CapSat-1 Satellite Technical Description

The overall goal of the CapSat-1 mission is to demonstrate the potential of commercial-off-the-shelf (COTS) capacitors for primary energy storage, and to validate a capacitor-based electrical power system (EPS), in a 1U CubeSat. The CapSat-1 has a primary purpose of education – by giving younger engineers the opportunity for hands-on experiential learning with how to develop, build, test, and fly a satellite, supporting a technology demonstration.

Currently, many CubeSats use lithium-ion polymer (LiPo) batteries as their primary source of power. Capacitors are potentially safer, more cost/volume-efficient, and more temperature-durable than LiPo batteries. This mission will investigate capacitor power storage and voltage stability, to compare with performance of current battery-based CubeSat EPS's in a space environment.

CapSat-1 will be carried as cargo to the ISS mid-to-late 2021. CapSat-1 will be deployed from the ISS into an orbit of about 410 km circular, at 51.6 degrees inclination. Transmission will begin NET 30 minutes after deployment, and cease upon the atmospheric reentry. Atmospheric friction will slow the satellite and reduce the altitude of the orbit, until de-orbiting occurs at less than 12 months following its deployment. See the Orbital Debris Assessment Report for details. The spacecraft is a single 1U CubeSat unit with the dimensions 10 cm x 10 cm x 11 cm, and its mass is about 1.2 kg.

+Z face Transmitting antenna -Z face Receiving antenna

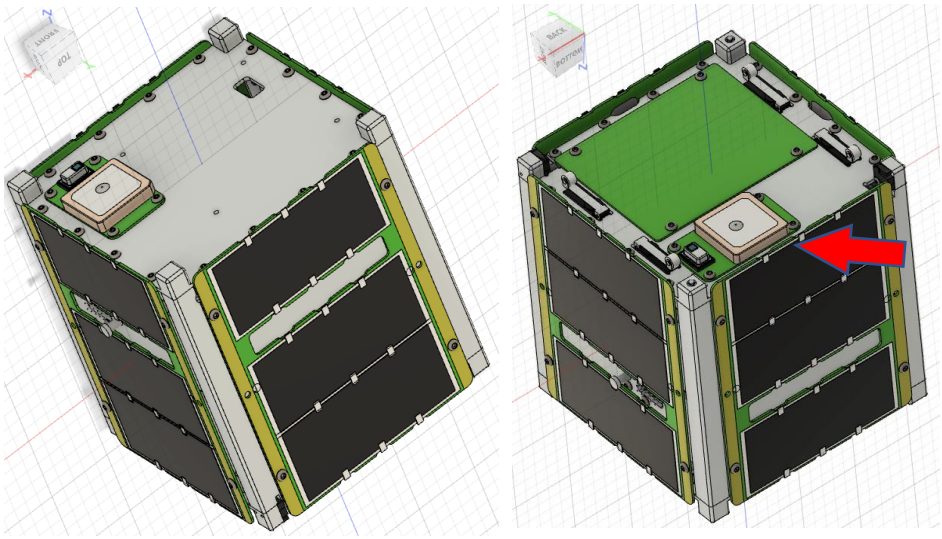

Figure 1: CapSat-1

Satellite Subsystems

<u>Guidance, Navigation and Control (GNC) Subsystem:</u> The CapSat-1 will not use an active GNC subsystem. A permanent magnet will encourage the orientation of the Globalstar patch antenna towards zenith, and the S band receiver antenna towards Earth. A horizon sensor on the transmit

antenna will support control of the Globalstar transmitter so that it only transmits in an upward direction.

Command and Data Handling (CDH) Subsystem: The two critical printed circuit boards in the CDH subsystem are the Level Zero (L0) and the Flight Computer (FC) boards. The L0 board operates regardless of FC operating state. It includes all comms interfaces to the transmitter, receiver and the FC, and performs basic spacecraft state of health maintenance.

Communications Subsystem (Comms): The EyeStar S3F transmitter will transmit up to 200 kbytes of data per day to Weiss School mission control, via the Globalstar system. The transmit patch antenna is shown in Figure 1. The NSL R25F S band radio receiver provides positive control over the Simplex transmitter, allowing a stop buzzer command to be transmitted from Earth.

Electrical Power Subsystem (EPS): The NSL electrical power system solar panels will generate up to 3.6 W in sunlight, providing 1 W orbit average power. A maximum power point tracker (MPPT) charges the 15.8 W-hr LiPo battery set, which is the primary bus power source. The EPS distributes nominal 5V and 3.3V output to the spacecraft. The power draw during transmission will be less than 1.9 W, and at other times the power draw is expected to be less than 250 mW.

The solar arrays utilize standard photovoltaic flexible cells, and the batteries are COTS Tenergy 32089 UL listed cells. The L0 board sends signals to the Power Switch Boards to control battery charging and load switching.

Thermal Control Subsystem (TCS): The TCS controls hardware temperature through cold biasing of the thermal design, utilizing a heater to stabilize payload temperatures during post-deployment experiment start-up procedure. Temperature sensors are connected to the L0 board, which hosts thermal control algorithms to control the heaters.

Structure Subsystem: The unibody structure is fabricated of anodized 6061 aluminum and is approved for use with PPOD and NANORACKS dispensers. The 1U structure includes access panels, inhibit switches, and antenna mounts.

Propulsion Subsystem: The CapSat-1 has no propulsion subsystems.

Payload Experiment Subsystem: The CapSat-1 payload includes two parallel sets of capacitors that will be charged and discharged in an alternating sequence. Each set consists of 10 individual Radial Electrolytic capacitors from Maxwell Technologies.

The experiment will power up thirty minutes after deployment. Telemetry will include capacitor voltage data at a rate of approximately 90 bytes per packet, with one packet transmitted every 10 minutes. Other telemetry includes the total charge taken by the capacitors, capacitor output voltage over a certain period of time, total current and leakage current, and the time required for each capacitor to fully charge, and discharge.