

ROCKSAT →←

# User Guide

**Pushing The RockSat  
Concept to New EXtremes**



Wallops Flight Facility (WFF)  
Wallop Island, Virginia

## 0.0 APPROVALS AND TRACKING

### 0.1. Signatures

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DRAFT



## Table of Contents

<b>APPROVALS AND TRACKING</b>	<b>2</b>
Signatures	2
Revisions	3
<b>INTRODUCTION</b>	<b>6</b>
RockSat Program	6
Participant Eligibility and Responsibility	6
Purpose	7
Getting Involved (Intent to Fly Forms)	8
Experiment Space	8
Refund Policy	9
Points of Contact	10
Applicable Documents and Links	10
<b>ROCKSAT-X OVERVIEW</b>	<b>10</b>
<b>ROCKET DESCRIPTION AND CAPABILITIES</b>	<b>12</b>
RockSat-X General Capabilities Description	12
Rocket Key Performance Parameters	13
Flight Environment Conditions	14
G Loading	14
Flight Environment	14
Disclaimer	15
<b>ORGANIZATIONAL RESPONSIBILITIES</b>	<b>15</b>
Customer and WFF Responsibilities	15
Ground Control	16
<b>Experiment DESIGN AND INTERFACE REQUIREMENTS</b>	<b>16</b>
Constraints On Experiment Types	16
Mechanical	16
Physical Envelope	16
Mechanical Interface	17
Mass Properties	20
Center of Gravity	20
G Loading	20
Material Selection	21

Heat of Reentry	21
Power and Telemetry	22
Power and Telemetry (PT) Interface	22
PT Interface Design	22
Electrical Interface	23
Power Provided and Activation	25
Independent Power Sources	26
Telemetry Provided	27
Telemetry Interface	27
Asynchronous Framing and Baud Rates	28
Space Environment	29
High Voltage	29
Electrical Harnessing and Staking	29
Radio Frequency Transmissions	30
Summary of Key Constraints	30
<b>EXPERIMENT HARDWARE INTEGRATION</b>	<b>31</b>
<b>EXPERIMENT TEST REQUIREMENTS</b>	<b>31</b>
Structural Testing	31
Vacuum Testing	31
Day in the Life Testing (DITL)	31
Wallops Flight Facility Testing	32
June Integration and Environmental Testing	32
August Integration and Launch	33
<b>SELECTION PROCESS</b>	<b>33</b>
<b>SCHEDULE</b>	<b>35</b>
<b>10.0 APPENDIX A: Mechanical Drawings/Interfaces</b>	<b>36</b>
<b>APPENDIX B: Environmental Testing Characteristics</b>	<b>38</b>
<b>APPENDIX C: Supplemental Telemetry Specifics</b>	<b>39</b>
<b>APPENDIX D: Summary of June Testing Operations</b>	<b>40</b>

## **1.0 INTRODUCTION**

### **1.1. RockSat Program**

RockSat-X is a follow-up program to RockSat-C and the RockOn Workshop where customers design their own sounding rocket experiment and compete for a spot on the launch vehicle. The RockOn Workshop teaches participants how to build a sounding rocket experiment in three days. The goal is that participants will take what they learn during the workshop and return the next year with an original experiment to fly with the RockSat-C or RockSat-X programs. Participation in the RockSat program starts with the submission and acceptance of the RockSat Intent to Fly Form (IFF) which is due in September.

The RockSat-X program is designed to provide students with access to low-cost flight opportunities and further develop their engineering skills. The RockSat-X flight is made possible through significant cost sharing provided by Wallops Flight Facility (WFF) and the RockSat Program Fee paid by RockSat-X teams.

The RockSat-X program uses experiment decks that allow for the standardized integration of the customer's experiment and the rocket. This simplifies final integration and allows for more focus on the design of the experiment. The organizers of the RockSat-X program guide the RockSat-X customers through the design process in the fall with multiple design reviews and test reviews in the spring. Since space on the rocket is limited, only the most developed and capable projects as well those who perform well during the design review are selected for flight in November following the Preliminary Design Review (PDR). Following selection and manifesting, the projects complete their Critical Design Review (CDR) in December and continue to have subsystem and system testing reviews with the RockSat-X organizers through May. Experiments are shipped to WFF in May. Teams travel to WFF in Virginia in June to support integration and testing of their experiment. All experiments remain integrated to the rocket until launch. If an experiment develops a mechanical failure during WFF testing, de-integration and repair may be permitted if WFF and RockSat organizers allow. The program culminates in August when the teams once again travel to WFF for inspection, final testing, launch, and recovery.

### **1.2. Participant Eligibility and Responsibility**

The intent of the RockSat-X program is to provide hands-on experiences to students and faculty advisors to better equip them for supporting the future technical workforce needs of the United States and/or helping those students and faculty advisors become principal investigators on future NASA science

missions. Therefore, RockSat-X is limited to U.S. educational institutions; only experiments from U.S. educational institutions are eligible to participate in the RockSat-X program. For the purpose of the RockSat-X, 'educational institution' is defined broadly and includes, but is not limited to, the following: universities, colleges, technical schools, public and private high school, middle school and grade school, science museums, etc. Organizations, which are not included in the above listing, are encouraged to contact Wallops at [rocksatprogram@gmail.com](mailto:rocksatprogram@gmail.com) to clarify their eligibility in the program. In addition, U.S. entities (e.g. industry, research institutions, etc.) that fall outside of the eligibility conditions listed above, but who are interested in participating in the program, are encouraged to team with an eligible U.S. educational institution. Teaming between educational institutions and industry or other interests is allowed and encouraged. However the experiment shall be a student project with students doing the design, build, test, documentation, operation, and data analysis. Participation in the RockSat-X program includes teleconferences with WFF employees and contractors as well as all integration, testing, launch, and recovery operations that take place at WFF. Normal access to WFF facilities and personnel is limited to U.S. persons only. Therefore, individuals participating in the RockSat-X program must be a U.S. Person. U.S. federal law defines a U.S. Person as: a citizen of the United States, an alien lawfully admitted for permanent residence, or a corporation that is incorporated in the U.S. (22 CFR 120.14, 15 – and by 8 U.S.C. 1101(a)(20)). Persons in the U.S. on a work visa are not considered U.S. persons.

Additionally, participants in the RockSat-X program shall comply with export regulations in regard to disclosures of technical data. All participants warrant and represent that they will limit disclosure of any technical data contained in, made available, or generated in the performance of their participation in the RockSat-X program in accordance with export restrictions imposed by the U.S. Export Administration Regulations, 15 C.F.R. Parts 768 et seq. and the International Traffic in Arms Regulation, 22 C.F. R. Part 120 et seq. This applies to all parties involved (such as an industrial partner to an educational institution). As a baseline, the RockSat-X program does not permit ITAR and/or Export Controlled hardware/experiments on the program. Teams may ask WFF for exception to this baseline during the CoDR and PDR design reviews.

### **1.3. Purpose**

The purpose of this document is to identify the interfaces, requirements, and logistics pertaining to the WFF RockSat-X program. This document also establishes the guidelines and requirements for qualifying an experiment for selection to be flown, along with the review and integration schedule. Experiments shall be student based with faculty and/or industry involvement

only. RockSat-X is not available to experiments that are profit related endeavors and/or solely industry research and development. Students shall be actively engaged and involved.

#### **1.4. Getting Involved (Intent to Fly Forms)**

Interested institutions/teams shall submit an Intent to Fly Form (IFF) in September by the due date listed on the IFF in order to be considered for participation in the RockSat-X program. IFF can be found here. <https://tinyurl.com/rocksat-24-iff> Although required, submission of the IFF does not mean that your team has been selected for flight on the RockSat 2023 program. Due to the limited experiment space on the RockSat launch vehicles, a down-selection process will be utilized after the successful completion of the RockSat Conceptual (CoDR) and Preliminary (PDR) design reviews.

#### **1.5. Experiment Space**

There are five full experiment spaces on the RockSat-X launch vehicle. These full spaces are allocated power, volume, weight, and power as described in the sections below. Teams can elect to use half of a full experiment space however the power and telemetry connections along with the weight and volume limits are reduced to approximately half of the full space limits. Specific allocations will be discussed with teams after the flight manifest is finalized after PDR. Half experiment space customers cannot use more than half the battery capacity. Telemetry lines must also be shared, but the Program Manager will do their best to partner shared customers so that both experiments can utilize all the telemetry lines that have been requested. Note that it is not guaranteed all the customer's requested telemetry lines will be granted. In the event that a subset of customers would like to redistribute allotments, all customers of the subset must contact WFF, and changes will only be made with written approval of all parties involved and WFF. The five full experiment spaces cannot be split into any size smaller than half.

#### **1.6. Program Fee**

The RockSat Program Fee pays for the RockSat Program. It covers the costs to administer, run, and manage the RockSat program which begins with reviewing the IFF and ends with the review of each team's final report. The Program Fees are used as teams progress through the program and are therefore non-refundable. See additional details below. The Program Fee associated with RockSat-X is contingent upon the amount of the experiment space being utilized. Teams will receive (1) RockSat-X experiment deck with power and telemetry interface connectors after their final of 2 payments has been made. Additionally, teams will receive 8 program t-shirts during the August launch trip. Travel costs to and from Wallops Flight Facility, lodging, meals, or other expenses incurred while supporting these trips are the responsibility of the teams.



The Program Fee for a full experiment space is \$27,000. The Program Fee for a half experiment space is \$15,000. The Program Fee is to be paid in 2 payments based on the schedule below. Payments shall be made by check, Purchase Order, or credit card. Details on where to send payment will be provided on the invoice. Payment is NET 30.

<b>Invoice Date</b>	<b>Due Date</b>	<b>Payment Amount</b>	<b>Notes</b>
09-20-2023	10-20-2023	Full = \$9,000 Half = \$5,000	
12-08-2023	01-08/2024	Full = \$9,000 Half = \$5,000	
02-27-2024	03-27-2024	Full = \$9,000 Half = \$5,000	Decks and connectors sent after this payment
	<b>Totals</b>	<b>Full = \$27,000</b> <b>Half = \$15,000</b>	

### 1.7. Refund Policy

The Program Fee is only refundable if a team is down-selected on November 28, 2023. Teams not selected for flight during this process will receive a full refund of program fees paid minus a small processing fee. Teams selected for flight will be responsible for completing their remaining two payments by the due dates. Additionally, launching rockets has inherent design issues, schedule risks, technical unknowns, and weather factors. While launch and recovery of the RockSat rockets is the intention of this program, it is not guaranteed. If in the event that the rocket is unable to launch due to any factor listed above or for some other reason beyond Wallops Flight Facility control (this has never happened), experiments will be returned to teams and there will not be a refund of the program fee. If the rocket is not recovered after launch (this has happened once) Wallops will not compensate teams for the lost experiment hardware, travel, etc and there will not be a refund of the program fee. If Wallops determines your team is non-compliant with the RockSat User Guide at any time (if possible, teams may be given time to become compliant) and/or if your experiment fails a pre-launch delivery and/or testing benchmark, you will be removed from the flight manifest. If integration to the rocket has already occurred, your experiment may still fly

as an inactive experiment or it may be returned to you. In both cases, you will not receive a refund of the program fee.

### 1.8. Points of Contact

At this time, RockSat Points of Contact (POC) are still being determined. For now please direct all inquiries to [rocksatprogram@gmail.com](mailto:rocksatprogram@gmail.com)

### 1.9. Applicable Documents and Links

- Sounding Rocket Program Office - Student Flight:  
<https://sites.wff.nasa.gov/code810/student.html>
- NASA Wallops Flight Facility:  
<http://www.nasa.gov/centers/wallops/home/index.html>
- NASA Sounding Rockets User Handbook  
<http://sites.wff.nasa.gov/code810/files/SRHB.pdf>

## 2.0 ROCKSAT-X OVERVIEW

The RockSat-X experiment deck is a modular system based around experiment decks designed for suborbital flights with the WFF RockSat-X experiment section called the Carrier of Rocket Learning Laboratories (CarRoLL). Figure 2-1a and Figure 2-1b (below) show the CarRoLL structure and plate layout, respectively. Figure 2-2 and further details on the RockSat-X mechanical interface can be found in Appendix A and auxiliary reference document: RS-X Mechanical Interface.

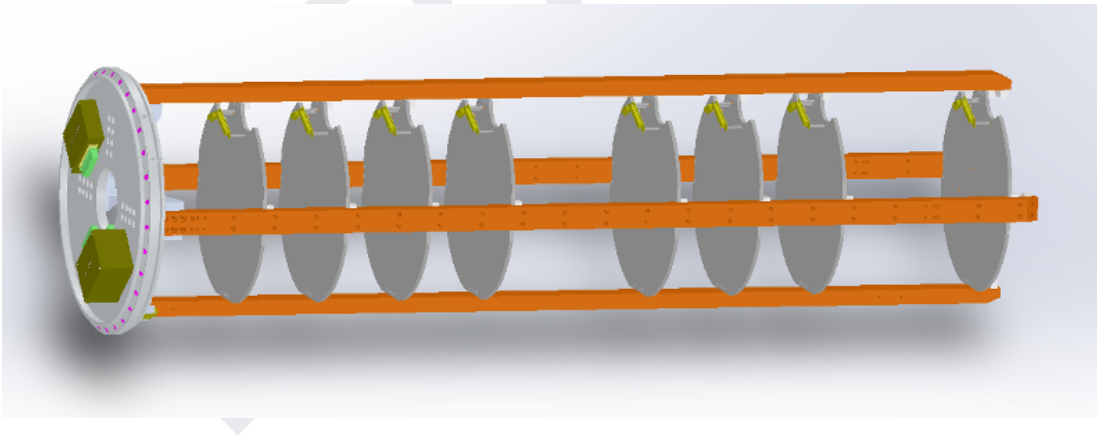
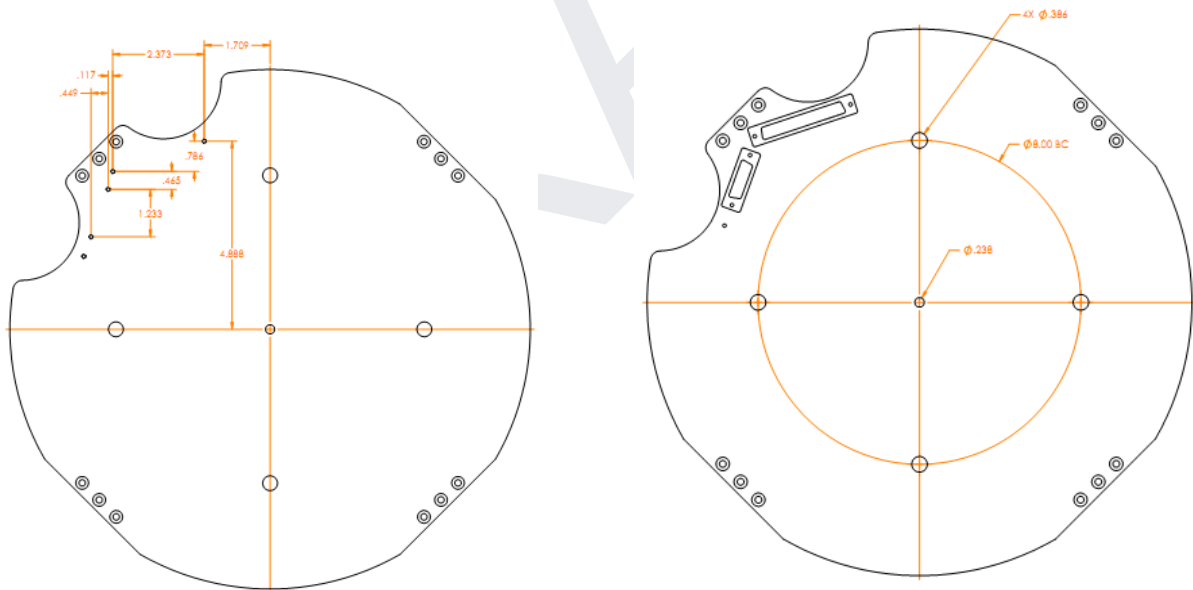


Figure 2-1a: RockSat-X Deck in Longeron Structure (Conceptual)



**Figure 2-1b: RockSat-X Deck in Longeron Structure (Actual)**



**Figure 2-2: RockSat-X Deck Layout**

The objective of the RockSat-X experiment deck is to give customers a design envelope to build around that will allow easy integration to any WFF rocket

using the CarRoLL experiment section design. This standardized approach provides customers low cost access to space.

RockSat-X will have an ejectable skin (the skirt) that will fully expose experiments to the space environment at apogee. Additionally, the rocket's Attitude Control System (ACS) will de-spin the experiment section twice during the flight from a rate of 5 to 7 Hz at launch to a rate of ~ 0.5 Hz shortly after second stage burnout and near 0 Hz at apogee to allow for a greater range of experiments. ACS can also provide experimenters with active pointing toward a specific target. This is contingent upon all the other experimenter's pointing requests. Wallops will also provide power and telemetry to each experiment deck. By providing these resources, experimenters can spend more time on experiment design and less on power and data storage systems.

### 3.0 ROCKET DESCRIPTION AND CAPABILITIES

This section covers key interfacing and launch vehicle capabilities that customers should be aware of for the design of their experiment.

#### 3.1. RockSat-X General Capabilities Description

Each RockSat-X deck will be attached to the CarRoLL structure in a stacked configuration. This structure consists of longerons that span the entire length of the experiment section (Figure 2-1a&b and Figure 3-1). With 5 RockSat full experiment spaces (decks), the launch vehicle (Terrier-Improved Orion or Terrier-Improved Malamute) is estimated to reach an altitude of approximately 150 – 170 km, or approximately 100 miles.

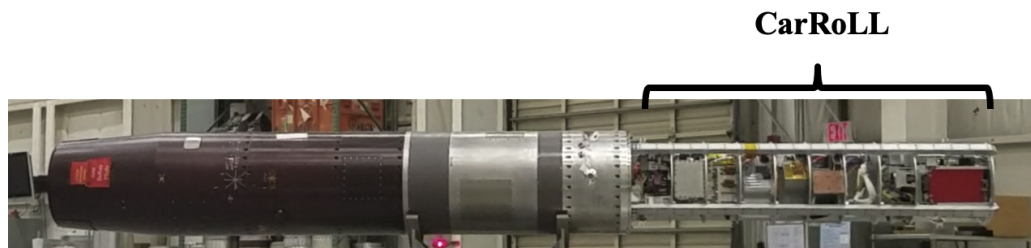


Figure 3-1: Payload Stack with CarRoLL Section

There will be a total of five full RockSat-X experiment spaces available for purchase. The full spaces can be split into half for a total of up to 10 experiments. Each of the five full experiment spaces shall be provided with

four timer controlled (4) power lines (TE) and associated ground wires that can be activated during flight at the experimenter's request. One (1) of these power connections will be redundant. Each full experiment space will also be provided with two (2) sets of power lines that can be activated prior to launch through the Ground Support Equipment (GSE) and as such have been dubbed GSE lines. It is highly recommended that main experiment activation occur through the GSE line. It is also required that any deployment actions not be triggered by GSE lines but by TE lines. Each full experiment section will have a 1 Amp Hour (Ah) battery available for the mission. Current draw on this battery is limited. Please see Figure 5-8. Customers will connect to power via the power and telemetry interface described further in Section 5.3.1. Please note that half experiment space customers will need to share these four TE and two GSE power lines as well as the 1 Ah battery with another half experiment space customer. The WFF RockSat-X program manager will coordinate these sharing arrangements.

Each full experiment space shall be provided with telemetry resources with access to ten (10) 0 – 5 Volts, 10-bit Analog to Digital (A/D) lines. Analog signals from 0 – 5 Volts will be digitized and streamed back to the ground station in real-time, which eliminates the need for on-board data storage. Additionally, each section will receive one (1) asynchronous line (SERIAL) at a 19,200 baud rate and a 16-bit parallel line (PARA). Customers shall output data via the power and telemetry interface described further in Section 5.3.1. More details on telemetry can be found in Section 5.3.2.3. Again, half space experiment sections will have to share these resources with another half space experimenter. The WFF RockSat-X program manager will coordinate these sharing arrangements.

The RockSat-X deck is circular in shape with a usable experiment space (design envelope) having a diameter of approximately 12 inches with a keep out area that is defined in detail in Section 5.2.2. Each full experiment space deck will have 10.75 inches of height (5.13 inches for half sections). Each full experiment space deck is allotted  $30\pm 1$  lbs ( $15\pm 0.5$  for half sections) including the deck and power and telemetry interface connectors. All experiments shall weigh in at  $30\pm 1$  lbs ( $15\pm 0.5$  for half sections). Experiments lighter than this shall provide their own ballast weights that are securely fastened to the deck to meet this weight requirement. Any violation of weight or volume requirements will result in the customer being removed from the flight.

### **3.2. Rocket Key Performance Parameters**

Below are the typical key performance parameters for the RockSat-X rocket. They are subject to change without notice.

**Table 3-1: Key Performance Parameters**

Key Performance Parameter	Value	Notes
Altitude (km)	~160 km	1,3,4
Spin Rate (Hz) at Burn-Out	~4.8 Hz at Malamute burn-out ~0 Hz at apogee	1,2,3,4
Maximum Ascent G-Load	25 G (Sustained) 50 G+ Impulses Possible	1,2
Rocket Sequence (Burn Timing)	5.2 second Terrier burn 12.2 second coast 11.7 second Malamute burn	1,3,4
Experiments Power Off	332 seconds	1,3,4
Chute Deploy (seconds)	460 seconds	1,3
Splash Down (seconds)	882 seconds	1,3

**Notes:**

1. All parameters are subject to change, but all customers will be notified of any changes.
2. Data from Rosanova 41.092 RDM (2011)
3. Data from Rosanova 46.004 MRR (2012)
4. Data from Koehler 46.012 MRR (2015)

**3.3. Flight Environment Conditions**

**3.3.1. G Loading**

During ascent and descent experiments will experience both sustained and vibrational accelerations. Typical quasi-static G loads can reach 25 Gs. Experiments shall be designed to withstand at least 25 Gs of quasi-static loading in all three axes with possible impulses of approximately 50 Gs in the Z (longitudinal) axis. Three axes vibration testing will be conducted by WFF before flight. Vibration/environmental testing will be completed approximately 1 month prior to launch. The specifics of this test can be found in Appendix B. Key structural parts of any RockSat-X experiment shall not be made of 3D printed materials.

**3.3.2. Flight Environment**

After second stage burn-out, the skin and nose cone will be ejected exposing all experiments to the vacuum of space. Experiments will be exposed to hard vacuum and varying temperature extremes. The primary mode of heat transfer at apogee will be radiation as convection becomes non-existent in the vacuum



of space. The vacuum environment will also lead to outgassing. Requirements for design to account for thermal extremes and vacuum conditions are not being imposed, but these factors should be considered in design. Outgassing becomes particularly important for optical experiments located near high outgassing materials. Outgassing properties for most materials can be found at: <http://outgassing.nasa.gov/>. Additionally, the experiment section will experience extremely high temperature heating during re-entry followed by exposure to saltwater for an extended period of time as the experiment section awaits water recovery. Pressure vessels that are low pressure are typically allowed on the flight but higher pressure vessels (greater than 25 psi) are prohibited unless explicit, written permission has been issued from Wallops Flight facility. Recovery of experiments is planned but not guaranteed. As with any flight, there are possible anomalies that can occur during the flight or recovery that can severely damage or destroy flight hardware. All selected teams should consider this and understand that space flight involves risks that WFF cannot plan for. Selected experiments assume all risks, and WFF shall not be held responsible in the event of an anomaly and/or unrecoverable experiment. Program Fee will not be refunded in the event that the rocket is not recovered. Customers should also be aware that thermal and structural loading will be substantial upon re-entry. Pending a successful recovery of the experiment section, customers should expect severe and un-repairable damage to flight hardware.

### **3.4. Disclaimer**

Recovery of experiments is planned but not guaranteed. As with any flight, there are possible anomalies that can occur during the flight or recovery that can severely damage or destroy flight hardware. All selected teams should consider this and understand that space flight involves risks that WFF cannot plan for. Selected experiments assume all risks, and WFF shall not be held responsible in the event of an anomaly and/or unrecoverable experiment. Program Fee will not be refunded in the event that the rocket is not recovered. Customers should also be aware that thermal and structural loading will be substantial upon re-entry. Pending a successful recovery of the experiment section, customers should expect severe and un-repairable damage to flight hardware.

## **4.0 ORGANIZATIONAL RESPONSIBILITIES**

### **4.1. Customer and WFF Responsibilities**

Component and functional design responsibilities are listed below.

#### RockSat-X Experiment Customer

- Experiment and support system.

Support system includes:

- Thermal system (if desired)
- On-site tools and hardware for environmental testing and final integration
- Sealed enclosure to protect hardware from water damage during splashdown and recovery
- All environmental sensors (if desired)
- Power regulation from nominal  $28V \pm 4V$  to any required experiment voltages
- Mechanical interface to RockSat-X deck
- Safety features for experiment-related hazards
- Power harness from experiment to power interface (minus connectors)
- Telemetry harness from experiment to telemetry interface (minus connectors)
- All required ground side data analysis equipment (computers not provided)

#### WFF

- Terrier-Improved Malemute rocket, range safety, launch support, recovery and tracking
- One (1) RockSat-X deck with power and telemetry interface with associated power and telemetry harness connectors and stand-offs
- Environmental testing and integration onto full rocket
- GSE testing (experiment verification) during June testing and August final integration
- Mission management support

#### **4.2. Ground Control**

After the RockSat-X decks have been integrated onto the RockSat-X experiment section of the rocket prior to launch, the customer will have very limited access to the experiments. WFF will handle all activities pertaining to final experiment preparation, launch, and recovery until the rocket has been recovered and the experiment is de-integrated.

### **5.0 EXPERIMENT DESIGN & INTERFACE REQUIREMENTS**

#### **5.1. Experiment Physical Envelope, Mass, and Center of Gravity Requirements**

The following subsections outline the physical requirements and constraints of the RockSat-X experiment deck.

##### **5.1.1. Constraints On Experiment Types**

The purpose or mission of an experiment is open to the customer. The customer shall design an experiment that by all standards (engineering and



layperson) would be considered safe and practical. Experiments shall not put other experiments, the WFF payload as a whole, WFF employees, or the launch vehicle at risk. All experiments shall be formally selected before the customer can become a contender for flight. This formal selection will come after acceptance of the IFF by WFF in September. This formal selection does not mean the experiment has been selected for flight. That will come when the official manifest is made in November. Experiments with stored energy devices, deployments, or separation systems will be subject to additional review and require hazardous procedure documentation approved and verified by WFF Management prior to integration and testing at WFF.

## **5.2. Mechanical**

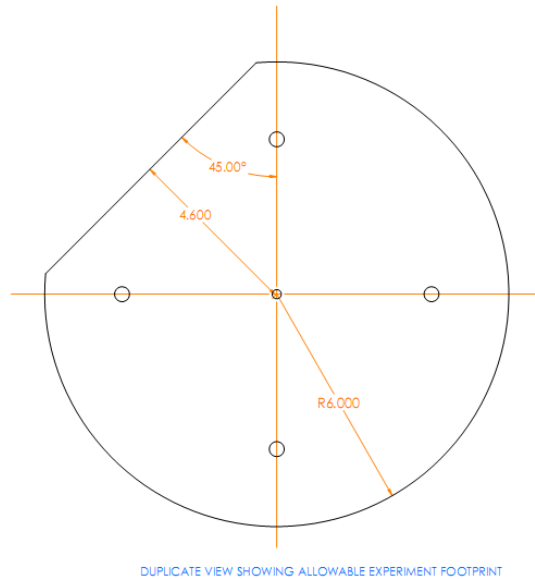
### **5.2.1. Physical Envelope**

RockSat-X is based around a deck rather than a canister like on RockSat-C. The customer is responsible for mounting their experiment to the plate in a manner that will ensure its survival during flight. Finite Element Analysis (FEA) is highly recommended but not required. All experiments will be environmentally tested at Wallops prior to flight, which is the ultimate test of structural integrity.

Customer experiments must be designed for integration to fit within the 12-inch diameter by 10.75-inch-high envelope (minus keep out area) already defined. Experiments can deploy booms and other mechanical devices once the skin has been ejected. Deployable or ejectable experiments introduce a new level of complexity and are subject to the more stringent design scrutiny from WFF. Release mechanisms such as compressed springs or Frangibolts must be approved prior to arrival at WFF and may require additional Hazardous Procedures to be approved by Wallops Ground Safety. These procedures must be submitted and approved by ISTR. All deployments require activation via a Timer Event (TE) line, and must deploy at a speed *less than* 1 inch per second.

### **5.2.2. Mechanical Interface**

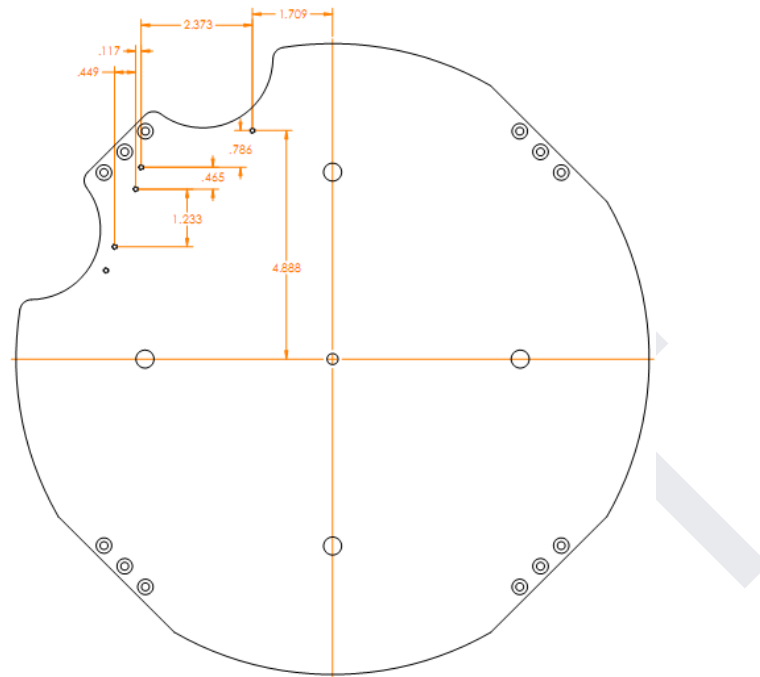
All experiments shall be designed to mount to the RockSat-X deck. The deck design envelope is 12 inches in diameter.



**Figure 5-1: RockSat-X Experiment Design Space**

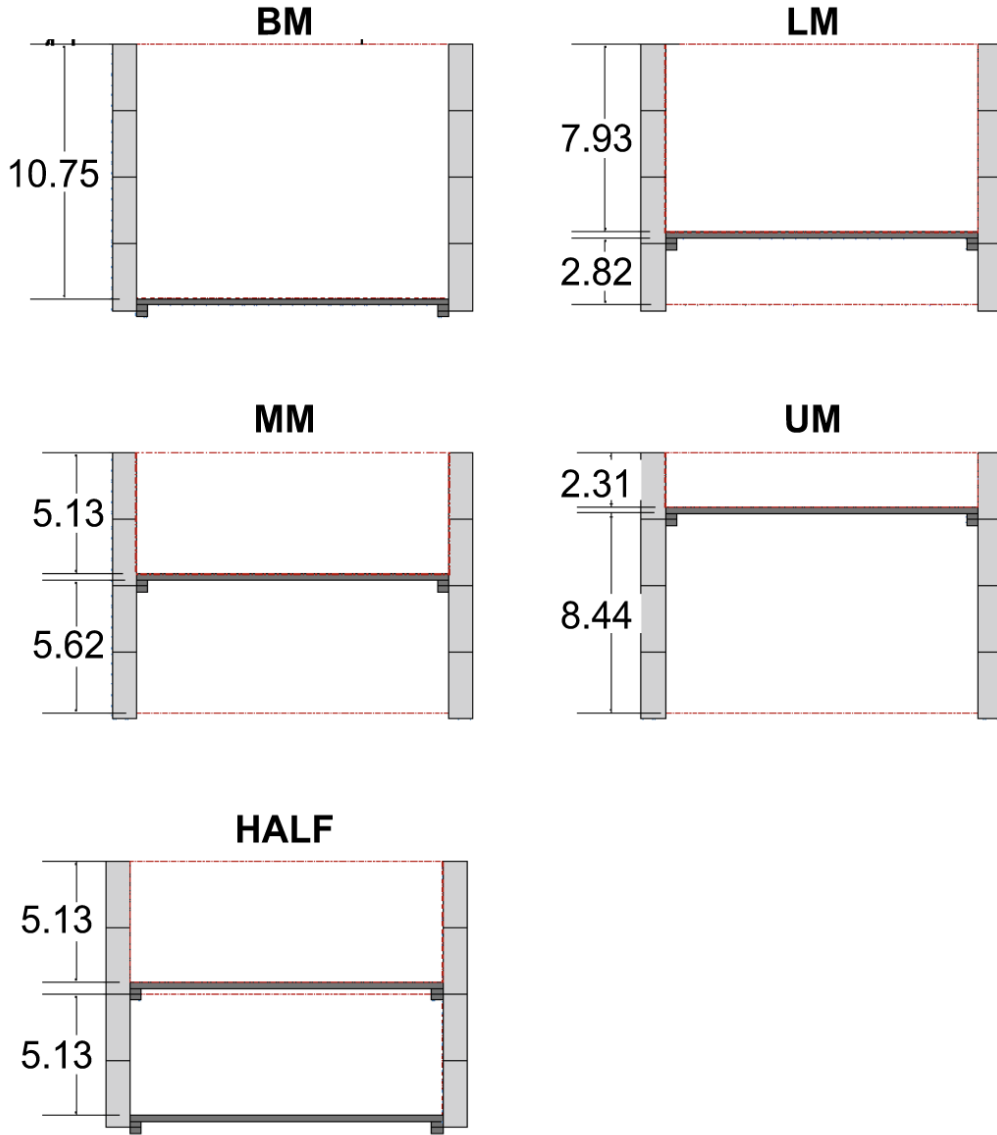
Figure 5-1 shows the footprint of the space that customers can utilize for the experiment. The diameter is 12 inches, and the excluded portion of the disk is a keep out area for the power and telemetry connectors and wire-ways to be discussed below. Any sufficient need to go into the keep out area shall be approved by WFF before teams can use this space. Customers may add holes to the plate but significant changes (more than 10% of material removed) will need to be approved by WFF. Please note that the telemetry connector impedes slightly on the keep-out zone when mounted.

The power and telemetry connectors will be provided by WFF. In addition to providing the connectors, each experiment space will be provided with a set of stand-offs to mount the connectors to the deck. For design purposes, relevant dimensions on the location of the holes for connector mounting are summarized in Figure 5-2. Additionally, a SolidWorks model of the flight deck is available.



**Figure 5-2: PT Connector Hole Dimensions**

Customers have four options for mounting their experiment deck to the CarRoLL experiment section if using a full experiment space. These options are a bottom, bottom mid, middle, and upper mid mounting. The bottom mounting (BM) deck provides 10.75 inches of height, where the mid mount (MM) provides 5.62 inches below the deck and 5.13 inches above. Lower mid mount (LM) provides 2.82 inches below the deck and 7.93 inches above. The upper mid mount (UM) provides 8.44 inches below the deck and 2.31 inches above. In addition, half experiment space decks (HALF) may use up to 5.13 inches above their deck unless otherwise approved by WFF. A pictorial representation of these options are presented below in Figure 5-3. Half experiment space customers shall use the bottom mount location. Other locations will be considered on a case by case basis but shall be presented no later than the PDR. All experiment decks shall countersink any fasteners on the underside of their decks. Nothing shall protrude from bottom of these decks to avoid interference issues with experiment decks that may be above or below these decks.



**Figure 5-3: Deck Mounting Options**

The mounting blocks between the experiment deck and the longerons shall be mounted aft of the deck, regardless of which way the experiment may be facing. This should be taken into consideration when designing and building the experiment. A visual representation of this is laid out in Figure 5-4, in which the nose of the rocket is to the left and the aft/motor mount is to the right.

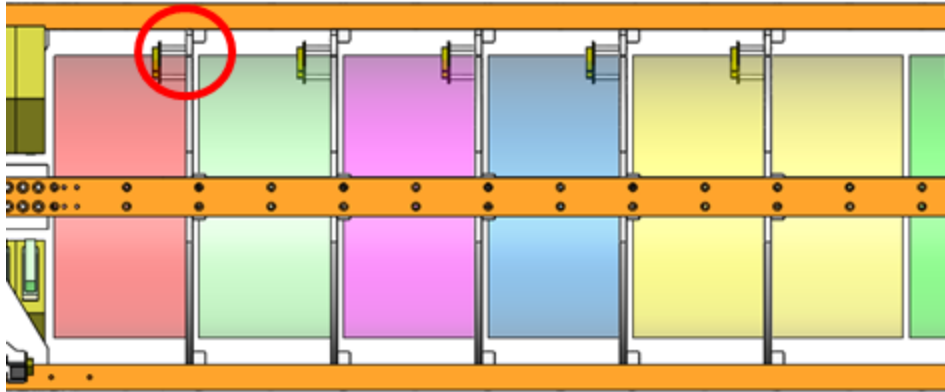


Figure 5-4: Mounting blocks aft of deck

### 5.2.3. Mass Properties

Each RockSat-X experiment (including deck and Power and Telemetry interface) shall be  $30.0 \pm 1.0$  lbf (13.61 kg). Fully assembled experiments will be weighed prior to Wallops integration. Experiments not conforming to the weight constraints will be removed from the flight. Each RockSat-X shared experiment (including deck and Power and Telemetry interface) shall be  $15.0 \pm 0.5$  lbf (6.8 kg). All experiments shall weigh in at  $30 \pm 1$  lbs ( $15 \pm 0.5$  for half sections). Experiments lighter than this shall provide their own ballast weights that are securely fastened to the deck to meet this weight requirement. Any violation of weight or volume requirements will result in the customer being removed from the flight.

### 5.2.4. Center of Gravity

All experiments shall be designed to have a center of gravity (CG) that lies within a 1 inch square in the plane of the RockSat-X deck. The center of mass in the longitudinal direction is less important but shall be accounted for in design reviews. To ensure stable flight, WFF may require a moment of inertia (MOI) test prior launch. This test will confirm that the CG of the experiment falls within the said requirement. Experiments that do not meet WFF's CG requirements may be removed from the flight. WFF understands that this test at the experimenter level may be difficult to perform and will accept analytical models showing compliance to this requirement.

### 5.2.5. G Loading

Each experiment will experience extreme and varying G-loads during the course of flight. It is not atypical to see up to 25 Gs in the positive Z (longitudinal) direction during ascent and experience about  $\pm 10$  Gs in the X and Y (lateral) axes. Experiments shall be designed to withstand at least 25 Gs of quasi-static loading in all three axes with possible impulses of

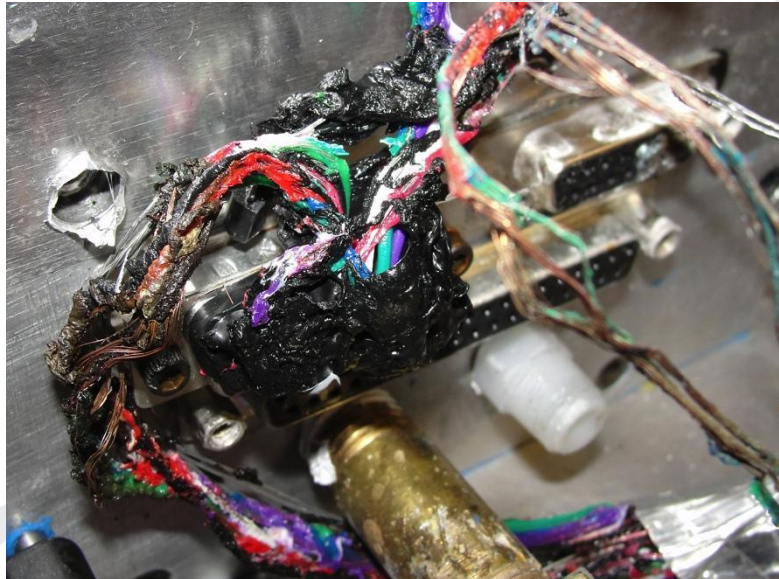
approximately 50 Gs in the Z (longitudinal) axis. In the event of a parachute failure, there will be more extreme loading in all three axes.

#### 5.2.6. Material Selection

When designing the structure for the experiment, materials with high resistance to stress corrosion cracking (SCC) are recommended. Materials that have worked well in the past have been aluminum (6061) and steel. Plastics or other petroleum-based materials shall be used sparingly. PLA/3D printed parts should not be used for key structural components.

#### 5.2.7. Heat of Reentry

Upon reentry, the vehicle (including the experiment section) will be subject to extreme thermal loading. The exact, maximum temperature is not known but it is speculated that experiments experience temperatures of at least 500°F.



**Figure 5-4: Thermal Reentry Damage from 2011**

Figure 5-4 shows thermal reentry damage experienced on the 2011 launch. The item pictured is a standard d-subminiature connector with standard PVC coated copper wire. The heat of reentry melted both the connector and the wire's insulation. In the far left, one will notice bare copper where the insulation has been completely stripped from the wires.

Although this damage is severe, it can be prevented. When selecting wire, use Teflon coated high temperature wire (PTFE). Experiments using this wire type saw little to no damage to their harnesses. All connectors being utilized should include a back shell filled with potting compound. If these guidelines are followed, thermal damage to critical electrical systems can be avoided. In

general, materials with melting temperatures less than 500 F should be avoided.

### **5.3. Power and Telemetry**

#### **5.3.1. Power and Telemetry (PT) Interface**

The RockSat-X program utilizes a standard interface to deliver power from the rocket to the customer. Additionally, said interface provides a standard for passing telemetry from the customer to rocket. Each experiment team shall complete the Interface Control Documents (ICDs) for both Power and Telemetry as part of their CoDR, PDR, and CDR deliverables.

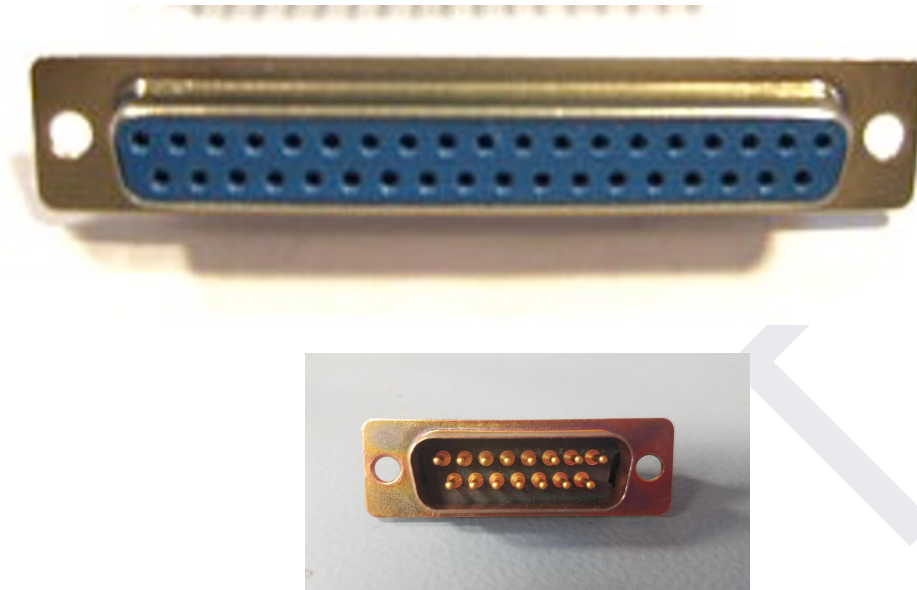
To keep this program low cost and low impact to WFF, a standard interface and number of power and telemetry lines was established for all experiment decks. The PT interface will mount to the RockSat-X experiment deck and will provide customer side and Wallops side connections. Using this standard will allow the use of an Electrical Ground Support Equipment (EGSE) suitcase. This suitcase will initially provide 28V ( $\pm 4V$ ) to power lines and allow monitoring of the telemetry lines to verify functionality prior to final integration to the rocket. The supplied voltage will increase to 32V at T-180s to simulate the switch to internal battery power.

##### **5.3.1.1. PT Interface Design**

The customer side Power and Telemetry Interface consists of two (2) d-sub connectors that are provided by WFF. Each experiment deck will receive one (1) thirty-seven (37) pin d-sub connector for telemetry and one (1) fifteen (15) pin d-sub for power. These connectors and associated mounting hardware (stand-offs) will be mailed to final down selected customers after the team's 3rd payment has been received.

Figure 5-5 shows a representative thirty-seven (37) female connector and fifteen (15) pin male connector that will be mailed.





**Figure 5-5: Telemetry (Top) and Power (Bottom) Connectors**

*Note that the pin numbers are engraved on the backside of the provided Cannon connector.*

Once the appropriate connections have been made, it is the customer's responsibility to mount the d-sub connectors to the plate with the associated mounting hardware. The mounting hardware should be securely fastened, but not over torqued to avoid damage to the connectors, standoffs, or deck. The exact location of these connectors is described in Section 5.2.2. The pin-outs for both connectors are located in Sections 5.3.2 and 5.3.1.

### 5.3.2. Electrical Interface

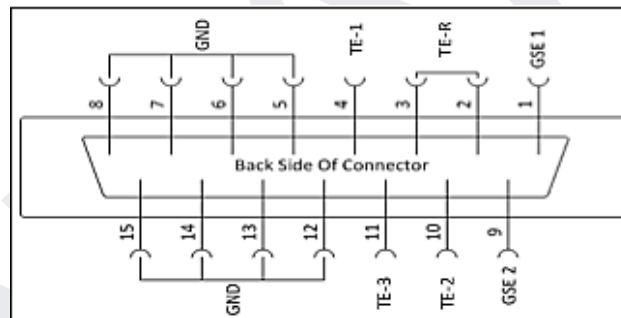
The power interface for each experiment deck shall consist of a single fifteen (15) pin Cannon connector (Figure 5-5). Customers will connect all power and ground lines to the pins on the back side, and Wallops will mate directly with an opposite gender connector on the front side. This connector and associated mounting hardware will be provided by WFF after final down selections.

Each full experiment space shall receive the above said four (4) timer controlled power lines. Additionally, each full experiment space receives two (2) GSE activated power lines. The pin-out convention is given below in Table 5-1. Also shown in Figure 5-6.



**Table 5-1: Power Interface Definition**

Pin	Function
1	+28 Volts (GSE 1)
2	Timer Event R1 (TE-RA)
3	Timer Event R2 (TE-RB)
4	Timer Event 1 (TE-1)
5	GND
6	GND
7	GND
8	GND
9	+28 Volts (GSE 2)
10	Timer Event 2 (TE-2)
11	Timer Event 3 (TE-3)
12	GND
13	GND
14	GND
15	GND



**Figure 5-6: Power Connector Pinout**

Pins 1 and 9 are GSE 1 and 2, respectively. These lines will become active at the customer specified T-X seconds prior to launch. T-X shall be less than 600 seconds but more than 180 seconds to prevent complications with the switch from external power to internal battery power. Pins 5-8 and 12-15 are experiment and Wallops ground. Customers can tie their experiment ground to all or any combination of these pins. Customers who are half experiment spaces will be assigned GSE and TE pins based on their experiment needs to avoid overlap of use by other half experiment space customers by WFF.

Pins 2 and 3 will be activated simultaneously for a customer specified activation time to provide redundancy. These lines will become active at the customer specified T+X seconds into launch. Pins 4, 10, and 11 are the non-redundant (TE) timer controlled power lines that will activate at independent times specified by the customer. These times shall occur after launch, as they are controlled by the launch timer.

### 5.3.2.1. Power Provided and Activation

The timed event lines (pins 2-4 and 10-11) can be activated at any time after the launch (T+X seconds) of the vehicle. The on-board timer controls the activation of these lines. These lines are characterized by three (3) states: on, dwell, and off. At a customer specified time ( $t_{on}$ ) after launch, the line will switch from off (no power) to on for a customer specified dwell time,  $t_{dwell}$ . After  $t_{dwell}$ , the line will switch from on to off and will remain in this state for the remainder of the mission until  $t_{splash}$ . Figure 5-7 shows the timing diagram for the four (4) timer controlled power lines. The green times indicate those specified by the customer. The  $t_{dwell}$  cannot exceed the experiment power off time, which typically is before the predicted maximum reentry heating of the flight. For 2012, this time was T+346 seconds. For 2013, this time was T+337 seconds.

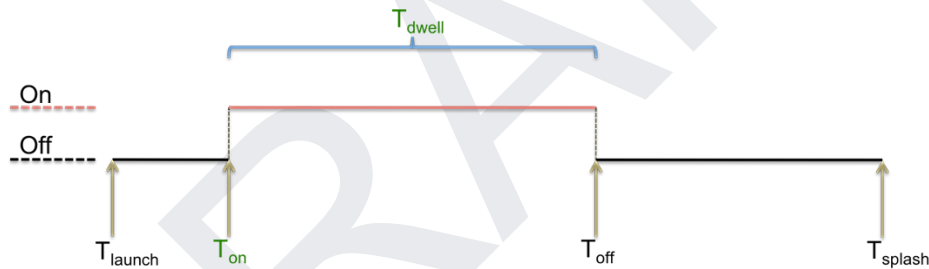


Figure 5-7: Timer Timing Diagram

Of the four power lines controlled by the timer, one (1) will be redundant. This line will have two dedicated timer events (occurring at the same time) and two independent solenoids for two levels of redundancy.

The fifth and sixth power lines (28V) are controlled by Wallops Ground Support Equipment (GSE), and can be activated up to six hundred (600) seconds (10 minutes) prior launch or as late as one hundred eighty (180) seconds (3 minutes) prior to launch. It is recommended that primary electronics be controlled through the GSE line with peripheral sensors and subsystems being activated through the above described timer lines. All deployments shall be powered by timer events. Additionally, Wallops will transfer power from your experiment by external power supply at ~28V to the internal battery which could be as high as 34V. It is important to design power conversion stages that can handle these transient voltages.

Wallops will activate the GSE lines during environmental and other testing on the rail prior to launch, which should be taken into consideration in electrical design. This means that your system will be turned on via GSE multiple times prior to launch and you will not have access to reset any systems. The provided power lines and timing are summarized in Table 5-2.

Table 5-2: Power Lines Provided

Type	QTY	Timing
Redundant (28V)	1	Customer specified, post launch (T+)
Non-redundant (28V)	3	Customer specified, post launch (T+)
Non-redundant GSE (28V)	2	Customer specified, pre-launch (T-)

Each full experiment space will be allotted a dedicated battery with 1 Ah of capacity. Additionally, current draw on the GSE lines and timed events will be limited as summarized in Figure 5-8. These limits will be enforced through the use of polyfuse switches on Wallops' power bus and EGSE. **NOTE: While the power system is capable of handling 3.75A per TE line, the maximum total current draw for any experiment space is limited to the 3.75A.**

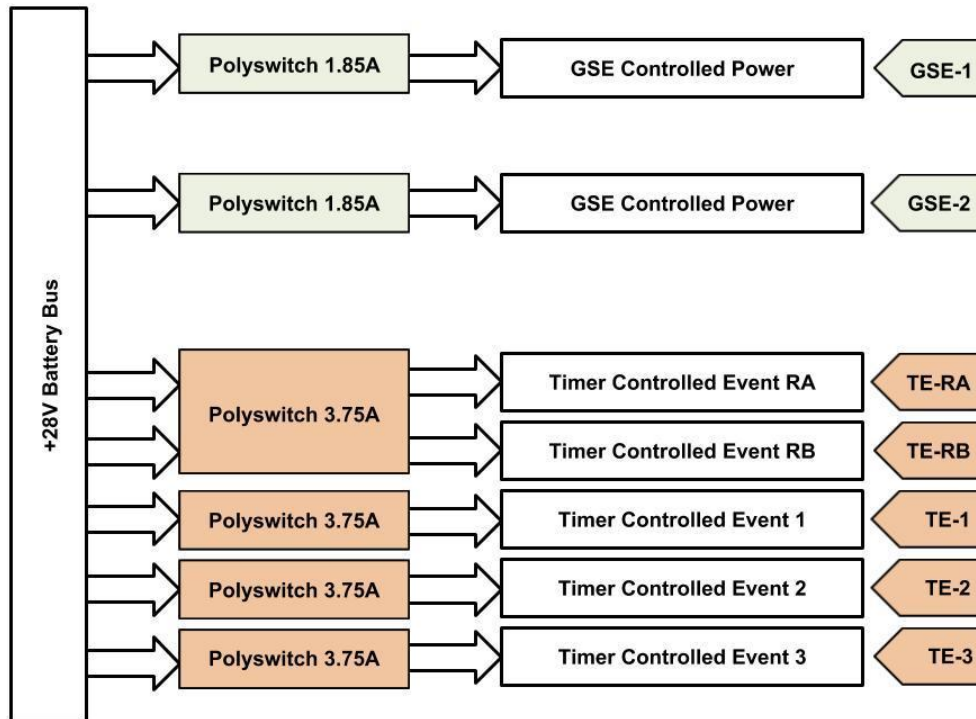


Figure 5-8: Current Limits

### 5.3.2.2. Independent Power Sources

Wallops Flight Facility shall provide the power for all experiments. In the event that an experiment needs a voltage greater than the provided 28V, the customer will be responsible for providing power. This power source must be cleared by both WFF, and a written, formal approval must be issued from the institution before the experiment can fly. Experiments utilizing high voltages must also conform to the requirements provided in Section 5.5. It is important that customers ensure that there is no voltage or current on their experiment deck or through any of their interface wires (power and telemetry) while inactive. Batteries and/or stored power sources shall be inhibited by either a GSE or TE line. Customers may use rechargeable lithium batteries, but rechargeable lithium ion batteries may not be recharged while the experiment is at WFF. Other types of rechargeable batteries may be used and recharged at WFF, such as NiMH. Non-rechargeable lithium ions are allowed. It is recommended that all experiments have their batteries approved by WFF before purchasing them. All rechargeable batteries that will require recharging at WFF shall have a UL listing on both the charger and the batteries. There are no exceptions to this requirement. Failure to follow this requirement will be cause for removal from the rocket. Real-time clocks and other devices requiring button cell batteries may be allowed but shall be presented no later than the PDR for WFF approval.

### 5.3.3. Telemetry Provided

Each RockSat-X full experiment space will be provided with ten (10) 10-bit 0 – 5V A/D lines. Customers must condition all sensor signals to 0-5V. These signals will be converted by Wallops to a 10-bit digital representation that will be sent down on the telemetry stream. These lines are high impedance into the A/D deck, so buffering the signals is not necessary. The A/D decks do not filter the data in any way; however, it is strongly recommended that each input be filtered appropriately to minimize undesired noise. The sample rate is fixed at 1 kHz.

In addition to the A/D lines, full experiment space customers will be provided with one (1) parallel line and one (1) asynchronous line. The parallel line will accept a 16-bit digital signal that will also be sampled according to the timing diagram in the auxiliary document: RS-X Telemetry ICD. Most customers use a parallel line to monitor status (on/off) of certain aspects of the mission. The asynchronous line will have a baud rate 19,200 bps.

**Table 5-3: Telemetry Lines Provided**

<i>Type</i>	<i>QTY</i>
10-Bit 0-5V A/D	10
Parallel (16 bit)	1
Asynchronous	1

**5.3.3.1. Telemetry Interface**

The telemetry interface for each experiment deck shall consist of a thirty-seven (37) pin Cannon connector (Figure 5-5). This connector and associated mounting hardware will be provided by WFF after 3rd payment has been received. The ten (10) A/D lines shall be conditioned to 0 – 5 volts and shall connect to pins 1 – 10 on the Cannon connector. Pins 11 – 16 will contain bits 1 – 6 of the parallel line with pin 11 being the Most Significant Bit (MSB). The final 10 bits shall be placed on pins 20 – 29, with 29 being the Least Significant Bit (LSB). Pin 30 is reserved for the parallel read strobe. The asynchronous connections shall be made on pins 32 and 33 for data to be transmitted and ground, respectively. Pins 18, 19, 36, and 37 shall be experiment ground, which will be tied into Wallops ground via the connector. Pins 17, 31, 34, and 35 will not be utilized (NC). This convention is summarized below in Table 5-4.

**Table 5-4: Telemetry Interface Definition**

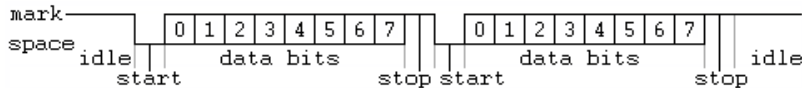
Pin	Function	Pin	Function
1	Analog 1	20	Parallel Bit 7
2	Analog 2	21	Parallel Bit 8
3	Analog 3	22	Parallel Bit 9
4	Analog 4	23	Parallel Bit 10
5	Analog 5	24	Parallel Bit 11
6	Analog 6	25	Parallel Bit 12
7	Analog 7	26	Parallel Bit 13
8	Analog 8	27	Parallel Bit 14
9	Analog 9	28	Parallel Bit 15
10	Analog 10	29	Parallel Bit 16 (LSB)
11	Parallel Bit 1 (MSB)	30	Parallel Read Strobe
12	Parallel Bit 2	31	N/C
13	Parallel Bit 3	32	RS-232 Data (TP1)
14	Parallel Bit 4	33	RS-232 GND (TP2)
15	Parallel Bit 5	34	N/C
16	Parallel Bit 6	35	N/C
17	N/C	36	Ground
18	Ground	37	Ground
19	Ground		

*Note that the pin numbers are engraved on the backside of the provided Cannon connector.*

### 5.3.3.2. Asynchronous Framing and Baud Rates

Customers utilizing the asynchronous line are responsible for correctly framing data before sending it to the telemetry connector. Framing is easily accomplished through a Universal Asynchronous Receive Transmit (UART). Most COTS microcontrollers have this ability (however they may not condition voltage levels appropriately for RS-232, so a level shifter may be required). The serial link uses the RS-232 protocol, which is further explained in the auxiliary document: RS-X Telemetry ICD.

All customers shall use the 8-N-1 convention. 8 indicates that each frame consists of 8 data bits, N indicates that no parity bits are being used, and 1 indicates a single stop bit. The typical 8-N-1 frame is summarized in Figure 5-9.



**Figure 5-9: 8-N-1 Asynchronous Serial Framing**

Source: [www.wikipedia.com](http://www.wikipedia.com)

The start bit is always a signal low followed by eight bits (0-7) of data, with a final stop bit at logic level high. A UART will complete all framing if implemented correctly. Customers can communicate over this serial connection at a baud rate of 19,200 bps.

Baud rate is NOT equal to data rate. 19,200 Baud implies that 19,200 characters per second can be communicated, where “characters” includes the required start and stop bits. For an 8-N-1 frame, 2 start/stop bits or characters are required per frame, which implies a 20% overhead (2 [start-stop bits]/10 total bits). Extrapolating this concept, a 19,200 Baud connection is capable of streaming 15,360 [0.8\*19,200] bits of actual data per second.

## 5.4 High Voltage

All experiments using the provided 28V from WFF are strongly encouraged to conformal coat all electronics to protect against coronal discharge. All experiments utilizing voltages higher than 28 V shall conformal coat all boards. Experiments utilizing higher voltages must obtain the written permission of both Wallops Flight Facility.

### **5.5. Electrical Harnessing and Staking**

All experiments shall harness wires with a nylon lacing tape or the equivalent. Wire harnesses that are excessively long should be staked to the structure to mitigate the risk of disconnects during flight. It is also highly recommended that all connectors and IC sockets be tied and staked in place using aerospace grade RTV (Such as Dow Corning 3145). Wallops Flight Facility payloads use Dow Corning products (734 and 736) for potting and electrical connection. These products can be purchased from McMaster Carr at: [www.mcmaster.com](http://www.mcmaster.com)

### **5.6. Radio Frequency Transmissions**

All experiments utilizing RF systems will be required to fully detail these systems. This will be done by completing a Frequency Utilization Request (FUR) form and submitting it to WFF through the Program Manager at CDR. Approval of RF systems will be conducted by WFF to ensure that there will not be interference with necessary WFF payload systems. All RF systems shall be designed to activate after launch, and cannot be based on a GSE line, only a Timer Event line. No RF transmissions will be allowed on the launch pad. All RF systems shall be operational during the June testing trip for the WFF GPS Roll-out test. These RF systems shall be able to turn-on with a GSE line for this test only or be able to be manually turned off and on. Experiments with non-functional RF systems during the June testing trip will not be flown regardless of FUR form approval.

**5.7. Summary of Key Constraints**

**Table 5-5: Summary of Key Constraints**

Type	Quantitative Constraint
Physical Envelope	Cylindrical**: Diameter: ~12 inches (minus keep out) Height: ~10.75 inches (5.13 inches for half) This height does not include the height of the deck. ** Deployables and booms are permitted once skin has been ejected
Weight	Experiment + deck shall be: 30±1 lbf (15±0.5 lbf for half) This weight includes the deck which weighs: 3.3 lbf
Center of Gravity	Lies within a 1 inch square in the plane of the RockSat-X deck
Power and Telemetry	Telemetry Ten (10) 0 – 5V 10-bit A/D Lines One (1) parallel line One (1) asynchronous line Power One (1) redundant power line (28±6V) Three (3) non-redundant power lines (28±6V) Two (2) GSE power line (28±6V) 1 Ah capacity
High Voltage	All experiments utilizing higher voltage (>28V) shall conformal coat all electronics.

**6.0 EXPERIMENT HARDWARE INTEGRATION**

The customer shall deliver (via shipment to WFF) a complete, functional, and fully integrated experiment to WFF in June. Prior to this delivery, a Visual Verification Check-in (VVC) shall be presented by the RockSat-X customer to WFF Management. The review shall demonstrate that the experiment meets all of the requirements of this document and is flight ready. If the experiment does not meet the specifications of this document or the expectations of WFF management, the customer will not be permitted to ship their experiment for integration and testing. All RockSat-X experiments will then be re-tested at WFF after shipment. If re-test is successful, the experiment will be integrated and undergo environmental testing in mid-June. After environmental testing,



experiments shall remain integrated at Wallops until August. Customers will then return in August for final sequence testing and RBF procedures.

## **7.0 EXPERIMENT TEST REQUIREMENTS**

Testing of the experiment shall be performed by the customer to ensure experiment functionality and survivability. All tests shall be documented and/or recorded for the testing reviews whose dates have been established in Section 5.0.

### **7.5. Structural Testing**

The customer shall perform any testing that they see fit to ensure that their experiment will survive the launch environment. In addition to the testing completed by the customer, WFF will perform a three axes vibration test in June. It is highly recommended but not required that customers perform vibration testing prior to arriving at Wallops Flight Facility. Details on the vibration testing levels can be found in Appendix B.

### **7.6. Vacuum Testing**

It is not required but highly recommended that the customer run a full mission simulation in a vacuum chamber.

### **7.7. Day in the Life Testing (DITL)**

The customer is required to run and document at least two (2) full mission simulations to demonstrate functionality of the experiment. This test should consist of the experiment being operated on the bench as an integrated experiment for the entire mission life (less than 30 minutes). The results of these tests will be presented at the weekly teleconferences as indicated on the schedule.

### **7.8. Wallops Flight Facility Testing**

#### **June Integration and Environmental Testing**

The June Integration and Environmental Testing (I&E) is the most important testing phase for RockSat-X experiments. This will be the closest to a true mission simulation that will be available. The experiments are installed onto the WFF experiment section and testing is conducted to ensure systems behave in a way that is safe and acceptable for flight. It is required that experiments be fully mechanically and electrically functional and active during the June testing. WFF will not allow or accept significant mechanical or electrical changes after the June testing has occurred. During all testing, experimenters should expect GSE and timer events to become active. The following tests will be conducted in June:

- Full electrical sequence
  - All systems will be turned on in accordance with GSE and TE specified timing.
  - Sequence testing will be done multiple times both before and after vibrational testing.
- Vibration
  - Full experiment stack will be tested on the vibration tables as described in Appendix B.
- Moment of inertia
- Spin balance
- Radio frequency interference (RFI)
  - Systems will be turned on and electrical noise and RF emissions will be detected and characterized.
  - The RF portion of your experiments shall be able to turn on and off either with a GSE line or a manual switch
- GPS Rollout
  - WFF will test the experiment GPS and telemetry systems fully.
  - Experiments with purposeful RF devices are required to be powered during this test and actively transmitting RF as it would be for flight.
  - The RF portion of your experiments shall be able to turn on and off either with a GSE line or a manual switch
- Skirt Separation
  - The experiment skirt separation using pyrotechnic devices will be tested for smooth operation.

A summary of the powered tests that will be completed at WFF during the June Testing and Integration week is available in Appendix D. Please note that any test may be repeated if WFF or RockSat-X PM deems it necessary. RockSat-X participants must be able to complete all testing in compliance with RockSat-X guidelines in order to launch. Experimenters are able to enable/disable inhibits in-between tests following documented and approved procedures.

### August Integration and Launch

During the integration portion of launch, the following tests will be conducted:

- Full electrical sequence
  - All systems will be turned on in accordance with GSE and TE specified timing. This will occur multiple times
- RFI Test (if needed)
- GPS Rollout (if needed)
- Check balance

- ACS Phasing Checks
- Turn on, vertical, horizontal checks on the launch pad
  - Each system will have GSE power turned on multiple times prior to launch. Experiment design must be able to compensate for turning on with no ability to reset experiment.

The August launch date is dependent on many factors that can cause a launch to slip beyond the intended launch window. All launches have a launch window of 3-4 days. While the first day of the window is ideal, weather, boats in the recovery area, issues with the launch vehicle, or other circumstances may cause a delay in the launch. In previous years, launches have been postponed a day in 2015, a month in 2012, and as much as seven months in 2014. For this reason, the RockSat-X program makes no promise of a launch on a specific date. Many launches do occur on time and without issue.

## 8.0 SELECTION PROCESS

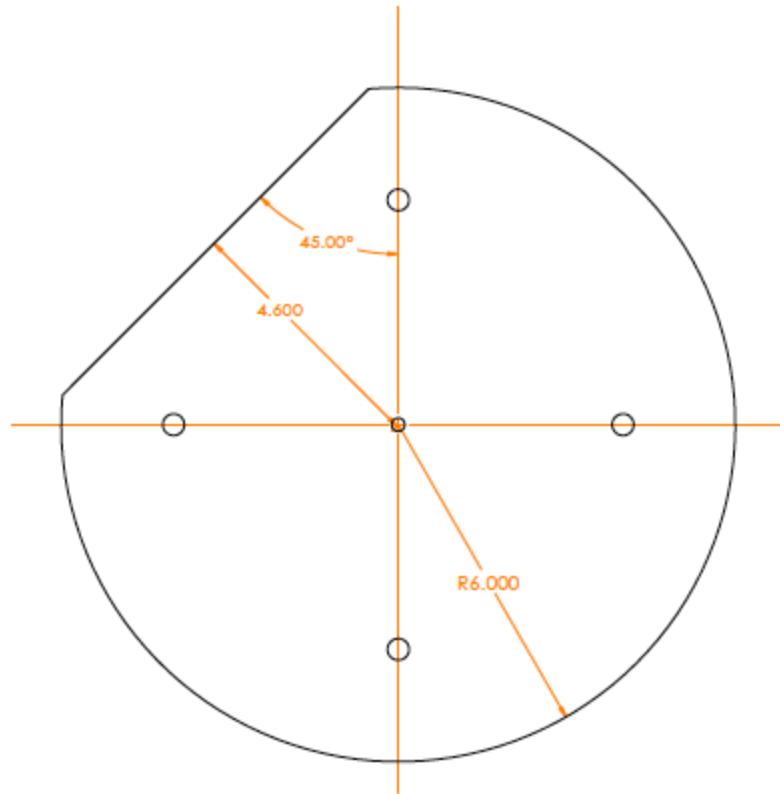
Any educational institution wanting to participate in RockSat-X shall submit the IFF in September. The completion IFF is required to participate in RockSat 2024 and is due no later than SEP 21, 2023 at 11:59 PM EDT. The IFF can be found here. <https://tinyurl.com/rocksat-24-iff> It is expected to take ~20 minutes to complete this form. Although required, submission of the IFF does not mean that your team has been selected for flight on the RockSat 2024 program. The IFF will be reviewed, and initial selections will be made by the end of September. Initially selected candidates will be chosen based on responses to the questions on the IFF. Due to the limited experiment space on the RockSat launch vehicles, a down-selection process will be utilized after the successful completion of the RockSat Conceptual (CoDR) and Preliminary (PDR) design reviews. Each of these presentations will be reviewed and used to determine the flight worthiness of all initially selected candidates. If a team is down-selected, a full refund for their first payment will be issued minus a small processing fee. No later than November, WFF will award flight opportunities (the flight manifest) to the RockSat-X experiments that are the most mature and ready to continue in the engineering process. Once a project has been selected, the customer's space has been reserved and no refunds will be issued for any reason; this includes but is not limited to failing to complete the experiment before launch or being removed from flight by either Wallops Flight Facility.

## 9.0 SCHEDULE

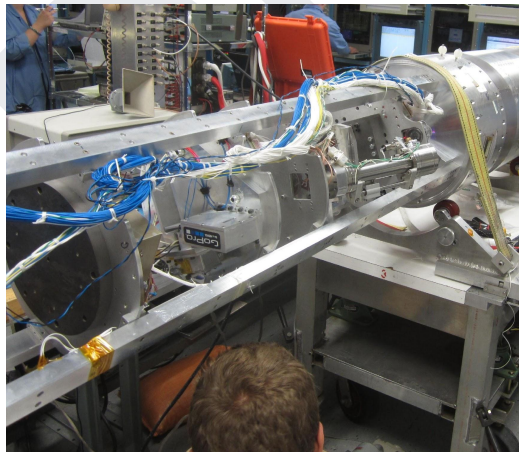
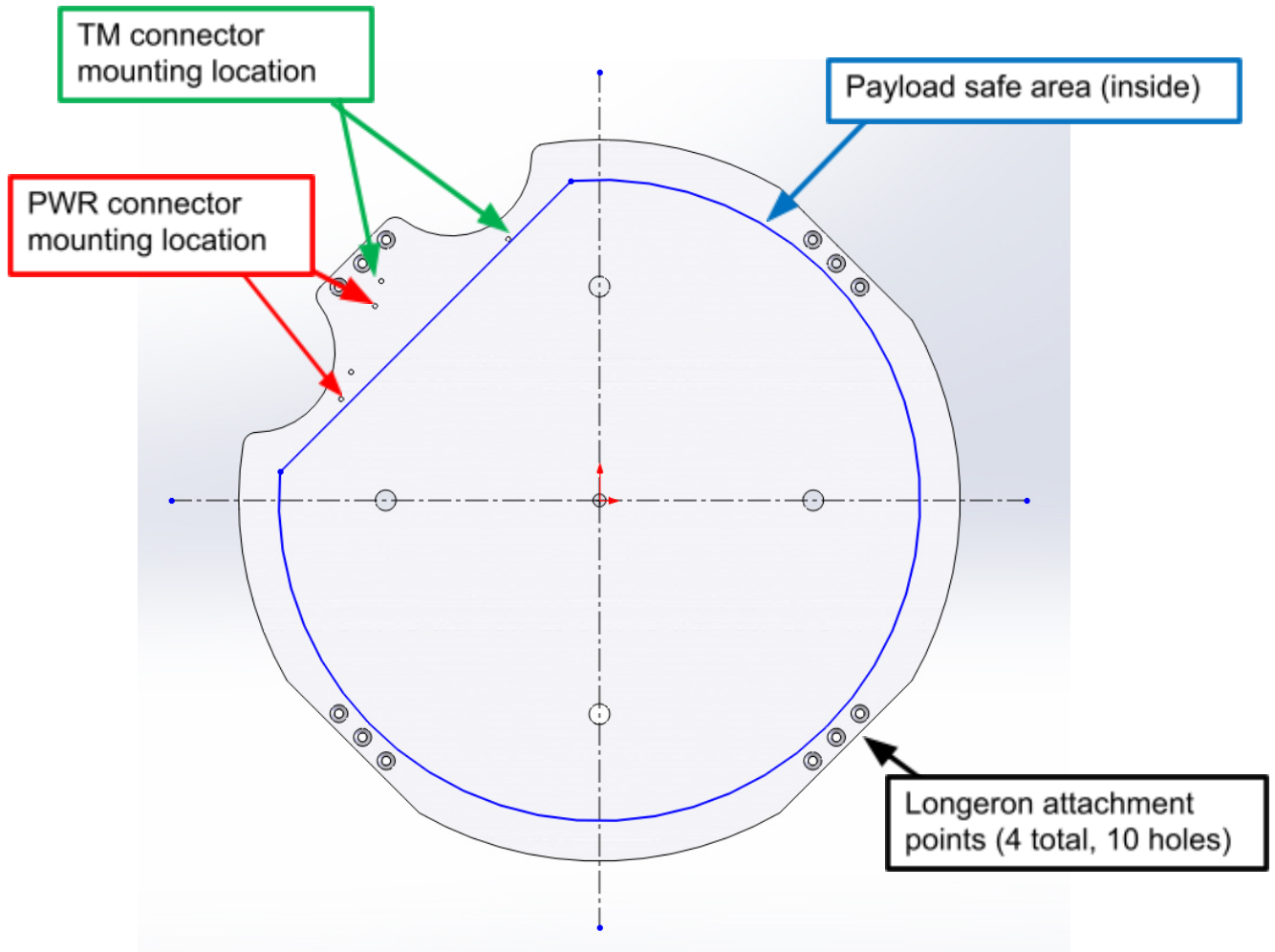
The following are key deadlines and reviews that the customer should be aware of and are subject to change.

<b>Date</b>	<b>Milestone/Event</b>
SEP 21, 2023	IFF DUE
OCT 09-13, 2023	CoDR (Review)
OCT 20, 2023	1st Payment DUE
NOV 13-17, 2023	PDR (Review)
NOV 28, 2023	Down-Select Complete and Flight Manifest
DEC 04-15, 2023	CDR (Review)
JAN 08, 2024	2nd Payment DUE
FEB 19-23, 2024	STR (Review)
MAR 18-22, 2024	ISTR (Review)
MAR 27, 2024	3rd Payment DUE
APR 22-26, 2024	FMSR (Review)
MAY 28-JUN 10, 2024	VVC (Review)
JUN 12, 2024	Ship Experiments
JUN 17-23, 2024	RockSat-X I&T @ Wallops
AUG 05-13, 2024	RockSat-X Launch Trip
SEP 16, 2024	RockSat-X Reports DUE

## 10.0 APPENDIX A: Mechanical Drawings/Interfaces



DRAFT



## 10.0 APPENDIX B: Environmental Testing Characteristics

\*\* NOTE: The following specifications are based on the levels used on RockSat-C/RockOn. If other levels are to be used, this section will be revised as necessary.

### ***Environmental Testing Characteristics:***

Wallops Flight Facility's Environmental Test for the RockSat Program has two components: The Sine Test and the Random Test.

#### ***Sine Test:***

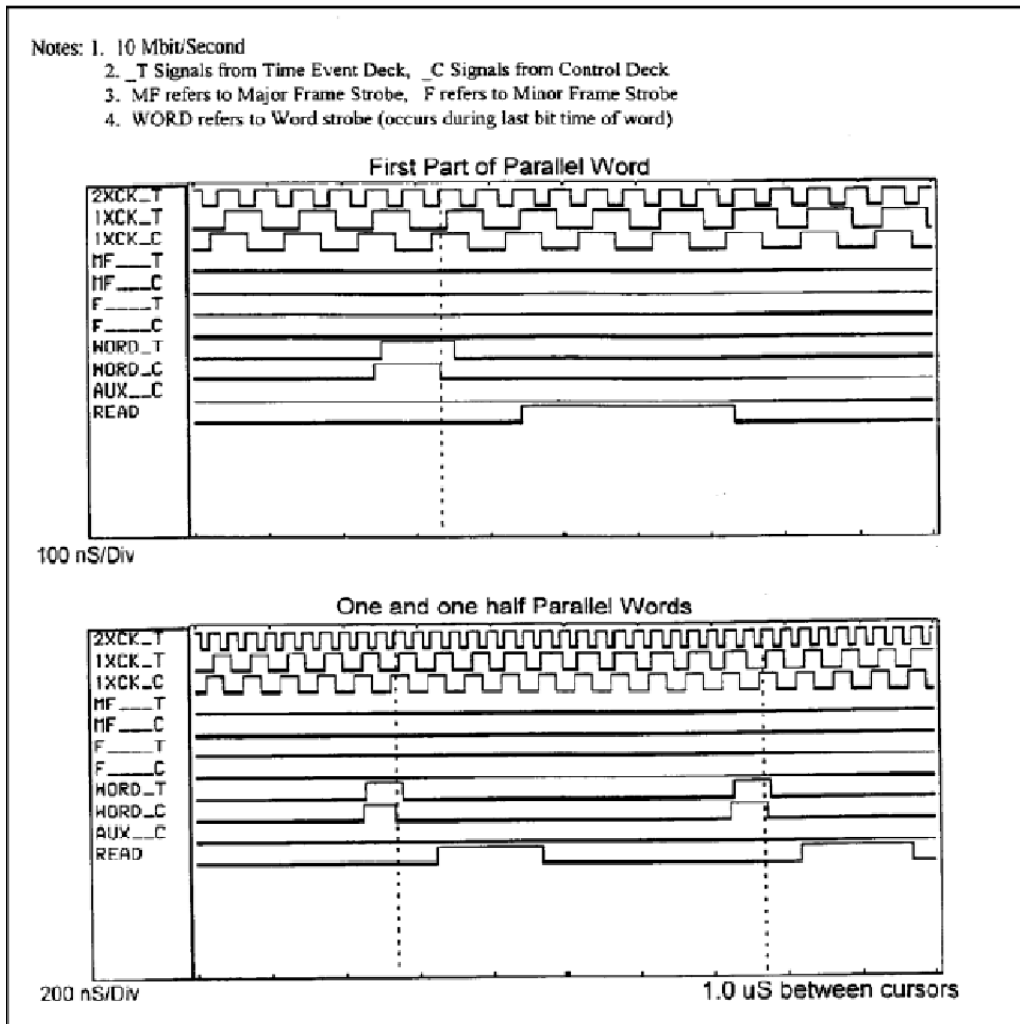
The Sine Test will vibrate the experiment along the thrust axis at no more than 3 in/s. These rates will occur between the frequencies of 10 and 144 Hz. The thrust axis will also see 7G from 144 to 2000 Hz. The sweep rate is 4 octaves per minute.

#### ***Random Test:***

The random test will be completed in all three axes: thrust, lateral, and 90 degrees from lateral. The test will begin at lower levels and gradually increase to full level. Each axis will see 20 seconds at full level.

**Thrust Full Level:**  $10 G_{\text{rms}}$  at  $0.051 G^2/\text{Hz}$  from 20-2000 Hz  
**Lateral and Lateral 90 Full Level:**  $7.6 G_{\text{rms}}$  at  $0.029 G^2/\text{Hz}$  from 20-2000 Hz

## 11.0 APPENDIX C: Supplemental Telemetry Specifics





## 12.0 APPENDIX D: Summary of June Testing Operations

Test	GSE Power	TE Power	TM Recorded	Notes
<b>GSE Checkout</b>	YES	YES	YES	<ul style="list-style-type: none"> <li>• Uses mobile EGSE equipment prior to mechanical integration.</li> <li>• Weight and height recorded.</li> <li>• Testing monitors flight deck, power, and telemetry voltages for compliance.</li> <li>• Full Mission simulation.</li> <li>• Tests may be repeated if an issue arises or if RockSat-X PM has a need.</li> </ul>
<b>Sequence Test 1</b>	YES	YES	YES	<ul style="list-style-type: none"> <li>• Occurs at WFF F-10 ground station with experiment mounted to the rest of the WFF payload.</li> </ul>
<b>Sequence Test 2</b>	YES	YES	YES	<ul style="list-style-type: none"> <li>• First round of Pre-vibration full sequence tests.</li> <li>• Full mission simulations.</li> <li>• Tests may be repeated multiple times if an issue arises or WFF has a need.</li> </ul>
<b>Vibration Test</b>	YES	NO	NO	<ul style="list-style-type: none"> <li>• Experiment GSE lines powered during multiple phases of vibration test. System could be turned on for over 10 minutes multiple times.</li> </ul>
<b>Sequence Test 3</b>	YES	YES	YES	<ul style="list-style-type: none"> <li>• Second round of full sequence testing.</li> <li>• Full mission simulations.</li> </ul>
<b>Sequence Test 4</b>	YES	YES	YES	<ul style="list-style-type: none"> <li>• Tests may be repeated multiple times if an issue arises or WFF has a need.</li> </ul>
<b>GPS Rollout Test</b>	YES	NO	NO	<ul style="list-style-type: none"> <li>• System check to verify WFF payload RF communications.</li> <li>• All RF experiments must be operational during this time.</li> </ul>