DISRUPTIVE SPACE SOLUTIONS FOR A BETTER TOMORROW

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ELEMENTS BROCHURE

6U | 12U | 16U PLATFORM

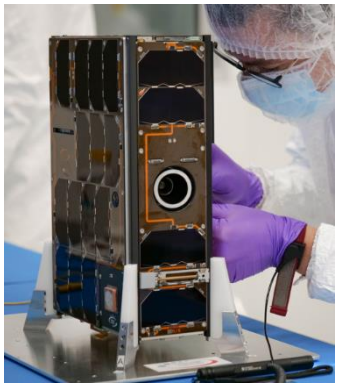
INTRODUCTION

The ISISPACE 6U Platform (or 'satellite bus') integrates reliable, off-the-shelf subsystems into a compact form factor with successful flight heritage since 2014. As every mission is one-of-a-kind, we have focused on a satellite platform design that enables the right balance between performance, flexibility, payload compatibility, reliability and cost. The ISISPACE Platforms are flight-proven and cost-effective, enabling rapid development and a reduced time-to-orbit. Our platform provides a perfect solution for Customers looking for affordable small satellite technologies without having to skimp on performance. With the platform delivering the power, structures, antennas, communications, on-board computer, and an attitude determination and control system, your team can focus your efforts on payload development and operation.

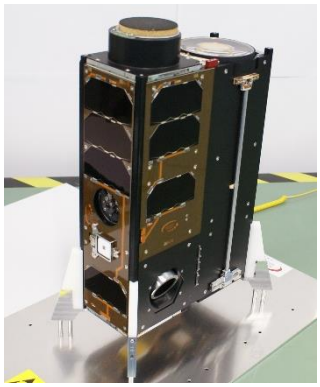
Our 6U platform can easily be expanded into a 12U or 16U platform for more payload volume, as each platform shares the same core avionics and systems architecture. This enables you to easily switch between platforms for other missions, without having to go through a learning curve again, nor having to acquire additional ground support equipment.

This document provides a commercial proposal of the 6U platform as developed by ISISPACE – Innovative Solutions In Space BV, and can form a baseline for further discussion and iteration. All our platforms are based on our modular, generic architecture, that we can further tailor to your mission requirements and budget. We remain open to adapt our offering to your needs and we look forward to hearing whether this proposal and approach is in line with your expectations.

ISISPACE is vertically integrated and combines research, design, manufacturing, testing, launch, and operations of small spacecraft in a single organization. This allows the company to accommodate customer's specific requirements, control quality and leverage core competencies to deliver flight hardware on a short schedule. Over the years, ISISPACE has gained experience building 50+ satellites of all sizes for a vast variety of missions and customers. We have also supplied its subsystems and components in support of 250+ satellites and missions.



Brik-II (2020)



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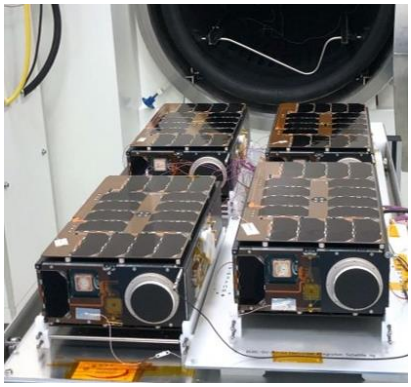
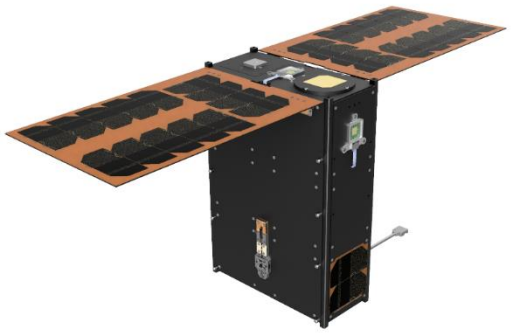


KSF-1 Cluster (2021)

TECHNICAL DESCRIPTION

PLATFORM DESCRIPTION



Our 6-Unit platform is based on our flight heritage designs that has supported multiple missions with diverse applications: ambitious military, commercial and scientific missions in domains such as Signals Intelligence (SIGINT), Geospatial Intelligence (GEOINT), Internet-of-Things services (IoT), air traffic monitoring (ADS-B), Earth Observation (EO) and Space Science. All components and sub-systems are TRL9 and ITAR-free. Our standard configuration comes with two deployable wings for maximum power generation and thermal dissipation, which can either be deployed or stowed depending on your mission characteristics.

Hardware Overview List

Satellite Segment	#	Subsystem
Mechanical	1	6UXL satellite structure
Power	1	Electrical Power system
	1	Solar panel set
Command & Data Handling System (CDHS)	1	On-board Computer
	1	Payload Data Handling System
Communication	1	S-band transceiver
	2	S-band patch antenna
Attitude Determination & Control System (ADCS)	1	ADCS computer
	1	Magnetorquer, incl. magnetometer boom
	3	Fine sun sensors
	3	Reaction wheels

For payloads that require more power than generated at that moment, the extra power shall be provided by the battery. To determine the allowable duty cycle of such payloads, the main drivers are:

- Satellite Power consumption: the total (nominal) power required to operate the platform and the payload, depending on the different operational modes.
- Power storage: the amount of excess energy that can be stored onboard.
- Recharge power: available power to recharge the batteries, which is the difference between the power generated and power consumed. For maximum recharge, the satellite shall be in idle and peak power generation (sun-pointing) mode.
- Depth of Discharge (DoD): the capacity that is discharged from a fully charged battery, divided by battery nominal capacity. Note that the DoD and number of cycles have an effect on the lifetime.

With the duty cycle, a (preliminary) mission profile can be determined, where there is a balance between operating the payload, recharging the batteries and mission lifetime. Please contact us, if more power

Platform Performance & Characteristics

Properties		Values	Comment
Platform			
Size		6UXL	ISISPACE CubeSat deployer compatible
Platform mass		< 6 kg	Including margins
Payload available volume		3U	
Payload available mass		6 kg	
Design lifetime		Up to 3 years	500 – 600 km orbit
Electrical Power System			
Power generation [1] (BOL)	**OAP**	Up to 14 W	SSO@500km | Nadir pointing
	Peak	Up to 41 W	@500km | Sun-pointing
Platform power usage	**Idle**	4.7 W	Orbital average, excluding payload operations
	Peak	12.3 W	
Power storage		96 Wh	
Payload power (peak)		96 W	
Payload voltage	**Regulated**	3.3V (2x) / 5V (2x) / 12V (4x)	2A max. per line.
	Unregulated	12.8 – 16.0 V (1x)	
Command & Data Handling Unit			
OBC Mass Data Storage		2x4 GB	Redundant SD-cards
SDRAM		64 MB	
Operating System		FreeRTOS	
Payload Data Interfaces		I2C (2x) SPI / LVDS (1x) RS-232/422/485 (4x)	More interfaces available on request
Communication			
Frequency		2200–2290 MHz	S-band
Data rate	Uplink	64 kbps	
	Downlink	Up to 4.3 Mbit/s	Useful information bitrate
Attitude Control & Determination System[2]			
Pointing accuracy (APE)	Sunlight	• 2 deg (nadir, inertial/sun) 5 deg (point tracking)	• Assuming full FSS coverage (during maneuvers) • Roll & pitch
	Eclipse	• 10 deg	
Pointing stability (RPE)		0.5 deg	Over a 1" window - Dependant on satellite configuration and orbit
Attitude knowledge (AKE)		2 deg	Sunlight
Slew rate		> 3 deg/s (peak)	Higher rate on request
Position determination		1.5 m	Determined by GNSS

Note 1 Pending solar activity and beta-angle. Defined by selected orbit and launch date.

Note 2 All values are 1σ STD and derived from typical ISISPACE flight SW. In-flight values depend on final satellite/payload configuration and of ADCS FSW implementation.

SUBSYSTEM DESCRIPTION

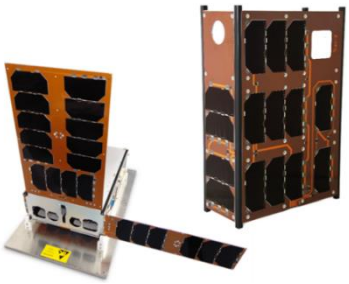
For more information on the ISISPACE subsystems, please visit the "ELEMENTS" section of our website (www.ISISPACE.nl). For more detailed information other subsystems, please contact ISISPACE.

MECHANICAL

The ISISPACE qualified structures are compatible with ISISPACE's and other nanosatellite dispenser systems. The primary outer structure acts as the payload mounting interface and an internal secondary structure accommodates avionics boards and components in a stack. Two redundant separation switches are built into the structure, which, when pressed, disconnects the battery from the rest of the platform, even with the ABF connector inserted.

SOLAR PANEL

ISISPACE provides high-performance solar panels and arrays across a wide range of sizes, all manufactured according to space standards. Using GaAs Triple-junction solar cells from AZUR Space, a solar panel solution can be provided that takes into account accommodation for sensors, apertures, etc. Body mounted panels and deployable arrays are supported for 1U to 16U sizes and are customized to meet a broad range of power requirements. A selection of body-mounted and/or deployable solar panels together with the iEPS form a robust, scalable spacecraft power system.



ELECTRICAL POWER SYSTEM

The ISISPACE Modular Electrical Power System (iMEPS) is designed for larger nano- and micro-satellites from 3U upwards. The modular architecture allows the EPS to be tailored to the platform requirements without customization, which yields benefits in mass, volume and reliability. The distributed design philosophy of the iMEPS allows flexibility in output bus count and voltage, and enables tailorable redundancy for selectable parts of the platform. The iMEPS consists of three main types of units that can be combined to form the platform EPS.

COMMAND & DATA HANDLING SYSTEM

The ISISPACE on-board computer (iOBC) is a flight proven, high performance processing unit based around an ARM9 processor with a clock speed of 400 MHz and offers a multitude of standardized interfaces. Combined with its daughterboard architecture, the iOBC allows for easy addition of mission specific electronics or interfaces (without the need to sacrifice additional volume), making it the ideal candidate for a main mission computer or payload processing unit. The iOBC can execute different platform modes depending on the mission design e.g. Deployment, Nominal and Safe mode.

S-BAND TRANSCEIVER

The ISISPACE S-band Transceiver is a high-bandwidth communication system designed with spectrum cleanliness in mind for nanosatellite and small satellite operations in the broadly used 2200-2290 MHz communication bands. The downlink covers the needs for high payload data throughput of up to 4.3 Mbps (usable information bit-rate at CCSDS transfer frame level) and includes an AX.25 uplink, offering a telecommand rate of up to 64 kbps. The transceiver allows in-flight configuration of data-rate, modulation scheme, frequency, and RF output power and is complemented with two ISISPACE S-band patch antenna allowing for robust telemetry and payload data transmissions

ATTITUDE DETERMINATION & CONTROL SYSTEM

The Attitude Determination and Control System (ADCS) provides attitude knowledge, 3-axis attitude control, and orbit determination and control. The ADCS is built around an ISISPACE ADCS OBC that can support all required modes and interfaces required by the mission, which allows the performance of the system to be tailored to the mission requirements.

The ADCS runs flight-proven IGRF and SGP4 models for magnetic field modelling and orbit propagation, supplemented by an advanced Unscented Kalman Filter that uses non-linear dynamics and sensor information fusion from all available sources to provide optimal estimates of attitude and angular rate of the spacecraft. The ADCS provides operational modes to enable spacecraft initial de-tumbling, magnetometer-only angular rate estimation, self-calibrating gyroscopes, full-state attitude and angular rate estimation, 3-axis control and spin-stabilization for orbital maneuvering.

ADCS Computer

Magnetorquer

Magnetometer boom

Sun Sensor

Reaction Wheel

GNSS Receiver

The ADCS computer includes a basic ADCS control algorithm that ensures the platform performance. Final values depend on satellite/payload configuration and ADCS FSW implementation, which is the responsibility of the Customer. This proposal excludes support for further development, improvements and/or modifications of this algorithm, or support for implementation of the algorithm into the flight software.

PRODUCT & QUALITY ASSURANCE

ISISPACE makes use of generic ISISPACE Product Assurance Plan which is based on the following standards and used during production:

- TEC-SY/129/2013/SPD/RW: Product and Quality Assurance Requirements for In-Orbit Demonstration CubeSat Projects
- TEC-SY/128/2013/SPD/RW: Tailored ECSS Engineering Standards for In-Orbit Demonstration CubeSat Projects

The Quality Assurance Plan (QAP) defines the quality control procedures used during production and AIV, i.e. it describes the measures and tools used to assure ISISPACE follows the agreed upon processes such as described in this document. The project QAP is written by the Quality Control Department of ISISPACE, with technical assistance from other disciplines.

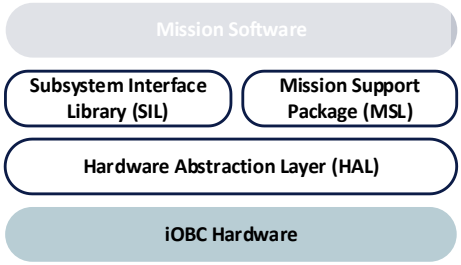
Software Development Kit

To jump start your mission/flight software development, we can provide our Software Development Kit (SDK), which is built around the ISISPACE OBC and is a general-purpose computing board that adheres to the CubeSat standard. The SDK provides all required drivers to allow interfacing with attached hardware, as well as libraries that use the drivers to perform various tasks. The SDK consists of the following parts:

- Eclipse Integrated Development Environment: for developing, compiling and debugging code
- ARM GCC compiler: used directly from Eclipse
- FreeRTOS: for simple multi-tasking of SW on the OBC
- Atmel SAM-BA: for flashing code to the OBC
- PuTTY console: for interfacing to the OBC
- Libraries from Atmel: for basic interfacing to the CPU
- FAT32 file system for SD-Cards
- ISISPACE Hardware Abstraction Layer with code examples to help users getting started quickly.

Hardware Abstraction Layer (HAL)

The HAL allows for easy, efficient and robust interfacing and consists of the following drivers, in addition to the libraries from Atmel and FAT32 file system: I2C, SPI, UART, ADC, PWM, GPIO, LED, FRAM, Timing, Watchdog and Reset, Supervisor interface. ISISPACE has developed additional libraries that can help in completing this task. Note that software for an entire mission involves some additional effort and shall be developed by the Customer. The OBC embedded SW can be developed and deployed to the OBC controller hardware using a computer running Microsoft Windows and a USB-to-Serial converter, which provides a separate full-duplex data channel between the development machine and the OBC controller.



Flight SW Layers

Programs that control the attached hardware by interacting with the installed drivers are contained within the SDK installer package, along with applications that provide translation of program code to machine instructions (the compiler/linker toolchain) and a programming environment that aids in efficiently producing embeddable software.

Subsystem Interface Library

The ISISPACE Subsystem Interface Library (SIL) aims to simplify interfacing with different subsystems by providing a full implementation of their software command and control interfaces. This reduces the time required to develop the mission flight software. This library has been developed for all ISISPACE subsystems and a number of third-party components.

Mission Support Package

The Mission Support Package (MSP) provides additional building blocks needed for robust and efficient OBC flight software. The following MSP libraries are currently available:

- **Parameters Storage –** Flight parameters are the key variables used to control the behavior of the satellite. The parameters storage system keeps these variables in FRAM (which is inherently very robust). In addition, it uses data protection and duplication schemes to provide additional reliability.
- **Robust Hierarchical Logging –** Much of the data acquired by the satellite is stored in non-volatile memory for later retrieval when the satellite passes over the ground station. Housekeeping data, error logs are some common examples. For simple missions, this can also

be used to store periodical payload data. This logging mechanism will store the latest data in reliable FRAM and older data in SD-Cards that have more capacity.

- **Persistent List** – This module allows for the creation and manipulation of a list of items with an arbitrary, but fixed, size, and has the ability to handle multiple of these lists simultaneously. These lists are stored in non-volatile memory and are therefore persistent between reboots.

Note that Flight software is excluded from this proposal and can only be provided as part of a full satellite delivery, which includes payload integration, EVT, Launch services and In-Orbit Commissioning. In support of software development, we can offer a one-day training session. Ask your sales representative for more information.

GROUND SUPPORT EQUIPMENT

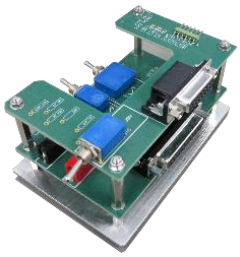
The following Ground Support Equipment (GSE) is included to ease the integration and test phases.

MECHANICAL INTEGRATION SUPPORT JIG SET

The integration support jig allows to integrate payloads and other equipment into the primary structure of the CubeSat in a safe manner. The increased height above the working surface in horizontal position makes the integration jig suitable for functional performance tests with deployable arrays and antennas.

ELECTRICAL GSE

The EPS Electrical Ground Support Equipment (EPS EGSE) is used to support various satellite operations during its integration and test phases. Through a single interface, the EPS EGSE allows for the charging of the batteries and the powering of the satellite subsystems through accessible switches. It also offers a direct path to the iOBC debug UART port, which is then accessible even when the satellite has been fully integrated. The EPS EGSE is delivered with its harness and own power supply.



OPTIONS

To increase the performance and functionality of our platform, we can include the following flight-heritage options in our 6U platform. Note that this will decrease the available payload volume. Please contact us for more information and additional platform options.

PLATFORM

HIGH-PERFORMANCE PDHU

For more demanding payloads, we can provide a high-performance PDHU that contains a hybrid environment of powerful multi-core CPUs and reprogrammable logic, providing consistent and reliable performance. This makes it ideally suited for onboard processing and Software defined radio applications. The library of logic and software functions is augmented by onboard digital I/O, which works in synergy with ISISPACE system architecture. In addition, the command interfaces and processing resources enable a direct data link to high data-rate radio transmitter (see section below).

Characteristics	Value	Comments
Low Speed Data Interfaces	I2C, SPI, CAN, RS-232/422/485	
High Speed Payload Interfaces	LVDS, SpaceWire, USB 2.0 & 3.1 Gigabit Ethernet (RJ45) Gigabit Transceivers (SATA, PCI express),	
Payload Mass Memory Storage	2x128 GB eMMC	Redundant Storage
DRAM	4 GB	LPDDR4 DRAM (with EDAC)
Operating System	Linux 4.14. LTS Robot Operating System (ROS)	
Control FPGA	Microsemi ProASIC3	FPGA bit-stream scrubbing included

HIGH DATA-RATE COMMUNICATION

For payloads that generate large amount of data, we can offer an extremely compact X-Band transmitter, specifically designed for CubeSat missions. This X-Band Transmitter is intended to be used as part of a PC/104 configured nanosatellite for 125 Mbps encoded data downlinks in the frequency range 8.025-8.4GHz. It implements DVB-S2 encoding with variable coding modulation (VCM) which is the next generation firmware to the previous version that implemented CCSDS concatenated encoding. The user data throughput at the highest MODCOD is over 105 Mbps after encoding and packetization overhead is considered.

Specification	Description/Value
Transmitter	
Frequency range	8.025 – 8.375 GHz frequency range in-flight configurable in 1 MHz steps
RF output power	27 to 33 dBm (1 dB steps)
Data rate	Up to 110 Mbit/s
Modulation	QPSK, 8PSK, 16APSK
Channel coding	DVB-S2
Antenna	
Antenna gain	7.75 dBi ± 0.5 dB
Polarisation	LHCP / RHCP
Return loss	< -15 dB
Axial Ratio	< 3 dB across the band

HIGH-PERFORMANCE ADCS

To increase the performance of the ADCS, both in eclipse as in sunlight conditions, an Auriga star tracker can be included, in combination with advanced control algorithms. The Auriga star tracker is based on the larger, highly successful Hydra, that has many years of in-orbit deployment including software, and is currently flying on the OneWeb constellation. It provides high-quality and robust performance characteristics, with a noise performance better than 27 arc-sec across bore-sight and 150 arc-sec around boresight. It can track at angular rates up to 3°/s. Includes a dedicated iOBC to run Star Tracker software for easy operation and interfacing.

Characteristic	Value[1]	Comment
Pointing accuracy (3 axes)	0.1 deg	Sunlight &eclipse (nadir & point tracking, expected slightly better for inertial pointing)
Pointing stability	0.02 deg	Over a 1" window
Attitude knowledge[2]	0.05 deg	Sunlight & eclipse
Angular rate knowledge	0.05 deg/s	Sunlight & eclipse
Slew rate	> 3 deg/s (peak)	Depending on S/C class and RWs used

Note 1 All values are 1σ STD and derived from typical ISISPACE flight SW. In-flight values depend on final satellite/payload configuration and of ADCS FSW implementation.

Note 2 Assumes corrected STR-Payload orientation bias. This requires optical calibration on ground and/or in-orbit calibration with the payload providing a suitable reference (e.g., imagery).

Optionally, we can offer a dedicated ADCS performance analysis and simulation, tailored to your mission and payload.

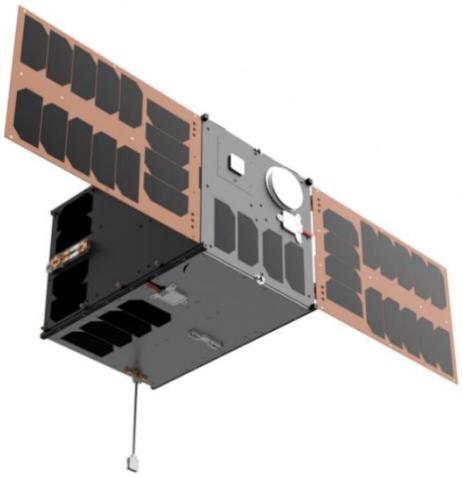
Propulsion System

ISISPACE is able to offer a range of propulsion systems to include in our platform, ranging from a basic, (cold gas) propulsion system for deorbiting and avoidance maneuvers, to an electrical propulsion system for full orbital and/or constellation maintenance.

Please contact us to further discuss your propulsion needs. We are in contact with many other propulsion systems, and are capable of tailoring our platform accordingly.

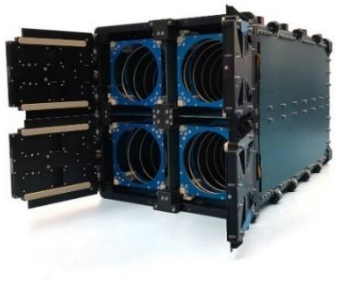
12U/16U Platform

We have developed our core avionics such that we can easily provide you more payload volume without loss of performance. Changing to our 12U or 16U platform, gives you respectively 8U and 12U total payload volume, with up to 15kg of available payload mass. As our 12U and 16U platform have the same core avionics, you can easily shift to different sizes, once you get experience with one of our platforms. Plus, there is no need to buy additional ground support equipment.

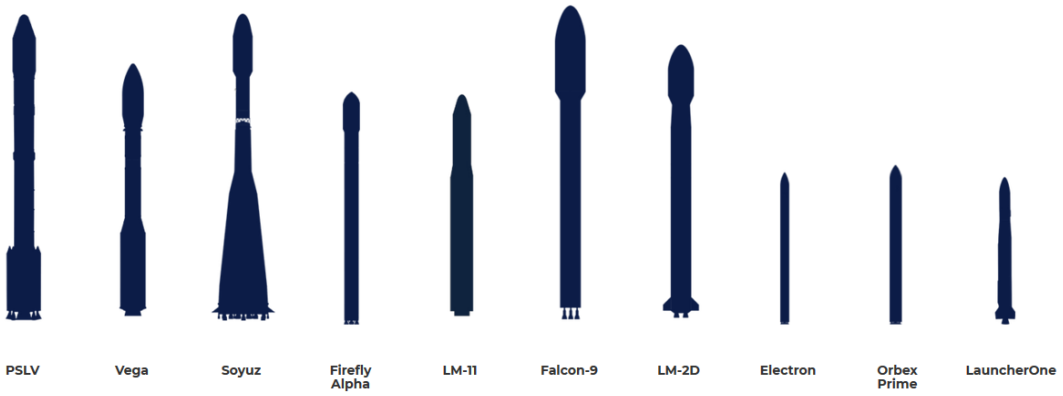


As a baseline, our 12U and 16U platform come with the same power system capabilities, but this can easily be increased. Please contact us if you require more power and/or battery capacity.

LAUNCH SERVICES



The launch of the satellite can be provided by ISISPACE's subsidiary ISILAUNCH (Innovative Solutions In Launch). ISILaunch's service model is to reserve and obtain bulk capacity on launch opportunities with the Launch Service Providers (LSP) directly, which allows ISILAUNCH to offer secondary payload capacity to multiple passengers per flight. This is a dynamic charter process that enables ISILAUNCH to be flexible both towards the customer and towards LSP, within the boundaries of constraints. ISILaunch is very proud of its launch manifest heritage, that, to date, contains a total of **622 satellites** delivered to orbit on six different launch vehicles through our Launch Campaigns



Starting from the effective contract date, the general campaign management and coordination is performed by ISILAUNCH and contains the following:

- Negotiation, arrangement, and reservation of a launch slot on board the Launch Vehicle.
- Included in the ISILAUNCH launch service is the use of an ISISPACE deployer.
- Technical and non-technical management of the arrangement of Launch for the customer satellite in terms of technical compatibility, schedule, and planning.
- Representation of the customer towards the Launch Service Provider and vice versa for technical and non-technical questions and meetings.
- Arrangement of the necessary technical and interface documentation to be provided to the Launch Service Provider.
- Detailed instructions and procedures for customer to fulfil its commitments and responsibilities.
- Regular reports and updates regarding the launch campaign.
- Arrangement and coordination of the pre-launch campaign at the Pre-launch Integration Facilities in the Netherlands.
- Logistics support for travel to and boarding and lodging near the Pre-launch Integration Facilities in the Netherlands for customer team members. It is clarified that actual travel, boarding and lodging costs are not included in the offering.
- Technical and logistical support from ISILAUNCH personnel and/or its affiliates to the launch team at the Pre-launch Integration Facilities in the Netherlands.
- Logistics support for travel to and boarding and lodging at the Launch Site for launch team members, if necessary and applicable. The actual costs for travel, boarding and lodging are not included in the offer.

Ground Support Equipment

RF Rack

Our RF rack enables easy and efficient verification of the RF satellite chain and communications of our 6U platform. It is fully compatible with ISISPACE's 6 – 16U platforms and comes in a transporter case making it easy to bring to test sites, and can even be used in ground stations for satellite operations. We can also include an X-band compatible modem (CCSDS on request), if you requested the high data-rate communication option.

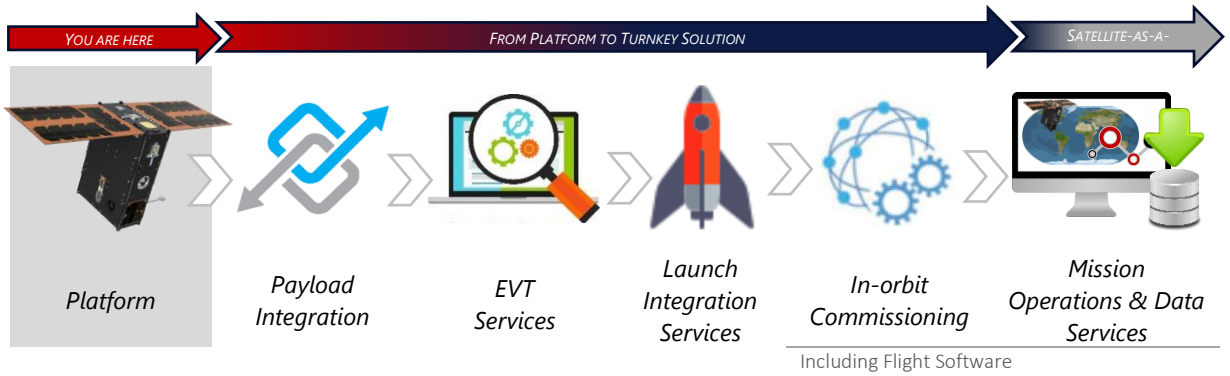
TestPOD

The ISISPACE TestPOD is a simple and inexpensive method for satellite developers to test their satellites for qualification levels of launch loads. It is a reusable test adapter for pico- and nanosatellites that adhere to the CubeSat interface standard, so that test conditions simulate the exact internal physical environment of the ISIPOD. Our 16U TestPOD is a versatile solution for the satellite developer to qualify a CubeSat design, ranging from 6U to 16U size.

Support & Services

Our experience and successful track record in providing turn-key solutions to a diverse range of customer segments (private/commercial, research institutions, agencies and military) for more than 17 years, allows us to be a key provider of full missions and data services.

#	Service Option	Remark
1	Payload Integration	Also in the form of consultancy/support
2	Environmental Test Verification services	
3	Launch integration services	Optional: launch slot and deployer
4	In-orbit Commissioning, incl. flight software	Only in combination with #1, #2 and #3
5	Ground Station	Optional: mission control center
6	Satellite registration & frequency filling support	
7	Knowledge Transfer & Capacity building program	More information on request
8	Engineering & (SW) Development Support	On hour-basis or Work Package



From Platform to Satellite-as-a-Service

MANAGEMENT PROPOSAL

MANAGEMENT APPROACH

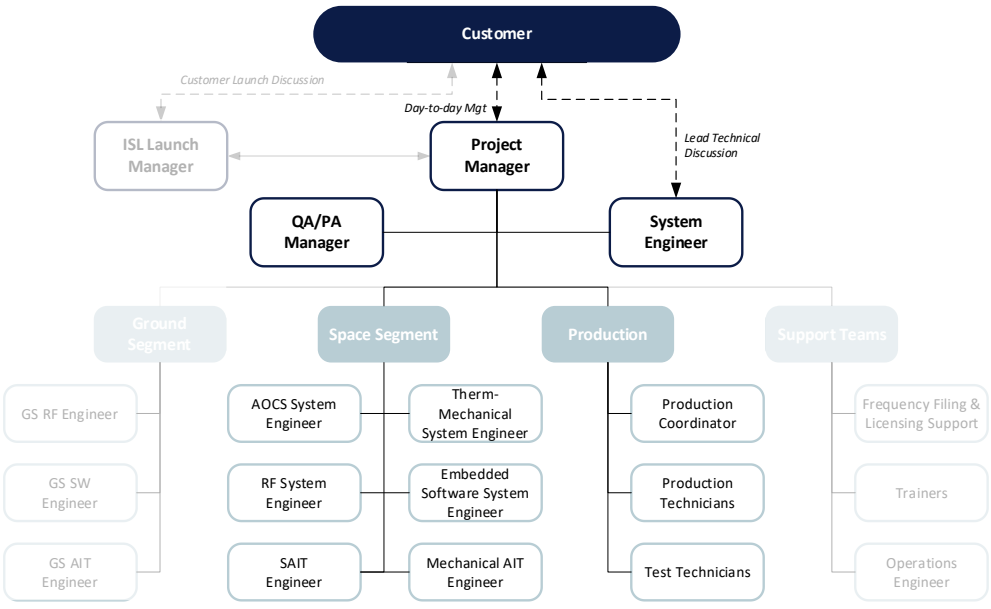
During its existence, ISISPACE has gained vast experience in designing, building, launching and operating satellites ranging from 1U to 16U. For the management of these projects, ISISPACE uses a management style based on the typical space project management principles, as listed in ECSS-M-ST-10C, but adapted for a lean project implementation like a CubeSat development. This means that, between the major milestone, ISISPACE executes the work iteratively and concurrently to develop the project more effectively.

Typical tools used are GANTT charts, Action and RID Trackers, Risk Management Matrix and deliverable status overviews. To update customers, ISISPACE follows a structure of periodic reporting and/or update calls. By using a flexible and lean project management style, ISISPACE believes to be able to deliver our platforms successfully in a short time frame and pragmatic way, while risks are controlled effectively.

PROJECT ORGANIZATION

ISISPACE has a standard project organization to serve their projects. The Project Manager is end-responsible for the project and the day-to-day communication with the customer, supported by the project System Engineer, who leads the technical discussions with the customer. PA/QA support is provided by the QA department to ensure that the technical and programmatic goals are met following the correct and traceable processes and standards.

On a lower level the project is divided into a space segment team and a production team. The production team is mainly involved in the procurement and production of the subsystems for the project, and provides support during the test campaigns.



Project Organization

COMMUNICATION

Throughout the execution of the platform activities the Customer is in direct contact with both the contract responsible and the project manager of the project via phone and e-mail. These contact details are provided once a project team is assigned. On the Customer side, ISISPACE also requests to provide the contact details of 1 or 2 representatives with a clear decision-making mandate for the project concerned within the Customer's organization.

REPORTING LINES

ISISPACE delivers project progress reports by email to the Customer on a monthly basis. The reports contain the progress update for ISISPACE work packages, open risks and issues within the project, list of open action items, planning for the next period, and major and critical non-conformances identified within the project.

MEETINGS

Within ISISPACE, regular internal project team meetings are held to manage:

- Progress within the work packages
- Assumptions, constraints, and dependencies of the project
- Identified risks and issues within the project.

In addition to them, regular internal program meetings are held to manage the processes, to determine the priorities at program level and to evaluate and manage the risks and the issues identified in different projects held within the program.