[SSC20-WP1-08]

PLD Space, "The European commercial launch service provider dedicated to small payloads and small satellites"

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ABSTRACT

PLD Space is a European company with the goal of providing easy and frequent access to space. The company aims to provide launch services for suborbital applications such as scientific research or technology development as well as orbital launches for small satellites. For this, PLD Space is developing two dedicated, reusable launch vehicles named MIURA 1 and MIURA 5.

MIURA 1 was conceived as a one-staged suborbital sounding rocket which uses a liquid propulsion system designed and built by PLD Space. MIURA 5 – uses five of the same engine propelling MIURA 1 – is a two-staged launch vehicle for small satellites.

The maiden flight of MIURA 1 is set to take place from the historical Spanish launch site “El Arenosillo” in the south-west of Spain. From there, the rocket will fly into south-westerly direction and after a flight time of about 12.5 minutes splash down about 40 km off the coast in the Gulf of Cadiz in the Atlantic Ocean.

In this first test flight, MIURA 1 will carry several payloads. Half of the total available payload capacity will be used by PLD Space. A variety of sensors will be integrated into the rocket with the intention to quantify the flight environment.

The other half of the available payload mass has been made available for the scientific community and will house several scientific experiments.

PLD SPACE

PLD Space was founded in 2011 and has the goal to become a European commercial rocket company that provides frequent access to space. The company aims to offer launch services for suborbital applications such as scientific research or technology development as well as orbital launches for small satellites.

The challenging task of the developing a completely new rocket has been broken down in smaller milestones that can be achieved step-by-step. The first technical development PLD Space focused on was the TEPREL liquid rocket engine. For this PLD Space, built its own propulsion test facility at the Teruel Airport in Spain. The first successful test of the TEPREL engine was performed in 2015. This was the first KeroLOX engine to be fully developed in Europe.

Figure 1. Test version of the TEPREL engine being fired in the propulsion test facilities of PLD Space

For the development of the launch vehicles, PLD Space continues with a staggered approach. The two launch vehicles, MIURA 1 and MIURA 5, were developed consecutively.

MIURA 1 is a completely reusable single stage sounding rocket. With this launch vehicle PLD Space wants to first serve the suborbital market by providing frequent flight access. Secondly, MIURA 1 serves as a technology demonstrator for MIURA 5, which was conceived as a two-staged launch vehicle for small satellites.

PLD Space headquarters are located in Elche, Spain. The headquarters also house the rocket factory, where MIURA 1 will be assembled, and the payloads are integrated.

THE MIURA 1 LAUNCH VEHICLE

Baseline Configuration

MIURA 1 is a single stage launch vehicle with a total length of 12.5 m, a diameter of 0.7 m and a lift-off mass of 2550 kg, MIURA 1 can lift a nominal net payload mass of 100 kg – not including the avionics system, recovery system, and payload bay structure – into a suborbital trajectory.
After a total flight time of about 12.5 minutes, including several minutes of microgravity, the rocket will splash down approximately 40 km off the coast. It will then be recovered by boat and the payload will be returned to the customer. An overview of MIURA 1 and its subsystems is shown in Fig. 4. Its main parameters are summarized in Table 1.

Table 1. MIURA 1 baseline configuration data

Feature	Value
Length	12.5 m
Diameter	0.7 m
Stages	1
Lift-off mass	2550 kg
Nominal payload mass	100 kg
Microgravity time	3 – 4 min
Flight time	12.5 min
Nominal apogee	150 km
Ground range	40 km
Recovery time	< 6 h
Main launch site	El Arenosillo, Spain

Propulsion System

MIURA 1 is propelled by a single regeneratively cooled TEPREL liquid engine powered by liquid oxygen and kerosene. The propellants are driven to the engine by using a pressure-fed cycle with Helium. The TEPREL engine produces a thrust of 30 kN at sea level for a duration of 122 seconds. It is equipped with actuators for an active thrust vector control (TVC) during the propelled ascent of MIURA 1.

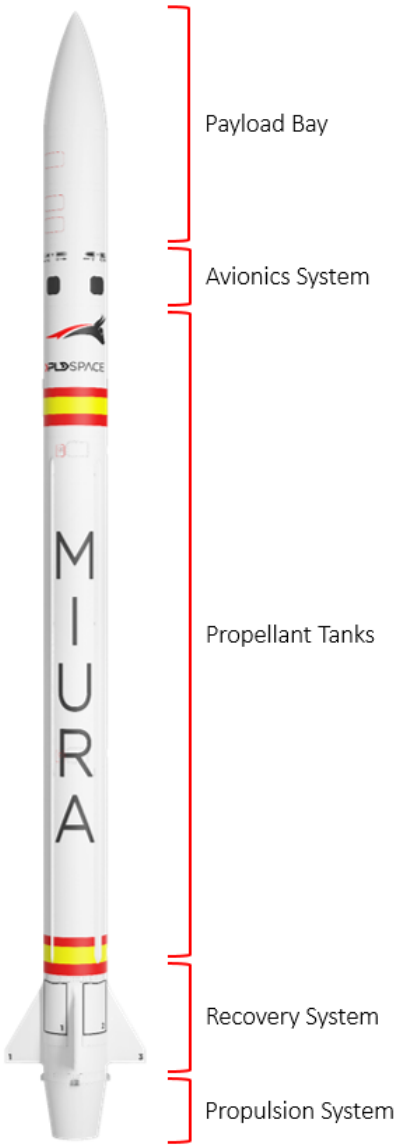

Figure 4. MIURA 1 vehicle subsystems

Recovery System

The recovery system on board MIURA 1 can safely return the whole launch vehicle to ground, enabling the payloads to be returned to the customers and the complete rocket to be used again. After re-entry, two parachutes are deployed consecutively. At an altitude of approximately 5 km, a drogue parachute decelerates the rocket, until the main parachute can be opened safely. At an altitude of approximately 3 km, the main parachute is deployed and further slows the descent of MIURA 1. Finally, the vehicle splashes down with a terminal velocity of 10 m/s. With the last known GPS position and a beacon system, it is then possible to locate the vehicle floating on the sea surface and recover it with a boat.

Avionics System

The avionics system, developed by the Spanish technology group GMV, controls all vehicle functions during the flight. It is also the only system directly connected to the payloads flying on MIURA 1, as it is responsible for their power supply, telemetry and command & data handling. The general functions of the avionics system are:

- Guidance, Navigation & Control: The avionics system controls the trajectory and the attitude of MIURA 1 during its flight by commanding the actuators of the main engine´s thrust vector control and by an additional reaction control system composed of cold-gas thrusters using nitrogen.
- Telemetry System: Establishes the communication between the vehicle and the ground station to transfer vehicle and payload telemetry.
- Power Storage and Distribution: Equipped with batteries for power storage and a power conditioning and distribution unit, the avionics system is responsible for supporting all remaining rocket systems and the payloads with power.
- Payload Management: A dedicated payload computer handles all communication between the avionics system and the individual payloads. It forwards the payload telemetry to the telemetry system, provides additional data storage capacities, and sends control signals to the payloads.
- Sensor Conditioning and Acquisition: The MIURA 1 rocket is equipped with various sensors that are used for rocket control loops, but also deliver valuable housekeeping data to analyze the rocket's performance after the flight.

Payload Bay

The Payload Bay of the MIURA 1 launch vehicle is composed of up to four standardized Payload Compartments (Fig. 5) which are situated directly underneath the nosecone. Each Payload Compartment can hold a payload mass of up to 25 kg at a volume of 77 liters. Furthermore, every Payload Compartment is equipped with a defined set of mechanical and electrical interfaces, supplying the payload with basic resources. Several Payload Compartments can be joined to form a bigger unit, increasing the available resources for the payload.

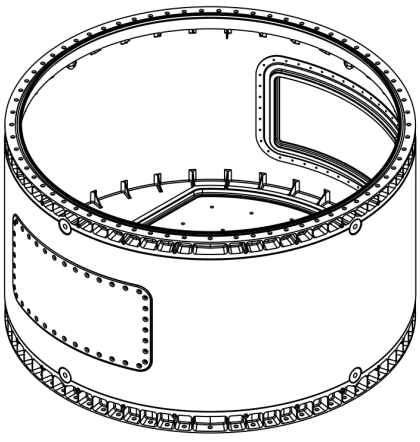

Figure 5. CAD illustration of a Payload Compartment

A bulkhead on the bottom of each Payload Compartment is equipped with an isogrid pattern of blind bolt holes in order to provide a flexible mounting interface to the payload. Furthermore, the bulkhead seals off each Compartment individually from each other and from the outside environment. This protects the payloads after the water landing and allows the Payload Compartments to fill with a customized atmosphere. As standard they are filled with nitrogen gas, but other inert gases can be used if required.

Each Payload Compartment is equipped with two hatches that facilitate the payload integration, allow for easier access during testing and can be used for a late access before the flight.

The main mechanical characteristics of a Payload Compartment are listed in Table 2.

Table 2: Mechanical characteristics of a MIURA 1 Payload Compartment.

Feature	Value
Payload Mass	25 kg
Payload Volume	590mm (d) x 280 mm (h)
Mounting	Isogrid pattern of 51 M6 bolt holes
Hatch Size	2 Hatches; 250 mm x 120 mm
Atmosphere	Sealed airtight, filled with N2

A basic power supply is provided as a standard service as well. Characteristics are listed in Table 3. The power supply is switched on 10 minutes before lift-off and initially provided via external umbilical. About 3 minutes before lift-off the power supply is switched to the internal batteries. The power stays switched on until the recovery team arrives at the vehicle.

Table 3: Payload power supply characteristics.

Feature	Value
Voltage	28V DC
Current	max. 10 A
Battery Capacity	0.5 Ah

Lastly, also an interface for payload control and data handling is provided. For this a simple Ethernet connection with the payload computer in the MIURA 1 Avionics System is utilized. On this interface, the payload can:

- Receive a control signal to trigger events in the payload. The control signal starts at T-60s and is sent at a frequency of 10 Hz. It consists of a timer and an indicator for the current flight phase.
- Receive telecommands from the payload's ground station. This is currently just available via an umbilical connection while MIURA 1 is on the launch pad. For this the telecommands can be sent via a transparent UDP connection to the payload on board of MIURA 1.
- Send telemetry data to the payload's ground station. This is also realized with a transparent UDP connection and available throughout the whole flight.
- Store data on the MIURA 1 on-board data storage.

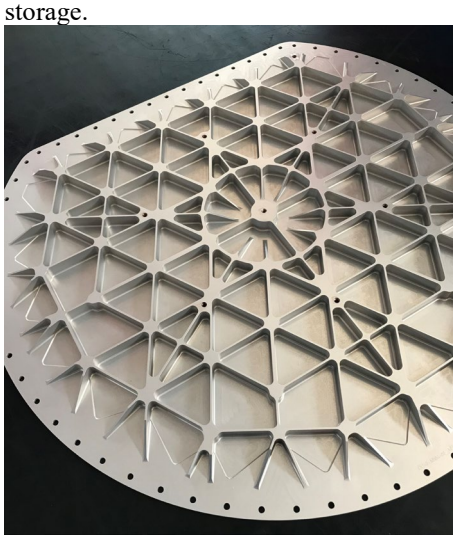

Figure 6. Baseplate MIURA 1

Table 4: Payload telemetry and on-board data storage characteristics.

Feature	Value
Telemetry Data-Rate	0.8 Mbit/s
On-board Data Storage max. Data-Rate	5 Mbyte/s

On-board Data Storage Space	16GB

Mobile Launch Ramp

To facilitate the launch preparations and operations, a mobile launch ramp is built. This mobile launch ramp does not only support the launch operations, it is also used for testing and transport of MIURA 1.

After the launch vehicle's propulsive stage has been assembled in the PLD Space headquarters, it is mounted to the mobile launch ramp and transported to PLD Space's propulsion test facilities in Teruel. The propulsive stage includes all vehicle subsystems from the engine up to the avionics system.

At the propulsion test facilities, the ramp is placed on a test stand that is designed to support a vertical propulsion test with the propulsive stage.

After a successful acceptance testing, MIURA 1 is then transported to the launch site. Here the ramp supports the vehicle during final integration and flight preparations, as well as for the hot countdown and launch. A 3D-model of the mobile launch ramp, with the MIURA 1 vehicle in vertical position is shown in Fig. 6.

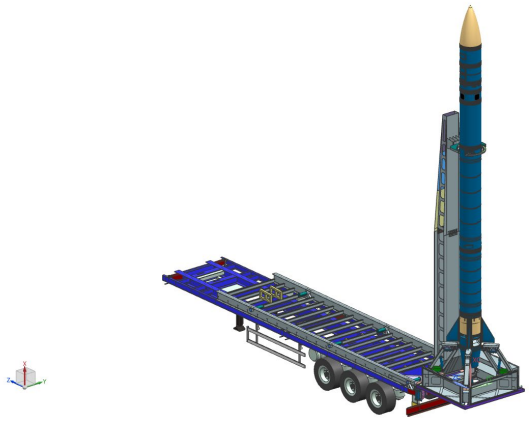

Figure 7. 3D-Model of the mobile launch ramp for MIURA 1 in launch setting

LAUNCH OPERATIONS

Payload Integration

Parallel to the acceptance testing of the launch vehicle's propulsive stage, the payloads are integrated into the payload bay. The payload integration is performed at the PLD Space headquarters in Elche. Here, some functional and interference tests are carried out. The event concludes with a full flight simulation for the vehicles upper stage. After this, the payload bay is sealed and stored until the launch campaign commences.

Launch Campaign & Flight

After the payload bay has been transported to the "El Arenosillo" launch site, final payload checks and refurbishment can be done. Then the payload bay is mated with the MIURA 1 propulsive stage. After a dress rehearsal of the countdown and flight, the vehicle is ready for the flight countdown. The countdown for MIURA 1 lasts approximately four hours. During this time, it is possible to perform a late access to the payload.

Shortly after lift-off, MIURA 1 starts to perform a first pitch maneuver to increase the ground distance to the launch site. This maneuver uses the main engine's TVC and ends shortly before the main engine cut-off (MECO) at T+122s.

After the MECO, MIURA 1 follows a ballistic trajectory. During this ballistic phase, a second pitch maneuver is performed to align MIURA 1 with the nose pointing down for the re-entry.

During re-entry, parachutes slow down MIURA 1 before it finally splashes down in the Gulf of Cádiz in the Atlantic Ocean at a downrange of approximately 40 km. The total flight lasts for about 12.5 minutes.

After splashdown, the complete vehicle is picked up by ship and brought back to El Arenosillo. There the vehicle is examined and disassembled by PLD Space personnel. After the payload bay has been separated, the customers get access to their compartment for dismounting of their payload.

CURRENT STATUS

The manufacturing of MIURA 1 flight hardware is ongoing. Critical subsystems have completed testing or are currently undergoing exhaustive testing. Two examples are the recovery system and the flight version of the engine.

Recovery System Drop Tests

Two drop tests have been performed successfully in order to verify the parachute design and recovery operations. The first drop test was performed in Eloy, Arizona in February 2019. A mass dummy was equipped with the MIURA 1 parachute system and dropped from an airplane. The test successfully verified the proper functioning of the drogue and main

parachute, but also the design of the parachute canister, proper hatch ejection and correct functioning of parachute deployment triggers.

Figure 8. MIURA 1 parachute system drop test in Eloy, Arizona

A second drop test was performed in April 2019 from INTA´s the "El Arenosillo" launch site in Spain, in the framework of ESA´s FLPP Program. A mock-up of the first stage of the MIURA 5 was dropped from a Chinook-CH47 helicopter into the Atlantic Ocean. Even though the used parachute system was scaled for MIURA 5, the subsystems controlling the deployment are identical to the ones used on MIURA 1.

This drop test was also used to test parts of the ground segment that is used for the MIURA 1 launches. Additionally, it provided PLD Space with an excellent opportunity to understand and train the procedures for the MIURA 1 sea recovery.

Figure 9. Sea recovery operations with MIURA 5 drop test mock-up

Flight Engine Qualification

The flight version of the TEPREL engine is currently tested at the propulsion test facilities in Teruel. An extensive test campaign is performed during which the burn time of the engine is gradually increased between tests. A burn time of four minutes is intended to be reached, which is twice the operating time as during the flight.

Figure 10. Flight version of the TEPREL engine being fired in the propulsion test facilities of PLD Space

Furthermore, a stainless-steel mock-up of the MIURA 1 propellant tanks and feed system is built. With this it will be possible to perform a representative verification test of the flight engines and feed system. For this, the mock-up can be mounted to the mobile launch ramp of MIURA 1 for a vertical propulsion test.

Figure 11. Stainless steel mock-up of the MIURA 1 tanks (foreground) and MIURA 5 drop test mock-up (background)

MAIDEN FLIGHT

The vehicle will be launched from the historical Spanish launch site “El Arenosillo” close to Huelva in the south-west of Spain.

This maiden flight already carries several payloads on board. About half of the available payload capacity is to be used by PLD Space. A variety of sensors are integrated into the rocket with the intention to quantify the flight environment and performance of the launch vehicle.

Two payload Compartments have been made available for the scientific community and house payloads from two customers. One Compartment is utilized by the German Center of Applied Space Technology and Microgravity (ZARM) which will integrate two experimental setups.

The American Embry Riddle Aeronautical University (ERAU) uses the second available Payload Compartment to send four student-faculty built experiments into space.

Combined operations are currently in progress between PLD Space and the customers to assure the compatibility of the systems.

MIURA 1 and MIURA 5 will enable PLD Space to provide worldwide commercial payload and small satellite launch services.