HOSTED PAYLOAD USER'S GUIDE

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Document Information

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0.2A	Clarification in revision numbering. Update to the section on frames of reference. Update to the section on electrical interfaces.	09/2023
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0.3C	Addition of illustration and numerous editions for added clarity.	11/2023
0.4A	Major addition of mechanical design drawings Added description of ground segment interfaces and high-level data flows	01/2024

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1 INTRODUCTION

1.1 User's Guide Purpose & Scope

The Hosted Payload User's Guide is intended to provide fundamental understanding of the necessary SpaceLocker Interface technical and operational information. This document is designed to help customers of SpaceLocker's payload hosting service, to support their program and engineering integration planning.

This Guide is divided into three main parts: The first (*1. Introduction*) provides context for the information that follows in the rest of the document; the second (*2. Overview*) presents the capabilities and uses of the Interface; and the third (*3. SpaceLocker Interface*) details the technical information necessary for the use of the Interface and describes its surrounding environment.

This Users Guide is being written concurrently with the development of the Interface. The information in this draft is subject to change as the designs are finalized, certified, and delivered.

In case of conflict between this Users Guide and other applicable design documents, the applicable document takes precedence.

SpaceLocker regularly updates this document as details become available along the path of development. The presence of systems which will only appear in later versions of the Interface has here been anticipated and mentioned.

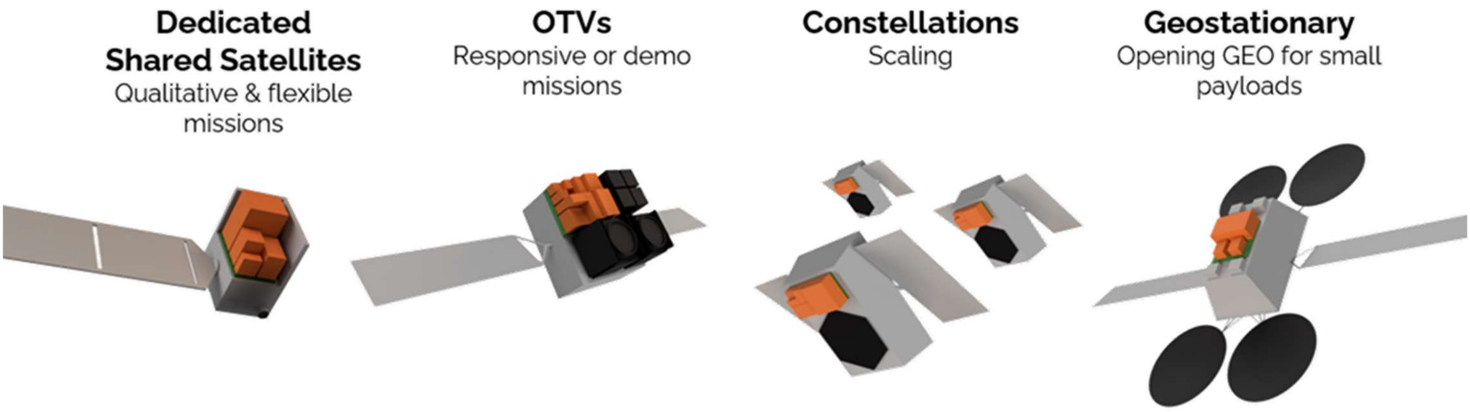
1.2 Company overview

SpaceLocker offers hosting services onboard spacecraft to make space missions more accessible, flexible, and sustainable. The company was founded on the philosophy of making satellite infrastructure reusable for a sustainable and cost-effective space industry. Answering the critical need to deploy hardware and software solution in orbit easily while enabling controlled scaling, SpaceLocker long-term vision is to develop a reusable satellite infrastructure at the heart of the in-orbit servicing economy.

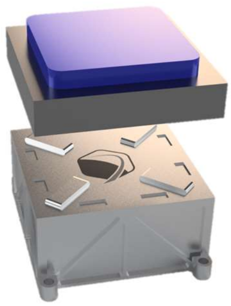
Established in 2022 by Theophile Lagraulet and Baptiste Fournier, SpaceLocker is a French company based in Paris and Toulouse. Backed by the French Space Agency (CNES), it has been the first company to be selected by Thales Alenia Space for its Space Business Catalyst and it is collaborating with numerous space firms building a true gateway to orbits with its first commercial flights starting in 2025.

SpaceLocker is building a diverse launch manifest to cover access to any orbit for all payloads up to 100kg. This flight catalogue is composed of dedicated shared satellites and partner vehicles with secondary hosting capabilities enabling to cover both tests and validation of new equipment but also generate space data at scale. Our offer is made to empower innovative players producing the space data needed to monitor, improve, and understand our world.

While SpaceLocker's offer is focused on efficiency and performance for its users, the company is firmly standing for a sustainable development of the space industry both on Earth and in orbit as mutualization and reusability appear as key solutions for preserving resources and limiting debris creation.



1.3 Universal Space Port Overview



Payload hosting has been mainly used by government agencies to deploy orbit capabilities for simpler, quicker, and cost-effective missions. Yet, it remained complex to implement technically and organizationally. To overcome this issue, SpaceLocker has developed a universal interface technology, the Universal Space Port (USP).

Similar to a "space USB port" and based on the idea of "plug & play" integration of payloads, this Interface allows the connection of practically any payload to any spacecraft, providing a 4-in-1 solution covering mechanical attachment, electrical connection, data exchange, and thermal coupling.

This asymmetrical interface is composed of two sides:

- the client side –the Key– has maximized simplicity, passivity, and mass-manufacturability.
- the receiver side –the Lock– bears the complexity, accompanying the logic of on-orbit satellite servicing.

Its fast integration capability allows SpaceLocker to offer a shortcut to orbit, cutting on the time and cost associated with developing and building a full satellite.

Reliability is a core element of the Universal Space Port. Designed with high levels of redundancy and safety margin, the USP is both designed to reduce at its minimum failure probability but also to improve anomaly detection and understanding.

Thanks to these capabilities, SpaceLocker's goal in the long run is to develop the Interface into a servicing port, ready for orbital assembly, repair, and upgrade to support the in-orbit economy with a universal standard.

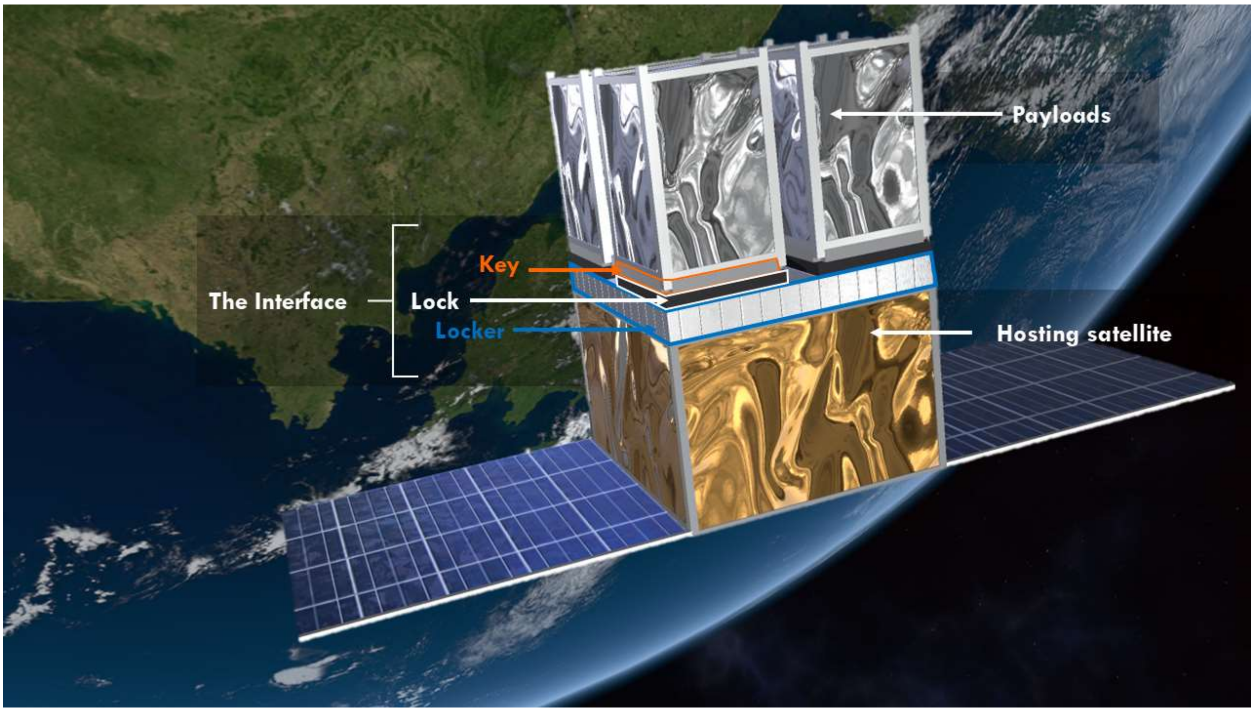


Figure 1: Schematic Illustration of The Key and The Lock Emplacement

1.4 Related Documents

The following documents are referenced herein and are intended to accompany this User Guide:

SPECIFICATION	TITLE
Assembly of the container with Rods	1.5U Assembly (Container)
Assembly of the Key with PCB and Connectors	Key Assembly (Key+PCB+Connectors)

1.5 Definitions

TERM	DEFINITION
Locker	SpaceLocker's orbital platform
Key	Payload side of the interface
Lock	Locker side of the interface
The Interface	The entire interface: Key + Lock + Locker

The diagram below describes the relations between the different terms defined in this section:

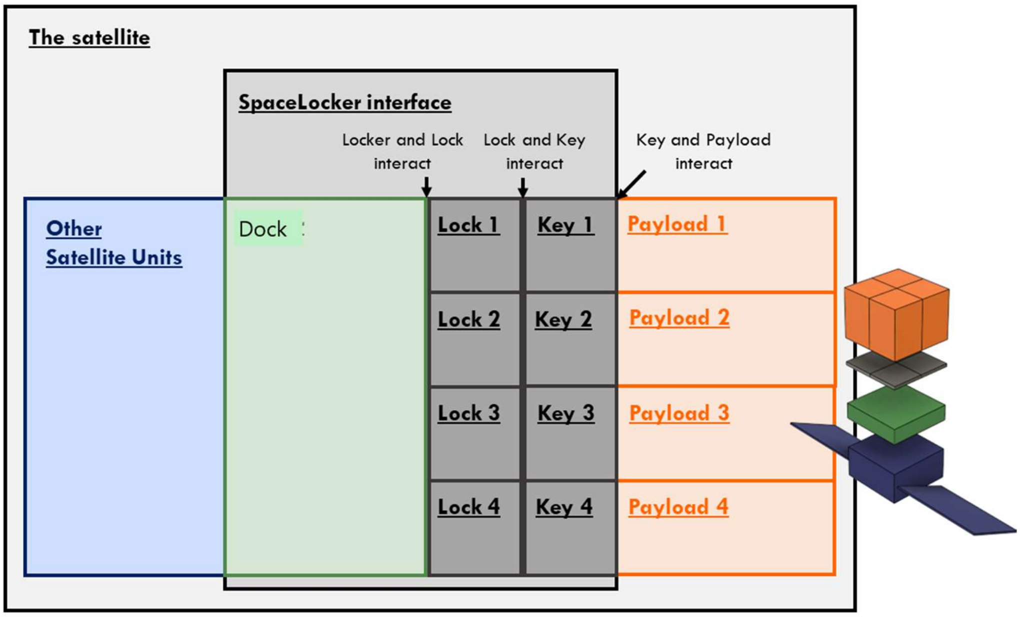


Figure 2: Simplified Graph of a SpaceLocker Satellite Components

1.6 Acronyms and Abbreviations

ACRONYM / ABBREVIATION	MEANING
GPIO	General Purpose Input/Output
ADC	Analog to Digital Converter
DAC	Digital to Analog Converter
ECSS	European Cooperation for Space Standardization
PDU	Power Distribution Unit
GND	Ground
SDK	Software Development Kit
EGSE	Electrical Ground Support Equipment
LEOP	Launch and Early Orbit Phase
FMECA	Failure Mode, Effects, and Criticality Analysis

1.7 Units and Coordinate Systems

Unless otherwise stated, all dimensions in this document are measured using the International System of Units (SI). All frames of reference are right-handed (the cross product of x and y gives z).

1.7.1 Orbital frame of reference.

As per the list of frames expected from ECSS-E-ST-10-09C31:

- **Inertial Coordinate System**

  Fixed inertial frame considered for orbits around Earth is the standard GCRF/J2000 frame.

- **Orbital Coordinate System**

  Local non-inertial frame used to express satellite attitude with respect to Earth is LVLH frame (+Z on nadir).

- **Earth-fixed, Earth-centric Coordinate System**

  Earth-fixed coordinate system considered for the location of objects on the surface of the earth is the standard ITRF frame, in its latest version (ITRF 2020 as the current revision of this guide).

- **Simulator Coordinate System**

  All simulators and software developed or distributed by SpaceLocker as part of the payload development kit, or other products, comply with the frames above unless stated otherwise.

1.7.2 Frame of reference attached to the Satellite.

The definition of the frame of reference attached to the Satellite is subject to change with the design of each platform offered on the booking platform.

In general, the +Z axis should be aligned with the direction of the satellite nominally pointed towards Earth ("Earth deck").

In general, the +X axis should be normal to the face of the satellite nominally pointed towards prograde, the positive velocity vector.

Figure 3: satellite frame of reference

1.7.3 Frame of reference attached to the Location.

Locations consist of a regular grid of "Lock" interfaces, repeated in two orthogonal directions in a single plane fixed relative to a surface of the satellite platform.

Locations are designated by their nominal attitude orientation, dependent of their position on the carrier satellite, and the nominal attitude of the carrier satellite.

The origin of the frame is at the **center** of a Lock in the corner of the pattern of Locks that constitute the Location.

The +X axis is aligned with the direction of the pattern with the most Locks, and +Y axis with the direction of the pattern with the fewer Locks.

The +Z direction is always normal to the surface, in the direction of space.

- When this definition gives four possible frames (for example, when there is an equal number of Locks in both directions of the pattern), the +X axis is chosen in the direction of the pattern that minimizes the dot product of $+X_{location}$ with $+X_{satellite}$. The +Y axis is chosen in the direction that closes the frame as a direct/right-handed frame of reference.

- When this definition gives two possible frames, the origin and directions are chosen, among the directions of the pattern, as to minimize the dot product of $+X_{location}$ with $+X_{satellite}$.

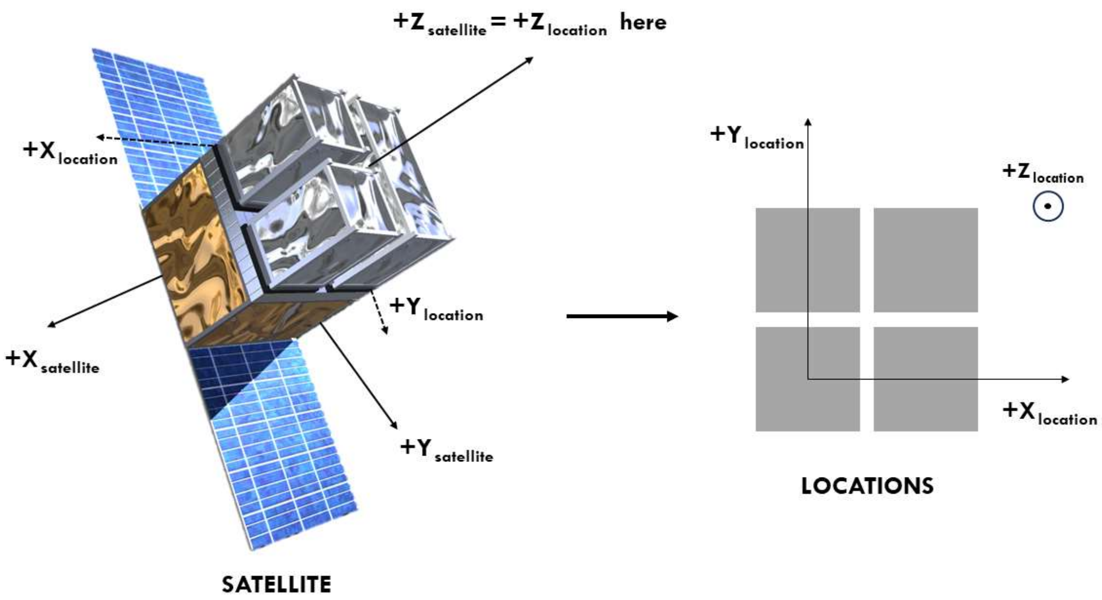


Figure 4: simple example of location frame

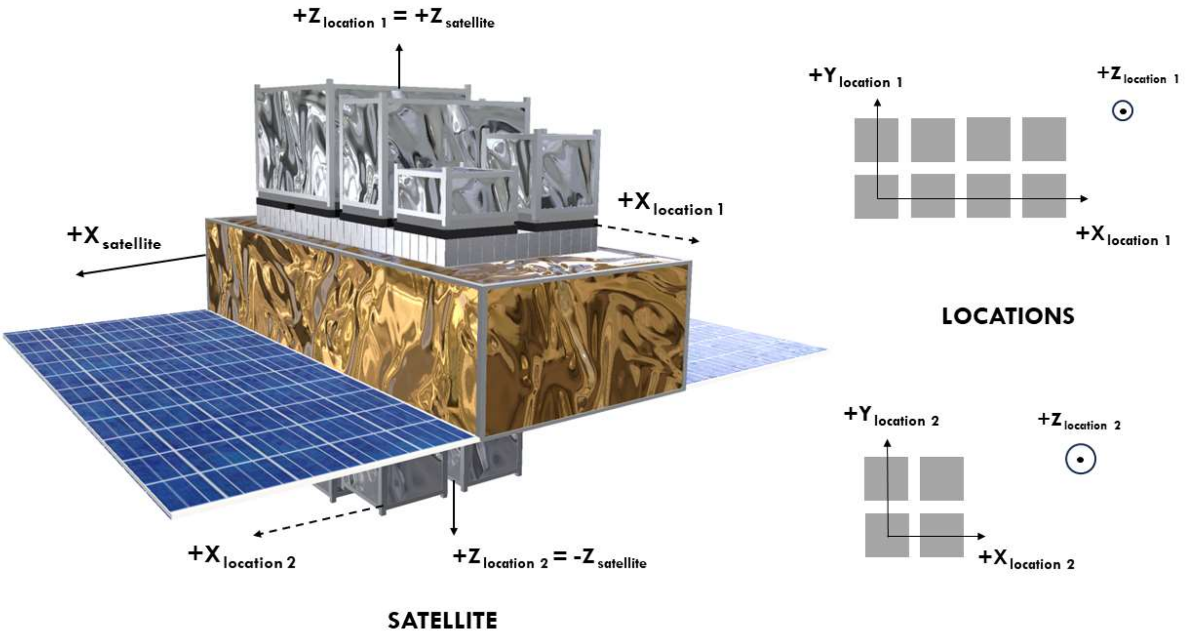
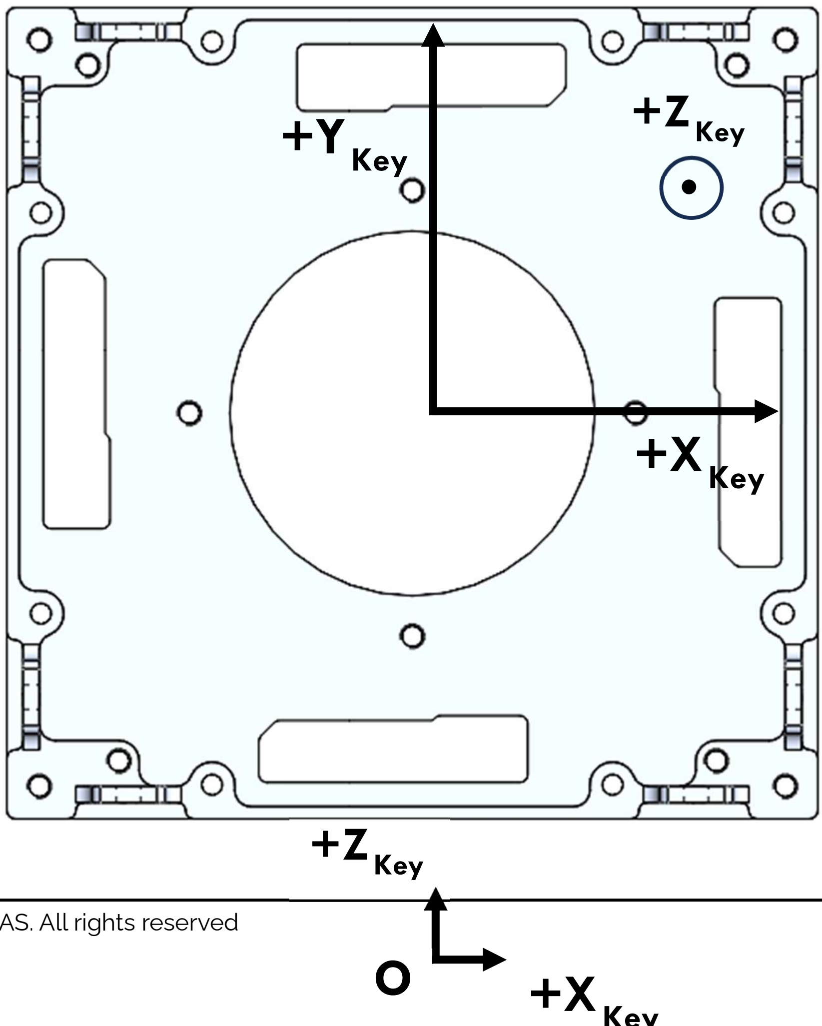


Figure 5: Second Example of Location Frames

1.7.4 Frame of reference attached to the Key and payload.

Once the frame of reference of the Location is defined, we can define the frame of reference of the Key (and payload) as follows:



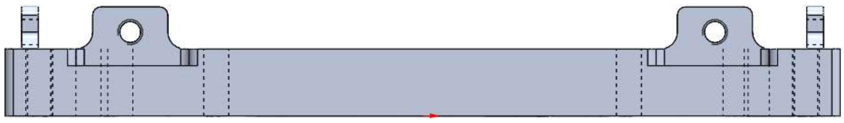


Figure 6: Key frame of reference (*Note: Some features of the Key are hidden*)

The center of origin (O in the figure) of the Key is situated in the geometric center of the Key, on the face that is in contact with the Lock.

The +X axis is parallel with the +X direction of the Location, and +Y axis is parallel with the +Y direction of the Location.

The +Z axis points from the bottom to the top of the Container (therefore being aligned with the Z+ direction of the Location).

2 SPACELOCKER MISSIONS

2.1 Applications

The Interface is designed to be standard and modular, maximizing flexibility in its applications. These can be divided into three main categories:

- **Hosting onboard a permanent orbital platform**: the SpaceLocker interface can be proposed on any type of platform to be able to host any type of payload. Thanks to the versability of the SpaceLocker interface design, any type of payload, compatible with the unit volume can be implemented even late during the program development.

- **Secondary hosted payload**: any type of secondary hosted payload can be easily implemented on any type of platform. Even if the secondary hosted payload mission is completely different than the main satellite mission, the design interface of SpaceLocker interface allows to have an easy access to the power, data handling and TM/TC of the main bus.

- **Shared single use missions**: any type of additional payload can be easily implemented on any type of platform. The flexibility of SpaceLocker interface design allows to implement any type of additional mission even late during satellite development.

2.2 Project management and development process

Note: For specific Manufacturing, Assembly, and Integration process, see section 3.11.

The project management and development process respect the following plan:

- Shortly after the frame contract is signed, or as part of the pre-sales process, the customer and SpaceLocker organize a **Preliminary Mission Review (PMR)**, to identify interfacing specifics, hardware requirements and design vigilance points.

- SpaceLocker provides, from one year before the flight, a flight model container including the structure and the Key, this user guide, software and SDKs, and some test equipment, including an EGSE for the reception interface.

- The customer is free to decide on the methodology and stages of development and qualification of the payload, and interacts with SpaceLocker to ensure the success of the mission:
  - No later than 6 months before launch, the customer invites SpaceLocker to take part in a **working day**. During this day, SpaceLocker helps to validate the interfaces planned in the flight design. At the end of this day, a specific flight opportunity is identified and booked.
  - No later than 3 months before the flight, SpaceLocker organizes a **delivery review panel**, in the presence of the customer, the launch supplier, and other technical and administrative players. This delivery review panel validates the payload's level of maturity and qualification and initiates its delivery.

- The payload is then received by SpaceLocker and mounted on a suitable satellite platform. The whole assembly undergoes launcher acceptance and mission qualification tests.

- The host vehicle is deployed in orbit, and the LEOP phase is carried out by SpaceLocker and its partners notably by relying on the payload's self-test capabilities.

- Once in orbit, the customer has direct access (SSH or equivalent) to the payload via SpaceLocker's network layer. They can then:
    - Retrieve data generated by their payload,
    - Control payload operations
    - Update or debug high-level payload administration software, which runs in the background on the payload processor,
    - Request platform operations from SpaceLocker (for example pointing, power or peak communication).

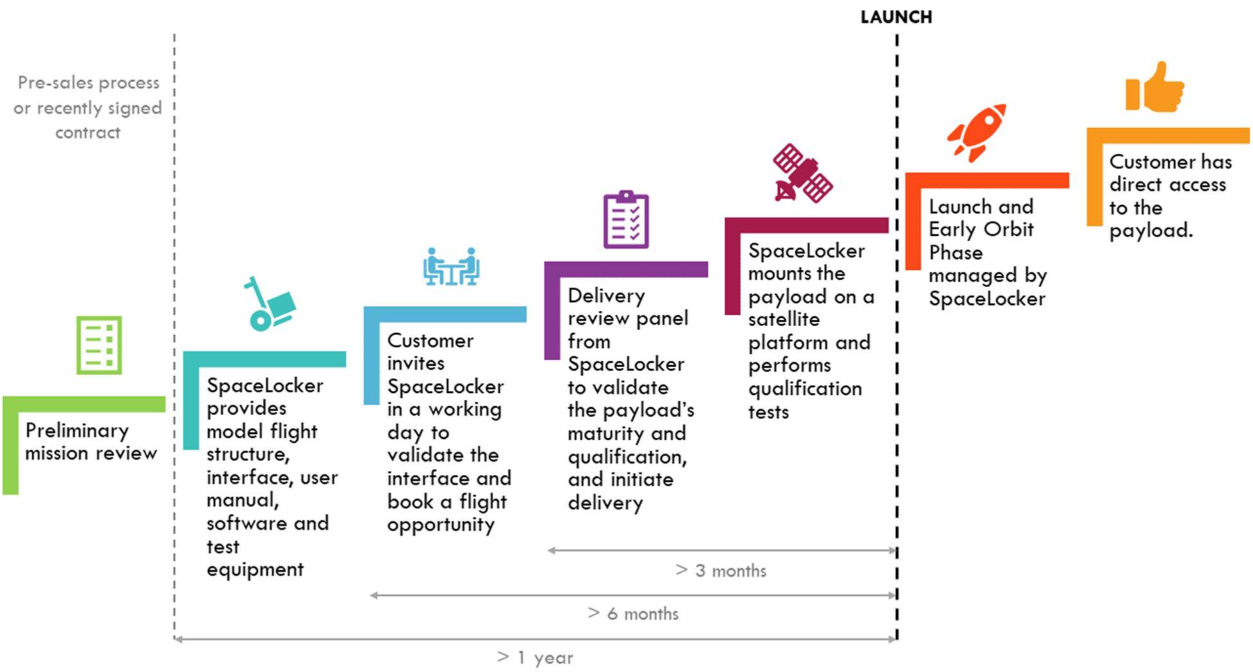


Figure 7: Diagram of Project Management and Development Process

3 SPACELOCKER INTERFACE

3.1 Overview

The Interface is a 4-in-1 solution covering mechanical attachment, electrical connections, data exchange, and thermal coupling.

The physical interface developed by SpaceLocker is highly asymmetrical by design to have a nearly passive, simple, and mass-producible client interface – the Key – and a much more complex and active receiver interface – the Lock.

Specifically, SpaceLocker's interface is based on the CubeSat standard with a 10x10cm footprint and is designed to be very compact with a Lock height of only 30mm and an even thinner Key.

The interface is modular to adapt to any client size. To do so, it perfectly fits in the square of its form factor and has 90-degree rotational symmetry. The 10x10cm size benefits from the standardization and technical progress made under the CubeSat standard, enabling maximum flexibility while maintaining enough room to fit the 4-in-1 set of interfaces. The modularity of the interface enables it to overcome the limitations of Cubesats, covering heavier payloads with lower constraints in volume, power consumption or data handling.

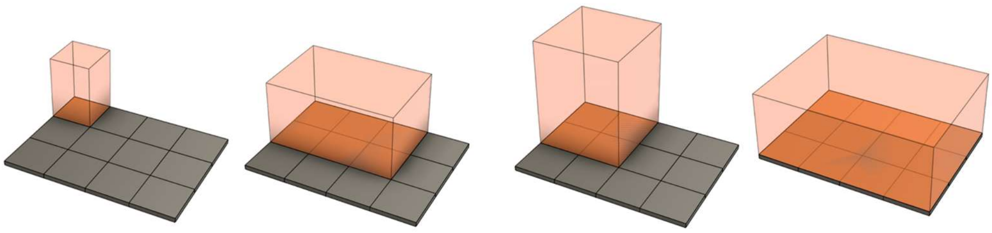


Figure 8 : Universal Space Port Modularity

3.2 Physical Properties

3.2.1 Dimensions

The Interface is based on the CubeSat standard to achieve maximum modularity across a variety of payload sizes, its footprint fitting into a 100x100mm square. The Key is maximum 10mm in height (see drawing below) and the Lock has a variable thickness depending on systems that need to be included in it.

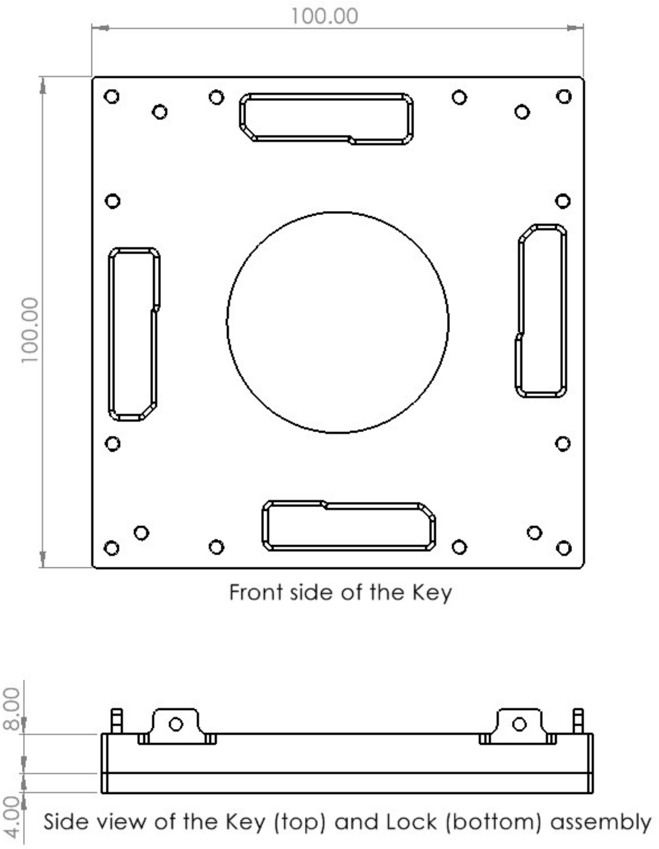


Figure 9: Dimensions of the Key

3.2.2 Backwards compatibility with CubeSat PC104 rods

The design of the Key is fully compatible with the PC104 convention, meaning that PC104-PCBs can be stacked up to the whole height of the structure if needed by the customer.

The Key is oriented in the way that is described below in 10.

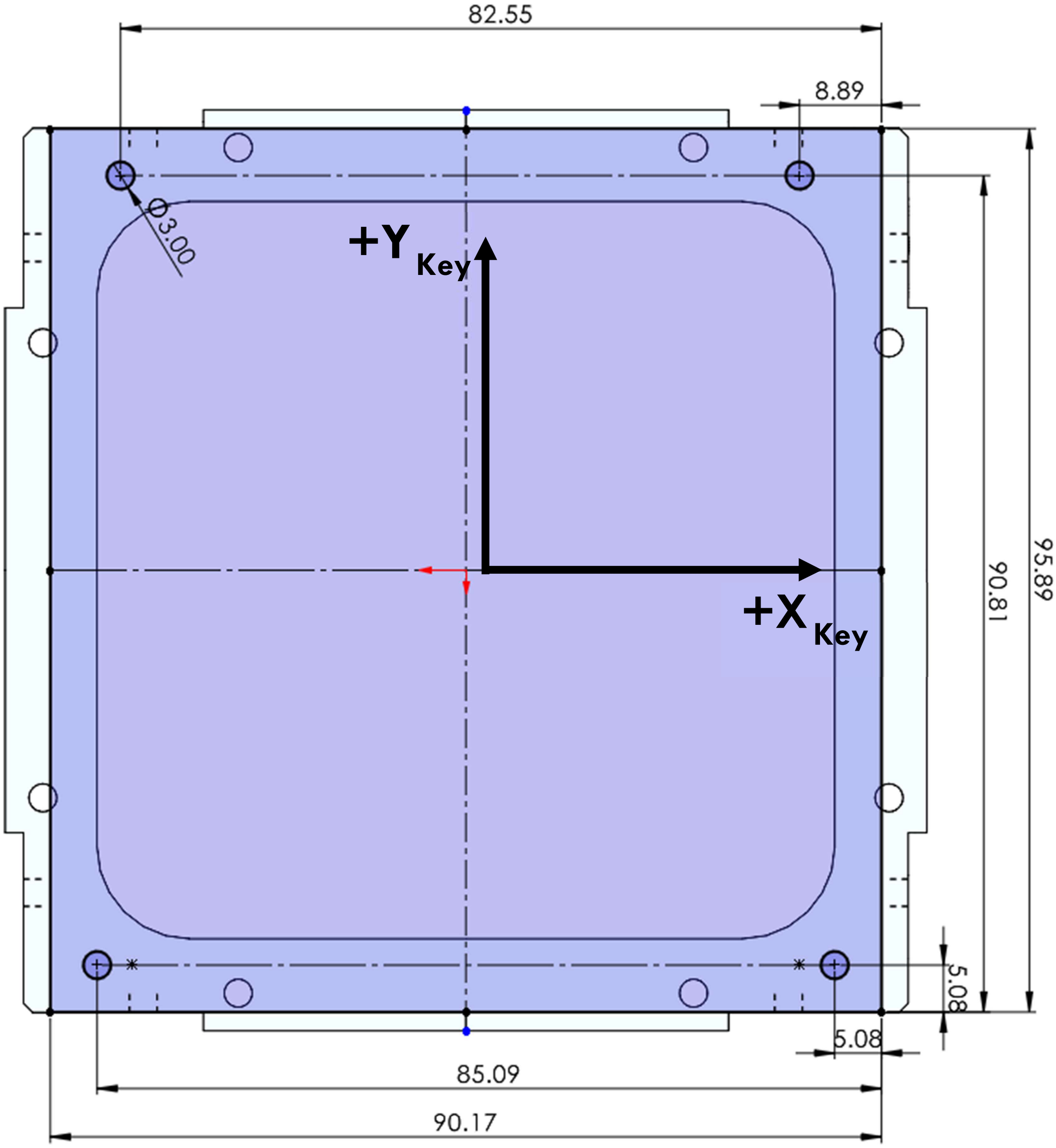


Figure 10: schematic of pc104 convention (here on the lid)

In the case of multiple keys payloads, the convention for the reproduction of keys follows the rules written and displayed in the example below in ***FIGURE 11***.

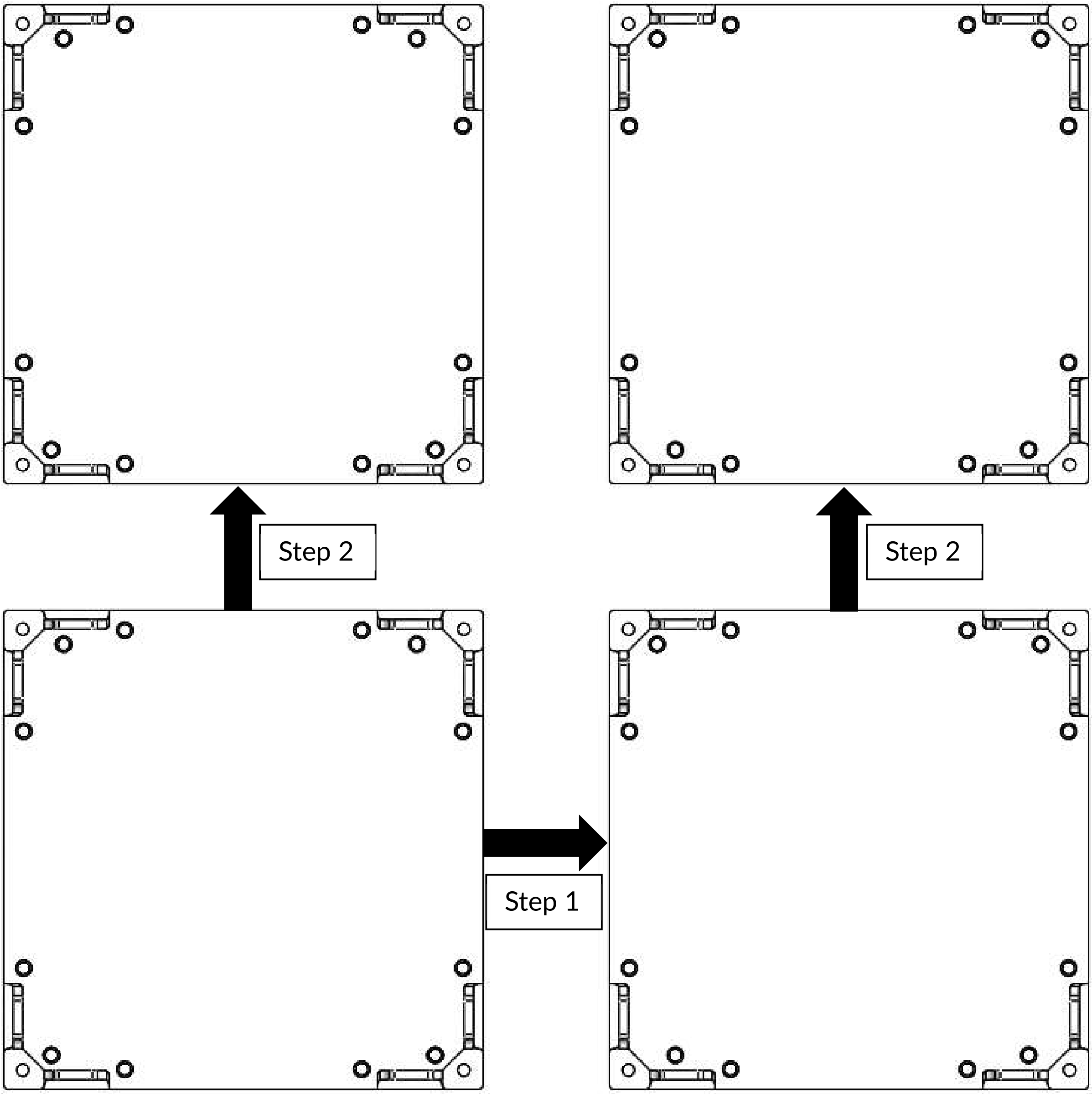


Figure 11: linear pattern of reproduction in multiple keys setups

<u>Step 1:</u> The Key is reproduced in a linear pattern in the direction where there is the highest number of Keys (X+ Direction). If the setup has the same number of keys vertically and horizontally then the key is reproduced as displayed in the example above.

<u>Step 2:</u> The Key is reproduced in a linear pattern in the other direction (Y+ Direction).

3.2.3 Robotic grabber interface

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3.2.4 Naming scheme

The proposed naming scheme is as such:

KEY-LL-WW-HH

- Where LL, WW and HH are the dimensions of the Key respectively for "length", "width" and "height",
- Where "width" is defined as the smaller of the two horizontal dimensions, and "height" as the vertical dimension.
- Where "height", when it is not a round number of tens of cm, is rounded to the higher number of tens of centimeters,
- Where the dimensions are expressed in tens of cm, and with leading zero in the case of values below one meter (i.e., below 10 tens of cm)

For example:

- A 374*268*143 mm payload, fitting in a 400 * 300 * 143 mm structure will have a structure named Key-04-03-02.
- 101*698*200mm payload, fitting in a 200 * 700 * 200 structure, will have a nomenclature KEY-02-07-02.
- 1268*1774*389 mm payload, fitting in a 1300 * 1800 * 389 structure, will have a nomenclature KEY-18-13-04.

3.2.5 Masses and Inertia

Note: For a reminder of the frames and units used in this section, see section 1.7.

TABLE 1.11.6-1 MASSES IN A 1X1 CONTAINER

PART	MASS (g)	QUANTITY
SLI-KEY-STR-FST-Front_Structure	66.95	1
SLI-KEY-ELE-PPC-Contact_Plane_Power_Connector	N/A	4
SLI-KEY-ELE-PDC-Contact_Plane_Data_Connector	N/A	4
SLI-KEY-ELE-IPC-Customer-facing_power_connector	N/A	2
SLI-KEY-ELE-IDC-Customer-facing_data_connector	N/A	2
SLI-KEY-ELE-PMB-Key_PCB_main_board	N/A	1
SLI-KEY-ELE-UCD-Key_Microcontroller_Daughterboard	N/A	1
CBO-STR-LID-1x1-1x1_Lid	19.98	1
CBO-STR-COR-1.5-1.5U_Corner	23.20	4
CBO-STR-INS-ROD-Rods	9.34	4

TABLE 1.11.6-2 MASSES IN A 2X1 CONTAINER

PART	MASS (g)	QUANTITY
SLI-KEY-STR-FST-Front_Structure	66.95	2
SLI-KEY-ELE-PPC-Contact_Plane_Power_Connector	N/A	8
SLI-KEY-ELE-PDC-Contact_Plane_Data_Connector	N/A	8
SLI-KEY-ELE-IPC-Customer-facing_power_connector	N/A	4
SLI-KEY-ELE-IDC-Customer-facing_data_connector	N/A	4

SLI-KEY-ELE-PMB-Key_PCB_main_board	N/A	2
SLI-KEY-ELE-UCD-Key_Microcontroller_Daughterboard	N/A	2
CBO-STR-LID-2x1-2x1_Lid	39.23	1
CBO-STR-COR-1.5-1.5U_Corner	23.20	4
CBO-STR-INS-ROD-Rods	9.34	4 or 8
CBO-STR-SSU-SU2-U2_Plate_Support	27.28	2
CBO-STR-LIS-1,0-1U_Lid_Support	3.29	1

TABLE 1.11.6-3 MASSES IN A 2X2 CONTAINER

PART	MASS (g)	QUANTITY
SLI-KEY-STR-FST-Front_Structure	66.95	4
SLI-KEY-ELE-PPC-Contact_Plane_Power_Connector	N/A	16
SLI-KEY-ELE-PDC-Contact_Plane_Data_Connector	N/A	16
SLI-KEY-ELE-IPC-Customer-facing_power_connector	N/A	8
SLI-KEY-ELE-IDC-Customer-facing_data_connector	N/A	8
SLI-KEY-ELE-PMB-Key_PCB_main_board	N/A	4
SLI-KEY-ELE-UCD-Key_Microcontroller_Daughterboard	N/A	4
CBO-STR-LID-2x2-2x2_Lid	58.53	1
CBO-STR-COR-1.5-1.5U_Corner	23.20	4
CBO-STR-INS-ROD-Rods	9.34	0
CBO-STR-SSU-SU2-U2_Plate_Support	27.28	4
CBO-STR-LIS-1.4-1.4U_Lid_Support	5.76	4
CBO-STR-INS-MU4-U4_Middle_Support_Plate	8.9	1

3.2.6 Materials and Finishes

TABLE 1.11.7-1 MATERIALS AND FINISHES

PART	MATERIAL	FINISH
SLI-KEY-STR-FST-Front_Structure	Al 7075	Anodized
SLI-KEY-ELE-PPC-Contact_Plane_Power_Connector	N/A	N/A
SLI-KEY-ELE-PDC-Contact_Plane_Data_Connector	N/A	N/A
SLI-KEY-ELE-IPC-Customer-facing_power_connector	N/A	N/A
SLI-KEY-ELE-IDC-Customer-facing_data_connector	N/A	N/A
SLI-KEY-ELE-PMB-Key_PCB_main_board	PCB	N/A
SLI-KEY-ELE-UCD-Key_Microcontroller_Daughterboard	PCB	N/A

CBO-STR-LID-1x1-1x1_Lid	Al 7075	Anodized
CBO-STR-LID-2x1-2x1_Lid	Al 7075	Anodized
CBO-STR-LID-2x2-2x2_Lid	Al 7075	Anodized
CBO-STR-COR-1.5-1.5U_Corner	Al 7075	Anodized
CBO-STR-INS-ROD-Rods	Stainless Steel A4	Raw
CBO-STR-SSU-SU2-U2_Plate_Support	Al 7075	Anodized
CBO-STR-LIS-1,0-1U_Lid_Support	Al 7075	Anodized
CBO-STR-LIS-1.4-1.4U_Lid_Support	Al 7075	Anodized
CBO-STR-INS-MU4-U4_Middle_Support_Plate	Al 7075	Anodized

3.3 Launch environments.

This section chronologically details the different cases of mechanical loading that a payload will encounter over the duration of its hosting.

3.3.1 Indicative Launch Loads

The following table contains typical values of loads experienced during launch. Please note that these values are only generally indicative, and that design should first and foremost be based on the launch vehicle manufacturer's requirements.

TABLE 3.3.1-1 INDICATIVE OVERALL LAUNCH LOADS

LOAD FACTORS (g)				
MASS RANGE	**UNDER 200KG**		**OVER 200KG**	
SPACECRAFT AXIS	*FORWARD MOUNTED*	*SIDE MOUNTED*	*FORWARD MOUNTED*	*SIDE MOUNTED*
AXIAL	12	10	9	6
RADIAL	10	12	6	9

Note: For information related to qualification and acceptance process, tests, and document, see section 0.

3.3.2 Soft Capture Loads

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3.3.3 Hard Capture Loads

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3.3.4 Orbital Loads

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3.4 Thermal Management

Note: For information related to qualification and acceptance process, tests, and document, see section 0.

This section details the thermal management of SpaceLocker's interface to maintain the customers payload at a working temperature.

The general philosophy of thermal management of payloads mounted on SpaceLocker flights is of isolation as best as possible from the outside environment, and tight coupling/forced management from the Lock interface.

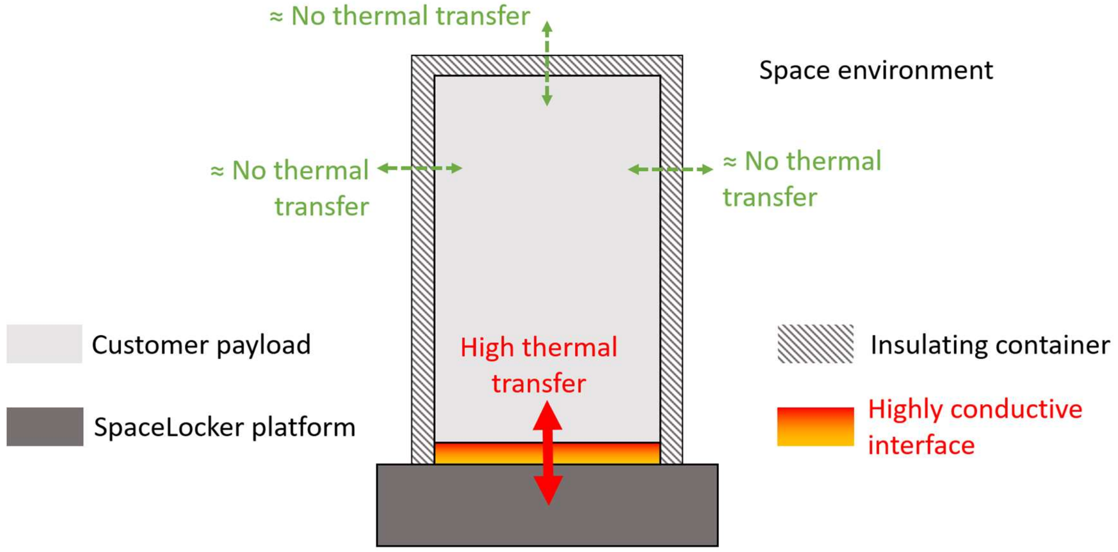

Figure 12: thermal transfer through surfaces of the payload.

3.4.1 Passive thermal management

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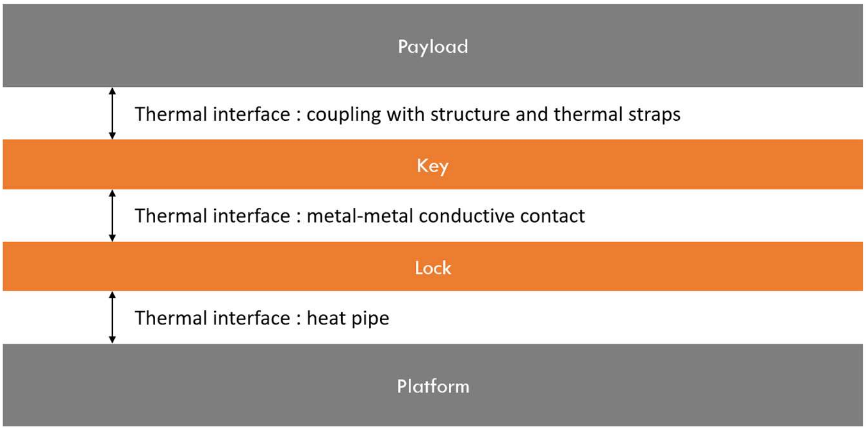
3.4.2 Active Thermal Regulation (For Thermally Regulated Versions)

Note: For details about mission modes, see section 3.10.3



Thermal regulation ensures good thermal conditions for the customer's payload, to enable it to function as intended, in the best conditions possible, despite the sun-exposed and eclipses phases and other space conditions.

Active thermal management features are included in the satellite platform, meaning that they are available during all mission including platform safe mode operation.

Heat dissipation

SpaceLocker platforms also includes in the Dock active thermal management components:

- A thermal switch, able to modulate the thermal conductivity between Lock and customer payload when required.
- A network of heat pipes to ensure excellent thermal transfer between the Lock and the support vehicle.

Thanks to this system, SpaceLocker is available to guarantee a specific temperature at the interface between the platform and the customer's payload.

TABLE 3.4.2-1 MAIN SURFACE REGULATION

MODE	MINIMUM INTERFACE TEMPERATURE	MAXIMUM INTERFACE TEMPERATURE
Survival	TBD	TBD
Nominal	20°C	25°C

Note: As of this version of the document, active dissipative thermal management is not yet available on SpaceLocker platforms.

Reheating

On request, SpaceLocker's customers are free to install reheaters (heat sensors and heating devices) inside its payload. SpaceLocker will then manage the temperature measurements and ensure power arrival for the heating device during the mission. The customer's hardware will therefore be heated adequately without the customer having to manage it. This option is available starting from SpaceLocker's first mission.

Here are the corresponding available connections:

- Connections for 2 (fully redundant) heading pads (up to 1A each) per Lock (see pinouts)
- Connections for 2 (fully redundant) thermistors per Lock (see pinouts)

SpaceLocker has no specific recommended heating pad technology as of this version.

3.4.3 Payload Thermal Design Guidelines

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3.4.4 Thermal Hardware Catalog

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3.5 Installation

3.5.1 Kit Contents

TABLE 3.5.1-1 KIT CONTENTS

PART	DESCRIPTION	QUANTITY (per Key)
S1SDT-15-X	Data connector and 30 AWG pigtail	2
UMPC-02-S-18-M-X	Power connector and 18 AWG pigtail	4
SLI-KEY-STR-FST-Front_Structure	Key front structure (to mount the corners)	1
SLI-KEY-ELE-PMB-Key_PCB_main_board	Key back PCB (assembly including mounted connectors)	1
CBO-STR-COR-1.5-1.5U_Corner	Side rails (corners)	4
CBO-STR-LID-1x1-1x1_Lid	Top cover (lid)	1 (for whole kit)
DIN976-1-M3X17.5	Rods (to mount PC104-PCBs)	4
DIN985-M3X0.5	Nylon Locking Nut	4
ISO14580-A4/70-TX10-M3X6	Structural screws	48

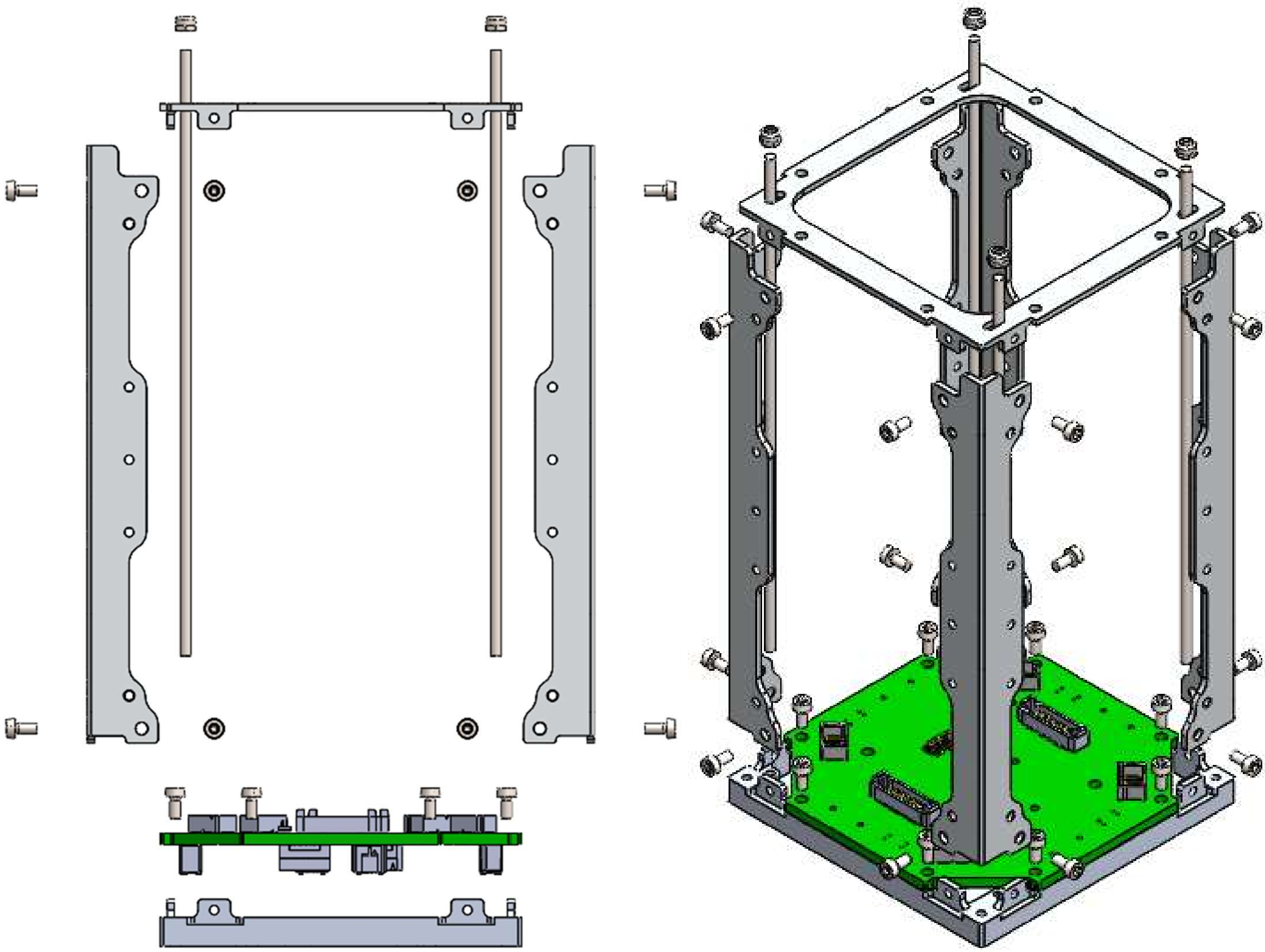

Figure 13: Exploded right and isometric views of the 1x1 Container.

3.5.2 Payload fixturing inside the containers.

With regards to every aspect, except the mounting interface, the design of the container is in par with the CubeSat standard. That includes the 1U definition (100x100x100mm), the internal mounting approach (stacked PC104 boards) and the "Tuna Can" protrusion. Besides the CubeSat mounting standard, SpaceLocker offers plenty of flexibility and freedom for mounting options especially when the mission is not constrained by a CubeSat deployer.

3.5.3 PC104 Fixturing System

The SpaceLocker's Key features 4 M3 Threaded holes in the PC104 Standard (see ***FIGURE 14***). The user can place threaded rods directly in the holes and then use a M3 Locking nut in the Lid of the container or in an intermediate plate to tension the rods and proper constrain the stacked PCBs as shown in

Figure 13.

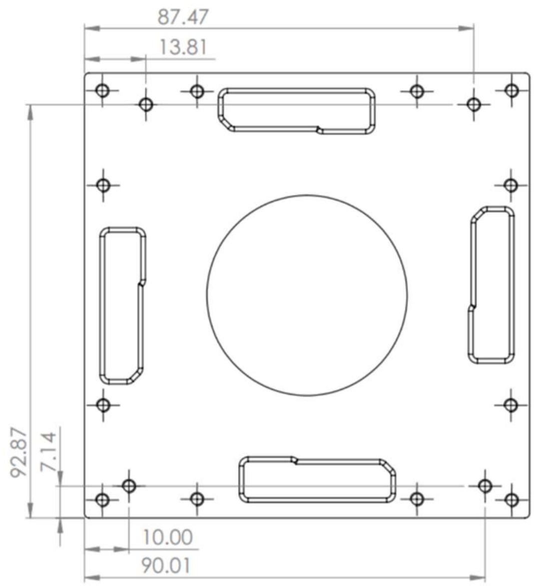

Figure 14: PC104 threaded holes spacing in the key.

3.5.4 Alternative mounting options

The container's rails feature a pattern of clearance holes for M3 bolts. Given that the constrains outlined in the **FIGURE 15** these holes can be used to mount parts directly to the sides of the container or as an anchor point for internal fixturing parts.

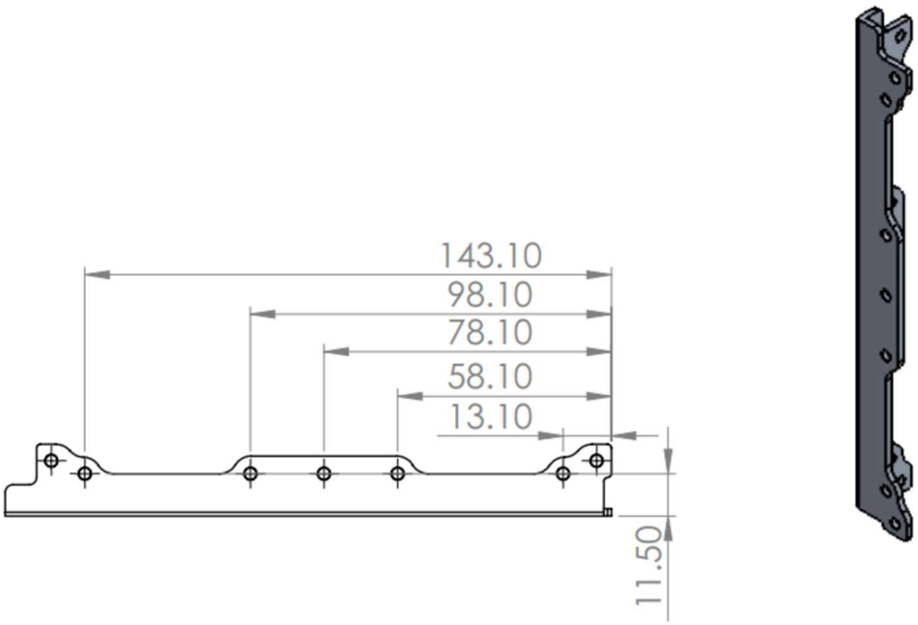

Figure 15: side mounting holes spacing in the 1.5u side rails.

3.5.5 Volume Constraints

To ensure successful operations and avoid interference with neighboring containers the existence of guidelines and constraints are introduced. To accommodate the possible flight configurations two sets of constraints are given:

- To manage the cases where the container is part of a CubeSat mission and therefore needs to follow the CubeSat specifications for the deployers,
- To manage the cases where the container is flown in a dedicated, non-CubeSat, satellite or as part of an OTV flight. In this configuration a more relaxed set of constraints is introduced.

1.1.1.1 Internal Volume

Internally SpaceLocker reserves the first 10mm in the $+Z_{key}$ direction for housing electronics and docking hardware. The rest of the internal heigh is available to the user (see ***FIGURE 16***)

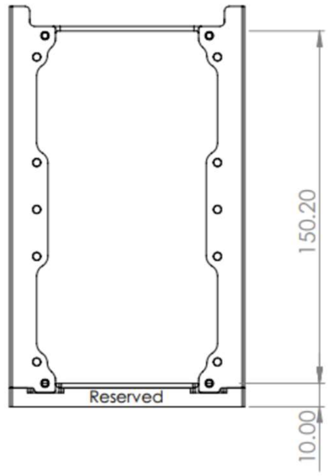

Figure 16: partitioning of the +Z_{key} direction for 1.5u container

At the present time SpaceLocker offers three size options with the same heigh of 1.5U, the available internal footprint for each of the options is shown in **FIGURE 17**.

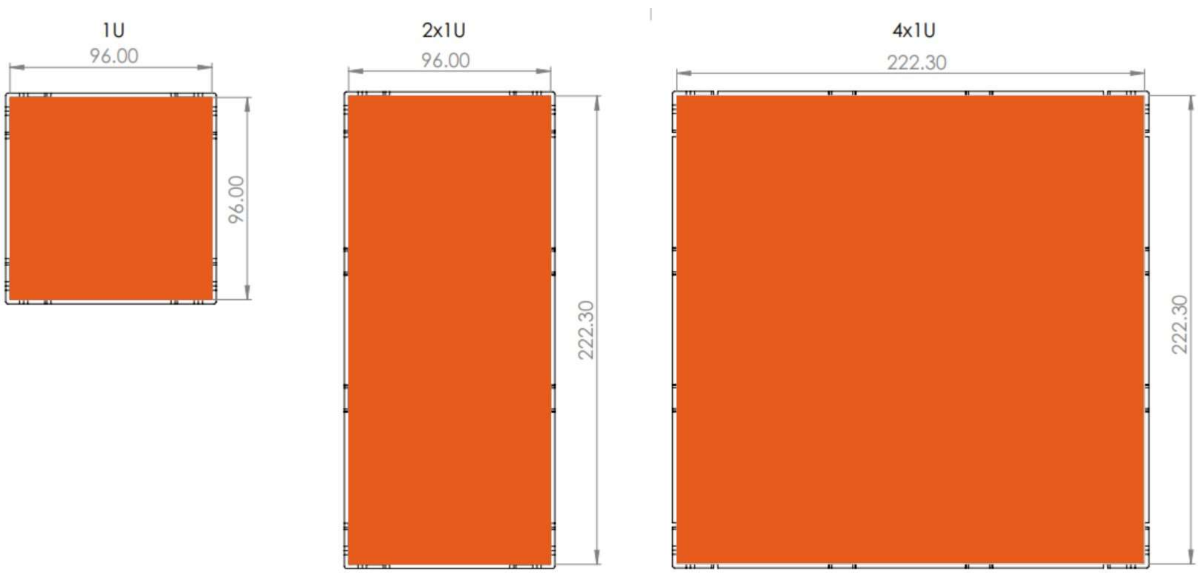

Figure 17: available footprint for the three available configurations

3.5.6 External Volume

3.5.6.1 Free Flight Configuration

When the mission is scheduled to launch on a dedicated, non-CubeSat, satellite, the available external volume is dictated by the grid spacing of the locker, which is 126.3mm. The footprint available to the end user is 125x125mm as shown in ***FIGURE 18***.

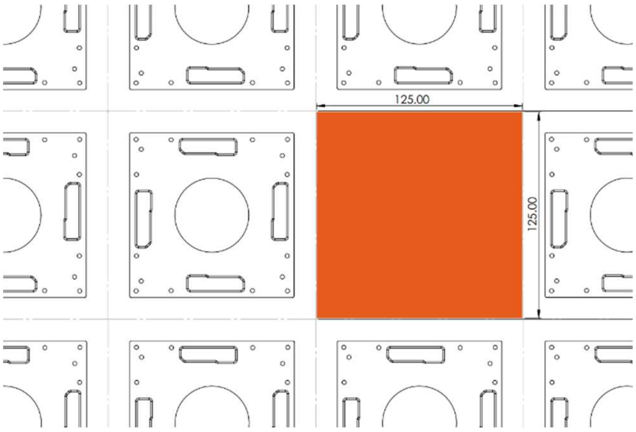

Figure 18: Available footprint in SpaceLocker's grid

The available height of the container in the $+Z_{key}$ direction is dictated by the launch provider and the compliance with the mass requirement outlined in TBD.

3.5.6.1.1 CubeSat Deployer

When the mission is in a CubeSat, the volume constraints are dictated by the deployer. In this flight configuration all the containers are of the same height (1.5U) and two of the four sides should be compliant with the deployer constraints as shown in the **FIGURE 4: SIMPLE EXAMPLE OF LOCATION FRAME** which is for a 12U CubeSat.

3.5.7 Internal Fixtures

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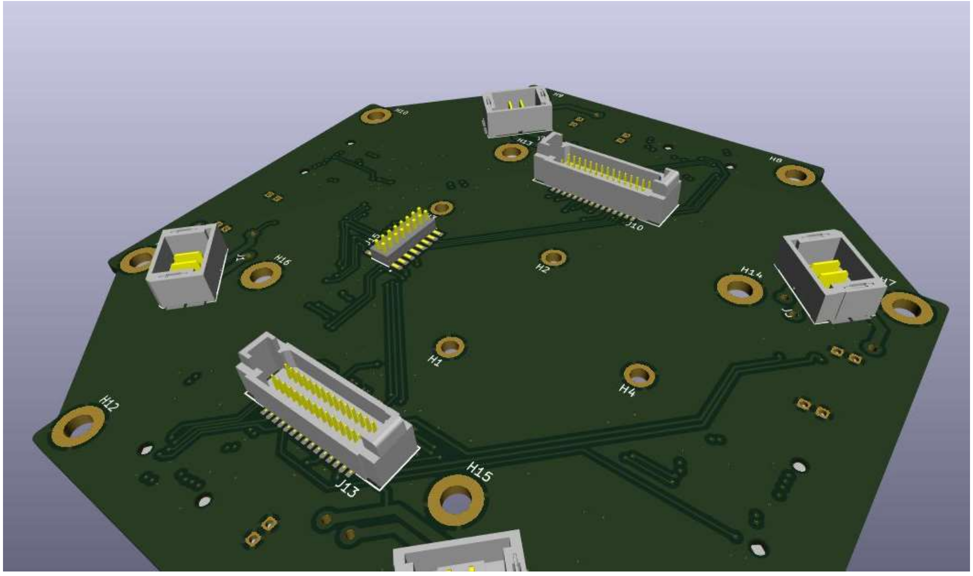
3.6 Electrical and data connections

This guide is written from the point of view of the "inside" of the Payload Container. For electrical interfaces at the Key/Lock interface plane, see the Key-Lock Standard ref TBD.



3.6.1 Electrical Power

Pinout

Redundancy scheme	Power rail P1 and P2 distributed from PDU P through connector PA.
	Power rail S1 and S2 distributed from PDU S through connector PB.
Connectors	**Baseline** SAMTEC – UMPC-02 with metal side latches *Mated with UMPT – 02 soldered on Key PCB* 18AWG pigtail included in Key and chassis kit, customer to terminate the cable on their end.
	Alternative SAMTEC UMPS-02 mounted on (advised flex-rigid) PCB interposer for power rails of highly integrated equipment. *Not included in kit.*
	Optionally customer-provided connectors for PA and PB *Contact us to ensure compatibility.*
Notes	DC rails are also accessible at a lower power rating through data connector pins. *See section 3.6.2.1 for details.*

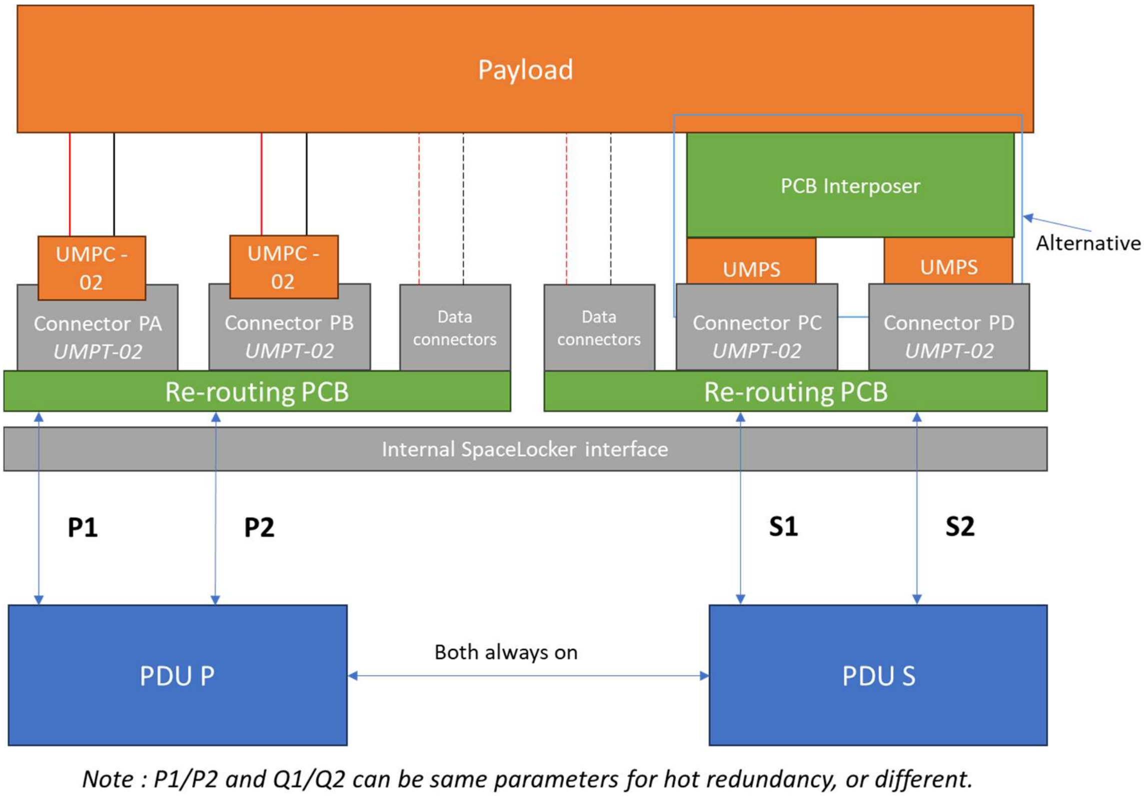


Figure 19: Electrical and data connections.

Connector	Pin number	Function
PA	1	PDU P - DC Rail P1 - LOW
	2	PDU P - DC Rail P1 - HIGH
PB	1	PDU P - DC Rail P2 - LOW
	2	PDU P - DC Rail P2 - HIGH
PC	1	PDU S - DC Rail S1 - LOW
	2	PDU S - DC Rail S1 - HIGH
PD	1	PDU S - DC Rail S2 - LOW
	2	PDU S - DC Rail S2 - HIGH

3.6.1.1 Performance and usage

Voltage and power ratings	Independent voltage setting for each rail, in range 3-48V DC.
	Power connectors rated 10A.
	Maximum power per rail: TBC W

3.6.1.2 Power-up procedure

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3.6.1.3 Deadfacing and hot plug

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3.6.1.4 Grounding

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3.6.2 Data Connections

3.6.2.1 Pinout

Redundancy scheme	TBD
Connectors	SAMTEC – S1SDT-15 *Mated with T1M soldered on Key PCB* 30AWG pigtail included in Key and chassis kit, customer to twist, shield and terminate the cable on their end as needed.
	Optionally other connectors, see below

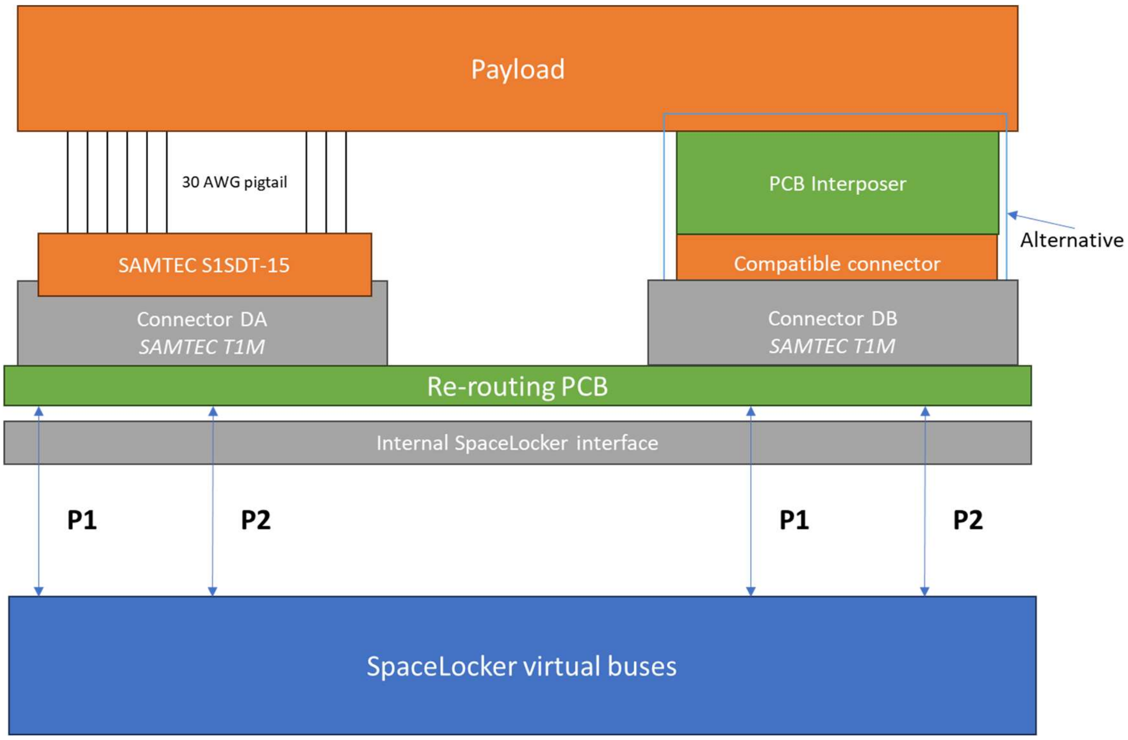

Figure 20: Electrical and data connections.

In option: replace on the Re-routing PCB the T1M connectors with customer-provided board connectors, 1 mm pitch, contained within TBD volume (Key PCB schematics openly available from SpaceLocker).

<table>
<tr><th>Connector</th><th>Group</th><th>Pin number</th><th>Function</th></tr>
<tr><td rowspan="30">DA</td><td rowspan="4">PWR</td><td>1</td><td>PDU A - DC Rail P1 - LOW</td></tr>
<tr><td>2</td><td>PDU A - DC Rail P2 - LOW</td></tr>
<tr><td>3</td><td>PDU A - DC Rail P1 – HIGH</td></tr>
<tr><td>4</td><td>PDU A - DC Rail P2 - HIGH</td></tr>
<tr><td>Grounding</td><td>5</td><td>Satellite GND</td></tr>
<tr><td rowspan="3">Reserved for Key active features</td><td>6</td><td>KEY-1 (see section 5)</td></tr>
<tr><td>7</td><td>KEY-2 (see section 5)</td></tr>
<tr><td>8</td><td>KEY-3 (see section 5)</td></tr>
<tr><td rowspan="3">Payload data passthrough:
Single ended data line 1</td><td>9</td><td>DT-TTL-1-GND</td></tr>
<tr><td>10</td><td>DT-TTL-1-A</td></tr>
<tr><td>11</td><td>DT-TTL-1-B</td></tr>
<tr><td>Grounding</td><td>12</td><td>Satellite GND</td></tr>
<tr><td rowspan="8">Payload data passthrough:
differential pairs</td><td>13</td><td>DT-DP-1-A</td></tr>
<tr><td>15</td><td>DT-DP-1-B</td></tr>
<tr><td>14</td><td>DT-DP-2-A</td></tr>
<tr><td>16</td><td>DT-DP-2-B</td></tr>
<tr><td>17</td><td>DT-DP-3-A</td></tr>
<tr><td>19</td><td>DT-DP-3-B</td></tr>
<tr><td>18</td><td>DT-DP-4-A</td></tr>
<tr><td>20</td><td>DT-DP-4-B</td></tr>
<tr><td rowspan="8">Thermal</td><td>21</td><td rowspan="2">Thermal sensor A</td></tr>
<tr><td>22</td></tr>
<tr><td>23</td><td rowspan="2">Thermal sensor B</td></tr>
<tr><td>24</td></tr>
<tr><td>25</td><td rowspan="2">Heater A</td></tr>
<tr><td>26</td></tr>
<tr><td>27</td><td rowspan="2">Heater B</td></tr>
<tr><td>28</td></tr>
<tr><td rowspan="2">Future use</td><td>29</td><td rowspan="2">N.C.</td></tr>
<tr><td>30</td></tr>
<tr><td rowspan="14">DB</td><td rowspan="4">PWR</td><td>1</td><td>PDU B - DC Rail S1 - LOW</td></tr>
<tr><td>2</td><td>PDU B - DC Rail S1 - LOW</td></tr>
<tr><td>3</td><td>PDU B - DC Rail S1 - HIGH</td></tr>
<tr><td>4</td><td>PDU B - DC Rail S2 - HIGH</td></tr>
<tr><td>Grounding</td><td>5</td><td>Satellite GND</td></tr>
<tr><td rowspan="3">Reserved for Key active features</td><td>6</td><td>KEY-4 (see section 5)</td></tr>
<tr><td>7</td><td>KEY-5 (see section 5)</td></tr>
<tr><td>8</td><td>KEY-6 (see section 5)</td></tr>
<tr><td rowspan="3">Payload data passthrough:
Single ended data line 2</td><td>9</td><td>DT-TTL-2-GND</td></tr>
<tr><td>10</td><td>DT-TTL-2-A</td></tr>
<tr><td>11</td><td>DT-TTL-2-B</td></tr>
<tr><td>Grounding</td><td>12</td><td>Satellite GND</td></tr>
<tr><td rowspan="2"></td><td>13</td><td>DT-DP-5-A</td></tr>
<tr><td>14</td><td>DT-DP-5-B</td></tr>
</table>

	Payload data passthrough: differential pairs	15	DT-DP-6-A
		16	DT-DP-6-B
		17	DT-DP-7-A
		18	DT-DP-7-B
		19	DT-DP-8-A
		20	DT-DP-8-B
	Thermal	21	Thermal sensor C
		22	
		23	Thermal sensor D
		24	
		25	Heater C
		26	
		27	Heater D
		28	
	Future use	29	N.C.
		30	

3.6.2.2 Flexible buses: usage and performance

Note: the usage of flexible buses depends on the use of the embedded computing power available to customers for their data interface, management, and pre-processing needs. For details on these capabilities, see section TBD.

SpaceLocker's Dock features a reconfigurable, flexible bus interface, supporting most differential and single-ended digital bus protocols available, such as

- UART, RS232, RS485, RS422, USB,
- Ethernet, SpaceWire, SpaceFibre,
- PCIe, CameraLink,

The payload data processor is responsible for direct level adaptation and physical layer management.

The complete list of supported buses is available on demand, with expected pinouts at data connector and available configuration options (speeds, parity bits, etc.).

Note: User-configured options are available from SpaceLocker, please contact us.

Groups of pins marked "Payload data passthrough" are routed directly through the electrical connections up to the flexible data bus endpoint.

- Pins marked "single-ended" are routed with constant impedance to their reference GND pin to single ended pins of the flexible data endpoint.
- Pins marked "differential pairs" are routed as 100 Ohm differential pairs up to differential IO at the flexible data bus endpoint.
- All data pins are capable of both input and output.

An interface to the physical layer I/O buffers and signals is available from within the embedded computing virtual machines, both as low-level devices and over network sockets.

SpaceLocker SDK provides a high-level handling to these low-level interfaces for Python and C. For some complex protocols with data-link layer and transport layer interfaces, SpaceLocker exposes SDK interfaces for Python and C.

Note: As of this version, the support of specific data buses, and the routing of data pins, is done on a case-by-case basis. Contact SpaceLocker to enquire about your specific application.

3.6.3 Electromagnetic cleanliness

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3.7 Embedded Software Systems

The Dock, that performs the interface adaptation layer from the carrier vehicle to the universal payload interface, includes high-level processing power, data storage, and other specialized processing capabilities. These are accessible from within the satellite, with software provided by the customer. They are linked to the ground segment through high-level network links, such as an IP local network connection.

The Key, the part of the universal docking port that is attached to the customer's payload, includes a small number of electronic components that enable active management features in it.

This includes administrative tasks such as monitoring features, but also provides the opportunity to expand the design tools available to the customer.

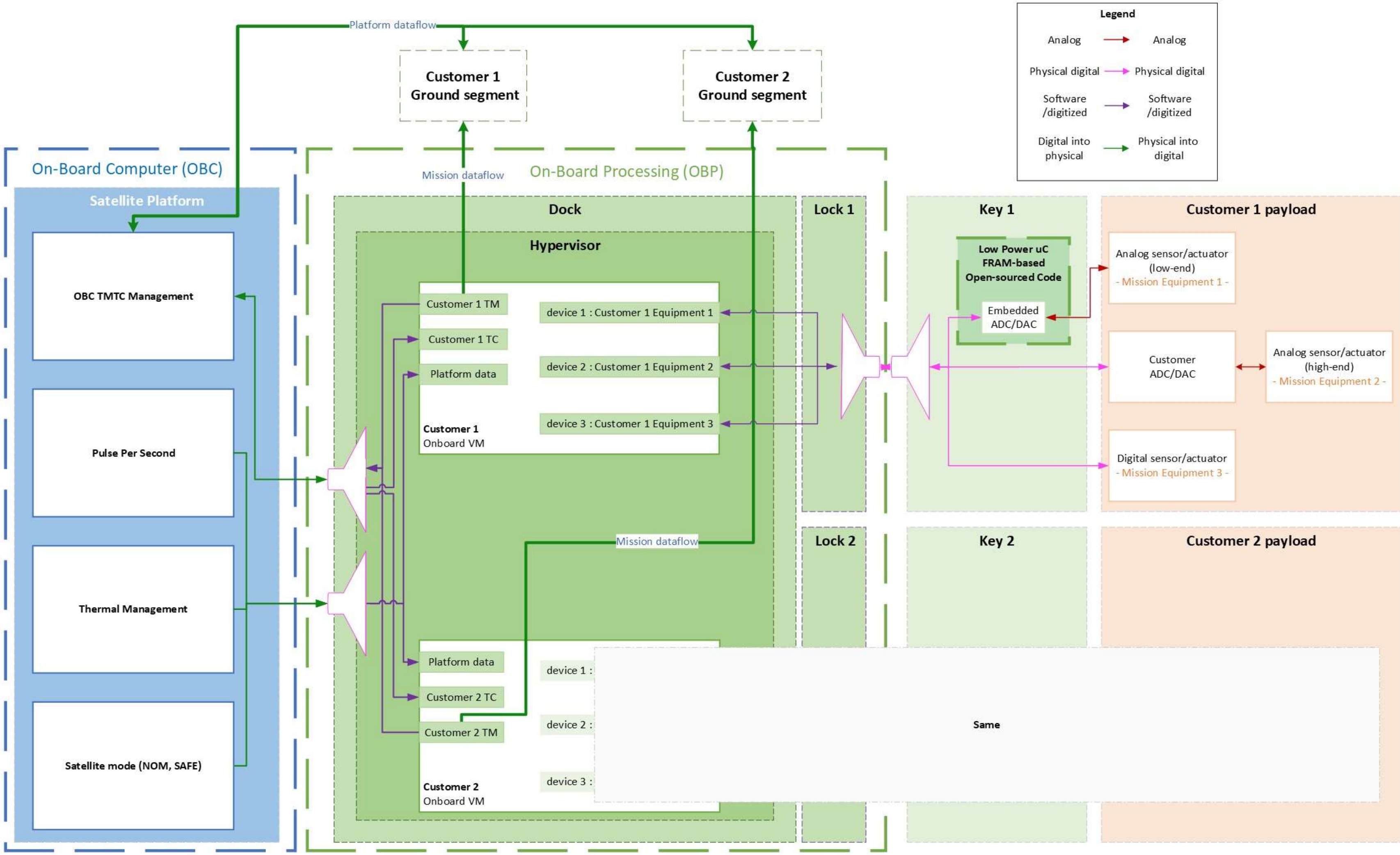


Figure 21: Onboard Design and Dataflow

3.7.1 Dock processing power

The Dock mainly consists of a software environment running on a Multi-Processor-System-On-Chip (MPSoC). It has 4 Armv8 application processors at up to 1,2 GHz.

3.7.1.1 Software execution and links to Ground Segment

The SpaceLocker Dock serves as a versatile platform capable of hosting multiple customers through the utilization of Virtual Machines (VMs). Each customer is granted access to a secure and isolated Linux environment, offering full sovereignty and the ability to interact with the equipment as if it were a physical device.

3.7.1.2 FPGA-Level Customization

One distinctive feature of the Dock is its capability to implement drivers at the FPGA level. This allows for a high degree of customization, empowering customers to tailor their computing environments to specific mission requirements.

3.7.1.3 Resource Allocation

The Dock allocates resources to each customer, including a specified amount of volatile and non-volatile memory (1 Gb of RAM and 1 GB of non-volatile memory per customer). Customers can request adjustments to their resource allocation by contacting SpaceLocker, offering flexibility to meet varying mission demands.

3.7.1.4 Data Handling

Customers are responsible for utilizing allocated resources effectively, especially in identifying and preserving proprietary data in case of power failure. SpaceLocker provides a snapshot service for VMs, with some exceptions (unexpected reboot, power failure, platform survival mode), enhancing data backup capabilities.

3.7.1.5 Hypervisor Management

The Dock leverages a hypervisor, overseen by SpaceLocker solely, to ensure accurate data routing from the equipment to guest VMs. This hypervisor acts as the means through which mission instruments are exposed as physical devices within the VM. It serves as an intermediary, controlling resource allocation and overseeing requests/responses between the physical layer and customer VMs.

3.7.1.6 Security

To secure data, the Dock employs data encryption keys loaded by customers onto the Key, granting end-to-end control over data protection.

3.7.1.7 Accessing Equipment Data

Utilizing a data multiplexer, the Dock fetches digitalized data from the Key, thereby establishing the connection between the flexible data bus plane and embedded processing systems.

3.7.1.8 Versatile Ground Segment Link

SpaceLocker introduces three versatile approaches to establishing ground segment links, each tailored to address diverse communication needs. These options provide users with the flexibility to choose the most suitable method based on the specific requirements of their missions.

The first option involves the utilization of the Packet Utilization Standard (PUS), a seasoned space standard (data link layer of the OSI model). PUS serves as a reliable framework for data exchange, offering a traditional yet effective method for communication in the space domain.

The second approach harnesses the OSI application layer, offering users the flexibility to employ various protocols, including, among others, AMQP (*Advanced Message Queuing Protocol* - application layer of the OSI model). This method is made possible through the SpaceLocker interface and the integration of Virtual Machines (VMs). By doing so, SpaceLocker provides a structured and organized means to manage asynchronous communication between the payload and the ground station. For instance, a user, even in an asynchronous mode, could securely downlink a file through a Secure Shell (SSH) connection, ensuring modern adaptability.

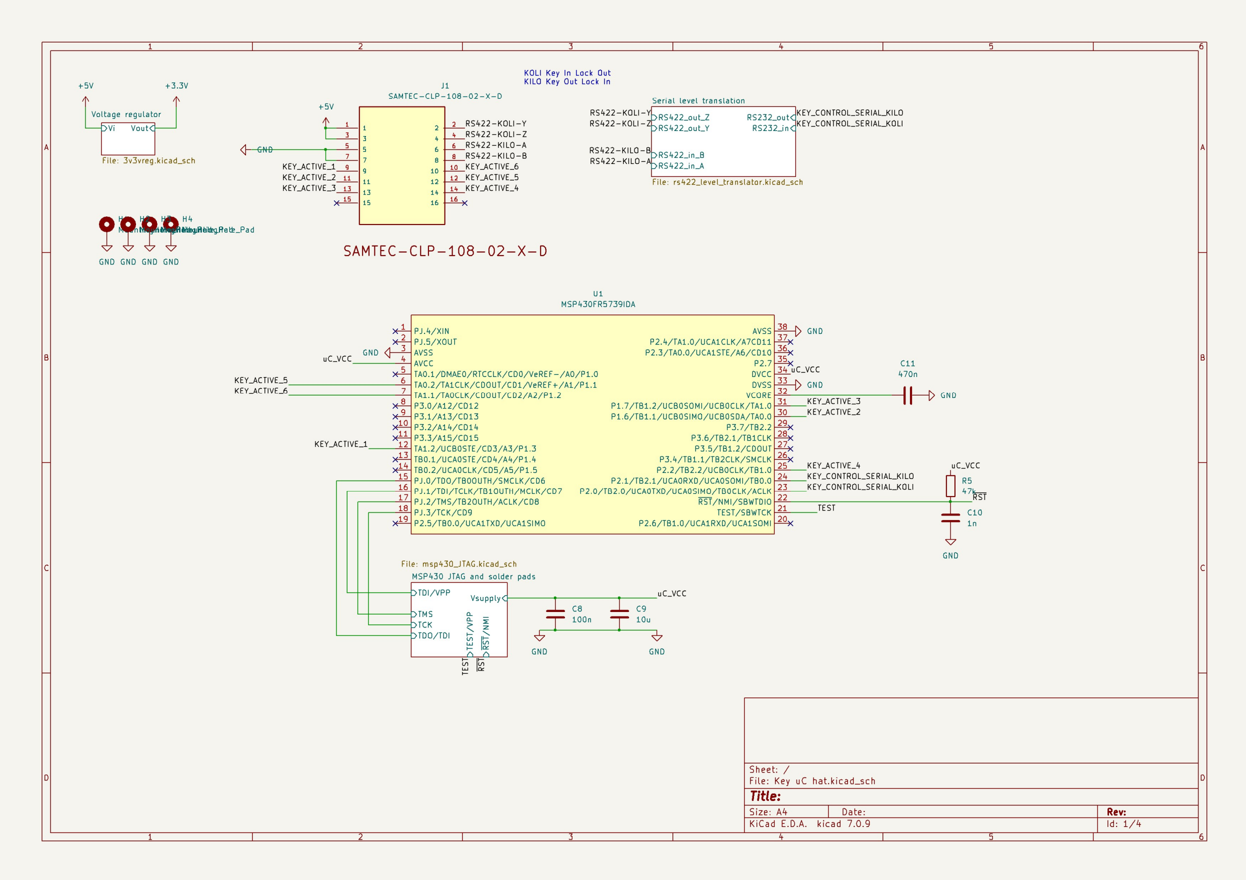
For scenarios demanding synchronization, the third approach incorporates a sync mode. This mode ensures that communication aligns precisely with specific ground station availability, establishing a timed connection for efficient data transfer (*e.g.*: TCP). Notably, in sync mode, downlink priority takes precedence, enhancing the reliability of data transfer in time-sensitive situations.

By offering these three flexible options, SpaceLocker empowers users to tailor their ground segment links according to the unique requirements of their missions. This adaptability ensures that SpaceLocker's communication solutions are not only robust and reliable but also capable of meeting the challenges posed by various space missions.

3.7.1.9 On-Board Computer / On-Board Processing Link

The OBC/OBP link provides crucial components, including the Pulse Per Second (PPS), enabling users to integrate this timekeeping precision seamlessly into the Linux environment for enhanced utility. Additionally, it relays comprehensive satellite status information (NOM, SAFE), vital for purposes such as operational monitoring and troubleshooting.

3.7.2 Key processing power



The embedded microcontroller is an MSP430FR5739, featuring very low power consumption and radiation-hard memory by design. Carrier board design and firmware are available from SpaceLocker under open-source licenses[1].

3.7.2.1 Virtual GPIO/ADC/DAC TODO

General description

Although the preferred way to deal with data transfers is through direct bus connection to the Lock data pins, over to virtualized peripherals in the onboard virtual machine, this may not be practical in certain cases, or a failover link may be desired.

The Key offers a few analog and digital I/O for simple interface with hardware through the Interface and exposes a limited API to interact with these I/Os.

Features and performance:

- 3.3V logic level operation
- Up to 3 channel ADC
  - up to 500 sample per second – 10 bits

[1] Microcontroller firmware including control protocol server is under GPLv3 license. Carrier board design under CERN-OHL-W-2.0

- Up to 6 virtual GPIO
  - either input or output
  - pull-up and pull-down resistors
  - timer capture-compare functionalities

- Analog comparator up to 3 inputs
  - External inputs
  - Internal reference voltage
  - Interrupt or pin output

- PWM capability
  - 3Vp-p
  - 4-bit precision
  - TBD operating frequency

- Full open-source remote control and acquisition protocol, with reference C and Python libraries to connect and control the virtual interfaces.

- Digital bus mirroring: remote control SPI slave, or embedded virtual machine I2C peripherals, from the embedded computing power, with no issues of data integrity.

3.7.2.2 Associated pinout:

All pins are capable of flexible GPIO operation and PWM output.

Data connector pin number		**FR5739 pin name**	**Exposed functions**
DA6	**EM12**	P1.3/TA1.2/UCB0STE/A3/CD3	ADC A3 SPI Slave Select TA1 CCR2 Out 2 Comparator D input CD3
DA7	**EM13**	P1.6/TB1.1/UCB0SIMO/UCB0SDA/TA0.0	TB1 CCR1 Out 1 SPI MOSI I2C data TA0 CCR0 Out 0
DA8	**EM14**	P1.7/TB1.2/UCB0SOMI/UCB0SCL/TA1.0	TB1 CCR2 Out 2 SPI MISO I2C clock TA1 CCR0 Out 0
DA9	**EM15**	P2.2/TB2.2/UCB0CLK/TB1.0	TB CCR0 SPI Clock
DA10	**EM16**	P1.1/TA0.2/TA1CLK/CDOUT/A1/CD1/VeREF+	ADC A1 Comparator D Output / Input CD1 Timer A CCR2
DA11	**EM17**	P1.2/TA1.1/TA0CLK/CDOUT/A2/CD2	ADC A2 Comparator D Output / Input CD2 Timer A CCR1

3.7.2.3 List of services: isolated and encrypted handling of commands

- Set virtual I/O config (this is an idempotent command, repeat use will not change anything):
  - Individual pin configuration choice
  - GPIO I/O bitmask (as per driver)
  - GPIO I/O pullup bitmask (as per driver)
  - ADC/PWM parameters vector

- Set virtual I/O state:
  - GPIO output vector
  - Set PWM DAC values.

- Read virtual I/O state:
  - ADC values
  - Read GPIO input vector.

3.8 Fluid Interface

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3.9 Ground Control Interface

Once the flight booking process has been finalized, SpaceLocker provides the customer with an online client portal consisting of three main features.

3.9.1 Monitoring dashboard

The first one is a standard generic dashboard able to display several pieces of information about the current mission status. Both processing VM health status and payload housekeeping telemetry are downlinked and made available to the end-user. The latter includes:

- Health status and mode signaled by the guest VM to the Dock
- Satellite mode (NOMINAL, SURVIVAL…)
- On-Board Time (OBT)
- Power consumption
- Dock overall telemetry data rate
- Message queue status for VM-inbound data and VM-outbound data buffers
- Payload to guest VM data rate

3.9.2 Direct console access

SpaceLocker ground segment grants the customer secure and direct access to their hosted VM thanks to a pre-configured network. When in sync with the onboard virtual machine, the end-user acquires the capacity to actively manage their environment in real-time (TCP like). This synchronization mode is accessible through the designated interface within the customer account. When within proximity, an item marked as "IN REACH" is highlighted in green, while it adopts a red status when beyond reach. Additionally, even when not within range, users can schedule UNIX commands, and these commands will be transmitted and processed once the satellite achieves synchronization. Notably, this capability ensures seamless control regardless of immediate proximity, should the customer not want to use the asynchronous satellite/ground link. For debugging purposes, the terminal associated to the current SSH session is available as well.

3.9.3 Billing, support, and options

This feature can be used to modify the options the customer has subscribed for, hence allowing flexible cost management based on the user's needs.

3.9.4 API access

Feature	Packet Utilization Standard (PUS)	Message Queue (MQ)	Virtual IP network
Primary Purpose	Standardized communication protocol for spacecraft and ground stations	Reliable and asynchronous data transfer between applications	Integration of IP-based applications with space communication systems
Data Format	Packet-based	Message-based	IP packet-based
Reliability	Employs error correction codes, packet retransmission, and data redundancy	Provides reliable data delivery by storing messages until they are successfully received by the intended recipients	Supports standard IP protocols mechanisms
Decoupling	Moderate decoupling	High decoupling	Limited decoupling
Scalability	Good	Excellent	Excellent
Complexity	Moderate	High	Moderate
Adoption	Widespread	Growing	Growing

3.9.4.1 Packet Utilization Standard (PUS)

The Packet Utilization Standard (PUS) is a protocol that facilitates efficient and reliable communication between spacecraft and ground stations. Its standardized framework ensures seamless data exchange, minimizing compatibility issues and enhancing mission success. PUS's robustness and reliability, achieved through error correction codes, retransmissions, and data redundancy, provide resilience even in challenging environments with high latency and interference. Just as importantly, PUS efficiently minimizes data transmission and conserves valuable bandwidth, making it indispensable for spacecraft with limited data transfer capabilities.

Use case: Let's take the On-Board Scheduling feature of the PUS (SVC11, OBS). A spacecraft engaged in Earth observation utilizes PUS service 11 to autonomously execute a sequence of image capture tasks. The ground station, upon receiving high-resolution imagery from the spacecraft, determines specific areas of interest for further observation. Using PUS service 11, it transmits scheduling information to the spacecraft, instructing it to capture detailed images of these designated regions. The spacecraft's onboard computer processes these instructions and autonomously executes the specified sequence, ensuring that the desired imagery is acquired without continuous ground intervention.

3.9.4.2 Message Queue (MQ)

Message queues (MQs) are a widely used networking technology that enables reliable and asynchronous data transfer between applications. They act as intermediaries, storing messages until they can be delivered error-free to the intended recipients. Aside from its loose coupling feature, MQs can also batch messages together and compress them before transmission, improving efficiency and reducing bandwidth consumption. Overall, this approach is particularly useful in space communication, where sporadic or unreliable communication conditions can arise.

Use case: Consider a scenario where a satellite is collecting data from various sensors and sending it back to Earth. Using MQs, the satellite can securely store this data within the queue until a direct communication pathway with Earth is established. This ensures that all data is received and processed. In fact, web developers, with their expertise in MQs, can seamlessly transition their skills into the realm of space applications. This is because MQs are extensively utilized in web applications to facilitate reliable and asynchronous data transfer between components.

3.9.4.3 Virtual IP network onboard

Virtual IP Network (VIPN) creates an immersive LAN experience between the satellite and the various end-users, seamlessly bridging the vast distance between space and Earth. This approach eliminates the complexities of traditional space communication protocols, enabling the customer on Earth to collaborate effectively with the spacecraft assets as if they were connected to a single network. By leveraging the familiarity and efficiency of IP-based technologies, VIPN streamlines data transfer, reduces operational costs without compromising on data security, all while providing a seamless user experience for both spacecraft personnel and terrestrial end-users.

Use case: Weather monitoring stations on Earth can access real-time satellite data through Virtual IP Network (VIPN). The satellite's assets, including data and equipment, are accessible as if they were located in a terrestrial data center like Azure or AWS. By integrating the satellite into the local area network (LAN), VIPN typically enables weather monitoring stations to seamlessly interact with the internet, providing access to a vast repository of weather data, models, and resources.

Note: GitHub access will be provided in a later revision.

3.10 Life Cycle

3.10.1 Storage Life

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3.10.2 AIT Life

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Note: For details on the AIT process, tools, etc. see section 3.12.

3.10.3 Modes of operation

SpaceLocker guarantees:

- A nominal platform operating time of over 90% per month
- And a payload computer availability of over 95% of operating time per day (the 5% left are for example needed to consider computer restart times caused by radiation).

The payload will be subjected to the following operating modes:

- Priority mode: satellite nominal mode when the customer's payload is the prioritized payload. There is a different priority mode for every customer on board, one for each payload.

- Nominal mode: satellite nominal mode when another payload has priority.

- Off mode : Safe satellite mode.

The total platform operation time is shared between the different payloads on board the SpaceLocker mission, for priority operations, for an average of 15% of the available mission time per individual customer. The remaining time is available on demand, in a coordinated manner. This time sharing is static in the mission proposed to the customer, based on an operations plan designed and optimized before launch.

When the payload is in operation (nominal and priority modes), the customer is free to organize the operation of equipment within the payload, as it wishes, from its virtual machine.

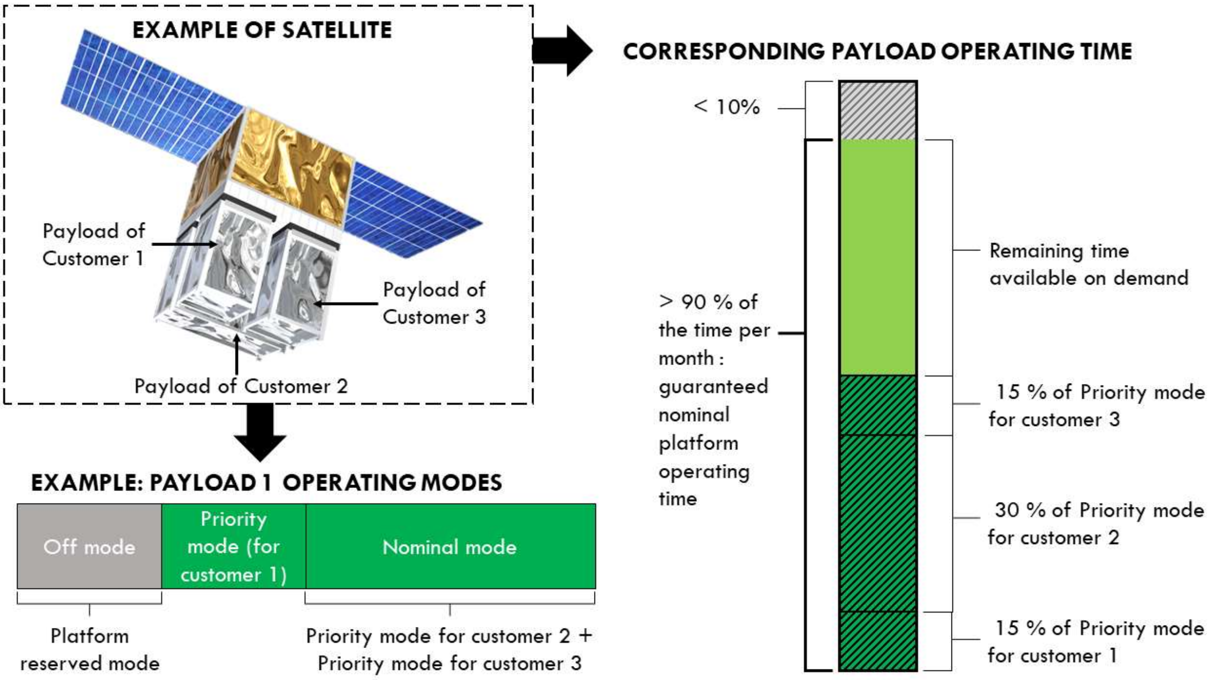

Figure 22: Operating modes and platform time management example.

3.11 Assembly, Integration and Testing

3.11.1 Assembly Guidelines

The following guidelines should be followed when assembling the container:

- All fasteners used in the container shall be made from Stainless Stell, preferably 316 alloy.
- All fasteners should be torqued in the manufacturer's recommended with a torque wrench.
- All bolted connections should use locking nuts, properly applied thread lock or any other mean of locking the fasteners for the intense vibrations.
- All nylon locking nuts should be used once and be replaced after a disassembly.
- All electrical and data connectors should be certified for launch environments or be properly secured in place.
- All soldering procedure shall be space qualified (ex: no pure tin soldering allowed)
- All soldered or connected cables should include a proper strain relief for the solder joint.

3.11.2 Mass Properties

The maximum allowed mass per key is 2kg the COG requirements are shown in the table below:

COG component	Deviation	Frame of Reference
X/Y	+2cm/-2cm	X_{key}/Y_{key}
Z	Max 137mm	Z_{key}

For payloads with COG on the Z_{key} direction larger mass can be tolerated upon further discussion with SpaceLocker.

3.12 Acceptance and Qualification of Finished Payload

3.12.1 Environmental conditions

For environmental conditions encountered during the orbital life of a payload integrated into a Payload Container, see section 3.3 and following.

Under some conditions, payloads may be allowed to avoid some subsystem qualification-level tests. See section 3.12.2 for more information.

3.12.1.1 Introduction

This section summarizes the different type of tests that can be foreseen at elementary level with the Container and its payload only and after final integration. Some of these tests are required, other are recommended.

Level	Required	Recommended
Container + Payload	- Random vibration	- Combined Thermal Vacuum and Thermal Cycle
Satellite	- Quasi Static Load - Random vibration - Electromagnetic Compatibility	- Sine Vibration - Acoustic - Shock - Combined Thermal Vacuum and Thermal Cycle

Note: Payloads containing pressure systems are usually forbidden, if concerned please contact us directly.

3.12.1.2 Quasi static load Test

Level	Qualification	Acceptance	Protoflight Qualification
Satellite	1.25 times the limit load in each of the 3 axes	1.1 times the limit load in each of the 3 axes	1.25 times the limit load in each of the 3 axes

3.12.1.3 Random vibration Test

Level	Qualification	Acceptance	Protoflight Qualification
Container + Payload	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 minutes in each of 3 axes
Satellite	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

Out of plane		**In Plane**	
Frequency	Levels	Frequency	Levels
20-50 Hz	+6 dB/oct	20 – 80 Hz	+6 dB/oct
50 – 200 Hz	0.8 g^2/Hz	80 – 500 Hz	0.03 g^2/Hz
200 – 2000 Hz	-9 dB/oct	500 – 2000 Hz	-6 dB/oct
Global : 14.6 g RMS		Global : 5 g RMS	

3.12.1.4 Electromagnetic compatibility Test

Level	Qualification	Acceptance	Protoflight Qualification
Satellite	6 dB EMISM by Test or 12 dB EMISM by Analysis	Not Required	6 dB EMISM by Test or 12 dB EMISM by Analysis

3.12.1.5 Sine vibration Test

Level	Qualification	Acceptance	Protoflight Qualification
Satellite	1.25 times limit levels, two octave/minute sweep rate in each of 3 axes	1.0 times limit levels, two octave/minute sweep rate in each of 3 axes	1.25 times limit levels, two octave/minute sweep rate in each of 3 axes

Out of plane		**In Plane**	
Range (Hz)	Levels	Range (Hz)	Levels
5-21	+/- 10 mm	5 – 17	+/- 10 mm
21 – 100	+/- 18 g	17 - 100	+/- 12g

Note: Sine test is mainly requested for a first flight model to confirm mechanical characteristics (modal frequencies) with mathematical model (FEM). Need frequency modes to be more than 40Hz.

3.12.1.6 Acoustic Test

Level	Qualification	Acceptance	Protoflight Qualification
Satellite	6 dB above acceptance for 2 minutes	MPE spectrum for 1 minute	3 dB above acceptance for 1 minutes

3.12.1.7 Shock Test

Level	Qualification	Acceptance	Protoflight Qualification
Satellite	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

Floor – Unit on panel		
Frequency (Hz)	Level (g) - Out of plane	Level (g) - In plane
100	10	5
3000	1000	1000
10000	1000	1000

Note: Mechanical tests can be replaced if workmanship can be confirmed during thermal cycling test with sufficient cycles and functional test. This approach shall be discussed and agreed with SpaceLocker.

3.12.1.8 Thermal environment Test

The complete assembly shall be thermal tested in the following temperature range for operational and non-operational conditions:

- T_{min} = -30°C
- T_{max}= 80°C

The assembly shall be tested with a minimum of three thermal cycles between T_{min} and T_{max}. Functionality shall be tested at the last cycle in hot plateau and cold plateau.

Level	Qualification	Acceptance	Protoflight Qualification
Container + Payload (TBC)	±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
Satellite	±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

Note: No active thermal control is present by default on the currently available hosting systems. By default, no heating system will be provided for the payload assembly.

If a heating system is necessary, this shall be discussed and defined jointly with SPACELOCKER to confirm feasibility and operational constraints.

3.12.1.9 Radiation

Active components (for example diodes) shall demonstrate a qualification for total dose of 30kRad.

The assembly shall be surrounded of aluminum panel (minimum thickness 0.5mm) to limit the inner part at 20kRad.

Note: If radiation analysis shows significant margin (typically >1.5 vs specification), no specific test will be required.

3.12.2 Pre-qualified Key structure

The Key structure has been qualified for launch (load behavior, vibration response) with side panels and with M3 rods using representative payload mass distribution.

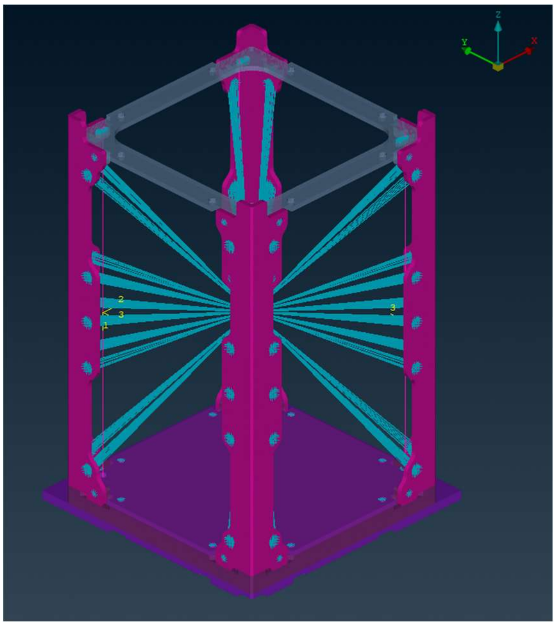

Figure 23: Finite element model of the container integrated with the Locker.

SpaceLocker accepts declarative compliance with structural qualification with no requirement for further testing if:

- The payload does not substantially influence frequency response of the Key+Payload assembly (for example, but not limited to, payloads that include spring-suspended mass, significantly off-centered equipment, or "tall and thin" elements),

- The structural frame was unmodified by the customer, and kept in the conditions of provision (kept within temperature range, not dropped, etc.) for all its life,

- Side panels are used as provided in the kit, or modified (cut, drilled, painted, etc.) for less than 30% (TBC) of their surface area,

- The customer can prove (through measurements, CAD, etc.) that the mass repartition in its payload is similar with the mass distribution used for qualification,

- The customer can prove (through analysis, bill of materials, key personnel CVs, etc.) that all fasteners, brackets, or other customer-furnished elements of structure are of sufficient quality for space flight, and assembled with the necessary workmanship care and skill,

- The customer waives responsibility for all damage occurring to the payload in later tests, as well as accepts responsibility for damage occurred by other equipment due to failure during acceptance tests.

Payloads, once assembled onto the carrier vehicle, remain subject to passing final acceptance tests by the launch providers.

3.13 Reliability

This section depicts the method and the result of the study that has been conducted to ensure the reliability of SpaceLocker's system.

3.13.1 Failure Mode Analysis: Method

A complete Failure Mode, Effects, and Criticality Analysis (FMECA) has been completed on the mechanical, power, data, and thermal subsystem of the first SpaceLocker dedicated shared satellite, the Out Of The Box (OOTB) mission, which is representative of other future missions.

This work has been pursued according to ECSS-Q-ST-30-02C standards.

FMECA is a reliability study that aims to identify all potential failure modes for each item of the system and characterize it:

		Probability category			
		Almost impossible	Remote	Probable, likely	Frequent, expected
Severity category	Criticality number	1	2	3	4
Catastrophic	4	4	8	12	16
Critical	3	3	6	9	12
Considerable	2	2	4	6	8
Negligible	1	1	2	3	3

Figure 24: FMECA Criticality Matrix

In its product assurance policy, SpaceLocker expands catastrophic impact failures to include all failures in customer's payloads failure that could damage other customer's payloads.

This point is a major focus: to have one customer's payload failure propagating to another payload must be avoided at all costs. The SpaceLocker interface and procedures are designed so that, for example, a short circuit in one of the payloads won't disrupt the overall power supply system and thus can't affect the power availability for other payloads.

3.13.2 Failure Mode Analysis: Results and Conclusion

The reliability analysis provided, for identified critical items, corrective design recommendations, new margins definitions, added testing requirements, or other actions necessary to eliminate, mitigate or control the risk, to optimize the SpaceLocker system's reliability.

Here are some examples of design recommendations that were added thanks to the reliability analysis.

- In case of a moving system in a payload, such as a deployment antenna, specify a deployment volume that cannot be exceeded including under actuator failure. Require documentation from the manufacturer if the moving system parts aren't directly manufactured by the customer.

- Conduct a fatigue analysis on the SpaceLocker structure (assess the maximal stress encountered and the number of cycles (frequency + duration) at the level of stress), with a Power Spectrum Density graph, especially for the launch).
- Put a physical margin space between the most sensitive equipment and the structure.
- Require a payload rebooting functionality.
- Add a "save and stop" functionality for the virtual machines on board.
- Ensure quality of encapsulated data using CRC (Cycling Redundancy Check)

An important outcome of the changes subsequent to this reliability analysis is that all failure from one payload propagating to other payloads are unlikely, with negligible severity or/and with solid compensating provisions.

4 CONTACT

If you are considering SpaceLocker payload hosting services, please contact the SpaceLocker Sales department:

SpaceLocker
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75006, Paris, France
sales@spacelocker.fr

APPENDIX A – Concept of Operations

TO COME IN A LATER VERSION OF THE DOCUMENT

APPENDIX B – Structural/Layout Checklist

TO COME IN A LATER VERSION OF THE DOCUMENT

APPENDIX C – Thermal layout/routing checklist

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APPENDIX D – EMC checklist

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APPENDIX E - Engineering Model connector

For ease of making a simple Engineering Model of the Key, the interfaces above can be used through a DB-25 (Male/Plug side on Payload side, Female/Socket side on the Test Bench/EGSE) connector as follows.

Figure 25: DB25 representation

DB25 PIN NUMBERS

Note: The plug body is connected to satellite GND.

Function	Name	Pin
DC circuit 1: Main (M)	DC-1-P-LOW	1
	DC-1-P-HIGH	2
	DC-2-P-LOW	3
	DC-2-P-HIGH	4
Single-ended Digital data passthrough	DT-TTL-1-GND	5
	DT-TTL-1-A	6
	DT-TTL-1-B	7
	DT-TTL-1-C	8
Future Use	N.C	9-11
Reserved for Key active features	KEY	12-17
Payload data: differential pair 1	DT-DP-1-A	18
	DT-DP-1-B	19
Payload data: differential pair 2	DT-DP-2-A	20
	DT-DP-2-B	21
Payload data: differential pair 3	DT-DP-3-A	22
	DT-DP-3-B	23
Payload data: differential pair 4	DT-DP-4-A	24
	DT-DP-4-B	25