AggieSat Laboratory

Performance Analysis Report - ATHENA

Overview

The ATHENA mission is a simulated planetary science mission. The mission objectives are to autonomously locate and locomote to an RF waypoint and to collect environmental data at the beacon's location. The system was deployed on April 28, 2025.

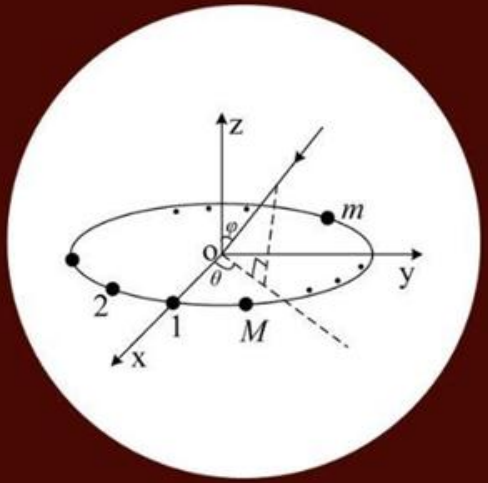
Mission Summary

Planned Mission Summary

The Athena system consisted of a rover and a ground station deployed into an outdoor environment on the RELLIS campus. Once the rover was deployed, it attempted to autonomously locate and navigate to a beacon transmitting operating in the 420-430 MHz band. Once the rover reached the beacon, it would stop its movement and begin recording temperature and wind data for five minutes, after which it would transmit this data to the ground station.

Phase 1
Initialization

- Startup Sequence
- Sensor arm deployment using spring release



Phase 2
Beacon Finding

- Listen for beacon transmission.
- Calculate three DoA vectors individually
- Calculation of position coordinates of transmitting beacon

Phase 3
Nominal Operations

- Scan environment with LiDAR
- Identify a traversable path
- Move along the determined path
- Repeat prior steps until the beacon is reached

Phase 4
Data Collection and Transmission

- Sensor Data Collection
- Radio Data Transmission
- Shutdown

ATHENA Mission Phases

System Design

TMS - Design [01]

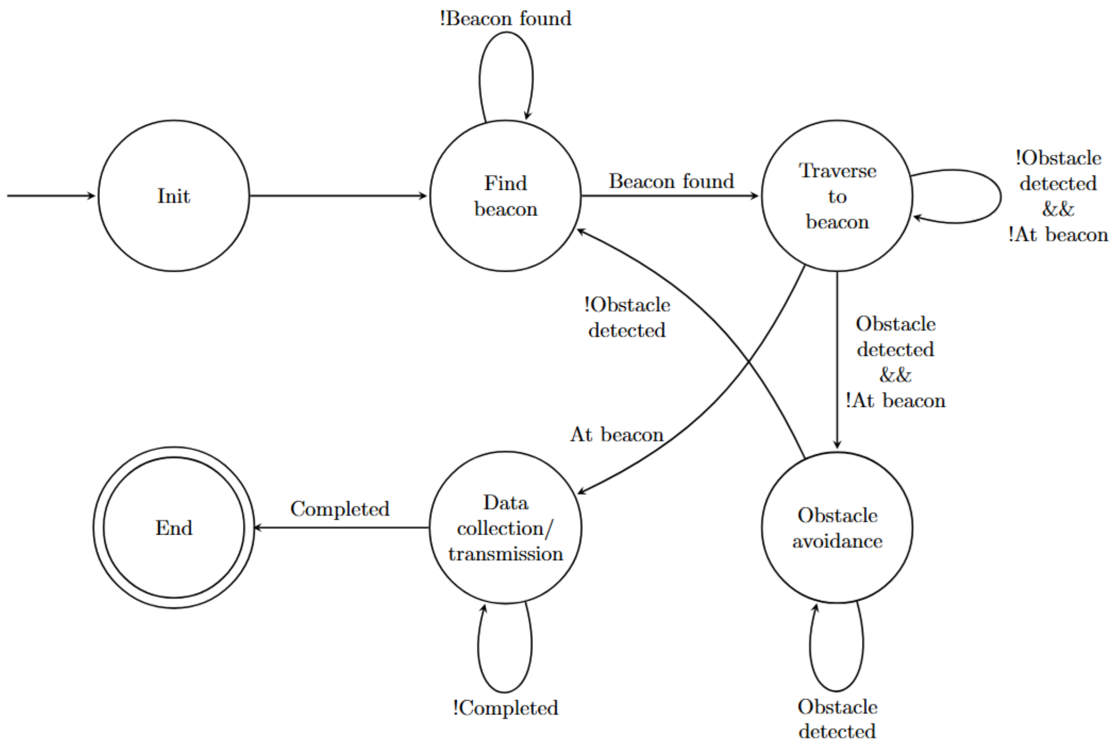
- Used Modular 3D print chassis for easy design changes, custom components, manufacturability
- Embedded bearings in the wheels, embedded collars in the motor gears and heat set inserts to maintain strength while allowing for modularity
- LiDAR and antenna mounts in optimal locations while protecting them from the environment

CDH - Design [02]

-FSM for general event checks and behavior transitions

-State Machine designed with main “Beacon finding -> Lidar -> Travel” loop in mind

-Weather data code was completed and implemented except for wind data

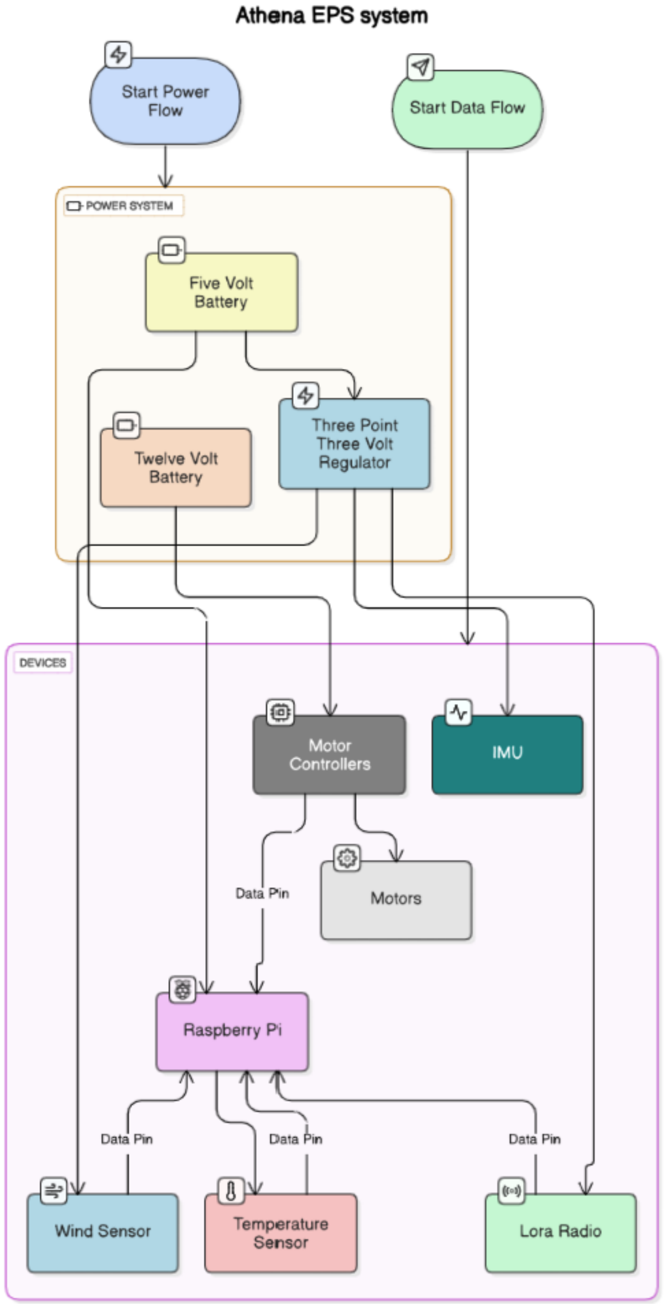


CDH - Expectations [02]

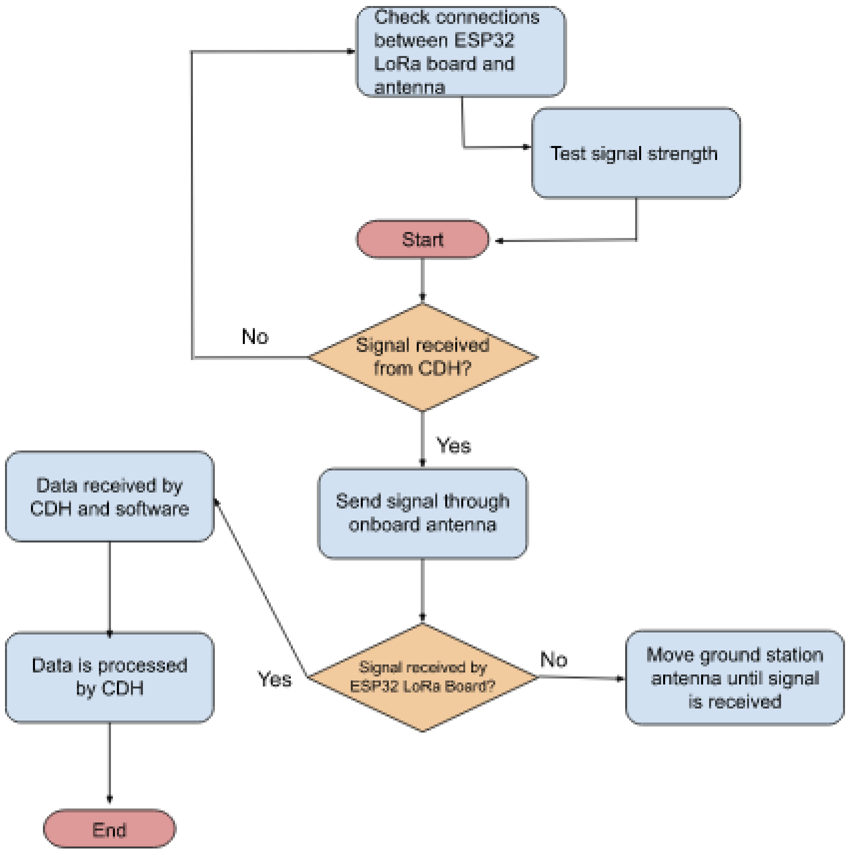
- Originally, the state machine diagram was meant to operate throughout the states: “Init” -> ”Find_beacon” <-> ”Traverse_to_beacon” -> ”Collect_and_transmit_data” -> ”End”
- Rover would reach beacon and transmit data
- Obstacle avoidance was to be used occasionally when the rover’s path was blocked
- LoRa was supposed to transmit readings of Temperature, Pressure, Humidity, and Wind Speed.

EPS - Design [03]

- Separate drivetrain and logic component batteries to ensure nominal behavior and mitigate power constraints.
- Common ground amongst all components to prevent frying
- Amperage and voltage requirements hit at all times during the course of the competition



COM - Design [04]



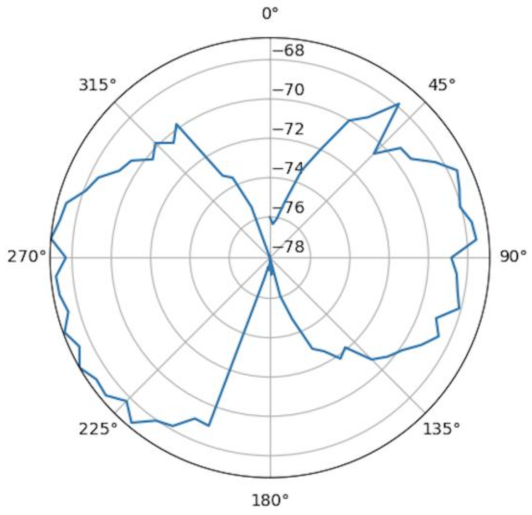
The COM Subsystem consists of a computer running the Python script, the ESP32, and the RFM9x radio module

Component	Radio Interface	Transmitting Frequency	Output Power	Cost	Notes
Adafruit RFM9x LoRa	LoRa	915 MHz	13-20 dBm	$19.95	Antenna not included, connected via RP-SMA

Component	Radio Interface	Band Width	COM Interface	Cost	Notes
MakerFocus ESP32	LoRa	915 MHz	SPI	$24.99	Antenna included (2 dBi wire antenna)

GNC - Design [05]

- A 433 MHz Taoglas Directional Helical Dipole Antenna was connected to a HackRF one to use Null Pointing for DoA Generation
- A RPLiDAR A1 was used for Obstacle Avoidance and Detection. The LiDAR generated a 2D point cloud that detected obstacles in its plane



Taoglas 433 MHz Tested Radiation Power

Performance Analysis

Review of Performance

- Upon deployment, the rover attempted to sense the beacon but interference, noise, and inaccurate turns reduced accuracy
- The ATHENA system repeatedly detected grass which kept it constantly in the obstacle avoidance state
- The ATHENA system was unable to turn in place in grass which meant that obstacle avoidance movements needed to be changed last minute
- The ATHENA system recorded 50 entries of weather data which was transmitted to the ground station system via WiFi

Listening System

- Upon deployment, the rover’s RF listening system was unreliable and prone to crashes. This necessitated repeated antenna restarts and reduced beacon finding accuracy.
- The chosen method for RF DoA Vector generation was null pointing.

Obstacle Detection and Avoidance

- Upon deployment, the rover had a functional obstacle avoidance and detection system. However, obstacle avoidance was overactive and kept detecting the surrounding grass.
- This stems from a lack of system-level testing to identify this issue.
- This led to ATHENA constantly turning a few seconds into deployment and circling until mission end.

Data Collection Successes and Failures

- The ATHENA rover collected 50 entries of temperature, humidity, and pressure data.
- The wind sensor was not integrated
  - the wind sensor was acquired shortly before the competition so there was no time to integrate it
- The LoRa module failed, preventing any data transmission
  - The LoRa passed unit level testing, however upon integration the module experienced issues

Data saved locally from flight computer

CDH - Future

- Build State Machine and perform subsystem integration sooner in order to iron out any faults in the states.

- Do extensive testing to ensure all components work before rover is required to be used. Ensure testing is done with all sensors wired in their final configuration as different pins may cause issues in coding and rover deployment

- Ensure components are acquired well before the deadline

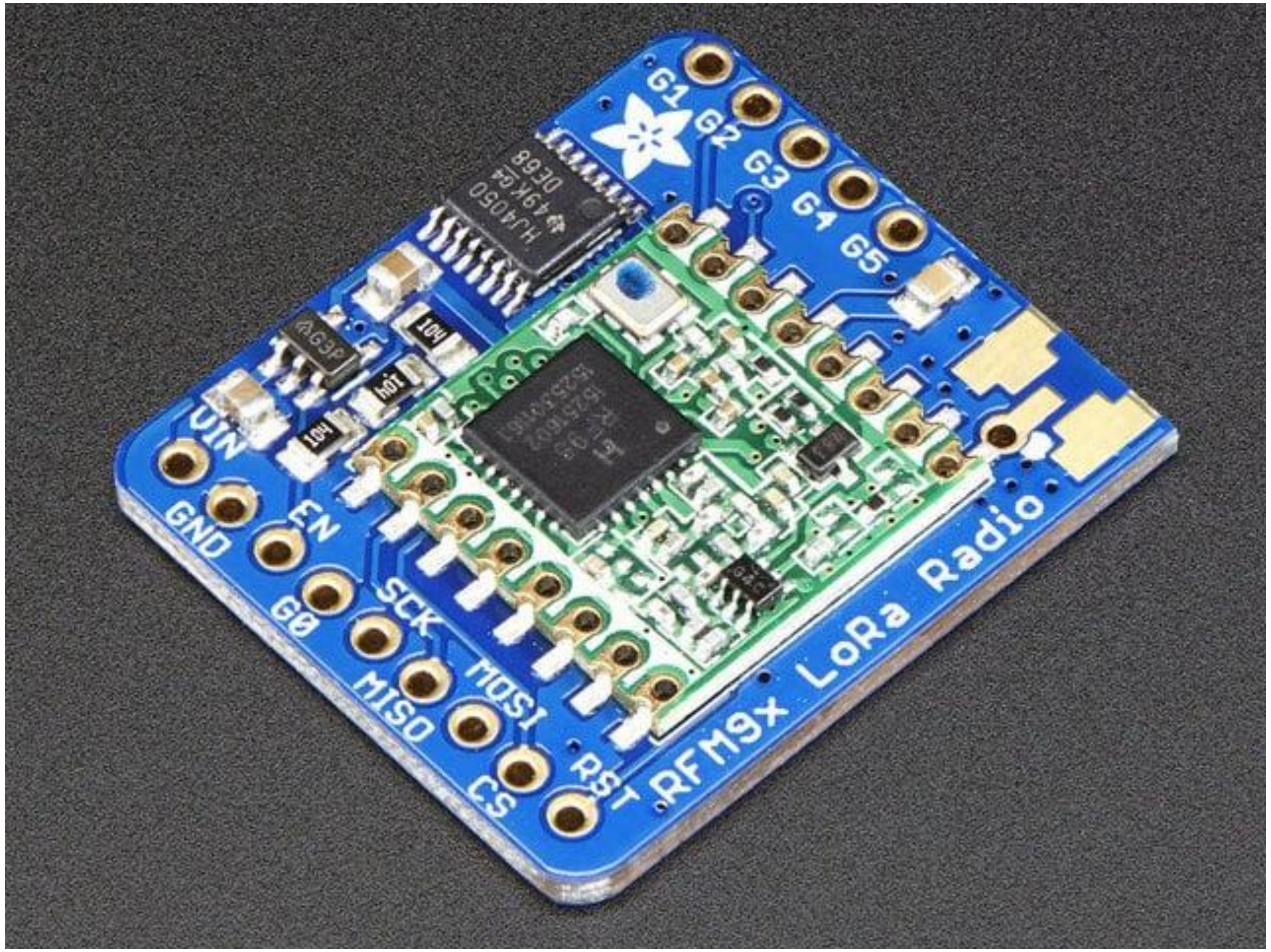
EPS - Performance

- EPS provided power during the duration of the competition.
- Power was sufficient and did not have any EPS related issues during the match.
- Needs integration with other systems earlier to ensure nominal behavior

COM - Performance

- The LoRa module was unable to be integrated fully into the system. We are currently not sure what the issue was because the LoRa passed several unit level and system level tests.
- The Rover was able to additionally communicate with the Ground Station system (Laptop Side) via SSH (WiFi).
- ATHENA was able to downlinke 50 data points of BME280 temperature, pressure, and humidity data on the second attempt via a WiFi link.

COM - Future



- Integrate earlier for testing.
- Look into microcontrollers that can take 3.3V or 5V input for powering the LoRa which would negate the necessity for a Printed Circuit Board (PCB)

GNC- Performance

- The Obstacle Detection and Avoidance System worked, however it was very sensitive which caused the Rover to move away from objects that did not exist due to uneven terrain
- While the Listening System did find general directions to the beacon, it was not very accurate according to the data collected after. Additionally the ATHENA system was unable to traverse accurately in a straight line which meant that even with a DoA ATHENA could not traverse accurately to it.

Lessons Learned

What Should've Been Done Differently

- Integration should of been done much much earlier to prevent the issues in system failures we had.
- A different systems engineering model for extremely small projects and project teams should have been considered. The time lost to documentation that was unnecessary for a 3 person team contributed to the delays in integration.

The End