**COM**

The communication subsystem provides a method of verification for the completion of each mission phase. It also provides a way to maintain communication with the primary spacecraft and serves as a means to power on and off the LEDs on the secondary spacecraft. Data sent over the RF link would be relative distances and velocities, images from the payload, and primary spacecraft health. Boeing is providing the communication subsystem on the primary spacecraft and the communication subsystem on the secondary spacecraft consists of an RF receiver and patch antenna.

The primary spacecraft will be sending down relative distances and velocities, images from the payload, and primary spacecraft health and a communication system to support the transfer of that data. The radio will be operating in the 430/440 MHz range using GMSK modulation. The uplink data rate will be at least 4000 bps and the downlink data rate will be at least 100 kbps. Knowing the health of the spacecraft is important, so data such as battery voltage, temperature data, solar panel current, etc. will beacon down periodically. Based off historical data and experience, finding a CubeSat early in its mission can be difficult, so the beacon interval will be no more than 10 seconds to make it an easy target to listen for.

The RF link between the secondary spacecraft and the ground is much simpler. One command needs to be sent to the secondary spacecraft to power the navigation aids on and off. An RF receiver on the secondary spacecraft will listen for a command sent from the ground. The receiver will operate in the 430 MHz range and use FSK modulation. The COM system consists of a 14-pin RF receiver from RF Solutions and a 433 MHz patch antenna. It will communicate with the microcontroller using SPI and run 3.3V. The figure below shows a block diagram of the subsystem.

C:\Users\MR LEO\Documents\GitHub\Preliminary-Design\Communication (COM)\Secondary COM Block Diagram.tif

In order to verify that the RF receiver would work on for the purpose it was need, the link budget was created. It looked at a 300 km orbit with the spacecraft at the worst-case angle of 5° above the horizon. The ground station used in the analysis was the ground station here at SLU, which has a transmit power of 50 W, an antenna gain of 15 dB, and a data rate of 1200 bps. The various losses were estimated using the AMSAT-IARU Link Budget. If the result is 0 or greater the link has closed, the great the energy per bit to noise density ratio is the less likely there will be a bit flip during transmission. As the table below shows, the link closed with plenty of margin.

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Units** | **Values** | **Comments & References** |
| **Uplink Frequency** | MHz | 433 |  |
| **Station TX power** | dB | 16.99 | 50 W transmit power |
| Gain | dBi | 15 |  |
| Ground Station Losses | dB | 3.6 | Internal Loss on the transmission lines |
| **EIRP** | dBW | 28.39 | Ground Station Effective Isotropic Radiated Power |
| Pointing Loss | dB | 0.2 | Ground station loss of 5° and spacecraft loss of 20° |
| Polarization Loss | dB | 0.2 |  |
| Atmospheric Loss | dB | 2.1 | Dependent on elevation angle |
| Ionospheric Loss | dB | 0.4 |  |
| Propagation Range | km | 1500 | Distance RF signal has to propagate |
| **Path Loss** | dB | 148.71 | This is the ultimate measure of the receiver's performance. |
| **Isotropic Signal @ S/C** | dBW | -123.22 | This is the signal level received in space in the vicinity of the spacecraft using an omnidirectional antenna. |
| G/T | dB-K | -21.17 | This is the ultimate measure of the receiver's performance. |
| **S/N0** | dBHz | 84.01 | S/C Signal-to-Noise Power Density |
| **Data Rate, B** | dB | 30.79 |  |
| **Eb/N0** | dB | **53.22** | Energy per bit to Noise Density Ratio |
| Bit Rate Error |  | 0.0000 |  |

**CDH**

The Command and Data Handling (CDH) subsystem is responsible for making on-orbit decisions, processing health sensor data, and managing data during downlink. The CDH subsystem will handle the images from the payload and the relative distances and velocities calculated by the payload system. It will also handle all health data and any commands that come from the ground.

PLD

Imager

µController

16GB SD Card

Image Processor

I2C

SPI

The figure above shows how the CDH system will interface with payload. Every 1.25 seconds a picture will be saved to an SD card and every second the relative distance and angle data will be saved to the SD card so they can be downlinked later. The table below shows how much data is generated. Most of the data is from pictures, the data generation was estimated with a 30 fps camera that took pictures that were 640x480 with 8-bit color. Only 12 GB of the 16 GB SD card is allowed to be used in order to have a 25 % margin.

|  |  |  |
| --- | --- | --- |
| Mission Segment | Duration (min) | Data Generated (GB) |
| ISK | 180 | 4.158 |
| Transition | 180 | 4.158 |
| RSK | 90 | 2.079 |
|  | Total | 10.394 |
|  | Margin | 5.606 |

The secondary spacecraft CDH is much simpler. It would the voltage to the radio and LEDs by providing 3.3V. It also handles the power cycle command for the LEDs. The system would be a microcontroller and a voltage regulator.

**MOP**

Due to the nature of the Rascal mission, it will have to be done quickly. Once regular communication has been established with the Rascal spacecraft, separation would be initiated and then there would a limited time to complete the mission. It would be run over the course of a few days before the relative distance between the two spacecraft became too great that mission cannot be completed. Each portion of the mission will be verified on the ground before moving to the next portion. The method of validation to move to the section of the mission will be the downlinking of relative distance and angle data to verify that the appropriate distance has been reached as well as a picture to serve as verification of the distance and angle measurements.



In order for a ground station to support the Rascal mission, the ground station has to meet several requirements. Since both spacecraft will be operating in 433/440 MHz range, the ground station must have an antenna that works at that frequency and a radio that operates in that range. The TNC at the ground station must be able to send and receive GMSK modulated signals from the primary spacecraft and send FSK modulated signals to the secondary spacecraft. The TNC must support an uplink data rate of at least 1200 bps and a downlink data rate of at least 100 kbps.

**Secondary ADC**

The secondary Attitude Determination and Control subsystem was designed to be simple to cut down on power draw and in turn extend mission lifetime. A nutation damping system of hysteresis rods and a permanent magnet were selected. There are several environmental torques that the secondary spacecraft have overcome in order to stabilize. There is the gravity gradient torque due to the gravitational pull from Earth. Then there is the torque from solar radiation that the spacecraft would experience in space. Finally, the atmosphere still exerts a torque at the 300 km altitude and that needs to be accounted for. A t root sum square was taken to find the average, which is used to find the magnetic dipole needed to create a control torque ten times that of the root sum square of the other environmental torques. That result is used to find a magnet strong enough to exert a magnetic torque ten times greater than the environmental torques the secondary spacecraft will experience. The table below shows the torques the spacecraft will experience and the magnetic torque a magnet will need to exert.

|  |  |  |
| --- | --- | --- |
| Torque Sources | Torque | |
| Gravity Gradient | 5.88E-07 | Nm |
| Solar Radiation | 7.22E-09 | Nm |
| Aerodynamic | 1.09E-06 | Nm |
| Magnetic Dipole Requirement | 2.55 | Am2 |