Requirements Specification

Satellite Earth Station Development

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1 Introduction

1.1 Purpose

The Colorado Space Grant Consortium has acquired a C-band radio dish which needs to be altered in order to send and receive S-band transmissions from the Polarcube cubesat. When the dish was purchased from NOAA, they removed the majority of the manual control system, necessitating the development of a new control system and user interface.

1.2 Scope

The Project is the design and fabrication of a new ground station for Spacegrant's S-band satellites using a newly acquired C-band dish and trailer as a framework, enabling them to better communicate with current and future projects than their current infrastructure allows.
In addition, Spacegrant requests that the new system interface with off-site computers, allowing the system to be monitored and operated remotely.

1.3 Definitions, Acronyms, and Abbreviations

- **Cubesat**: A satellite designed to be small and light enough to launch into space relatively cheaply and gather scientific data.
- **LEO**: Low Earth Orbit
- **NOAA**: National Oceanic and Atmospheric Administration
- **PolarCube**: A Cubesat payload designed to measure weather and climate data currently under development by CU's Space Grant program.
- **TLE**: Two Line Element. This is a data format used to specify the orbit of an object in space. It can be used to calculate the object's position at any given time.
- **UHF**: Ultra High Frequency: Frequencies between 300 MHz and 3GHz
- **Synchrodrive** (or **Synchro**): A variable transformer which can be used to measure the orientation of a rotating object.
- **Radome**: Spherical weatherproof enclosure surrounding the radar dish.

1.4 References

1.5 Overview

This document provides an overview of the proposed project and our initial plans to complete it. Section 2 details the product's structure and basic design. Section 3 is a diagram of thedesign based on user requirements, and Section 4 is the use case the average user experiences.

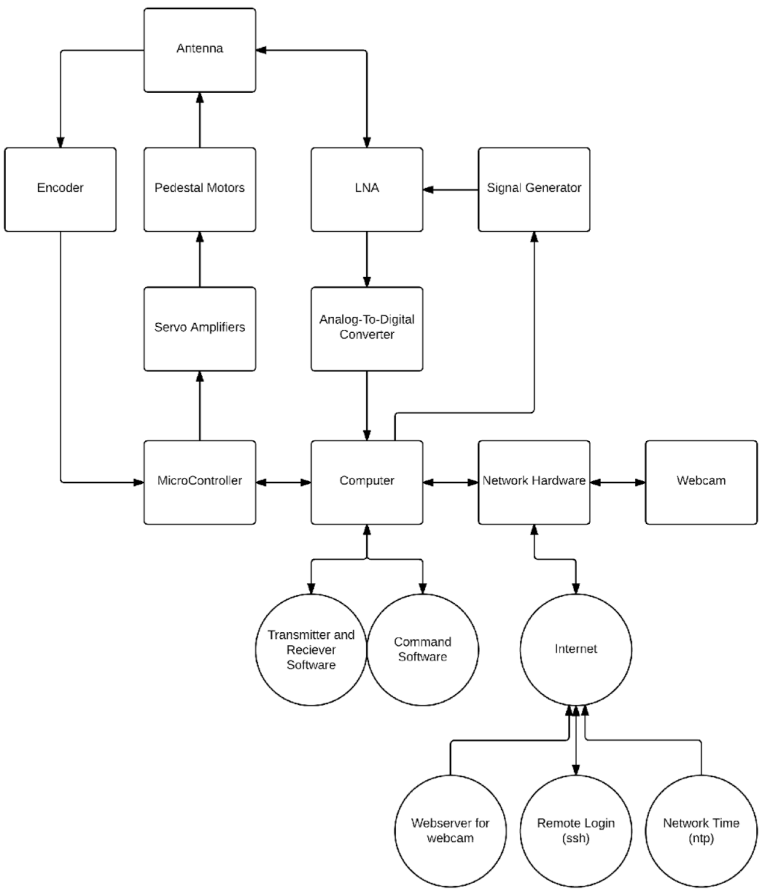
Commented [1]: what problem is your product solving?

Commented [2]: Doesn't sound correct grammatically.

Commented [3]: problem with editing.

2 Overall Description

2.1 Product Perspective



Commented [4]: This diagram should be broken down into physically-separable units, such as: Satellite, Antenna, computer, Network Hardware, web servers.

2.2 Product Functions

2.2.1 Essential Functions

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- User shuts down power in software (soft shutdown).
- User shuts down power in hardware with a switch (hard shutdown).
- User terminates power abruptly with a panic kill switch, preventing damage and/or injury.
- Unit monitors temperature of essential power electronics. Unit powers down if maximum operating temperature is exceeded.
- Unit autonomously powers down motors if it has jammed to prevent damage to the motors and pedestal.
- User sets the dish to a “Home” position, which is a default position of the dish that allows the system to be oriented in an absolute coordinate system (e.g. Home may be Elevation 0° and Azimuth oriented to a particular direction on the unit).
- User defines Latitude, Longitude and orientation of the unit.
- User adjusts azimuth (Az) and elevation (El) manually.
- User reads the orientation of the dish.
- User reads the gain in dB of the signal from the feed.
- User provides a Two-Line Element Set (TLE) that characterizes the orbit of an object; the radar unit tracks the object on that orbit.
- Once the unit is given an object’s orbit to follow, the unit initiates a search pattern to find the desired signal. Once the unit has “found” the object, the unit displays the Azimuth and Elevation error and automatically corrects.
- User observes signals from the main feedline on a display.
- User transmits signals on a UHF antenna mounted to the dish.
- User executes basic diagnostic and calibration functions to prepare the unit for object tracking (home position, tracking sun and/or moon, GPS calibration).
- User accesses the radar unit remotely over network using Secure Shell (ssh).
- User observes position of the dish using a web-camera.
- User records signal from the dish to a file
- User records signal from the dish to a network target.
- System timestamps file and logs dish orientation
- Webcam can be viewed via webserver and local display

2.2.2 Highly Desirable Functions

- User provides orbital information in another format (XML or CSV). Unit tracks object according to the information in the file.
- User selects search pattern type, range.
- User schedules tracking episodes in advance
- System time set via network

2.2.3 Desirable Functions & Extensions

- User interfaces with unit using a rack-mounted touch screen.
- Unit determines its position on the surface of the Earth and automatically calibrates using a GPS unit.

2.3 System & User Characteristics

The system will be going into a larger system (the old radar unit housed in the trailer), and it will also be used by others outside of our team. This section is intended to address the characteristics of both the user and this larger system.

2.4 Design Constraints

- Old equipment should be used as much as possible
- Space for the main unit is constricted to a rack-mount width
- Licensing for operating the unit is an open question
- System requires three-phase power to completely operate
- Azimuth rotary joint cannot handle more than 100mA

2.5 Assumptions and Dependencies

2.5.1 Assumptions

- Power usage/efficiency is not a concern.
- Existing equipment, such as the amplifier, old motors, synchro, etc. are in working order.
- Elevation moves on a range from 0° to 90°.
- Azimuth pedestal moves continuously
- Documentation is accurate.
- Assembly of pedestal is possible
- Slew rate is, at most, 60°per second.

2.5.2 Dependencies

- Unit is currently located in Erie, CO on NOAA property. Space Grant and CET are in process of acquiring land on University of Colorado Boulder property. Until resolved, access to the unit is heavily restricted (requires a NOAA member with particular credentials to be present at the site).
- Pedestal assembly, radome and dish have not been assembled and cannot be assembled until the unit is moved to a more permanent location
- Three-phase power may not be available at the old NOAA site and possible at the new site on CU property.

Commented [6]: Good. These mostly look like design implementation restrictions that are being imposed on you by the larger pre-existing system.

Commented [7]: Guessing that you are actively investigating. This is more of an Assumption such as, "We will have an operating license for the unit throughout the duration of our project."

Commented [8]: I think you are referring to existing documentation for the larger system.

Commented [9]: Perhaps add "(Currently un-assembled from previous use.)"

Commented [10]: Slew rate of what? Just looking for what part of the system in general.

Commented [11]: "...and must be possible..." ?

3 Specific Requirements

Marketing Requirements	Engineering Requirements	Justification/Rationale
1,2	Positioning accurate to within XX degrees of satellite location	Enables the system to linkup with the satellite for communication
5	Unit shuts down in the event of overheat	Shutting down has been implemented so that expensive equipment does not get destroyed
5	Unit shuts down in the event of an emergency situation (overheat, mechanical jamming)	The servos move heavy objects at high speeds, if something goes wrong the uses have a way to safely shutdown the system to minimize damage to equipment and personal.
2	Amplification for S-band is XXdB	Brings input data from the antenna up to power levels that a microcontroller can interpret.
1,4	Has a "home" orientation that the system can reset to	Makes control of the pedestal simple, and provides a standard that the system can always fall back on
1	Interface to the power amplifiers	Allows us to control the servos to move the dish
1,4	Encoders read dish orientation	Knowing the dish orientation is essential to knowing where the dish should move next and by how much
1,3,4	Magnetometer returns base station orientation	The 'home' position is always pointing a certain way and having this requirement provides the system with a standard to point at.
4	Single Unit Interface	A main station to interface to the dish. This takes in information from the position of the dish, and the received data from the dish. Using this data it can compute where the dish should go and send that data appropriately to the power amplifiers.
4,6	System outputs diagnostic information about all active systems	this makes the system easier to use for users, and makes maintenance easier
1,2,4	System can track a satellite given its two line element set	given the equation describing the motion of the satellite, the system is capable of accurate tracking
1,2,4	system can engage a search pattern of movement to track a satellite in the absence of the two line element set	in the absence of a satellite's TLE, it tracks a satellite using a circular tracking pattern and basic analysis of signal strength
1	UHF antenna has a gain of XXdB	The UHF antenna has a gain capable of uplink to a satellite in LEO

Commented [12]: You've already stated this above. Consolidate or remove overheat from this box.

Commented [13]: All the time, upon request, periodically?

Commented [14]: This could be consolidated with row 1 above.

4,7,8	system supports secure remote login and commands	For ease of use, the system supports external login to its main control system, and can receive cryptographically secure commands to control the dish
1,2	system has a slew rate of XX degrees/second	to appropriately communicate with satellites in LEO, it must move at a sufficient speed

Commented [15]: By what hardware? Ethernet, Wifi, 4G?

Marketing Requirements Summary

1. System can track an object in orbit
2. System can communicate to satellites that are being tracked
3. System is mobile
4. System is easy to use
5. System is safe
6. System has both digital and physical interfaces
7. System commands are secure
8. System can be controlled remotely

Commented [16]: What are the power and size marketing requirements?

Commented [17]: Are the servos part of the system or separate components to which you send control signals to?

Commented [18]: Not sure what you mean by mobile. Does this system run off batteries? Are you trying to say that it is small in size?

Commented [19]: Marketing requirement serve as a contract between you and the customer. Upon product completion you will have to prove that these marketing requirements are met. "Easy to use" is open to interpretation.

Commented [20]: Physically safe from harming people or encrypted safe?

Commented [21]: Define the interfaces here. How will the user interact with the system? Will data be displayed to an integrated screen or an external monitor? Perhaps the data will be available via some sort of data port (USB, Ethernet, etc.)?

4 Use Cases

UC1: System Power Up

Scope: Normal operation

Level: Sub function

Commented [22]: Why is this a sub function? In what way are you thinking about this?

Primary Actor: User

Stakeholders/Interests:
User - Needs to transmit and receive data from an overhead s-band satellite. This includes the ability to manually reposition the dish, transmit data, and view received data.
Space Grant - Implementing a safety so no equipment is ever damaged.
Team - Manual inputs and breakpoints at each of the 'blocks' for easy debugging.

Commented [23]: What does "implementing a safety" mean? Sounds like football.

Preconditions: The system is off and positioned in such a way that it has line of sight access to 60% of the sky.

Main Success Scenario:
1)User turns on main power
2)User boots up main computer
3)User logs in to main computer
4)computer "wakes" other subsystem
5) System runs start up test
    5a) User Confirms Test successful
6) System returns ready signal

Commented [24]: You can have these in the main computer or you can make them part of the preconditions -- that these things have happened.

Commented [25]: Goes with comment related to 1,2.

Commented [26]: always? If so, ok. If not, how does the user indicate *when* to wake up the subsystem?

Extensions:
*a) System returns any errors

1. System logs error
2. System reports error to user
    3. System shuts down

*b) User encounters system error
1. Team diagnoses error
2. Team fixes errors

4a) wakes pedestal control system
1)pedestal system reads magnetometer
    2)pedestal resets to “Home” position
    3)computer powers receiver ADC
    4)computer powers transmitter DAC

5a). System test in unsuccessful
1. User runs calibration procedure
2. System returns to step 5

Commented [27]: Was this word supposed to "is"?

Commented [28]: Is calibration part of the functionality that you are providing? If so, is there a use case for it?

Special Requirements:

Technology and Data Variation List:

UC2: Finding and tracking satellite

Scope: Normal Operations

Level: User goal

Primary Actor: User goal

Stakeholders/Intresets:
System - The MCU is able to find a satellite.

Preconditions: The system is powered on and running. There is an existing TLE.

Main success scenario:
1. user provides satellite location info (in the form of TLE)
1. system calculates orbit of satellite from TLE
1. system moves pedestal to predicted orbit position
1. system locates satellite
1. system moves pedestal to follow orbit equation
1. system reads power from antenna
1. system records data to log file

Extensions:
a*) At any time, if an error associated with the moving the pedestal is detected:
1. User or system, depending on who detects the error, suspends motor operation
2. System returns location of error
3. User or system corrects error

4. System continues to find/track selected satellite

4a) System does not locate satellite
1. System starts “area search” program
2. System finds satellite and proceeds to tracking mode

Special Requirements:
-System must be able to shut down in a way that prevents damage to uses and hardware.

Technology and Data Variation List:

UC3: System Communications with Satellite

Scope: Normal operations

Level: User goal

Primary Actor: System’s main computer

Stakeholders/Interests:
Space Grant/User-Needs to send and receive usable data to/from satellites

Preconditions:
UC1 & UC2 have successfully completed

Main Success Scenario:
1. System establishes a communication link with the satellite
2. System receives payload data from satellite
3. System translates and stores datastream
4. User specifies commands to be sent to the satellite
5. System translates digital commands through signal generator
6. System sends commands to satellite

Extensions:
3a. System translates and sends datastream to network user

Special Requirements:
- receiver has gain of XXdB
- receiver and transmitter both fit inside ray dome and are both mounted on pedestal
- System as XX bandwidth for transmitting and XX bandwidth for receiving

Commented [29]: How does it know which one to connect with?

Commented [30]: Is there a step before this one where system asks user a question or something?