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Space Rider System Capabilities for Orbital Robotics

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ABSTRACT

The SPACE RIDER long-term objective is to define and develop an affordable reusable European space transportation system able to perform experimentation and demonstration of multiple future application missions in low Earth orbit, benefiting to the maximum extent possible from existing launchers technologies, and addressing where relevant progressive technological challenges with limited risks and minimal financial efforts for Europe.
The system shall be able to implement a commercially viable, sustainable and scalable business case; as such, the system shall demonstrate to be commercially self-sustained in the long-term perspective. To this end robotic technologies are of key interest and their implementation and service exploitation should be pursued in the context of the Project development activities.

1. INTRODUCTION

Space Rider System (SRS) is designed to be an affordable, independent, reusable end-to-end integrated space transportation system for routine access to and return from low earth orbit. Integrated with the Launcher System, thanks to its dynamic configuration Space Rider allows payloads for an array of applications, orbit altitudes inclinations, and mission durations.
The Project builds on the ESA development, qualification and flight experience of Vega launcher and IXV (Intermediate Experimental Vehicle), enabling users access to and return from low Earth orbits for a wide variety of applications, such as (but without being limited to):

- Micro-gravity experimentation;
- In-orbit Demonstration & Validation of technologies for exploration, orbital infrastructure servicing, Earth and space observation, Earth science, Telecoms;
- In-orbit Applications for Earth monitoring, satellites inspections;
- Educational missions;
- European pathfinder for commercial services in access and return from Space.

In terms of supported potential applications, the above list is developed as follows:

Life Science R&D and manufacturing

- Cell culture
- Molecule crystallisation
- Microorganisms
- 3D bioprinting
- Accelerated disease models
- Medical devices

Physical science R&D and manufacturing

- Deposition
- Formulation
- Furnace crystallization
- 3D printing
- Metal combustion

Remote sensing

- Visible, NIR/SWIR, Thermal IR, Radar, RF

In Orbit Servicing

- Satellite and Payload deployment and retrieval
- In-Orbit assembly and replacement
- Payload In Orbit Services

2. SPACE RIDER ARCHITECTURE

The SR is composed by the following two modules:

- the SR-AOM (AVUM Orbital Module);
- the SR-RM (Re-entry Module), reusable and refurbished after each flight.

Fig. 1 – Space Rider

The SR-AOM is a modified version of the Vega-C upper stage, able to supply power, manoeuvres and attitude control in orbit to the whole SR system, up to the separation of the two modules prior to return to Earth. It is in turn made of the AVUM that includes some modifications to support the system operative orbital lifetime and the ALEK, newly developed module whose purpose is to provide energy source and thermal control means during the mentioned operative time of the system.

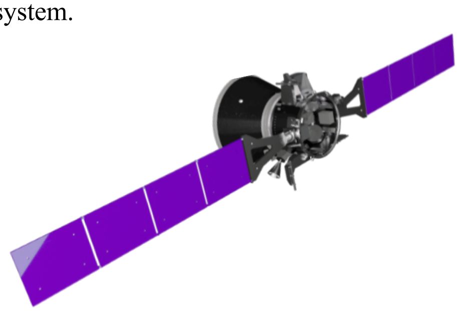

Fig. 2 – SR AOM

The SR-RM is a modified version of the IXV (Intermediate eXperimental Vehicle) demonstrator, integrating a Multi-Purpose Cargo Bay (MPCB) for payloads integration, able to perform ground landing and to re-fly after limited refurbishment.
At end of its designed operative flight time (2 months as a minimum), the RM is separated from the AOM and re-enter with its load of Payloads, to be retrieved by the final Customers for mission post-processing. Each Flight Model of the RM is designed for 6 flights.

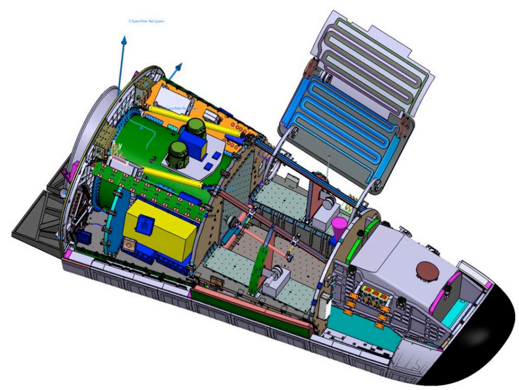

Fig. 3 – SR RM

The SR stack is designed to be accommodated on the launcher that will enable its orbital insertion; after that event, the SR stack is completely autonomous to perform its designed mission for the planned operative flight time.
The SR stack is therefore performing the core part of its mission as a payload of the chosen launcher system and it will be as such treated in respect to the process of preparation of the missions.

On its first mission (Maiden Flight), the Space Rider is launched atop the Vega-C launcher from Europe's Spaceport in Kourou, French Guiana, it will stay in orbit 2 months or more and it will re-enter on Earth at Kourou Landing Site for the recovery of the Payloads.

The reference Space Rider System maximum performance, to be intended as available mass allocated to Payloads inside the MPCB (Multi Purpose Cargo Bay) is of 600 kg, for an allowable volume of 1,2 m³. This is driven by current Re-Entry Module (RM) configuration and by the design assumption used at system level with an overall RM mass of 2,950kg maximum.

Performance as given above, is then to be further framed and specified in function of:

- the orbit characteristics (and relevant landing site);
- the characteristics of the payloads aggregate and the relevant optimized mission profile;
- the performances of the launch system.

3. SPACE RIDER CHALLENGES

The Project major goals correspond to the major innovations introduced by the Space Rider initiative, they are summarized as follows:

- To develop and qualify the first European reusable system to perform multiple missions into space, enabling Europe to gain practical experience on flight reusability of flown hardware

- To commercialise a novel service for a variety of commercial and institutional space and non-space applications

Specific solutions are conceived in the design and development process of the vehicle and of the flight services for a positive resolution of the two above key elements.

4. SPACE RIDER CON OPS

Building on Vega experience on launch preparation and service implementation, the major phases of a generic Space Rider mission can be synthesized as follows: **Pre-launch phase**: pre-integration and tests, transport to launch site final integration and tests, installation on launcher and transport to launch pad;

1. **Launch and ascent phase**: launch vehicle mission, into a near-circular orbit, nominal inclinations ranging between 5 and 55 deg, extendable up to SSO;

2. **Orbital flight phase**: payloads operations for a period of two months and more, each orbit lasting approximately 90 minutes;

3. **De-orbiting phase:** reconfiguration of the Space Rider System for Deorbit, execution of the Deorbit itself, separation of AOM and RM;

4. **Re-entry and Landing phase**: AOM destruction and RM landing, the latter going from hypersonic to transonic flights till the triggering of a subsonic parachute deployment, slowing down the RM until M=0.2 at an altitude between 6 and 10 Km, followed by the deployment of a guided parafoil for a controlled descent till the landing site,

5. **Post-Landing phase:** payloads retrieval and RM transportation to refurbishment facilities;

6. **Post-Flight phase**: RM inspection, analysis and refurbishment for next flight, within six-month timeframe.

In particular, the Maiden Flight mission is designed to take the vehicle and its Payloads to a 400 Km circular, equatorial orbit.

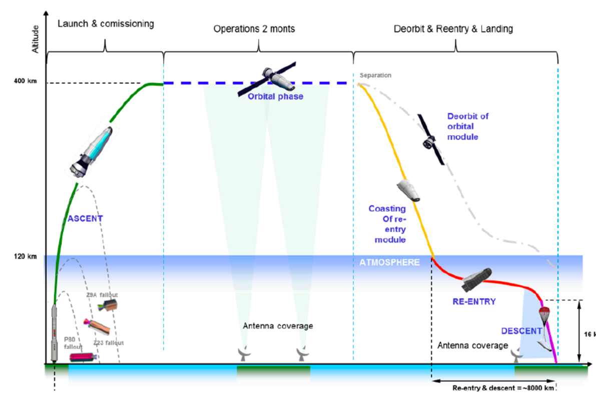

Fig. 4 – Space Rider generic mission

5. SPACE RIDER DESIGN TO SERVICE

In this section highlights about design aspects of the system that positively impact on its overall capability to encounter Payload needs and requirements and position the the Project in a commercially promising market area.

The vehicle design is based on existing and flight proven hardware; the RM is derived from the successfully flown IXV, in particular, the critical external shape and hot structure including external thermal protection system are identical to the precursor, the cold structure is strictly derived from the precursor and reinforced to sustain both the novel cargo bay area and the increased mission requirements connected to the orbital and reentry phases.

The system is designed according to un-manned safety standards; this implies remarkable simplifications if compared to other servicing platforms.

Vehicle dimensions, limited vehicle-produced disturbances and routine in-flight vehicle operations allow for long high quality micro-g standard (1E-6 g) periods at defined conditions, compared to other platforms.

Together with return capability, after landing operations and GSE design allow fast recovery of experiment sample results on the airfield and return of Payload hardware to owners.

Dedicated flight service organization, optimizing involvement of selected service providers, allow minimal effort by experiment owners on interface management with the vehicle

Unlike other platforms, Space Rider is suitable for in-space manufacturing, that will allow to pave the way for opening of new markets to in-space operations

The system reusability roadmap is structured in such a way that flights will be possible at 2/Y rate

Flight and Ground segments comm network is structured to allow maximum User data privacy on data, operations, industry knowledge protection.

6. FOCUS ON THE CARGO BAY

The vehicle cargo bay: Multi Purpose Cargo Bay (MPCB) is conceived to allow maximum standardization of Payloads accommodation effort and preparation of services.

The MPCB mechanical interfaces with Payloads are standardized by means of vehicle Support Plates whose positioning covers the available sides of the bay.

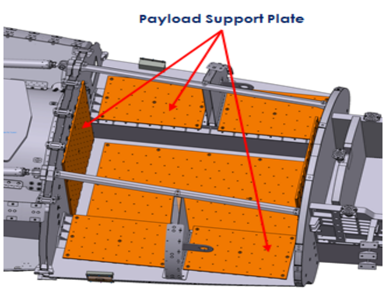

Fig. 5 – MPCB Payload support plates

The MPCB opening port is designed to allow 90 deg Field of View to Payloads dedicated to observation missions, deployment or external operations.

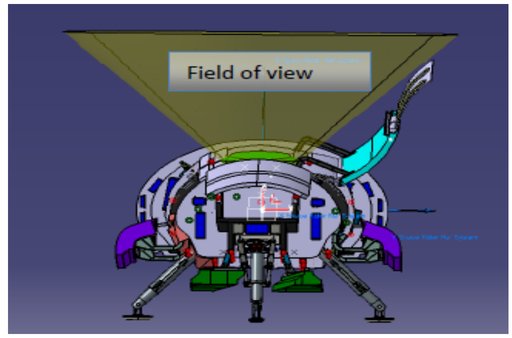

Fig. 6. – MPCB upper 90 deg cone angle FoV

Micro-g life science Payloads will need late access, this is made possible until 24 hours before Lift Off by two lateral doors dedicated to this function. Note also the launcher fairing is designed to allow the loading operations through dedicated window.

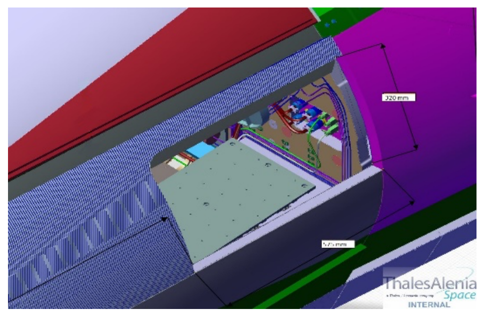

Fig. 7 – Late Access doors

The concept of Virtual Lockers (VL) was defined to this end.

VLs are virtual volumes that subdivide the MPCB and are characterized as follows:

- Stay-in Volume
- Power, thermal (in every direction including the cold face), data and mechanical interfaces
- Maximum power and a power schedule over the mission
- Maximum data rate and data relay (TM & TC) over the mission
- Mass and MCI allocation
- Specific services (e.g.: late access, field of view)

The eight defined VLs are as follows dedicated:

- 2 lockers for Late Access
- 4 lockers for μ-G
- 1 locker for Field of View
- 1 locker for Space Exposure

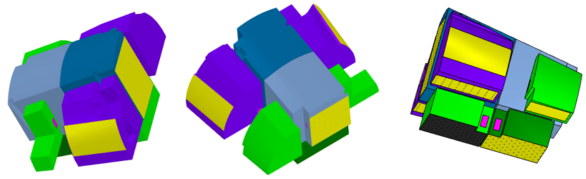

Fig. 8 – Virtual Lockers

9. SERVICE GOVERNANCE

Flight preparation and implementation service to Payload will adopt service provider entities with expert knowledge on Payload Users management from technical and programmatic stand points.

This approach will allow a standardization of the Payload preparation processes and simplify the effort from vehicle system of the complex definition and management of the Payload Aggregate.

The design of the Aggregate will be at the system level in charge of SRS Industry Primes, to guarantee compliance with vehicle capabilities and meeting of harmonized requirements of all Payloads in the Aggregate.

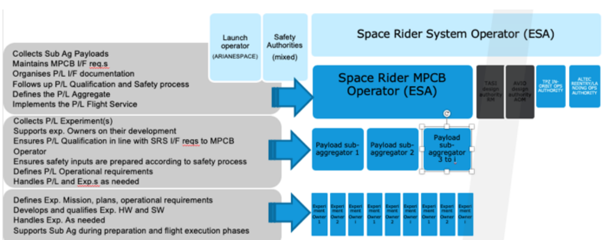

Fig. 9 – Payload service governance

8. SPACE RIDER SERVICES

- Late access and early retrieval
  - 20 hours before launch
  - 2 hours (TBC) after landing
- Launch and landing labs
  - 20 hours before launch
  - 2 hours (TBC) after landing
- Micro-g
  - during vehicle free drift, 10e-6 g max.
- Deep space observation
  - From upper MPCB door, in central VLs, upon suitable vehicle attitude placement, 90 deg Field of View
- Earth monitoring
  - from upper MPCB door, in central VLs, upon suitable vehicle attitude placement, 90 deg Field of View
- Power
  - Available to Virtual Locker locations with the relevant number of power lines 40 to 400 W according to line characteristics, total simultaneous power feed from vehicle: 600 W
- Temperature control
  - Payload I/F plates will be thermally controlled, T 15-40 C, max. total dissipation possible corresponding to 600 W
- TM/TC
  - Shared among Aggregated Payloads, TM: Peak 250-500 Mbyte/day, TC: Peak 600 Mbyte/day
- Accommodation
  - According to VL configuration, P/L mass 60 to 150 Kg/VL, CG height 178 to 783 mm from I/F plate

9. SPACE RIDER FOR ORBITAL ROBOTICS

SRS Project aims at preparing technologies and knowledge to enable in-orbit servicing using the Space Rider vehicle.

The vehicle viewed as laboratory and production facility can provide robotic technologies opportunities and support to areas of research and engineering developments for space applications, either as an individual un-interactive robotic project or interactive project with the system.

Examples of the first mentioned area of interest for robotics may be for technology developments to the effects of 0-g and space environment for materials and/or control performances, particularly for TRL raising and products maturation to demonstrate configuration functions; the second, may be for development of programs with higher maturity level, able to perform more complex operations such as objects capturing and interaction with the system and its environment.

The on-board services are provided by the SRS to the robotic by accommodation and arrangement to the standard interfaces offered by the MPCB. These include a standard pattern on payload plates for mechanical restraints, to accommodate the arm base, hold downs equipment and for the electronic units as required. The payload plates provide controlled temperature conditions for thermal dissipation by interface conductance, the thermal power is then dissipated trough radiators provided on the deployable door. The electrical interfaces are provided through ECSS standard type connectors for power and data services provided by the vehicle interfaces within the MPCB.

The exploitation of space mission environment will be extended by robotics beyond the MPCB volume with the cargo bay door open, allowing for:

- exposure to the space environment of Payloads to open field of view
- deployment/retrieval of Payloads as required beyond the physical volumes of the MPCB, to reach out to the external space environment
- handling of Space Rider Payloads within the cargo bay

The following images are prepared to illustrate sample concepts of robotic arm configurations and potential operations such as object release or more complex object capturing in space within the scope of SRS.

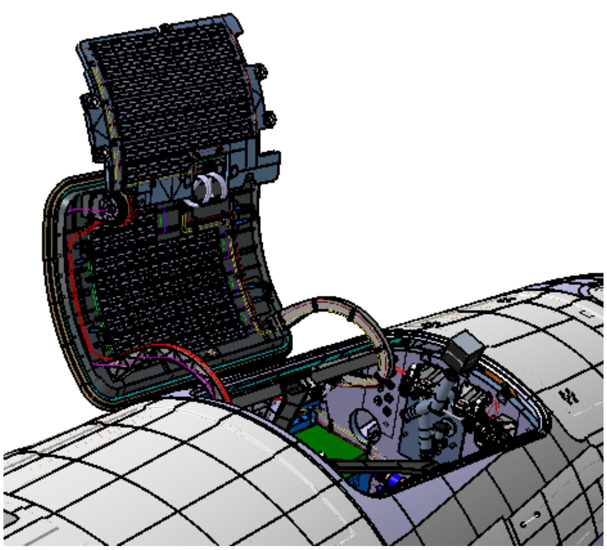

Fig. 10 – Sample accommodation of a reference robotic arm concept

Within a volume of about 1.2 cubic meter for the cargo bay and an inertial mass of the vehicle close to 3 tons (at full load capacity) robotic operations have the potential to be designed and performed relatively safe for constraints within the workspace volume and to the concern of perturbations to the vehicle free flying condition, potentially affecting both the vehicle AOCS and the robotic controllability for targeting and trajectories.

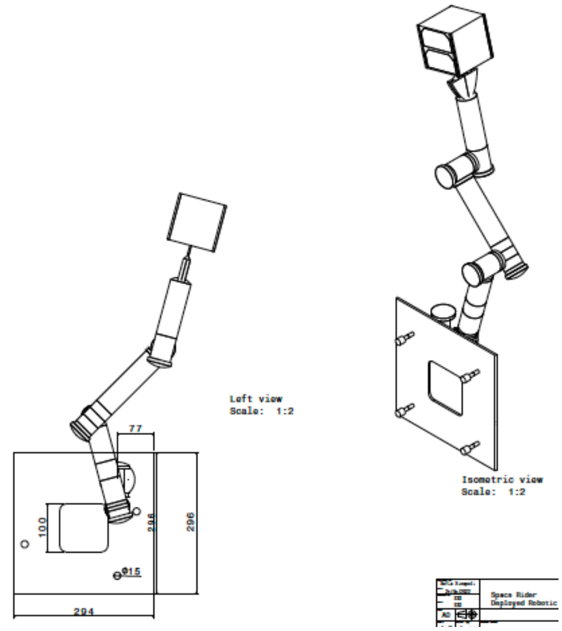

Fig. 11 – a reference robotic arm concept

Therefore, under the scope SPACE RIDER mission and services, the vehicle can support several IOD/IOV dedicated to Robotics, grouped by maturity and complexity these may be programs scoped for:

- Robotic arm technology developments; to develop and demonstrate products or equipment for robotics in orbital space environment, with the key opportunity to retrieve tests data and the equipment after the mission allowing on ground inspections and examination post flight for insights.
- Robotic system developments including equipment for service/operations, for functional and control systems architecture developments, with the key opportunity to retrieve costly equipment at the end of the mission and opportunity for re-utilization
- On-orbit servicing and operations with SRS, for enhanced mission servicing for on-orbit operations.

10. CONCLUSIONS

This paper provides an overview to the SPACE RIDER SYSTEM program and scope, describing the potential the design and services can provide to benefit and support Robotic programs for on-orbit space operation applications development and exploitation.

The SR vehicle provides a cargo bay serviced by standard interfaces (mechanical, thermal and electrical) and mission opportunities to customer Payloads for multipurpose applications. Within the scope, of primary interest for SR are robotic technologies for their in-flight validation and R&D and to implement synergies with robotic program applications to meet Payload exploitation needs. This paper has presented the main characteristics of the vehicle, aiming to inform the community and encourage Users interested to come forward for further specific discussion about needs and solutions.

11. ACKNOWLEDGMENTS

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