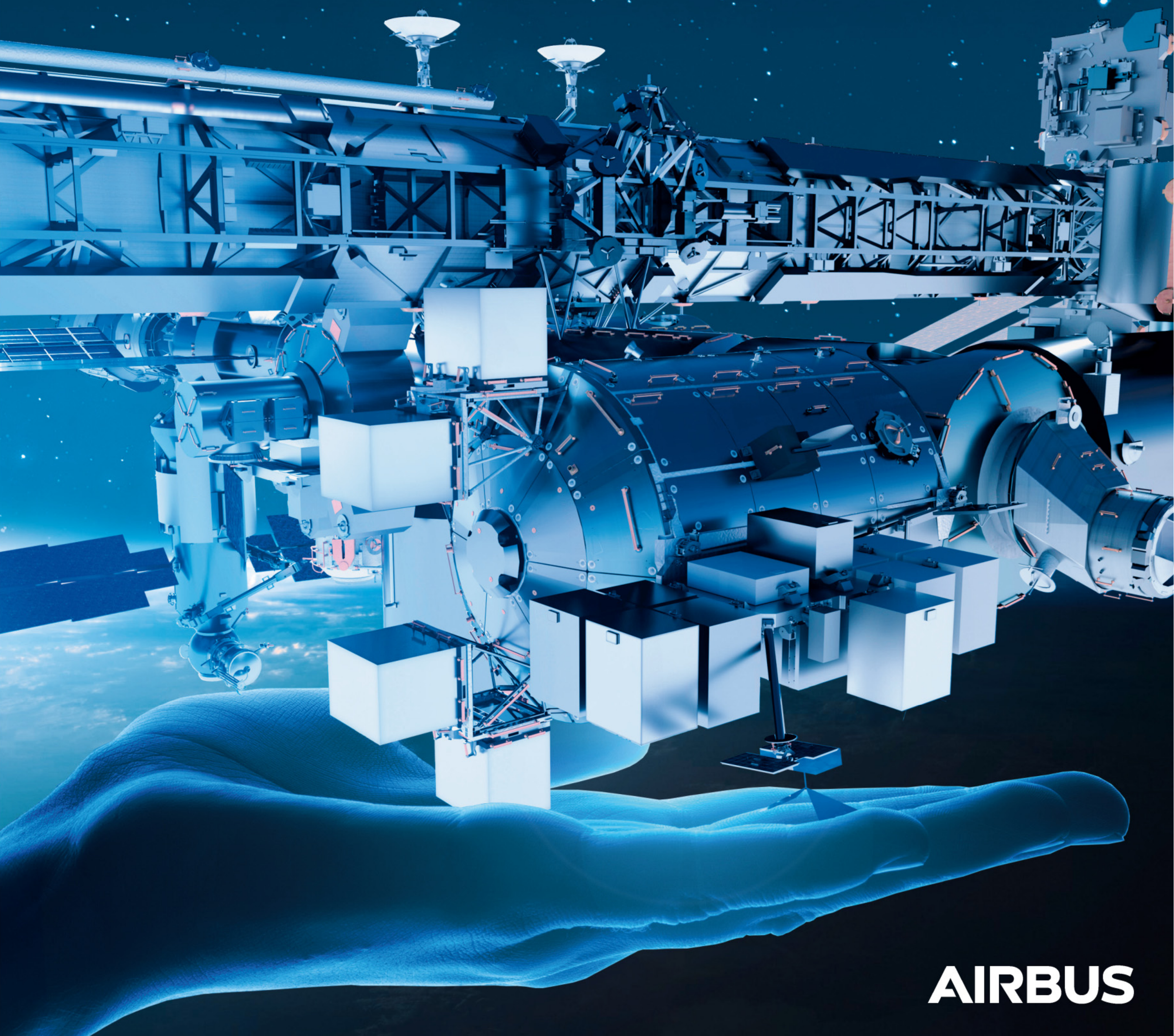
DEFENCE AND SPACE
Space Systems

BARTOLOMEO

Bartolomeo

Your All-in-One
Space Mission Service



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Bartolomeo User Guide

Issue 1

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List of Abbreviations

A/L	Airlock
payload	*Bartolomeo* Customer Payload
BOM	Bill of Materials
BTL	*Bartolomeo*
CASIS	Center for the Advancement of Science in Space
CC	Control Center
C&M	Command and Monitoring
CoFR	Certification of Flight Readiness
CoG	Center of Gravity
COL	*Columbus*
COL-CC	*Columbus* Control Center
COMMS	Communication System
CONOPS	Concept of Operations
CTB	Cargo Transfer Bag
DHS	Data Handling System
DMS	Data Management System
EMC	Electro-magnetic Compatibility
EMI	Electro-magnetic Interference
ESA	European Space Agency
ESD	Electrostatic Discharge
EVA	Extravehicular Activity
EVR	Extravehicular Robotics
FRAM	Flight Releasable Attachment Mechanism
GOLD-2	General-purpose Oceaneering Latching Device 2
ICD	Interface Control Document
ICA	Interface Control Agreement
IP	Internet Protocol
IPR	Intellectual Property Rights
ISS	International Space Station
IVA	Intravehicular Activity
JAXA	Japan Aerospace Exploration Agency
JEM	Japanese Experiment Module
JEM-A/L	Japanese Experiment Module Airlock
JOTI	JEM ORU Transfer Interface
LAN	Local Access Network
LCT	Laser Communication Terminal
LEO	Low Earth Orbit
LVLH	Local Vertical Local Horizontal
MEVR	Maximum Effective Vent Ratio
MoI	Moment of Inertia
MPCC	(*Columbus*) Multi-Purpose Computer & Communication system
N/A	Not Applicable
NASA	National Aeronautics & Space Administration
NRAL	NanoRacks Airlock
OGS	Optical Ground Station
OPS	Operations
OSS	Oceaneering Space Systems, Inc.
OTCM	ORU / Tool Change out Mechanism
PDCU	Power Distribution & Control Unit

P/L	Payload
PSD	Power Spectral Density
RH	Relative Humidity
RMS	Remote Manipulator System
SPDM	Special Purpose Dexterous Manipulator
SME	Small and Medium Enterprise
SRA	Slot Reservation Agreement
SSRMS	Space Station Robotic Manipulation System
TBC	To Be Confirmed
TBD	To Be Determined
TC	Tele Command
TDRS	Tracking & Data Relays Satellite
TDRSS	Tracking & Data Relays Satellite Service
TEA	Torque Equilibrium Attitude
TM/TC	Telemetry and Telecommand
TMM	Thermal Mathematical Model
USOS	United States Orbital Segment
VPN	Virtual Private Network
XCMU	(*Columbus*) External Command & Monitoring Unit

1 INTRODUCTION

Airbus Defence and Space (Airbus) provides a new external payload hosting facility to the European *Columbus* module on the International Space Station (ISS) called *Bartolomeo* after the younger brother of Christopher *Columbus*. *Bartolomeo* enables the hosting of external payloads in Low-Earth Orbit (altitude: ~400 km), onboard the International Space Station (ISS, Figure 1). Application areas include but are not limited to Earth observation, robotics, material science and astrophysics. Payloads can be hosted for public and private organizations alike.

Bartolomeo complements the ISS with its unique capabilities and resupply logistics:

- Access to best viewing angles in nadir, zenith and limb directions with minimal obstructions from other ISS elements
- Choice between unpressurized and pressurized launch of payloads to ISS
- Payload or sample return option into the ISS or to ground
- Enhanced data downlink service of up to 2 Terabyte per day via optical communication.

Figure 2 shows a close-up view of the platform installed at *Columbus*.

The platform is embedded into the *Columbus* system and operated by Airbus in public-private partnership with the European Space Agency (ESA) and the Center for the Advancement of Science in Space (CASIS) through its *Bartolomeo All-in-one Space Mission Service*. Bartolomeo is motivated by the growing shortage of available ISS external payload sites suited to address the demand for e.g. ISS-based remote sensing and imagery, data, and other products to benefit both the private and commercial sector as well as institutional research.

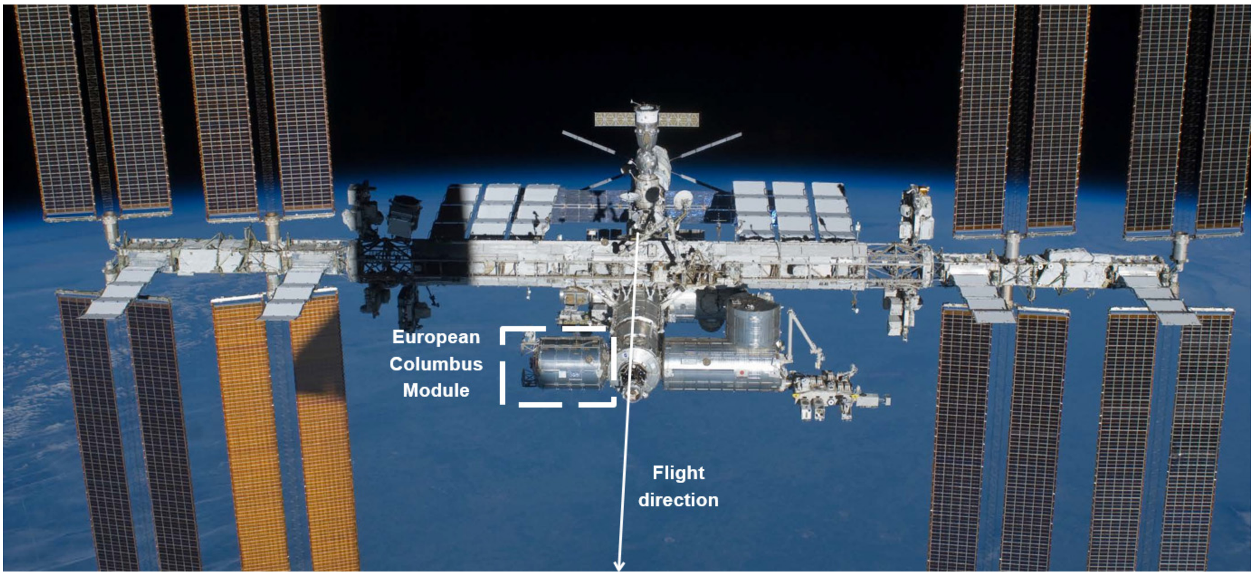


Figure 1 ***Bartolomeo*** **location on the International Space Station (ISS)**

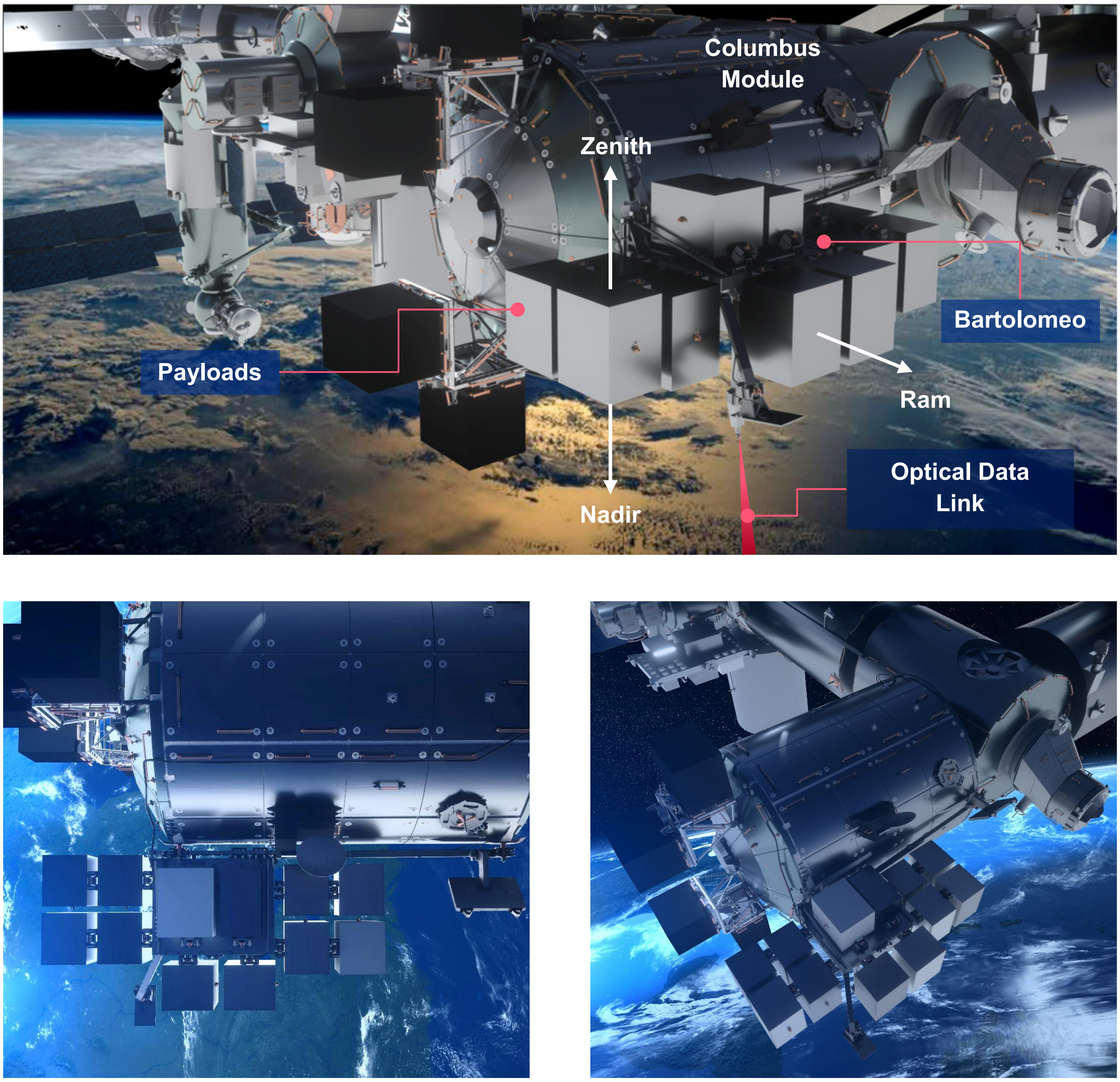


Figure 2 ***Bartolomeo* located on the ram-side of the *Columbus* module at the front of the International Space Station**

Bringing a payload to the *Bartolomeo* platform is a highly cost-efficient and flexible way of operating a space mission in low Earth orbit. With the *Bartolomeo* All-in-One Mission Service, the Customer benefits from Airbus' over 20-year experience in developing, integrating and operating payloads on the ISS. The service provides all mission-related elements, as illustrated in Figure 3, and can even assist in building the actual payload. This Customer-oriented service lets the Customer concentrate on the mission objective without the need to worry about the platform environment, developing a complex space system to carry their payload, or having a deep understanding of the ISS.

Bartolomeo offers 12 payload sites, all of them at the forward-facing side of *Columbus*. Eight sites are provided via standard payload interfaces directly mounted on the *Bartolomeo* platform structure, whereas four additional active sites are provided in a linear series configuration. These sites also offer the capability to combine two stacked payloads into one large payload (Double slot). The payload configuration was optimized to give best viewing conditions to as many payloads as possible. Payloads are accommodated using the General Oceaneering Latching Device (GOLD-2) as standard mechanical and electrical interface which enables full robotic servicing of the facility. Through its payload interfaces *Bartolomeo* provides a versatile hosting infrastructure for payloads of a mass range from 50 to 450 kg. Smaller payloads can be accommodated by sharing one standard slot using the *ArgUS* multi-ayload adapter system.

The *Bartolomeo* flight segment accommodates the payload and operates it using ISS power and data resources. Furthermore, *Bartolomeo* provides additional own data downlink capability by hosting the German Aerospace Center's OSIRISv3 laser communication terminal. This terminal downlinks payload data directly to Earth to an optical ground segment.

With *Bartolomeo*, mission preparation is easy, with lead times as short as 20 months, depending on payload readiness and certification status. This is made possible through Bartolomeo's standardization of payload sizes, interfaces, preparation steps and integration processes. This also makes hosting a payload on *Bartolomeo* very cost-efficient. Customers can save significantly compared to traditional missions, which opens up opportunities for a variety of new types of missions. Figure 4 shows a cost comparison between *Bartolomeo* and classic satellite solutions with payloads in the 100 kg class. As seen, *Bartolomeo* offers a cheaper solution over the typical 3-5 year mission duration period.

When compared to other ISS solutions, *Bartolomeo* is versatile in its offering providing accommodation for various payload classes, with exceptional field of views and performant data downlink enabling many different missions. Table 1 summarizes examples of missions.

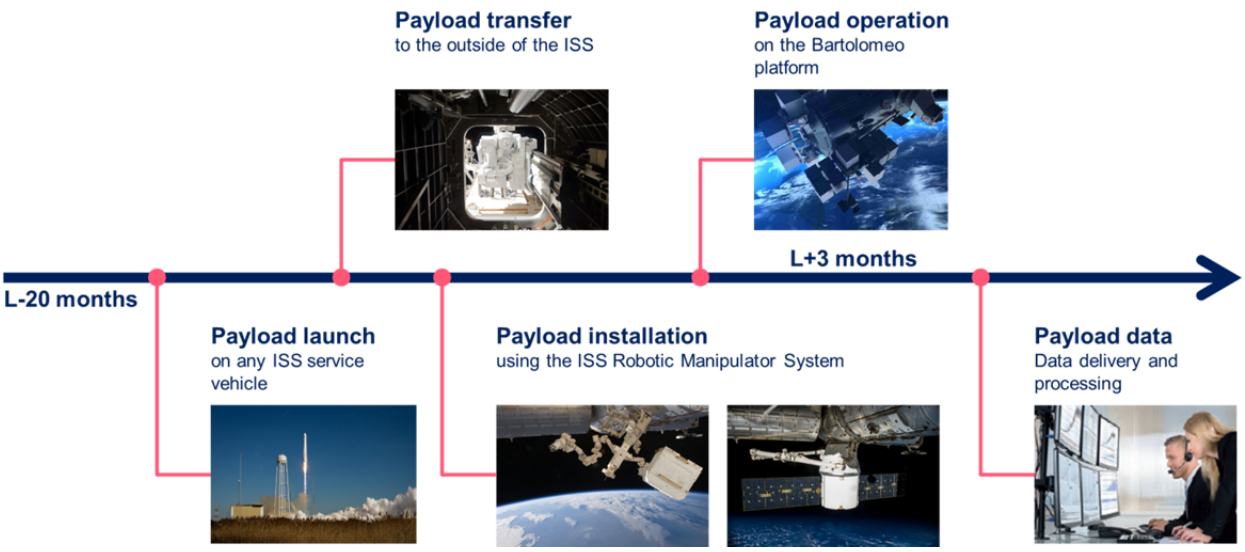


Figure 3 ***Bartolomeo All-in-one Space Mission Service***

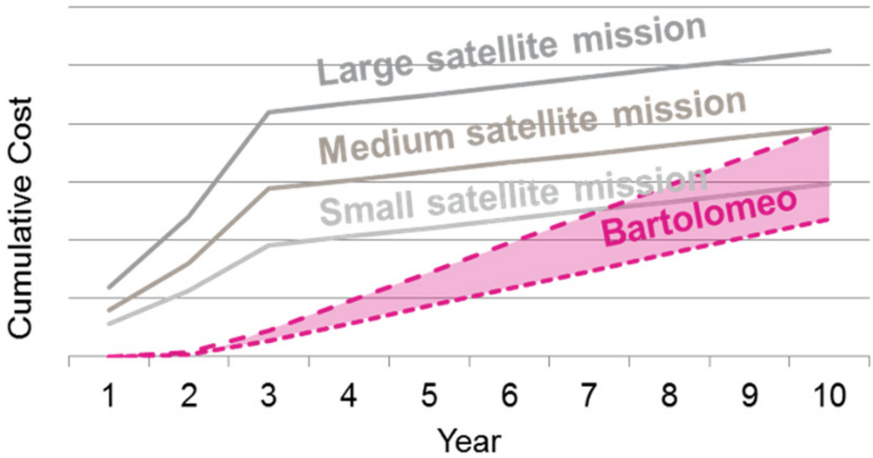


Figure 4 ***Bartolomeo*** **versus satellite solutions cost comparison with launch assumed at the 3-year mark**

Table 1 Example missions

Use Case	Description
Remote Sensing	• The unobscured view of Earth from *Bartolomeo* in approximately 400 km orbit altitude enables high quality imaging with cost-efficient instrumentation • Line-of-sight pointing and stabilization systems may be made available as optional service, if necessary
Astrophysics / Heliophysics	• *Bartolomeo* offers among the best view towards the Zenith direction • Line-of-sight pointing and stabilization systems may be made available as optional service, if necessary
Atmospheric Research	• All forward-facing payloads have unobstructed view to the space / atmosphere boundary • Usually, Limb-oriented instruments do not require specific pointing or stabilization and can be hosted on *Bartolomeo* very easily • Broadband data downlink capabilities of *Bartolomeo* allows for a high data production rate
Space Weather	• The unobstructed Zenith-oriented view allows cost-efficient space observation, e. g. for solar activity monitoring
On-orbit Assembly for Exploration	• *Bartolomeo* payloads have only some restrictions regarding their volume in space • *Bartolomeo* can provide an opportunity to assemble space system components on-orbit and deploy them with appropriate systems • Short-term realization of a long-term vision to provide larger space systems unrestricted by the launcher payload fairing for exploration
Robotics Testing	• *Bartolomeo* payloads have only some restrictions regarding their volume in space • *Bartolomeo* can provide an opportunity to perform robotic operations in a protected testing environment
In-orbit Testing	• With power, data and viewing available *Bartolomeo* can serve as general in-orbit demonstration test bed • If compliant with safety regulations any technology can be tested on ISS as long as it is of civilian purpose
Propulsion Testing	• With power available up 800 W per payload *Bartolomeo* can serve as testbed for new electric space propulsion systems
Material Science	• With unobstructed Zenith-oriented view *Bartolomeo* gives the opportunity to expose material samples to space and solar radiation • With unobstructed Ram-facing view the effects of atomic oxygen can be studied on samples
Spacecraft Deployment	• One of the *Bartolomeo* payload sites can be converted to a small satellite deployment system • If deployed directly from *Bartolomeo* satellites can have more mass than deployable by existing systems
In-space Manufacturing	• Via *Bartolomeo* and its large / extendable payload envelopes on orbit in-space manufacturing can be performed to produce large space structure with 3D printing or other appropriate methods

2 *BARTOLOMEO* ALL-IN-ONE SPACE MISSION SERVICE

The *Bartolomeo All-in-One Space Mission Service* covers all aspects of a space mission end-to-end by combining all required mission elements in one commercial contract. The *s*ervice aims at bringing Customer payloads to the ISS on a fast track. Figure 5 shows an overview of the standard mission phases in the service.

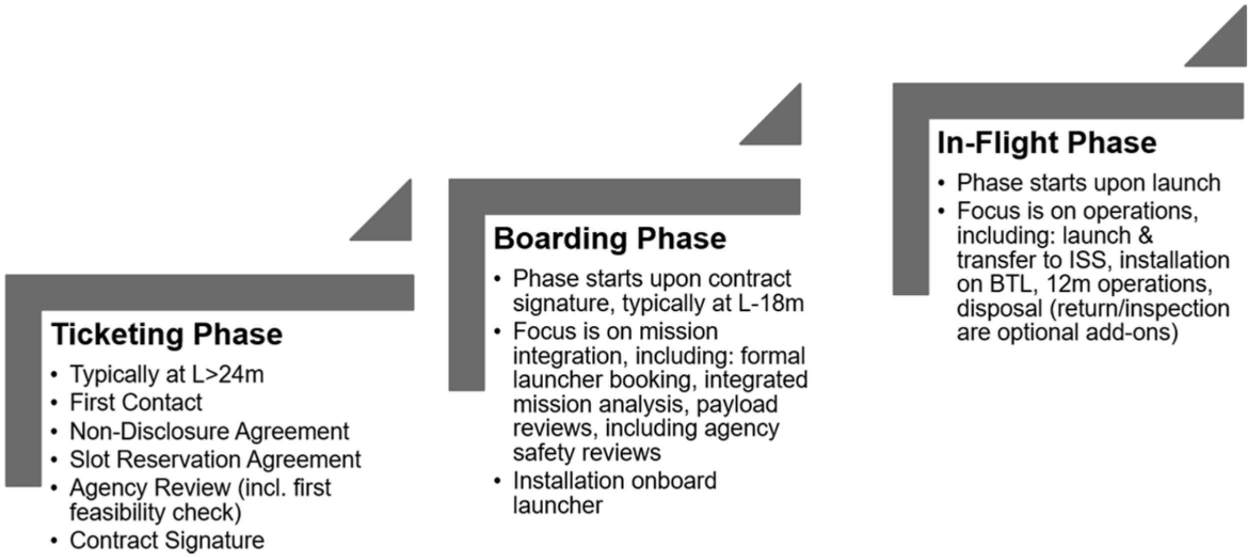


Figure 5 Mission phases within the *Bartolomeo All-in-one Space Mission Service*

2.1 SERVICE SCOPE

All mission elements necessary to perform the basic payload mission are included in the standard service scope. The standard services are summarized in Table 2. Optional add-on services can be provided if the Customer requires the use of technical resources beyond the standard services Some optional services are listed in Table 3.

Table 2 Standard service scope

Service Element	Scope
Programmatic Support	Customer mission acceptance at ESA or CASIS
Interface Control Agreement	Interface definition between the payload and the platform
Safety certification	Inputs to ISS payload safety analysis from the Customer are processed for ISS Payload Safety Review Panel (PSRP)
Manifesting	Slot allocation on platform and launch vehicle with ESA / CASIS
Payload ground testing	Functionality and interface testing with the *Bartolomeo* simulator
Launch processing	Payload processing for launch in cooperation with ESA / CASIS
Launch, on-orbit installation	Payload launch, airlock operations, robotic installation on platform in cooperation with ESA / CASIS
Payload Commissioning	Payload commissioning support to the Customer
Mission Operations	Health & status monitoring and payload commanding via the internet-based *Bartolomeo* Console in cooperation with the *Bartolomeo* Control Center and *Columbus* Control Center
Data Delivery	Internet-based payload data delivery through the AirCloud

Table 3 Optional add-on service elements

Phase	Optional Services
Pre-Flight Services	• Design and analysis of payload itself • Random vibration flight acceptance testing • Flight acceptance testing for any batteries, if required • Off-gas and/or out-gas testing, if required • Electromagnetic compatibility verification with ESA and NASA requirements • Tailoring of interfaces to the launcher, airlock or *Bartolomeo* platform • Payload transportation of Customer payload to Airbus DS Space Systems Houston • Payload processing through customs for temporary import to the USA
In-Flight Services	• Return of all or part of the payload or samples to the Customer after the flight • Custom payload data archiving and access to archived data via the internet-based ground operations console

2.2 STANDARD MISSION INTEGRATION SCHEDULE

The service follows a standard mission integration schedule which is adjusted to the needs of the customer. Usually, the schedule is to be synchronized with the payload flight hardware development. The typical mission integration schedule is presented in Table 4 with dates indicated with respect to the launch date (L).

Table 4 **Payload mission preparation schedule and tasks**

Time Frame	Customer and Industrial Team	ISS Partners
L-20 to L-18 months	• Mission integration kick-off • Payload mission and functional description • Payload mass, power and data budget definition • Safety Data Package Phase 0 (TIM overview) provision	• Initiation of manifesting process • Initiation of ISS Safety process
L-18 to L- 9 months	Interface Control Agreement core baseline Safety Data Package Phase I and II provision	ISS Safety Review Phase I and II
L-9 to L-6 months	Integrated payload complement mission analysis (thermal, structural)	
L-6 months	• Description of Flight Operations • Results of mandatory payload verification (vibration, EMC, outgassing, thermal-vacuum tests) as applicable • Safety Data Package Phase III provision • Verification closeout	• ISS Safety Review Phase III • Review and approval of verification closures
L-6 to L-3 months	Functional and interface verification tests completion	Confirmation of requirements verification final closeout
L- 3 months	Hardware turnover to Cargo Mission integrator (Pressurized payloads)	Hardware turnover documentation
L-2 months to L	• Payload processing at the launch site (unpressurized launch payloads only) • Handover to launch service provider and NASA	Certification of Flight readiness
L		Launch with ISS supply vehicle
L to L+1 month	Payload commissioning and initiation of mission	Payload installation on-orbit Mission support

2.3 RESOURCE MANAGEMENT WITH ISS PARTNERS

On Bartolomeo electrical power resources as well as data transmission capabilities are shared with other payloads and system components of *Columbus* and the ISS.

The availability of power will be scheduled by Airbus in coordination with ESA and ISS Partners to meet the payload mission requirements. The schedule will be established and updated according to the installed payloads for each operational Increment. Resources management plans and schedules are established to allocate available resources to payload requirements.

The same applies for the payload data transmission capabilities. Depending on the data access to the *Columbus* Data Management System (COL DMS) the data transmission speed and volume will be scheduled. The Communication System (COMMS) bandwidth will be allocated to payloads according to the agreement between *Bartolomeo* and the payload providers.

3 *BARTOLOMEO* FLIGHT SEGMENT

3.1 GENERAL CAPABILITIES

The *Bartolomeo* mechanical payload interfaces are capable of carrying up to 250 kg of payload mass. The basic mass capability of each payload slot is 125 kg. Payloads above this basic mass figure require dedicated analysis for integration. For very large payloads there are 4 locations on *Bartolomeo* with a Double payload capability of up to 450 kg.

Bartolomeo is able to host 12 Single payloads in parallel. The *Bartolomeo* payload slots follow the numbering scheme as depicted in Figure 6

All payload slots allow the accommodation of payloads up to 700 x 800 x 1000 mm (27" x 31" x 39"), as displayed in Figure 7. This maximum payload envelope can only be used by payloads which are launched unpressurized. Depending on the availability of launch slots most of the payloads will be launched pressurized onboard an ISS supply vehicle, requiring the use of one of the payload airlocks for transfer to the outside of the station. These payload airlocks define additional constraints to the payload overall volume as described in section 3.6.

Payloads on slots 1A, 2A, 5A and 6A have linear series connections. On these slots the payload needs to feature both the active GOLD-2 connector for the *Bartolomeo* platform interface and the passive GOLD-2 connector on the outer payload envelope for the outer payload to be attached later on. For the structural support of the outer payloads, the load path leads through the structure of the linear series payloads. Therefore, Airbus provides a support frame to the Customer, which is capable to support the respective structural loads.

The *Bartolomeo* platform features one dedicated zenith payload site and one dedicated nadir facing payload site. The maximum payload envelope can only be used if the payload is launched unpressurized.

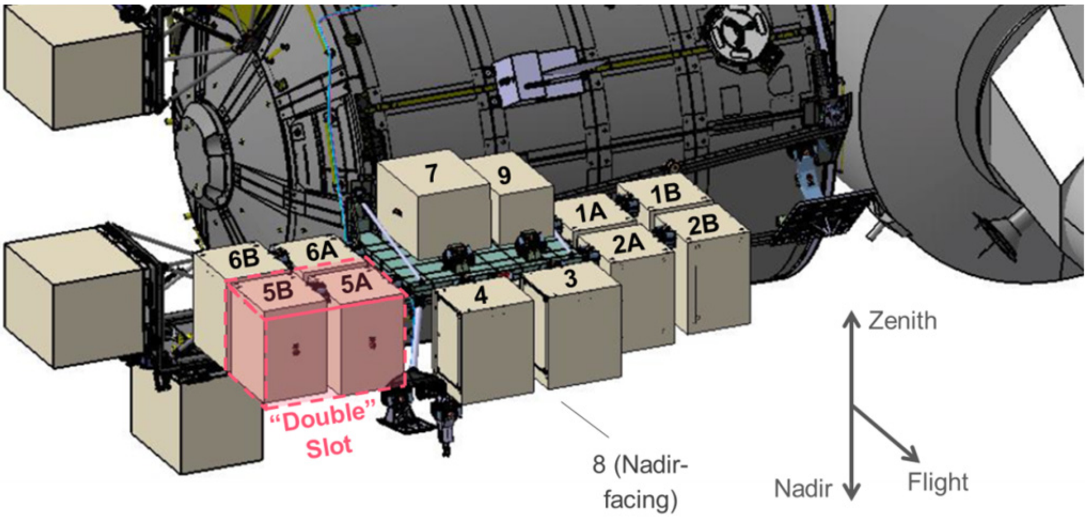


Figure 6 ***Bartolomeo* payload slot designations**

Bartolomeo is also capable of hosting payloads of sizes smaller than the Single payloads. The smaller payloads share a single slot using a payload frame with its own sub-avionics capable of monitoring and controlling the sub-payloads, their power consumption and data flows. This feature allows cost sharing for smaller payloads which do not require the full capacity and resources of a standard *Bartolomeo* payload. Table 5 gives an overview of the different payload slot capabilities, payload sizes and resources are summarized in Table 6.

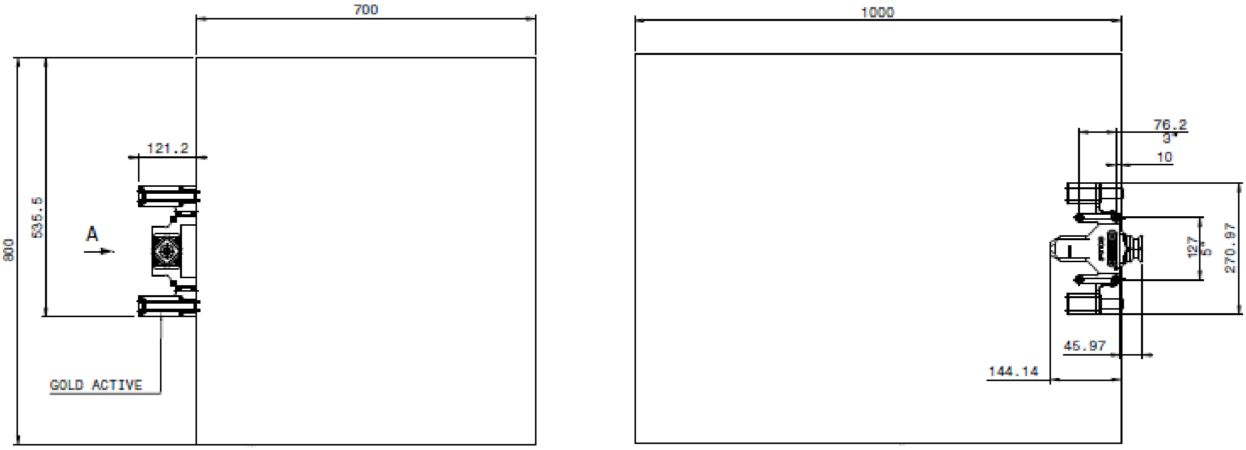


Figure 7 ***Bartolomeo*** **standard (maximum) payload envelope dimensions**

Table 5 **Specific payload slot capabilities**

SLOT POSITION		1A	1B	2A	2B	3	4	5A	5B	6A	6B	7	8
Option to combine two slots into one													
Power	800 W			x		x	x	x					
	400 W				x					x			
	180 W	x	x						x		x	x	x
View	[Ram]			x	x	x	x	x	x				
	[Nadir]	x	x	x	x	x	x	x	x	x	x		x
	[Zenith]	x	x	x	x	x	x	x	x	x	x	x	
	[Port/ Starboard]		x		x	x	x		x		x	x	x
Safety-critical operations enabled				x	x	x	x	x		x			

Table 6 Payload sizes, budgets and resources

Item	Single Payload Slot	Double Payload Slot	ArgUS Accommodation
Standard Service			
Geometric envelope	up to 1000 x 800 x 800 mm	up to 1000 x 800 x 1600 mm	up to 356 x 300 x 1000 mm or 392 x 300 x 1000 mm
Payload Mass	125 kg nominal[1]	250 kg nominal[1] up to 450 kg maximum	Not specified
Power (operation-al)	120 VDC 180, 400 , and 800 W[2]	120 VDC up to 2x800 W[2]	28 VDC up to 140 W
Power (survival)	120 VDC limited to 20 W	120 VDC limited to 40 W	28 VDC up to 20 W
Data downlink	0.1 - 1 Mbit / s	0.2 - 2 Mbit / s	0.1 - 1 Mbit / s
Commanding and Monitoring	Near Real time through *Columbus*		
Robotic interface (mechanical)	included in the standard payload interface		N/A
Optional Service			
Return capability	Yes, if airlock compatible size	No	Yes
Enhanced data downlink	2 TB / day via laser terminal		
Robotic interface (electrical)	to be included into the payload		

Notes:
[1] Overall payload mass budget of the platform to be taken into account
[2] Depending on availability and location

The *Bartolomeo* platform also provides three locations equipped with a coax cable which is routed to the inside of the *Columbus* module. These locations can be utilized for antennae and provide a robotically compatible GOLD 2 connector. Facilities utilizing these antennae would typically be installed in the interior volume of the *Columbus* module. Use of this feature requires a unique Customer agreement with the European Space Agency facilitated by Airbus.

3.2 *ARGUS* MULTI-PAYLOAD PLATFORM

ArgUS is an innovative new payload hosting option offering ISS external payload customers an unparalleled level of options and flexibility. Designed to occupy a single payload slot on the *Bartolomeo* platform, *ArgUS* supports up to 10 small to mid-size external payloads, providing managed power, high-speed data (via laser downlink), access to the AirCloud client portal, and flexible mounting locations for several nadir, zenith and limb views in the ram velocity vector.

ArgUS provides for internal ISS payload removal and replacement, transfer of integrated payload through ISS JEM Airlock (JEM-A/L) or the larger NanoRacks Airlock (NRAL) to the *Bartolomeo* External Facility.

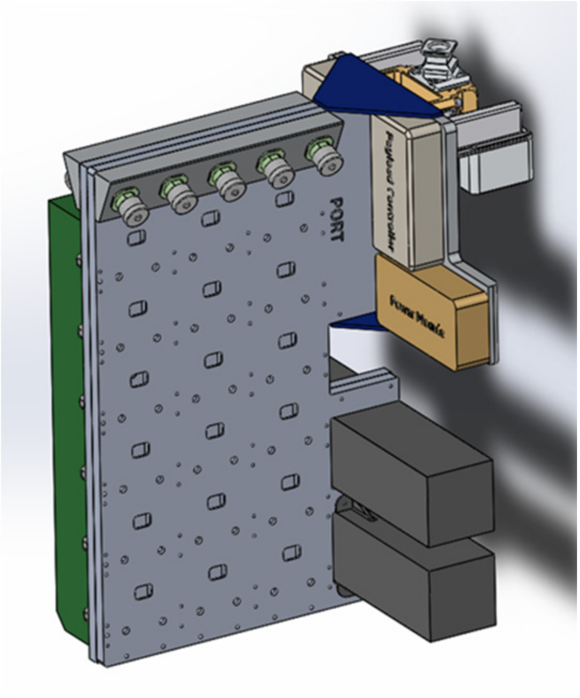
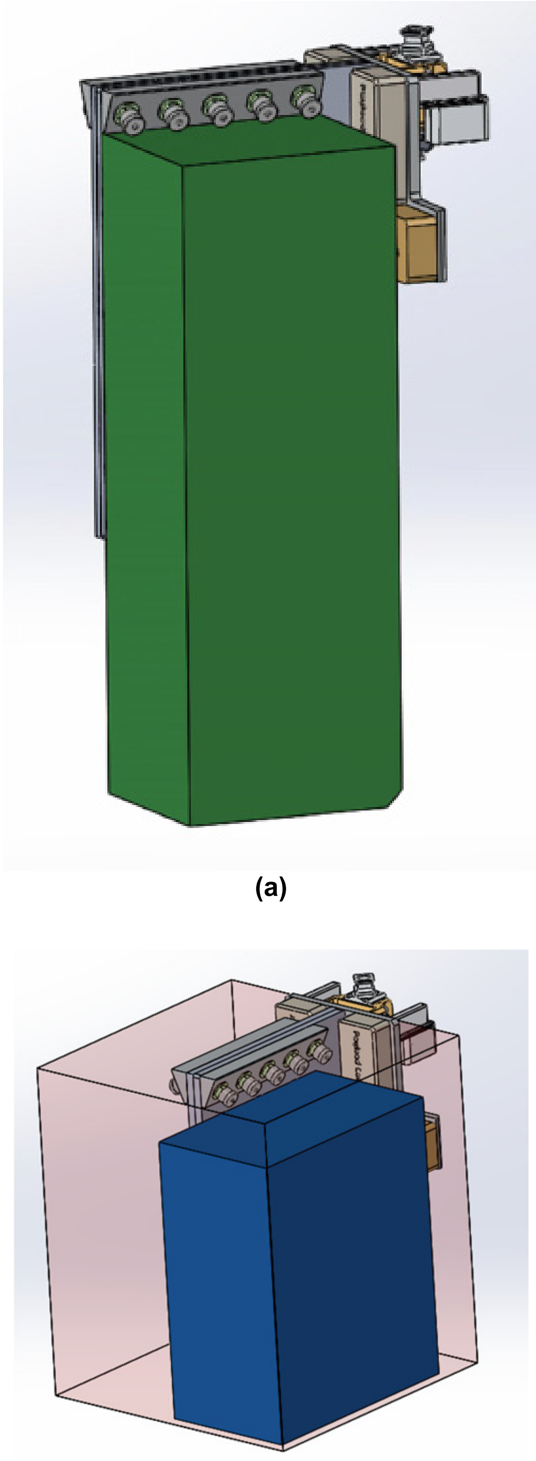


Figure 8 ***ArgUS* payload platform**

The *ArgUS* mechanical plate standard dimensions are 476 mm x 700 mm, however it also allows certain overhang of payloads, restricted by the maximum available airlock envelope.

The Argus platform allows for various configurations with different standard sizes of payloads. An example is shown in Figure 9. Payloads are typically oriented vertically. The Argus plate can accommodate horizontal placement for limited payload slots.

Payloads with non-standard sizes may either use the available attachment interfaces and volume on the experiment base plate or, in case of large payloads they may use the entire available volume.



(a)

(b)

Figure 9 ***ArgUS* payload platform with maximum payload size (a) for JEM-A/L, (b) for NRAL with overhanging payload.**

3.2.1 *ARGUS* PAYLOAD POWER

Electrical services are available via 10 *ArgUS* payload interface connectors. The connectors are located at the upper side of the base-plate. The interface to the payload provides a switchable 28 VDC power outlet with a maximum power dependent on the size of each payload. Total power available to all *ArgUS* payloads is 140 W/5A in a 180 W *Bartolomeo* payload location (Table 5). The power allocation is to be divided between all *ArgUS* payloads to be accommodated in a mission specific configuration. If other slot locations are allocated to *ArgUS*, higher power can be provided to *ArgUS* payloads accordingly.

3.2.2 *ARGUS* COMMANDING AND DATA HANDLING

The *ArgUS* platform has a payload control computer onboard. Along with a power control module, *ArgUS* handles all communications and manages power for all experiments. All commanding is handled through a simple TCP protocol. Health & Status and experiment payload data is transferred to the *ArgUS* payload controller using TCP and UDP protocols and streams.

The *ArgUS* payload controller communicates directly with the *Bartolomeo* DHS using a TCP message bus. The *ArgUS* payload controller enables transferring data to the AirCloud for client use. The AirCloud environment allows *ArgUS*-based experiments to command, control and transfer data and scripts between the ground and the experiment on the *ArgUS* platform.

3.3 *BARTOLOMEO* FIELD OF VIEW CONDITIONS

The position of the *Bartolomeo* platform on *Columbus* facing forward provides very good viewing conditions in the Zenith, Nadir and Forward direction, reduced viewing sideward and some limited viewing in the Wake direction. The results of a field of view analysis for representative payloads on the pallet are presented in Figure 10 for the Zenith-, Nadir-oriented half spheres for Slots 1 and 3. In this stereographic projection the blue areas indicate the temporary obscuration of the payload view towards space or Earth, caused for example by the rotating solar panels of the ISS.

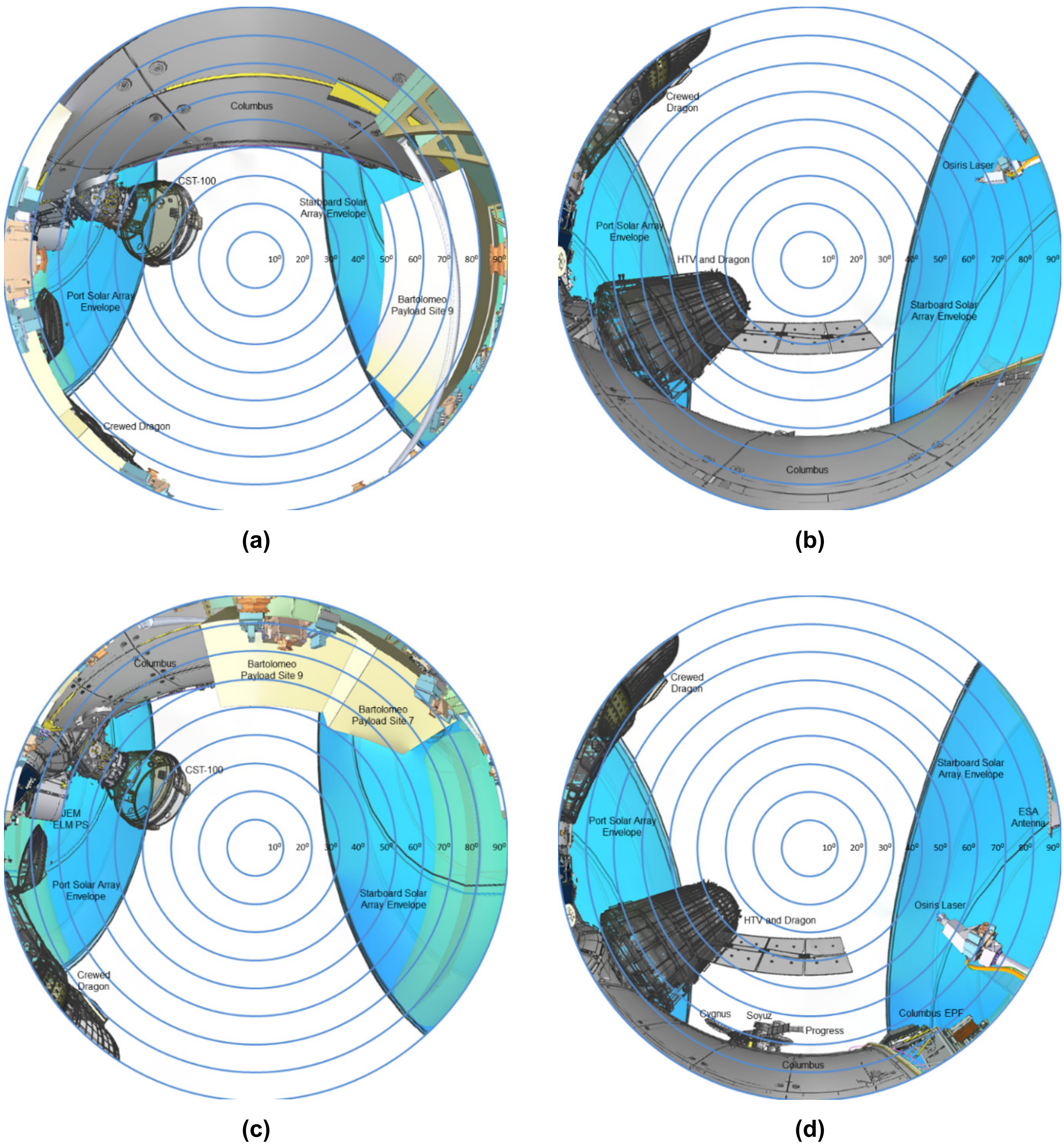


Figure 10 **Payload fields of view From *Bartolomeo* in stereographic projection with regions of permanent obscuration by ISS structures and temporary obscuration by visiting vehicles, and by ISS solar arrays indicated in blue, (a) site 1 Zenith, (b) site 1 Nadir, (c) site 3 Zenith and (d) site 3 Nadir.**

3.4 INTERNATIONAL SPACE STATION ORBIT AND ATTITUDE CHARACTERISTICS

The *Bartolomeo* platform is installed onboard the International Space Station (ISS). Therefore, the payload attitude is always determined by the ISS attitude. Table 7 summarizes the ISS orbit parameters. The orbit altitude of the ISS is under influence of the residual Earth atmosphere and is maintained by re-boost maneuvers in regular intervals. With its 51.64° inclined orbit plane the solar beta angle, i.e. the angle between the orbital plane and a line drawn from the Sun to the Earth, undergoes a sinusoidal variation (Figure 11). As the beta angle increases, the ISS and its external payloads are exposed to more sunlight per orbit, and eventually it is in constant sunlight. In other words, there is no passing into the Earth's shadow for extended periods of time, and the payloads are only shaded by other ISS elements.

Normally, the ISS is oriented in an LVLH (Local Vertical, Local Horizon) attitude. As the beta angle increases, the solar arrays can no longer stay perpendicular to the solar vector and fail to produce adequate power. During these high beta ranges, the ISS reorients to different attitudes as summarized in (Table 8).

Table 7 ISS orbit parameters

Parameter	Value
Orbital inclination	51.64 deg
Orbit altitude	403 to 408 km
Orbital period	92.89 minutes
Solar beta angle variation	-75 to +75 deg
Position error	6 m
Semi-major axis error	20 m

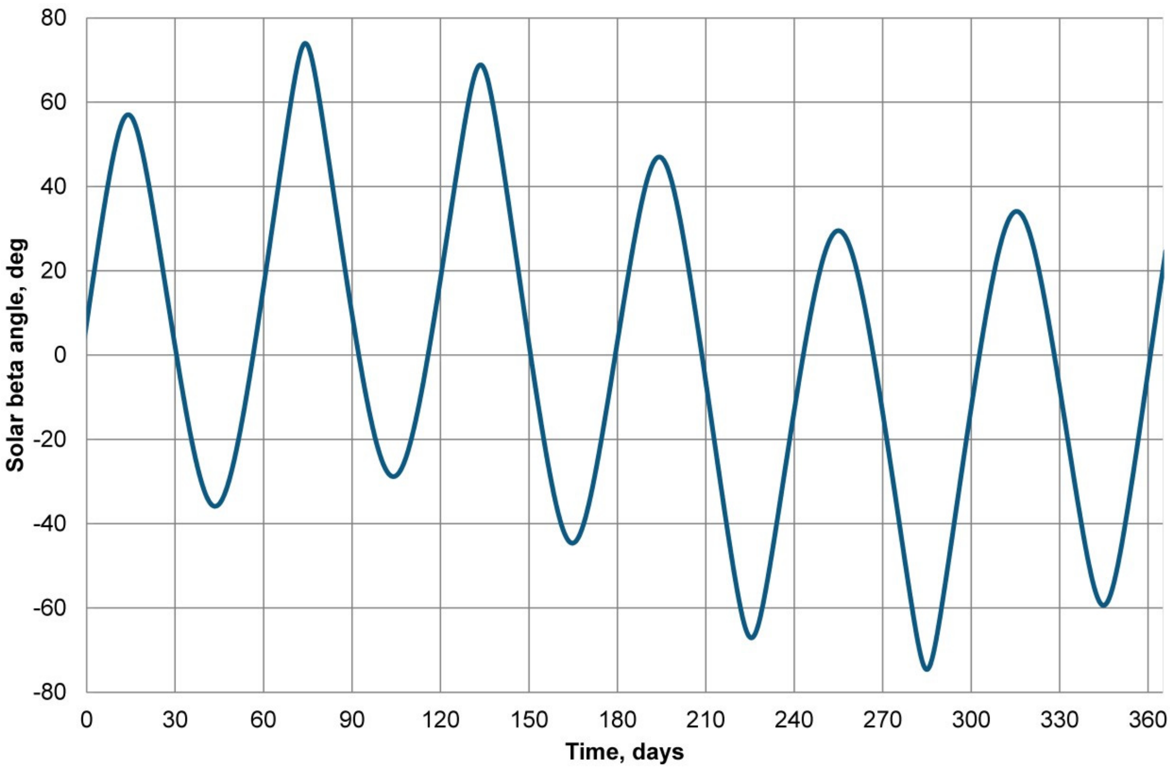


Figure 11 Solar beta angle variation over one year, time scale referenced to the vernal equinox and the right ascension of the ascending node referenced to epoch time 15005.54694699.

The ISS has a quasi-constant attitude aligned with its orbital flight direction. Due to the constantly changing configuration of the ISS with approaching and departing docking vehicles or activated and deactivated radiators, the attitude may vary within a certain range, to allow momentum equalization resulting from atmospheric drag forces. The standard attitude range in all 3 rotational dimensions is given in Table 8. In very rare occasions, the ISS attitude may exceed those defined limitations, in order to avoid potential collisions with debris objects.

Table 8 ISS flight attitudes

ISS Attitude Type	Attitude Reference Frame	Solar Beta Angle	Yaw	Pitch	Roll	Time in Attitude
+XVV +Z Nadir (TEA, see note)	LVLH	-75° to +75°	-15° to +15°	-20° to +15°	-15° to +15°	No Limit
-XVV +Z Nadir	LVLH	-75° to +75°	+165° to +195°	-20° to +15°	-15° to +15°	No Limit
+YVV +Z Nadir	LVLH	-75° to +75°	-110° to -80°	-20° to +15°	-15° to +15°	No Limit
-YVV +Z Nadir	LVLH	-75° to +75°	+75° to +105°	-20° to +15°	-15° to +15°	No Limit
+ZVV -X Nadir	LVLH	-75° to +75°	-15° to +15°	+75° to +105°	-15° to +15°	3 Hours
-ZVV -X Nadir	LVLH	-75° to +75°	+165° to +195°	+75° to +105°	-15° to +15°	3 Hours

Note: ISS normally (>90%) stays in the first attitude in Torque Equilibrium Attitude (TEA – a subset of the first attitude where CMGs are the only thing controlling attitude and thrusters are inhibited)

3.4.1 PAYLOAD ATTITUDE STABILITY

Limitations exist for the degree of pointing accuracy on any external payload attachment site. The general ISS alignment error is 0.2 to 0.5°/axis, 3σ. Further there is a periodic alignment error with a period of the order of an orbit of ±0.08° for roll and pitch, and +0.23/-0.10° in yaw due to thermal bending of the ISS truss. The ISS random error is 0.001 to 0.02°/axis, with 3σ in attitude awareness.

Furthermore, the ISS elements undergo a constant jitter motion affecting payload attitude stability. A specification of the guidance navigation and control performance under the effect of ISS jitter motions is given in Table 9. Please note that the pointing jitter due to microgravity disturbances is estimated to be on the order of 0.03 degrees when inactive.

Independently from ISS pointing accuracy the *Bartolomeo* structure is subject to thermal expansion based on orbital cycles. The maximum angular displacements based on the thermal analysis are given in Table 10.

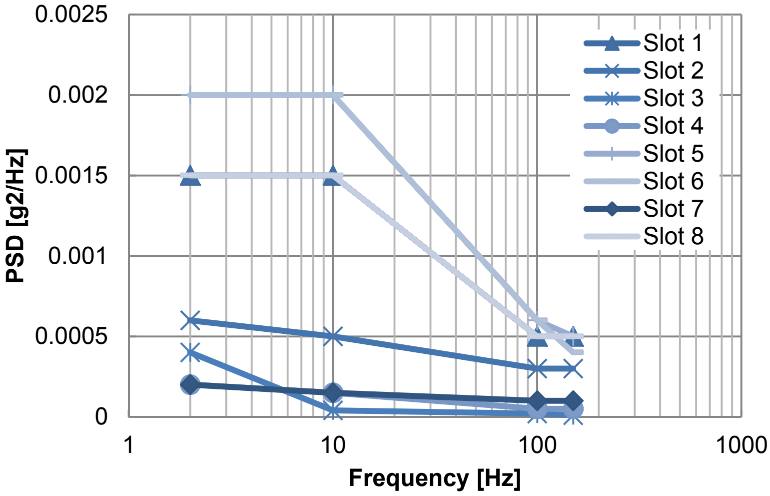
The *Bartolomeo* platform has very modal frequency between 1 and 4 Hz depending on the payload configuration and mass distribution. Therefore, *Bartolomeo* payloads experience only minor random vibrations exerted from the *Columbus* module via the structural interfaces as summarized in Figure 12 for the different payload slots. Slots 3 and 4 offer the best viewing conditions which is supported by the low random vibrations expected there.

Table 9 Pointing performance under the influence of jitter motions

Parameter	Requirement	Typical Performance
Attitude rate non-micro-gravity mode	±0.02 deg/sec/axis	±0.05 deg/sec/axis
Attitude knowledge at ISS navigation base (S0 truss)	±0.5 deg/axis (3σ)	<0.25 deg/axis (3σ)
Attitude knowledge on *Bartolomeo*	3.0 deg/axis (3σ)	<1.0 deg/axis (3σ)

Table 10 ***Bartolomeo* platform angular deflections**

Rotation Axis	Deflection [deg]
X	0.010
Y	0.381
Z	0.012



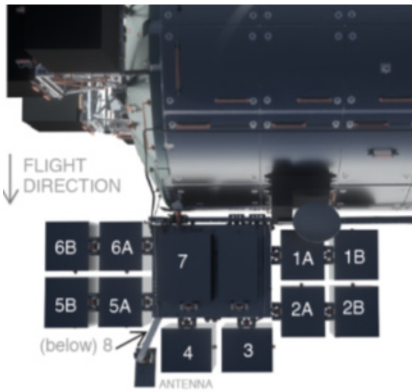
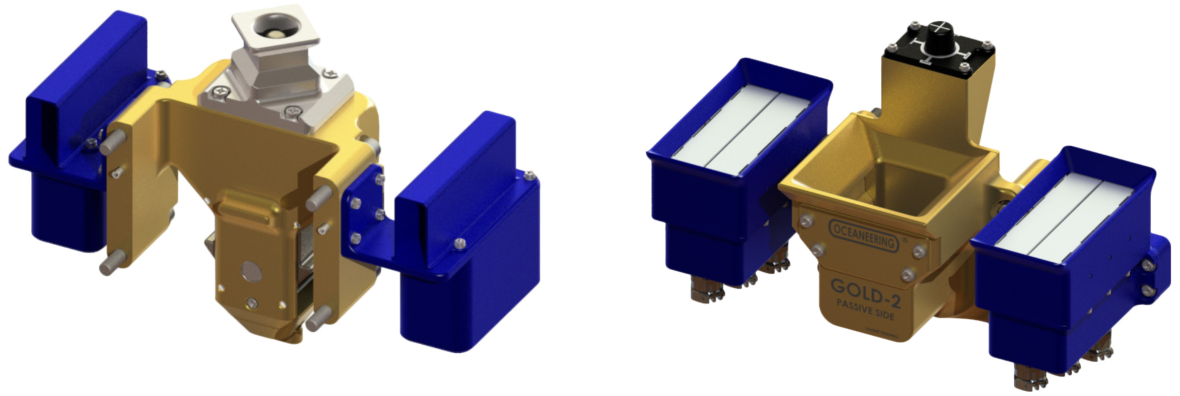


Figure 12 **On-orbit random vibration environment expected at *Bartolomeo* payloads.**

3.5 STANDARD MECHANICAL AND ELECTRICAL INTERFACE

The *Bartolomeo* external payload hosting facility is equipped with General-purpose Oceaneering Latching Devices (GOLD-2) which provide mechanical, electrical and data connectivity. The GOLD-2 design can accommodate payloads up to 450 kg. Figure 13 provides an overview of both parts of the GOLD-2 interface. The GOLD-2 active side (left) is part of the payload integrated by the Customer and is provided as part of the standard service. The GOLD-2 passive Side (right) is integrated on the *Bartolomeo* Platform in a fixed position for each of the 12 payload locations. The GOLD connectors are qualified to on-orbit system life of 10 years and they are compliant with all ISS Robotic requirements.

Each GOLD-2 connector is equipped with two electrical Smiths interconnect L-Series. In the standard payload configuration, only one connector is used by any one payload, whereas the second Smiths connector is reserved for the stacked payload. For optional accommodation to a double payload slot, both connectors may be used by one Double payload to benefit from double availability of power and communication resources. The Smiths connector Interconnect L-Series in combination with an H-type frame is defined as interface standard for all payload slots.



[Image credit: Oceaneering Space Systems, Inc.]

Figure 13 General-purpose Oceaneering Latching Device (GOLD-2)

3.6 PAYLOAD AIRLOCK AND ROBOTICS INTERFACES

In the nominal scenario a payload is launched pressurized and transferred to outside the Space Station either by the Japanese Experiment Module Airlock (JEM-A/L) or the NanoRacks Airlock (NRAL).

During robotic operations heater power can be provided through the SPDM/OTCM Umbilical Interface is used. In order to mate to the OTCM umbilical, the payload needs to have a corresponding umbilical interface located appropriately next to the GOLD-2 interface's micro square. The Umbilical Interface is provided by the *Bartolomeo* Service as optional service in case it is needed by the payload. For the JEM-A/L utilization the payload must be able to survive up to 10 hours unpowered, as there is no power available. This requirement is mitigated by using the NRAL with its ability to provide heater power during airlock operations.

Airlock cycles require a significant upfront planning and coordination. In general being compatible with the JEM Airlock already envelops volumetric compatibility with the NRAL, therefore staying within the envelope of the JEM A/L increases on-orbit operational flexibility for deployment.

3.6.1 JAPANESE EXPERIMENT MODULE AIRLOCK INTERFACES

The payload interface to the JEM Airlock Slide Table is the JEM Orbital Replacement Unit Transfer Interface (JOTI) which clamps the payload to the Slide Table. Therefore, if launched pressurized and planned for JEM Airlock deployment, the payload needs to meet dedicated JOTI interface requirements. The JOTI features clamping jaws to hold the payload on the slide table. For compatibility with the JEM-A/L envelope, the payload including the GOLD-2 payload connector needs to fit inside this envelope. All payloads to be transferred by JOTI are expected to utilize the baseline method of being clamped between the JOTI walls and caged within the JOTI walls and retention fingers. Alternative use of JOTI hardware may be negotiated on a case by case basis. The JOTI payload envelope is provided as CAD-file for payload design support. Figure 14 shows as an example the *ArgUS* payload envelope accommodated in the JEM-A/L. The maximum lengths is about 1440 mm (56.75”) following the available envelope and 760 mm (30”) wide. Various configuration are possible.

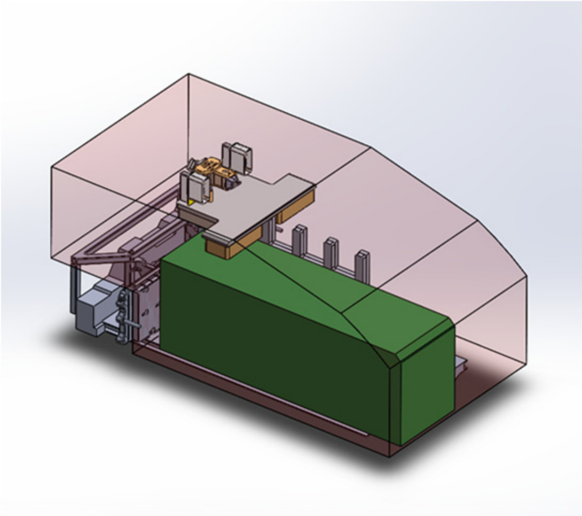


Figure 14 *ArgUS* **payload in the JEM A/L envelope (example)**

3.6.2 NANORACKS AIRLOCK INTERFACES

The NanoRacks Airlock (NRAL) also uses the GOLD-2 payload interface in the identical configuration as the *Bartolomeo* platform. The NRAL maximum payload envelope can accommodate up to four single size *Bartolomeo* payloads up to the maximum allowed standard envelope specified in section 3.1.

3.7 COMMANDING, MONITORING, DATA HANDLING AND POWER FUNCTION

The Avionics System provides power, communication, commanding and monitoring for all *Bartolomeo*-hosted payloads. The Avionics System overview is shown in Figure 15.

There are two types of commanding and monitoring (C&M) levels for each *Bartolomeo* payload: platform level and payload level. The platform C&M comprises standard monitoring and control capability for each slot and is under the responsibility of the *Bartolomeo* Control Center (BTL-CC) in cooperation with the *Columbus* Control Center (COL-CC). The payload C&M is the responsibility of the Customer and is design dependent.

Bartolomeo provides telemetry, commanding and data link capabilities using two different paths to communicate with the *Bartolomeo* ground system to support different payload data transmission needs:

- Near Real Time data transmission through the *Columbus* Multi-Purpose Computer Communication (MPCC)
- High capacity data downlink with the OSIRISv3 laser communication terminal (BTL-LCT)

Figure 16 gives an overview of the *Bartolomeo* communications infrastructure. The COL MPCC link provides the telemetry and commanding function with limited data capability. The Customer can operate and control their payloads directly via Ethernet protocols and under the protection of a Virtual Private Network (VPN) between the MPCC and the BTL-CC at Airbus in Bremen. The telemetry monitoring and commanding of payloads can be done directly by each Customer through an individual web console operating in the AirCloud.

Bartolomeo's OSIRISv3 laser communication terminal (BTL-LCT) has a channel data rate of 10 Gbps. Link budget and availability analyses performed by the German Aerospace Center predict a daily throughput of 0.5 to 3.75 Terabyte for a ground segment with 8 Optical Ground Stations (OGS). The data received by the ground stations is temporarily stored locally and forwarded directly to the AirCloud. With every Customer having personalized access to the AirCloud all payload data is accessible directly by the Customer’s individual web console. The BTL-LCT is available as an optional service.

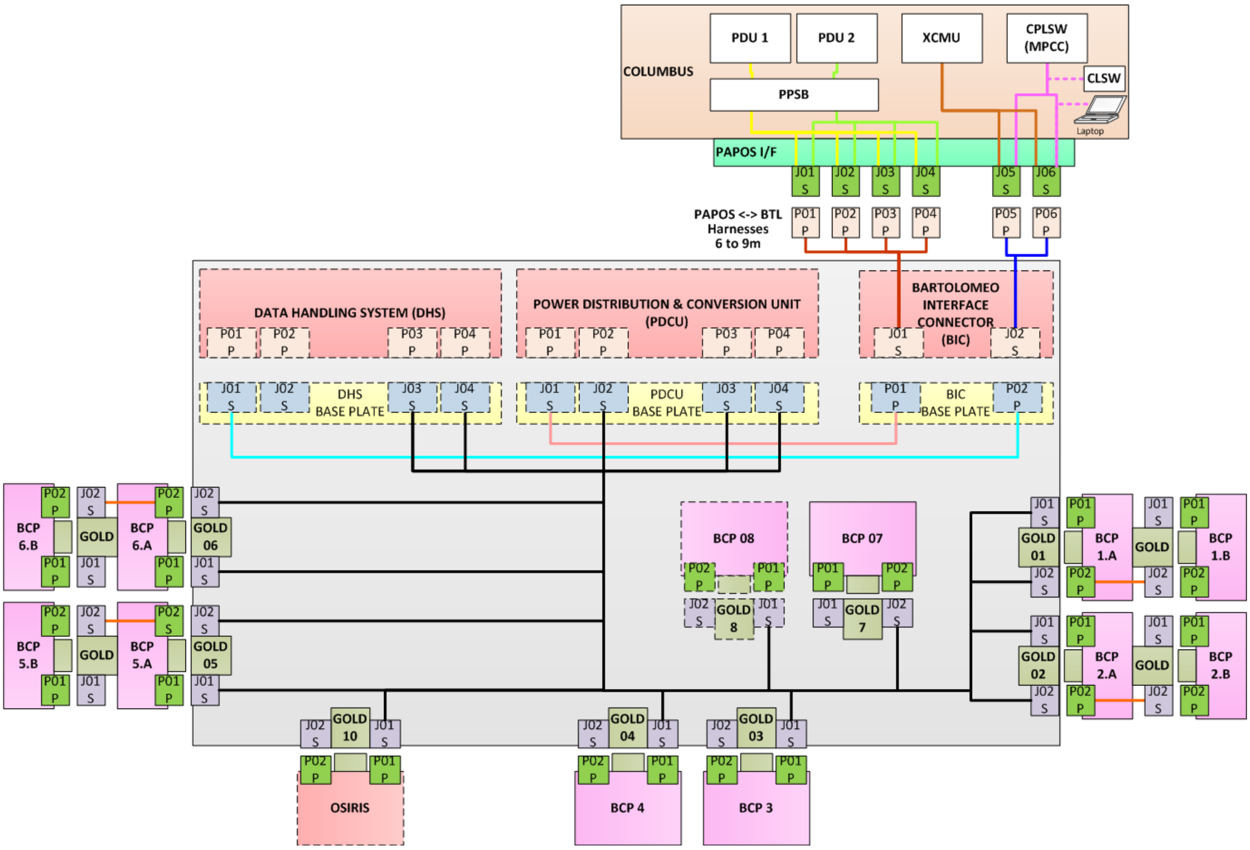


Figure 15 ***Bartolomeo* avionics system overview**

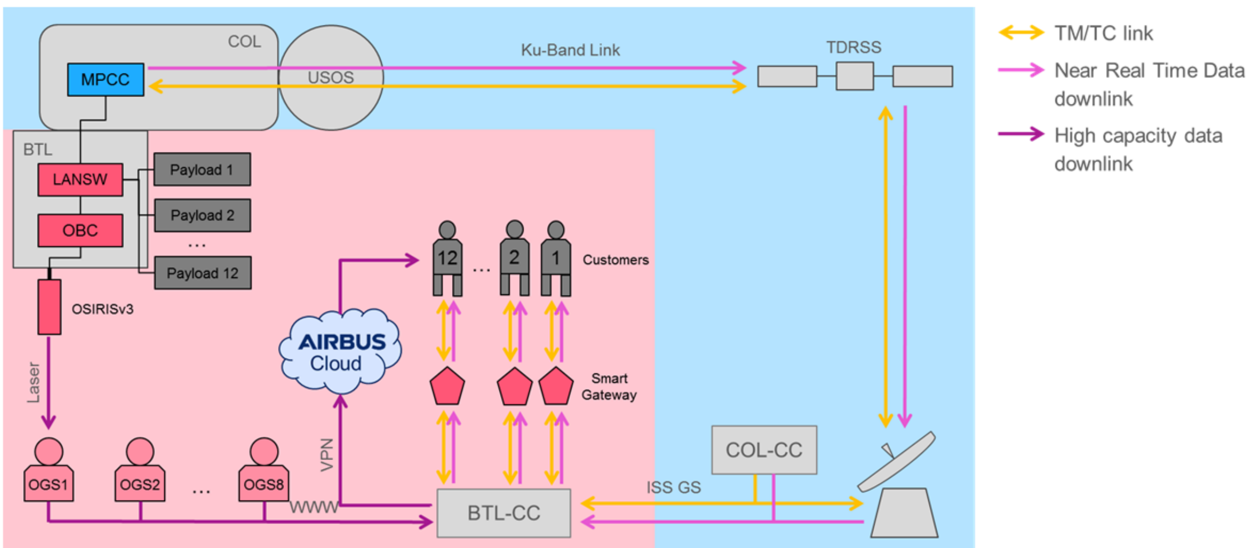


Figure 16 ***Bartolomeo* communication architecture**

3.7.1 COMMUNICATION FUNCTION

The *Bartolomeo* payload communication system uses two networks onboard the platform: the Payload Local Access Network (BTL-PL-LAN) and the Payload Local Access Network (BTL-COM-LAN). Payloads can decide either to dump data to ground via the BTL-LCT or via the MPCC using different subnet addresses. Payload data sent to the BTL-LCT is buffered first in the BTL-LCT mass memory before being dumped to ground. Data transferred to the MPCC is buffered in the MPCC attached drop box and then automatically sent to ground via the ISS link.

The BTL-PL-LAN is in any case used for monitoring and commanding of payloads.

3.7.2 POWER FUNCTION

The *Bartolomeo* platform routes power from *Columbus* to all payload slots. The voltage of power supply is 120 VDC with a nominal operational power provision of 180 W. Larger power consumptions up to 800 W are possible. Besides the operational power supply, all payload locations have an additional survival heater power supply of 20 W nominal at 120 VDC.

All interfaces have the same pin-out. The primary and survival heater power is distributed to payloads in groups of five. A mono-stable relay allows switching between payload power and payload survival heater power. The relay control is under the responsibility of platform operations and affects one complete group. In case of BTL-DHS power loss, the relay switches automatically to survival heating.

4 GROUND SEGMENT

The *Bartolomeo* ground segment is integrated into the *Columbus* ground segment. The BTL-LCT downloads the data to a separate Optical Ground Segment routing from the ground terminals directly to the AirCloud.

4.1 AIRCLOUD

The AirCloud represents a storage and data processing facility provided by Airbus. The AirCloud is part of the Airbus digital ecosystem. It is equipped with best-in-class cyber security features to support the distributed *Bartolomeo* user community as well as engineering and operations teams. The platform contains collaboration tools, ready-to-use apps for customers, engineers and system operators as well as an App-Store and marketplace to allow a distributed community of engineers to add value to the *Bartolomeo* software tool portfolio.

The Customer has restricted access to a separated area within the cloud. Only the customer and the BTL-CC have access to this area for control and monitoring of the payloads. Airbus also has access to all areas of the cloud for maintaining and controlling the cloud operations.

The AirCloud platform is configured with separate security domains for each *Bartolomeo* payload, as well as for system operations. In order to protect Customer Intellectual Property Rights (IPR) and ensure system safety and security at the same time, only selected Telemetry / Tele Command (TM/TC) is exchanged between payload security domains and system operations security domain. The security setup is shown in Figure 18, as well as the interactions of the different influences on the cloud environment.

Further, a container-based approach in the cloud platform will allow:

- modular provisioning of software apps to users
- scalability to support many users and processing- intensive functions
- failsafe operation and high service level
- efficient software lifecycle enabling continuous improvement and innovation

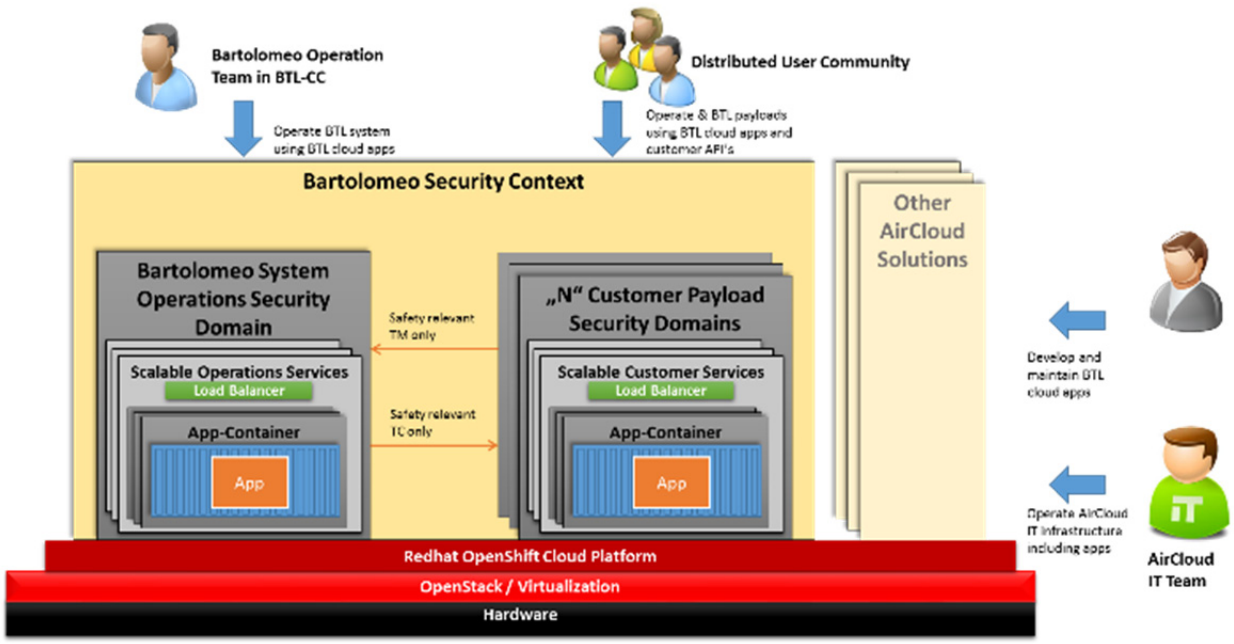


Figure 17 ***Bartolomeo* cloud as part of the AirCloud**

The cloud infrastructure is accessible through web portals as well as API(s) / interfaces. Furthermore, the onboard "Smart Gateway" serves as a highly convenient onboard-counterpart of the ground-based AirCloud infrastructure, hiding the complexity of the communication infrastructure from the user. It allows store & forward functionality through off-the-shelf message-oriented middleware, configurable routing logic as well as processing capacity to host custom onboard applications.

Every customer can fully customize the ground console

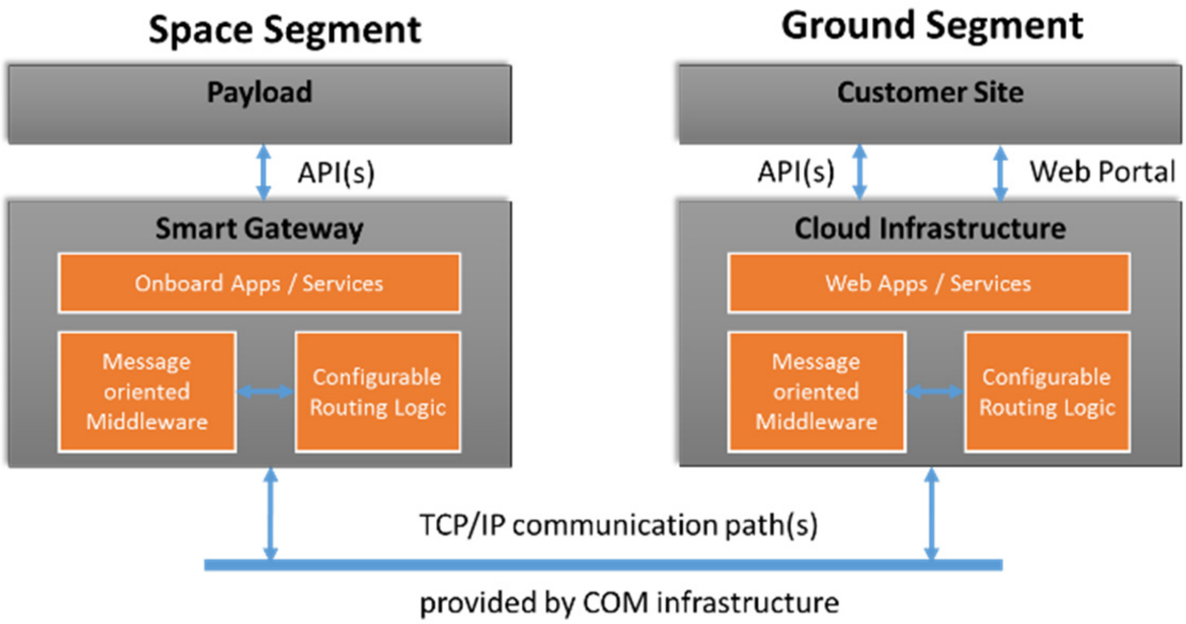


Figure 18 Communication between Space and Ground Segment

As part of the standard service, *Bartolomeo* provides a web-based user portal to easily monitor and control its payloads. Airbus hosts dedicated infrastructure domains and separated data storage per Customer through its cloud infrastructure.

The interface to the web portal is provided through the *Bartolomeo* onboard computer. In particular, for TM/TC, a Message Queuing Telemetry Transport (MQTT) message broker is provided. The *Bartolomeo* web portal allows the Customer to:

- create and modify user defined dashboards with pre-defined, data-bound widgets that support telemetry charts, numeric values, texts, data-enriched vector graphics, video, files,
- Perform interactive commanding within the constraints of the payload's safety plan,
- Access archived payload data,
- Upload of new payload software, and request for additional payload resources (e.g. high-rate data slots, additional power slot) or command execution requiring manual approval.

Figure 19 shows an example of a user interface layout. The Customer has full flexibility to create his own user layout in order to access their payload data in the most convenient manner.

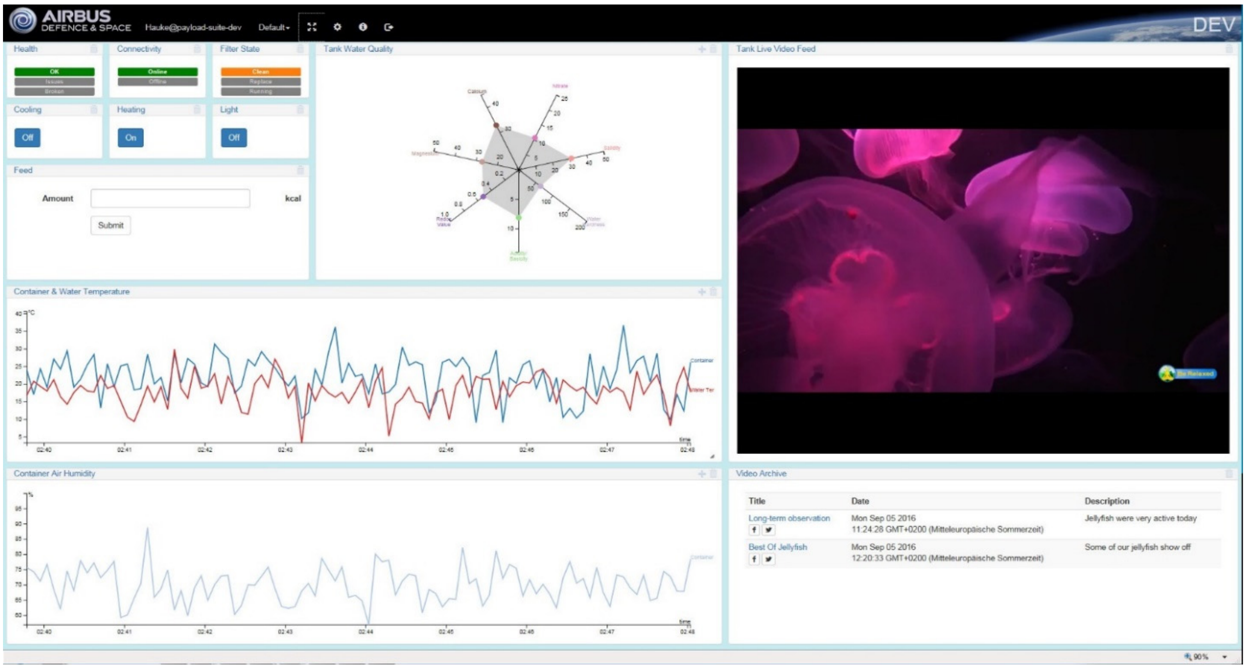


Figure 19 AirCloud web portal (example layout and example data)

5 PAYLOAD LIFE CYCLE

The payload processing is illustrated in Figure 20. Based on the payload conceptual baseline, a feasibility analysis in combination with the *Bartolomeo* facility is performed to analyze the payload compatibility with the platform and ISS interface and operational requirements. Upon contract signature, the *Bartolomeo* program organizes the suitable launch depending on the payload needs and specifications as well as availability in the ISS program. Based on the launch manifest and the integration time line, the *Bartolomeo* engineering team provides the payload integration schedule and all interface requirements as relevant for the payload development.

The payload development itself is the responsibility of the Customer. The following tests are required as a minimum, details are agreed on during the mission integration process:

- Vibration test to verify the structural margin of the payload and the ensure launch survival
- Thermal test to verify the thermal ranges of the payload, analysis may be sufficient in specific cases.
- Electro-Magnetic Compatibility and Electro-Static Discharge (EMC/ESD) test to validate electromagnetic compatibility
- Functional tests to validate all functional requirements of the payload
- Power quality and interface test
- Command and Data handling interface test

Portable test equipment is available to test the payload interfaces to *Bartolomeo*, typically performed shortly before hand-over. However, depending on the particular payload may be arranged earlier at the payload developer site to avoid late identification of interface issues.

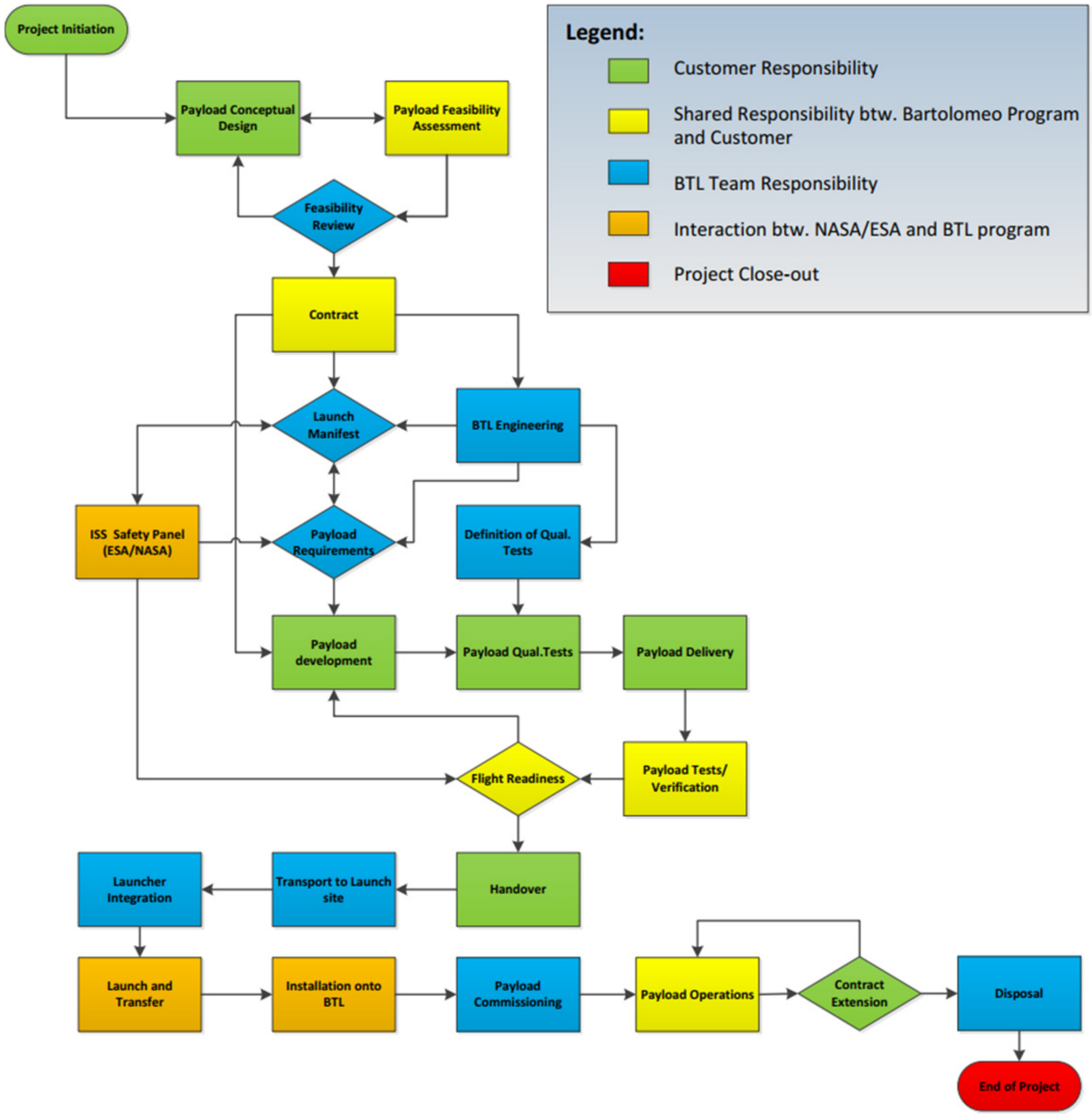


Figure 20 Payload life cycle

Upon completion of qualification tests the payload is delivered to Airbus DS Space Systems Inc. in Houston, Texas (ADSH) under Customer responsibility. In Houston, final interface tests, fit checks and safety relevant activities are performed and supported by the *Bartolomeo* integration team. These final acceptance tests are followed by a Readiness Review held in Houston and is supported by the *Bartolomeo* engineering team. The successful completion of the Readiness Review results in the Certification of Flight Readiness (CoFR) for the payload reported to NASA.

Upon the successful CoFR the payload is handed over to the ISS Partners for launch. After successful launch and on-orbit payload installation the payload is commissioned by the Customer supported by the *Bartolomeo* team. As soon as the nominal operation capability is established the payload operations phase starts with support from the *Bartolomeo* team in close cooperation with the Customer. At the end of the contractual life time the disposal phase is initiated. The standard disposal foresees the robotic detachment of the payload from *Bartolomeo* and reintegration into a visiting vehicle for destructive re-entry. Payload or sample return is available as optional service.

5.1 PAYLOAD OPERATIONAL CONCEPT OVERVIEW

For the purposes of operational classification, the *Bartolomeo* payloads fall under options as shown in Table 11 below, where one option from each column applies to a given payload.

Table 11 Relevant payload options

1. Launch	2. Disposal/Return	3. Slot Size	4. Daisy-Chain
1.1 Pressurized After reaching flight readiness, the payload is installed in a Carto Transportation Bag (CTB) and transported pressurized to the ISS. The payload is transferred to *Bartolomeo* via the JEM-A/L or the NRAL by ISS crew and robotics.	**2.1 Pressurized & returned** Transferred from *Bartolomeo* into the ISS via the JEM-AL or the NRAL using ISS crew and robotics The payload is returned to Earth.	**3.1 Single-Slot** The payload fits from a mass and volume perspective within a single payload-envelope on *Bartolomeo*, and uses a single GOLD-2 interface.	**4.1 Chainable** The payload has two GOLD-2 interfaces, allowing for a daisy-chain approach to connecting other payloads to *Bartolomeo*. A chainable payload can operate even when no other payload is daisy-chained to it. This applies to Slots 1A, 2A, 5A, and 6A.
1.2 Unpressurized After reaching flight readiness, the payload is installed into the trunk of a cargo vehicle. Transfer to *Bartolomeo* via EVR from the cargo vehicle trunk via EVR using the GOLD-2 I/F.	**2.2 Pressurized & destructive reentry** As per pressurized & returned but there is no need to return it to ground. The ISS crew packages the payload, for destructive reentry within a departing cargo vehicle.	**3.2 Double-Slot** The payload requires one or two payload slots from a mass and volume perspective and / or requires high power.	**4.2 Non-Chainable** The payload has one GOLD-2 interface, meaning it either connects directly to the *Bartolomeo* platform or it connects via another chainable payload. Like chainable payloads, Non-chainable payloads may be deactivated and moved to another slot using EVR.
	2.3 Unpressurised & destructive reentry Transferred from *Bartolomeo* to the trunk of an outgoing resupply vehicle via EVR. The payload is destroyed during reentry.		

5.2 PAYLOAD LAUNCH OPTIONS

There are two principal options to launch a *Bartolomeo* payload depending on its size and mass properties.

Payloads may be launched unpressurized, extracted from the visiting vehicle unpressurized cargo compartment (Figure 21) by the ISS Remote Manipulator System (RMS) and installed directly on the platform, or may be launched pressurized in a standard Cargo Transportation Bag (CTB) (Figure 22). The selection of the launch option is strongly dependent on resource availability at the ISS program and shall be investigated and coordinated as early as possible in the payload life cycle. The nominal process is the pressurized launch in a cargo bag and transferred via one of the ISS airlocks.

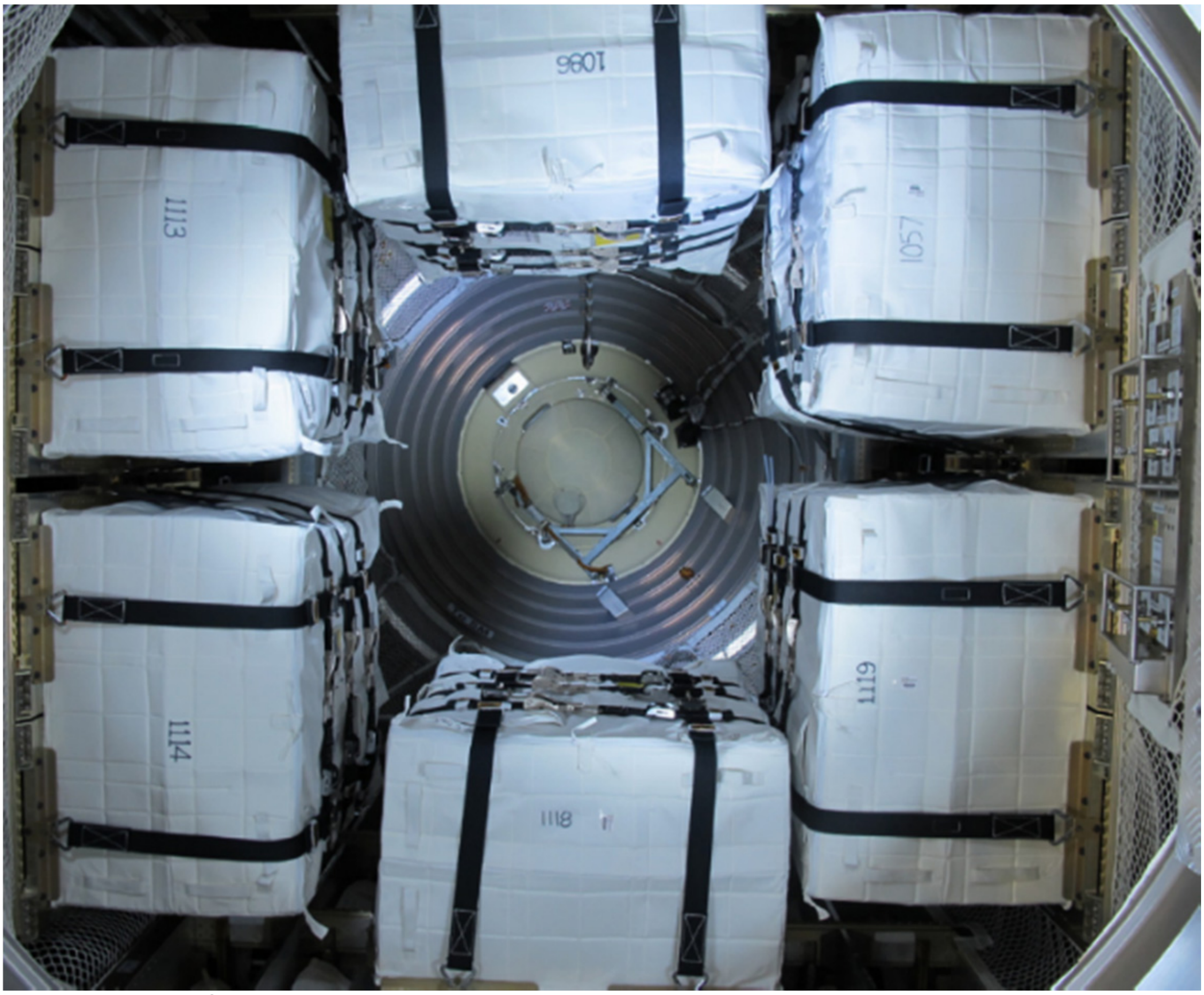
An unpressurized launch option would require to be compatible with the unpressurized accommodation options, typically a Flight Releasable Attach Mechanism (FRAM). Currently there is no yet a GOLD-2 interface available to launch unpressurized payloads. The development is ongoing at Oceaneering.

Pressurized launch slots are much more often available, as payload items are transported among other resupplies required by the station operations. Another attractive feature of the pressurized launch option is the relaxed vibrational environment experienced by the payload during launch, due to the transportation of payloads packed in foam.

The current commercial resupply vehicles provide late load and access capability, which however is a limited resource and restricted by certain volume and individual cargo requirement. Late load and access would require a specific non-standard agreement.

[Image credit: NASA]

Figure 21 Unpressurized payload launch in ISS visiting vehicle trunk

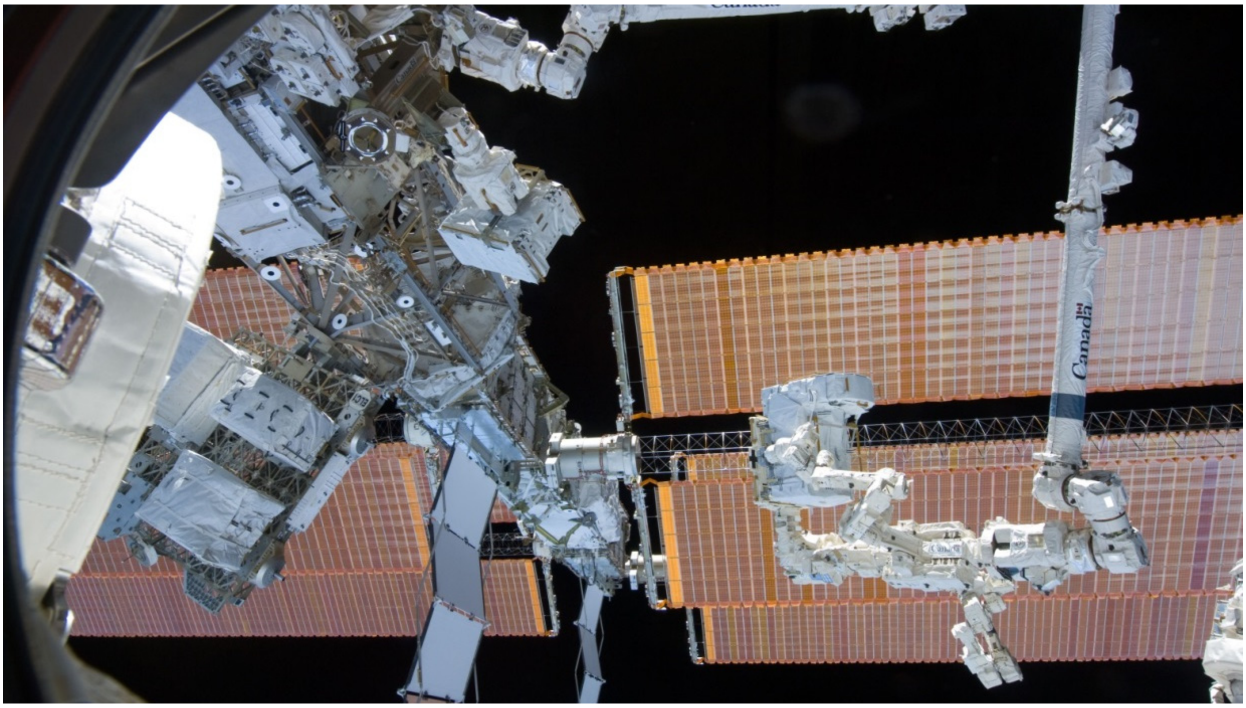


[Image credit: NASA]

Figure 22 Pressurized payload launch in ISS visiting vehicle pressurized compartment

5.3 PAYLOAD ON-ORBIT INSTALLATION

The Special Purpose Dexterous Manipulator (SPDM), or Dextre, in conjunction with the Space Station Remote Manipulator System (SSRMS), is used to install and uninstall payloads on the platform. Dextre and the SSRMS are two external components of the ISS. Direct robotic interactions with payloads for installation and de-installation are entirely through Dextre.



[Image credit: NASA]

Figure 23 ISS Dextre (SPDM) on the ISS

Dextre's manipulation control is provided by two seven-jointed arms, with Orbital Replacement Unit (ORU)/Tool Change-out Mechanisms (OTCMs). The OTCMs attach to micro fixtures, provided by the GOLD-2 interfaces on the payload, and feature a retractable motorized socket wrench used to torque bolts, a camera and lights used for close-up viewing and to align the OTCM with the fixtures using targets. In order to access the micro fixture, a payload must leave enough space around the fixture to accommodate the OTCM clearance envelope. For *Bartolomeo* payloads the robotic interface is provided through the GOLD-2 payload interface including targets. For heater power provision during robotic transfer the OTCM umbilical interface needs to be installed on the payload.

5.4 PAYLOAD INITIALIZATION AND OPERATION

5.4.1 CUSTOMER PAYLOAD GROUND OPERATION

Ground operation for the payload calls for an acceptance test at the *Bartolomeo* test facility, to show compliance with the GOLD-2 *Bartolomeo*-payload interface and to provide evidence that the payload performs as requested for power switching and data transmission via the Ethernet connection. Once flight readiness is achieved, the payload is prepared for flight either as a pressurized or unpressurised payload.

5.4.2 PAYLOAD ON-ORBIT INSTALLATION, UNINSTALLATION AND SLOT SHIFTING

Payloads are launched and transferred to *Bartolomeo* in a deactivated state. No payload is operational during the robotic operations. Each payload contains a GOLD-2 interface on which a robotic interface exists for EVR purposes.

5.4.3 CUSTOMER PAYLOAD ACTIVATION

Once the payload is installed using Extra-vehicular Robotics (EVR), a signal is received confirming that the GOLD-2 interface is properly engaged.

Once the robotic activity has been completed, and at an activation time is agreed with ISS operations, COL-CC switches on the power supply and send a command to the payload for activation.

Once power is applied to the payload, it connects itself to the *Bartolomeo* Ethernet. COL-CC informs the *Bartolomeo* team, who performs checks and then works with the payload provider to activate and commission their payload. Each payload can be monitored and commanded by the Customer at their premises, as well as at the BTL-CC.

5.4.4 PAYLOAD OPERATIONS

The payload is operated by the Customer supported by the BTL-CC and COL-CC.

The payload is operated by the payload provider through the payload User Web Console based on the AirCloud. The AirCloud is the system that combines both the MPCC-routed data and the BTL-LCT-provided data. This same ground software interface is used for both payload commanding and data access. As the interface is accessible over the internet, the payload provider is expected to monitor and operate their system from their own premises.

- The User Web Console has the capability to:
- Switch their payload on and off
- Send Telecommands (TLC) and software updates to their payload
- Send requests to the *Bartolomeo* user center

During the operational phase with attached payloads, the BTL-CC and COL-CC monitors for each payload:

- The electrical current between the payload and *Bartolomeo*
- A single temperature reading for each payload.
- The voltage line activation to each payload (binary), through a watchdog
- GOLD-2 contact (binary), although this is only used as a check during installation and de-installation

The BTL-CC has the capability to:

- Switch the payloads individually on and off
- Switch a group of payloads between operational power and heater (i.e. survival) power
- Switch the payload off for hazard control purposes

5.4.5 OFF-NOMINAL PAYLOAD OPERATIONS

Due to the baseline requirement that all payloads have to be inherently safe no payload activity or status may lead to an off-nominal situation. All issues like unclear power consumption increase, undefined temperature increase or similar measured issues lead to the switch-off for the payload either by the payload user or BTL-CC/COL-CC.

The proper operational performance of a payload is not assessed by the control centers and is within the responsibility of the Customer.

An off-nominal situation may occur if within *Columbus* or the United States Orbital Segment (USOS) part of the ISS a sudden resources diminishment occurs which leads to the shutdown of power, loss of communication etc. Off-nominal situations also may occur in case a major reconfiguration or maintenance activities have to be performed and power resources and lines have to be switched.

In these cases, all possible precautions are initiated to avoid data loss. Data is stored either in the BTL-LCT terminal waiting for laser transmission to ground, or needs to be stored on-board the payload.

5.4.6 PAYLOAD DEACTIVATION

In nominal, planned, deactivation scenarios, payload deactivation is similar to the activation in reverse order. Firstly, the payload provider puts the payload in a safe state and informs BTL-CC to go ahead with the switch off of the power supply by sending a ground command.

In off-nominal deactivation scenarios, the payload is put into a safe mode or shut off completely by the payload User Web Console, the BTL-CC or the COL-CC, depending on the scenario.

The payload is required to survive in unpowered state for 6 hours

5.5 PAYLOAD DISPOSAL OR RETURN

After completion of the contractual payload hosting period, the payload disposal phase begins. The standard payload life cycle does not foresee a payload or sample return service. However, sample return or return of a payload might be possible as an option. The following sections describe both cases.

5.5.1 STANDARD PAYLOAD DISPOSAL

In the standard payload disposal scenario payloads are detached from *Bartolomeo* by the SPDM and disposed as pressurized trash after being returned to the interior ISS volume via one of the payload airlocks. In the nominal case the payload burns up during reentry into the Earth's atmosphere.

5.5.2 PAYLOAD RETURN OPTION

The return option is available based on ISS visiting vehicles able to return cargo. That means that the payload item or payload sample requires compatibility with an ISS payload airlock to be transferred inside the ISS. From inside the ISS the return item is stowed inside the pressurized return capsule. During reentry the return item needs to withstand the reentry environment as present inside the return capsule.

The major requirements for returning payloads or samples are the compatibility with the following interfaces:

- Accessibility by the dexterous manipulator (SPDM) of the ISS (fulfilled by use of GOLD-2)
- Compatibility with the ISS Airlock interfaces and requirements
- Compliance with requirements for ISS pressurized payloads for launch and return

In principle, early retrieval of samples can be accommodated, but it depends on various factors and requires a specific agreement for an optional service.

6 PAYLOAD DESIGN GUIDELINES AND REQUIREMENTS

This section provides an overview of certain design guidelines and requirements, further details are being developed throughout the mission integration process.

6.1 ELECTRICAL DESIGN

Customer payloads shall comply with the *Bartolomeo* electrical interfaces described in the *Bartolomeo* / Payload Interface Definition Document (IDD).

6.2 SOFTWARE DESIGN

The payload shall provide LAN connection by using IP4 protocol.

The payload shall support telemetry via two sub addresses, one IP address shall be used for data uplink and for housekeeping data downlink to a *Bartolomeo* Ground station via the BTL-DHS that creates a VPN tunnel through ISS, one IP address shall be used for data transfer to the BTL-LCT.

A virus/malware protection software shall be implemented.

6.3 VARIOUS DESIGN REQUIREMENTS

6.3.1 SECONDARY LOCKING FEATURE

A secondary locking feature is required for fasteners external to the payload chassis that is not held captive by the spacecraft structure and enclosure should they come loose.

6.3.2 BATTERIES

The use of batteries in payloads is restricted. Approval of the use of batteries must be obtained on a case by case basis.

6.3.3 PRESSURE VESSELS

Pressure vessels may be made acceptable for flight safety with proper hazard controls. If pressure vessels are used, documentation is required on materials used, pressure vessel history (including cycles and life time assessment) and control measures to assure pressure vessel integrity (damage control plan), testing performed, fracture control measures planned, inspection process and methods, etc. wherever hazard potential is present.

6.3.4 HAZARDOUS MATERIALS

Payloads shall comply with NASA guidelines for hazardous materials. The Customer shall submit a Bill of Materials (BOM) to the service provider for assessment. Beryllium, cadmium, mercury, silver or other prohibited materials shall not be used.

6.3.5 MICROGRAVITY ENVIRONMENT

Micro-vibrations generated from all of the ISS systems may be transmitted throughout the structure, and may affect sensitive payloads. The payload shall restrict mechanical vibrations to the levels defined in the *Bartolomeo*-IDD in order not to disturb sensitive payloads while the ISS is in microgravity mode.

6.3.6 MICROMETEOROIDS AND ORBITAL DEBRIS

Impacts from micrometeoroids may cause permanently degraded performance or damage to the hosted payload instrument. Further details are defined in the IDD.

6.3.7 ATOMIC OXYGEN

The average atomic oxygen flux of 5.0×10^{21} atoms/cm²/year is expected for the *Bartolomeo* external payload locations.

6.3.8 SOLAR ULTRAVIOLET RADIATION

For design and analysis purposes payloads shall comply with the on-orbit solar ultraviolet radiation environment requirements

6.3.9 ROBOTIC TRANSFER ENVIRONMENT

All payloads are handled and installed on *Bartolomeo* via the robotic system of the ISS. The expectation is that a payload is “fail-safe” in the event power cannot be applied within the payload’s analyzed survival clock. In case of need, payloads may receive heater power at 120 V through the OTCM Umbilical Interface which has to be designed into the payload.

6.4 MECHANICAL ENVIRONMENTS

The launch environment is the driving mechanical environment for the payload structural design. The standard option is a pressurized launch where the payload is packed soft mounted inside a CTB in contrast to the unpressurized launch, where the payload is hard mounted to the Visiting Vehicle structure.

6.4.1 LAUNCH LOAD ENVIRONMENT

Payload safety-critical structures shall provide positive margins of safety to the static launch environment acting in all six degrees of freedom simultaneously (Table 12).

Table 12 Launch static load environment

Visiting Vehicle Accommodation	Nx[g]	Ny[g]	Nz[g]
Unpressurized compartment	+/10	+/8	+/8
Pressurized compartment	+7.0/-7.0	+/-4.0	+/-4.0

Payloads launched pressurized packed in foam or bubble wrap and soft stowed in a CTB shall meet the specified performance requirements when exposed to the maximum flight random vibration environments defined in Table 13 which envelopes all environments defined for the pressurized compartment. For unpressurized vibration environment refer to the IDD.

Table 13 Launch random vibration environment.

Visiting Vehicle Accommodation	Frequency [Hz]	PSD [g^2/Hz]
Pressurized compartment	All Axes	
	20	0.02
	200	0.02
	2000	0.001
	Grms	3.2
	Duration	60 sec

Payloads packed in the foam or bubble wrap materials do not experience significant mechanical shock. Shock verification is not required for launch events. Any mechanical or electrical components that are highly sensitive to shock should be assessed on a case-by-case basis.

Safety-critical structures packed in foam or bubble wrap and enclosed in hard containers such as CTB’s or similar structures, shall meet the specified performance requirements when exposed to the maximum flight random vibration environments.

6.4.2 ROBOTICS LOAD ENVIRONMENT

For EVR operations, the payload shall meet structural integrity requirements in an on–orbit acceleration environment having peak transient accelerations up to 0.2 g, with a vector quantity acting in any direction.

While being manipulated robotically a payload can be at risk for impact when clearances between the payload and some other structure are within certain ranges. Payloads that interface with the SPDM are expected to be able to take a 1 Joule impact in any area that is within the clearance range. The contact areas are determined with the help of the robotics community supported by *Bartolomeo* engineering. Areas at risk for impact are expected to be fail safe and not result in a structural failure.

6.5 THERMAL ENVIRONMENT

The payload sites do not provide active thermal control interfaces. The attached payload needs to be designed to rely solely on its own thermal control mechanisms, such as optical coating selection, insulating blankets, heater circuits, heat-pipes, or radiators. Based on selection of the specific payload site restrictions may apply and are subject to system analysis by the *Bartolomeo* engineering team.

6.5.1 PAYLOAD THERMAL ANALYSIS

As a standard environment the temperature ranges defined in Table 14 need to be considered. A payload thermal analysis needs to be performed with the parameters defined in Table 15 in order to demonstrate that the payload remains safe during all mission phases.

Table 14 Expected thermal environments

Environment	Temperature
Ground processing	10°C to 35°C
Visiting Vehicle pressurized compartments	10°C to 46°C
ISS pressurized modules	16.7°C to 28.3°C
Robotic installation	-40°C to +60°C

Table 15 Thermal environment parameters

Case	Solar Constant [W/m²]	Earth Albedo	Earth OLR [W/m²]	Altitude [km]
Hot	1321	0.2	206	500
Cold	1423	0.4	286	278

6.5.2 UNPOWERED SURVIVAL

The payload shall be able to survive 6 hours without power during phases of planned loss of power.

6.5.3 THERMAL CONDUCTION

The external payload cannot use the platform as a heat sink due to lack of thermal contact to the structure.

6.5.4 THERMAL RADIATION

All external payload heat rejection requirements shall be met through radiation to the environment with all thermal radiators being confined to the *Bartolomeo* payload envelope dimensions. Payloads shall not employ thermal control methods that reject heat to neighboring payloads. The payload slot is allocated taking into account the payload thermal radiation requirements.

6.6 ELECTROMAGNETIC COMPATIBILITY

The payload must comply with the *Columbus* and Bartolomeo electromagnetic compatibility requirements, verification methods and testing setups as defined in the *Bartolomeo* IDD.

7 SAFETY

Bartolomeo is part of the International Space Station, all payload operations are required to be compliant with the existing ISS Safety requirements which are designed to ensure ISS system, crew and visiting vehicle safety.

The safety requirements and review processes are well-defined and straight-forward. The Bartolomeo technical team takes care of the payload safety certification based on Customer payload design and requirements verification. This section on payload safety describes the boundary conditions under which the Customer needs to design the payload.

7.1 HAZARD DEFINITION

Catastrophic hazards are defined as any condition which may result in either:

- A disabling or fatal personnel injury,
- Loss of the ISS,
- Loss of a crew-carrying vehicle
- Loss of a major ground facility

The payload shall be designed such that no combination of two failures, two operator errors (or one of each), can cause a disabling or fatal personnel injury or loss of one of the following: loss of ISS, loss of a crew-carrying vehicle, or loss of major ground facility.

A critical hazard is any condition which may result in either:

- A non-disabling personnel injury or illness
- Loss of a major ISS element
- Loss of robotic system use

The payload shall be designed such that no single failure or single operator error can cause a non-disabling personnel injury or illness, loss of a major ISS element, loss of redundancy (i.e. with only a single hazard control remaining) for on-orbit life sustaining function, or loss of use of the Space Station Remote Manipulator System (SSRMS).

Typical hazards to be assessed for hazard potential (critical or catastrophic):

- Structural failure
- Pressure System Failure, Leakage
- Propulsion system hazards
- Deployment of appendages
- Radio Frequency (RF) system operation
- Battery Failure
- Flammable or toxic material usage
- Frangible material usage
- Electrical system failures, and (EMI)
- Magnetic field
- Collision with ISS
- Sharp edges, pinch points, touch hazards
- Operational hazards

7.2 CONTROL OF HAZARDS

Control of hazards shall be appropriate for the hazard type and occurrence.

Control of hazards have to be appropriate for the hazard type and occurrence. Typical hazard controls are summarized in Table 16.

Table 16 Typical hazard controls

Hazard	Control
Structural hazards	• Application of factor of safety with positive margin; design for minimum risk • Fault tolerance where applicable • Redundant mechanism
Electrically operated systems	• Inhibits to control inadvertent operations appropriate to the hazard level • Redundancy as necessary to perform required functions, Design controls i.e. EMI
Leakage of toxic substances	• Fault tolerance in seals appropriate • Structural strength of containers
Flammable materials	• Elimination of flammable materials • Containment • Wire sizing and fusing
Pressure systems	• Factor of safety
RF systems	• Design to have power below hazard level and frequency in approved range • Inhibits to control inadvertent operations appropriate to the hazard level
Battery hazards	• Containment • Protection circuits
Any hazard occurring during specific flight phases which cannot be controlled otherwise	Payload switch-off with fault-tolerance against inadvertent switch-on (provided on Slots 2A, 2B, 3, 4, 5A, 6A)

AIRBUS

8 RISK SHARING WITH CUSTOMERS

8.1 CUSTOMER RESPONSIBILITIES

The following provides an overview of *Bartolomeo* customers responsibilities, details are defined via the IDD and contracts proceedings:

- The Customer agrees to furnish Airbus with all necessary material and data required to assure compliance with the Airbus and NASA safety regulations.
- The launch and insertion of a payload on the *Bartolomeo* platform may be subject to regulatory requirements. The Customer needs to ensure compliance with any and all applicable domestic and/or international regulations.

8.2 SERVICE CONDITIONS

Some or all aspects of the space flight program, including the flight opportunity and the launch date, the time on-board ISS, the insertion onto the *Bartolomeo* platform, the ability of the crew to interface with the payload, or the specific mission that will carry the payload may change in date or duration, or become unable to be realized. The following list identifies potential situations which may impact a payload deployment but are outside the control of Airbus, detailed agreements will be agreed upon in the service contract:

- Cancelled flight opportunity.
- Launch failure resulting in the loss of the Customer payload.
- Mission becomes unable to be realized due to any change in policy, procedure or agreement instituted by ESA or NASA or any organization
- Customer payload failure.
- NASA is the final arbitrator on all issues related to the flight opportunity including, but not limited to, flight manifest, safety review, and technical review, access to crew time, deployment and return.
- Airbus and its commercial partners do not retain any intellectual property rights from data, research or commercial products resulting from Customer payload missions. The Customer may protect his intellectual property by appropriate technical means when it is within the perimeter of the *Bartolomeo All-in-one Mission Service*.

8.3 PRIORITY OF USE

Any schedule or milestone in the Customer contract, is estimated based upon the parties' current understanding of the projected availability of Airbus's ISS allocations. The use of the ISS by all parties is subject to and contingent upon the availability of ESA and NASA goods, services, facilities, or equipment. The Customer accepts the risk that ESA or NASA priorities may impact Customer's priority and use of the ISS. User further acknowledges that the availability of these ESA or NASA resources may be outside the authority and control of Airbus..

9 ITEMS TO BE DELIVERED BY THE CUSTOMER

9.1 MISSION INFORMATION FOR ISS PARTNERS

For general understanding of the payload mission objectives by the ISS Partners the following payload mission information is required:

- Short summary of the activity in the targeted *Bartolomeo* payload facility, including the research scope and objectives. Brief description of the experimental setup.
- Brief description of the provided hardware
- General description of the expected scientific deliverables (e.g. returned samples, sensor data, housekeeping data, and experiment timing data)
- Description of the end-to-end experiment process including, duration, timeline
- Programmatic status, hardware development status, target turnover date and desired on-orbit performance window

9.2 INITIAL PAYLOAD SPECIFICATION

For the initial payload feasibility assessment, the following data shall be provided by the Customer:

- Preliminary payload property data: mass, volume, dimensions (for up/download)
- Power consumption data (peak, average, minimum)
- Battery type and toxicity code (if applicable)
- Emissions (type, quantity if applicable)
- Substances inside/hazardous materials? (Type, quantity, and hazard response level), release of (toxic) constituents etc.
- Conditioned stowage required? (during upload, on-orbit, download), including the following information: quantities (mass, volume, dimensions), toxicity level, desired temperature, coldest/warmest temperature allowed, loss of science temperature (warmest/coldest), total loss of science temperature (warmest/coldest), post-landing optimal temperature (min/max); specific packaging and orientation requirements,
- Volume of real-time data or video up/downlink required (estimate);
- Experiment duration; continuous, intermittent
- Margins in case of launch delays (including rationale) – how long can the experiment/samples survive without service in case of delays?
- On-orbit operations (OPS) start constraints;
- Launch site preparation requirements (including start date in L-days), and launch site laboratory requirements (e.g. consumables, hardware);
- Payload orientation requirements;
- Disposal type (post-Ops);
- Other/unique payload constraints;
- Project schedule

9.3 CUSTOMER DELIVERABLE ITEMS IN SUPPORT OF PROJECT IMPLEMENTATION

All items to be provided by the Customer are defined in the IDD and later baselined in a payload specific Interface Control Agreement (ICA). Depending on specific design and complexity date delivery requirements start at about L – 18 months until the Certificate of Flight Readiness around L- 4 months.

10 FREQUENTLY ASKED QUESTIONS

What happens if my payload fails to launch on schedule?

Answer: Airbus cannot control any changes in launch schedules, delays or cancellations for launches. If your payload is impacted by these changes, Airbus will work to resolve the issue to ensure that your payload gets to fly as close to originally scheduled as possible.

Can Airbus help with the "paperwork" of obtaining launch readiness?

Answer: Yes! Airbus can assist with every part of the process if requested by the client. These additions will be built into the contract between the payload Customer and Airbus. Airbus can even help to develop the payload if needed.

What if my payload fails to perform as planned during its time on orbit?

Answer: Airbus will work to ensure success to the best of their ability during time on orbit, although some issues cannot be resolved while in orbit. Airbus will work with the client to make sure that they are setup for success before, during and after flight.

How long will the entire process be from start to finish?

Answer: The length of the process is dependent on the amount of additional services requested by the client. If the client comes with a ready-to-fly payload, it can take as little as 10 - 12 months before launch, but depending on development status, it could typically take 24 months until turnover for launch. Airbus works diligently to provide flexible timelines and launch opportunities to all its customers, depending on complexity and readiness status.

What if the slot on Bartolomeo I wanted is already booked for launch?

Answer: There are many slots that share capabilities and viewing advantages, although they may go fast. To best guarantee a slot that will fit your needs for launch, you may need to look at further out launch dates or consider "ride sharing" with another Customer. Airbus will work with each Customer to make sure that they each get the best outcome from their projects.

What is the difference between the different payload volumes described in this document?

Answer: First there is the maximum payload envelope which *Bartolomeo* can accommodate. This is given by the total *Bartolomeo* volume available for payloads, minimum clearances, CoG requirements and structural capabilities.

The NanoRacks airlock which is currently finalizing their design is planned to accommodate up to 4 *Bartolomeo* payloads within one airlock cycle.

The smaller volume is determined by the JEM airlock JOTI adaptor, ref. section 3.6, which can accommodate only one smaller *Bartolomeo* payload at a time, however this size provides the greatest flexibility because it can use either airlock based on first availability. Payloads using an airlock will be launched soft stowed in the pressurized volume.

Contact

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