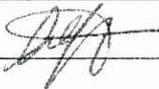
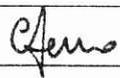
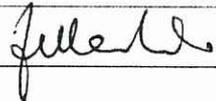


**RADFLIGHT PHASE A STUDY
EXECUTIVE SUMMARY REPORT**

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1. INTRODUCTION

The main objective of the RADFLIGHT Phase A Study has been to demonstrate the capability and feasibility to perform an "in flight research project" associated with the gathering of radiation/ablation flight data using state of the art intrusive and non-intrusive measurement techniques on board of a ballistic capsule, launched by the VOLNA launcher and providing re-entry speeds up to 11 km/sec thereby simulating a Lunar and/or Mars sample return re-entry mission environment.

Based on the recommendations drawn from the lessons learned from 2 planetary entries (Huygens, Galileo) and 2 Earth re-entry flights (Fire II, Re-entry F) the following flight data are required:

- Radiation/ablation coupling:
 - spectral radiation in the UV and visible bandwidths; other spectroscopic measurements contributing to the understanding of radiation coupling
- Pressure and temperature evolutions at different locations on and inside the TPS
 - radiative and convective heating
 - laminar to turbulent transition
 - turbulent / ablative heating especially in shoulder regions
- Base flows with attention to the existence of a supersonic wake closure
- Air data system

Presently large margins are taken for the design of the TPS for high speed science exploration sample return vehicles. This is due to large uncertainties on influence of radiation, radiation/ablation coupling and the occurrence of transition from a laminar to turbulence boundary layer.

Hence, the final goal of this in flight research project is to improve management of uncertainties associated with:

- physical modelling: non equilibrium thermo chemistry , absorption and emission, ablation, spallation and pyrolysis
- flight measurement techniques calibration and their integration into TPS
- knowledge of free-stream conditions

RADFLIGHT Project is included in the ESA Class 3 In Flight Technology Demonstrators family, which is of primary interest since the relevant activities address design tool improvements associated with critical phenomena or technologies to be mastered, for subsequent application in a Class 2 and 1 vehicles design process.

1.1 Acronyms

ADB	Aerodynamic Data Base
ATDB	Aero Thermal Data Base
BE	Booster Element
CFRP	Carbon Fibre Reinforced Plastic
CP	Carbon Phenolic
CV	Capsule Vehicle
DPIU	Data & Power Integrated Unit
EIP	Entry Interface Point
ESA	European Space Agency
ETA	Explosive Transfer Assembly
FPA	Flight Path Angle
I/F	Interface
IP	Instrumentation Package
RD	Reference Document
RV	Reentry Vehicle
S/S	Subsystem
TAS-I	Thales Alenia Space Italia

1.2 Definitions

The **RADFLIGHT System** (see Figure 1-1) consists of the following main elements: 1) **The Booster Element (BE)**, mainly composed of the propulsion stage and relevant accessories devoted to accelerate the Reentry Vehicle, 2) **The Capsule Vehicle (CV)**, which is the element sustaining the atmospheric reentry phase and equipped with the Instruments to fulfill the mission objectives. **The composite (BE + CV)** is called **Re-entry Vehicle (RV)**. **Instrumentation Package** is the assembly of instruments necessary to investigate the radiation/ablation coupling phenomena.

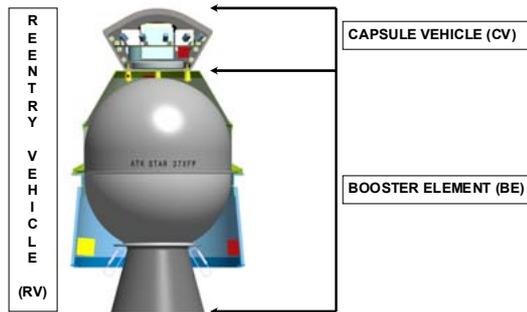


Figure 1-1 RADFLIGHT System Breakdown

2. RADFLIGHT MISSION OVERVIEW

RADFLIGHT will fly a suborbital ballistic trajectory from the Pacific Ocean near the peninsula of Kamchatka to a landing site located on the Kanin peninsula as shown in Figure 2-1.

The reference re-entry speed at the EIP of 100km altitude is 11 km/s. RADFLIGHT will be launched with a Russian converted ICBM, Volna from a submarine.

The RADFLIGHT mission can be segmented into the phases schematically shown in Figure 2-2 and hereafter described:

- **Launch and ascent:** the RV is injected by the launcher in an (sub)orbital kinematics condition allowing the efficient acceleration of the composite towards the EIP targeted state.
- **Coast and acceleration:** after separation from launcher upper stage, the RV will be spin-stabilized and placed in the correct attitude to prepare for booster ignition, which occurs close to EIP.
- **Atmospheric entry:** the RV is separated from the BE and perform the atmospheric entry phase profile as determined by the conditions at EIP (mainly velocity and flight path angle).

After the re-entry phase the CV will be slowed down using a staged parachute system that will allow a nominal landing speed of about 5 m/s. The recovery will be done via helicopters that will track the signal of an on board beacon. The CV is equipped with a crash proof and redundant memory package in order to protect the data in case of a crash landing.

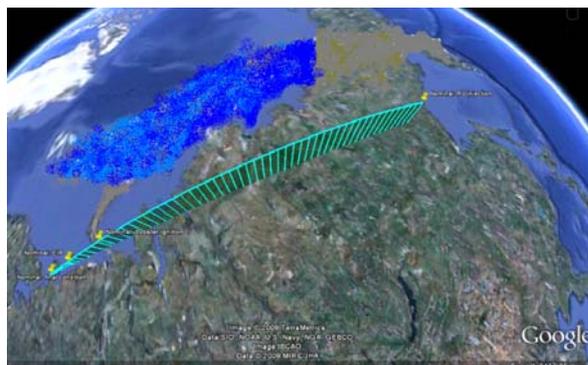


Figure 2-1 RADFLIGHT Ballistic Trajectory

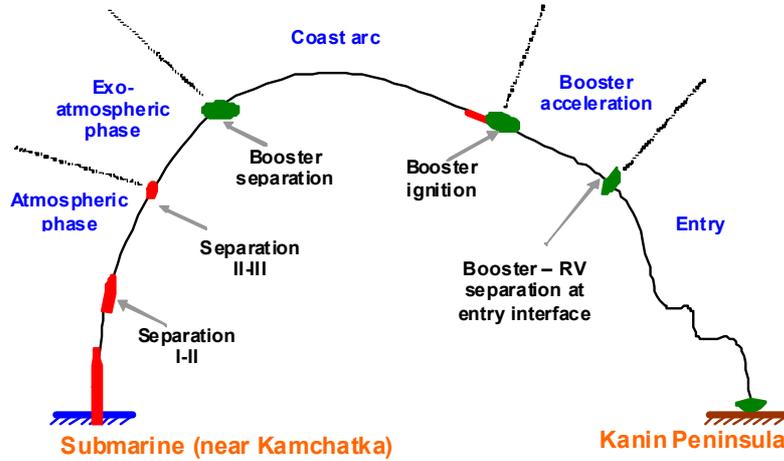


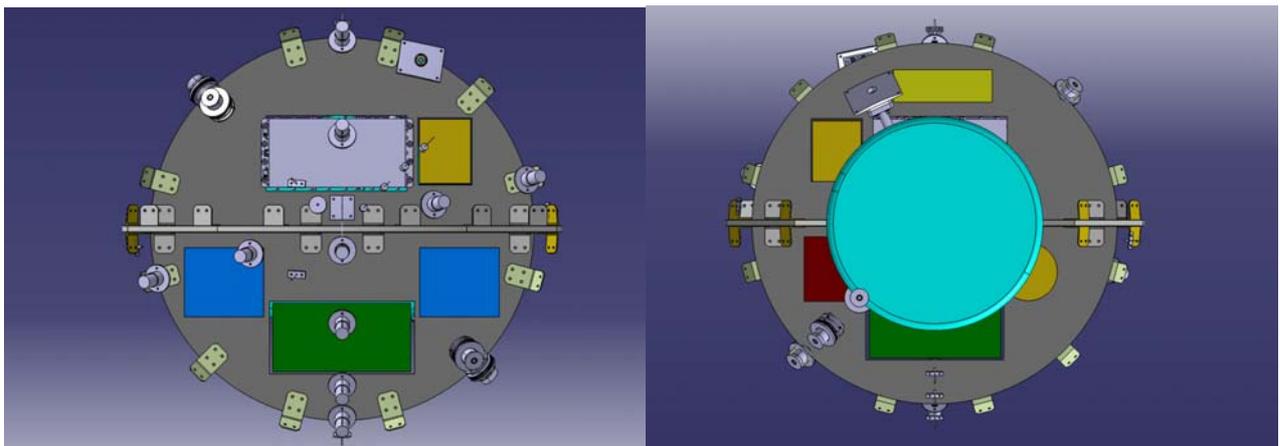
Figure 2-2 RADFLIGHT Mission Phases

3. INSTRUMENTATION PACKAGE OVERVIEW

The RADFLIGHT contains a set of Instruments, accommodated inside the CV, for a total of two main experiments and sensors hereafter listed:

- The SPECTROMETER (4 x sensors, 1x electronic) - shock layer chemical composition Radiation/ablation coupling measurement
- The RADIOMETER (2x) - total radiative flux measurement
- The Heat Flux Pyrolysis (HFP) sensors (10x) - total heat flux pyrolysis gas rate surface temperature measurement
- The Combined Heat Flux/Pressure (CFP) sensors (5x) – heat flux and pressure measurement

Complete the reference Instrumentation Package the Pressure Sensors (6x), the Recession Sensors (5x) and the Termocouples (3x). The Instrumentation Package layout inside the CV is depicted in Figure 3-1



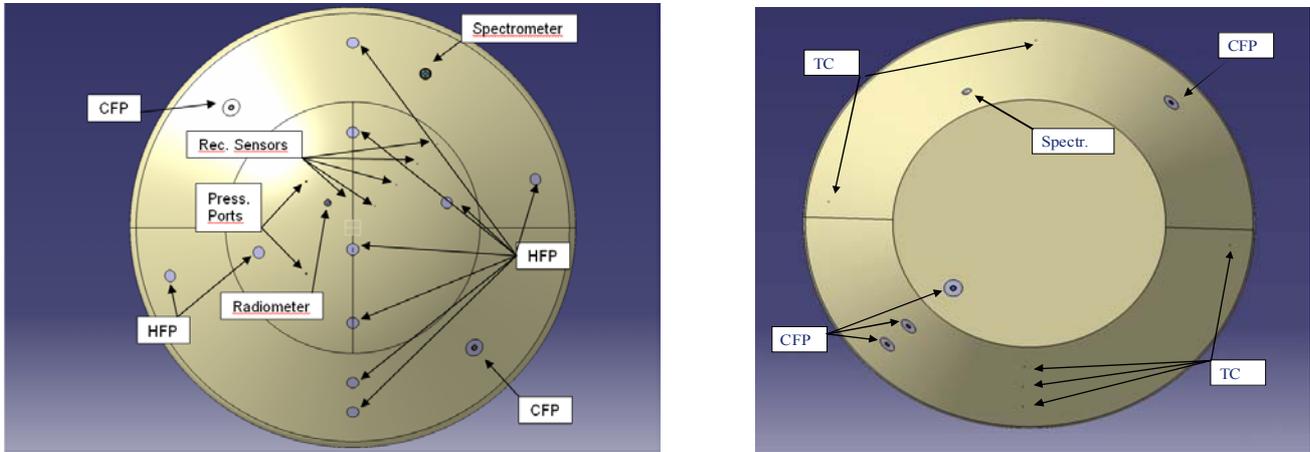


Figure 3-1 RADFLIGHT Instrumentation Package Layout inside CV: Front Side (left) – Back Side (right)

4. AEROTHERMODYNAMICS ENVIRONMENT

The RADFLIGHT RV is injected with a velocity of 11 km/s at the EIP which is defined at an altitude of 100 km. In this initial condition the nominal flight path angle is -18.2 deg. The nominal entry trajectory has been selected imposing several mission constraints such as 1) max load factor 100g, 2) max total heat flux 12MW/m², 3) max total heat load 200MJ/m². The typical evolution of the heat fluxes is shown in Figure 4-1.

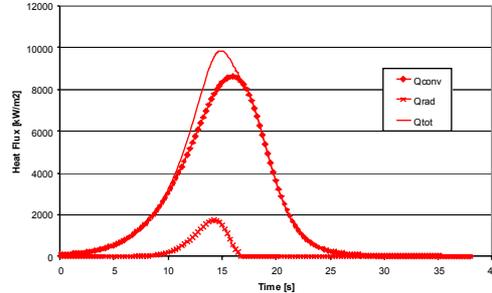


Figure 4-1 Heat Fluxes Evolution

The maximum heat flux is expected to happen on the stagnation point which is located on the CV nose. For the nominal trajectory, the expected maximum total heat flux is 10.35 MW/m² of which 8.98 MW/m² is the convective contribution and 1.92 MW/m² is the radiative contribution. The percentage of radiative to total heat flux is about 19%.

The total heat load is not exceeding 112 MJ/m². Radiation/ablation 11-species modelling shown a recession slightly superlinear with the heat flux input leading to a total maximum recession at stagnation point of about 2-2.5 mm, as shown in Figure 4-2

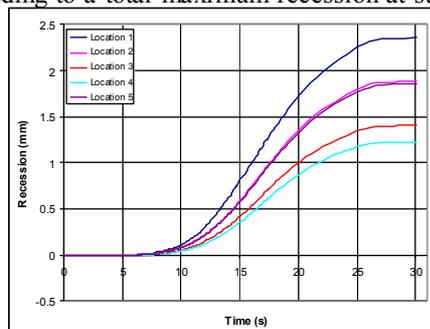


Figure 4-2 Recession History

5. RV ARCHITECTURE AND MECHANICAL DESIGN

The RV assembly consists of the following main elements: 1) the **Solid Rocket Motor (SRM)**, 2) the **Capsule Vehicle (CV)**, accommodating the system equipment and Instrumentation Package, 3) the **Upper Structure (US)**, providing the mechanical interfaces with CV and SRM as shown in Figure 5-1

The RV architecture and dimension are driven by the Volna allowable envelope as shown in Figure 5-2

The RV is housed inside the Volna second stage tank, in an upside down configuration with the nose pointing downwards. The whole RV mass at launch is 936 kg, including all margins, compatible with Volna launch capability.

More than 85% of the overall RV mass is propellant

The CV is a Stardust-like shape capsule, with a 700 mm diam and 60 deg half-cone angle.

The CV mass, including all margins, is 44 kg.

The main drivers for the mechanical design are the loads during launch (whole RV) and the deceleration due to the aerodynamic drag and parachute opening which will be experienced during re-entry (CV only). The maximum expected deceleration peak, acting during entry on the CV only, is about 93 g's.

The VOLNA launcher imposes first natural frequencies of 20 and 35 Hz for the payload in lateral and axial axes respectively. The Quasi-Static Loads (QSL) for Volna is 8 g longitudinal and ± 2 g lateral.

Both RV and CV structures are based on CFRP skin-Al core honeycomb concept.

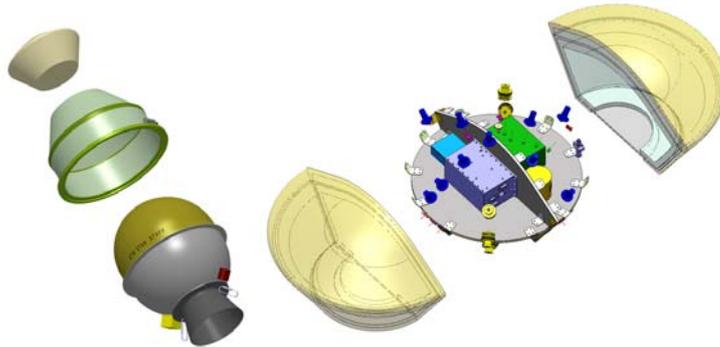


Figure 5-1 RV (left) and CV (right) Exploded View

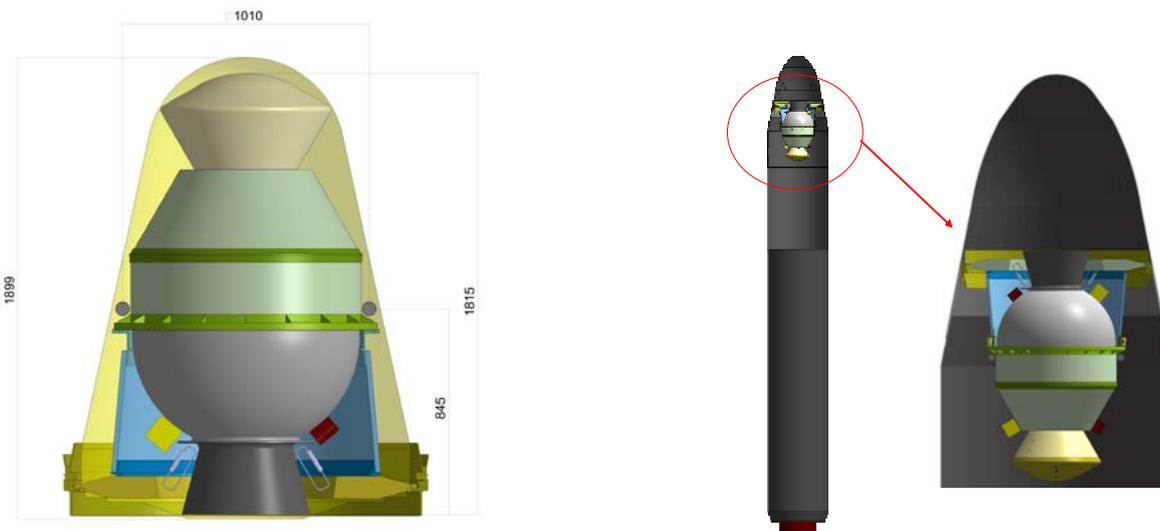


Figure 5-2 RV inside Volna Allowable Envelope (left) and in Launch Configuration (right)

6. PROPULSION AND SPIN UP SYSTEM

The propulsion system provides the required delta-V to allow the RV reaching the 11 km/s velocity at EIP. An extensive trade off has been performed since the beginning of the study to identify the most suitable propulsion technology for RADFLIGHT. Among solid, liquid and hybrid propulsion system the first one has been found the (only) profitable solution. The selected Solid Rocket Motor is the ATK Star 37-XFP model, short nozzle configuration, effective Isp 286 s. The nominal propellant loading for RADFLIGHT mission is in the range 799-805 kg.

The propulsion system is completed with a Safe & Arm Device and ETA lines.

Before SRM ignition, the RV requires to be spin stabilized (22-25 rpm) via the activation of two small solid rockets placed in the RV CoG plane. The Propulsion and Spin-up system schematic are shown in Figure 6-1.

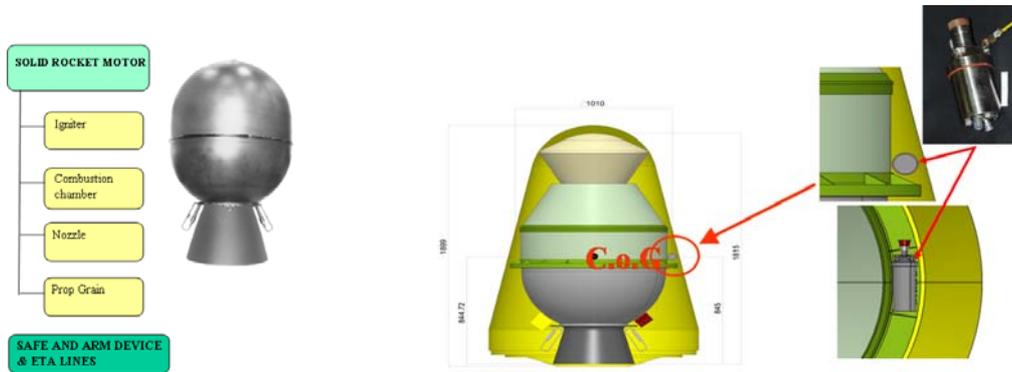


Figure 6-1 Propulsion (left) and Spin Up (right) System Schematic

7. TPS/TCS DESIGN

The selected CV TPS/TCS concept is based on front shield light ablator material (PICA-like), low density RVC insulator and SLA material for back shield, as shown in Figure 7-1.

The TPS is sized for the maximum expected heat peak fluxes plus suitable margins and capable to assure an airframe temperature lower than 150°C and internal instrumentation temperature lower than 60°C, as shown in Figure 7-2. During the study it has been investigated a different Front Shield TPS concept using a heavy ablator (MC-CFRP Carbon cloth layers impregnated with phenolic resin) and a layer of RVC insulator. Despite the advantages offered by the CP materials (good mechanical properties, very high heat flux capability, due to high density, helps to maintain the CV CoG in an optimal location towards the nose, due to less thickness, allows a larger CV internal volume for equipment accommodation) this application has been abandoned due to unaffordable mass impact on CV.

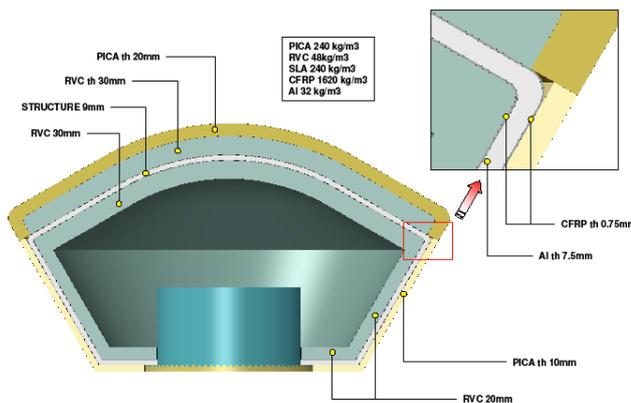


Figure 7-1 CV TPS/TCS Architecture

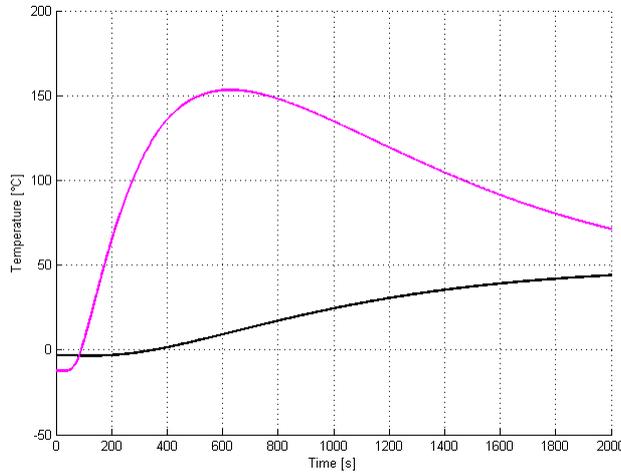


Figure 7-2 CV Temperature Time History

8. AVIONICS ARCHITECTURE

The Avionic system controls and monitors RADFLIGHT during the mission. Mission data are recorded on board in on-board redundant mass memory package. A schematic of the avionic architecture is shown in Figure 8-1.

The avionic main functions encompasses with: 1) Electrical Power Supply, Distribution and Control, 2) On-board Data Handling, 3) On-Ground Localization support

The electrical power subsystem distributes the power provided by the batteries via the power control and distribution units to all the sub-systems of the RV and to the CV accommodated instruments.

The data handling subsystem provides the timer sequence reference and issues the command for the mission profile events. It is also able to store on the memory the housekeeping and system data as well as the instruments collected data. The on-ground localization subsystem provides means (RF beacon) for an easy and quick CV localization after landing for recovery operations. The majority of the avionic equipment are accommodated inside the CV; hence, due to the limited available volume the utilization of miniaturized component is strongly envisaged.

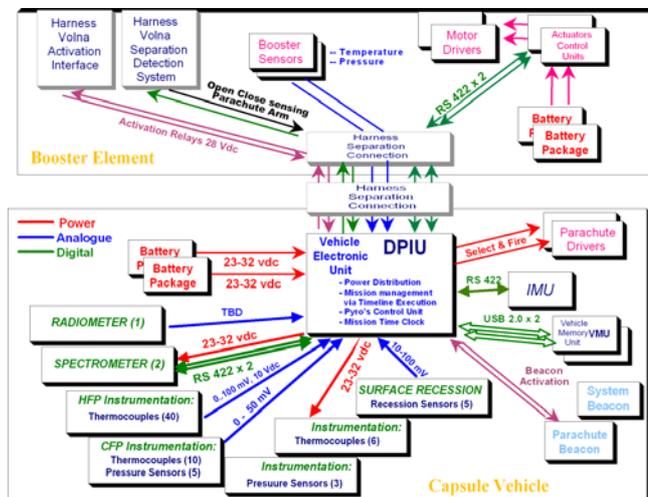


Figure 8-1 RADFLIGHT Avionic Architecture

9. DESCENT AND LANDING SYSTEM

A two stage Descent and Landing System (DLS) has been selected as baseline, based on Stardust concept. The system includes: 1) a Pilot Chute including canopy, lines, riser, and bridle, Deployment Device (mortar), and Bridle Release Mechanisms, 2) a Main Parachute including canopy, lines, riser, bridle, deployment bag, deployment lanyard, and Bridle Release Mechanisms, 3) a Parachute canister (rigid container) including structural cover and mortar release mechanism. The Main Parachute provides the landing conditions with a landing speed of about 5 m/sec. The supersonic pilot chute is about 0.83 m diameter while the triconical main parachute is about 6 m diameter. A schematic of the descent and landing profile is shown in Figure 9-1

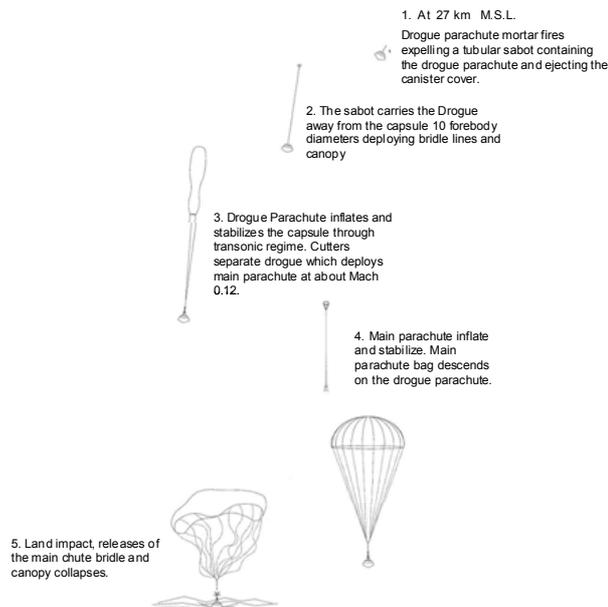


Figure 9-1 CV Descent and Landing Profile

10. CONCLUSION

The major conclusions at the end of the RADFLIGHT Phase A Study are:

- 1) The RADFLIGHT mission, as studied during present study, does not present elements which are preventing its feasibility,
- 2) Dedicated attention will be spent during phase B to the recoverability of the capsule in case of water ditching as back-up scenario,
- 3) Dedicated development studies shall be spent to consolidate critical technologies, such as TPS, miniaturized avionics, aerodynamic/aerothermal databases,
- 4) An efficient thermo-mechanical approach, including samples of different TPS solutions, appeared to be feasible at present status of technology. However aerothermal loads refinement and TPS testing activities are suggested to be anticipated in the early phases,
- 5) A simple avionic architecture, with maximum use of OTS, has been selected to be the basis for a streamlined system approach and consequent mission performance improvement,
- 6) A positive margin for mass properties tuning has been shown to look for mission and aerothermodynamic characteristic improvement,
- 7) The RADFLIGHT looks a good candidate as an atmospheric reentry demonstrator, taking advantage of past EXPERT experience and technical knowledge on similar demonstrators using the same launcher,
- 8) VOLNA launcher is compatible with mission needs,
- 9) Programmatic assessment is in the expected range of intermediate class of demonstrators,
- 10) High synergy with European past (ARD, X-38), present (Expert, IXV) re-entry demonstration programs are envisaged,
- 11) No major technical showstoppers have been highlighted.

END OF DOCUMENT