WARG

WATERLOO AERIAL ROBOTICS GROUP

Beginning of Term Meeting

Competition Date: May 1st – 3rd

(aka….. LESS THAN FOUR MONTHS AWAY!)

Prepared by Mitchell Hatfield

What is a Student Design Team?

- Meant to be like a Small Business, teaching students:
  - Project Management
  - Time Management
  - Real-World Experience
  - Working as a Team
  - Etc.
- With this in mind, would it be expected that when you’re allocated a task, your manager does the task and then teaches you what they did? Or is it on you to learn and gain the skills required for the task?

What is the WARG? – Design Team

- We create fully autonomous UAVs that are capable of surveying an area of interest (approx. 2km by 1km) and processing data for the "client"
- The system is a lot more than just the aircraft itself, which is about 25% of the overall project on its own
- We (at this time) do not design or build aircrafts due to the size of our project, time restrictions, and we avoid the addition of more "unknowns" to the system. We instead modify purchased aircraft.
- We create a UAV that is capable of flying itself from takeoff to landing, but further enhance our capabilities by adding ground control / communication with the aircraft that enables us to modify the aircraft's tasks on the fly. Example – changing flight path for a closer view of identified targets

What is the WARG? – Student Learning Team

- WARG has always held student learning as a primary goal of the team
- Due to the number of competition based tasks, it became harder and harder for WARG leads to give student’s these tasks and help them along
- For the majority of the time, this turned out to be a “hand holding” exercise, where WARG leads would do the task, and then teach the students, which took time away from the leads to work on other items
- Focus was taken away from the main project, and time that could be spent assisting more experienced students with developing their tasks
- Students who tried to do main tasks, required hand holding because the task would be a bit challenging to jump into when first starting off, for this reason… this method of providing students with learning opportunities was not fair for all parties, and discouraged students directly involved

R/C Car Competition

Designed for Students, By Students

R/C Car Competition – What's it All About?

- Designed to give students learning experiences that would be the same as those gained by participating in UAV based tasks
- The competition is designed to take students through the development of a path following system, which is very similar, if not the same as the one used on the UAV
- Development time and risk is greatly reduced by using an R/C Car for this process instead of an aircraft, actually, students working on the Path Following algorithms of the UAV will actually use the R/C Car in their development phase as it drastically increases project efficiency

R/C Car Competition – What We Give You

- A Bootstrap containing functions / variables that interact with the sensors, and functions to control the steering / throttle of the car
- The control board and sensors are all connected, it is your job to create and develop the control code so that the car will autonomously follow a path with no human intervention
- The car, batteries and other items are also provided
- We have two vehicles in place so that teams can ensure faster testing and development time

R/C Car Competition – The Competition

- Note that the following phases are subject to change, and weight shifting of the phases may occur
- There is a $5 registration fee per student (membership fee, prizes, etc.)

Phase	Task	Skills Acquired	Weighting
I	-Drive Forward 10sec -Drive Backward 10sec -Turn Right 10sec -Turn Left 10sec	Can you *call* a function? Can you make a loop?	2.5% each (10% total)
II	-Drive Forward 10m -Drive Backward 10m	Can you *make* a function?	5% each (10% total)
III	-Drive Forward 5m, then Turn Right 90 degrees then Turn Left 90 degrees	Can you think in terms of Heading?	15%
IV	-Drive a Straight Line while Maintaining Heading Stop after _(100)_m	Can you put everything together and create a Control Program?	15%
V	-Drive from Point A to Point B Stop within a _(5)_m Radius		15%
VII	Follow _(10)_ Waypoints		35%

The Competition

The Competition – The Scenario

- Small Canadian Remote Village in the middle of no where
- Train Wreckage that was carrying oil containers
- Some containers have blown up and destroyed / damaged buildings
- Some people have been injured and immobilized
- Oil is leaking and contaminating the surround crops / environment
- Wreckage is spread out over a large area, partially inside the village, and partially on the outside

The Competition – What it Requires

- Fly over an area (approx. 2km by 1km), our goal is in a single flight
- Capture images of the entire area in order to locate “targets”
- Must geo-locate all targets and:
    - Find surface area of the target
    - Find the volume of the target
    - Identify the target visually (rate of damage, medical state of person)
    - Identify target by means of barcode / QR code
- Create an entire map of the area of interest (big mosaic image)
- Provide photos of each target and their corresponding data

3. Object Characteristics

3.1 Contaminated fields

Each contaminated field will be delineated by a border made from wide colored ribbon (about 40 inch wide) that has good contrast with the underlying terrain. Only the corners of the areas will be highlighted. Typical shapes are shown in Fig. 2. Teams are asked to calculate the enclosed surface area of the shape and to geo-locate the centroid of the figure. The X will not be visible in the field. It is provided here for illustration purposes only.

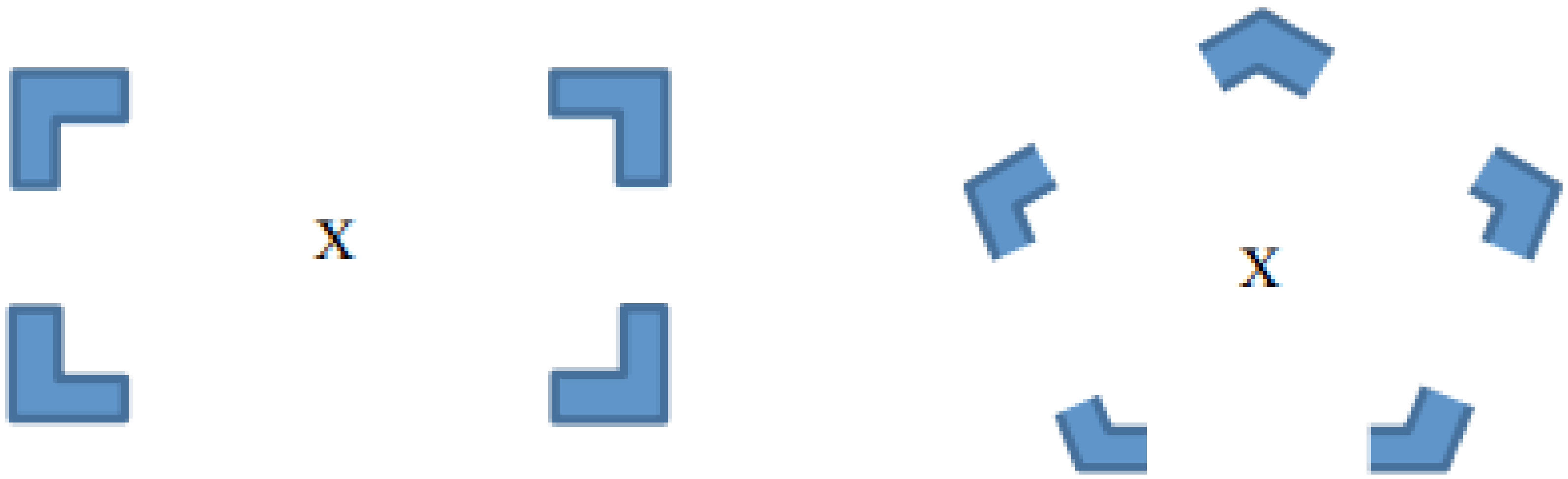


Fig. 2 – Typical features of simulated contaminated fields

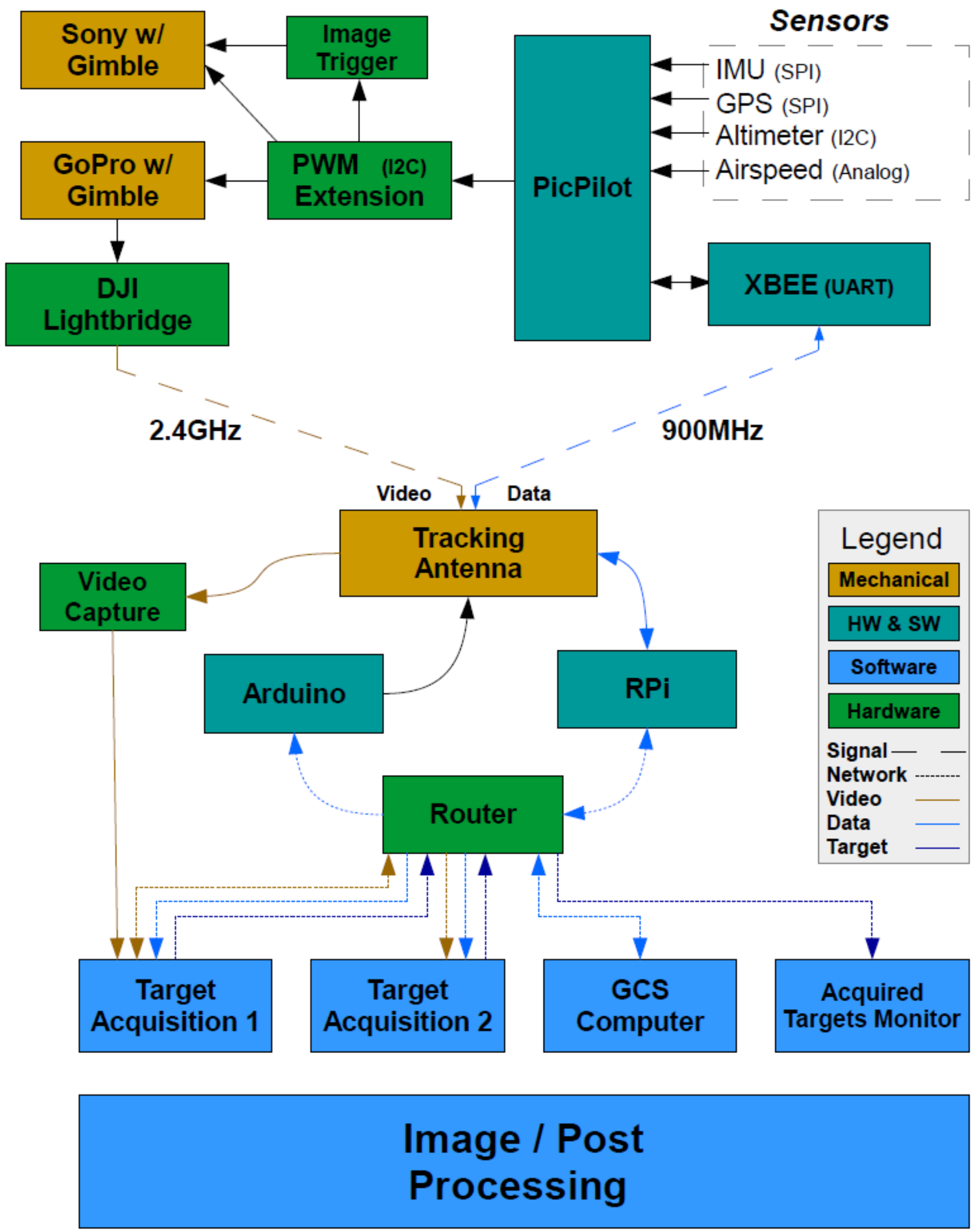
Fancy Picture of the Competition Area

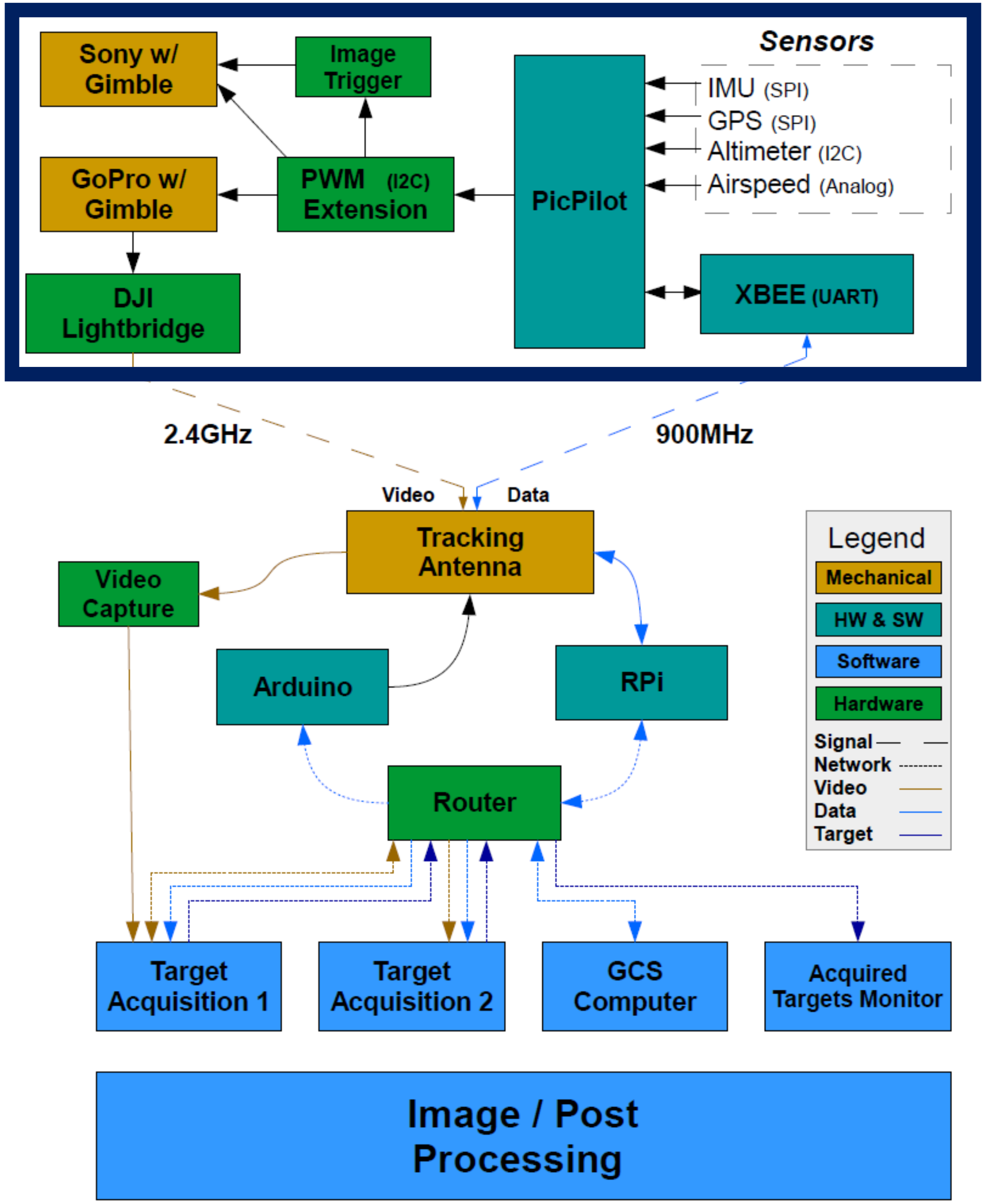
Located at an airport in
Alma, Quebec

What do we need from our system?

- Aircraft
- Autonomous Capabilities
- Imagery
- Signal Reliability
- Real-Time Target Acquisition / Computer Vision
- Image Processing / Post-Processing

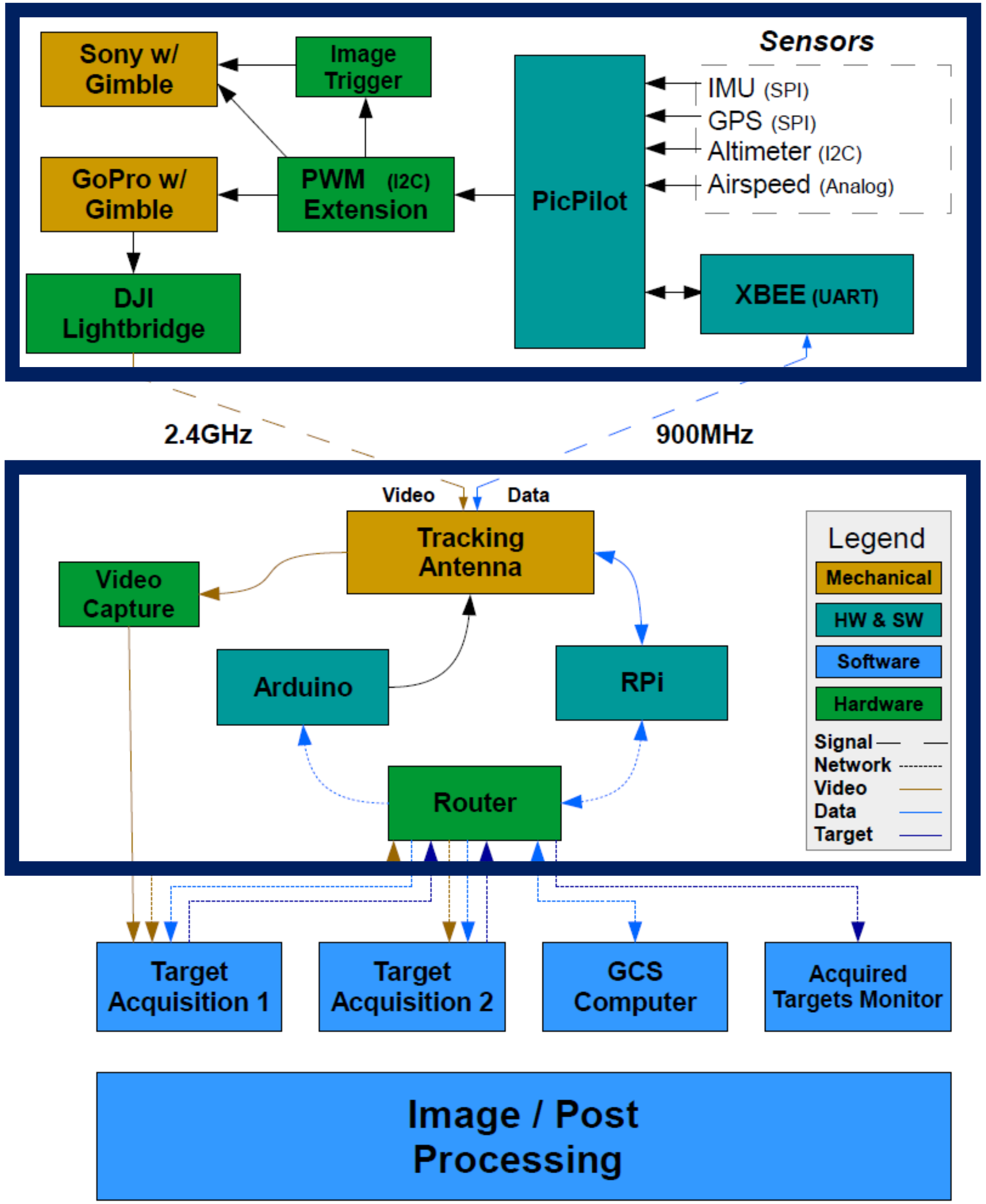
System Design Map





System Design Map

- System overview can be broken up into four sections:
  - The UAV



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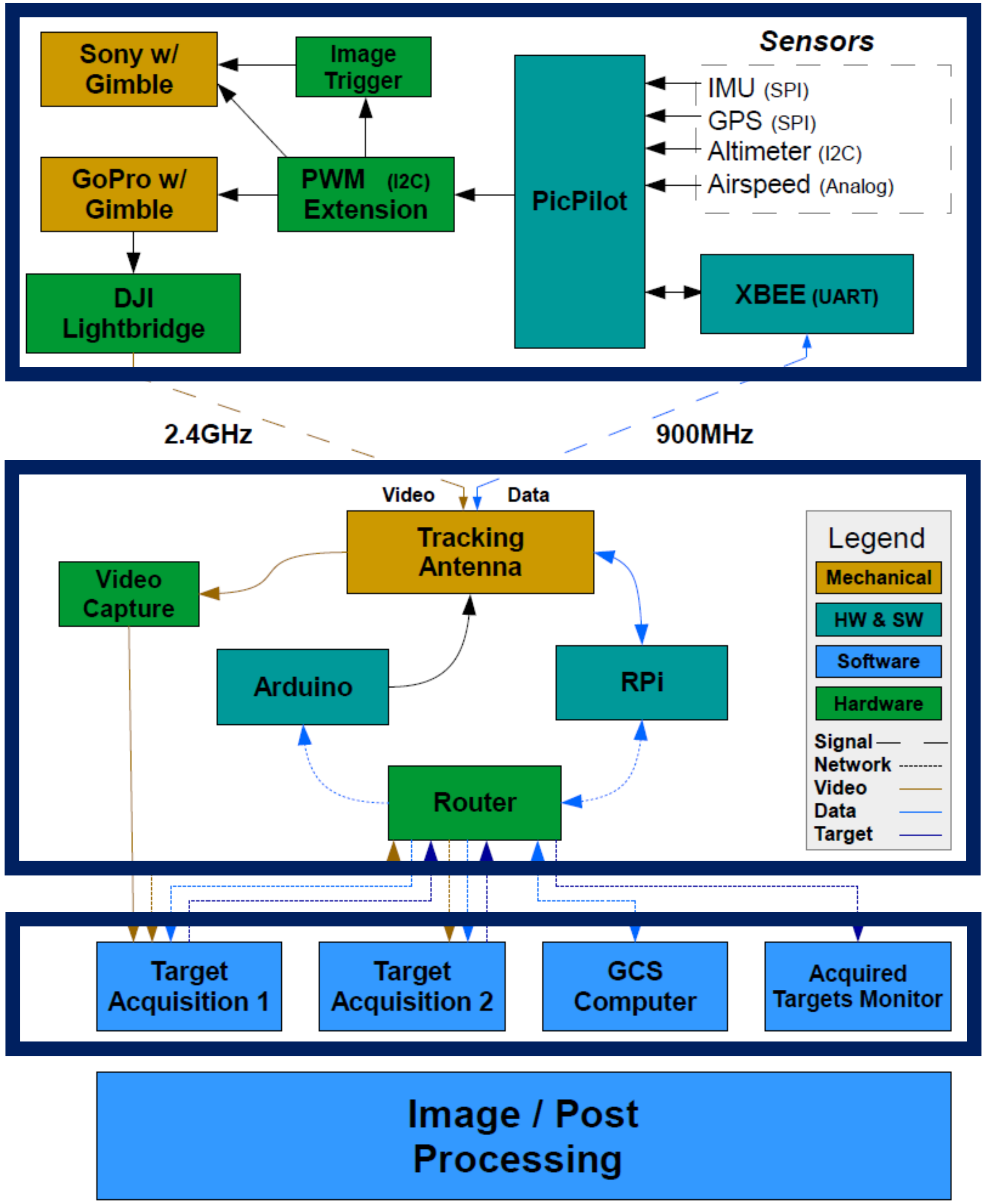
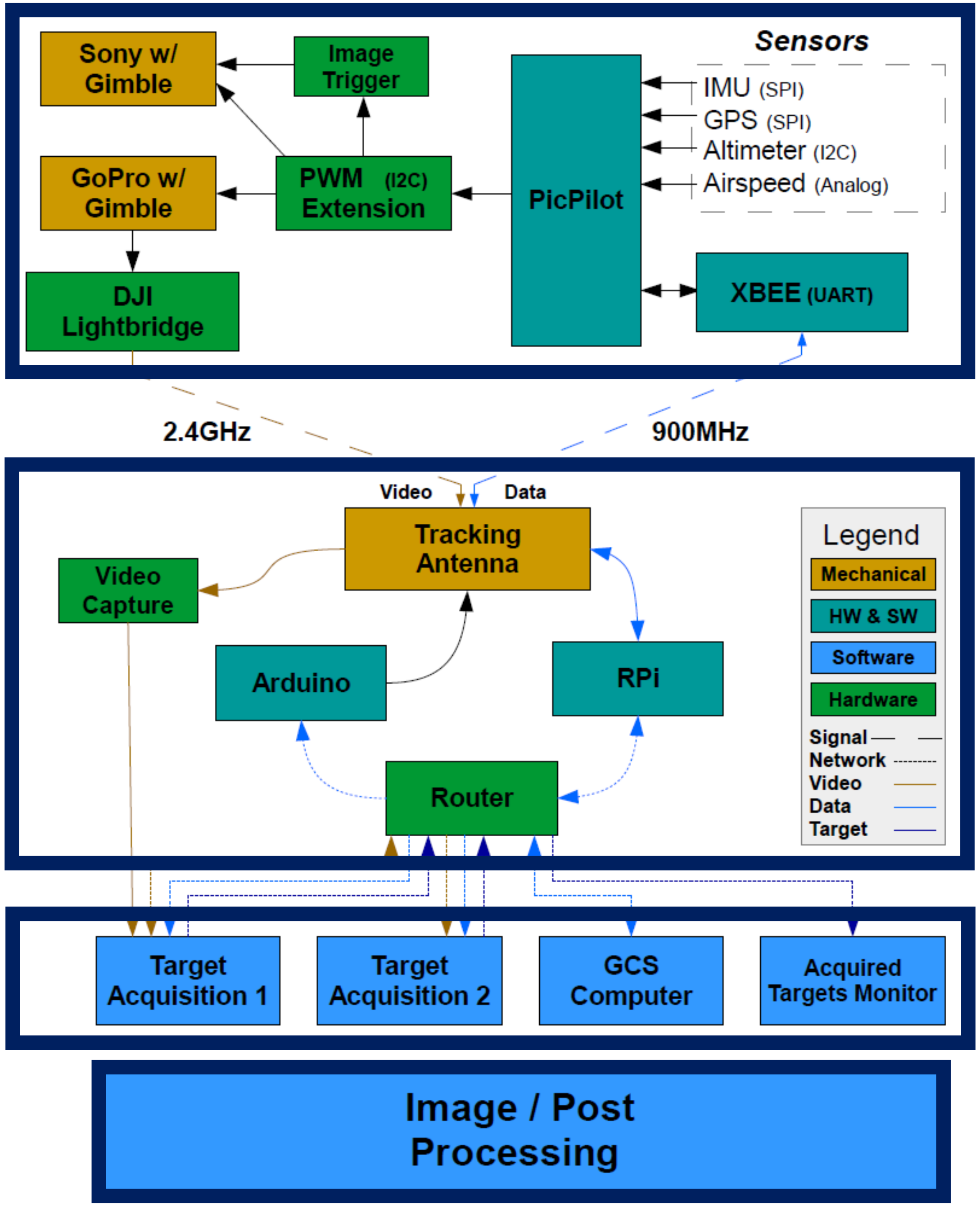
  - Ground Station (Control and Planning)





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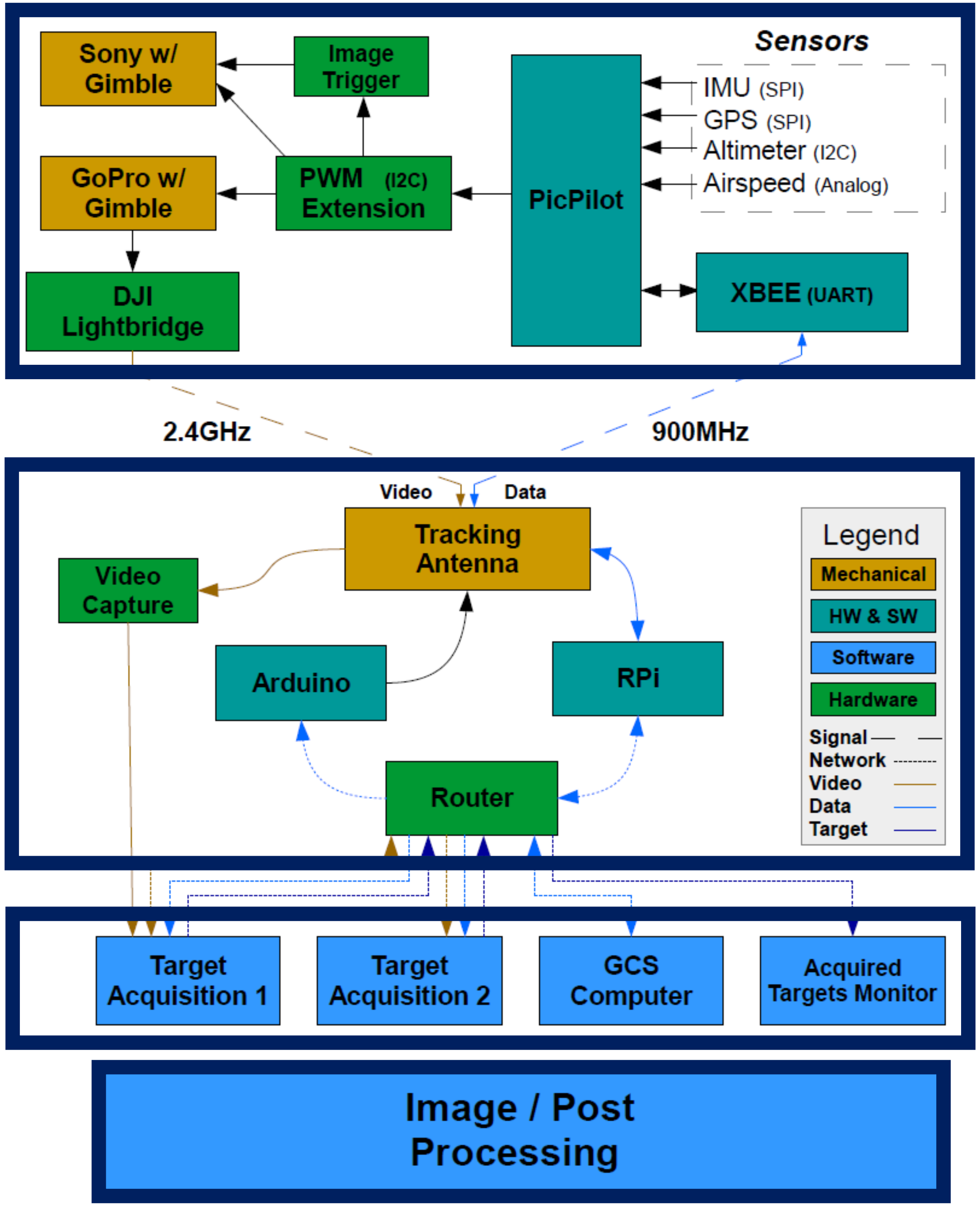
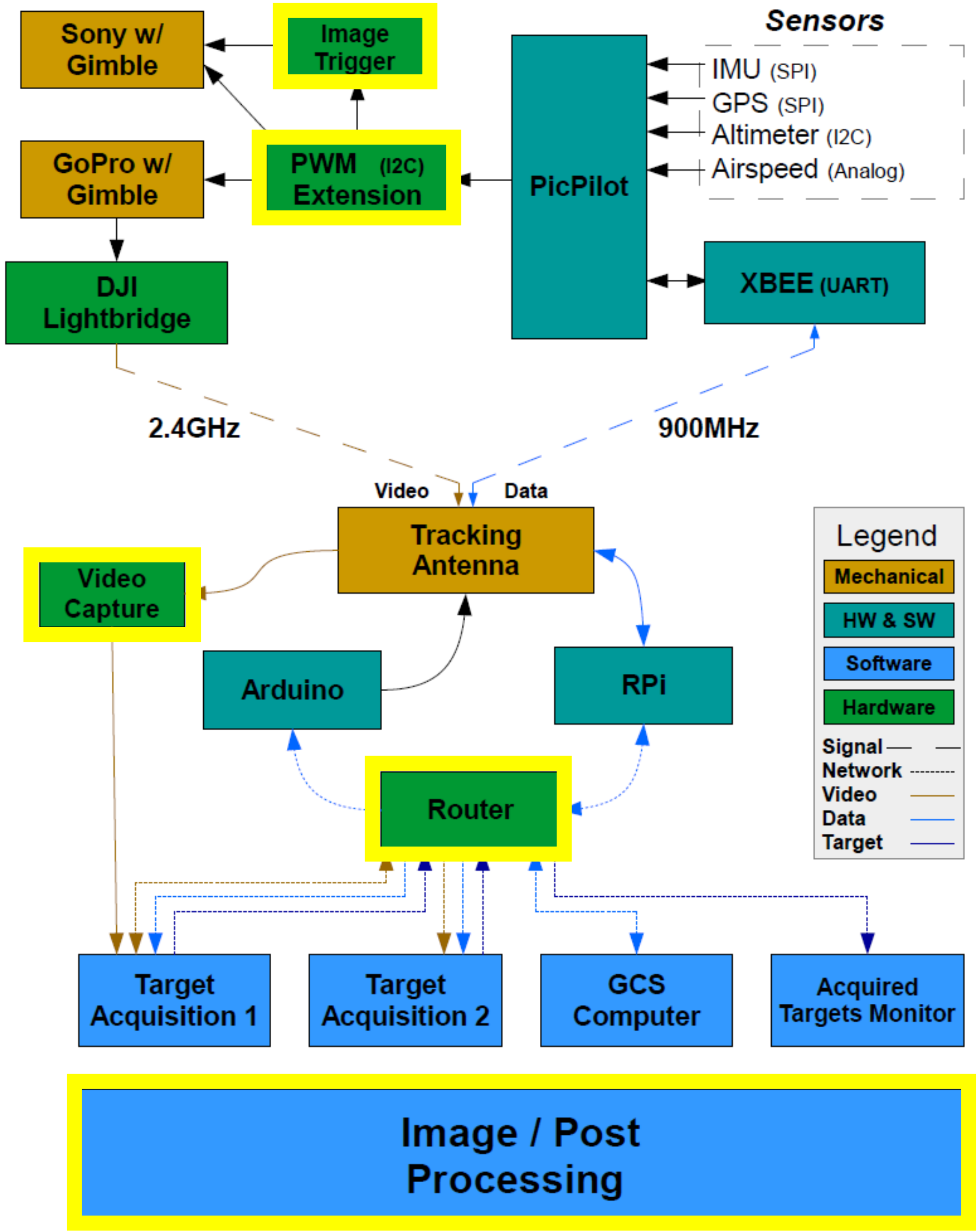
  - Post-Processing



System Design Map

- System overview can be broken up into four sections:
  - The UAV
  - Signal Reliability and Communication
  - Ground Station (Control and Planning)
  - Post-Processing
- ***NO ONE COMPONENT IS ANY LESS IMPORTANT THAN ANOTHER!!!***
- We are not a strong team for practical, hands-on experience in mechanical and electrical work. More then likely, there will not be any PCB development. The “Image Trigger,” and the tracking antenna power system are the only components that will currently have some true electrical thought possibly required. On the other hand, we are pretty heavy in design, and thinking things through (i.e. how is everything fitting inside the aircraft?)
- However, electrical items may arise, so we always need those skill sets hanging around (i.e. gimbal control may change)



System Design Map

- Yellow bordered items are components we do not yet have in-hand or possibly not selected
- Have acquired software capable of finding the volume of an object from a set of images, and creating a mosaic (map of the area)…. Need to figure out how the system works, become awesome and fluent in it, and create a time-efficient work flow of how we're going to use this at competition

5.7 Score calculation

The team score will be calculated according to Table 5.

Table 5 – Score tabulation

Item	Weight	Calculation	Sub-total
Presentation	$W_{pres} = 15$	$T_{pres} = \frac{W_{pres}}{M_{pres}} score_{pres}$ (ref. Sec. 5.1)	T_{pres}
Area	$W_{area} = 15$	$T_{area} = \frac{W_{area}}{M_{area}} \sum_{i=1}^{N_{area}} score_{i_{area}}$ (ref. Sec. 5.2)	T_{area}
Volume	$W_{vol} = 15$	$T_{vol} = \frac{W_{vol}}{M_{vol}} score_{vol}$ (ref. Sec. 5.2)	T_{vol}
Geo-loc	$W_{loc} = 15$	$T_{loc} = \frac{W_{loc}}{M_{loc}} \sum_{i=1}^{N_{loc}} score_{i_{loc}}$ (ref. Sec. 5.3)	T_{loc}
Photo	$W_{photo} = 10$	$T_{photo} = \frac{W_{photo}}{M_{photo}} \sum_{i=1}^{N_{photo}} score_{i_{photo}}$ (ref. Sec. 5.4)	T_{photo}
Identification	$W_{obj} = 10$	$T_{ID} = \frac{W_{ID}}{M_{ID}} \sum_{i=1}^{N_{obj}} score_{i_{ID}}$ (ref. Sec. 5.5)	T_{ID}
Report	$W_{rep} = 20$	$T_{rep} = \frac{W_{rep}}{M_{rep}} score_{rep}$ (ref. Sec. 5.6)	T_{rep}
		Total ($T_{pres}+T_{area}+T_{vol}+T_{loc}+T_{photo}+T_{ID}+T_{rep}$)	T_{tot}

Note: M_{pres} is the maximum score for the presentation.
M_{area} is the maximum score for N_{area} areas in the competition flight area.
M_{vol} is the maximum score for the volume in the competition flight area.
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- WE ARE A TEAM MADE UP OF MORE THAN JUST A PLANE THAT FLIES!!!

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- WE ARE A TEAM MADE UP OF MORE THAN JUST A PLANE THAT FLIES!!!
- This is the marking scheme for the competition, do you see any marks awarded for the aircraft?....... Nope
- The competition organizers don't care how you gather the data, they just care that you did. What they care about is if you can identify the items for the "client" and provide them with clear, concise information in a report
  - Note that in order to process this data, we must in fact have a reliable system of retrieving the data. This is where our awesome UAV system comes into play

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M_{rep} is the maximum score for the report.

What is there to do?....... LOTS!

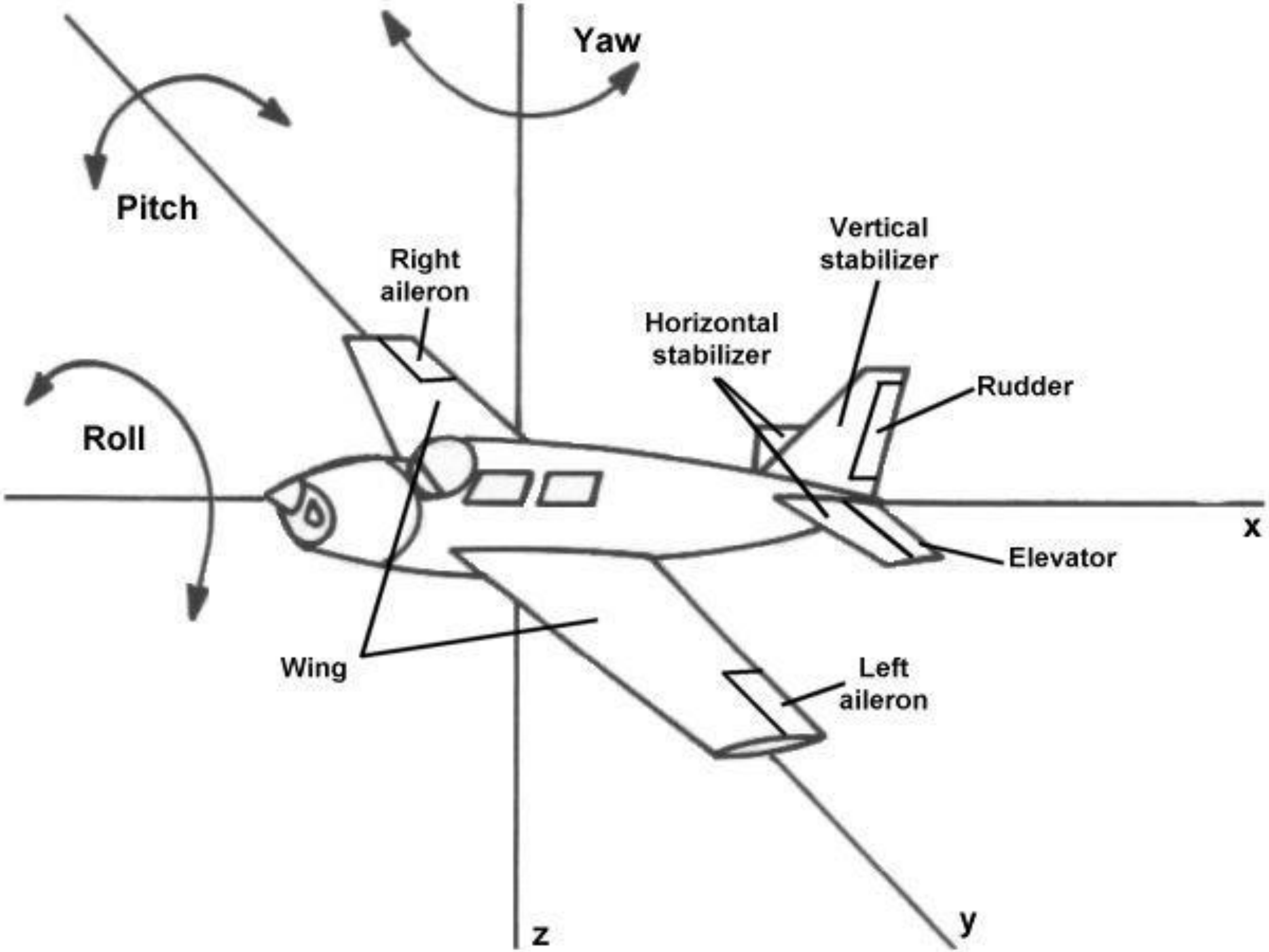
Task Breakdown

- Aircraft Capabilities – Stabilization, Path Following, and System Design
- Signal Reliability – Tracking Antenna, Network, and Communication
- Ground Station – Control, Planning, and Target Identification
- Post-Processing – Object Recognition, Image Map, and Target Identification

Aircraft

Aircraft – Control Teams

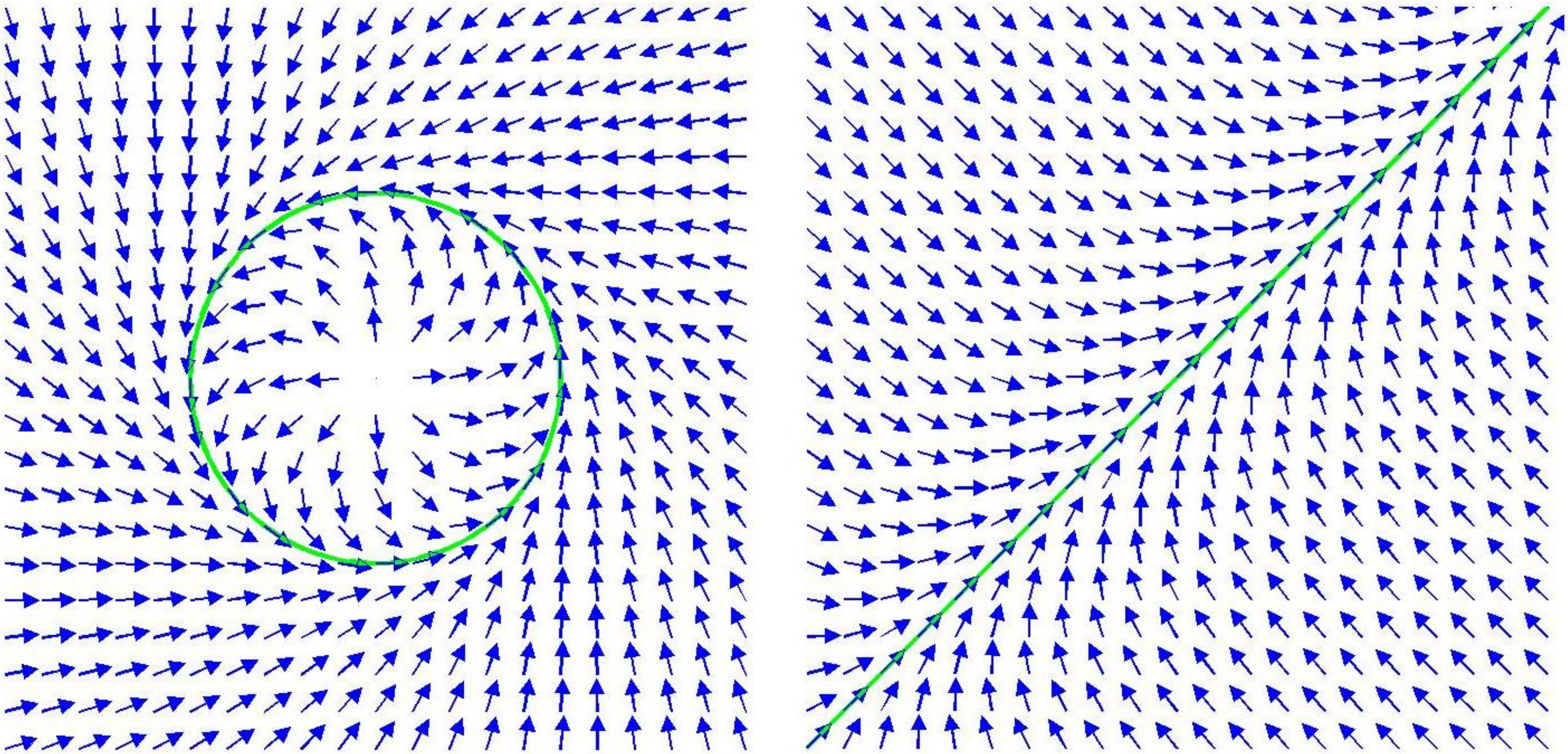
- Add airspeed into the control loops, which provides us with various advantages to the system (autonomous takeoff / landing, “Close-up” photograph ability by utilizing the flaps – slowing down the plane for a low-pass image capture, more stable path following)
- Add flaps into the control system (low-pass image capture and takeoff / landing automation)
- Add autonomous takeoff / landing
- Improve / redesign current control system of the aircraft
- Know the control code of the aircraft inside and out in order to make changes on the fly throughout the testing phase


Yaw
Pitch
Roll
Right aileron
Vertical stabilizer
Horizontal stabilizer
Rudder
x
Elevator
Wing
Left aileron
y
z

Aircraft – Path Following / Path Management

- Improve / Redesign / Optimize Path Following algorithms
  - better algorithms to use do exist, which will more accurately make the plane track / stay on it's path
  - Issues arise where set altitude is 100m, yet aircraft sits at 120m – due to lift
- Develop Path following in 3D in order to support low-pass flights
  - Currently path following is only developed for a 2D model
- Improve / Redesign / Optimize Path Management system
  - Modify path, add waypoints, delete waypoints, clear path, etc.

```c
//Structs and typedefs
typedef struct _waypointWrapper{
    long double longitude;  //TODO: Longitude and Latitude is bulky. If problems arise, change the format.
    long double latitude;
    float altitude;
    float radius; //Radius of turn
    char nextId; //For use with insertNode() or operations that require reference to another node
    char previousId; //For use with insertNode() or operations that require reference to another node
    char id;    //Array ID
}WaypointWrapper;
```



Aircraft – Capabilities Enhancement

- Add new GPS to the system, gathering data and distributing it (UART)
- Add new airspeed sensor to the system, distribute data (Analog)
- Enhance IMU capabilities by providing the aircraft's velocity vector to the VN100 IMU, which will enhance orientation precision and accuracy, greatly improving stabilization
- Work with sensors to get more accurate data
- Add new hardware as required (PWM Extension board, etc.), developing software for said hardware
- Improve Interchip communication
    - SPI / DMA data between chips becomes corrupted at times, and a full system power reset is necessary in order to sync the two chips….. Somebody please fix this

Aircraft – System Design / Integration

- Design the system internals of the aircraft and how everything will be placed and setup, which is crucial and a lot harder then you think…
- Add new control surfaces of the aircraft, ensure mechanics are tuned
- Design and create Camera Gimbal(s) that fit in the decided location

Aircraft – Imagery

- How will we trigger an image to be captured by the Sony Camera?
- How do we ensure the video downlink and the telemetry data correspond to one another?
  - Time?
  - On Screen Display in video downlink?
  - Some binary metadata in video, or secret code embedded in video?
- Mechanically ensuring the camera’s are pointing in the direction we think they are (the camera gimbal’s point down like we assume)
  - Do the servos / mechanical system work linearly?
  - Is it calibrated mechanically to down? How do we know?

Signal Reliability

Signal Reliability – Tracking System

- Control Code / Theory development to ensure the antennas area always pointing in the direction of the plane
- How will the system be initialized?
  - Compass (sensor or manual)
  - How does it know which direction it's currently pointing in?
- How will we know its own GPS location?
- How do we know what angle the tracking antennas are pitching at?
  - One time mechanical calibration?

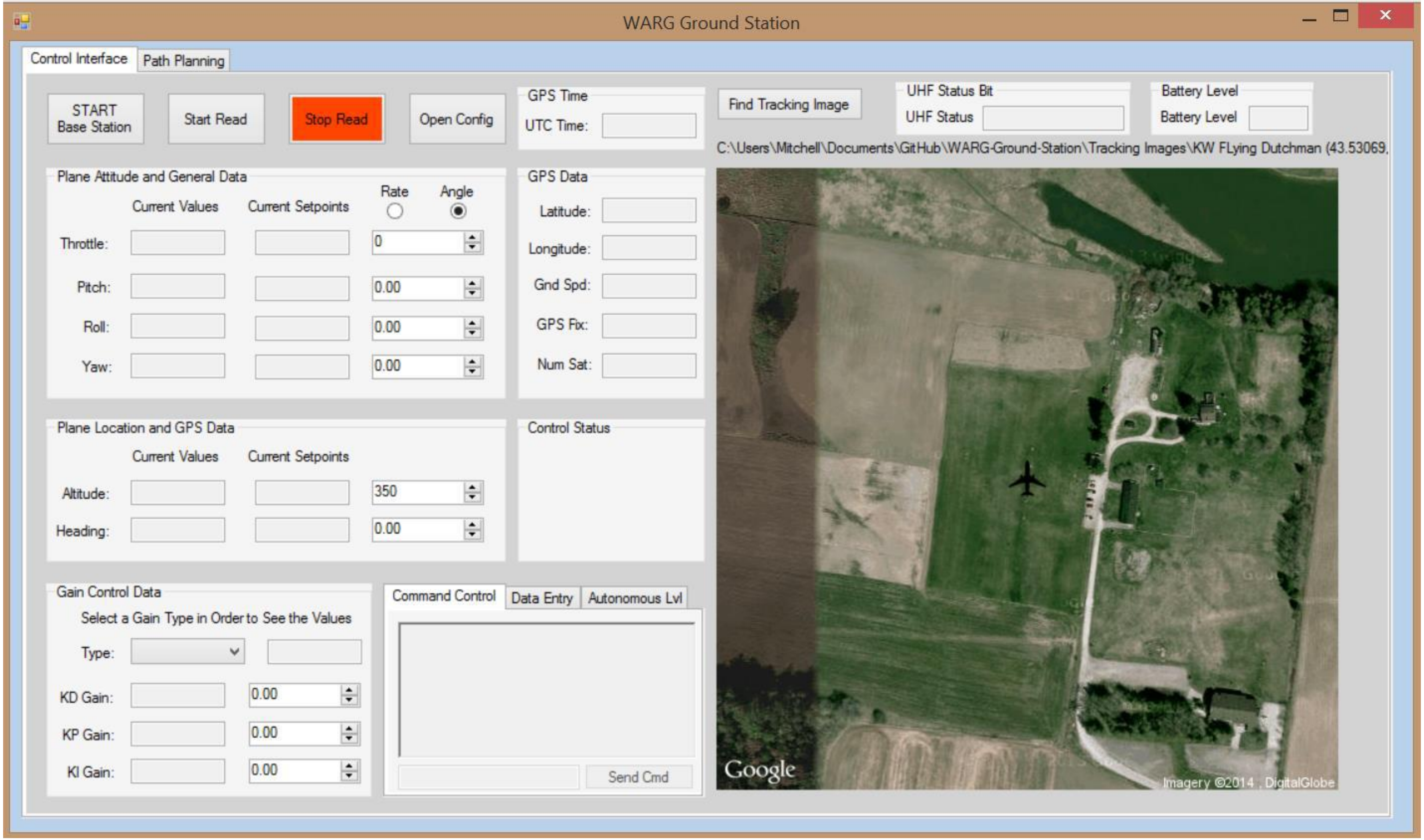
Signal Reliability – Tracking Antenna

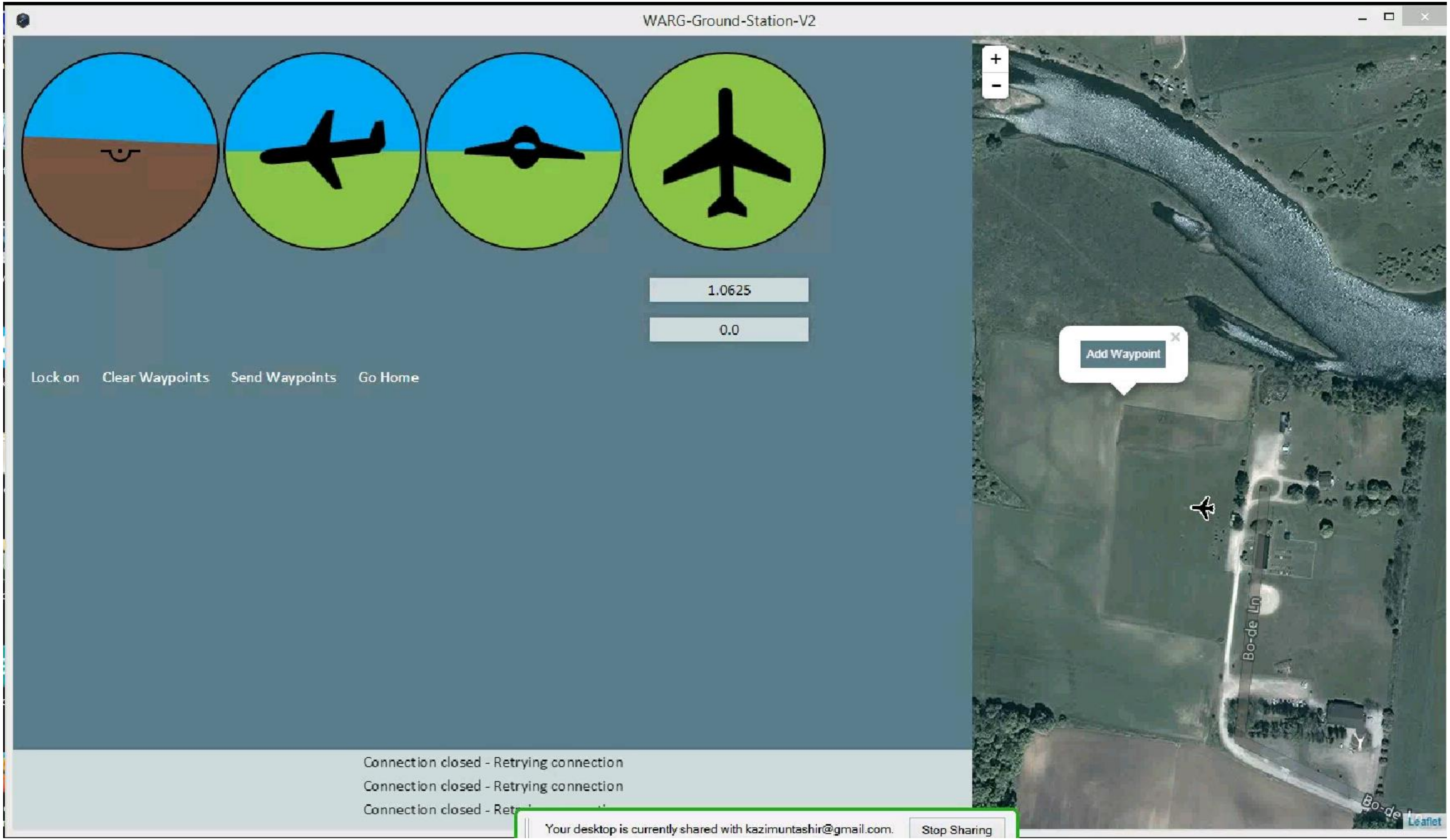
- Testing and Development to ensure reliable signal strength at all times (up to 2km away from the Ground Control Station)
- Design and Manufacture customs parts for the Tracking Frame
  - Tracking Frame to Base
  - Tracking Frame to Antennas
- Development of the system so that all communication / connections work properly and each system is receiving the information that it needs
- Network communications – getting data and information where it needs to be
- Power system for the antenna (servo power, signal power, etc.)

Ground Station

Ground Station – Ground Control Station

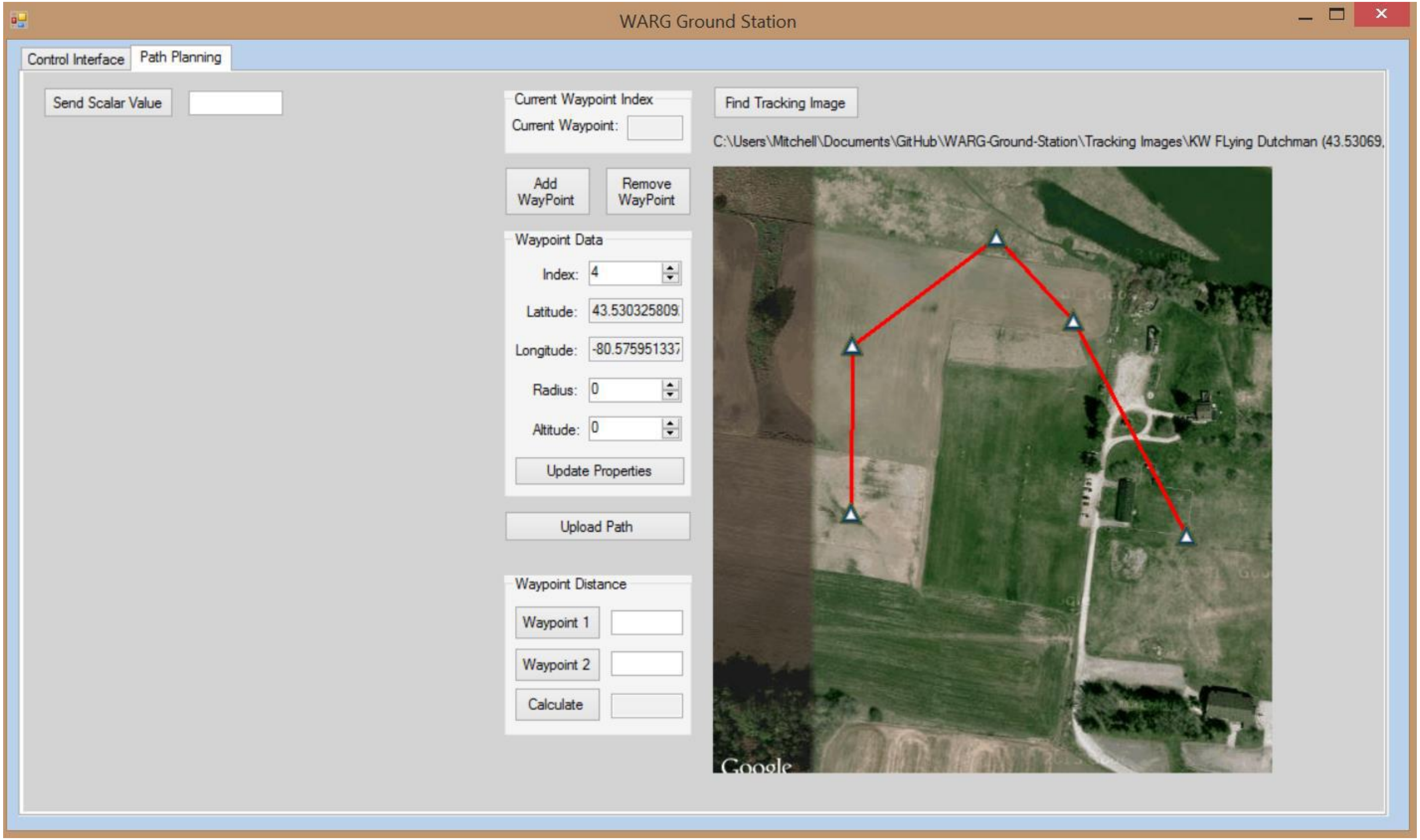
- Aircraft Monitoring / Direct Control
- Direct control of orientation, autonomous level, altitude, etc.
- Modify control gains and other aspects during testing phase
    - This is key to time efficient testing, instead of landing each time to re-program the autopilot
- Full system monitoring with quick commands to control aircraft
- Clean up the UI and organize the Front End better
- Display various characteristics of the plane
    - Battery level, UHF / Signal Connection strength, etc.

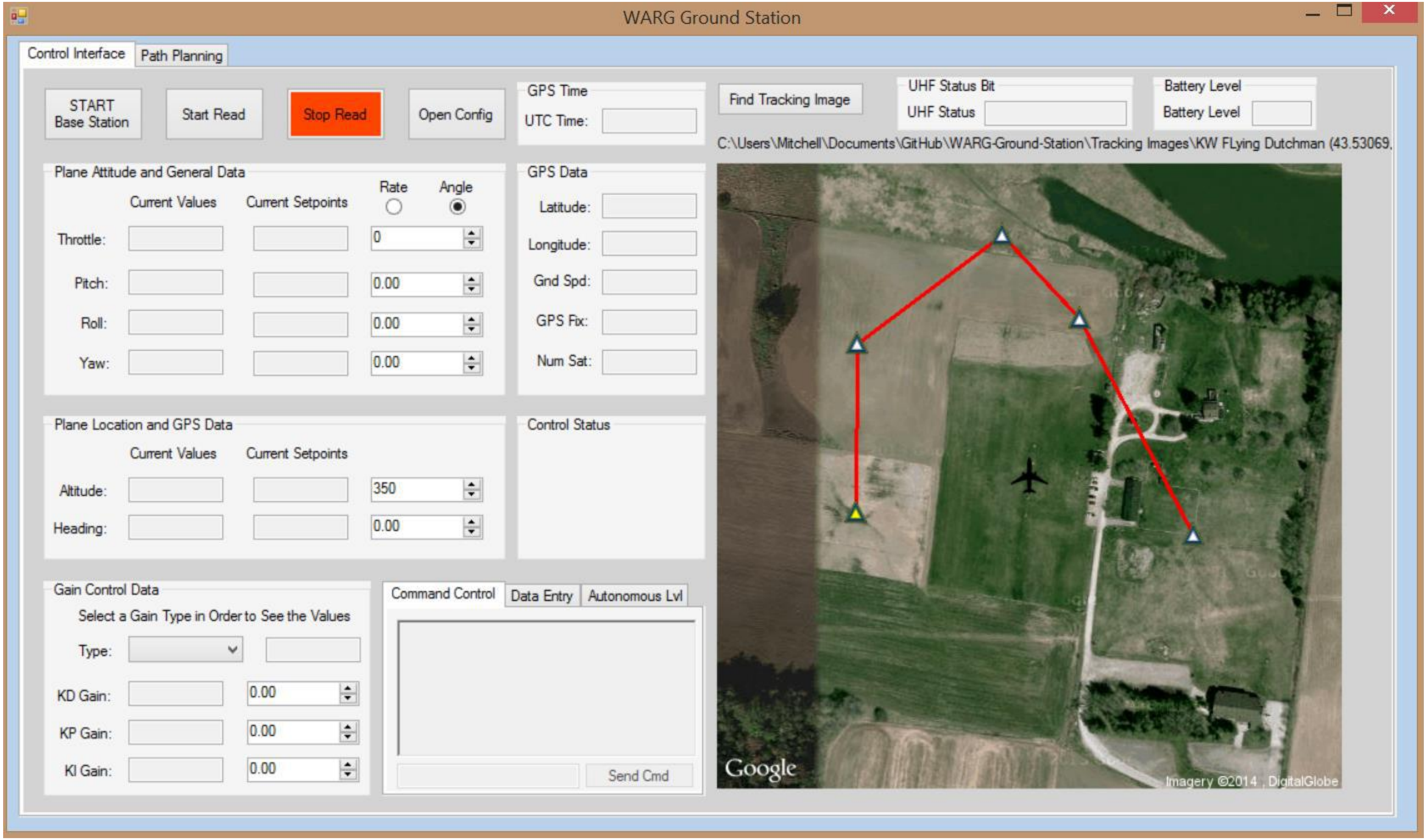

WARG Ground Station
Control Interface
Path Planning
START Base Station
Start Read
Stop Read
Open Config
GPS Time
UTC Time:
Find Tracking Image
UHF Status Bit
UHF Status
Battery Level
Battery Level
C:\Users\Mitchell\Documents\GitHub\WARG-Ground-Station\Tracking Images\KW FLying Dutchman (43.53069,
Plane Attitude and General Data
Current Values
Current Setpoints
Rate
Angle
Throttle:
Pitch:
Roll:
Yaw:
0
0.00
0.00
0.00
GPS Data
Latitude:
Longitude:
Gnd Spd:
GPS Fix:
Num Sat:
Plane Location and GPS Data
Current Values
Current Setpoints
Altitude:
Heading:
350
0.00
Control Status
Gain Control Data
Select a Gain Type in Order to See the Values
Type:
KD Gain:
KP Gain:
KI Gain:
0.00
0.00
0.00
Command Control
Data Entry
Autonomous Lvl
Send Cmd
Google
Imagery ©2014 , DigitalGlobe


WARG-Ground-Station-V2
1.0625
0.0
Lock on
Clear Waypoints
Send Waypoints
Go Home
Add Waypoint
Connection closed - Retrying connection
Connection closed - Retrying connection
Your desktop is currently shared with kazimuntashir@gmail.com.
Stop Sharing
Bo-de Ln
Leaflet

Ground Station – Path Planning

- Waypoint / Path Creation process to find the most efficient path in order to perform surveillance on the entire area of interest
- Assist in R&D of new path following / planning algorithms, and develop the software to create this path and upload to the plane
- Must be easy to modify the path immediately, so that the operator can make quick changes during the flight and alter the path as desired
- Be able to save paths, upload previously created paths, and modify these paths as desired
- Path Planning is reliant on inputs of altitude, camera viewing angle, and desired image overlap


WARG Ground Station
Control Interface
Path Planning
Send Scalar Value
Current Waypoint Index
Current Waypoint:
Find Tracking Image
C:\Users\Mitchell\Documents\GitHub\WARG-Ground-Station\Tracking Images\KW FLying Dutchman (43.53069,
Add WayPoint
Remove WayPoint
Waypoint Data
Index: 4
Latitude: 43.530325809
Longitude: -80.575951337
Radius: 0
Altitude: 0
Update Properties
Upload Path
Waypoint Distance
Waypoint 1
Waypoint 2
Calculate
Google


WARG Ground Station
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START Base Station
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Stop Read
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GPS Time
UTC Time:
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Current Values
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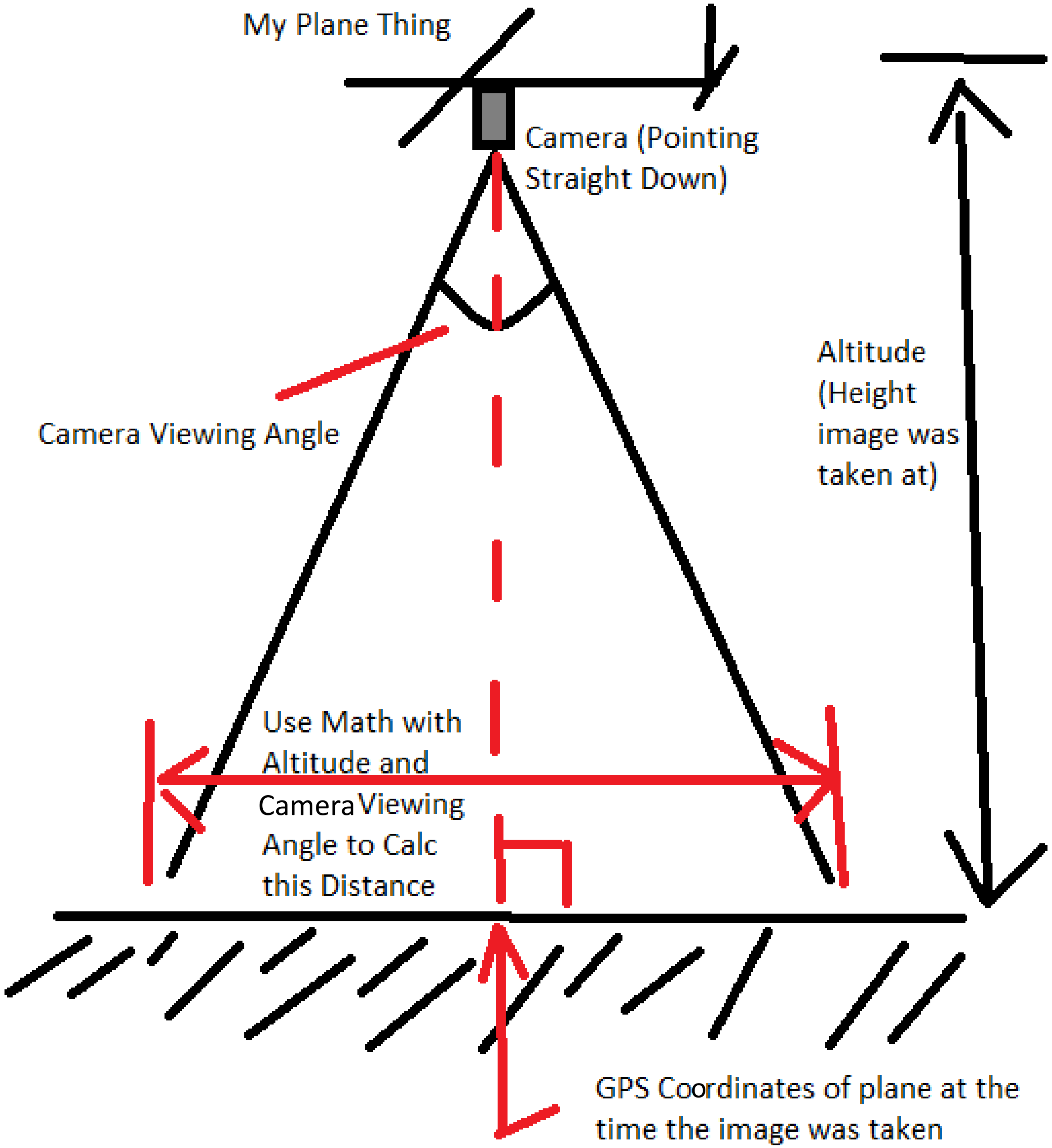
Rate
Angle
Throttle:
Pitch:
Roll:
Yaw:
0
0.00
0.00
0.00
GPS Data
Latitude:
Longitude:
Gnd Spd:
GPS Fix:
Num Sat:
Plane Location and GPS Data
Current Values
Current Setpoints
Altitude:
Heading:
350
0.00
Control Status
Gain Control Data
Select a Gain Type in Order to See the Values
Type:
KD Gain:
KP Gain:
KI Gain:
0.00
0.00
0.00
Command Control
Data Entry
Autonomous Lvl
Send Cmd
Google
Imagery ©2014 , DigitalGlobe

Ground Station – Real-Time Target Acquisition

- Software to receive live video, and allow user to identify targets live
- “Freeze Frame” the incoming video in order to select a target
- Calculate target location from the video, and identify target type
- Will possibly integrate with Computer Vision software, but for now is simply to assume a human operator


My Plane Thing
Camera (Pointing Straight Down)
Camera Viewing Angle
Altitude (Height image was taken at)
Use Math with Altitude and Camera Viewing Angle to Calc this Distance
GPS Coordinates of plane at the time the image was taken

Ground Station – Acquired Targets Monitor

- Takes input from the real-time target acquisition system
- Places targets on a large map of the entire surveillance area
- Target icons will be colour coded
  - There are two target acquisition operators, and each operator will have an allocated colour, indicating who saw what target
  - Perform estimation to figure out if both operators saw the same target, give a target seen by both operators a different colour coded icon (indicating a reliable target location)
- Should integrate into the GCS main control interface so that the GCS operator can see the targets and aircraft, making decisions as required
- Also a secondary program to view on tablets / other monitors if desired

Post-Processing

Post-Processing – Target Characteristics

- Locate images with targets in them
  - Utilize information gained from Real-Time Target Acquisition in order to narrow down which images have the targets, based on time image was taken
- Calculate the GPS location of targets in the image
- Find the area of targets that require it
- Identify the target by processing QR codes on the targets
- Identify the target by visual characteristics
  - Level of damage of “structure,” medical state of person, etc.
- Match necessary information to a given target, with a photo of the target (cropped), make it into a nice package that can be placed into the report

Post-Processing – Object Recognition

- Software that can locate and identify targets in both the live video downlink and high resolution images that are gathered after the aircraft has landed

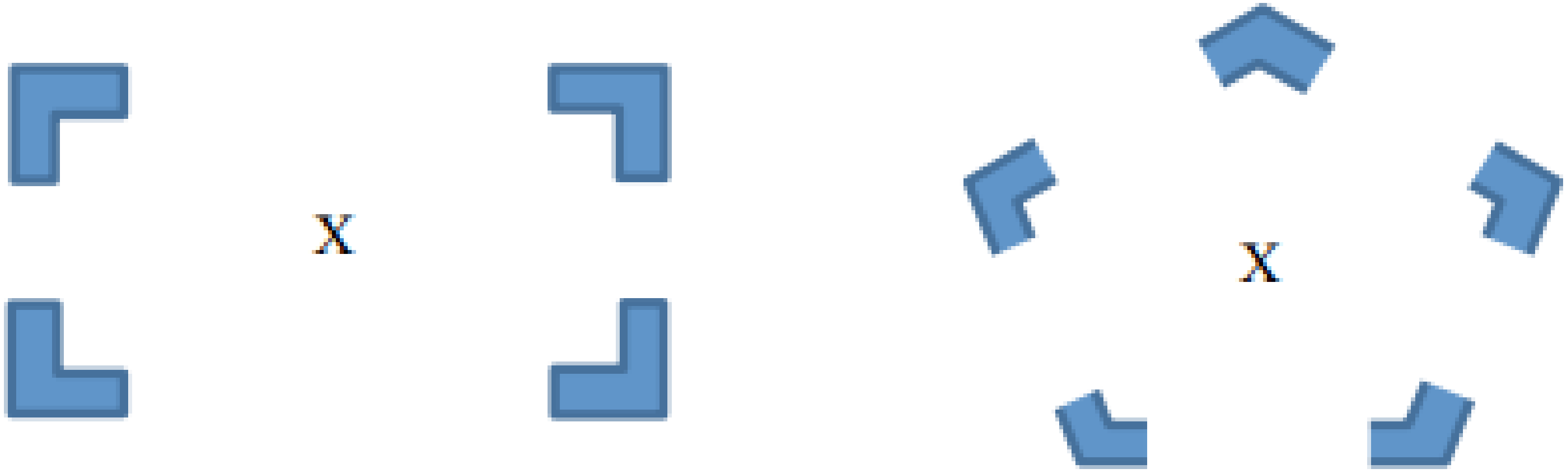
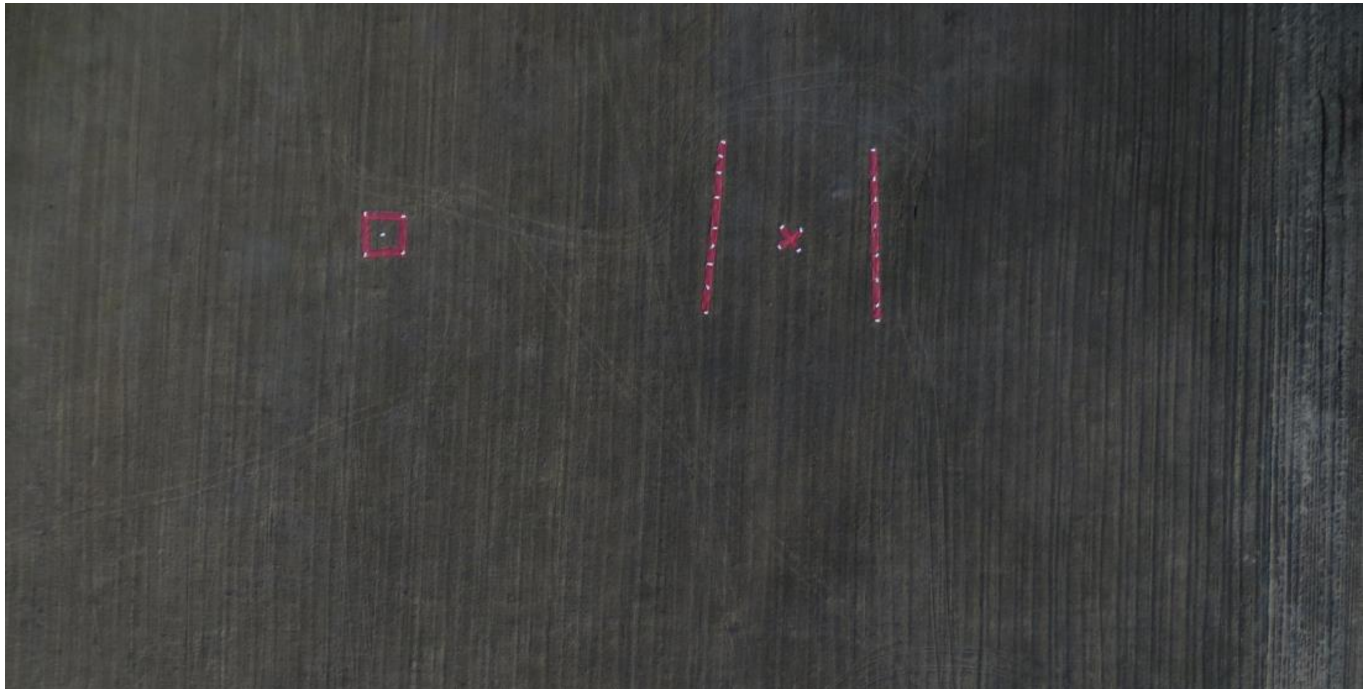


Fig. 2 – Typical features of simulated contaminated fields



Post-Processing – Image Map

- Image stitching to create a large image of the entire area of interest
- Potentially using the software we’ve gained from the sponsor
- Image stitching can also help us more accurately Geo-locate targets, by performing math techniques in order to re-adjust the GPS coordinates of individual images

Post-Processing – Volume Calculation

- Become a complete badass in using the sponsored software to find the volume of various objects (harder than pressing a few buttons…)

Post-Processing – Report Automation

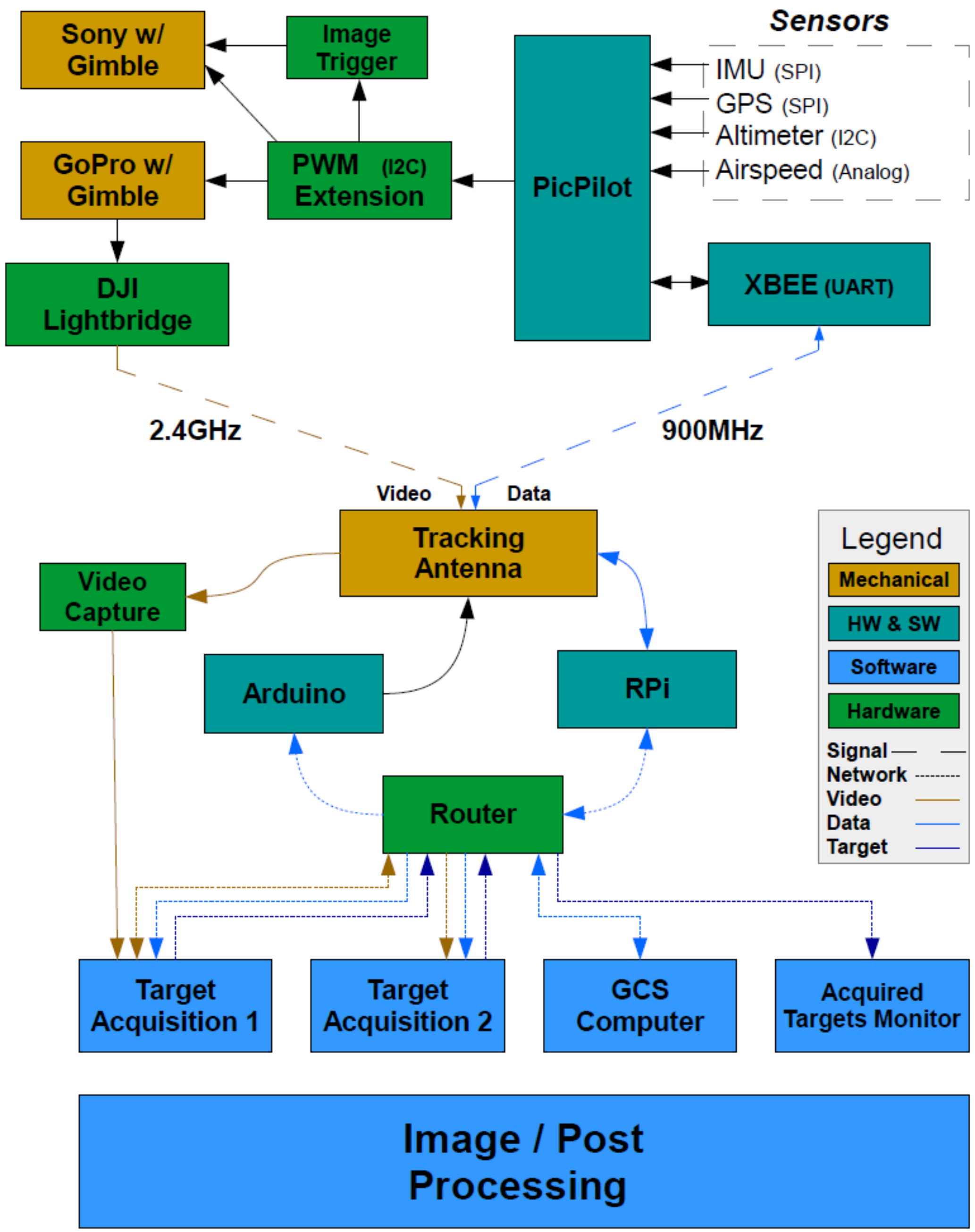
- All of this information / data has to flow nicely into a report
- We are given 60 minutes after the flight in order to create this report
- There should be some automated process for each aspect of Post-Processing that combines the data and throws it into the report / into a format that we can easily paste into the report

THANKS FOR COMING OUT!

Again… We'd like 2 people per task in order to move things forward quickly and successfully

There's 14 weeks until competition!

We'd like everything completed the development phase by the end of February


Sensors
Sony w/ Gimble
Image Trigger
IMU (SPI)
GPS (SPI)
Altimeter (I2C)
Airspeed (Analog)
GoPro w/ Gimble
PWM (I2C) Extension
PicPilot
DJI Lightbridge
XBEE (UART)
2.4GHz
900MHz
Video
Data
Tracking Antenna
Video Capture
Arduino
RPi
Router
Legend
Mechanical
HW & SW
Software
Hardware
Signal
Network
Video
Data
Target
Target Acquisition 1
Target Acquisition 2
GCS Computer
Acquired Targets Monitor
Image / Post Processing

Questions?