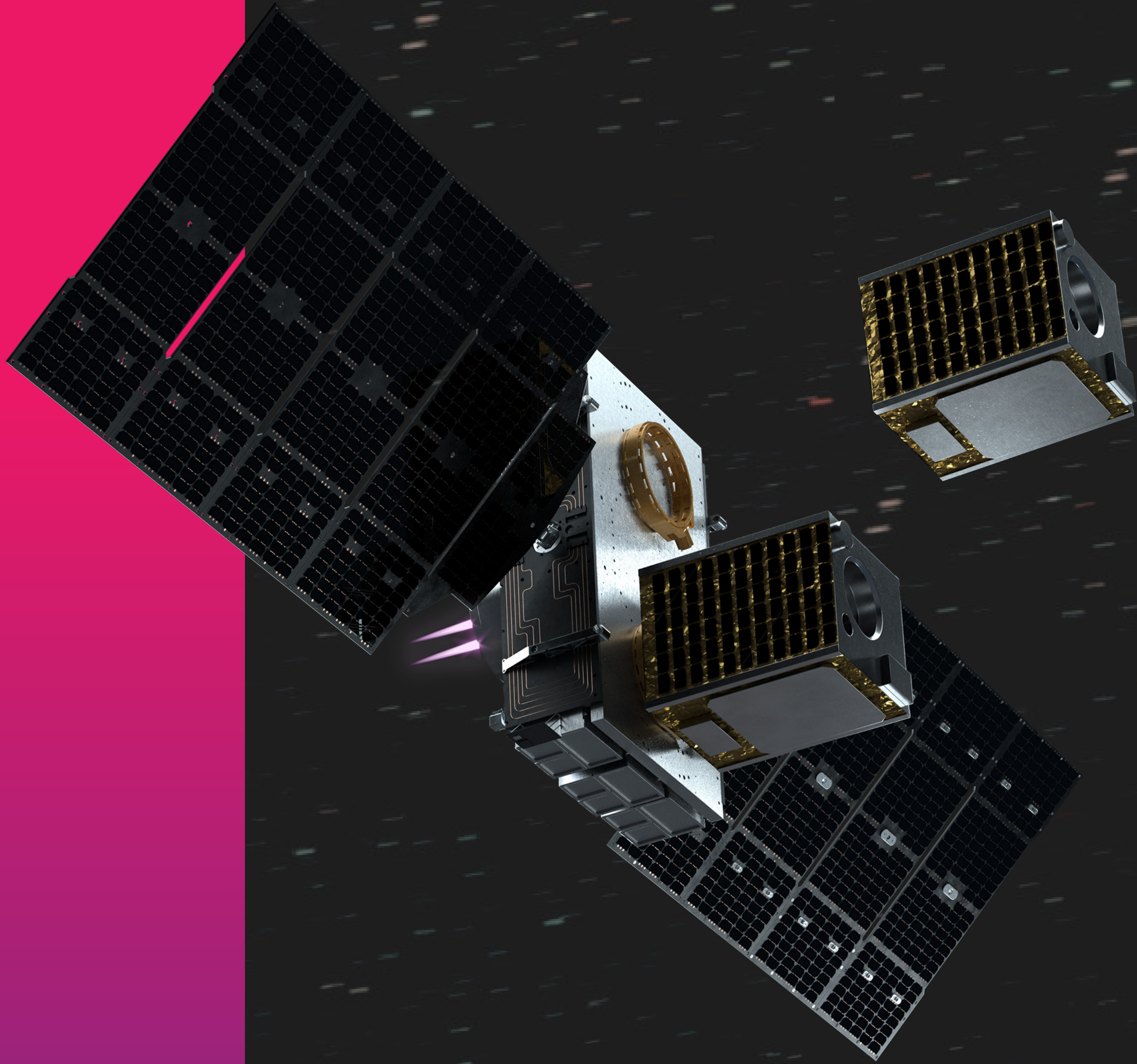

MOMENTUS

MOMENTUS™
USER'S GUIDE

YOUR CONNECTING FLIGHT IN SPACE

VERSION 4 - FEBRUARY 2023

NOT EXPORT CONTROLLED
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THIS DOCUMENT CONTAINS NO EXPORT CONTROLLED TECHNICAL DATA.

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ACRONYMS

A/R	As Required
CAD	Computer Aided Design
EGSE	Electrical Ground Segment Equipment
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EMISM	Electromagnetic Interference Safety Margin
GEO	Geosynchronous Equatorial Orbit
GSE	Ground Support Equipment
GTO	Geosynchronous Transfer Orbit
ICD	Interface Control Document
LEO	Low Earth Orbit
LTAN	Local Time of Ascending Node
LTDN	Local Time of Descending Node
LV	Launch Vehicle
LSP	Launch Service Provider
MEO	Medium Earth Orbit
MEOP	Maximum Expected Operating Pressure
MiB	Mebibyte (2^{20} or 1,048,576 bytes)
MPE	Maximum Predicted Environment
MPT	Maximum Predicted Temperature
N/A	Not Applicable
OSV	Orbital Service Vehicle
PSD	Power Spectral Density
RAAN	Right Ascension of the Ascending Node
RCS	Reaction Control System
RF	Radio Frequency
SRS	Shock Response Spectrum
SSO	Sun-Synchronous Orbit

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REFERENCE DOCUMENTS

DOCUMENT TITLE	DATE	REVISION
Cal Poly Cubesat Design Standard (CDS)	07/2020	14
Range Safety User Requirements Manual Launch Vehicles, Payloads, and Ground Support Systems Requirements, Volume 3 (AFSPCMAN 91-710)	07/01/2004 05/19/2019	-- --
United Nations Transportation of Dangerous Goods Manual of Tests and Criteria, Section 38.3	2019	7
17050-1 Conformity Assessment — Supplier’s Declaration of Conformity — Part 1: General Requirements	2004	--
17050-1 Conformity Assessment — Supplier's Declaration of Conformity — Part 2: Supporting Documentation	2004	--
2000785H Motorized Lightband Mk II User Manual	06/07/2022	H

VERSION HISTORY

VERSION	DATE	UPDATES
1	Dec 2020	Initial release
2	May 2021	
3	Jun 2021	
4	Feb 2023	SECTION 2 • Merged with Section 3 and renumbered Sections SECTION 3 (OLD) • Updated Table 3-2 Offerings SECTION 4 (OLD) • Clarified definition of fully containerized payload • Added information on ground and mission interfaces • Added general design requirements SECTION 5 (OLD) • Updated flight environments • Added test requirements • Updated launch site and launch vehicle radiation emission levels • Updated non-containerized and containerized payload test requirements APPENDICES • APPENDIX A - Updated responsibilities and timelines • APPENDIX F - Removed

SECTION 1
INTRODUCTION

The Momentus User's Guide (MUG) is intended to help customers understand Momentus' standard services and the Customer requirements to utilize these services. For inquiries that fall outside the standard offerings, please contact Momentus.

Momentus offers on-orbit infrastructure services that provide increased access to standard and tailored orbits. Incorporated in 2017, the company is creating the first hub and spoke model by offering last-mile delivery and hosted payload services in partnership with leading launch providers on large and mid-size rockets. Momentus builds and operates orbital service vehicles (OSVs) that carry customer payloads between orbits using a water-based, microwave electrothermal propulsion system.

Momentus reserves the right to update this guide as service capabilities are improved and expanded.

Contact Momentus at sales@momentus.space for pricing information.

SECTION 2
SERVICES

The Momentus OSV has space for multiple payloads from different customers on a single mission. Momentus aggregates the customers for a given mission and then optimizes the configuration to meet each customer's needs. Detailed mission requirements and interfaces (i.e., location, footprint, mass, power, data, pointing, etc.) are defined in a payload Interface Control Document (ICD) prepared by Momentus with the customer. Customers using the standard offerings are afforded easy access to space at reduced prices. The vehicle also allows tailoring for specific customer solutions beyond these standard offerings. For example, the customer may purchase and combine several "blocks" of standard offering capabilities into one service to support its payload or use the entire OSV as a dedicated vehicle and access the maximum capabilities of the vehicle.

Momentus offers two distinct services: Delivery **FIGURE 2-1** and Hosted **FIGURE 2-2**. Delivery provides point-to-point transportation and deployment of the Customer payload in the desired orbit. Refer to **TABLE 2-1** for Delivery service capabilities. Hosted service provides orbit transfer and maintenance, attitude control, and power and communications interfaces to the OSV for telemetry, commanding, and downlinking of payload data for the full duration of the Customer mission. Refer to **TABLE 2-2** for Hosted service capabilities. Custom power & data options will be assessed upon request. Accessible orbits for Hosted payloads are identical to those given in **TABLE 2-1** for Delivery service.

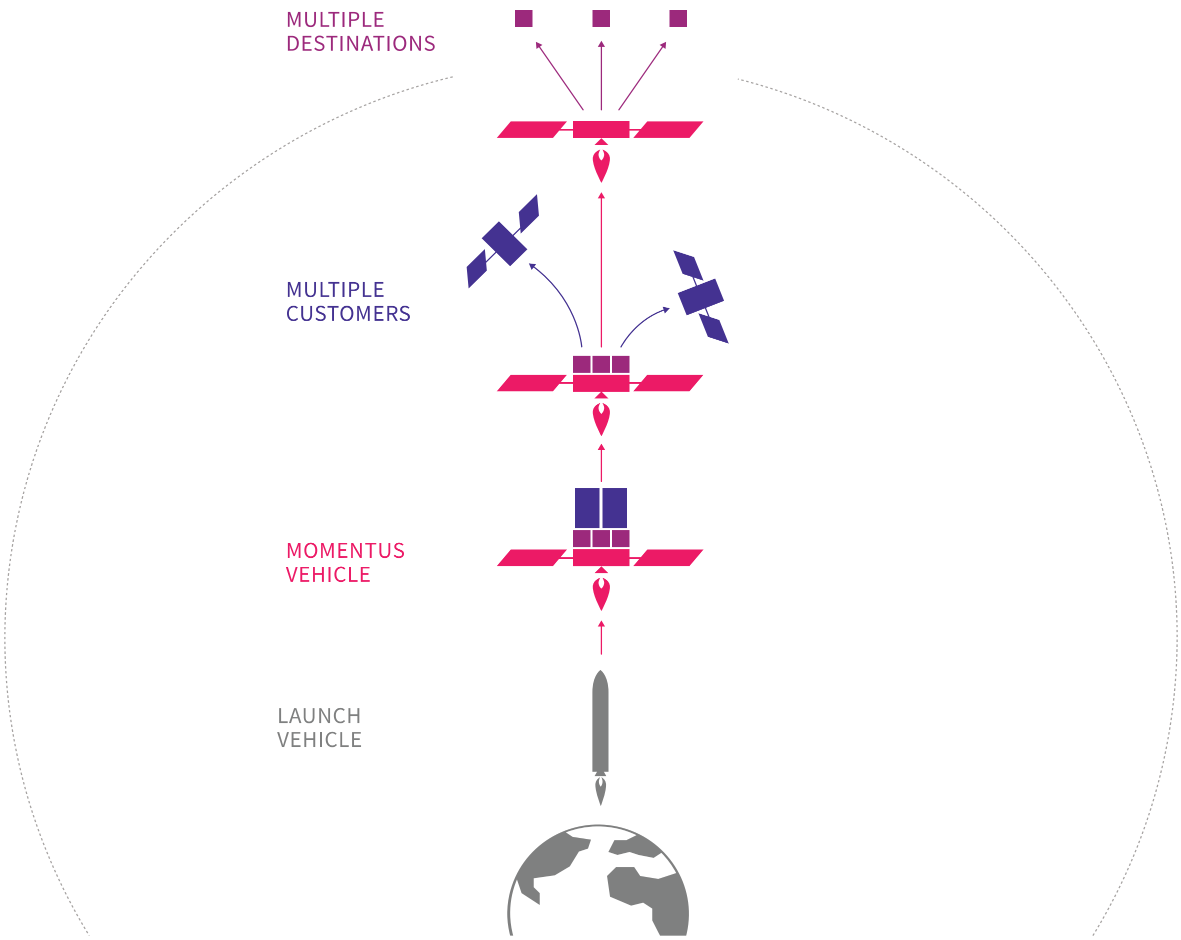

FIGURE 2-1 DELIVERY SERVICE

TABLE 2-1 DELIVERY SERVICE CAPABILITIES

INSERTION PARAMETERS				OSV DELIVERY CAPABILITIES		
ORBITS		**STARTING INCLINATION (DEG)**	**STARTING ALTITUDE (KM)**	**ALTITUDE RAISE (KM)**	**INCLINATION CHANGE (DEG)**	**LTDN & RAAN SHIFT**
Low Earth Orbit[1] (LEO)	Sun-Synchronous (SSO)	97.5 ± 0.5	>250	Up to 2000	3 - 7[2]	LTDN: ± 3.0 hrs
	Mid-Inclination	53 ± 2.0				RAAN: ± 45 deg
	Low-Inclination	25.6 - 28.5				
Geosynchronous Transfer Orbit (GTO)		27.0 - 28.5	185 - 400 x 35,786	Contact Momentus for more information about delivery to GEO/ LLO.		

1. Additional inclinations are available upon request for LEO missions.
2. Maximum inclination change capability depends on starting altitude and payload mass.

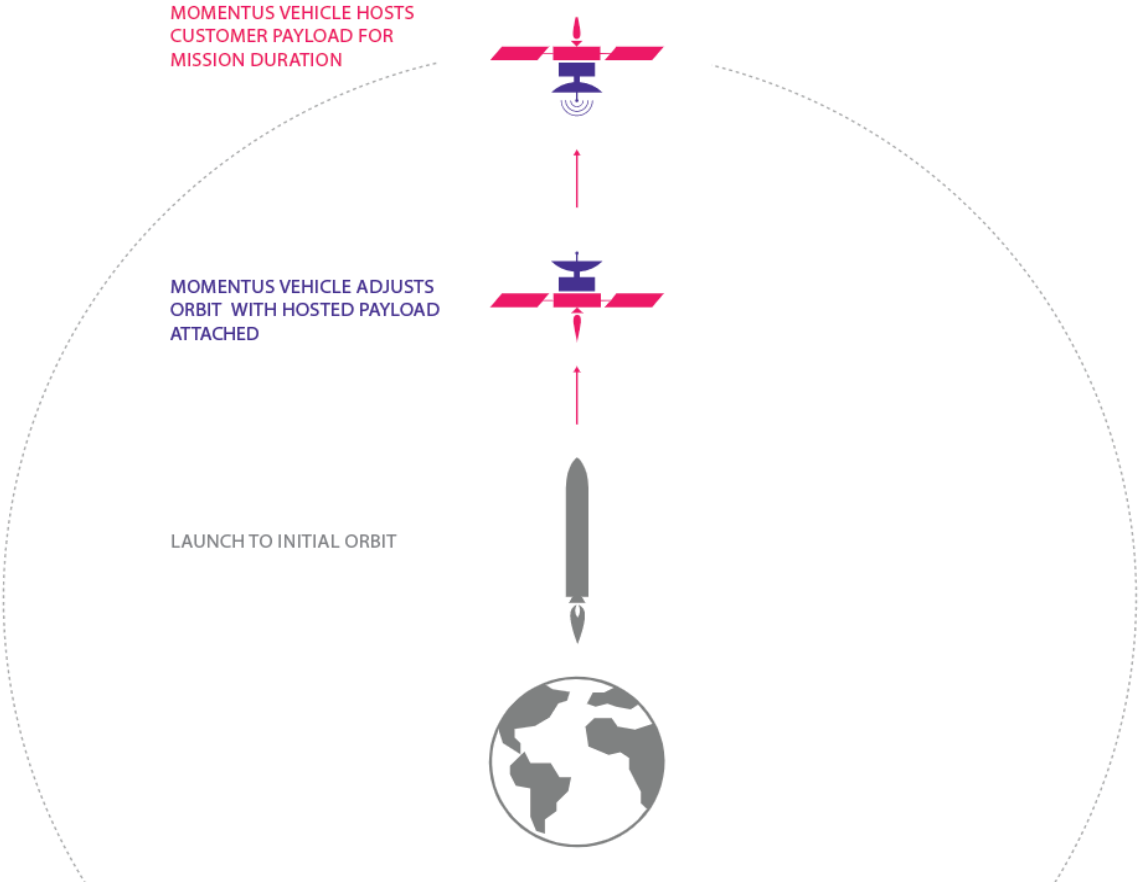

FIGURE 2-2 HOSTED SERVICE

TABLE 2-2 HOSTED SERVICE POWER & DATA

POWER	STANDARD	MAXIMUM
Peak Current	2.5 A	4.5 A
Orbit Average Power	25 W	125 W regulated 225 W unregulated
Voltage	Regulated DC: 28.0 V ± 2.0 V	Unregulated Bus: 50 V

TABLE 2-3 HIGH POWER OFFERING

POWER	
Peak Current	35 A
Orbit Average Power	1 kW
Voltage	Unregulated Bus: 50 V

SECTION 3
PAYLOAD INTERFACES

Customers are encouraged to follow industry accepted engineering practices and standards when designing their payloads. Momentus classifies customer payloads as either Containerized or Non-Containerized. Containerized payloads (such as CubeSats, Picosats, and PocketQubes) are transported in a deployer which protects the payloads during launch and releases the payload upon arrival at their destination. Non-Containerized payloads are mounted external to the OSV via mechanical fasteners or a separation system (i.e., MicroSats). All payloads must comply with the design guidelines outlined in this User's Guide.

3.1 CONTAINERIZED PAYLOADS

3.1.1 Containerized Payload Definition

Payloads are considered fully containerized if there are no holes in its encapsulating dispenser/deployer larger than 0.250” (6.35 mm) in diameter, and holes make up less than 10% of the total surface area of the dispenser. Payloads to be integrated into Momentus-supplied deployers are considered fully containerized. All dispensers/deployers themselves, whether Momentus-supplied, or provided by the Customer, are classified as non-containerized and must comply with non-containerized payload specifications.

3.1.2 Payload Coordinate Frame

Payload orientations are referenced relative to a right-hand X-Y-Z coordinate system with $+X_{PL}$ in the deployment direction. The origin of the coordinate system is fixed at the center of the mechanical interface plane between the Payload and the deployment mechanism (e.g., the plane defined by the end of the CubeSat rails interfacing with the pusher-plate) as shown in **FIGURE 3-1**.

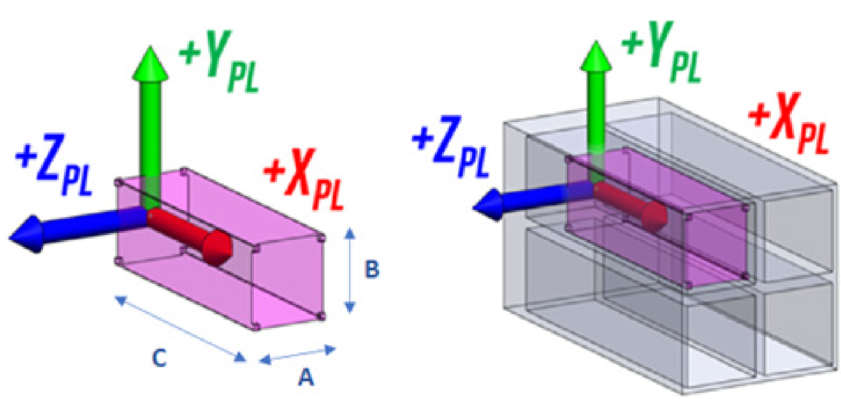

FIGURE 3-1 CONTAINERIZED PAYLOAD COORDINATE SYSTEM

3.1.3 Mechanical Interface

Momentus can accommodate both rail-based and tab-based deployment systems. Rail-based systems are assumed unless otherwise stated. Tab-based payloads must adhere to the Canisterized Satellite Dispenser Data Sheet 2002337G.

3.1.4 Available Volume & Mass Properties

Containerized Payloads to be carried by Momentus deployers in **FIGURE 3-1** must adhere to the dimensions and mass limits listed in **TABLE 3-1**. Additional volume beyond the rails is allowable based upon the mission specific deployer, including tuna-cans. XL versions of specific U-form factors may be available upon request.

TABLE 3-1 CUBESAT DIMENSIONS & MASS LIMITS

SIZE	A (MM)	B (MM)	C (MM)	MAXIMUM MASS (KG)
1U	100 ± 0.1	100 ± 0.1	113.5 ± 0.1	2
2U	100 ± 0.1	100 ± 0.1	227 ± 0.1	4
3U	100 ± 0.1	100 ± 0.1	340.5 ± 0.1	6
3U XL	100 ± 0.1	100 ± 0.1	365.9 ± 0.1	6
6U	100 ± 0.1	226.3 ± 0.1	340.5 ± 0.1	12
6U XL	100 ± 0.1	226.3 ± 0.1	365.9 ± 0.1	12
12U	226.3 ± 0.1	226.3 ± 0.1	340.5 ± 0.1	24
12U XL	226.3 ± 0.1	226.3 ± 0.1	365.9 ± 0.1	24
16U	226.3 ± 0.1	226.3 ± 0.1	454 ± 0.1	24

3.1.5 Electrical Interface

Containerized payloads typically do not have an electrical interface with the OSV. These payloads will be in a powered-off state from time of integration until delivery on-orbit. Therefore, payload battery life must be at least 6 months in this powered-off state, plus any on-orbit transit time, which is determined on a mission-specific basis.

3.2 NON-CONTAINERIZED PAYLOADS

3.2.1 Payload Mounting and Coordinate Frame

The Payload will utilize a right-hand X-Y-Z coordinate system with $+X_{PL}$ normal to the primary mechanical interface plane. For deployed Payloads, this is in the deployment direction. The origin of the coordinate system is fixed at the center of the mechanical interface plane between Customer provided hardware and Momentus provided hardware. See **FIGURE 3-2** and **FIGURE 3-3** for examples.

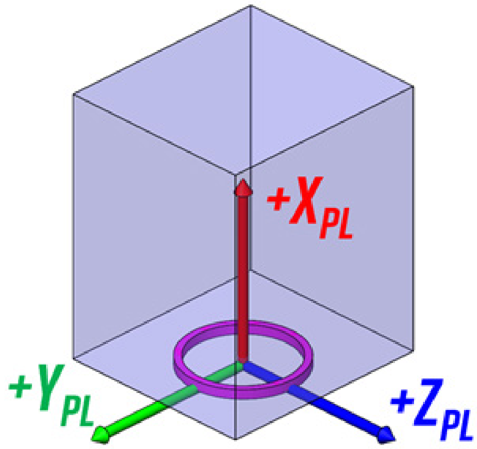

FIGURE 3-2 NON-CONTAINERIZED PAYLOAD COORDINATE SYSTEM

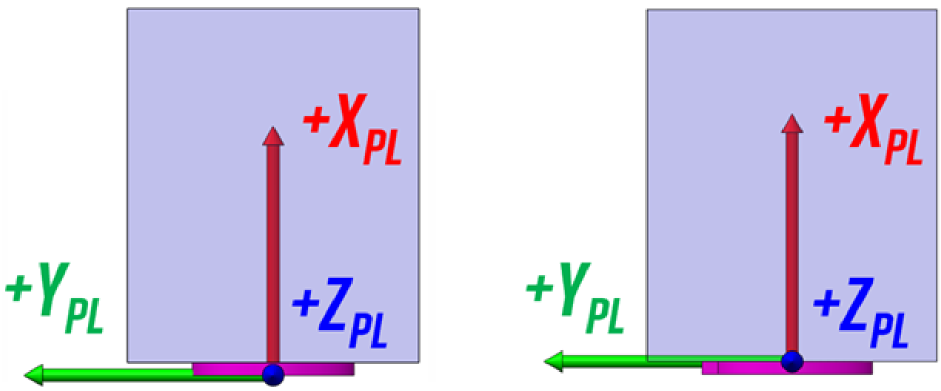

FIGURE 3-3 NON-CONTAINERIZED PAYLOAD COORDINATE SYSTEM WITH CUSTOMER/MOMENTUS PROVIDED SEPARATION SYSTEM (LEFT/RIGHT)

3.2.2 Mechanical Interface

The standard mechanical interface between the OSV and non-containerized payloads will be either an 8", 15", or 24" diameter bolt pattern on the OSV payload deck. Standard rectangular interface plates and custom interfaces are available as needed. Refer to Appendix B for mechanical drawings and dimensions. The OSV payload deck will utilize threaded inserts for mounting. Momentus will provide OSV-side fasteners and the customer will provide payload-side fasteners with two forms of retention. The customer is responsible for submitting a structural analysis of the payload-side fasteners demonstrating positive strength margin.

Unless otherwise approved by Momentus, all payloads are prohibited from using mechanical vibration isolators anywhere in their system.

3.2.3 Available Volume & Mass Properties

Non-Containerized payloads are classified by volume and mass as shown in **TABLE 3-2**. Payload classifications are determined based on the highest value of any property (in stowed configuration) in **TABLE 3-2**. Contact Momentus if a more tailored volume and mass configuration is needed.

TABLE 3-2 NON-CONTAINERIZED PAYLOAD VOLUME & MASS RANGES

SIZE CLASS	STANDARD INTERFACE	FOOTPRINT	HEIGHT	MASS RANGE	CG HEIGHT RANGE
Nanosat	8” ring	40 x 40 cm	60 cm	28 – 40 kg	6 – 30 cm
		45 x 45 cm	70 cm	35 – 50 kg	7 – 35 cm
Microsat	15” ring	60 x 60 cm	80 cm	50 – 80 kg	7 – 35 cm
		80 x 80 cm	80 cm	80 – 160 kg	8 – 40 cm
Smallsat	24” ring	90 x 90 cm	90 cm	95 – 155 kg	9 – 45 cm
		120 x 110 cm	90 cm	160 – 300 kg	9 – 45 cm

3.2.4 Electrical Interface

Non-containerized payloads will be in a powered-off state from time of integration onto the OSV until delivery on orbit or the start of hosted operations. Payload battery life must be at least 6 months in this powered off state, plus any on-orbit transit time, which is determined on a mission-specific basis.

As a standard service, the OSV provides separation and umbilical connectors for separation initiation and telemetry and on-orbit keep-alive power. Non-containerized payloads will have access to the power and data. Momentus will provide both the deploy and umbilical harness, and customers will provide payload side connectors. Detailed electrical characteristics and connector pinouts will be captured in the ICD.

TABLE 3-3 STANDARD OFFERING UMBILICAL CHANNELS

CHANNEL TYPE	NUMBER OF CHANNELS
Power (28V or V_{BUS})	1
Serial Data (RS-485)	2
Ethernet	1
Inhibit Signal	1

3.2.5 On-Orbit Command and Data Handling

No restriction is placed on the quantity of data the customer may store within their payload as long as the data sent to the OSV does not exceed the relevant storage allocation in **TABLE 3-4**, and that all needed data can be downlinked within the mission lifetime. The payload may send data to the OSV to store in a circular buffer until it is downlinked to the ground. Commands for the payload are routed through the OSV after review by Momentus Operations Team, any commands that run solely on the payload may be encrypted by the customer.

TABLE 3-4 DATA OFFERINGS

DATA	STANDARD	MAXIMUM
Throughput	Uplink: 0.5 MiB/day Downlink: 1 MiB/day	Uplink: 5 MiB/day Downlink: 200 MiB/day
Command and Handling	Store-and-forward Protocol: RS-485 UART or Ethernet Bandwidth: Contact Momentus for payload specific information	
Storage	160 MiB	350 MiB

3.2.6 Ground Interface

Commanding and telemetering your payload from the ground is performed through a dedicated customer API endpoint that Momentus will provide through a cloud-based RESTful Application Programming Interface (API). Commands can be sequenced and scheduled by the customer through the API, which then submits it to a Momentus mission operations task list for execution. Standard telemetry available to the Customer's payload, and streamed from the API, includes attitude, power, ephemeris and spacecraft state that have been processed by the OSV. Additional details for usage are provided to the customer in an ICD, and test interfaces are available to verify payload integration.

3.3 GENERAL DESIGN REQUIREMENTS

Once the customer is assigned a mission, the customer's payload must meet all the requirements specified in the launch service provider's User's Guide (e.g., SpaceX Rideshare User's Guide). Momentus will work with the customer to accommodate specific design needs. The following are specific requirements the customer should incorporate into their design.

3.3.1 Design Factors of Safety

Payload systems and structural components should hold a minimum design factor of safety of at least 1.40 for all ground operations, and at least 1.25 for all combined loads seen in flight.

3.3.2 Fasteners

Any fasteners used on the primary structure of a non-containerized Payload or used to hold external components onto the Payload that are removed after acceptance testing must meet the following requirements:

- Fasteners have a diameter of .190 inch (#10 size, metric: 5 mm) or larger.
- Fasteners have a form of retention that is not reliant on preload to function (e.g., prevailing torque feature like distorted thread locking nut or patched fastener, lock wire/lock cable, cotter pin, thread locker with proper application process check, etc.)

- Fasteners be installed by means of an installation procedure that uses a calibrated torque tool, measures installation torque, and verifies retention is functional (e.g., measures prevailing torque and compares to limits, visual verification on lock wire/cable, test coupon for thread locker to test breakaway torque, etc.)
- Fasteners have a minimum acceptable thread protrusion beyond the end of a nut or nut plate of one thread pitch width. This will ensure that all of the fully formed threads on the fastener can carry load and that the prevailing torque feature (if present) is engaged properly.

3.3.3 Pressure Vessels and Systems

If the payload has a pressure vessel or pressure system, the customer should contact Momentus for specific instructions on design and test requirements.

SECTION 4
ENVIRONMENTS

Customers should design their payloads to be compatible with the payload Maximum Predicted Environments (MPE) described in this section for ground processing, launch, and on-orbit transit. Some environments are coupled (i.e., attenuated or amplified) by the launch vehicle, OSV, and co-passengers, so Momentus will perform analyses on the overall system for the mission. If predicted levels exceed the environments specified in this section, Momentus will provide the affected customers with the appropriate levels for design and test.

4.1 TRANSPORTATION ENVIRONMENTS

The transportation environments are enveloped by flight environments listed in Section 4.3.

TABLE 4-1 TEMPERATURE AND CLEANLINESS

PHASE	CONTROL SYSTEM	APPROXIMATION DURATION	TEMP. (C)	HUMIDITY (%)	CLEANLINESS (CLASS)
Transit to Launch Site	Transport Container HVAC	1 week	21 ± 3.0	50 ± 15	Isolated

4.2 CLEANROOM ENVIRONMENTS

While at the Momentus and launch site integration facilities, customer payloads will experience cleanroom environments as defined in **TABLE 4-2**.

TABLE 4-2 CLEANROOM ENVIRONMENTS

PHASE	TEMP. °C (°F)	HUMIDITY (%)	CLEANLINESS (CLASS)
Momentus payload integration facility	21 ± 3 (70 ± 5)	50 ± 15	100,000 (ISO 8)
Launch Base Integration and Transport	21 ± 3 (70 ± 5)	30 - 65	100,000 (ISO 8)

4.3 FLIGHT ENVIRONMENTS

4.3.1 Payload Natural Frequencies

Payloads must have a first mode (or elastic natural frequency) greater than 50 Hz in all axes to ensure the requirements defined here are sufficient to cover expected flight environments. The first mode is based on the frequency response of any part of the payload with a modal participation as computed by a fixed-base modal analysis.

4.3.2 Quasi-Static Loads

Flight loads are a function of the launch vehicle, OSV, and Payload structural properties. Generally, the payload must be compatible with the quasi-static load environment defined in **TABLE 4-3**. Momentus will notify the Customer if it expects the loads to exceed these levels. Momentus will conduct mission-specific analysis for all payloads greater than 100 kg.

TABLE 4-3 PAYLOAD LAUNCH LOAD FACTORS

PAYLOAD MASS (kg)	MAXIMUM IN ALL AXES (g)
1	25
25	16
50	12
100	11

4.3.3 Random Vibration

Containerized Payloads

The payload random vibration environment for containerized payloads integrated into a Momentus-provider deployer in all axes is given in **FIGURE 4-1** and **TABLE 4-4**. The Customer is responsible for verifying compatibility with this environment. Mission-specific analysis will not be provided by Momentus for containerized payloads.

Non-Containerized Payloads

The random vibration environment for non-containerized payloads is influenced by the OSV payload deck layout and overall payload complement, and therefore varies by mission (i.e., not necessarily the same as the levels found in the launch service provider's User's Guides). Momentus will provide mission-specific vibration MPE for non-containerized payloads.

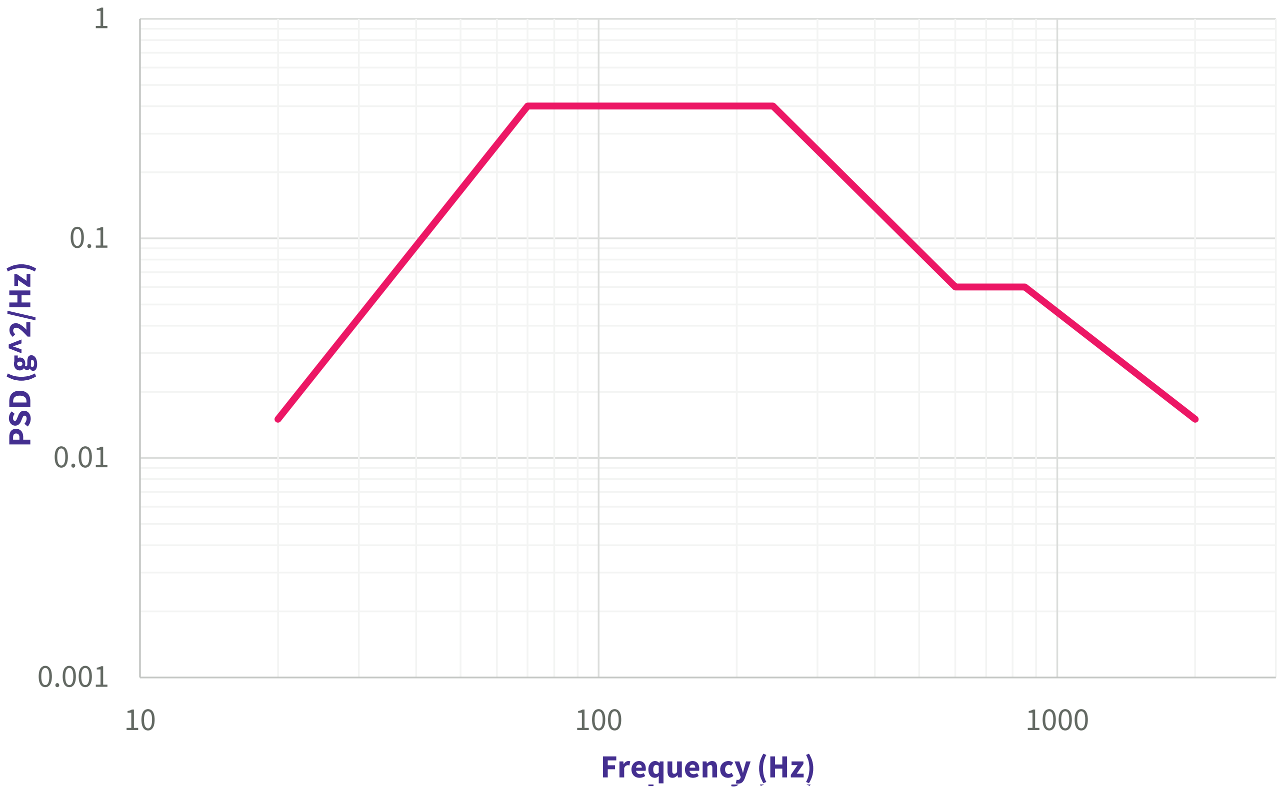

FIGURE 4-1 RANDOM VIBRATION MPE FOR CONTAINERIZED PAYLOADS IN MOMENTUS-PROVIDED DEPLOYERS

TABLE 4-4 RANDOM VIBRATION MPE FOR CONTAINERIZED PAYLOADS IN MOMENTUS-PROVIDED DEPLOYERS

FREQUENCY (Hz)	PSD (g^2/Hz) (all axes)
20	0.015
70	0.4
240	0.4
600	0.06
850	0.06
2000	0.015
GRMS	**13.45**

4.3.4 Acoustic

Payloads that are susceptible to acoustic loading may experience the maximum acoustic environment (defined as the spatial average and derived at a P95/50 level) shown by a full-octave curve in **FIGURE 4-2** and **TABLE 4-5**. A mission-specific environment will not be provided by Momentus.

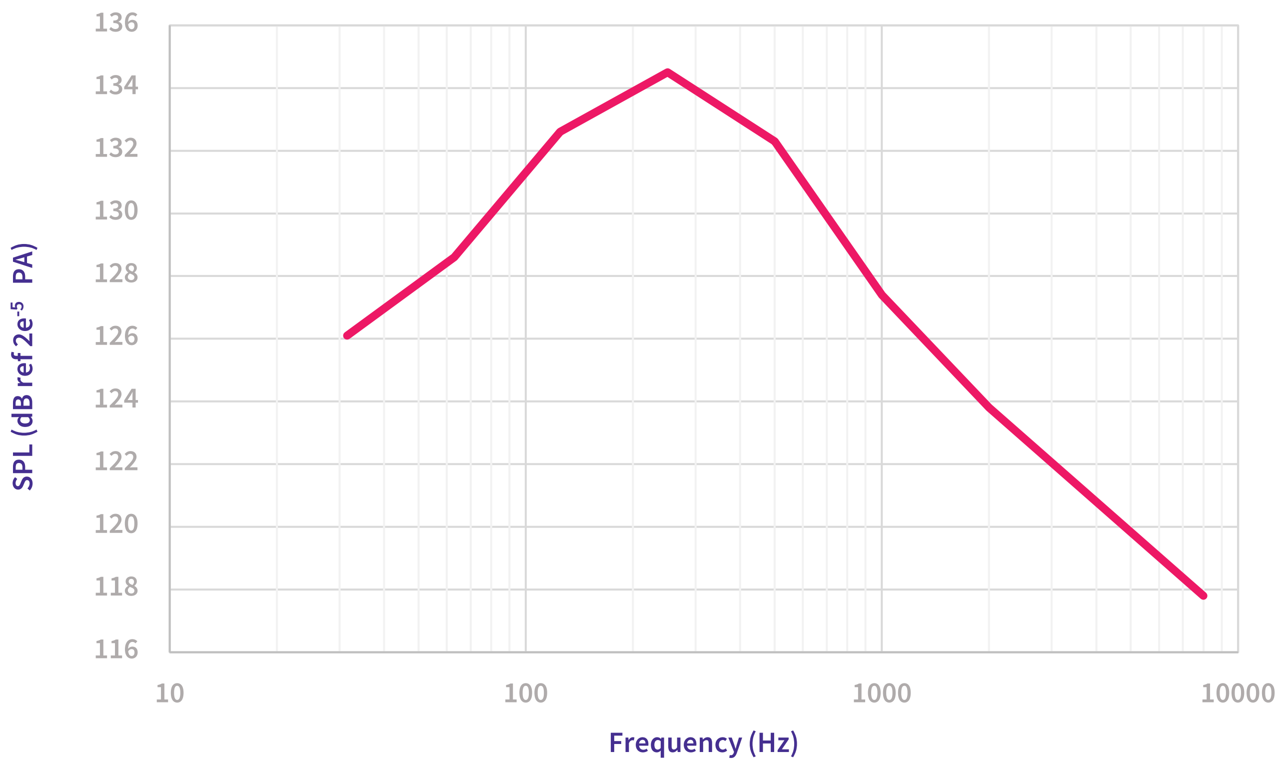

FIGURE 4-2 ACOUSTIC MPE

TABLE 4-5 ACOUSTIC MPE

FREQUENCY (Hz)	SPL (dB)
31.5	126.1
63	128.6
125	132.6
250	134.5
500	132.3
1000	127.4
2000	123.8
4000	120.8
8000	117.8
OASPL	**139.3**

4.3.5 Shock

The shock environment at the OSV to Payload mechanical interface during launch and co-payload separation events is defined in **FIGURE 4-3** and **TABLE 4-6**. These levels do not include the shock load induced during Payload separation, because that environment is defined by the payload-specific separation mechanism. Separation systems provided by the Customer must be approved by Momentus. The Customer must consider the envelope of **TABLE 4-6** and the shock environment of their selected separation mechanism to determine the payload-specific shock MPE.

The Customer is responsible for verifying compatibility with this environment. A mission-specific analysis will not be provided by Momentus.

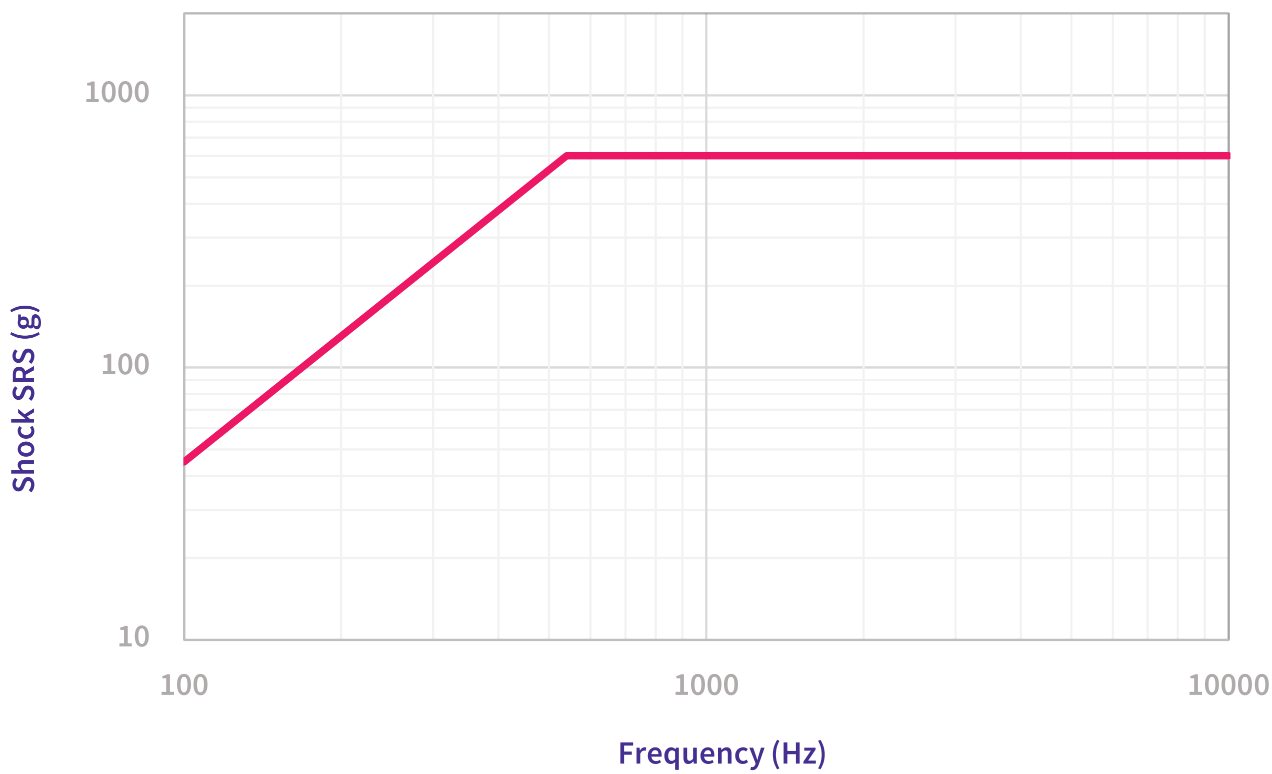

FIGURE 4-3 SHOCK SRS

TABLE 4-6 SHOCK SRS

FREQUENCY (Hz)	SRS (g)
100	45
540	600
10000	600

4.3.6 Electromagnetic Environment

The Customer is responsible for verifying compatibility with this environment. A mission-specific analysis will not be provided by Momentus. Payload radiated susceptibility will be recorded in the Payload to OSV Interface Control Document (ICD).

4.3.6.1 Pre-Flight and In-flight Radiated Emissions

The Payload must be compatible with the radiated environments shown in **FIGURE 4-4**, **TABLE 4-7**, **TABLE 4-8**, and **TABLE 4-9**. These limits envelope the expected radiated emissions from Launch Site, launch vehicle, and OSV transmitters. The values given do not include any EMI Safety Margin (EMISM).

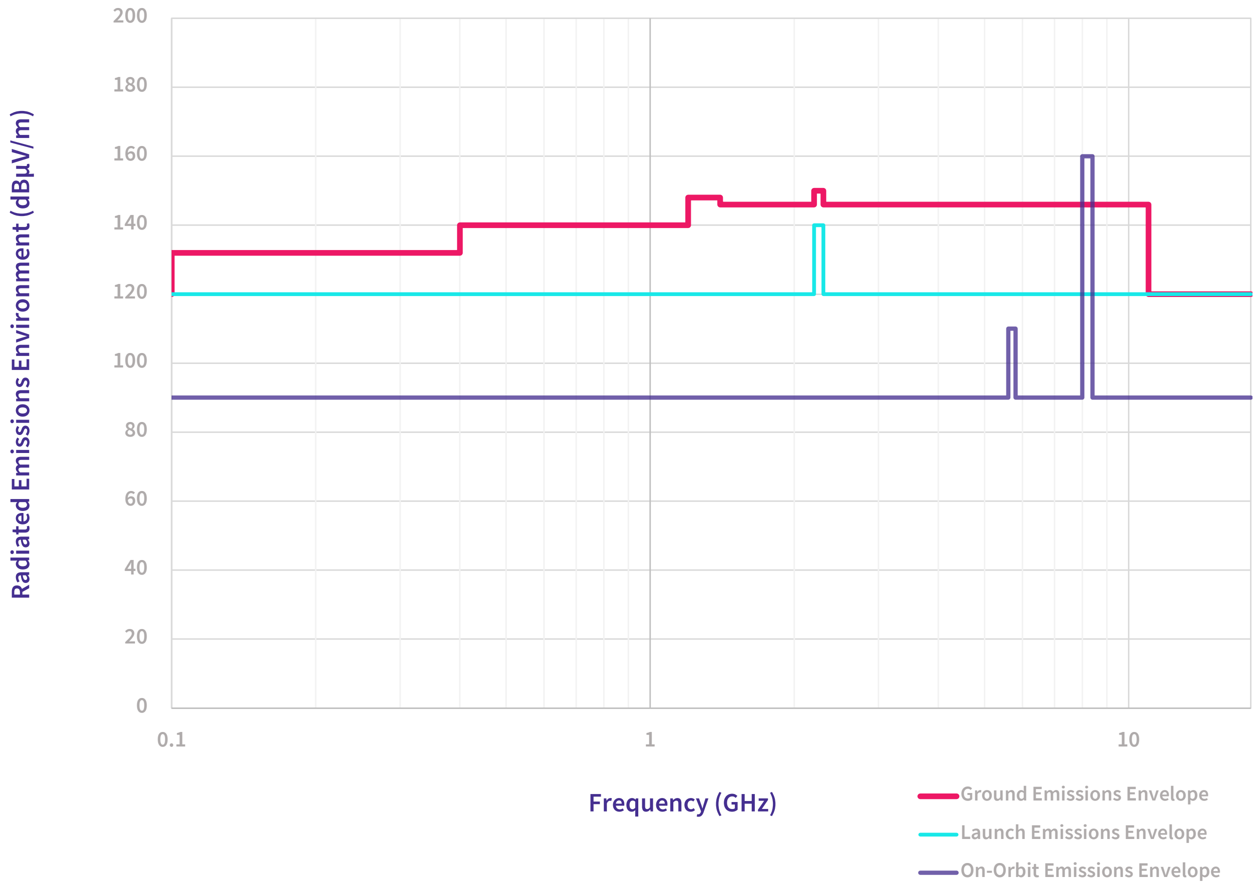

FIGURE 4-4 RADIATED EMISSIONS ENVELOPE

TABLE 4-7 GROUND EMISSIONS ENVELOPE

FREQUENCY (GHz)	RF ENVIRONMENT (dBuV/m)	FREQUENCY (GHz)	RF ENVIRONMENT (dBuV/m)
0.001 - 0.1	90	1.4 - 2.2	146
0.1 - 0.4	132	2.2 - 2.3	150
0.4 - 1.2	140	2.3 - 11	90
1.2 - 1.4	148	11 - 18	160

TABLE 4-8 LAUNCH EMISSIONS ENVELOPE

FREQUENCY (GHz)	RF ENVIRONMENT (dBuV/m)
0.001 - 2.2	120
2.2 - 2.3	140
2.3 - 18	120

TABLE 4-9 ON-ORBIT EMISSIONS ENVELOPE

FREQUENCY (GHz)	RF ENVIRONMENT (dBuV/m)
0.001 - 5.6	90
5.6 - 5.8	110
5.8 - 8.0	90
8.0 - 8.4	160
8.4 - 18	90

4.3.6.2 Payload Emission Limit

The Customer is not permitted to operate Payload transmitters from the time of integration until either delivery on-orbit or the start of Hosted Payload operations. Deployed payloads are required to delay emitting RF for two minutes post-deployment from the Momentus vehicle. Payloads utilizing S-band (2025-2110 MHz) transmitters are required to delay RF emissions based on transmitter EIRP and separation velocity, as defined in **TABLE 4-10**.

TABLE 4-10 PAYLOAD RF TRANSMITTER DELAY

TIME DELAY (MIN)

	EIRP (W)						
Separation Velocity (m/s)	**0.01**	**0.1**	**1**	**10**	**20**	**100**	**1000**
0.1	5	15	50	150	215	475	1490
0.2	5	10	25	75	110	240	745
0.5		5	10	30	45	95	300
1			5	15	25	50	150
2			5	10	15	25	75
3				5	10	20	50
4				5	10	15	40
5				5	5	10	30

4.3.7 Fairing Pressure

From liftoff until fairing separation, the internal fairing pressure will decay at a rate no greater than 2.8 kPa/sec (0.40 psi/sec), except for brief periods where pressure decay will be no greater than 4.5 kPa/sec (0.65 psi/sec) for up to 5 seconds.

4.3.8 Thermal Environment

Containerized Payloads

Containerized payloads will experience a conductive boundary thermal environment from launch through deployment as defined in **TABLE 4-11**. The Customer is responsible for using these values to conduct Payload-specific thermal analysis. A payload-specific analysis will not be provided by Momentus.

TABLE 4-11 CONTAINERIZED PAYLOAD THERMAL MPE

TEMPERATURE (°C)

Low Temperature	-20
High Temperature	+50

Non-Containerized Payloads

Customers with Non-Containerized payloads are required to submit a Thermal Finite Difference Model (FDM) to include in Momentus' system level thermal model in order to verify acceptable boundary temperatures for both the Customer and OSV on-orbit. Submission guidelines for the Thermal FDM are given in Appendix E. Payloads may experience free-molecular heating during launch ascent, and customers are responsible for conducting analysis of this environment on their payload should they choose.

Customers should baseline designing their payloads to be thermally isolated from the OSV with an interface temperature of -20C to +60C. Customers may contact Momentus for options to thermally couple/control payload temperatures to the OSV (e.g., heaters) or operationally (e.g., sun-pointing). Customers need to consider minimum survival temperature limits for their payloads since the mission may be shared with other customers.

4.3.9 Contamination

Payload contamination requirements are given in **TABLE 4-12**. The Customer is responsible for verifying compliance to these requirements. A mission-specific analysis will not be provided by Momentus. The following requirements from **TABLE 4-12** apply to Non-Containerized payloads only:

- Non-Metallic Materials
- Metallic Materials
- Silicone Sensitivity
- Visual Cleanliness

TABLE 4-12 PAYLOAD CONTAMINATION REQUIREMENTS

NAME	CONTAMINATION CONTROL
Non-Metallic Materials	Vaccuum-exposed non-metallic materials list delivered to Momentus • Material list including surface area or mass Vacuum-exposed non-metallic materials when tested per ASTM E595 • Must not exceed mass loss of 1.0% • Collected Volatile Condensable Material (CVCM) must be <0.1%
Metallic Materials	Selection consideration of metallic materials in order to reduce particulate contamination: • corrosion • wear products • flaking • shedding Avoid contact of dissimilar metals unless protected
Prohibited Materials	The following materials are not to be used on Payload hardware • Cadmium parts • Cadmium plated-parts • Zinc-plating • Mercury, compounds containing mercury • Pure tin or tin electroplate (except when alloyed with lead, antimony, or bismuth)
Silicone Sensitivity	Silicone materials may harm co-payloads through inadvertent transfer, and Momentus notification, coordination, and approval is required before use: • Silicone rubber • RTV silicones
Visual Cleanliness	Payload must be cleaned to VC-HS standards per NASA-SN-C-005D prior to integration.
Particulate Generation	Payload will not create particulate during all mission phases.
Payload Deployment	Payload deployment will not include the use of uncontained pyrotechnics (e.g. Frangible nuts).
Propulsion	Payload propulsion systems will not be operated in close proximity (within 1km) of the Momentus vehicle.

4.4 ENVIRONMENTAL TESTING

4.4.1 Verification Approach

To assure successful delivery of the customer's payload to its intended destination, the customer is required to verify payload compatibility with all environments defined in Section 4.3. Both Containerized and Non-Containerized payloads shall be analyzed and/or tested by the customer prior to arriving at Momentus for integration. Environmental testing of the payload must be performed as either:

1. Fleet Qualification:
    - Qualification testing on a single flight unit
    - Acceptance testing on flight unit(s)

OR

2. Single-Unit Qualification
    - Proto-qualification testing on flight unit(s)

Test parameters for Containerized and Non-Containerized payloads are given in **TABLE 4-12** and **TABLE 4-13**, respectively. The customer will present a verification approach and test results to Momentus for review. Deviations may be acceptable but must be reviewed and approved by Momentus and the launch provider prior to test execution. "Advised" tests are intended to ensure on-orbit functionality of the payload but are not required to fly. "Required" tests must be completed by the customer. If a customer chooses not to complete any "Advised" tests they will be required to submit a letter accepting the inherent risks to the payload by not completing those tests. An environmental test report indicating success completion of all required tests must be submitted prior to Payload integration with the OSV.

All payloads with an independent power source (i.e. cubesats, hosted payloads with batteries, microsats) are required to verify that the payload does not power on during vibration testing. This is a mandatory verification regardless of which method is used to demonstrate electromagnetic compatibility.

4.4.2 Test-Like-You-Fly Exceptions

It may be necessary for some test approaches to perform tests as "test-like-you-fly" as opposed to the full acceptance or proto-qualification tests. These exceptions include all changes from the flight configuration to the test configuration. Common examples include:

- Not testing propulsion systems at flight pressure during the test
- Not filling propulsion tanks with reactive propellants during the test
- Not including separation system during the test
- Mass models or engineering models used in place of flight hardware

In this case, the Customer submits to Momentus for approval the proposed change and rationale for the deviation. The deviation request will be reviewed by Momentus and the launch provider on a case-by-case basis.

4.4.3 Deployer Activation Test

Prior to integration of customer furnished deployers onto the OSV, an electrical interface test shall be performed using either a Flight Model (FM) deployer or a functionally identical Engineering Model (EM) deployer and the Momentus deployment sequencer. This test will verify successful activation of deployment mechanism and readback of any telemetry.

4.4.4 Electromagnetic Compatibility

Customers are required to have a mechanical battery isolation inhibit strategy that is verified during vibration testing. Verification is accomplished by ensuring that the spacecraft remains powered-off throughout the test as indicated by payload computer boot count or other means of verification. The customer must also provide both an electrical inhibit schematic and description of the inhibit strategy.

Customers may demonstrate electromagnetic compatibility via analysis or test. Verification by analysis must provide at least one of the following:

A. A board-level and signal distribution-level dipole harmonic analysis of on-board signal frequencies vs. current amplitudes

B. Dispenser shielding information showing margin to requirement; Momentus will provide shielding information as available

Verification by test may be performed per MIL-STD-416, with supporting test documentation or obtained from an IEC-17025 accredited (or equivalent) test facility.

4.4.5 Containerized Payload Test Requirements[1]

TABLE 4-13 CONTAINERIZED PAYLOAD TEST REQUIREMENTS

	FLEET QUALIFICATION APPROACH		SINGLE-UNIT APPROACH	
TEST	**QUALIFICATION**	**ACCEPTANCE**	**PROTO-QUALIFICATION**	**REQUIRED/ ADVISED**
Random Vibration[2]	3 dB above acceptance for 2 minutes in each of 3 axes	MPE spectrum for 1 minute in each of 3 axes	MPE spectrum for 1 minute in each of 3 axes	Required
Shock	6 dB above MPE, 3 times in each of 3 orthogonal axes	Not required	3 dB above MPE, 2 times in each of 3 orthogonal axes	Advised
Static Load	Not Required			
Sine-Vibration	Not Required			
Acoustic	Not Required			
Electromagnetic Compatibility[3,4]	6dB EMISM by Test and/or 12dB EMISM by Analysis	N/A	6dB EMISM by Test and/or 12dB EMISM by Analysis	Required
Combined Thermal and Vacuum Cycle[5]	±10°C beyond acceptance for 27 cycles total	Envelope of MPT and minimum range (-24 to 61°C) for 14 cycles total	± 5°C beyond acceptance for 20 cycles total	Advised

TABLE 4-13 CONTAINERIZED PAYLOAD TEST REQUIREMENTS (CONT.)

	FLEET QUALIFICATION APPROACH		SINGLE-UNIT APPROACH	
TEST	QUALIFICATION	ACCEPTANCE	PROTO-QUALIFICATION	REQUIRED/ ADVISED
Pressure Systems[6,7]	Pressure as specified in Table 6.3.12-2 of SMC-S-016 following acceptance proof pressure test, duration sufficient to collect data	1.5x MEOP for pressure vessels and pressure components. Other metallic pressurized hardware items per References 4/5 from SMC-S-016	See Note 5 below	Required
System-Level Pressure Leak Test[8]	Not Required	Full Pressure System MEOP Leak Test	Full Pressure System MEOP Leak Test	Required
Pressure Vessel Leak Test[8]	Not Required	Pressure Vessel Level MEOP Leak Test	Pressure Vessel Level MEOP Leak Test	Required
Shock	6 dB above MPE, 3 times in each of 3 orthogonal axes	Not required	3 dB above MPE, 2 times in each of 3 orthogonal axes	Advised

Notes for Table 4-13: Containerized Payload Test Requirements

1. For fully containerized payload qualification testing and acceptance testing. Testing may be performed at the payload level.
2. Random vibration testing on containerized payloads is required to no less than the MPE levels defined in Section 4.3, however it is strongly advised to test to the MPE derived from fully integrated OSV assembly level testing. Failure to use derived random vibration levels should be understood by the Customer to be an under-test to the expected flight environments.
3. Verification by test may be performed in-house per MIL-STD-461 with supporting test documentation or obtained from an IEC-17025 accredited (or equivalent) test facility. Verification by analysis must provide (1) a mechanical battery isolation inhibit strategy verified in vibrational testing or (2) electromagnetic circuit and wiring emissions analysis. For Payloads with GPS receivers, verification by analysis may be achieved through demonstration of self-compatibility with on-board GPS navigation systems.
4. EMISM (6 dB by test, 12 dB by analysis) is already included in the level specified in Section 4.3.6.2.
5. Thermal cycles can be accrued as a combination of thermal cycling in air and thermal vacuum. It is recommended to include at least four cycles of thermal vacuum unless strong rationale exists that the Payload is not sensitive to vacuum.
6. Pressure systems cannot be proto-qualified at the payload level. Pressure systems must therefore be qualified via the fleet qualification approach at the component level. Supplier qualification testing is acceptable in place of fleet level qualification testing if approved by Momentus.
7. For all Non-US Department of Transportation (US DOT) rated pressure vessels, please contact Momentus for detailed qualification and testing requirements.
8. Contact Momentus for specific leak testing requirements.

4.4.6 Non-Containerized Payload Test Requirements

Once installed onto the OSV, the payload and OSV will undergo an integrated spacecraft test in accordance with **TABLE 4-14** as a proto-qualification test approach. ***Integrated spacecraft testing does not obviate the requirement for Customers to perform environmental testing on their hardware prior to delivery to Momentus.***

TABLE 4-14 NON-CONTAINERIZED PAYLOAD UNIT TEST LEVELS AND DURATIONS

	FLEET QUALIFICATION APPROACH		SINGLE-UNIT APROACH	
TEST	**QUALIFICATION**	**ACCEPTANCE[1]**	**PROTO-QUALIFICATION[1]**	**REQUIRED/ ADVISED**
Random Vibration	6 dB above acceptance for 2 minutes in each of 3 axes	MPE spectrum for 1 minute in each of 3 axes	3 dB above acceptance for 1 minute in each of 3 axes	Required
Electromagnetic Compatibility[2,3]	6 dB EMISM by Test and/or 12 dB EMISM by Analysis	Not Applicable	6 dB EMISM by Test and/or 12 dB EMISM by Analysis	Required
Combined Thermal and Vacuum Cycle[4]	± 10°C beyond acceptance for 27 cycles total	Envelope of MPT and minimum range (-24 to 61°C) for 14 cycles total	± 5°C beyond acceptance for 20 cycles total	Advised
Pressure Systems[5,6]	Pressures as specified in Table 6.3.12-2 of SMC-S-016 following acceptance proof pressure test, duration sufficient to collect data. Minimum 2.0 times MEOP	1.5 times ground MEOP for pressure vessels and pressure components. Other metallic pressurized hardware items per References 4 and 5 from SMC-S-016	See Note 5	Required
System-level Pressure Leak Test[7]	Not Required	Full Pressure System MEOP Leak Test	Fully Pressure System MEOP Leak Test	Required
Pressure Vessel Leak Test[7]	Not Required	Pressure Vessel Level MEOP Leak Test	Pressure Vessel Level MEOP Leak Test	Required
Shock	6 dB above MPE, 3 times in each of 3 orthogonal axes	Not Required	3 dB above MPE, 2 times in each of 3 orthogonal axes	Advised
Static Load[8]	1.25 times the limit load	1.1 times the limit load	1.25 times the limit load	Required
Sine-Vibration	1.25 times limit levels, two octave/minute sweep rate in each of 3 axes	1.0 times limit levels, four octave/minute sweep rate in each of 3 axes	1.25 times limit levels, four octave/minute sweep rate in each of 3 axes	Advised[9]
Acoustic	6 dB above acceptance for 2 minutes	MPE spectrum for 1 minute	3 dB above acceptance for 1 minute[10]	Advised

Notes for Table 4-14: Non-Containerized Payload Unit Test Levels and Durations:

1. Must be performed on fully integrated OSV assembly.
2. Verification by test may be performed in-house per MIL-STD-461 with supporting test documentation or obtained from an IEC-17025 accredited (or equivalent) test facility. Verification by analysis must provide (1) a mechanical battery isolation inhibit strategy verified in vibrational testing or (2) electromagnetic circuit and wiring emissions analysis. For Payloads with GPS receivers, verification by analysis may be achieved through demonstration of self-compatibility with on-board GPS navigation systems.
3. EMISM (6 dB by test, 12 dB by analysis) is already included in the level specified in Section 4.3.6.2.
4. Thermal cycles can be accrued as a combination of thermal cycling in air and thermal vacuum, it is recommended to include at least four cycles of thermal vacuum.
5. Pressure systems cannot be proto-qualified at the payload level. Pressure systems must therefore be qualified via the fleet qualification approach at the component level. Supplier qualification testing is acceptable in place of fleet level qualification testing if approved by Momentus.
6. For all Non-US Department of Transportation (US DOT) rated pressure vessels, please contact Momentus for detailed qualification and testing requirements.
7. Contact Momentus for specific leak testing requirements.
8. Static Load testing can be achieved through a sine-burst test. Loads may occur simultaneously, so the test should ensure the structure will sustain the total combined loads.
9. Only applicable to customer payloads required to perform Sine-Vibration testing according to Section 4.3.3. Mission-specific MPE levels will be provided by Momentus.
10. Single-unit acoustic testing approach should use test levels and a test duration consistent with NASA 7001/7005 Proto-flight testing.

SECTION 5
MISSION INTEGRATION & SUPPORT

5.1 CONTRACTING

To contract Momentus' services please contact a Business Development representative at sales@momentus.space or visit the Momentus website: www.momentus.space.

5.2 US IMPORT & EXPORT CONTROL LAWS

All items, information, and services identified by Momentus in the Customer Service Agreement that are to be provided to a foreign person (including Customer and Customer Third Parties, as applicable), are subject to US export control laws including the ITAR and EAR. The customer must comply with all US import and export control laws.

5.3 LOGISTICS

5.3.1 Payload Delivery

The customer is responsible for the shipment of their payload and necessary GSE to Momentus integration facilities in San Jose, California, United States. Momentus Mission Management and Logistics teams will support customer logistics planning and will assign a freight carrier to act as an agent of record to expedite customs clearance at SFO and LAX. All shipments to Momentus will be classified as DAP (Delivery At Place). International customers must declare themselves as the importer of record for imports into the United States.

The customer is expected to review and comply with applicable IATA (International Air Transport Association) regulations regarding air shipment of lithium-ion batteries or battery assemblies. Specifically, for lithium-ion batteries, the United Nations Transportation of Dangerous Goods Manual of Tests and Criteria, Section 38.3 testing criteria must be met, otherwise a special permit from the customer's air carrier may be required.

Momentus will transport the OSV and integrated payloads to the launch base via soft-ride truck. The transport will be environmentally controlled and telemetered for temperature, humidity and shock, as per Section 4.1.

5.3.2 Test Pod

Momentus offers customers the option to utilize a 3U, 3UXL or 6UXL Cubesat test pod for vibration testing and fit-checks, free of charge. Test pod inventory varies, so customers should check with Momentus Mission Management to determine test pod availability for a given timeframe.

Smaller payloads will utilize spacers to adjust the volume of the test-pod as needed. The customer is responsible for providing the spacer.

Shipment of test pods to customer facilities will be organized and paid for by Momentus. International customers should inform Momentus of test pod needs several weeks prior to the desired shipment date to ensure sufficient time for the export process. The customer is responsible for the organization and payment of the return shipment to either Momentus' facilities or to another Momentus customer. A test pod shipment to Momentus or to another customer will be classified as Delivered at Place (DAP).

5.3.3 Facilities

Customer payload integration activities take place at Momentus' facilities in San Jose, California. Customers have access to a 100K Class integration room equipped with ESD-protected tables, electrical power, and standard laboratory consumables. Momentus does not provide Cubesat jigs or stands.

Entry to the integration room is via a dedicated gowning room. Standard FOD mitigation protocols will be in effect when entering or exiting the customer integration room.

Power conditioning (voltage, amperage, frequency and plug type) will be organized in advance of customer arrival and shall be specified within the customer Interface Control Document (ICD).

While at Momentus facilities, customers are not permitted to take photographs on personal devices. Momentus will provide a camera and review all photographs prior to distribution to the customer. The layout of customer integration and workspace areas are shown in **FIGURE 5-1** and **FIGURE 5-2**.

TABLE 5-1 MOMENTUS FACILITY OVERVIEW

RESOURCE	SIZE (SQ. FT.)	CLEANLINESS
Airlock	625	N/A
Spacecraft Integration Cleanroom	4,500	100,000 (ISO 8)
Spacecraft Test & Customer Integration	500	100,000 (ISO 8)

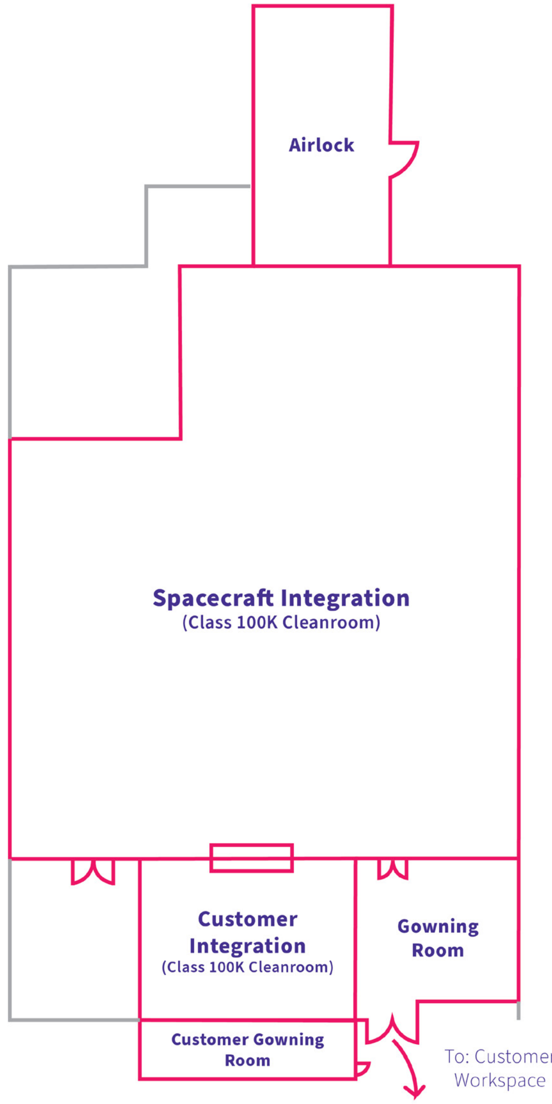

FIGURE 5-1 CUSTOMER INTEGRATION FACILITY LAYOUT

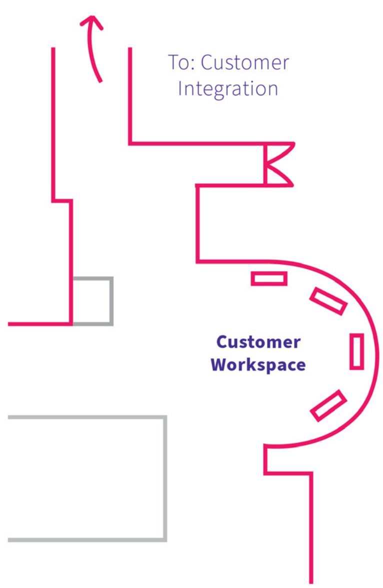

FIGURE 5-2 CUSTOMER WORKSPACE LAYOUT

5.4 INTEGRATION & LAUNCH

5.4.1 OSV Payload Integration

All customers should expect to travel to Momentus' facilities and participate in the final checkouts and closeouts of their payload(s). Following checkout, Momentus and customer personnel will integrate the payload with the OSV and ensure the payload is properly configured with the separation system, when applicable. Joint payload integration is encouraged to ensure safety of the payload, the OSV, and the integration personnel. Additionally, potential payload troubleshooting and risks can be mitigated by customer personnel on-site. For any payload integrations that cannot supported by customer personnel on-site, Momentus must review and approve of the proposed integration plan and reserves the right to decline performance of high-risk procedures.

5.4.2 Launch Campaign

Customer payloads will be in a powered-off state from integration until mission handover on-orbit. Following integration, no further customer participation is expected until handover on-orbit. Therefore, it is anticipated that the customer has no required responsibility to support the launch campaign. Hazardous propellant loading is available as an optional service, in which case it is expected that the customer will attend the launch campaign, however, this is not a standard offering.

5.4.3 Launch

Containerized payloads will typically not have access to power from either the OSV or launch vehicles. Non-Containerized payloads will have access to power and electrical interfaces to the OSV or launch vehicles, as defined in the Service Agreement.

Momentus will organize customer access to the launch base through launch provider VIP services upon request. Momentus cannot guarantee that the launch provider will approve all requests.

Customers will be responsible for all personal travel costs.

Customer access to the launch site is subject to launch site security policies and procedures. Customers must provide Momentus with required personal identification no later than L-60 days. Momentus cannot guarantee customer access to the launch base because it is solely determined by the cognizant local authority (Cape Canaveral Air Force Station, Florida – 45th Space Wing or Vandenberg, California – 30th Space Wing). Customers not traveling to the launch base may view a live-stream of their launch as available from the launch vehicle provider.

5.5 MISSION OPERATIONS

Following a successful launch, Momentus will relay confirmation of successful OSV separation from the launch vehicle (by the launch vehicle provider). Depending upon the contracted service type (i.e, Delivery or Hosted), the following Mission Operations will occur, as specified in **TABLE 5-2** and **TABLE 5-3**.

5.5.1 Delivery Service CONOPS

Following OSV separation from the launch vehicle, the OSV will enter a commissioning phase which lasts approximately 14 days. During this time, Momentus will provide to the customer periodic status updates regarding health and safety of the payload. Periodic updates will continue throughout the transit phase of the mission, the duration of which is unique to that mission. Momentus will conduct a pre-deployment review with the customer present and provide an initial set of orbital insertion parameters to assist in ground station preparation.

TABLE 5-2 DELIVERY CONOPS TIMELINE

TIMELINE	DESCRIPTION
Prior to Launch	Operational handover planning and notional payload deployment window
<1 day after Launch	Confirm successful launch and OSV separation
2-14 days after Launch	Updated payload deployment window
Transit (as applicable)	Weekly status updates • OSV health updates • Mission progress updates
Deployment - 2 days	Updated payload deployment window
Payload Deployment	Customer confirmation of payload acquisition and object registration

5.5.2 Hosted Service CONOPS

During the mission planning phase, Momentus and the customer will work together to develop a tailored in-space Mission Operations Plan, which is documented by the Momentus Flight Operations team. This goal of this document is to provide optimal CONOPS given the expected capabilities of Momentus' OSV and the customer's mission objectives.

Following OSV separation from the launch vehicle, the OSV will enter a commissioning phase which lasts approximately 14 days. During this time, Momentus will provide to the customer periodic status updates regarding health and safety of the payload. At a time specified in the Mission Operations Plan, customer operations will commence and last for a duration specified in the Service Agreement.

Depending on the assigned mission, the hosted payload may be captured by an onboard camera on a best-effort basis. However due differing payload layouts and angles, Momentus cannot guarantee specific view angles or exact timing of photographs or video. Additionally, photos and videos will not be available in real-time.

TABLE 5-3 HOSTED CONOPS TIMELINE

TIMELINE	DESCRIPTION
Prior to Launch	Hosted mission operations planning and review
<1 Day after Launch	Confirm launch success and OSV separation
Transit (as applicable)	Weekly Status updates • Vehicle health updates • Mission updates
Hosted Mission Operations	Momentus and customer execute contractual Hosted mission operations
Completion of Hosted Mission Operations + 1 month	Decommissioning of Hosted Payload

5.6 MISSION SUPPORT

5.6.1 Mission Management

Momentus will provide the customer a dedicated mission manager for the duration of the contracted mission. The mission manager will be the sole point of contact (POC) for all aspects of the mission, including documentation of deliverables and licenses, scheduling meetings and reviews, and coordination of technical activities. Hosted Payload missions will also be heavily supported by Engineering, Program Management, and Flight Operations team members for coordinating technical aspects of the mission. The mission manager also works closely with the launch vehicle provider to ensure all Range Safety requirements are met. Under no circumstances should the customer contact the LSP directly.

Following contract signature, Momentus Mission Management will conduct a kick-off meeting with the customer to review mission parameters and LSP/Range Safety requirements. Following this meeting, Momentus will create and maintain the payload ICD, which is jointly developed with the customer. At a minimum, the ICD defines all mechanical and electrical interfaces, mission requirements, and payload MPEs. The ICD remains in draft until it is signed just prior to payload integration, at which point it enters configuration control and takes precedence over the Statement of Work (SOW). A Mission Operations Plan will be developed in addition to the payload ICD for all Hosted payloads.

See Appendix A for mission deliverable timelines and a breakdown of standard Momentus and customer responsibilities according to the contracted service. Non-standard responsibilities may be added based on the Service Agreement. Mission Management will work with the customer to ensure that all deliverables are submitted on time. **Failure of the customer to meet deliverable due dates will impact Momentus' ability to successfully launch the payload on time.**

5.6.2 Coupled Loads Analysis

In support of the launch vehicle Coupled Loads Analysis (CLA), Momentus requires the customer to provide a finite element model (FEM) for all non-containerized payloads. The customer provided FEM will be combined with the OSV FEM, prior to delivery of the combined FEM to the launch vehicle provider.

CLA is used to verify mission specific maximum predicted dynamic environments. It is solely at the discretion of the LSP to supply CLA outputs (i.e, maximum accelerations and interface loads). Typically, only exceedances, if any, are provided by the LSP. Submission guidelines for the customer FEM are given in Appendix D.

5.6.3 Thermal Analysis

Momentus will perform a thermal analysis for each mission in order to verify acceptable orbit temperatures for both the customer payload and OSV. Customers with non-containerized payloads are therefore required to submit a thermal Finite Difference Model. The customer-furnished thermal FDM submission guidelines are detailed in Appendix E.

Containerized payloads are not required to submit a thermal FDM, nor will they receive a payload-specific thermal analysis unless the mission analysis determines that environments exceed those provided in this User's Guide.

5.6.4 Conjunction Analysis

Momentus will perform a conjunction analysis for each deployed payload such that the separation timing precludes any re-contact between the customer payload, co-payloads, and OSV within a minimum of 3 orbits following separation. For reference, there is typically a minimum of several hours between payload separation events to reduce risk of collisions.

5.6.5 Separation Fit-Check Analysis

For customers with a non-containerized payload, hosted payload, deployer or separation system, Momentus will organize a pre-integration fit-check at the San Jose, CA facilities. The fit check will cover both mechanical and electrical interfaces and PASS/FAIL criteria will be clearly documented within the payload ICD.

5.6.6 Licensing Review

Momentus will work with the customer and launch vehicle provider to ensure that the customer payload is properly licensed. Prior to payload integration, the customer will submit a letter certifying that all required licenses have been obtained and that all payload information provided to Momentus and/or any licensing agencies is complete and accurate. Payloads will not be integrated with the OSV unless the required licenses are obtained.

5.7 SAFETY & MISSION ASSURANCE

Customers are required to submit documentation verifying payload compliance to the applicable launch base Range Safety authority requirements. For U.S government launch bases, the AFSPCMAN 91-710, Vol 3 (including Vol. 6 if participating in launch campaign activities) design requirements must be met. For any non-compliance, the customer will need to create a tailoring request which is submitted to the Range Safety authority for review and approval. International standards can be used in substitution but must also be submitted to the Range Safety authority for review and approval. Momentus will assist the customer through the tailoring process wherein support does not consist of an export. If any unique hazards are identified, additional data may be requested. Tailoring requires significant coordination and should not be considered standard practice.

Providing approval for the launch of all payloads is the sole responsibility of the Range Safety authority (and neither Momentus nor the launch vehicle provider). As such, the customer is recommended to consider these requirements well in advance of payload design and testing.

Momentus manages risk to ensure safety through all phases of ground operation, launch, and on-orbit operations. Momentus is implementing a risk management system according to the guidelines and requirements of ISO 17666 Space Systems — Risk Management. This system evaluates the likelihood and consequence of various types of risks, which are mitigated with controls appropriate to the risk level.

Momentus will act to enforce the on-orbit safety of both the OSV and other spacecraft. This includes restricting hazardous operations such as using thrusters, activating deployables, and emitting high power RF, or using high power lasers. These operations will need to be directly coordinated with Momentus and may be restricted based on coordination with other parties such as the US Space Force, NASA, FAA, or other Momentus customers.

Appendix A

TIMELINES & RESPONSIBILITIES

TABLE A-1 MOMENTUS DELIVERABLE TIMELINE & RESPONSIBILITIES

TIMELINE	DELIVERY SERVICE	HOSTED PAYLOAD SERVICE
Contract + 2 weeks	Mission Integration Kickoff Package Initial inputs to Interface Control Document (ICD)	Mission Integration Kickoff Package Initial inputs to Interface Control Document (ICD)
L-8 months	Thermal FDM Results (Non-Containerized only) Random Vibration MPE (Non-Containerized only)	Thermal FDM (Non-Containerized only) On-Orbit Operations Plan Random Vibration MPE
L-3 months	Pre-Ship Review	Pre-Ship Review
L-2 months	-	Operations Checkout
L-0	Launch	Launch
Variable	OSV Status Updates	OSV Status Updates
L+[TBD]	Payload Deployment	[Start of Hosted Operations - *Details captured in Service Agreement and Operations Plan*]

TABLE A-2 CUSTOMER DELIVERABLE TIMELINE AND RESPONSIBILITIES

TIMELINE	CONTAINERIZED PAYLOADS	NON-CONTAINERIZED PAYLOADS	HOSTED PAYLOADS
Kick-Off + 2 weeks	Constituents List	Constituents List	Constituents List Regulatory worksheet inputs
L-11 months	-	Inputs to ICD Payload CAD model Payload dynamic model	Inputs to ICD Payload CAD model Payload dynamic model Initial on-orbit CONOPS Initial mass properties Test approach Test deviation requests Mechanical interface definition Electrical interface definition
L-10 months	Inputs to ICD Initial mass properties Test approach Test deviation requests	Initial on-orbit CONOPS Inputs Initial mass properties Test approach Test deviation requests Mechanical interface definition Electrical interface definition	-
L-9 months	Inputs to ICD Initial mass properties Test approach Test deviation requests	-	-
L-8 months	-	Range safety checklist Payload program introduction AFSPCMAN 91-710 tailoring AFSPCMAN 91-710 compliance letter Integration Procedures	Range safety checklist Payload program introduction AFSPCMAN 91-710 tailoring AFSPCMAN 91-710 compliance letter Integration Procedures
L-7 months	Range safety checklist Payload program introduction AFSPCMAN 91-710 tailoring AFSPCMAN 91-710 compliance letter	Final mass properties update On-orbit CONOPS update	Final mass properties update On-orbit CONOPS update

TABLE A-2 CUSTOMER DELIVERABLE TIMELINE AND RESPONSIBILITIES (CONT.)

TIMELINE	CONTAINERIZED PAYLOADS	NON-CONTAINERIZED PAYLOADS	HOSTED PAYLOADS
L-6 months	Updated mass properties Integration procedure	Final Integration procedure update Verification of compliance to ICD Facility visitor paperwork Hazardous materials list Environmental Test Report Contamination Compliance EMC Verification	Final Integration procedure update Verification of compliance to ICD Facility visitor paperwork Hazardous materials list Environmental Test Report Contamination Compliance EMC Verification
L-5 months	-	Payload delivery Measured mass License certification letter Copies of on-orbit license (non-FCC)	Payload delivery Measured mass License certification letter Copies of on-orbit license (non-FCC)
L-4 months	Final integration procedure update Verification of compliance to ICD Facility visitor paperwork Hazardous materials list Battery life Environmental Test Report Contamination Compliance EMC Verification	Last battery charge date and time Launch readiness certification	Last battery charge date and time Launch readiness certification
L-2.5 months	Payload delivery Measured mass License certification letter Copies of on-orbit licenses	-	-
L-2 months	Last battery charge date and time	-	-

Appendix B

MECHANICAL DRAWINGS

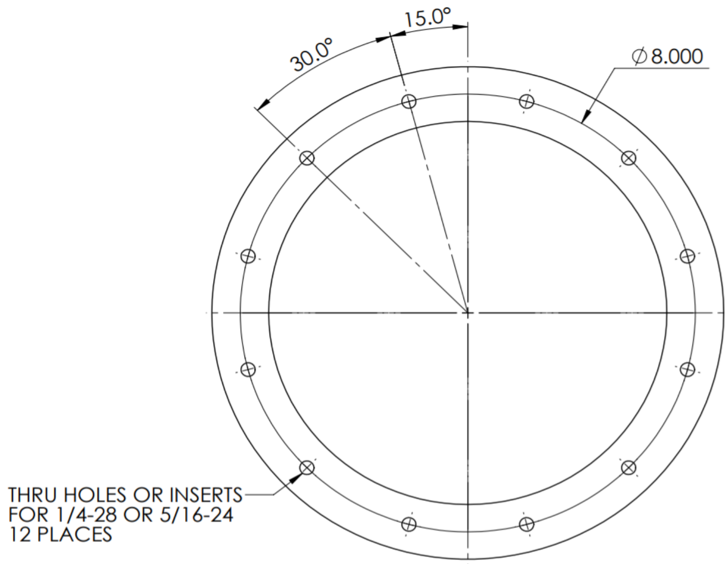

FIGURE B-1 STANDARD 8-INCH RING MOUNTING INTERFACE BOLT PATTERN

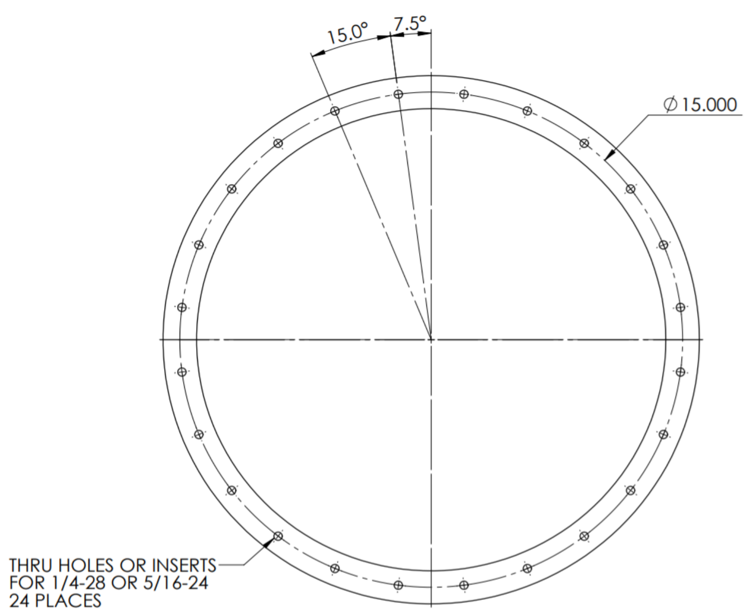

FIGURE B-2 STANDARD 15-INCH RING MOUNTING INTERFACE BOLT PATTERN

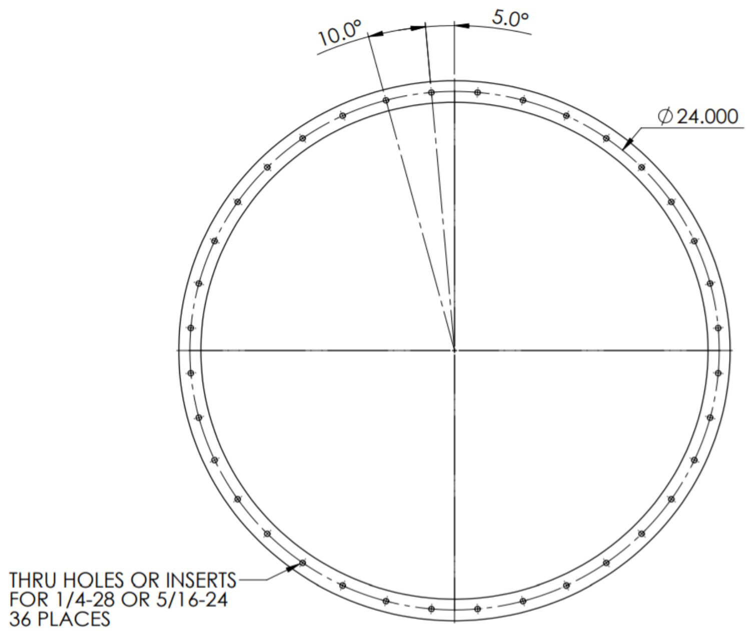

FIGURE B-3 STANDARD 24-INCH RING MOUNTING INTERFACE BOLT PATTERN

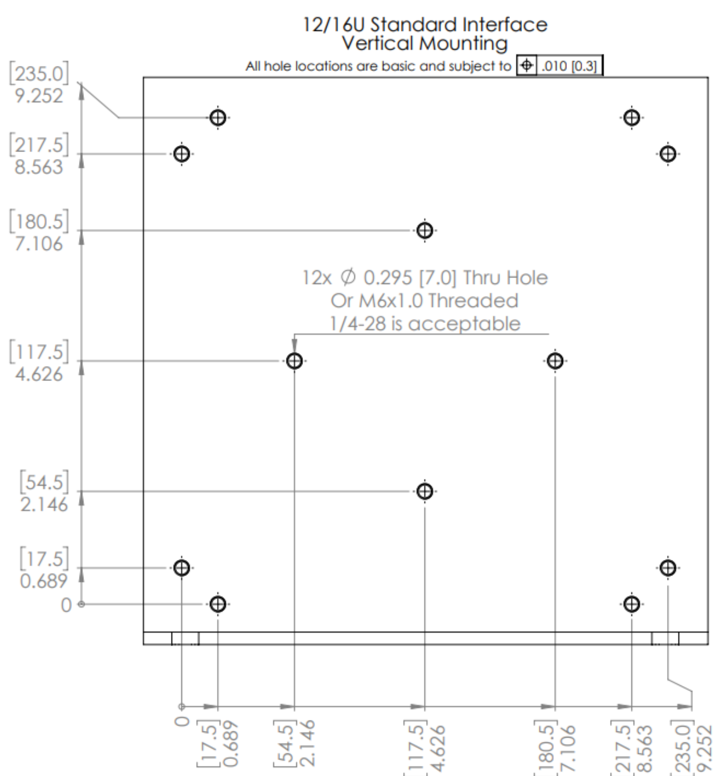

FIGURE B-4 STANDARD SQUARE MOUNTING INTERFACE BOLT PATTERN

Appendix C

CAD SUBMISSION GUIDELINES

FORMAT REQUIREMENTS

- STEP file format instead of native SolidWorks files
- Remove all detail screws, electronics connectors, and PCBS (especially PCBS)
- Include those features where they are needed to reference as part of an interface between payload and spacecraft

MODEL REQUIREMENTS

- Stowed (model or envelope)
- Deployed (model or envelope) - if applicable
- Dynamic envelope (volume sweep to complete deployment/operations) - if applicable

Appendix D

FEM SUBMISSION GUIDELINES

All requests below are for the payload in launch configuration (deployables stowed):

- Analysis code (ANSYS, NASTRAN, ABAQUS, etc.)
- Analysis model units (length, mass, time)
- Number of elements and nodes
- Is the satellite release mechanism included in the model? (Yes/No)
- Coordinate system definition, with picture
- Table of FEM mass properties (mass, CG, and MOI)
- Table of payload current best estimate mass properties (mass, CG, MOI), if different from above
- Definition of damping value
- List of fixed-base primary structure modes (modal effective mass >5%) in launch configuration
- Pictures and descriptions of primary mode frequencies and mode shapes (fundamental modes in X, Y, and Z directions, and other major modes)
- Analysis mesh in NASTRAN format (.blk, .dat, etc.) OR reduced Craig-Bampton FEM, if available
- Additional requests if FEM delivery is a reduced Craig-Bampton:
    1. Definition of boundary/interface nodes, with locations and coordinate system defined
    2. Comparison of unreduced (FEM) and condensed (Craig-Bampton) models:
        - Mass
        - Center of gravity relative to interface
        - First nine modes of free-free analysis
        - Fixed-based modal analysis from 0-1000 Hz, including modal effective mass

Appendix E

THERMAL FDM SUBMISSION GUIDELINES

Customers with non-containerized payloads are required to provide a simplified Thermal Finite Difference Model to include in the system-level thermal model in order to verify acceptable temperatures for both customers and the OSV while on orbit.

Option 1: **Customer Supplied FDM**

A customer-supplied thermal FDM maximizes the probability that the customer payload is accurately modeled. The requirements for creating the thermal FDM are listed below:

1. The model shall be in .DWG format and compatible with Thermal Desktop/Sinda 2021.
2. The maximum number of elements and nodes combined shall be 25.
3. Any spacecraft adapters or release mechanisms shall be included in the model.
4. For Hosted payloads, heat flux into the mounting interface shall be represented in the model with the model matching the overall predicted on-orbit heat flux for each operating mode within 5% accuracy.
5. For Hosted payloads, time-dependent heat flux will be pre-programmed in the FDM to account for duty-cycled components and operating-mode dependent heat loads.
6. Customers will submit a Powerpoint slide deck that includes the following information:
    - Model units (mass, power, length, temperature)
    - Overview of the FDM.
    - Number of elements and nodes.
    - Coordinate system definition with picture.
    - A summary of any thermal analysis results available from the customer. This will help verify that the customer FDM has been properly implemented in the Momentus system-level model
7. Customers will submit the supporting information listed in TABLE E-1.

Option 2: **Momentus Builds FDM for Customer**

If the customer is unable to provide a thermal FDM, Momentus will build a simplified FDM of the customer payload. Technical interchanges between Momentus and the customer will occur as necessary to discuss the thermal modeling strategy for the payload. The customer will submit the supporting information listed in TABLE E-1 to facilitate these discussions.

TABLE E-1 THERMAL FDM REQUIRED SUPPORTING INFORMATION

FDM SUPPORTING INFORMATION	DELIVERY	HOSTED
Mass (kg)	x	x
Thermal mass (J/K)	x	x
Thermo-optical properties of all surfaces	x	x
Mounting interface	x	x
List of sensitive components[1]		x
Operating modes with associated duty cycles		x
Heat flux into mounting interface for each operating mode		x

1. Sensitive components are defined as mission-critical components that need to be kept inside a tighter operating temperature range than -5 °C to +50 °C.