Chapter 2 Launch Vehicle Description

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2 Launch Vehicle Description

2.1 General Characteristics and Description

Rockot/Breeze-KM is a fully operational, three stage, liquid propellant Russian launch vehicle being offered commercially by EUROCKOT Launch Services for launches into low earth orbit. EUROCKOT, a German-Russian joint venture company, was formed specifically to offer this vehicle commercially.

The *Rockot* launch vehicle uses the SS-19/RS-18 Stiletto ICBM for its first two stages. The SS-19, which was originally developed as the Russian UR-100N ICBM series, was designed between 1964 and 1975. Over 360 SS-19 ICBMs were manufactured during the 70s and 80s. A photograph of the SS-19 ICBM being transported to EUROCKOT's launch pad at Plesetsk Cosmodrome can be seen in Figure 1-11. The *Breeze-KM* upper stage uses a re-startable storable liquid propellant engine that has been used in many other Soviet space projects.

Figure 1-3 depicts a *Rockot* launch from Plesetsk. From Plesetsk Cosmodrome, *Rockot* is launched above ground from a conventional launch pad. However, it is still launched from the same transport and launch Container (TLC) that is used for the silo launches. This is to retain the commonality and heritage of the previous missile launches.

The *Rockot* vehicle offered by EUROCKOT is a commercialised version of the basic *Rockot* vehicle launched three times from Baikonur. This commercial version, the *Rockot* launch vehicle with the *Breeze-KM* upper stage, is the only version to be offered by EUROCKOT and is fully described in the following sections of this chapter.

Table 2-1 provides an overview of the main characteristics of the launcher.

Characteristic	Value
Lift-off mass	107 tons
Number of stages	3
Fuel	N2O4 / UDMH for all 3 stages
Length	29.15 m
External diameter	2.50 m (Payload fairing 2.5 x 2.62 m)
Maximum payload performance	2140 kg into 200 km circular orbit inclined at 63.2°

Table 2-1 Main characteristics of the *Rockot/ Breeze*-KM launch vehicle.

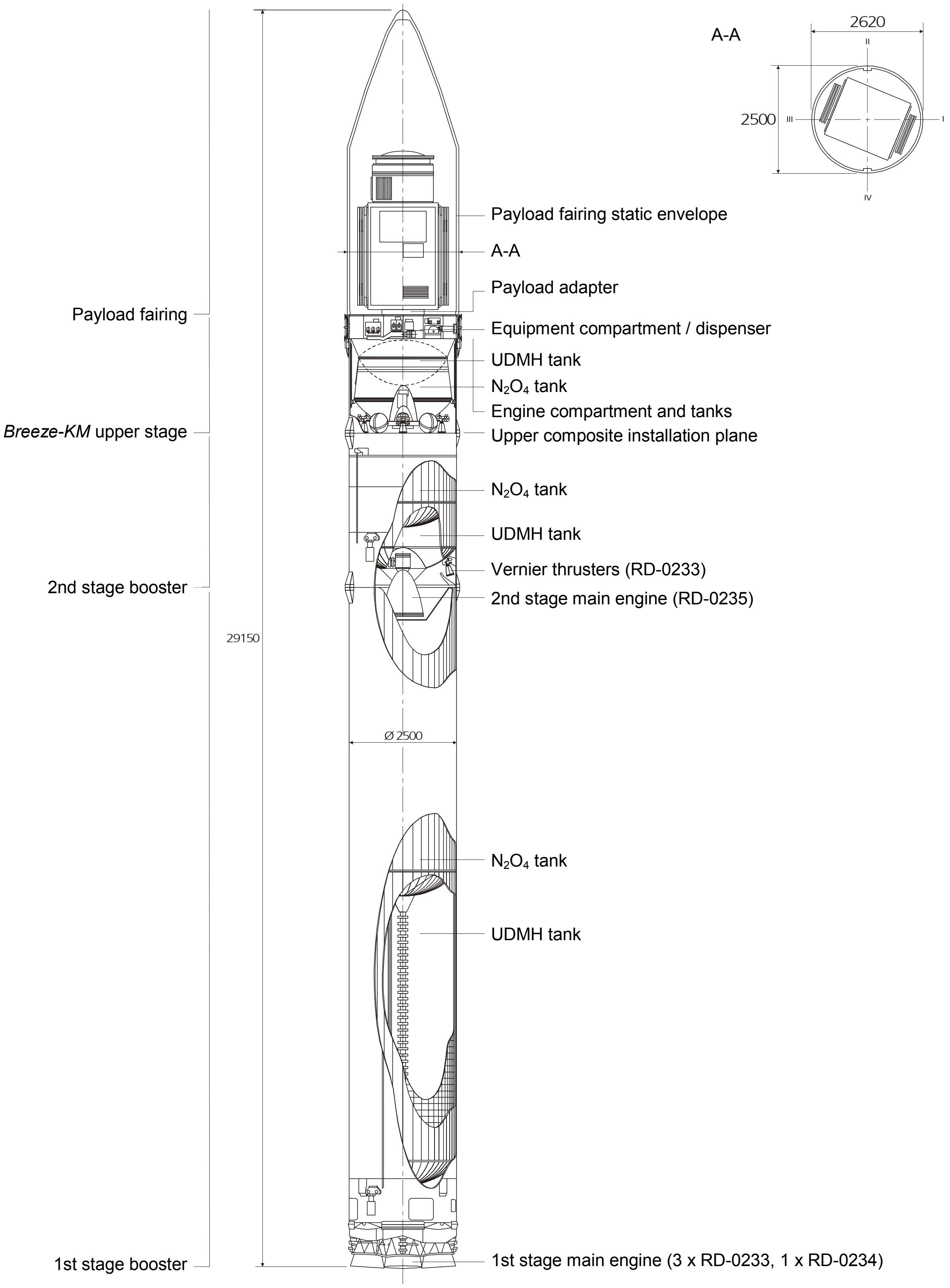

Figure 2-1 *Rockot* launch vehicle configuration.

The booster unit, which provides the first and second stages of *Rockot*, uses existing SS-19 missiles and is accommodated within its existing transport and launch container. The third stage, which provides the orbital capability of the launcher, is newly manufactured. This upper stage contains a modern, autonomous control and guidance system which controls all three stages. The upper stage multiple engine ignition capability allows implementation of various payload injection schemes. Figure 1-10 to Figure 1-30 show the different components of the *Rockot* launch vehicle including the SS-19 booster stage contained within its transportation container, the payload fairing and the *Breeze-KM* upper stage.

Specifically, the *Rockot* launch vehicle comprises:

- An existing SS-19 booster unit providing the 1st and 2nd stages
- An upper composite

The upper composite comprises:

- *Breeze-KM* upper stage
- Payload fairing
- Payload adapter or dispenser
- Spacecraft

The launch takes place from the transport and launch container erected above ground. The launcher rests physically on a ring at the bottom of the launch container. The umbilical between the launcher and the launch container is mechanically separated at lift-off. During lift-off, the launcher is guided by two rails within the launch container. The container protects the launch table environment from the engine plumes and gases, and ensures that the correct temperature and humidity are maintained during storage and operation. The container is only used once.

2.1.1 First Stage

The *Rockot* first stage has an external diameter of 2.5 metres and a length of 17.2 metres. The main body of the stage contains N2O4 and UDMH tanks separated by a common bulkhead. Tank pressurisation is achieved by means of a hot gas system. The engines are cardan-gimballed, closed-cycle, turbopump-fed engines, three being type RD-0233 and one type RD-0234. Figure 1-3 shows a close-up view of the *Rockot* launch vehicle with the four engines ignited during lift-off. The first stage contains four solid fuel retro rockets for the first stage separation.

The main stage characteristics are shown in Table 2-2 below.

Main engines 3 x RD-0233, 1 x RD-0234	
Propellant	N2O4 / UDMH
Sea level thrust	1870 kN (each engine 470 kN)
Vacuum thrust	2070 kN (each engine 520 kN)
Sea level specific impulse	285 s
Vacuum specific impulse	310 s
Burn time	121 s

Table 2-2 First stage main engine characteristics.

2.1.2 Second Stage

The *Rockot* second stage has an external diameter of 2.5 metres and a length of 3.9 metres. It contains a closed-cycle, turbopump-fed, fixed main engine designated RD-0235 and vernier thrusters designated RD-0236 for directional control. The four vernier thrusters have individual combustion chambers which are fed from one turbopump. Each thruster can be gimballed around one axis. The separation of the first and second stages is performed with the vernier engines ignited just before the separation. The exhaust gases are diverted by special hatches within the first stage. After separation, the first stage is decelerated by retro rockets before the second stage main engine is ignited. Like the first stage it contains a common bulkhead and a hot gas pressurisation system.

Main engine RD-0235	
Propellant	N2O4 / UDMH
Vacuum thrust	240 kN
Vacuum specific impulse	320 s
Burn time	183 s

Table 2-3 Second stage main engine characteristics.

Vernier thrusters RD-0236 (One turbopump and four thrusters)	
Fuel	N2O4 / UDMH
Vacuum thrust in total	15.76 kN
Vacuum specific impulse	293 s
Burn time	200 s

Table 2-4 Second stage vernier thrusters characteristics.

2.1.3 *Breeze-KM* Upper Stage

Figure 2-2 shows the *Breeze-KM* upper stage as part of the upper composite. In addition to Breeze-KM, the upper composite consists of the payload fairing, the spacecraft adapter and the spacecraft. The spacecraft adapter is a mission specific item, for details refer to Chapter 4.

The commercial version of *Rockot* uses the *Breeze-KM* as the standard upper stage and is a close derivative of the original *Breeze-K* flown during the first three *Rockot* flights. It comprises three main compartments which include the propulsion compartment, the hermetically sealed equipment compartment and the interstage compartment. To allow larger satellites to be accommodated and to reduce dynamic loads, structural changes to the *Breeze-K* stage were introduced. The structure of the equipment bay of the original *Breeze-K* stage has been widened and flattened by a redistribution of the control equipment.

The equipment compartment can also double as a payload dispenser allowing multiple satellites to be easily accommodated. Additionally, the compartment has been stiffened by the insertion of stiffening walls to give adequate structural rigidity. Furthermore, the *Breeze-KM* upper stage is no longer attached to the launcher at its base but suspended within the extended interstage. The interstage is a load-bearing structure which provides the mechanical interface with the booster unit and accommodates the *Breeze-KM* separation system.

Consequently, the fairing is attached directly to the equipment compartment. A large variety of different payload configurations can be accommodated, ranging from single to multiple satellite launches, positioned either on a single level or on two or more levels using a customised dispenser.

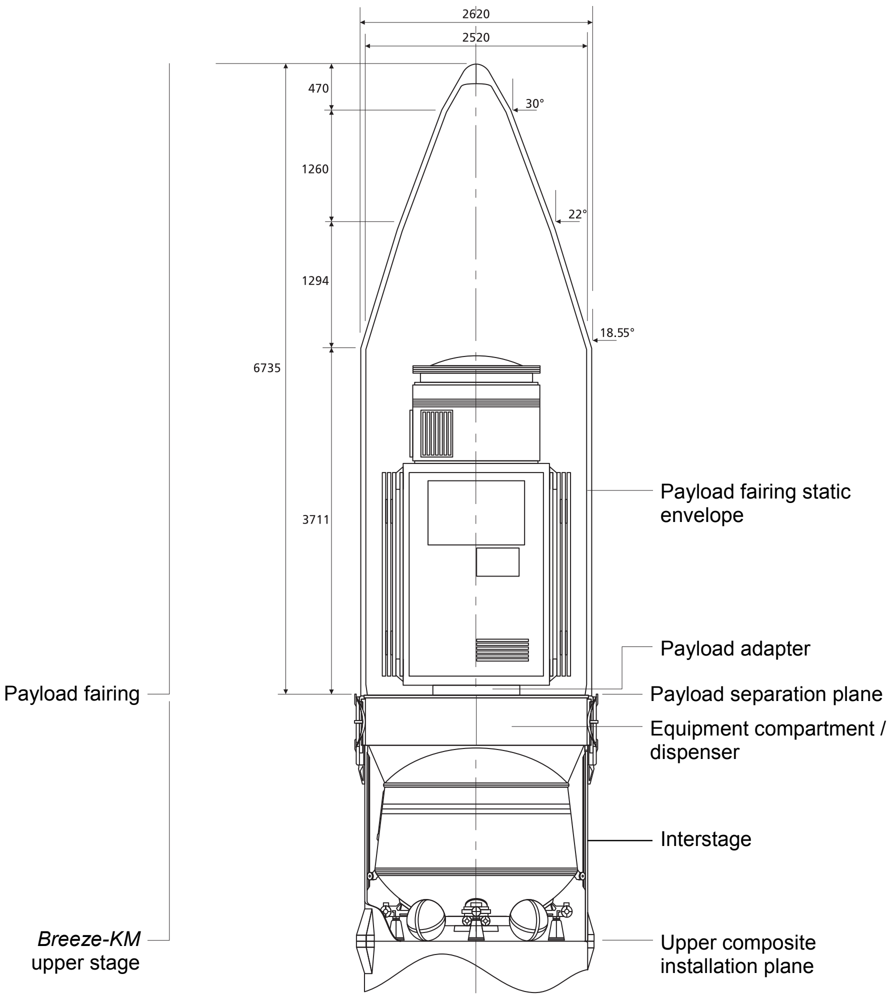

Figure 2-2 Upper composite with payload.

The *Breeze-KM* equipment compartment contains:

- A telemetry system including transmitters and antennas. *Breeze-KM* also contains tape recorders for store-and-forward telemetry capability.
- A guidance, navigation and control system for all flight phases and manoeuvres before and after spacecraft separation. It contains an inertial guidance system based on a 3-axis gyro platform with an on-board computer. The control system has three independent channels with majority voting and is totally autonomous with respect to ground control.
- A tracking system with receiver/ transmitter and antennas

The *Breeze-KM* can be equipped with two or three batteries which can supply both *Breeze-KM* and payload systems, see section 4.3.4.2 for further details. The propulsion compartment consists of fuel compartment and engines including associated equipment.

The *Breeze-KM* propulsion compartment contains propellant tanks and the propulsion systems. The low pressure fuel tank (UDMH) and the oxidiser tank (N2O4) are separated by a common bulkhead. The lower oxidiser tank surrounds the 20 kN main engine. Each tank contains equipment such as baffles, feed pipes and ullage control devices to facilitate main engine restarts in weightlessness.

The *Breeze-KM* propulsion system includes the main engine, the attitude and orbit control system (AOCS) and vernier thrusters together with propellant feed lines and spherical nitrogen gas tanks. The 12 x 13 N attitude control engines control the pitch, roll and yaw degree of freedom of the *Breeze-KM* vehicle. The 4 x 400 N vernier thrusters which are located at the base of the *Breeze-KM* are used for propellant settling and orbital manoeuvres. The 20 kN main engine provides the major impulse required to achieve the final orbit. The characteristics and extensive flight heritage of all these engines are shown in Table 2-5 to Table 2-7. Table 2-8 summarizes the mass breakdown of *Breeze-KM*.

Type	Closed cycle turbo pump fed
Vacuum thrust	20 kN
Vacuum specific impulse	325.5 s
Number of ignitions	up to 8
Total available impulse	2 x 107 Ns
Minimum impulse bit	25000 Ns
Maximum burn time	1000 s
Minimum burn time	1 s
Off time	15 s to 5 hours
Previous flight heritage	Phobos-1, Phobos-2 and Mars 91 space vehicles.

Table 2-5 *Breeze-KM* upper stage main engine characteristics.

Type	Bipropellant pressure fed
Vacuum thrust (each)	400 N
Total available impulse	141120 Ns
Minimum impulse bit	40 Ns
Operation mode	Pulse or steady state
Previous flight heritage	Polyus, Kvant.2, Krystall, Spectr, Priroda, FGB.

Table 2-6 *Breeze-KM* vernier engine characteristics.

Type	Bipropellant pressure fed
Vacuum thrust (each)	13 N
Total available impulse	-
Minimum impulse bit	0.068 Ns
Operation mode	Pulse or steady state
Previous flight heritage	Polyus, Kvant.2, Krystall, Spectr, Priroda, FGB.

Table 2-7 *Breeze-KM* AOCS engine characteristics.

Component	Mass, kg
Dry mass	1320
Oxidiser N2O4	max 3310
Propellant UDMH	max 1665

Table 2-8 Estimated *Breeze-KM* mass breakdown.

2.1.4 Fairing

The payload fairing has been specially designed for the commercial version of *Rockot* and is based on proven technology from other KSRC programmes.

The fairing is mounted on top of the equipment bay of the upper stage. The fairing separation and jettison are performed by releasing mechanical locks holding the two half-shells together along the vertical split line via a pyrodriver located in the nose of the fairing. This pyrodriver has redundant firing circuits. Immediately following the release of the locks, several pyrobolts on the fairing's horizontal split line are fired to allow the half-shells to be driven sideward by spring pushers. The half-shells rotate around hinges located at their base and are subsequently jettisoned.

The design concept is based on the current commercial *Proton* fairing design. The fairing is fabricated from a three layer carbon fibre composite with an aluminium honeycomb core. KSRC has been using these materials for payload fairings since 1985. They are especially suitable for absorbing acoustic noise.

The fairing separation system has an excellent design heritage. Its mechanisms have been extensively ground- tested and successfully used in numerous flights of different KSRC programmes.

The payload fairing dynamic envelope is given in chapter 4.

2.1.5 Transport and Launch Container

A special feature of the Rockot launch vehicle is the use of a transport and launch container (TLC), providing the following functions:

- Storage of booster unit under climatically controlled conditions
- Booster unit transportation
- Launch vehicle erection on pad
- Launch vehicle pre-launch preparation and environmental protection
- Launch vehicle physical guidance during lift-off

It consists of:

- A cylindrical container
- An extension for the upper stage and payload fairing
- Internal guiding rails
- Systems for fuelling, pressurisation thermal control and electrical support

2.2 *Rockot* Qualification and Flight History

The *Rockot* launch system has a long flight heritage with an excellent record. To maintain this impressive track record, which includes an unbroken run of over 80 launches of the *Rockot* booster stage (SS-19) without launch failure since 1983. EUROCKOT has purposely retained as much of this heritage as possible in its commercial version of the vehicle.

Rockot's first three launches took place with the *Rockot/Breeze-K* configuration and were launched with a small fairing from a silo in the Baikonur Cosmodrome. Launches one and two were performed on 20th November 1990 and 20th December 1991, respectively. Geophysical experiments were performed during these flights. During these launches, after first and second stage burn-out, separation of the upper stage *Breeze-KM* from the second stage booster was successfully performed and a sub-orbital controlled and stabilised flight of the upper stage, which carried the scientific equipment, was undertaken to a maximum altitude of 900 km and inclination of 65°.

Multiple restarts of the upper stage main engine were performed during every flight. The first launches permitted testing of the efficiency of all the launch vehicle's equipment and systems, estimation of the upper stage dynamic performance in weightless conditions during the propulsion unit multiple restarts, and acquisition of the data on levels of shock, vibrational and acoustic loads.

The third launch of *Rockot* was successfully performed on 26th December 1994. As a result of this launch, the Radio-ROSTO radio-amateur satellite having a mass of about 100 kg was injected into a circular orbit of 1900 km at an inclination of 65°. Multiple restarts of the upper stage main engine were also performed during this flight.

Since the *Rockot/Breeze-K* configuration launched from Baikonur could not adequately serve the high and polar inclination market identified by EUROCKOT and, furthermore, did not allow large LEO payloads to be accommodated within the existing envelope, EUROCKOT modified the *Rockot/Breeze-K* launch vehicle for commercial operations and opened up a new launch base at Plesetsk Cosmodrome in Northern Russia. To retain the heritage of *Rockot/Breeze-K* and SS-19 missile launches from the silo-based TLC, an identical system of launching from a container is used for *Rockot/Breeze-KM* version launched from above the ground at Plesetsk Cosmodrome. Similarly, no major systems such as the vehicle avionics and control system or propulsion have been modified for the commercial *Rockot/Breeze-KM* launcher, only structural changes to the upper composite have been made (section 2.1.3).

All modifications underwent a thorough ground qualification program prior to the first launches.

All following launches were performed using the commercialised *Rockot*/*Breeze-KM* version. They were prepared and conducted from EUROCKOT's dedicated launch pad and facilities in Plesetsk Cosmodrome. The first launch to be performed under EUROCKOT management was the Commercial Demonstration Flight (CDF) which injected two satellite simulators SIMSAT-1 and SIMSAT-2 extremely accurately into their intended orbit. The CDF launch enabled the following objectives to be demonstrated:

- Readiness of *Rockot* installations in Plesetsk for commercial operations
- Provision of flight verification of the *Rockot*/*Breeze-KM* configuration
- Injection of two satellite simulators SIMSAT-1 and SIMSAT-2 into a 547 km circular orbit at 86.4° inclination
- Testing and verification of technical facilities, the launch pad, fuelling systems, operations, electrical ground support equipment, and data measurement, recording and processing systems
- Measurement and evaluation of the payload environment during flight and confirmation of User's Guide data
- Demonstration of the *Rockot* launch vehicle system's inherent reliability

A full list of the payloads launched by *Rockot/Breeze-KM* is shown in Table 2-9.

No.	Payload	Date	Comments
1	**Commercial Demonstration Flight** [EUROCKOT, Germany]	16.05.00	*Rockot/Breeze-KM* from Plesetsk, operated by EUROCKOT, success
2	**GRACE 1, GRACE 2** [German Aerospace Centre DLR and National Aeronautics & Space Administration, USA]	17.04.02	*Rockot/Breeze-KM*, operated by EUROCKOT, success
3	**Iridium SV97, Iridium SV98** [Iridium Satellite LLC, USA]	20.06.02	*Rockot/Breeze-KM*, operated by EUROCKOT, success
4	**Multiple Orbit Mission (MOST, MIMOSA, 6 Nanosatellites** [Canadian Space Agency, Czech Astronomical Institute and different research institutes and universities, Czech Republic, Canada, Japan, Denmark and USA]	30.06.03	*Rockot/Breeze-KM*, operated by EUROCKOT, success
5	**SERVIS-1** [Institute for Unmanned Space Experiment Free Flyer, Japan]	30.10.03	*Rockot/Breeze-KM*, operated by EUROCKOT, success
6	**CryoSat** [European Space Agency]	08.10.05	*Rockot/Breeze-KM*, operated by EUROCKOT, failure
7	**KOMPSAT-2** [Korean Aerospace Research Institute KARI, South Korea]	28.07.06	*Rockot/Breeze-KM*, operated by EUROCKOT, success
8	**GOCE** [European Space Agency]	17.03.09	*Rockot/Breeze-KM*, operated by EUROCKOT, success
9	**SMOS, PROBA-2** [European Space Agency]	02.11.09	*Rockot/Breeze-KM*, operated by EUROCKOT, success
10	**SERVIS-2** [Institute for Unmanned Space Experiment Free Flyer, Japan]	02.06.10	*Rockot/Breeze-KM*, operated by EUROCKOT, success
Additionally, three successful *Rockot/Breeze-K* launches were performed in the early 1990s. In parallel to EUROCKOT activities starting in 2005 the actual *Rockot/Breeze-KM* version has been used for five Russian federal launches, of which four were successful. For further information on details of these launches and the achieved injection accuracies please contact EUROCKOT directly.			

Table 2-9 EUROCKOT launch record with *Rockot/Breeze-KM*.

2.3 Revalidation of SS-19s used by EUROCKOT

The SS-19 booster units used by EUROCKOT for the *Rockot* launch vehicle are existing ICBM assets which have been assigned to EUROCKOT by the Russian government. SS-19s received by KSRC principally undergo a revalidation programme prior to being used for the *Rockot* launch vehicle. The revalidation procedure is beyond the scope of this User's Guide. However, the procedure includes the following steps:

- After draining of the fuel, the SS-19s are removed from their silos for storage
- The SS-19s are stored under climatically controlled conditions in a defuelled state within their transport containers until the beginning of launch preparations. The atmosphere within the containers is climatically controlled at all times using dry nitrogen gas.
- Constant quality control checks of stored batches of SS-19s via a regular test programme which involves subjecting parts of the batches to flight tests, engine hot firing tests and destructive physical analyses including metallurgical tests as well as functional tests on the stored boosters.