

ROCKSAT →

User's Guide

Pushing The RockSat

Concept to New EXtremes



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Wallops Flight Facility (WFF)
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1.0 APPROVALS AND TRA KING

1.1. Signatures

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WFF Concurrence:



10-03-2012

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Sounding Rockets Program Office

Date

1.2. Revisions

Revision	Description	Date	Approval
DRAFT	Initial release	08/06/2010	SMC
Revision 1	Major updates include: mechanical interface definition, power interface definition, telemetry interface definition, preliminary environmental testing characteristics, mechanical drawings, power and telemetry connector pictures, parallel timing diagram (Appendix C)	10/22/2010	SMC
Revision 2	Complete overhaul for 2012.	08/02/2011	SMC
Revision 3	Numerous updates for 2013 program and clarification on U.S. Person restrictions, Export Control, and ITAR language.	10/02/2012	CJK
Revision 4	Added diagrams for payload safe area. Added photos for longeron attachment points. Updated dates for June and August trips.	01/31/2013	CJK
Revision 5	Numerous updates for 2014 program.	09/25/2013	CJK
Revision 6	Updates for the 2015 Program	7/31/2014	JMA
Revision 7	Updates for the 2016 Program -RF testing -June and August testing -Additional clarifications	8/24/2015	JMA
Revision 7.1	Fixed error in schedule on p.26	9/2/2015	JMA
Revision 8	Updates for the 2017 Program -Integration testing schedule -Keep-out zone note -Power D-sub redefined	7/12/2016	JMA AJH
Revision 9	Updates for 2018 Program Updates to shared experiment requirements	7/11/2017 9/20/17	AJH LJH
Revision 10	Updates for 2019 Program Updates to polyfused diagram and addition of "RockSat Program" section	9/19/18	LJH

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Revision 11	Updates for 2020 Program	7/31/19	LJH
Revision 12	Added integration block clarification	9/18/19	CJH

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2.0 INTRODUCTION

2.1. RockSat Program

RockSat-X is a follow-up program to RockSat-C and the RockOn Workshop where customers design their own sounding rocket payload and compete for a spot on the launch vehicle. The RockOn Workshop teaches participants how to build a sounding rocket payload in three days. The goal is that participants will take what they learn during the workshop and return the next year with an original payload to fly with RockSat-C or RockSat-X programs.

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 program fees paid by RockSat-X teams. A portion of the RockSat-X program fees are invested back into the RockOn Workshop.

The program uses payload decks that allow for the standardized integration of the customer's payload and the WFF. This simplifies final integration and allows for more focus on the design of the payload. The organizers of the RockSat-X program guide the RockSat-X customers through the design process in the fall with multiple design reviews, leading projects to a Critical Design Review level design in December. Based on available space in the rocket, the most developed and capable projects are selected for flight in January. These projects then make their first payment and begin building. The projects continue to have subsystem and system testing reviews with the RockSat-X program manager through May. Any special requirements that arise for payloads are communicated to WFF through the RockSat program manager. Teams then fly out to WFF in Virginia in June for integration and testing of their experiment. Teams are then allowed to take their payload home to fix any issues that arose during testing. The program culminates in August when the teams once again travel to WFF for inspection, final integration to the rocket, launch, and recovery.

2.2. 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

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above listing, are encouraged to contact COSGC 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.

Participation in the RockSat-X program includes teleconferences with NASA Wallops Flight Facility (WFF) employees and contractors as well as all integration, testing, launch, and recovery operations that take place at NASA's 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).

2.3. Purpose

The purpose of this document is to identify the interfaces, requirements and logistics pertaining to the University of Colorado at Boulder (CU-Boulder) Colorado Space Grant Consortium's (COSGC) 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 payloads that are profit related endeavors and/or industry research and development. Students must be actively engaged and involved.

2.4. Getting Involved (Intent to Fly Forms)

Interested institutions will need to submit an Intent to Fly Forms (IFF) in September by the date listed on the IFF. In October, *each* initially selected institution will make a \$2,000 earnest deposit. This deposit is fully refundable until the customer has been down selected as a finalist. Further details on the selection process can be found in Section 8.0.

2.5. Sharing

There are five full experiment spaces, which can be used as up to 10 half experiment spaces on the RockSat-X vehicle. Customers that desire to share a full experiment space and associated weight allocated to that space shall indicate this on the submitted Intent to Fly Form (IFF). Full experiment spaces can only be shared in halves.

Customers are encouraged to collaborate and pair prior to the submittal of the IFF, however it is not a requirement. Customers wanting to share experiment space/weight can pair off with one other institution for a total of not more than two (2) educational institutions per experiment space. Greater than two (2) experiments per space will not be permitted. ***Sharing customers should be aware that the power and telemetry connections available are per experiment space and those customers must share the standard resources described in the sections below.*** (i.e. additional power and telemetry connections will NOT be provided to spaces with customers sharing space.)

After final down select, all pairings, mass allotments, and volume allotments are final and cannot be changed without written consent of COSGC. In the event that a subset of customers would like to redistribute allotments, all customers of the subset must contact COSGC, and changes will only be made with written approval of all parties involved and COSGC. Cost sharing is covered in Section 1.5.

Customers that share an experiment space are responsible for sharing resources with their partner. Power and telemetry are allocated based on experiment space, so customers that share the space are only allocated half of those resources. This means that sharing customers cannot use more than half the battery capacity. Telemetry lines must also be shared, but the Program Manager will do his/her best to partner shared customers so that both payloads 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.

2.6. Cost

The cost of a flight is contingent upon the amount of the experiment space being utilized. This cost covers the following expenses: launch costs, use of one (1) RockSat-X payload deck with power and telemetry interface, mission management support, environmental testing, and other amenities provided during the weeks of environmental testing and launch.

During the weeks of environmental testing and launch, the cost includes approximately four breakfasts and lunches for four (4) participants per team. Additionally, each of the four (4) members will receive a RockSat-X t-shirt. Additional meal options and shirts will be available for additional team members beyond the primaries at

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a TBD cost. Please notify the RockSat-X program manager (PM) as soon as possible if this will be the case. ***The program cost does NOT cover travel to and from Wallops Flight Facility, lodging, or other expenses incurred while supporting these trips.***

2.6.1. Dedicated Customers

A dedicated customer is an institution whose experiment will occupy an entire experiment space. The total cost of a dedicated experiment space is \$24,000. If a dedicated customer's experiment is chosen to fly at the final down select, he/she will then make two (2) equal payments of \$11,000 in addition to the initial deposit, per the schedule in Section 9.0. ***After receipt of the first installment of \$11,000, each customer will be sent one (1) RockSat-X experiment deck with a power and telemetry interface contingent upon machining completion, and all deposits shall become non-refundable.*** All payments must be made in the form of a check made payable to: University of Colorado. Payments should be sent to:

Colorado Space Grant Consortium
Discovery Learning Center Room 270
520 UCB
Boulder, Colorado 80309-0520

2.6.2. Share Customers

A share customer is an institution whose experiment will occupy only half of an experiment space. The total cost for half of an experiment space is \$14,000. How each shared customer occupies his/her territory is up to the customers in a specific experiment area. Shared customers will each get their own payload deck but are only allowed to use half the payload space volume (ie. the height is approximately half the height of the full experiment space). At the time that earnest deposits are due, all shared customers shall still pay the earnest deposit of \$2,000 made payable in the same method as described in Section 1.5.1. ***After receipt of the first installment of \$6,000, each customer will be sent one (1) RockSat-X experiment deck with a power and telemetry interface contingent upon machining completion, and all deposits shall become non-refundable.*** These payments will be made on the dates indicated in the schedule (see Section 9.0). It is the customer's responsibility to coordinate sharing the deck for fit checks and integration prior to travel for environmental and functional testing in June.

2.7. Points of Contact

Program points of contact (POC) is as follows:

RockSat-X Principle Investigator Colorado Space Grant Director University of Colorado at Boulder	Chris Koehler 303-492-4750 koechler@colorado.edu
RockSat-X Program Manager University of Colorado at Boulder	Corey Huffman 254-289-9973 rocksatx@gmail.com

2.8. Applicable Documents and Links

- Colorado Space Grant Consortium RockSat website:
<http://spacegrant.colorado.edu/national-programs/rs-x-home>
- 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>

3.0 ROCKSAT-X OVERVIEW

The RockSat-X payload deck is a modular system based around experiment decks designed for suborbital flights with Wallops Flight Facility's (WFF) RockSat-X experiment section called the Carrier of Rocket Learning Laboratories (CarRoLL). Figure 2-1 and Figure 2-2 (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***.

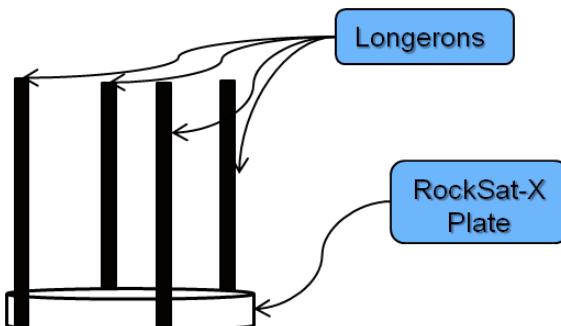


Figure 2-1: RockSat-X Deck in Longeron Structure (Conceptual)

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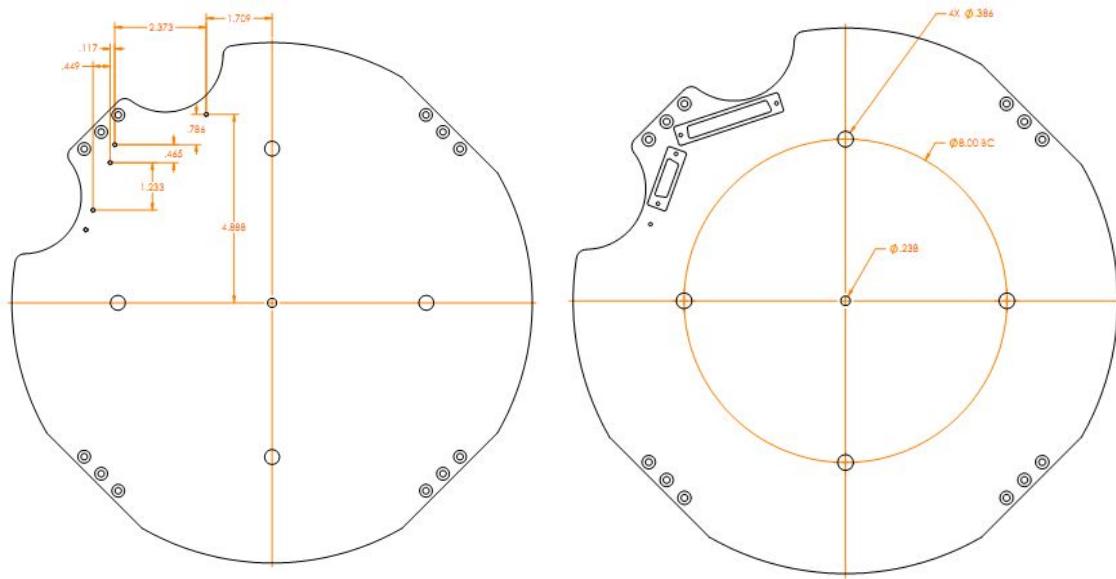


Figure 2-2: RockSat-X Deck Layout

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.

The RockSat-X deck is the next phase in a partnership with Wallops Flight Facility designed to give students access to space. The predecessor, RockSat-C, will continue to run concurrently, and it is COSGC's and WFF's goal to pipeline students, faculty mentors, and industry partners from the RockSat-C program into the RockSat-X program, which is designed to be more capable and more technically challenging.

RockSat-C provides a standard canister for customers to build, design, test, and fly experiments in. RockSat-C provides optical and atmospheric ports for various experiments, but it is full access to the space environment that opens the door to endless possibilities on sounding rockets. RockSat-X will have an ejectable skin and nose cone 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.

Wallops will also provide power and telemetry to each experiment deck. By providing these amenities, experimenters can spend more time on payload design and less on power and data storage systems. The payload section also has the opportunity to have an

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Attitude Control System (ACS) to align the rocket to positions deemed necessary by the experiments.

4.0 ROCKET DESCRIPTION AND CAPABILITIES

This section covers key interfacing and launch vehicle capabilities that customers should be aware of for the design of his/her payload.

4.1. 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 2-1 and Figure 3-1). With 5 RockSat decks with one typically including a camera/data payload flying, 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.

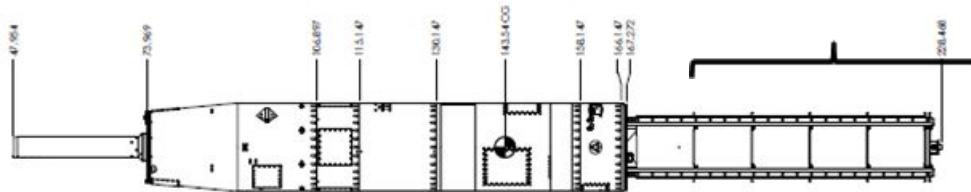


Figure 3-1: Payload Stack with CarRoLL Section

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. One half experiment space is typically reserved for a high-definition video recording system and the footage will be available to all participants.

Each of the five experiment spaces shall be provided with four timer controlled (4) power lines 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 experiment 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. ***Each section will have a 1 Amp Hour (Ah) battery available for the mission.*** Customers will connect to power via the power and telemetry interface described further in Section 5.3.1. ***Please note that sharing customers will need to share these four timer controlled and two GSE power lines as well as the 1 Ah battery.***

Each experiment section shall be provided with telemetry. Each section has 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,

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which eliminates the need for on-board data storage. Additionally, each section will receive one (1) asynchronous line at a 19,200 baud rate and a 16-bit parallel line. Customers will 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 experiment sections will have to share these resources with another experimenter.***

The RockSat-X deck is circular in shape with a useable payload 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 payload deck will have 10.75 inches of height (5.13 inches for half sections). Each RockSat-X deck is allotted 30 ± 1 lbs (15 ± 0.5 for half sections) including the deck and power and telemetry interface connectors. All payloads must be designed to this mass. ***Violation of this rule will result in the customer being removed from the flight.***

4.2. Rocket Key Performance Parameters

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)

4.3. Flight Environment Conditions

4.3.1. G Loading

During ascent and descent payloads 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.

4.3.2. Space Environment

After second stage burn-out, the skin and nose cone will be ejected exposing all payloads 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 payloads located near high outgassing materials. Outgassing properties for most materials can be found at: <http://outgassing.nasa.gov/>.

4.4. Disclaimer

Recovery of payloads 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 neither COSGC nor WFF can plan for. Selected experiments assume all risks, and neither of the said institutions shall be held responsible in the event of an anomaly and/or unrecoverable payload. Customers should also be aware that thermal and structural loading will be substantial upon re-entry. Pending a successful recovery of the payload section, customers should expect severe and un-repairable damage to flight hardware.

5.0 ORGANIZATIONAL RESPONSIBILITIES

5.1. Customer and COSGC Responsibilities

Component and functional design responsibilities are listed below.

RockSat-X Payload Customer

- Experiment and support system.
 - Support system includes:
 - Thermal system (if desired)

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- On-site tools and hardware for environmental testing and final integration
- All environmental sensors (if desired)
- Power regulation from nominal 28V to any required payload voltages
- Mechanical interface to RockSat-X deck
- Safety features for experiment-related hazards
- Power harness from payload to power interface (minus connectors)
- Telemetry harness from payload to telemetry interface (minus connectors)
- All required ground side data analysis equipment (computers not provided)
- Required interfacing between sharing customers

COSGC and WFF

- Terrier-Improved Malamute 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
- Some breakfasts and lunches during the weeks of testing (June) and launch (August)
- GSE testing (experiment verification) during June testing and August final integration
- Mission management support

5.2. 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 payload preparation, launch, and recovery until the rocket has been recovered and the payload is de-integrated.

6.0 PAYLOAD DESIGN AND INTERFACE REQUIREMENTS

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

6.1.1. 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 laymen) would be considered safe and practical. Experiments shall not put other experiments, the payload as a whole, WFF employees, COSGC employees, or the launch vehicle at risk. All experiments shall be formally selected before the customer can become a contender for flight. This approval will come with signatures on the IFF that will be submitted in September. The RockSat-X experiment space can be sub-halved

between other customers to share space and cost. If experiment space is to be shared, this should be documented on the IFF. Experiments with stored energy devices, deployments, or separation systems will be subject to additional review and require hazardous procedure documentation approved and verified by COSGC and WFF prior to integration and testing at WFF.

6.2. Mechanical

6.2.1. Physical Envelope

RockSat-X is based around a deck rather than a canister. A deck gives customers more freedom. The customer is also responsible for mounting his/her 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 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 the more stringent scrutiny from COSGC and Wallops. Release mechanisms such as compressed springs or Frangibolts must be approved prior to arrival at Wallops and may require additional Hazardous Procedures to be approved by Wallops Ground Safety. All deployments require activation via Timer Event, and deploy at a speed *less than* 1 inch per second.

6.2.2. Mechanical Interface

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

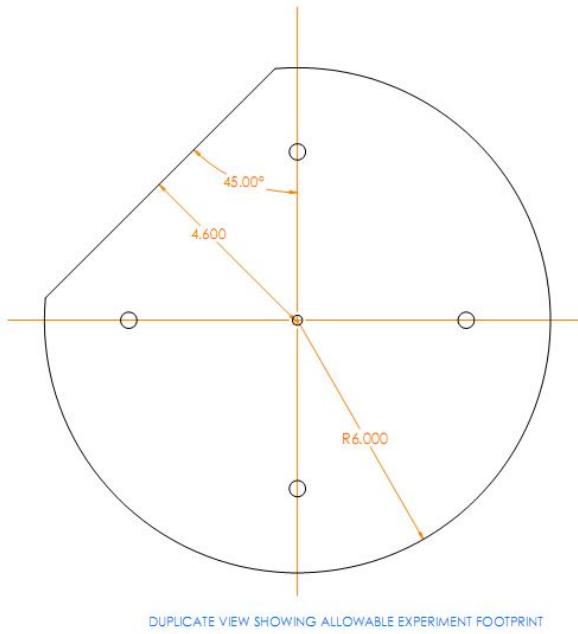


Figure 5-1: RockSat-X Payload Design Space

Figure 5-1 shows the footprint of the space that customers can utilize for the experiment.

The diameter is 12", 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 COSGC and WFF. Customers may add holes to the plate but significant changes (more than 10% of material removed) will need to be approved by COSGC and 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 and COSGC. 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.

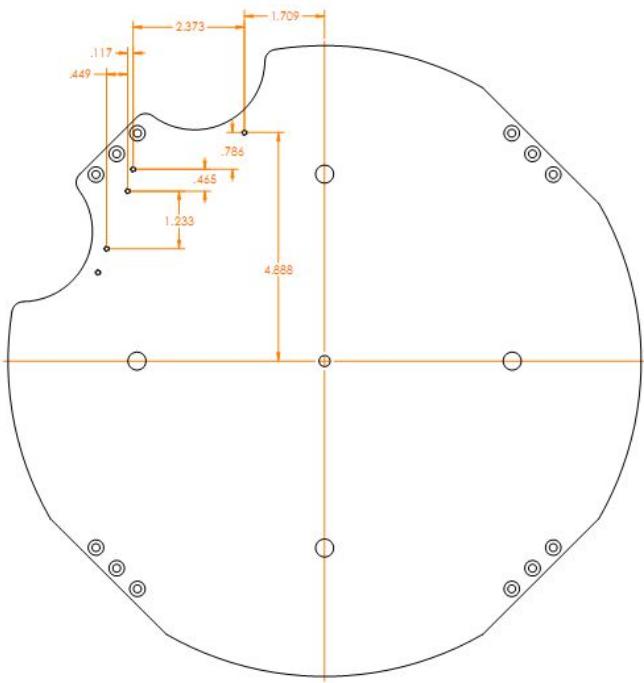


Figure 5-2: PT Connector Hole Dimensions

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 deck provides 10.75 inches of height, where the mid-mount provides 5.62 inches below the deck and 5.13 inches above. Lower mid provides 2.82 inches below the deck and 7.93 inches above. The upper mid mount provides 8.44 inches below the deck and 2.31 inches above. In addition, shared decks may use up to 5.13 inches above their deck unless otherwise agreed upon. A pictorial representation of these options are presented below in Figure 5-3. Customers who share one half of the experiment space will likely have one experiment deck as a bottom mount location and the other experiment deck at the mid mount location. ***All bottom mounted experiment decks as well as all decks in a shared experiment space shall countersink all 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.

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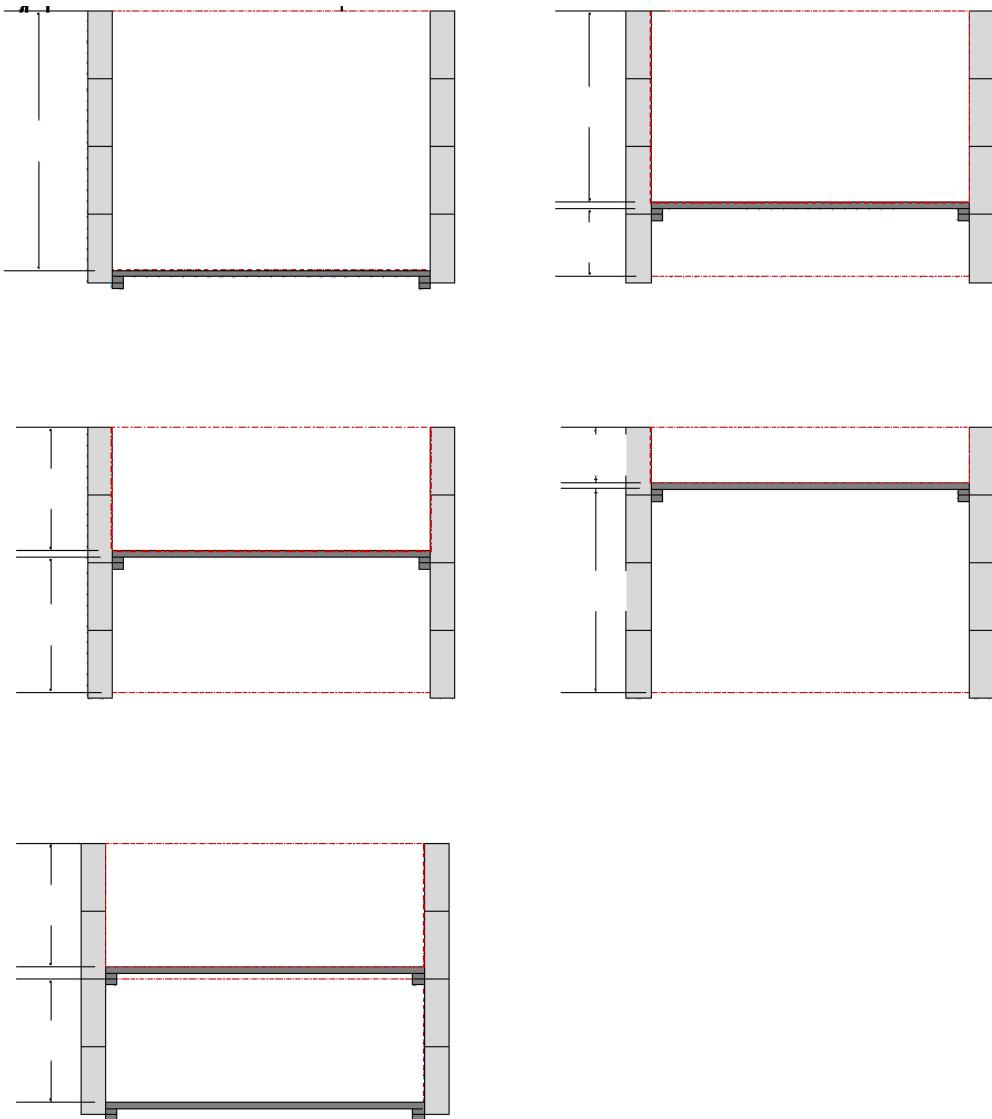


Figure 5-3: Deck Mounting Options

The mounting blocks between the experiment deck and the longerons shall be mounted aft of the deck, regardless of which way the experiment maybe 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.

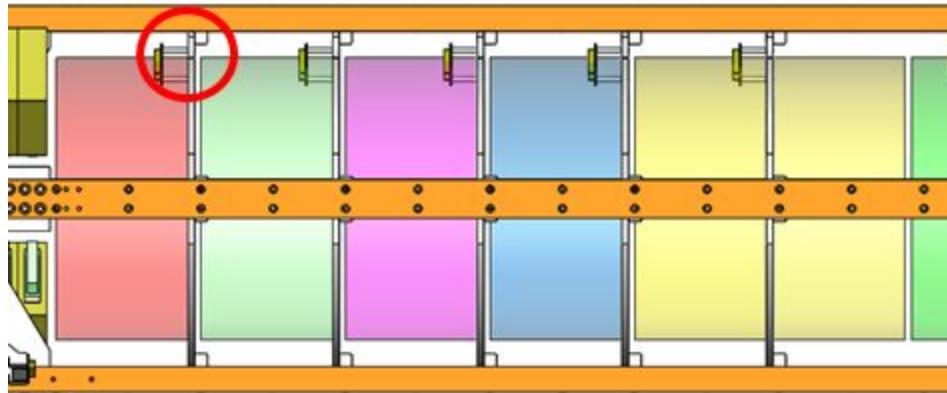


Figure 5-4: Mounting blocks aft of deck

6.2.3. Mass Properties

Each RockSat-X experiment (including deck and PT interface) shall be 30.0 ± 1.0 lbf (13.61 kg). Integrated experiments will be weighed prior to integration. **Experiments not conforming to the weight constraints will be removed from the flight.** **Each RockSat-X shared experiment (including deck and PT interface) shall be 15.0 ± 0.5 lbf (6.8 kg).**

6.2.4. 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 payload falls within the said requirement. **Experiments that do not meet WFF's CG requirements will be removed from the flight.**

6.2.5. 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 +/- 10 Gs in the X and Y (lateral) axes. In the event of a parachute failure, there will be more extreme loading in all three axes.

6.2.6. 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.

6.2.7. Heat of Reentry

Upon reentry, the vehicle (including the experiment section) will be subject to extreme thermal loading. The exact, maximum temperature was not quantified on the 2011 and 2012 flights, but it is speculated that experiments experience temperatures of at least 500° F.

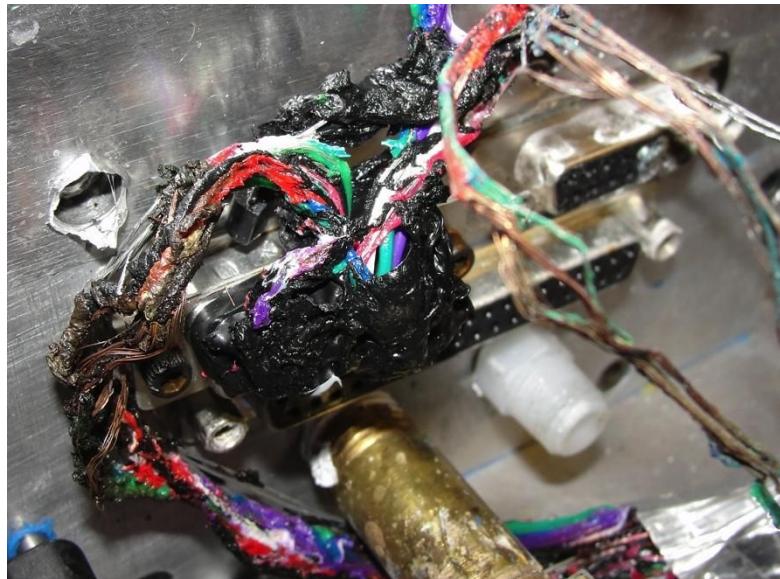


Figure 5-4: Thermal Reentry Damage from 2011

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 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.***

6.3. Power and Telemetry

6.3.1. Power and Telemetry Interface

The RockSat-X program utilizes a standard interface to deliver power from Wallops Flight Facility to the customer. Additionally, the said interface provides a standard for passing telemetry from the customer to WFF. This standard interface

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has been referred to as the Power and Telemetry interface to this point, but from herein may be referred to as the PT interface. **Each experiment team shall complete the Interface Control Documents (ICDs) for both Power and Telemetry.**

To keep this program low cost and low impact to both Wallops Flight Facility and COSGC, a standard interface and number of power and telemetry lines has been established for all payload decks. The PT interface will mount to the RockSat-X deck and will provide customer side and Wallops side connections. Using this standard will allow COSGC to develop an Electrical Ground Support Equipment (EGSE) suitcase. This suitcase will provide 28V ($\pm 1\text{V}$) to power lines and allow monitoring of the telemetry lines to verify functionality prior to final integration to the rocket.

6.3.1.1. PT Interface Design

The customer side Power and Telemetry Interface consists of two (2) d-sub connectors that are provided by Wallops Flight Facility. 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.

Figure 5-5 shows 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.

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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 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.

6.3.2. 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 and COSGC after final down selections.

Each experiment deck shall receive the above said four (4) timer controlled power lines. Additionally, each experiment deck 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

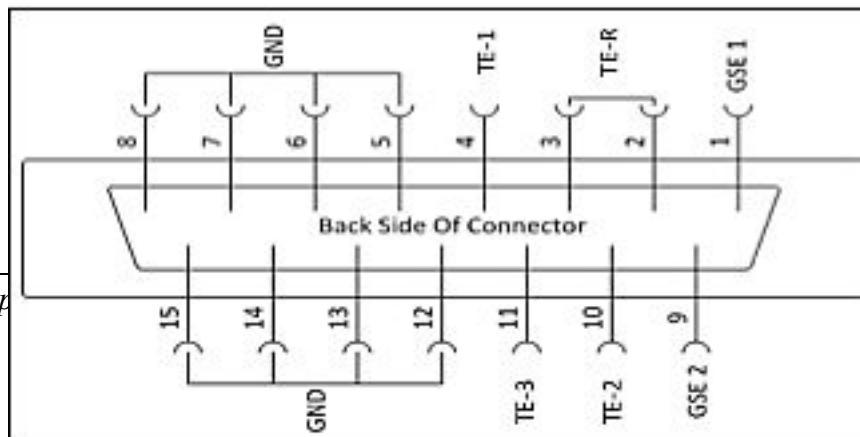


Figure 5-6: Power Connector Pinout

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. X should be less than 600 seconds but more than 180 seconds to prevent complications with the hot count. Pins 5-8 and 12-15 are payload and Wallops ground. Customers can tie their experiment ground to all or any combination of these pins.

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 timer controlled power lines that will activate at independent times specified by the customer. These times must occur after launch, as they are controlled by the launch timer.

6.3.2.1. 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.

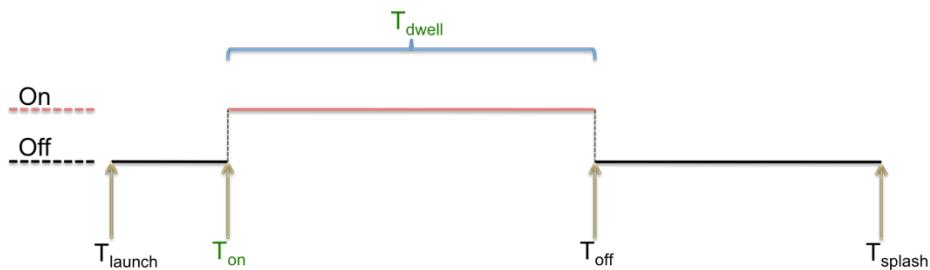


Figure 5-7: Timer Timing Diagram

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 subsystem being activated through the above described timer lines. All deployments must be powered by timer events. Additionally, Wallops will transfer power from your experiment by external power supply at ~28V to 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	Number	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 experiment section will be allotted 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 COSGC's GSE.

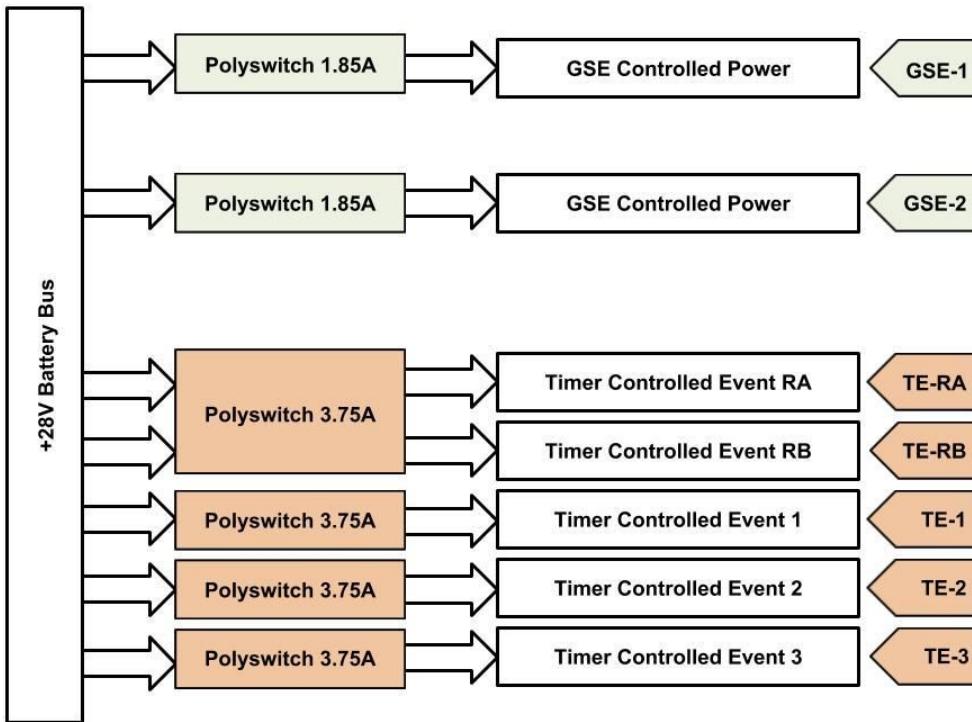


Figure 5-8: Current Limits

6.3.2.2. Independent Power Sources

Wallops Flight Facility shall provide the power for all instruments. 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 COSGC, and a written, formal approval must be issued from both institutions before the payload can fly. Experiments utilizing high voltage 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 payload deck or through any off their interface wires (power and telemetry) as this will be cause for removal from the rocket.

6.3.2.3. Telemetry Provided

Customers will not be responsible for storing data internally. Each RockSat-X deck will be provided with ten (10) 10-bit 0 – 5V A/D lines. ***This implies that 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, so 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, 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 at according to the timing diagram in 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

Type	Number
10-Bit 0-5V A/D	10
Parallel (16 bit)	1
Asynchronous	1

1.1.1. 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 and COSGC after final down selections.

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 payload 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		
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.

1.1.1.1. 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.

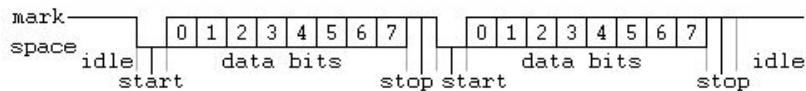


Figure 5-9: 8-N-1 Asynchronous Serial Framing

Source: www.wikipedia.com

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 ($2 \text{ [start-stop bits]} / 10 \text{ total bits}$). Extrapolating this concept, a 19,200 Baud connection is capable of streaming 15,360 [$0.8 * 19,200$] bits of actual data per second.

1.2. Space Environment

Experiments will be exposed to a large variety of environments; the most extreme of these environments will occur at apogee. All experiments will be exposed to the vacuum and thermal extremes of space. Time spent in this environment will be minimal due to the suborbital nature of the flight, but experiments shall be designed to survive vacuum conditions. ***Pressure vessels are prohibited unless explicit, written permission has been issued from COSGC and Wallops Flight facility.***

The vacuum of space will also lead to outgassing. Customers should strive to design with low outgassing components. Customers should also design payloads to survive thermally considering the absence of convection. On board computers may need additional heat sinking to prevent thermal failures that otherwise wouldn't be a concern in the presence of a convective medium.

1.3. High Voltage

All experiments using the provided 28 V 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 and COSGC.

1.4. 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 and COSGC 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

1.5. 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 RS-X Program Manager. 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 must 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 must be operational during the June testing trip for the GPS Roll-out test. These systems must 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.

1.6. 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 shared) 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 shared) 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 plate.
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 ± 6 V) Three (3) non-redundant power lines (28 ± 6 V) Two (2) GSE power line (28 ± 6 V) 1 Ah capacity
High Voltage	All experiments utilizing higher voltage (>28V) shall conformal coat all electronics.

2.0 EXPERIMENT HARDWARE INTEGRATION

The customer shall furnish a complete, functional, and fully integrated experiment to COSGC and WFF on the first day of integration in both June and August. Prior to this delivery, an Integration Readiness Review (IRR) in June and a Launch Readiness Review (LRR) in August will be conducted. Both reviews shall demonstrate the experiment meets all of the requirements of this document. Customers shall present IRRs and LLRs to COSGC and WFF personnel to ensure compliance with the requirements of this document and to give an update on the flight readiness level of the experiment. All

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RockSat-X experiments will then be integrated and undergo environmental testing in mid-June. After environmental testing, experiments will be returned and customers will have approximately 3 to 5 weeks to resolve issues associated with environmental testing that occurred due to vibration testing or electrical sequence testing. Customers will then return in August for the LRR. Experiments deemed flight ready, will then be integrated for flight in August.

3.0 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 9.0.

3.1. Structural Testing

The customer shall perform any testing that he/she sees fit to ensure that his/her 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.

3.2. Vacuum Testing

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

3.3. 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.

3.4. Wallops Flight Facility Testing

3.4.1. June Integration and Environmental Testing

The June Integration and Environmental Testing (I&E) is the most important testing phase for experiments. This will be the closest to a true mission simulation that will be available. The experiments are installed onto the WFF payload 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 present and active during the June testing. WFF and COSGC 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 payload 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 must be able to turn on and off either with a GSE line or a manual switch
- GPS Rollout
 - WFF will test the payload 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 must be able to turn on and off either with a GSE line or a manual switch
- Skirt Separation
 - The payload 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.

3.4.2. August Integration and Launch

In August, experiments are expected to be nearly identical to what was delivered in June. Any changes must be approved by WFF and COSGC. Significant changes would include mechanical additions or subtractions, complete electrical re-design, or addition of entirely new systems or subsystems. Minor changes that are acceptable would include software behavior, addition of sealing materials, final staking and conformal coating to electronics. 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
- 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 re-set 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.

4.0 SELECTION PROCESS

Any educational institution wanting to fly shall submit the IFF either via email or by fax in September. The IFF will be emailed along with this document upon its release.

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. Institutions that submit an IFF will be expected to pay a refundable earnest deposit of \$2,000 in October. All payments must be in the form of a check made payable to the University of Colorado (Section 1.5.1). At this point in the selection process, there may be more candidates than available spaces on the rocket. Over the following three months, candidates will refine their mission and complete three (3) design reviews. The first review is the Conceptual Design Review (CoDR), which will mature to a Preliminary Design Review (PDR), which will ultimately end with a Critical Design Review (CDR). Each of these presentations will be reviewed and used to determine the flight worthiness of all initially selected candidates.

No later than January, COSGC and WFF will award flight opportunities 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 payload before launch or being removed from flight by either Wallops Flight Facility or COSGC.*** Up to two decks of customers may be kept as reserve payloads, and will continue in the design process.

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If an institution is NOT selected at final down select, their earnest deposit will be refunded in full. Those institutions that are awarded flights will continue to the next step of the engineering process. The selected payload teams and the reserve customer(s) will make the first non-refundable installment in February. The final non-refundable installment will be due in April. For further details concerning the engineering/design process after final down select, please see the schedule in Section 9.0.

In the event that a customer cannot complete his/her payload or does not follow requirements set forth in this document, a reserve customer will become a primary customer, and the primary customer will **not** be refunded or compensated in any way. In the event that the payload finalists all launch, the reserve customer(s) will be refunded the cost of flight, but will NOT be compensated for any hardware, travel, or miscellaneous expenses incurred in the engineering process.

5.0 SCHEDULE

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

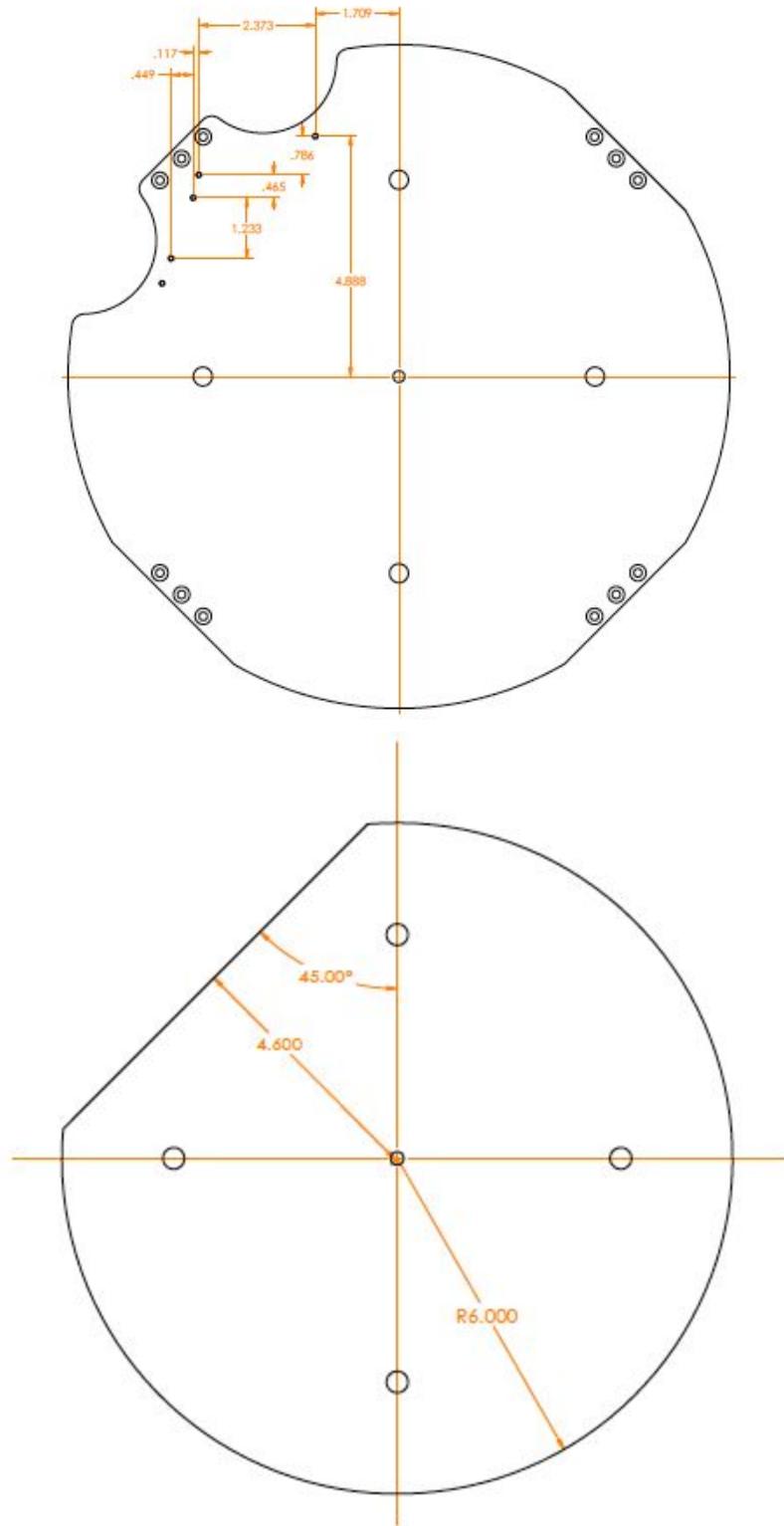
Mid-September	Intent to Fly Forms (IFF) DUE
End of September	Initial Down Selections Made/Welcome Letters Sent
October	Conceptual Design Review (CoDR) Teleconferences
October	Earnest Deposit of \$2,000 DUE
November	Preliminary Design Review (PDR) Teleconferences
December	Critical Design Review (CDR) Teleconferences
January	Final Down Select—Flights Awarded
February	First Installment Due
February	Subsystem Testing Review (STR) Teleconferences
March	Experiment Decks and Connectors Sent to Customers
March	Integrated Subsystem Testing Review (ISTR) Teleconferences
April	Final Installment Due
April-May	Full Mission Simulation Review (FMSR) Teleconferences
May	Weekly Teleconferences Begin
June	Integration Readiness Review (IRR) Teleconferences
June	GSE Checkouts at Refuge Inn
June	Testing and Environmental with Wallops
July	Weekly Teleconferences Resume
July	Launch Readiness Review Packages (LRR) DUE
August	GSE Checkouts at Refuge Inn
August	Final Integration at Wallops

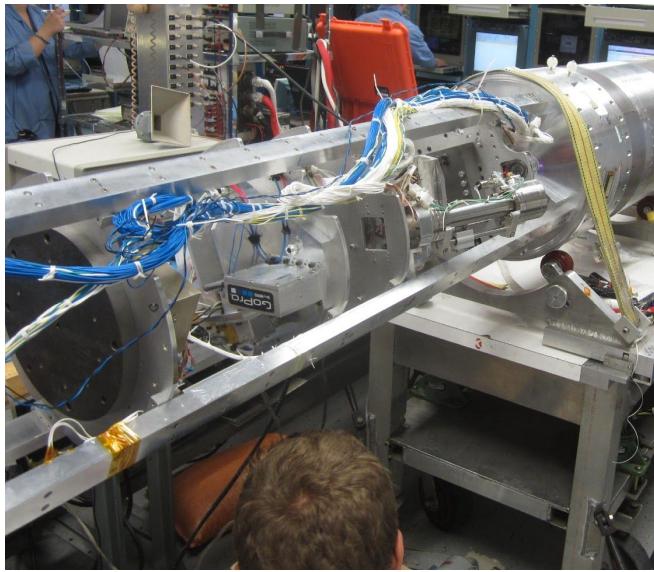
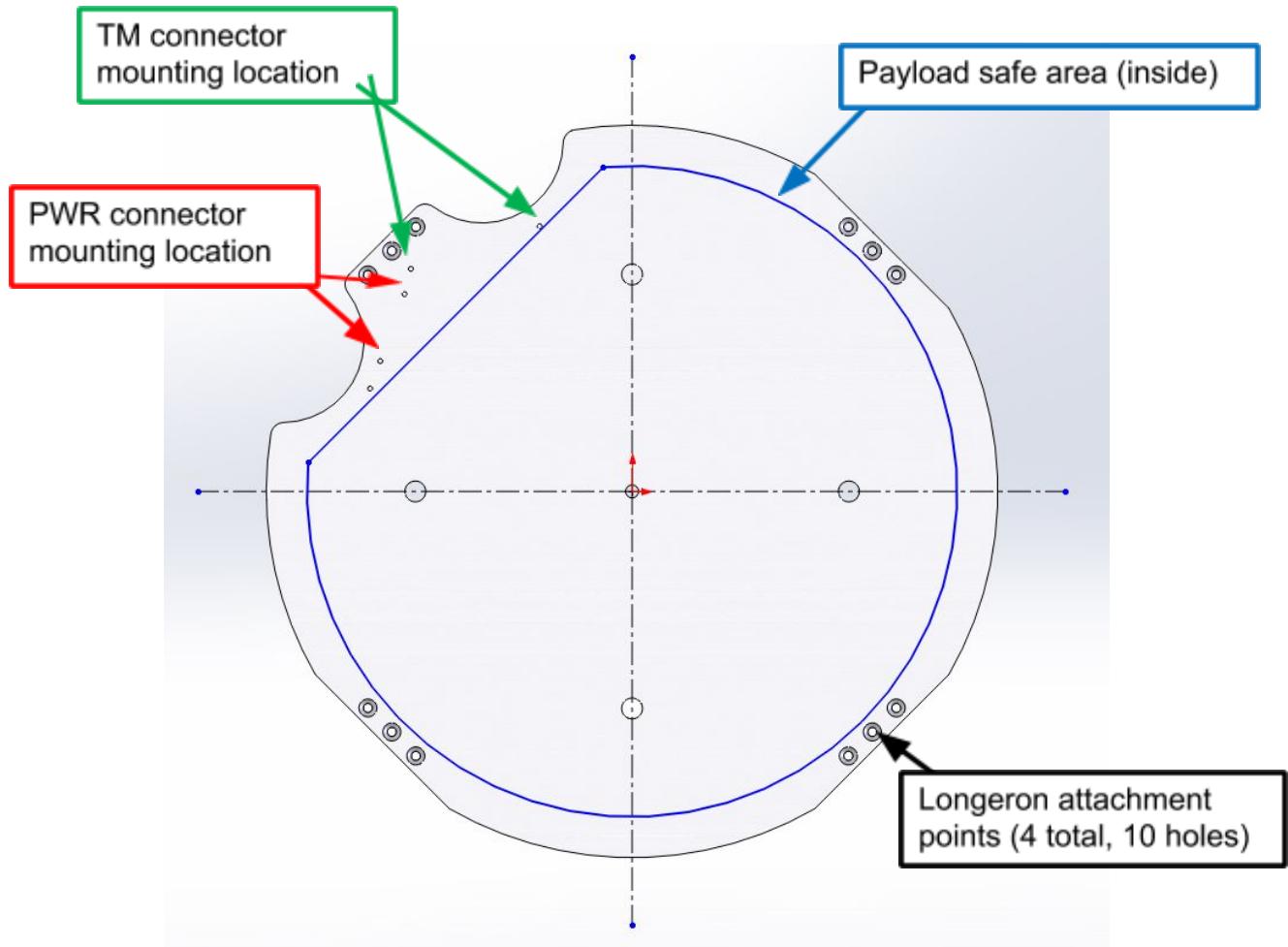
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August	Launch and Recovery
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Note: The official schedule is kept on the RockSat-X website calendar. Please view the schedule section of the website at
<http://spacegrant.colorado.edu/national-programs/rs-x-home>

10.0 APPENDIX A: Mechanical Drawings/Interfaces





6.0 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 payload 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.

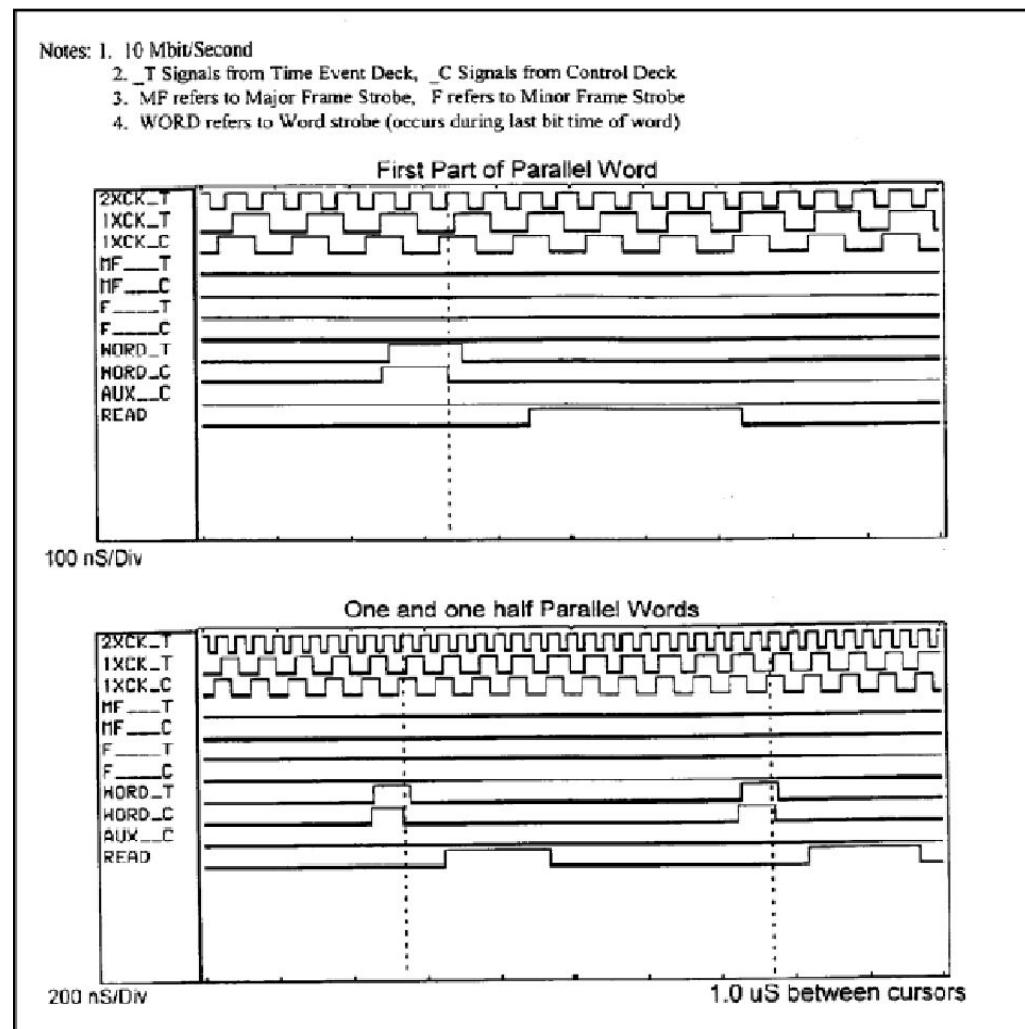
Random Test:

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: $10 \text{ G}_{\text{rms}}$ at $0.051 \text{ G}^2/\text{Hz}$ from 20-2000 Hz

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

7.0 APPENDIX C: Supplemental Telemetry Specifics



8.0 APPENDIX D: Summary of June Testing Operations

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