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# Moon Buggy Telemetry Program Report

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# Honors Capstone

by


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An Honors Capstone

submitted in partial fulfillment of the requirements

for the Honors Diploma

to

The Honors College

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## Abstract

To complete the Honors Capstone required for each Honors student seeking a diploma, a telemetry device for the University of Alabama in Huntsville's 2020 Lunar Rover team was researched and created in hopes of receiving an award outlined in the official NASA HERC guidebook. This award is referred to as the AIAA Telemetry/Electronics Award. According to the guidebook, this award "recognizes the development and operation of the most innovative and useful real-time telemetry system at the Rover Challenge." Being able to transmit and receive real time location data from the rovers would have been extremely useful while training on the practice course, as well as competing in the actual competition. This project utilized an Automatic Packet Reporting System (APRS), an amateur radio-based system for transmitting real time data in the local area. In this case, the transmitted telemetry information is the GPS location data of the human rover.

## Requirements

The design criterion for this device was created using the requirements set forth by two entities: the American Institute of Aeronautics and Astronautics and the UAH Honors College.

The requirements as described by AIAA are those illustrated in the official 2020 NASA HERC guidebook. Criterion is listed to ensure that a telemetry device is created for a competitive lunar rover in order to qualify for a design-based award.

The requirements state that the telemetry device must be built with the intentions of completing one of the following tasks:

1. Transmit Real-Time Video.
2. Transmit Real-Time Sensor Data.

The ability to meet one or both of these requirements is judged primarily based upon the device's design choices with respect to its usefulness to the crew and innovative design. It is worth noting that the device may still qualify for the award given a failure to record during competition. The device is judged significantly upon its presentation and a report written by the team to describe its key features and usefulness.

The second set of requirements is listed by the UAH Honors College, for which this report is written in order to complete the official Capstone requirements. The purpose of the Capstone is essentially to produce a new and original product within the respective field of study. The Capstone can fulfill one of two formats: a thesis or a project. The telemetry device described here falls into this second category to be completed in a senior design course. The most prominent requirement for this project is to provide a product that has justifiable importance and originality.

Based upon these requirements, a design was implemented to provide a GPS-inspired telemetry device to track the movement of the lunar rover in a competitive setting.

## Design and Components

The telemetry device and its corresponding systematic components were designed to fulfill the following tasks: establish position once in a given time period, relay packet information containing locational data once in a given time interval, receive the information at a distanced receiving station, plot such data as velocity and geographic coordinates, and save this data to a .csv file for post-processing.

To complete these tasks, the following design was created and modified upon given its theoretical use in competition. Attached to the human rover would have been a radio transmitter and Raspberry Pi, which together would have worked to beacon the rover's location with a time stamp. The Raspberry Pi was programmed to record and transmit live location data. Since it was not feasible for a stationary observer to have a wired connection to a moving vehicle, the radio transmitter would have allowed for the transmission of this location data to another radio at a central receiving station somewhere off-course.

The data received by the receiving radio would then be fed to a computer to allow for a more clear and readable display of this data for the crew, which would have been located at the central station. Although radios would have been implemented in this system, the communication itself would have been entirely digital. The radios would transmit the digital data as it is, without converting it to a noise audible to humans. The data, including the rover's location in longitude and latitude and the time at which the location was recorded, would then be plotted using external applications such as Excel.

This system would have used a data link layer protocol of AX.25, which is commonly used with microprocessors and even personal computers. This protocol would allow the data to transmit without a Wi-Fi signal, producing a more reliable - and therefore competitive - process.

Figure 1 displays the general setup for the telemetric system. The Raspberry Pi located on the rover also would have had a digital display screen, which would have allowed the location data to be viewed in real-time not only by the crew located at the central station, but also by the riders on-board the rover. Because the system would have utilized a microprocessor and radio, it would have been relatively small and lightweight, allowing for more space to be given to the other necessary tools such as those used to complete course objectives. A case for the system would have been 3-D printed from PLA filament to keep the system well-contained on the rover and protected from the turbulence and dust of the course while still maintaining its small and lightweight status.

**Figure 1: Raspberry Pi setup, with the microcontroller, radio transmitter and receiver**

**Note:** Given the circumstances surrounding the novel coronavirus, the telemetry system was not fully refined. The setup shown above depicts an early model for the overall system layout. Cases and rover attachments were designed in theory.

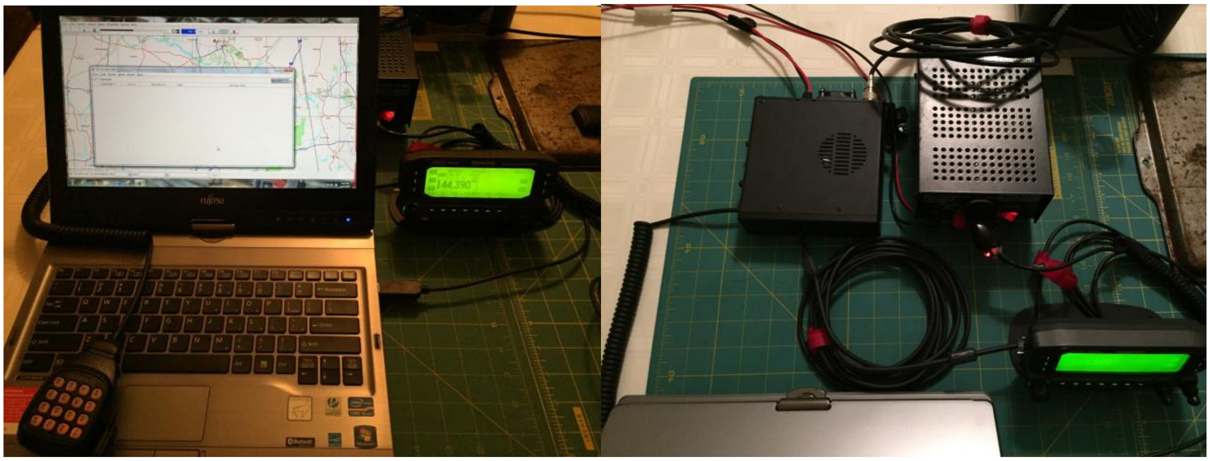

**Figure 2: Final Base Station Setup**

Figure 2 shows the final setup of the base station. This includes a radio to receive the data transmitted by the rover, and a laptop to display the real time data in a more graphical format.

Figure 3 shows the final setup of the mobile station. This is what would have been attached to the human rover. This includes a Raspberry Pi to record and display data, and a radio to transmit this data to the base.

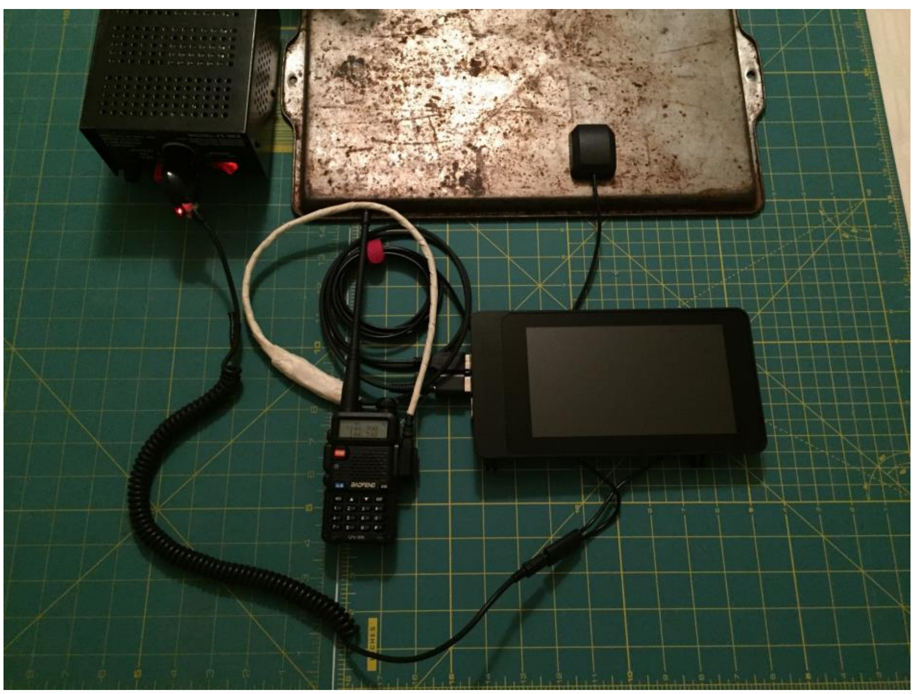

**Figure 3: Final Mobile Station Setup**

## Testing and Modifications

Testing of the initial telemetry system was performed by mounting the transmission station in a moving vehicle. Operating conditions were exaggerated to test the maximum capability of the telemetry device. The receiving station was located at approximately 10 miles away, well above the expected distance of the station during competition, which would ideally be within 1 mile of the rover's location at all times. Over 100 data points were collected from a plotted course at a higher average velocity than would be demonstrated by the rover during competition.

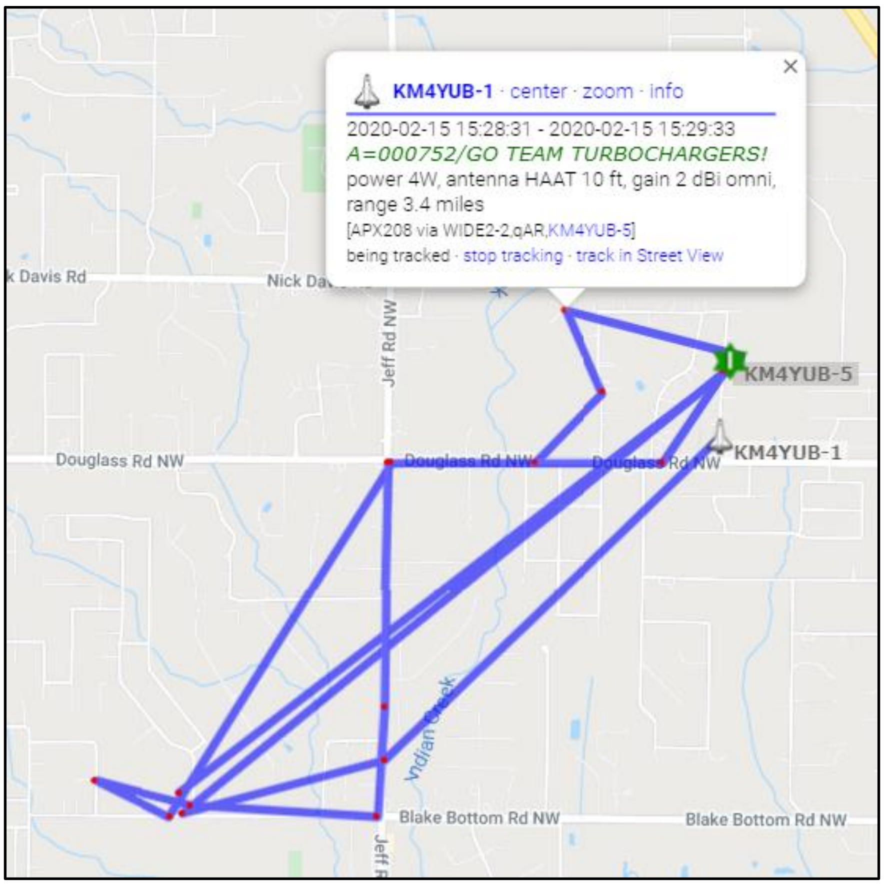


**Figure 4: Graphical Depiction of APRS Data**

Figure 2 depicts the data obtained in the testing phase of the device. This figure depicts the ability of the system to record and transmit GPS location data in a situation similar to that of a rover moving throughout a simulated course. The red points represent the location beacon, or the time at which the location of the vehicle is beaconed from the transmitter to the receiver. The system transmits the vehicle's location by connecting the red points with the blue line markers as depicted in the figure. The green *I* is the stationary receiving end, and the shuttle symbol represents the moving vehicle. The initial data recorded is numerical but is converted to the graphical format as seen above.

Originally, this system would have been modified to transmit locational data every 20 seconds during the operational period of the device. During competition, a map of the course located at the U.S. Space and Rocket Center would be plotted similar to Figure 1.This map of the buggy's location would be used in tandem with the timestamps received of each beacon to determine the rover's trajectory throughout competition.

Figure 5 shows a map of NASA's human rover course, as well as theoretical APRS data that could have been made by the rover if the competition had indeed taken place. Each blue dot represents a data point where data would have been collected and transmitted to the central station.

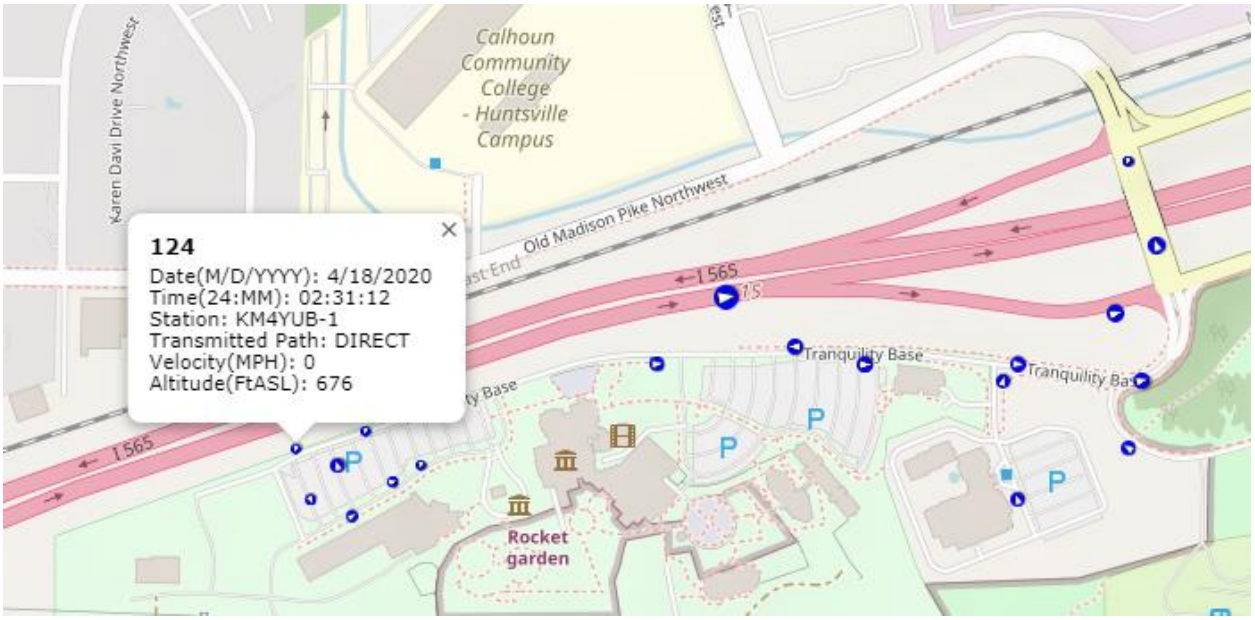


**Figure 5: Graphical Depiction of APRS Data with Course Overlay**

## Usefulness and Innovation

The locational data provided the telemetric system would have been especially useful to the moon buggy team because it would have provided a detailed map of how long it takes the human rover to complete each obstacle and task. This information would have allowed the team to make decisions about how to best optimize the collection of the maximum number of points possible without exceeding the time limit. This data would have been especially useful during the practice run the day before the competition, when the team would have been able to strategize the best plan of action for the buggy for the actual competition using data obtained from the actual course. Moreover, the innovative design of the telemetry does not rely on cables or Wi-Fi to communicate between the buggy and central station, but rather radio waves, allowing for reliable transmission in a variety of environments. This system would be further improved by encasing it in filament that would protect the hardware from damage given any tipping or collision between objects and the buggy.

With communication between the central station and the riders on the day of the competition, live data would have given the team a competitive advantage as it would allow the team to make rapid but informed decisions about whether or not to bypass an obstacle or task to save time. This ability to make last-minute decisions regarding the application of our products would provide the team with a competitive edge throughout the course.

## Summary

Given the requirements set forth by both AIAA and the UAH Honors college, the telemetry device described here fulfills the qualities of being both an innovative and useful design. The use of GPS signaling in tandem with radio transmission is an uncommon yet reliable method to transmit data in the condition that there is a significant distance between the transmitter and receiving stations. The telemetry device’s design fulfills the criterion of transmitting real-time data for use in a competitive setting, in which the UAH Lunar Rover team would have utilized this information for strategic purposes given the NASA HERC competition had not been cancelled due to unforeseen events.

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**David Cook <dac0010@uah.edu>**

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# Re: Honors Capstone Approval

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**David Fikes** <fikesd@uah.edu> Wed, Apr 22, 2020 at 10:49 AM
To: Keith Hollingsworth <dkh0010@uah.edu>, wilkerw@uah.edu, dac0010@uah.edu
Cc: Erin Corum <enc0007@uah.edu>, Grace Babb <geb0007@uah.edu>, David Fikes <fikesd@uah.edu>

4/22/20
I approve of the Moon Buggy Telemetry Honors Program Report by Grace and Erin.
Please contact me in you have any questions,
David Fikes , instructor

On Wed, Apr 22, 2020 at 10:27 AM Grace Babb <geb0007@uah.edu> wrote:

> Attached is the Capstone Manuscript and the title page and copyright for Grace Babb and Erin Corum. As the project director, you can approve it by emailing your approval back to me, while also copying the department chair (keith.hollingsworth@uah.edu), the honors chair (wilkerw@uah.edu), and David Cook (dac0010@uah.edu). It is important to copy all three of these people into this email. You do not have to physically or electronically sign anything. The email itself will be recognized as an official signature. Please let me know if you have any further questions.
>
> -Grace Babb