6 FOTON RETRIEVABLE CAPSULES

This section is aimed at providing new and experienced users with basic utilisation information regarding Foton retrievable capsules. It begins with an introduction to the Foton capsule.

6.1 Introduction to Foton Capsules

6.1.1 What Are Foton Capsules?

Foton capsules (Figure 6-1 and Figure 6-2) are unmanned, retrievable capsules, derived from the design of the 1960's Soviet Vostok manned spacecraft and the Zenit military reconnaissance satellite. These capsules are very similar to the Bion and Resurs-F satellites introduced by the Soviets in the 1970's, for biological research and Earth natural resources investigation, respectively. The first Foton capsule was launched in 1985 as Cosmos 1645 and only with the fourth launch in 1988 was the spacecraft officially designated Foton (Foton-4). These capsules are launched into near-circular, low-earth orbits by a Soyuz-U rocket, providing researchers with gravity levels less than 10^{-5} g, for missions lasting approximately 2 weeks. 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. 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. In 2002, ESA provided a large number of experiments for the Foton-M1 mission (the first flight of an upgraded version of the Foton spacecraft). This mission ended in disaster when the Soyuz launcher rocket exploded shortly after lift-off due to a malfunction in one of its engines. Most of the experiments lost during the accident were re-flown during the Foton-M2 mission in launched on 31 May 2005, with further flight opportunities also available to ESA on the Foton-M3 mission in September 2007.

6.1.2 What Do Foton Capsules Offer?

Foton capsules offer users the following:

- 12-18 days exposure to low gravity and/or the space environment;
- A high quality weightless environment with levels $\leq 10^{-5}$ g;
- Reduced safety constraints for the experiments, with respect to manned space missions;
- Medium access times (a payload usually flies approximately 2 years after experiment approval);
- Direct involvement of users in hardware development, and in experiment preparation and execution;
- Use of interactive experiment operations (telescience);
- Possibility of relatively late experiment installation ("late access" – 48-72 hours before launch);
- Availability of a series of flight proven experiment and support facilities for different scientific disciplines.

6.1.3 Why Use Foton Capsules?

Foton capsules provide ideal conditions for scientists who intend to fly experiments requiring excellent and unperturbed microgravity conditions and/or exposure to the space environment for a typical period of 2 weeks, and who have already executed preliminary experiments on shorter duration platforms (i.e. Drop Towers, Parabolic Flights, Sounding Rockets). The Foton environment gives users the opportunity to test their hardware under longer microgravity conditions, so that any necessary modifications can be made to future experiments (e.g. a longer duration opportunity on the ISS). On the other hand, for some experiments, users may not require extremely long periods of microgravity (of the order of months), as will be the case with the ISS, to obtain good scientific data. But, at the same time, they may find that the conditions provided by shorter duration microgravity platforms are not sufficient for their experiments. In these cases, Foton capsules act as intermediate microgravity research platforms, providing the necessary scientific environment at a substantially lower cost and faster access times. Moreover, Foton capsules provide users with the possibility of performing re-entry studies.

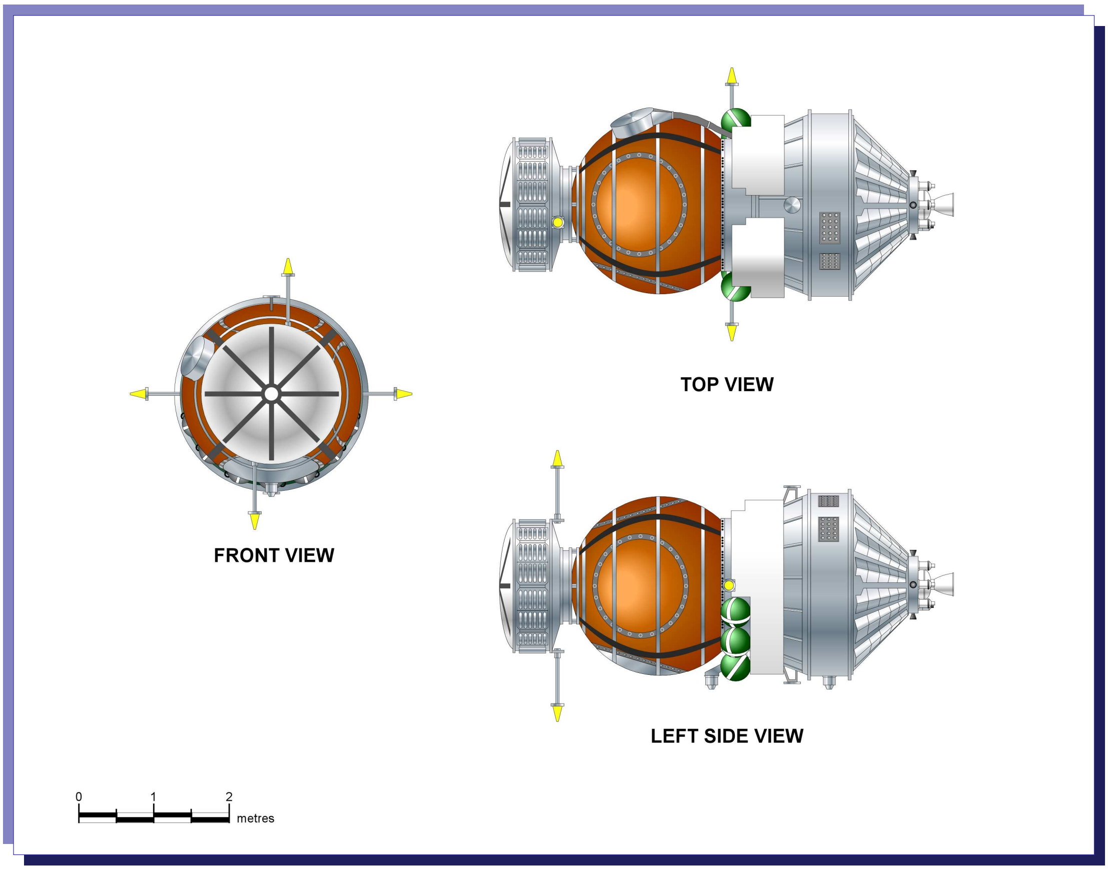

Figure 6-1: Schematic of Foton capsule (without protective covers and blanketing)

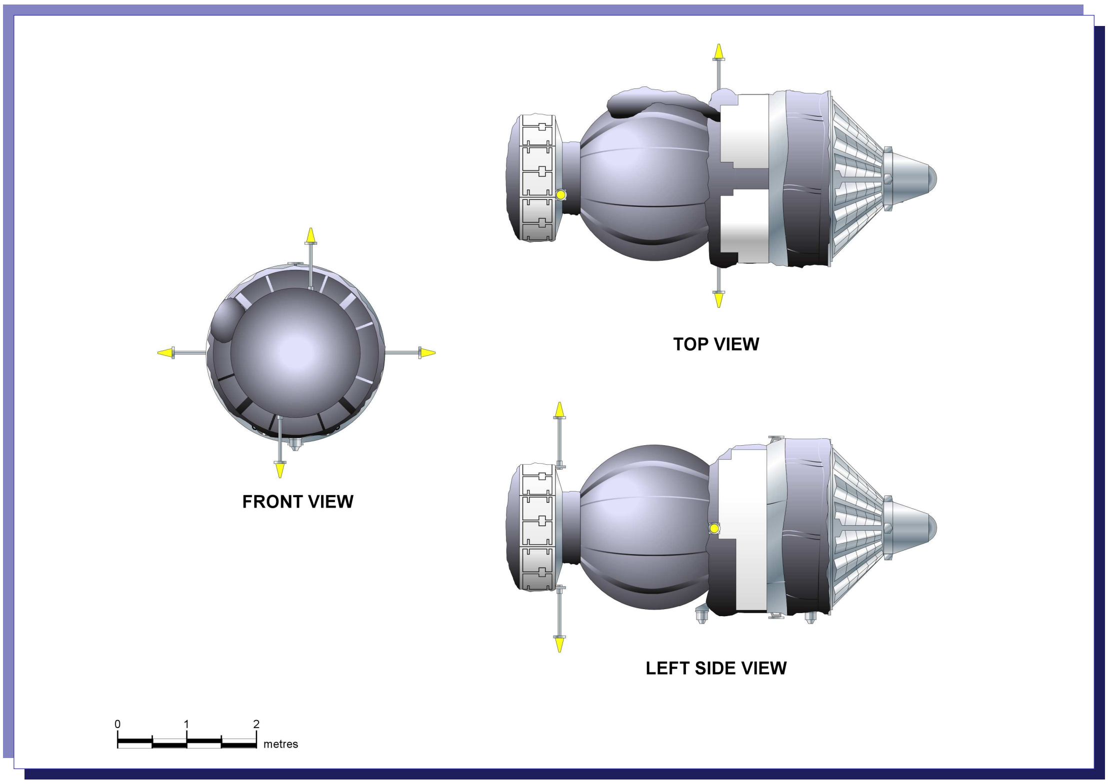

Figure 6-2: In-flight schematic of Foton spacecraft (with protective covers and blanketing)

6.1.4 Principal Characteristics of a Foton Spacecraft

Foton spacecraft (Figure 6-3) are designed and built by the State Research and Production Space Rocket Centre TsSKB-Progress in Samara, Russia. The spacecraft have a typical mass of 6500 kg, a length of 6.2 m, can carry a scientific payload of up to 650 kg and are made up of three main modules: the service module, the battery module and the re-entry module, the latter module being the only one retrieved after landing.
The launch vehicle used to place the Foton capsule into orbit around the Earth is a Soyuz U (type 11A511U) rocket (see 6.1.4.4).

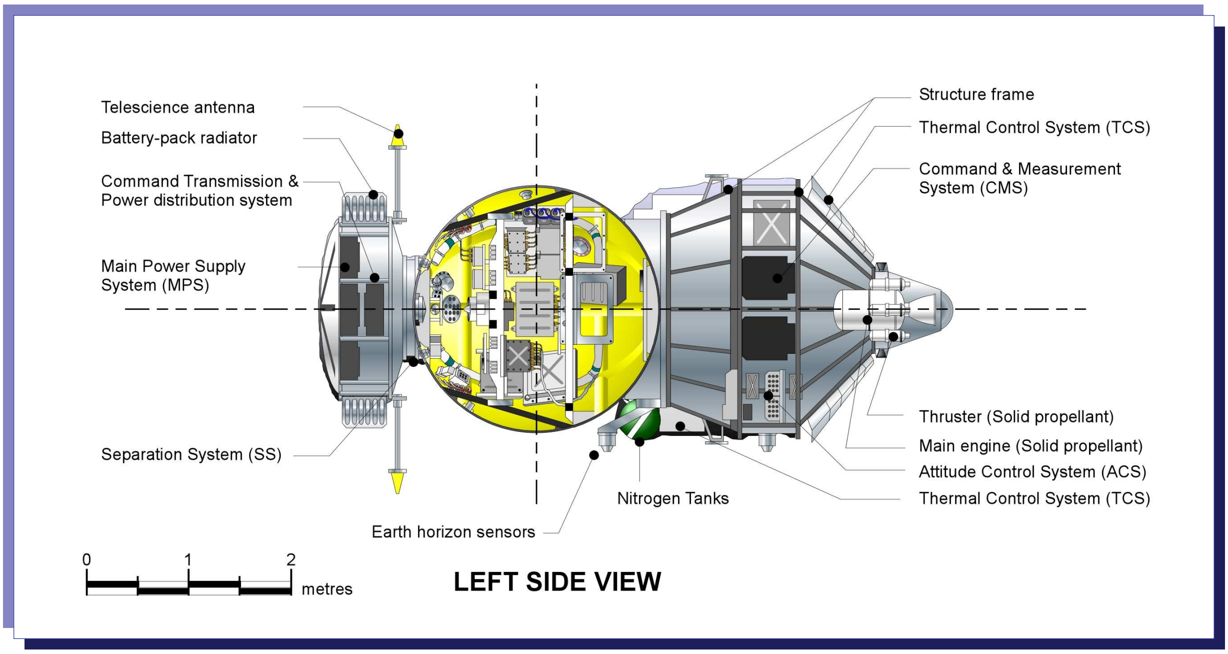

Figure 6-3: Foton spacecraft structural layout

6.1.4.1 The Service Module

The service module (Figure 6-4) 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 (around 0.1 rpm) without having a significant effect on the level of microgravity. 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, after which it is jettisoned.

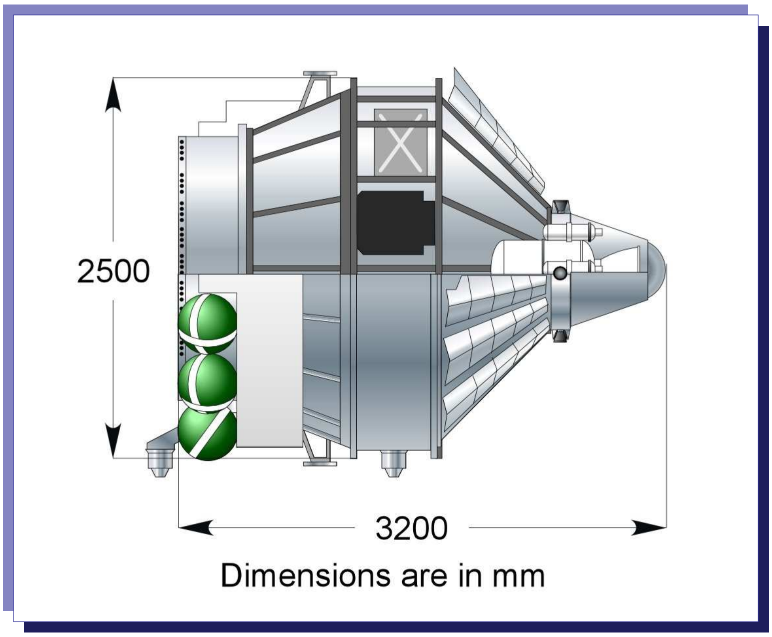

Figure 6-4: The service module of the Foton capsule (top part is a cutaway view)

6.1.4.2 The Battery Module

The battery module (Figure 6-5), containing lithium cells and AgZn batteries, is the 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 800 W of electrical power during a typical 2-week mission. The battery pack is jettisoned a few hours before re-entry.

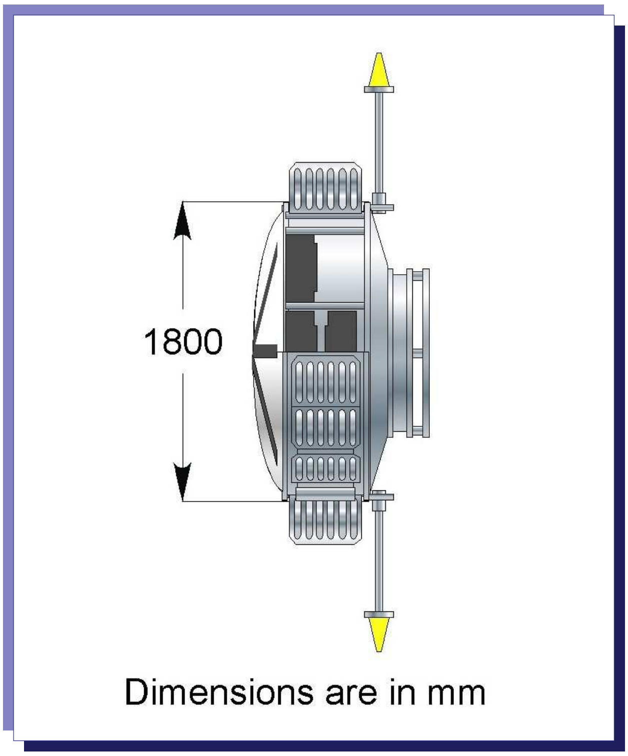

Figure 6-5: The battery module of the Foton capsule (top part is a cutaway view)

6.1.4.3 The Re-Entry module

The re-entry module (Figure 6-6), a 2.2 m diameter sphere with a mass of around 2.5 tons, 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 for protection against frictional heat during re-entry. Landing is assisted by parachutes and retro-rockets to cushion the impact on the ground. The final vertical landing velocity is approximately 3 m/s.

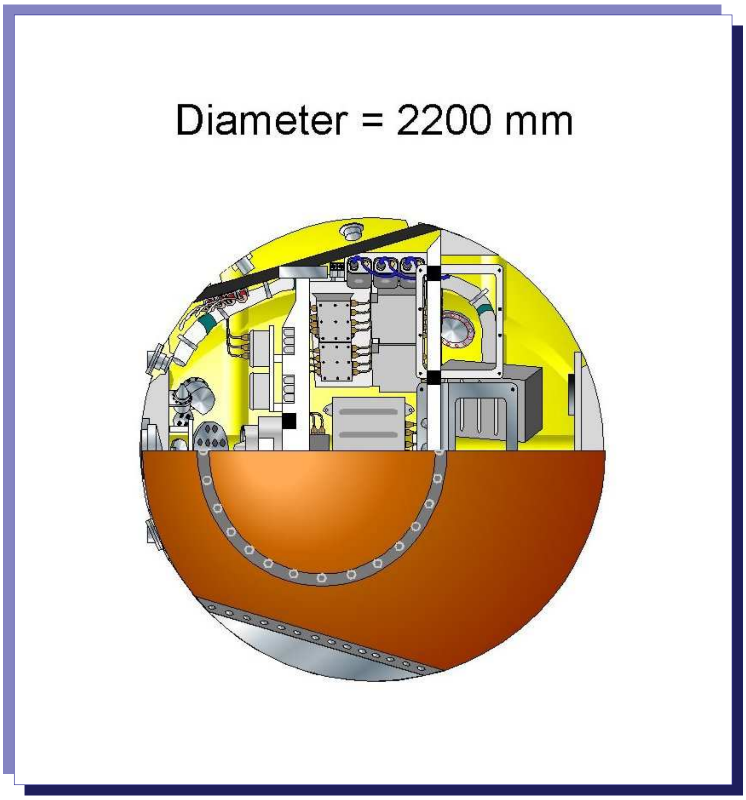

Figure 6-6: The re-entry module of the Foton capsule (top part is a cutaway view)

6.1.4.4 The Launch Vehicle

The Foton capsule is placed into orbit by a 3-stage Soyuz-U (type 11A511U) launch vehicle (Figure 6-7). The major characteristics of the launcher are summarised in the following table:

Table 6-1: Soyuz U principal characteristics

PARAMETER	VALUE
Total length with Foton spacecraft	43.44 m
Core diameter	2.95 m
Lift-off thrust	4030 kN
Total mass	310000 kg
1st stage thrust (vacuum)	405600 kgf
1st stage burn time	120 seconds
2nd stage thrust (vacuum)	101675 kgf
2nd stage burn time	120+166 seconds
3rd stage thrust (vacuum)	30400 kgf
3rd stage burn time	250 seconds

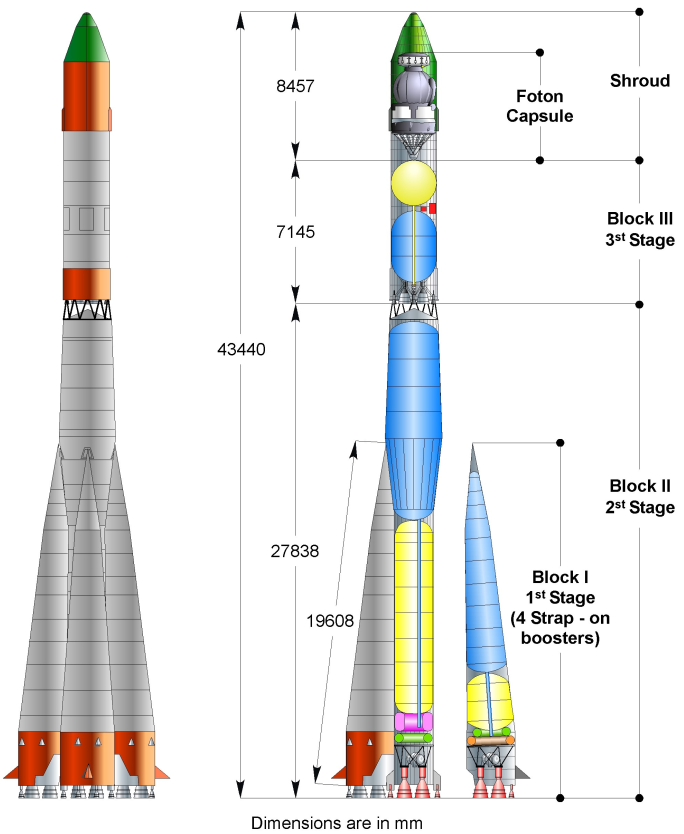

Figure 6-7: Soyuz U (11A511U) launch vehicle

6.1.5 Foton Mission Profile

In the past, Foton capsules (including the failed Foton-M1 mission) were launched from the Plesetsk Cosmodrome (62.8°N, 40.1°E) in the Arkhangelsk Region of North-Western Russia, approximately 800 km north of Moscow. Beginning with the Foton-M2 mission (launched on 31 May 2005), the Baikonur Cosmodrome (45.6°N, 63.3°E), located in the barren steppes of Kazakhstan, is used to launch the capsules into Earth orbit.

Figure 6-8: The locations of the Plesetsk and Baikonur cosmodromes

6.1.5.1 Launch Phase

Referring to Figure 6-9, the launch phase of a Foton mission is made up of the following sequence of events. The Soyuz first stage and second stage are ignited simultaneously (1), so that the vehicle takes off using five engines. The four boosters of the first stage separate approximately two minutes after lift-off (2), leaving the vehicle to be propelled by the second stage for just under three more minutes (3). The third stage is linked to the second stage by a latticework structure. When the second stage's powered flight is complete, the third stage engine is ignited. Separation of the two stages occurs by the direct ignition forces of the third stage engine (4). The third stage engine is fired for about 4 minutes (5), and cut-off occurs when the calculated velocity increment is reached. At this point, the upper section containing the Foton spacecraft is separated by springs (6). At approximately nine minutes after lift-off, the spacecraft and its payload are now in microgravity. After injection into the operational orbit, the spacecraft is oriented to its orbital coordinate system. At this point the control system is switched off. The precise duration of the Foton mission depends on the energy consumption by the experiments, but is usually between 13 and 16 days long.

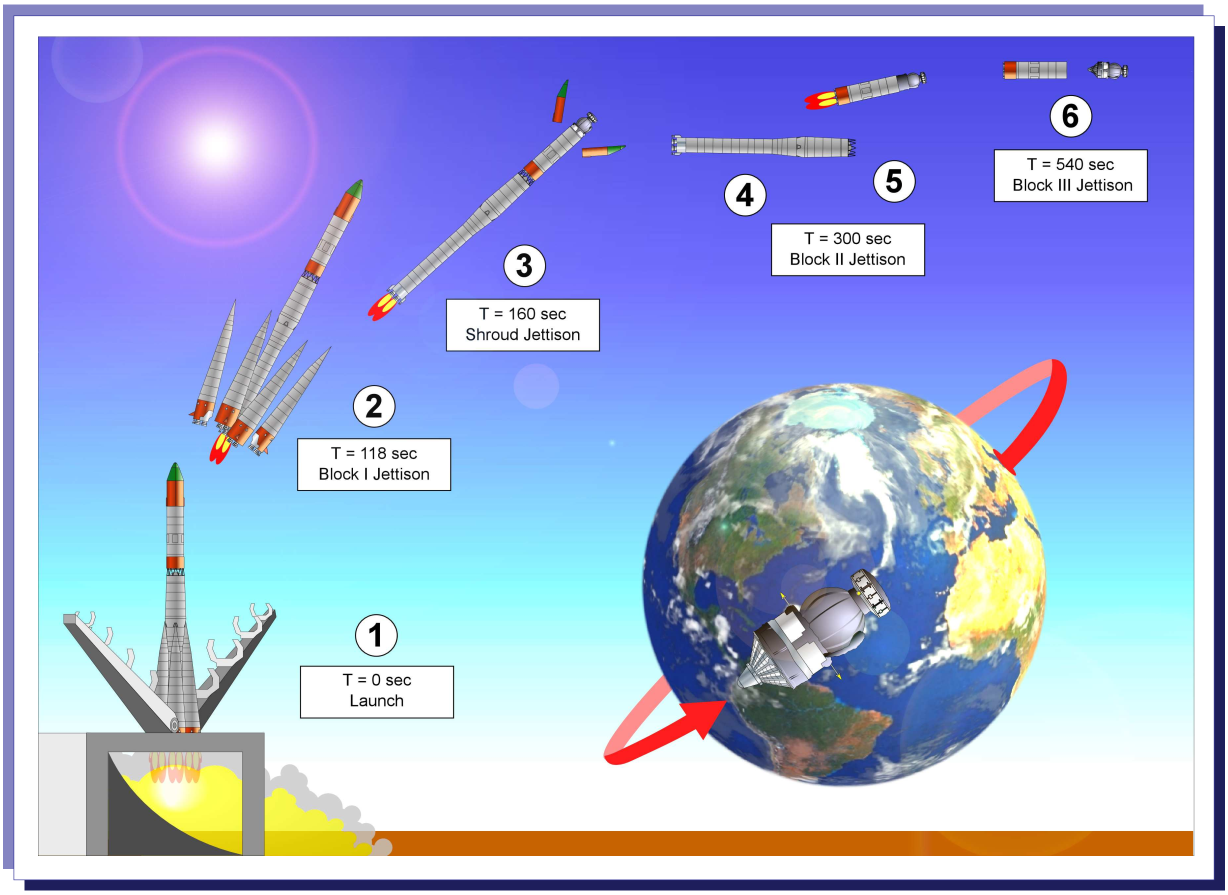

Figure 6-9: FOTON launch and orbit insertion

6.1.5.2 Orbital Phase

Following the launch phase, Foton is inserted into a near-circular orbit around the Earth, inclined at 63°, with maximum (apogee) and minimum (perigee) altitudes of around 305 km and 260 km (eccentricity $e \leq 0.01$), respectively. During its 2-week microgravity phase, Foton will orbit the Earth anywhere between 225 and 250 times (16 times per day), each orbit lasting 90 minutes.

6.1.5.3 Re-Entry and Landing Phases

Approximately 1 day before the Foton capsule is due to land, the control system is once again switched on (1) (Figure 6-10). Three hours before landing, the battery module is jettisoned from the remainder of the vehicle (2). The de-orbit phase of Foton begins at its cruising altitude of around 300 km, 30 minutes before landing, when the spacecraft finds itself over South Africa and has a velocity of 7.8 km/s (the orbital velocity). At this point, the retro-rocket is fired, burning for 45 seconds (3). Once the retro-rocket has completed its burn, the re-entry module is separated from the service module (4). The service module will continue moving in a degrading orbit, eventually burning up as it enters the atmosphere. The spherical re-entry module enters the stratosphere 20 minutes before landing (5).

As the sphere moves deeper into the atmosphere the heating rate, temperature and deceleration increase, reaching maximum values of about 1600 kW/m^2, 2000 °C and 9g, respectively (1) (see Figure 6-11). At 8.5 minutes before landing (2), a drogue parachute is deployed, which in turn opens a brake parachute (3), reducing the descent speed from supersonic to subsonic. Thirty seconds later, at an altitude of 2.5 km, the main parachute is deployed, reducing the speed further to 10 m/s (4). The Foton craft is cushioned during landing by a brake rocket, which is ignited 0.35 seconds before impact bringing the final landing speed down to 3 m/s (5).

The landing is usually scheduled in the morning, to take advantage of the calm air conditions in the upper layers of the atmosphere and to ensure that search and recovery operations can be completed in daylight.

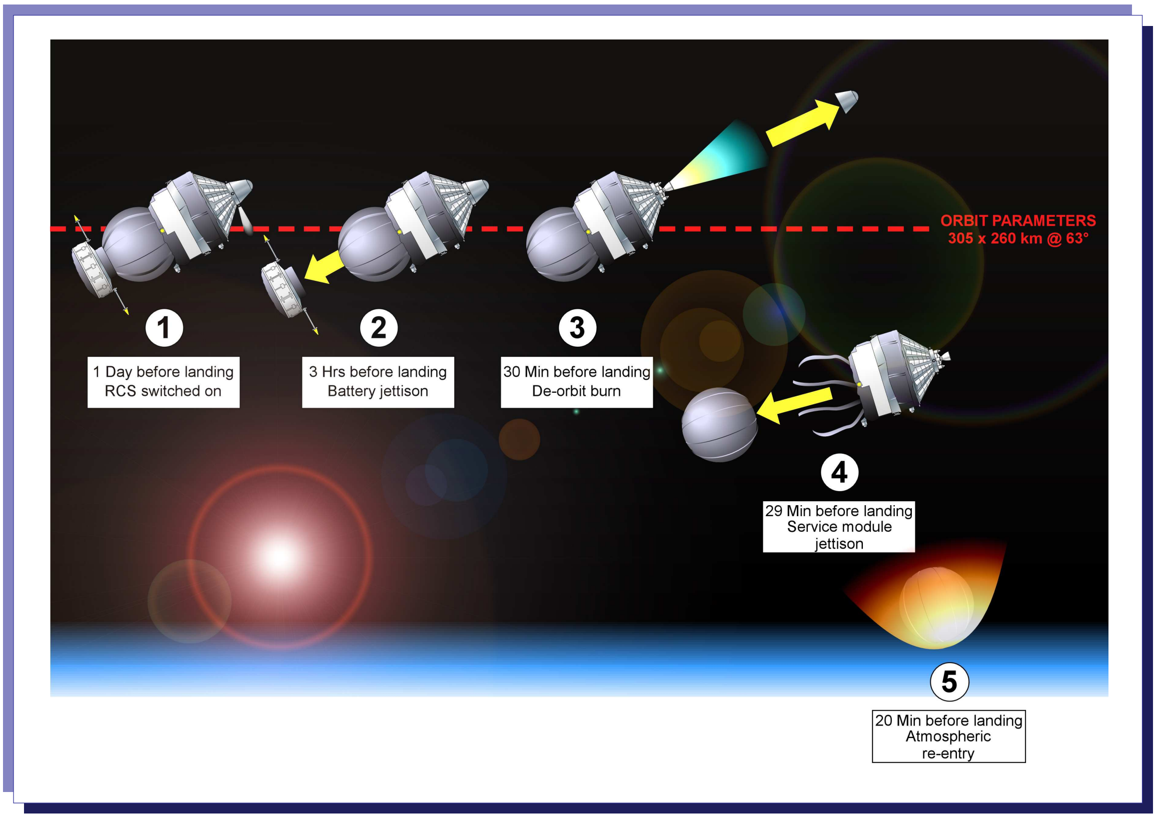

Figure 6-10: Re-entry sequence of the Foton capsule

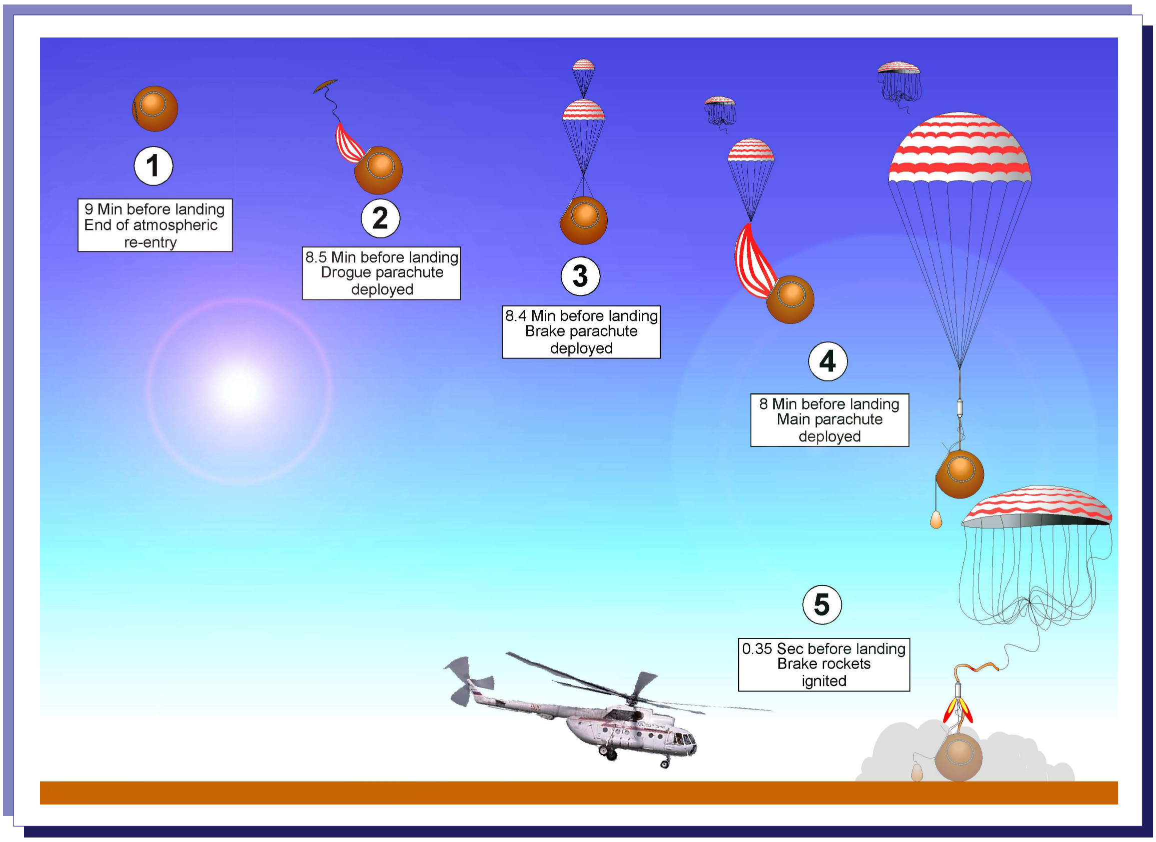

Figure 6-11: Landing sequence of the Foton re-entry capsule

6.1.6 Launch and Landing Site

6.1.6.1 Baikonur Location and Map

The Baikonur Cosmodrome (also known as Tyuratam) is the oldest (and Russia's largest) space launch facility in the world. In the 1950's, the Soviet Union announced that space launch operations were being conducted from the Baikonur Cosmodrome. Some concluded that this facility must be near the city of Baikonur, Kazakhstan. In truth, the launch facilities are located 400 km to the southwest near the town of Tyuratam (Figure 6-12). The Soviets built the city of Leninsk near the facility to provide apartments, schools, and administrative support to the tens of thousands of workers at the launch facility. The first satellite to orbit the Earth, Sputnik-1, was launched from here.
The Baikonur cosmodrome extends for 85 km from North to South, and from 125 km from East to West (Figure 6-13). Aside from dozens of launch pads it includes five tracking-control centres, nine tracking stations, and a 1500 km rocket test range. Since the demise of the Soviet Union, Kazakhstan has claimed ownership of the facility. But in 1994 the Russian Federation and Kazakhstan concluded a leasing arrangement whereby Baikonur would come under control of the Russian Federation for an annual fee. Most of the skilled workers and the military forces protecting some of the facilities are, however, Russian. There are ten operational launch pads as well as three Energia launch pads, which are no longer in use. Unlike many space launch facilities in the World, Baikonur is not directly situated on or near a coast. This situation limits the permissible launch azimuths to avoid impacts near populated or foreign regions, e.g., due east launches (the most advantageous) from Baikonur are forbidden since lower rocket stages would fall on Chinese territory. Consequently, the lower, sub-orbital stages of boosters normally fall back on former Soviet territory.

Figure 6-12: Map of Kazakhstan Region

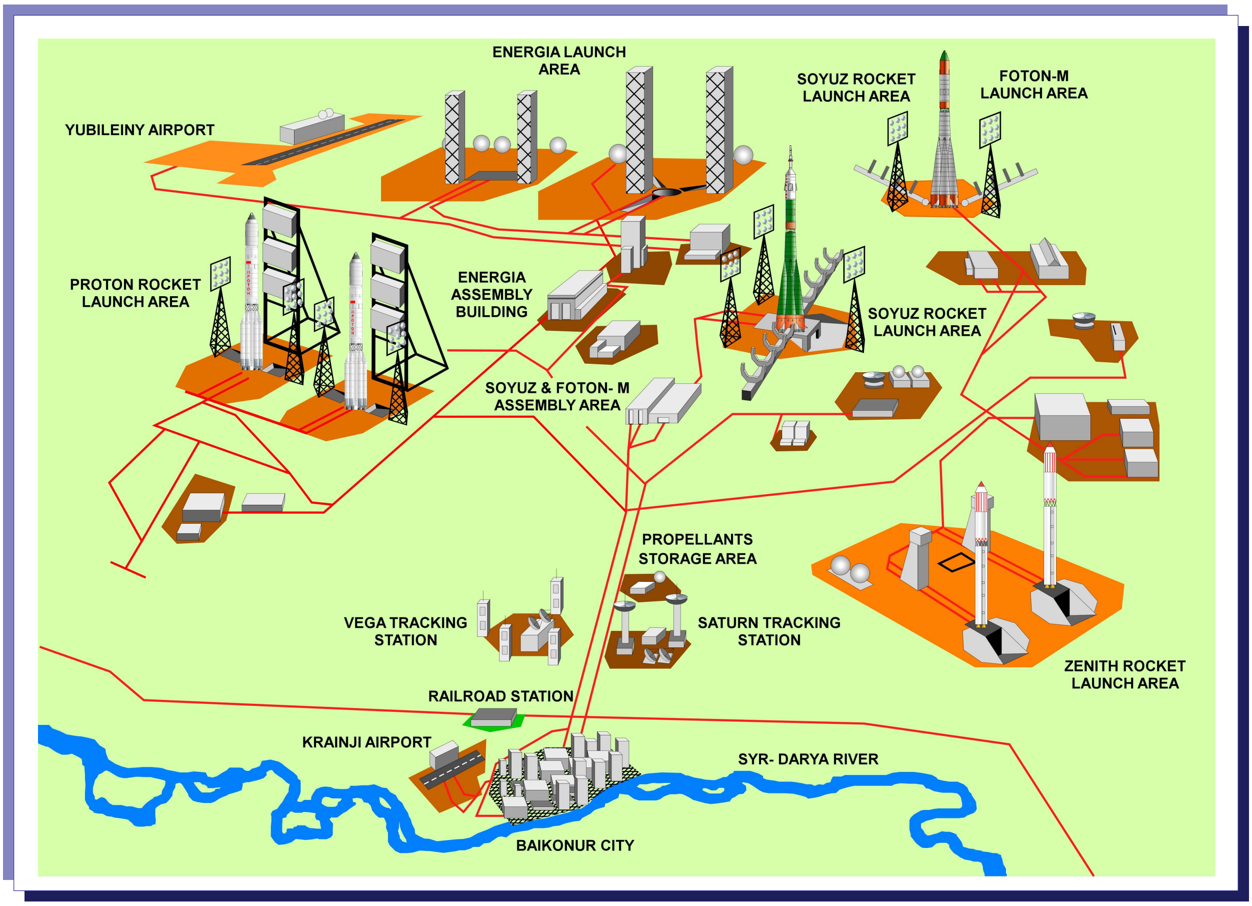

Figure 6-13: Baikonur Cosmodrome layout and main infrastructure

6.1.6.2 Map of Landing Area

The map below (Figure 6-14) shows the designated landing areas for manned and unmanned capsules launched from the Baikonur Cosmodrome. The circled numbers refer to the Foton (in white) and Bion (in blue) missions with ESA equipment on board that have taken place in the past. Before the break up of the Soviet Union most capsules landed within the borders of Kazakhstan. Once the latter became an independent state, the Russian Federation decided to also designate a landing area for unmanned capsules within the borders of Russia (official government regulation no.772, July 1995). Since then, most landings have taken place in (or very close to) the Russian sector, to avoid the extra costs resulting from transportation to and from Kazakhstan.
The landing site of the Foton-M2 capsule (June 2005) was very close to those of Foton-9 (indicated by a 9 in a white circle) and Bion-9 (indicated by a 9 in a blue circle).

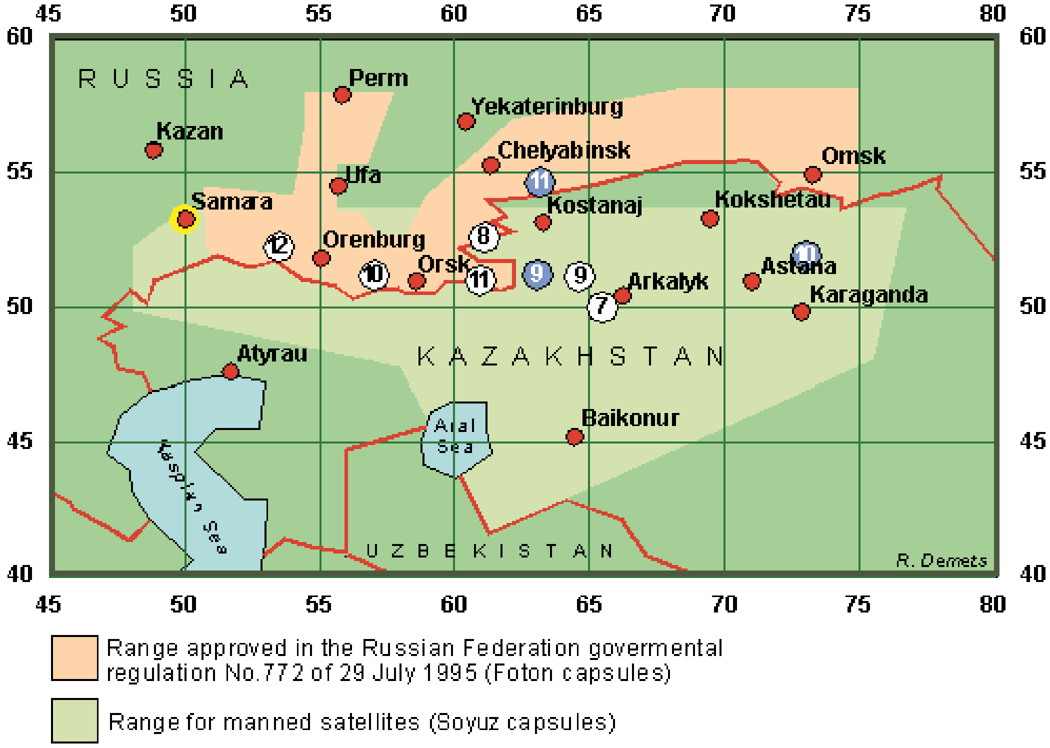

Figure 6-14: Landing area for Baikonur launches (Image: R. Demets)

6.2 Physical Environment

The following sections provide a brief description of the conditions of the internal and external environments, which are encountered during a Foton mission.

6.2.1 Internal Environment

6.2.1.1 Gravity Levels

While orbiting the Earth, the attitude control system of the Foton spacecraft is not used, allowing it to slowly spin as it moves along its path. This rotation, together with atmospheric drag and the motion of the platform along its trajectory create a residual gravity.
During the Foton-12 mission (1999), different instruments for measuring the micro-accelerations on-board were set-up in the re-entry module. The data collected from these instruments and their extrapolations show that these accelerations are $\leq 10^{-5}$ g.
The acceleration experienced during the final stages of landing can be as high as 40g (maximum landing shock when the capsule hits the ground) for a very brief period of time (of the order of 5×10^{-2} seconds).

6.2.1.2 Pressure

Within the pressurised environment of the spacecraft, the experiment hardware can be exposed to normal pressure levels – ranging between 46 kPa (0.454 atm) and 152 kPa (1.5 atm) – during flight. Generally, the pressure is quite stable at around 1 atm. Should a leakage in the parachute hatch during the re-entry phase occur, the hardware could be exposed to reduced pressures, with values as low as 5.34 kPa (0.053 atm), for up to 30 minutes.

6.2.1.3 Radiation

No dosimeters are included in the standard spacecraft sensor package, but user-provided dosimeters have been flown on Foton missions in the past. The data recorded by these dosimeters show that the internal experiment hardware could be subjected to ionising radiation of the following nature:

- *Background radiation*: up to 0.055 rad/day (5.5×10^{-4} Gy/day);
- *Solar flares*: 50 rad (0.5 Gy), possible during the whole mission;
- A *gamma source* inside the re-entry capsule with a total radiation dose of 0.104 rad/day (1.04×10^{-3} Gy/day) at a distance of 500 mm from the source.

6.2.1.4 Air Composition

The gaseous medium inside the pressurised Foton capsule consists of air, which can contain up to 0.01 % of Helium and 2.0 % of Hydrogen.

6.2.1.5 Humidity

The relative humidity levels within the spacecraft can vary between 25 % and 80 %.

6.2.1.6 Temperature

During flight, the temperature within the Foton capsule will typically be between 19 °C and 26 °C. After landing, the experiment hardware could be exposed to temperatures ranging between 0 °C and 40 °C. During the transportation phases of the experiment hardware, the air temperature can be anywhere between –20 °C and +50 °C.

6.2.2 External Environment

6.2.2.1 External Vacuum

The vacuum pressure in orbit for a Foton mission can be as low as 0.133×10^{-6} kPa (1.313×10^{-9} atm).

6.2.2.2 External Temperature

For a worst-case scenario, the temperature on the exterior surface of Foton while in orbit can range from –150 °C to +120 °C.

6.2.2.3 Atomic Oxygen

No atomic oxygen levels have been specified by the spacecraft manufacturer, but from data recorded during the Foton-8 mission (1992), the impact of atomic oxygen in the ram direction of the spacecraft was 10^{20} oxygen atoms/cm^2/day.

6.2.2.4 Cosmic Radiation

During a Foton mission the following maximum external radiation levels can be encountered:

- *Background radiation*: 600 rad/day (6 Gy/day);
- *Solar flares*: a maximum of 3.7×10^4 rad (370 Gy) for the duration of the entire mission.

6.2.2.5 Solar Light

Irradiation of solar light into externally mounted payloads on Foton depends strongly on the spacecraft attitude and orbital characteristics. Based on the daily dose recordings obtained during past missions (see Table 6-2), the solar constant hour (SCh) per day ranges between 2.0 and 2.8.

Table 6-2: Daily Solar Constant Hour (SCh) recordings on past missions

MISSION	SOLAR CONSTANT HOUR (SCh) PER DAY
Foton-8	2.14
Foton-9	2.80
Foton-11	2.65
Foton-12	2.02

6.3 Scientific Research Suitable to Foton Capsules

The following blocks (Figure 6-15) highlight the various scientific fields, which are suitable for research on Foton capsules. It is important to note, however, that these fields are based on the data from current and past research carried out on Foton, and should therefore NOT be considered exhaustive by the user. Scientists should view the fields presented below as a guide, but are encouraged to propose new research areas, as long as their experiments can be executed within Foton flight limitations.

FLUID AND COMBUSTION PHYSICS

Structure and dynamics of fluids & multiphase systems
- Boiling
- Diffusion
- Properties of organic compounds
- Evaporation
- Marangoni-Bernard instabilities
- Thermal radiation forces
- Fluid physics

BIOLOGY

Plant Physiology
- Graviresponses
- Plant bacterial symbiosis
- Plant biology

Cell and developmental biology
- Radiation biology
- Unicellular organism motility
- Microbiology
- Cell cycle kinetics in algae
- Gene expression in osteosarcoma cells
- Human fibroblasts
- Development in flies
- Water micro-organisms
- Neurobiology

Biotechnology
- Cartilage formation
- Protein crystal growth
- Microbial filters
- Space technology

ASTRO/EXOBIOLOGY

Origin, evolution and distribution of life
- Survival rate of terrestrial organisms in open space
- Chemical evolution
- Radiation biology
- Meteoritics

Preparation of human planetary exploration
- Radiation dosimetry
- Space technology

MATERIALS SCIENCE

Thermophysical properties
- Measurement of diffusion coefficients in melts

New materials, products and processes
- Convection and segregation in crystal growth
- Diffusion in alloys
- Space technology

Figure 6-15: Research fields carried out on Foton capsules, based on past experiments

6.4 Payload Accommodation

6.4.1 Total Scientific Payload Envelope

Within the 2.20 metre sphere of the re-entry capsule the volume is shared between experiment hardware, satellite subsystem hardware, landing parachutes, free volume for hardware access and air circulation. As a result, although the total internal volume of the sphere amounts to 4.6 m^3, only 1.6 m^3 is available for experiment hardware. A maximum of about 650 kg of scientific payload can be installed inside the available volume. Figure 6-16 illustrates the intricate shape of the total payload envelope and the payload orientation within the capsule.

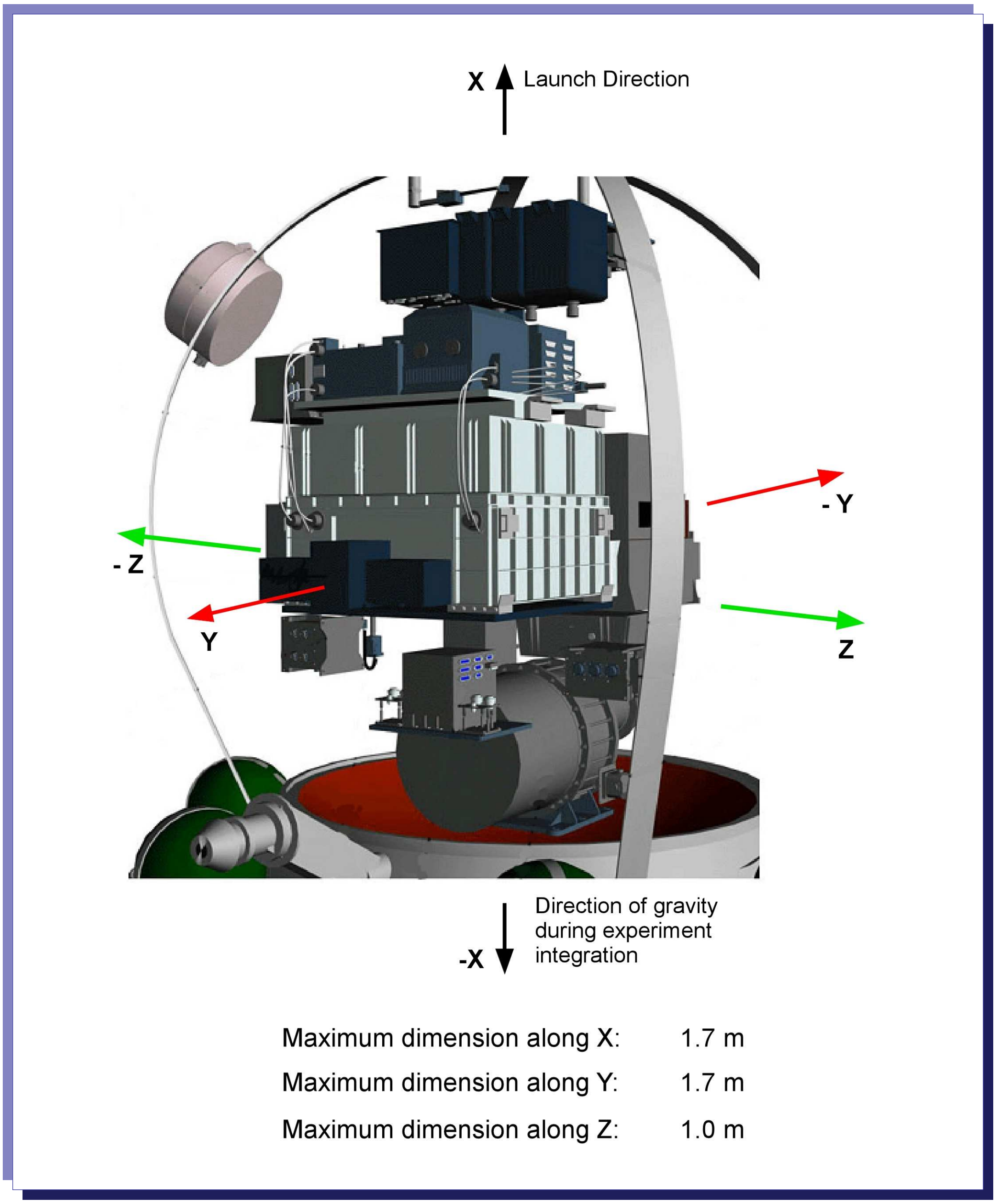

Figure 6-16: Foton payload envelope and orientation (Image: A. Verga)

6.4.2 Size and Mass of a Single Experiment

As a rule the user is required to produce 3 identical sets of experiment hardware:

- *Flight model*: payload which will be used in flight during the mission;
- *Ground control model*: payload which operates on-ground during the mission;
- *Contingency model*: payload that will replace either the flight or ground model if required.

The size and mass of a single experiment is not limited by any specific criteria and will be established by ESA on a case-by-case and mission-by-mission basis. Any restrictions will depend on the scientific mass and volume that ESA is allocated for each mission, following negotiations with the Russian Federal Space Agency (FSA). However, as a rule of thumb, users should reduce mass to a bare minimum and should try to keep their payload volume within the following dimensions:

- Length – 265 mm
- Width – 157 mm
- Height – 157 mm

Users also have the possibility of choosing a qualified experiment container made available by ESA, called a Type III container (see Figure 6-17). This is an aluminium rectangular parallelepiped consisting of a baseplate, with four protruding feet, and a hood that slides over the baseplate. The hood attaches to the sides of the baseplate with 12 screws. The Type III container is fixed to the spacecraft by means of 4 screws, which engage the container's protruding feet. The container cannot be sealed since the baseplate has 11 circular ventilation holes. The feet also serve to raise the baseplate 1.5 mm above the spacecraft mounting plate to allow for ventilation. The dimensions of the Type III container are summarised in Table 6-3. The total empty mass of the Type III container is 650 grams.

Table 6-3: Dimensions of Type III container

	LENGTH (mm)	WIDTH (NOT INCLUDING MOUNTING FEET) (mm)	WIDTH (INCLUDING MOUNTING FEET) (mm)	HEIGHT (mm)
External dimensions	178.0	127.0	157.0	116.0
Internal experimental volume	174.5	123.5	N/A	105.5

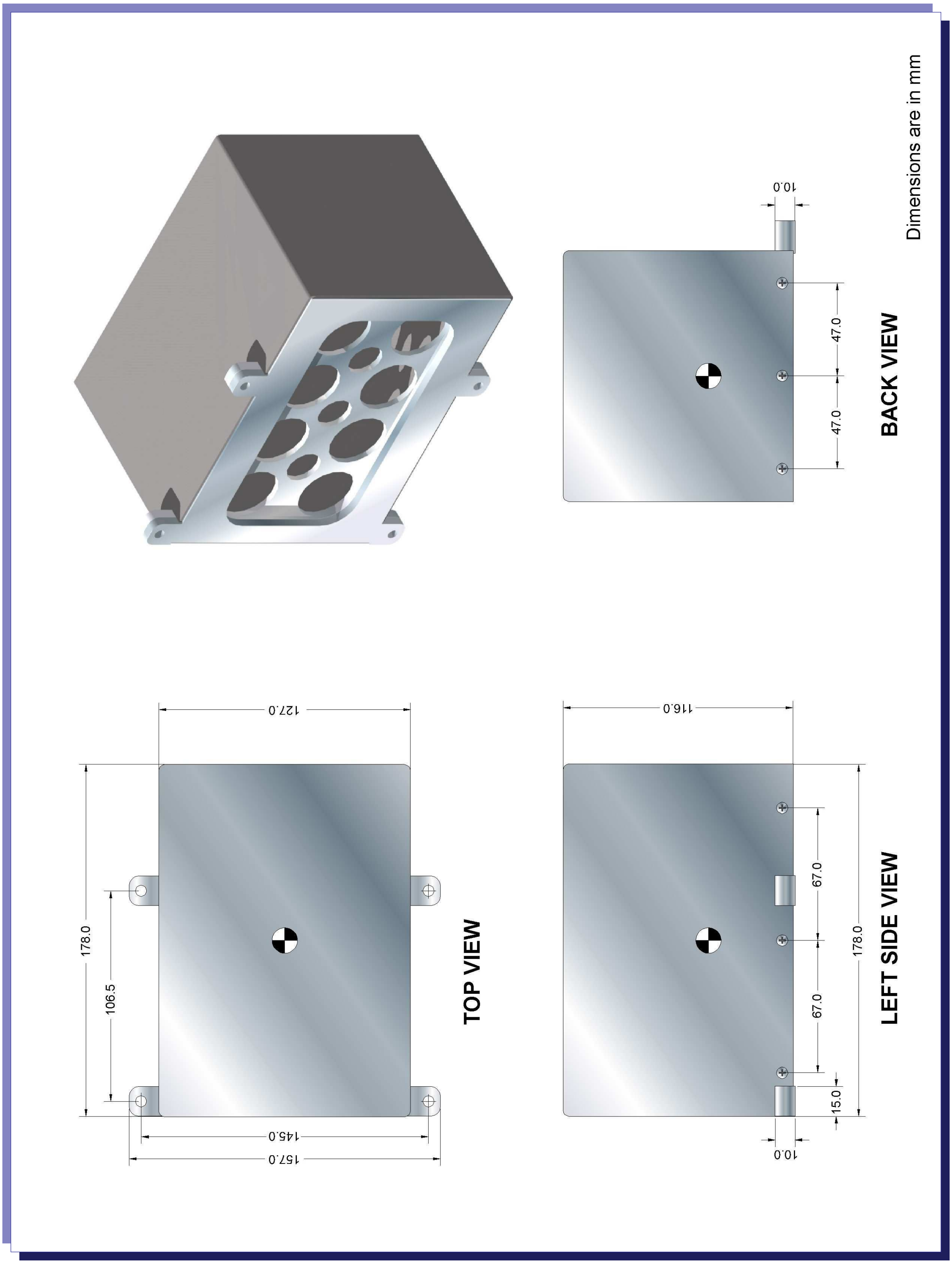

Figure 6-17: Type III container

6.4.3 Mechanical Compatibility

No standard specifications exist for the mechanical interface between unique experimenter supplied hardware mounted directly to the spacecraft. Any hardware built by the user for direct mounting to the spacecraft, as opposed to fitting into an existing Type III container, will be handled on a case-by-case basis and will require a unique interface definition.
When using a Type III container, it must be kept in mind that there are no internal attachment structures, therefore any experiment hardware should be designed for a snug fit within the container, using foam or rubber as filling material.

6.4.4 Vibration and Shock Test Levels

This section identifies the vibration and shock test levels used when testing the experiment hardware.

6.4.4.1 Linear Accelerations

6.4.4.1.1 For Launch

For test purposes, the maximum launch linear accelerations to which the payload is subjected are ± 10g for 600 seconds, along any of the principal axes of the hardware.

6.4.4.1.2 For Re-Entry

The maximum re-entry linear accelerations to which the payload is subjected are ± 16g for 20 seconds and ± 9g for 100 seconds, along any of the principal axes of the hardware.

6.4.4.2 Sinusoidal Vibrations (Resonance Survey)

For all axes the following sinusoidal vibrations shall be applied during testing:

Table 6-4: Sinusoidal testing vibrations

FREQUENCY RANGE (HZ)	LEVEL (g)	SWEEP RATE (OCT/MIN)
5 - 2000	0.5	2

6.4.4.3 Random Vibrations

For all axes the following random vibrations shall be applied during testing. Each test shall have a duration of 480 seconds:

Table 6-5: Random testing vibrations

FREQUENCY RANGE (HZ)	LEVEL (g^2/HZ)	SLOPE (dB/OCT)
20 - 100	0.02	
100 – 200	0.02 – 0.05	+4
200 - 500	0.05	
500 - 1000	0.05 – 0.02	-4
1000 - 2500	0.02	

6.4.4.4 Landing Shock Levels

To test shocks during the landing phase the following will be applied:

Table 6-6: Landing shock test levels

PHASE SIMULATED	AMPLITUDE OF SHOCK (g)	PULSE DURATION (MILLISECONDS)	NUMBER OF SHOCKS
Parachute deployment	40g	5 – 10	5
Landing	40g	40 – 50	1

The direction of the shocks may be along any of the three principal axes of the experiment (see Figure 6-18). The structural integrity of the experiment must be guaranteed after exposure to these shocks.

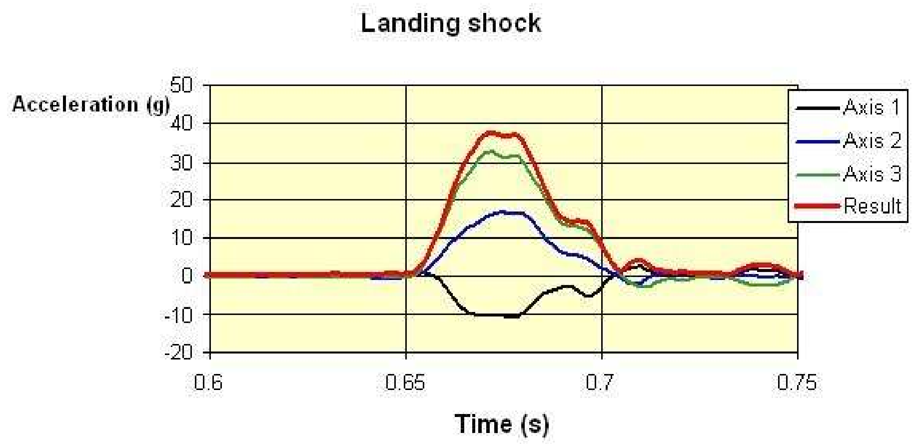

Figure 6-18: Landing shock **(Image: A. Verga)**

6.4.5 Inspection Criteria

ESA will perform a minimum of 2 detailed inspections of the experiment hardware. The first inspection is carried out after the hardware has been manufactured, which corresponds to the closeout of Phase II (see paragraph 6.8.2). After the inspection, a Hardware Inspection Report is completed. The report identifies inspection criteria and provides details on the results of the inspection. Any discrepancies identified as a result of the inspection shall be corrected prior to acceptance of the experiment hardware for flight.
During the first inspection attention will be given to the following items:

- Mass;
- Drawing compliance;
- Protective devices, if any;
- Cleanliness;
- Labels;
- Mechanical fit.

The second experiment hardware inspection occurs just before flight and is for flight acceptance, which corresponds to the closeout of Phase III (see paragraph 6.8.3). The Hardware Inspection Report will concentrate on cleanliness and labelling of the hardware. Any discrepancies identified during the first inspection must be corrected prior to the second inspection.
During the second inspection attention will be given to the following items:

- Mass;
- Protective devices, if any;
- Cleanliness;
- Labels.

Labelling of experiments is very important. The following colour code shall be used when labelling the experiment hardware:

- Green = flight model;
- Red = ground control hardware;
- Yellow = contingency hardware.

6.4.6 Import/Export Requirements

The experimenter is responsible for transporting his hardware to and from his home institute to ESTEC in Noordwijk, The Netherlands. It will then be ESA's responsibility to take care of all customs procedures and to transport all experimental hardware to Baikonur. The experimenter can hand-over the hardware to ESA at the latest one day before ESA personnel leave the Netherlands for Baikonur, typically 5-6 days before the launch date. ESA delivers final versions of pro-forma invoices, packing lists, electronic pictures and technical descriptions to TsSKB (in copy to the ESA Moscow Office) at least 15 days before shipment, while drafts are delivered at least 30 days before shipment. Users must provide ESA with all the necessary information to carry out the import/export procedures well in advance of the afore-mentioned deadlines. This information package includes:

- The names, addresses, telephone numbers, fax numbers and e-mail addresses of the scientific coordinators and associates;
- A statement that the equipment is scientific hardware with no commercial value;
- A brief technical description of the experiment hardware;
- A statement that the experiment is not harmful;
- Electronic pictures of the experiment hardware and samples;
- Any special requirements (and relative justifications for these) when handling the experiment hardware.

TsSKB will complete Customs clearance and return all experiment items to ESTEC within 1 month after the launch date. The experiment hardware will then be handed over to the users, who will then be responsible for their own experiments from that point on.

6.5 Available Flight Resources

The following sections provide some information regarding in-flight resources and space-qualified facilities available to users.

6.5.1 Flight Facilities

Instead of developing new experimental facilities, users also have the option of integrating their experiments into already existing, space-qualified ESA facilities that, as previous versions, have flown in space during past missions.

6.5.1.1 Biobox

Biobox is a programmable, space-qualified incubator for cell biology research in space, offering a controlled thermal environment and allowing for fully automated execution of biological experiments, with limited use of telecommands. The first version of Biobox was developed in 1990/1991 and since then four missions have been successfully flown (Bion-10 in 1992, Foton-10 in 1995, Foton-11 in 1997 and STS-95 in 1998) before the last unit was lost on the fatal STS-107 flight.

To rule out flight effects other than weightlessness, an in-flight 1g centrifuge is installed in Biobox, permitting 1g control experiments to be conducted on-board the spacecraft.

The telecommand capabilities of Biobox are primarily used to back up the on board automatic commands that initiate the experiment sequence, to control the centrifuge activation and speed, as well as to change the temperature set point of the incubator modes, allowing for a certain control of the facility power consumption. The telemetry data are mainly used to monitor the health of the Biobox and its response to the telecommands sent to it. Within certain environmental conditions the incubator temperature can be selected to any value between 4 °C and 37 °C.

A new version of Biobox (Biobox-6) is currently under development in preparation for the Foton-M3 flight in September 2007. In the new Biobox the well-proven capabilities of the old model will be maintained in combination with the introduction of new features, based on technical upgrading and on scientific recommendations of the ESA Topical Team Cell Biology Report from 2000. To increase the number of experiment positions, a double incubator is foreseen, driven by a single electronics control unit. The temperature profiles and the experiment timelines of the two incubators can be programmed independently in accordance with the experiment needs.

The new Biobox will weigh an estimated total of 65 kg, including the 2 incubators and the Foton Interface Box, which controls power and data distribution to both incubators. The mass of each incubator and of its embedded electronics is around 30-32 kg. Biobox measures 550.8 mm x 504.4 mm x 275.2 mm and utilises an average of 40 W of power in the heating and running modes, but 80 W in the storage mode (which can last for many days, depending on the experiment duration). Power peaks of up to 140 W during transient phases (especially cooling) can be reached.

The accommodation of experiment samples in the two incubators allows for a 1:1 ratio between micro-g and 1-g samples, with the option of adding '*zero-time references*' whereby a sub-set of biological samples is fixed immediately after orbital injection, to 'freeze' in time any effect due to the launch loads. This approach will result in scientifically more solid and convincing experiments than before, eliminating possible flaws due to *'artefacts'*, which have been identified in the past.

For more information regarding the Biobox facility, users are requested to contact either the project manager (Dr. Pietro Baglioni) or the project scientist (Dr. René Demets) at the following:

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6.5.1.2 Biopan

Biopan is an externally mounted, recoverable, pan-shaped, multi-user facility for research on biological samples exposed to cosmic radiation, extreme temperatures, solar light, microgravity and the vacuum of space (Figure 6-19 and Figure 6-20).

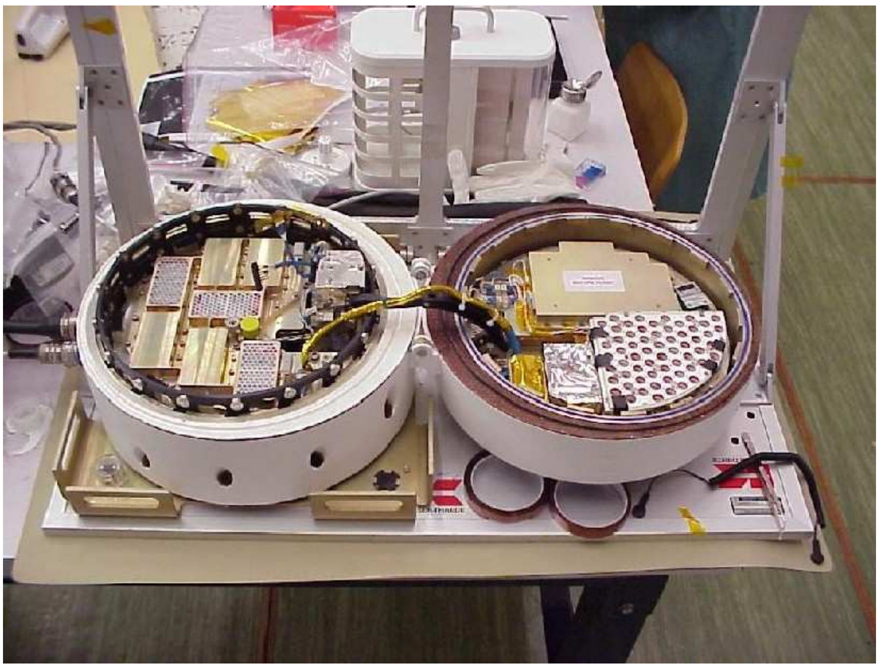

Figure 6-19: Open Biopan facility before installation on Foton **(Image: R. Demets)**

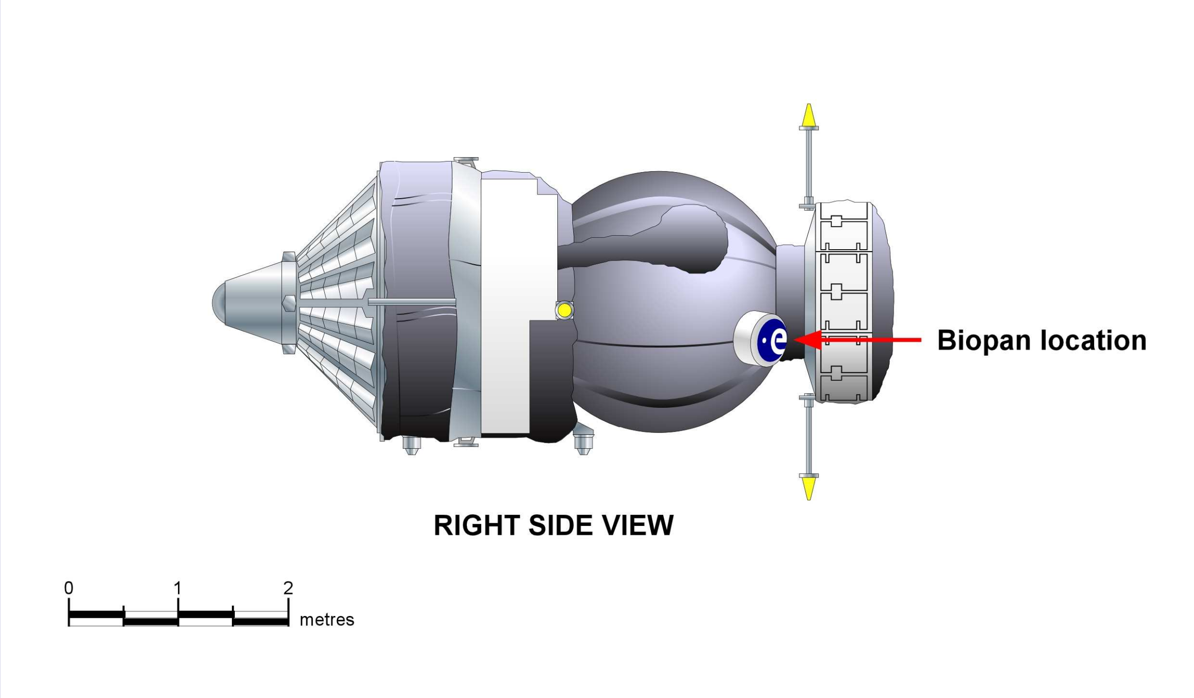

Figure 6-20: Biopan location

Biopan is an aluminium, circular structure (35 cm in diameter and 19 cm high including heat shield) with a motor-driven, hinged lid that can open to 180° in-orbit (Figure 6-21). Experiments can be mounted on experiment support plates in the top and bottom part of Biopan. The facility is thermally insulated from the Foton capsule, and during launch and re-entry the lid is closed, hermetically sealed and secured with a locking ring. Biopan is covered externally with ablative shielding material to protect the experiments from the heat produced during re-entry.

Depending on the shielding density, experiments in Biopan can be exposed to maximum radiation levels of up to 6 Gy/day (600 rad/day), or 80 Gy/mission (8000 rad/mission). Biopan provides for stable thermal control in the range of +15 °C to + 25 °C. If no thermal control is used, temperatures can fluctuate between less than –40 °C and greater than +60 °C. The facility can also be flown in a mixed thermal mode, i.e. one set of experiments can be thermally controlled, while another is not.

Also, Biopan can be partially controlled with telecommands, to open and close the lid, even if these functions are nominally automatically activated (by a pre-programmed timeline or by temperature sensors detecting extreme environmental conditions, dangerous for the on-board electronics).

Biopan is equipped with thermometers, a UV-B sensor, a UV-C sensor, a broadband radiometer and a pressure sensor. The sensor data are acquired and stored on-board.

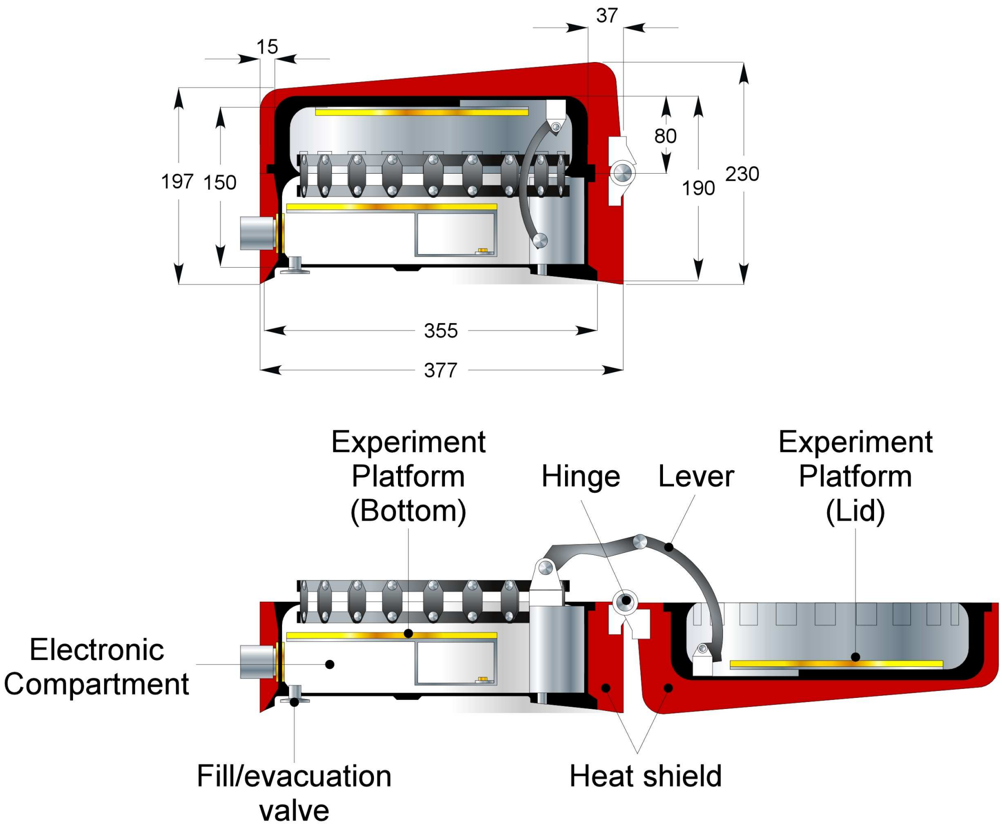

Figure 6-21: Biopan cross-section and dimensions

6.5.1.2.1 Experiment Design Requirements

The maximum experiment envelope and mass available to experimenters is shown in Table 6-7. If more than one experiment occupies the Biopan platform the exact area for each experiment will be defined on a case-by-case basis. The mass of the experiments should be uniformly distributed over the experiment platforms.

Table 6-7: Biopan experiment envelope and mass

PARAMETER	VALUE
Maximum height	2 x 25 mm
Bottom experiment platform area	480 cm^2
Lid experiment platform area	510 cm^2
Total experiment mass in Biopan (max)	3.50 kg
Total mass on one experiment plate (max)	1.75 kg

For more information regarding the Biopan facility, users are requested to contact either the project manager (Dr. Pietro Baglioni) or the project scientist (Dr. René Demets) at the following:

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6.5.1.3 Stone

The Foton spacecraft is not only used for microgravity experiments, but also for experiments whereby the samples are fitted onto the outer surface of the capsule, directly exposed to the harsh space environment. In this way the effects of unfiltered solar light and non-shielded cosmic rays can be studied (see previous section 6.5.1.2).

A fairly new development is a class of experiments aimed at testing the effects of the re-entry environment. Pieces of material are fixed into the heat shield of the Foton capsule, which at the end of the flight, are exposed to the complete re-entry load profile in terms of temperature, pressure, velocity and surface boundary interactions. This kind of experimentation began with the testing of new types of heat shield materials, but in later missions pieces of rock replaced the sample materials, acting as 'artificial meteorites'. In this guise, the re-entry experiments from ESA have been labelled 'STONE'. A further step is to load these rocks with microbes to test whether the Earth may be contaminated by simple forms of life carried by meteorites. The Foton capsule is equipped with four annular sample holders to accommodate four disc-shaped test samples. For each sample, the exposed area is a 6-cm diameter circle.

For further details on carrying out Stone-type experiments, users are requested to contact either the project manager (Dr. Pietro Baglioni) or the project scientist (Dr. René Demets) at the following:

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6.5.1.4 FluidPac

The FluidPac (Fluid Physics Facility) facility (Figure 6-22) is an experimental facility developed for fluid physics research that allows for three to four experiments to be conducted in weightlessness. It is characterised by a large volume (approximately 700 litres), a relatively low mass (185 kg) and a high power handling capability (500 W).

The facility comprises two separate assemblies: The Experiment Box and Electronic Boxes, which together occupy 650 litres (almost half of the total volume available inside Foton). Both blocks are dimensioned to sustain high mechanical loads (up to 90g).

The FluidPac is characterised by very accurate (±0.1 °C) temperature control between temperatures of 5 °C and 80 °C, with good stability conditions (±0.01 °C/hour). The facility heat rejection capability at the experiment cold plate for a temperature of 5 °C is 30 W (120 W at 40 °C). Also, the disturbances induced within the facility by moving parts are very low.

The optical diagnostics of FluidPac are made up of 13 different tools, including 3 interferometers and one infrared camera. Users also have the option of selecting image compression for 2- to 20-fold data reduction. The on-board data storage capacity of Fluidpac is 8 Gbytes.

For more detailed information regarding the Fluidpac facility users are requested to contact the Fluidpac ESA Technical Officer:

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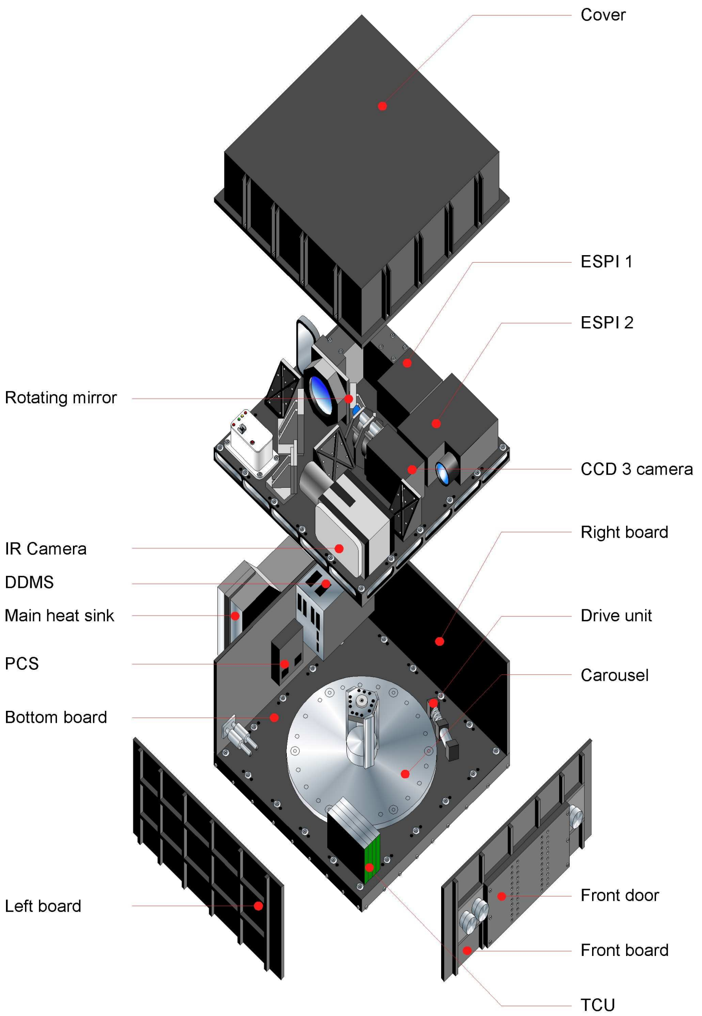

Figure 6-22: Exploded schematic of Fluidpac facility

6.5.1.5 TeleSupport Unit (TSU) and Telescience

The TeleSupport Unit (TSU) consists of a data handling and transmitter/receiver assembly that is able to acquire, process, and transmit experiment data from the Foton capsule to the ground. Conversely, a limited set of commands can be up-linked from the ground to Foton to modify the experiments. The purpose of the TSU is to allow the experimenters to follow their experiment's progress throughout the mission. The TSU was flown for the first time on Foton-12 in combination with FluidPac.
The TSU consists of the following:

- AFD – Antenna Feeder Device;
- DHU – Data Handling Unit;
- TCU – Telescience Central Unit;
- TSU – Harness;
- RFU – RF-Unit.

The TCU subsystem contains the following parts:

- Power unit;
- Battery unit;
- Housekeeping unit;
- Power switch unit;
- Master unit;
- Foton interface unit.

The Master unit houses a number of sub functions in the TCU. These are:

- CPU with command interpretation;
- Downlink coding interface;
- Telemetry generator;
- User telemetry/telecommand (TM/TC) interface.

The main functional requirements of the TSU are to:

- Collect housekeeping and scientific telemetry from the experiments and forward it to the users on ground;
- Collect digital video from the experiments, perform classical and customised video processing procedures together with data compression. The data will be forwarded to the users on ground in a format compatible with the communication system;
- Send telecommands to the experiments in a transparent manner;
- Generate and transmit to the ground the TSU's own housekeeping data, in order to allow monitoring of the correct functioning of all its subsystems;
- Receive and execute the telecommands directed to change the configuration of the TSU system itself;
- Modify the image processing parameters and/or algorithms during the mission;
- Store a meaningful sample of the scientific data (telemetry and video) produced by the experiments during any of the periods in which Foton is not 'visible';
- Interface the spacecraft telemetry/telecommand (TM/TC) subsystem;
- Provide a central point of control in the ground station from where it shall be possible to display all the telemetry data and the processed images received from the on-board TSU and issue telecommands for both the TSU and the experiments.

The main non-functional requirements of the TSU are:

- Generate its own regulated power supply voltage, starting from the power source as provided by the Foton spacecraft power system;
- Provide an adequate level of fault tolerance;
- The TSU shall be compatible with the resources available on-board the Foton spacecraft. In addition, the TSU shall also take into consideration the resource consumption of the experiments.

For uplinking the S-band is used. The receiving system consists of a filter (to eliminate disturbances from the transmitter), a phase modulated receiver and an FM receiver. The bit rate is 19.2 kbit/s.
The downlink uses a phase modulated S-band transmitter. The downlink bit rate is 1 Mbit/s.

The ground station and main operation centre for telescience activities will be Esrange (67° 54' N, 21° 04' E), which is located in northern Sweden 200 km above the Arctic Circle and 43 km east of the town of Kiruna. The TSU is switched off during launch and the Foton power system switches on the TSU in orbit. The TSU is in interactive mode during the mission, i.e. it is possible to change the modes of operation by command at a passage over Esrange after having evaluated data from real time or previous orbits. The scientific data received at Esrange will be made available to experimenters via Internet and FTP. Foton is 'visible' (i.e. possibility of uplink/downlink) from Esrange during 5 consecutive orbits, daily. For each of these 5 orbits, transmission is possible for approximately 5 minutes. As an example, Figure 6-23 shows the telemetry distribution architecture for the Foton M2 mission (May-June 2005).

For more detailed information regarding the TeleSupport Unit and telescience capabilities, users are requested to contact the Foton ESA Technical Officer:

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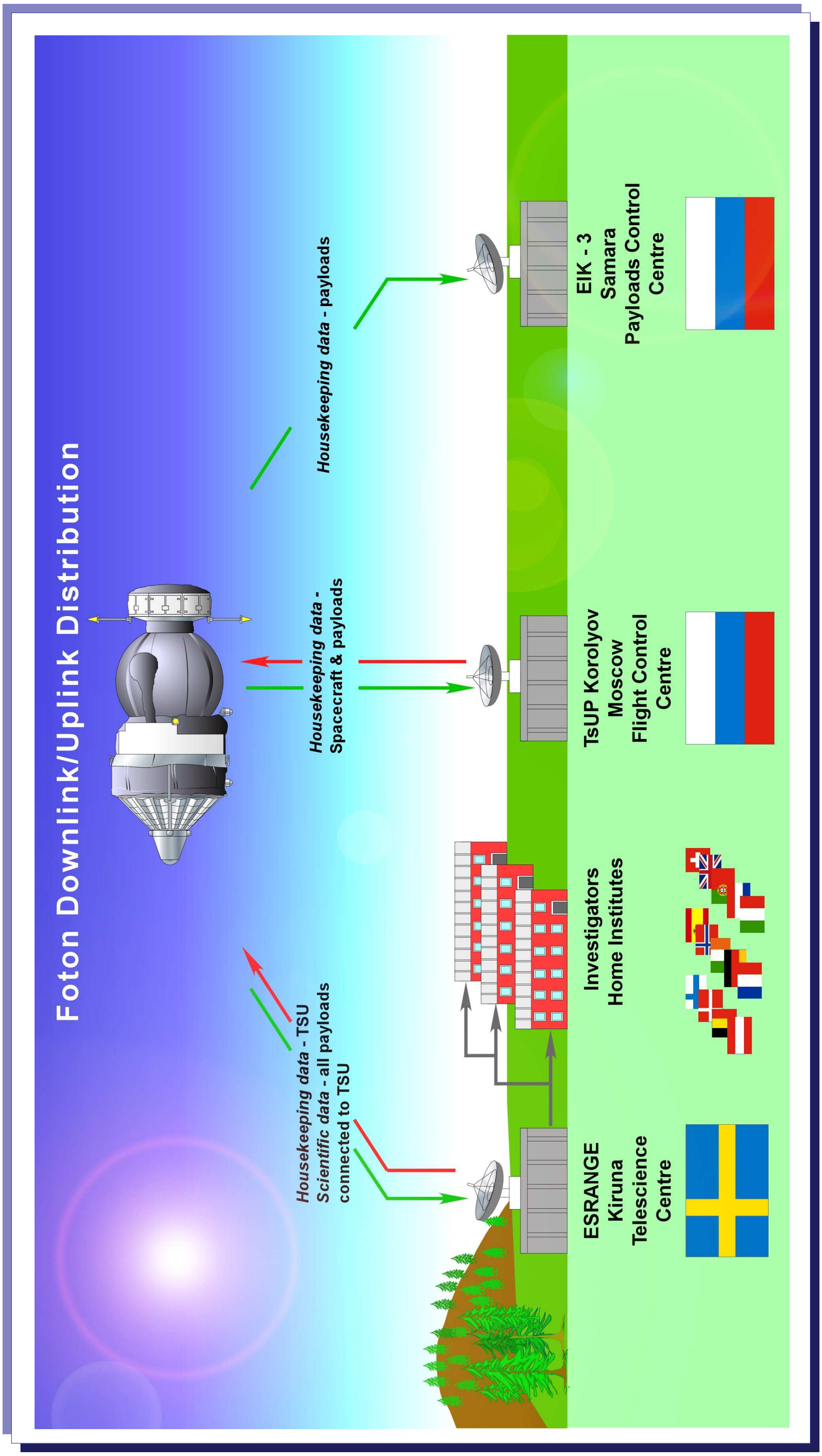

Figure 6-23: Foton M2 telemetry distribution architecture

6.6 Ground Support Facilities

The following sections provide some information related to the ground facilities and logistics available to the users.

6.6.1 Transport Containers

ESA has a limited number of temperature-controlled containers for transporting experiments from ESTEC to the launch site, and from the landing site back to ESTEC. The transport containers have the following internal dimensions:

- Length = 180 mm
- Width = 160 mm
- Height = 174 mm

The containers have active cooling/heating and the temperature can be set anywhere between 1 °C and 40 ºC. Power is provided by 220 V for use at home, by 12 V for transport by car (connected to the cigarette lighter) or by internal batteries for transport when no 220 V or 12 V power supply is available. Depending on the ambient temperature the batteries can provide power for approximately 12 hours. The containers are also equipped with an integrated temperature logger, which records temperatures during transport.

6.6.2 Travel and Accommodation

Users who wish to be present at Baikonur for late preparation and launch of their experiments, will travel together with ESA coordinators, and must therefore follow all the procedures set out by ESA. The most important thing that must be dealt with before anything else is to apply for a visa. This can be done through ESA, and must be done as early as possible. Users will provide all data requested by personnel at ESTEC in the Netherlands. Once all data has been collected for all those requiring a visa, the information package is sent to the ESA Moscow Office (EMO). The EMO then sends all documentation to the Russian Federation Ministry of Foreign Affairs (MID) where visa processing takes place. The processing takes 5-7 working days for single/double-entry visas, and 10-15 working days for multiple visas. MID then sends a telex to the Russian consulate in the city where the user plans to collect his/her visa. The EMO then receives the reference number for this telex from the MID and informs the applicants. When collecting visas, users should, in addition to the reference number, provide a completed consular form, a valid passport, photos and medical insurance. The maximum period of visa validity is 3 months for single/double-entry visas, and 1 year for multiple visas. It is important to note that passports must be valid for at least 3 months following the end of the period for which the visa is requested.

ESA arranges for one flight to transport all scientists, late-access equipment and ESA coordinators to Baikonur. The flight departs from Rotterdam Airport and stops-over in Samara, where TsSKB is based. During this stop, lasting 4-6 hours, last minute checks and passport/documentation controls are carried out. From Samara the flight then continues to its final destination, Baikonur. The duration of the flight from Rotterdam to Baikonur, including stopover, is less than 24 hours. ESA will also arrange to obtain access permits to the Baikonur Cosmodrome.

There are a number of accommodation possibilities in and around Baikonur, and this will also be arranged by ESA. Some of the major space industries own their own hotels in Baikonur, so in most cases it will be likely that accommodation will be arranged in a TsSKB-owned hotel.

6.7 Safety

To ensure that safety is designed into the payload the user must perform safety assessments in a systematic and iterative manner beginning in the early project phases. Hazards must be properly identified, classified, controlled and verified for each payload life-cycle stage, including landing, recovery and maintenance. The user must deliver the safety assessment to ESA at the time of the safety reviews and in the form of a technical note complying with the content of the relevant Document Requirement Description (DRD). The initially delivered safety assessment will be progressively detailed and completed as the design proceeds.
As a guideline and reference, users must comply with the two following ESA documents (in order of precedence):

1. GPQ-010 Issue 2, "Product Assurance Requirements for payload projects", June 2003;
2. GPQ-010-PSA-105 Issue1.0, "Safety and materials requirements for ESA microgravity payloads (unmanned pressurised capsules)".

Both documents can be downloaded from the website of the Product Assurance and Safety Office of the Department of Microgravity and Space Station Utilisation, within ESA's Directorate of Human Spaceflight, Microgravity and Exploration Programmes. (http://www.estec.esa.nl/gpqwww/home/pasof2.htm)

GPQ-010-PSA-105 defines the programmatic requirements for Safety, Mechanical-Parts, Materials, and Processes that are applicable to microgravity research payloads to be flown in unmanned retrievable pressurised capsules. This annex is applicable to payload hardware, software, and ground and flight operations.

Safety reviews will be carried out by ESA as an integral part of the planned major project reviews established by the contract. The objectives will be to verify the following points:

1. *At the end of phase B or early in phase C/D*: proper identification of hazards, their causes and related controls.
2. *In phase C/D, at the end of the detailed design*: adequate hazard controls verification methods identified and incorporated in the payload verification programme.
3. *In phase C/D, at the acceptance*: safety verification activities successfully completed and relevant reports made available.

The following sections provide some initial guidelines to the safety design requirements that must be taken into account.
All the ECSS series of documents referred to in the following paragraphs can be downloaded from the European Cooperation for Space Standardisation (ECSS) website (http://www.ecss.nl).

6.7.1 Materials, Mechanical Parts and Processes

All safety issues related to Materials, Mechanical Parts and processes must comply with the requirements of ECSS-Q-70A, "Space Product Assurance: Materials, Mechanical Parts & Processes", 1996.
Initial material selection must be made following the guidelines of ECSS-Q-70-71, "Space Product Assurance: Data for selection of space materials and processes", 2004.
The material and mechanical part evaluation programme must include the following analyses as applicable.

6.7.1.1 Stress Corrosion

Items intended for structural applications shall possess a high resistance to stress-corrosion cracking. Structural products of a metallic nature shall be selected from ECSS-Q-70-36A, "Space Product Assurance: Material selection for controlling stress-corrosion cracking", 1998. Only those products found to possess a high resistance to stress-corrosion cracking may have unrestricted usage in structural applications. All metals shall be corrosion resistant or protected against corrosion including galvanic corrosion that might be caused during operation or storage.

6.7.1.2 Flammability

Materials used for the payload shall be evaluated for flammability resistance. ECSS-Q-70-21A, "Space Product Assurance: Flammability testing for the screening of space materials", 1999, defines the requirements for flammability testing.

6.7.1.3 Offgassing and Toxic Analysis

For biological payloads an offgassing evaluation may be necessary depending on the nature of the experiment samples envisaged. On a case-by-case basis ESA will determine the applicability of the requirements set out in ECSS-Q-70-29A, "Space Product Assurance: The determination of offgassing products from materials and assembled articles to be used in a manned space vehicle crew compartment", 1999.

6.7.1.4 Supplementary Tests

The user shall review his material, and mechanical-part test programme for specific project requirements and add any other test to the above mentioned tests to prove material, mechanical-part and process suitability (e.g. compatibility, thermal vacuum, thermal cycling, radiation, atomic oxygen). The tests should be specified where possible in international or in national test specifications, and be subject to ESA approval.

6.7.1.5 Forbidden Materials

The following materials constitute a safety hazard and are prohibited from being used without prior approval from ESA:

- Beryllium (for structures);
- Beryllium oxide;
- Mercury;
- Cadmium;
- Zinc;
- Polyvinyl chloride (PVC);
- Radioactive materials.

6.7.2 Electrical, Electronic, Electromechanical (EEE) Parts

The user shall be responsible for the selection of EEE components that are capable of meeting the performance, lifetime, stability, environmental, material, safety, quality and reliability requirements. The user shall ensure that exposed materials of EEE components meet the safety requirements established for the project regarding outgassing, flammability, toxicity or other criteria as required for the intended use. Components containing materials that may constitute a safety hazard are prohibited from being used without prior approval by ESA for each individual application. Hazardous materials are identified in the applicable Project Specific Annex (PSA).
Use of EEE components with the following characteristics shall be prohibited except where specifically agreed on a case-by-case basis:

- Limited life;
- Known instability;
- May cause a safety hazard;
- May create a reliability risk.

6.7.3 Pressure Vessels/Sealed Containers

If the experiment requires that pressure vessels or sealed containers be used, the following requirements are applicable:

- Pressure vessels shall be designed in compliance with the standards of the country in which they are procured;
- Sealed containers shall be capable of withstanding the maximum pressure differential associated with the flight profile including a depressurisation of the volume surrounding the sealed container.

Proof by test that these requirements are met by the hardware shall be provided by the user before acceptance.

6.7.4 Batteries

Where batteries are provided by the user inside their containers, it is essential that the battery itself and the circuit and application it powers conforms to the safety standards of ESA. Batteries should be selected to be fully qualified for the environment to which they will be exposed during their installation, storage, flight and removal. Testing of the batteries will be agreed with ESA and discussed on a case-by-case basis. Approval of the batteries by ESA prior to flight is required. As a guideline for safety requirements of batteries used in the payload, users should refer to the “Manned Space Vehicle Battery Safety Handbook”, JSC 20793, 1985, downloadable from the NASA JSC public Payload Safety website (http://jsc-web-pub.jsc.nasa.gov/psrp/).

6.8 Payload Life-Cycle and Major Milestones

The payload life cycle varies from experiment to experiment, and depends strongly on the complexity of the hardware as well as the flight opportunities available to ESA. For experiments approved following submission of a proposal in answer to an Announcement of Opportunity (AO), the time from experiment approval (following the review process) to assignment of a flight can also vary greatly, again depending on the flight opportunities. Ideally, 24 to 36 months is required for experiment design, development, qualification, final acceptance and hand-over to ESA. But this can, for simpler experiments, even be less than 12 months. Payload handover to ESA should take place as early as possible, but again, this can vary anywhere between L-6 months (i.e. 6 months prior to launch) and L-7 days for late access experiments.

To obtain optimal transparency of experiment development progress, three phases have been defined and are described below. Initiation and completion of each phase is accompanied by the signing of a Certificate of Conformance by the User/Scientist and the Foton Project Team at ESTEC.

6.8.1 Phase I: Design

Phase I starts with the identification and description of the experiment as part of a specific Foton payload, and with the definition of the applicable acceptance tests by the Foton team in conjunction with the user. At this point, the first certificate, called the Interface Agreement is signed.
During Phase I, the user will submit as much information as is available and, in conjunction with the Foton team, will describe the procedures of the applicable tests. During Phase I the experiment concept will gradually crystallise into a concrete design and prototype hardware will become available.
At this point, the EAR (Experiment Acceptance Review) will be held. The experiment is now fully specified and will be baselined. After baselining, changes in the experiment are still possible, but now they require official approval from ESA. After the EAR, Phase I is concluded by the signing of the Certificate of Conformance for Phase I.

6.8.2 Phase II: Qualification

During Phase II, the flight programmes will be finalised and flight representative experiment hardware will be manufactured. The experiment will be subjected to the tests defined in Phase I. At the end of Phase II the entire experiment, as it is to be performed during the actual spacecraft mission, will be simulated in an EST (Experiment Simulation Test). Upon successful completion of the EST, the Certificate of Conformance for Phase II is signed. Any malfunctions experienced in the EST are to be documented in an NCR (non-conformance report).

6.8.3 Phase III: Fine-Tuning

Errors detected in the EST can be corrected in Phase III. At the end of Phase III, the experiment hardware is handed over to ESA. At this point, the Certificate of Conformance for Phase III will be signed. After the flight, any technical malfunctions in the experiment are to be described in an NCR.

Figure 6-24 below, represents a typical timeline with major milestones of an experiment for a Foton mission, beginning with the release of an Announcement of Opportunity (AO). The user must keep in mind that, although the tasks displayed in the timeline are standard, and are meant to be a guideline, the periods are based on a generic case, and will differ, as described above, from experiment to experiment. The timeline is given in terms of months with respect to the launch (L).

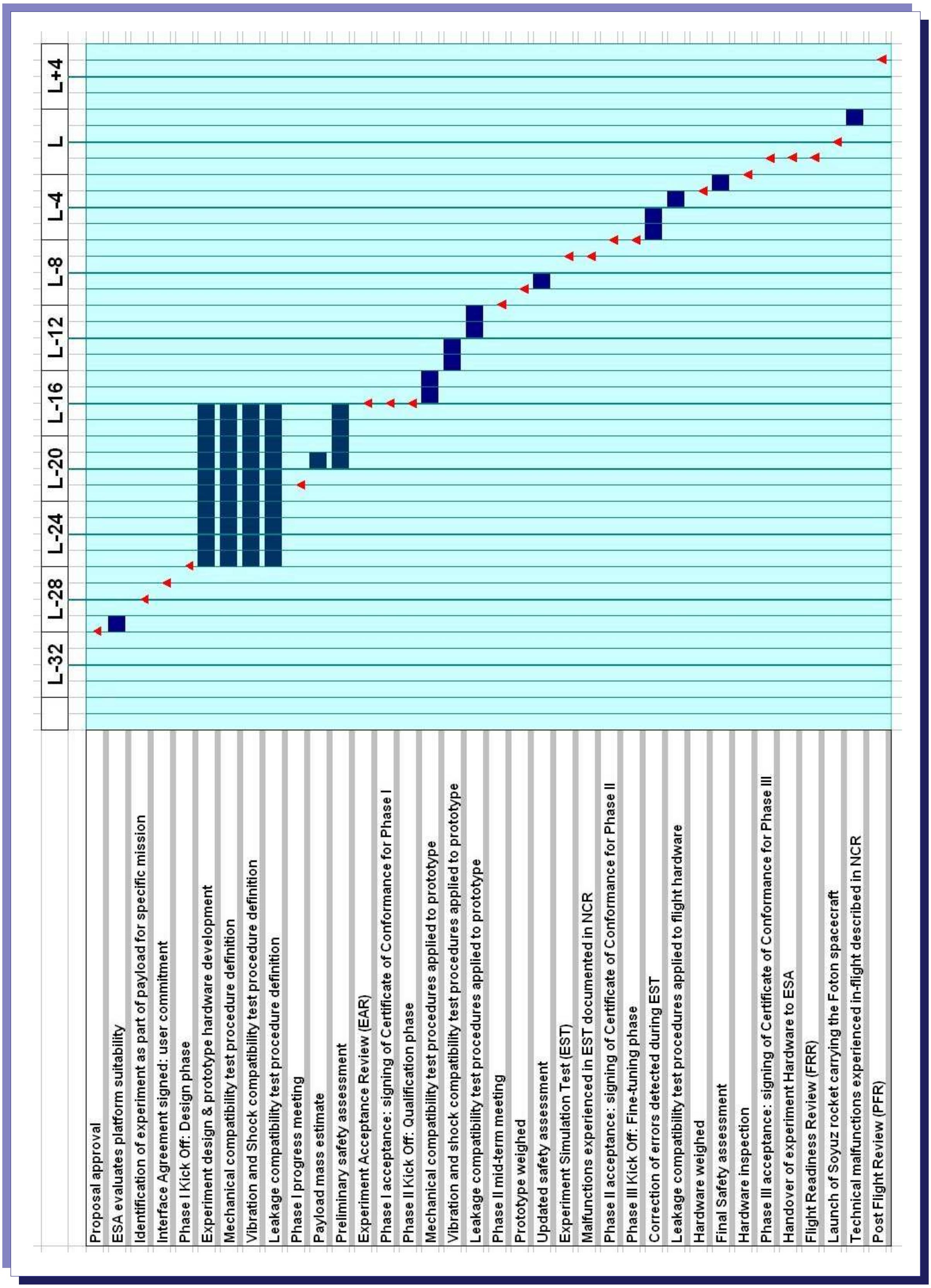

Figure 6-24: Typical timeline for the concept, design and development of an experiment for a Foton mission

6.9 Payload Documentation Development

There is no standard documentation that has to be produced and delivered by a user/scientist during the life cycle of his experiment, i.e. from the moment his experiment is assigned to a flight to the point where he is handed back his experiment. Documents are prepared on a case-by-case basis, and will be different from experiment to experiment. There is however a standard set of four certificates that have to be signed off by the user and by ESA as soon as a certain stage of the experiment has been completed (see section 6.8). But, even those certificates are somewhat adapted for each experiment.

6.10 Operational Cycle of a Foton Campaign

The following provides a general outline of the major events that take place during the operational cycle of a Foton campaign. Scientists should use this as a reference and should keep in mind that the list below may vary from mission to mission. ("L" refers to the time of launch of the Foton capsule, "R" refers to the time of landing of the Foton capsule). Figure 6-25 summarises the sequence of events during a Foton launch campaign.

Table 6-8: Major events in the Foton operational cycle

TIME	EVENT
Up to L-6 days	Scientists hand-over their experiments to ESA at ESTEC in the Netherlands
L-6 days	Deadline for Phase III acceptance certificate signature
L-6 days	❑ Departure of ESA personnel and accompanying scientists to launch site, together with experiments ❑ Flight leaves Rotterdam airport for Samara
L-6 to L-5 days	❑ Stopover in Samara for customs control
L-5 days	❑ Flight from Samara to final destination Baikonur ❑ Customs control in Baikonur
L-5 to L-3 days (sometimes L-4 to L-3 days)	❑ Hardware is inspected, tested and integrated into the Foton spacecraft at the Baikonur launch site ❑ During this phase the Foton spacecraft is in the normal (vertical) position for launch
Up to L-3 days	Ground control hardware set-up and inspection (Not at launch site)
L-1 day	The Foton spacecraft is tilted on its side to allow mating with the launcher, which is lying horizontally on a railroad car
L-1 to L	The spacecraft-launcher assembly is transported to the launch pad and raised into the launch position
L	Launch of Soyuz rocket with Foton capsule on board
L to L+16 days	Ground activities during flight: ❑ Monitoring of the payload telemetry and the scientific telemetry (if applicable) at Esrange, Kiruna
Less than R+6 hours	Recovery of the capsule
R+6 to R+24 hours	Retrieval of experiment samples and transport to Samara
Less than R+24 hours	Hand-over of experiment samples to ESA in Samara
R+3 days	❑ Transport of experiment samples back to the Netherlands ❑ Return of scientists and ESA personnel to the Netherlands
R+3 to R+4 days	Hand-over of experiment samples to scientists at ESTEC, the Netherlands
R+5 to R+9 days	Uninstalling of payloads from the Foton capsule by TsSKB in Samara
Within R+15	TsSKB return experiment hardware to ESTEC
After R+15	Experiment hardware handed over to users by ESA

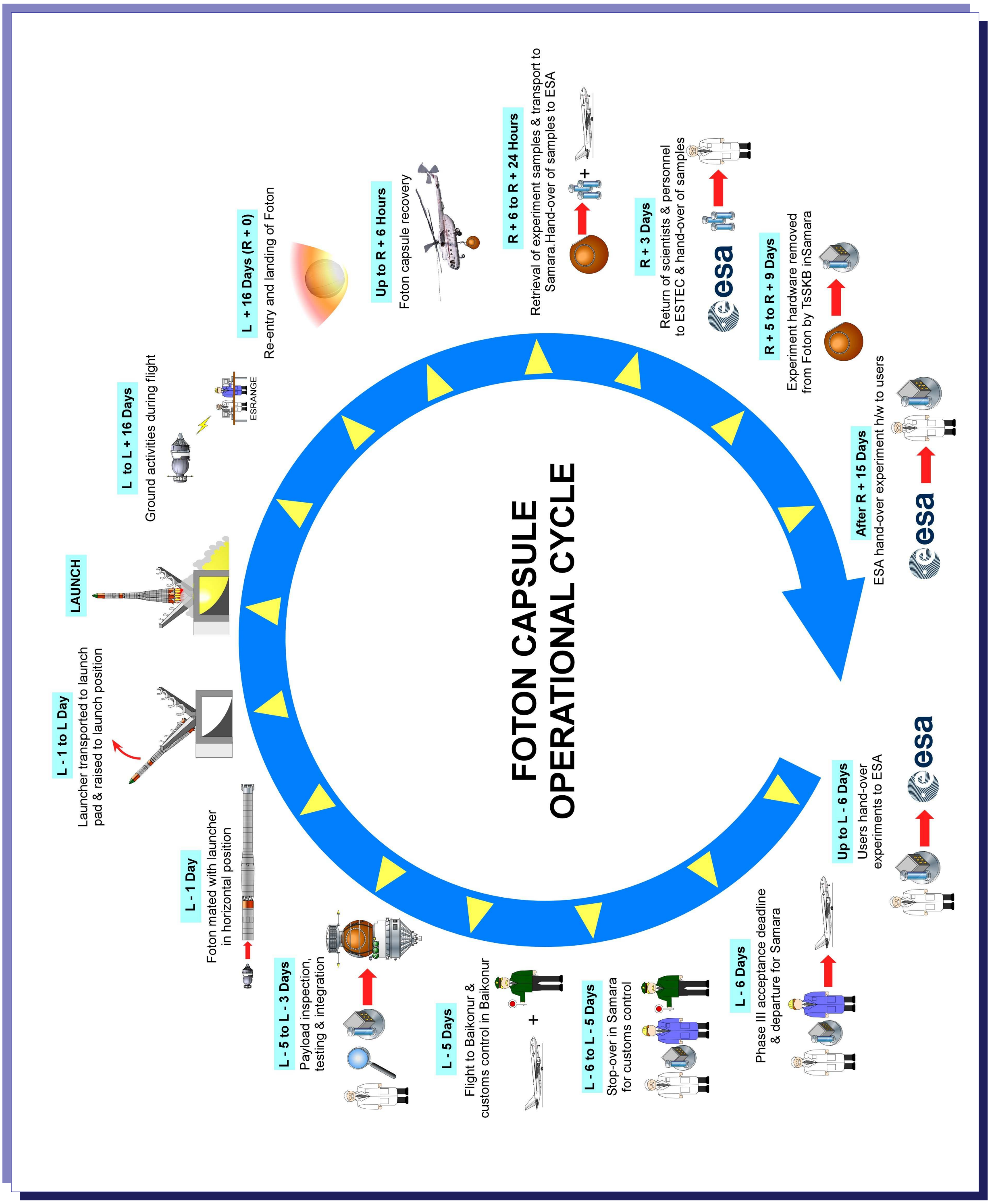

Figure 6-25: Schematic of the FOTON operational cycle

6.11 References

Users can refer to the following documents and web addresses for further information regarding the Foton retrievable capsules and relative research.

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