1. VE Scope

The Government is seeking a readily available (Off the Shelf) vault electronics (VE) package with space flight heritage for use in the Shields-1 CubeSat. The Government will provide the housing (Structure) for the VE, the technology demonstration Instrument, the solar power assembly (solar arrays), omnidirectional antenna, internal environmental sensors, and write application flight software for installation into the VE. The Vault structure will provide a shielded environment equivalent to low earth orbit (LEO) total ionizing dose (TID) levels. The Government will integrate and test the CubeSat, support launch vehicle integration and satellite deployment, and operate the CubeSat for one year.

1.1. The VE will consist of the following logical assemblies (see Figure 1-2):

- Power Distribution
- Transceiver
- Command &Data Handling
    - Processor
    - Memory
    - General Purpose Digital I/O
    - I^2C Interface
    - RS 422 Interface
- Batteries (with heaters if necessary)

2. VE specifications

2.1. General

2.1.1. [VE-001] The VE shall operate in the environment of Table 5-1 for a minimum of one year.

Table 5-1: VE Operational Environment within the Vault

Parameter	**Value/Range**
Radiation	5 kilorad total dose
Temperature	- 50 to 40 degrees centigrade
Pressure	$<10^{-5}$ torr

2.2. Functional/Performance

2.2.1. [VE-002] The VE shall store a minimum of 0.3 Mbytes of data in each of two physically redundant memory modules for redundancy and to accommodate up to six days between ground contacts.

2.2.2. [VE-003] The VE shall include a battery with storage capacity to power normal operations for up to 2.4 hours in the Earth's shadow (no solar power input) every orbit to operate in worse case orbit with loss of on solar energy. Note: See 5.3.7 for load expectation.

2.2.3. [VE-004] The VE shall provide access to all available internal engineering data via the API to monitor health and status.

2.2.4. [VE-005] The VE shall provide capability to turn transceiver on and off via the API to meet FCC regulation and enable power down during high proton environment. Note: Power on/off capability to include turning receiver and transmitter on/off separately.

2.2.5. [VE-006] The VE shall provide an event timer or clock accessible by API for use by Government to control data acquisition and other events.

2.3. Interface Requirements

2.3.1. [VE-007] The VE shall obtain and utilize power from a readily available CubeSat solar power source specified by the Contractor. Note: For Government provision and CubeSat integration, see SOW requirement 4.5.2. (See *CubeSat Design Specification Rev. 12*, The CubeSat Program, Cal Poly SLO)

2.3.2. [VE-008] The VE shall include an interface connector for the solar power source. Note: The Government will supply the interface cable between the VE and the solar power source.

2.3.3. [VE-009] The VE shall provide a software API to include access to hardware configuration, programmable I/O, housekeeping measurements, test points, analog data acquisition interfaces, and communication channels to configure hardware and access features.

2.3.4. [VE-010] The VE shall provide a minimum of one I^2C (inter integrated circuit) communication channel accessible by a PC-104 connector to collect science data from the Instrument.

2.3.5. [VE-011] The VE shall provide a minimum of one bidirectional RS-422 communication channel accessible by a PC-104 connector to collect science data from the Instrument.

2.3.6. [VE-012] The VE shall provide a minimum of 40 bits of general purpose digital I/O accessible by a PC-104 connector with input/output selection via API to control Instrument data acquisition and data transfer and antenna deployment.

2.3.7. [VE-013] The VE shall provide one switched 5.0 +/- 0.5 VDC and one switched 3.3 +/- 0.3 VDC with total power of 5 watt peak, 1 watt average power output accessible via the API to turn the Instrument on and off.

2.3.8. [VE-014] The VE shall provide three each switched 3.3 +/- 0.3 VDC outputs for 60 - 75 ohm resistance ADCS accessible via the API for attitude control.

2.3.9. [VE-015] The VE shall provide an interface for loading/installing Government developed flight software into the VE processor board.

2.4. RF Communications

The Government has used the 18 meter dish earth station at the Wallops Flight Facility (WFF) for this design specification. The antenna system has a gain of 35 dBi, G/T of 10.6 dB/K, and transmitter output power of up to four watts. Uplink and downlink will occur in a 30 minute contact when CubeSat is 15 degrees over the horizon view and within an 8,000 – 15,000 Km slant range. Minimum time between passes can be as low as 22 hours to as high as five days.

2.4.1. [VE-016] The VE shall receive and transmit RF signal via redundant SMA connectors with 50 ohm impedance from/to Government supplied Vault-mounted zero gain *omni-directional* antenna.

2.4.2. [VE-017] The VE shall accept RF uplink commands using the AX.25.2.2 Link Access Protocol for Amateur Packet Radio for ground commanding.

2.4.3. [VE-018] The VE shall include an RF Receiver with the following characteristics to be compatible with the WFF ground station:

2.4.3.1. Frequency: User tunable between 400 – 480 MHz +/- 1Hz

2.4.3.2. Bit rate: 9600 bps

2.4.3.3. Bandwidth: 15KHz at -20dB

2.4.3.4. Frequency stability: 10 ppm

2.4.3.5. Polarization: Linear

2.4.3.6. Modulation: GMSK

2.4.3.7. BER: 10^{-5}

2.4.4. [VE-019] The VE shall downlink data using the AX.25.2.2 Link Access Protocol for Amateur Packet Radio to transmit stored data to the ground.

2.4.5. [VE-020] The VE shall include a transmitter with the following characteristics to be compatible with the WFF ground station:
- 2.4.5.1. Frequency: User tunable between 400 – 480 MHz +/- 1Hz
- 2.4.5.2. Frequency stability: 10 ppm
- 2.4.5.3. Bandwidth: 50 kHz at -20 dB
- 2.4.5.4. Bit Rate: 38.4 Kbps
- 2.4.5.5. Bit error rate: 10^{-5}

2.4.6. [VE-021] The VE shall have selectable power in three steps, low (in the milliwatts) for testing, medium, high (full power) for on orbit operations.

2.5. Physical Characteristics
- 2.5.1. [VE-022] The VE shall have maximum footprint dimensions of 87mm x 87mm.
- 2.5.2. [VE-023] The VE shall have board stack height of less than five centimeters to fit within the allocated volume of the 1U vault structure.

2.6. Verification & Validation
- 2.6.1. [VE-024] The Contractor shall conduct procedure controlled acceptance activities prior to delivery that verify by inspection, demonstration, analysis, or test all requirements of section 5 in a laboratory environment with simulated external interfaces.

3. Software EDU specifications

3.1. [SEDU-01] The software EDU shall support operation of the API for development purposes.

3.2. [SEDU-02] The software EDU shall duplicate/simulated VE interfaces with regard to hardware configuration, programmable I/O, housekeeping measurements, test points, analog data acquisition interfaces, and communication channels.

4. Deliverables

The Government is seeking to procure the necessary electronics to control the CubeSat and collect science data via electrical, electronic, and mechanical interfaces to the Instrument and structure of the Shields-1 vault for the Shields-1 CubeSat. The statement of work is given below.

4.1. [VE-T1] The Contractor shall provide one integrated VE that meets all requirements delineated in this document, delivered within 90 days after receipt of order (ARO) or earlier.

4.2. [VE-T2] The Contractor shall provide a second integrated VE that meets all requirements delineated in this document, delivered within 120 days ARO or earlier.

4.3. [VE-T3] The Contractor shall provide a software engineering development unit (EDU) for use by Government to develop and test flight software within 30 days ARO or earlier.

4.4. [VE-T4] The Contractor shall provide copies of test procedures/reports/results, including data, with delivery of the hardware as evidence of successful verification.

4.5. [VE-T5] The Contractor shall provide the follow work products (documentation) in hardcopy and electronic file form as soon as possible, but no later than with delivery of the VE hardware.
- 4.5.1. A software application developer's user guide with operating system description and thoroughly documented application program interface (API) and function library for use by flight software developer, including instructions for access to VE features and application-operating system interface description.
- 4.5.2. Specifications for a solar power source composed of four 3U panels for use by Government to obtain and integrate onto opposite sides of the CubeSat.

4.5.3. An RF performance analysis showing expected uplink and downlink margins at specified bit error rate, data rates, and other RF parameters in section 5.4 below to allow the Government to assess the overall CubeSat RF performance.

4.5.4. All DD1494 parameters for Government use to obtain frequency licensing.

4.5.5. Engineering drawings that indicate component location and physical configuration (assembly drawings) of the delivered VE.

4.6. [VE-T6] The Contractor shall provide up to 100 hours of post-delivery support to resolve technical problems or questions.