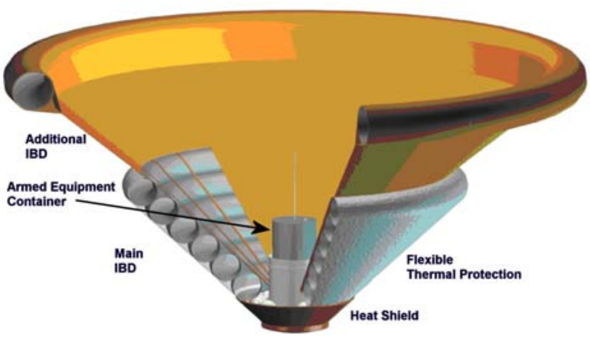
Inflatable Re-entry Demonstrator Technology (IRDT)

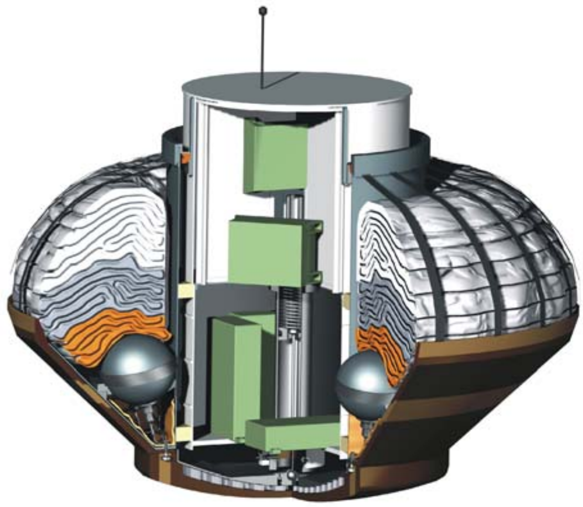

Artist's impression of IRDT entering Earth's atmosphere with flexible heat shield deployed (Image: ESA)

IRDT is an ESA technology demonstrator project for a new concept, which enables re-entry from orbit and landing without the need of a heavy heat shield and parachute system. The 140 kg demonstrator vehicle system consists of a small ablative nose from which a cone-shaped flexible heat shield is inflated to provide braking and thermal protection during re-entry.



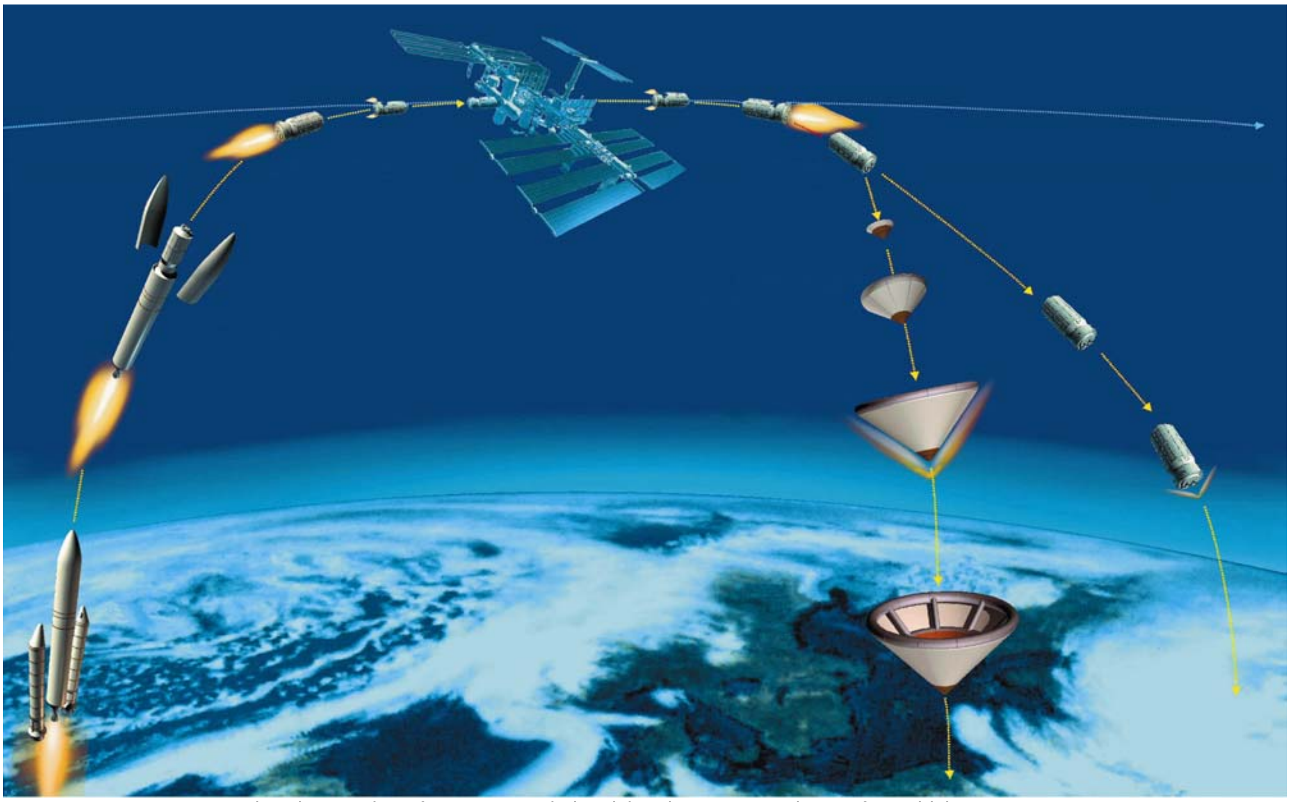
Cut out artist's impression of IRDT with flexible heat shield and inflatable extension deployed (Image: ESA)

When the flexible heat shield is deployed, it increases the capsule diameter from 80 cm to 2.3 m. This flexible shield consists of an internal network of rubber hoses pressurised with nitrogen, covered by an insulating layer (Multi-Layer Insulation) protected by a silica-based fabric impregnated with an ablative material. As its temperature increases, this ablative material decomposes, absorbing heat and thereby limiting the heat input to the capsule's interior. The thickness of the material, i.e. number of layers, is designed to cope with the expected atmospheric-entry heat loadings with some margin.


Artist's impression of IRDT prior to heat shield deployment (Image: ESA)

In place of a parachute system, a second inflatable extension of the cone is opened, which further increases the capsule's diameter to 3.8 m. This reduces the speed of the Demonstrator during subsonic flight to ensure a safe landing at a velocity in the order of 13 -15 m/s.


IRDT nosecone (Image: ESA)



Artist's impression of IRDT scenario involving the Automated Transfer Vehicle (Image: ESA)

The inflation process is triggered by the sequential firing of a series of pyro-valves, which progressively empties a set of 13 nitrogen bottles into the envelopes, at different stages of the mission. To ensure adequate stability during all phases of re-entry and provide proper deceleration, a sphere-cone shape, with a nose radius of 0.61 m and a cone half angle of 45º has been selected.

Soyuz Fregat upper stage entry configuration with IRDT flexible heatshield deployed (Image: ESA)

The inflatable heat shield has a number of advantages over existing designs. Not only can it be folded into a very small package, but it is lightweight and cost-effective. Once verified, this new technology can be used for re-entry scenarios such as payload recovery from low Earth orbit, atmospheric research and as a means to return launcher upper stages for the planetary landers used for science missions.

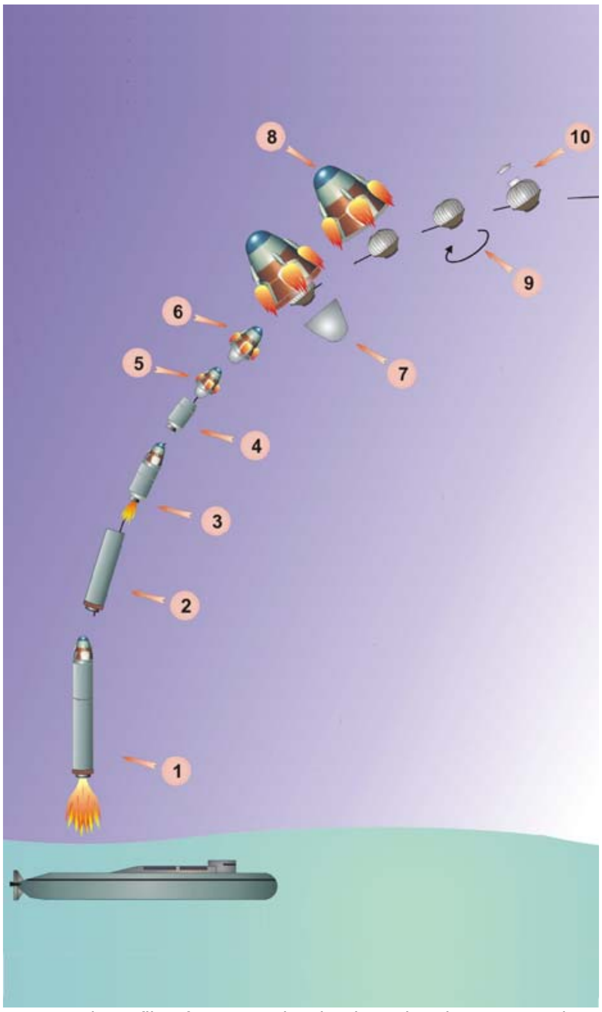
To facilitate post-landing recovery, a beacon similar to that on the Soyuz capsule was installed. A dedicated sensor package will monitor and record the flight parameters including two three-axis accelerometers, three gyroscopes, 23 temperature sensors in different internal locations and 81 CIMTs (Crystal Indicators of Maximum Temperature), within the ablative front shield at depths of 3, 6 and 9 mm. The crystals can be analysed post landing in order to determine the maximum temperature on re-entry. Such crystals can measure temperatures up to 2000ºC.

The IRDT is only dealing with atmospheric re-entry and landing operations. For its launch into space and injection into a re-entry trajectory, it depends on a carrier vehicle such as a rocket.

One spin-off of this technology that was partially funded through ESA's Technology Transfer Programme was a way to escape burning buildings. This idea was shown at the Paris Air Show in 2005.

Mission Profile

For the test flight of the Inflatable Re-entry and Descent Technology (IRDT) in Autumn 2005, the IRDT will be launched into a sub-orbital ballistic re-entry trajectory by a Volna rocket, which is fired from a Russian naval submarine positioned in the Barents Sea in the area of Severomorsk, Russia.



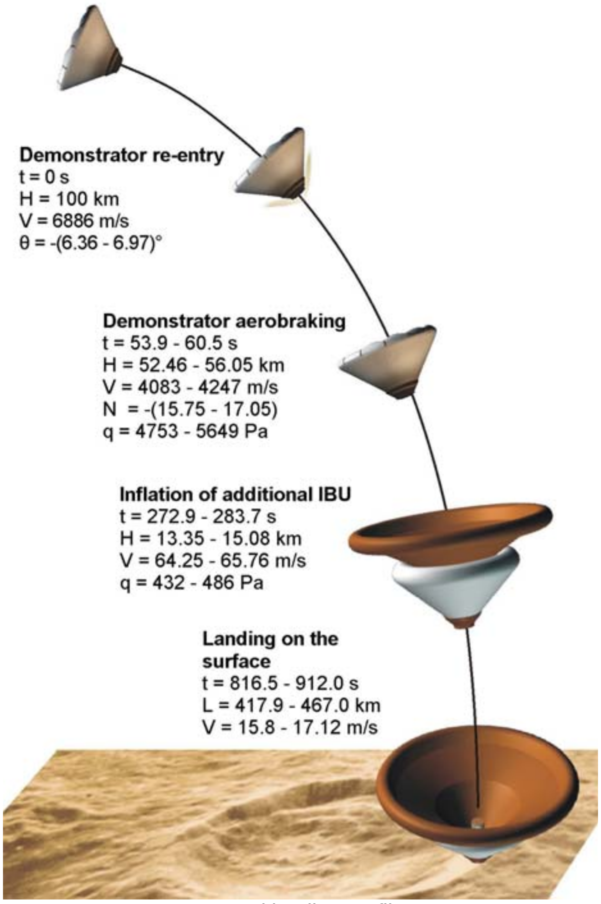
Launch profile of IRDT and Volna launcher (Image: ESA)

The launch is scheduled to take place at 23:30 Central European Time. Following lift-off the Volna launch vehicle will go through different stages of separation. Once the first stage propulsion system has finished firing this stage will separate from rest of the launch vehicle and its payload. This will coincide with ignition of the second stage engines (2/3 in above image). Once these have finished firing, this stage will also separate. At the same time with third stage engines will be ignited (4/5 in above image).

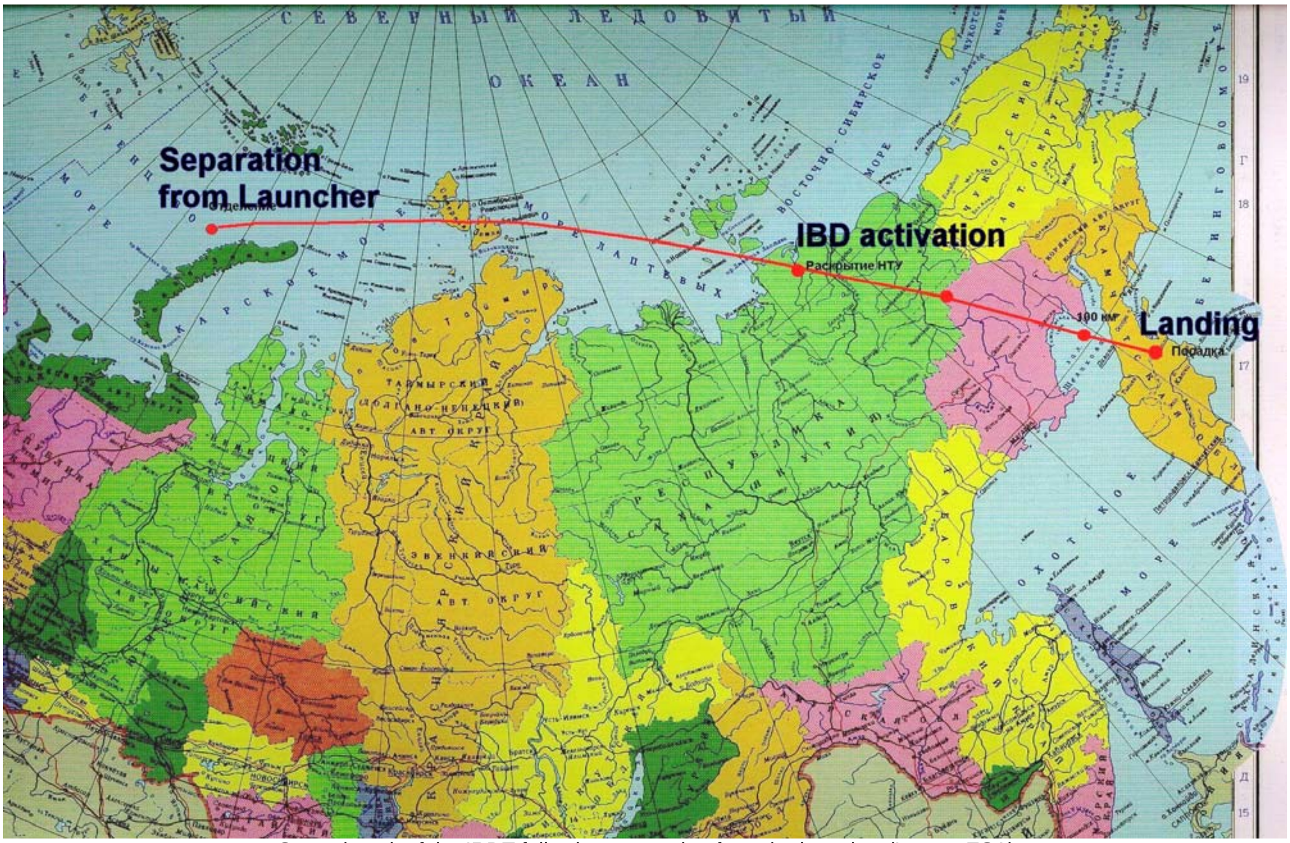
During the third stage firing, the payload compartment will be depressurised. Towards the end of the third stage sequence the spacecraft will be reoriented on its trajectory before the capsule cover is jettisoned (7 in above image). Separation of the IRDT from third stage follows (8 in above image). This occurs at five minutes and six seconds after launch at an altitude of 202.75 km.

The IRDT is now free from the launch vehicle and continues on a ballistic trajectory. 2.6 seconds following final separation, the IRDT spins up around its axis of symmetry (9 in above image).

Six seconds later at five minutes and 12 seconds after lift-off, the experiment compartment is ‘armed’ and the platform covering the experiment container jettisoned (10 in above image).



IRDT re-entry and landing profile (Image: ESA)

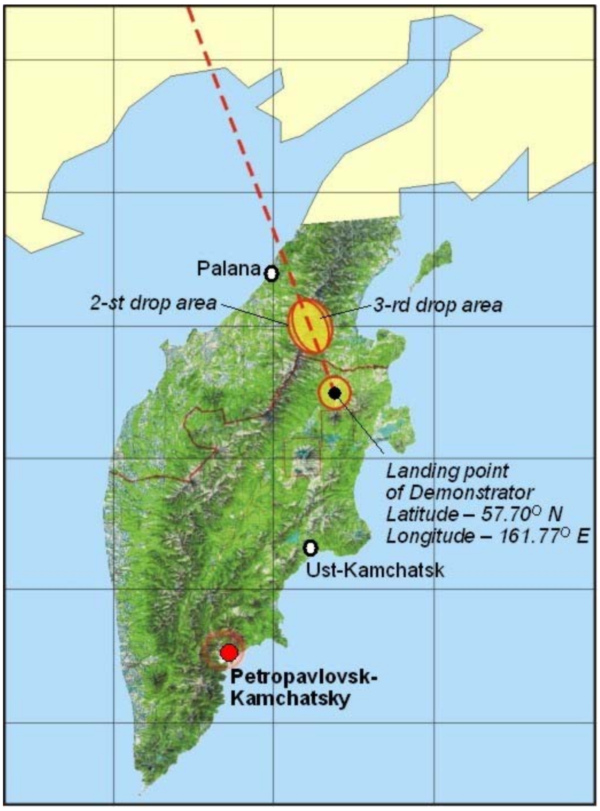


Ground track of the IRDT following separation from the launcher (Image: ESA)

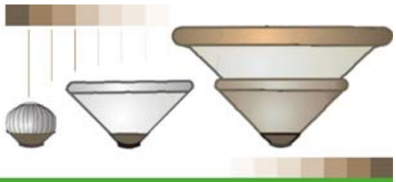
After this event, the IRDT reaches its maximum altitude of 258.2 km. At 11 minutes and 2 seconds after launch, the IRDT is now on the downward part of the flight trajectory at an altitude of 238.5 km and travelling at 6.7 km/s. At this point the pyro-valves are fired, which empty the nitrogen bottles which inflate the flexible heat shield.

Four minutes later at 15 minutes and six seconds after launch, the IRDT is entering the Earth's atmosphere at an altitude of 100km and an angle of -6.84º. At this point the IRDT is travelling at a velocity of 6.9 km/s. Passing through the upper atmospheric layers imposes the highest dynamic pressure, heat flux and acceleration loads onto the system.

After 20 minutes following launch the IRDT has greatly reduced its velocity to approximately 230 km/h and is at an altitude of between 12-14 km. At this point the second cascade is inflated. This further reduces the speed to 15.1 m/s on landing. This is at approximately 30 minutes after launch.



IRDT landing Site (Image: ESA)



Development

In 1997 ESA, the European Commission and the German company DaimlerChrysler Aerospace (DASA, now part of EADS) decided to co-fund a joint effort with NPO Lavochkin, the Russian company that developed the original IRDT technology.

The Russian spacecraft Mars'96, which was launched in November 1996, carried two modules designed to land on that planet's surface. This mission was unfortunstely lost due to a launcher failure. For the last part of the mission, the use of an Inflatable Re-Entry and Descent Technology (IRDT) had been forseen. The main components of this system were an aerobraking and thermally protective shell, a densely packed inflating material and a pressurisation system.

The first flight opportunity thereafter was on 9 February 2000. This was a low-cost opportunity as it was also the first test flight of the Soyuz-U launcher with a Fregat upper stage. The Soyuz-U/Fregat was undergoing its first of two flight tests as part of the contract to launch the Agency's four Cluster satellites. However, a tear in the inflatable heat shield caused a higher than planned velocity impact.

An international team developed the IRDT project under a European Space Agency contract with European industry with EADS Space Transportation in Bremen, Germany, as a prime contractor and NPO-Lavochkin as a major subcontractor. For the launch of the IRDT Demonstrator-2R in October 2005, this programme was performed in cooperation with, among others, the Russian Federal Space Agency, the International Scientific and Technical Centre, the State Rocket Centre (Makeev Design Bureau), the Space Research Institute (IKI) of the Russian Academy of Sciences, the Russian research institute TsNIIMash and the Russian Navy.

NPO Lavochkin developed the IRDT Demonstrator within the framework of the Moscow based International Science and Technology Centre (ISTC) - an intergovernmental organisation dedicated to non-proliferation. DASA built the sensor package and the demonstrator's payload. ESA contributed to the project both via ISTC and through a contract with DASA.

The 2005 flight opportunity of the Demonstrator-2R is the third flight vehicle of the IRDT series as the first two attempts to launch an IRDT spacecraft were unsuccessful. It was sent to Severomorsk to begin launch preparations on 24 May 2005.

The launch was originally planned for December 2004 but postponed at the request of engineers working on the project, who wanted to carry out further tests to increase the spacecraft's reliability.

The pressure regulation system and the launcher interface have been improved, and the heat shield strengthened. Telemetry and navigation systems allowing better descent monitoring and more efficient recovery operations have also been introduced, and a camera will provide images of the various stages of deployment.

Among several longer-term improvements to the capsule, it is foreseen to increase the payload/ mass ratio and offer soft-landing capabilities. In addition to applications such as for low Earth orbit sample return, as a planetary entry and landing system and as launcher upper stage return, a number of other applications have been identified, and will be more thoroughly investigated.