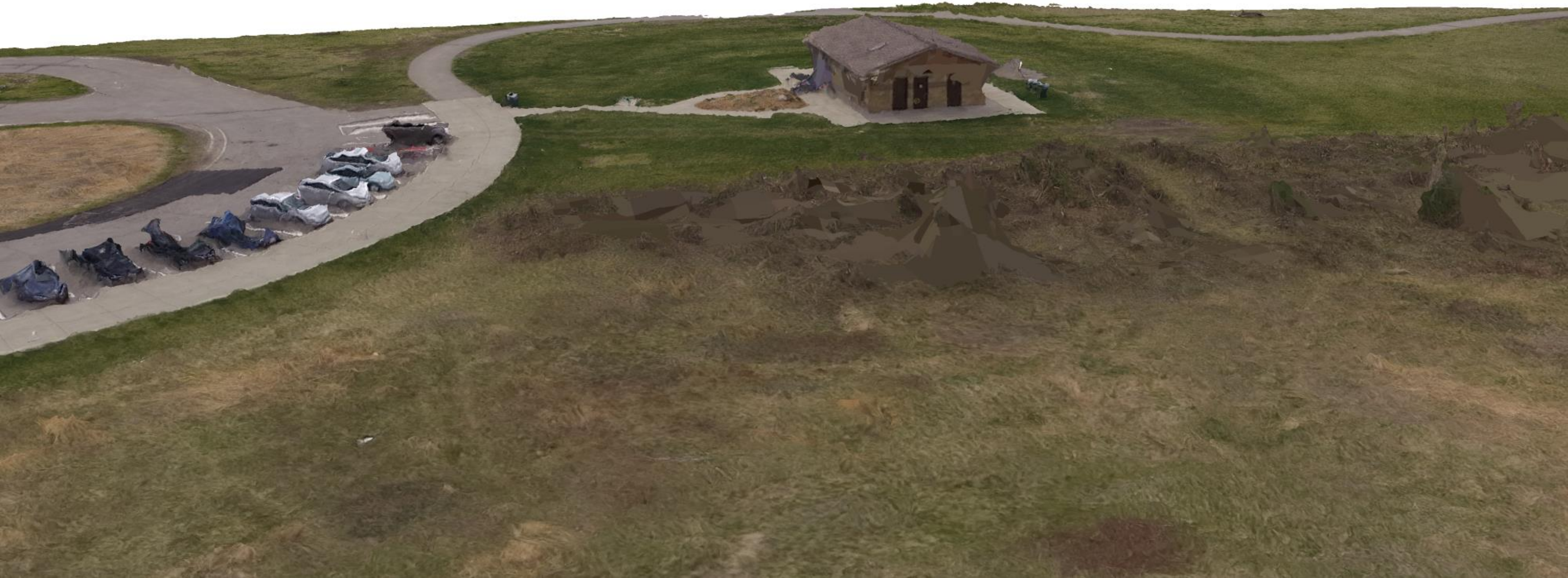
Integration Testing

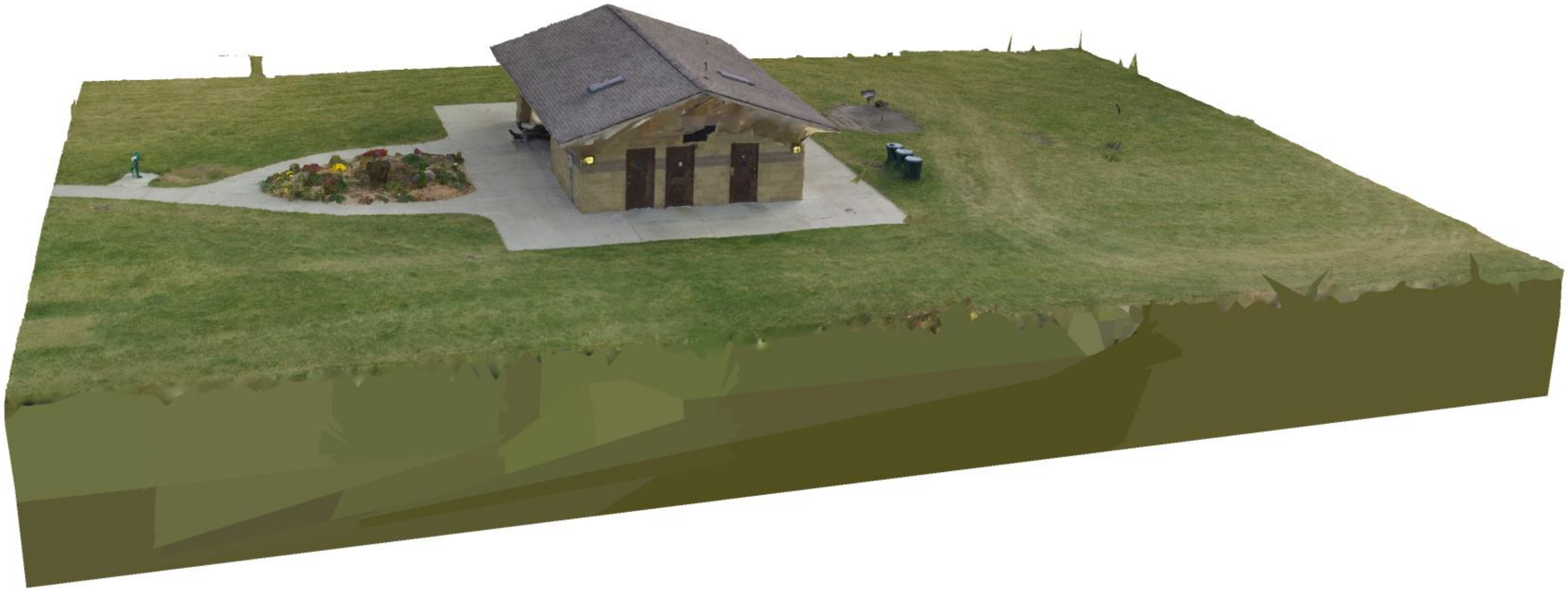
- Waypoint Transfer
  - Error Conditions
  - Corrupted Data
  - Verify Network Traffic
- Quadcopter Communications
  - Quadcopter accepts mission
  - System safety features

Photogrammetry Testing

- Visual inspection
- Considerations
  - Size
  - Texture resolution
  - Accuracy







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Conclusions

- Account for unforeseen difficulties
  - Iowa is windy
  - FAA drone registration
- Good documentation can make or break a library
- Functional prototype delivered

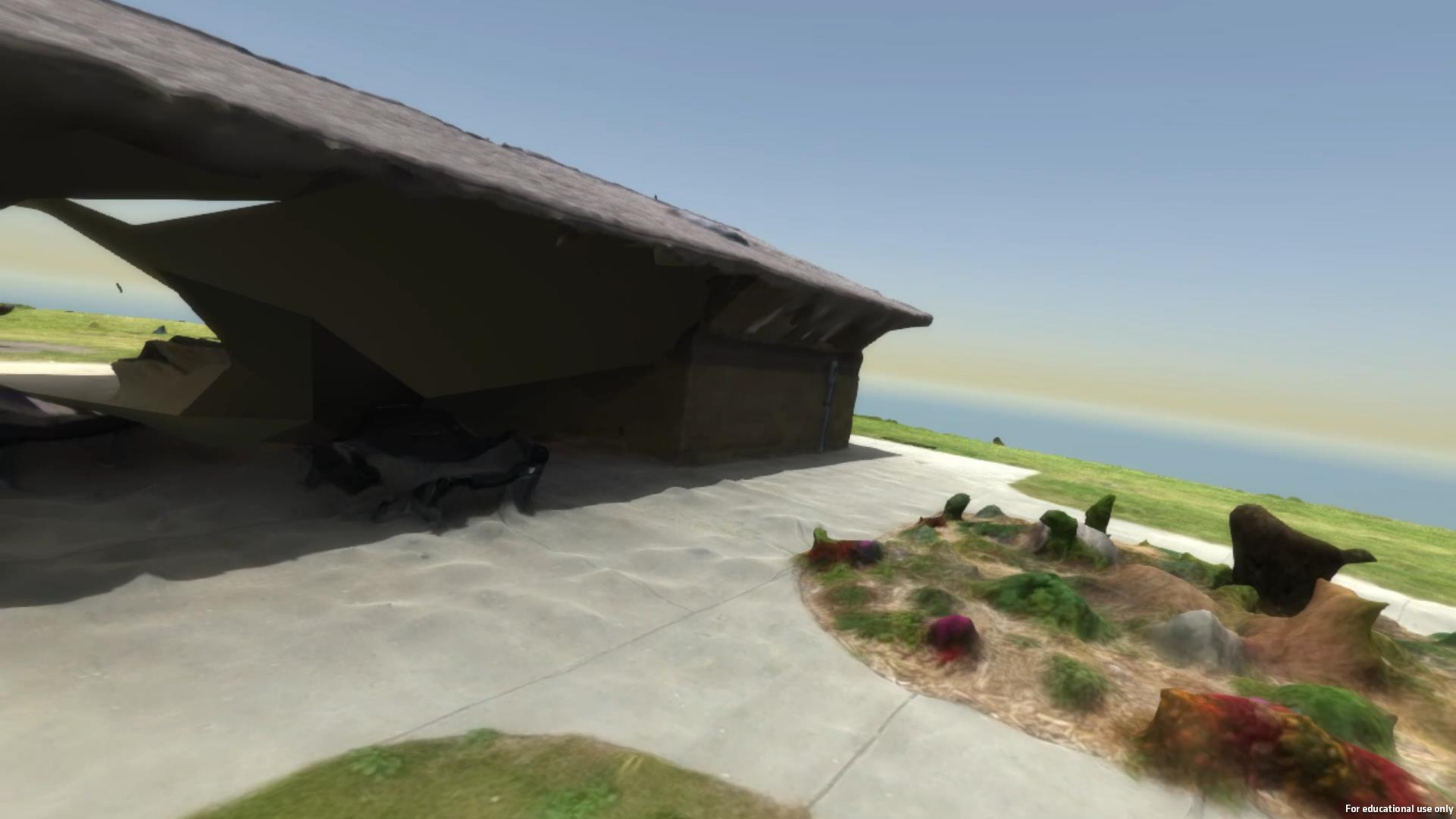
Future Work

- Windows
  - Increase Google Maps Responsiveness
  - Add Additional Flight Patterns
  - Flight boundaries
- Android
  - Polish UI
  - Improve photo download
  - Send drone status to PC

Future Work

- Networking
  - SSL secure communications
  - Improve error handling
- Photogrammetry
  - Automate model generation
  - Model decimation
  - Model accuracy analysis


Microsoft Hyperlapse Pro



Questions

Schedule

September	Plan the high-level project and conduct market research
October	Purchase components Plan the Windows and Android applications
November	Begin work on Windows and Android applications Testing of photogrammetry software
December / January	Working prototypes of Windows and Android applications
February	Working prototype of communication between subsystems 3D Model Generation from captured images
March	Completed system - Windows and Android applications done Photogrammetry pipeline integrated into system
April	Bug fixes

Photogrammetry Process

1. Feature Detection
2. Pairwise Matching
3. Sparse Reconstruction
4. Dense Reconstruction
5. Texture Application
6. Model Output

Image Generation Pattern