Modular Robotic System for Future Servicing and Deorbiting Missions

PIAP SPACE

Clean Space Industry Days (CSID) – ESA-ESTEC, Noordwijk, The Netherlands, 13 October 2022

Agenda

1. PIAP Space Information
2. Space Robotic portfolio & heritage
3. TITAN manipulator
4. EROSS+ gripper
5. Units developed in the ORBITA project

SPACE ROBOTICS

MGSE
(Mechanical Ground Support Equippment)

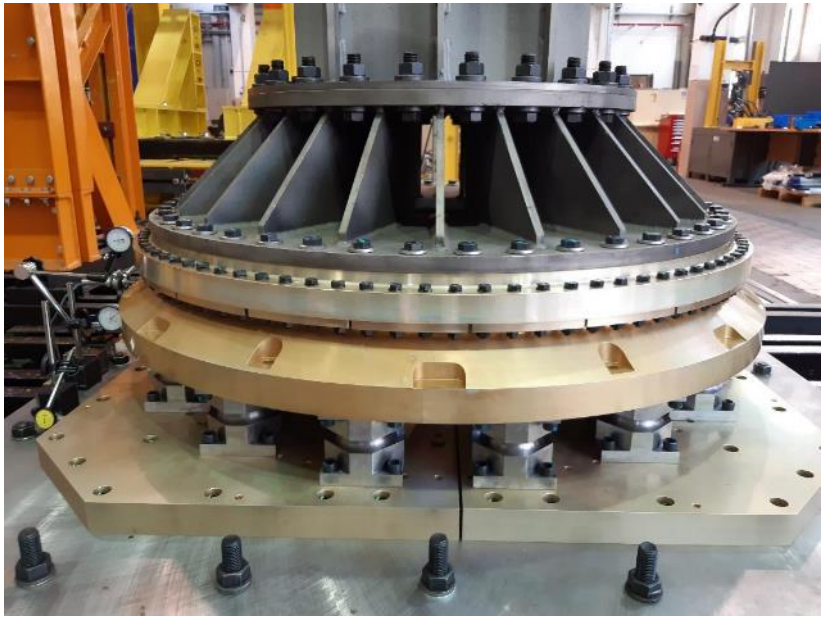
Robotic Subsystems for Space Missions

END EFFECTORS
- LAR GRIPPER
- MULTIPURPOSE GRIPPER

ROBOTIC ARMS

SENSORS FOR SPACE ROBOTICS
- F/T SENSOR
- VISION SENSOR

MGSE



BIOMASS adaptor during the internal tests

INTEGRATION STANDS
(PIS, PIT)

ADAPTERS (GHA, VTA)
AND CLAMP BANDS

HOISTING / LIFTING DEVICES

RaCER

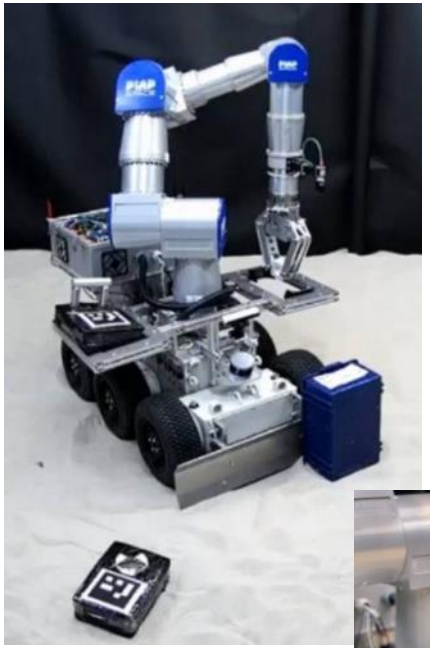
The RACER project was carried out by PIAP Space on behalf of ESA to characterize the realistically achievable maximum speed of a remotely controlled Moon exploration rover on terrain of varying difficulty.

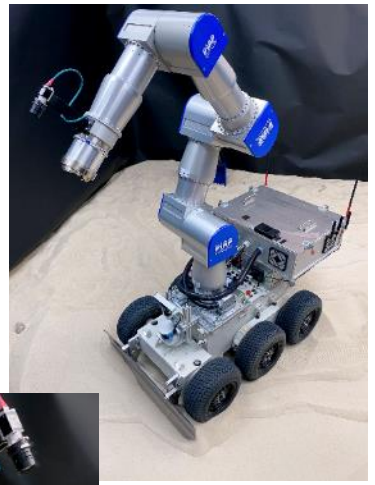
The tests were performed to simulate a lunar-like environment and a rover steered from the orbit of the Moon and Earth.

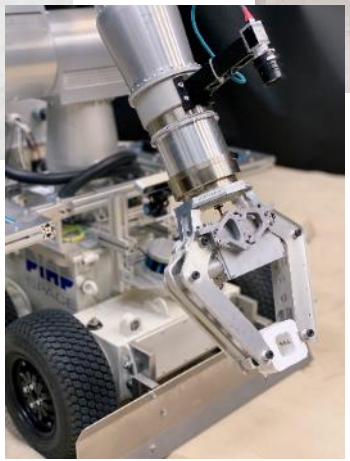
PRO+ACT

Development and demonstration of cooperation and manipulation between three robots for the Lunar Capability Extraction Station (ISRU).

PIAP Space was responsible for delivering the VELES - an UGV platform, equipped with a robotic arm with 7 degrees of freedom. It is a mobile platform with great off-road capabilities, with great towing capacity and the ability to carry large loads. The platform is completed by a griding blade, as well as exchangeable tools: gripper, shovel.



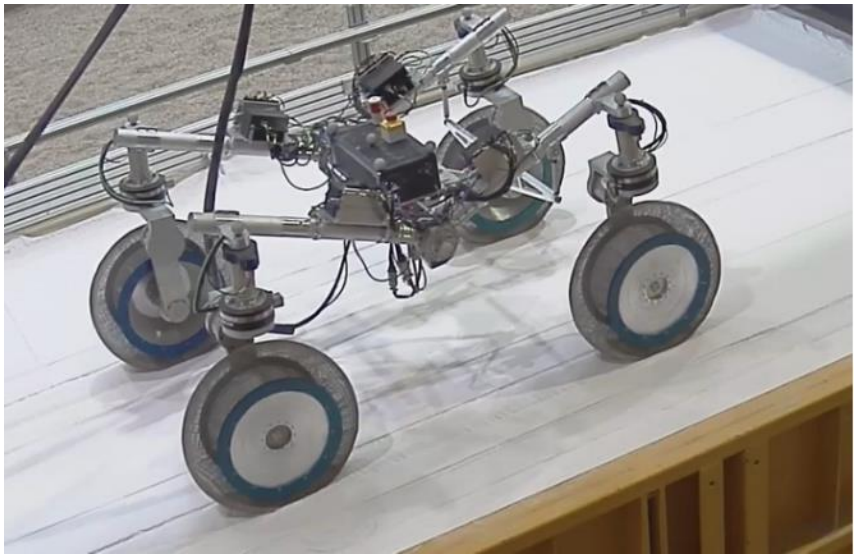




CHABLIS - The Characterization Breadboard for Locomotion on Sample Fetch Rover

CHABLIS during assembly in PIAP Space

In 2021 PIAP Space delivered CHABLIS rover for MDA as a Built to Print project.

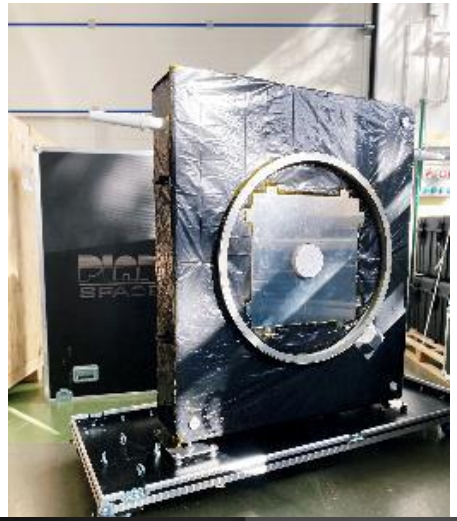


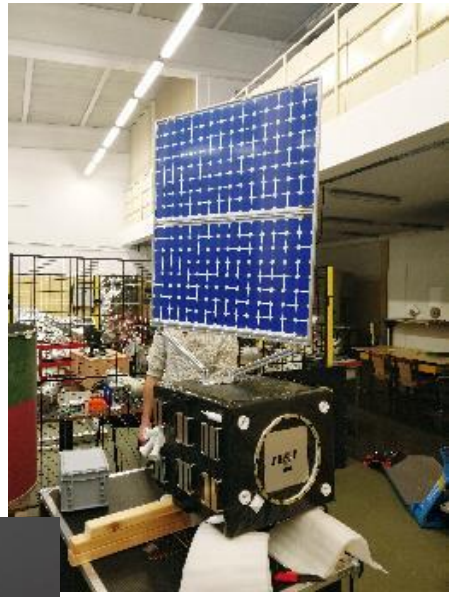
CHABLIS during test campaign in RUAG

PIAP Space provided LAR Gripper for the berthing operation, F/T sensor for robotic arm and Satellite mock-ups for demonstration purposes

LAR Gripper parameters:

Mass:	8 kg
Dimensions:	410 x 245 x 161 mm
Power consumption:	50 W
Operating temperature range:	-40 to 80 deg. C
Grasping envelope (translational)	40 x 40x 40 mm
Grasping Envelope (angular)	+/- 5 deg.
Actuation duration (ridigization)	<20 s
LAR compatibility:	PAS_1666_S PAS_1666_MVS PAS1194_VS SENTINEL3
Standard Interface:	HOTDOCK





ROBOTIC ARM DEVELOPMENT FOR ON-ORBIT SERVICING OPERATIONS (TITAN)

PIAP Space – Prime Contractor

100 % Polish Industrial Consortium

ESA Contract No. 4000131444/20/NL/RA

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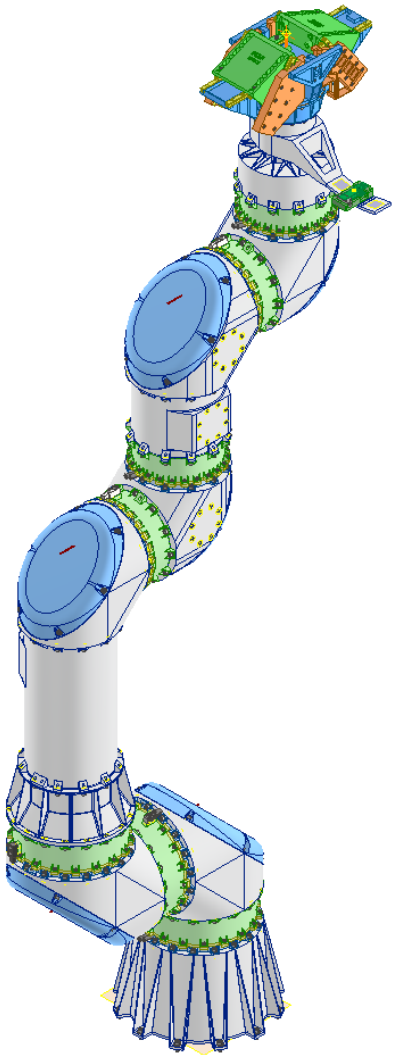
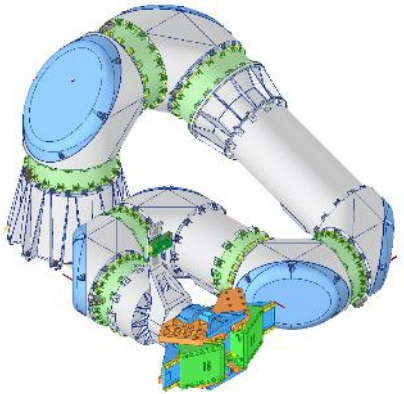


TITAN

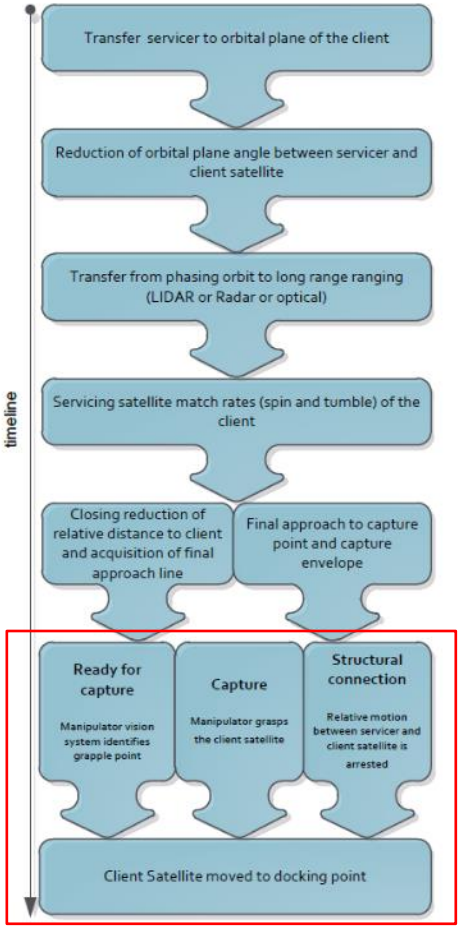
Project goal: to develop a prototype of a multi-articulated robotic arm for future deorbitation and servicing of in-orbit satellites. Targeted TRL: 6

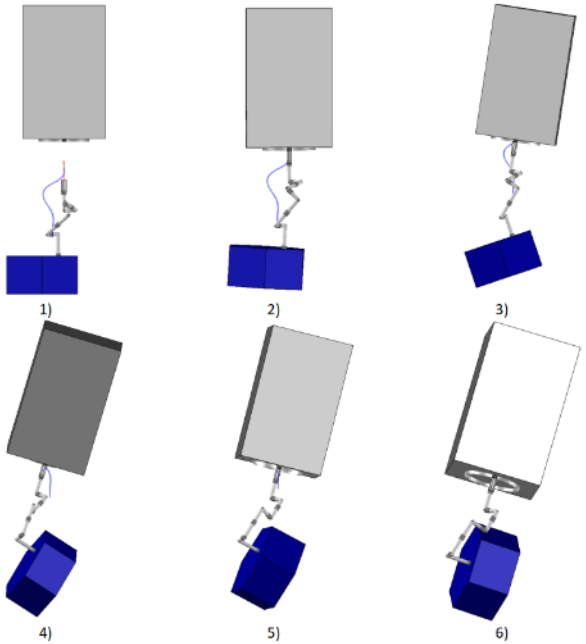
Technical parameters:



- maximum tip force and torque: 50N / 50Nm (0g); 10N / 10Nm (1g)
- positioning accuracy: +/- 0.1 degrees and +/- 5 mm on each axis
- range: 2m
- redundancy:
  - full redundancy of: F/T Sensor, thermal control subsystem (heaters and thermistors),
  - independent power lines for each joint,
  - redundant data buses,
  - joint level redundancy by 7th joint.

TITAN - Reference mission

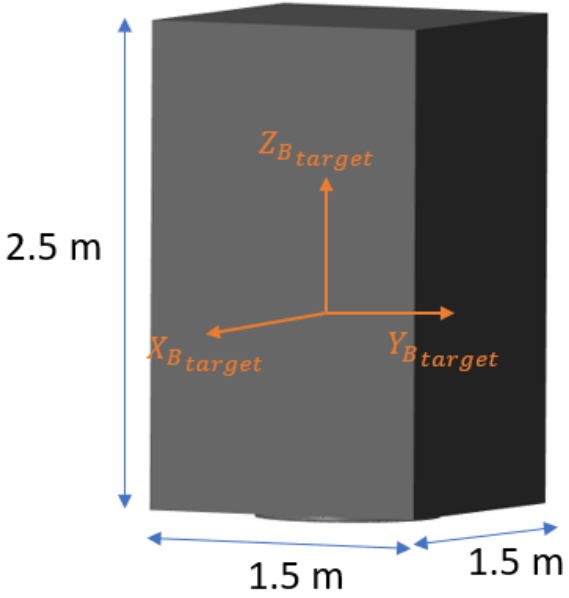




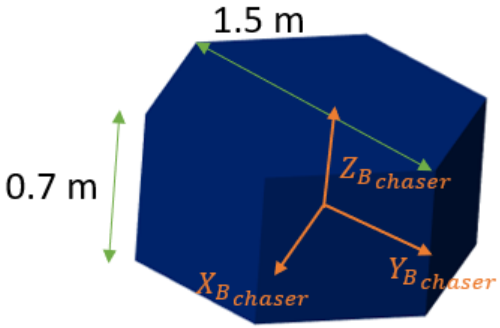
1 Initial state
2 Gripping and braking
3-5 Transfer to docking position
6 Target in the docking position

TITAN – Reference mission

Max. translation rates: 20 mm/s in main axis, 5 mm/s in two other axes
Max. rotational rates of: 0,9 deg/s in main axis, 0,3 deg/s in two other axes

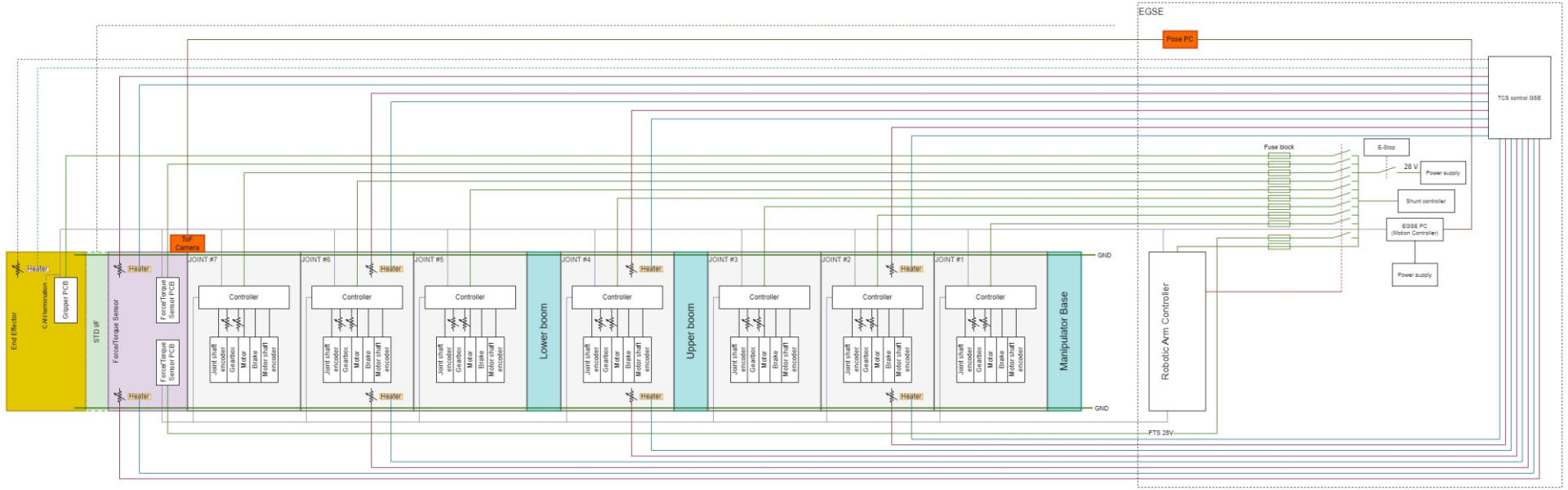


1000 kg

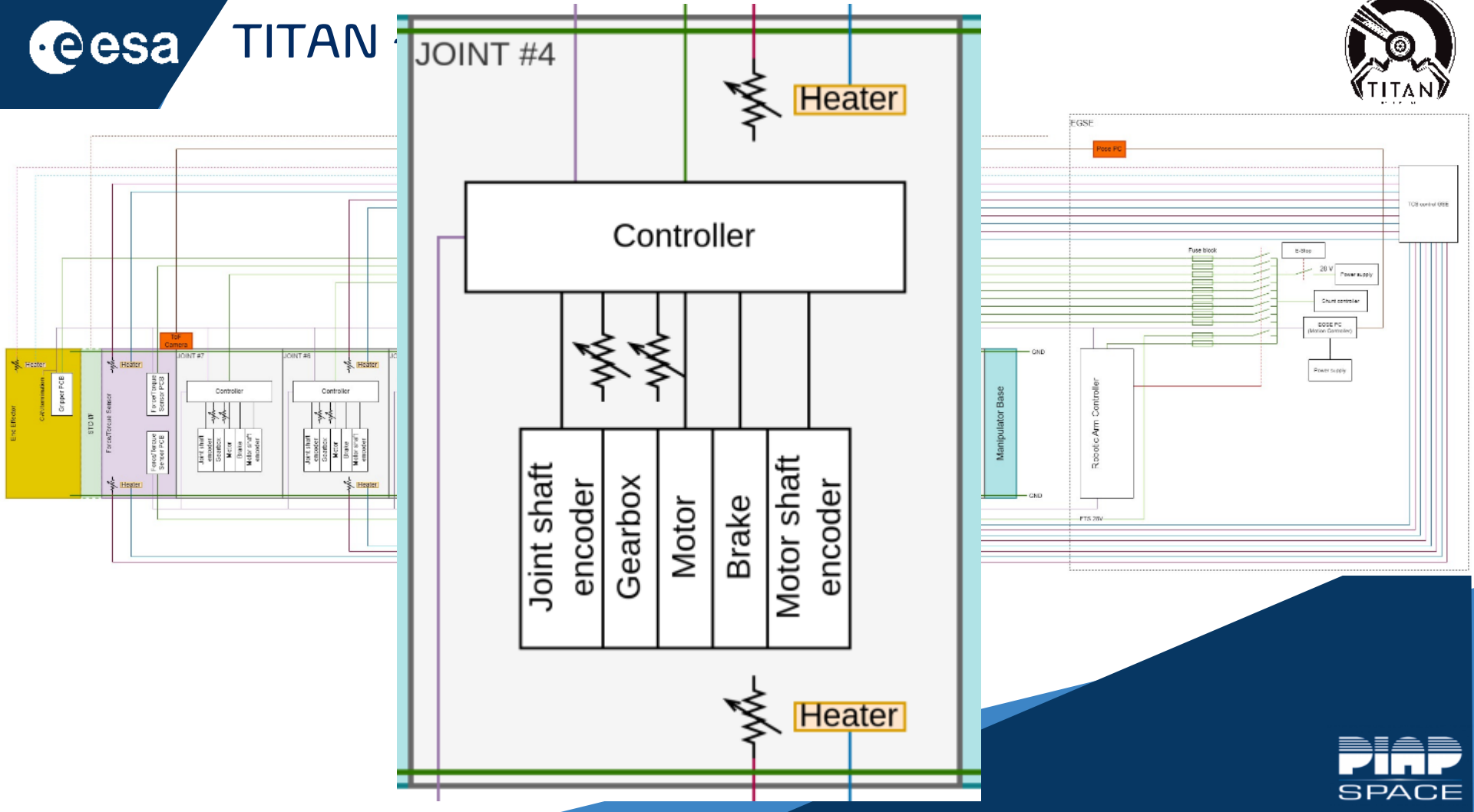


500 kg

TITAN – Architecture

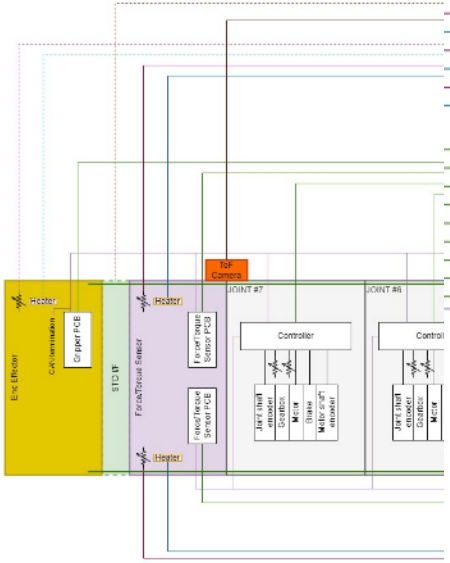


TITAN

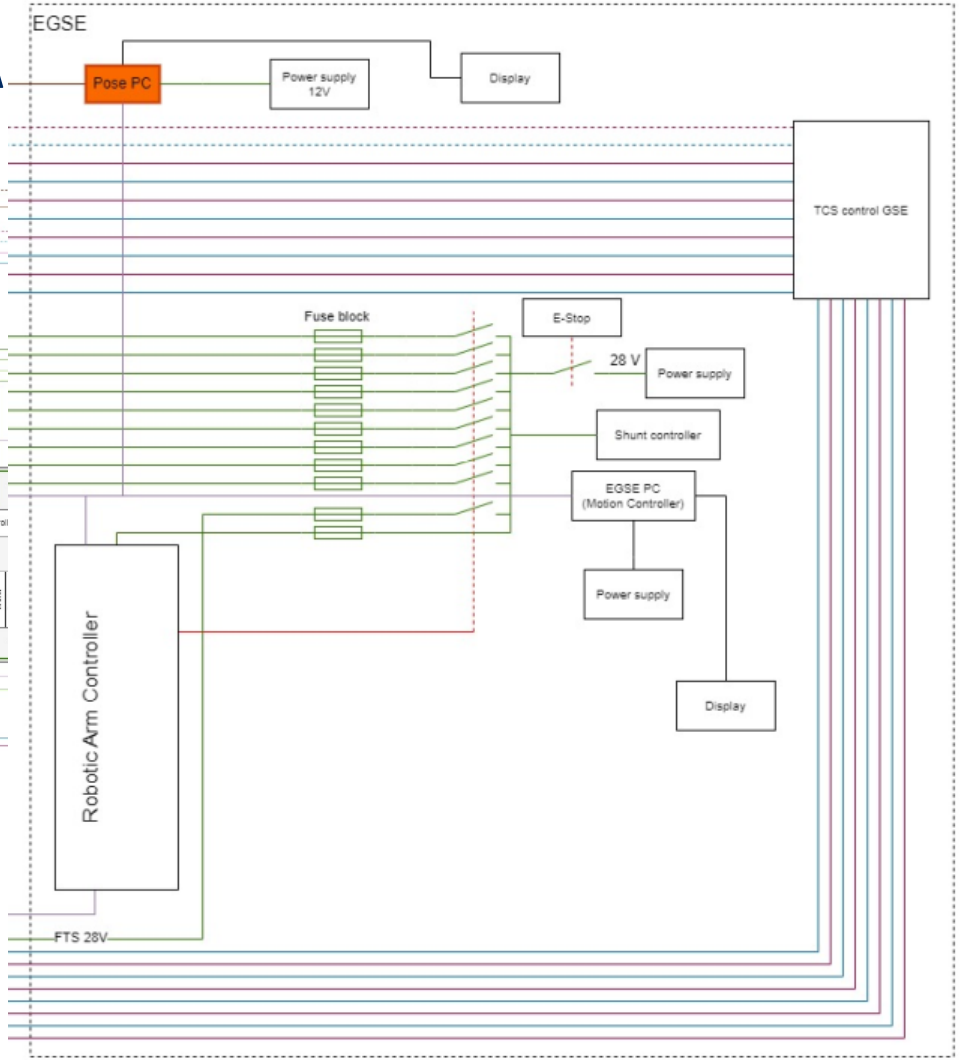


JOINT #4
Heater
Controller
Joint shaft encoder
Gearbox
Motor
Brake
Motor shaft encoder
Heater
Heater
Controller
Controller
Manipulator Base
Robotic Arm Controller
Pose PC
Fuse block
Power supply
Shunt controller
Power supply

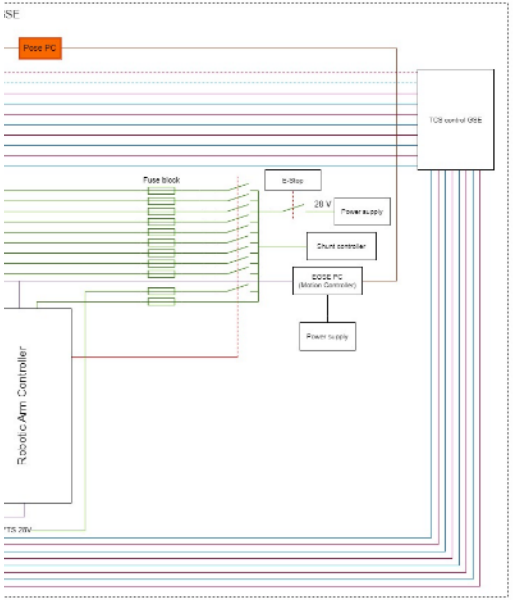
TITA



Heater
End Effector
Gripper PCB
STC I/F
Force/Torque Sensor
Heater
Force/Torque Sensor PCB
Heater
ToF Camera
JOINT #7
JOINT #6
Controller
Joint shaft encoder
Gearbox
Motor
Brake
Motor shaft encoder



EGSE
Pose PC
Power supply 12V
Display
TCS control GSE
Fuse block
E-Stop
28 V
Power supply
Shunt controller
EGSE PC (Motion Controller)
Power supply
Display
Robotic Arm Controller
FTS 28V



Pose PC
TCS control GSE
Fuse block
E-Stop
28 V
Power supply
Shunt controller
EGSE PC (Motion Controller)
Power supply
Robotic Arm Controller

TITAN – Models philosophy -Joint level

Joint Development Model including DM Joint Controller PCB (BB level):

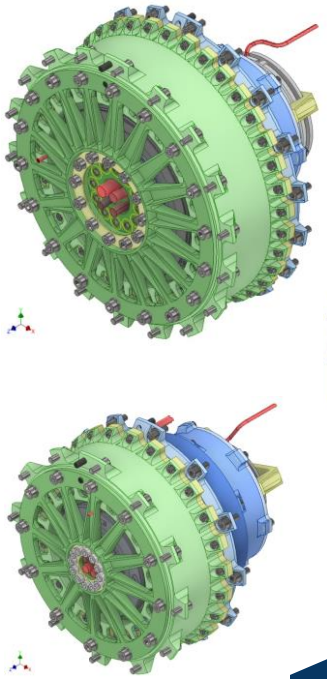
- Mechanical performance tests
- PCB and harness integration
- Basic functional tests, SW integration, Joint level control loop preliminary tuning
- Preliminary vibration and shock tests
- Preliminary EMC/EMI tests

Joint Engineering Model:

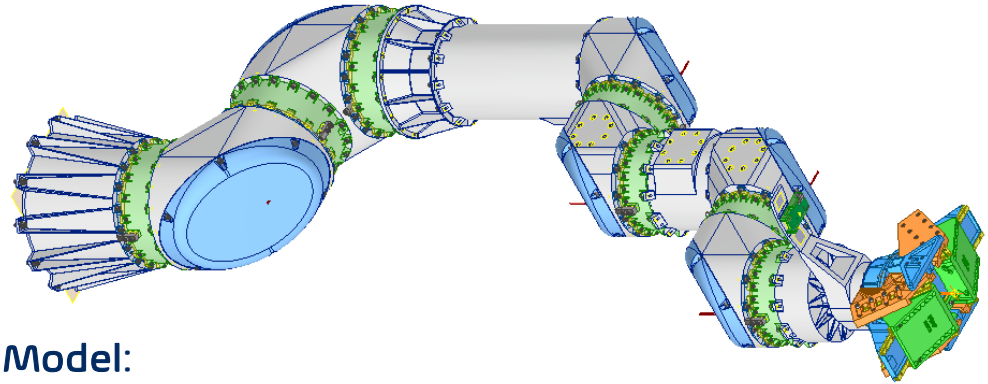
- As for DM Joint
- Thermal Control System integration
- Functional tests in TVAC
- Lifetime tests in TVAC

Dedicated BBs for harness routing verification, processes development etc.

Simplified manipulator (2 joints) for stability tests on **air bearing table**



TITAN – Models philosophy – manipulator level



TITAN manipulator **Engineering Model**:

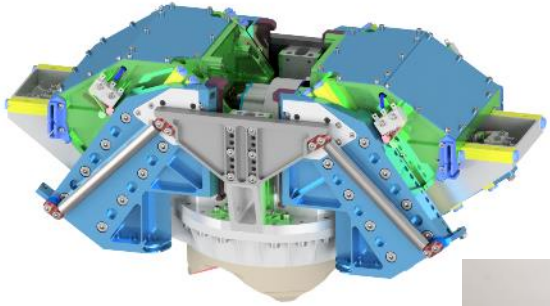
- Functional tests in 1g (constrained working space etc.)
- Calibration an accuracy/repeatability tests
- EMC/EMI tests
- Vibration tests (random, sine, QSL)
- Shock tests
- MLI integration

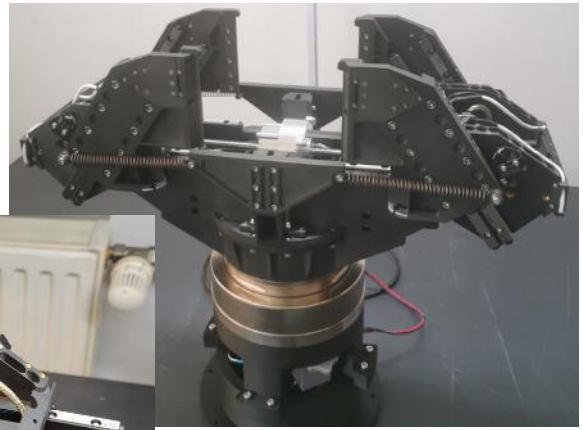
Supporting **GSE**:

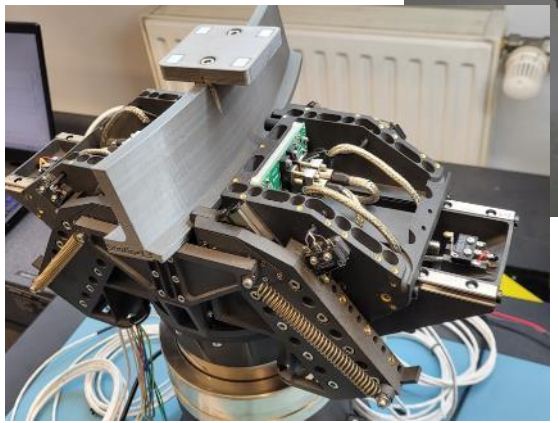
- Target satellite mock-up suspended on Kuka robot
- EGSE: Vision system, Motion Controller, Power sub-system
- GSE: Base and safety modules

GRIPPER description

The LAR Gripper design is characterised by compatibility with multiple LAR with adequate grasping envelope. The grasping concept was examined on a first Development Model. The Gripper is currently in the phase of the Engineering Model integration.







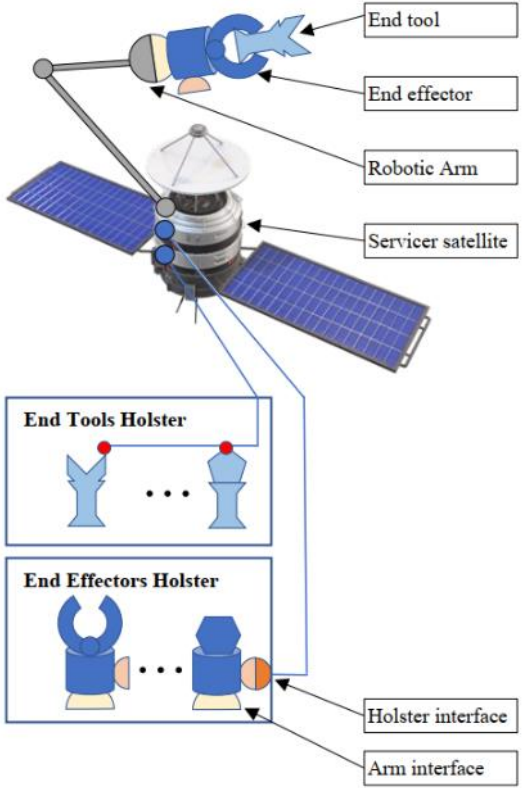
Technical parameters:

Mass	5 kg
Max dimensions	444 x 168 x 189 mm
Power consumption	50 W
Operating temperature range	-40 to 80 °C
Grasping envelope (translational)	40 x 40 x 40 mm
Graspin envelope (angular)	± 5 °
Actuation duration (digiduzation)	<20 s
LAR compatibility	S3 LVA Ring 937 PAS_1666_S PAS_1666_MVS PAS_1194_VS
Standard Interface	HOTDOCK

https://youtu.be/_3NtCvMo6ks

European Commission
Horizon 2020
European Union funding
for Research & Innovation

MULTIPURPOSE GRIPPER (1/2)



Multipurpose Gripper – Concept Schema

- PIAP Space is developing the Multipurpose Gripper for performing **various servicing activities** on orbit.
- The proposed design of Multipurpose Servicer Gripper follows the **European** paradigm that focuses on development of universal **building blocks** in order to create new modular robotic solutions for on-orbit and planetary exploration missions.
- The Multipurpose Servicer Gripper is to be equipped with an assortment of **robotic tools** that can provide on-orbit satellite repairs by fulfilling the main functions:
  - ✓ Visual inspection augmentation;
  - ✓ Support for antenna and solar panel deployment;
  - ✓ Insulation regeneration;
  - ✓ Module replacement.

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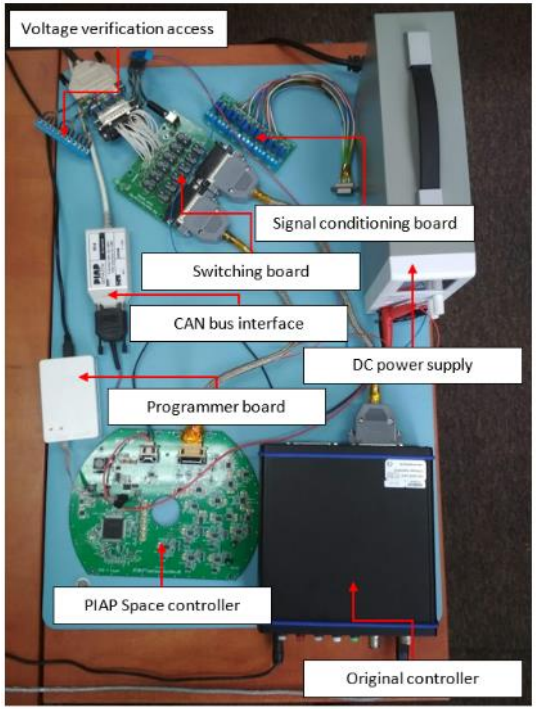
MULTIPURPOSE GRIPPER (2/2)

Multipurpose Gripper
Preliminary Design

- The developed gripper consists of **gripping claws** that is capable of unlimited rotation and able to use interchangeable tools.
- The **Engineering Model** of Multipurpose Servicer Gripper with Technology Readiness Level 6 is foreseen to be completed in the turn of the year 2024/25.
- **Future considerations** for the Multipurpose Service Gripper include expanding its functionality by developing new tools, both universal and tailored to specific mission, and also by enlarging its sensor suite.

Force and Torque Sensor (1/2)

Off the shelf forces and torques sensor



Electronic components of the force and torque sensor

- PIAP Space is developing 6 axis Force and Torque Sensor for space applications in the scope of ORBITA project.
- The force and torque sensor is to be employed between the robotic arm and its end effector on a servicer satellite.
- The strain gauge sensor enables sensing loads acting upon the manipulator and allows detecting contact between the end effector and gripped part.
- PIAP Space is also developing a custom electronic controller that is on a path to flight. The controller is currently used to drive off-the-shelf sensor during validation and verification phase.
- A proprietary software can be embedded in its microcontroller. It enables calculating the forces and torques acting upon the sensor from the strain gauge bridges signals.

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Force and Torque Sensor (2/2)

Interface of the force and torque sensor software

Workbench for applying loads to the sensor.

- A proprietary software can be embedded in its microcontroller. It enables calculating the forces and torques acting upon the sensor from the strain gauge bridges signals.
- The main PCB contains microcontroller that receives measurement signals after they have been amplified and offset. Analogue to digital converters are used to transduce the signals that are then sent on a CAN bus. Original controller is used to verify the accuracy of the measurements. Separate board is employed as a switch. A coupling and bias matrices are employed to translate the signals from voltage drops to forces and torques.
- The company has also built a workbench intended for testing the sensor by applying known loads. Larger calibration station that allows applying loads simultaneously in multiple axes is being worked on. An approach to thermal compensation of the sensor is being developed. Development of customised sensor compatible with space environment is ongoing.

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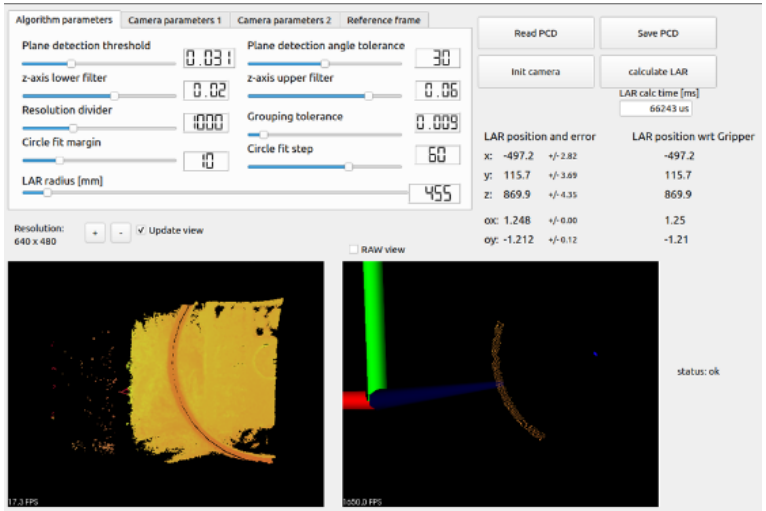
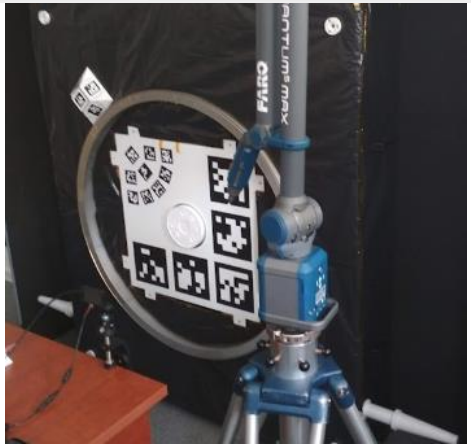
VISION SYSTEM





- PIAP Space is developing vision system for space applications in the scope of ORBITA project target TRL4.
- The vision system role is to estimate LAR pose of target satellite
- Target range of measurement 50-1000 mm
- Target linear accuracy 4-10mm
- Target angular accuracy 1°
- Target readings refresh 10Hz
- ToF camera is used to collect 3D data as cloud of points
- Algorithm processing is executed on Nvidia Jetson TX2
- Communication with external modules by CAN

Development plan summary for space robotics

	2022	2023			
	Q4	Q1	Q2	Q3	Q4
TITAN					
DM joint	TRL4				
EM joint				TRL6	
EM Manipulator					TRL6
EROSS +		TRL6			
EROSS IOD			2025->		
ORBITA					
Multipurpose gripper					TRL4/5
FTS					TRL6
Vision System					TRL4

Any questions?

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