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MIURA1: The Reusable Sounding Rocket. Recovery and Reusability Strategies

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Abstract
Reusability in Launchers has been a topic of research and interest in the last years to improve the Access to Space. In Europe, PLD Space is one of the few companies betting in the concept of recovery and reusability in the launchers sector. With MIURA1, a sounding rocket and technology demonstrator of a microlauncher, PLD Space wants to demonstrate a potential recovery and reusability strategy for small launchers. MIURA1, designed to be used up to three times, is a liquid propellant rocket with the capability of carrying up to 100 kg of payload to an apogee of 120 km. Its recovery system is characterized by a deceleration system and a two-stage parachutes system. The sounding rocket will be launched from CEDEA Launch Site at the South of Spain in 2020 and will be recovered after splashdown at around 80 km (nominal case) from the Gulf of Huelva.
MIURA1, after reaching apogee, will slow-down until it will reach handover conditions for the two-stage parachutes opening. The first-stage parachute, the drogue chute, will be opened at 5 km, while the second-stage parachute, the main chute, will be opened at 3 km. After splashdown, the sounding rocket and the parachutes system will be recovered by a tugboat and transported to the harbour. After arriving at the harbour deck, MIURA1 will be transported at PLD Space HQ to follow final recovery and reusability procedures. The aim of this paper is to describe the Recovery System, the Recovery Operations and the Reusability Strategies applied to the reusable sounding rocket MIURA1.

Keywords: Recovery, Reusability, MIURA1, Arion1, PLD Space, Sounding Rocket

Nomenclature

CEDEA	Centro de Experimentación De El Arenosillo
ESA	European Space Agency
FLPP	Future Launchers Preparatory Programme
HQ	Headquarters
INTA	Instituto Nacional de Técnica Aeroespacial
LPSR	Liquid Propulsion Stage Recovery
M1	MIURA1
M5	MIURA5
CG	Centre of Gravity
SSO	Sun Synchronous Orbit
LOX	Liquid oxygen
TVC	Thrust Vector Control
CFD	Computational Fluid Dynamics
d-bag	deployment bag
AFSAT	Air Force Subscale Aerial Target
N/A	Not Applicable
ASNA	Airborne Systems North America
HQ	Headquarters

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1. Introduction

Recovery and Reusability have been a topic of great interest for the aerospace companies in the worldwide in the last years. The main object of the reusability is the reduction of the costs for the access to space and the launch, retrieving the flown hardware and refurbishing it to be reused for other several times. In the 21st century the interest in reusability has grown and the space launch systems have been focused on the design for recovery and reusability.

In Europe, one of the company betting on the recovery and reusability concepts is PLD Space, which is focusing on the development of a fully reusable suborbital rocket and a partial reusable orbital launcher. The fully reusable suborbital rocket is a sounding rocket, known as MIURA1 (M1), with the aim of recovering the flown hardware to be refurbished and reused. Nevertheless, PLD Space is also designing and developing a partial reusable orbital rocket, known as MIURA5 (M5), to retrieve the first stage and reuse it. M1 is designed to carry up to 100 kg of payload for a suborbital flight to an apogee of 120 km, instead M5 is designed to carry up to 300 kg of payload for 500 km Sun Synchronous Orbit (SSO).

PLD Space is a European aerospace company based in Elche, Spain, focused on the development of launcher technologies to provide suborbital and orbital commercial launch services with capability for transporting small payloads.

PLD wants to demonstrate a potential recovery and reusability strategy to be applied for small launchers. In fact, in April 2019, PLD has accomplished a successful Drop Test representative of the recovery for the first stage of the orbital rocket M5, developed under the FLPP-LPSR (Future Launchers Preparatory Programme - Liquid propulsion Stage Recovery) contract funded by the European Space Agency (ESA). The Drop Test has been performed in Huelva, South of Spain, at CEDEA- INTA (Centro de Experimentación De El Arenosillo - Instituto Nacional de Técnica Aeroespacial) launch base. The scope of the FLPP LPSR Drop Test Campaign was to demonstrate the recovery and reusability strategies and operations defined for both suborbital and orbital rockets. The test performed aimed to reproduce representative characteristics of the orbital space vehicle in the last stage of the descending phase, and proper handover conditions for the parachutes subsystem to analyse the descent phase up to the splashdown in the ocean.

2. MIURA1

MIURA1, formerly known as Arion1 has been designed for suborbital flights in order to provide commercial and scientific access to space. M1 is a single stage launch vehicle powered by liquid oxygen (LOX) and kerosene engine, with a 12.7 m overall length and a 0.7 m diameter. The entire flight of the suborbital rocket is around 12.5 minutes, with a microgravity phase between 3.7 and 4.7 minutes [1], that splashdown in the Gulf of Huelva, at about 80 km from the coast (Table 1). M1 will be recovered by a tugboat to retrieve the entire flown hardware.

Table 1 - MIURA1 Baseline data

MIURA1	
Number of stages	1 [-]
length	12.5 [m]
diameter	0.7 [m]
Lift off mass	2550 [kg]
Nominal payload mass	100 [kg]
Microgravity time	3.7-4.7 [min]
Flight Time	12.5 [min]
Nominal apogee	120 [km]
Ground range	80 [km]

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MIURA1 will be launched from CEDEA-INTA launch base, located in South-West of Spain (37°05'59.96"N, 06°44'10.63"W), using a mobile launch ramp which will be laid down and then elevated to aid the vertical position of the rocket prior to launch.
The entire mission profile of M1 is shown in Figure 1 and the flight events are defined in Table 2. The mission starts with the lift off event at T-0, but the engine ignition starts at T-2. The ascent phase is driven by the propulsion system, which engine is a single regeneratively cooled TEPREL - 1B engine. The design of the engine has been studied to optimize the performances for every flight. TEPREL – 1B is characterized by a pressure-fed cycle with Helium and provides a total thrust at sea level of 30 kN for a duration of 122 seconds until depletion of the propellant tanks. The propulsion system is equipped by actuators to tilt the engine for an active Thrust Vector Control (TVC) during propelled ascent of M1.

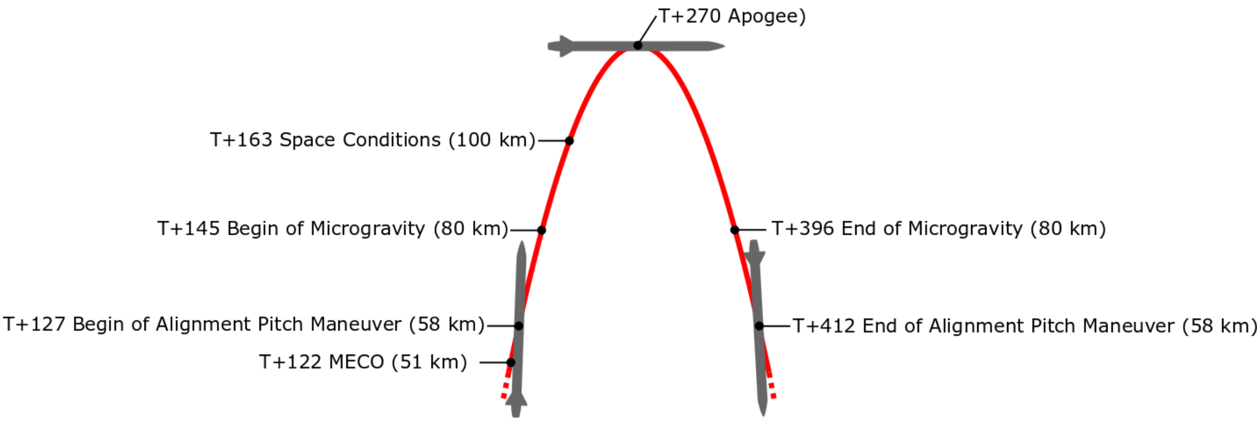

Figure 1 - MIURA1 Ballistic Phase

Table 2 - MIURA1 Flight Events

Event	Time*, [T±s]	Altitude*, [km]
Engine ignition	T-2	0
Lift-off	T±0	0
Begin of downrange pitch maneuver	T+15	0.4
MECO	T+122	51
Begin of alignment pitch maneuver	T+127	58
Begin of microgravity	T+145	80
Space conditions (100 km)	T+163	100
End of Microgravity	T+396	80
End of alignment pitch maneuver	T+412	58
Drogue parachute open	T+484	5
Main parachute open	T+526	3
Splashdown	T+750	0

*Estimations for a payload mass of 100 kg

The descent phase starts at T+396, and it is composed by a passive aerobraking phase and a parachute braking phase that ends up in a splashdown at T+750. The zone of the impact will be at about 80 km from the Mazagón Harbour (Figure 2) for the nominal mission.

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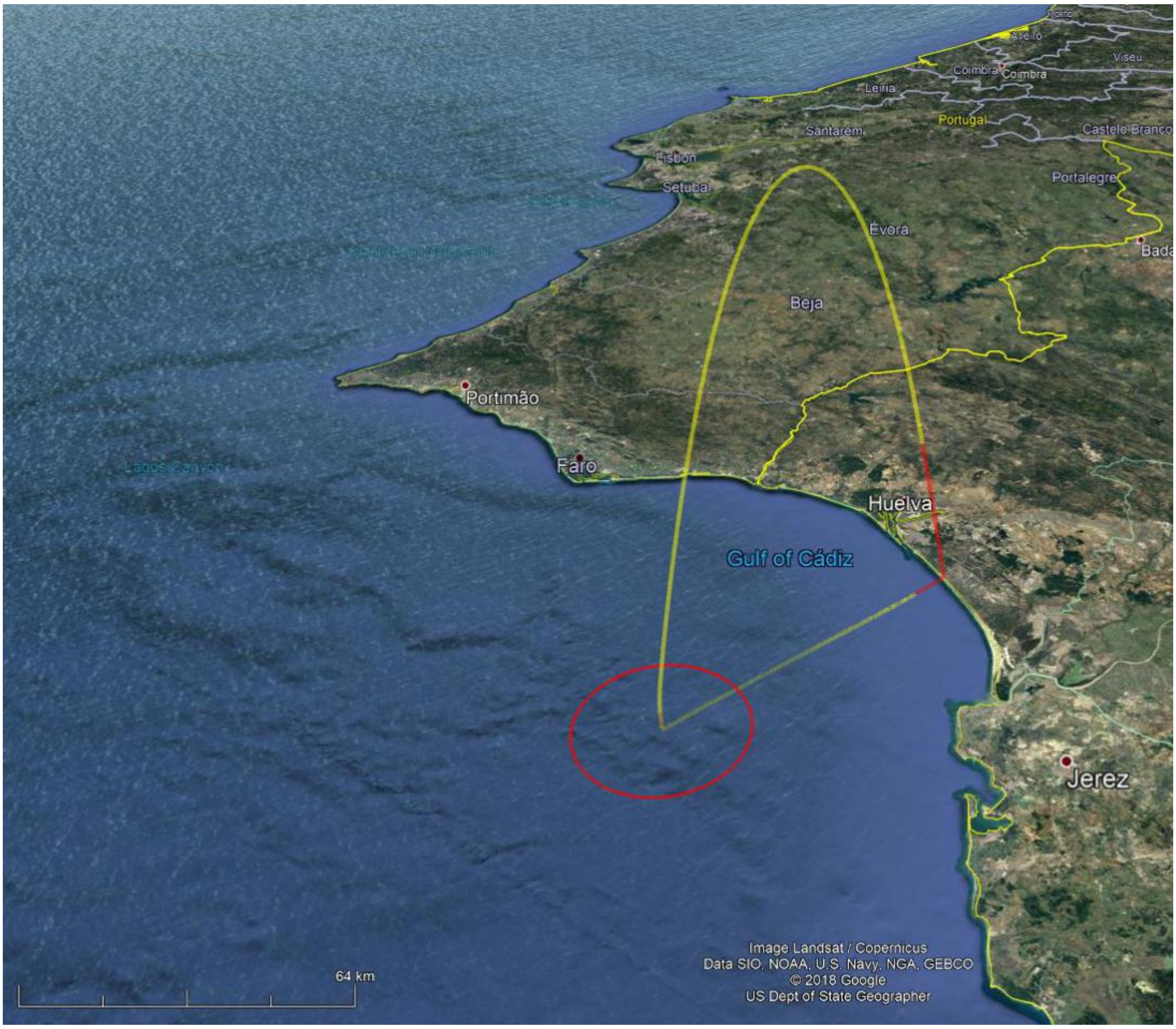

Figure 2 - MIURA1 Splashdown zone

3. Recovery & Reusability Design Drivers

The main drivers for the recovery and reusability of M1 have been defined in the preliminary design, focusing on the terminal velocity, from where the design has started. The vehicle shall have a terminal velocity lower than 11 m/s at splashdown, hence this requirement has driven the design of the descent system. The impact conditions at splashdown have been analysed by CFD (Computational Fluid Dynamics) studies (Figure 3) to examine the behaviour of the vehicle at splashdown, specially at structural level. These studies have been decisive to define the terminal velocity that the vehicle could withstand at splashdown, considering also the horizontal component of the velocity.

The study of the recovery has been steered by the trajectory analyses, considering the safety analysis to define the drop zone exclusion safety conditions, which ensure the whole 3-Sigma drop area is inhabited area with sea and air traffic restriction.

The reusability study has been focused on the 3-time reuse concept, to ensure all the components could be reused after flight without any significant loss of performances. M1 subsystems have been sized and designed applying design margins for the structure, the engine and the parachutes system in order to re-use them at least 3 times.

The engine has been designed to be easily disassembled and inspected after flight. The components of the engine have been sized to withstand the hostile temperature environment for the exposition during at least 3 flights. Nevertheless, the engine has been sized to withstand the axial loads applied during the entire flight and the combustion chamber has been designed for being used for the entire engine lifecycle.

The entire structure of M1 has been designed considering safety and design margins to ensure the reuse of the overall structure after loads exposure during flight and splashdown.

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The recovery system has been studied to withstand the foreseen loads (axial and normal) for 3 times, to ensure the textile performances for the canopy, the suspension lines and the other flight components, considering the possible strength loss due to the fatigue, friction, joint, abrasion and environmental exposure.

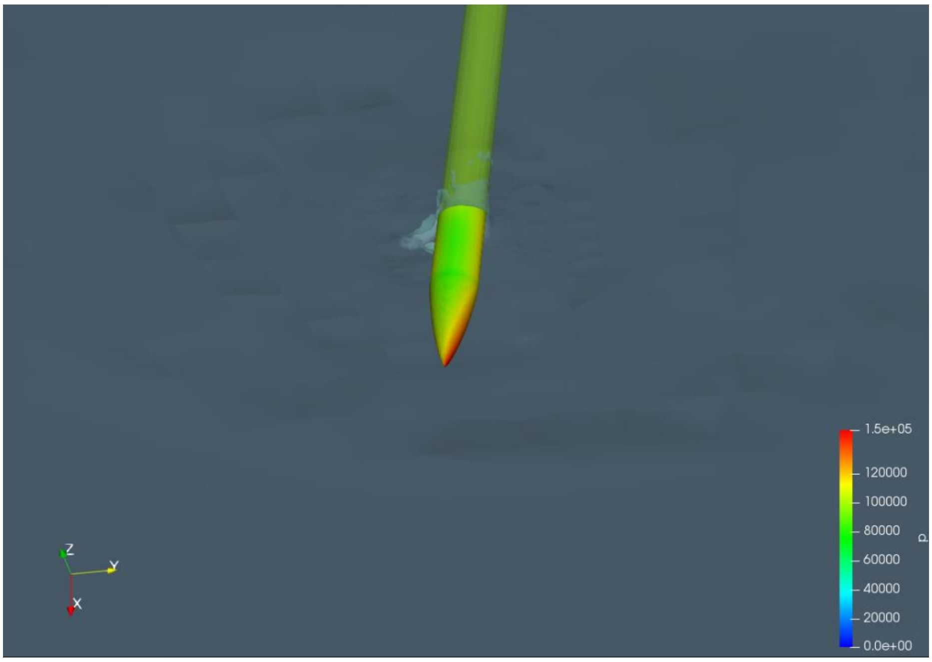

Figure 3 - M1 Splashdown study

4. Recovery System

After the microgravity phase, the vehicle is decelerated during the passive aerobraking phase, corresponding to phase A shown in Figure 4.
Once M1 vehicle has achieved the desired handover condition, the first-stage parachute (drogue chute) will be deployed by means of an ejected hatch (Figure 4 - M1 Descent Phase; events B and C).
The hatch ejection, activated by pyrotechnic initiators, will pull out the drogue d-bag (deployment bag) from the compartment, also known as canister. Then, the drogue d-bag will be taken away from the vehicle by the hatch inertia and the drogue parachute will deploy (Figure 4 - M1 Descent Phase; events C and D). Under the drogue parachute, M1 will be stabilized and decelerated until the achievement of the handover conditions for the main parachute opening.
The main parachute will be deployed by the drogue parachute, which riser will be cut by a sequence cutter activated by a pyrotechnic initiator. The drogue will pull out the d-bag of the main parachute (event E) from the canister. The main parachute will decelerate the vehicle until splashdown, acting under one-stage reefing (events F and G). The parachutes system will be connected to the vehicle until the recovery team will disconnect them through a quick release mechanical link. The drogue and the main parachutes will be connected each other through the kill-line, in the same system configuration as the AFSAT (Air Force subscale Aerial Target) program [2].

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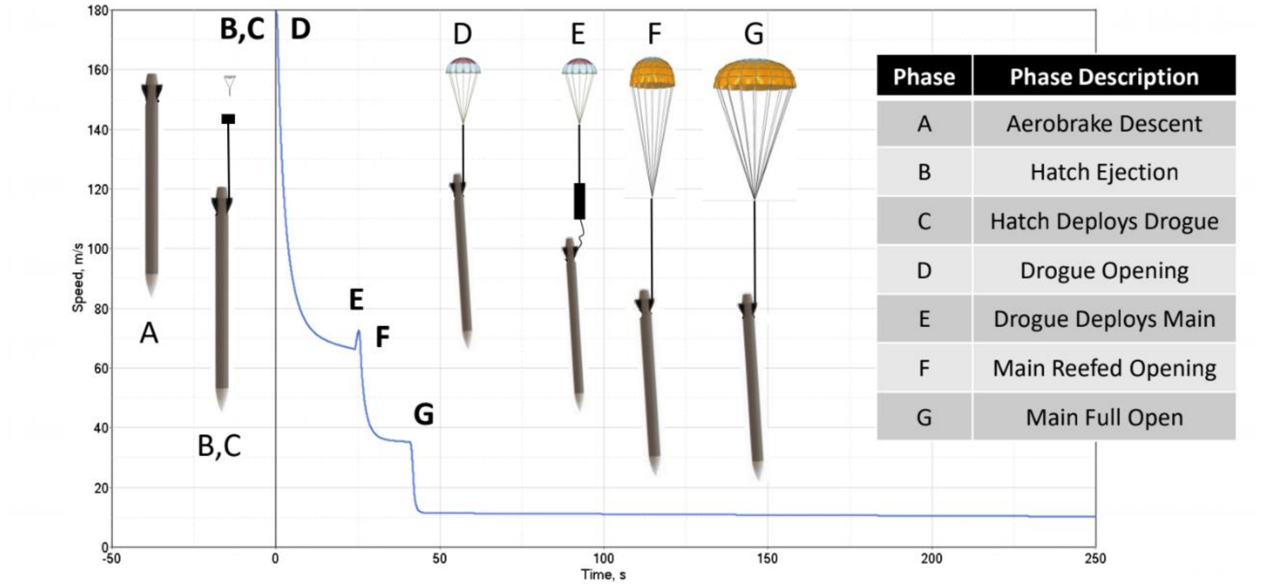

Figure 4 - M1 Descent Phase

4.1 Parachutes System Definition

The parachutes system has been designed jointly by PLD Space and Airborne Systems North America (ASNA), fulfilling the requirements of M1 mission. The vehicle mass and the terminal velocity at splashdown have been the main drivers for the parachutes design. The area and the reference diameter of the main parachute have been defined considering the terminal velocity at the end of the launcher recovery phase, required to be lower than 11 m/s.
The design study has considered the standard day sea level density and the nominal dry mass of M1. The area of the main parachute has been evaluated:

$$\boldsymbol{w = \frac{1}{2}\rho v^2 C_D S_0} \tag{1}$$

Where w is the weight of the vehicle, ρ is the sea level density, v is the terminal velocity, C_D is the conservative drag coefficient obtained from test data and S_0 is the reference surface of the parachute.
Hence, after the preliminary study, the main parachute selected has a reference diameter of 50.4 ft (15.36 m).
The parachute selected is a *Quarter Hemispherical hybrid* chute, a down-scaled version of the main canopy designed for the BQM-167A [2], as part of the AFSAT program. The main parachute is a single stage reefed parachute. The reefing status has been considered to mitigate the loads at inflation.

The main parachute sizing has driven the definition of the drogue parachute characteristics, considering the handover conditions to be achieved for the main parachute deployment. The drogue parachute has been sized for achieving a terminal velocity conditions at a dynamic pressure between 2 and 3 kPa, to ensure a correct deployment of the main parachute. Hence, the reference diameter of the drogue parachute, obtained from (1), has been set as 9.85 ft (3 m). The parachute selected is a *Conical Ribbon* chute, in the same version as the drogue parachute designed for the AFSAT program [2].

Both selected parachutes are flight heritage from the AFSAT program, which is characterized by parachutes designed for splashdown and sea recovery. The selection of COTS (Components Off The Shelves) parachutes reduce the costs for the parachutes recovery system development and qualification, taking advantage from the flight heritage data and the previous flight qualifications.

Both parachutes are stored inside a single canister, one after the other, being the drogue parachute stored between the main parachute and the hatch. As described in 4, the ejected hatch pulls out the drogue d-bag from the compartment, allowing the parachute deployment. The main parachute is deployed once the drogue chute is cut and released, pulling the main parachute d-bag from the canister.

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However, the parachutes system has the same flight configuration as the ASFAT program [2], where the first and second stage of the parachutes system are connected by the *kill-line*. The latter deflates the drogue parachute by "killing its drag" and at the same time pulling the main parachute. Furthermore, the kill-line keeps both parachutes attached, so that it simplifies the recovery of both parachutes.
The parachutes system for AFSAT program was studied and designed for three-time saltwater landings. Nevertheless, some secondary components shall be replaced after each recovery.

4.2 Parachutes System Testing

The parachutes system of M1 has been already tested in ground and flight. Several tests have been performed to analyse the cutting and the hatch ejection events. Nevertheless, a Drop Test has been performed to test the parachutes system in flight, analysing the performances of the descent system and the flight configuration.

4.2.1 Ground Tests

The parachutes and flight components have been tested in early February 2019 at ASNA HQ (Headquarters) to carry out the d-bag fitting, the strip-out, the hatch ejection and the cutting tests. Each test has been successfully accomplished, with very minor design changes when needed.
In particular, the d-bag fitting has been performed to verify the d-bag size and the required features.
The strip-out test is performed to test the correct sequenced deployment of the parachute and verify if other textile elements are needed to have a clear sequence of deployment.
The hatch ejection test data (videos and accelerations) has been analysed to verify the behaviour of the drogue d-bag at hatch opening, to ensure the correct trajectory of the hardware and avoid interference with the drogue parachute deployment, while ensuring the hatch has the needed kinetic energy to ensure drogue deployment.
The cutting test has been carried out to prove the cutting of the riser extension in order to ensure the correct deployment of the main parachute by releasing the drogue parachute.

4.2.2 Flight Test

The Drop Test has been successfully performed in Eloy (AZ) in February 2019, at ASNA Drop zone. The drop test has been performed by dropping a test article from a SkyVan to be recovered by means of the M1 parachutes system.
The test article, a streamlined cylinder, was accommodating inside it a representative canister of M1 rocket, as well as all the elements of the parachute system of M1 including parachutes system, sequence cutters, raiser attachments points locations, etc.

The goal for M1 Drop Test was the achievement of the nominal opening conditions for both drogue and main parachutes, verifying the hatch ejection and consequent drogue parachute opening. Furthemore, the test has also verified the shape of canister and the correct parachutes deployment events.

M1 Drop test has been performed by using a testing article with a representative parachutes system, with main characteristics reported in Table 3. It is worth to mention the fact that there was a third parachute used during a Drop-Test; a conical ribbon parachute used as programmer parachute to ensure stability during the early free-fall phase. The first and second stage parachutes are fully representative of M1 flight configuration, with exception of the main parachute reefing time, which was different from the actual M1 parachutes system.

The objectives of the Drop Test have been successfully accomplished, proving the correct hatch ejection and the parachutes deployment as shown in Figure 5. Thus, the vehicle has been decelerated until the touchdown, achieving a terminal velocity at touchdown of 10.4 m/s.

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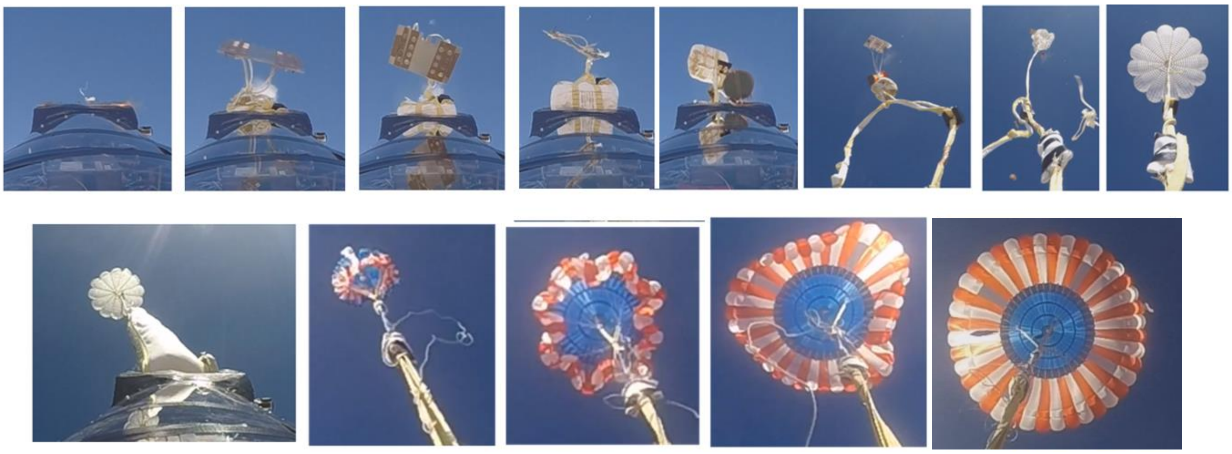

Figure 5 - M1 Drop Test: Sequence of Deployment

Table 3 - M1 Flight vs Drop Test

	MIURA1	M1 Drop Test
Vehicle Length	12.7 m	3.07 m
Vehicle Mass	965 kg	832 kg
Programmer Parachute Type	N/A	Conical Ribbon (for stabilization)
Programmer Parachute D_0	N/A	9.85 ft
Programmer Reefing Ratio	N/A	50 %
Drogue Parachute Type	Conical Ribbon	Conical Ribbon
Drogue Parachute D_0	9.85 ft	9.85 ft
Main Parachute Type	Hybrid Slotted Polyconical	Hybrid Slotted Polyconical
Main Parachute D_0	50.4 ft	50.4 ft
Main reefing ratio	10 %	10 %

5. Recovery Operations

The Recovery Operations will start after M1 splashdown in the ocean. The rocket will be recovered by a tugboat and the recovery operations will be aided by a group of five experienced divers. The number of divers and the type of equipment needed have been defined considering the Spanish National Law, entered into force on February 2018, related to diving and marine operations.
The main drivers for the definition of the recovery operations and the choice of the tugboat have been steered by M1 dimensions, in terms of length and dry mass. In fact, the Recovery tugboat has been chosen considering the dimensions of the free deck and the deck crane lifting capability.
The definition of the recovery operations has led the design of the hoisting points to ensure the retrieval from the ocean. The recovery operations have been identified in nominal and non-nominal cases, reported in the subsections below, to identify all the possible scenarios and the likelihood of occurrence.

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5.1 Recovery Process

M1 will be recovered from offshore at about 80 kilometres from the Gulf of Huelva by the recovery tugboat. The nominal recovery operations are identified in successful splashdown, without significant structural damages, and favourable sea conditions, i.e. sea waves lower than 1.5 meters, where safe diving operations can be ensured.
In case of nominal conditions, the rocket will be retrieved after splashdown by the divers, approaching to M1 by a speedboat, that will be unloaded from the recovery tugboat moments before the splashdown.

M1 will impact the water in a defined zone while the tugboat and the recovery personnel will wait in the safety zone, far from the impact point for safety issues. The recovery operations will follow the same recovery procedures as the FLPP LPSR demonstrator, taking advantage of the experience and the lessons learnt from the successful recovery operations performed in April 2019 to recover the demonstrator and the parachutes system after the FLPP Drop Test.

Once reached the rocket, the divers, on board of the speedboat, will switch off the avionic and telemetry systems to proceed with the retrieval of the flown hardware.
The divers will recover the parachutes system, disconnecting the main parachute from the vehicle through the quick release link. The parachutes will be pulled on the speedboat to be moved later in the barrels with fresh water on the free deck.

After parachutes recovering, the divers will tug the demonstrator close to the tugboat to ease the hoisting to the free deck by the deck crane. The vehicle will be lifted by the defined hoisting points to avoid structural damages. The number of hoisting points has been defined considering the stability of the vehicle during the hoisting focusing on the Centre of Gravity – CG location.
Once lifted from water, M1 will rest on wooden cradles, conveniently secured and fixed on the free deck. Hence, the flown hardware will sail back to the shore of the Harbour of Mazagón. During the sailing to the shore, the flown hardware will be cleaned with fresh water to reduce and mitigate the impact from saline environment. The cleaning procedure is preparatory for accomplishing the reusability strategies.

6. Reusability Strategies

After recovery, M1 will be cleaned on the free deck with fresh water to mitigate the sea water impact and ensure the reusability of the flown hardware. The parachutes, after retrieval from sea, will be submerged in a barrel and rinsed with fresh water to avoid sea water impact on the textile components, which could affect the parachute performances.

The flown hardware, after sailing to shore, will be transported at PLD HQ in Elche, to perform the cleaning procedures and the post flight inspections. The latter are decisive for the reusability of the launcher, in order to identify possible damages and consumable items to be refurbished for re-use.

Even if the entire rocket has been designed to be reused three times, some flight components need to be substitute after each flight because are expendable. Indeed, the recovery system has some one-use elements, which should be replaced after each flight, as the pyrotechnic initiators, the reefing cutters and the riser extensions for the drogue parachute.

The engine has been designed to be fully reusable, but the post- flight inspections are mandatory to verify the status of each component after flight to ensure the foreseen performances.

7. Recovery and Reusability: FLPP Case Study

The FLPP LPSR demonstrator has been for PLD an excellent training for PLD to understand the good practices of the recovery and reusability operations, which has been accomplished in April 2019 in Huelva, South of Spain.
The Drop Test, as above mentioned, was meant to demonstrate the recovery of the first stage for M5, reproducing the descent phase under the recovery parachutes system, and reproducing also the recovery operations to retrieve the FLPP demonstrator from ocean. The Drop Test has been performed at CEDEA-INTA launch base, with the aid of the helicopter CH-47 from the Spanish Army.

The FLPP demonstrator, representative of M5 first stage, which dimensions are shown in Table 4 has been dropped from the CH-47 Chinook helicopter at above 5 kilometres of altitude.

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The FLPP recovery system, representative of the conceived one for the actual first stage of M5, is composed by a two-stage parachutes system. Furthermore, during the FLPP Drop-Test, a third parachute; a conical ribbon programmer parachute, was used in order to provide stability during the initial free fall phase.

The parachutes characteristics are shown in Table 5.

Table 4 - FLPP LPSR Demonstrator

FLPP LPSR Demonstrator	
Vehicle Length	15.07 m
Vehicle Diameter	1.4 m
Vehicle Mass	1710 kg

Table 5 - FLPP LPSR Drop Test: Parachutes Properties

FLPP LPSR Demonstrator			
	Type	D0	Reefing Ratio
Programmer Parachute	Ribbon	9.85 ft	70 % (permanent)
Drogue Parachute	Ribbon	14.55 ft	N/A
Main Parachute	Hybrid Slotted Polyconical	75 ft	10 %

All the parachute deployment sequence after helicopter release has been performed using time-triggered events. The helicopter hook was connected to the programmer parachute static line by a carabiner, which has pulled the programmer d-bag allowing the programmer parachute deployment and inflation (Figure 6) right after the vehicle release. Once reached the representative drogue opening conditions, the programmer riser has been cut by a sequence cutter, activated via a pyrotechnic device. When released the programmer parachute, this pulls out from the canister the drogue d-bag, permitting the drogue parachute deployment and inflation (Figure 7). Once the vehicle has been decelerated and stabilized under the drogue action, the drogue parachute has been cut by the cutter, pulling out the main d-bag from the canister and starting deploying and inflating the main parachute. The FLPP demonstrator has been slow-down under the main parachute until impacting the water at foreseen terminal rate of descent (Figure 8).

It is important to highlight the fact that neither of the three parachutes were connected between themselves, contrary to the M1 parachutes, which are connected by the kill-line (drogue and main parachutes).

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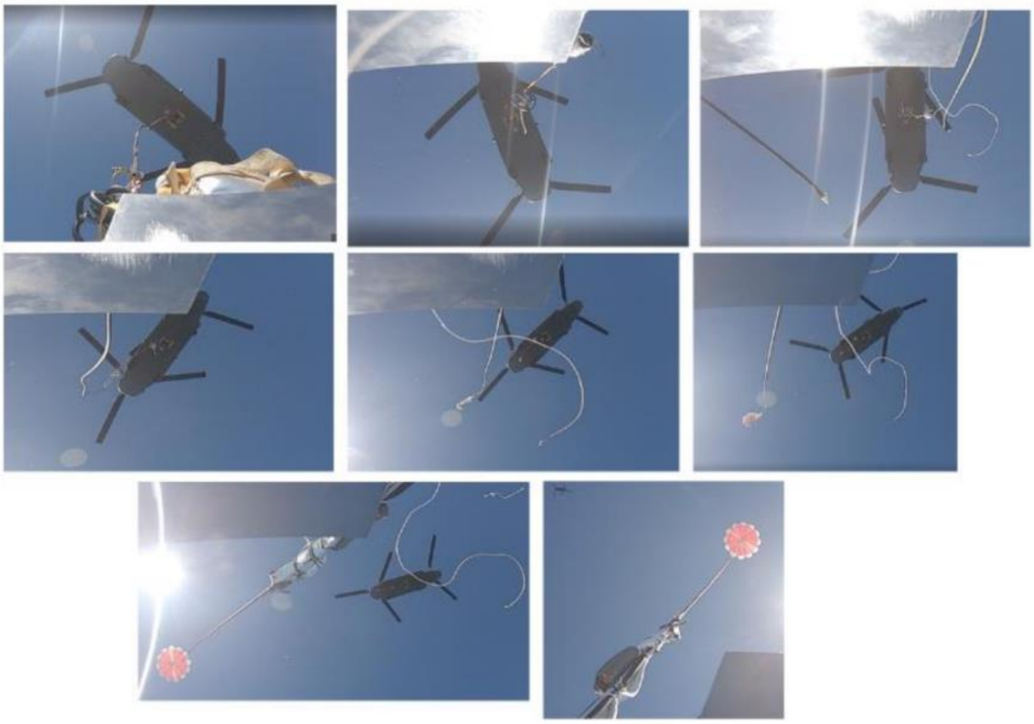

Figure 6 - FLPP LPSR Drop Test: Helicopter Release and Programmer Stage

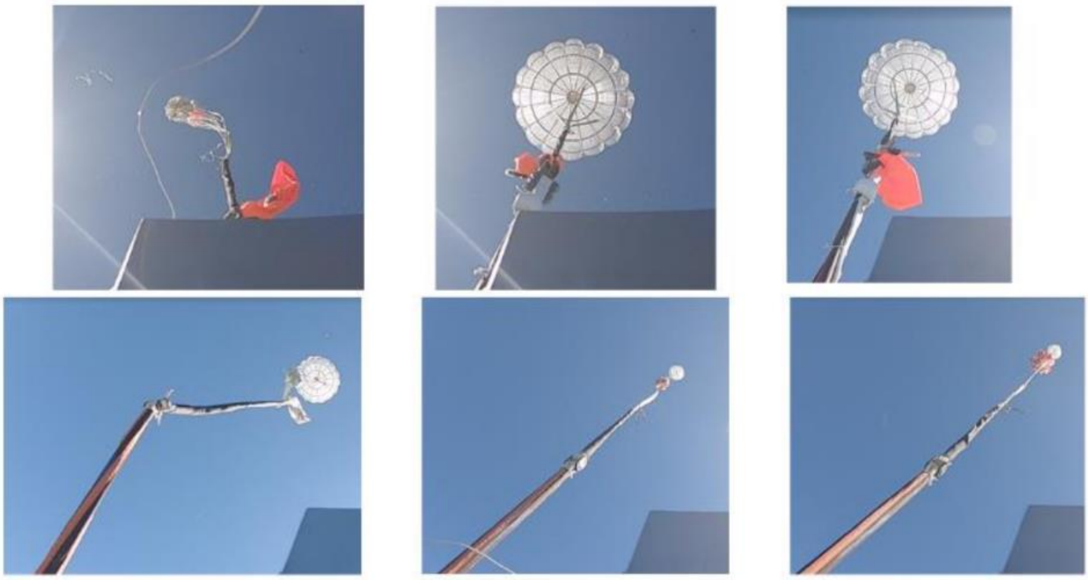

Figure 7 - FLPP LPSR Drop Test: Drogue Stage (inflation up-row, cutting & pulling main bottom-row)

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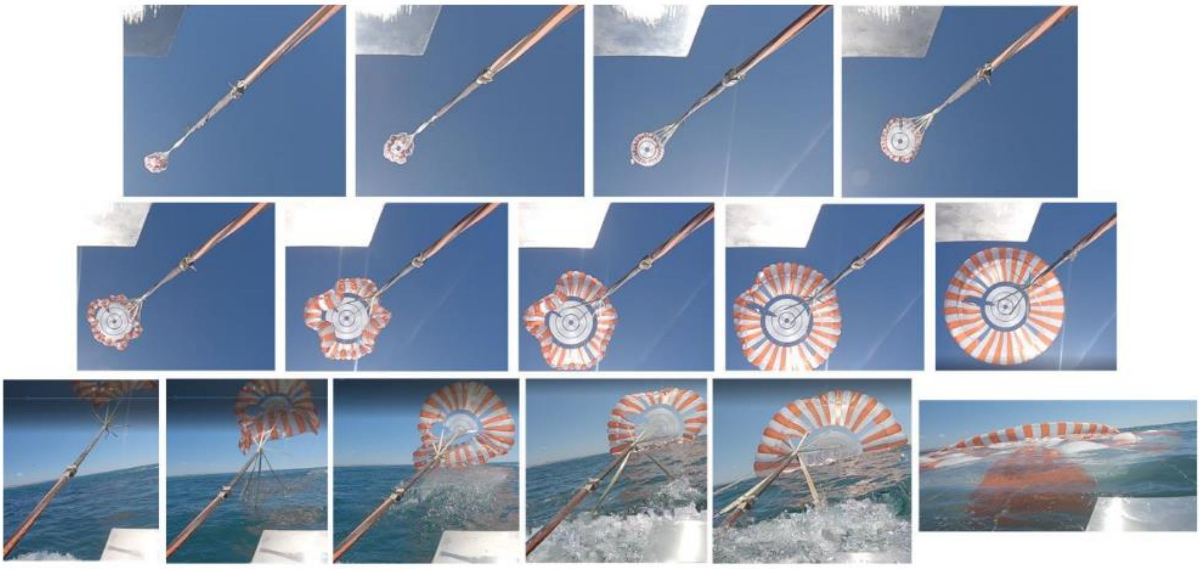

Figure 8 - FLPP LPSR Demonstrator Drop Test: Main Stage and Splashdown

7.1 FLPP Case Study: Recovery Operations

The Recovery Operations for the FLPP LPSR Demonstrator were defined considering the vehicle characteristics and the drop and impact zone. The flown hardware has been recovered by a tugboat, aided by a number of experienced divers' team. The tugboat was chosen considering the free deck and deck crane lifting capabilities to ensure safe and feasible recovery operations.
The zones of interest are shown in Figure 9, where the dotted yellow arrow shows the mean of winds the day of the drop-test, the orange arrow means the simulated helicopter direction and the white arrow represents the real direction of the helicopter during the Drop Test day. Nevertheless, the yellow and red circles show respectively the 1-Sigma and 3-Sigma winds expected coverage zone of possible impact.

Figure 9 - FLPP LPSR Drop Test: Foreseen vs Real Drop and Impact Points

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The tugboat was located outside of the safety zone, shown as the yellow pin in Figure 9. After splashdown, the tugboat has approached the zone of impact to start the recovery operations. Once on site, the divers have approached the demonstrator by a speedboat, following the foreseen sequence of operations.
The recovery team has shut down the avionics and telemetry systems by accessible external buttons and then has proceeded to recovery the main parachute by disconnecting it through the quick release link. After main parachute retrieval, the divers have tugged the demonstrator close to the tugboat to ease the hoisting operations.
The demonstrator has been lifted by the deck crane on the free deck (Figure 10), where has been secured on wooden cradles. Once secured the demonstrator, the main parachute has been submerged inside a barrel with fresh water to mitigate the saltwater impact. Finally, the demonstrator and the flown hardware has been sailed to shore.

The recovery operations have been supported by INTA speedboats to aid the retrieval of the programmer and drogue parachutes, which were equipped by floats and beacon devices to help the tracking in the ocean. The programmer parachute has been successfully recovered, instead the drogue parachute was lost.

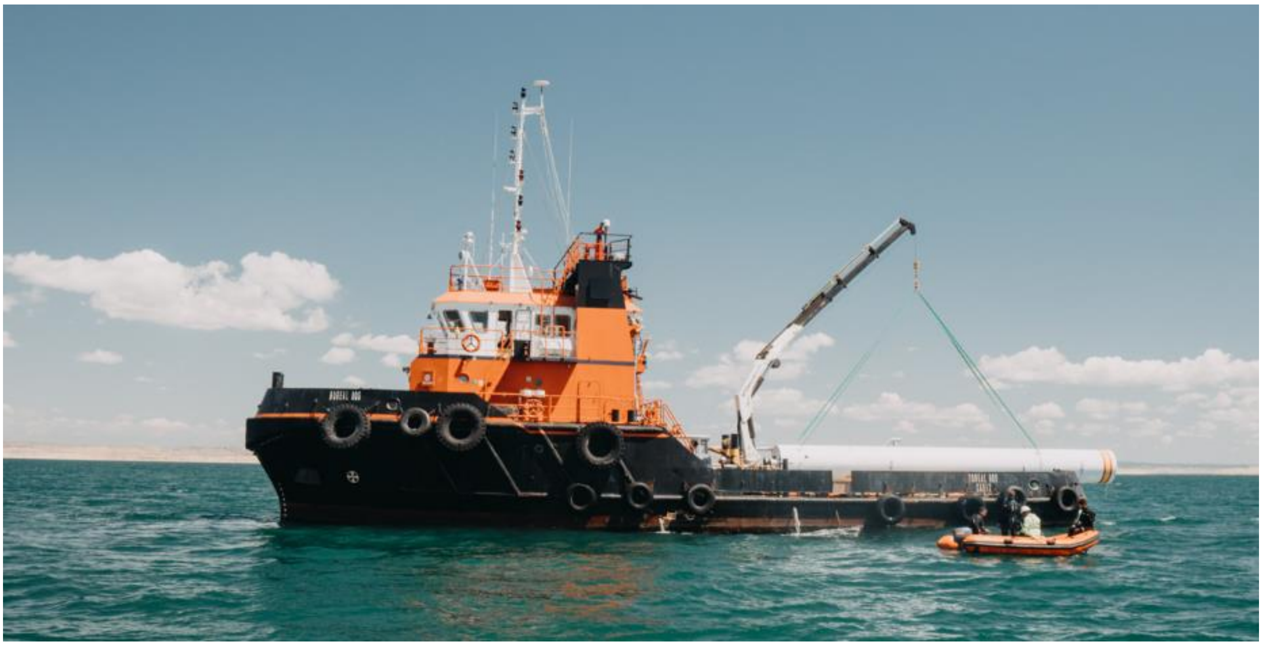

Figure 10 - FLPP LPSR Drop Test: recovery Operations

7.2 FLPP Case Study: Reusability Strategies

The reusability strategies for the FLPP LPSR demonstrator have been focused on the cleaning and post flight inspections. The preventive cleaning from saltwater has been performed on the tugboat while sailing to shore, then the complete cleaning procedure has been accomplished at PLD HQ.
The overall structure and the parachutes have been rinsed with fresh water and have been dried. In the case of the parachutes system, they have been dried using two hanging points (Figure 11).

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Figure 11 - FLPP LPSR: Reusability Procedures

8. Conclusions

This paper meant to demonstrate the development of the recovery and reusability strategies studied by PLD Space, applying these technologies to orbital and suborbital microlaunchers. The accomplishment of the recovery and reusability applied to MIURA1 and MIURA5 will show the accessibility to space and the cost reduction.

PLD Space has already successfully demonstrated the application of the recovery and reusability strategies for the FLPP LPSR Drop Test, showing to the European Space Agency the recovery operations and the reusability studies and procedures for the demonstrator of the first stage of orbital rocket MIURA5 that will be launched in the near future. The FLPP LPSR has been a fully representative demonstration of the recovery descent system analysing the performances and behaviour during the descent phase.

Furthermore, the recovery strategy will also be tested during the first flight of MIURA1 in the next year, showing the capability of the recovery system during the descent phase from apogee to splashdown. The first test flight of MIURA1 will also analyse the recovery operations at about 80 kilometres from the coast and the post flight procedures for reusability studies.

Acknowledgments

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References

[1] M. F. Nürmberger, F. Garcia and R. Torres 2018. ARION 1 – Payload User Guide from PLD Space website (http://pldspace.com/new/wp-content/uploads/2018/06/ARION1_Payload_User_Guide_V1-2_180606.pdf)
[2] R.J. Farhall, R. J. Sinclair, D.A. Meyer. 2007. Design and Testing of the BM-167A Parachute Recovery System