KickSat-2 Operational Summary

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Abstract:

KickSat-2 is a CubeSat technology demonstration mission designed to demonstrate the deployment and operation of prototype Sprite "ChipSats" (femtosatellites) developed at Cornell University. ChipSats like the Sprite represent a disruptive new space technology that could enable new kinds of science and exploration missions, as well as dramatically lower the cost of access to space. Sprites have been developed and tested to Technology Readiness Level (TRL) 5-6 and an orbital demonstration is necessary for their continued advancement.

The Sprite is a tiny spacecraft that includes power, sensor, and communication systems on a printed circuit board measuring 3.5 by 3.5 cm with a thickness of a few millimeters and a mass of four grams. It is intended as a general-purpose sensor platform for micro-electro-mechanical (MEMS) and other chip-scale sensors with the ability to downlink data to ground stations from low Earth orbit (LEO).

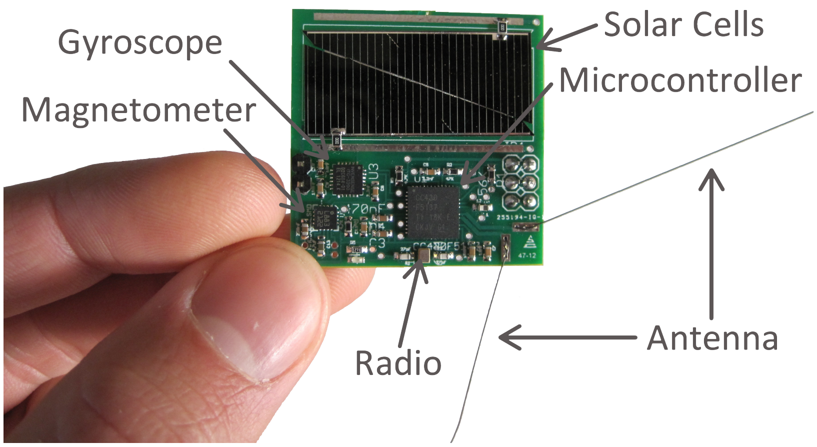

Figure 1: Sprite Spacecraft

KickSat-2 is a 3U CubeSat built as much as possible from commercial off-the-shelf (COTS) and flight-proven components. A 1U bus provides power, communications, and command and data-handling functions while a 2U Sprite deployer houses 100 Sprites. Sprite deployment can be triggered in a number of ways depending on mission-specific and launch-safety requirements. Timer and GPS triggers are available to ensure deployment at a specified time, at a specified orbital altitude, or at a desired location over the Earth. Triggering deployment manually with an encrypted signal from a ground station is also possible. The Sprites' extremely low ballistic coefficient guarantees a predictably quick reentry, mitigating orbital-debris risk. After deployment their altitude drops precipitously, moving them well away from the launch vehicle and preventing recontact.

KickSat-2 Spacecraft:

KickSat-2 is a 3U CubeSat designed to carry 100 Sprites into space and deploy them in low Earth orbit. It is built into a 3U CubeSat structure with a 1U avionics bus providing power; telemetry and command (T&C); and command and data handling (C&DH) functions and a 2U deployer housing the Sprites.

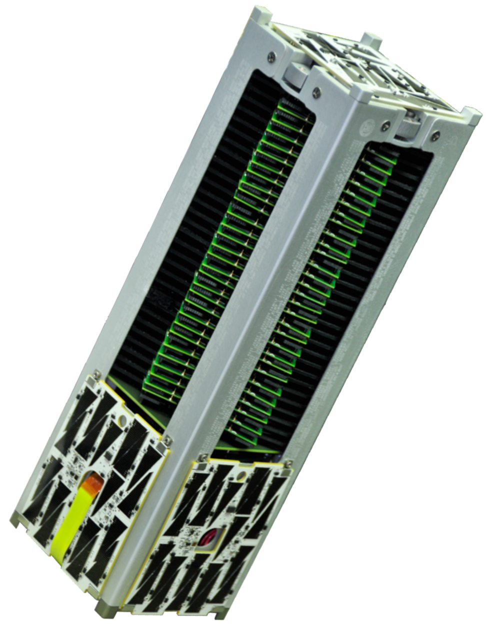

Figure 2: KickSat 3U CubeSat

KickSat-2 is based largely on the design of KickSat-1. The majority of its components have flight heritage and are considered TRL 6-7. KickSat-1 flew on the CRS-3/ELaNa-5 mission in April 2014. Sprite deployment, which was planned for the mission's 16^{th} day, was not possible due to a power anomaly that occurred in the spacecraft bus during the mission's 14^{th} day. Several design improvements, including a more robust power system, improved radios, and the addition of a GPS receiver, have been incorporated into KickSat-2 to address the issues encountered during the KickSat-1 mission.

The KickSat bus is equipped with six 1U solar panels, a pair of lithium polymer battery packs with a total capacity of 75 watt-hours, a Cornell-developed flight computer board, a COTS 70 cm band radio transceiver, and a COTS GPS receiver that has been modified and tested at Cornell for use in space. KickSat's burn wire and antenna deployment systems were flight proven on KickSat-1.

Deployment System:

The Sprite deployer has been designed for simplicity and robustness while minimizing attitude disturbances on the spacecraft during deployment. The deployer contains 100 Sprites stacked in four columns in a 2-by-2 arrangement. Each Sprite is housed in an individual slot and constrained by a carbon fiber rod that runs the length of the column, passing through a hole in the corner of every Sprite (Figure 3). The nitinol wire antennas on the Sprites are coiled in such a way that they act as springs to push the Sprites out of their slots.

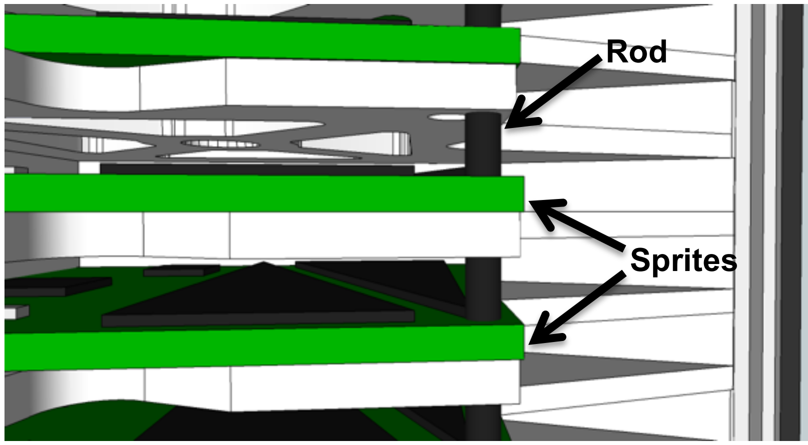

Figure 3: Sprites in Deployer

All four carbon-fiber rods are attached to a single plate at the end of the deployer (Figure 4) that is actuated by a compressed spring and held in place by two fully-independent mechanical inhibits that must both be released in series to initiate deployment.

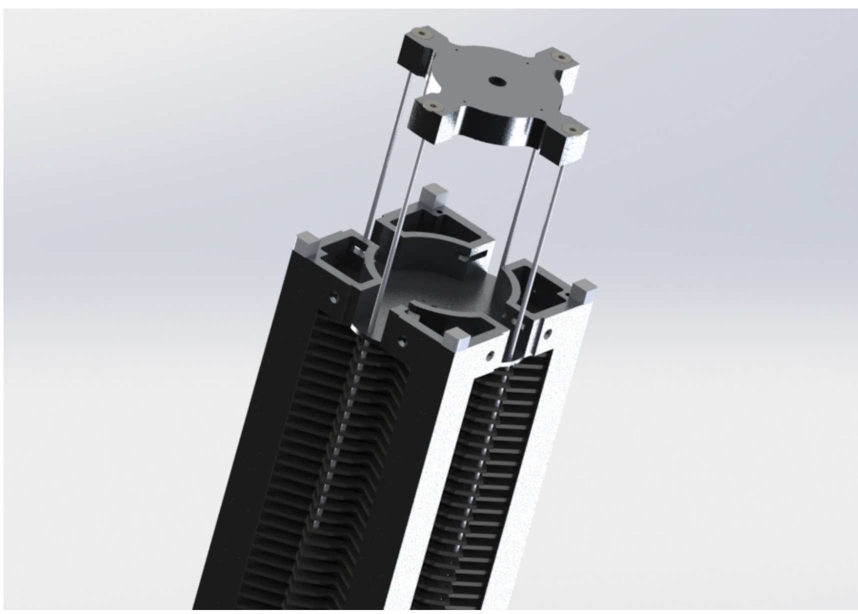

Figure 4: Carbon-Fiber Rods Secured to End Plate

The primary mechanical inhibit consists of a nylon screw which secures the end plate assembly to the spacecraft structure (Figure 5). The secondary mechanical inhibit consists of a monofilament tie-down which also secures the end plate to the spacecraft structure. Deployment is initiated by first cutting the monofilament tie-down with a nichrome burn wire, then cutting the nylon screw with a second burn wire. Both burn wires operate on independent electrical circuits and require independent signals from the flight computer to be switched on.

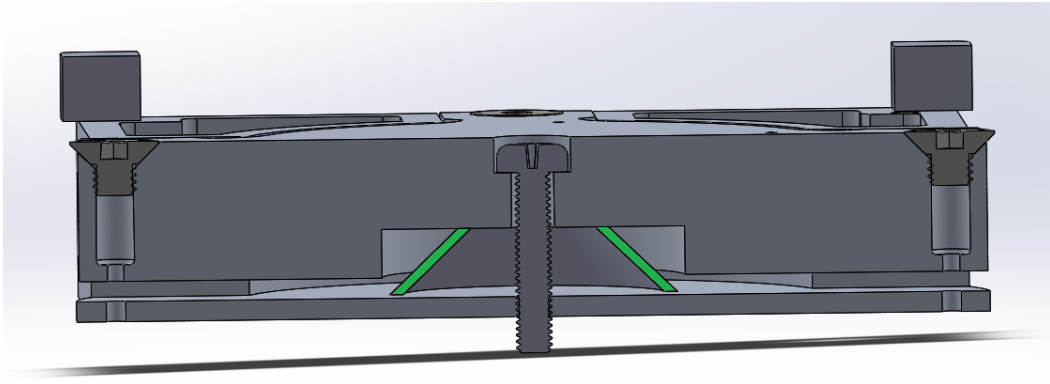

Figure 5: Cutaway View of Primary Mechanical Inhibit

In addition to the two mechanical inhibits, a third software inhibit will act as an additional safety mechanism to prevent deployment. A number of possible software inhibits can be implemented as required, including a maximum orbital altitude measured by the GPS receiver, a time window, and/or a manual "arming" command from a ground station. After all software and hardware inhibits have been disabled, the compressed spring pulls the four rods out and the Sprites' antennas then push them from the deployer housing, as shown in Figure 6, with an estimated ΔV of 5-10 cm/sec.

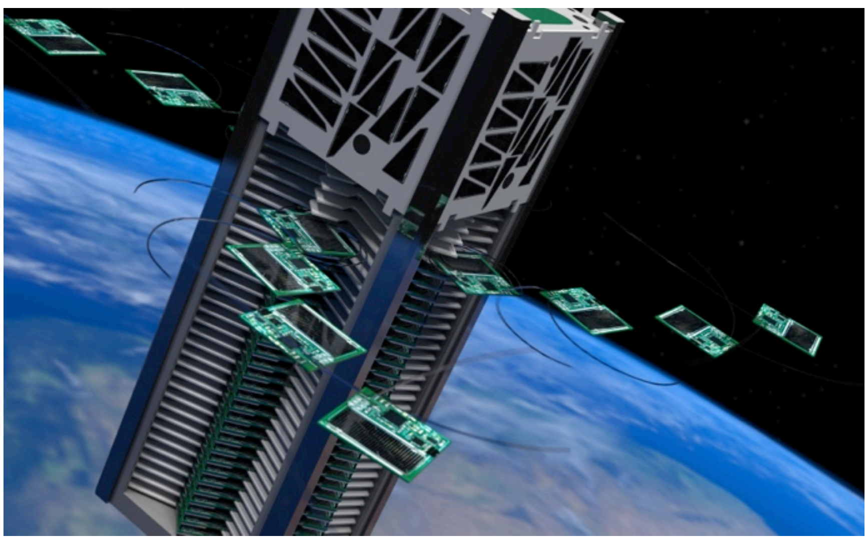

Figure 6: Sprite Deployment

Mission Timeline:

After being deployed from the ISS, KickSat-2 will wait 45 minutes before deploying its primary antenna and activating its radio beacon. The spacecraft will then calculate its orbital position and velocity and set its real-time clock using the onboard GPS receiver. It is expected that contact will be established with either Cornell's ground station or partner ground stations within the spacecraft's first few orbits.

After performing checkout operations, the spacecraft will be put into a power-safe mode with its radio beacon transmitting at regular intervals. Orbital elements will be propagated by the flight computer and updated using the onboard GPS receiver once per day. KickSat's orbit will be allowed to decay until an altitude of 325 km is reached. Simulations indicate that this will take several months given the current altitude of the ISS.

Once the target altitude of 325 km has been reached, the Sprites will be deployed. The Sprites are expected to have an orbital lifetime of approximately 5 days before reentry under typical atmospheric conditions. Bounding test cases with extremely high and extremely low atmospheric density give a range of orbital lifetimes between approximately 2 and 14 days (Figure 7). The Sprites are constructed of materials with low melting temperatures and are expected to completely demise upon reentry.

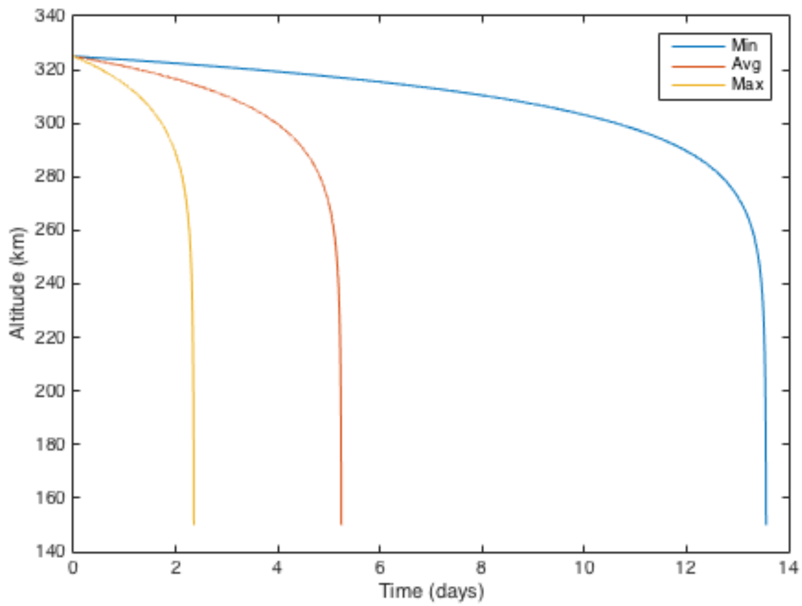

Figure 7: Sprite Orbital Altitude After Deployment