Ground Station Tracking System

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Abstract

One of the Eclipse Ballooning Project's main goals was to stream live video of the eclipse to the internet. To accomplish this task a tracking antenna was built to follow the balloon payload. As an added challenge, the task had to be completed on a budget. The "ground station" is the center for communication between the payload and user. This system utilizes GPS position reports from the payload via the Iridium network to determine the balloons position. The computer algorithm takes in additional GPS and IMU data from the ground station to determine a relative heading to orient the antenna to point at the balloon payload. The heading and pitch are controlled with independent servos. These subsystems all jointly interact to keep the antenna pointed at the balloon to within a few degrees or the communication would be lost.

Background

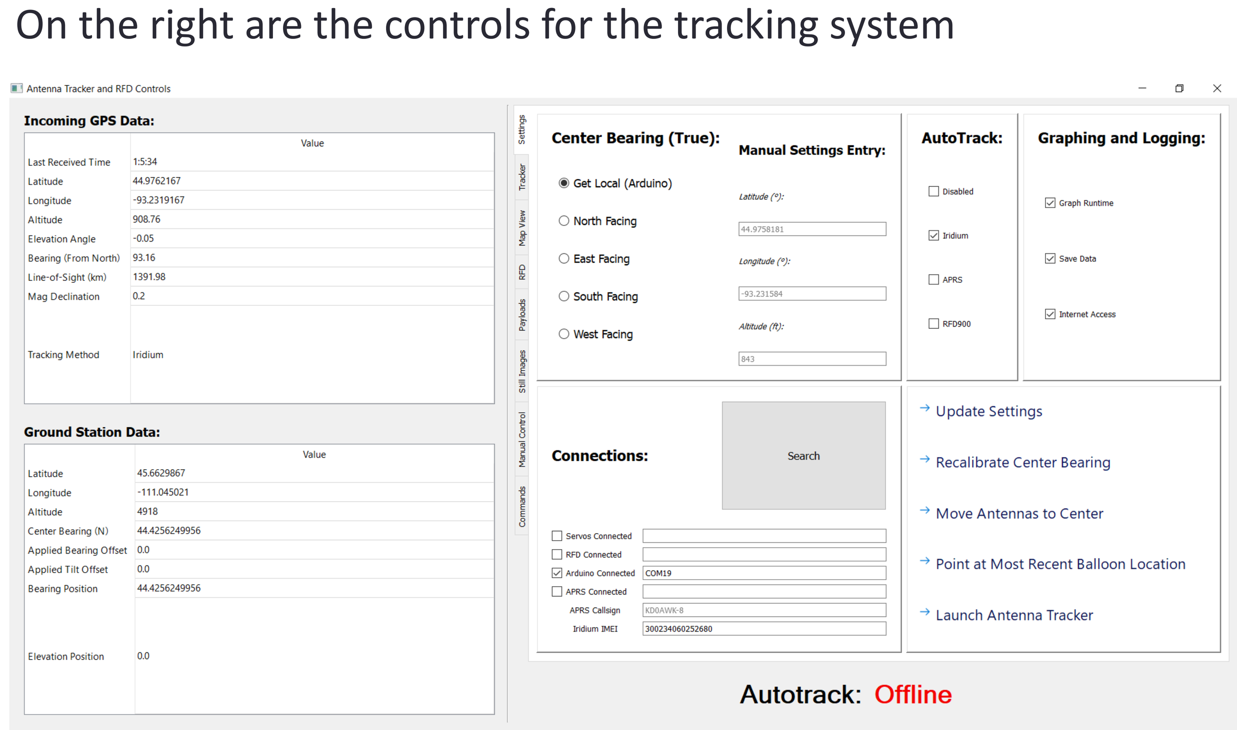
The Project was a joint venture of 55 teams with Montana State University taking the lead role. The multi team project needed a realistic budget, and easy to use hardware/software systems. Many of the teams involved had little experience in electronics, software, or ballooning requiring an easy to use graphical user interface.

To keep the video systems streaming the tracking system had to continuously calculate the bearing and pitch to point the antenna. This also required us to be able to move our antenna to the newly calculated direction. It was very important we could accomplish this task accurately. As the signal strength dropped dramatically the further off center you are.

The position of the balloon needs to be known at all times. This was accomplished with a GPS and a satellite modem (Iridium Network) to relay the positional information of the payload to the ground station over the internet.

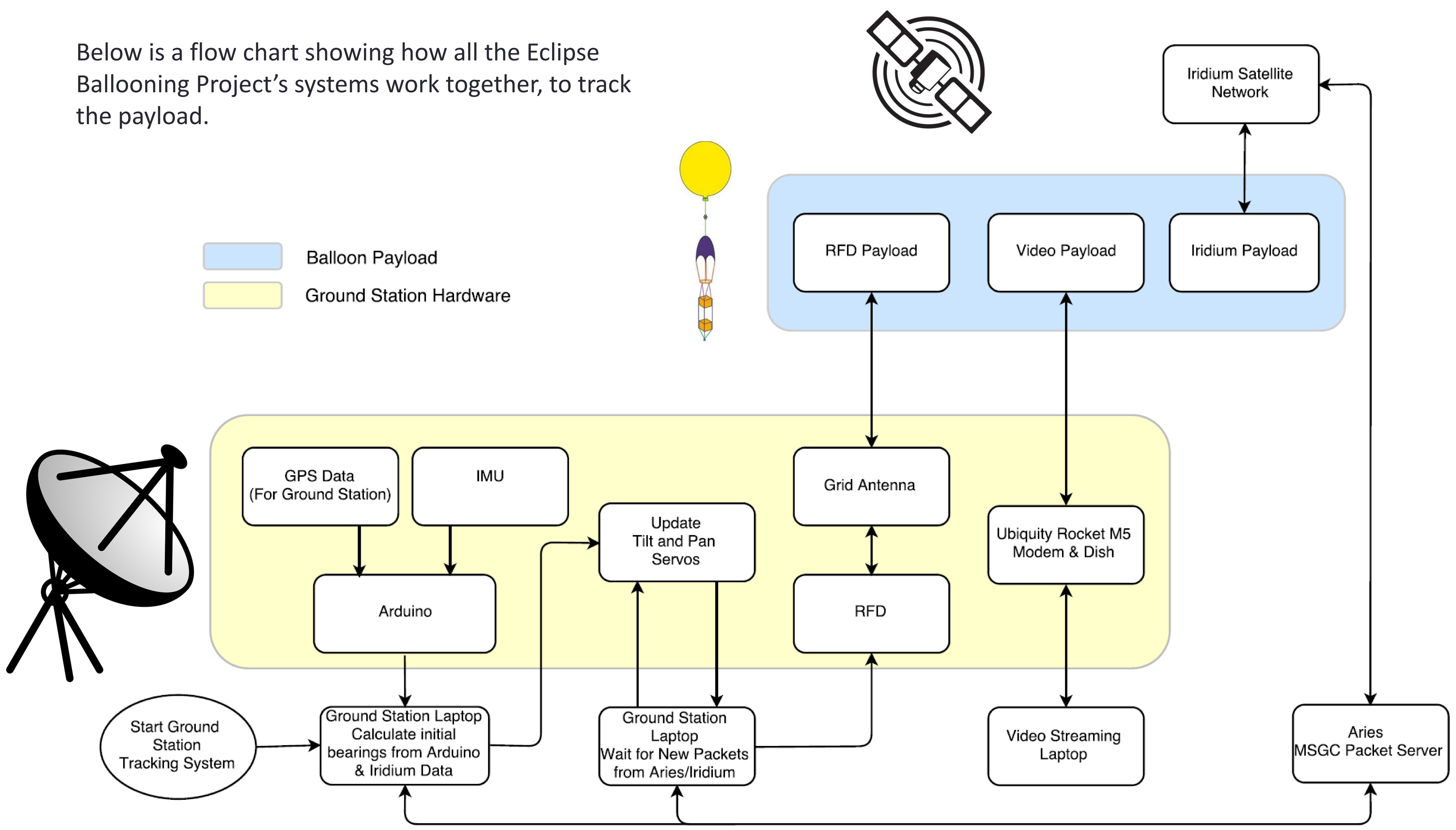
Graphical User Interface

A screenshot of the graphical user interface is seen below. On the left is the GPS data for both the ground station and payload. On the right are the controls for the tracking system



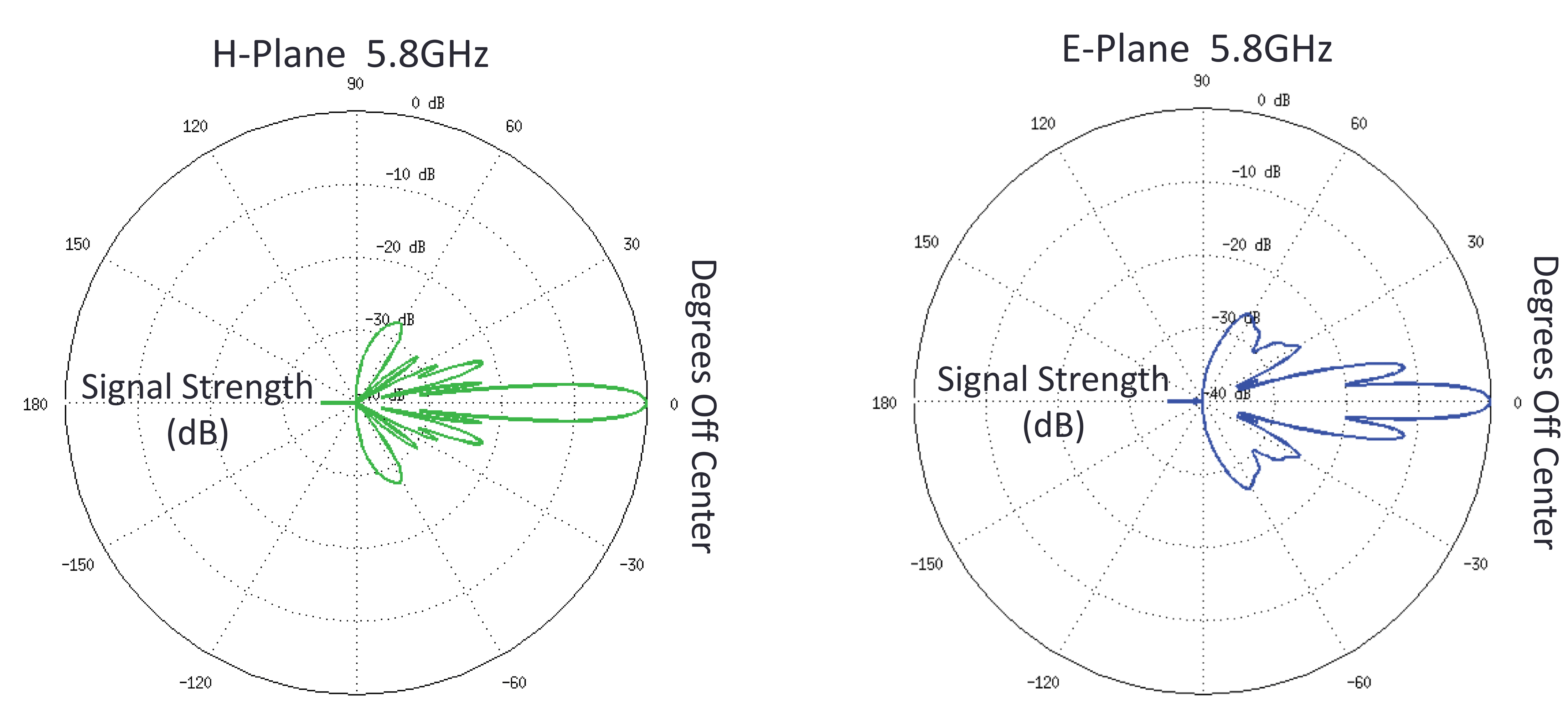
Ground Station Flow Chart

Below is a flow chart showing how all the Eclipse Ballooning Project's systems work together, to track the payload.



Signal Strength

The EM radiation pattern of the antenna can be seen below. Degrees from center of propagating signal are plotted verses loss in signal strength. It can be seen that if the beam was more than 2.9 degrees off then the signal loss will be greater than 3dB or 50%. Note that this is at a constant distance. The signal also degrades over distance by a factor of the distance squared.



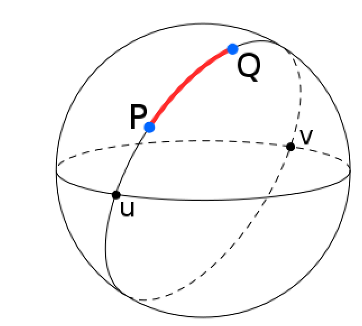
RD-5G30-LW Ubiquity Rocket Dish Antenna

Antenna Pointing

Antenna pointing is a geometry problem requiring the position of the balloon, the ground station and the orientation of the antenna. GPS systems provide the positions, while an IMU provides the orientation of the antenna. Navigation equations are used to calculate the direction and elevation angle that the antenna must be moved to using the associated servo motors.

Distance/Bearing/Elevation

The haversine formula calculates the distance between two points on a sphere. It is based on the law Of haversines, which is a relation Between angles and sides of a spherical triangle.



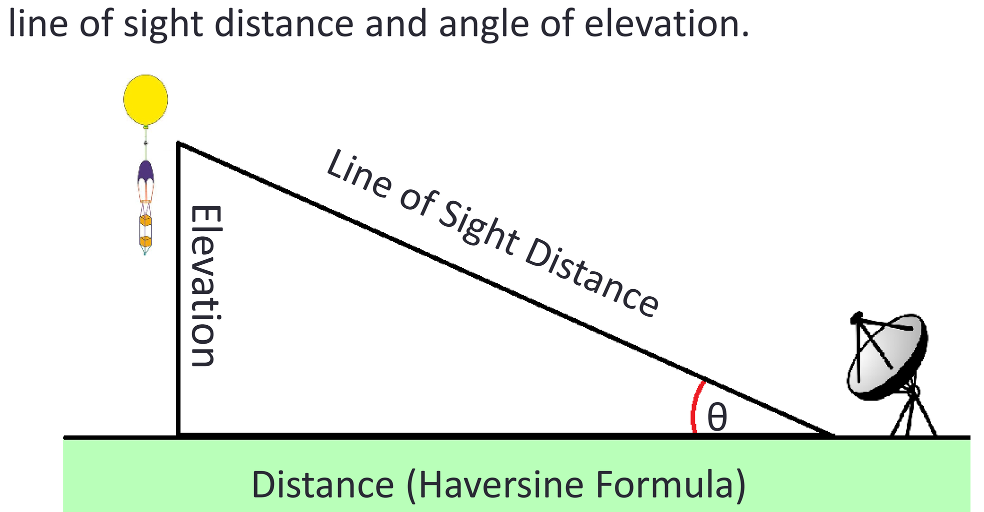
$$D = 2r * arcsin\left(\sqrt{sin^2\left(\frac{\varphi_2-\varphi_1}{2}\right) + cos(\varphi_1)cos(\varphi_2)sin^2\left(\frac{\lambda_2-\lambda_1}{2}\right)}\right)$$

(Haversine Formula)

$$B = atan2\left(\sin(\lambda_2-\lambda_1)\,cos(\varphi_2),\ sin(\varphi_2) - sin(\varphi_1)cos(\varphi_2)cos(\lambda_2-\lambda_1)\right)$$

φ_1 latitude of point 1 λ_1 longitude of point 1
φ_2 latitude of point 2 λ_2 longitude of point 2
r radius of the earth D the distance between the two points
B Bearing between the two points relative to true north.
θ Elevation angle

The elevation of the payload is reported back with the GPS data via the iridium Network. With the lateral distance to the balloon known and the elevation known, the Pythagorean theorem can be used to calculate the line of sight distance and angle of elevation.



Servos

Two servo motors were used to move the antenna. One was used for changing the bearing, and one was used for changing the tilt/elevation angle. The servos were mapped to all 360 degrees relative to the initial orientation of the ground station. Once the new bearing and elevation angle were determined the servos could then receive their new input and move the antenna to its new position.