**Revision Matrix**

| Revision | Date | Description |
|---|---|---|
| 1 | 12/6/2018 | Joshua Griffin created doc |
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# Radio Frequency Tag Satellite (RFTSat) Overview

**Mission Summary**

The Northwest Nazarene University Radio Frequency Tag Satellite (RFTSat) team is designing and building a 3U CubeSat to demonstrate the application of radio frequency (RF) energy harvesting and backscatter communication to the problem of distributed sensing in space. For this mission, a passive RF tag containing various space weather sensors will be mounted at the end of a boom that is extended from the satellite. The tag will not contain a battery, but will be powered by energy emitted from an RF reader onboard the satellite. The tag's sensor data will be wirelessly sent back to the reader via backscatter communication, and then to the Earth via a Globalstar satellite constellation link. RF tags equipped with sensors could be added to a spacecraft, like the ISS, without additional wires or power supplies and provide a means to monitor structural integrity, space weather, or make sensitive electric/magnetic field measurements.

**Spacecraft Operations**

The purpose of RFTSat is to demonstrated the use of RF energy harvesting and backscatter communication in space. The beauty of this type of backscatter system is that all of the complexity and power consumption is kept on the reader (powered by its own source) allowing the tag to be made very inexpensively and without batteries or wires. In such a system (shown in **Error! Reference source not found.**), a reader communicates with a small tag that can be adhered to an object (such as a distant spacecraft surface) much like a postage stamp or barcode sticker. The tag does not contain a battery, but instead powers itself by harvesting energy from the RF signal incident on it from the reader. The tag communicates data back to the reader by modulating the RF signal that is scattered (i.e., reflected) from its antenna. The information transmitted from the tag could be any type of digital or analog information, including data from various sensors on the tag.

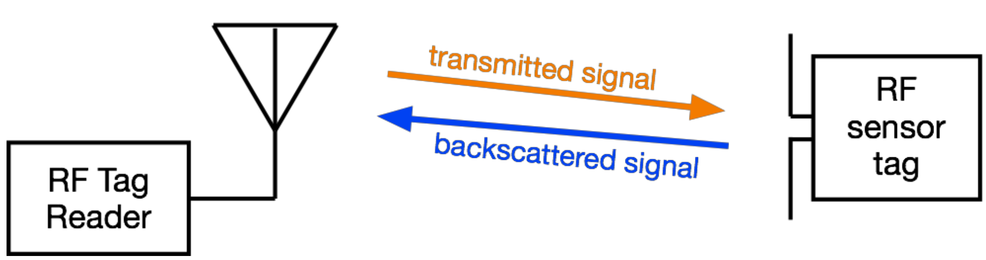

*Figure 1:A backscatter RF tag system is divided into two parts: a reader and a tag. The transmitted signal is harvested to provide energy to the tag and the backscatter signal provides low-power communication from the RF tag back to the reader.*

On RFTSat, the RF tag reader will be housed in the body of the satellite and the RF tag will be extended some distance away (max 60 cm) from the reader on a deployable boom. The RF tag will contain a 3-axis accelerometer, total ionizing does radiation sensor (i.e., a RadFET), and a temperature sensor. The RF tag reader has two antennas: a transmitter antenna (microstrip patch antenna) that emits a continuous-wave signal at 5.8 GHz and a receiver antenna (microstrip patch antenna) that receives the modulated backscatter signal from the RF tag. The tag also contains two antennas: a harvester antenna (i.e., a two-element microstrip patch antenna array) that passes energy from the continuous-wave signal emitted by the reader to the tag's energy harvester circuit and a communication antenna (microstrip patch antenna) that modulates the portion of the reader's transmitted signal that it scatters. This backscattered signal is modulated with the data from the tag's sensors.

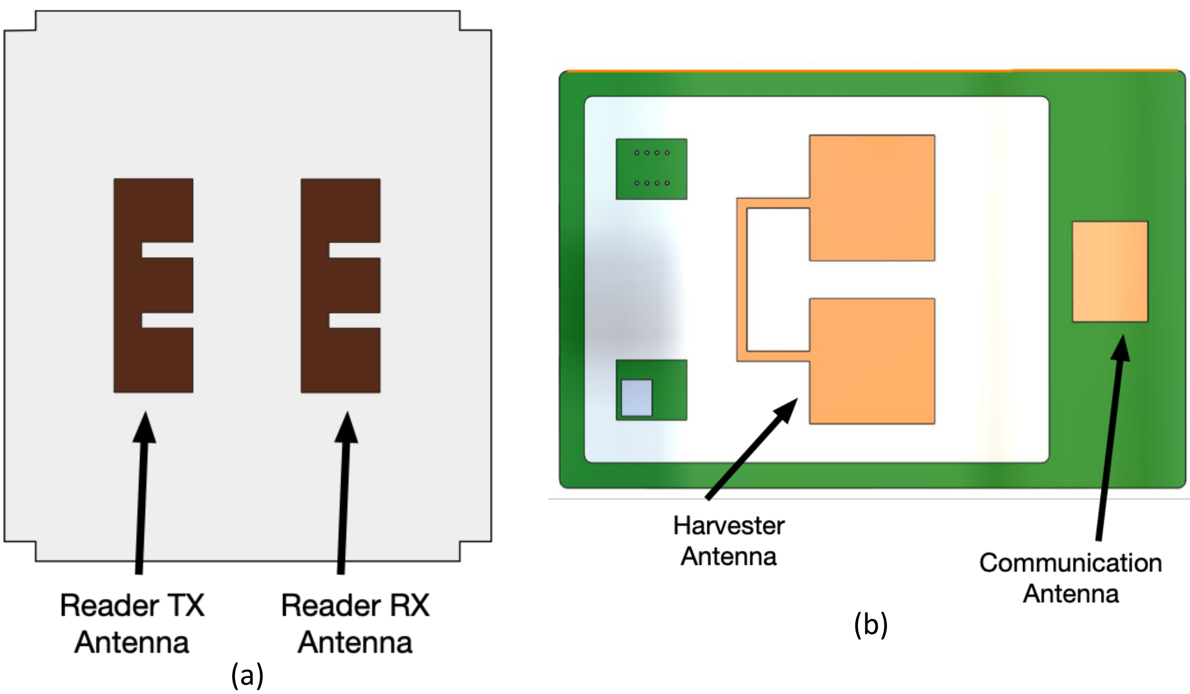


*Figure 2: The (a) RF tag reader transmit and receive antennas and (b) the harvester and communication antennas of the RF tag.*

The RF tag system described above is fundamentally different than many radio systems used on satellites. The RF tag system establishes an intra-satellite communication link that contains three parts: a reader transmitter, a reader receiver, and a passive RF tag. The RF tag transmitter emits a continuous-wave signal at 5.8 GHz that is absorbed by the tag's energy harvester antenna. The reader transmitter's continuous wave emissions are also scattered by the RF tag's communication antenna and received by the RF reader receiver. Communication between the tag and reader is achieved by the tag varying the phase of the signal scattered off its antenna.

RF tag is a passive device. It does not generate or emit an RF signal; instead, it simply changes the phase of the signal scattered by its antenna by changing the electrical impedance attached to the its antenna.

Once in orbit, the 3U satellite will release the two panels containing solar cells, shown in Figure 3 and Figure 4. They will fold out from the X+ and X- side of the satellite and are hinged on the Z+ end of the satellite. Once the satellite batteries are sufficiently charged, the RF tag (approximately 8 cm x 10 cm) will be read by the reader while the tag is stowed. With the tag stowed, there is an approximately 4 cm separation distance between the tag and the reader transmit/receive antennas. Once the rotations induced by the satellite deployment have stabilized, the RF tag will be extended away from the satellite on a carbon fiber boom. The maximum distance between the reader's antennas and the RF tag is expected to be 60cm. The tag will be read repeatedly and the data from the tag downlinked via EyeStar Simplex Globalstar radio from Near Space Launch.

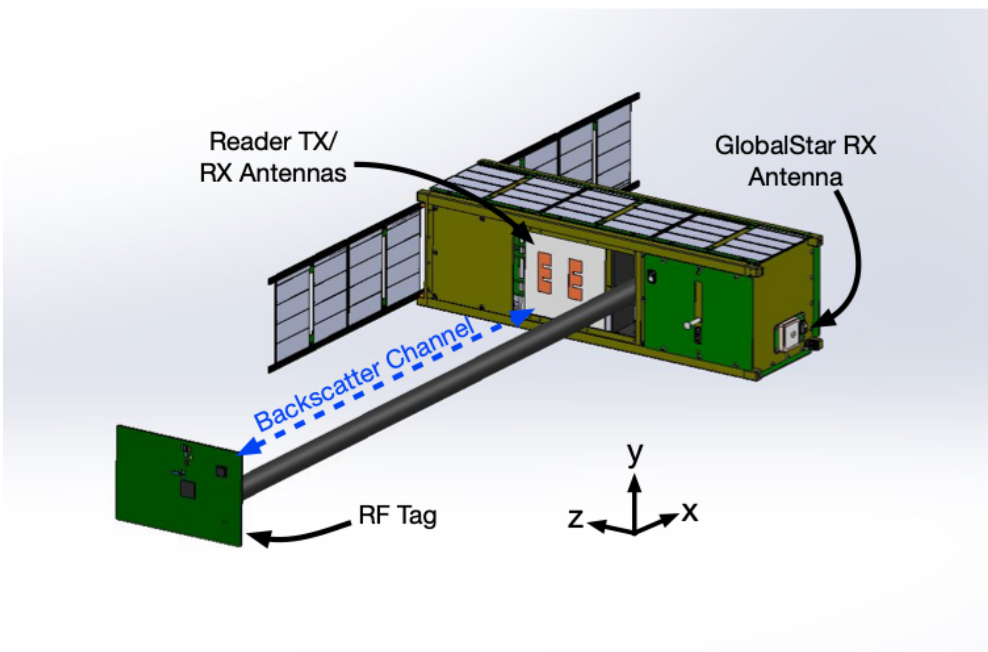


*Figure 3: View of RFTSat with the tag and solar panels deployed. The backscatter channel is the radio link between the RF tag reader and the RF tag.*

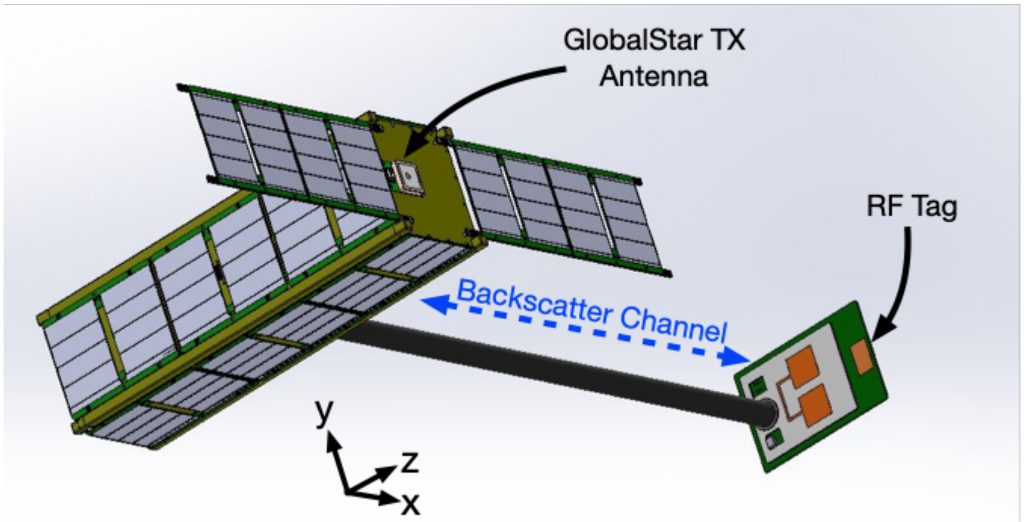

*Figure 4: View of RFTSat with the RF tag and solar panels deployed. The backscatter channel is the radio link between the RF tag reader and the RF tag.*

**CONOPS Overview**
Minor details of the CONOPS provided are subject to change; however, the CONOPS shows the basic flow of the mission.

*Phase 0: Deployment*
RFTSat will deploy from the dispenser and start a 50-min inhibit timer during which time no radio transmissions will be made.

*Phase 1: Stabilization (Week 1)*
The solar panel arrays will be deployed and RFTSat will fly without deploying the RF tag boom to allow the satellite to stabilize (1-2 days). Every 60 minutes, 2 sequential NSL health beacons will be transmitted. NNU will read the RF tag, the internal IMU, and the temperature sensor board and transmit this data via GlobalStar occasionally once the battery has sufficiently charged (perhaps days 3-5).

*Phase 2: Science (Weeks 2-4)*
During the Science phase, RFTSat will collect data from the RF tag, the internal IMU, and the temperature sensor board and transmit to GlobalStar periodically before deploying the boom. RFTSat will then slowly begin to extend the boom, extending 5 cm over 5 seconds once per day. After each extension, NNU will read the RF tag, the internal IMU, and temperature sensor board and send this data GlobalStar periodically. Every 60 minutes, 2 sequential NSL health beacons will be transmitted.

*Phase 3: Long Term Science (Weeks 4-8)*

During the Long Term Science phase, RFTSat will decrease power consumption by reducing the RF tag read rate. NNU will continue to read the RF tag, the internal IMU, and the temperature sensor board and transmit it to GlobalStar periodically. Every 60 minutes, 2 sequential NSL health beacons will be transmitted.

*Phase 4: NSL Phase (Weeks 9-Re-Entry)*
During this phase, NSL will shut down the NNU payload and will use the remainder of the satellite's life to test the longevity of their hardware systems. NSL will continue to transmit satellite health beacons and data from their sensors (two 8x8 pixel infrared horizon sensors, Langmuir plasma probe, and pin diode particle detectors) to Globalstar periodically.

**Deployables**

RFTSat contains three deployables: two panels containing solar panels and are hinged on the Z+ end-plate and lay against the X- and X+ faces of the satellite while stowed. The hinged panel attached to the X+ access panel serves to hold the RF tag in place when stowed. Each panel is 2U in length and are released by a burn-wire mechanism. All of this hardware will be provided by Near Space Launch. The figures below show RFTSat in all of its deployed and stowed configurations.

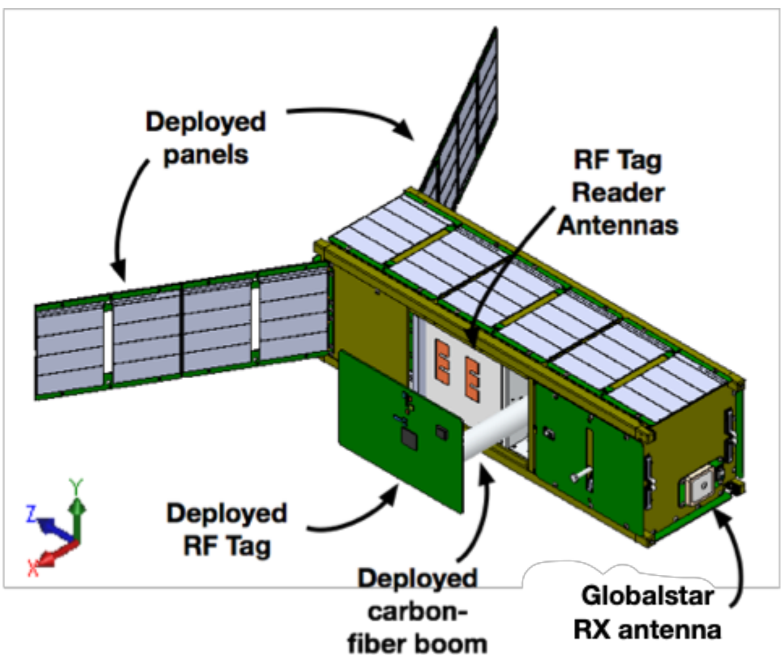

*Figure 5: RFTSat with the solar panels, RF tag, and boom deployed.*

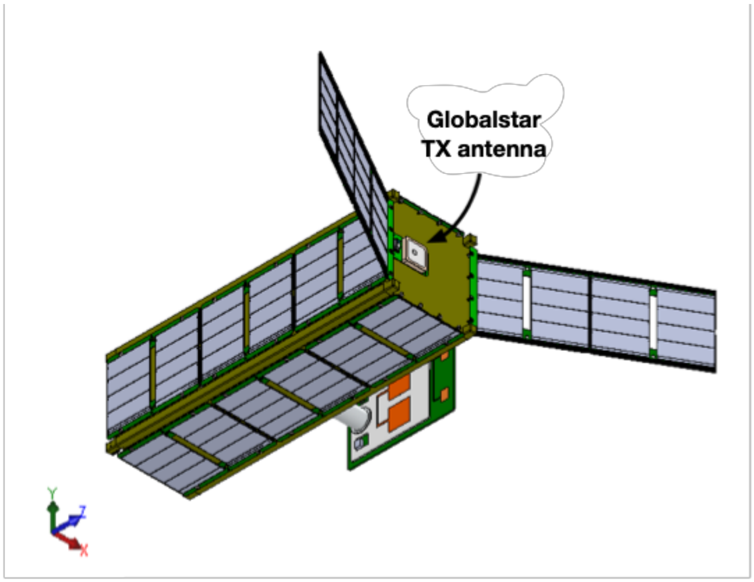


*Figure 6: RFTSat with the solar panels, RF tag, and boom deployed.*

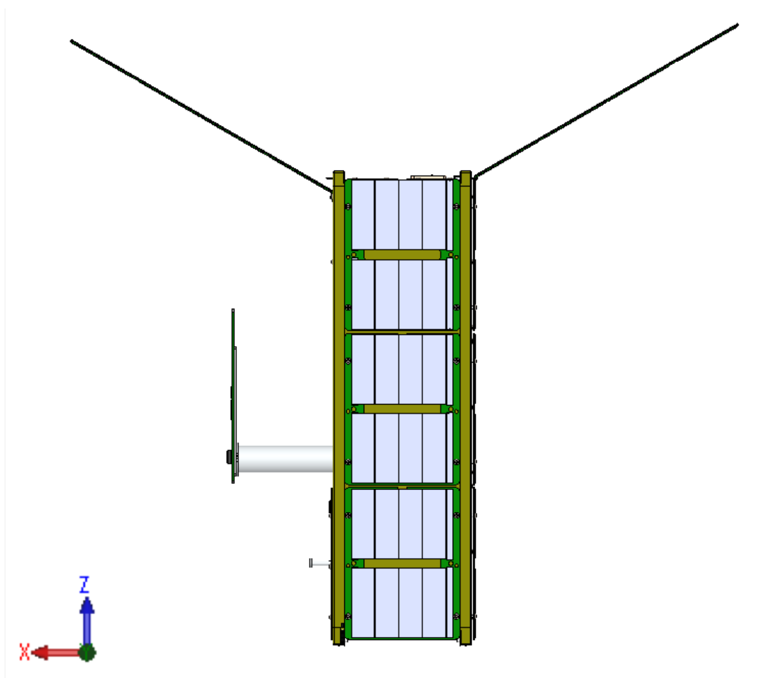

*Figure 7: RFTSat with the solar panels, RF tag, and boom deployed.*

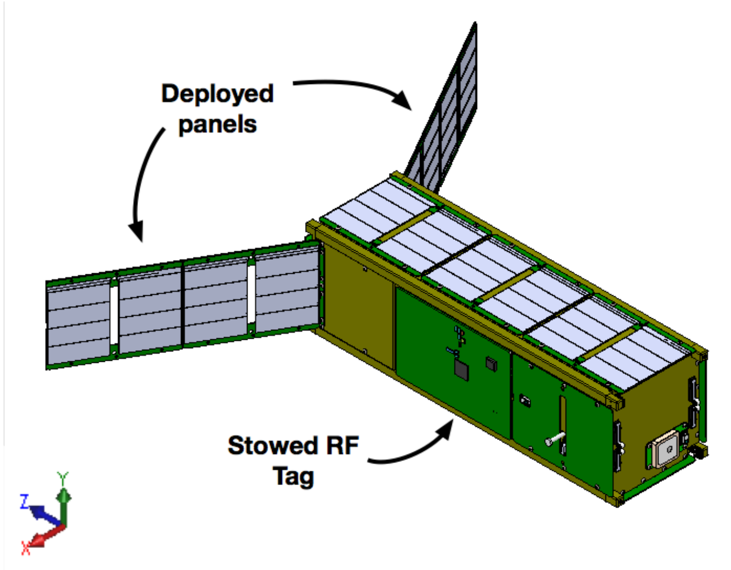

*Figure 8: RFTSat with only the solar panels deployed. The RF tag and boom are stowed.*

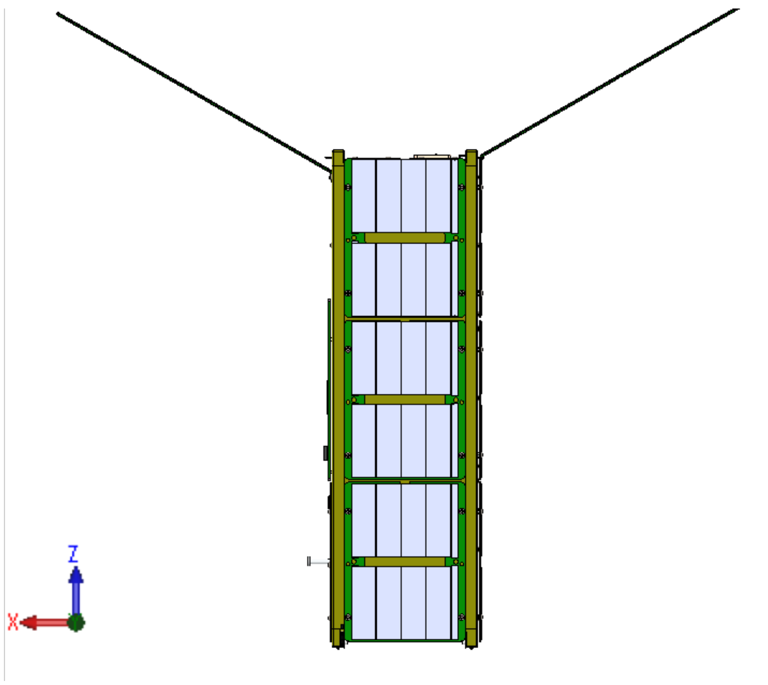

*Figure 9: RFTSat with only the solar panels deployed. The RF tag and boom are stowed.*

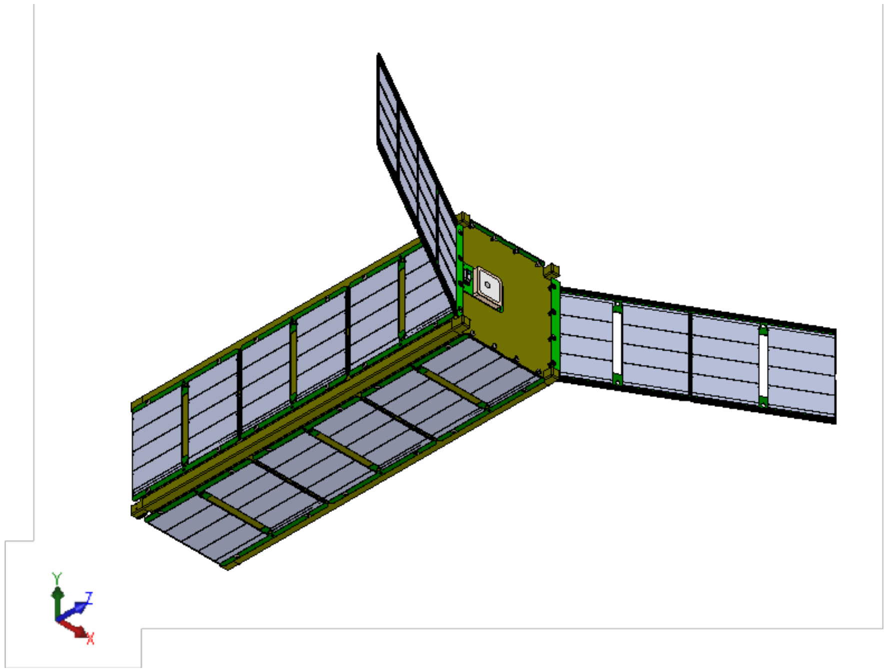


*Figure 10: RFTSat with only the solar panels deployed. The RF tag and boom are stowed.*

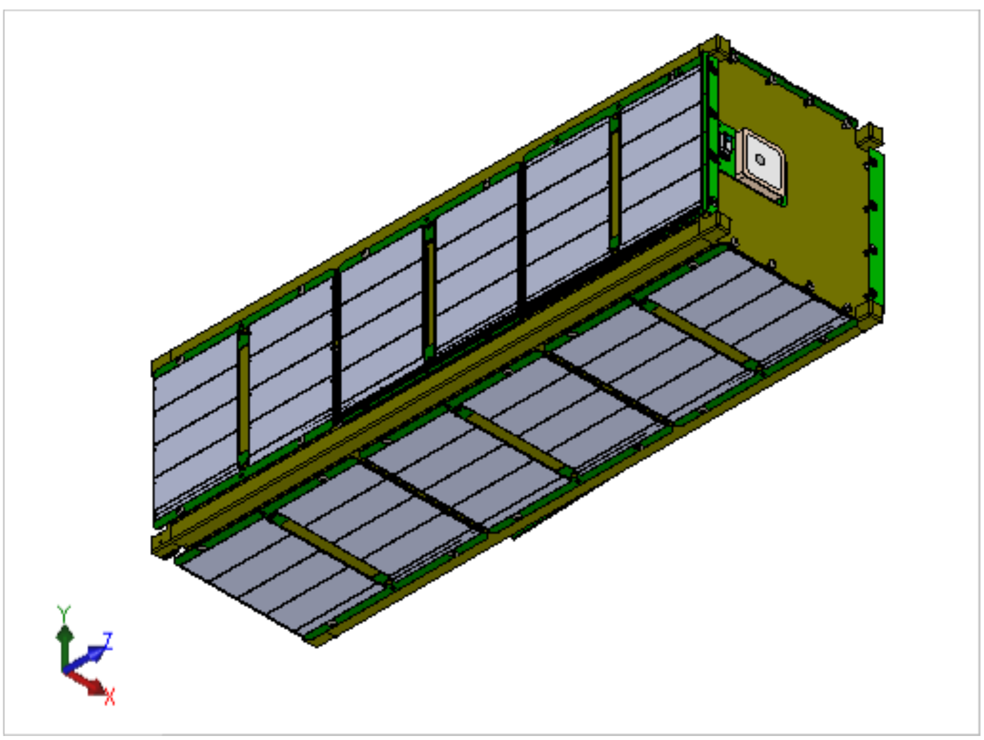


*Figure 11: RFTSat with all deployables stowed.*

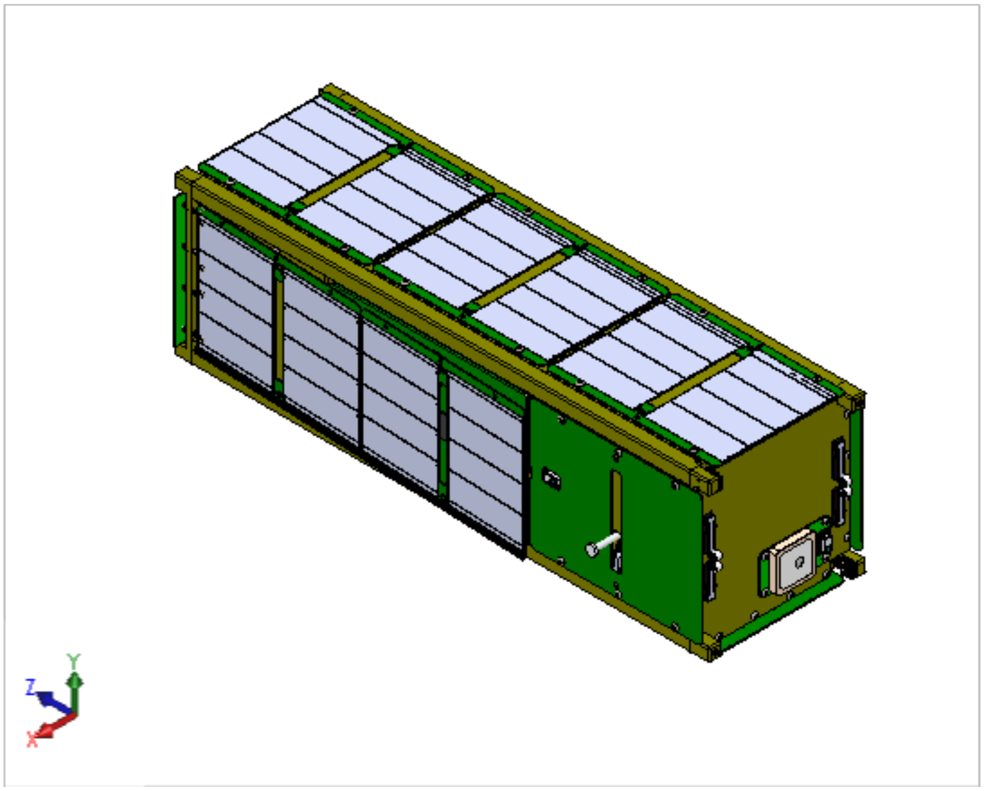

*Figure 12: RFTSat with all deployables stowed.*