Educational Payload Test Plan

FAST Bartolomeo, Neumann Space

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List of Revisions

Revision	Revision Date	Revised By	Revision Description
0.1	13 June 2017	Oliver Grenfell	First Draft Release

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1.0 Introduction

Space is a harsh environment. Spacecraft, satellites, payloads, and astronauts must be able to survive the variety of natural and induced environmental conditions: vibrations, shock forces, high accelerations, extreme temperatures, solar radiation, and the vacuum of space to list a few.

To ensure that humans and all human-made objects can survive in space, rigorous testing is done on them in conditions in as near to what will be experienced during the time in space. Should the testing be passed, mission planners and designers can be confident of their mission surviving the environment of space.

1.1 Purpose

The Educational Payload Test Plan (EPTP) describes a basic testing plan that can be used by payload designers during the design and manufacture of their payload without the need for sophisticated equipment or techniques.

Professional space flight certification can be expensive and time consuming, especially should a component or system within the payload fail and require redesign and retesting. The EPTP aims to reduce the likelihood of this occurring, by stepping payload designers through some basic tests that can be done by themselves with minimal equipment. While the tests detailed within the EPTP are not comprehensive on the magnitude or types of loads the payload may experience while in space, it can provide payload designers some confidence on the mechanical and electrical integrity of their payload prior to the spaceflight certification process.

Payload designers are not required to use any or all of the tests described within the EPTP to manufacture a space-worthy payload, however it is recommended that payload designers should attempt as many as that are feasible. This way, payload designers hopefully will correct any design flaws that may exist in the payload design prior to the professional testing process.

Payloads that fail any of the tests described within this document shall be required to be redesigned to ensure that the payload can be space flight certified.

1.2 Scope

This document is to be used for payloads which are to be launched to the International Space Station (ISS) as part of the FAST Bartolomeo program. This program details the requirements for a Falcon 9 rocket launch of a JEM-AL-compatible, pressurised launch of payload to Airbus Defence and Space's Bartolomeo mission service.

This document details through some of space environment conditions which will be experienced by the payload through the space flight certification process. The levels detailed within the EPTP may be of lesser or equal magnitude to the space flight certification load levels, and as such, compliance with this document does not guarantee the payload is capable of withstanding the rigours of spaceflight. Space flight certification shall only be conducted through a professional testing facility.

The space flight certification requirements are detailed within the FAST Bartolomeo Technical Requirement Specifications document, NS-1-FAST-S005.

1.3 Document Format

The EPTP provides both the explicit requirement that the payload must comply with, along with some recommendations on how to test the requirement.

Each requirement is stated as a numbered point. This is for easy referencing within later documentation for ease of requirement referencing. The source of the reference is provided at the end of the requirement in brackets.

Just after the requirement is a small description of how this test can be conducted on your payload, and any other comments relevant to the requirement.

An example of a requirement is provided below:

<Start Example>

3.1 Acceleration Loads

1. The payload must be able to withstand an acceleration load of +7.4 g acting on all three axis (RD1).

A simple manner to test the acceleration load acting on the payload would be to place an object of suitable mass on each of the faces of the payload. The required mass of the object can be calculated by multiplying the mass of the payload by the desired acceleration of the payload (in g's).

Note that while this method is quick to conduct, it only tests the capability for the structure of the payload to withstand the acceleration.

Another method of testing the payload is to rotate the payload in a circle of constant radius and at a constant rotational velocity. In this manner, the entire payload (including internal components) are exerted upon by the acceleration load, which in this case, is equal to the radial acceleration exerted on the payload (see Equation 3.1-1).

$$[Radial\ Acceleration] = \frac{[Linear\ Velocity\ of\ the\ Payload]^2}{[Radius\ of\ the\ Circle]} = [Rotational\ Velocity\ of\ the\ Payload]^2 \times [Radius]$$

Equation 3.1-1: Radial Acceleration Load

The minimum length of time for the test is 5 minutes (RD1).

< End Example>

The numbering of requirements used within the EPTP is:

[Section Number]-[Requirement Number]

So the example requirement above has a reference number of 3.1-1.

2.0 Related Documents, Acronyms, and Definitions

The environmental conditions detailed within the EPTP that the payload must withstand have all been sourced from the documents detailed in Table 2.0-1. If payload designers desire to be provided the original source material of the requirements, they should contact their Neumann Space representative.

Table 2.0-1: Referenced Documents

Document Code	Document No.	Revision	Title
RD1	NS-1-TRSTN-S001	0.1	TRISSTAN Technical Requirement Specifications Document

Websites used as general reference resources during the EPTP are detailed in Table 2.0-2.

Table 2.0-2: External Websites

Document Code	Resource Reference
ED1	SpaceX 2017, *Falcon 9*, accessed 19/05/2017, http://www.spacex.com/falcon9
ED2	Tustin, W 2007, *Why Is Random Vibration Quantified In Strange g2/Hz Units?*, accessed 19/05/2017, http://www.cemag.us/article/2007/07/why-random-vibration-quantified-strange-g2hz-units
ED3	Motisan, R 2009, *High Frequency Solid State Tesla Coil (HF SSTC)*, http://www.pocketmagic.net/high-frequency-solid-state-tesla-coil-hf-sstc/, accessed 13/06/2017

Tables 2.0-3 and 2.0-4 provide acronyms and definitions of terms used within the EPTP.

Table 2.0-3: Abbreviations and Acronyms

Acronym	Definition
EM	Electromagnetic
g	Acceleration due to Gravity (9.8 m/s^2)
HFTC	High-Frequency Tesla Coil
ISS	International Space Station
MMOD	Micrometeoroid and Orbital Debris
RMS	Root Mean Square, shown on units in the manner of $\langle Unit\rangle_{RMS}$
UV	Ultra-Violet Light

Table 2.0-4: Definitions of Terms

Term	Definition
FAST Bartolomeo Payload	The overall payload structure placed on the Bartolomeo on the ISS. The structure is designed and built by Neumann Space.
Payload	The structure that has been designed by yourselves. This will be part of the FAST Bartolomeo Payload.

3.0 Induced Environment

This section details the induced environmental conditions that the payload will have to withstand. The majority of these conditions of when the payload is launched into space.

3.1 Acceleration Loads

1. The payload must be able to withstand an acceleration load of +7.4 g on all three axis (RD1).

A simple manner to test the acceleration load acting on the payload would be to place an object of suitable mass on each of the faces of the payload. The required mass of the object can be calculated by multiplying the mass of the payload by the desired acceleration of the payload (in g's).

Note that while this method is quick to conduct, it only tests the capability for the structure of the payload to withstand the acceleration.

Another method of testing the payload is to rotate the payload in a circle of constant radius and at a constant rotational velocity. In this manner, the entire payload (including internal components) are exerted upon by the acceleration load, which in this case, is equal to the radial acceleration exerted on the payload (see Equation 3.1-1).

$$[Radial\ Acceleration] = \frac{[Linear\ Velocity\ of\ the\ Payload]^2}{[Radius\ of\ the\ Circle]} = [Rotational\ Velocity\ of\ the\ Payload]^2 \times [Radius]$$

Equation 3.1-1: Radial Acceleration Load

The minimum length of time for the test is 5 minutes (RD1).

2. The payload must be able to withstand an acceleration load of -6.0 g on all three axis (RD1).

Testing of constant negative acceleration on the payload for a prolonged period of time would be difficult to be conducted without high starting speeds or specialised equipment. Repeated testing of accelerations of lesser magnitude or for a time less than 5 minutes would be an acceptable substitute to understand how the payload structure may perform in this environment.

3. The payload must be able to withstand an angular acceleration load of +/- 13.5 rad/sec^2 around all three axis (RD1).

To test the capability of the payload to withstand angular acceleration, the payload's angular motion should be rapidly accelerated and decelerated.

The typical angular motion sensor would measure the angular velocity of the payload. To convert this measurement into angular acceleration, measure the angular velocity at either end of a measured time period (see Equation 3.1-2).

$$[Average\ Angular\ Acceleration] = \frac{[Final\ Angular\ Velocity] - [Initial\ Angular\ Velocity]}{[Measured\ Time\ Period]}$$

Equation 3.1-2: Angular Acceleration

Note that the smaller the measured time period becomes, the closer the average angular acceleration reaches the instantaneous angular acceleration of the payload.

3.2 Vibration Loads

1. The payload shall withstand vibration loads of 0.2 g^2/Hz from 2 to 2000 Hz (ED1).

To properly test the payload's resilience to the launch vibration loads, payloads should be placed on a vibration testing machine. The required level of force or g's can be calculated using equation 3.2-1.

In the absence of a vibration testing machine, payload developers can rapidly shake their payload from side-to-side. Any component which rattles, sways excessively, or comes loose will be a potential vibration risk, and should be fixed in a manner appropriate to the component and issue. This however is a basic testing method, and does not properly inform designers the integrity of their payload to vibrational loads.

$$[Experienced\ g's] = \sqrt{0.2\ g^2/Hz \times [Frequency\ Bandwidth]}$$
$$[Force\ on\ Payload] = [Mass\ of\ Payload] \times (9.8 \times [Experienced\ g's])$$

Equation 3.2-1: Vibration Requirement Conversion

Reference. ED2

The method of converting from 0.2 g^2/Hz to g_{RMS} or force is detailed within ED2. First, multiply 0.2 g^2/Hz by the frequency bandwidth used for the vibration machine test. Take the positive square-root of the resultant value to get the maximum allowable g_{RMS} level, converting to force through Newton's Second Law of Motion.

3.3 Acoustic Loads

1. The payload shall be compatible with sound loads of 119.5 dB, ref. 20 µPa during launch at the position of the payload (RD1, ED1).

The payload should not suffer any adverse effects or create any safety risks to itself, other payloads or the ISS after being placed in this acoustic environment.

To test the payload's compatibility with the acoustic environment, payload designers should place their payload beside a sound pressure level (SPL) measurement device and a loud noise source for approximately 5 minutes (based on the primary stage launch time detailed in ED1). In the absence of SPL measuring devices to determine the SPL of a noise source, the following levels can be used as an approximation:

- 110 dB for a chainsaw at a distance of 1 metre
- 105 dB for a bandsaw at a distance of 20 cm

If payload developers have access to a sound source which produces sound at a high SPL, the appropriate distance between the sound source and the payload can be determined using Equation 3.3-1.

$$[SPL\ at\ Position\ 2\ (dB)] = [SPL\ at\ Position\ 1\ (dB)] - \left|20 \times log\left(\frac{[Radius\ of\ Position\ 1]}{[Radius\ of\ Position\ 2]}\right)\right|$$

Equation 3.3-1: Sound Pressure Level at Different Distances Equation

It is strongly recommended that people in the vicinity of the tests wear proper acoustic protection.

2. The payload shall be compatible with sound loads of 127.5 db, ref. 20 µPa during the disposal of the payload (RD1).

Test this requirement on the payload using similar method as requirement 3.3-1. However, payload designers just need to show that the payload does not fall apart and/or have structural failure. Components are not required to be operate during or after these sound conditions.

Removal of potentially fragile components to avoid damage to them due to the excessively high sound levels is allowed in the testing of this requirement, provided the component is not used for structural rigidity within the payload and is replaced with an object of similar mass and dimensions.

3.4 Thermal Loads

1. The payload shall be capable of safely operating in a temperature range of -20^{o} to +50^{o} Celsius (RD1).

To simulate these temperature conditions, the payload can be placed inside a standard home freezer and an oven. The payload should be able to safely operate when exposed to both extremes of the temperature range, and afterwards, as it cools/heats back to ambient room temperature (approximately +25^{o} Celsius).

While the extremities of the FAST Bartolomeo payload can get to far colder temperatures, the temperature range experienced by payloads within the FAST Bartolomeo payload during on-orbit operations on the ISS is between -20^{o} and +50^{o} Celsius.

2. The payload must be able to operate after 6 hours without power during on-orbit operations (RD1).

The supplied power to the payload may be switched off for a variety of reasons: loss of supplied from Bartolomeo to the FAST Bartolomeo payload, or an immediate / urgent need for power redistribution within the FAST Bartolomeo payload. As such, the payload must be able to survive in the full range of the exposed thermal environment without power, using the method and temperature range detailed in Requirement 3.4-1.

Note that the payload will need to survive for a longer period of time without power during ground transportation prior to launch, however the temperature range which the payload will be exposed to can be assumed to be ambient room temperature.

3.5 Shock Loads

1. The payload shall be compatible with the launch shock loads, where each shock load event is equivalent to a 9.73 g_{RMS} acceleration load for a period of 60 seconds (RD1).

To simulate each shock load event on the payload, use the same method described for Requirement 3.1-1, however for a minimum testing time of 60 seconds. Further testing time is not required.

3.6 Ground-Handling Loads

1. In its ground transportation configuration, the payload shall be compatible with rapid shock loads of 20 g pulses with a duration of 10 ms (RD1) along each of the payload axes.

To simulate these rapid shock loads to the payload during ground transportation, the payload should be dropped from a height of 20 cm onto firm carpet. This should be conducted repeatedly without alterations to the payload to properly simulate the potential shock loads onto the payload.

4.0 Natural Space Environment

4.1 Electromagnetic Environment

4.1.1 Electromagnetic Field Environment

1. The payload shall be compatible with the Electromagnetic (EM) field conditions described in Table 4.1.1-1 (RD1).

Table 4.1.1-1: Specific EM External Field Frequency Ranges

Reference. RD1

Frequency Range	Maximum Field Strength (V/m)
10 kHz to 0.2 GHz	5
0.2 GHz to 8 GHz	60
8 GHz to 12 GHz	20
12 to 40 GHz	15

The EM environment experienced by the payload can be simulated using a High-Frequency Tesla Coil (HFTC). A suitable method of constructing a HFTC is detailed in Appendix 1, using the resource provided in ED3.

Payload developers should note that there are significant technical difficulties when developing EM systems of frequency greater than 50 MHz, due either to the very high power requirements or very small available testing volume. It is not expected that experiments are to be pre-testing for frequencies greater than 50 MHz.

Payload developers should also note that these systems will produce significant EM emission all around the testing device, and as such, should avoid moving any personal electronic devices near the testing area.

4.1.2 AC Magnetic Field

1. The payload shall be compatible with an AC magnetic field environment of maximum magnitude of 150 dBpT from 30 Hz to 3 kHz (RD1).

To create the AC magnetic field environment, payload designers are recommended to use a short, wide solenoid connected to an AC power source. The payload is then placed inside the solenoid, where the magnetic field is of a uniform strength (defined in Equation 4.1.2-1).

$$[Magnetic\ Field\ Strength\ in\ A/m] = \frac{1.26 \times 10^{-4} \times [Number\ of\ Turns\ in\ the\ Solenoid] \times [Imput\ Current\ in\ Amps]}{2 \times [Radius\ of\ the\ Solenoid\ Coil]}$$

Equation 4.1.2-1: Short, Wide Solenoid Strength Equation

4.2 Incident Solar Thermal Environment

1. The payload shall be compatible with incident solar-thermal environment of maximum magnitude 1423 W/m^2 (RD1).

A low power heat lamp can be used to appropriately simulate the incident solar thermal environment acting on the exposed surfaces of the payload, suspending the heat lamp over the payload surface. The required distance between the heat lamp and the payload surface can be calculated using equation shown in Equation 4.2-1.

$$\frac{[Payload\ Surface\ Area] \times [Power\ Output\ of\ Heat\ Lamp]}{[Desired\ Power\ on\ Payload\ Surface]} = [Surface\ Area\ of\ Light\ Coverage] = \pi \times [Distance] \times tan^2([Angle\ of\ Light\ Spread\ from\ Vertical\ Axis])$$

Equation 4.2-1: Required Distance between Lamp and Payload

Note that this test is only required for payload surfaces directly exposed to solar energies.

4.3 Incident Solar UV Radiation

1. The payload shall be compatible with incident UV radiation environment of maximum magnitude $7.5x10^{-3}$ W/m^2 in the 100 to 150 nm wavelength range (RD1).

The solar UV radiation environment on the payload can be simulated using a similar testing procedure as described for Requirement 4.2-1, replacing the heat lamp for a UV lamp.

Note that this test is only required for payload surfaces directly exposed to solar energies.

5.0 Electrical Interface

Despite best efforts to provide a constant, reliable power source to each payload, the FAST Bartolomeo payload may be provided DC power with an injected AC sine wave, or with an overvoltage or undervoltage power surge. As there is no guarantee that these will be attenuated for internal systems, internal payloads within the FAST Bartolomeo payload will have to survive equivalent power scenarios.

1. The payload electrical systems shall be compatible with a sine wave superimposed with the input voltage, with a maximum magnitude of 2.5% of the input voltage (RD1).

The sine wave injection scenario can be simulated by using an AC power supply in series with the DC power supply, setting the magnitudes of the both power supplies as appropriately.

Payload designers should assume that a sine wave injection into the DC power supply can occur for any amount of time while the payload is operating in space, and as such, should use repeated tests of various time periods.

2. The payload electrical systems shall be compatible with a change of voltage from the provided input voltage to 0 V (or any other voltage) and back to the input voltage for a duration of 50 µs (RD1).

This scenario can be simulated using the voltage circuit shown in Appendix 2, using the following values for electrical components:

- V_{DD} = Provided Input DC Voltage (V)

3. The payload electrical systems shall be compatible with an overvoltage of magnitude 29.2% of provided input voltage for a duration of 2 ms (RD1).

This scenario can be simulated using the voltage circuit shown in Appendix 2, using the following values for electrical components:

- V_{DD} = DC Voltage of magnitude 129.2% times the Provided Input DC Voltage (V)

6.0 General Safety

6.1 Fatigue Considerations

1. The payload shall not suffer from fatigue such that the safety of the payload is compromised during the entire operation of the payload (ED1).

The only method of testing this requirement for the payload is to conduct repeated tests of the payload. If feasible, these tests should be conducted prior, during, and after each of the expected payload environments. Payload designers should monitor and inspect all systems and components before, during, and after these tests where feasible to detect any potential degradation of payload safety to itself and any potential surrounding payload structures.

Note that the payload will operate in orbit for a period of 1 year. There will be insufficient time to test the payload continuously for the entire year. As such, payload developers must ensure that the the payload is tested through all potential environments and situations that may occur over a one year period.

As a general rule of thumb, it is always better to do too much testing that not enough.

6.2 Materials

1. The payload shall not have any material or component which has not been approved of by Neumann Space.

Inspect the payload to check that all materials and components used in its construction have received permission for use by Neumann Space. All approved materials and components are either stated on the Bill of Materials (provided by Neumann Space), or is stated as an approved material /component through written communications.

Note that recommendations made by other reputable aerospace companies have an equal standing to the recommendations made by Neumann Space.

7.0 Other Considerations

There are many other environments and situations that should be considered during the design and construction of the payload which have not been detailed within the EPTP. However, these tests require more advanced testing procedures and equipment than is reasonably expected for non-professional developers. Therefore, the primary requirements of the payload that should be considered have been briefly listed with any appropriate accompanying notes.

It is not expected that payload developers are able to test any of these requirements, however they should consider then during the design and construction of their payload to ensure that the payload can pass the in-depth tests later done at a professional testing facility.

7.1 Pressure

1. All surfaces of the payload and components exposed to the vacuum of space shall be compatible with a vacuum environment of $3.6x10^{-08}$ Pa (RD1).

2. The payload shall be compatible with a maximum pressure environment of 129.3 kPa (RD1).

7.2 Micrometeoroids and Orbital Debris (MMOD)

1. The payload shall not cause a hazard to itself, other payloads, or the ISS if impacted by MMOD (RD1).

As a general rule, protection against MMOD is required for stored energy devices, pressurised systems, or other materials / components that may fragmentate when impacted / penetrated by MMOD. However, payload developers should communicate with Neumann Space regarding their individual payload’s need for MMOD protection.

As a precaution, payload developers should avoid unnecessary sealed volumes of space to mitigate the amount of MMOD protection required, if any.

7.3 Ionising Radiation

1. The payload shall not produce an unsafe condition or potentially cause damage to itself, other payloads, or the ISS as a result of exposure to ionising radiation environment (RD1).

The payload will be exposed to ionising particles during on-orbit operation, which include: trapped electrons, trapped protons, and solar, anomalous, and galactic cosmic rays. The effect of ionising radiation on the payload is manifested as the gradual degradation of electronic devices and material performance during the payload’s operation period. Payload developers should communicate with Neumann Space regarding the potential effects of ionising radiation on their payload and potential mitigation strategies.

Appendix 1: High-Frequency Tesla Coil

This section details the method of constructing a High-Frequency Tesla Coil (HFTC) for the EM emission environment testing procedure, using the design detailed in ED3 and as shown in Figure A.1-1. The HFTC design makes use of commonly-available components, has been shown to operate up to frequencies of 50 MHz.

A quick method of determining if the HFTC is operating correctly is to hold a fluorescent tube close to the tesla coil during operation. The tube will become excited by the EM field generated and turn on. The distance at which the fluorescent tube will turn on will be at a closer distance than required for EM field strength environment testing.

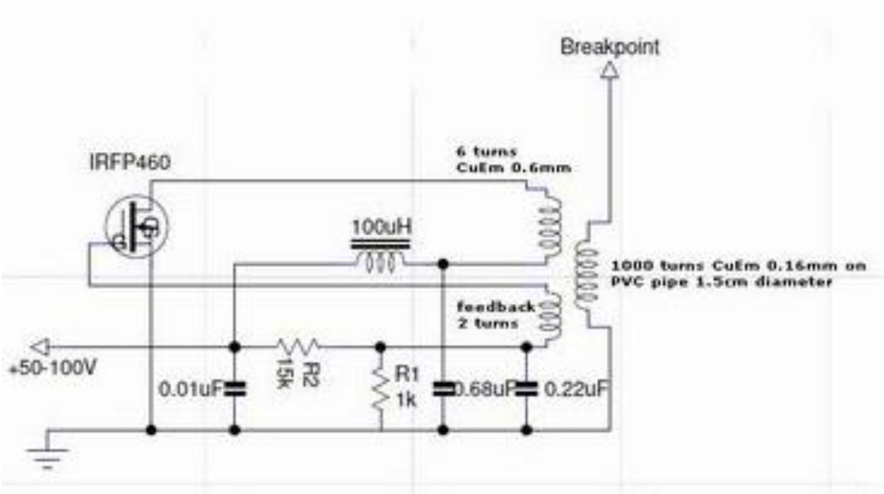

Figure A.1-1: High-Frequency Tesla Coil Design
Reference. ED3

Arcs produced from a tesla coil will generate significant EM fields that can be used to pretest the payload electrical system, by placing the electrical system near the operating tesla coil.

A voltmeter can be used to accurately determine the correct location of the payload electrical system. Both positive and negative voltmeter contacts should be disconnected and at a known distance from each other. The correct distance from the HFTC is when the ratio between the voltmeter contacts and the distance between the contacts are equal to the EM field strength requirement. If possible, the voltmeter contacts both be of equal distance to the HFTC.

Power can be supplied to the HFTC either using a laboratory power supply, or a mains transformer and rectifier.

If using a laboratory power supply, it should output 10 A at 24 V_{AC}. The voltage will need to be increased using a voltage tripler, as shown in Figure A.1-2.

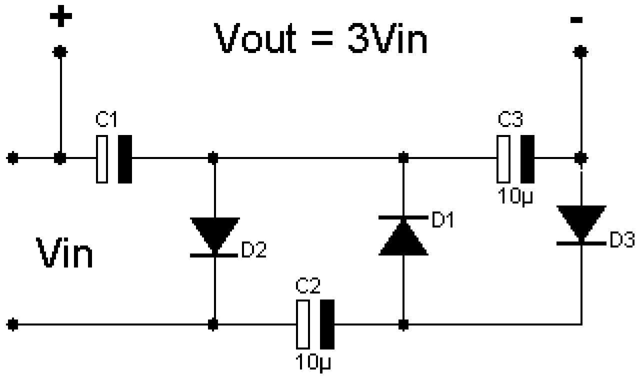

Figure A.1-2: Voltage Tripler
Reference. ED3

Using a mains transformer and rectifier allows the conversion from 50 to 100 V_{DC} that the tesla coil needs for operation. If using this method, do not use a ripple capacitor. Additionally, the transistor will require a large heat sink to radiate excess heat to allow safe operate, especially during higher frequency operation.

Appendix 2: Electronic Voltage Switch Circuit

The Electronic Voltage Switch Circuit is designed to rapidly switch between input voltages to the Payload Electronic Circuit. Human-operated switches would not be able to switch between the two voltages at the required speeds, and as such, the switching must be made electronically.

The example circuit is based around the use of two n-channel MOSFETs. When the 'Gate' pin of the MOSFET (numbered as 2) is powered 'high', the MOSFET allows current to pass from pin 1 to pin 3. This completes the circuit, powering the Payload Electrical Circuit.

The alternate voltage to the supply voltage is achieved by the addition of a high resistance resistor into the circuit. This decreases the voltage supplied to the Payload Electrical Circuit. In this example circuit, we used a linear potentiometer for ease of switching between different voltages.

There is no requirement for payload developers to use this example circuit or the attached Arduino code. You are welcome to design and program your own should you wish to.

Components:

- Microcontroller
    - It is preferable to have a 5 V Voltage output from the microcontroller maximise conduction capability of the MOSFETs.
    - The microcontroller will require an external power source. This can be done using a power supply or using a USB to micro-USB cable to a computer.
- Two N-Channel MOSFETs
    - Must have a threshold voltage lower than the microcontroller output voltage.
- Linear Potentiometer
- Voltmeter
- Your Payload Electrical Circuit
- Power Supply
    - Ensure that the power supply can supply 130% of the payload desired input voltage. For example, for a 12 V input to the circuit, the power supply should be able to supply 15.6 V.
    - Some power supplies do not have a variable voltage. In this case, it may be required to use multiple different power supplies to attain the required voltages.
- Breadboard
- Connection cables

Assembly:

1. Connect the positive rail of the Payload Electrical Circuit to the Power Supply (PS1), and the negative rail to a switch rail (SR) on the breadboard.
2. Connect the 'Drain' pin of each MOSFET to the SR.
3. Connect the 'Gate' pin of each MOSFET to separate digital output pins on the microcontroller.
4. Ensure that the ground of the microcontroller is connected to the ground of the power

supply to enable correct circuit operation.

5. For MOSFET-1, connect the ‘Source’ pin to the ground rail of the power supply.
6. For MOSFET-2, connect the ‘Source’ pin to the middle pin of the potentiometer.
7. Connect one of the side pins of the potentiometer to the ground rail of the power supply.
8. Test using the voltmeter which rotational direction increases / decreases the resistance between the middle potentiometer pin and the ground rail of the power supply.
9. Program and upload the code to the microcontroller.

Operation:

1. Set the power supply to provide the desired voltage, V_{DD}, but keep the power supply turned off for the moment.
    a. For the testing of requirement 5.0-2, V_{DD} shall be desired input voltage to the Payload Electrical Circuit (5 V, 12 V, 24 V, or 120 V).
    b. For the testing of requirement 5.0-3, V_{DD} shall be 129.2% of the desired input voltage to the Payload Electrical Circuit.
2. Alter the resistance of the potentiometer to provide the desired test voltage to the Payload Electrical Circuit.
    a. When MOSFET-2 is switched on during the testing of requirement 5.0-3, the supplied power to the Payload Electrical Circuit shall be the desired input voltage.
3. Power the microcontroller and turn on the power supply. The code should run automatically.

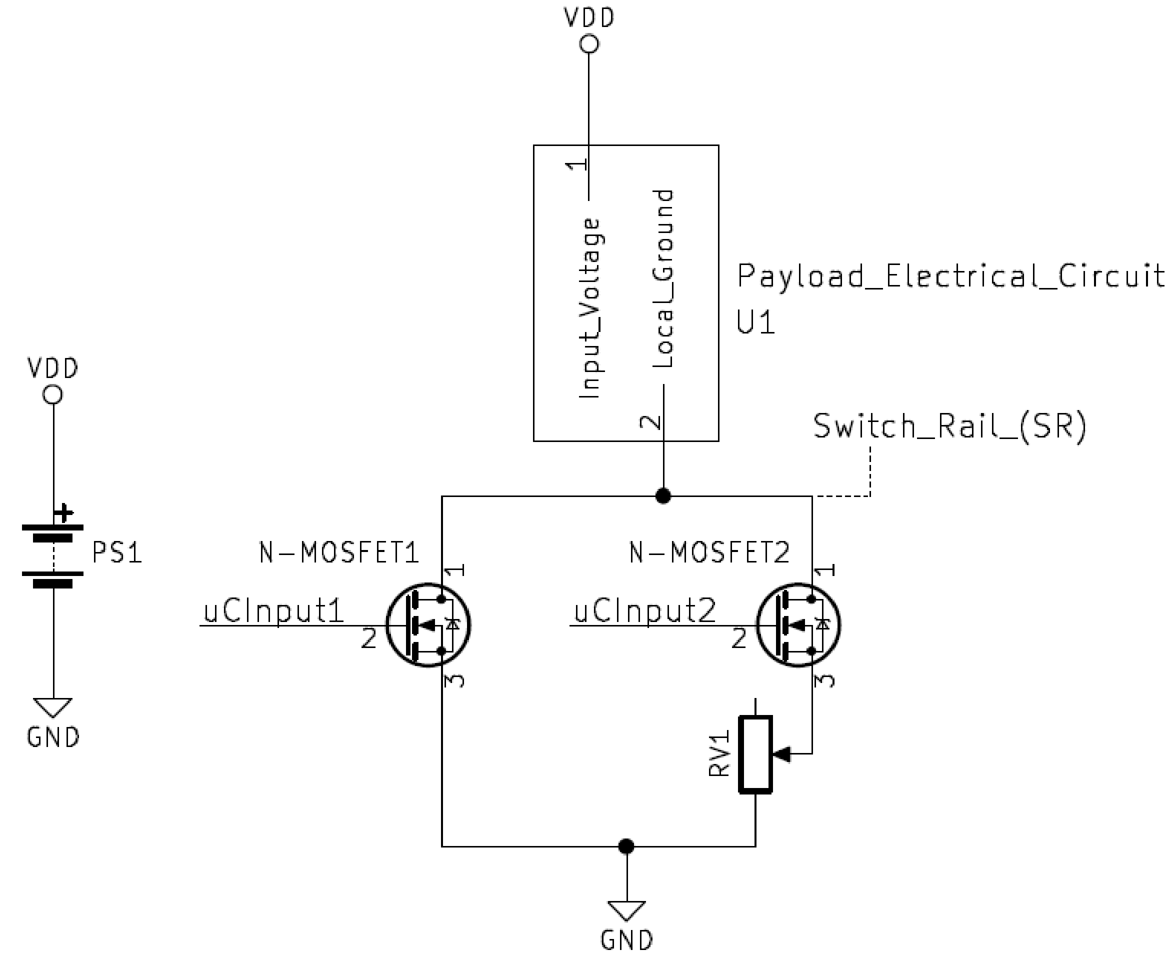

Figure A.2-1: Electronic Voltage Switch Circuit

Example Arduino code for the microcontroller is shown below. This code is based upon testing requirement 5.0-3, where the payload electrical circuit is required to withstand a overvoltage for a duration of 2 ms. This code can be adapted for your own use if desired.

Arduino Code:

```
/*
  Electrical Switch Controller
  Oliver Grenfell, Lab Engineer, Neumann Space
  9 June 2017

  Operation:
  Switches the provided voltage to the 'load circuit' between two different voltages.
  Provides the capability to rapidly switch between the two voltages, simulating on-orbit electrical
environments.
  Microcontroller outputs two high signals.
*/

// Run the setup function when the reset button is pressed or the board is powered
```

```
void setup() {
  // initialize digital pins 12 & 13 as outputs.
  pinMode(12, OUTPUT);  // In this example, pin 12 controls MOSFET-1
  pinMode(13, OUTPUT);  // In this example, pin 13 controls MOSFET-2
}

// Initialise both outputs to be LOW
void initialise() {
  digitalWrite(12,LOW);
  digitalWrite(13,LOW);
  delay(1000);              // Wait for 1 second for the power supply to be turned on
}

// Switch between the two voltages forever
// For each switch, ensure that the ex-HIGH pin is set LOW before the ex-LOW pin is set high
void loop() {
  // Provide the steady-state input power to the Payload Electrical Circuit by switching on MOSFET-2
  digitalWrite(12, LOW);
  digitalWrite(13, HIGH);
  delay(4000);              // Delay for 4 seconds to get a steady-state condition
  // Provide an overvoltage the Payload Electrical Circuit by switching on MOSFET-1
  digitalWrite(13, LOW);
  digitalWrite(12, HIGH);
  delay(2);                 // Delay for 2 ms, as per requirement 5.0-3
}
```