Inflatable Reentry and Descent Technology (IRDT) – Further Developments

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ABSTRACT – The new lightweight Inflatable Re-entry and Descent Technology (IRDT) has been demonstrated in a first test flight in February 2000 within a Babakin Space Center (a Lavochkin Association subsidiary), Astrium GmbH, ESA/ESTEC and International Science and Technology Centre (ISTC) / European Union program. This technology is designed to reduce the mass and cost of future re-entry systems for Earth and planetary. This paper outlines the further technology development with a second test flight in 2001 and the definition of an operational International Space Station ISS Download System for the European Automated Transfer Vehicle and Russia's Progress cargo vehicle.

1 - INTRODUCTION

Within the Mars-96 program a new inflatable re-entry and descent technology (IRDT) has been developed by Lavochkin (Babakin's mother company) for re-entry and landing on Mars. Due to the failure of this mission in 1997 the technology could not been demonstrated in flight. In 1998 Lavochkin and Dasa joint in the development and marketing of this technology. As result of these activities a demonstration mission was performed on 9.2.2000 to demonstrate the feasibility of this technology under a contract of the International Science and Technology Center (ISTC) with ESA and Dasa as collaborators. After launch from Baikonur and 6 orbits the IRDT flight Demonstrator landed southwest of the city of Orenburg near the Russian – Kasachian border. The flight Demonstrator included a 100 kg vehicle compiling the two stage inflatable IRDT system incl. the necessary service equipment (avionics, tanks, etc.) as well as a sensor package with IMU, temperature and gas sensors for flight performance verification. After landing the vehicle was recovered for post-flight evaluation. Despite of some minor deficiencies the mission confirmed the basic feasibility of the IRDT technology (see [1] and [2]). For the further development in 2001 it was concluded that a second test flight and the detail design of an operational ISS Download System shall be performed. This shall complete the technology development by demonstrating the IRDT maturity with re-entry and landing from low Earth orbit as well as to provide a program proposal for an economic application within the ISS scenario. Again the program will be executed by Babakin and Astrium funded by ISTC / EU, ESA and Astrium.

This paper reviews the IRDT technology and will focus on the second demonstration mission IRDT-2 planned for autumn 2001 as well as the envisaged ISS Download System.

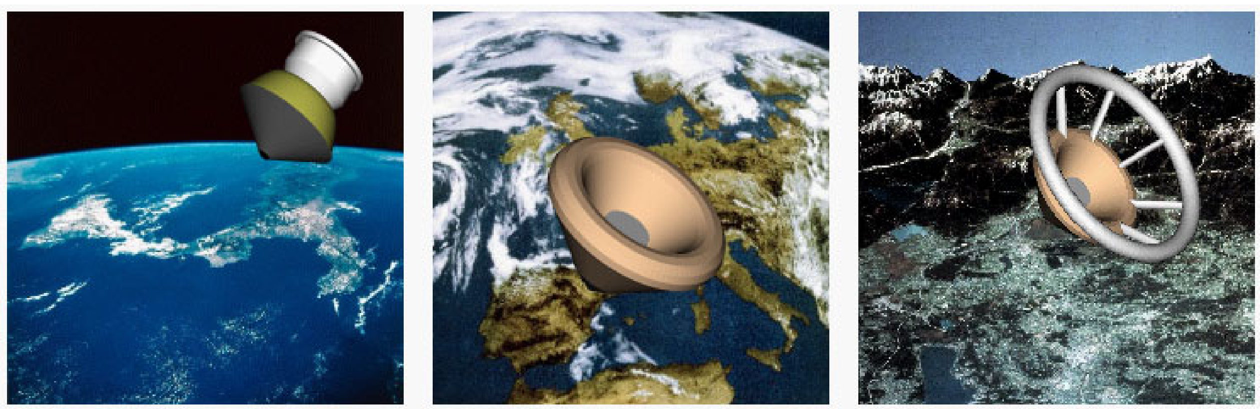
2 – TECHNOLOGY DESCRIPTION

The Inflatable Reentry and Descent Technology concept will be capable to replace conventional reentry subsystems, as used for e.g. the Russian Soyuz and Foton, the US Apollo or European missions like Express and ARD. The three main reentry subsystem elements are combined by the IRDT technology, i.e.

1. Thermal Protection System (TPS) for Reentry
2. Parachute System for Descent
3. Damping/Floatation System for Landing

This results in simple and cost effective design of the re-entry system, which will provide sufficient aerodynamic and aero-thermodynamic behavior during the critical reentry phase and will allow for touch-down of the vehicle in the predefined landing area.

The three typical mission configurations for an IRDT system for e.g. an earth reentry mission are shown in figure 1 illustrating the working principle. The inflatable material is densely packed during launch and orbit phase making optimum use of the space available and without the need of having already its final aerodynamic shape. The flight configuration will be placed onto the re-entry trajectory by a de-orbit maneuver of e.g. the upper stage or an own de-orbit motor. Prior to entering the thinner layers of the atmosphere, the first cascade of the IRDT device will be inflated by gas, released through a pyro valve from the storage tanks of the pressurization subsystem or a gas generator. The inflatable braking shield consists of different layers of multi layer insulation and flexible ablative layers arranged on a flexible inflatable kernel. This kernel provides the form and stiffness of the inflatable braking shield. The resulting re-entry configuration, which is inflated within seconds, will perform aero-braking to subsonic speed while flying through the atmospheric layers. The resulting aero-braking shield will give the reentry configuration sufficient aerodynamic stability during all reentry flight regimes. For braking to moderate landing velocities of about 10 m/s and less the second cascade will be inflated. This further increases the braking area and serves as replacement of a parachute. Depending on the shock requirements for landing further a damping system may be added to the configuration.



Orbital Configuration **Reentry Configuration** **Landing Configuration**

Figure 1 : IRDT configurations

3 – DEMONSTRATION MISSION IRDT-2

The objective of the IRDT-2 test flight is to verify the enhanced system concept under representative orbital flight conditions. Following the IRDT-1 flight the system concept was enhanced following the recommendations of the flight evaluation. This includes improvements in the shield design, the internal pressure control and monitoring, a telemetry system for the landing phase as well as an enriched sensor package providing the flight evaluation data.

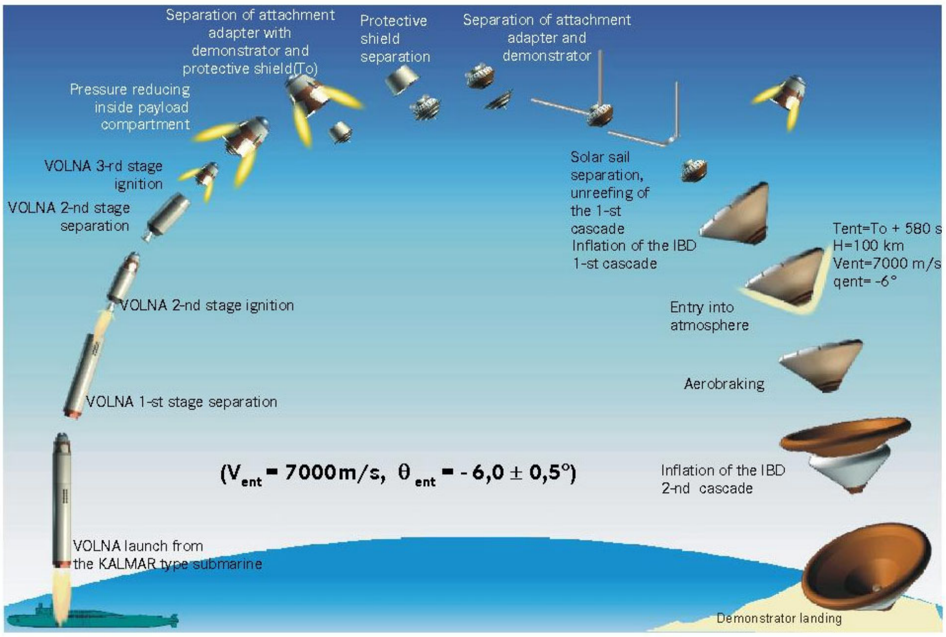


Figure 2 : IRDT-2 Mission Profile

The IRDT-2 mission will be a suborbital flight using a Russian Volna submarine rocket from Design Bureau Makeev. Although suborbital the entry conditions of 7000 m/s entry velocity and -6 deg entry angle will be representative for an orbital entry with around 7800 m/s and –2 deg in terms of thermal flux and g-loads which mainly determine the design of the heat shield. Figure 2 and 3 illustrate the mission scenario with the Volna launch from a Russian submarine in the Barentsee near Murmansk and landing on the Kamshatka peninsula.

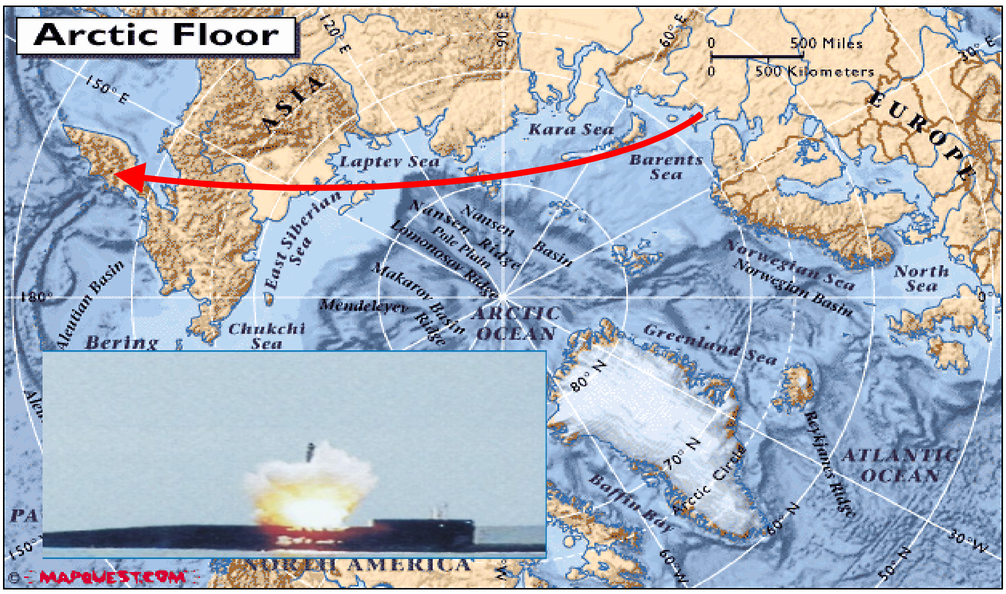


Figure 3 : Volna launch and IRDT-2 flight path

The IRDT-2 test article consists of an enhanced version of the IRDT-1 vehicle. Figure 4 shows the vehicle design in the packed and deployed configuration. It is composed of four main elements i.e. the inflatable braking device, the rigid nose and the equipment container built by Babakin as well as the sensor package built by Astrium. The total mass will be about 140 kg.

The braking system is composed of an ablative rigid nose, the main part of the Inflatable Deceleration Unit (IDU) for braking down to subsonic speed and the Additional IDU deployed at about 25 km altitude and used for further deceleration down to landing velocity of about 10 m/s.

The equipment container contains all vehicle control elements like filling system, accelerometers, on-board computer and a radio search system using the COSPAS-SARSAT satellite system.

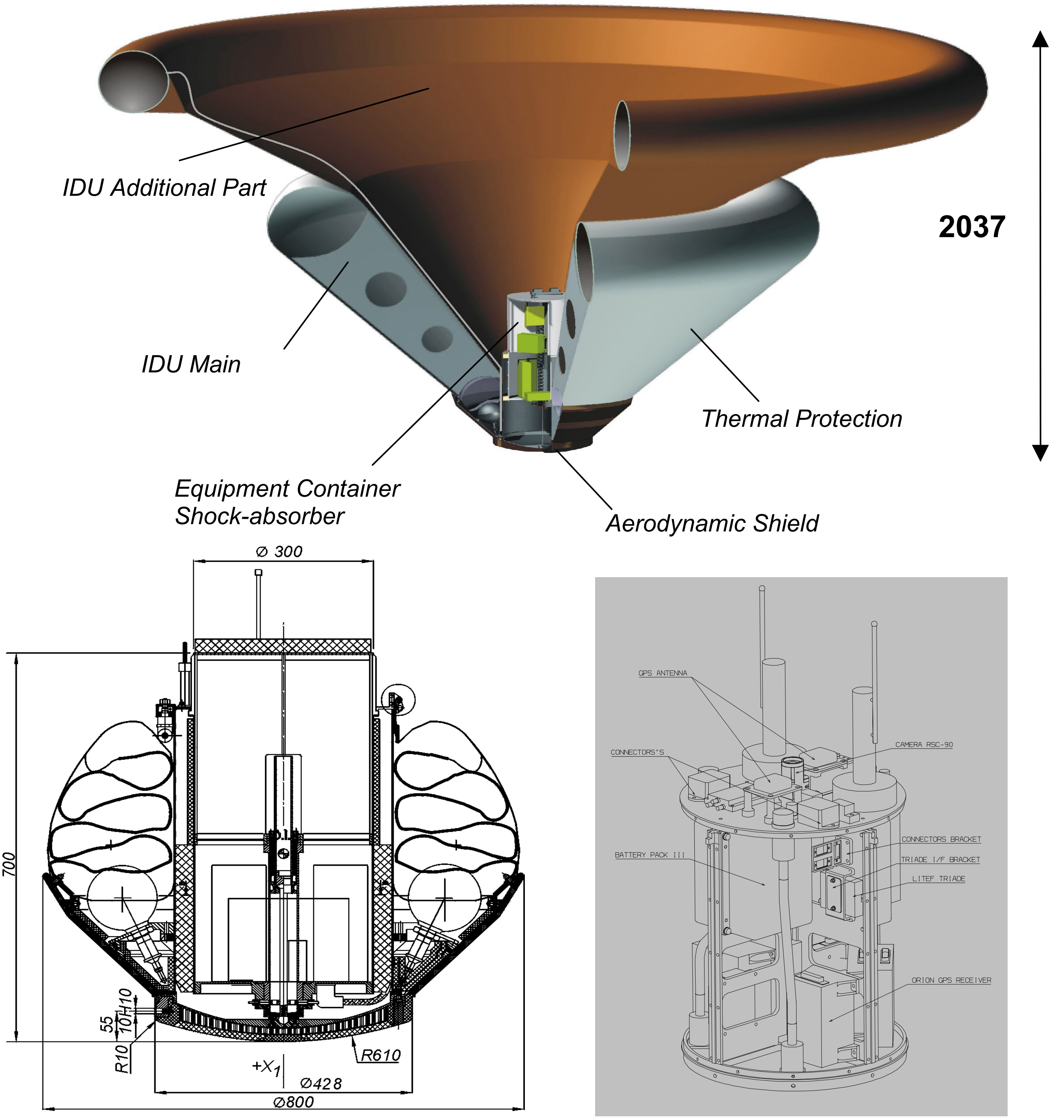


Figure 4 : IRDT-2 vehicle design

Figure 5 gives examples (C_N and C_P) of parameters of the aerodynamic database of the IRDT-2 vehicle.

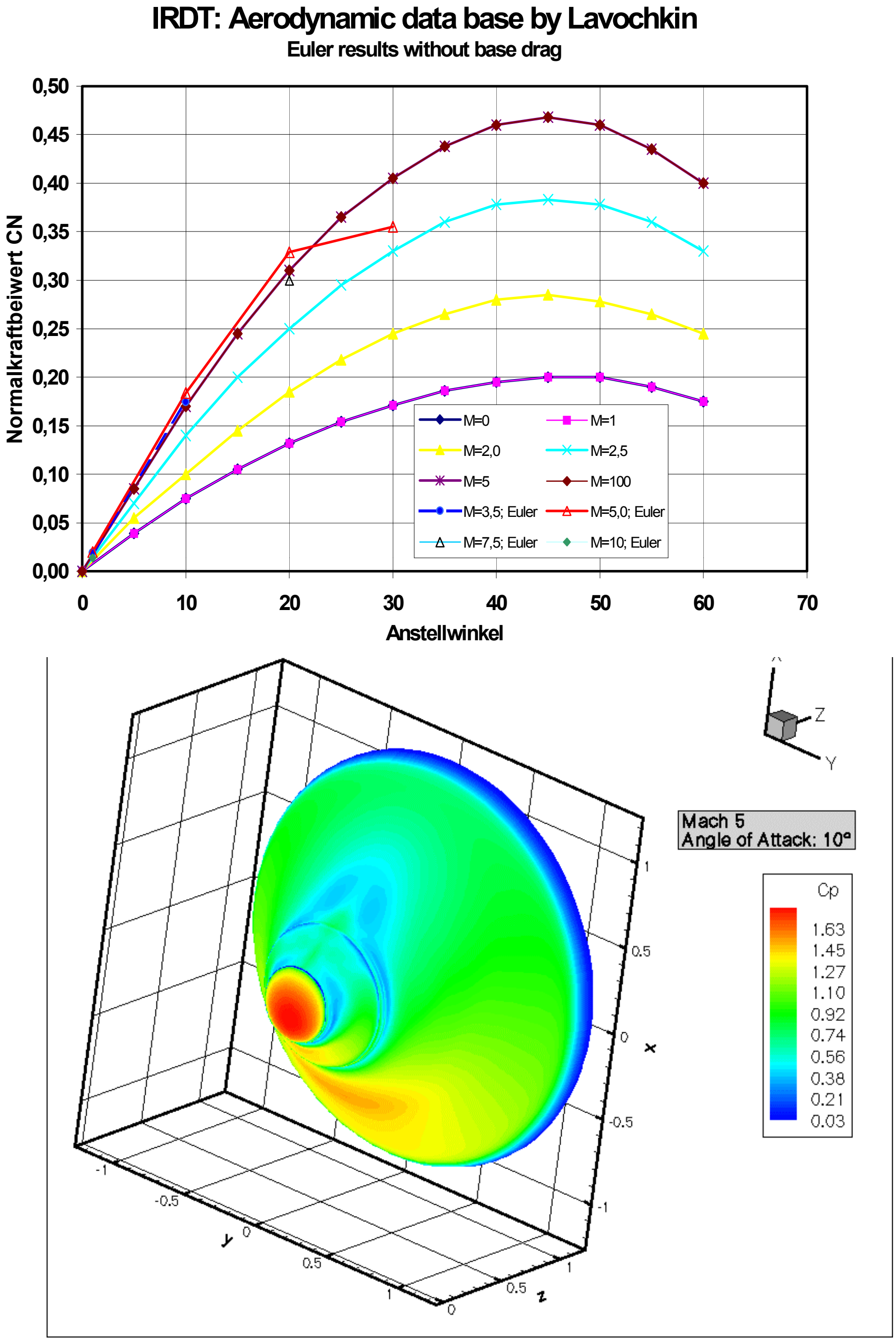


Figure 5 : IRDT-2 Aerodynamic Data

The IRDT-2 payload includes the scientific sensor package (25 kg) designed and intergrated by Astrium. Its purpose is to perform flight performance measurements and scientific experiments for the post-flight evaluation. The sensor package compiles the following sensors :

- 3 fibre optic gyros (LITEF μ-FORS 6) to measure the angular motion
- 1 3-axis accelerometer (LITEF Triade B-290) to measure the translational forces
- RAFLEX air-data system (HTG Göttingen) to measure pressure and thermal flux
- A spaceborne GPS (DLR GSOC) for trajectory data

- 8 thermal couples
- Color video camera (SEKAI RSC-90) with wide angle lens pointing leeward for optical monitoring of the behaviour of the inflatable shield
- Oxygen sensor FIPEX (IRS Stuttgart)
- Quartz Crystal Microbalance QCM (ESA/ESTEC) for contamination measurements
- UHF Radio system incl. 2 airborne GPS receiver for search and recovery
- the on-board systems DHS, PCU, batteries, structure (Vectronic and Astrium)

4 – ISS Download System

Cost efficient and flexible transport to and from ISS is a key element for the exploitation of the space station. Especially download from ISS is currently limited to the Space Shuttle and some marginal Russian capability with Soyuz. Neither Europe nor Japan has an own capability. For ESA alone more than 600 kg of download is predicted per year, which today is foreseen to be returned with the Shuttle at high cost of 22 – 26.4 K$/kg and according to the Shuttle flight schedule. Thus an extra download capability at cheaper prices and independent from the Shuttle will be an attractive complement to the existing scenario.

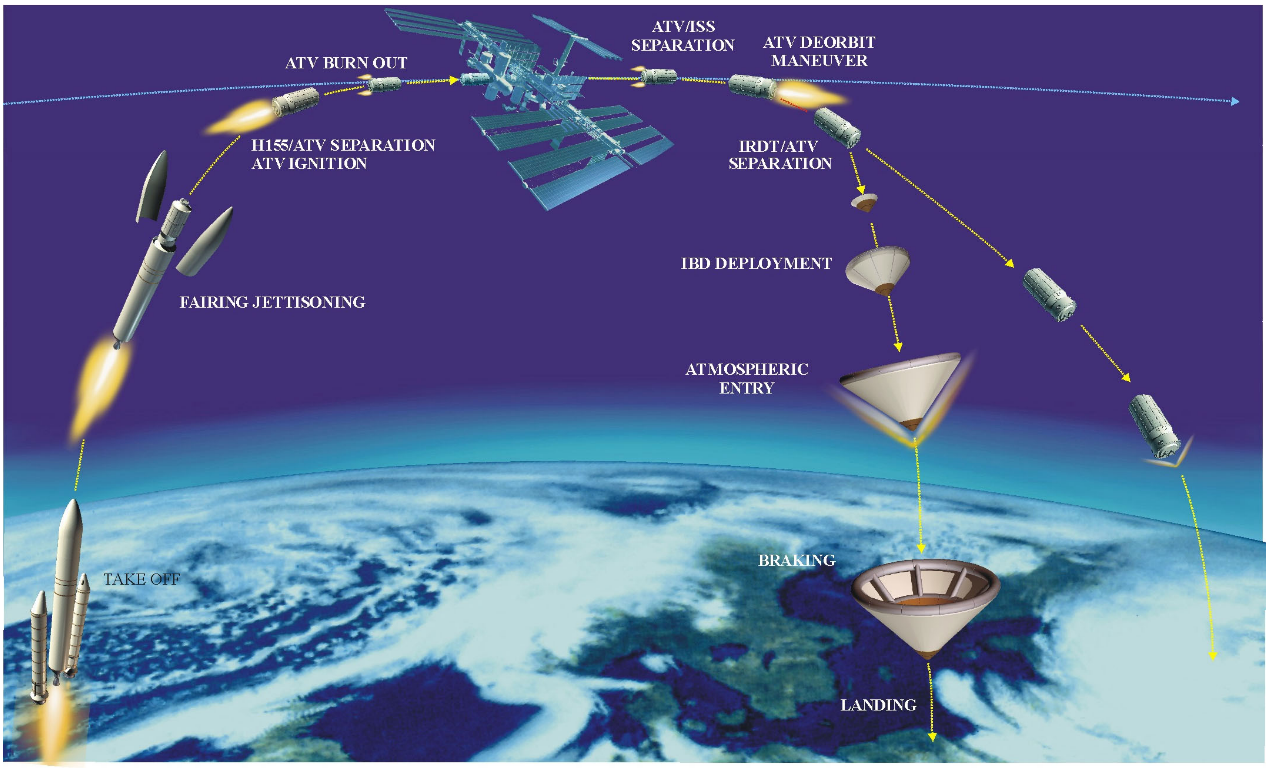


Figure 6 : ISS Download System Mission Scenario

Well suited for such a capability are the European ATV and the Russian Progress cargo carriers. Both are de-orbited after leaving space station, i.e. they are on a re-entry trajectory to Earth but burning up due to the missing thermal protection. However jettisoning a small re-emtry capsule filled with the down payload will bring the capsule on the way home without the need for an own de-orbiting system. With the plans of about 1 ATV and 6 – 7 Progress per year several flights might be executed each year. Assuming e.g. 3 flights per year with 200 kg each over 10 years 6000 kg can be brought back to Earth which would could 150 M$ when returned with the Shuttle. As ATV and Progress are going to fly anyway this figure clearly shows the economic potential of such capability.

The basic technical concept is like the Russian Raduga system, i.e. the installation of a small capsule inside the docking adapter before undocking from ISS and its jettisoning after execution of the de-orbit burn. This allows access from inside the ISS for payload packing and flight preparation, however the docking port diameter (about 800 mm) provides a major limitation in the system size. First analyses of such a system show that a payload of 200 – 250 kg per flight (twice than Raduga) might be returned to Earth. Figure 10 illustrates the mission scenario.

Figure 7 illustrates the interface and handling at ISS. Both Progress and ATV are docking to the backward ISS docking port at the Zvezda service module. The empty download system will be launched and transported to ISS in the pressurised cargo compartment (for ATV = Integrated Cargo Carrier). Before undocking from ISS it will be loaded, prepared for flight and finally installed into the docking port.

After undocking from ISS and execution of the de-orbit burn the capsule will be jettisoned. Then the main IDU (1st cascade) of the capsule will be inflated and the re-entry performed in the same way as during the test flights. The second cascade again ensures proper landing conditions for the retrieval by the ground recovery team. As for the Russian Soyuz and previous Progress/Raduga the baseline return will be to the Russian/Kasachztan landing zones which were also used for IRDT-1. Maximum g-loads during re-entry and landing will be less than 20 g. Temperatures will be around room temperature.

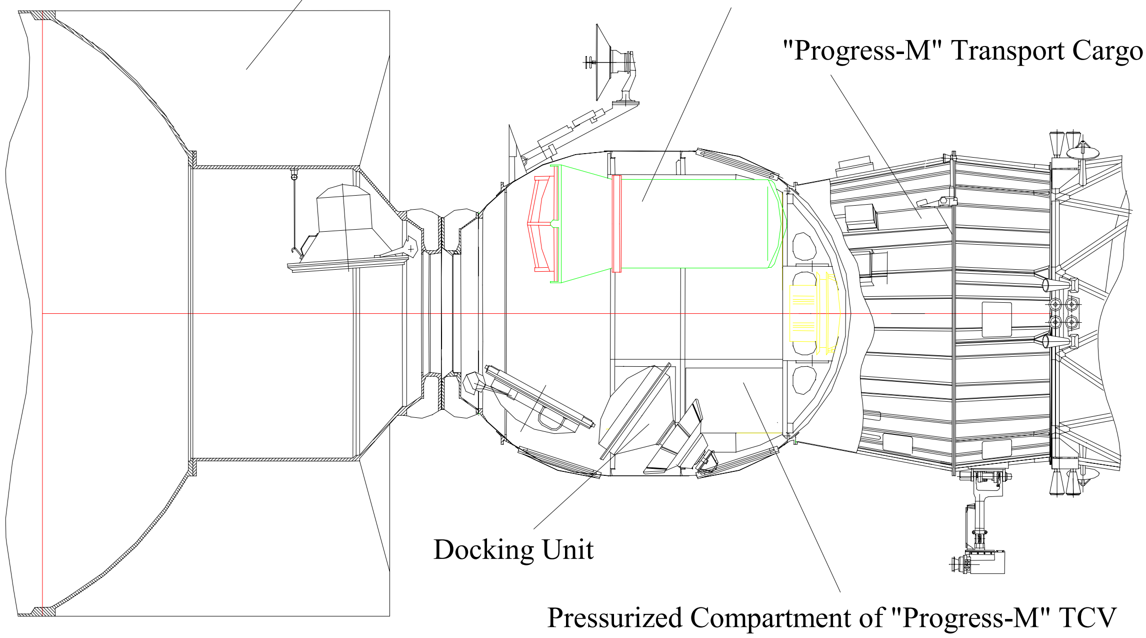


Figure 7 : Interface with ISS

The capsule design will be an evolution of the system used for the test flights. It also will employ the two cascade braking flexible device however also with a flexible but not rigid nose and a larger nose cone angle of 120 deg rather than 90 deg in order to optimise the ballistic coefficient for Earth re-entry.

The key design goal is to maximise the payload mass / volume for an economic transport. As such maximum use of the limited space inside Progress and ATV will be made. This is supported by the IRDT feature of the possibility to pack the flexible shield within the available volume for transport and to deploy it to the required re-entry configuration only after separation from the carrier. Further the system design shall minimise all system elements to a minimum. Important elements here are gas generators for the filling system or a miniaturised avionics system. With this at present a payload volume of at least 300 liters (-> average payload mass about 200 kg at 0.7 kg/l) with a system dry mass of about 100 kg is expected.

Figure 8 shows two configurations of the ISS Download System. The packed configuration inside ATV / Progress and the re-entry configuration with the main IDU deployed.

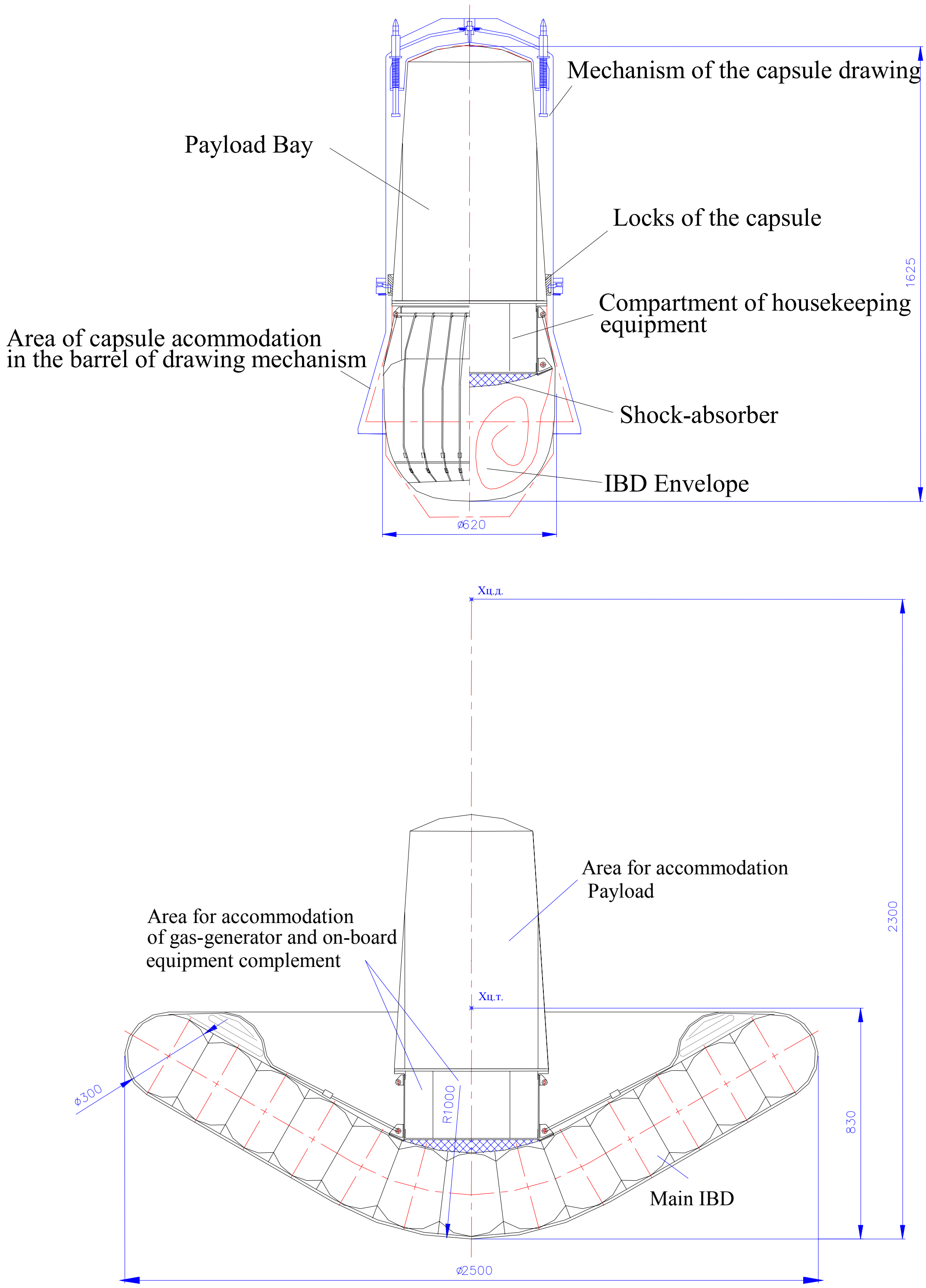


Figure 8 : ISS Download System Configurations

5 – SUMMARY AND OUTLOOK

With the activities planned in 2001, the second test flight and the detail definition of an operational ISS Download System, the IRDT technology is expected to reach operational maturity to provide enhanced and cost efficient re-entry capabilities.

The envisaged ISS Download System has a high potential to provide an independent European and Russian download capability for ATV and Progress. As such it will not only provide an added-value to ATV and Progress but also reduces download prices and complements the Shuttle capabilities by providing ISS download independent from the STS flight schedule. Due to the simplicity of the operational concept and the expected maturity of the IRDT such system can be operational already in 2003.

Beyond this the IRDT is also attractive for other operational applications e.g. of future Reusable Launch Vehicles (RLV), return of launcher stages or elements, planetary missions to Mars or an extended ISS download capability also using ATV.

6 – REFERENCES

[1] Inflatable Re-entry and Descent Technology (IRDT), D. Wilde et al.,
15 th International Symposium on Spaceflight Dynamics, Biarritz, June 2000

[2] IRDT : Flight Demonstration and Future Prospects, L. Marraffa et al.,
ESA Bulletin no. 103, August 2000