2 Launch Vehicle Description

2.1 General Characteristics and Description

Rockot is a flight-proven, three stage, liquid propellant Russian launch vehicle which is being offered commercially by EUROCKOT Launch Services for launches into low earth orbit. Following its three successful flights in the early 1990s, the German-Russian joint venture company EUROCKOT was formed specifically to offer this vehicle commercially.

The *Rockot* launch vehicle uses for its first two stages the SS-19/(RS-18) Stiletto ICBM. 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. The SS-19, which provides the first two stages of the *Rockot* launcher, has successfully flown 141 out of 144 times. A photograph of the SS-19 ICBM stored in a container in the Khrunichev facilities can be seen in Figure 1-16. The *Breeze*-KM third stage, which is both flight and ground qualified, uses a re-startable storable liquid propellant engine that has been used in many other Soviet space projects. In total, the complete *Rockot* launch vehicle, which includes the SS-19 first and second stages and the *Breeze* third stage, has flown twice suborbitally and twice orbitally launched from a silo on three occasions from the Baykonur Cosmodrome and most recently from the new facilities in Plesetsk in May 2000. Figure 1-3 depicts the *Rockot* CDF launch. The environmental data presented are to a large extent, therefore, based on flight measurements conducted during these three flights as well as the Commercial Demonstration Flight (CDF). Acoustic noise levels for an above-ground launch as opposed to a silo launch have been based on ground hardware tests on the new payload fairing, by analysis and by dedicated acoustic noise measurements obtained during the CDF.

The *Rockot* vehicle offered by EUROCKOT is a commercialised version of the basic *Rockot* vehicle. This commercial version, the *Rockot Breeze*-KM, was demonstrated during the Commercial Demonstration Flight (CDF) and incorporates only structural changes to the basic vehicle so as to retain its impressive flight heritage. These changes include the provision of a larger payload fairing to accommodate spacecraft from commercial Customers; this is based on the Proton vehicle design, which has an extensive flight heritage. In addition, the third stage attachment to the second stage has been modified and the upper equipment compartment which serves as the interface to payloads has been stiffened. This results in a reduction of the maximum quasistatic loads of the vehicle and allows larger payloads to be accommodated than would be permitted with the earlier *Breeze*-K version.

The Commercial Demonstration Flight also allowed EUROCKOT to commission its brand new state-of-the-art launch facilities at the Plesetsk Cosmodrome. These include an extensively refurbished and modified former Cosmos pad from which the *Rockot* vehicle is launched above ground from within its transport and launch container to retain commonality with the previous silo launches. The launch site also includes completed payload processing facilities featuring the most up-to-date equipment and practices which would be expected from a modern launch service provider. This includes large 100,000 class clean rooms containing spacecraft check-out areas, a hazardous processing facility for fuelling spacecraft, and safety systems. EUROCKOT also provides modern offices within these facilities as well as a modern international standard hotel and a remote mission control centre located near the hotel. Also provided is a communications infrastructure which includes high-speed local area networks between facilities and the outside world and hand-held walkie-talkies for direct dialup communication within and outside the Cosmodrome.

Characteristic	Value
Lift-off Mass	107 tons
Number of Stages	3
Fuel	N_2O_4 / UDMH for all 3 stages
Length	29 m
External Diameter	2.5 m (PLF = 2.6 m)
Max Payload Performance	1950 kg into 200 km inclined at 63°

Table 2-1: Main Characteristics of the *Rockot* Launch Vehicle

Table 2-1 provides an overview of the main characteristics of the launcher, and the accompanying Figure 2-1 shows the launch vehicle's principal axes.

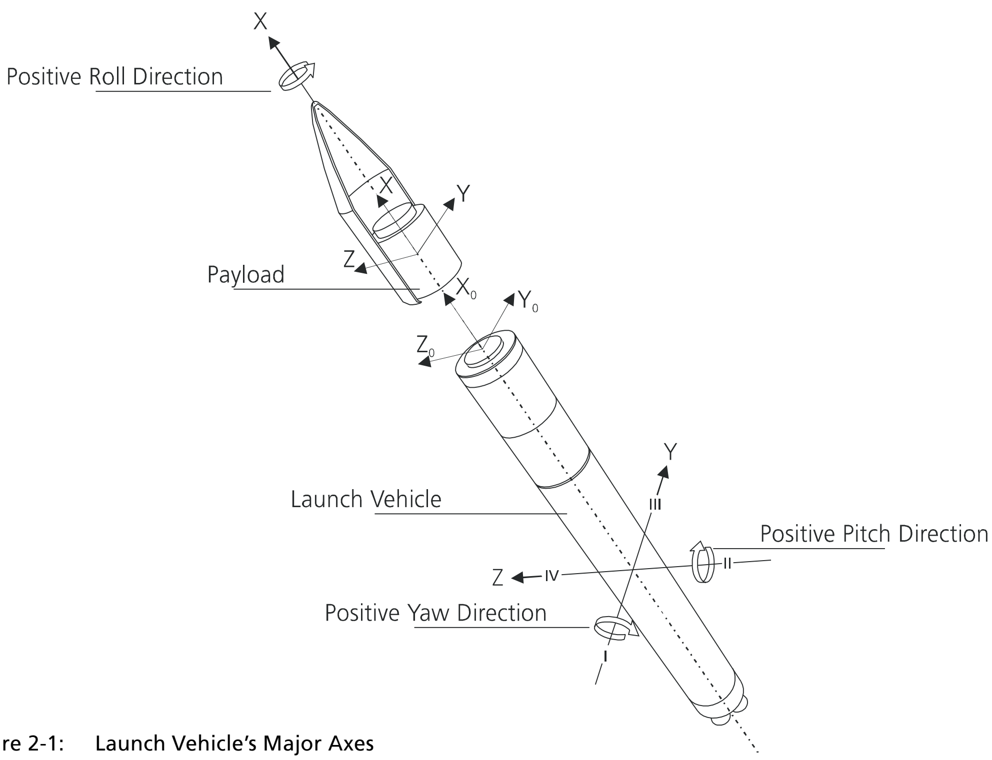
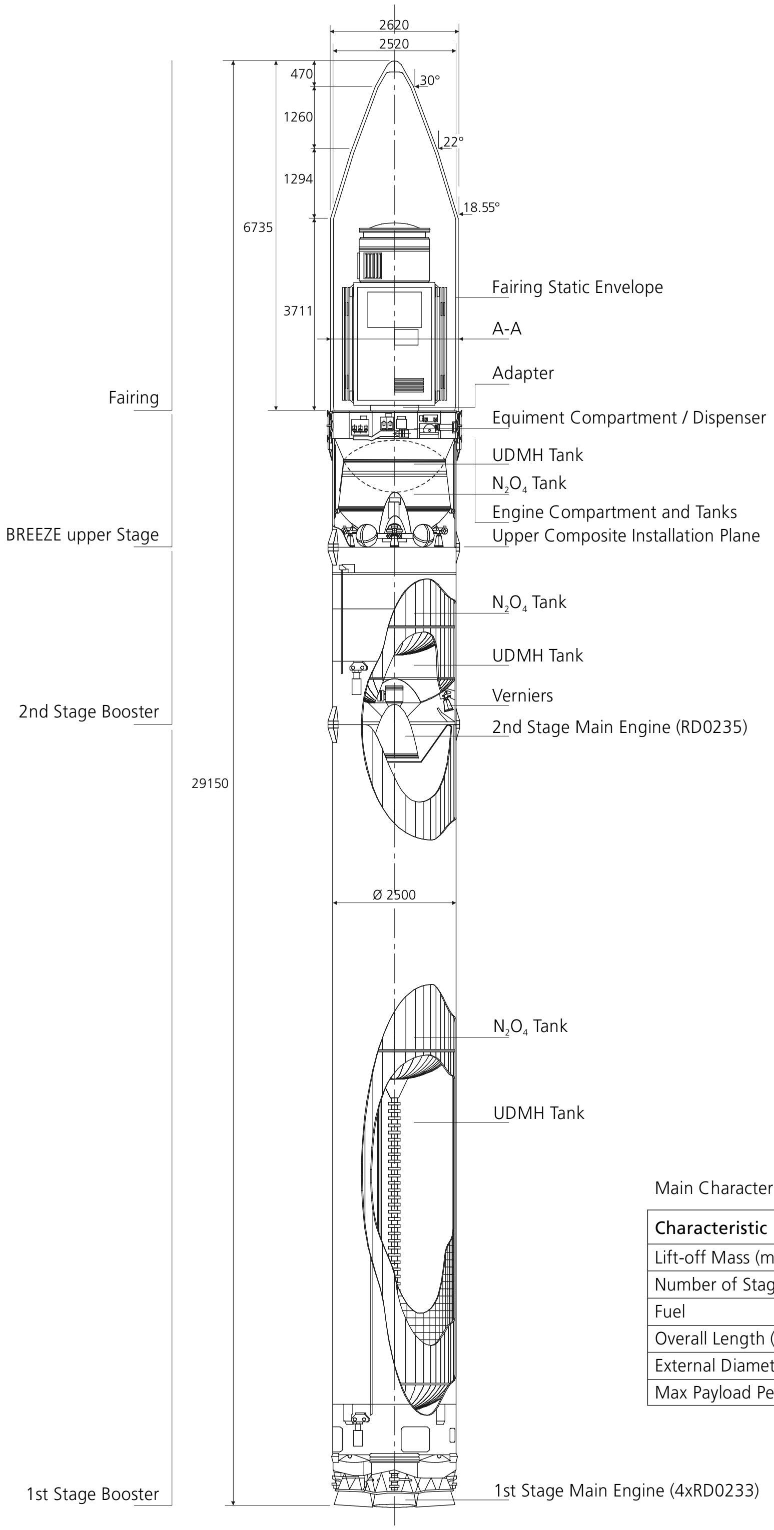
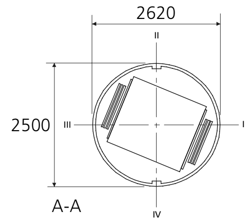


Figure 2-1: Launch Vehicle's Major Axes





Main Characteristics of the Rockot Launch Vehicle

Characteristic	Value
Lift-off Mass (metric tons)	107
Number of Stages	3
Fuel	N2O4 / UDMH for all 3 Stages
Overall Length (m)	29
External Diameter (m)	2.5 (PLF 2.6)
Max Payload Performance	1950 kg into 200 km @ 63°

Figure 2-2: *Rockot* Launch Vehicle Configuration

The booster unit which provides the first and second stages of Rockot is taken from existing SS-19 strategic missiles and is accommodated within an existing transportation/launch container. The third stage which provides the orbital capability of the launcher is newly manufactured. The fully flight and ground qualified third stage named Breeze contains a restartable liquid propellant main engine which has successfully demonstrated its capabilities in space. Furthermore, this upper stage contains a modern, autonomous control/guidance system which controls all three stages. The upper stage multiple engine ignition capability allows implementation of various payload injection schemes. Depicted in Figures 1-3 to 1-8 are the various stages of the Rockot launch vehicle including the SS-19 booster stage (1st and 2nd stages) contained within its transport container, the flight payload fairing and the Breeze-KM restartable 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
- Spacecraft adapter
- Spacecraft

The launch takes place from the transport/launch container erected above ground (silo launches are also performed from the same container). 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 the lift-off, the launcher is guided by two guide rails within the launch container. The container is only used once because of the degradation due to fire exposure. 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.

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 N_2O_4 and UDMH tanks separated by a common bulkhead. Tank pressurisation is achieved by means of a hot gas system. The engines comprise four cardan-gimballed, closed-cycle, turbopump-fed engines with the designation RD-0233 from Design Bureau Khimavtomatiki in Voronezh. Figure 1-3 shows a close-up view of the *Rockot* launch vehicle with four RD-0233 engines ignited during lift-off. The first stage contains four retro rockets for the first/second stage separation.

The main stage characteristics are shown in Table 2.1.1-1 below.

Main Engine	**RD-0233**
Fuel	N_2O_4 / 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 2.1.1-1: 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 verniers designated RD-0236 for directional control. Separation of the first and second stages is a hot separation due to the fact that the vernier engines are ignited just before the separation. The exhaust gases are diverted by special hatches within the first stage. After separation, the first stage is braked by retro rockets, then 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	
Fuel	N_2O_4 / UDMH
Vacuum Thrust	240 kN
Vacuum Specific Impulse	320 s
Burn Time	183 s

Table 2.1.2-1: Second Stage Main Engine Characteristics

Verniers: RD-0236 Contains one turbopump and 4 combustion chambers (each can be gimballed in one direction)	
Fuel	N_2O_4 / UDMH
Vacuum Thrust in total	15.76 kN
Vacuum Specific Impulse	293 s
Burn Time	200 s

Table 2.1.2-2: Second Stage Vernier Engine Characteristics

2.1.3 Upper Composite

Figure 2-3 shows the upper composite consisting of the *Breeze* stage, payload fairing, spacecraft adapter and spacecraft.

2.1.3.1 Breeze Third Stage

The *Breeze*-K stage of *Rockot* has a proven track record due to its flight history, the proven heritage of its of major components and its extensive ground qualification series. The *Breeze*-KM stage which has now been adopted as the standard version of the third stage for the commercial version of *Rockot* is a close derivative of the original *Breeze*-K stage flown during the three previous *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, these structural changes to the *Breeze*-K stage were introduced. The structure of the equipment bay of

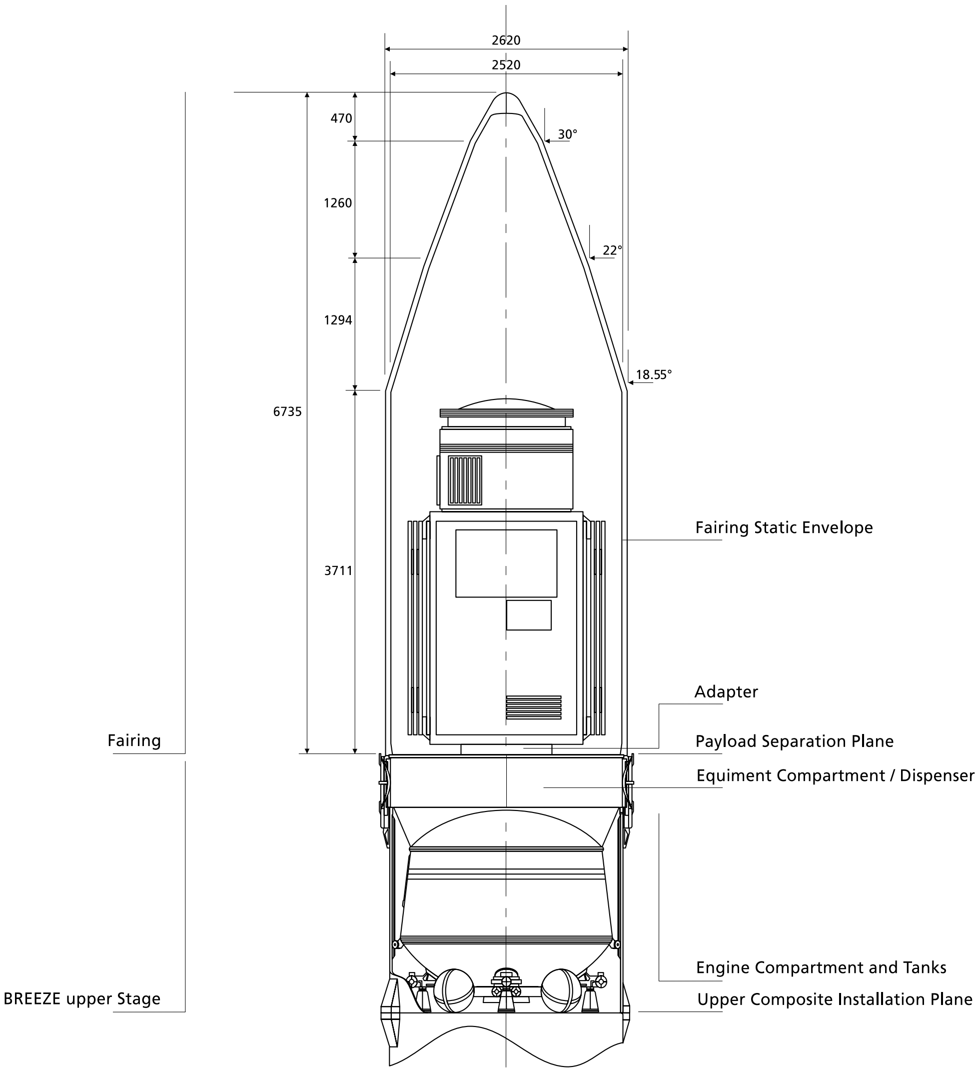


Figure 2-3: Upper Composite with Payload

the original *Breeze*-K stage has been widened and flattened by redistribution of the control equipment. The new equipment bay will 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 is suspended within the extended transition compartment. The transition compartment is a load-bearing structure which provides a mechanical interface with the booster unit and accommodates the *Breeze*-KM separation system.

Consequently, the fairing is now 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.

The *Breeze* equipment bay contains:

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

The *Breeze* can also be equipped with up to three Ag/Zn batteries which can supply both *Breeze* and payload systems, see section 4.3.4.2 for further details. The propulsion compartment consists of fuel compartment and rocket engines including associated equipment.

The *Breeze* fuel compartment consists of a low pressure fuel tank (UDMH) and an oxidiser tank (N_2O_4) separated by a common bulkhead. The lower oxidiser tank is toroidal in shape and surrounds the 20 kN main engine. Each tank contains equipment such as baffles, feed pipes and ullage control devices to facilitate main engine restarts during weightlessness.

The *Breeze* attitude control and vernier engines are located at the base of the propulsion compartment together with propellant feed lines and spherical nitrogen gas tanks. The 12 x 16N attitude control engines control the pitch, roll and yaw of the *Breeze* vehicle. The 4 x 400 N verniers which are located at the base of the *Breeze* are for propellant settling and orbital manoeuvres. The main engine characteristics and their extensive flight heritage are shown in Tables 2.1.3.1-1 and 2.1.3.1-2.

Type	**Closed Cycle Turbo Pump Fed**
Vacuum Thrust	20 kN
Vacuum Specific Impulse	325.5 s
Maximum Number of Ignitions	up to 8
Total Available Impulse	2×10^7 Ns
Minimum Impulse Bit	25000 Ns
Max Burn Time	1000 s
Min Burn TIme	1 s
Off Time	15 s to 5 hours
Previous Flight Heritage	Phobos-1, Phobos-2 and Mars 91 space vehicles.

Table 2.1.3.1-1: Third Stage Main Engine Characteristics

Type	**Bipropellant Pressure Fed**
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, Piroda, FGB.

Table 2.1.3.1-2: Third Stage Vernier Engine Characteristics

Type	Bipropellant Pressure Fed
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, Piroda, FGB.

Table 2.1.3.1-3: *Breeze* AOCS Engine Characteristics

Dry Mass	1600 kg
Max. Oxidiser N_2O_4 Mass	3300 kg
Max. Propellant UDMH Mass	1665 kg

Table 2.1.3.1-4: Approximate *Breeze* Stage Mass Properties

2.1.3.2 *Fairing*

The *Rockot* 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 *Breeze* third stage. The fairing separation and jettison are obtained 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 this event, several pyrobolts on the fairing's horizontal split line are fired and the half-shells are then free to be driven apart 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 (see Figure 1-6).

KSRC has been using carbon fibre composites 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 flown at least 18 times in several programmes.

The payload fairing layout is shown in Figure 2-3 and the dynamic envelope is described in Chapter 4.

2.1.4 *Transport/Launch Container*

The transport/launch container (TLC) provides the following functions:

- Storage of booster unit under climatically controlled conditions
- Booster unit (stages 1 and 2) transportation
- Launch vehicle erection on pad
- Launch vehicle pre-launch preparation and environmental protection
- Launch

It consists of:

- A cylindrical container
- An extension for the third stage/ payload
- Internal guides
- Systems for fuelling, pressurisation thermal control and electrical support
- Hot firing tests (tanks and engines)
- Hydraulic tests (fuel system)
- Tests of antenna/transmitter devices
- Tests of electrical model
- Pathfinder tests (transportation, handling, integration)
- Filling operation training at Cosmodrome

2.2 Rockot Qualification, Flight History and Heritage

2.2.1 Breeze-K Qualification Tests

The following ground qualification tests have been performed successfully on the *Breeze*-K upper stage:

- Static tests (internal pressure, mass-inertial loads etc.)
- Vibration tests including sinusoidal, random and transportation loads
- Component level tests, i.e. engine feed systems, pneumatic-hydraulic systems, spring pushers, pyro-locks etc.
- Thermal tests (engine compartment, equipment compartment, units)

2.2.2 Breeze-KM Qualification Tests

The following ground-based delta qualification tests for the modified *Breeze* stage (to version KM) and for the larger payload fairing were conducted prior to the Commercial Demonstration Flight (CDF).

- Static tests (internal pressure, mass inertial loads etc.)
- Vibration tests including sinusoidal, random and transportation loads
- Pathfinder tests including transportation, handling and integration in Moscow and at Plesetsk
- Fuelling tests at the Cosmodrome
- Payload fairing separation tests
- Payload fairing acoustic tests within an acoustic chamber.

2.2.3 Rockot System Flight Qualification

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 since 1983 without launch failure for the *Rockot* booster stage (SS-19) and the *Rockot* vehicle, EUROCKOT has purposely retained as much of this heritage as possible in its commercial version of the vehicle.

To provide commercial operations of the *Rockot* vehicle for injection into polar and sun-synchronous inclinations, EUROCKOT opened up a new launch base for the *Rockot* at Plesetsk Cosmodrome in Northern Russia. To retain the heritage of over 140 successful flights from the silo-based transport and TLC, an identical system of launching from a container is used for the above-ground launched version from Plesetsk. Similarly, no major systems such as the vehicle avionics/control system or propulsion have been modified for the commercial *Rockot Breeze*-KM system. Only structural changes to the upper composite have been made (these have been described in earlier sections of this chapter).

This section provides a summary of the *Rockot's* impressive track record.

The complete *Rockot* vehicle including the *Breeze* upper stage has been launched a total of four times. In the first three cases the vehicle was launched with a small fairing from a silo at Baykonur Cosmodrome. The first two launches of the *Rockot* launcher were performed from the Baikonur Cosmodrome on 20th November 1990 and 20th December 1991. Geophysical experiments were performed during these flights.

During these launches, after first and second stage burn-out, separation of the upper stage *Breeze* from the second stage booster was successfully performed and a sub-orbital controlled and stabilised flight of the upper stage, which carried scientific equipment, was undertaken (Hmax = 900 km, i = 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 linear, shock, vibrational and acoustic loads.

The third launch of *Rockot* was successfully performed from the Baykonur Cosmodrome 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 orbit (Hcirc = 1900 km, i = 65°). Multiple restarts of the upper stage main engine were also performed during this flight.

The fourth launch of *Rockot*, the so-called "Commercial Demonstration Flight" (CDF), was successfully performed from EUROCKOT's dedicated launch pad and facilities at Plesetsk Cosmodrome in Northern Russia and injected two satellite simulators SIMSAT-1 and SIMSAT-2 extremely accurately into their intended orbit.

This launch enabled the following objectives to be demonstrated:

- Achieving of operational readiness of 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 an 86.4°, 547 km circular orbit
- 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

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 currently undergo a revalidation programme prior to being used for the *Rockot* launch vehicle. The detailed treatment of such a revalidation procedure is currently beyond the scope of this User's Guide; however, the procedure involves of the following:

- 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 by means of 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.