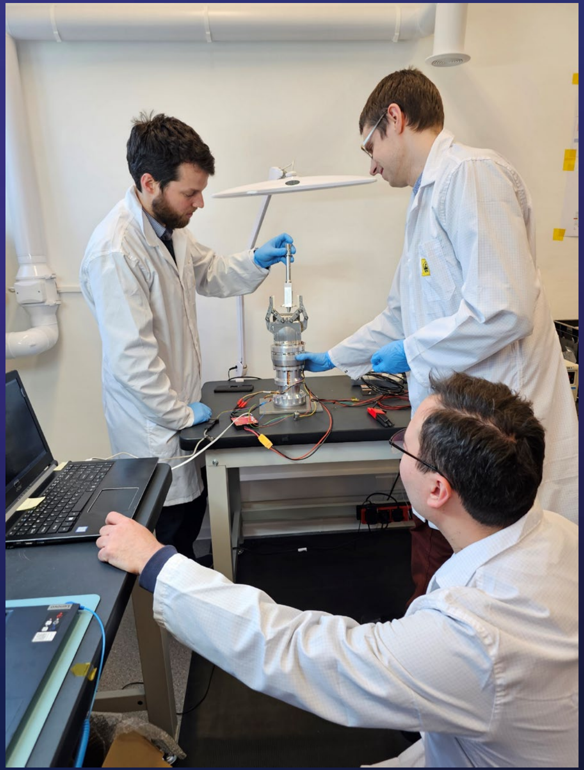
Extending the Life Cycle of Satellites – PIAP Space's Building Blocks for In-Orbit Operations

Business Development Department

PIAP SPACE

PIAP Space in numbers

- Established in 2017
- Based in Warsaw, Poland
- First 100% government-owned company in Polish space sector
- Owners: Industrial Development Agency JSC, Łukasiewicz Research Network – Industrial Research Institute for Automation and Measurements PIAP
- 50 employees including 43 engineers
- ISO 9001:2015 certification in 2021



CENTRUM CERTYFIKACJI JAKOŚCI
QUALITY CERTIFICATION CENTER

CERTIFICATE

This is to certify that quality management system in

PIAP Space Sp. z o.o.

ul. Stefana Batorego 107, 87-100 Toruń – miejsce rejestracji
Al. Jerozolimskie 202, 02-486 Warszawa - miejsce prowadzenia działalności

complies with the requirements of

ISO 9001:2015

Scope of certification:

Design, development, manufacturing, assembly and tests in the scope of space technology and robotics.

Certificate No 1438/S/2021 is valid from 23.09.2021 to 22.09.2024, under condition of fulfillment of the requirements contained in the confirmation, which is an integral part of this certificate. Initial certificate issue: 23.09.2021. Information about the certificate is available at www.ccj.wat.edu.pl. Edition: A, date of issuing: 23.09.2021.

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Joanna Jasińska Ph.D. Eng.
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IAF

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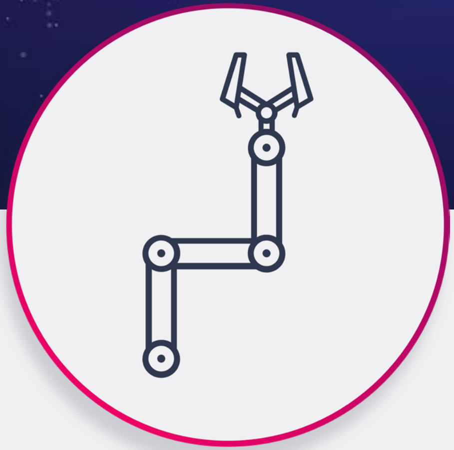
SPECIALISATION

SPECIALISATION

PIAP Space focuses on two specialisation



Space Robotics

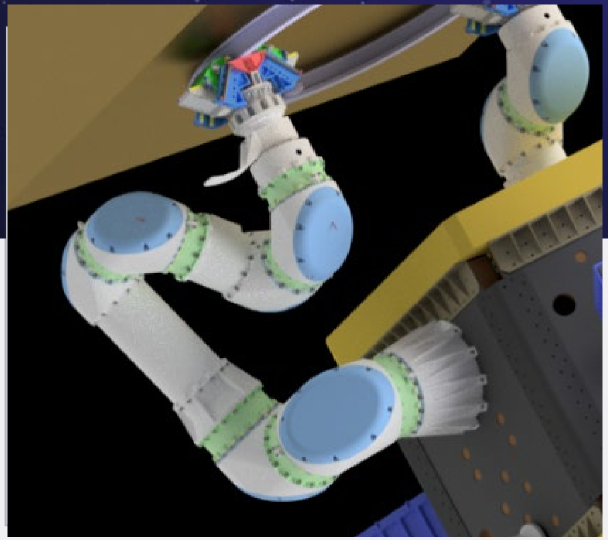
PIAP Space develops technologies and products in the space robotics domain for In-Orbit Servicing and future ISAM missions.

Mechanical Ground Support Equipment

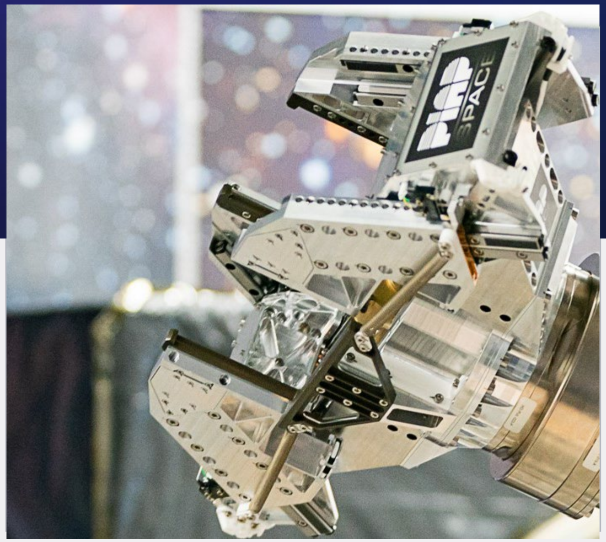
PIAP Space offers various types of devices for the assembly, integration, and testing of satellites and their subsystems.

EXTENDING THE LIFE CYCLE OF SATELLITES – KEY ENABLING BUILDING BLOCKS

Key Enabling Building Blocks for IN-ORBIT SERVICING, ASSMBLY, MANUFACTURING, REFUELLING



TITAN



LARIS

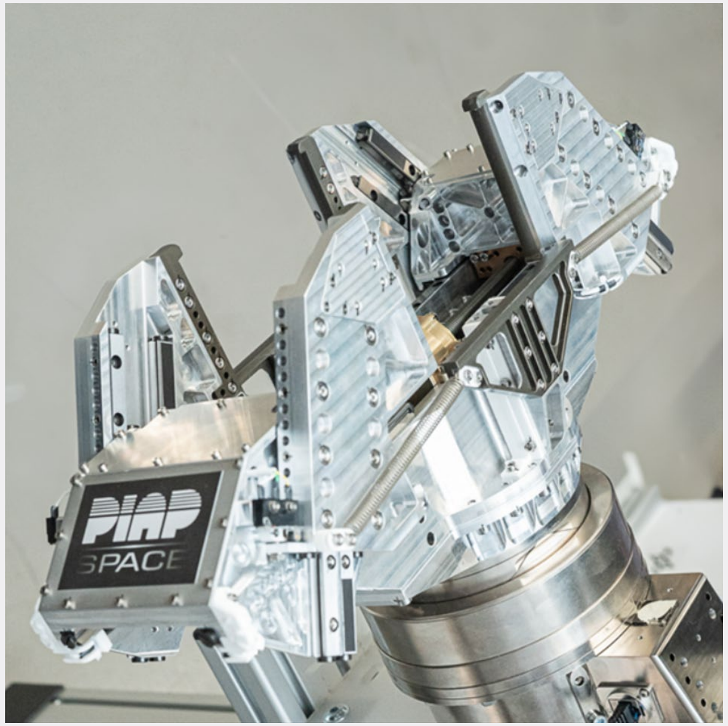
SGF

To address both architectures and the needs of In-Orbit Servicing, Life Extension and Deorbiting operations providers PIAP Space is actively developing key building blocks aimed at enabling reliable client satellite capture and manipulation.

This proposed device family, built on the LARIS Gripper and TITAN Arm, **offers high modularity and scalability**.

LARIS Gripper

LARIS (Launch Adapter Ring Interface System) is an End-effector for a Robotic Arm of a servicing satellite, designed to grasp the client satellite during capturing manoeuvre in order to enable maintenance, repair, trajectory control or deorbiting. LARIS is intended to be compatible with **both prepared and unprepared spacecrafts.**



The most important required characteristics and constraints for the LARIS Gripper:

- Compatibility with multiple types of Launch Adapter Rings (LARs)
- Adaptability to large misalignments of grasped feature (+/-20 mm, +/-5°, all axes simultaneously)
- Presence of soft and hard capture stages
- Nominal loads applied to the LAR: 20 N, 20 Nm (overloads: 80 N, 80 Nm)
- Capability to provide grappling status telemetry
- Low mass (< 5 kg)
- Peak power consumption below 50 W

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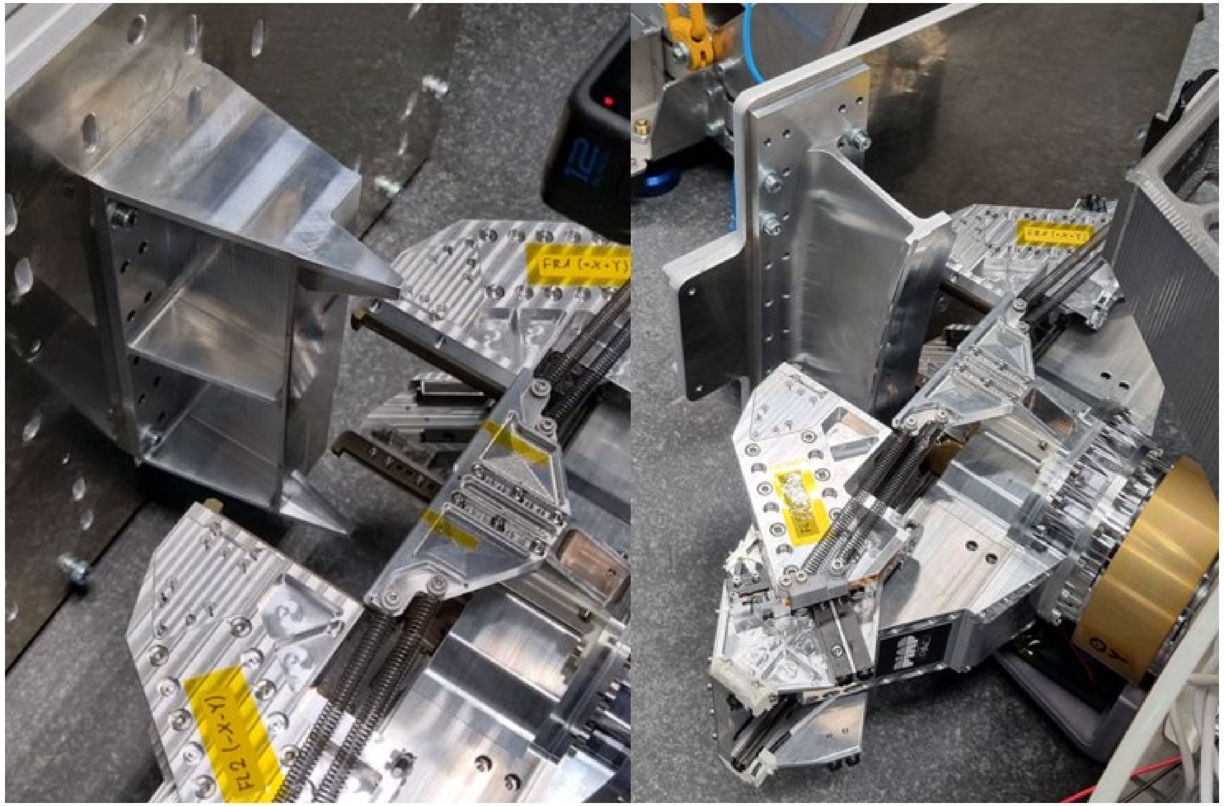
The project has received funding from the European Union's Horizon Europe Research and Innovation Programme under Grant Agreement No. 101082464.

LARIS Gripper: free floating validation

The test configurations included both the LAR and the SGF.

For the LAR configurations, two distinct setups were prepared: one with a tightly arranged Multi-Layer Insulation (MLI) and another with a loosely arranged MLI. Each of these configurations—both LAR and SGF—underwent testing under static and dynamic conditions to evaluate their performance comprehensively.

The variety in MLI arrangements for the LAR was specifically designed to assess how different insulation setups affect the gripper's ability to securely capture and hold the satellite interface.



LARIS Gripper during tests with SGF (right) and LAR (left) configurations.

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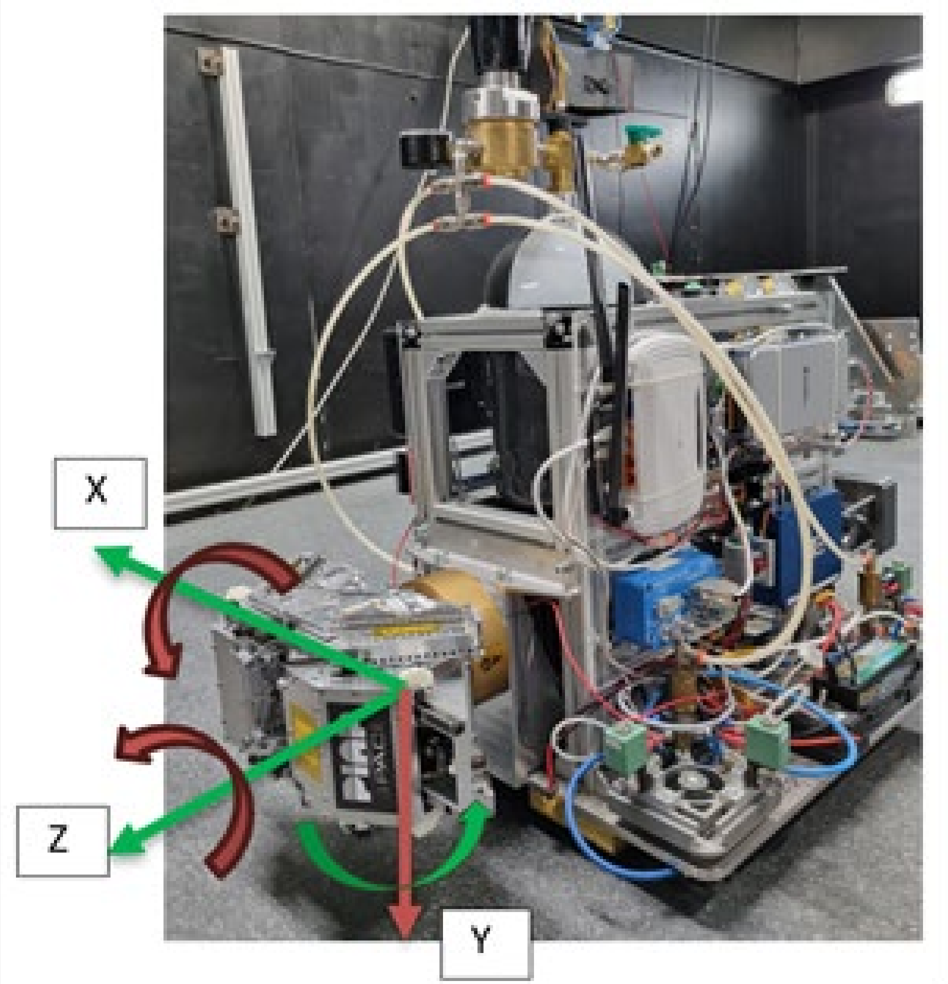
LARIS Gripper: free floating validation



The LARIS gripper was **tested in a planar air-bearing microgravity simulator**. This type of simulator offers three degrees of freedom, including two linear dimensions and one rotational axis. Free-floating tests help to validate the gripper's real response during the capture of objects in a non-gravity environment.

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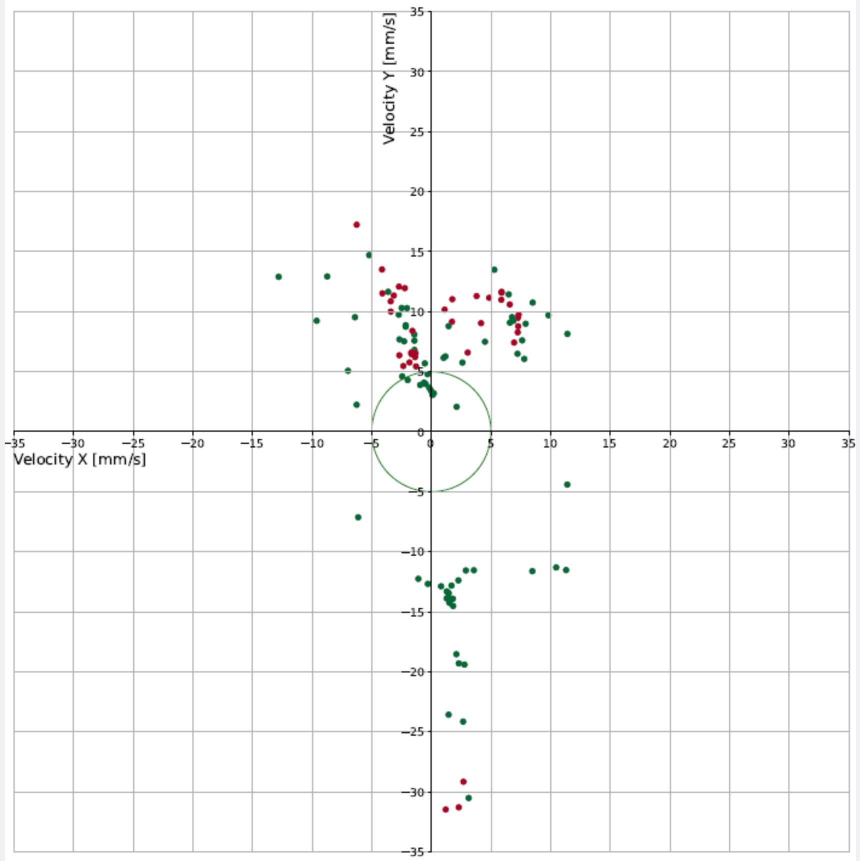
LARIS Gripper: free floating validation



These experimental results will be compared with computational simulations and subsequently extrapolated to account for varying mass ratios between the target and chaser spacecraft. This analysis will enhance our understanding of the LARIS performance across a spectrum of potential mission scenarios.

The results illustrate the velocity components in the X and Y directions for dynamic test cases. The color of the dots indicates the outcome of the grappling attempt—green for success and red for failure. The circle at the center represents the required relative velocity of 5 mm/s.

All test cases within this required range were successful.

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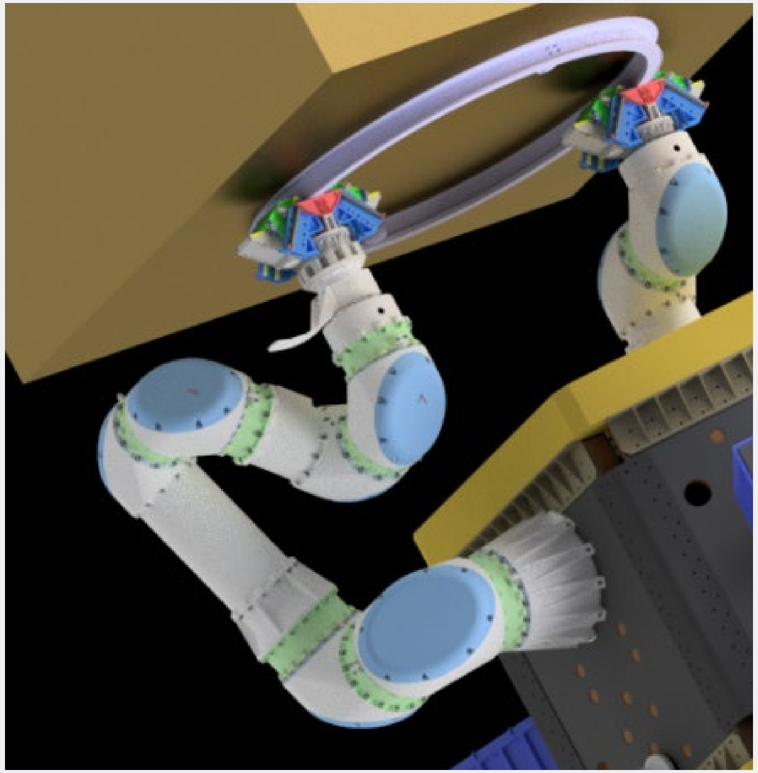
TITAN Manipulator

The **TITAN Robotic Arm** is a manipulator system designed for In-Orbit services in ISAM missions. One of the unique features of the TITAN Manipulator is its self-lifting capability, which significantly enhances the efficiency of on-ground testing.



Applications:

- Uncooperative Prepared and Unprepared Small Debris Removal Cooperative Prepared and Unprepared Servicing (GEO or LEO)
- Manipulator operations include: approach, inspection, capture, payload positioning, docking and tool positioning, operations
- Can be tailored to capture different size target satellites and to perform dexterous operations of repair and inspection

TITAN Manipulator design

TITAN robotic arm design is based on **3 Large and 4 Small Joints** used to actuate movement of the structure. Introducing a family of 2 different Joint sizes can be seen as a compromise between limiting design complexity and mass/performance optimization.

Technical Parameters	
Tip velocity	10 cm/s; 5 °/s
DoF	7 (possible scale-down)
Reach	1.5 – 2 m
Tip force/moment	20 N, 20 Nm
Communication	CAN
Stowed dimensions	1079 mm x 873 mm x 565 mm (W x L x H)
Power Supply Voltage	28 ± 6 V DC
Positioning accuracy	0.2 °; 5 mm on each axis
Reference payload mass	1 000 kg
Manipulator Power Consumption (nominal)	20 – 150 W (depending on movements)
Manipulator Power Consumption (max)	300 – 360 W
Survival temperature range	-40 +80 °C
Operational temperature range	-20 +60 °C

TITAN esa

Standard Gripping Fixture

SGF is a passive mechanical interface **designed for grappling, berthing, and docking** customer satellites. Its distinctive section profile allows it to be compatible with the same devices used for capturing the Launch Adapter Ring (LAR). This enables the same robotic end-effector or docking system to be utilized for both unprepared and prepared client satellites, offering greater operational flexibility.

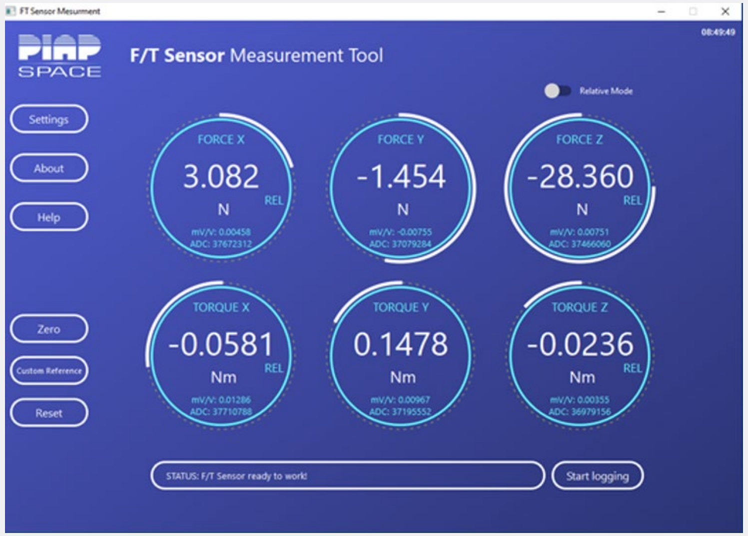
Applications:

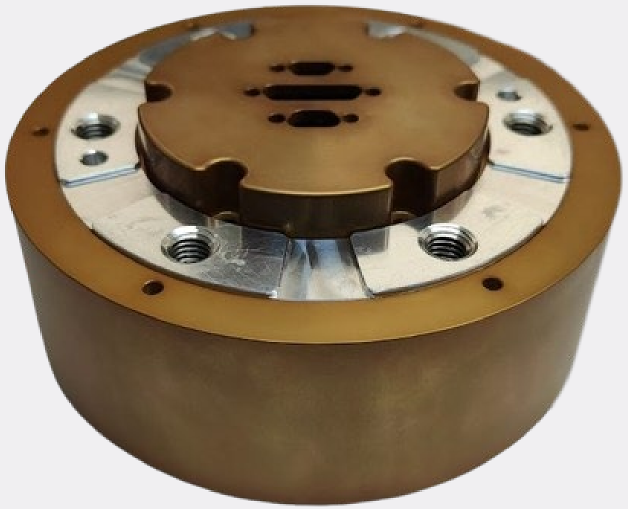
- Satellite grappling and berthing for servicing, deorbitation and transportation services
- Shape and sections similar to Launch Adapter Ring
- Grasping of prepared satellites

Force and Torque Sensor

A universal 6 Degrees of Freedom (DoF) Force and Torque Sensor (FTS) for space mission applications.

The strain gauge sensor enables sensing loads acting upon the manipulator and allows detecting contact between the end-effector and gripped part It also allows performing active back-driving by compliant force and torque control of motion.



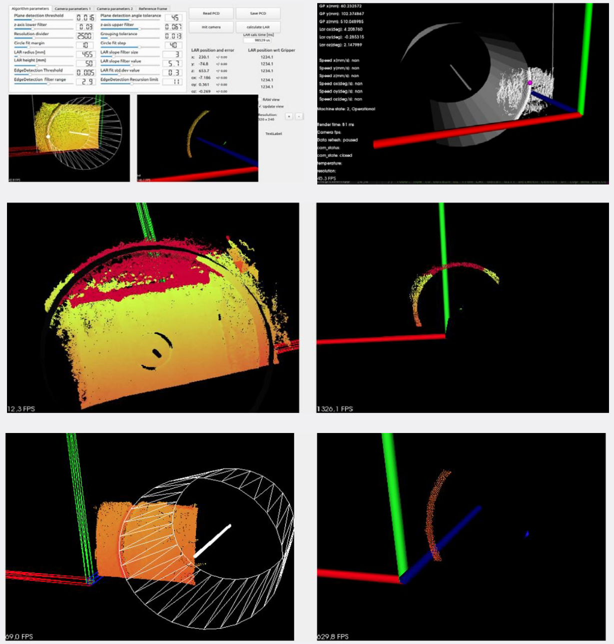


Applications:

- Key elements of general-purpose Robotic Arm system
- Mobile robotics
- Detecting contact between End-effector and gripping object

Vision System

The gripping point pose estimation algorithm. The algorithm is part of a vision system for a Robotic Arms that is designed for capturing unprepared satellites. The algorithm **detects and determines the position** on the Launch Adapter Ring (LAR) that is to be grappled by the dedicated mechanism.



Specification:

- 6 DoF LAR pose estimation
- Based on ToF Camera
- Estimated accuracy: ± 4 mm and ±1°
- Working range specified for close / final approach (1.2 - 0.2 m)
- Data frequency 30 Hz for accurate close-loop trajectory planning

EXTENDING THE LIFE CYCLE OF SATELLITES – DEVELOPING NEW DOCKING SYSTEM

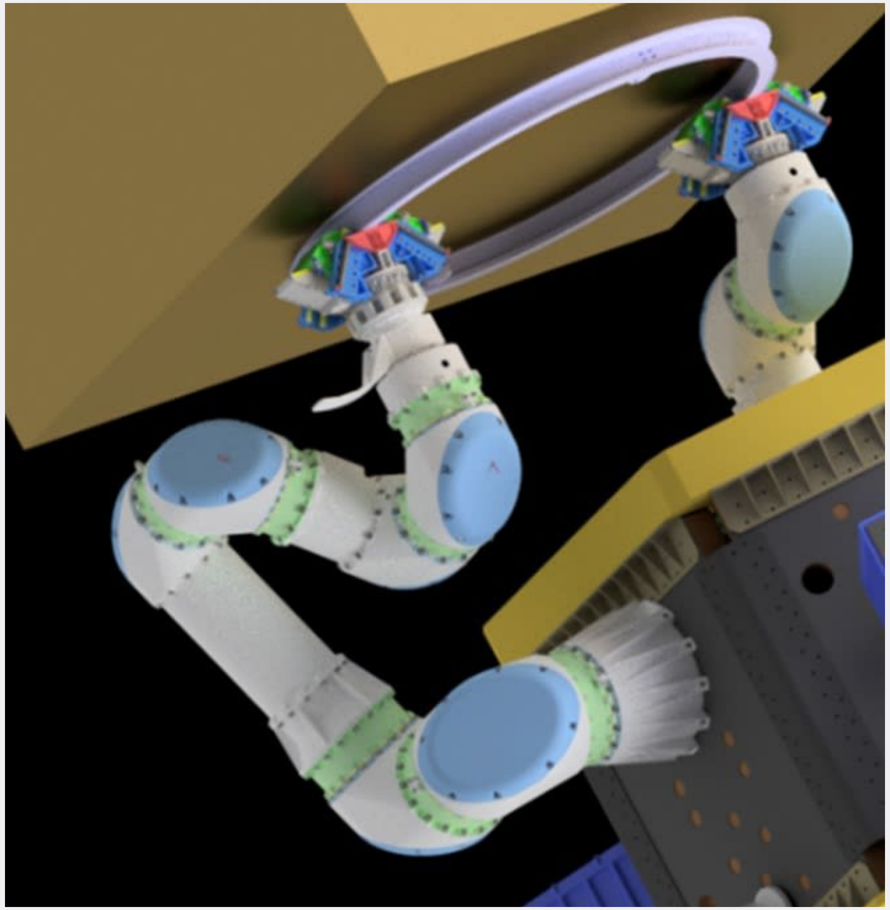
Docking System Architectures

PIAP Space's portfolio includes two basic Docking System architectures.

The first is deployable, which in the stowed position fits inside the body of the servicing satellite, and the second is based on the PIAP Space's TITAN robotic arm, located outside the servicing satellite.

The Docking System can be configured to work with different types of LAR.

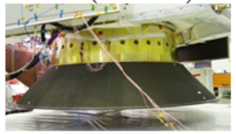
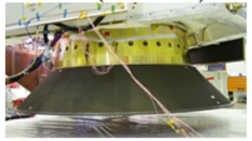
The key difference between docking and berthing is the use of a robotic arm in berthing. While both require grappling and securing mechanisms, docking can combine these into one interface, whereas berthing needs two separate ones. This affects the alignment approach, with docking aligning along the interface axis.



Docking system - Building Blocks

The table below outlines the devices and interfaces PIAP Space can provide based on the previously defined architectures. Following the table, each building block is described in detail.

Table 3. Devices and interfaces / PIAP Space

	ACTIVE side	PASSIVE side
Berthing		
Grappling	LARIS Gripper 	SGF (or LAR) 
Arm	TITAN 	N/A
Securing	LARIS-S 	LAR (or 3x SGF) 
Docking		
Grappling and Securing	LARIS-DSP 	LAR (or 3x SGF) 

Docking System Architectures

Tables 1 and 2 detail the necessary components and interfaces for both methods, along with their specific requirements. **The goal for both docking and berthing is to create a secure, rigid connection capable of transferring loads and maintaining spacecraft alignment.** Careful coordination with the client satellite manufacturer is essential to ensure the interface can distribute loads without compromising the satellite's integrity during post-docking maneuvers.

Table 1. Docking architecture.

	Direct Docking
Grappling	The device shall accommodate a wide range of relative misalignments—lateral, angular, and relative velocities—of mating parts, collectively referred to as the reception range. The passive interface, in conjunction with the docking device (active interface), shall also incorporate mechanisms to prevent the target from escaping the reception range due to rebound motion after initial contact and before docking is completed. Additionally, the system shall provide shock attenuation during the impact between the target and the chaser. The required shock attenuation depends on various factors including the structure of the interface itself and the spacecraft structure in the vicinity of the interface. It is also contingent upon the guidance, navigation, and control (GNC) system, specifically its ability to closely match mutual velocities and promptly react to external disturbances. Furthermore, the system shall enable both sides of the interface to achieve proper alignment, facilitating latching in the final securing step.
Securing	The active and passive interfaces shall establish a highly rigid structural link between the two spacecraft, capable of withstanding the entire spectrum of anticipated loads. Furthermore, it shall support and distribute these expected loads effectively, ensuring the structural integrity and stability of the coupled system.

Table 2. Berthing architecture.

	Berthing
Grappling	The device shall accommodate a wide range the reception range. It should incorporate mechanisms to prevent the target from escaping the reception range due to rebound motion after initial contact however this functionality can be also fulfilled by the arm. Additionally, the interface shall provide the necessary stiffness and structural support to facilitate the transfer and secure insertion of the target spacecraft.
Arm	The system shall provide means to track and attenuate the relative motion between the two spacecraft. Furthermore, it shall facilitate the transfer and precise guidance of the target spacecraft to the securing interface, ensuring proper alignment and secure attachment.
Securing	Same as for Direct Docking.

PIAP Space aims to provide systems for both prepared and unprepared spacecraft. To this end, the company has introduced the Standard Gripping Fixture (SGF) interface, which, when utilized on client spacecraft, broadens the range of possible applications and operational flexibility.

Let your next mission be our common success

THANK YOU

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