THE ICARUS FLIGHT TEST: A SOUNDING ROCKET PLATFORM FOR AN INFLATABLE AERODYNAMIC DECELERATOR EXPERIMENT

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ABSTRACT

ICARUS is a project funded by the European Union's HORIZON EUROPE program under the grant agreement No 101134997. It targets to bring up to TRL6 the maturation of enabling technologies in the field of re-usable space transportation systems, addressing the innovative re-entry solution based on Inflatable Heat Shields (IHS), deemed applicable for recovery of launch vehicles or their stages.
This paper will present the design of the ICARUS flight test with respect to the mission ConOps, sounding rocket platform selection, sounding rocket configuration, payload accommodation and a test range description with its facilities.

***Index Terms*—** Inflatable Heat Shields, Re-entry Technologies, Aerodynamic Decelerators, Flexible TPS, Inflatable Structure, Health Monitoring Sensors, Launcher Reusability, Entry Descent Landing

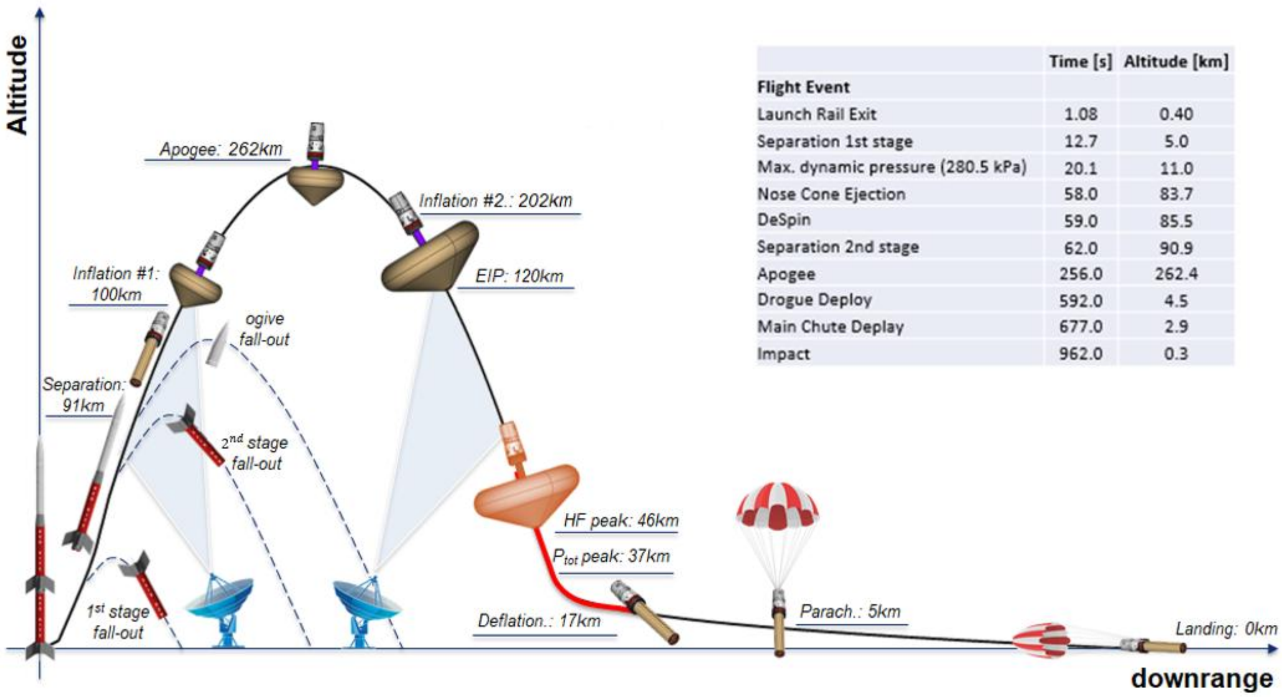
1. INTRODUCTION

Sounding rockets are a unique experimental infrastructure for a broad variety of research disciplines. The unmanned, highly customizable and cost-effective research platform provides high quality, multi-minute experimental conditions for example for microgravity research with residual accelerations as low as 10^{-6} g for experiments in research areas such as material physics, life sciences, fluid dynamics, as well as also atmospheric and hypersonic research. Technology testing under space or re-entry conditions complete the service portfolio of sounding rockets for scientific purposes. The German Aerospace Center (DLR) with its Mobile Rocket Base (MORABA), provides a "mix-and-match" concept in the adaption and combination of vehicle systems and rocket motors that, together with new developments and optimizations, results in a full performance portfolio of launch vehicles carrying payload masses from the lower spectrum (100 kg to altitudes of 100 km) to higher performances (400 kg to altitudes of 260 km) or above. The adaptability and versality is demonstrated by a launch vehicle configuration that transports an experimental re-entry vehicle to representative flight conditions (1). In the scope of the ICARUS (Inflatable Concept Aeroshell for the Recovery of a re-Usable launcher Stage) joint project led by INDRA DEIMOS, a powerful two-stage sounding rocket vehicle is being designed that safely separates the re-entry experiment vehicle from the second stage when the experimental environmental conditions are reached. This active separation system differs from the "classic" variants, as the payload has to be pulled out of a protective cover over its entire length. The experimental vehicle layout is presented with the focus on payload subsystems for data handling and transmission, avionics, power control, parachute recovery and rocket motor system. The launch campaign will be carried out at SSC's launch range ESRANGE in northern Sweden, where a wide range of ground infrastructure is available for demanding sounding rocket missions including a vast land recovery area.

2. MISSION CONOPS

The ICARUS demonstrator mission is closely derived in terms of trajectory from a standard 6 min micro-gravity trajectory that builds the backbone of many scientific research programs in Europe as i.e. DLR's material physics research program MAPHEUS, the German national microgravity research program TEXUS or SSC's Suborbital Express program. The trajectory consists of a classical nearly vertical trajectory with launch elevations between 85 and 89 deg and maximum ground ranges up to 90 km with an apogee in the order of 250 km. During the flight, the vehicle configuration will change to the reentry and experimental configuration and expose the Aerodemonstrator with the additional payload subsystems. During the ascent phase the inflatable aeroshell with the corresponding subsystems is integrated into a cylindrical payload structure and design studies investigate the maximum available volume by considering as well important constraints. Opposite to the classical micro-gravity missions, the focus of the ICARUS project is set to the reentry experiment window opening at 120 km on the downleg until ≈17 km altitude. The reentry experiment vehicle has to be recovered after the flight for post flight inspection, analyses and onboard data retrieval. The ICARUS mission develops through the following phases:

A. Pre-launch: pre-integration and tests, transport to launch site, storage, final integration and tests, installation on launcher and transport to launch pad
B. Launch: lift off and ascent in thrust phase by the rocket motor system
C. Coasting: RV ascent in ballistic mode only (RMS no longer attached – no thrust)
D. Re-entry: RV ballistic gliding re-entry driven by the inflated-shape aerodynamics
E. Tumbling: RV descent driven by the imploded-shape aerodynamics
F. Parachute Descent: RV descent driven by the parachute aerodynamics
G. Recovery: Post-landing operations (incl. retrieval, transport to integration facility, recovery and post-flight inspection/analysis of flight data)



Flight Event	Time [s]	Altitude [km]
Launch Rail Exit	1.08	0.40
Separation 1st stage	12.7	5.0
Max. dynamic pressure (280.5 kPa)	20.1	11.0
Nose Cone Ejection	58.0	83.7
DeSpin	59.0	85.5
Separation 2nd stage	62.0	90.9
Apogee	256.0	262.4
Drogue Deploy	592.0	4.5
Main Chute Deplay	677.0	2.9
Impact	962.0	0.3

Figure 1: ICARUS Mission ConOps

Apart from delivery in the pre-launch phase, the first key event is the lift off on-board of the Red-Kite sounding rocket during the launch phase.

After the launch, a first ascent takes place with the thrust generated by the Red Kite/Red Kite rocket vehicle, until the separation of the spent second stage motor will occur allowing the Re-entry Vehicle to continue its ascent in ballistic mode with still the payload subsystems attached to the Aerodemonstrator in a stowed configuration and the RS ogive attached as well.

Afterwards, the confinement-bag is released, and a few seconds later the first inflation action will take place bringing the RV to sort of 'partial deployed configuration'. Before the apogee is reached (≈255 km) the rocket ogive is also separated and the second inflation action is commanded by the on-board avionics: this will ensure a fully inflated configuration is in place before atmospheric entry occurs.

Then, the RV will continue its ballistic trajectory down to Earth entering the atmosphere at an altitude of about 120 km performing a ballistic uncontrolled flight driven by the inflated aeroshape aerodynamics and starting the experimental phase of the mission.

During this phase, the RV will experience an increase of velocity along with peaking of mechanical and aerothermal environment, allowing the key technologies to be flight-tested.

At the end of the experimental phase (≤17 km), most likely the inflatable shield will implode due to the over-pressure onset with respect to the inflation level, then a tumbling phase will start bringing the system to fall down with dynamics driven by the drag-area of a tumbling tube.

Once a certain level of static pressure will be reached (i.e.: 6÷8 kPa) the parachute deployment is initiated, and the RV will descent under the parachute till the landing on ground.

Finally, the RV will be recovered relying on dedicated means and people. The recovered system will be transported to the test range facility in order to execute a first inspection after flight and also to retrieve flight data from the crash-resistant storage devices (2).

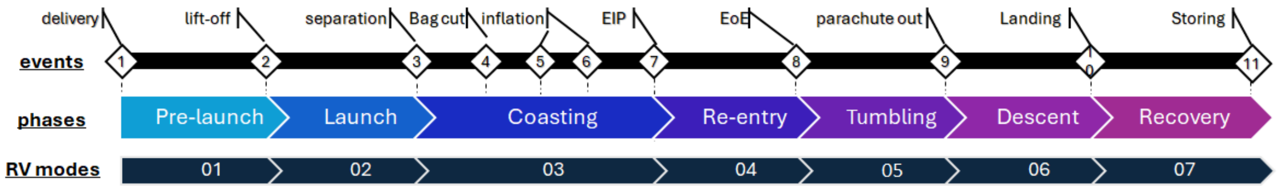


Figure 2: ICARUS Mission phases

3. SOUNDING ROCKET PLATFORM SELECTION

Based on (3) two Launch vehicles seem to be suitable for the mission: The VS-50 and the VSB-30 Launch Vehicle.
The two stage VS-50 is a large sounding rocket to support heavy weight payloads that require insertion into extended micro-g duration (> 10min) or high enthalpy (Ma > 15) trajectories. It is currently under development in a joint project of DLR, the Department of Aerospace Science and Technology (DCTA) of Brazil and the Brazilian space agency AEB. The thrust vectored first stage of the VS-50 is called S50 and features a carbon fiber reinforced motor case containing 12 to of composite propellant. The flight proven S44 is used as second stage and controlled in attitude by a cold gas system to warrant flight path accuracy. The vehicle is launched from a dedicated launch stool.
Maximum acceleration is reached at thrust tail-off during the 85s burn phase of the first stage and amounts to 7g.
The VS-50 in single or two stage configurations can accommodate a wide range of payloads under its 5m long fairing of 1.5m diameter. MORABA offers the provision of Service Module (including Telemetry and Telecommand options), Rate and Attitude Control (mechanical and/or Cold Gas) Systems.

The VSB-30 constitutes the work horse of the German and Brazilian sounding rocket activities. High performance capacity is obtained by a simple vehicle concept thereby keeping cost reasonably low. This was achieved by developing a booster stage for the previously existing S30 in a joint effort by the Brazilian Department of Science and Technology (DCTA) and the German Aerospace Center DLR, called S31. This booster stage was designed using many of the features and manufacturing techniques used in the S30 program, but trimmed to deliver a high initial thrust necessary to meet the stringent impact dispersion requirements of ESRANGE, Sweden. Three solid rocket spin motors accommodated in the interstage adapter support the mitigation of dispersion by imparting a vehicle roll rate right after launcher exit. Fin incidence is used to further improved trajectory accuracy and imparts a final spin rate of around 3Hz. The first stage is drag separated after burnout. To optimize performance, the second stage is usually ignited shortly after separation, but also longer coast phases are possible to obtain a suppressed trajectory meeting the interests of hypersonic research. Including tailcan sections, interstage and motor adapter, the rocket motor system measures 7.3m and weighs2.2to of which 700kg (S31) and 900kg (S30) are net explosive mass. With its 22” main diameter, the VSB-30 accommodates a wide range of payloads. Even hammerhead payloads have been successfully flown. Typical payload weights range from 350 to 450kg. Payload lengths up to 5.3m have been supported. A Service Module (including Telemetry and Telecommand options), a Parachute Recovery, Rate and Attitude Control (mechanical and/or Cold Gas) Systems can be provided.

As direct alternative to the VSB-30, also the Red Kite/Red Kite two stage vehicle can be considered in the launch vehicle selection. The Red Kite is a new sounding rocket motor in the one-ton-class, manufactured by Bayern-Chemie in Germany and developed in cooperation with DLR MORABA. The thrust profile supports both, booster and sustainer unitization and in its stacked two stage configuration the vehicle slightly exceeds the performance of the VSB-30 while maintaining the same main dimensions. The Red Kite hat its maiden flight in 2023 with so far two follow-on missions in 2024 within DLR’s MAPHEUS microgravity research program. The rocket motors can be provided in short lead times.

The Red Kite is a dual thrust burner with a boost phase of 5 seconds, a sustainer phase of 7 seconds and a 0.7 second tail-off. The total action time is 12.7 seconds. The total mass is 1160kg with 915kg of composite propellant, leading to a specific impulse of 2.3MNs. The length is 3.5m with a diameter of 559mm (22”) and fully compatible to the VSB-30 standard motor hardware as tailcans, fins, motor adapters or interstage adapters.
In view of the fact that VS-50 is still under development and the Red Kite is already flight proven, a double-stage version of the Red Kite was chosen for this project. This minimized the risk of a possible non-available LV when needed in project process.

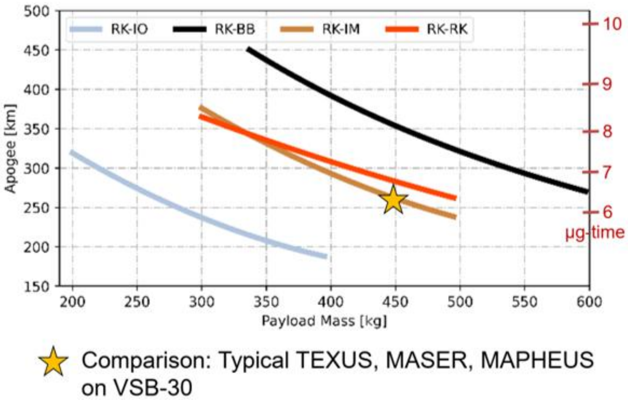


Figure 3: Performance overview of Red Kite based vehicle solutions in comparison to VSB-30

Alternatively, a variety of alternative motor combinations are possible as shown in the figure above (i.e. Red Kite/Black Brant, Red Kite/Imp. Malemute etc.) in combination with the corresponding performance and flight dynamics analysis. Operation of mobile TM, tracking Radar and launcher infrastructure is possible and alternative launch sites can be assessed. The mission scenario can be adapted to standard µ-g missions with ground ranges and dispersions that comply with the Esrange test site in Northern Sweden. Land recovery of the payload is possible, TM coverage and flight safety aspects are close to standard missions.

4. SOUNDING ROCKET CONFIGURATION AND SUBSYSTEMS

A launch vehicle is configured according to its intended use. The complete vehicle consists of the two rocket motor stages with its corresponding motor hardware as i.e. tailcans, fins, interstage adapters, spin-up systems and the payload with the Aerodemonstrator as experimental payload and a number of payload subsystems. For the payload subsystems, the ERS parachute recovery system for safe recovery of the payload and the Service Module as core on-board processor and data handling unit are particularly important. The separation system between the rocket motor system and the payload are discussed in the next chapter.

4.1 European Recovery System (ERS)

The European Recovery System Assembly (ERS) is designed to recover payloads of up to 450 kg mass. It features a separating ogive nose tip with a forward deploying recovery parachute. The assembly incorporates a 3:1 fineness ratio ogive whose forward portion is ejected after atmospheric exit to permit subsequent parachute recovery system operation. The tip ejection principle is an already flight-proven standard design.

The recovery system activation is controlled by barometric switches is combination with an electronic timing activation unit. During ground operations the recovery system is inactive and disarmed by a SAFE connector. During countdown operations, the system is armed by the main ARM connector.

In the ascent phase the safety chain consists of a lift-off pin and a 5 kft (1.520 km) barometric switch, normal closed until passing 5 kft (1.520 km) of altitude. The 15 kft (4.570 km) recovery sequence activation switch is closed until passing 15 kft (4.570 km). The activation unit connects the pyrotechnic battery circuit at T+50 sec when the vehicle has reached altitudes of approx. 50 km. The forward ogive is then timer controlled ejected at 55 sec.

On the descent trajectory the recovery sequence is activated when passing 15 kft (4.570 km). The barometric switch closes and activates the heat shield guns for heat shield jettison. Together with the heat shield the drogue parachute is deployed. The payload is now stabilized and decelerated. After 10 sec. of reefing time the drogue parachute deploys to full size and will be released after a total action time of 25 seconds by timer-controlled activation of the drogue parachute release guillotine which is cutting the drogue parachute harness. Before the drogue parachute separates completely from the system, it extracts the reefed main parachute out of the deployment bag. After 10 seconds of reefing time the main parachute opens to full size and remains open until impact. The sink rate at impact will be approximately 8 m/sec.

The ERS will be armed with implementation of the ignition circuit and ignition electronic batteries and connection of battery connector, performance of the arming procedure (measurement of zero-voltage, pyro impedance, etc.) and connection of the pyro arming plugs.

The Recovery System is armed via a latch type relay switch (Pre-Arm Relay) inside the ignition unit. The arming is forced from EGSE control unit panel by 28V commands via range umbilical. System status control functions are implemented to the control unit.

The system is activated by a dedicated lift-off switch with separate layers for the redundant ignition circuit parts of the ignition unit. The switch is closed when lift-off pin is inserted and opened when extracted. Then signal change from closed to open is acquired from the ignition unit. Redundant g-switches are used for alternative activation.

The final arming is accomplished at T0 + 50 sec at time-out of Timer 0 with switching of the Arm Relay. This is performed by the ignition unit but supplementary inhibited by means of a 5 kft baro-switch (1.5 km altitude) for ground safety.

The nose tip is attached to the payload by a segmented manacle ring. The manacle ring parts are flexibly connected and held together by a locking mechanism, which is released by a pneumatically actuated piston. The forward ogive (nosecone tip) ejection is initialized by electronic Timer1 after T0 + 55 sec (above 1.5 km altitude) via Solid State Relay circuitry inside the ignition unit. The manacle ring release is initiated by pyrotechnics and the forward ogive ejection follows subsequently after manacle ring separation by springs.

Two heat shield guns are mounted 180° apart in the aft ogive section with pistons installed. The heat shield is attached to the aft ogive module lip with two socket-head cap screws. On payload descent, after re-entry, at an altitude of 15 kft (4.6 km), the heat shield release is initialized by means of a baro-switch, activated by the ignition unit. The pressure of the cartridges in the heat shield deployment guns drive pistons against the heat shield, which break the attachment screws and forces the heat shield away from the parachute compartment. The heat shield deployment and the parachute sequence are video and status monitored.

The drogue parachute deployment bag is attached to the rear side of the heat shield and is extracted with heat shield jettison initiating the recovery sequence. Subsequently the reefed drogue parachute is deployed from the packing bag while the main parachute is fixed with the main harness to the main parachute brackets. The stab parachute deploys first in reefed condition and is de-reefed after 10 sec. At the same time, the ignition unit initializes a 25 s timer for the stage line cutter. After time-out the drogue parachute harness is cut by a pyrotechnically operating guillotine knife, which is fixed in the center on the rear side of the parachute system container.

The separating drogue parachute extracts the main parachute. The main parachute first inflates in reefed condition and is de-reefed after 10 sec. With fully inflated main parachute the payload is decelerated to a sink velocity of 8 m/s.

During the ascent phase until separation of the forward ogive the GNSS tip antenna is used for reception of GNSS signals on the spin stabilized vehicle. After tip separation the system is switched inside the GNSS receiver to a secondary antenna system, located externally to the ERS Recovery System. The sequence is controlled by the service system timeline.

The beacon system is activated on the decent by means of a 15 kft baro-switch, however inhibited by the ignition unit. According the timeline it activates the beacon at 750 sec.

The heat shield deployment and parachute sequence are video monitored with means of an analogue type industrial camera. The camera activation is controlled via telecommand to the ignition unit and override with beacon transmitter activation after 750 sec.

Nose tip ejection, heat shield separation, cut of stage line and parachute deployment are status monitored with break wire signals.

4.2 Service Module

The Service Module is responsible for the communication between the subsystems within the Service Module, between the experiments and Service Module and to establishes the down link communication via hardline umbilical (pre-liftoff) and RF (during flight). In order

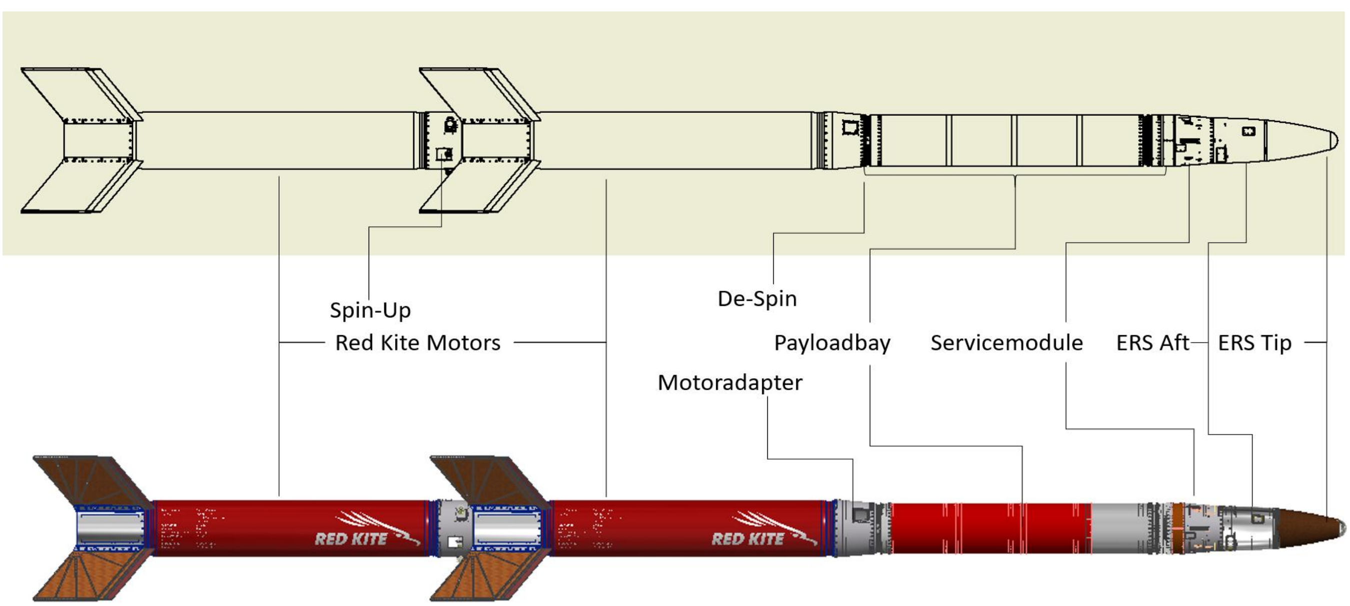


Figure 4: Overview of the complete launch vehicle

to fulfill all the tasks for the missions following subsystems/components have to be accommodated within the

SM: Main Ebox, precise atomic clock, batteries, TM transmitters and couplers, inertial platform (IMU), GNSS receivers, GNSS antennas, S-Band antennas.

All the data of the SM is collected, formatted and transferred to the S-Band TM transmitters. For transmission to ground packet
telemetry is used. All data sets have the same priority. A so-called forward error correction (FEC) is overlaid to the serial data in order to allow the correction of 1-bit error within 8 bits. The serial data is transferred as RS422 data stream to one of the transmitters. The experiment data is formatted within the service system and transferred as RS422 data stream to the transmitters.

A wrap-around antenna for the reception of L-Band signals is installed in order to receive GNSS RF signals and to feed these signals into the GNSS receivers. The receivers use these RF signals to calculate the navigation data. The LNA (low noise amplifier)
amplifies the L-Band signal and feeds the amplified signal into a power splitter. This power splitter provides one RF signal for each GNSS receiver.

The SM battery set consists of two identical battery packages (NiMH), which deliver the energy for the SM and the experiments. The SM features also power switching and control for all experiments. Both batteries are connected by diodes to give a redundant supply capability. The voltage range can differ from 24 to 36 Volts, depending on the charge status. The capacity of each package is 3.2 Ah after a complete charging cycle.

Transmitter bandwidth and/or number of transmitters as well as transmission output power can be adapted to the specific requirements of the Aerodemonstrator and power budget analyses gear the battery capacity or switching logic during the flight.

4.3 Motor Adapter

The Motor Adapter contains the autonomous redundant ignition system for second stage ignition in flight and activation of additional pyrotechnic mission critical events as yo-yo despin and payload separation. While the first stage ignition can be entirely ground controlled via direct firing leads and external power supplies and Ledex safety systems, this is naturally not possible for second stage ignition. The ignition of the second stage must be entirely independent from ground support during flight, but provides monitoring and control during pre-launch operations.

DLR MORABA's second stage ignition system provides this functionality by incorporating an electronic Ignition Unit (IU) with a Remote Arming Device (RAD). These two devices can be used separately, but, for mission and safety critical events, operate as one unit (IU/RAD). The unit is housed in the motor adapter that acts as an interface between the second stage motor and the payload. The mechanical interface to the Aerodemonstrator and payload subsystems is releasable in flight by a manacle ring. Barometric switches are connected to a circular line that connects four pressure ports. Four ports are provided to ensure that the average ambient pressure is measured and angle of attack effects are minimized. The two switches activate at a nominal altitude of 5000 feet and thereby provide a positive confirmation that the rocket has reached altitude and it is therefore safe to ignite the second stage motor. The pressure is also monitored by the Ignition Unit directly by an on-board pressure sensor

The complete motor adapter consists of several modules that basically from a long shroud that houses the stowed Aerodemonstrator and adapt on the rear side to the second stage motor. One optional module can be a ring that houses the yo-yo despin system that will reduce the induced roll rate during vehicle ascent down to nearly zero after activation. The despin system is activated by wire cutter that cut the fixation cable of the two yo-yo masses. The manacle ring connecting to the forward part of the payloads is released by a pyrotechnic manacle ring opener that is also controlled by the ignition system and activated by timeline. In case a despin to zero longitudinal rates for the RV is not preferred, this ring can be simply omitted.

The separation system is planned to be designed as pneumatic telescope cylinder that interfaces with the front nose section of the Aerodemonstrator and presses at activation safely the complete RV out of the motor adapter structure. Additional gliding rods shall avoid any induction of disturbances during separation.

4.4 Rocket Motor System

The selected rocket motor system for the ICARUS project is the Red Kite/Red Kite vehicle. The Red Kite/Red Kite motor combination consists of two identical solid propellant Red Kite rocket motors that act as either a booster (first stage) or sustainer (second stage) in this configuration (4).

The rocket motors are designed and developed in a cooperation of Bayern-Chemie GmbH and DLR MORABA and manufactured by Bayern-Chemie GmbH in Germany. The Red Kite is a commercially available, serially produced solid propellant sounding rocket motor in the class of one ton of net explosive mass. It was developed for high performance sounding rocket vehicles. Designed primarily to be employed as a powerful booster for military surplus and commercial second stages, it can also be used as a sustainer when boosted by either an even larger motor or by another Red Kite.

Typical payloads range between 200 to 600 kg. When used in a mission design tailored to microgravity research, typical apogees range between 250 to 300 km, while the needs of the hypersonic community can be met by a suppressed trajectory design, typically providing horizontal flight at Mach numbers between 6 to 9 in the altitude band 30 to 60 km.

Following a Phase A definition study in 2017, the German Aerospace Center DLR contracted Bayern-Chemie GmbH in 2020 for the development and manufacturing of the Red Kite motor. Subsequent to preliminary design and materials selection phase, ground testing of mechanical, pyrotechnical and electrical subsystems was conducted. Finally, two full scale qualification motors were successfully test-fired in August 2023 at Esrange Space Center, with the test models tempered to the upper and lower limits of the operational temperature envelope. Following the successful qualification, serial production was initiated and serial motor number one released for a maiden flight from Andøya Space Center in November 2023, proving the design in flight successfully. With the launch of MAPHEUS 14 in spring 2024, Red Kite became a fully operational member of MORABA's rocket family.

Red Kite Main Characteristics (nominal at +10°C)

Parameter	Units	Value
Gross Mass	[kg]	~1170
Propellant Mass	[kg]	~910
Main Diameter	[mm]	559
	[inch]	22
Length (Front Flange to Nozzle Exit)	[m]	3.440
Total Impulse (Vacuum)	[MNs]	2.3
Burn Duration (T = 10°C)	[s]	~13
Maximum Thrust (Vacuum)	[kN]	~240

Figure 5: Red Kite Main Characteristics

The Red Kite was designed as a dual thrust burner. High initial thrust warrants high acceleration at launch, which effectively reduces the trajectory dispersion of unguided sounding rockets caused by prevalent side winds. The figure below illustrates the temperature dependency of the thrust profile. To enable launches from arctic as well as tropical launch ranges without requiring thermal conditioning equipment, the motor was qualified for firing within a window of -20°C to +50°C.

The Red Kite/Red Kite vehicle is a two stage, solid propellant, unguided, rail launched, sounding rocket. Each of the stages is fin stabilized using three standard S30 fins, in case of special payload configurations the number of fins can be increased. The second stage contains an independent ignition system which is monitored and controlled prior to first stage ignition. Three spin-up motors are mounted on the first to second stage interstage adapter to enhance the spin rate of the vehicle early in flight and to reduce impact dispersion. These spin-up rocket motors also have an independent ignition system that is monitored and controlled prior to first stage ignition. The Red Kite/Red Kite vehicle for this mission is planned to be launched out of the Skylark Tower.

5. PAYLOAD ACCOMODATION

During the ascent phase, the payload is separated from the burnt-out second stage rocket motor. Active separation takes place pneumatically via a pyrotechnically triggered mechanism that separates two interfacing payload structures. In many standard sounding rocket applications, the separated modules are ejected from each other by means of pressurized plungers. For the separation of the modules three pneumatic plungers are used, acting on the heat shield of the aft ogive. The separation plungers consist of housing, piston with end cap and a support to attach to the structure. The pipe system consists of 3/8" steel pipes (max. operation pressure 5000 psi / 345 bar) connected by standard fittings to EAGER-PAK, opener and plunger. The maximum stroke of the separation piston is 90 mm.

Pneumatic tubes via pressure manifold are used for the distribution of the gas to the manacle release mechanism and the separation pistons (plungers), as well. After the manacle ring opening the under upper segment is released with mechanical forces actuated by the separation pistons to the top of the heat shield. The separation plungers are fixed to the forward ogive and placed 120° apart.

In this case, however, an approx. 1.8-metre-long structure has to be ejected safely from the motor adapter structures. The Aerodemonstrator must not be damaged during the process and introduction of any disturbances during separation shall be avoided. Pushing off in the typical variant with plungers can possibly lead to an asymmetrical course and thus to a collision of the motor adapter structure with the inflatable aeroshell. Furthermore, the plungers require an installation space that is not available in the given situation.

For this reason, the actual separation should be carried out conventionally with a pyrotechnically triggered manacle ring opener and ejection via a telescopic cylinder. The cylinder is placed on a bulkhead at the lower end in the conical part of the motor adapter. It is pressurized with nitrogen and its piston presses centrally on the steel cone of the heat shield cap. To further minimize the risk of collision, guiding rails are to be placed around.

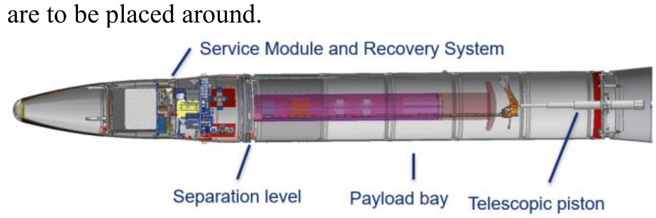


Figure 6: Sectional view of the Re-entry vehicle in a non-deployed configuration

6. TESTRANGE DESCRIPTION

It planned to conduct the flight campaign at Esrange in northern Sweden to benefit from its unique land recovery area. In addition to Esrange, DLR MORABA operates a wide range of mobile infrastructure.

6.1 ESRANGE Space Center

Esrange Space Center is the main operational and launch facility of SSC (Swedish Space Corporation), located in northern Sweden above the Arctic Circle. There is a fenced base area where various test and launch facilities, including facilities for sounding rockets, can be found, as well as a huge land impact area (5).

In the main building there are an Operations Center, a Safety Operations Center, a Telemetry Station and a Scientific Center for user support.

The Operations Center (OPS) is the primary control room for scientific sounding rocket mission, consisting of console positions for the Operations Manager and a Safety Officer, plus one additional position for either customer or SSC personnel. The OPS Center can also be used to support other types of missions (e.g. balloon launches or solid rocket motor static test firings) depending on schedule and availability.

The Safety Operations Center (SOC) is used by the flight safety team and consists of several different console positions. Tasks performed in the SOC include:

- Simulation and prediction of flight trajectories before launch
- Wind measurements for rocket and balloons launches
- Air Traffic Control (ATC) monitoring
- Display of real-time tracking information for rockets, balloons and other airborne vehicles
- Manual flight termination, of vehicles equipped with a non-autonomous Flight Termination System (FTS)

The Telemetry Station (ETM) is a receiving station for telemetry downlink transmitted from sounding rockets and stratospheric balloons. Received data is relayed from the TM Station in real-time to the SOC for Flight Safety purposes, and to the Scientific Center for monitoring by range users. User commands can also be routed through the TM Station to airborne vehicles via Radio Frequency (RF) uplink.

The Scientific Center is one of the primary mission control rooms for range users. Data to and from airborne vehicles is routed through the TM Stations to this room, where range users can install their own equipment to display and control their experiments. Data from various ground-based instruments can also be displayed in the Scientific Center, to enable range users to survey the real-time data in support of mission-critical decisions.

The Esrange impact area is a large restricted ground space in the uninhabited Swedish tundra region. In accordance with Swedish law, only space-related activities, reindeer herding and mobile recreational activities are allowed in this downrange area. The impact area extends 120 km north from the Esrange Space Center, and is 75 km wide, providing a rhomboid-shaped area of 5,200 km² in total. The area is divided into three zones (A, B and C), access to each of which can be restricted by SSC in conjunction with launch activities. Zone A is the primary impact area for the first stages of suborbital launch vehicles, and can also be extended if needed. Zones B and C are used as impact areas for suborbital LV upper stages and/or payloads. The preferred impact point typically chosen for suborbital payloads is situated approximately 60 km north of the sounding rocket launch pads, in Zone B. Zone C is available for use as an impact area during the period of 16^{th} of September to 30^{th} of April each year.

6.2 Moraba Mobile Infrastructure

In addition to the Esrange facilities, MORABA's Mobile Telemetry Station (DTM), the Mobile Range Instrumentation Radar (RIR) and the MAN 2 Mobile Launcher should also be listed here (6).

Mobile TM/TC Station:

MORABA maintains and operates a mobile telemetry, tracking and telecommand station in the S-band frequency spectrum. The station is composed of CSC standard ISO containers and as such can be set up around the globe with minimal requirements on the site. The 1.5m Secondary Antenna can be stored in boxes and used as aiding antenna together with the 5m Primary Antenna or as independent highly flexible receiving station. The Antenna Pedestals are designed for high angular velocities and accelerations to maintain a reliable tracking even for highly dynamic vehicles. The control station is equipped to simultaneously receive, record and support several Telemetry and TV streams with various modulation schemes. It is self-contained and adaptable to a variety of configurations.

Mobile Tracking Radar RIR-774C:

DLR-MORABA's tracking radar RIR-774C is a highly mobile and highly accurate C-Band (5.4-5.9 GHz), Monopulse, single target tracking radar. The station is composed of 4 CSC standard ISO containers and as such can be set up around the globe with minimal requirements on the site. The 8-foot antenna can be stored inside the Pedestal-Container for transport. The Antenna-Pedestal-System is designed for high angular velocities and accelerations to maintain a reliable tracking even for highly dynamic vehicles. The Radar can track in Skin- (passive reflection) or Beacon-Mode (active transponder on-board). A solid ground platform is needed for the containers (5 to 13 tons of weight). The internal analog intercom system (4-wire) for communication can be adapted to other intercom systems. To synchronize the time code generator an external IRIG-B signal or the internal GPS clock can be used. Tracking data will be recorded on the radar computer internal (hard disk) or external (USB device) in 100 Hz. Online tracking data (target position data only in 10 Hz) and the antenna camera video can be sent externally by an Ethernet link. Further technical specifications of the radar, such as pedestal, antenna, transmitter, receiver, optics, etc., are listed in the attached spec-sheets from the manufacturer of the radar.

Mobile Rocket Launcher MAN2:

The MAN Mobile Launcher N° 2 was built by Maschinenfabrik Augsburg-Nürnberg AG (MAN) in 1976 on behalf of DLR. It was designed for DLR Mobile Rocket Base as an universal sounding rocket launcher with remote control and is capable of being easily dismantled and shipped to a distant range. By mounting different launch rails on the launcher beam, various types of rockets can be launched. The launcher is designed for a maximum rocket launch weight of approximately 4 metric tons. In principle every Sounding Rocket vehicle used by MORABA can be launched from the MAN 2 Launcher.
The MAN 2 Mobile Launcher can be moved to principally every launch site allowing fully independent launch operations at remote locations. For weather and wind protection during the preparation phase, the launcher can be covered by a tent which is movable on railway tracks.
The complete launcher including movable tent can be transported in three 20 ft. ISO-Containers as well as an open-top container for the main part.

7. REFERENCES

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More information at:

- https://www.he-icarus-project.eu/
- https://cordis.europa.eu/project/id/101134997

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