Automated Multi-Frequency Antenna System for Stratospheric Research Balloon Telemetry

Weber State University

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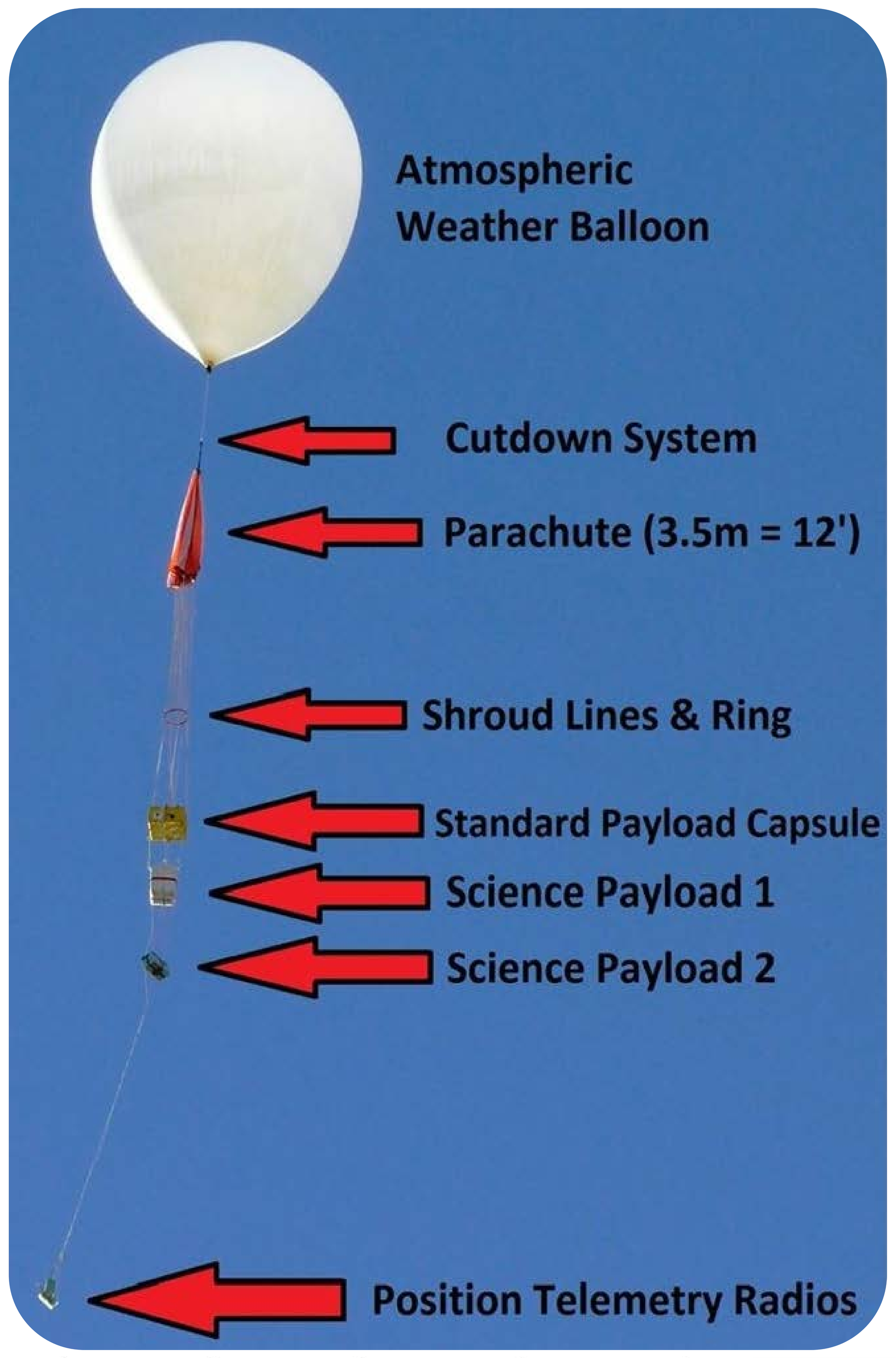
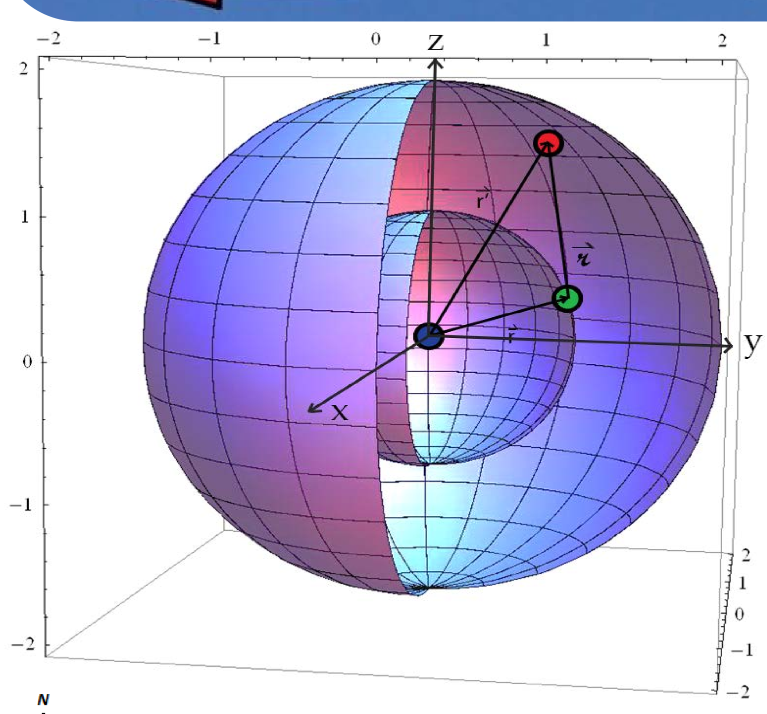
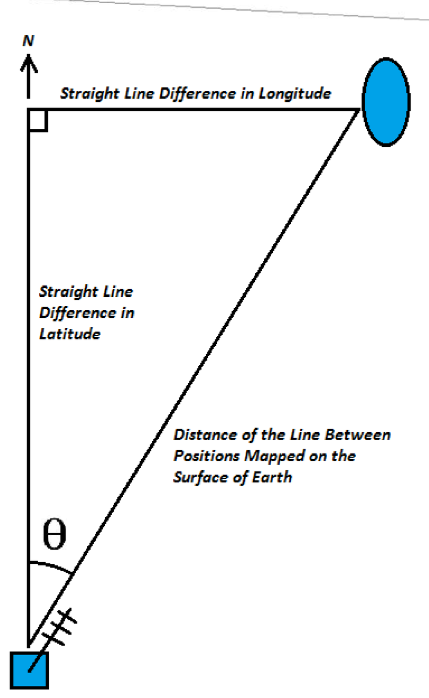


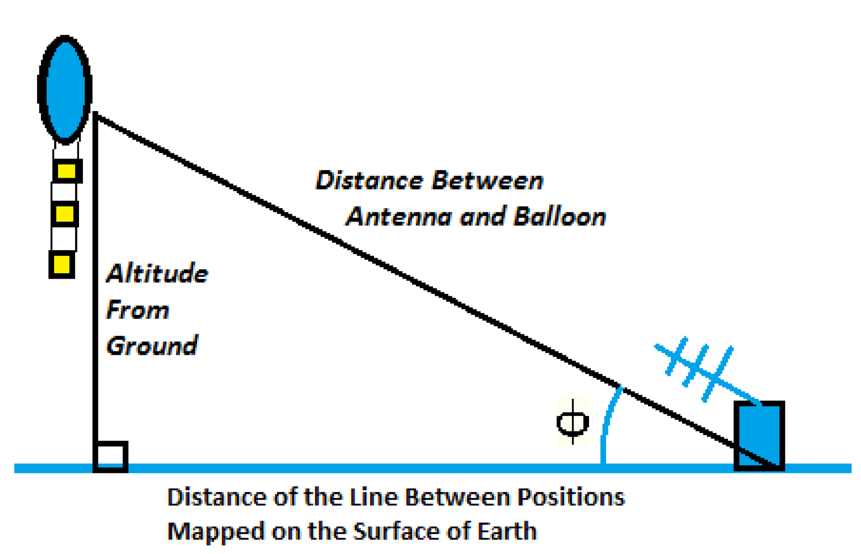
(left) Shown is a typical HARBOR flight setup. The position telemetry radios are what provide our system with telemetry data from the balloon in order to be tracked. One of the science payloads requires line-of-sight tracking for data collection.

Because flight radios must be lightweight, they tend to be low power, thus, the HARBOR team requires line-of-sight antenna tracking for data collection and interfacing capabilities. This new system provides automated tracking of the near-spacecraft during the entire flight. The previous system required visual contact with the flight package to allow manual pointing of the antenna. Difficult in the best of situations, manual tracking completely fails when there is cloud cover.

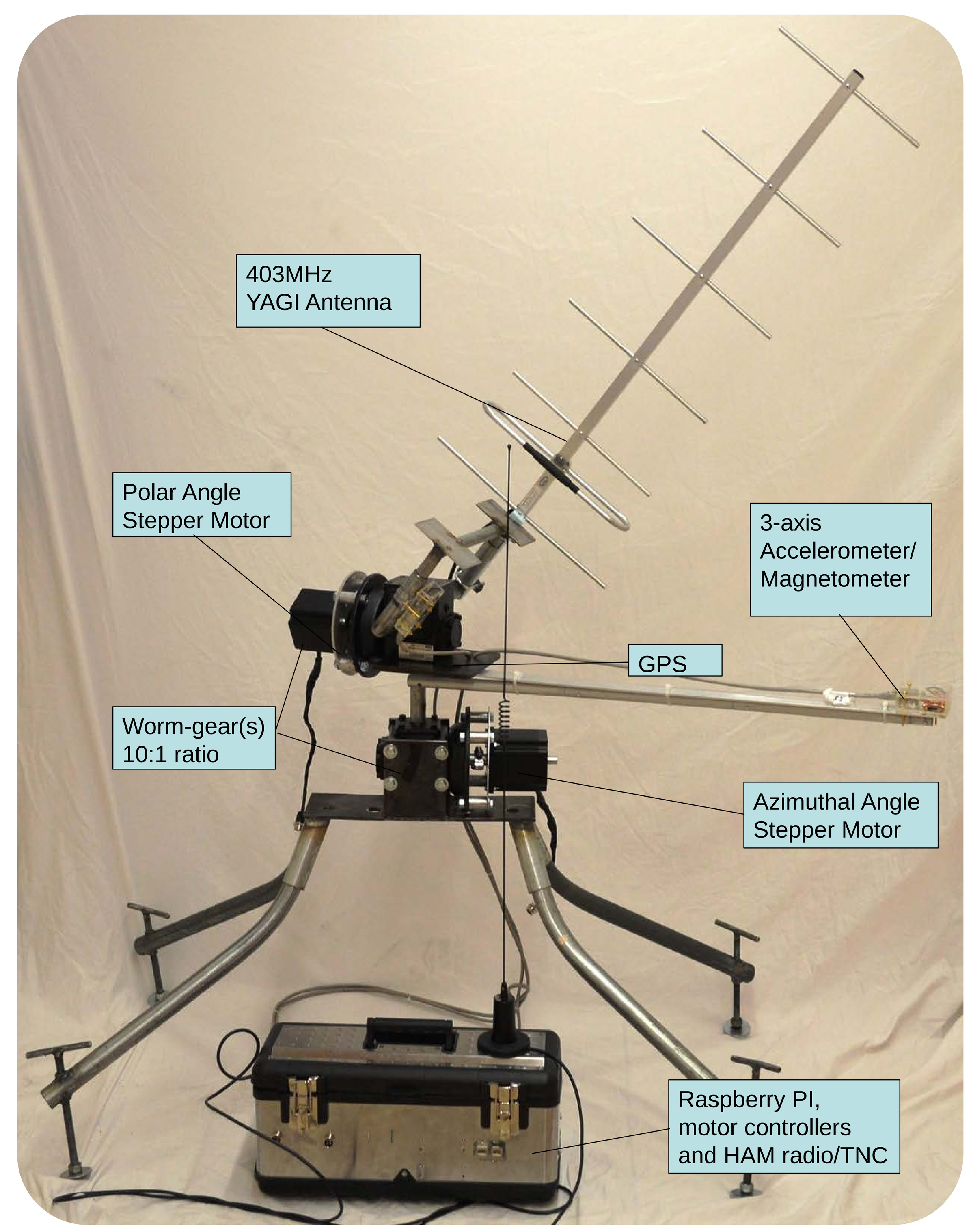


$$x = rSin(\theta)Cos(\phi)$$
$$y = rSin(\theta)Sin(\phi)$$
$$z = rCos(\theta)$$
$$\mathscr{r} = r - r'$$
$$r = \sqrt{x^2 + y^2 + z^2}$$
$$\theta = Cos^{-1}\left(\frac{z}{r}\right)$$
$$\phi = Tan^{-1}\left(\frac{y}{x}\right)$$





(upper left) GPS coordinates are reported as altitude (radial distance from Earth's center, but referenced to sea level), longitude (polar angle), and latitude (azimuthal angle). We can use spherical coordinates to describe the position of the ground station and the near-spacecraft. We can think of these coordinates as a position on concentric spheres, and the antenna needs to point towards a position on the second sphere. The smaller sphere represents Earth, while the larger sphere represents the spherical position of the near-spacecraft. Note: positions are exaggerated for visual aide. The blue dot represents the center of Earth, the green dot represents the tracking antenna, and the red dot represents the target. (upper right) Provided are the equations for transformation between spherical and Cartesian coordinates. (lower left) For our current design, we first find the rotational angle from north to the balloon, and the horizontal separation distance between the antenna and the balloon. (lower right) Next we find the azimuthal angle using the balloons GPS altitude and the calculated separation distance. This also provides us with a line-of-sight distance between the antenna and the near-spacecraft.



Future advancements:

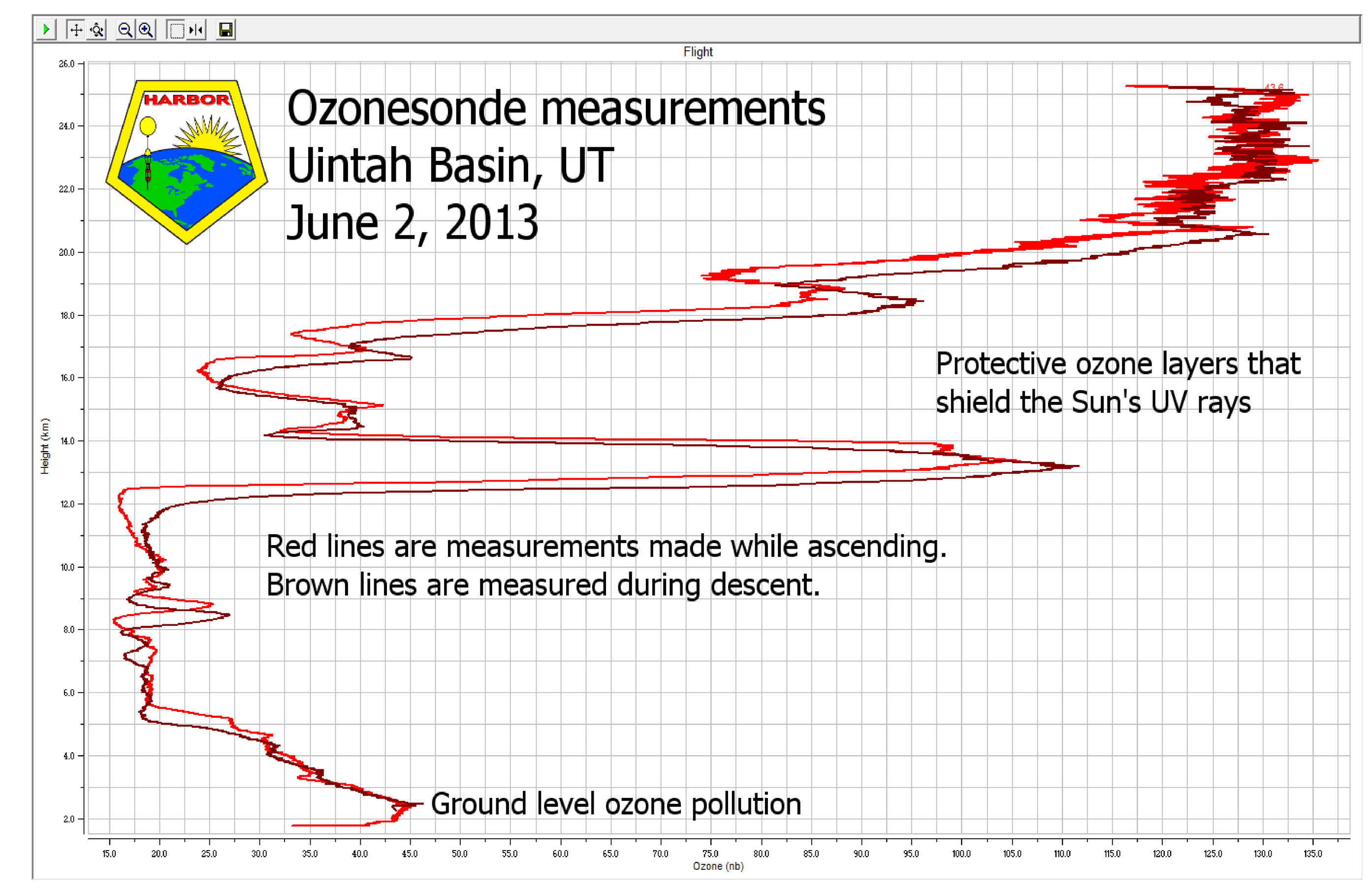
The current system is dependent on a level platform oriented towards magnetic south. We would like to use µ-metal to shield our 3-axis magnetometer from the magnetic field induced by the stepper motors. Shielding would remove the need of the extended arm holding the 3-axis accelerometer and 3-axis magnetometer, allowing us to mount the system on top of a moving vehicle while tracking.

(upper left) This is a pre-manufactured tracking antenna design created by a company called Optimum Solutions (image from Optimumsolutions.com). The cost of this model is approximately $15,000-$50,000 depending on added features and accuracy capabilities. (right) We see the current model for the student designed and constructed automated tracking antenna (ATA). It has only been tested with ground-based signals, but is considered functional. It will provide ground support for its first HARBOR flight this coming May. The final cost of the project unit was roughly $1,500.

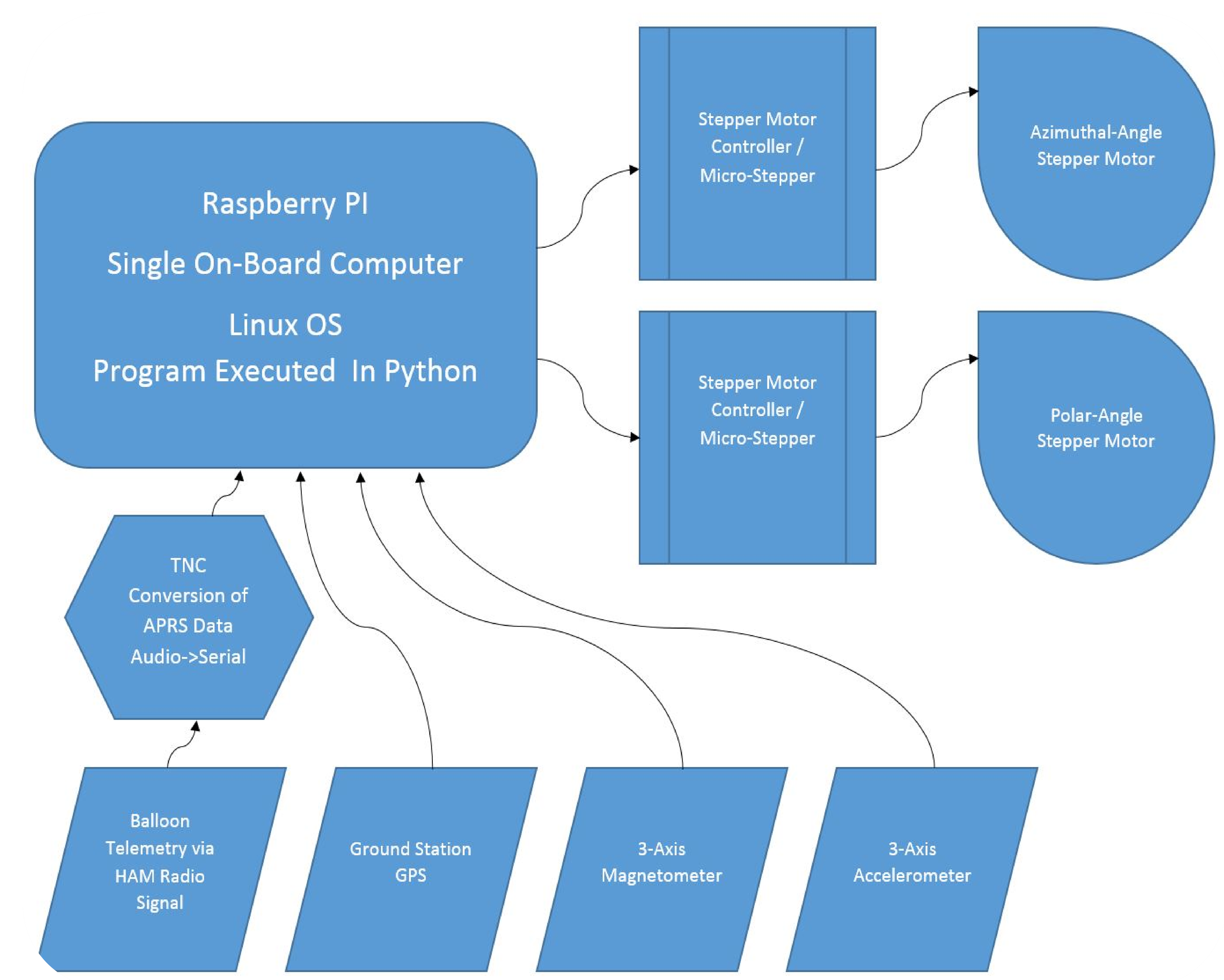
The original tracking antenna design used powerful stepper motors without the aide of worm-gears. Upon calculating the expected torque load on the motor, we determined a stepper motor of this capability would be too costly; thus, the implementation of worm-gears was introduced. Worm gears will reduce the rotational velocity output of a motor, while equally increasing the effective torque output by a fixed ratio. For this project, we used a ratio of 10:1 (factor-of-10 decrease in rotational velocity output with a simultaneous factor-of-10 increase in torque output).

Stray magnetic fields became a serious problem. The large currents flowing through the coils of the stepper motors created strong electromagnetic fields, causing sensor measurement corruption in the 3-axis magnetometer (measuring Earth's magnetic field). In order to correct for this, the sensors had to be placed at a distance from the stepper motors, at the end of the extended arm - shown above.

(left) The Ozonesonde, or ozone-detector, is like a small chemical laboratory. It has a small pump which takes in surrounding air and passes it through two chambers of chemicals. If ozone is present, the chemicals react, creating a potential cell that outputs direct current. The level of the current is transmitted to the ground station as data to be collected.



(above) Ozone data from the Ozonesonde. Line-of-sight tracking is required since the ozonesonde radio is weak. The data are then interpreted at the ground station from current levels to ppm measurement of ozone at specific altitudes. Other data are also in the downlink including position, temperature, and humidity.



(above) This is the dataflow of the information in the tracking system. There is a single-board computer called a Raspberry Pi, which runs Python code on a Linux operating system. Both the operating system, and the tracking program are saved on a removable SD card. The inputs to the Pi consist of the balloon telemetry data and the antenna GPS locational coordinates for position identification, and 3-dimensional magnetometer and accelerometer data for relating the direction the system is pointing. These data are processed and directed as an output command to the motor controllers to rotate the motors. As the motors rotate, the sensors provide the effective feedback to monitor the directionality of the antenna.