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The Reusability Flight Experiment – ReFEx: Trimming and Full System Bench Test as Final Preparation for Flight

P. Rickmers^{a*}, W. Bauer^a, Olaf Essmann^a, K. Temmen^a, T. Delovski^a, R. Schulz^a, Martin Sippel^a

^aGerman Aerospace Center (DLR), Institute of Space Systems, Robert-Hooke-Str. 7, 28359, Bremen, Germany

* Corresponding Author

Abstract

The Reusability Flight Experiment (ReFEx), developed by the German Aerospace Center (DLR), is a technology demonstration mission aimed at validating key technologies for aerodynamically controlled reusable launch vehicle (RLV) stages. Scheduled for launch in 2027 from the Koonibba Test Range (KTR) in South Australia, ReFEx will be carried by a VSB-30 sounding rocket to a trajectory representative of a returning RLV first-stage. The experiment seeks to autonomously guide the vehicle as far back as possible toward the launch site using only aerodynamic control surfaces, demonstrating fully autonomous flight control capable of critical heading changes and energy-efficient returns.

ReFEx features a compact design, measuring 2.7 meters in length with foldable wings and a mass of approximately 450 kg. The mission will test advanced guidance, navigation and control (GNC) systems, aerodynamic control strategies, structural resilience under hypersonic and subsonic conditions. By collecting flight data to validate aerodynamic models and control algorithms, ReFEx aims to enhance the development of future European reusable launch vehicles, contributing to more sustainable and cost-effective space access.

As was described in previous papers, a key aspect of the project is a rigorous pre-flight verification campaign, including structural integrity tests, avionics integration and environmental simulations. This paper in particular, will describe the trimming process and verification of system functions prior to shipment of the flight vehicle to its launch site. Trimming is a critical and challenging process as two not necessarily compatible sets of requirements need to be satisfied. One, the payload which is aerodynamically active has to be trimmed so that it can safely be launched on a sounding rocket and two, the trimming must be compatible with the deployed flight configuration. In both cases stringent requirements in terms of centre of gravity location as well as moments of inertia have to be satisfied.

In addition, the flight vehicle, also known as the re-entry segment, will have to be functionally checked out prior to flight. The key here is to verify proper system responses to flight conditions, while only being able to simulate very limited parts of the flight environment in the lab. As such a combination of subsystem HiL (Hardware in the Loop) tests and specific complete system tests were devised and will be described in this paper.

Keywords: RLV, hypersonic, flight experiment, AIV, integration

Acronyms/Abbreviations

AIV	Assembly Integration and Verification
CALLISTO	Cooperative Action Leading to Launcher Innovation in Stage Toss back Operations
CoG	Centre of Gravity
CAST	Core Avionics System Testbed
DHS	Data Handling System
DLR	German Aerospace Center
EI	Entry Interface
EoE	End of Experiment

GNC	Guidance Navigation and Control
HiL	Hardware in the Loop
KTR	Koonibba Test Range
MoI	Moments of Intertia
PDU	Power Distribution Unit
PFM	Proto-Flight Model
RCS	Reaction Control System
ReFEx	Reusability Flight Experiment
RLV	Reusable Launch Vehicle
VSB	Veículo de Sondagem Booster

1 Introduction*

The increasing interest in reusable launch vehicles (RLVs) has established reusability as an important element in the development of future space transportation systems. Besides the potential for reducing recurring launch costs, the reuse of flight-proven hardware can provide increased reliability, launch cadence and operational flexibility. However, the design of a reusable launch vehicle is strongly dependent on its mission and operational requirements. In particular, the return of a spent stage can be achieved either predominantly by propulsion, by aerodynamic means, or by a combination of both. These approaches impose substantially different requirements on vehicle design, guidance and control, aerothermodynamics, propulsion and landing systems [1], [2].

The Reusability Flight Experiment (ReFEx) of the German Aerospace Center (DLR) addresses the aerodynamic end of this spectrum. The experiment is designed as a technology demonstrator for a winged, aerodynamically controlled reusable launch vehicle stage and is intended to provide flight-proven experience with the technologies and operational challenges associated with such a return mode [1], [2], [3]. In contrast to a conventional ballistic re-entry experiment, ReFEx is required to autonomously control its trajectory from hypersonic to subsonic velocities and to perform a substantial cross-range manoeuvre representative of the return of a reusable first stage, which tries to return as far as possible towards its launch site. The experiment therefore deliberately combines the characteristics of a high-speed re-entry vehicle with those of a future reusable launch vehicle stage [2], [3].

The primary mission objective is to demonstrate an autonomously controlled aerodynamic return following separation from the launch vehicle. ReFEx shall perform a controlled heading change of more than 30° and subsequently reach a predefined End-of-Experiment (EoE) target with specified limits for position, altitude and velocity [2]. The trajectory is designed to reproduce the characteristic flight conditions of an aerodynamically returning RLV stage while conserving sufficient energy to enable a return as close as possible to the launch site. Importantly, the main atmospheric manoeuvre is

performed without propulsive control; a small cold-gas reaction control system is used only during the exo-atmospheric phase to establish and maintain the required attitude before aerodynamic control becomes effective [3], [4].

A further objective is to demonstrate the autonomous guidance, navigation and control (GNC) functions required to cope with significant uncertainties. ReFEx is launched by an unguided VSB-30 sounding rocket, resulting in considerably greater dispersion at the beginning of the guided flight than would be expected following the controlled ascent of an operational RLV stage. The GNC system must therefore determine the achievable return trajectory based on the actual post-separation state and continuously compensate for deviations arising from navigation, modelling and control uncertainties [3], [5]. The capability to divert towards predefined contingency targets is an additional relevant feature for future reusable stages, for which recovery of an off-nominal but otherwise functional vehicle is preferable to terminating the flight [2], [5].

Beyond the demonstration of the flight trajectory itself, ReFEx is intended to generate flight data for the validation of aerodynamic, aerothermal, flight-mechanics and control models and tools. Such data are particularly valuable because the coupled hypersonic-to-subsonic flight environment and the interaction between vehicle aerodynamics, thermal loads and active flight control cannot be fully reproduced by ground testing alone [2], [6]. The experiment consequently serves not only as a demonstration of individual technologies, but also as a means of reducing uncertainties in the prediction and design of future reusable stages.

ReFEx therefore constitutes an important element of DLR's broader RLV technology programme. Together with the CALLISTO flight experiment, which investigates propulsive vertical take-off and landing, ReFEx provides complementary experimental experience at the two ends of the RLV return spectrum. The resulting design, manufacturing, operational and flight experience is intended to support the maturation and future development of reusable launch vehicle technologies in Europe [1], [2].

* The introduction & flight events sections were generated from several recent ReFEx papers using AI

(see Acknowledgements) and was subsequently proof-read and edited.

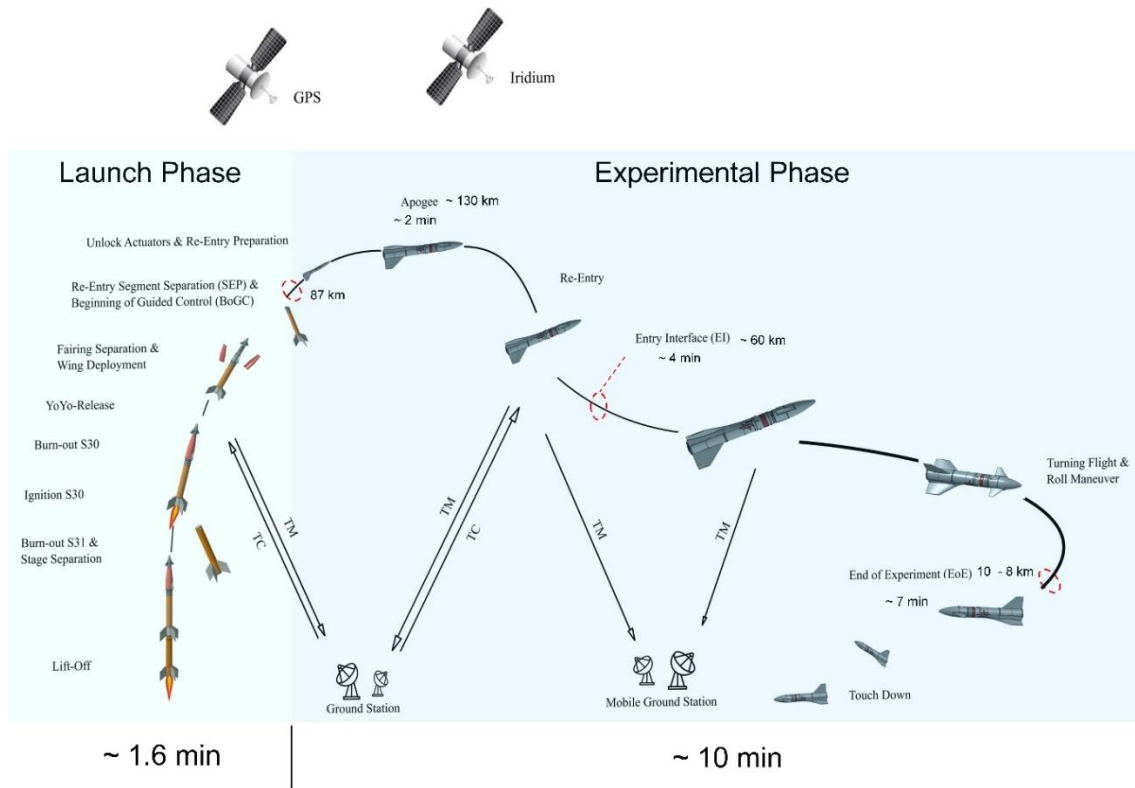


Fig. 1: ReFEx mission flight events and timeline

1.1 Flight Events*

The ReFEx flight experiment is designed to reproduce the characteristic return trajectory of an aerodynamically controlled reusable launch vehicle stage within the constraints of a sounding-rocket-based flight experiment. The vehicle is launched from the Koonibba Test Range (KTR) in South Australia on a two-stage VSB-30 sounding rocket [7].

Since the carrier is passively stabilized and unguided, the trajectory at separation exhibits significantly higher dispersion than would be expected for an operational RLV stage launched by a thrust-vector-controlled launch vehicle. This characteristic is incorporated into the mission design, requiring the ReFEx Guidance, Navigation and Control (GNC) system to autonomously compensate for the resulting deviations during the subsequent return flight [5], [7].

Following ascent and separation from the VSB-30, the re-entry segment (i.e. ReFEx experimental vehicle) reaches an apogee of approximately 135 km at a velocity slightly above Mach 5 [2].

After burnout of the second stage of the sounding rocket, a Yo-Yo system reduces the spin induced for stabilization during the ascent. The ReFEx re-entry segment is subsequently separated from the carrier and

deploys its folding wings. During the initial ballistic, near-vacuum phase, aerodynamic control is ineffective; therefore, a cold-gas reaction control system provides the required attitude control, reduces further any residual disturbances left over from the Yo-Yo manoeuvre and establishes the orientation for atmospheric entry [2].

At the Entry Interface (EI), defined by the dynamic pressure at which aerodynamic control becomes effective and located at approximately 60 km altitude for the nominal trajectory, ReFEx transitions to actively guided flight. The aerodynamic control surfaces—comprising canards and rudder—are then used to control the vehicle throughout the hypersonic and subsequent flight phases. A central mission objective is the execution of a heading change exceeding 30°, representing the lateral manoeuvre required to redirect a returning first stage back towards its launch site [2], [3].

The subsequent trajectory is autonomously adapted to the actual flight state and follows a predefined return strategy towards the designated End-of-Experiment (EoE) point. Thus, the experiment does not merely demonstrate aerodynamic control under nominal conditions, but also tests the capability of the complete GNC system to recover from the initial trajectory

dispersion introduced by the unguided carrier. Successful compensation of this dispersion and convergence towards the predefined target is consequently a key element of the ReFEx flight demonstration [2], [5], [7]. The experiment terminates in an unpowered hard landing within the designated safety area, with impact-resistant onboard data recorders preserving the flight data required for subsequent analysis and model validation.

1.2 Current Status of the AIV Campaign

At the time of writing this paper, the final phase of the so-called AIV PFM campaign is underway. The vehicle is divided into the following segments.

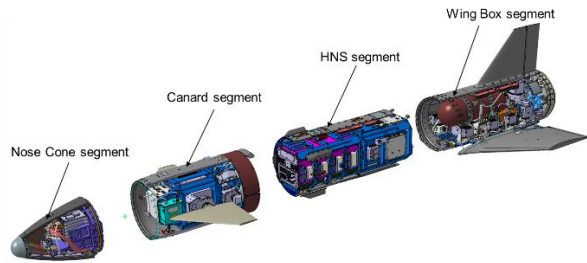


Fig. 2: Segments of the ReFEx vehicle

S1: The nose cone segment is the frontmost part of the vehicle. Among others it contains electronics box 1 (EBX1) as well as the flush air system (FADS), which are a critical part of the flight control loop of the GNC system. They provide the actual aerodynamic angles (yaw, pitch and roll) with respect to the oncoming flow vector. This data is critical to maintain flight stability and can not be established by any other means. Picture of this segment is given in Fig. 3

S2: The Canard segment houses the Guidance & Control Computer (GCC), the canards (including their actuators) and the actuator control electronics. It also contains a C-band radar system and several camera systems. Some of these focus rearward towards the main wings, while others are infrared cameras of the flight instrumentation, monitoring the heat distribution of the canards during reentry. In addition, hardware for the real time telemetry is located in this segment.

S3: The HNS module and the Rear HNS module are physically housed within the same fuselage segment, the HNS Segment. The name derives from the Hybrid Navigation System (HNS), a key component of the vehicle, which provides the navigation message containing a fused solution of several sensors which contains the position and orientation of ReFEx with high special and temporal resolution [8], [9], [10].

The Rear HNS module is located directly behind the HNS in the same fuselage segment and comprises of several hardware components for the flight instrumentation as well as the data handling system (DHS), which is a key component of the avionics architecture of ReFEx. It gathers information on all subsystems, multiplexes these into a single telemetry data stream and transmits this data to the ground via the TM/TC system. In addition, it also provides the return communication path, allowing telecommands to be sent from the ground to each of the subsystems for configuration just before flight, as well as some critical commands that might be needed during flight.

Due to active work schedule a picture of this segment including HNS and Rear HNS module cannot be presented here.

S4: The Wing Box segment forms the rear end of the vehicle. It houses the tailplane and the foldable horizontal wings, the associated actuators including electronics, the RCS including the fuel tank.

Picture of this segment is given in Fig. 5 and Fig. 6.

Active work is still ongoing in most segments, however all segments except S3 are mostly completed sometimes including final check-out.

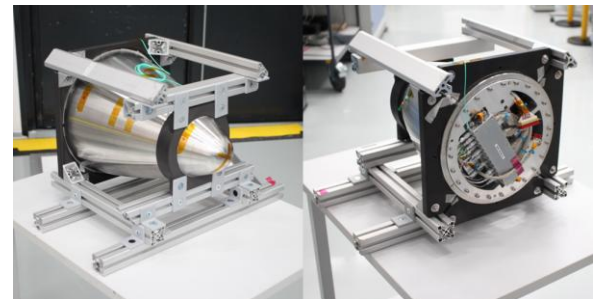


Fig. 3: Nose Cone segment

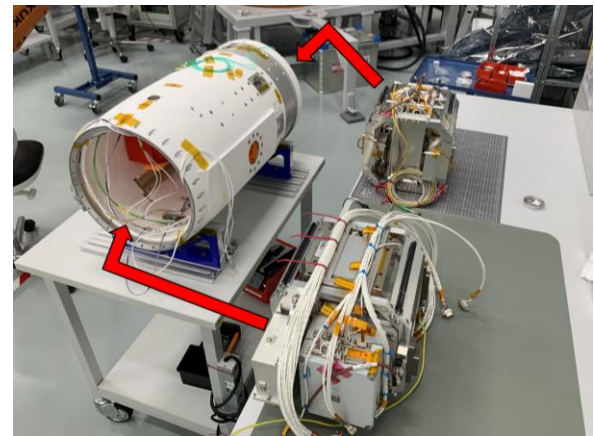


Fig. 4: Canard segment with Canard & TM/TC module

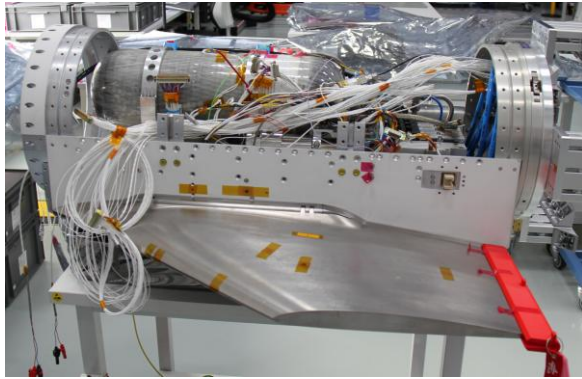


Fig. 5: Wing Box segment (open) with RCS module

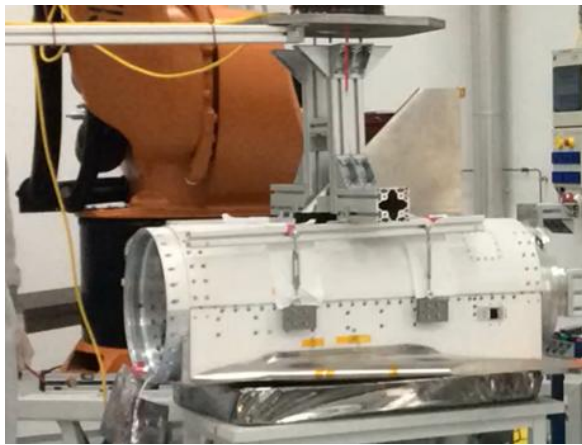


Fig. 6: Wing Box segment (closed)

1.3 Harness Design Challenges

As can be gathered from the figures of the individual segments, the harness is one of the biggest challenges in this project, which is not only down to the integration of ReFEx (mostly volume constraints) but also to design decisions at system and subsystem level.

It all starts with the overall structure that is split into 8 core subsystems. Within these subsystems, there are a total of 55 units – that is, electronic boxes containing the components' electronics. These units contain at least one, but sometimes several, connectors. These connectors are used to interconnect the units; for example, they supply power or exchange data with other units.

In ReFEx, there are a total of 225 connectors on the various units. The first challenge for the harness here is that there are many different types of connectors. In total, there are more than 35 different connector types, such as D-SUB, HD-SUB, Combo-D, LEMO, SMA, etc.

One of the biggest challenges becomes apparent when planning the different connectors and their pinouts. As already mentioned, there are 225 connectors used to link the units. A connection between two units is referred to as an interface. An interface can be many things, such as a power connection or a communication channel. In an ideal world, there would be one connector per interface, meaning there would always be 1:1 connections only between two units. In practice, however, this is unrealistic and often not even feasible for example due to mechanical reasons. Consequently, several interfaces are combined on a single connector. The problem is that the different interfaces on the connector also have different destinations. If, for example, a connector carries a power interface and a data interface, then the power interface must be routed to the power system and the data interface to the data-handling system. This results not in a 1:1 connection, but in a 1:2 connection within the harness. As the addressed systems are rarely located directly next to one another, but are spatially separated, the connections within the harness have different lengths and must be routed differently.

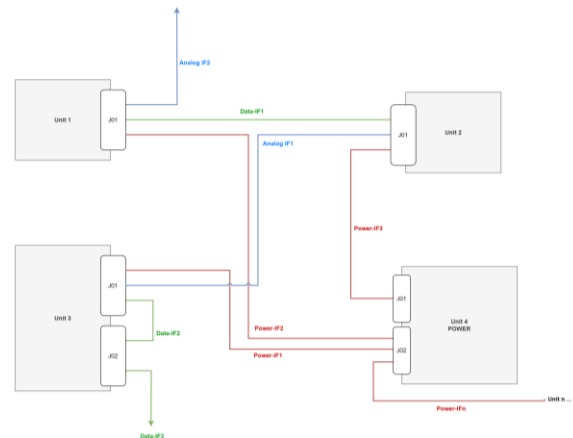


Fig. 7: Harness design challenges example

In ReFEx, the key components for the harness are the power system and the data-handling system (DHS), as these subsystems are connected to all other subsystems. Large connectors have been used for both subsystems, with various interfaces combined onto them. The power system has two large connectors, and all 22 channels are distributed across these two. This means that a single PDU (power distribution unit) connector must already connect 11 different units using a single harness. When looking at the first connection from the PDU to Unit 1, one can observe that a connector containing several interfaces has also been used here. This means that from Unit 1, the connection continues via the same connector to Unit 2 via a data link and to a different Unit via an analogue

connection. This complexity continues for Unit 2 and Unit 3. Both require power, but both also communicate with the data-handling system. The consequence is, that in principle, everything is interconnected. The harness consists of a single long string of unites (see Figure 1). This poses a major challenge not only for cable routing but also for the design and manufacture of this wiring harness, as the units are physically separated from one another, resulting in varying cable lengths and routing paths that must first be synchronised with the cable routing plan.

So far, the overall harness and connection structure only have been considered on paper. However, the complexity goes one step further, as accommodation and the vehicle itself must also be considered.

ReFEx consists of a primary and a secondary structure. The secondary structure is a cage into which the units are fitted and later slid into the primary structure. At first glance, this is a flexible design meant to simplify integration, as the secondary structure can be integrated on the workbench and then slid into place at the end. In ReFEx, however, changes have been made to this concept for various reasons. The primary and secondary structures consist of a total of four segments (see Fig. 2 and Fig. 8).

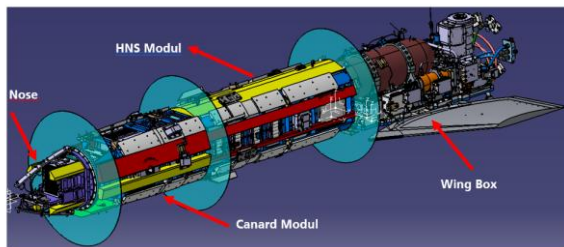


Fig. 8: Subsystem of ReFEx with segment boundaries indicated.

These four segments are assembled individually and joined together at the very end. Within the two central segments, there is also a further division within the secondary structure. The cage is therefore divided into two parts, with one part being slid into the primary structure from one side and the other part from the opposite side. This assembly process makes working on the harness immensely challenging, but was necessary due to other design constraints.

The cages are still integrated on the workbench, with the units being bolted into place. As everything is packed very tightly, some connectors become inaccessible once fitted. Consequently, parts of the harness must already be connected during the cage integration process. If there are connections between two cages, the vehicle cannot be assembled due to the integration sequence described above. Either a very

large loop would form in the harness, or it would be impossible to feed it into the primary structure at all.

To make this integration feasible at all, a further 48 intermediate connectors (known as segment connectors) had to be introduced in addition to the 225 connectors. These bundle the interfaces from one cage that led into another cage or segment and route them to the nearest physical separation point. There, these segment connectors can then be connected to one another at the very end, when the vehicle is finally assembled.

This increases the planning effort involved and the risk of errors increases (more connections), as some interfaces have to be routed via several segment connectors before they reach their destination. The same applies to units attached to the primary structure, such as antennas or sensors. These must be routed to units within the secondary structure. Due to this plug-in system, the integration and harness routing also present a major challenge.

Furthermore, due to the system's compact design and experimental nature (design changes still occurring late in the development process), compromises had to be made during the manufacture of the harness to implement the harness in this project such as dispensing with backshells or further splitting the harness where bending radii were too tight.

1.4 *Trimming the Flight vehicle*

In principle there are two trimming conditions to be met. One is the configuration for launch with the wings folded and the fairing attached, while the second is the re-entry configuration, detached from the carrier rocket and wings unfolded.

The first configuration needs the CoG (Centre of Gravity) to be on the centre line of the launch vehicle and sufficiently forward to conform to the static margin requirements during launch [11]. Since the wings are folded, this means that the CoG of the re-entry segment alone is not on its dorsal-ventral mid plane. This is only the case for the flight configuration, with the wings unfolded. In addition, the rudder of the re-entry segment is significantly heavier than the dummy rudder on the opposite fairing section. The trimming for the launch configuration can hence only be accomplished via the fairings. Here additional masses are added on the fairing section containing the dummy rudder and these re meant to shift the CoG to the midline of the integrated stack for launch.

The flight configuration is trimmed during the integration process in its fully deployed form using

several internal and external trimming masses to achieve the proper CoG position. This trimming strategy will be explained further in the following sections.

The trimming strategy for the flight configuration is based on the mathematical module of the system, managed via CAD. During the design phase of the system, the CAD model was used to calculate the CoG as well as the moments of inertia (MoI). Due to the unknown difference between the designed CoG and its actual position, locations for trim masses were added, see Figure 1

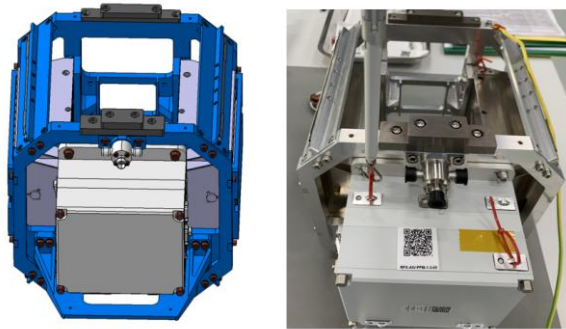


Figure 1: Trim masses as designed (left), as build (right)

These trim masses can be adjusted as needed during the integration of the vehicle. To accomplish this, every compartment and unit of the system was measured during the integration process. The information about the actual weight of a component is fed back into the CAD module in order to calculate the center of gravity as accurately as possible.

The challenge here is the influence of the harness. Although the harness is designed within the CAD and the actual weight of each harness item was measured; the positioning of the harness can never be perfectly accurate. Therefore, under the approximation, that the difference between design and actual positioning of the harness is evenly distributed over the whole vehicle, each segment will be measured separately with high accuracy using the measurement method by Resonic. The segments can be positioned separately on the Resonic measurement table with the loose harness, which is used to connect the segments suspended by hanging ropes. After each measurement a trimming step is planned to adjust the trim masses if needed. The overall vehicle CoG is then calculated as sum of the segments.

1.5 Functional Checkout

The functional verification of the reentry segment comprises three overarching, mission-critical functional groups:

- Mechanisms
- Thermal
- Electrical

Mechanisms

The ReFEx re-entry segment is equipped with three deployment mechanisms, three actuators and one Reaction Control System (RCS). The verification of the system functionality is done using end-to-end testing with gradually increasing system complexity. All tests are directly linked to the sine- and random vibration environmental tests, resembling the vehicle ascent phase.

Thermal

The thermal design of the RFX vehicle is intended to ensure that the maximum permissible temperature of its critical components is not exceeded by the end of the flight. To ensure this, the equilibrium temperature must be stabilised at a value of approximately 20°C prior to launch. As the vehicle is protected from external influences at the launch site KTR by a polystyrene box, active cooling must be used to maintain the desired equilibrium at least temperature inside the box. A special pre-launch mode is used to calibrate the vehicle using the minimum necessary systems. Should the temperature inside the vehicle exceed the maximum permissible temperature for launch, active cooling will also be required within the vehicle itself. To this end, an interface for the supply of cooled air has been incorporated into the design of the primary structure. Verification is carried out on the fully integrated PFM.

Electrical

Electrical verification of subsystems follows a three-step approach. Subsystem verification has been carried out on the Core Avionics System Testbed (CAST). Verification within CAST is similar to the procedure used for spacecraft, whereby a so-called 'Flatsat' setup is used to verify that all subsystems and software are functioning correctly on interface and protocol level. Following verification in CAST, the subsystems are gradually transferred to the secondary vehicle structure and finally brought into their final configuration together with the primary structure. Before the secondary structure is finally joined to the

primary structure to form the finished vehicle, the individual segments are electrically connected to one another in order to identify any potential faults whilst the subsystems are still accessible. This procedure on the PFM is familiar from traditional bench tests and differs from the Flatsat approach described, in which there is no longer an intermediate step prior to integration into the flight model. Whilst the bench test in the second step involves verifying data integrity, functionality and electrical continuity, the third and final step focuses on full system verification (SVT), including thermal and mechanical.

a) Lift-Off and Separation Switches

Verification of the functionality of all release switch systems. This includes the Lift-Off switch, the fairing release switches and the vehicle separation switch in a simulated mission timeline. The release actuation shall trigger the expected mode switch and validate the harness design.

b) RF Compatibility Test

The RF compatibility test verifies the functionality of the RF communication infrastructure, including TMTC, Flight Termination System (FTS), GNSS and ground segment equipment (GSE).

c) Sensory

ReFEx is equipped with a wide range of different sensors. These include various types of temperature and pressure sensors, as well as optical and infrared cameras.

d) EMC, Plugs-Out-Test, Countdown training

This combined test is the last step in the PFM functional verification. The PFM will be operated standalone with the payload adapter and the ground segment for a full mission simulation. The EMC compatibility of the fully integrated vehicle is cross-checked with the subsystem EMC behaviour. After that, the countdown elements, ground operations and the mission timeline are simulated to the extend manageable in an on-ground setup to train the operations and cross-check the vehicle functions in the complete system setup.

2 Conclusions

The Reusability Flight Experiment, ReFEx, has reached an important milestone on its way to flight. The PFM campaign at the DLR Institute of Space Systems in Bremen has entered its final phase, with the focus now on final integration, system-level verification, and testing of the flight vehicle. The activities performed during this campaign demonstrate the considerable effort and complexity involved in bringing a technology demonstrator from the development phase to flight readiness, in particular when integrating a combination of newly developed and flight-proven technologies into a complete experimental vehicle.

Following the completion of the remaining integration and test activities, ReFEx will undergo its final acceptance review before being shipped to the Koonibba Test Range in South Australia. Based on the current schedule in the first half of 2027. During this period, the remaining acceptance and flight preparation activities, transportation to Australia, and the subsequent launch campaign will lead to the final flight readiness of the experiment. The upcoming flight will represent the culmination of the ReFEx development and qualification activities and will provide valuable flight data on the aerodynamic and flight-dynamic behaviour of a reusable, aerodynamically controlled reusable stage. These data will contribute to the validation and refinement of models and simulation methods and, ultimately, support the further development of technologies for future reusable launch vehicle stages.

Acknowledgements

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References

- [1] W. Bauer *et al.*, 'DLR Reusability Flight Experiment ReFEx', *Acta Astronaut.*, vol. 168, pp. 57–68, Nov. 2019.
- [2] P. Rickmers *et al.*, 'The CALLISTO and ReFEx flight experiments at DLR - Challenges and opportunities of a wholistic approach', *Acta Astronaut.*, vol. 225, pp. 417–433, Dec. 2024, doi: 10.1016/j.actaastro.2024.09.024.
- [3] P. Rickmers, W. Bauer, G. Wübbels, and S. Kottmeier, 'ReFEx: Reusability Flight Experiment – A Demonstration Experiment for Technologies for Aerodynamically Controlled RLV Stages', presented at the Aerospace Europe

Conference 2023, Lausanne, Switzerland, Jul. 2023.

- [4] P. Rickmers *et al.*, ‘The Reusability Flight Experiment - ReFEx: A Project Update and Insight into Pre-flight Test Campaigns’, in *Proceedings of the International Astronautical Congress, IAC*, Milan, Oct. 2024. Accessed: Jun. 25, 2025. [Online]. Available: <https://elib.dlr.de/213596/>
- [5] J. L. Redondo Gutierrez, D. Seelbinder, and S. Theil, ‘Design of ReFEx Guidance: Trajectory Correction after Ascent’, in *AIAA Science and Technology Forum and Exposition, AIAA SciTech Forum 2023*, National Harbor, MD, USA: American Institute of Aeronautics and Astronautics, Inc., 2023. doi: 10.2514/6.2023-1995.
- [6] M. Franze *et al.*, ‘Aerothermal Loads Analysis of ReFEx by coupled CFD Calculations’, in *HiSST: 3rd International Conference on High-Speed Vehicle Science and Technology*, Busan, Korea: CEAS, Apr. 2024, pp. 1–15. Accessed: Jul. 26, 2024. [Online]. Available: <https://elib.dlr.de/204469/>
- [7] P. Rickmers, W. Bauer, K. Temmen, T. Delovski, A. Schmidt, and J. Göser, ‘The Reusability Flight Experiment – ReFEx: Details of the Protoflight-model Integration Campaign and Final Update Prior to Flight’, in *Proceedings of the International Astronautical Congress, IAC*, Sydney, Australien, Oct. 2025. Accessed: Apr. 01, 2026. [Online]. Available: <https://elib.dlr.de/223776/>
- [8] R. Schwarz *et al.*, ‘Overview of Flight Guidance, Navigation, and Control for the DLR Reusability Flight Experiment (ReFEx)’, presented at the 8TH EUROPEAN CONFERENCE FOR AERONAUTICS AND SPACE SCIENCES (EUCASS), Madrid, Spain, Jul. 2019.
- [9] J. L. Redondo Gutierrez *et al.*, ‘ReFEx: Reusability Flight Experiment – Architecture and Algorithmic Design of the GNC Subsystem’, presented at the Aerospace Europe Conference 2023, Lausanne, Switzerland, Jul. 2023.
- [10] R. Schwarz *et al.*, ‘Architectures of Hybrid Navigation Systems (HNS) for Reusable Space Transportation Systems’, in *70th International Astronautical Congress (IAC)*, Washington, D.C., United States, Oct. 2019. Accessed: Aug. 28, 2023. [Online]. Available: <https://elib.dlr.de/130465/>
- [11] A. Schmidt, R. Kirchhartz, and W. Jung, ‘ReFEx Launch with a Sounding Rocket - A Challenging Mission on a Reliable Carrier’, presented at the 8TH EUROPEAN CONFERENCE FOR

AERONAUTICS AND SPACE SCIENCES (EUCASS), Madrid, Spain, Jul. 2019.

- [12] OpenAI. (2026). *ChatGPT (Aug 09 version) [Large language model]*. [Online]. Available: <https://chat.openai.com/>