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THE COSMOS LAUNCH SERVICES AND LAUNCH SYSTEM MODERNIZATION PROGRAM

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ABSTRACT

The COSMOS launch vehicle system has been the workhorse for the Russian (formerly Soviet) government since the 1960´s. Over the past four decades, COSMOS has been launched over 740 times with a unique success record. COSMOS is manufactured by the company POLYOT, Omsk, to launch military and scientific satellites. In addition to launch orbital payloads, it has been used for sub-orbital ballistic and re-entry tests. COSMOS is used to inject satellites in both, circular low Earth and elliptical orbits. Nowadays COSMOS is launched from Plesetsk, as well as from Kapustin Yar for commercial and military missions. The direct SSO ascent is now available for COSMOS from Plesetsk launch site. OHB-System co-operates since 1994 with the COSMOS manufacturer POLYOT, in Russia and has successful launched two missions 1999 and 2000.
For the future scientific, commercial and military satellite launch services a launch vehicle modernization program is taking place.

INTRODUCTION

COSMOS is a two stage space transportation system with liquid propellant rocket engines. COSMOS is used to place satellites of up to 1.500kg in both circular low Earth and elliptical orbits with high inclination. COSMOS is launched today both from Plesetsk and Kapustin Yar for commercial, as well as for military missions. At these sites, integration facilities, transport systems, vehicle shelters, fuelling systems, launch pads and other ground support equipment, built specifically for COSMOS, are utilized. The COSMOS Launch Complex is functionally connected to the Launch Site measurement complexes for reception, recording, processing and output of telemetry data and trajectory measurements.
The very high number of launches and the achieved success rate makes this space transportation system one of the most reliable and successful launchers in the world. According to mission needs, the COSMOS vehicle is continuously adapted and improved.
This paper provides a overview of COSMOS launch history, the short description of the launch vehicle itself with its performance and interfaces, an overview on the launch service organization, the offered services, and launch campaign. The main focal points of the ongoing modernization program are depicted.

COSMOS-3M Launcher Overview

Launch History

The COSMOS Launch Vehicle is one of the most reliable and successful space transportation systems of the world [2]. Up to now, the rocket has been launched 746 times with a success rate of more than 97,4% and is currently full operational and continuously used. The Figure 1 shows the pedigree and heritage of the COSMOS-3M launcher.

Technical Overview

COSMOS-3M is a two stage space transportation system with liquid propellant rocket engines.

Summary description of the launch system:

- Two stage launch system
- Engines: liquid propellant rocket engines
- Oxidizer + Fuel: N_2O_4 + UDMH
- Vehicle launch mass: 109 t
- Vehicle length: 32,4 m
- Payload mass: up to 1500 kg (multiple launch capability)
- Payload dimensions:up to 2.2 m / 4.7m (diameter/length)
- Target orbits: elliptical or circular
- Target Orbit altitude: 250 - 1700 km
- Target Orbit inclination: 48°, 51°, 66°, 74°, 83°, 87°, 98° (SSO)
- Injection Accuracy:
  - Semi major axis: ± 25 km (± 16 km)
  - Inclination: ± 0.04°
- System reliability: 97,4%

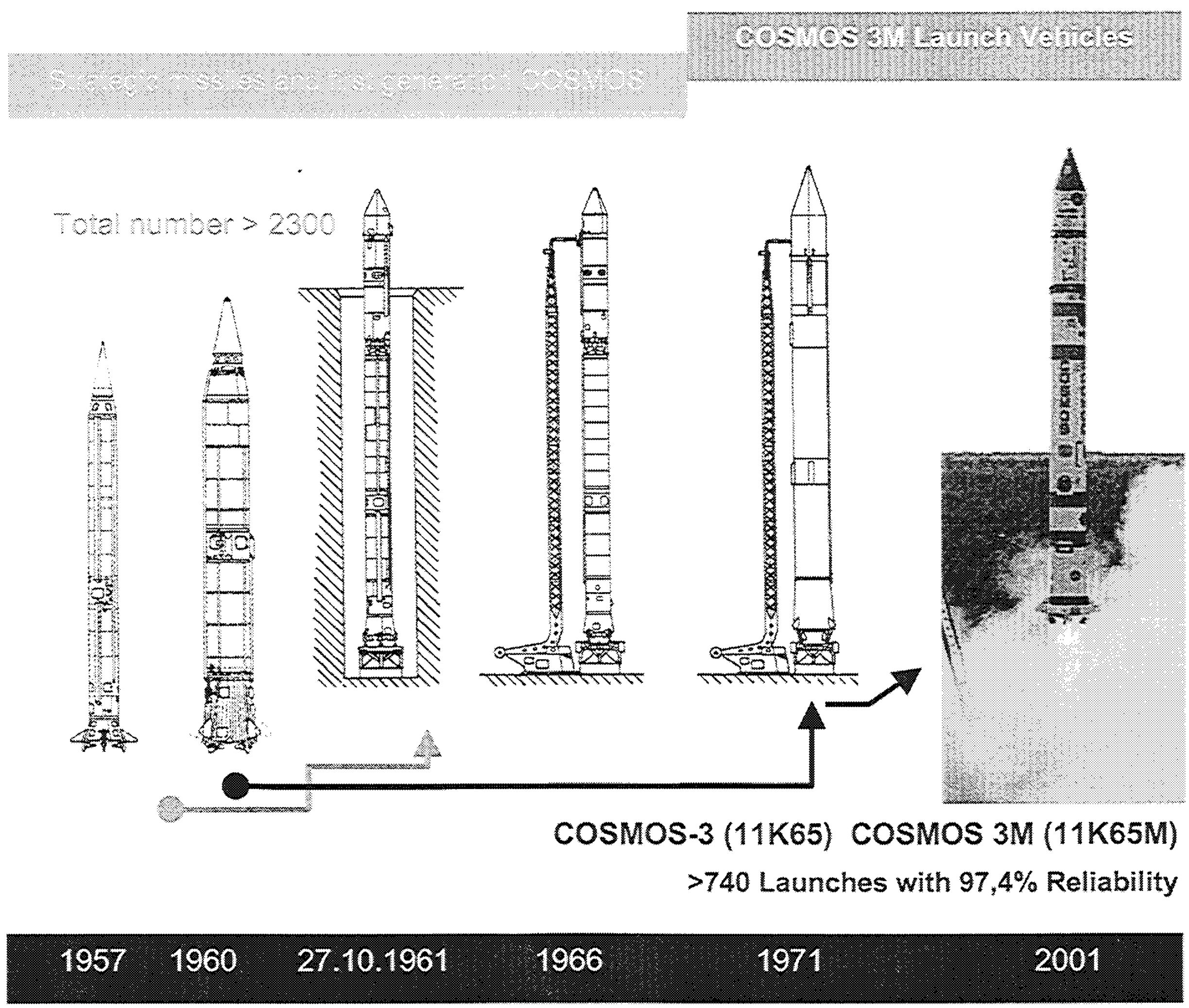

Figure 1: Pedigree and Heritage of the COSMOS-3M Launcher

Rocket Engines

Both stages are equipped with engines which burn high boiling hypergolic propellant components:

- Oxidizer: 27% solution of nitrogen tetroxide in nitric acid (N_2O_4)
- Fuel: Unsymmetrical Di-Methyl Hydrazine (UDMH)

The 1st stage engines provide thrust during the first flight phase. Jet vanes in the exhaust plume accomplish thrust vector control for steering. The propulsion system is composed of four engines and combustion chambers, which are fed by two turbo pumps. The assembly is fixed to the load bearing ring of the stage via a frame.

The 2nd stage engine provides thrust during the second flight phase. The engine consists of the main combustion chamber, the turbo pump and four steerable jet clusters. Each cluster contains a larger jet vane for steering purpose and a smaller jet vane for low thrust periods. The main engine is able to be re-ignited a second time and to work at different thrust levels.

Performance

The performance capability of the COSMOS Launcher for different inclinations and Orbit altitudes from Plesetsk launch site is shown in Figure 2.

For an example circular Orbit of 500km COSMOS guarantees for a payload capability of 1055kg. The highest payload mass flown up to now was 1.500kg for the test campaigns of the Buran model (BOR-5), which took place in the years 1984 to 1988 from Kapustin Yar. All inclinations of 48° and 51° will be launched from Kapustin-Yar. The others (66° to SS) have to be launched from Plesetsk.

The above described inclinations are mostly standard, they are used by Russia for their launches and can be used without any new evaluation. All other inclinations have to be negotiated with respect to populated areas in the flight corridor and the related possible drop areas of rocket parts, like fairing halfs and 1st stage.

Trajectory and Drop Area

A typical trajectory of the COSMOS with its major events is depicted in Figure 3.

Typical for the COSMOS and of great advantage for permission of new inclinations is the common drop area for the 1st stage and the fairing halfs.

The major events during ascent are:

- Shut-down and separation of the 1st stage
- Jettision of the front fairing
- 1st shut-down of the 2nd stage and entering in a low thrust phase to reach the final Orbit
- End of low thrust phase, second ignition of the 2nd stage
- Shut down of 2nd stage engines
- Separation of payload is 20sec later
- Activation of a solid booster for 2nd stage rotating. This optional service can be used to move the stage away from the payload and guarantee for TM contact to the ground station.

The launcher provides a continuous TM contact to the ground antenna of the launch site and optional to other dedicated ground station, transmitting first status data of the rocket and later information on the release time and orientation of the second stage.

Injection Accuracy

The Orbit injection accuracy of the COSMOS launcher is depicted in Tab.1. Shown are the worst case deviations and the nominal values for circular low earth Orbits of about 500 to 600km.

Parameter	*Accuracy*	*Remark*
Semi-major axis	better ±40 km for all Orbits	Nominal: ±16 km for Orbits of 500 to 600 km
Inclination	± 3,6 arc minutes	-
Eccentricity	< 0,005	Nominal: < 0,001 for Orbits of 500 to 600km

Table 1: COSMOS Injection Accuracy

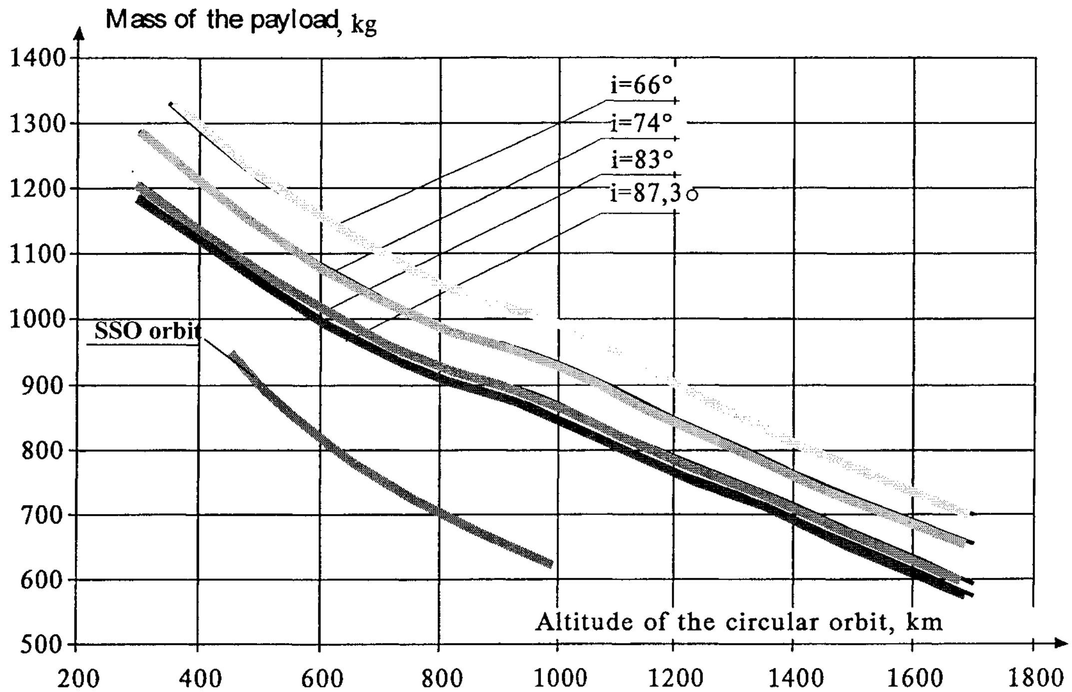

Figure 2: COSMOS Payload Capability

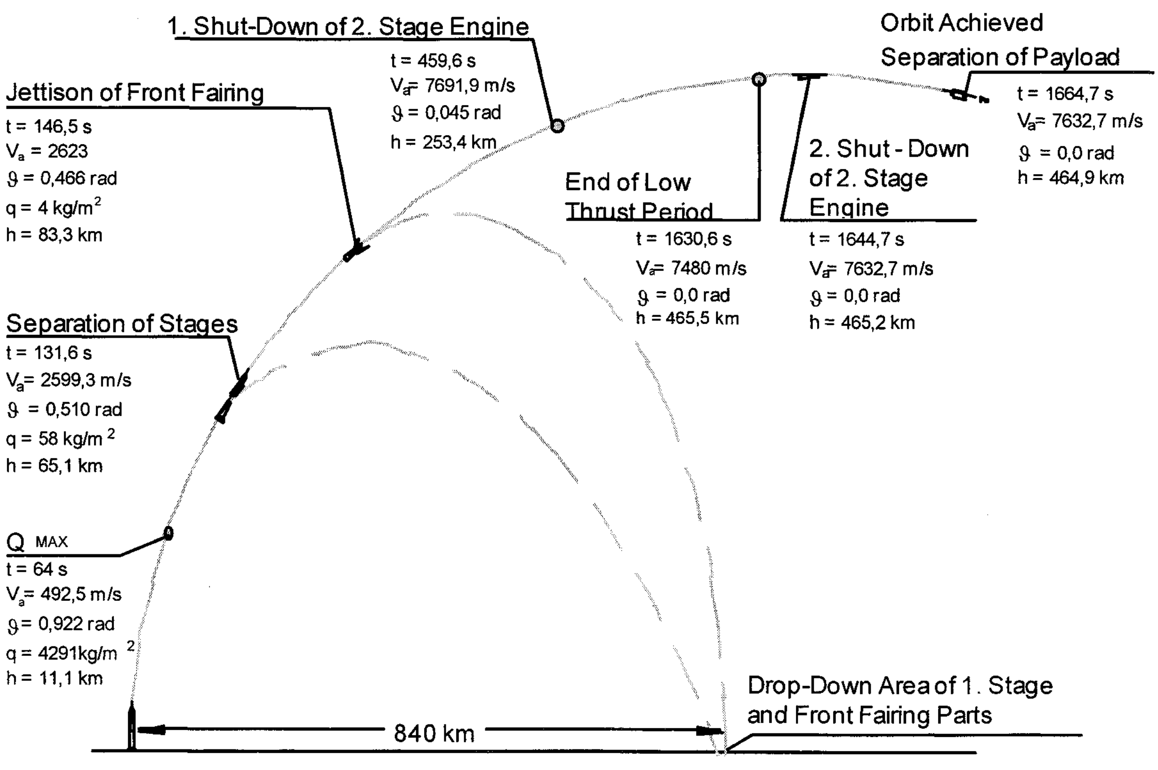

Figure 3: Typical COSMOS Ascent

Flight Environment

The COSMOS rocket can be considered as a very smooth launch vehicle. The vibrations, as well as the acoustic noise levels are very moderate. Tab.2 shows the COSMOS flight environment overview.

Environment	*Load*
Random Acceleration	7,6 grms
Acoustic Vibration	138dB
Max. Steady State Acc. in Thrust Axis	6,8g
Low Frequency Vibration (0,5 to 100Hz, long.)	≤ 0,6g
Shock (1000 to 5000Hz)	1000g

Table 2: COSMOS Flight Environment

Also the thermal conditions during accent are without any specialty. During ground transportation and on the pad a special air condition can be provide and will be used if the environmental conditions are out of the range 10°C to 30°C.

For more information see [1].

Fairing

The front fairing protects the payload against aerodynamic effects during ascent and against environmental conditions during ground operation. The fairing will be jettisoned after leaving the dense Earth atmosphere.

The fairing structure is a riveted aluminum alloy construction with a cylindrical part and conical section, shaped as a truncated cone, including a spherical end closure of compressed material which withstands high temperatures. Main dimensions are:

- Cylindrical part: diameter 2400 mm and height 2673 mm
- Conical section: height 2864 mm, opening angle of 20°, radius of spherical end closure 138 mm

The fairing is built up from two symmetrical halfs which are connected to each other by mechanical lever/roll locks. So called „Patephon"-locks serve as mounting of the fairing to the equipment bay. The typical payload envelope is depicted in Figure 4-a.

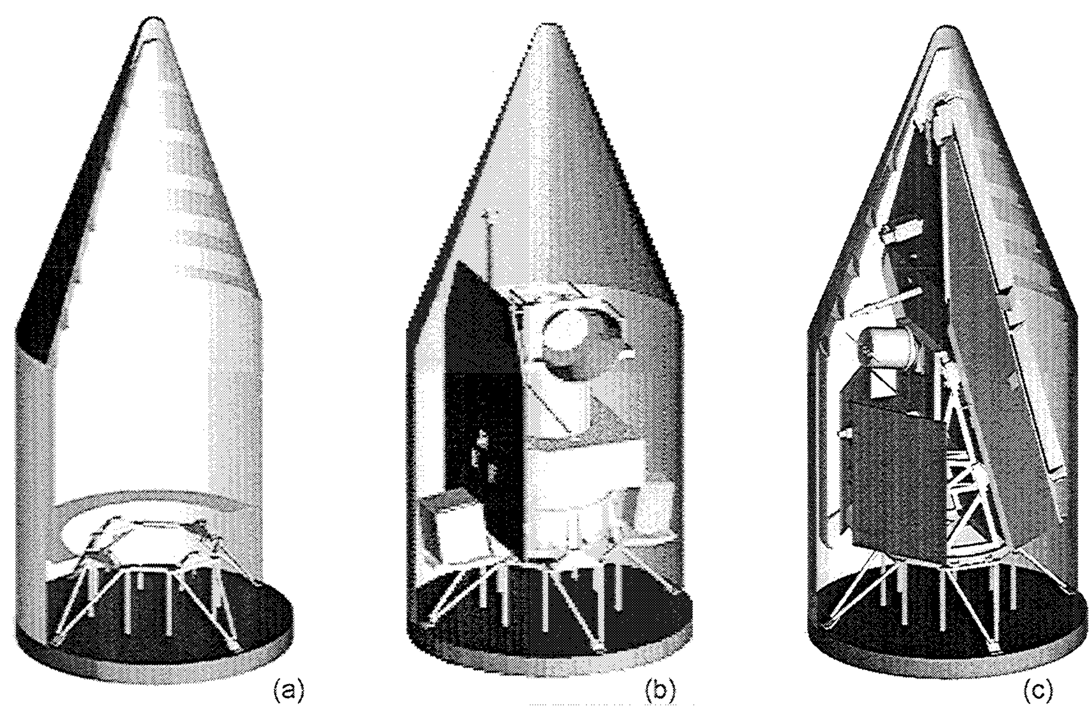

Figure 4: COSMOS Fairing Envelope and satellite accommodation examples: (a) - standard payload adapter and dynamic envelope, (b) -ABRIXAS with secondary payloads on standard adapter, (b) - CHAMP, MITA, BIRD-Rubin on spezial payload adapter.

Payload Accommodation

Figure 4-b and 4-c shows the payload accommodation examples. A very dedicated payload configuration is depicted in Figure 4-c. For the CHAMP / MITA / Rubin launch configuration a special adapter has been designed to adapt the three satellites in a manner that the CHAMP interface- and release requirements could be met. The adapter with its payload has been mounted to the equipment section and replaces there the separation system which was in this case use on the adapter to separate CHAMP. For MITA a dedicated, also at POLYOT available, smaller separation system for satellites up to 200kg was used.

Access to the payload is possible, also after fairing closure:

- in the integration hall and
- after transportation to the pad and lift-up and positioning of the rocket until app. L-5h, the start of the fuelling
- if necessary also in the time after fuelling until L-1h

Several hatches and if necessary special doors with feed-through for power , gases e.g. guarantees for an continuos access to the payload, as well as for a late supply if needed are available.

Interfaces

COSMOS has accommodated a wide variety of spacecraft over the last thirty years. The basic separation system consists of four mounting points - see Figure 6, and provides a low-shock, no-debris, gas-free separation with a variable separation velocity and low residual mass remaining on the satellite.
The interface is sufficiently simple to accommodate also a customer-designed separation interface with no loss of COSMOS reliability.

The four pads are manufactured and arranged such that all of the critical dimensions are centered on a ring with a diameter of 1060 mm. The pads are the load bearing contact points between the spacecraft and the launch vehicle, and contain the pneumatic lock/pushers of the separation system centered between two guide pins on each of these attachment points.

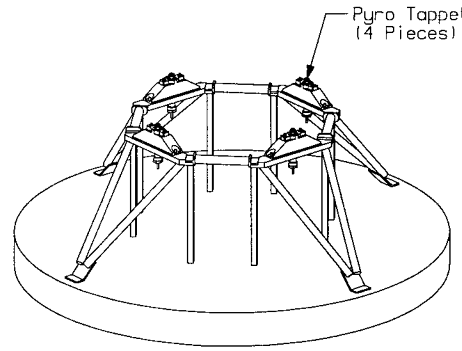

Figure 6: Standard payload adapter with separation system

A full scale replica of the payload interface (drill template), lower part of payload fairing with access doors, and stage 2 equipment bay are available for design studies and fit checks (see Figure 7) at OHB-System in Bremen. The adapter can be delivered to the satellite manufacture for fit check on request.

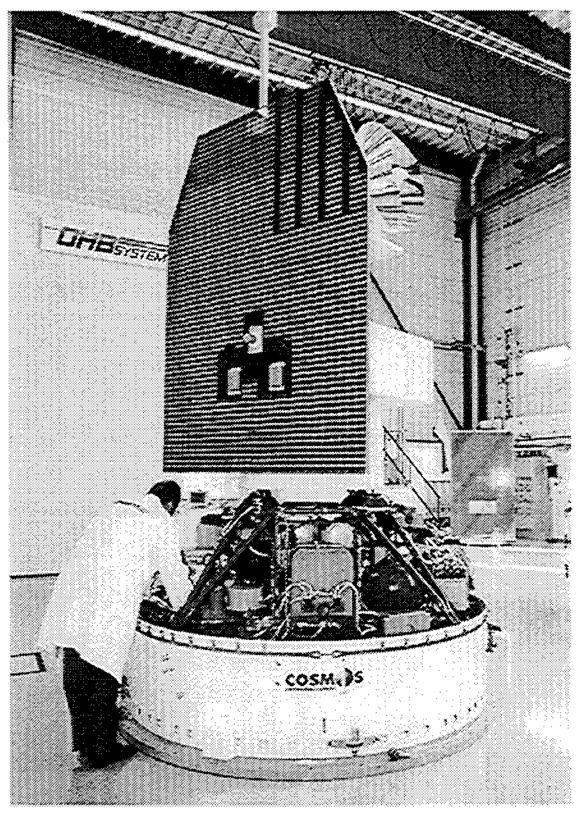

Figure 7: Replica of COSMOS equipment bay with payload adapter and ABRIXAS satellite dummy at OHB-System, Bremen

Electrical Interface

Three standard electrical interfaces between launcher and the spacecraft are available. These interfaces are:

- with the launch vehicle control system
- with the launch vehicle telemetry system
- with the spacecraft ground support equipment

The interfaces consist of five connectors:

1) Onboard Communication Connector

Up to eight messages can be sent to the spacecraft from the launch vehicle indicating launch sequence events have occurred.

2) Telemetry Communication Connector

This connector sends a signal to the launch vehicle telemetry system indicating that the electrical connections between the spacecraft and launch vehicle have been broken (spacecraft separation) for forwarding to telemetry stations.

3) Transit Communication Connector

This connector provides communication between the spacecraft and ground support equipment.

4) and 5) Ground Communication Connectors

These umbilical connectors provide for Satellite/GSE hookup through the umbilical tower, which will be removed 2 minutes prior to launch. The ground connectors are connected to the umbilical tower by means of disposable cables.

The data can be received by the satellite EGSE either directly at the rocket inside the integration hall or in the control shelter near the launch pad.

Launch Sites

Plesetsk is the most frequently used launch site for COSMOS rockets. The COSMOS launch facilities are located within this range, which is located about 800km north-east of Moscow at 62,7° northern latitude and 40,3° eastern longitude.

The infrastructure of the Launch Site of Plesetsk consists two launch pads, integration facilities, the residential district (the town Mirny), the railway station "Plesetsk" and the air port.

Launcher and payload preparation takes place in the integration and test center. This building accommodates all test and technical installations for launcher and payload, as well as the working and social rooms for the integration team.

The integration and test center is equipped with:

- two overhead bridge cranes,
- supply for technical gases,
- electrical power supply,
- air conditioner,
- sanitary facilities,
- communication facilities and
- railway connection.
- The preparation of launcher and payload will be performed at dedicated working places.

The second launch site is part of the launch and test range Kapustin Yar, which is located about 150km south-east of Volgograd. 48,5° northern latitude and 46,3° eastern longitude. The facilities in Kapustin Yar are very similar to those in Plesetsk. Only the integration and test center is separated from the rocket preparation facility. Hotel and guest houses are located in the town of Znamensk.

COSMOS LAUNCH SERVICES

Team Organization

The launch services organization is under the overall responsibility of COSMOS International (Germany) and includes the following partners (see Figure 8):

- POLYOT (Russia)
- ROSOBORONEXPORT (Russia)
- OHB-System (Germany)

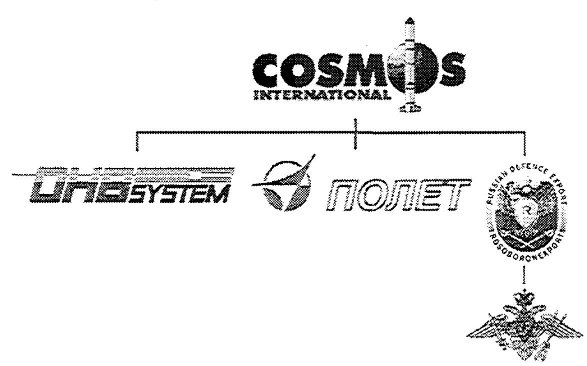

Figure 8: COSMOS Launch Service Team

POLYOT is the manufacturer and provider of the COSMOS-3M launch vehicle, ROSOBORONEXPORT as Russian state company and representative of Russian Space Forces is amongst others responsible for the launch of COSMOS, as well as on all Russian internal affairs. COSMOS International is responsible for contractual matters supported by OHB-System which is responsible for all technical aspects and the interface to the customer.

Services

The launch service provided by COSMOS International contains a comprehensive package which covers on the one hand the spacecraft manufacturer and on the other hand the launcher with all interfaces to Russia. The complete interface will be handled including all support for the satellite with respect to design and verification support. Also the transport of hardware and team, including the team allocation at the launch site will be organized. The share of responsibilities inside the team is as follows: COSMOS International is responsible for:

- Launch contract negotiation and implementation
- Financial management
- Insurance service/provision on request
- Overall co-ordination and interface control
- Schedule
- Co-ordination of required launch services incl. payload processing facilities
- Inputs to launch campaign plan and preparation of plans and procedures to be used at launch site
- Transport of satellites and equipment from customer site to the launch site, storage of equipment and return of equipment back to the customer
- Translation service

OHB-System is responsible for the following activities:

- Launcher/satellite interface engineering (ICD), coupled analysis and separation strategy
- Test-Interface and support between launcher and satellite
- Quality Assurance

PO/KB POLYOT as launch vehicle manufacturer is responsible for:

- Provision of the launch vehicle COSMOS
- Design and manufacturing of satellite specific launch adapter
- Production of a flight identical adapter for fit-check and vibration testing
- Provision of separation bolts, pyros and employment springs
- Mission analysis, payload analytical and physical integration
- Inputs to plans and procedures
- Provision of vehicle licenses
- Launch preparatory operations at Launch Site
- Flight evaluation.

ROSOBORONEXPORT and Russian Space Forces:

- Responsible for all operations at the launch site
- Team accreditation
- Team and hardware transportation in Russia and accommodation close to launch site
- Responsible for the launch
- Provision of dedicated launch license (Governmental Decree of Russian Federation)

Launch Campaign

Transport

The transport of payload, ground support equipment and other load is performed in several stages, i.e. delivery of the payload to the launch site and the transport within the launch site premises. The transport of payload and other equipment to the launch site will be carried out by air plane and / or by railroad in special carriers. Unloading from the air plane and transportation to the integration hall are carried out by launch site personnel and equipment. A launch site truck performs transport of the payload to the propellant loading site.

The transport to the launch sites can be performed either via Moscow or directly by plane to Arkhangelsk for launches in Plesetsk or to Volgograd for launches in Kapustin-Yar. These direct transport via plane saves a lot time (it takes about 24hours) and is much more save with respect to the payload.

The team transport can be performed, from Moscow, via train or plane back and forth to the launch site. The team accommodation will take place in hotels directly inside the launch districts.

Integration

After finalization of the autonomous satellite preparation and check-out in the satellite preparation area the satellite will be transported to the launch vehicle. The mating operations take place in the integration and test center, see Figure 8. Before starting these operations the launcher has completed the entire sequence of electrical tests and has been placed on an integration and test trolley. Mating of the payload assembly with the launcher will be performed in horizontal position with a specific hoisting gear.

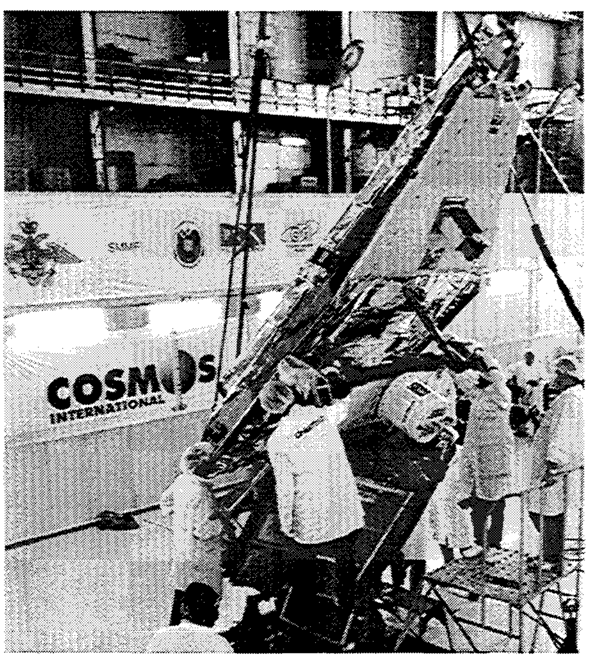

Figure 8: Mating operations in the COSMOS integration and test center (integration of CHAMP satellite on payload adapter)

The work flow for launch preparation of the launcher / payload assembly in the integration hall and the launch itself on the launch pad are carried out according to a technique, which is common to both launch sites. This technique is based on integration of the launcher / payload assembly and its transport to the launch site in the horizontal position and erection of the assembly into the vertical position on the launch pad.

After erection and alignment of the launcher the function of the feed and drain valves are checked. It follows a check-out of the steering and telemetry system. In addition the health status of the payload will be monitored.

After loading the launcher with the two propellant components and pressurized gases the launcher is turned into the launch plane. The thermal conditioning of the payload starts after the launcher has been put in upright position and ends 1,5 hours before launch.

After completion of the launch preparation the countdown starts.

Task	**typical allocated time**
Payload arrival at launch site	L-13d*
Autonomous payload check-out	L-12d to L-3d*
Payload accommodation to rocket	L- 3d*
Fairing closure	L-44h
Launcher transport to the pad	L-30h
Final Launcher Preparation	L-24h to L-6h
Final satellite check	L-22h to L-12h*
Ready for fuelling	L-5h
Fuelling	L-4h to L-2h
Final launch release	L-1h
Payload separation	≈L+0,5h
First measured Orbit data	≈L+2,5h

*depends on the payload needs

Table 3: Time Table at Launch Site

Table 3 depicts the general task flow at launch site. Depending on the payload needs, the campaign takes about two to three week, including transport. The nominal allocated time frame from the beginning of the payload mating to the rocket, up to the launch is three days. The length of the launch campaign is very much driven by the payload.

COSMOS Modernization Program

The COSMOS rocket hat passed several development steps [2] since the first version was launched in the 60´s, so that today a reliable and precise launch system is available. Nevertheless a continuous improvement and modernization of the system is foreseen and partial running – see overview in Figure 9:

- Implementation of secondary telemetry system via satellite networks. A first step has been done during the CHAMP/MITA launch. The communication system RUBIN has been tested.
- Enlarged fairing is available on request. The main characteristics of the enlarged fairing are:
  - increased diameter and height of cylindrical part
  - reduction of weight by composite structure
  - using of proven standard jettisoning mechanisms
- Active adapter will be tested in the frame of new technology development and German-Russian co-operation program (under participating of DLR institute for structural mechanic)
- COSMOS offers hypersonic, sub-orbital and re-entry test opportunities for new re-useable launcher development programs, e.g. in the frame of German national program Astra. The boosters are similar to the used in the Russian Buran/Bor tests and are available on stock.

References

[1] COSMOS International GmbH.: Cosmos Users Manual

[2] COSMOS Flight Record

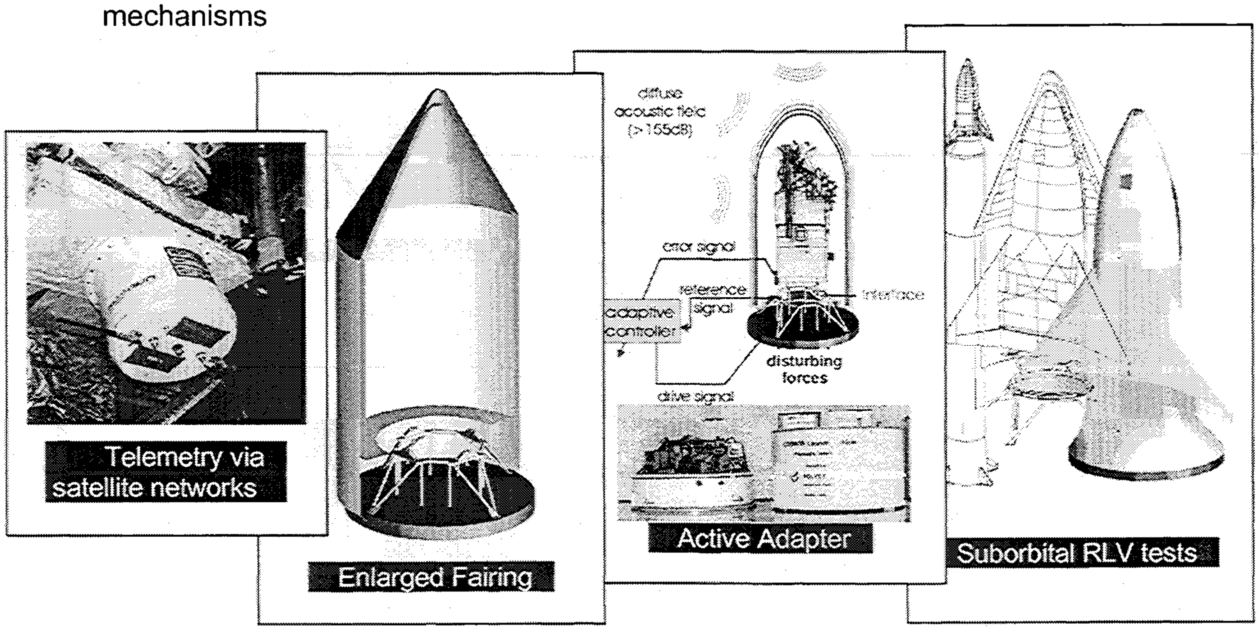

Figure 9: Main Activities in the COSMOS launcher modernization program