Soyuz Launcher

All previous Foton spacecraft since the first mission in April 1985 have been launched into orbit by a Soyuz-U launcher. Foton-M2 will also be launched into orbit by a Soyuz-U launcher though this will be the first time that it takes place from the Baikonur Cosmodrome in Kazakhstan. All previous launches had taken place at the Plesetsk Cosmodrome, in the Arkhangelskaya Region of North-Western Russia, approximately 800 km north of Moscow.

The history of the Soyuz launcher developed from the Russian military rockets, which started production in the late 1940’s with the R-1 and R-2 rockets, the R standing for ‘Raketa’. Further developments led to the launch of the first intercontinental ballistic missile, the R-7, or ‘Semyorka’ on 21 August 1957, Semyorka meaning “The Seven” in Russian. It was the R-7 launcher configuration, which put Sputnik 1 into orbit on 4 October 1957.

Russian launchers normally take their name from the payload or spacecraft they are launching. The R-7 that launched Sputnik 1 into orbit was therefore called the ‘Sputnik launcher’. The Sputnik launcher thereafter developed into the three-stage Vostok-L launcher for launching lunar probes and then the Vostok launcher, which put Yuri Gagarin into orbit in 1961.

After six further manned Vostok missions, the Vostok launcher was developed into the 4-stage Molniya launcher, for putting satellites into high elliptical orbits, and the Voskhod 2 launcher. This led to the development of the Soyuz launcher, which used a stronger third rocket stage. It was first launched on 16 November 1963 and was named after the manned Soyuz spacecraft for the launch of which it was designed.

The first manned Soyuz launch took place on 23 April 1967. In 1971 this developed into a more powerful version called the Soyuz-U, which further developed into the Soyuz-U2 in 1982, a rocket with a 7 tonnes maximum payload that used a new synthetic kerosene called Sintin, whose use is now discontinued for cost reasons. The Soyuz-U launcher, which will launch the Foton-M2 into orbit was previously used for both unmanned missions, such as Foton and Bion and for launching manned missions such as the Soyuz missions to the Salyut Space Stations and the Soyuz Apollo docking missions to the Soyuz T-2 to Soyuz T-11 (June 1980 – April 1984, T1 was unmanned), Soyuz TM-24 to Soyuz TM-34 (Feb 96 – April 2002), the last flight of a Soyuz TM on the Marco Polo mission with ESA astronaut Roberto Vittori. The Soyuz-U also launched the first Expedition Crew to the ISS.

The Soyuz U launcher is currently no longer used for manned missions. The current version of launcher is the Soyuz FG, which was used for the first time on 30 October 2002 to launch the Soyuz TMA-1 spacecraft on ISS flight 5S with ESA astronaut Frank De Winne from Belgium on the Odissea Mission. The FG stands for...
‘Forsunochnaya Golovka’ meaning injection head in Russian. It is an improved version of the Soyuz-U as the injection head in the FG has 1000 holes instead of 200 for distributing kerosene and liquid oxygen to the combustion chamber. This leads to a 1.3% higher specific impulse, which increases the thrust by 500 kN. This in turn leads to an increase of 250-300 kg in the payload.

The Soyuz launcher and all its predecessors consist of four conical lateral boosters, which first appeared on the R-7 rocket, arranged around a core stage. In Russian terminology, the core stage and the lateral boosters are called “blocks”.

Each block of the launcher is designated a letter, which follows the Cyrillic alphabet. The lateral boosters are called blocks B, V, G and D. Together they make up what in western terminology would be called stage one as they are the first stage to finish burning and separate after launch. The central block, or second stage, is called block А and the final block or third stage is called block I. Each block runs on a fuel mixture of kerosene and liquid oxygen.

In the Soyuz U configuration, each lateral booster is about 20 metres long by up to 2.7 metres in diameter. Each has an RD-107 propulsion unit. In combination the four boosters have an empty mass of 15 tonnes and a capacity for nearly 160 tonnes of fuel.

The boosters are ignited at launch together with the central block or second stage. This provides a thrust at lift-off of 4030 kN. The boosters have finished burning after two minutes when they separate.

The central block, block А, is nearly 28 metres long and up to nearly 3 metres in diameter. It has an RD-108 propulsion unit and an empty mass of 7 tonnes, which provides a capacity for 95 tonnes of fuel. It provides a thrust of 1000 kN and continues to power the flight for a further three minutes after separation of the lateral boosters.

The central core stage is linked to the second stage by a latticework structure. When the core stage’s powered flight is complete, the third stage’s RD-0110 engine is ignited. This is five minutes after launch. The ignition forces induce separation of the second and third stages. The third stage powers the flight until nine minutes after launch when it is cut-out and thereafter jettisoned. This third stage or block is nearly 7 metres long. This stage has an empty mass of nearly 2.5 tonnes with provision for up to 23 tonnes of fuel. It has a liquid fuel propulsion system, which provides 300 kN in thrust.
Foton spacecraft are based on the design of the Russian Vostok spacecraft, in which Yuri Gagarin was put into orbit in 1961 and the Zenit military reconnaissance satellite. However, whereas the original Vostok design has been developed into the Soyuz spacecraft for manned missions, it has maintained its principal design aspects for the unmanned Foton, which is primarily used for physics and materials science experimentation in weightlessness.

Bion was the first of the Foton type of unmanned spacecraft to be launched in 1973. The goal of the Bion missions was to investigate how the space environment acts on living creatures, with the emphasis on physiological changes in primates and rodents, gravitational biology, radiation biology, radiation dosimetry and radiation protection. As the only consistent biosatellite in existence, over the years Bion attracted worldwide attention. NASA and CNES were actively involved in Bion missions since the Bion-3 mission in 1975. ESA started using Bion with Bion-8 (1987) and Bion-9 (1989), culminating in a major payload on the Bion-10 mission (1992).

The second member of the family of recoverable spacecraft is Resurs-F, which is basically a Bion spacecraft equipped with cameras for Earth observation. Resurs-F made its maiden flight in 1979. Between 1979 and 1994 Resurs-F consistently flew several times per year. The re-entry capsule of Resurs-F is occupied by cameras and ancillary equipment, with only a limited capacity for additional scientific equipment, which is occasionally occupied by western European customers.

Foton was first launched into low-earth orbit by a Soyuz-U launcher in 1985, as Cosmos 1645 (Cosmos is a generic designation used by the Russians for a majority of their missions). It did not receive the official designation of Foton until its fourth flight, Foton-4 in April 1988. A typical Foton mission lasts about 15 days. The earlier Foton missions were conceived primarily for
materials science research, but later missions also began to include experiments in the fields of fluid physics, biology and radiation dosimetry.

From 1985 till 1992 Foton flew one time per year. After 1992, the frequency was reduced to approximately one flight every two years. Starting with Foton-5 in 1989, scientific payloads from western Europe have regularly flown on Foton. ESA's participation in the Foton programme began in 1991 with a protein crystallisation experiment on-board Foton-7, followed by a further 35 experiments up to and including the Foton-12 mission in 1999. The re-entry capsule of Foton-12 is on exhibition in the Erasmus building at ESTEC.

In 2002, ESA provided a large number of experiments for the Foton-M1 mission. This was the first flight of an upgraded version of the Foton spacecraft. Foton-M is an improved version of the spacecraft, with larger battery capacity, enhanced thermal control and increased telemetry and telecommand capabilities for increased data flow. The Soyuz-U launcher, which puts it into orbit is equipped with a new third-stage engine, which provides a more circular orbit, in combination with a more even mass distribution within Foton. This will further reduce the residual onboard acceleration. The upgraded Foton also allowed for longer missions, three weeks rather than two. This mission ended prematurely when the Soyuz launcher exploded shortly after lift-off due to a malfunction in one of its engines. Most of the experiments lost during the accident will be re-flown by ESA during the Foton-M2 mission with further flight opportunities also available to ESA on the Foton-M3 mission in 2006/2007. All previous Foton missions were launched from the Plesetsk Cosmodrome, about 800 km north of Moscow, but beginning with Foton-M2 the Foton missions will now be launched from the Baikonur Cosmodrome in Kazakhstan.

Designed and built by the Central Specialised Design Bureau of the State Research and Production Space Rocket Centre (TsSKB-Progress) in Samara, Russia, Foton consists of three modules: the re-entry module, the battery pack, and the service module. During a mission, Foton orbits at a maximum altitude of about 304 km and a minimum altitude of about 262 km, inclined at 63º. The spacecraft has a total mass of 6500 kg and can accommodate up to 650 kg of experimental payloads. The humidity level inside the spacecraft can vary between 25% and 80% and the internal air pressure is similar to that on Earth.

The Service Module
The service module is 3.2 m long and 2.5 m wide. It contains the attitude control system, the telemetry/telecommand equipment and the retrorocket. The attitude control system incorporates nitrogen jets and Earth horizon sensors for alignment of the spacecraft in preparation for its re-entry. While orbiting, the attitude control system is not used, allowing the spacecraft to spin slowly without having a significant effect on the level of weightlessness. Firing the retrorocket reduces the spacecraft's velocity so that it falls into a lower orbit and re-enters the atmosphere. The service module remains attached to the re-entry capsule by four retaining straps until the retrorocket burn is over.
The Battery Module
The battery module, containing lithium cells, is the main energy source for the satellite and its payload. It is a 1.8 m diameter cylindrical section, closed by dome-shaped ends and attached to the re-entry module by four legs. It provides the scientific payload with an average daily power budget of 500 W of electrical power during a typical 2-week mission, with peaks of 700 W. The battery pack is jettisoned before re-entry.

The Re-entry module
The re-entry module, a 2.2 m diameter sphere with a mass of around 2.5 tonnes, is the only retrievable part of the satellite. The capsule houses the scientific payload and the landing parachute. It is equipped with three circular hatches, two on opposite sides for payload installation and removal, with a third hatch giving access to the parachute trunk. The capsule’s aluminium-alloy structure is covered with ablative material (heat shield) for protection against frictional heat during re-entry. The acceleration experienced during the final stages of landing can be as high as 40g for a very brief period of time. Landing is assisted by parachutes and retro-rockets to cushion the impact on the ground. The internal temperature ranges from 10º to 30º C while the external temperature can range from -150ºC to +120ºC.

The Foton spacecraft will be equipped with sensors over its external surface for different purposes: Two dust sensors will help determine the levels and effects of cosmic dust on the spacecraft. Cosmic dust can adversely affect surfaces of optical glass and lower the efficiency of solar batteries for example; Two Ionic Filling Flow Sensors will determine parameters such as pressure changes outside of the spacecraft, which can affect the motion characteristics of the spacecraft. This can affect the quality of the experimentation taking place on the spacecraft by affecting the quality of weightlessness; Six magnetometers will be located inside the re-entry module. This system of sensors will measuring the magnetic field inside the re-entry module to help improve interpretation of results coming from experiments; Further sensors will measure the distribution of electrical charge across the external surface of the spacecraft, which could potentially cause interference to electronic and optical equipment; Satellite radio navigation equipment will help to determine spatial orientation and dynamics, which can affect micro-accelerations inside the spacecraft.