OmniTeq

16U Equalizer / Modularity Space Interface Control Agreement

OmniTeq
2233 Yale Street, Suite 140
Houston, TX 77008

www.omniteq.com

Prepared By:

Dana Gomez
Mission Management/Quality, OmniTeq

Dana L. Gomez

Approval:

Michael D. Johnson
Chief Scientist, OmniTeq

Change Log

Date	Revision	Author	Changes
10/31/2021	0	Dana Gomez	Baseline release

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1 Introduction

1.1 Scope

This Interface Control Agreement (ICA) is the technical interface agreement between the Customer (Modularity Space) and the Equalizer Service Provider (OmniTeq) for the accommodation and deployment of the Modularity Space 16U CubeSat. The ICA defines the physical, functional, software and environmental interfaces in compliance with the Equalizer Interface Control Document (ICD).

This ICA is applicable to all phases of the Rideshare mission from preparatory activities on-ground/mission integration and operation through point of separation from the Equalizer.

1.2 Configuration Control and Change Procedure

This document is maintained under configuration control by OmniTeq. All changes to this document are to be approved jointly by the parties involved.

2 Acronyms, Definitions and Applicable Documents

Table 2-1: Acronyms

Acronym	Definition
16U	16 Unit
BOM	Bill of Materials
CG	Center of Gravity
EMI	Electromagnetic Interference
FCC	Federal Communications Commission
ICA	Interface Control Agreement
ICD	Interface Control Document
ITU	International Telecommunication Union
LEO	Low Earth Orbit
NTIA	National Telecommunications and Information Administration
RBF	Remove Before Flight
RF	Radio Frequency
SSO	Sun-synchronous Orbit

Table 2-2: Applicable Documents

Document # / Release Date	Document Name
07-22-2020	Equalizer Interface Control Document
AFSPCMAN 91-710	Air Force Space Command Range Safety User Requirement Manual
MSFC-SPEC-522	Design Criteria for Controlling Stress Corrosion Cracking

3 Mission and Requirements Description

Specific mission requirements and assumptions are listed below:

- Single mission, one (1) 16U turnkey cubesat deployment
- Scope includes Equalizer Deployer, mission integration and operation through point of separation
- Sun-synchronous Orbit (SSO), Launch Q3 2022 – SpaceX SmallSat Rideshare
- Deployment via Equalizer SmallSat Rideshare via SpaceX at 500-600km
- Customer responsible for satellite design, development, regulatory licensing
- Customer will use Equalizer Deployer flight article for fit check and environmental testing

4 Equalizer Deployment System Overview

The Equalizer deployment system (patent pending) is designed to mount on the SpaceX Falcon 9 Rideshare 24” adapter and deploy cubesats from the mounted deployers. The Equalizer deployment system utilizes the SpaceX Rideshare Program to provide 96U per 24” launch adapter to orbit and is compatible with Modularity Space’s 16U cubesat.

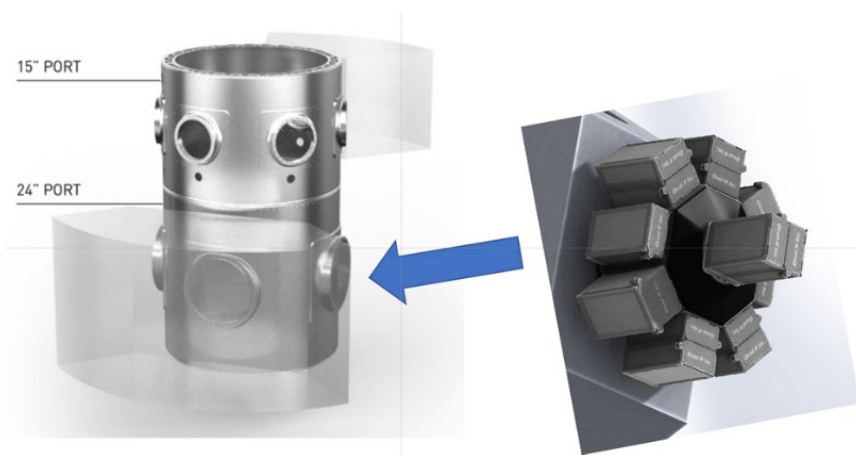


Figure 4-1: Equalizer Deployer Configuration on SpaceX Falcon 9 Rideshare Adapter

The Equalizer deployment system is comprised of the following major components:

1. Up to 96U preloaded deployers including a 16U deployer
2. Preprogrammed control box for deployer selection and control
3. SpaceX Rideshare Adapter structure.

Components are launched via the Falcon 9 and deployed on-orbit. Currently, SpaceX Rideshare missions go to Synchronous Orbit (SSO) and to Low Earth Orbit (LEO) (~190 km/53^o) missions as secondaries on the Starlink Constellation launches, 16U deployer details are shown below in Figure 4-2.

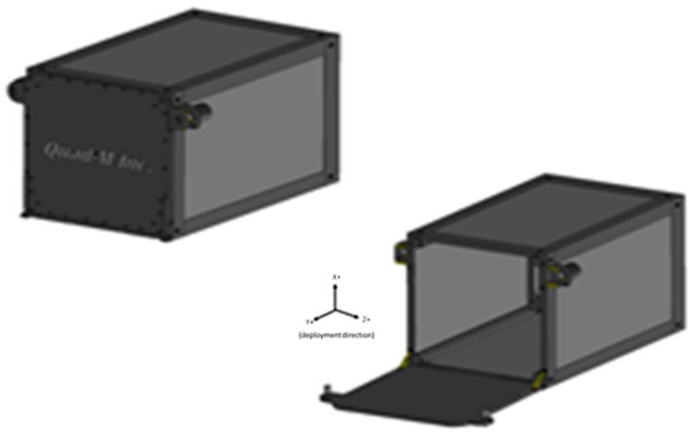


Figure 4-2: 16U Equalizer Deployer Details

The Equalizer Deployer utilizes a resettable shape memory alloy separation nut that can be tested and reset multiple times prior to launch. Equalizer has a separate controller that when commanded by the SpaceX Falcon 9 launch vehicle commences to open the deployer at a preprogrammed rate. The Equalizer assembly is not powered or active until deployment and power is applied through a redundant self-contained battery pack.

5 Payload Mechanical Design / Interfaces

Modularity Space will provide the format (16U rail or 16U tab), length of the satellite, mass, Center of Gravity (CG) location and any deployable appendage dimensions (either constrained by the satellite or constrained by the deployer).

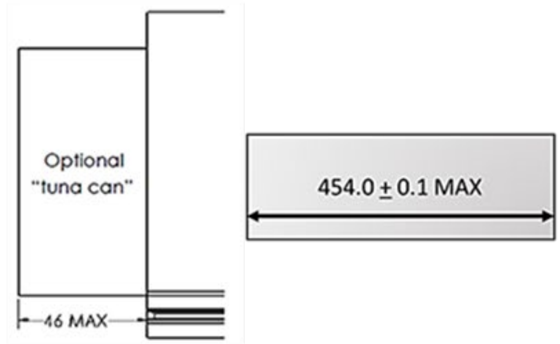
5.1 16U Cubesat CAD Model

Modularity Space will provide a CAD Model of the 16U cubesat for use in the virtual fit check of the satellite in the Equalizer deployer. This can be a stripped down model showing the main body and any deployable appendages (e.g. antennas, solar panels)/ OmniTeq will also need to know inhibit switch throw details (e.g. location of switch(es), amount of travel required for activation, etc.) for the Equalizer deployer tolerance stack-up analysis.

5.2 Payload Dimensions

The Modularity Space 16U CubeSat shall meet the dimensions shown in Figure 5-1 (Rail type with optional 4x “tuna cans”). The maximum dimensions referenced apply after plating on all surfaces. The maximum dimensions referenced are the satellite’s dynamic envelope and shall include all load cases (vibration, thermal, acoustic, etc.).

Cubesat Length, Rail to Rail Maximum Dimensions [mm]



16U Cubesat with 4x optional "tuna cans"

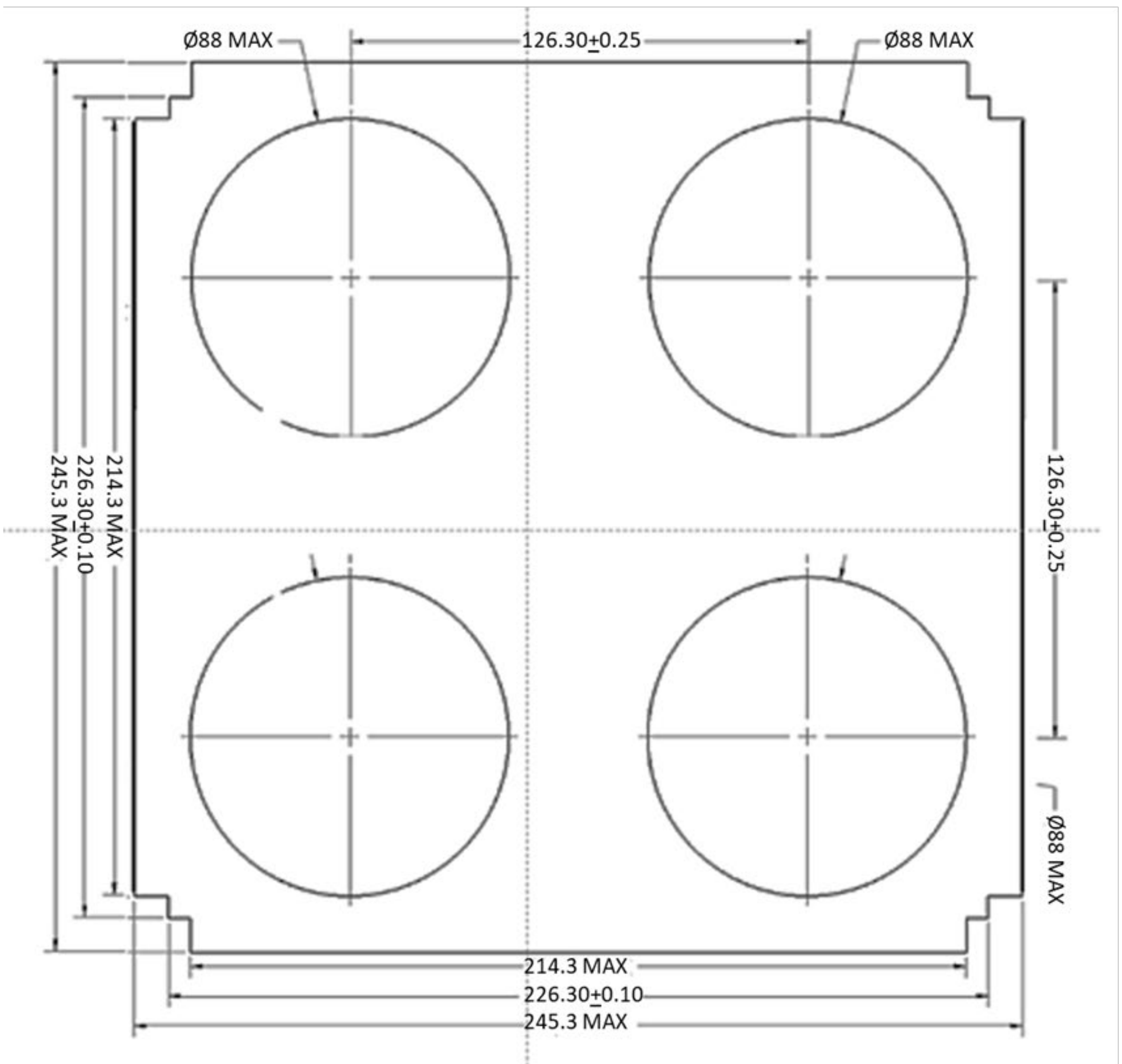


Figure 5-1: 16U Cubesat Dimensions – Rail Type

5.3 Payload Mass

The Modularity Space 16U Cubesat maximum allowable mass is 29.0 kg. NOTE: the typical mass of a 16U cubesat is 16.0 kg.

5.4 Safe/Arm Plug

If necessary, shall reside in specified access zones.

5.5 Deployables / Appendages

All deployables shall be constrained during deployment via burn wires or other mechanisms. No appendages or any part of the satellite shall contact the walls of the deployer.

5.6 Debris

No generation of debris shall inhibit separation.

5.7 Plungers

Rail end separation plungers must be removed before integration with the deployer.

5.8 Materials

Stress corrosion resistant materials used from MSFC-SPEC-522 are preferred. Table II materials will be reviewed by OmniTeq and Table III materials shall be avoided.

A bill of materials (BOM) must be provided to OmniTeq for verification.

5.9 Deployer/Cubesat Interface

Once the satellite is integrated, there will be no gap at the Y+ end of the satellite; the deployer pusher plate will push the satellite to the door and the pusher plate will be secured with a locking jam nut. The satellite will be contacted via rails in the deployer as shown in Figure 5-2.

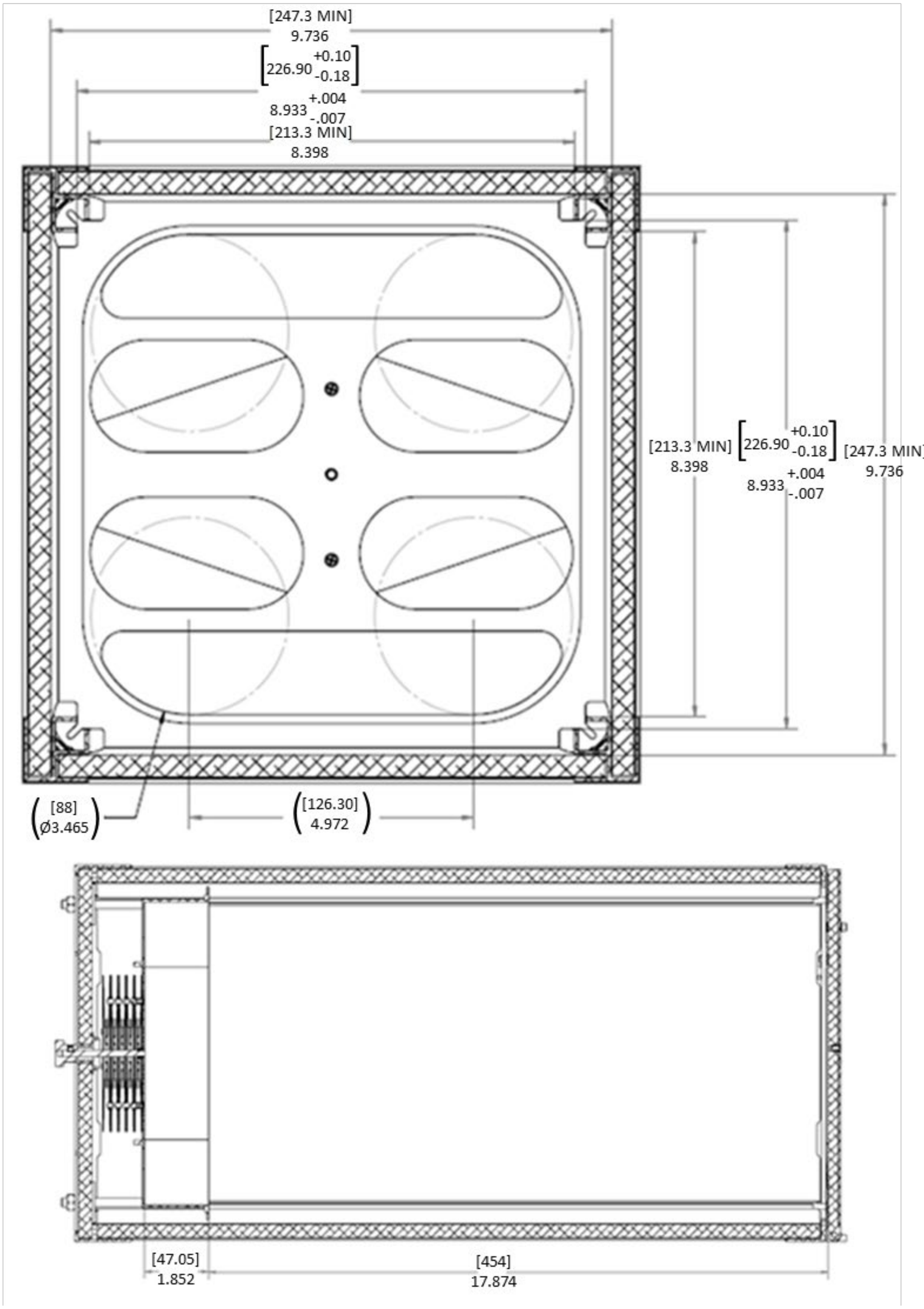


Figure 5-2: 16U Rail Contact and fit (max volume shown – dimensions are in inches)

6 Payload Electrical Design / Interfaces

6.1 Electrical System Design and Inhibits

All electrical power shall be internal to the satellite. The satellite system must be safe without electrical services. The satellite system shall adhere to the following requirements:

1. Satellite operations shall not begin until a minimum of 30 minutes after deployment. Only an onboard timer system may be operable during the 30-minute post-deploy timeframe. Any timer operation initiated by the satellite inhibits must automatically reset should inadvertent separation switch operation occur.
2. If activation of the satellite creates a hazard (e.g. activation of a powerful radio transmitter, activation of propulsion system, activation of a non-eye safe laser, etc.) the Satellite Electrical system design shall incorporate a minimum of three (3) inhibit switches actuated by physical deployment switches as shown in Figure 6-1. If activation of the Satellite does not present a hazard to ground crew or hardware one or two inhibit switches are satisfactory.
3. The Satellite Electrical system design shall not permit the battery charging circuit to energize the satellite systems (load), including flight computer. See Figure 6-1. This restriction applies to all charging methods.
4. Remove Before Flight (RBF) pins are required. Arming switch or captive jumpers may be an acceptable alternative – contact OmniTeq.
5. The RBF pin shall prevent any power from any source operating any satellite functions except for pre-integration battery charging.
6. RBF pins must be capable of remaining in place during integration with the deployer.
7. All RBF pins, switches, or jumpers utilized as primary electrical system and RBF inhibits must be accessible for removal just prior to closure of the deployer.

6.2 Electrical Schematic of Inhibits

Modularity Space shall provide an Electrical Inhibit Schematic and Plan showing how the satellite (battery) power is isolated when in the deployer. See example in Figure 6-1.

Electrical Subsystem Block Diagram (note: RBF pins switches not shown)

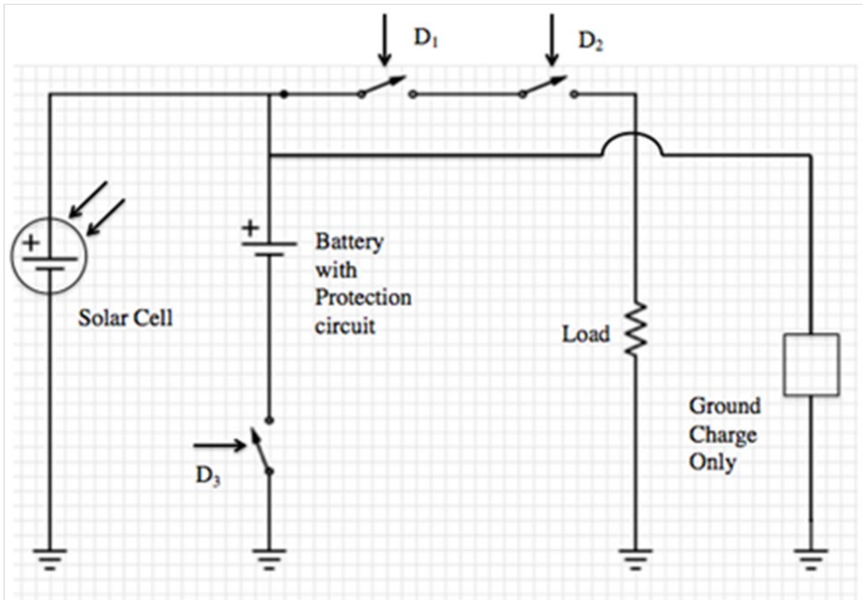


Figure 6-1: Electrical Inhibit Schematic (example)

6.3 Inhibit / Activation Switches

1. The Modularity Space 16U Cubesat shall have a minimum of (1) deployment switch that corresponds to the independent electrical inhibits on the main power system.
2. The deployment switch(es) that utilize the Deployer rails in the +/-X and Z axes as the mechanical interface shall have a minimum actuation travel of 1 mm to accommodate for design tolerance extremes of the cubesat and deployer rails. NOTE: Roller/lever switches along the rails are less reliable and subject to rigging issues and damage during satellite handling.
3. The CubeSat deployment switch(es) shall reset the payload to the pre-launch state if cycled at any time within the first 30 minutes of the switch(es) closing (including but not limited to radio frequency transmission and deployable system timers).
4. The CubeSat deployment switch(es) shall be captive.
5. For plunger switches used in the +/-Y axis or roller switches used in the +/-X and Z axes, the total force of the switches shall not exceed 18N.
6. The CubeSat deployment switch(es) that utilize the Deployer rails in the +/-X and Z axes as the mechanical interface shall maintain a minimum of 75% (ratio of roller/slider-width to guiderail width) contact.

6.4 Batteries

Battery requirements for the Equalizer system are derived from the Air Force Space Command Range Safety User Requirement Manual (AFSPCMAN 91-710) as tailored for the Mission. The required provisions encompass hazard controls, design evaluation, and verification. Evaluation of the battery system must be complete prior to certification for flight and ground operations. To support this objective, information on the battery system must be provided to OmniTeq as soon as possible. Information required includes the cell manufacturer, cell part numbers, quantity of cells and how they are connected (series/parallel). Cell charging while on the launch vehicle is prohibited.

6.5 Radio Details

6.5.1 Radio Transmitter/Receiver

For each radio transmitter and receiver specify the upper and lower transmission frequencies, the power output (in Watts) of each transmitter, the type of transmitter antenna used and the gain of each transmitter antenna.

The following information shall be completed/provided for the RF Transmitters to evaluate any potential hazards:

Table 6-1: RF Transmitter Details

Transmitter Specification	
Manufacturer	
Model	
Maximum power output to antenna [W]	
Maximum transmitter field strength (volts/meter); assume 1 meter from the source and transmitter radiating with deployed antenna	
TX Manufacturer	
TX Model No	
TX Antenna Manufacturer:	
Antenna Gain: [dBi]	
Frequency Upper [MHz]	
Frequency lower [MHz]	
Circuit Loss: [dB]	
Antenna Type: Other, dipole, helix, horn, loop, monopole, patch, phased array, reflector, slot, spiral	
Antenna Polarization: [Other, Horizontal, Left Handed Elliptical, Right Handed Elliptical, Vertical	
Antenna Axial Ratio: [dB]	

Antenna location (with respect to CubeSat body)	
Emission Bandwidth: -3 db [MHz], -20 db [MHz], -40 db [MHz], -60 db [MHz]	
Data Rate (Digital) or Bandwidth (Analog): [Mbps] or [MHz] Modulation Scheme: Other, AM, ASK, BPSK, FM, FSK, GMSK, MSK, QAM, QPSK	
Receiver Specification	
Frequency Upper [MHz]	
Frequency lower [MHz]	
RX Model No	
RX Antenna Manufacturer	
Circuit Loss: [dB]	
Antenna Type: Other, dipole, helix, horn, loop, monopole, patch, phased array, reflector, slot, spiral	
Antenna Gain: [dBi]	
Antenna Polarization: [Other, Horizontal, Left Handed Elliptical, Right Handed Elliptical, Vertical]	
Antenna Axial Ratio: [dB]	
Receiver Noise Figure: [dB]	
Antenna Noise Temperature: [dBK]	
RF Selectivity Bandwidth: -3 db [MHz], -20 db [MHz], -40 db [MHz], -60 db [MHz]	
Antenna location (with respect to CubeSat body)	

6.5.2 Radio Frequency License Application

Modularity Space should provide the country of origin radio license application (FCC if in the United States), or NTIA application and the ITU notification for each on-board radio and ground station planned to be used. Preliminary submittal license application will be acceptable, followed by the final approval prior to satellite turnover. No satellites will be loaded on the launch vehicle without appropriate licensing.

6.6 Electromagnetic Interference

The Modularity Space 16U cubesat may be exposed to the following EMI environment on the SpaceX Falcon 9:

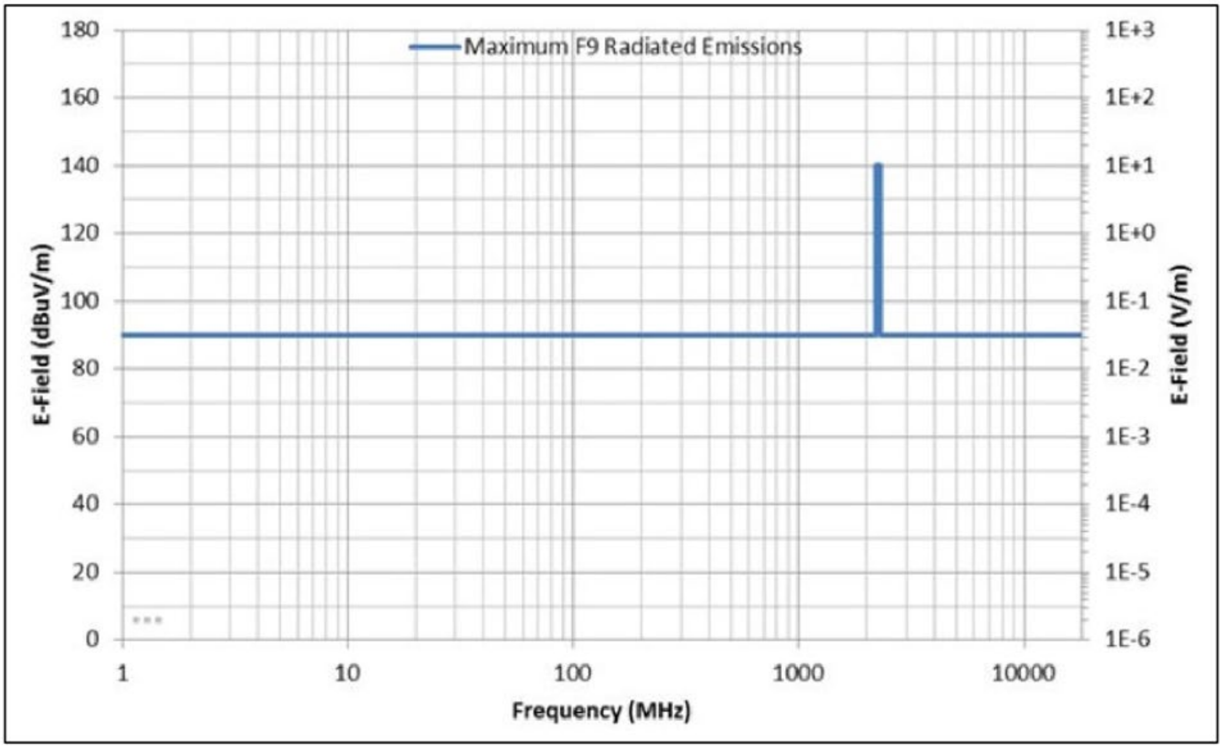


Figure 3-5: Launch Vehicle Radiated Emissions

Table 3-8: Launch Vehicle Radiated Emissions

Frequency Range (MHz)	E Field Limit (dBμV/m)	Launch Vehicle Transmit System
1.00 – 2200.0	90	
2200.0 – 2300.0	140	S-band telemetry and video
2300.0 – 18000.0	90	

Figure 6-2: Launch Vehicle RF Emissions (courtesy of SpaceX)

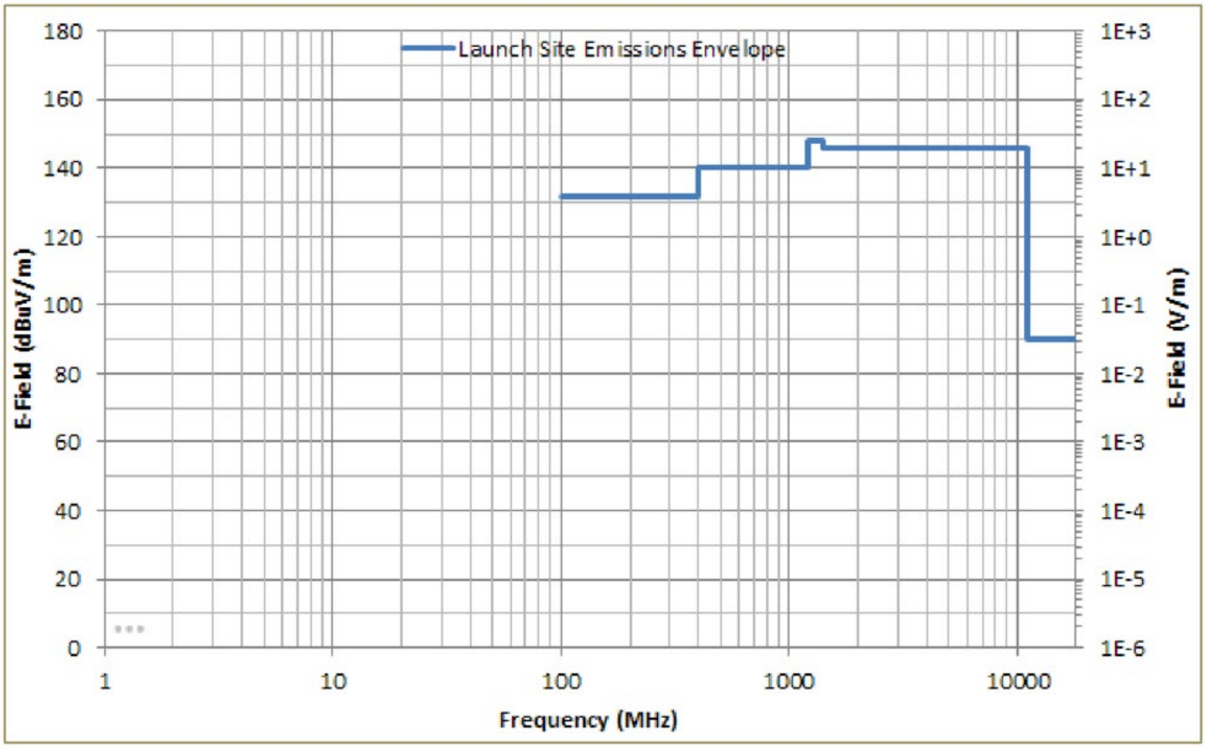


Figure 3-6: Launch Site Emissions

Table 3-9: Launch Site Emissions

Frequency Range (MHz)	E Field Limit (dBµV/m)
100 – 400	132
400 – 1200	140
1200 – 1400	148
1400 – 11000	146
11000 – 18000	90

Figure 6-3: Launch Site RF Emissions (courtesy of SpaceX)

7 Propulsion Systems

7.1 Propulsion System

If the 16U satellite includes a propulsion system, Modularity Space should provide a schematic diagram of the propulsion system as well as the location of the satellite thruster(s). Other details such as propellant type, inhibit scheme, commanding scheme, operations concept (detailed enough to gather propulsion plan), magnitude of thrust per thrust event, total delta V, etc. will be required.

If the Modularity Space 16U cubesat has a propulsion system, it will need to be assessed for hazard potential. OmniTeq will assist in the identification of hazards. Mechanical hazards may be related to pressure containment, flow containment, leakage, etc. Systems may also have hazard potential if inadvertent operation of the propulsion system could cause a collision hazard. Depending on hazard potential, both mechanical and electrical fault tolerance may be required.

Systems with toxic or explosive propellants must be coordinated with OmniTeq.

7.2 Pressurized Systems / Pressure Vessels

If the 16U cubesat includes a pressurized system or pressure vessel, Modularity Space should provide a schematic diagram of the system and details including maximum operating pressure, factors of safety, rated burst pressure, materials of construction and materials compatibility assessment as well as proof testing performed.

Pressure vessels (i.e. any vessel able to hold more than 2 atm of pressure at any time in its operation) must be coordinated with OmniTeq. Providers should expect to provide documentation with respect to the materials used, tank history (including cycles and life time assessment) and control measure to assure tank integrity (damage control plan), testing performed, fracture control measures planned, inspection process and methods, etc. wherever hazard potential is present. All pressure vessels shall be DOT certified or have a DOT issued waiver for transportation across the U.S. Use of non-DOT certified pressure vessels generally is not be permitted. Exceptions must be coordinated with OmniTeq. Systems will have to demonstrate via test that required factors of safety are present for tanks, lines and fittings that can be exposed to maximum design pressure. Pressure vessels and components procured from third party vendors must have proper certification records or the customer must develop the appropriate records to assure that the systems are safe for satellite use.

8 Environments

8.1 Ground Handling and Transportation Loads

Satellite safety-critical structures shall (and other satellite structures should) provide positive margins of safety when exposed to these accelerations.

Table 8-1: Ground Handling and Transportation Load Factors

	Nx (g)	Ny (g)	Nz (g)	Rx (rad/sec^2)	Ry (rad/sec^2)	Rz (rad/sec^2)
I (1,2)	+/- 5.0	+/- 3.5	+2.0/ -3.5	N/A	N/A	N/A
S (1,2)	+/-2.0	+/- 2.0	+2.0/ -3.5	N/A	N/A	N/A

Notes:

1. The reference frame for the ground handling and transportation load factors with respect to the directions of motion is as follows:

   X: Longitudinal direction along axis of motion.

Y: Y axis is perpendicular to the x and z axes and completes the right-handed coordinate system.

Z Z axis is perpendicular to the x and y axis. Positive direction is vertically upward. Gravity (g) is acting in the z axis in the negative direction.

2. (I) indicates that the loads occur independently in the three directions (except for gravity). (S) indicates the loads occur simultaneously.
3. These levels envelope the maximum ground handling and transportation loads.

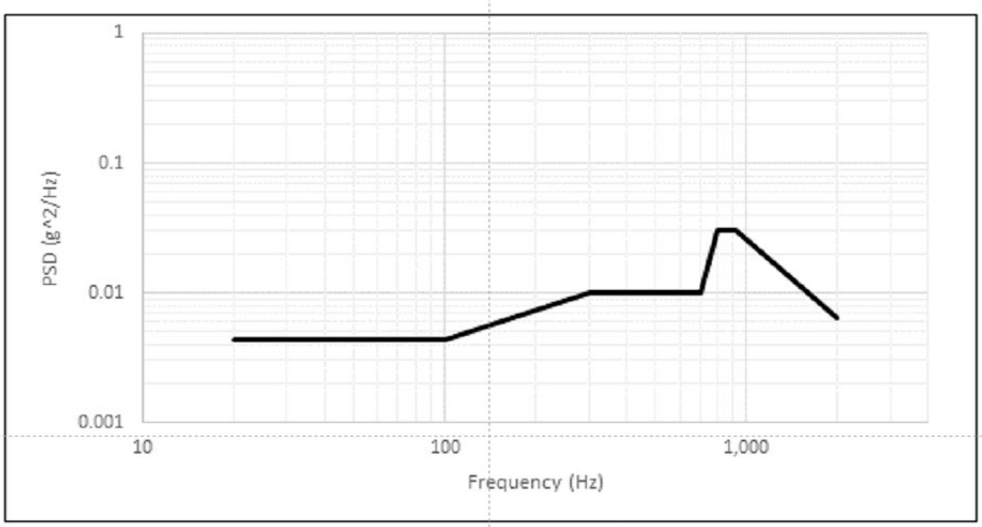
8.2 Acceleration Loads

Satellite safety-critical structures shall (and other satellite structures should) provide positive margins of safety when exposed to 9G's in all axes.

8.3 Random Vibration Environment

See Table 9-1 (courtesy of SpaceX) for the potential random vibration environments experienced on the SpaceX Falcon 9.

Table 8-2: Random Vibration Environments



Random Vibration MPE

Random Vibration MPE

Frequency (Hz)	Random Vibration MPE (P95/50), All Axes
20	0.0044
100	0.0044
300	0.01
700	0.01
800	0.03
925	0.03
2000	0.00644
GRMS	5.13

Table 2.4-3
Generalized Random Vibration Test Levels
Components (ELV)
22.7-kg (50-lb) or less

Frequency (Hz)	ASD Level (g^2/Hz)	
	Qualification	Acceptance
20	0.026	0.013
20-50	+6 dB/oct	+6 dB/oct
50-800	0.16	0.08
800-2000	-6 dB/oct	-6 dB/oct
2000	0.026	0.013
Overall	14.1 G_{rms}	10.0 G_{rms}

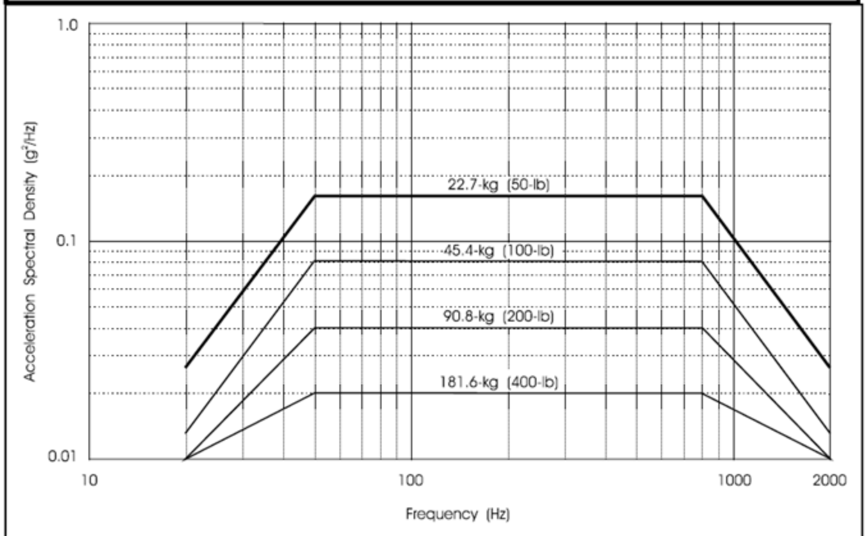
The acceleration spectral density level may be reduced for components weighing more than 22.7-kg (50 lb) according to:

	Weight in kg	Weight in lb	
dB reduction	= 10 log(W/22.7)	10 log(W/50)	
$ASD_{(50\text{-}800\ Hz)}$	= 0.16•(22.7/W)	0.16•(50/W)	for protoflight
$ASD_{(50\text{-}800\ Hz)}$	= 0.08•(22.7/W)	0.08•(50/W)	for acceptance

Where W = component weight.

The slopes shall be maintained at + and - 6dB/oct for components weighing up to 59-kg (130-lb). Above that weight, the slopes shall be adjusted to maintain an ASD level of 0.01 g^2/Hz at 20 and 2000 Hz.

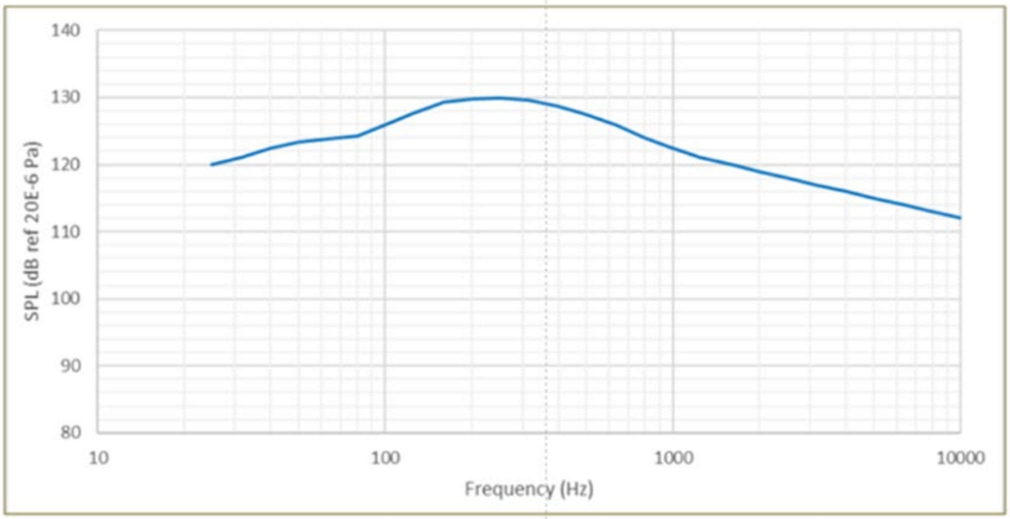
For components weighing over 182-kg (400-lb), the test specification will be maintained at the level for 182-kg (400 pounds).



8.4 Acoustic Environment

See Table 8-3 (courtesy of SpaceX) for the potential acoustic environments experienced on the SpaceX Falcon 9.

Table 8-3: Acoustic Environments



Rideshare Payload Maximum Predicted Acoustic Environment (Third Octave)

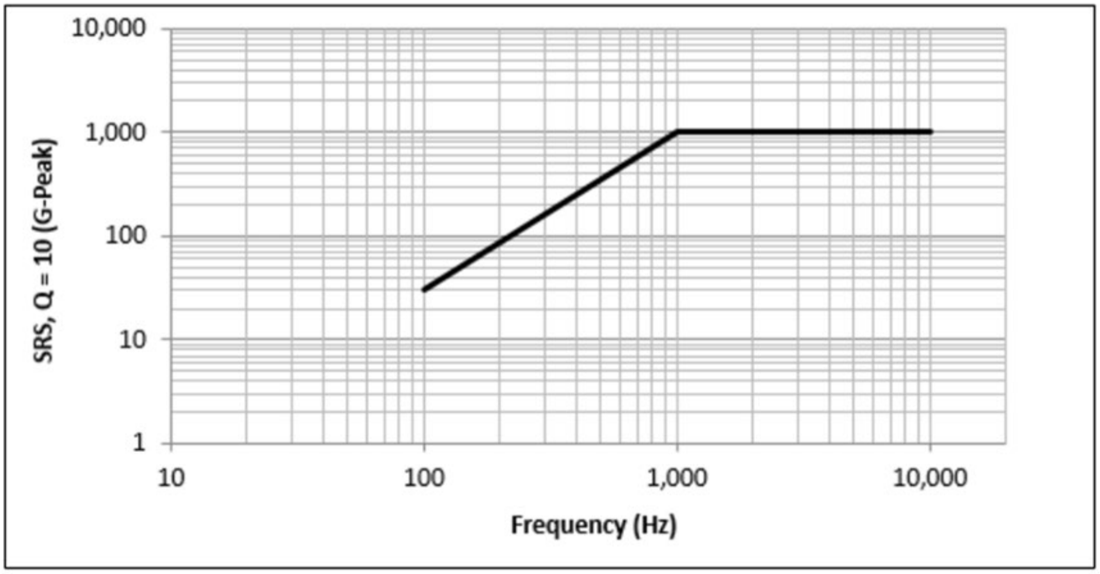
Rideshare Payload Maximum Predicted Acoustic Environment (Third Octave)

Frequency (Hz)	Acoustic MPE (P95/50, Space Average, 60% Fill, 4.1 in. Min Clearance)
25	120.0
31.5	121.0
40	122.5
50	123.4
63	123.8
80	124.2
100	125.9
125	127.7
160	129.3
200	129.8
250	129.9
315	129.6
400	128.7
500	127.4
630	126.0
800	124.0
1000	122.5
1250	121.0
1600	120.0
2000	119.0
2500	118.0
3150	117.0
4000	116.0
5000	115.0
6300	114.0
8000	113.0
10000	112.0
OASPL (dB)	**139.3**

8.5 Shock Environment

See Table 8-4 (courtesy of SpaceX) for the potential shock environments experienced on the SpaceX Falcon 9.

Table 8-4: Shock Environment



Payload Mechanical Interface Shock Induced by Launch Vehicle and Co-Payload(s)

Payload Mechanical Interface Shock Induced by Launch Vehicle and Co-Payload(s)

Frequency (Hz)	SRS (g)
100	30
1000	1000
10000	1000

8.6 Pressure Loading

Integrated end items must maintain positive margins of safety when pressure effects (operational and pressurization/depressurization environments).

Integrated end items shall maintain positive margins of safety and not induce a hazard during or after exposure to a maximum pressure environment of 129.3 kPa (18.8 psia) and a minimum pressure environment of 0.0 psia. These values are an envelope of the launch vehicle pressure design environments.

Integrated end items shall maintain positive margins of safety when exposed to a depressurization rate of 13.3 kPa/second (116 psi/minute).

8.7 Temperature

Integrated end items shall meet all performance and safety requirements after being exposed to temperatures ranging from 0°C to +50°C (32°F to 122°F). This includes the Equalizer external environment when mounted on the Falcon 9 Launch Vehicle.

8.8 Humidity

Integrated end items shall operate properly after being exposed to a ground processing and launch atmosphere ranging from -34°C (-29.2°F) dewpoint to 90% relative humidity (at 20°C (68°F)).

9 Equalizer Integration Schedule

Table 5-1 provides the Equalizer/16U Modularity Space Integration Schedule.

Table 9-1: Equalizer/16U Modularity Space Integration Schedule

Milestone/Activity	Responsible Party	Launch-minus Dates (months)
Regulatory Compliance Start (Spectrum Coordination License, Remote Sensing License)	Modularity Space	L-14
Feasibility Study/Contract Signing	OmniTeq/Modularity Space	L-9
OmniTeq/Modularity Space Data Call Phase I	Modularity Space	L-8.75
OmniTeq Safety Initial Assessment Complete	OmniTeq	L-8.25
OmniTeq/Modularity Space Data Call Phase II	Modularity Space	L-7
Safety/Mass Properties Data Package Submittal to SpaceX	OmniTeq	L-6
Safety Review	OmniTeq	L-5
Satellite-Separation System Fit Check/Vibration Testing	Modularity Space	L-4
OmniTeq/Customer Data Call Phase III	Modularity Space	L-3
Final SpaceX Regulatory Data Package Submittal	OmniTeq	L-2
Nominal Satellite Delivery to OmniTeq	Modularity Space	L-1.5
OmniTeq Delivery to SpaceX	OmniTeq	L-1