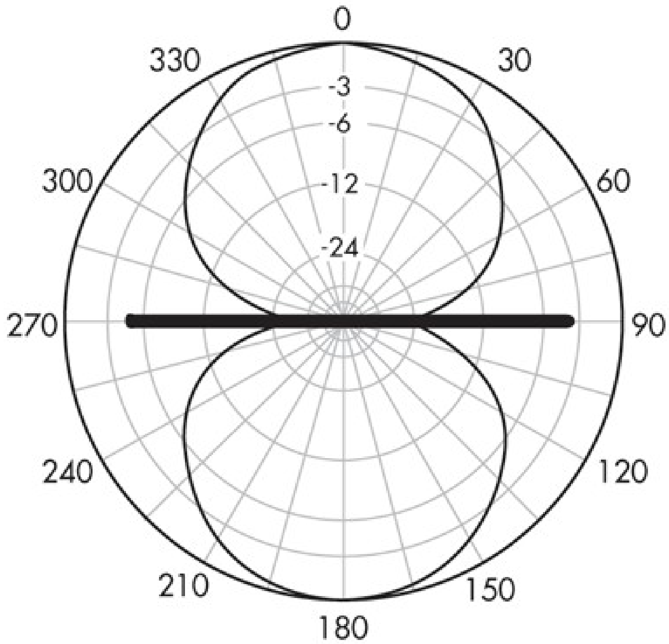
Flight Antenna – Equivalent Simple Dipole Design



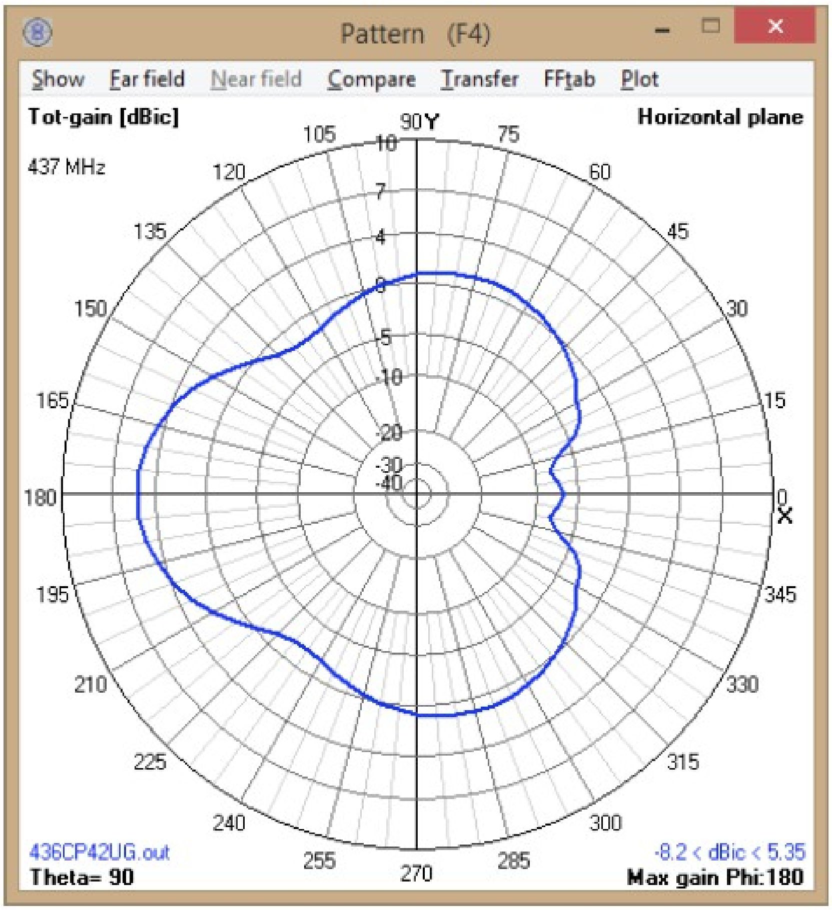
Transmit Power	0. dBW	1 W
Coupling Loss	-0.4 dB	
Antenna Gain	0. dB	Dipole Average
EIRP	-0.4 dBW	0.912011 W
Path Loss	-154.8 dB	437 megahertz 3000 kilometers
Antenna Gain	14.2 dB	
Polarization Loss	-3.0103 dB	RHCP
Coupling Loss	-2.3 dB	
Received Power	-146.31 dBW	2.33876×10^{-15} W
Receiver temperature		150. K
Bit Rate		19 200. b/s
Eb/N0	17.6951	
Threshold	9.4 dB	GMSK Theoretical 10^-4 BER
Demod loss	-3. dB	Practical
Link Margin	5.29511 dB	

Flight Equipment

Transmitter RFM22B

Note: This flight and ground system shown here have worked with a previous CubeSat see URL: //lbym.sonoma.edu/T-LogoQube (aka Eagle1 by AirForce). We can operate our RFM22B transceiver at a lower rate ~500 baud if we need extra bandwidth margin.

Ground System



Transmit Power	18.7506 dBW	75 W
Coupling Loss	-3. dB	
Antenna Gain	14.2 dB	RHCP
EIRP	29.9506 dBW	988.693 W
Path Loss	-154.8 dB	437 megahertz 3000 kilometers
Antenna Gain	0. dB	Average
Polarization Loss	-3.0103 dB	Dipole
Coupling Loss	-0.11 dB	
Received Power	-127.97 dBW	1.59605×10^{-13} W
Receiver temperature		1200. K
Bit Rate		9600. b/s
Eb/N0	30.0151	
Threshold	9.4 dB	GMSK Theoretical 10^-4 BER
Demod loss	-3. dB	Practical
Link Margin	17.6151 dB	

Ground Equipment

RFM22B Transceiver
Baojie BJ-450 UHF 420-430Mhz Radio Amplifier
MSP136VDG-160 Preamp 136-138 (preferred frequency range)
M2 436CP42UG
MSP136VDG-160 Preamp 136-138 (preferred fre

EdgeCube Satellite

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Jernigan can send ground commands to turn off all RF either temporarily or permanently

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EMC Analysis of EdgeCube

Summary of EdgeCube

EdgeCube is a 1U CubeSat being launched into a circular orbit at 500-km altitude, and 51.5 degree inclined orbit. EdgeCube is operated from a single ground station location at Sonoma State University in California. The frequency used for space to earth communication and earth to space communication is 437.465 MHz (assigned by IARU). This report reviews the situation as regards other authorized operators in this frequency range and operating range. No significant interference is reasonably expected to occur with the local amateur radio club due to the low power (0.5 watt) of the omni-directional RF radiation from EdgeCube.

Compliance with Local Amateur Radio Operators

Because the operating frequency is in the amateur frequency range, we consulted with the local amateur radio club. Jernigan also obtained his Technical Ham license for transmitting commands from the EdgeCube ground system located on the SSU campus. The license test was administered by this same local Ham club.

For a previous CubesSat the operator of the S/C has discussed the situation with the local amateur radio club in Santa Rosa the largest nearby city. Previously we operated a CubeSat in this band called T-LogoQube. All communication with the CubeSat occurred at elevations with high gain antennas at angles greater than 30 degrees. Longer duration downlink communications have a maximum RF power of 0.5 watt. We can examine any situation for a downlink and see the RF path is clear and halt any overlapping transmissions if necessary. Past experience with cubesats has shown that significant interference is unlikely at RF powers less than 0.5 watt. All EdgeCube downlink transmissions will be under 0.5 watts of RF power.

Interference would only occur for a physically nearby satellite using the same frequency. FCC frequency coordinated assignment should avoid this possibility. Even if this type of interference were to occur we can cease transmission for a modest period until differential drag physically separates the two spacecraft.

Rare short duration uplinks, typically less than ~1 sec, at higher power are implemented with high gain pointed Yagi antennas on the ground for which the RF power is directed away from any ground RF sources to avoid any nearby receivers. The likelihood of any interference could cause the loss of data reception by the CubeSat with no likely interference with any nearby HAM communications. It is possible that nearby HAM activity could effect communication with EdgeCube. It is unlikely that the lower power communications with EdgeCube would effect or even be noticed by any normal HAM operations.

Compatibility within Operating Range

ITU radio regulations provide power flux density (PFD) limits, above which coordination with terrestrial and aeronautical mobile systems is required.

* Terrestrial Services: -125 dBW/m2/4KHz

* Aeronautical Mobile (R): -125 dBW/m2/4KHz

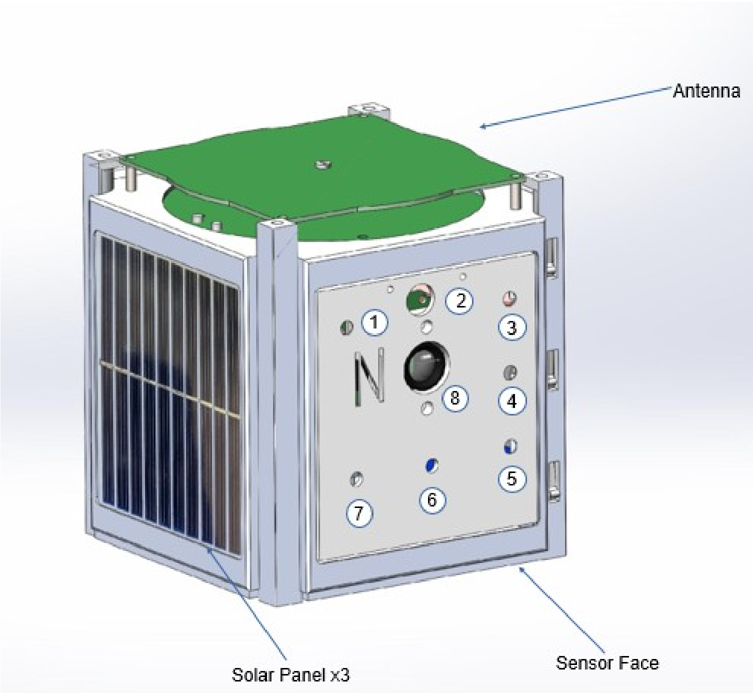
* Aeronautical Mobile (OR): -140 dBW/m2/4KHz

These specified power levels typically would adversely effect the RF environment are much lower than the omni-directional emission expected from a <0.5 watt transmitter used by the EdgeCube CubeSat. Clearly this fact would not be the case for higher levels of power which transmit data at higher baud rates. We will not be using any such higher power transmissions.

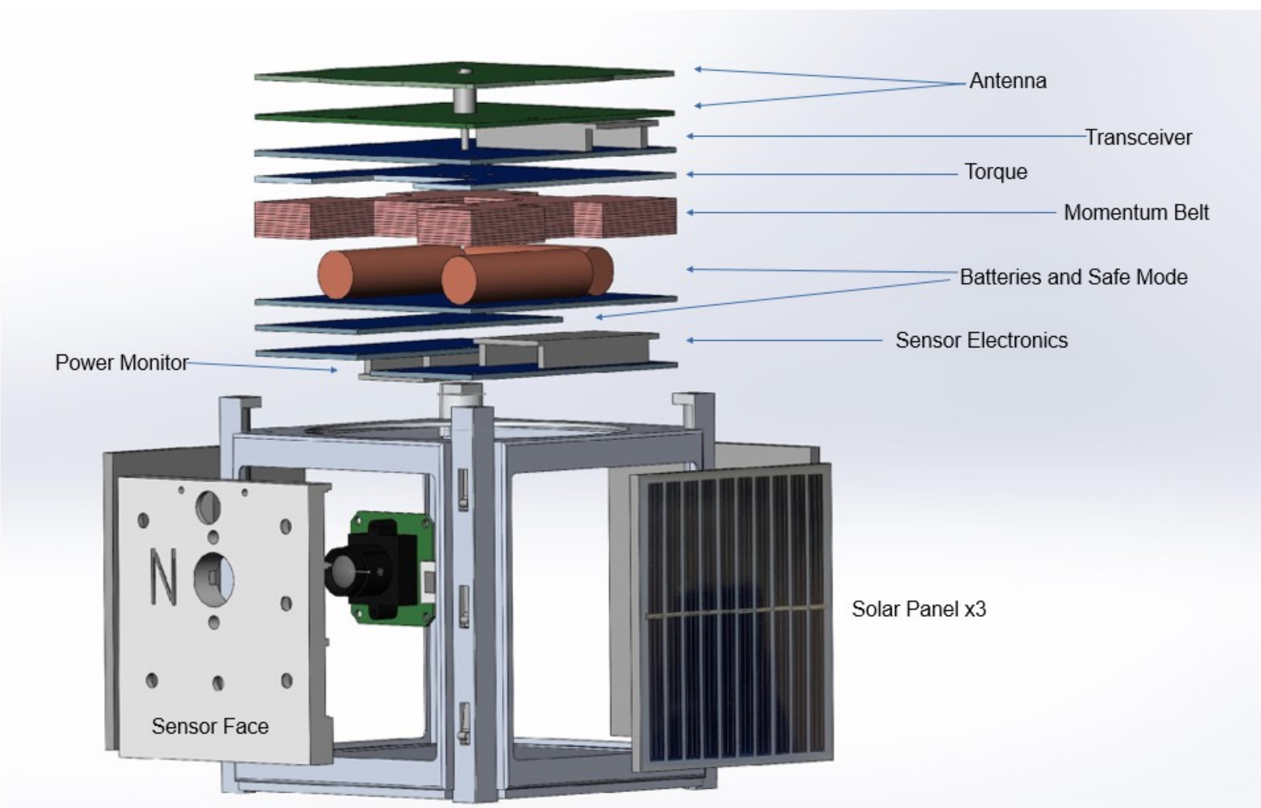
EdgeCube Satellite Technical Description

Mission Overview: EdgeCube will make a global measurement of the red edge that monitors a sharp change in leaf reflectance in the range 600 to 800 nm from changes in vegetation chlorophyll absorption and mesophyll scattering due to seasonal leaf phenology or stress. EdgeCube has been specifically designed to monitor the red edge characteristics of ~200 km areas of the earth using 9 narrow spectral bands in the wavelength range 600-800 nm. Two additional sensors will be flown: one will measure the optical and Infrared broadband signal in order to measure the incoming solar radiance. The incoming solar radiance is needed in order to calculate the top-of-atmosphere reflectance (at-sensor radiance/incoming solar radiance), thus normalizing the data through the seasons and by latitude. Although EdgeCube's ground spatial resolution is substantially larger than conventional multispectral satellites, its design will monitor changes in the red-edge on a global scale within the telemetry limitations of a CubeSat.

The satellite will be launched as a payload on a Falcon 9 scheduled for launch during December 2019 as part of a service mission for the ISS. Once at the ISS EdgeCube will be boosted to a higher circular orbit 500 km. On orbit operations would begin in Mid-January 2020. Atmospheric friction will eventually slow the satellite and reduce the altitude of the orbit, until de-orbiting occurs years after launch. (See the Orbital Debris Assessment Report for details.)



Wavelength Table	
1.	Open (full optical, full NIR)
2.	Brightness Sensor
3.	NIR 700 nm
4.	NIR 740 nm
5.	NIR 780 nm
6.	NIR 610, 680, 730, 760, 810, 860 nm
7.	Optical 450, 500, 550, 570, 600, 650 nm
8.	Camera



Figures: These figures shows a CAD image of the EdgeCube flight electronics. The upper panel shows the external view. The lower panel shows an expanded view of the internal structure of system. The 1U board stack is arranged in the planned flight configuration. The stack of flight electronics includes the science electronics for operating the NIR sensors, the S/C power monitor, the torque board for controlling the spin rate and pointing of the S/C. The stack also includes a copper block to define the principle momentum axis (total S/C mass of 1U S/C ~1.5 kg). The NIR collimator and the sensor face that carries hold the sciences sensors are shown in the upper panel separately for clarity. One of the three solar panels is also shown in the upper panel.

The upper most PC board shown in both the upper and lower panels forms a fixed omnidirectional antenna with unity gain. We no longer plan to deploy a popup antenna. Therefore there is only one configuration. There is no longer any concept of a stowed and non-stowed configurations.

The satellite contains the following systems: **Attitude Determination and Control (ADC), Command and Data Handling (CDH), Communications (COM), and Electrical Power System (EPS).**

Attitude Determination and Control (ADC) Subsystem: The ADC is a purely electromagnetic system to keep EdgeCube's spin axis pointing within ~30 degrees of the north pole. The system consists of 2 torque coils, triaxis magnetometer, triaxis rate gyros, and a sun sensor. The spin rate is controled via a torque coil normal to the spin axis.

Command and Data Handling (CDH) and Communications (COM) Subsystem is integrated into a single COM concept.
EdgeCube's CDH system is a distributed network which integrates the data gathering process across many nodes on a network. There is a special network node that monitors the power system. A special node called the uStar gathers all the telemetry data from all the nodes on the network. This

function is integrated into the tiny simple OS. This tiny OS also sends all telemetry packets to the ground using an RFM22B packet transceiver.

Electrical Power Subsystem (EPS): The Electrical Power Subsystem is based on three fixed identical solar module arrays. A fourth face houses the sciences sensors. The system uses 3 five watt solar panels and one 1 amp-hour NiCd battery pack (3 AA batteries). The system has a power point tracker.

Thermal Control Subsystem (TCS): The TCS moderates temperature changes passively using a large copper heat sink. The heat sink resides near the CG of the S/C also serves as a momentum reservoir for spin stabilization.

Structure Subsystem: The 1U structure is fabricated with Aluminum that is 3D printed.

Propulsion Subsystem: No propulsion subsystem is included.

Payload Subsystem: The payload consists of a set of single element NIR sensors with narrow band filters.

The Goal of the EdgeCube Missions

The overall goal of the EdgeCube mission is to map the surface of the Earth (~200 km resolution) in chlorophyll using ~10 narrow band NIR filters.
The radio communications links are necessary to support control of the experiment, and to transmit the telemetry data to the University.