

DEVELOPMENT OF A CONSUMER SATELLITE INTERNET MODEM SYSTEM AND A REENTRY VEHICLE FOR CUBE SATELLITE USE

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Presenter Biography: Avery Brock is a recent graduate from the University of Idaho, having earned his Bachelor of Science in Electrical Engineering. His research has included solid-polymer electrolysis, weather balloon-based local positioning systems for Martian exploration, high-altitude balloon payloads, and cube satellite communication and power systems.

Introduction: While the barriers to space flight have been reduced due to the privatization of launch vehicles, two large hurdles remain for those seeking to conduct research in space: orbit-to-ground communication, and reentry recovery. Our work seeks to reduce these barriers through research in these areas.

Communication costs can be reduced by using consumer satellite phone modems, specifically the Iridium Core 9523, to give satellites in low Earth orbit (LEO) access to a constant internet connection. Satellites and other devices operating at or below LEO and equipped with such a module would be able to stream data to Earth without the need for users to apply for frequency licenses, while also eliminating the need for prohibitively expensive radio equipment.

Additionally, our research looks to solve the current lack of recoverability of small satellites. Through the development of a Tube Deployed Reentry Vehicle (TDRV), we will allow satellites a means of surviving reentry so that equipment can be reused, or physical samples collected and returned to Earth.

Cube Satellite Internet Modem: Continuing work started by the Technical Education Satellite (TechEdSat) research group led by Marcus Murbach at NASA-ARC, we are utilizing the Iridium satellite constellation to communicate with satellites in LEO. The TechEdSat team has demonstrated that Iridium modules such as the 9602 Short Burst Data (SBD) transceiver are fully functional in orbit and are able to communicate with the Iridium constellation. The next step in this research is to develop a carrier module for the Iridium Core 9523 modem that adapts the core for use in a cube satellite. The Iridium Core supports a 2.4 kbit/s data stream compared to the 9602's 340-byte packets. The 9523 is currently used in NASA's Reentry Breakup Recorder (REBR) to transmit reentry data while falling at sub-sonic velocity post-reentry [1]. As such, we believe the 9523 shall also operate normally in LEO and provide a stable data connection.

Iridium Carrier Module: The carrier module is designed to seamlessly integrate the Iridium 9523 with the existing TechEdSat electronics stack but can easily be configured to work with any satellite able to supply approximately 30 watts of power. The module is currently in the testing phase and has not yet been adapted to the circuit board form-factor used by the TechEdSat team.

The test module uses a 5VDC supply to power an onboard microcontroller and power management devices, while an 8VDC input powers the Iridium Core. A CAD rendering of the module is shown in Figure 1. The module communicates via a configurable universal asynchronous receiver-transmitter (UART) port, with an onboard 32-bit 48Mhz ARM Cortex-M0+ microcontroller running configuration, monitoring, and data packet formation software, allowing these tasks to be offloaded from the main satellite CPU. These features give the module a sort of 'plug and play' functionality with any existing satellite architecture. To enhance this ability, the microcontroller is functionally equivalent to an Arduino M0, allowing inexperienced programmers to change the software as needed via a dedicated programming USB port.

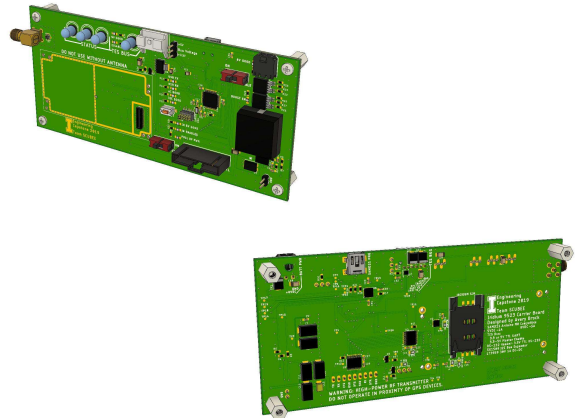


Figure 1: Iridium 9523 Carrier Module test model top view (top) and bottom view (lower).

The satellite-ready variant of this module will be stripped of all non-essential components such as indicator LEDs, configuration switches and headers, and debugging connectors to reduce size and power consumption. Our goal is to have such a module built and tested so that it may be flown by the TechEdSat team on the next TES-N satellite mission.

Tube Deployed Reentry Vehicle: The NASA-ARC TechEdSat group has also been working to develop a three-stage Small Payload Quick Return (SPQR) device designed to return small payloads from the ISS back to Earth in a temperature and pressure-controlled environment. The middle stage of this device is developed under this project and consists of the TDRV.

TDRV Operation: The TDRV is designed to be deployed at hypersonic velocity near the Karman Line altitude from either a carrier satellite deployed from the ISS or a sounding rocket, depending on its mission. Once deployed, the TDRV uses a conical drag device to slow its decent and maintain a vertical orientation during reentry. After reentry, a parachute is deployed, and the TDRV closely matches the behavior of the NASA REBR and initiates an Iridium call using the previously discussed Iridium Core 9523 Carrier Module. The TDRV is then able to be recovered. A diagram of an ISS deployment mission is shown in Figure 2.

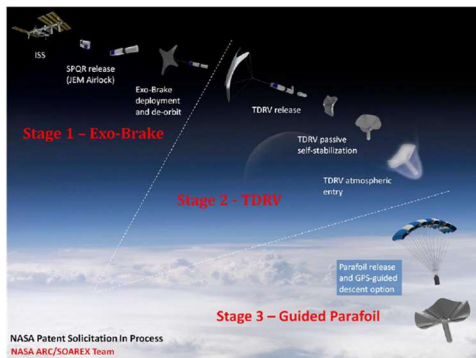


Figure 2: SPQR and TDRV reentry behavior diagram, NASA-ARC TechEdSat.

Current Progress: The TDRV is currently in the modeling and prototype phase and is undergoing testing. A 3-D printed model has been created for rough aerodynamic and high-altitude testing, a CAD rendering of which is shown in Figure 3. Our current goal is to design and test aluminum and plastic functional models of the TDRV at subsonic velocities through high-altitude weather balloon drop tests before manufacturing higher-cost models capable of supersonic descent out of exotic and composite materials.

System Controls and Communication: The TDRV is powered by onboard lithium-polymer batteries and controlled via an onboard microcontroller. Onboard GPS, altimeter, and inertial measurement units (IMU) record flight data. Tracking of the TDRV is currently provided via the amateur radio automated packet

reporting system (APRS). Eventual integration of the Iridium Carrier Module will allow for a constant data stream from the TDRV. GPS, FM, and Iridium antennas are aft-mounted with a ground plane formed both by the TDRV and the use of conductive materials in the drag device to improve signal reception.

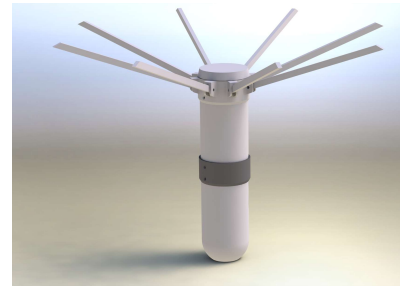


Figure 3: TDRV device mechanical design, multilayer drag material not shown in rendering.

Summary: Through the development of a module designed to integrate the Iridium Core 9523 into a cube satellite, and a TDRV device designed to allow the recovery of small payloads from orbit, we are reducing the cost of space exploration, allowing more research groups access to orbital research. We present the current state of our research and device development and outline future research goals to forward our progress towards flight-ready hardware.

References:

[1] A.S. Feistel, et al. “Comparison of Reentry Breakup Measurements for Three Atmospheric Reentries”, 6th IAASS Conference 2013.