SPACE-RIDER

the reusable orbital /re-entry vehicle for Europe

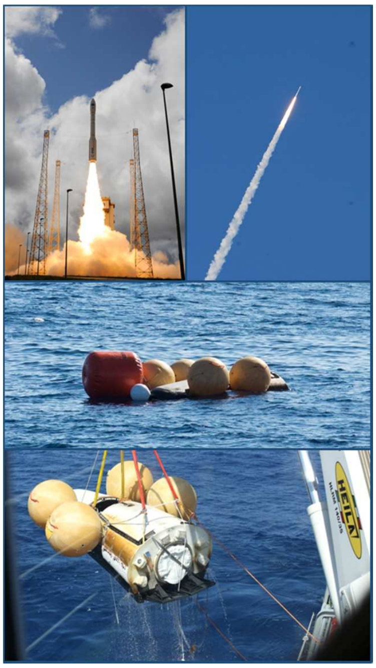
CESMA Hypersonic flight symposium #2
ROME, 30/6 – 1/7 2016

Program Objectives

- ✓ Define and develop an affordable reusable European space transportation system able to perform in-orbit operations, experimentation and demonstration of technologies for application missions, de-orbit, return from orbit and precision land on ground for re-flights, addressing progressive technological challenges with limited risks and minimal financial efforts for Europe.
- ✓ Provide Europe with an autonomous system that can guarantee not only routinely access to space but also return from space, allowing the implementation of several application scenarios.
- ✓ Maximize competitiveness through the use of the cheapest European launcher solution and system reusability with limited refurbishment costs.
- ✓ Capitalize to a maximum extent European investment in VEGA and IXV projects, exploiting technological commonalities and lesson learned.

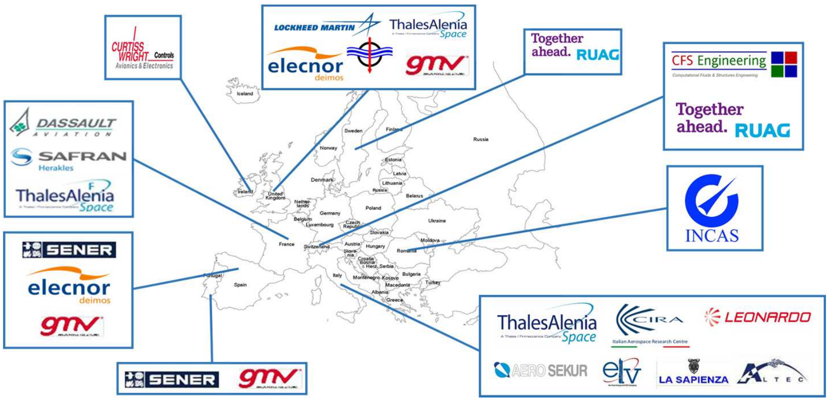
Building on IXV success

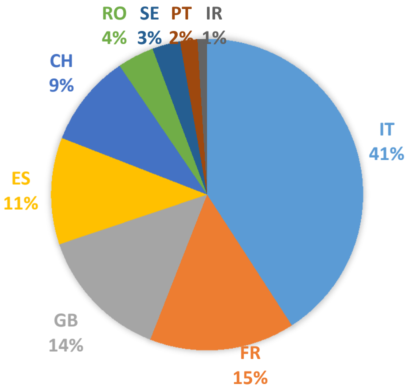
- ✓ The IXV mission was successfully performed on the 11th of February 2015, with all flight hardware and all flight data successfully recovered, through flight segment telemetry transmission and ground segment acquisition, and on-board recording, with the confirmation that the flight data is complete and consistent among the various sources.
- ✓ The IXV system, and all associated technologies, have successfully performed the whole flight program in line with the commanded maneuvers and trajectory predictions, performing an overall flight of approximately 25.000 km including 8.000 km in hot atmospheric re-entry environment with automatic guidance, starting from an orbital velocity of ~7.5 km/sec (Mach=27), concluding with precision landing.
- ✓ 100% of the IXV mission, system and technologies objectives have been successfully achieved.



Space-Rider Implementation

- ✓ Following the CM-14 decision, at the end of 2015 ESA has designated TAS-I and CIRA as Co-Primes for the implementation of SPACE-RIDER Phase A/B1.
- ✓ An industrial team composed of 25 companies distributed in 9 countries (IT, FR, GB, ES, CH, RO, SE, PT, IR) has been set-up by the Co-Prime according to geo-return rules.





PARTICIPATING STATES (%)

Co-Primes Roles

CIRA
Italian Aerospace Research Centre

- Project Management interface vs ESA
- Vehicle Architecture and Technology Identification
- Coordination at system level of:
    - Aerodynamics and Aerothermodynamics
    - Thermal Protection System
    - Descent and Landing System
    - ASCS
- Responsible at subsystem level of:
    - Ceramic TPS component
    - Anisogrid Composite Structure element
    - Support to GNC technologies trade-off

ThalesAlenia Space
A Thales / Finmeccanica Company

- System Engineering Management
- Mission Definition
- System Configuration
- Thermal and Mechanical Analysis
- Product Assurance
- Coordination at system level of:
    - Cold Structure & Mechanism
    - Environmental Control System
    - Propulsion
    - Avionics

Industrial Team Roles

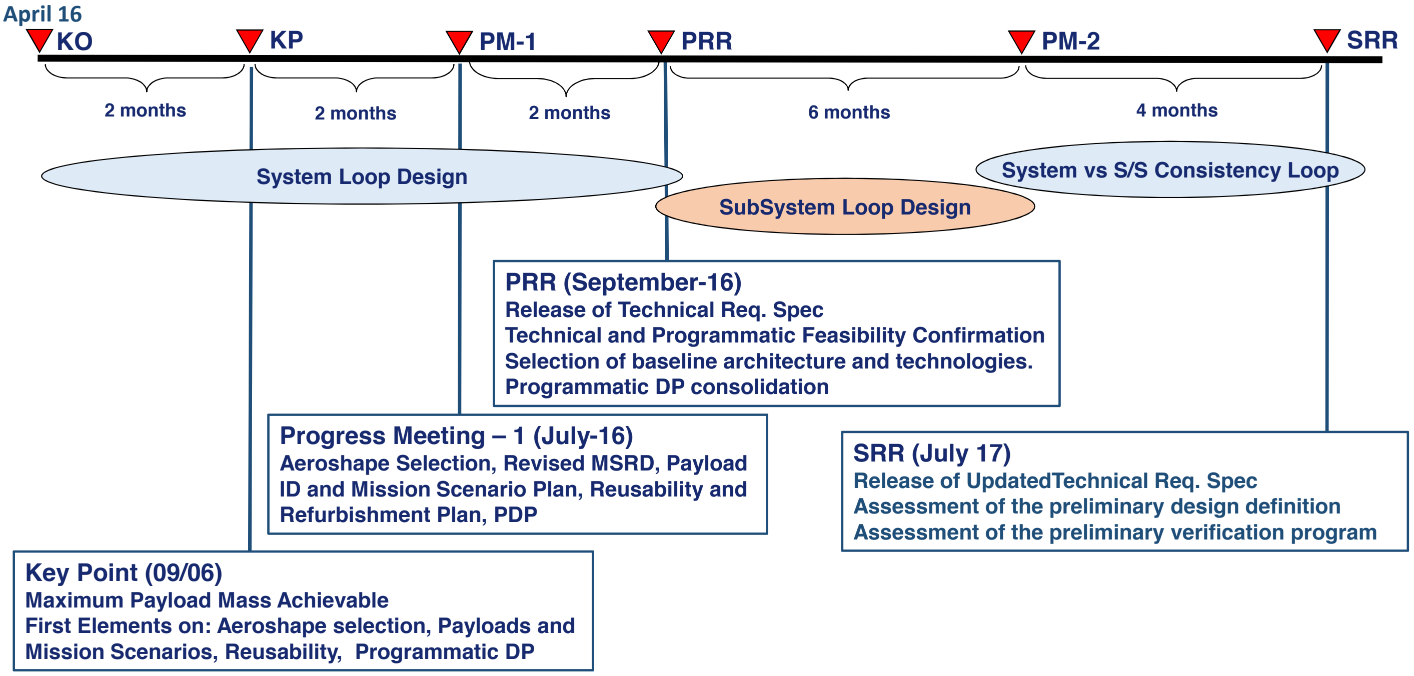
🇫🇷	DASSAULT AVIATION	Aeroshape, Aerodynamics and Aerothermodynamics
🇷🇴	INCAS	Wind Tunnel Testing
🇨🇭	CFS Engineering	AED, ATD Analysis
🇬🇧	Fluid Gravity LTD	AED, ATD Analysis
🇮🇹	LA SAPIENZA	AED, ATD Analysis
🇫🇷	SAFRAN Herakles	Nose & Windward CMC TPS
🇬🇧	LOCKHEED MARTIN	Landing System, Mid Air Retrieval, ASCS
🇮🇹	AERO SEKUR	Descent System

SENER elecnor deimos gmv	Mission Analysis and GNC Software	🇪🇸 🇬🇧 🇵🇹
LEONARDO	Avionics Architecture	🇮🇹
CURTISS WRIGHT Controls Avionics & Electronics	DHS Support	🇮🇪
elv	Launcher Compatibility and Commonallities	🇮🇹
ALTEC	Ground Segment and Operations	🇮🇹
Together ahead. RUAG	Cold Structure & Mechanism	🇨🇭 🇸🇪
ThalesAlenia Space	*UK* Propulsion System	🇬🇧
	France Solar Array	🇫🇷

Program Drivers

- ✓ Launched with VEGA C / VEGA C+ and injected in Circular LEO orbit. Target orbit for system sizing: ISS (400 km – 52deg)
- ✓ In Orbit operational phase mission duration longer than 2 months
- ✓ Payload mass larger than 450 kg and payload volume larger than 0.8
- ✓ Precision ground landing allowing fast payload recovery time. Main landing site European.
- ✓ System reusability with minimum refurbishment for 6 missions.
- ✓ Maximization of IXV heritage
- ✓ Exploitation of synergy with VEGA system in terms of technologies development commonalities
- ✓ Therefore the PRIDE-ISV mission and system design shall be the result of a process of optimization of the following parameters:
  - o Payload Mass and Volume Maximization;
  - o Cost minimization (development and operational including refurbishment);
  - o Maximization of Payload mass/EUR ratio ("pure-payload mass" over "round-trip cost");
  - o Maximization of reusability;
  - o Minimization of risk;
  - o Maximization of reliability.

Planning overview



PRR (September-16)
Release of Technical Req. Spec
Technical and Programmatic Feasibility Confirmation
Selection of baseline architecture and technologies.
Programmatic DP consolidation

Progress Meeting – 1 (July-16)
Aeroshape Selection, Revised MSRD, Payload ID and Mission Scenario Plan, Reusability and Refurbishment Plan, PDP

SRR (July 17)
Release of UpdatedTechnical Req. Spec
Assessment of the preliminary design definition
Assessment of the preliminary verification program

Key Point (09/06)
Maximum Payload Mass Achievable
First Elements on: Aeroshape selection, Payloads and Mission Scenarios, Reusability, Programmatic DP

SPACE-RIDER - Applications

- With the objective to identify key assets of SPACE-RIDER platform and to better tailor its design, a survey of potential applications and market trends is being performed.
- Class of applications:
  - Free Flyer: Microgravity Lab
  - Rendezvous & Capturing
  - Free Flyer: IOD – In Orbit Demonstration (as secondary P/L)
  - Surveillance applications (e.g. earth monitoring, satellite inspection)
- World Wide main platforms
- SPACE-RIDER advantages

Free Flyer: Microgravity

- **Microgravity experimentation has been of interest to many fields of research, engineering development and commercial manufacturing.**
- **Despite the success obtained by many of such experiments, the way to access to space resulted to be too limited to promote a continued commitment of the community.**
- **Occasional flight opportunities, limited re-flight options, very long integration times, compliance with crew safety requirements results in obstacles to allow robust commercial business models and continued research programs.**
- **Increase in systematic flight opportunities at low cost and shorter lead time is expected to induce a significant thrust to microgravity research.**

Microgravity Key Platform asset

- ✓ Reduced Paylod integration process time (e.g. ISS ~36Months)
- ✓ Reduced time to re-fly experiment
- ✓ Late accessibility to payload before launch
- ✓ Extended duration of experiments (order of months)
- ✓ Stable and optimal μ-g environment
- ✓ Early recoverability of payloads after re-entry
- ✓ Maximum Experiments monitoring including video-link
- ✓ Extendend coverage from ground or relay satellites during experimentation phase for P/L data download and/or commanding.

Rendez-vous and Capturing

- ✓ Capturing payloads from ISS
  - o So far retrieving payloads (experiments) from ISS is possible only with spacecrafts that perform docking/berthing (i.e. Soyouz and Dragon).
  - o High costs associated with compliance to ISS safety regulations.
  - o Opportunities to fly and recover payloads are driven by re-supply missions timeline
  - o Availability to retrieve experiments at low costs and higher time flexibility could be a strategic asset
- ✓ Capturing payloads from LEO
  - o Scientific Payload are routinely launched as piggy-back of other missions at relatively low cost but without possibility to be recovered.
  - o Capability to retrieve experimental payloads after long duration orbit permanence can be an asset

Rendez-vous and capturing Key Platform asset

✓ great flexibility for payloads retrieval because:

- retrieval is independent from ISS re-supply missions
- retrieval can be managed with neither need to operate with docked platforms nor busying crew time and hand-operations
- fast on-demand retrieval of specific payloads (can be scheduled in relatively short time)
- reduced mission costs for retrieval

✓ validation of RdV/Capture techniques and solutions with near-eye evaluation and fast feedback (e.g.: satellite servicing)

Why In Orbit Demonstration ?

✓ A number of European technologies in particular generic technologies and techniques supporting industry competitiveness, require in orbit demonstration to achieve and demonstrate their maturity

✓ A number of mission concept require validation in space before being used in applications and main stream missions

✓ A number of space companies want to acquire/demonstrate space experience

✓ An increase shall be expected in spin-in ground technologies to space; in orbit demonstration could be a cost effective way of showing their suitability for space

✓ Some technologies require real in orbit environment, GPS, star tracker, GNC

✓ Some development approaches enabled by new D&D and AIV techniques need to be tried for real in “simple” but representative missions – e.g. PROBA-1 GNC/SW approach

✓ Some basic modelling requires in-orbit datalike propagation studies, signal at satellite altitude, sloshing (FLEVO), Bi-static data, GNSS reflectometry, fluorescence, low energy detection …

IOD Key Platform asset

- ✓ Reduced Mission costs related with the possibility to fly as secondary payload.
- ✓ Flexibility in mechanical/electrical I/Fs
- ✓ Extendend coverage from ground or relay satellites during experimentation phase for P/L data download and/or commanding
- ✓ Possibility to analyze the payload demonstrator after retrieval

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World-Wide Platforms

System / Criteria	SPACE RIDER (EU)	DragonLab (US)	Foton/Bion (RU)	DreamChaser (US)
				
Payload Mass/Volume	>450 Kg download mass >0.8m3 Payload volume in MPCB	Up to 3000 kg download mass P/L Vol: $10m^3$ pres 14 m^3 unpres	Total Return Payload Mass: 650kg Total Return Payload Volume: 1,6m3	Download capability: 1750 kg
Mission Type	Microgravity research, Rendezvous and Capturing from ISS and LEO, Small Sats deployment, Space physics and relativity experiments, Radiation effects research (in LEO), Earth sciences and observations, Materials and space environments research, In orbit Demonostration, Inspection and Robotic servicing	Instruments and sensor testing, Spacecraft deployment, Space physics and relativity experiments, Radiation effects research, Microgravity research, Life science and biotech studies, Earth sciences and observations, Materials and space environments research, Inspection and Robotic servicing	Dedicated to microgravity experiments with both pressurized and unpressurized (Biopan) payload hosting. Possibility to fit samples onto the outer surface of the capsule in one of the four annular sample holders to test effect of re-entry environment	Free flyer applications. Docking to ISS capability (not for DC4EU). (DC4Science: Spacecraft version dedicated to microgravity experiments)
In-Orbit duration	> 2 month	1 week to 2 years	12-18 days (up to 60 days Bion)	Up to 1year
Payload integration time	Late load: T-(TBD) hours	Payload Integration timeline: Nominal: L-14 days. Late-load: T-9 hours	Late-load: 48/72 hours before launch	TBD (depends on LV: Atlas V, A6, etc.)
Re-entry environment	<2g entry and soft runway landing under parafoil	5g entry and water splashdown under parachutes	High forces on reentry, up to 8 to 9g and 40g shocks at parachute opening	1.5g entry and gentle runway landing
Payload retrieval	Immediate access to payloads upon convenient runway landing (3-6 hrs TBC)	Payload Return: Nominal: End-of-Mission + 14 days Early Access: End-of-Mission + 6 hours	From 6 to 24hrs for payload retrieval and additional 24 hrs for availability of payloads in laboratories (e.g. Moscow)	Immediate access to payloads upon convenient runway landing, all cargo can be accessed within 24 hours
Time to re-fly	180days	Unknown	Not appicable (expandable)	60days (without considering launcher availability)

Advantages of SPACE-RIDER

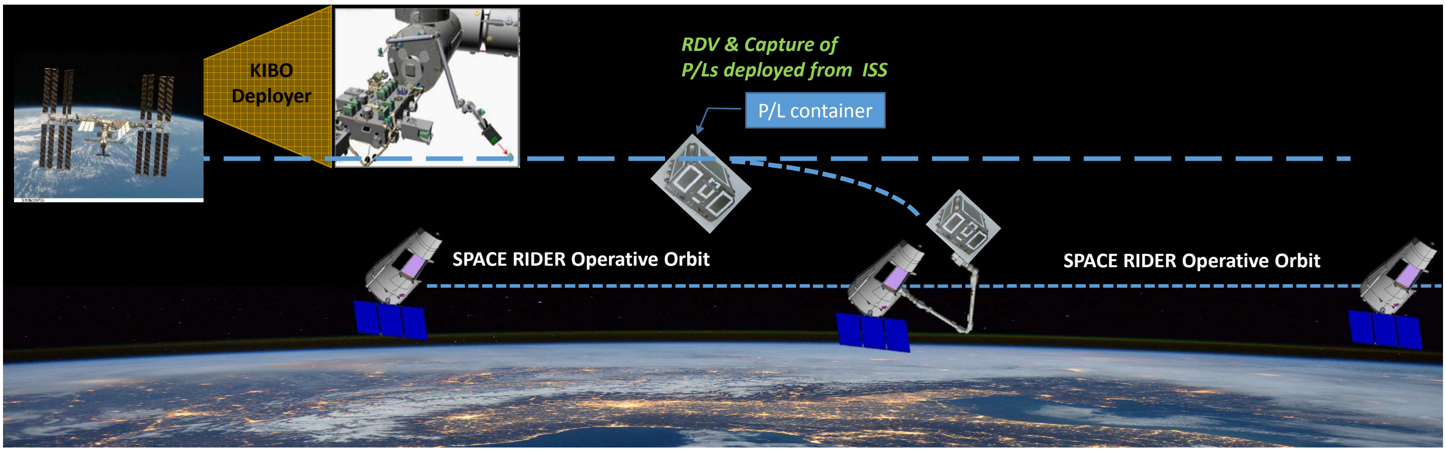
- ✓ Fully European System. Conceived and developed to avoid dependence on non EU countries.
- ✓ Space Transportation System fully operated in Europe, from launch to landing.
- ✓ Optimal microgravity environment in free flyer scenario.
- ✓ Low Deceleration profile during Re-Entry and landing for experiments survivability
- ✓ Early retrieval of payloads, exploitable soon after ground landing (landing site potentially equipped with laboratory)
- ✓ Flexibility of the platform in terms of payload capability and mission scenarios.
- ✓ Payload capacity well suited for Microgravity experiments market, avoiding long pipeline to be filled in order to be price competitive.
- ✓ Capability to fly very often.
- ✓ Low overall mission costs.

SPACE RIDER SYSTEM FEATURES

- ✓ The SPACE RIDER platform allows flexible management of different P/Ls arrangement, depending on the priority for:
  - ✓ a full cargo bay uploading with different P/Ls having common environments and experimentation objectives or
  - ✓ a privileged and customized flight environment offered to a specific P/L
- ✓ Different altitudes for experimentation purposes can be managed according to the VEGA launcher performance capabilities
- ✓ The orbital phase durations are designed to satisfy P/Ls needs.
- ✓ The System is designed to cover 6 flights with minimum of maintenance and refurbishment
- ✓ The SPACE RIDER Platform will exploit at the maximum extent the commonality with the IXV System in order to save design and development effort.
- ✓ The capture of equipment commonalities with the VEGA Launcher represent a major program direction.

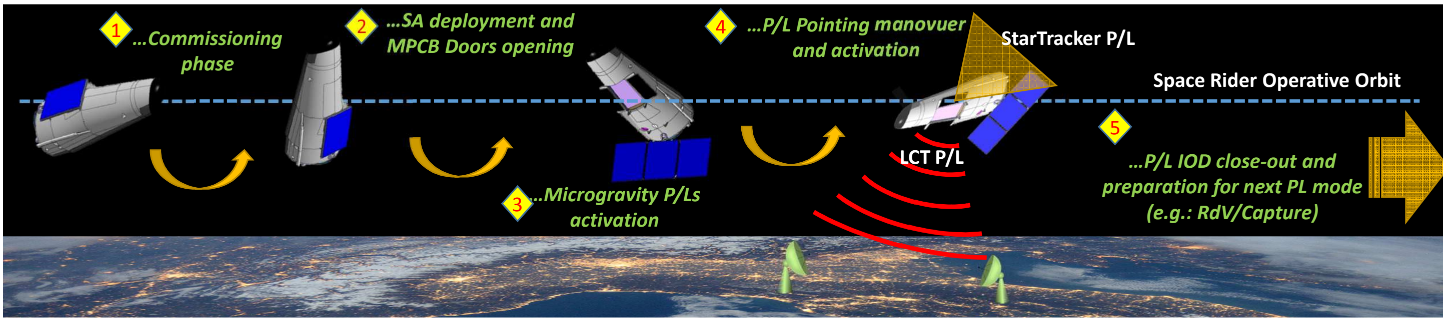
Mission Scenarios
ISS Cargo return

- <u>ISS Cargo return</u>
  - RDV, capture and soft re-entry of P/Ls experimented inside the ISS.
  - The SPACE RIDER vehicle allows to achieve the ISS orbits, perform RDV & Capture operations through the manipulator arm located inside the Multi Purpose Cargo Bay (MPCB) and store the P/Ls inside the MPCB for return to Earth.

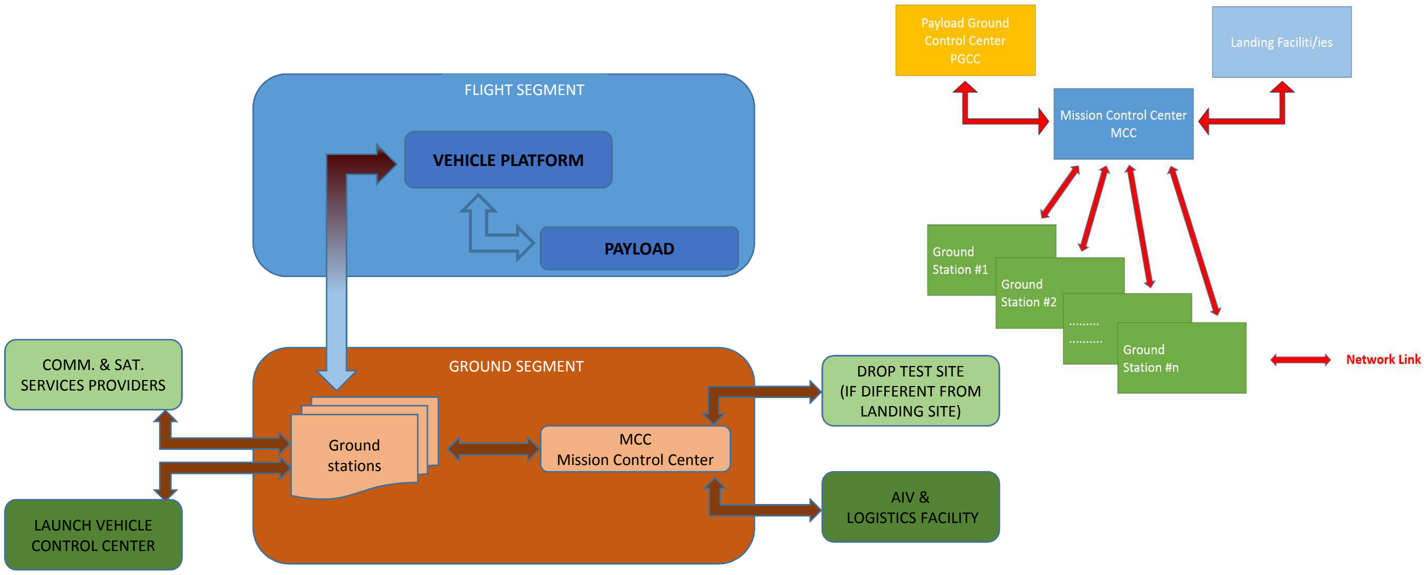


Mission Scenarios
Free-flying

- <u>Microgravity</u>
  - Long orbital microgravity experimentation (2 months min) w/o any re-boost disturbance for P/Ls uploaded by Space Rider platform and successive soft re-entry acceleration environment
  - Possibility for extended orbital coverage to ensure experimentation data monitoring and consequent command (if needed)
  - Quick retrieval of the experimentation P/L for post-flight evaluation.
- <u>IOD</u>: the Space Rider vehicle allows to perform orbital experimentation of different P/Ls categories
  - Science and technology demonstration
  - Communication P/L
  - Observation P/L
- <u>Surveillance</u>:
  - Earth monitoring (e.g. disaster monitoring)
  - Satellite inspection



System Architecture Overview



FLIGHT SEGMENT

VEHICLE PLATFORM

PAYLOAD

GROUND SEGMENT

Ground stations

MCC
Mission Control Center

COMM. & SAT. SERVICES PROVIDERS

LAUNCH VEHICLE CONTROL CENTER

DROP TEST SITE
(IF DIFFERENT FROM LANDING SITE)

AIV &
LOGISTICS FACILITY

Payload Ground Control Center
PGCC

Landing Faciliti/ies

Mission Control Center
MCC

Ground Station #1

Ground Station #2

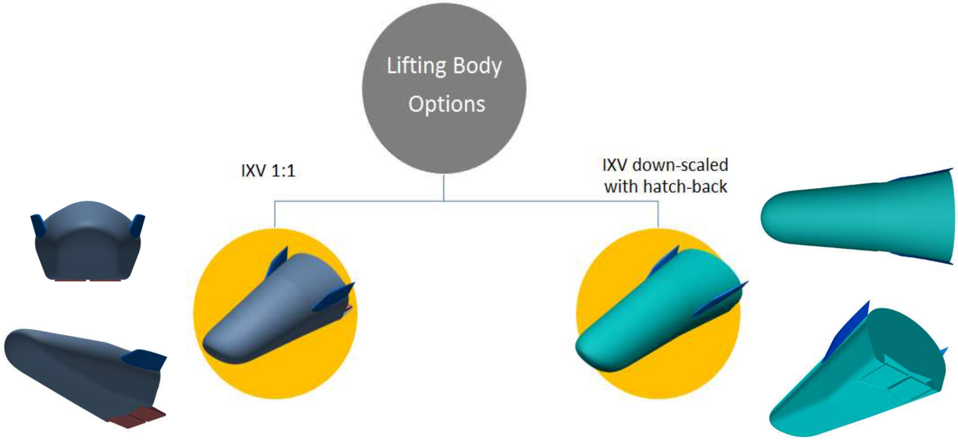
……….
……….

Ground Station #n

Network Link

Aeroshape

- ✓ **Alternatives will be traded-off against the following objectives:**
  - ✓ maximize capability to fly the wide envelope from re-entry down to landing
  - ✓ maximize payload mass/volume capability
  - ✓ maximize compatibility with VEGA
  - ✓ maximize of IXV heritage
- ✓ **Shapes: two options are under evaluation in the Lifting Body class.**



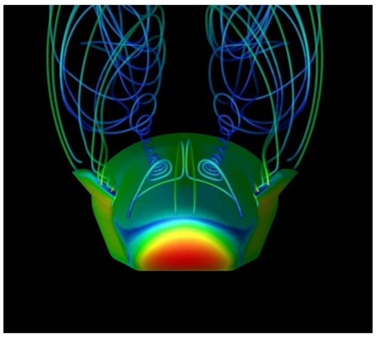
Lifting Body Options

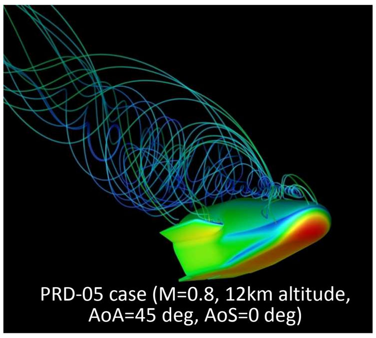
IXV 1:1

IXV down-scaled with hatch-back

Aeroshape

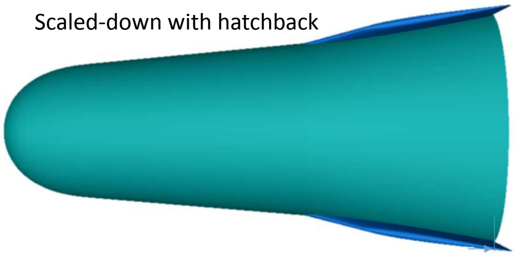
- ✓ CFD simulations are being performed to characterize the aeroshape in subsonic/transonics → fly at lower AoA (with higher L/D) and with enhanced lateral-directional stability.
- ✓ WTT will be also a key contribution for consolidation of aerodynamics.

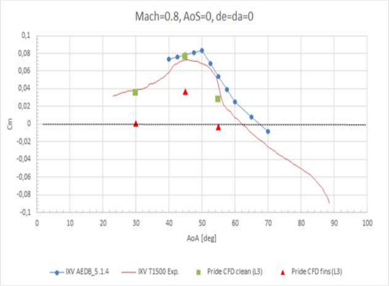


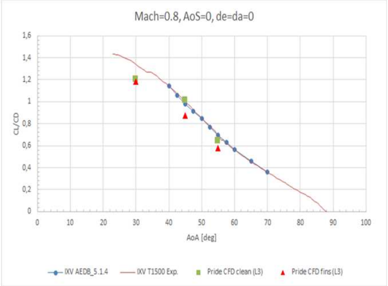


PRD-05 case (M=0.8, 12km altitude, AoA=45 deg, AoS=0 deg)

Scaled-down with hatchback



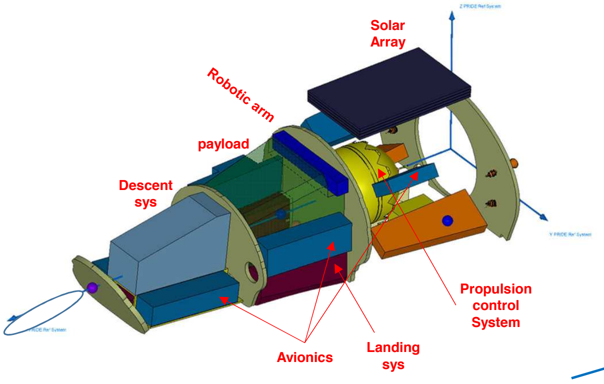


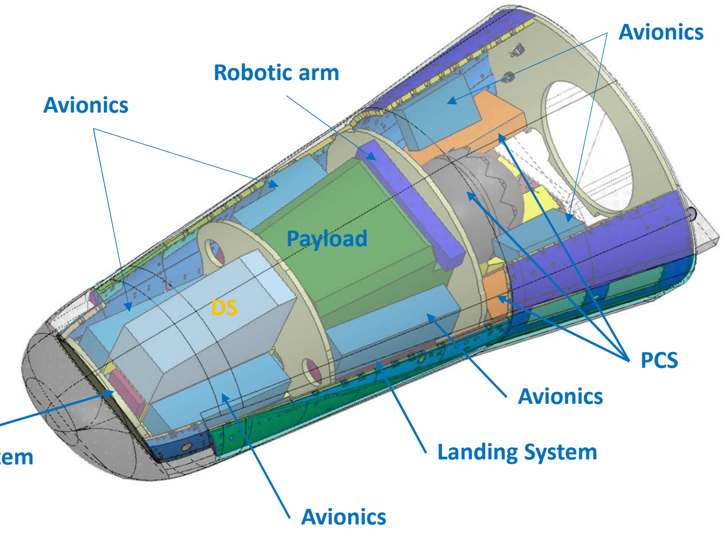


System architecture

Selected configuration and volumes allocation

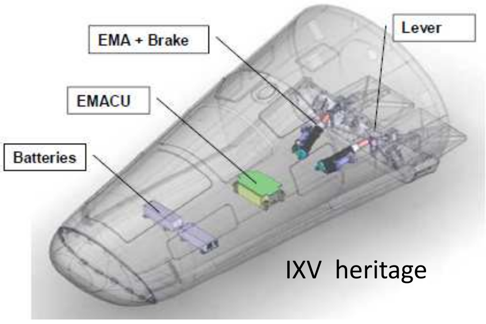
- ✓ The preliminary main sub system volumes allocation, meeting up/down CoG requirements, is depicted here below:



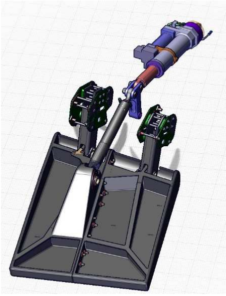


System Architecture
ASCS

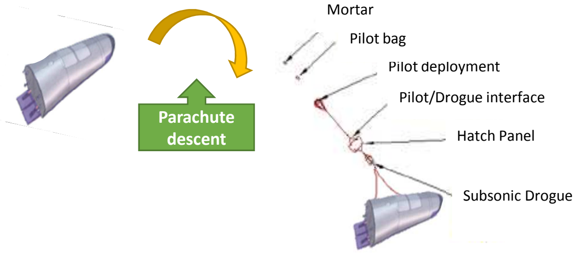
- ✓ The Aerodynamic Surfaces Control System provides the system with the control authority of the Flaps during the flying part of the mission from re-entry till triggering of parachute.
- ✓ The ASCS includes two electro-mechanical actuators (EMA) each with the related control unit (EMA-CU).
- ✓ Starting configuration relies on IXV Flap Control System with VEGA Zefiro-9 Actuators and relevant electronics.
- ✓ Alternative solutions are under investigation to verify adoption of aerospace actuators for system-level optimization purposes.



IXV heritage



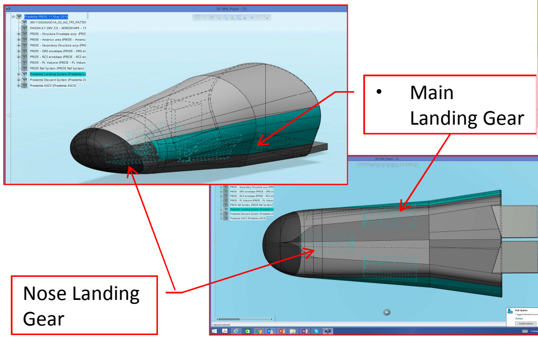
System Architecture
Descent System

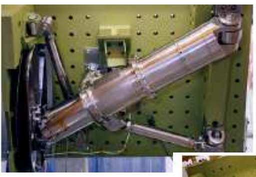


- ✓ A 2-stage Descent System (Pilot/Subsonic Drogue + Parafoil) allows the vehicle to manage the last part of the mission till landing.
- ✓ The Pilot + Drogue slows down the vehicle to a speed compatible with the opening of the Parafoil.
- ✓ The Parafoil gives controllability in the last phases of the descent allowing to achieve a soft and precision landing.

System Arcitecture
Landing System

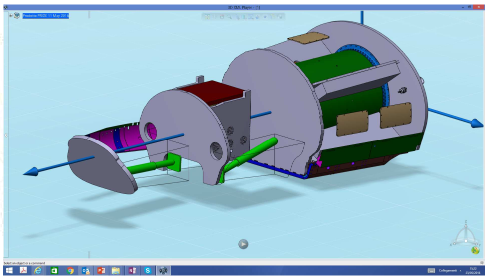
- ✓ The Landing System allows the vehicle to manage the landing at touchdown by sustaining the loads and providing stability during rolling on the soil.
- ✓ A classical tricycle solution is under design with a Main Landing Gear at the mid center of the vehicle and a Nose Landing Gear in the front.
- ✓ A trade-off will be done between sleeds and heels.





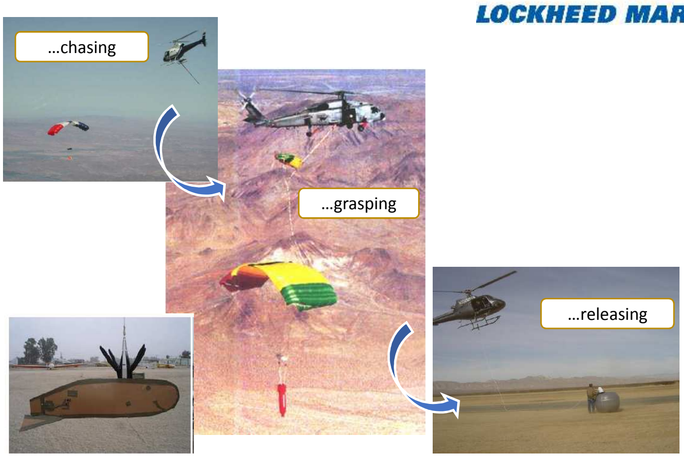
X-38

X-38

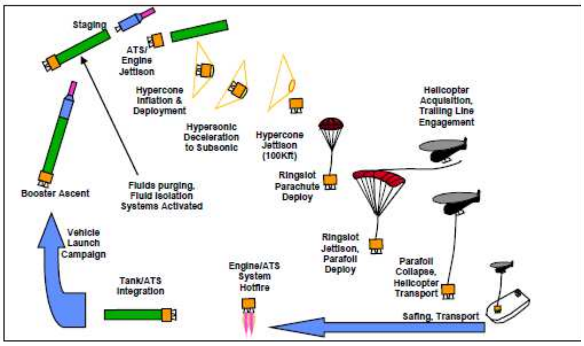


System Architecture
Mid Air Retrieval (MAR)

- ✓ As part of Mission Strategy trade-off, the **Mid-Air Retrieval** alternative is under evaluation in the Phase-A.
- ✓ This technique could be used as an alternative to a conventional wheeled or skidded landing gear system, as previously developed for NASA sample return missions and now undergoing internally funded development programme.



MAR Concept of operations



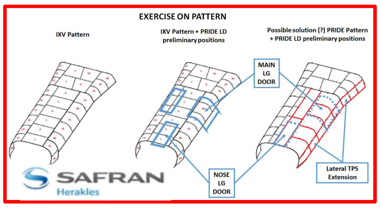
System Architecture

TPS

- ✓ IXV heritage will be widely exploited as baseline (i.e. Ceramic Nose, Windward and flaps, Ablative lateral and leeward).
- ✓ Effort will be put in place to account for specificities of Space Rider as reusability and landing.
- ✓ Alternatives are under investigation to optimize the IXV solutions w.r.t.
  - Baseline upward shift of boundary between ablative and CMC on the lateral side;
  - Alternative solution (e.g. FEI/SPFI) in place of ablative could be evaluated in favour of reusability;
  - pattern re-distribution for Landing Gear integration
  - definition of interface solutions to ease integration/dis-installation

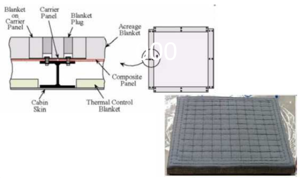
IXV Ceramic Windward and Flap

IXV Ablative Leeward



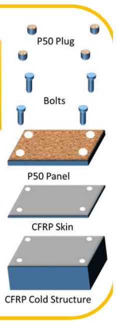
Fully reusable TPS elements

Extension of Shingles upwards
Use of flexible external insulator (FEI/SPFI)



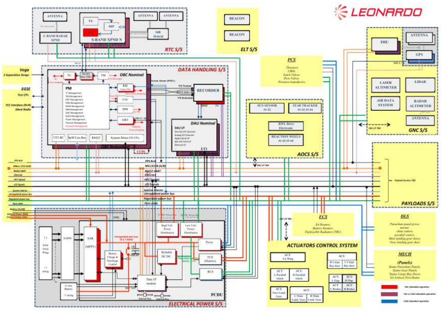
Low cost replaceable TPS elements

Redesign of ablative tiles for easy mountling /dismountling

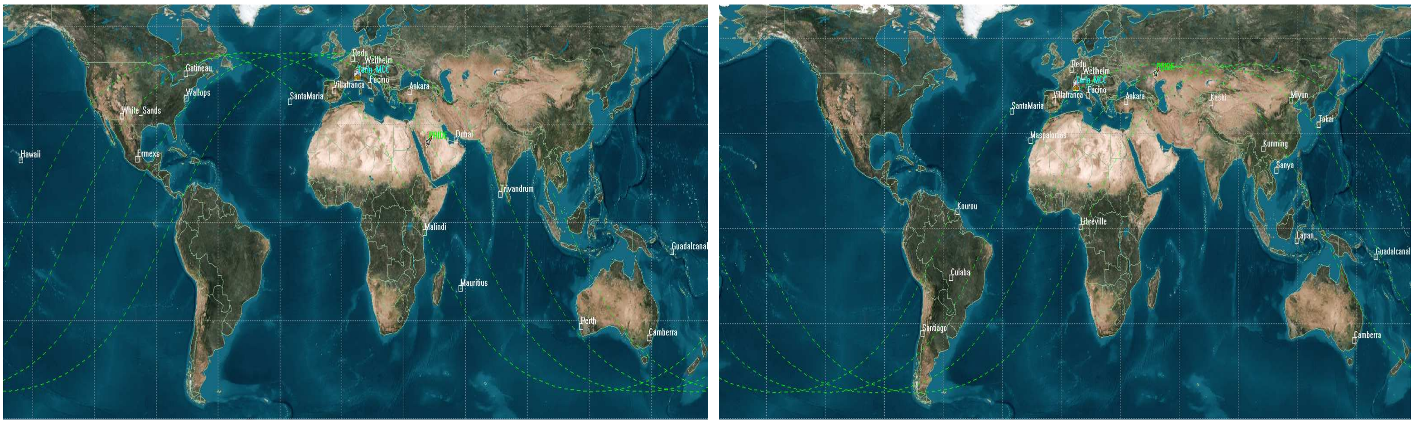


System Design – AVIONICS

- ✓ **POW:**
  - ✓ **Power systems architecture similar to a typical LEO satellite architecture, with power flow provided**
    - ✓ from solar generator system in sunlight phase orbit
    - ✓ from internal battery system during autonomous phases during eclipse and re-entry
    - ✓ from EGSE when on ground.
  - ✓ **Power architecture based on a Dual bus 72/28 Vdc**
  - ✓ **Full redundancy in the Power distribution**
- ✓ **DHS:**
  - ✓ **FT On-Board Computer as central core of the Vehicle Avionics**
  - ✓ **Interfaces provided for all GNC sensors/effectors**
    - ✓ Redundant IMU/GPS
    - ✓ Sun Sensors, Star Trackers, Reaction Wheels… to be finalized on
- ✓ **RTC:**
  - ✓ **includes** TM/TC antennas, S-Band Transponders, C-Band Radar Transponder, C-Band Antenna, GPS Antennas



Communication Links

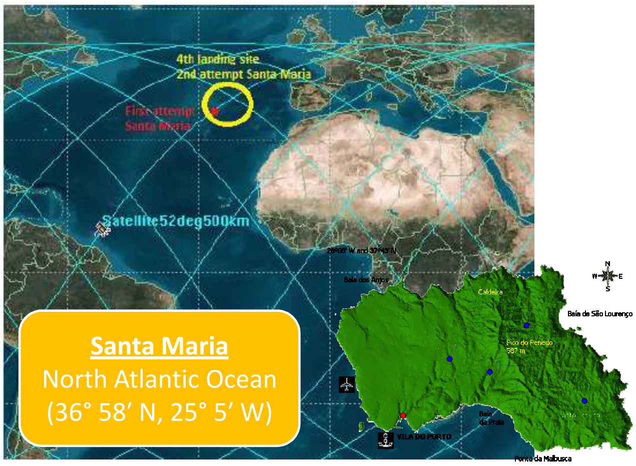


- ✓ **Available Ground Stations during last 2 hrs of ascending and descending arcs before landing at S. Maria.**
- ✓ **Extension of orbital communication coverage is possible through Ground Stations network collaboration and inter-satellite links.**

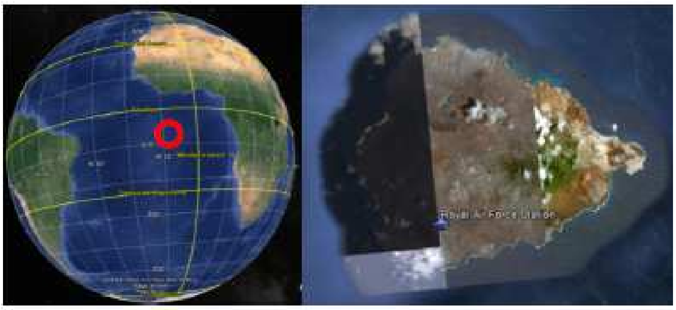
Landing Sites

- ✓ Two landings sites are in baseline:
  - Santa Maria in Azores Islands (Portugal), return from ISS orbit
  - Ascension Island (UK), return from lower inclination orbits

Ascension Site
Southern Atlantic Ocean
(07° 58' S, 014° 23' W)



Santa Maria
North Atlantic Ocean
(36° 58′ N, 25° 5′ W)



System Architecture

Next Steps

- ✓ The activities currently in progress are focusing on:
  - ✓ the definition of the mission scenarios which the platform can provide
  - ✓ the preliminary functions analysis and the subsequent flowdown of functions at lower levels
  - ✓ the decomposition of the MSRD requirements and their allocation to the preliminary system functions
  - ✓ the evaluation of alternative architectures solutions to better answer system requirements in terms of performances and reusability
  - ✓ The short term objective is the achievement of a consistent set of system requirements by PRR (end of Phase A) with associated the system architecture which already captured the major S/S features to efficiently start the phase B1.
  - ✓ A parallel investigation for possible commonalities between VEGA and PRIDE will represent a major support to a cost-effective architecture