KREPE Inadvertent Transmit Inhibits

INTRODUCTION

The Kentucky Re-Entry Probe Experiment (KREPE) is a research project developed by the University of Kentucky. The project is supported by various NASA centers. The goals for the mission payload are to: 1) provide an affordable technology testbed for atmospheric re-entry experiments; and 2) collect material response data for Thermal Protection Systems (TPS) in order to allow validation of computational models. The intention for the KREPE project is to be a "One Time Flier" experiment. Refer to the submitted application attachment "KREPE FCC technical description" for an overall description of the KREPE experiment.

KREPE MISSION FUNCTIONAL DESCRIPTION

Each of the three KREPE capsules will use an Iridium modem and antenna for data communications. The capsules will be transported to the International Space Station (ISS) via a visiting vehicle. While in transport to the ISS, the KREPE capsules will be unpowered and housed inside an RF-shielding housing (KREPE Release Mechanism – KREM). Figure 1 shows a KREPE capsule inside a KREM Faraday cage.

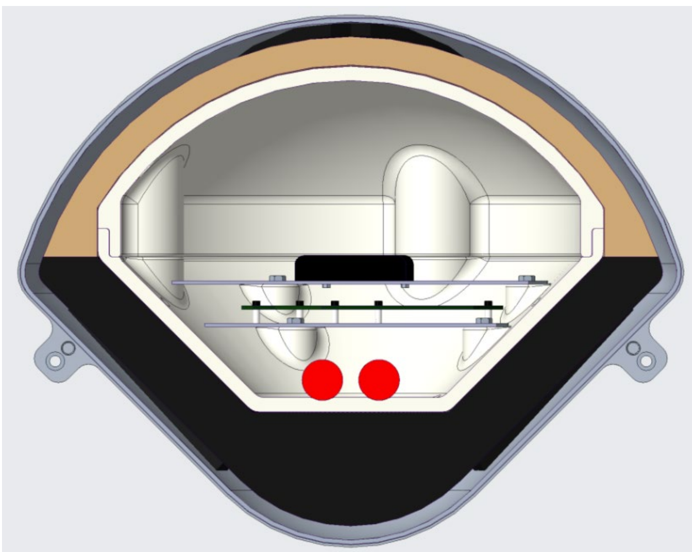

Figure 1. KREPE capsule installed in a KREM RF-shielding housing (gray outer shell)

Figure 2 shows a block diagram of the KREPE flight computer.

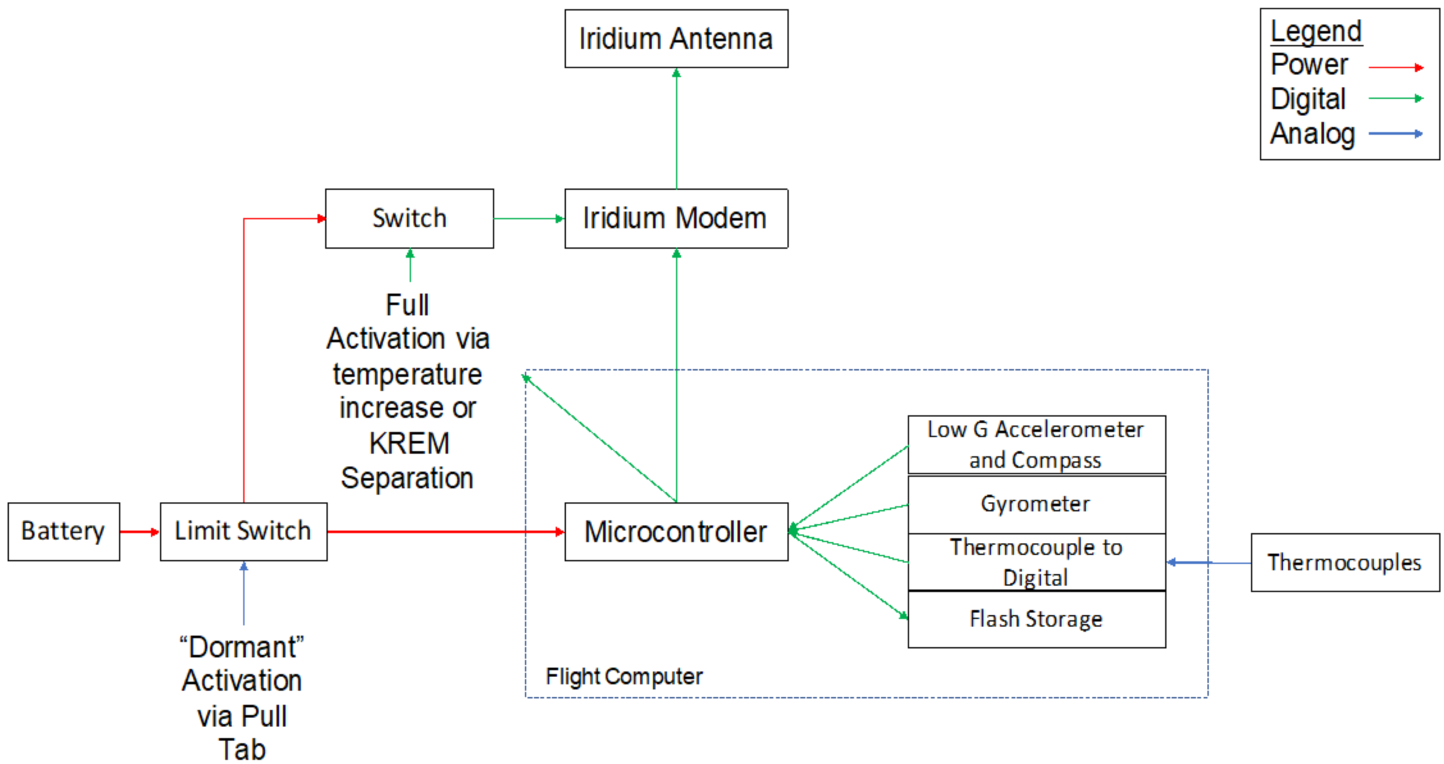

Figure 2. KREPE flight computer block diagram

After loading capsules into the return vehicle, the ISS crew will pull a tab to enable power to the flight computer (Arduino Teensy microcontroller). Once the tab is pulled, the flight computer is powered on and software initiation places it in a stand-by mode. In the stand-by mode, the microcontroller only monitors sensors that will be used later for activation when the return vehicle has departed the ISS. The activation will be described below.

The "Switch" (solid-state relay) is controlled by an output of the microcontroller. The switch is initially in the open state and battery power for the Iridium radio is disabled, preventing any RF transmission. The open switch is the first inhibit to any inadvertent transmission of the Iridium modem and remains in that state until descent. The KREM Faraday cage is still in place and provides a second inhibit to prevent accidental transmission (per NASA safety requirements). The KREPE capsules will remain in this stand-by, shielded state until the return vehicle has departed the ISS, de-orbited, and re-entry breakup has occurred.

The visiting vehicle will be released from the ISS and de-orbited. The KREPE capsules are designed to survive the return vehicle breakup as it re-enters the atmosphere. The KREPE flight computers remain in the stand-by state (Iridium modem unpowered) and the capsules are still encased in the KREM shield until breakup of the return vehicle is detected. Upon breakup, the capsules will be ejected from the visiting vehicle debris field at an altitude of approximately 50 – 60 km altitude and the KREM RF shield will be released when the plastic bolts holding the shield melt.

After breakup, activation involves detection of two events: a significant increase in temperature and release of the KREM RF shield. Thermal sensors provide the microcontroller with data to sense the heating event. A capacitive sensor is used to provide the microcontroller with data to indicate the shield has been released. In the active state, the KREPE systems begin initialization, including applying power to the Iridium modem. Activation of the Iridium radio is expected to occur at around 20 km altitude. At that time, the capsules will begin transmitting data, via Iridium, from the various KREPE sensors until splashdown. The descent only lasts for a few minutes.

The descent time is not sufficient to upload all the sensor data due to the limited Iridium bandwidth. Should the KREPE capsules survive splashdown and not sink, they will continue to send transmissions until the modest battery is drained. Under normal operation, the post-splashdown transmissions could continue for 5-6 hours.

KREPE PREVENTION OF RF TRANSMISSIONS DUE TO ABNORMAL CONDITIONS

INITIAL UNPOWERED STATE

The KREPE capsules are transported to the ISS in an unpowered state. A pull-tab power interrupt prevents the battery from energizing the electronics. This eliminates the possibility of any RF transmissions for the majority of the mission.

KREM RF SHIELD

Once the KREPE capsules are stowed in the return vehicle, the pull-tab power interrupt is removed by an astronaut and the electronics are placed in a stand-by mode. Under normal operation, software inhibits prevent powering up the Iridium by disabling a switch (see Fig. 2) between the battery and the Iridium modem. Were there some type of unanticipated anomaly causing the modem to transmit, the KREM RF shield, acting as a Faraday cage, will contain the RF emissions. Note that the KREM cage is also NASA-required safety inhibit to prevent interference with ISS command and control.

The KREM RF shield is maintained in place until the return vehicle departs the ISS, de-orbits, and the capsules are released into the atmosphere after the vehicle break-up. At that time, the shield will be released and power will be applied to the Iridium modem. The KREM RF shield, thus, prevents any RF transmissions for the majority the mission. After shield release, RF transmissions during descent would last no longer than a few minutes before splashdown.

KREPE CONTROLLER - POWER ANOMALY PROTECTION

RF transmission is possible during descent, once the KREM RF shields are released from the KREPE capsules. Each of the KREPE capsules uses a Teensy 3.5 microcontroller. The Teensy controller powers up into a known safe reset state. No outputs occur until the processing state is initiated (see Fig. 3).

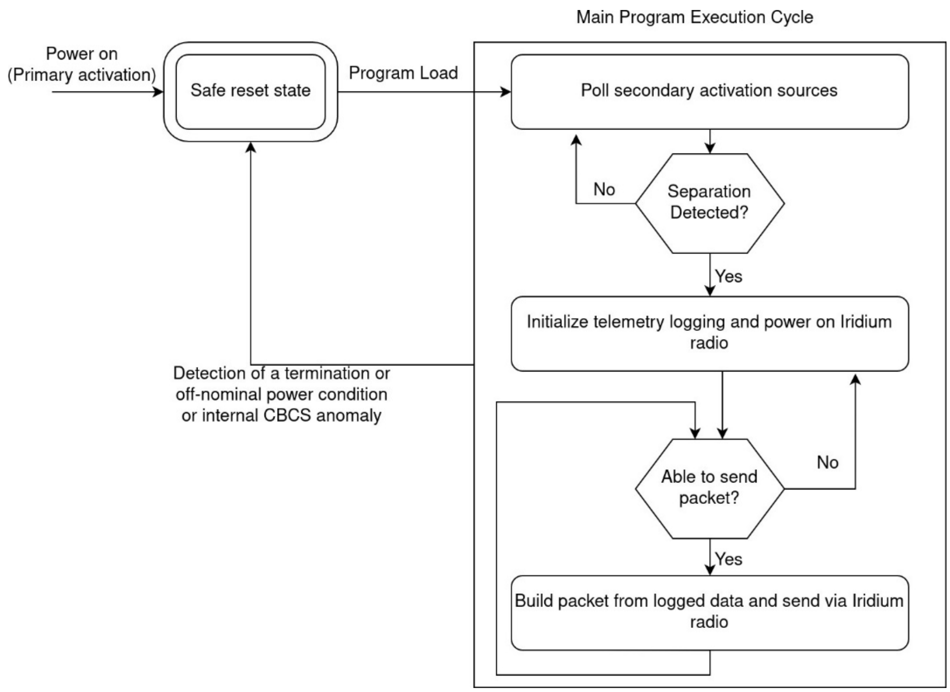

Figure 3. Overview of main execution cycle showing return to safe high impedance reset state upon startup and abnormal power condition.

Upon both power up (after primary activation via pull-tab) and detection of an off-nominal power condition, the Teensy microcontroller will enter a safe reset state, where all GPIO pins controlling critical system functions are set to a high impedance value. This high impedance state removes power to the Iridium radio by opening the switch from the battery (see Fig. 2), preventing Iridium transmission due to a possible off-nominal power malfunction.

KREPE CONTROLLER – SOFTWARE ANOMALY PROTECTION

During descent, after release of the KREM RF shield, a programmed “watchdog timer” will monitor the software program to ensure that the software process is progressing as designed. In the event a timer-anomaly is detected, the Teensy microcontroller will enter the safe reset state, setting all GPIO pins to the high impedance value. This high impedance state removes power to the Iridium by opening the switch from the battery (see Fig. 2), preventing Iridium transmission due a software anomaly.

KREPE CONTROLLER – IRIDIUM MODEM TRANSMITTER CONTROL

During descent, after release of the KREM RF shield, for an Iridium data transmission to occur, two things have to happen. First, the command to the switch (see Fig. 2) connecting the battery to the Iridium modem through the switch has to be given. At that time, the modem enters a stand-by, non-transmitting state. The second thing that has to happen is the Teensy microcontroller forms a data packet and gives the command for the Iridium modem to transmit. When transmitting, the Iridium modem outputs a “transmit-active” command, which is read by the microcontroller. This command is monitored throughout the software program. In the event transmission is detected outside of normal operating conditions, the Teensy microcontroller will enter the safe reset state, setting all GPIO pins to the high impedance value. This high impedance state removes power to the Iridium modem by opening the switch from the battery (see Fig. 2), preventing Iridium transmission due to some other unforeseen anomaly.

KREPE BATTERY CAPACITY LIMIT

The KREPE capsules are relatively small, about 11 inches in diameter. Thus, the battery has limited energy capacity (6400 mAH). The descent time to splashdown only lasts a few minutes. This is not enough time to transmit all the collected sensor data. In the event a capsule survives splashdown and does not sink, RF transmissions could continue until the battery is sufficiently drained. The estimate for any post-splashdown RF transmissions is a limit of about 5-6 hours. This would be the ultimate time window for any RF transmissions, should all other inhibits fail. If the capsules do not survive splashdown operating normally or sink, then the time window for RF transmissions is that of the descent, on the order of a few minutes.