Satellite Antenna Tracking Mount

****Research Document

| Hunter Britton |  |
| --- | --- |
| David Santos | Version 1.0 |
| Michael Raabe | 31 January 2023 |

Concept of Operations

For

Satellite Antenna Tracking Mount

Team 35

Approved by:

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Project Leader Date

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Prof. Kalafatis Date

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# Document Control

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# 1. Executive Summary

This document outlines the specifications, constraints, and central design features that enable remote operation of satellite rotators. Current remote operation systems rely on proprietary software and can not be accessed through a web browser. The improved, internet-of-things (IOT) system will require little configuration and be open-source so users can easily add features. It will also incorporate secure user authentication and multiple modes of operation using the Google Cloud Platform.

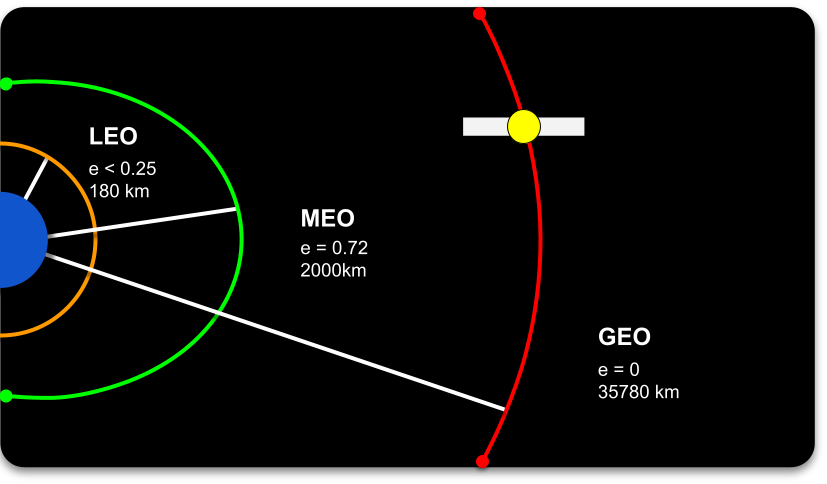
# . Introduction

Satellite communication has become increasingly more affordable and user-friendly with recent advancements in digital technology. One major factor that contributes to this, is the widespread use of Software Defined Radios (SDRs), which drastically reduce costs by performing signal processing tasks through digital implementations rather than with analog components. Additionally, satellite tracking software has completely automated the tedious calculations required to track the planetary movement of satellites based on a set of parameters and relative position of the observer. Amateur radio operators have benefited by using this technology to enhance their systems which consist of a directional antenna, a rotator, and transceiver. The rotator can be controlled either manually with precision dials or automatically through the use of motors and computer software. The objective of this project is to design a system that will allow for low-cost remote operation of the satellite antenna rotator. This is achieved by incorporating a microcontroller for sensor and motor control as well as a web application for user interface. The result is a more convenient and efficient way to control the satellite from any location. Amateur radio enthusiasts, such as our sponsor David Gent, will be able to enjoy satellite communication with greater ease and flexibility.

***Keywords:*** Software Defined Radios, Yagi-Uda Antenna, Altazimuth

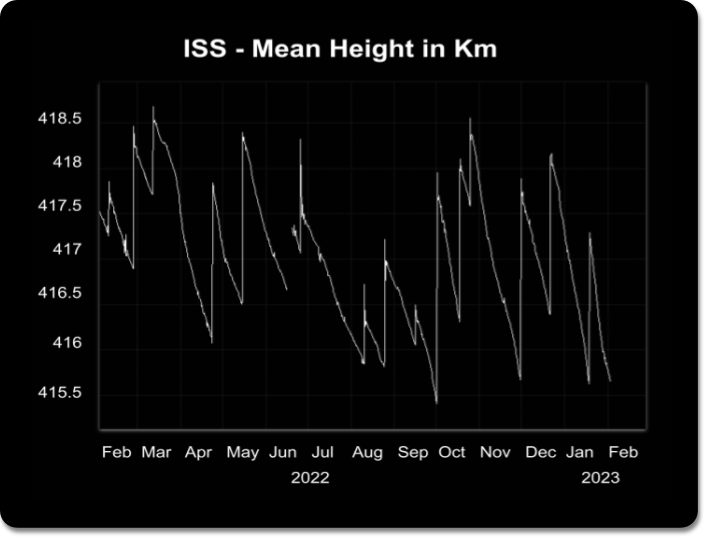
## 2.1 Background

### 2.1.1 Orbital Motion



***Figure 2.1:*** *Diagram of**Earth’s Satellite Orbits*

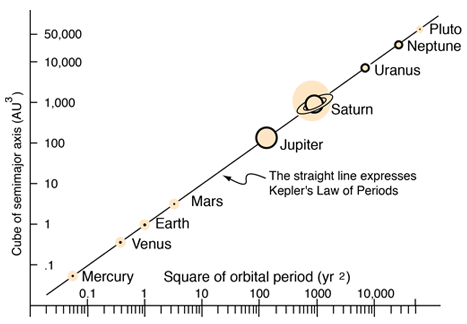
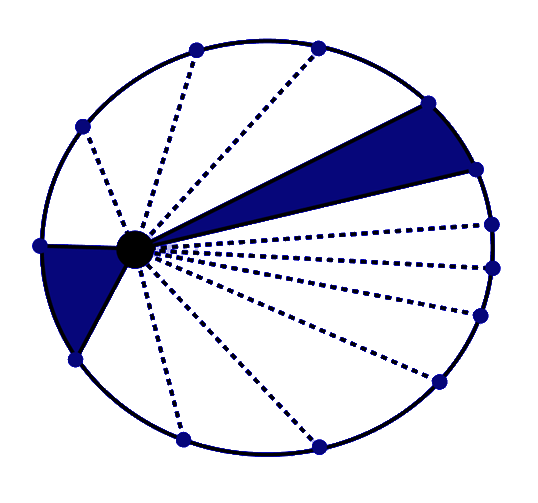
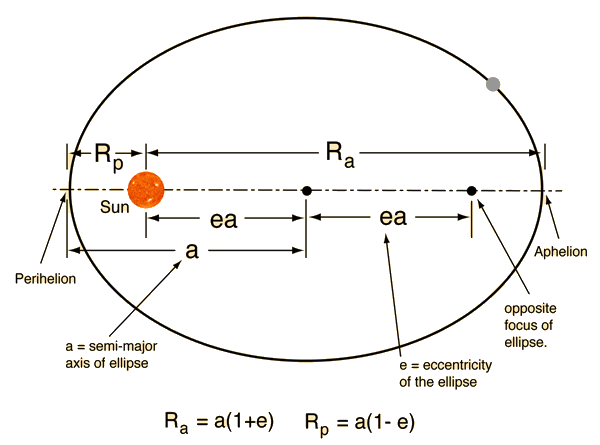
Satellite orbits refer to the elliptical path that a satellite follows as it revolves around the earth, shown in Figure 2.1. These orbits can vary in shape, altitude, and relative location due to perturbations like planetary gravitational pull and atmospheric resistance.[1] The Low Earth Orbit (LEO) is one of the three classes, found between 180 to 2000 km from the earth’s surface and is primarily used for weather and scientific satellites. LEO’s somewhat circular trajectory and close proximity to earth allows for shorter communication, making it ideal for real time data transmission like amateur radio. Additionally, the satellites in the lowest orbit experience the most orbital decay due to earth’s gravitational pull, meaning that more correctional maneuvers are required for them maintain their altitude.[2]



***Figure 2.2:*** *ISS Mean Height in Km (Feb 2022 - Feb 2023) src:* [*Heaven-Above.com*](https://www.heavens-above.com/IssHeight.aspx)

The ISS currently sits at 418 km as of February 2, 2023 according to the latest trajectory ephemeris message found on NASA’s website. The jagged figure above illustrates how often the thrusters are used to keep the ISS between 410 and 419 km. The medium earth orbit (MEO) is the second closest to earth lying between 2000 to 35780 km and has much less orbital decay. This also means that satellites in MEO revolve faster around the earth, completing an orbit every 12 hours or so. Here, short communication routes are traded for broader coverage of the earth surface, often being used in global positioning systems (GPS). Lastly, is the high earth orbit (HEO) and includes satellites outside the range of 35780 km. This orbit is geosynchronous in that it remains in a fixed position relative to earth, allowing for continuous coverage of a specific area. Weather satellites fall into this category and relay information regarding clouds, wind, and other meteorological data back to earth. [2] HEO satellites require less ground control operation since they do not suffer significantly from the Doppler effect and can cover a wide area.

Modern science has been able to predict orbits with high precision despite their complex movements. The first mathematical descriptions of planetary motion evolved in the early 17th century when Johannes Kepler, a German mathematician, published a series of laws on two body systems following the observations of Galileo. [1] The first of which called the Law of Orbits stated that planetary bodies travel elliptically with the sun at one focus. Ellipses are characterized by their eccentricity, a value between 0 and 1 that describes the deviation of a circle, and their foci, two reference points such that the sum of their distance to any surrounding point is constant. His second law was the Law of Areas which drew a positive correlation between the velocity of planets relative to their distance to the sun expressed as constant rate of change of area for each section of the orbit. His last law, the Law of Periods, suggested that the square of the planet’s period is proportional to the cube of the axis of its orbit. These three laws would equip Isaac Newton’s Gravitational Laws and later outline the modern Keplerian elements used today. [3]

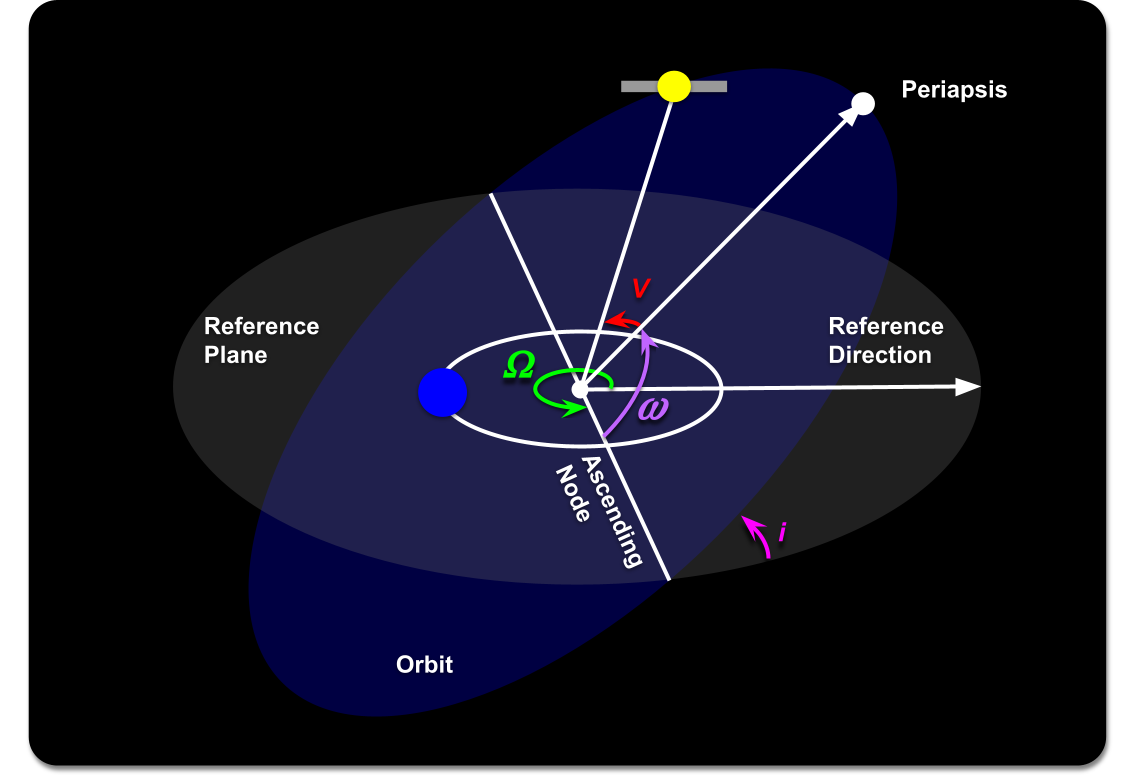


(a) Law of Orbits (b) Law of Areas (c) Law of Periods

***Figure 2.3:*** *Kepler’s Laws [4]*

Keplerian Elements, also called the classical orbital elements, are a set of six parameters unique describe its motion of an object, such as a planet or satellite and are as follows [5,pg 58]:

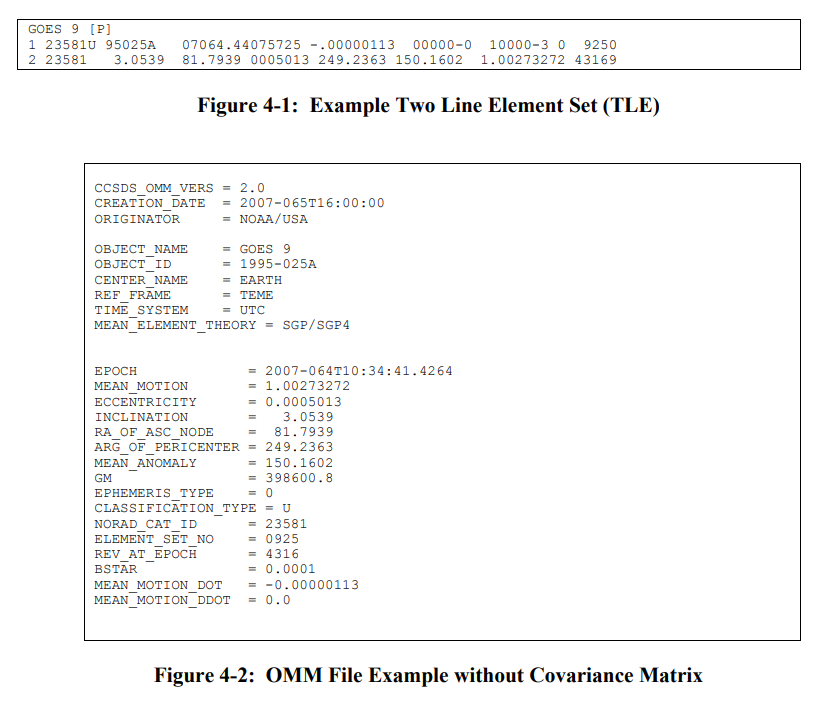
1. : describes the distance between the centers of each body
2. : describes the shape of the orbit
3. : describes the vertical tilt of the orbit with respect to a reference plane
4. : describes the horizontal tilt as the angular distance between the reference direction and the ascending node
5. : describes the angular position of periapsis along orbit
6. : describes angular position of satellite along orbit

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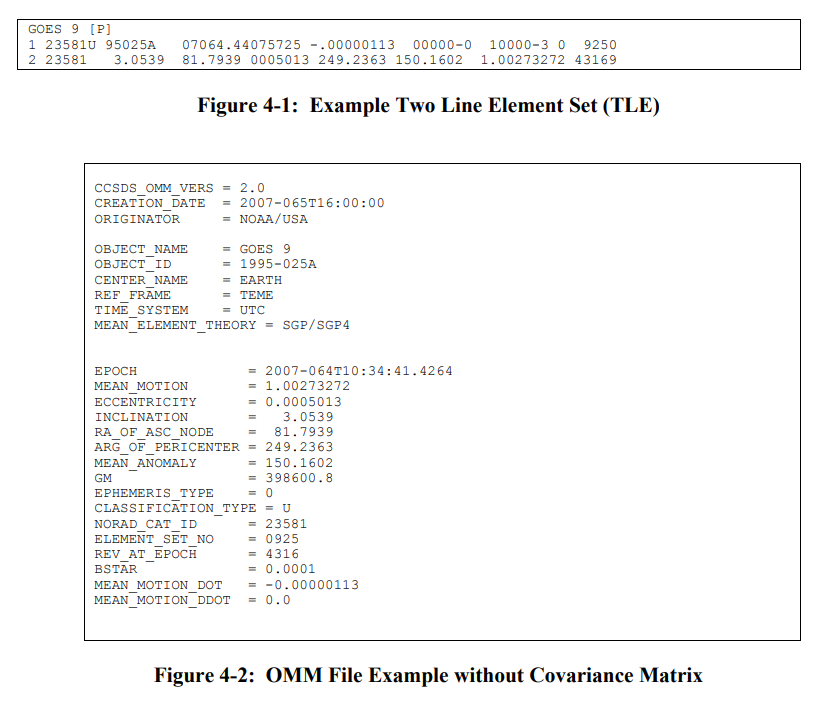
***Figure 2.4:*** *Keplerian Element Diagram src:* [*spaceacademy.net*](https://www.spaceacademy.net.au/watch/track/orbspec.htm)

Calculating the orbital propagation of a satellite for a given time, an epoch, requires rigorous vector and differential mathematics that would be too cumbersome to do by hand. Instead, software can be designed to implement the computations in a fraction of the time. However, in the 1970’s, the best computer was IBM’s 7090 which used data in the form of 80-column punch cards to compute. This meant that in order to handle the computations efficiently, the orbital elements would need to be in the most compact, simplified format possible while maintaining accuracy. The method developed by NASA is still sometimes used today, the Two-Line Element (TLE). [7]

The most modern TLE format, 3LE, actually features three lines, the first of which contains 1-24 characters that are used for unique identification under a common satellite catalog. For example, the ISS uses the name “ISS (ZARYA)”, after its first cargo module. The next two lines have 69 alphanumeric characters for the satellite’s classification, time stamp, and the Keplerian elements. [8] The limitations of TLE become more apparent following Y2K since only 2 two digits were designated for a year.[9] Similarly, only 5 characters were given to assign each satellite, allowing up to 99999 objects. In order to overcome this limitation, there have been a few attempts to accommodate more objects. The first was the United States Space Force, who proposed the use of numbers and letters to represent an object in a numbering scheme called Alpha-5. While this did increase the number of objects to 339,999, it was really only an intermediary solution to accommodate the influx of smaller objects. More recently in 2020, two non-profit space contractors developed the Orbit Mean-Elements Message (OMM), extending the number of catalog objects to 999,999,999. Similar software compatible formats followed this standard such as XML, KVN, JSON. TLE is still used today, but exclusively for objects with low catalog numbers.

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*(a) Two-Line Element Format (TLE)*

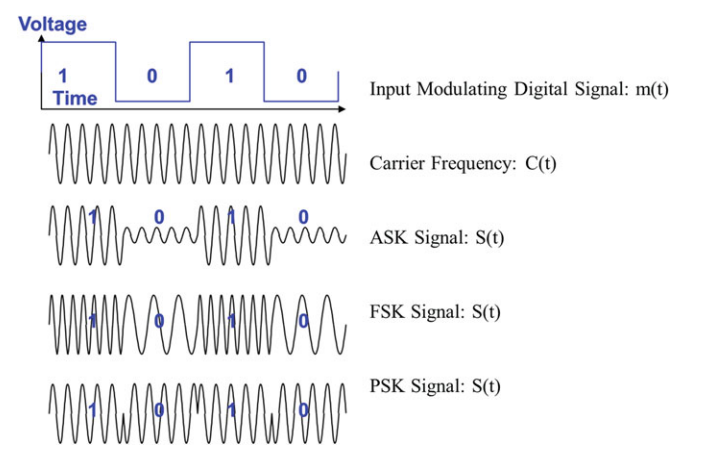
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*(b) Orbit Mean-Elements Message (OMM)*

***Figure 2.5:*** *GP Data Format Comparison [10, pg 34]*

### 2.1.2 Radio Communication Systems

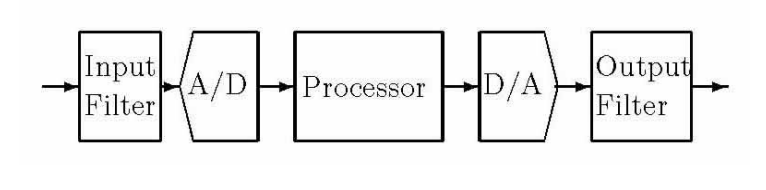
Satellite communication was first developed in 1945 by Arthur Clarke who noted the ideal conditions of the GEO orbit for communication. However, it was not until the Soviet Union created the first satellite, Sputnik 1, that significant progress was made. [6] The United States would subsequently pass the Communications Satellite Act in 1962 to authorize the commercialization of satellite communication under the regulation of the FCC and NASA. Satellites are now a fundamental component of our infrastructure and with thousands orbiting the earth as of today they have become one of the largest technological industries. Satellite communication relies primarily on two components, the transceiver launched into orbit and the ancillary ground stations located across the globe that are responsible for transmitting and receiving signals, also known as uplink and downlink. [10, pg 325-263] Signals can also be amplified, translated into another frequency, or repeated until another signal is received. These stations are often categorized by their environment; land, aeronautical, or maritime to ensure the necessary variables are accounted for.

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***Figure 2.6:*** *Types of Modulation Techniques | [11]*

Radio signals are modulated to transmit information by imposing an input signal with data contents onto an underlying carrier wave. This information signal is formed by changing its amplitude, frequency, or phase to represent binary symbols, in a process known as modulation.[11] In amplitude modulation (AM), the amplitude of the carrier wave is changed in proportion to the information signal, while in frequency modulation (FM), the frequency of the carrier wave is changed to carry the information. The signal is then transmitted as electromagnetic waves to be received by an antenna and demodulated into the original information signal. The range of these radio waves can be influenced by many factors such as atmospheric conditions, terrain, and other electronic devices using radio communication. The range of radio waves is determined by their frequency, with low frequency waves boasting a wider range and high frequency waves having a limited range, constituting a tradeoff between data rate and coverage.

Radio frequency (RF) bands are segments of the electromagnetic spectrum measured as a range of frequencies in Hertz. Each band is characterized by this frequency range, the number of bands or “bandwidth”, and their propagation through a medium. For example, submarines often rely on extremely low frequency (ELF) radio waves that have a frequency range of 10-100Hz for their communication systems because they can travel long distances in the water without being absorbed. [13] Conversely, Wi-Fi uses ultra high frequency (UHF) and super high frequency (SHF) at 2.4 Ghz and 5Ghz respectively which can be further divided into subchannels. Unlike submarines which need a long range with no obstacles, Wi-Fi requires line-of-sight connection between an access point and a mobile antenna to access better data rates.[14] One other band is the extremely high frequencies (EHF) which range from 30 to 300 GHz. It is also known as the millimeter wave band due to its relatively short wavelength. This band has a large bandwidth, making it ideal for high-speed data transmission, such as in fifth generation (5G) mobile networks.[16] Additionally, EHF’s data throughput is well-suited for applications that require high-resolution imaging, such as medical imaging and remote sensing. However, due to its high frequency, EHF signals are easily absorbed by atmospheric gasses and absorbed by solid objects, making it necessary to have a direct line-of-sight connection between the transmitter and receiver. The demand for high-speed communication and the development of Internet of Things (IOT) are expected to drive growth despite these challenges.[17]

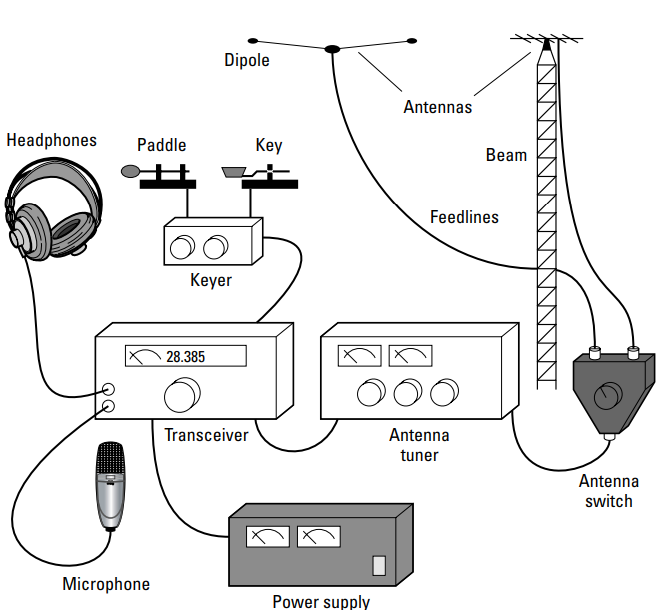
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***Figure 2.7:*** *Basic Architecture of Software-Defined Radio | [15,pg 2]*

For a majority of the past century, the development of radio transmitters and receivers has been dominated by analog implementations of signal processing.[15] However, digital circuits have replaced these inefficient systems, allowing for improved performance, interoperability, and reduced power consumption. The basic architecture of the SDR receiver is illustrated in Figure 2.7, where a raw analog signal passes through a bandpass filter to select the frequencies before it is digitized by the analog to digital converter (ADC). The computational workload is then typically handled by Digital signal processors (DSP) or field programmable gate arrays (FPGA) for reconfigurability. They also are responsible for modulating the transmitted signal before it goes through a digital to analog converter.

Amatuer radio, also known as Ham radio, is a worldwide community of radio communication enthusiasts who participate in various activities such as emergency communication and radio competitions. In the late 19th century, interest in radio communication grew into diy antennas, transceivers, and morse code to communicate over long distances. In this context, it is important to note that the term “amateur” is used to separate this community from commercial practices such as broadcast radio and television.[12] The International Amateur Radio Union (IARU) was later established to promote the development and regulations of Ham Radio. Ham radio, which once saw upwards of 3 million users, has seen a decline since the invention of mobile communication devices like the smartphone and the internet.[18]

The FCC offers three license classes; technician, general, and extra. Technicians are entry-level operators with access to amateur radio frequencies above 30MHz.The General license gives operators access to all VHF/UHF amateur bands and HF privileges as well as all operating modes. These licenses require a 35 question exam covering regulations, theory, and applications. The Extras license essentially expands HF frequencies to all that is allocated for amateur radio operators because they may be crowded. [19] The Extra license is a 50-question written exam covering obscure regulations, advanced electronics, and radio design. It used to require proficiency in Morse code (5 wpm), but it was discontinued in 2007 in as it was considered to be “an unnecessary regulatory burden that may discourage current amateur radio operators”.[20]



***Figure 2.8:*** *Basic HAM station with common accessories | [21, pg 23]*

Amateur radio operators are always looking for better, more cost-effective gear such as tall antenna towers or the latest transceiver in order to improve signal strength and increase the range of frequency bands. Figure 2.8 shows a basic HAM station from the early 2000’s, but not a lot has changed in terms of function. Dipole antennas or multiple element antennas are still used to capture the signal at some multiple of the quarter wavelength of the desired frequency. The signal is then processed in a SDR or transceiver before it can be heard as an audio signal. Some operators still use morse code keyers, but for the most part they are obsolete.

Operators are given a unique alphanumeric identifier when they pass the licensing exam referred to as a “call sign”. [21, pg 58] Each call sign is composed of a prefix and suffix specific to the operator's country and license class. For example, the U.S. licensees all have call signs starting with K,A, N, or W. Similar to call signs, are Q-Signals, a shorthand system of abbreviations used to communicate common information between operators who may not share a common language. [22] Abbreviations must start with Q, have three letters, and can either be a question or statement depending on if there is a question mark. For example, “Who is this?” can be translated to “QRZed?”. Letters are usually communicated using the ITU phonetic alphabet, so this question would be “ Quebec, Romeo, Zulu’d?”.

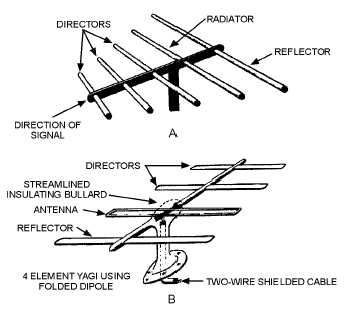
Remote operation allows operators to control their equipment over the internet anywhere in the world. Protocols such as Remote Radio Head (RRH), Radio over IP (RoIP), or Internet Radio Linking Project (IRLP) can be used to receive audio and control signals over the internet as a data packet. The remote operator can then control the transceiver and participate in real time communication. Software such as PstRotator is also available for $25 to control the rotator over a TCP client and RS232 communication. [23] However, current remote operation systems are only available for personal computers whereas web applications save storage and can be accessed from any device, even mobile.

### 2.1.3 Antenna and Rotator

Shown below is the main type of antenna that is going to be used for the operation of this device. The Yagi-Uda antenna was invented in 1926 by a pair of engineers. The main inventor was Shintaro Uda, who was a graduate student under Hidestugu Yagi, who’s name is more attached to the invention. The main Yagi-Uda antenna, normally shortened to just Yagi antenna, has multiple parts that allows it to do its intended function.

As shown in the figure below the main parts of a Yagi antenna are the directors, the radiator, and the reflectors. [24] The arrow shown for the direction of signal showcases the direction that the transmission and receiving would be. The directors on the antenna help direct the signal and to minimize the spread of the signal and allows it to direct it to a single point. The reflectors help bounce the signal back on the directors and increase the magnitude of the signal and allow it to travel further. The radiator is the main point where the signal originates from. There are a multitude of Yagi antennas that are able to be mounted on the Yaesu-G5500 rotator, and we will use different antennas depending on the range of signals we wish to receive and send.

Different Yagi antenna models are able to reach different distances, with some of them being powerful enough to break through the ionosphere and communicate with satellites, while others are not powerful enough to break through the ionosphere and instead bounce off, allowing you to communicate with others on the surface of the earth in a different area.



***Figure #:*** *Parts of Yagi-Uda Antenna*



***Figure #:*** *Parts of Yaesu-G5500 Rotator*

As shown in the figure above, the rotator that will be used in this operation is the Yaesu-G5500. This rotator takes in 110 - 120 VAC or 200 - 240 VAC and then uses that to power the 24 VAC motors inside to help rotate the antennas. The two motors inside the Yaesu control the rotation in the azimuth direction, or what most would consider the side to side motion, and the other motor controls the elevation direction, or what most would consider the up and down motion. The Yaesu gives an accuracy of ±4 percent in each direction allowing the antennas to be controlled to a high level of accuracy. One of the downsides of the motor comes from the maximum continuous run time of 5 minutes. With an object like the International Space Station in its best orbit over the antenna, the maximum viewing length can be up to 10 minutes, though with Kepler's second law of planetary motion, which can be applied to satellites, there will be time to allow the rotator to freeze motion at each end of the spectrum and only needing to be in motion while the Satellite is directly above the antenna. [25]

According to the user’s manual for the Yaesu-G5500, the rotation time to go the full range of motion for the azimuth is 58 seconds, and for the elevation it is 67 seconds. This allows the antenna direction to be controlled to a precise level from the control box, as well as from a remote controlled state.

One of the parts of the Yaesu-G5500 also includes the controller box which has multiple DC pins on them. Due to this fact a power inverter will be needed for that specific application of the control box. The best way to achieve this is to convert the AC power that is being supplied to the rotator from the wall outlet and to convert that to DC power. This would also allow us to convert the AC signal into a DC signal that the microcontroller needs to operate.

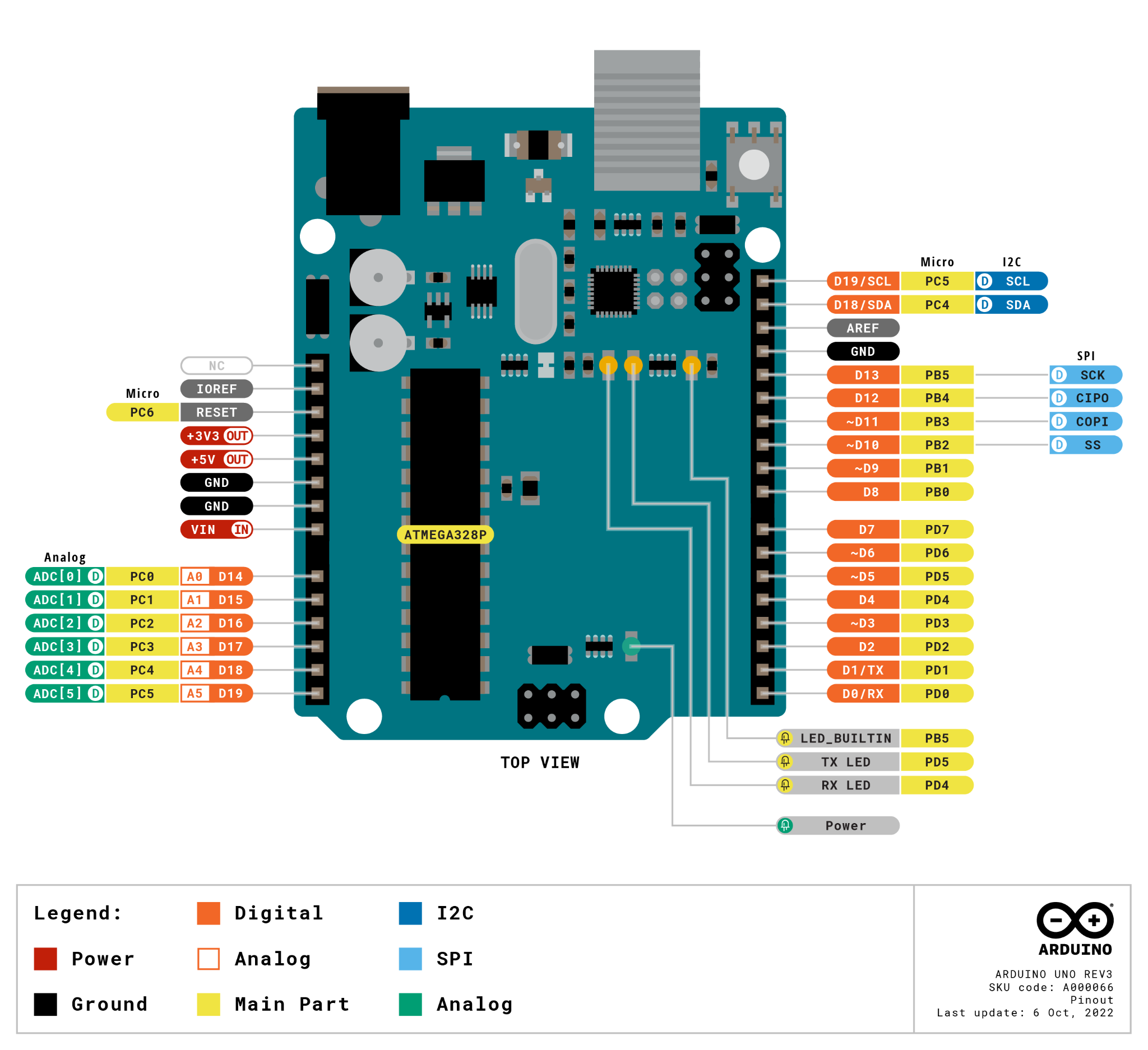
Another type of circuit needed for the rotator and the control box would be a pulse width modulator, otherwise known as a PWM. This would allow a specific AC signal to be put into the rotator and then be converted to a higher AC to allow an operation at a higher level and reduce the time it takes to rotate each motor, as well as allow the AC signal to be lowered leading to an increase in the maximum continuous operation. The PWM is able to take the digital signal output from a microcontroller and convert it to an analog signal that the rotator can take and drive the motors. [26]

### 2.1.4 Microcontrollers

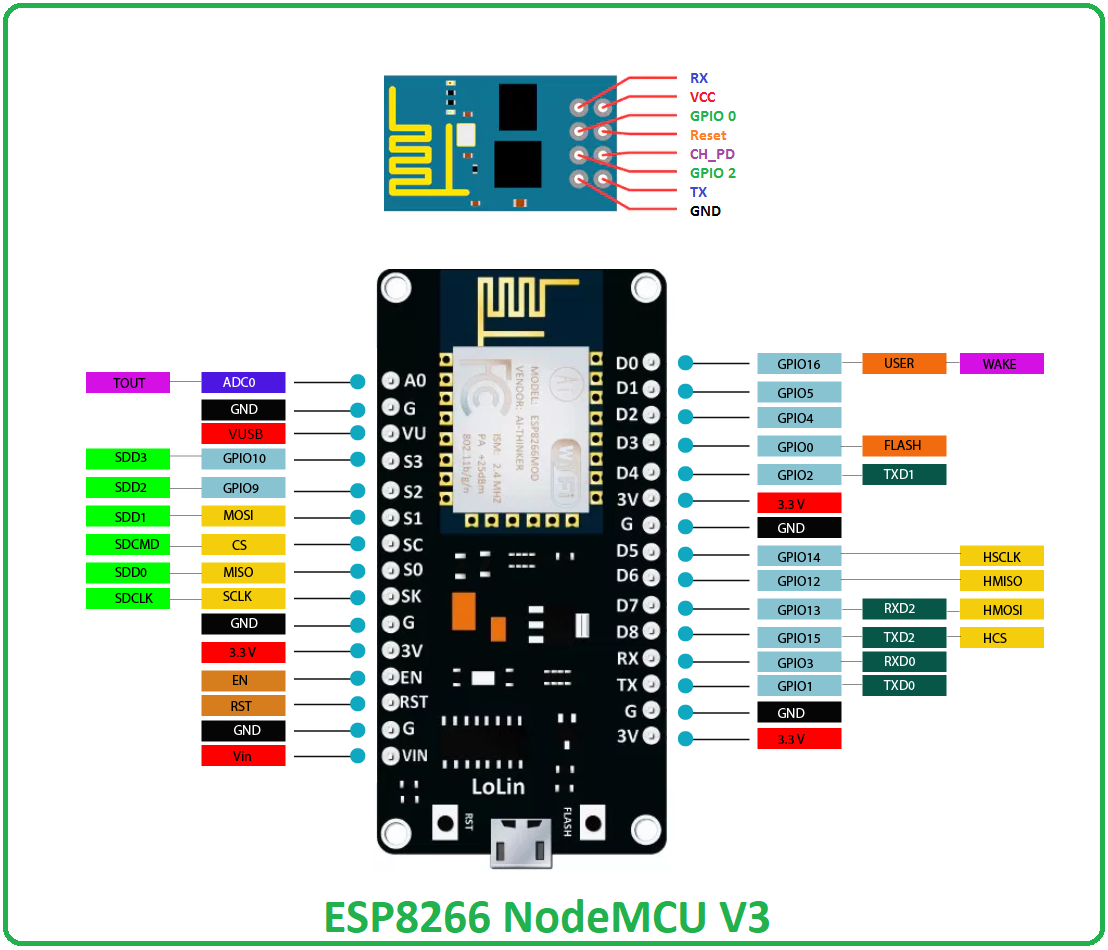
The microcontroller that has been selected for this project is the Arduino Uno. The Uno is based off of an ATmega328P microcontroller. The Uno takes in 7 to 12 Volts and has both analog and digital output pins in order to communicate with the motors for the Yaesu.

The Arduino itself can host the web application with an ESP8266 that can be accessed remotely to allow manual remote control of the antenna as well as a script that allows the user to select a specific satellite and automatically track it.

Working with an Arduino also allows you to work with a lot of libraries that other users have created and tested. One of these libraries that is needed for this project is the two line element library, otherwise known as the TLE library. This library is able to compute and calculate the locations and projected locations of two line elements from a given input file that the arduino is able to pull from various sources. This library in particular allows the arduino to be able to plot and track the various satellites and track them in the sky depending on the specific time and location of the rotator.



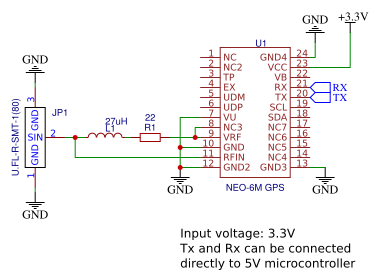
***Figure #:*** *Arduino Uno Schematic*



***Figure #:*** *ESP8266 Wifi Module Specifications*

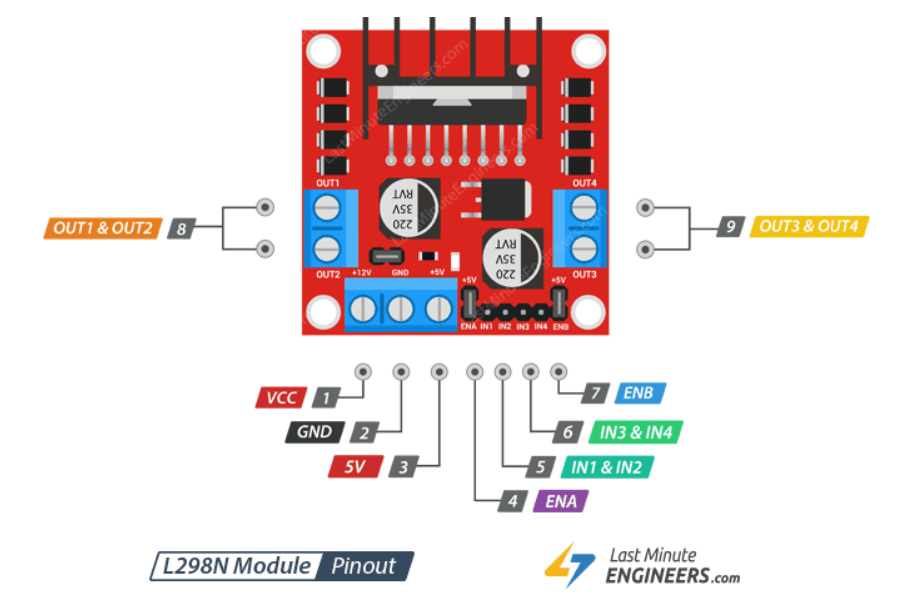
The wifi communication aspect of this project is extremely important for the correct operation. Communicating over wifi allows the user to interact with the arduino from any location with a wifi connection, as well as allow the arduino to communicate with any other device that also has wifi.

Connecting this module to the arduino allows the arduino to host the web application needed, as well as pull the data that is required for the two line element library to work.

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***Figure #:*** *GPS Module Specifications*

The GPS module chosen is the Neo-6m. The GPS module is important in order for the antennas to determine where they are in location to the satellite and allow the arduino to calculate the correct tracking arc. Without the GPS module the arduino will not be able to compute the correct direction to point the antennas and can miss the orbit of the satellite.

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***Figure #:*** *Motor Driver Specifications*

### 2.1.5 Power Supply Unit

The L298 Motor Driver has a voltage drop of 2 V. This means that to power the 12 V DC motors inside the rotator, the supply voltage must be 14 V. Each motor inside the rotator operates at 12 V with a maximum current draw of 2.5 A. The L298 Motor Driver will be sufficient in this case because it has a supply range of 5 V to 35 V and is capable of 2 A of continuous current per channel. To run the logic circuitry inside of the L298, it requires 5 V to 7 V of input voltage. [28]

The Arduino Uno will also require a DC power supply of 7 V to 12 V and it has a maximum current draw of 500 mA. The Arduino Uno board comes with an AC socket that can be used if you have a power supply adapter that will provide 7 V to 12 V DC. This adapter will be plugged directly into the wall with the other end plugged into the AC socket on the board. This means that there will be two separate power supplies being used. One power supply for the Arduino Uno and another power supply for the L298 Motor Driver. [29]

### 2.1.6 Firebase Web Applications

Firebase is a collection of web services developed by Google and will serve as the web application hosting platform. Similar to Amazon Web Services (AWS), it provides functions typically handled by the server, such as real-time databases and user authentication, through the cloud. It was designed to enable rapid prototyping and scalability, making it perfect for IoT applications that use web hosting. Firebase works on multi-tier payments to cater to the diverse users, ranging from hobbyists to professionals.[27] The “Spark Plan” is the free version and provides all the necessary features for this project with the option to upgrade. Firebase incorporates the REST API, which is a software architecture that uses HTTP requests, such as “GET”, “POST”, “PUT”, and “DELETE”, to interact with resources on the server. HTTP can use URLs to access resources with a variety of formats like JSON or XML. The lightweight, user-friendly interface of the Google Cloud Platform will allow for easy web development.

Arduino has its own cloud platform called the “IoT Cloud”, but it is limited in its free tier, is severely limited and does not really allow web applications, just variables on their dashboard.

## 2.2 Overview

The IoT Satellite Antenna Rotator can be separated into three subsystems to handle each component's complexity. The central microcontroller system, an arduino, will interface between the web application, various IO components and use a TLE library for satellite tracking. The power/motor control system will provide power to the rotator’s azimuth and elevation motors as well as the arduino. Finally the web application will allow the user to communicate with the arduino through google firebase, while displaying real-time data. Features and updates may be added to the web application to improve functionality and ease-of-use.

## 2.3 Referenced Documents and Standards

***Table #: Reference Documents, Manuals, and Datasheets***

| **Device** | **Manufacturer** | **Release Date** | **Document Title (Link)** |
| --- | --- | --- | --- |
| G5500 Rotator | Yaesu Musen LTD. | 2015 | [Instruction Manual](https://www.yaesu.com/downloadFile.cfm?FileID=8814&FileCatID=155&FileName=G%2D5500%5FIM%5FENG%5FE12901004.pdf&FileContentType=application%2Fpdf) |
| Arduino Uno R3 | Arduino LLC | 7/2/23 | [Datasheet](https://docs.arduino.cc/static/99defc00d52a56086523996603126e26/A000066-datasheet.pdf) |
| ATmega328P | MicroChip |  |  |
| ESP8266 | Espressif | 2022 | [Datasheet](https://www.espressif.com/sites/default/files/documentation/0a-esp8266ex_datasheet_en.pdf) |
| GPS |  |  |  |
| LED Display |  |  |  |
| Firebase | Google | 10/17/22 | [Documentation](https://firebase.google.com/docs/reference/js) |

***Table #: Regulations and Standards***

| **Standard/Regulation** | **Revi/Release Date** | **Document Title (Link)** |
| --- | --- | --- |
| IEEE 802.11 | February 9, 2011 | Defines Wifi protocols and data rates... |
| CCSDS 502.0-B-2 | October 2020 | Defines standard of orbital Data |
| FCC 97.213 |  | Defines rules for remote operation of amateur radio |
| CFR P97T47 |  | Ham Radio Regulations |
|  |  |  |
|  |  |  |

# Operating Concept

## 3.1 Scope

## 3.2 Operational Description and Constraints

### 

### 3.2.1 Operational Description

***Table #: Qualitative Objectives***

### 

| **Requirement** | **Description** |
| --- | --- |
| Primary | Device should connect to wireless networks |
|  | Device should provide pertinent data to user |
|  | Device should be efficient and accurate |
|  | Device should abide by all relevant laws/regulations |
| Secondary | Web Application should be secure and limit user access |
| Implicit | Web Application should be easy to use and have all needed information to operate |

### 

***Table #: Quantitative Objectives***

### 

| **Requirement** | **Description** |
| --- | --- |
| Primary | Signal Strength = |
|  | Latency = |
|  | Positioning Accuracy < 4% |
| Secondary | GPS Antenna Length = |
|  | GPS Accuracy = |
|  |  |

### 

### 3.2.2 Constraints

### 

| **Constraint** | **Description** |
| --- | --- |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |

### 

## 3.3 System Description

### 3.3.1 System Requirements and Overview

### 

***Figure #: System Block Diagram***

### 

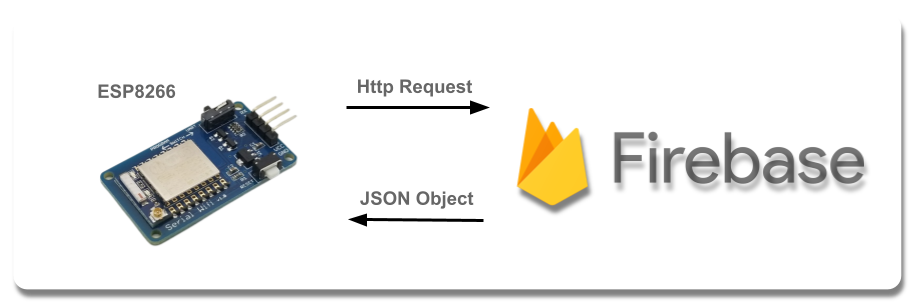
### 3.3.2 Motor Driver and Power Supply

For the purpose of powering the Arduino Uno, a dedicated power supply adapter will be employed and interfaced directly with the AC power socket. The L298 Motor Driver is utilized for the control of two 12 V DC motors, each rated at 2 A. To ensure proper operation of the system, it is necessary to use a power supply that provides a minimum output voltage of 14 V, taking into account the voltage drop across the L298 of 2 V, and a current capacity of 4 A.

### 3.3.3 Arduino Microcontroller and IO Control

The arduino will act as an interface between the rotator and web browser. Firmware will be written to take in the current azimuth and elevation of the rotator as well the GPS location and then send it to the web application. It will then receive the information needed to move the motors. Finally information will be output onto a display and the web application.

### 3.3.4 Remote Operation Web Application



The web application will allow the user to control the rotator from the browser using HTML, CSS, and Javascript. Hosting will be on Google Firebase. For added security, user authentication to restrict access.

## 3.5 Modes of Operations

Provide detail on the different modes of operation of your proposed system.

### 3.5.1 IP Address Configuration

### 3.5.2 Automatic/Manual Remote Satellite Tracking

### 3.5.3 Automatic Local Satellite Tracking

## 3.6 Users

***Figure #: David Gent (year)***

David Gent and his background, qualifications

The main users of the system would be David Gent, W5AC, and the Aggie Radio Club.

This system should only be used by those who have a ham radio license and call sign due to the fact that this system would be interfacing with antennas and will be transmitting and receiving information that is protected by the American Radio Relay League.

The level of training for this system would be minimal since the use is mainly for those who have a ham radio license, but for those that are not licensed the basic knowledge of antennas, radio waves, and satellite movements are necessary.

Demographic who would also be interested:

## 3.7 Support

Github Repository w/ manuals

Provide details on how support would be given to users. User manuals, tech support, etc…

## 

# Scenario

## 4.1 Local Access

Describe the use case scenario for your project. Use a separate subsection for each scenario.

## 4.2 Remote Access

# Analysis

## 5.1 Summary of Proposed Improvements

Describe/list the improvements that the proposed system will provide.

## 5.2 Disadvantages and Limitations

Describe/list any disadvantages and limitations that the proposed system will have.

## 5.3 Alternatives

Describe/list any alternative solutions and what any trade-offs may be to contrast your proposed project to the alternative.

## 5.4 Impact

Describe/list the impact your project has to the environment, society as well as ethical concerns.

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# Appendix A: Verification Plan

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# Appendix B: Reference Documents

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# Appendix C: Acronyms & Abbreviations

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# Appendix D: Definitions