EUROCKOT
Launch Service Provider

Rockot User's Guide

EHB0003, Issue 5, Revision 0
August 2011

EUROCKOT Launch Services GmbH
www.eurockot.com

EUROCKOT
Launch Service Provider

Dear Customer,

It is my pleasure to present to you issue 5 of the EUROCKOT User's Guide in succession to issue 4 which was published in 2004. A notable milestone occurred when our company performed its tenth Customer mission with the successful launch of SERVIS-2 in June 2010. The year 2010 also marked the tenth anniversary of becoming operational, recalling the first flight of the *Rockot* with the *Breeze-KM* upper stage in May 2000.

I am also happy to report that our manifest will see launches continuing for the European Space Agency starting in 2012 with the joint launch of the three SWARM satellites, underpinning our success as a leading provider of launch services in the small launcher market segment. We look forward to serving you, our Customer, with the reliability, flexibility and commercial benefits you have come to know during the course of this decade.

EUROCKOT is the joint venture of Astrium (51%) and Khrunichev State Research and Production Space Center (49%) and performs commercial satellite launches with the Russian *Rockot* launch vehicle from modern and service-oriented spacecraft processing, launch, mission control and Customer facilities at Plesetsk Cosmodrome in Northern Russia. *Rockot* is the only Russian small vehicle that has benefited from any investment of this kind. *Rockot* builds on sufficient numbers of SS-19 stocks which are used as the two booster stages and uses as the third and upper stage the newly Khrunichev-produced *Breeze-KM* upper stage. The heritage of the SS-19 family comprises a total of nearly 160 flights. Next to being used by Eurockot, *Rockot* is also employed as a small launcher for Russian government launches.

EUROCKOT Launch Services pursues a pricing policy of "no additional charges" to make launch cost transparent and better assessable: as a principle, the launch contract price agreed with the Customer will cover all expenses and services in the context of performing a launch. This also comprises duty-free importation of the spacecraft, all transport and logistical services within Russia and all launch licenses.

The new issue of our User's Guide will acquaint you in detail with the capabilities of the *Rockot/Breeze-KM* launch system, with the management responsibilities EUROCKOT holds vis-à-vis the Customer and with the ground facilities and services we have at our disposal. The User's Guide was designed to serve you as an initial reference and I invite you to address me or my colleagues to verify your findings and with any enquiry you may have - you will be served with a quick response. With hindsight, I suggest that it is always better to contact us to draw on the knowledge and experience of my staff whose specific role it is to advise you.

Sincerely,

Dr. Matthias Oehm
CEO
EUROCKOT Launch Services GmbH

EUROCKOT
Launch Service Provider

Preface to
***Rockot* User's Guide, EHB0003, Issue 5, Revision 0**

This new issue of the *Rockot* User's Guide is intended to completely replace the previous version of the *Rockot* User's Guide Issue 4, Revision 0. EUROCKOT has now conducted 10 commercial launches and successfully injected 20 spacecraft into orbit. The *Rockot* Launch System described herein is therefore fully operational and integrated in the market of small launchers. All the aspects of the launch service from mission management and analyses, importation of spacecraft, launch campaign through to lift-off and spacecraft separation using a variety of flight proven adapter and separation systems have been demonstrated successfully.

Furthermore, Eurockot could increase the *Rockot* mass performance incrementally during the last years, mainly by mass improvements of the upper stage. In parallel the portfolio of flight qualified mechanical interfaces to the spacecraft, namely adapters and separation systems were increased during the last missions for a wide variety of Customers including both commercial and institutional and for scientific and commercial satellites since the last issue of the User's Guide.

The User's Guide has been updated to reflect all the technical and service improvements that have been obtained through our previous and existing Customers.

York Viertel
Technical Director
EUROCKOT Launch Services GmbH

Bremen, August 2011.

Document Change Record

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Initial release	30.11.1994	-	Muss
Issue 1	20.01.1995	-	Muss
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Issue Number	Date	Revisions	Approved
Issue 3/ Rev 0	31.1.01	Completely revised issue taking into account results of CDF and completion of payload processing facilities. In addition, performance figures for Baikonur are included now.	Dr. M. Kinnersley Dr. T. Miski
Issue 3/Rev 1	30.04.01	Editorial changes	Dr. M. Kinnersley Dr. T. Miski
Issue 4/ Rev 0	1.11.04	Completely updated issue taking into account the commercial launches of EUROCKOT.	Dr. M. Kinnersley
Issue 5/ Rev 0	31.7.11	Completely updated issue, in particular sections 1, 3 and 4 to reflect upgrades in mass performance, mechanical interfaces and services during the last commercial launches	Y. Viertel

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Acronyms and Abbreviations

AC	Alternating Current
AOCS	Attitude and Orbit Control System
CCTV	Closed-circuit Television
CDF	Commercial Demonstration Flight
CDR	Critical Design Review
CEO	Chief Executive Officer
CIS	Commonwealth of Independent States
CLA	Coupled Loads Analysis
CoG	Centre of Gravity
COP	Combined Operations Plan
DC	Direct Current
DPA	Destructive Physical Analysis
DT	Direct Transmission Mode (Telemetry)
DTSA	Defense Technology Security Administration
DQR	Design Qualification Review
EGSE	Electrical Ground Support Equipment
EOGS	End of Gyro Setting (= Mission Zero Time)
EMC	Electromagnetic Compatibility
FMAD	Final Mission Analysis Documentation
FMAR	Final Mission Analysis Review
FS	Factor of Safety
GMF	Ground Measurement Facility
GMI	Ground Measurement Infrastructure
GN2	Gaseous Nitrogen
GPS	Global Positioning System (US),
GLONASS	Global Navigation Space System (CIS)
GSE	Ground Support Equipment
ICBM	Intercontinental Ballistic Missile
ICD	Interface Control Document
ILV	Integrated Launch Vehicle
IRD	Interface Requirements Document
JOP	Joint Operations Plan
KSRC	Khrunichev State Research and Production Space Center
LCR	Launch Control Room
LER	Launch Evaluation Report
LOS	Launch Operation Schedule
LRD	Launch Requirements Document
LRR	Launch Readiness Review

LSM	Launch Service Manager
LV	Launch Vehicle
LVM	Launch Vehicle Manager
MA	Mission Assurance
MAR	Mission Analysis Review
MCC	Mission Control Centre
MGSE	Mechanical Ground Support Equipment
MIK	Spacecraft Integration Facility for ROCKOT in Plesetsk
MLS	Mechanical Lock System
MM	Mission Manager
MoI	Moment of Inertia
N2O4	Nitrogen Tetroxide (Oxidizer)
O(A)SPL	Overall Sound Pressure Level
PDR	Preliminary Design Review
PLF	Payload Fairing
PMAD	Preliminary Mission Analysis Documentation
PMAR	Preliminary Mission Analysis Review
PoE	Port of Entry
PSD	Power Spectral Density
QA	Quality Assurance
RAAN	Right Ascension of Ascending Node
REC	Data Record Mode (Telemetry)
REP	Data Replay Mode (Telemetry)
RF	Radio Frequency
RMS	Root Mean Square
RPM	Revolutions per Minute
SC	Spacecraft
SDR	Systems Design Review
SMD	Spacecraft Mission Director
SOP	Spacecraft Operations Plan
SOTP	Spacecraft Operations Test Procedure
SPPA	Single Pyro Released Point Attachment System
SSO	Solar Synchronous Orbit
TA1	*Rockot* Low Rate Telemetry Device
TA2	*Rockot* High Rate Telemetry Device
TAA	Technical Assistance Agreement
TIM	Technical Interchange Meeting
TLC	Transport and Launch Container
UDMH	Unsymmetrical Dimethyl Hydrazine (Fuel)

Chapter 1 Introduction

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1 Introduction

This User's Guide is provided by EUROCKOT Launch Services to familiarise potential customers with commercial launch services using the operational Russian *Rockot* launch vehicle. The guide provides background information on the *Rockot* launch vehicle as well as information on the whole range of launch service activities. This includes the heritage and previous flight history of *Rockot*, a technical overview of the complete launcher, payload performance, payload accommodation and interfaces, launch environment, payload dimensioning and verification requirements, safety, mission management, mission analysis, the launch site and operations.

This current issue of the User's Guide has been extensively updated to take into account the experience gained since the last edition. Following EUROCKOT's successful maiden launch in 2000 with the Commercial Demonstration Flight many commercial payloads and missions have been successfully launched by EUROCKOT. EUROCKOT's customers include many of the world's major space agencies and satellite manufacturers.

The *Rockot* family in all its variants has now completed over 160 launches. The commercial version of the *Rockot* launch vehicle is equipped with the *Breeze-KM* upper stage (*Rockot/Breeze-KM*) and is operated by EUROCKOT. Up to now EUROCKOT has orbited a total of more than 30 spacecraft including two GRACE spacecraft from a joint DLR/NASA project, two Iridium spacecraft and Japan's SERVIS-1 from the institute of Unmanned Space Experiment Free Flyer (USEF).

Today, the *Rockot/Breeze-KM* launch vehicle through its successful commercial launches, is now a firmly established and operational system offering a complete all inclusive transportation service to low earth orbit and beyond.

EUROCKOT's previous missions and launch campaigns have now fully demonstrated the major capabilities of the *Rockot* system and associated launch services. This includes all the aspects of the incoming transportation logistics for spacecraft importation, launch campaigns with sophisticated spacecraft, different types of trajectories such as polar and sun-synchronous orbits, multiple re-start capability of the upper stage for plane changes and orbit raising, injection of spacecraft into different orbits in one mission and more.

With launches being offered from Europe's closest orbital launch site together with competitive terms and conditions, EUROCKOT is well placed to serve the world's small satellite community in the years to come. As well as LEO launches for scientific, earth observation and commercial telephony/ messaging payloads and constellations, innovative solutions are offered for customers requiring launches to higher orbits and interplanetary missions, enabling such missions to be accomplished reliably and at an affordable price. Furthermore through incremental product improvements which preserve the historical reliability of the launcher, EUROCKOT aims to stay as the leader in this market segment.

Thanks to the use of existing SS-19 assets as the basis for the launch vehicle, EUROCKOT is able to offer the *Rockot* launch system under highly competitive terms and conditions. In addition, EUROCKOT offers a 24-month cycle between contract signature and launch as a baseline. Finally, the use of the modern re-ignitable *Breeze-KM* upper stage allows high injection accuracy and complex manoeuvres to be achieved.

The *Rockot* launch vehicle is marketed and operated under the aegis of the German-Russian joint venture company “EUROCKOT Launch Services” which was founded in March 1995 to exclusively market and perform launch services with this vehicle.

Astrium GmbH of Germany holds 51% of the capital, with Khrunichev State Research and Production Space Center (KSRC) of the Russian Federation holding the remaining 49% as shown in Figure 1-1.

EUROCKOT is the interface to the customer. It is responsible for all commercial activities, launch contract conclusion and launch implementation as the single prime contractor for the customer and as the sole industrial partner for all legal aspects. EUROCKOT is a company established under German law and offers all legal safeguards provided by a western company.

As a partner and constituent company of EUROCKOT, Khrunichev Space Center (KSRC) of Russia provides the launch vehicle and the launch services under subcontract to EUROCKOT (see Figure 1-2).

The *Rockot* programme is guaranteed by a Russian Government decree which authorises the EUROCKOT joint venture to use these missiles and the dedicated launch pad and integration facilities in Plesetsk. *Rockot* uses existing SS-19 ICBM assets retired under the Strategic Arms Reduction Treaty for its first and second stages. A third stage, *Breeze-KM*, is added to achieve orbital injection.

A sufficient number of SS-19 booster units for EUROCKOT use is at the disposal of KSRC. If the need arises many more than 100 SS-19s are available at Russian Defence Organisations for potential EUROCKOT purposes.

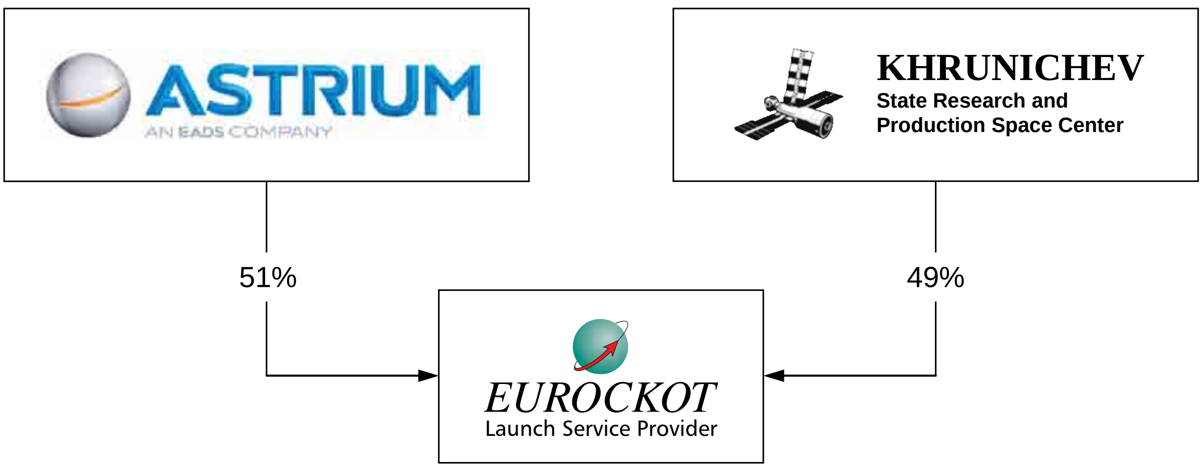

Figure 1-1 Shareholders in the EUROCKOT joint venture

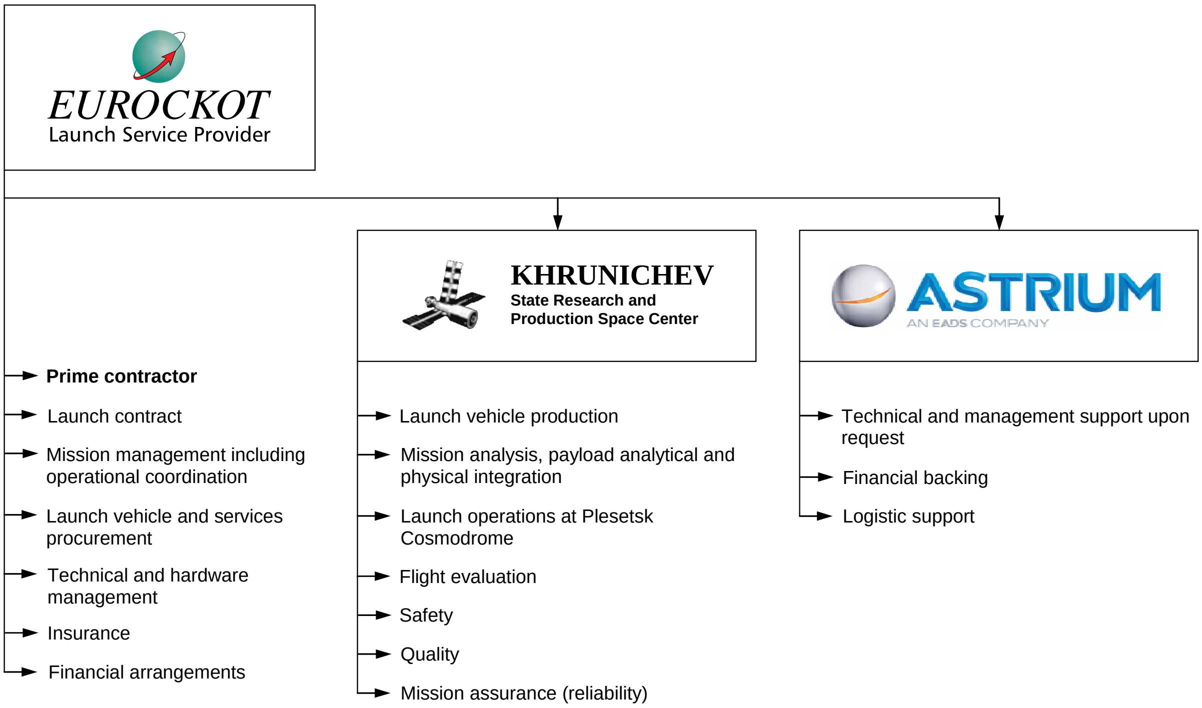

Figure 1-2 EUROCKOT roles and responsibilities.

1.1 Reasons for Selecting EUROCKOT

EUROCKOT offers the following unique benefits and discriminators as a launch service provider:

- A highly reliable, operational launch system available today.
- A complete and proven launch services package with highly competitive terms and prices.
- A customer-oriented, comprehensive range of services, including logistics for the spacecraft and associated equipment.
- Experienced EUROCKOT and subcontractor teams assuring a high quality service.
- High accuracy of spacecraft injection and re-ignition capability with the modern *Breeze-KM* upper stage for flexibility in mission design.
- Strong, well-established parent companies, namely Astrium GmbH and KSRC
- Rapid launch rates and launch campaigns
- State-of-the-art dedicated launch operations facilities including pad and integration facilities in Plesetsk
- The *Rockot* launcher is part of the Russian long-term space programme backed by guarantees from the Russian and German Governments

1.2 EUROCKOT Photograph Gallery

Photographs of the *Rockot* launch vehicle system including the launch vehicle, facilities and factory are shown on the following pages (Figure 1-3 to Figure 1-41).

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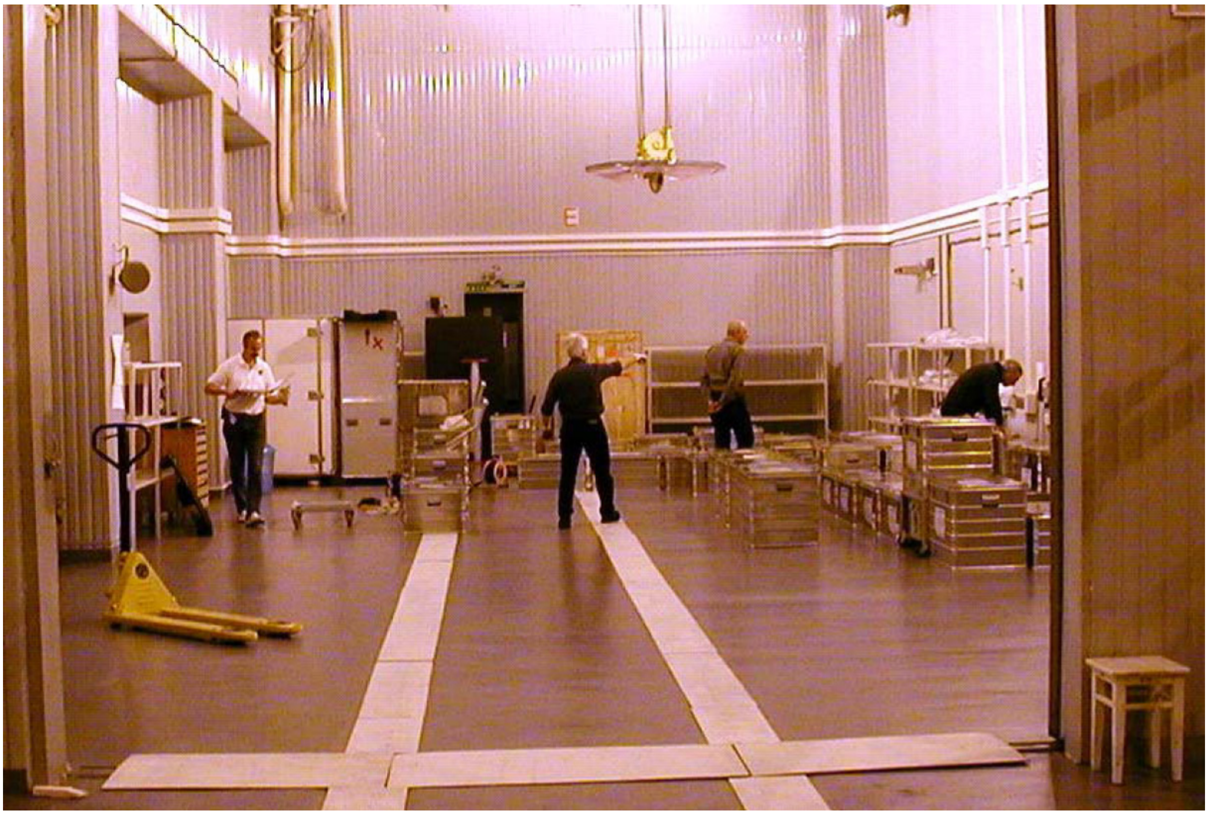

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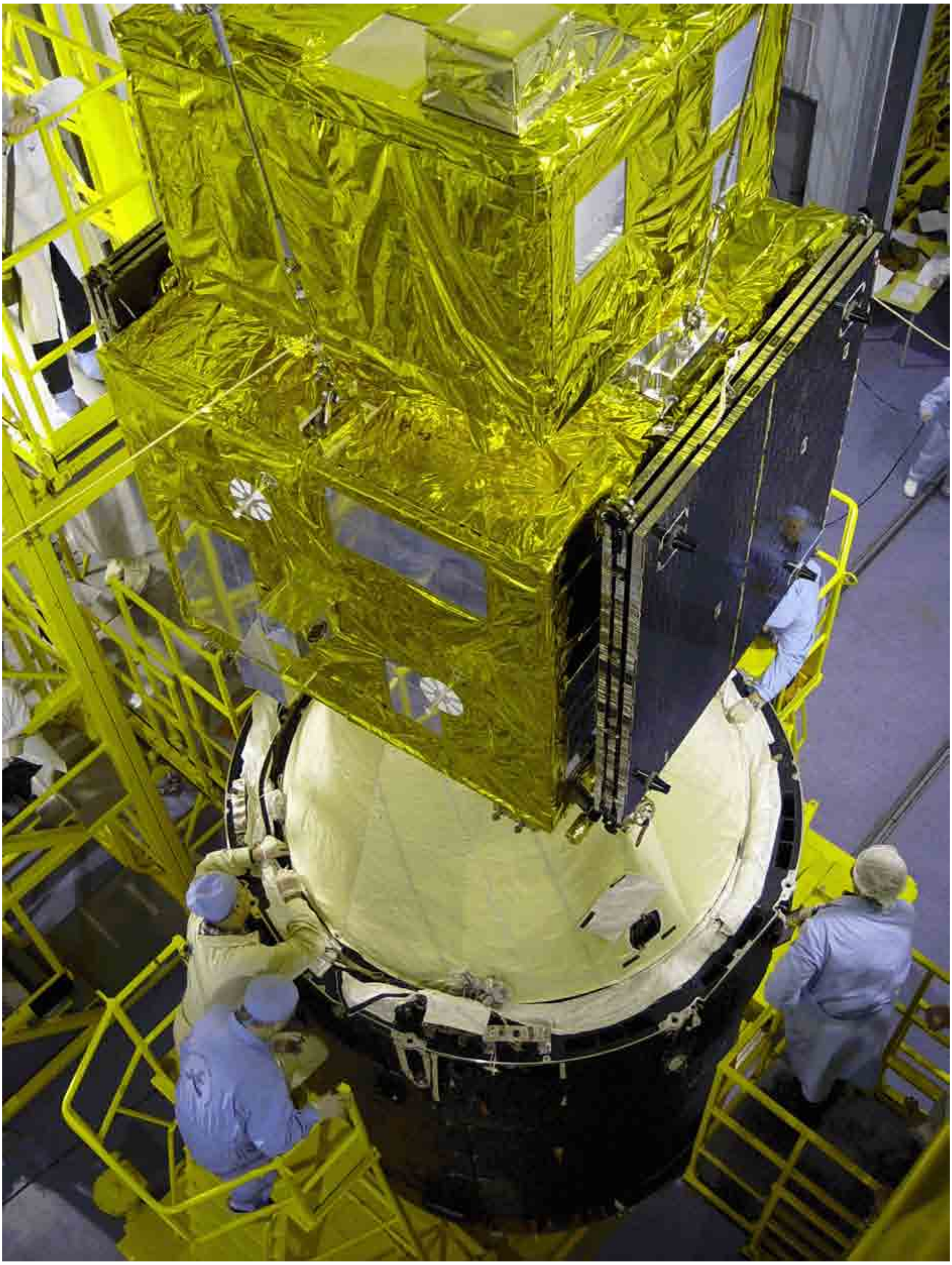

Figure 1-21 **Mating with the *Breeze-KM* upper stage (SERVIS-1, 2003).**

Figure 1-22 Mating of GOCE spacecraft (2009).

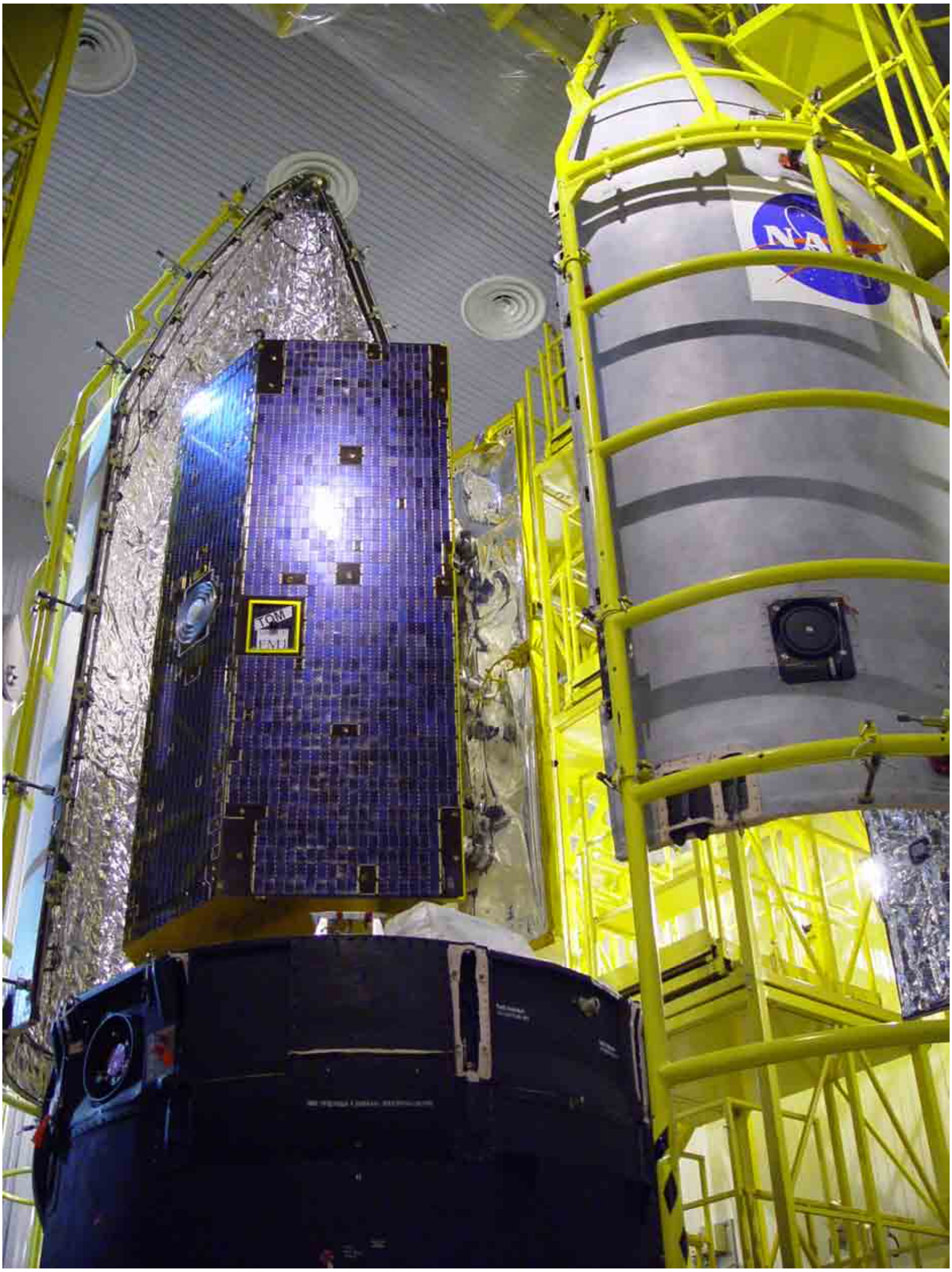

Figure 1-23 Final encapsulation operations (GRACE, 2002).

Figure 1-24 Final encapsulation operations (SERVIS-1, 2003).

Figure 1-25 Completion of payload encapsulation (GRACE, 2002).

Figure 1-26 ***Rockot* upper composite with thermal conditioning unit rail car protected by thermal cover for transfer to the launch pad.**

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Figure 1-28 Hoisting of upper composite at the *Rockot* service tower.

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Figure 1-30 ***Rockot* ready for launch with the mobile service tower retracted.**

Figure 1-31 ***Rockot*** **launch (Iridium, 2002).**

Figure 1-32 **EUROCKOT remote Mission Control Centre (MCC).**

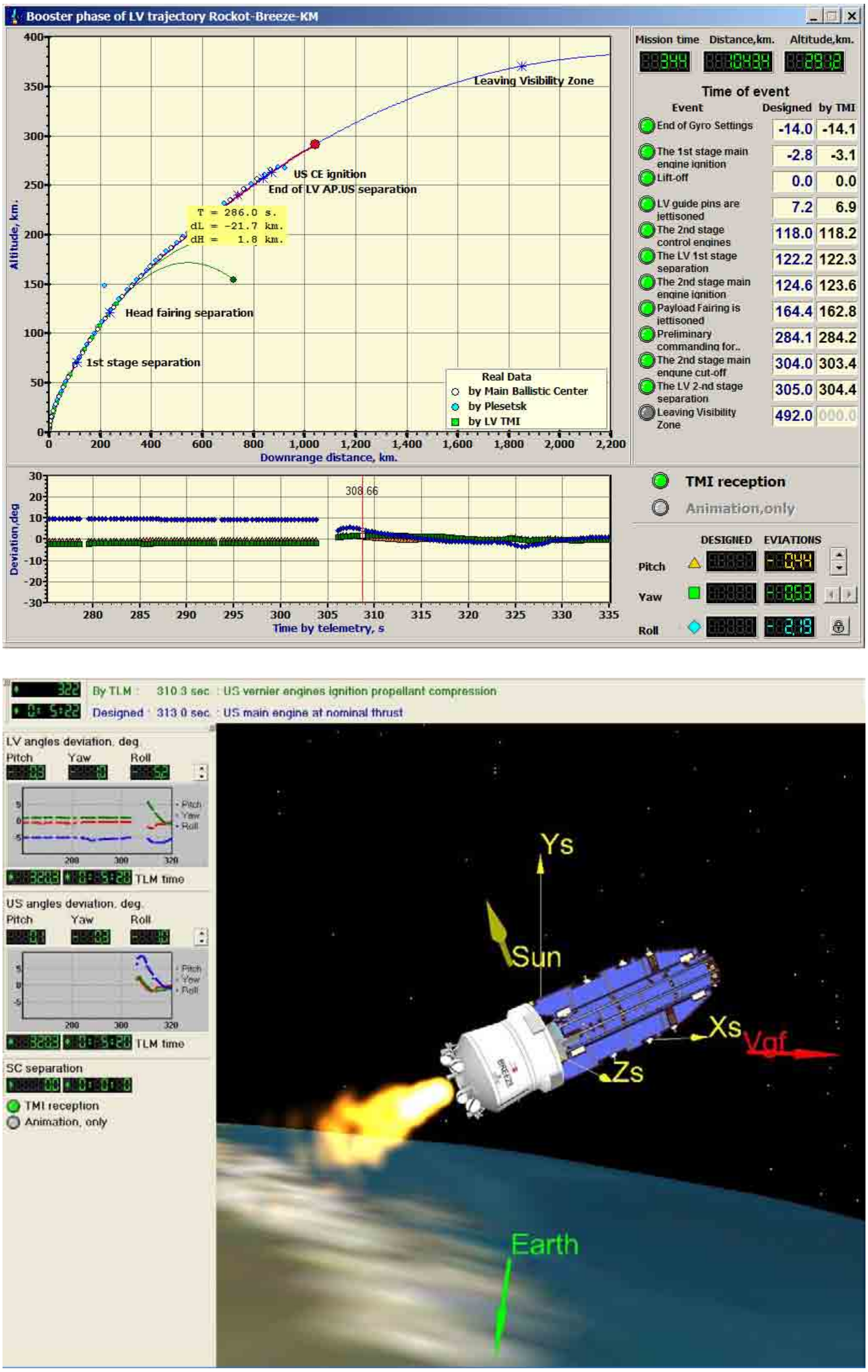
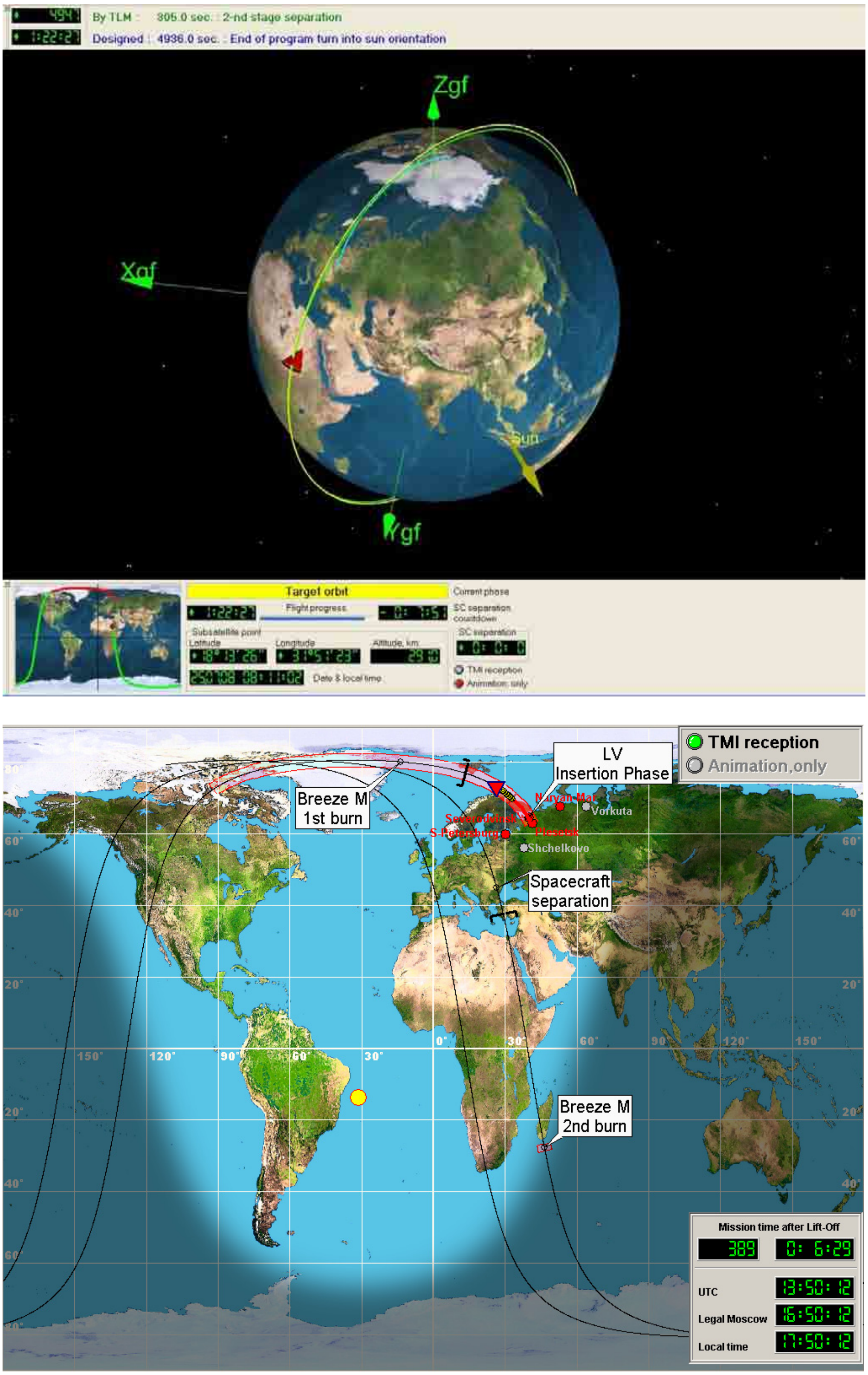


Figure 1-33 Display of live telemetry in the MCC.



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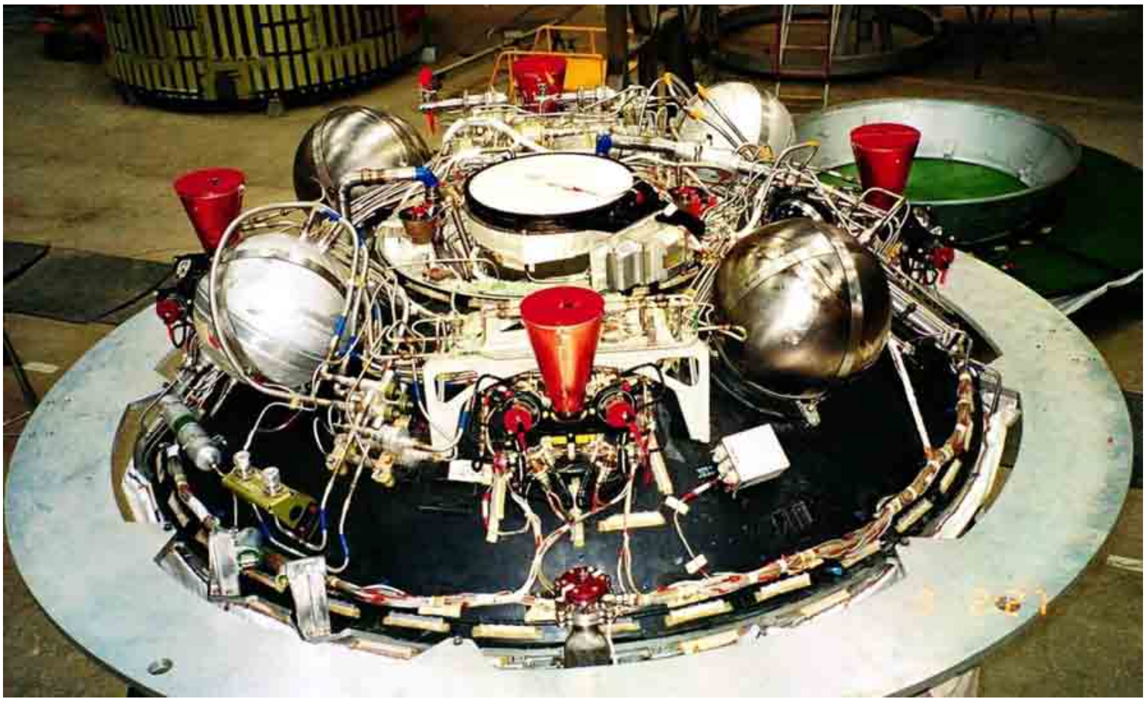

Figure 1-39 Aft view of the *Breeze-KM* propulsion compartment.

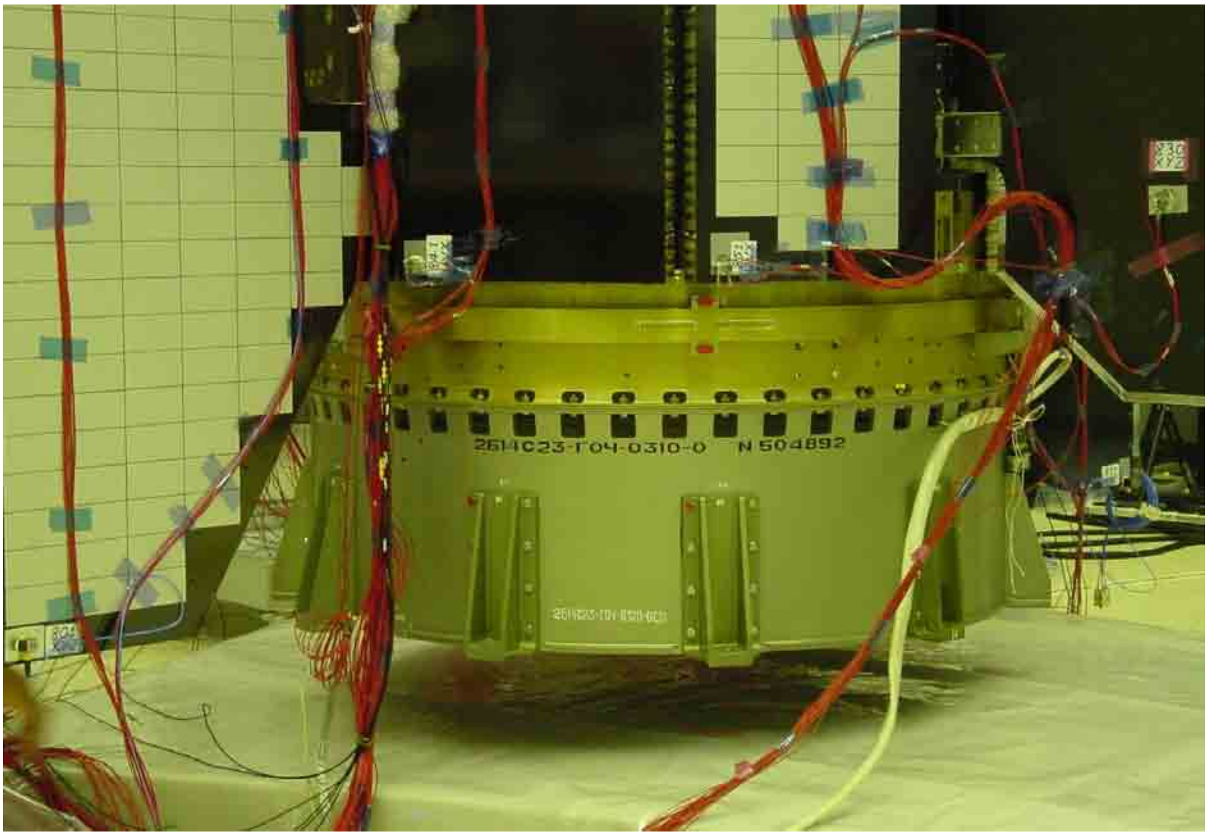

Figure 1-40 Spacecraft separation shock test at the Customer's facilities (GOCE, 2008).

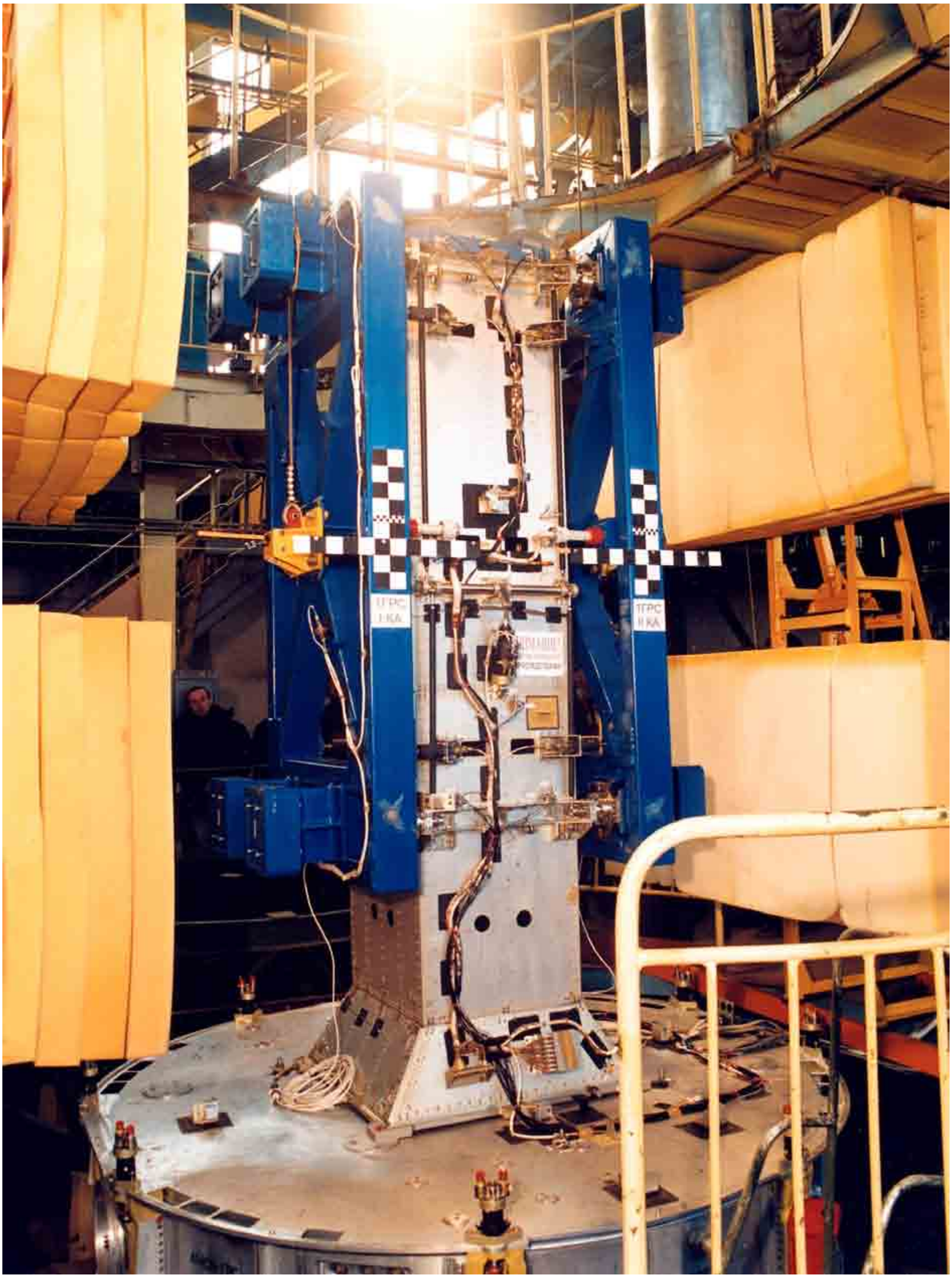

Figure 1-41 Typical spacecraft separation test using simulators at KSRC facilities, Moscow.

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.

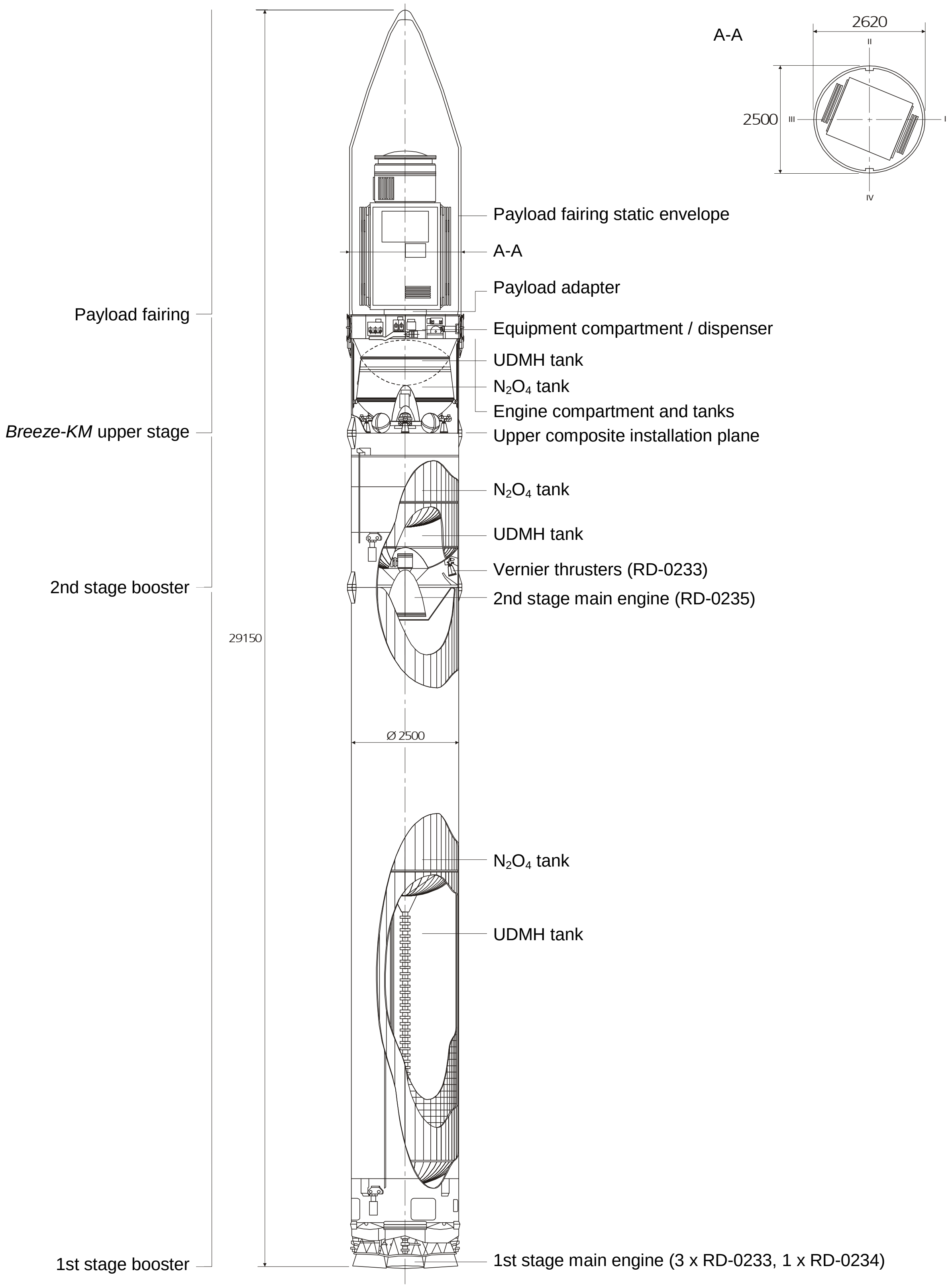

Figure 2-1 *Rockot* launch vehicle configuration.

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.

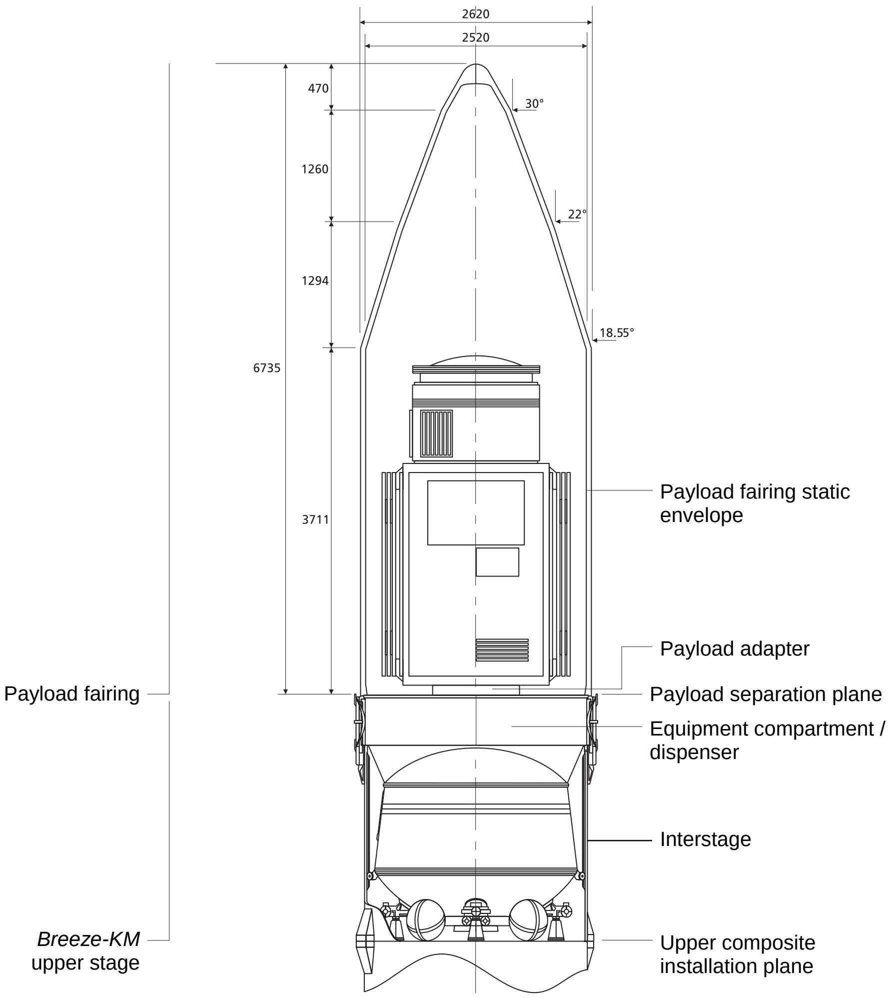

Figure 2-2 Upper composite with payload.

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.

Chapter 3 General Performance Capabilities

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3 General Performance Capabilities

This chapter describes the performance of the *Rockot/Breeze-KM* launch vehicle into circular and elliptical low earth orbits from its launch site in the Plesetsk Cosmodrome, Northern Russia, as well as its potential launch base in Baikonur. Background information and the assumptions made for the performance curves are presented.

3.1 Introduction

The launch vehicle payload performance is driven by many variables and includes amongst others the specific launch vehicle characteristics, launch pad location, allowable launch azimuths, drop zones, and the availability of ground measuring stations for telemetry information reception. The *Rockot* launch site in the Cosmodrome Plesetsk, historically the most active launch site in the world with over 1700 launches, is well situated for polar and high inclination launches due to its northerly latitude. *Rockot/Breeze-KM* launched from Plesetsk Cosmodrome and equipped with its modern restartable upper stage *Breeze-KM* can serve a wide range of both circular and elliptical orbits in the range from 200 km up to over 2000 km and a range of inclinations from 50° to SSO by direct injection or via orbital plane change.

3.2 Launch Azimuths and Orbit Inclinations from Plesetsk

The Plesetsk Cosmodrome is located about 200 km south of the port city of Archangel in Northern Russia at geographical coordinates 62.8°N and 40.3°E. The location of populated areas drives the allowable launch azimuths and drop zones available from this launch site. Launch azimuths and resulting orbital inclinations achievable from Plesetsk are listed in Table 3-1.

Launch Azimuth	Corresponding Orbital Inclination
76.2°	63.2°
41.6°	72.0°
13.7°	82.5°
15.2° to 4.8°	82.0° to 86.4°
4.8°	86.4°
341.5°	SSO and other retrograde orbits

Table 3-1 Allowable launch azimuths that can be served from Plesetsk.

Rockot/Breeze-KM, equipped with its modern inertial based control system is able to perform dog-leg manoeuvres during the second stage operation so that inclinations beyond these allowable launch azimuths can be reached. The dog-leg manoeuvres may result in a decrease of payload mass.

In coordination with the Customer and their demands the *Breeze-KM* upper stage enables high flexibility in the selection of the ascent profile provided by its attitude- and orbit correction system, precise guidance, navigation and control electronics including a three-axis gyro system and long life batteries. This enables a Customer adapted ascent profile and payload deployment scheme under consideration of radiovisibility by Russian ground tracking stations, earth shadow phases, separation time and other constraints.

To achieve inclinations other than those indicated in Table 3-1, *Breeze-KM* also provides the possibility to change inclination up to ±17° by a main engine ignition in the vicinity of the equatorial node of the transfer orbit. In such cases the possible decrease of the payload mass has to be determined for each specific mission profile. The minimum possible orbital inclination for the launches from Plesetsk cosmodrome without dog-leg manoeuvres and/or main engine ignition in the vicinity of the nodes is 62.8°.

The propellant consumed by *Breeze-KM* during possible payload collision and contamination avoidance manoeuvres is minor and will not affect the payload performance. On the other hand, fuel consumption for possible *Breeze-KM* deorbitation must be subtracted from the performance capacity.

3.3 Low Earth Orbits

The payload performance of the *Rockot/Breeze-KM* vehicle has been calculated for both circular and elliptical orbits from the Plesetsk launch site. To attain the maximum payload capacity for a dedicated mission, two injection schemes are generally used:

- The target orbit is achieved via a single burn of the *Breeze-KM* upper stage main engine.
- The *Breeze-KM* upper stage with a payload is injected into an elliptic parking orbit with the first burn of the main engine and one or several adjustment burns to form the target orbit.

Note: If the required altitude of the orbit does not exceed 400 km, both injection schemes can be used, and if the orbit altitude is higher than 400 km, the second injection scheme is generally used.

All payload performances are calculated for the standard *Rockot/Breeze-KM* configuration including the payload fairing as described in chapter 2. The requisite payload adapter fitting/ dispenser masses plus the separation system must be subtracted from these figures.

Usually, the payload fairing is not jettisoned until the free molecular heat-flow has dropped below 1135 W/m^2.

The performance values are confirmed by the data of former *Rockot/Breeze-KM* commercial launches as well as the over 150 SS-19 missile flights.

It should be noted that the performances given in this user guide are generally based on conservative assumptions. Furthermore, due to mass saving measures such as incremental improvements to the upper stage, an increase in payload performance can be expected. In specific cases, where such additional performance is necessary, the Customer is invited to contact EUROCKOT directly for a dedicated mission analysis.

3.3.1 Payload Performance for Circular Orbits

Figure 3-1 illustrates the performance capabilities associated with the corresponding circular orbits that can be served from the launch site in Plesetsk using the allowable launch azimuths indicated in section 3.2. It should be noted that direct injection into inclinations that lie between $i = 82.0°$ and 86.4° are possible but subject to a dedicated internal Russian approval process for the overflight permission. Inclinations not shown in the performance graphs can also be served by *Rockot/Breeze-KM*, but only via a dog-leg manoeuvre during the 2nd stage burn or a plane change manoeuvre performed by the upper stage. In these cases, performances should be calculated on a case by case basis by EUROCKOT, a linear interpolation between the curves is not possible. Some loss of performance can be expected due to the necessity to perform dog-leg or plane change manoeuvres.

3.3.2 Performance for Elliptical Orbits

The *Rockot/Breeze-KM* performance capabilities for elliptical orbits with inclinations of 63.2°, 72.0° and 82.5° are presented in Figure 3-2 to Figure 3-4. Any argument of perigee can be achieved according to the Customer's requirements.

3.3.3 Sun-Synchronous Orbits

Sun-synchronous orbits (SSO) can be served from the Plesetsk launch site via use of the 341.5° launch azimuth corridor. Different ascent trajectory options are available depending on the requirements of the dedicated mission.

The launch vehicle is initially launched with an azimuth of 341.5° from Plesetsk. Yaw manoeuvres during the second stage burn allow the second stage drop zone to be precisely positioned outside of any foreign country's territorial waters.

The upper composite comprised of *Breeze-KM* and the payload is injected into a 96.7° or 99.5° inclined parking orbit. Finally, the target orbit inclination is reached via a plane change manoeuvre carried out by a *Breeze-KM* main engine ignition near the equator crossing.

The payload performance for SSO is depicted in Figure 3-1. It corresponds to the payload capacity into the required orbit with the SSO typical combination of target altitude and inclination.

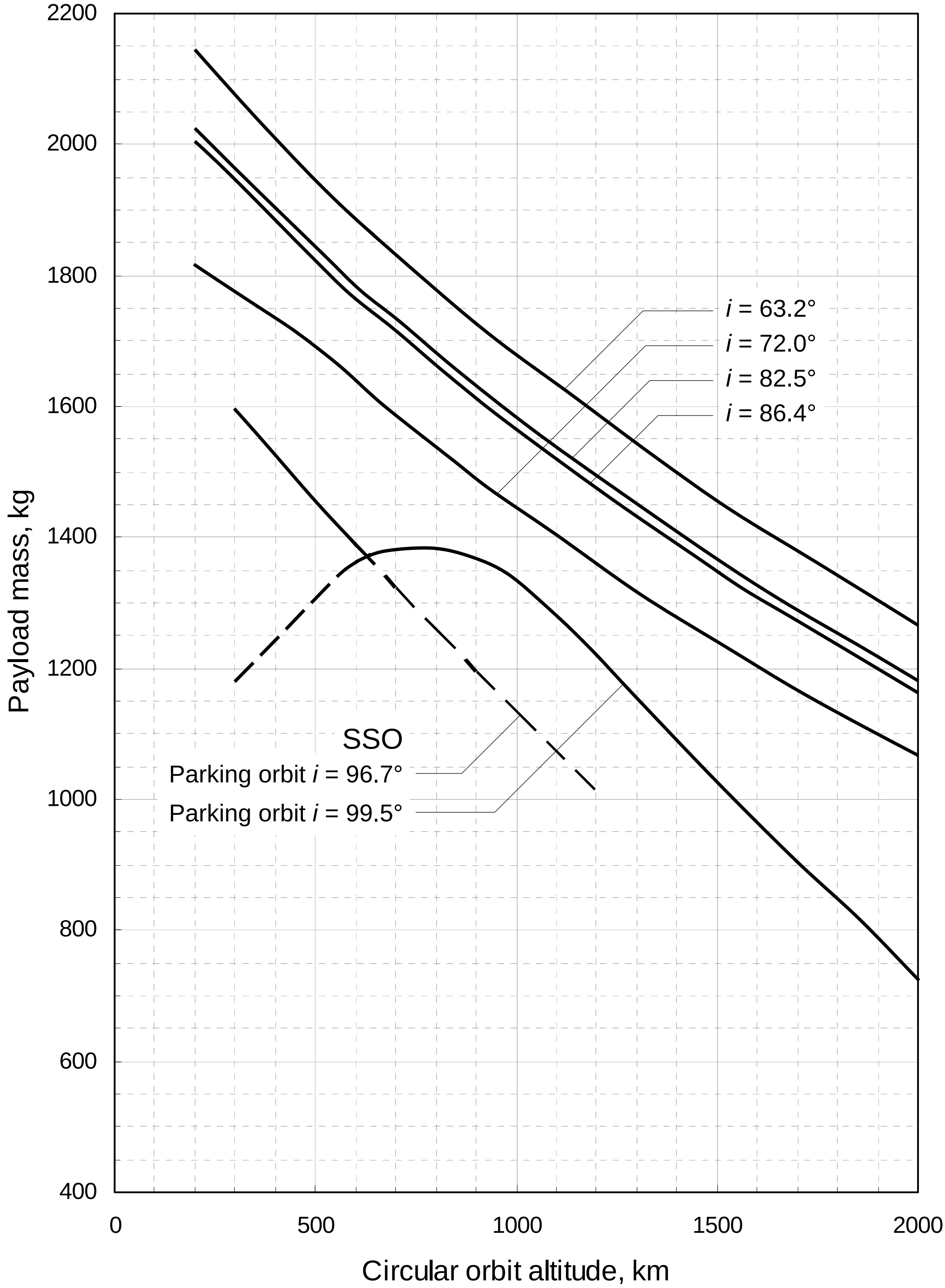


Figure 3-1 ***Rockot/Breeze-KM*** **payload performance for circular orbits.**

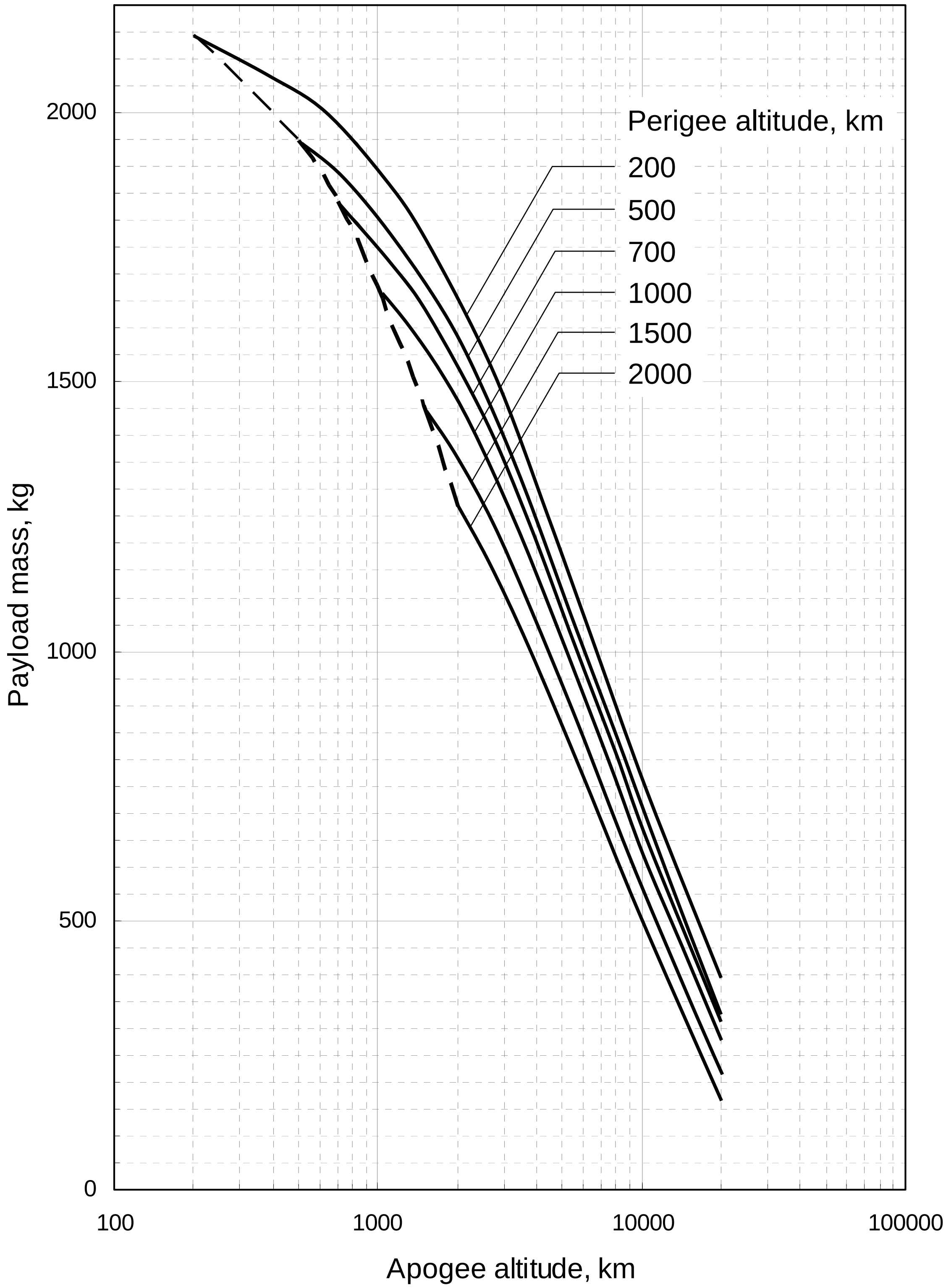


Figure 3-2 ***Rockot/Breeze-KM*** **payload performance for elliptical orbits at 63.2° inclination.**

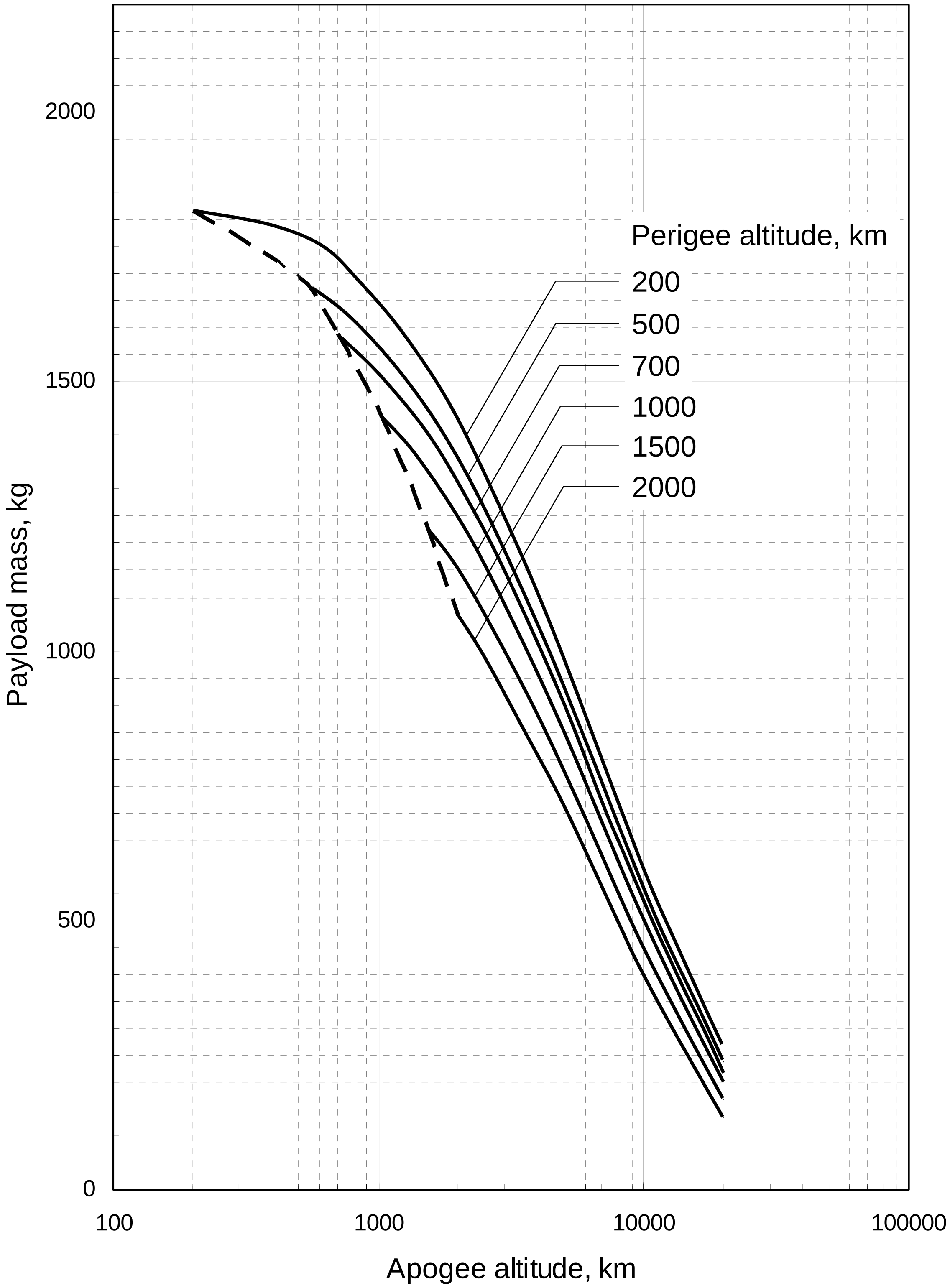


Figure 3-3 ***Rockot/Breeze-KM*** **payload performance for elliptical orbits at 72.0° inclination.**

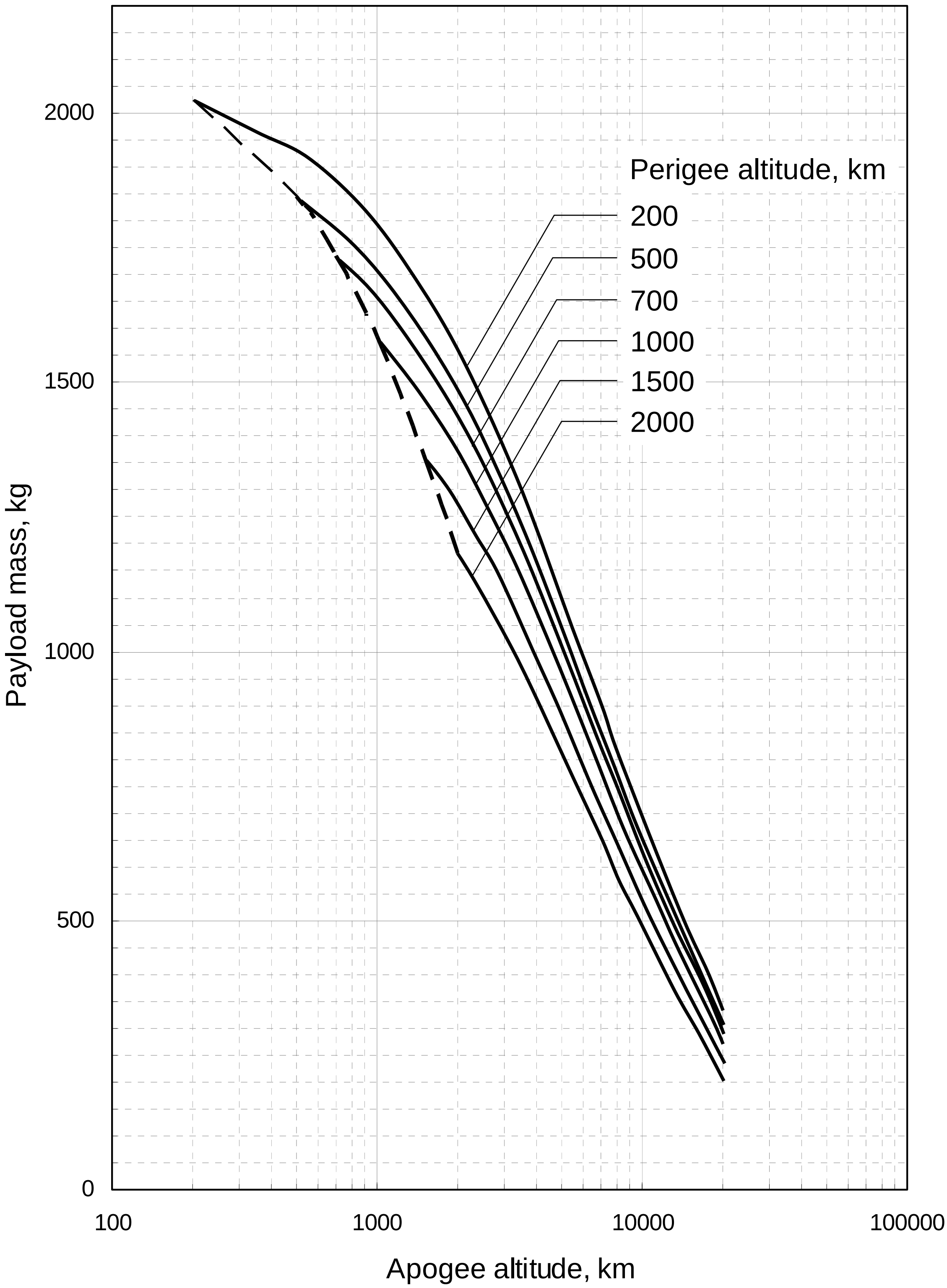


Figure 3-4 ***Rockot/Breeze-KM*** **payload performance for elliptical orbits at 82.5° inclination.**

3.4 Mission Profile Description

This section describes typical circular low-earth mission profiles and presents examples of trajectories.

The selected flight trajectories take into account the dedicated impact sites permitted for *Rockot* elements.

The launch sequence begins with Stage 1 ignition. The first stage propels the vehicle to approximately 60 km height and impacts some 990 to 1100 km down range. The ignition of the Stage 2 vernier engines occurs shortly before Stage 1 burn-out.

After shut down of stage 1 engine, stage 1 is separated using its solid retro rockets. Once the free molecular heat-flow has fallen below 1135 W/m^2, usually, the payload fairing is jettisoned.

The second stage's propelled flight phase is completed by the successive shut down of the main engine and vernier thrusters. The following stage separation is assisted by use of the second stage's retro rockets.

The *Breeze-KM* upper stage manoeuvres begin immediately after stage 2 separation and are performed by the upper stage main engine, which can be ignited several times, if required. An initial burn is performed in the boost mode directly following stage 2 separation. Further ignitions of the main engine are performed in accordance with the specific flight programme.

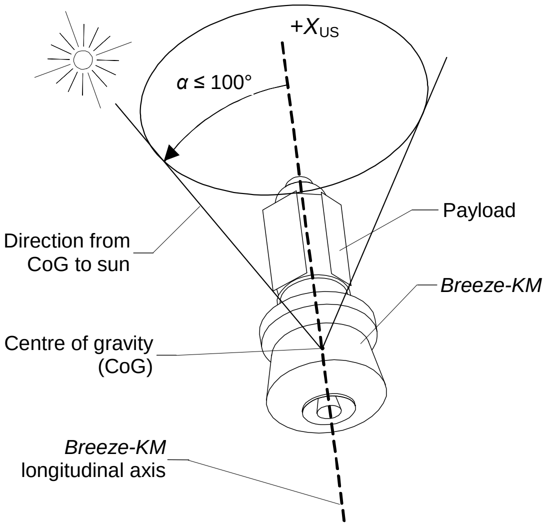
During the coast phase between the main engine burns *Breeze-KM* generally follows a sun-oriented flight programme to meet the Customer's specific requirements between the main engine burns. For instance, for thermal sensitive payloads, a step-wise rotation about any axis can be performed. In the absence of any specific requirements, *Breeze-KM* performs manoeuvres to meet its own thermal requirements. For 1 hour the $+X_{US}$ axis is oriented towards the sun. If coasting continues for more than one hour, the $-X_{US}$ axis is oriented towards the sun for the next half an hour. During $+X_{US}$ orientation, the angle between the $+X_{US}$ axis and the direction of sun light should be $\alpha \le 100°$. During $-X_{US}$ orientation, the angle between the $-X_{US}$ axis and the sun direction should be $\alpha \le 50°$ (Figure 3-5).

For a chosen orientation, an accuracy of 10° about each of the three axes of stabilisation can be provided during the coast phase.

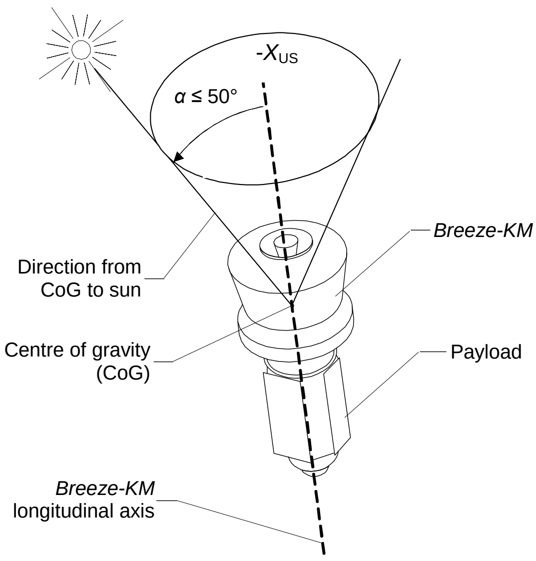
Typical trajectories for *Rockot* missions with different numbers of upper stage ignitions are shown in Figure 3-6 to Figure 3-8. These figures show the main events of the mission: main engine burns and cut-offs, the Spacecraft separation and trajectory characteristics, such as:

- flight time *t* counted from launch, s
- relative velocity *v*, m/s
- relative flight path angle *θ*, deg
- dynamic pressure *q*, kg/m^2
- altitude *h*, km

Figure 3-9 shows a typical injection scheme for sun-synchronous orbits.

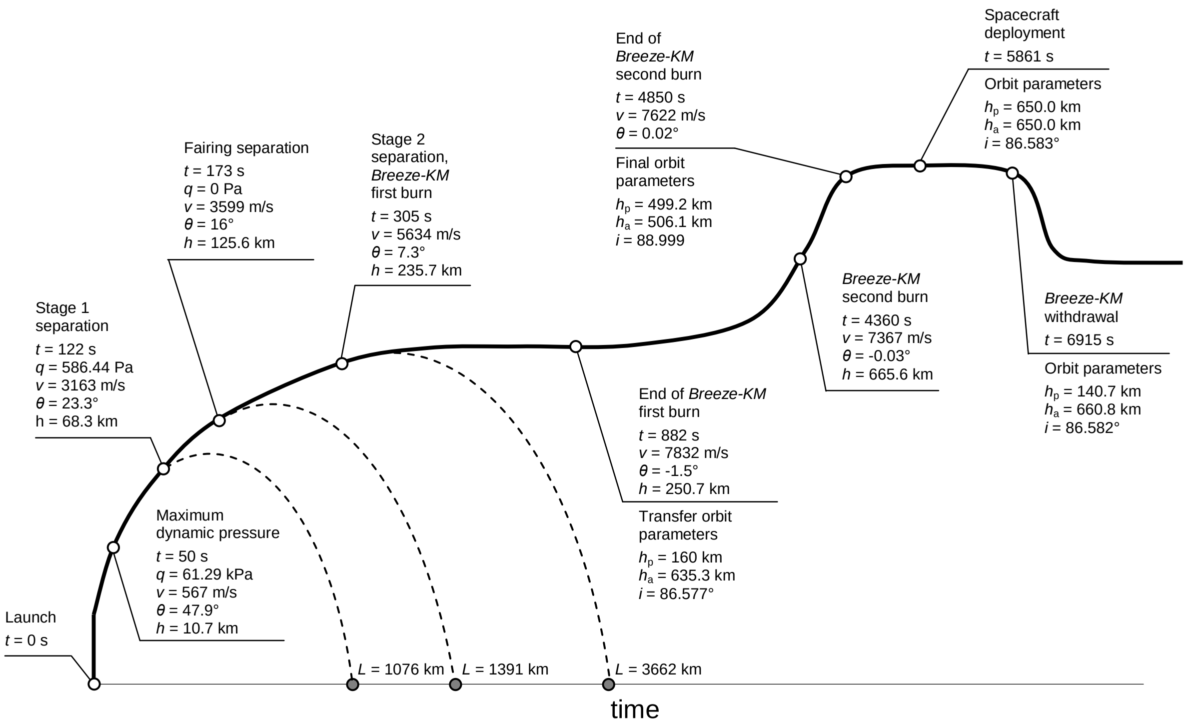


(a)

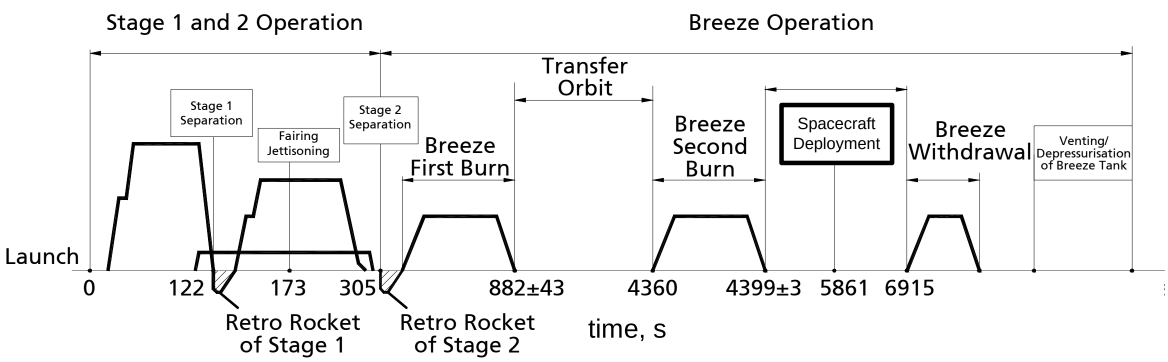


(b)

Figure 3-5 **Cycling orientation of *Breeze-KM* relative to the sun during coast flight maintained for one hour (a), and for half an hour (b).**

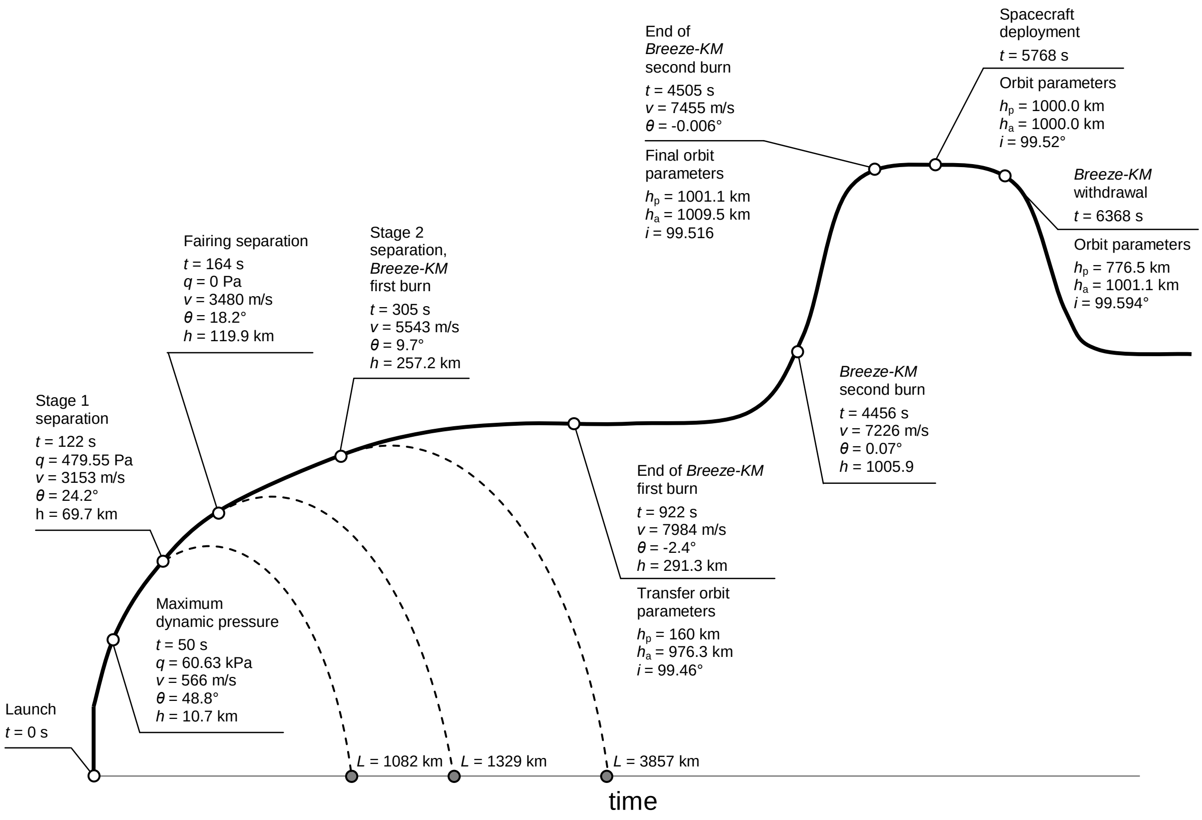


(a)

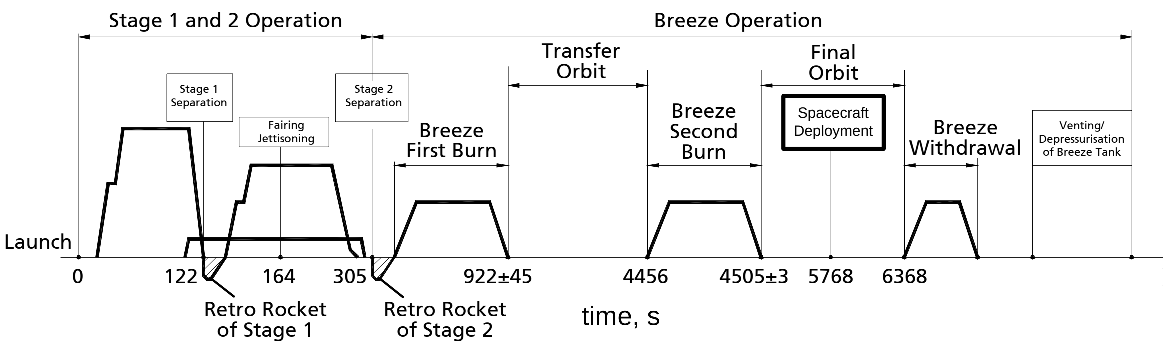


(b)

Figure 3-6 Typical *Rockot/Breeze-KM* ascent (650 km circular, 86.583° inclination). (a) Trajectory. (b) Acceleration timeline.

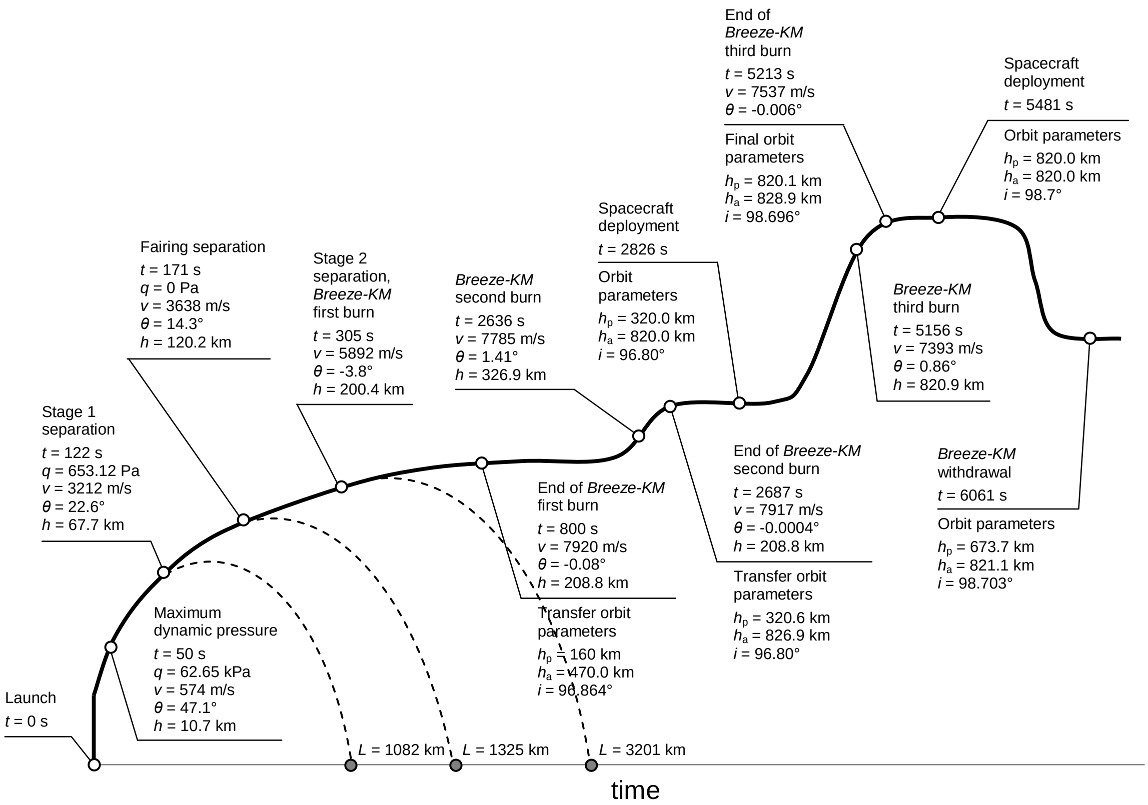


(a)

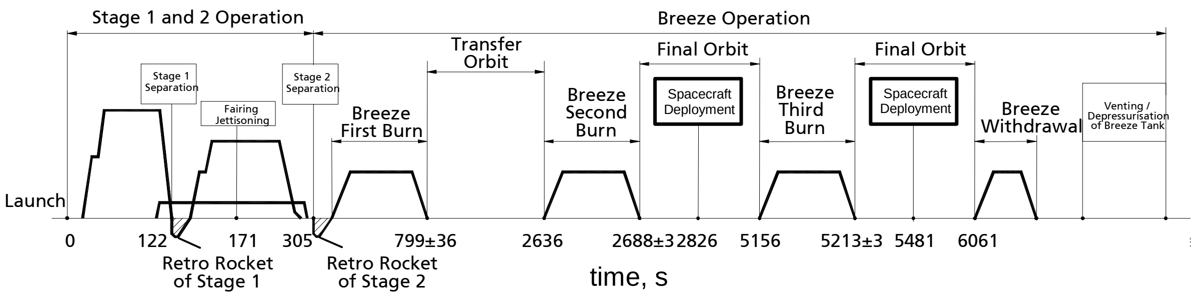


(b)

Figure 3-7 **Typical *Rockot/Breeze-KM* ascent (1000 km circular, 99.52° inclination). (a) Trajectory. (b) Acceleration timeline.**



(a)



(b)

Figure 3-8 **Typical *Rockot/Breeze-KM* ascent (320 km perigee, 820 km apogee at 96.8° inclination and SSO 820 km, at 98.7° inclination). (a) Trajectory. (b) Acceleration timeline.**

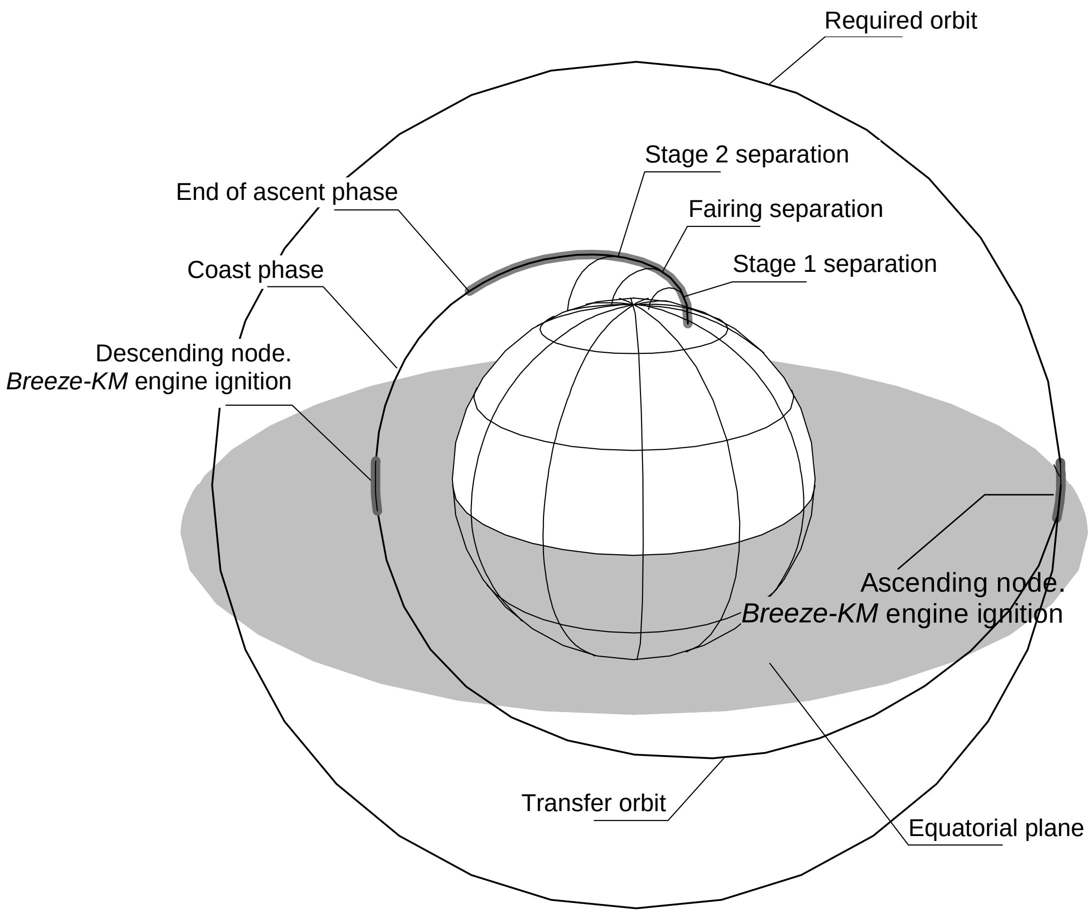


Figure 3-9 Sun-synchronous orbit injection scheme.

3.5 Baikonur Performance

Although *Rockot* launches have occurred in the past from Baikonur cosmodrome, it is currently no longer operational for *Rockot* launches. An activation of the site for *Rockot* requires extensive upgrades and modifications to existing facilities. A decision for site activation will be made on a case-by-case basis, should the need arise. The information contained in this section is for customers interested in the potential use of this launch site for their missions. Baikonur is particularly suited for serving inclinations in the 50° range, which cannot be efficiently reached from Plesetsk due to its northerly latitude. The achievable mass performances from Baikonur for inclinations from about 50° to about 65° are subject to detailed analyses. However, they can be assumed to be slightly above the mass performance for launches from Plesetsk. For more detailed information regarding Baikonur launch performance, EUROCKOT should be contacted, directly.

3.6 Spacecraft Injection and Separation

Rockot, equipped with the *Breeze-KM* upper stage allows a large variety of options with regard to spacecraft orbital injection and separation. The following sections provide information about the orbital injection conditions and the separation possibilities for payloads.

3.6.1 Injection Accuracy

Table 3-2 provides 3-sigma orbital injection errors depending on the average altitude of the target orbit ensured by accuracy properties of the *Rockot/Breeze-KM* launch vehicle control system.

In particular cases the injection accuracies given in Table 3-2 can be improved after the specific trajectory analysis.

3.6.2 Spacecraft Separation

The spacecraft separation from *Breeze-KM* can take place in a number of different ways and is driven primarily by the

- characteristics of the separation system, e.g. stiffness of spring pushers,
- type of release mechanism,
- the direction of the separation impulse of the payload,
- payload mass, moments of inertia,
- the *Breeze-KM* burn-out mass

Spacecraft can either be spun-up along the *Breeze-KM* longitudinal axis or released from the upper stage in a three-axis stabilised mode.

3.6.2.1 Spin Stabilised Separation

Spin stabilisation is performed around the upper stage longitudinal axis with rates of up to 10°/min. Higher spin rates may be considered upon Customer's request.

Spin parameters are to be agreed individually for each specific payload taking into account:

- Payload mass distribution (MoI), centre of mass (CoM) position and spacecraft dynamic properties
- Customer requirements for the spin regime such as:
  - attitude orientation and its accuracy during upper stage spin manoeuvre
  - orientation accuracy of the payload after its separation
  - other payload requirements for the Breeze-KM upper stage
- Necessity to continue flight control of the upper stage after payload separation

Controlled deorbiting of the upper stage after separation can be provided, if required. On the completion of the mission, *Breeze-KM* vents all its tanks to put the stage in a safe mode.

Orbital parameters error type	3-Sigma error
Average orbital altitude	±1.5%
Inclination	±0.06°
Eccentricity (for circular orbits)	≤0.0025
Right ascension of ascending node	±0.05°
Argument of perigee (for elliptical orbits)	depends on eccentricity

Table 3-2 Orbital injection accuracy.

3.6.2.2 Three-Axis Stabilised Separation

In general, any required payload attitude can be provided. Following orbit insertion, the *Breeze-KM* avionics subsystem can execute a series of pre-programmed commands to provide the desired initial payload attitude prior to its separation.

This capability can also be used to reorient *Breeze-KM* for the deployment of multiple payloads with independent attitude requirements.

The 3-sigma attitude error about each spacecraft geometrical axis will not exceed 1.5° - 3° depending on the spacecraft properties.

The maximum angular velocities of the combined *Breeze-KM* / spacecraft prior to the payload deployment are:

$\omega_x = \pm 1°/s$
$\omega_y = \pm 0.5°/s$
$\omega_z = \pm 0.5°/s$

The spacecraft separation scheme system design including the number of pushers, their allocation and energy is developed in accordance with the requirements for ensuring the spacecraft normal operations. The schemes are selected by EUROCKOT and agreed with the Customer.

As a possible way to reduce potential disturbances acting on the spacecraft during separation, the following measures shall be applied:

- Selection of pusher with optimal characteristics including their energy
- Adjustment of pusher position for compensation of lateral offset of the CoM

Besides, electrical connectors can be selected taking into account their separation forces characteristics.

Analysis shows that even for light spacecraft having a mass of not more than 500 kg and moments of inertia of up to 50 kg·m^2 the total angular velocities ω_y and ω_z will not exceed 2.5°/s and the longitudinal component of ω_x will not exceed 1.5°/s after separation, if the above methods are combined. For spacecraft of larger size and higher inertia the disturbance values are smaller.

Please note that these values shall be considered as conservative ones. The actual parameters can be smaller depending on the properties of the specific spacecraft.

To fulfil the Customer's requirements for the spacecraft separation, EUROCKOT selects the best suited of above methods to provide an optimal solution.

3.6.2.3 Typical Multiple Satellite Deployment Scenarios

Breeze-KM is able to perform a wide variety of complex pre-programmed manoeuvres using a combination of its main, vernier and attitude control engines, that allow to implement injection of several payloads into specified target orbits.

Depicted in the figures below are two typical payload deployment schemes. Figure 3-10 shows the sequential separation of three spacecraft with Δv added to each spacecraft to aid in-orbit plane phasing. Figure 3-11 shows a sequence in which six spacecraft are released simultaneously.

The separation scenario of the spacecraft is laid out in accordance with number, arrangement and energy of the pushers and their requirements for normal operation of the satellite. The separation scenario is selected in cooperation with the Customer.

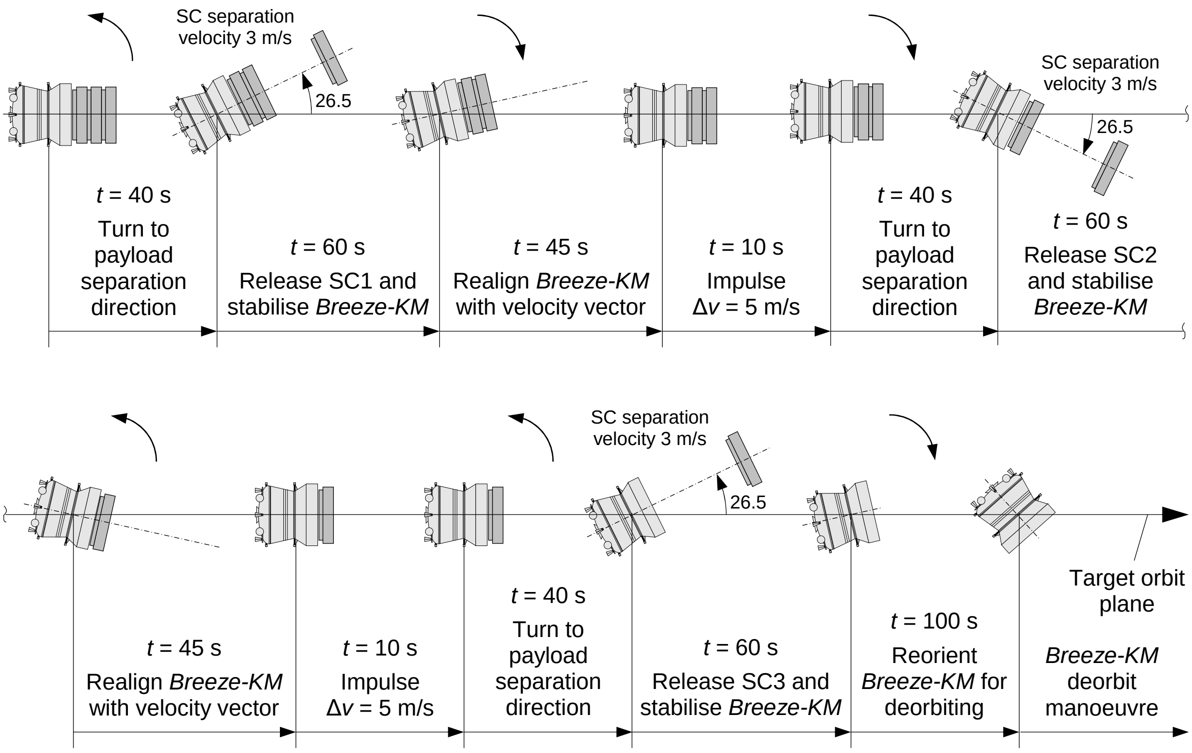


Figure 3-10 Example of sequential deployment of three spacecraft.

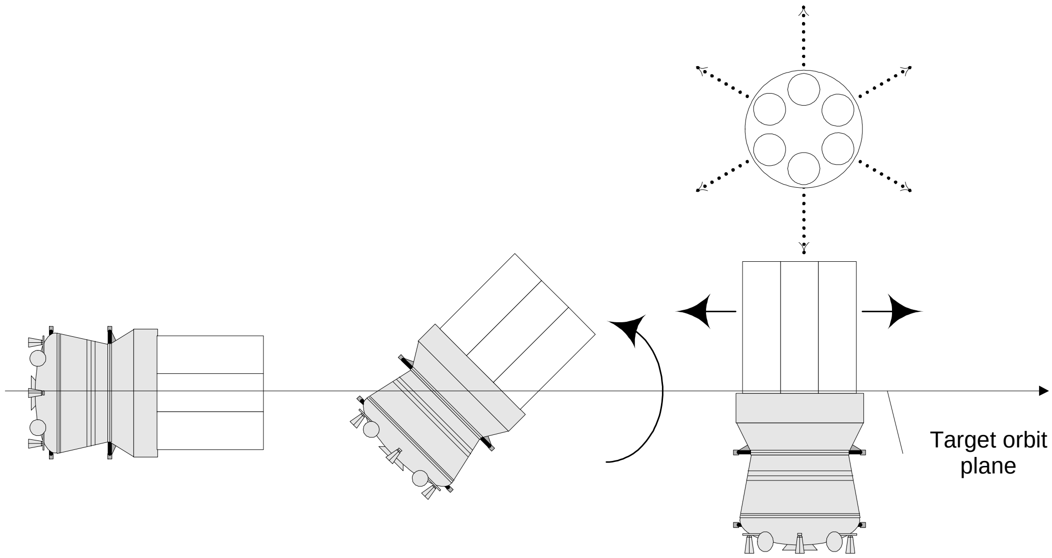


Figure 3-11 Example of simultaneous deployment of six spacecraft.

Chapter 4 Spacecraft Interfaces

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4 Spacecraft Interfaces

4.1 Mechanical Interfaces

4.1.1 Payload Accommodation

The main mechanical interfaces of the *Rockot* launch vehicle to the Customer's spacecraft are described in this section. Examples and illustrations are provided for the mounting of single or multiple spacecraft to the launch vehicle adapter or dispenser assembly equipped with a suitable separation system. Additionally, the allowable envelope within the *Rockot* payload fairing is described.

The following terminology is used within this chapter and defined below to avoid confusion:

- (Payload) adapter: the mechanical structure mounted on the launch vehicle which supports the mated spacecraft via the spacecraft interface ring
- (Payload) adapter system: the adapter plus the appropriate hardware to interface to the spacecraft interface ring or interface points, i. e. separation system, spring pushers, umbilical connectors and separation monitoring switches
- Separation system: the complete separation system including the pyrotechnical devices and their electrical initiation system, e. g. a CASA CRSS clamp band system or the Mechanical Lock System
- Dispenser (system): adapters that are built for multiple satellite accommodation or side mounted accommodation
- Launch vehicle interface ring: the top part of the payload adapter made of aluminium alloy, part of the adapter interfaces to the spacecraft interface ring and connected to it via a clamp band separation system
- Spacecraft interface ring: the ring attached to the normally lower part of the satellite that interfaces with the adapter or dispenser system of the launch vehicle, used with clamp band systems
- Spacecraft interface points: the interface points that are attached to the satellite to interface with the adapter or dispenser system of the launch vehicle, used with the Mechanical Lock System for point attachment

It should be noted that it is standard practice for EUROCKOT to provide the appropriate qualified adapter or dispenser system including all the associated equipment necessary such as a separation system, spring pushers, umbilicals and separation monitoring switches to the customer as part of the launch services contract. Hence, the interface of the adapter or dispenser to the *Breeze-KM* upper stage is entirely the responsibility of EUROCKOT and, therefore, not covered here.

To accommodate individual Customers' different needs and satellite designs, EUROCKOT offers a wide variety of options for interfacing their spacecraft to the launcher. The adapter or dispenser systems offered include Russian point attachment separation systems as well as classical clamp band separation systems using well established western suppliers.

As well as dedicated single payload launches, EUROCKOT also provides diverse accommodation schemes for multiple payloads in order to make maximum use of available resources such as volume and performance.

As an example, Figure 4-1 depicts a multiple satellite accommodation. This particular arrangement of small satellites around a main payload was exercised for the Multiple Orbit Mission (MOM) in June 2003. Eight small satellites weighing from 1 kg to 68 kg accompanying a larger 250 kg main payload were accommodated.

The necessary dispensers and adapters for the respective accommodation schemes of the individual satellites will be part of the mission-dependent equipment and will generally be developed and provided by EUROCKOT. Because of the diversity of the mechanical interfaces, only generic interface details are described here. Further details should be coordinated with EUROCKOT.

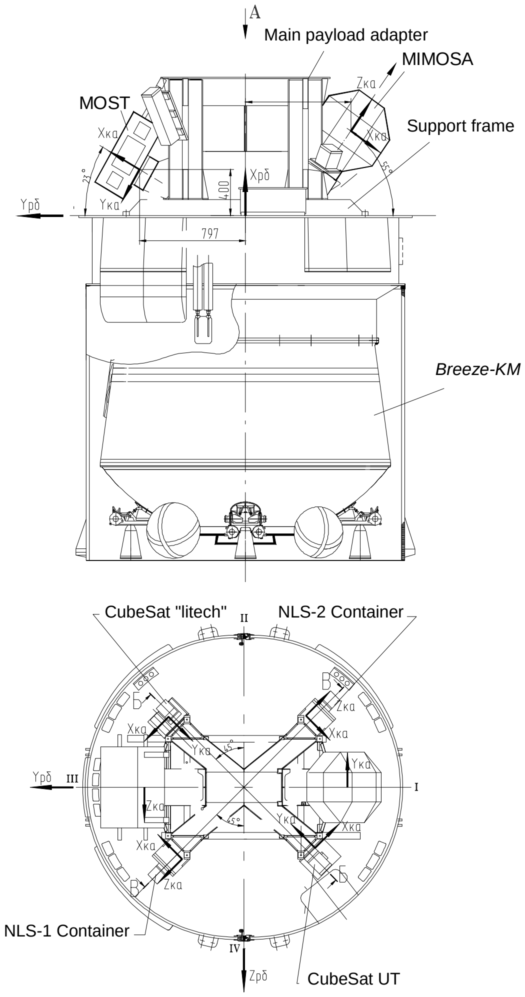


Figure 4-1 **Multiple payload accommodation for MOM without main payload.**

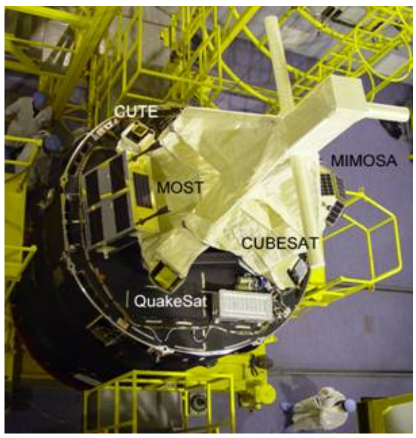


Figure 4-2 **Integrated MOM payload with main payload simulator.**

4.1.2 Usable Volume for Payload

The layout of the payload-usable volume, which is the maximum dynamic envelope above the *Breeze-KM* interface plane, is shown in Figure 4-3.

This figure reflects the maturity of the commercial payload fairing design which performed its maiden flight in May 2000. The usable volume has been defined conservatively taking into account the following items:

- Maximum dynamic movement of fairing
- Maximum manufacturing tolerances of the fully integrated fairing
- Maximum mounting error of the fairing
- A minimum guaranteed clearance between the spacecraft and the fairing
- Estimated maximum spacecraft dynamic movement for a typical base-mounted configuration. For a side-mounted spacecraft located on a vertical payload dispenser, this value will be the subject of a dedicated dynamic analysis.
- Estimated maximum spacecraft mounting error and manufacturing tolerance of a typical base-mounted adapter system

EUROCKOT can also provide a three-dimensional -IGES- file for a preliminary spacecraft accommodation investigation by the Customer.

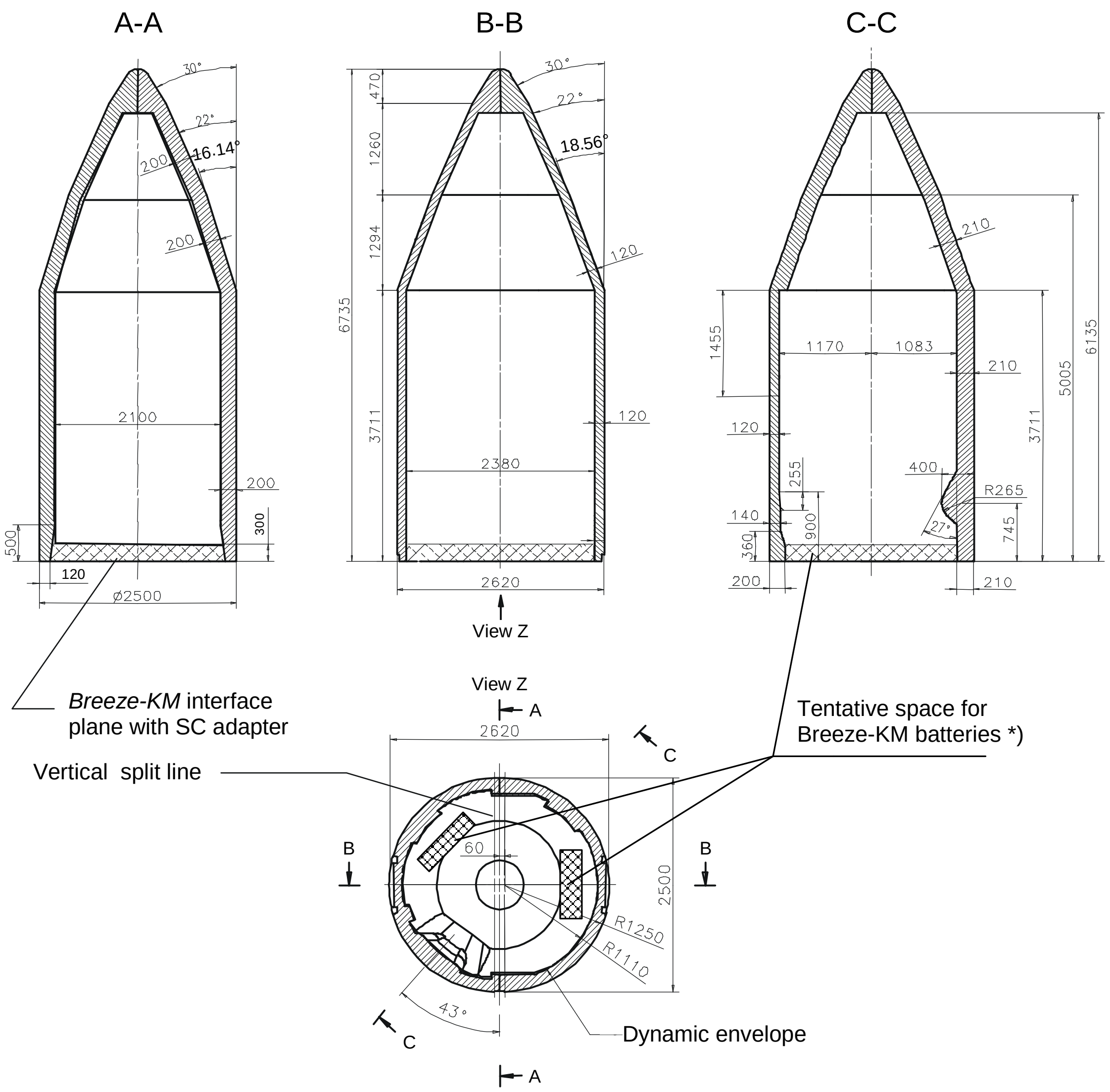
Customers may in certain cases to exceed the maximum dynamic envelope shown above. However, the acceptance of such a case is subject to a detailed clearance analysis following a coupled loads analysis and will involve the assessment of all available margins within the envelope. It should be noted that EUROCKOT recommends to all Customers with payload elements that are predicted to have less than 40 mm clearance from the maximum usable envelope, e.g. antenna, solar arrays etc., should contact EUROCKOT directly for precise determination of actual clearances.

4.1.3 Spacecraft Accessibility

Mechanical access to the payload after encapsulation is not foreseen as a standard service. Principally, fairing access hatches are possible provided that an acceptable cleanliness scenario at the Launch Pad can be agreed. However, access via umbilical connectors will be provided during any operation phase after encapsulation, e. g. for battery trickle charging, communication, etc. Should a late intervention at the spacecraft be necessary, the upper composite will be destacked from the booster unit and transported back to the payload integration facility.

4.1.4 Separation Systems

This section describes potential options for providing high quality attachment and separation between the Customer's spacecraft and the *Breeze-KM* upper stage. The selection of one of these interface solutions is driven by constraints such as spacecraft geometry, mass and related properties, stiffness and so on. However, cost aspects and maximum acceptable mechanical loads during spacecraft separation are design drivers, as well.



*) Potential interference zone with *Breeze-KM* batteries for extended missions. Please co-ordinate with EUROCKOT for precise information.
Please note that the stay-out zone of 300 mm at the *Breeze-KM* interface plane may be reduced to 100 mm after the successful qualification of new batteries in 2012.

Figure 4-3 *Rockot* maximum usable payload envelope, all dimensions given in mm.

Three types of separation system which are used to retain and then release the satellite are offered:

- Flight-proven Marmon clamp bands from EADS CASA
- The KSRC-supplied, flight-proven Mechanical Lock System
- A minisatellite separation system

All adapter concepts and separation systems described in this chapter, except for the Launcher Payload Separation System (LPSS), are flight-proven and can be procured as off-the-shelf equipment. Other types of separation system can be considered and developed upon Customer's request. The Customer can also provide his own separation system. In this case the choice of the adapter has to be agreed with EUROCKOT.

The separation system also comprises spring loaded pushers, separation monitoring switches and umbilical connectors attached to suitable brackets which are items to be accommodated in the payload adapter. The pushers can be selected for separation velocities between 0.1 and 0.8 m/s upon Customer's request. The spring pushers are so aligned that the resultant force will act along the spacecraft's centre of mass in the desired separation direction, thereby reducing the spacecraft tip-off rate.

4.1.4.1 Clamp Band Separation Systems

The EADS CASA Clamp Ring Separation System (CRSS) is proposed for use on *Rockot* payload adapters. The system is applied with a thermal cycle using electrical heaters. Figure 4-4 to Figure 4-7 provide examples of compatible CASA clamp bands including typical interface and stay-out zone details. Please note that for the CRSS a distance of 60 mm from the separation plane to the spacecraft bottom has to be respected as axial stay-out zone. The figures are provided for example only. For formal interface data, EUROCKOT provides the dedicated specification ESPE-0018.

Taking into account the maximum *Rockot* payload performance, CASA clamp rings are qualified for standard interface diameters of 937 and 1194 mm. The systems are procured with low shock clamp band opener devices which are fully qualified. Typical shock response spectra for these systems are given in chapter 5. For even lower separation shock spectra, the EADS CASA Launcher Payload Separation System (LPSS) can adapted for *Rockot*. For specific information on low shock systems, the Customer is advised to contact EUROCKOT directly.

The choice of the manufacturer for the adapter as well as specific data on interface requirements (hole patterns, stay- out zones, electrical connectors etc.), are subjects for mutual discussion and development, as EUROCKOT offers maximum design flexibility to its Customers.

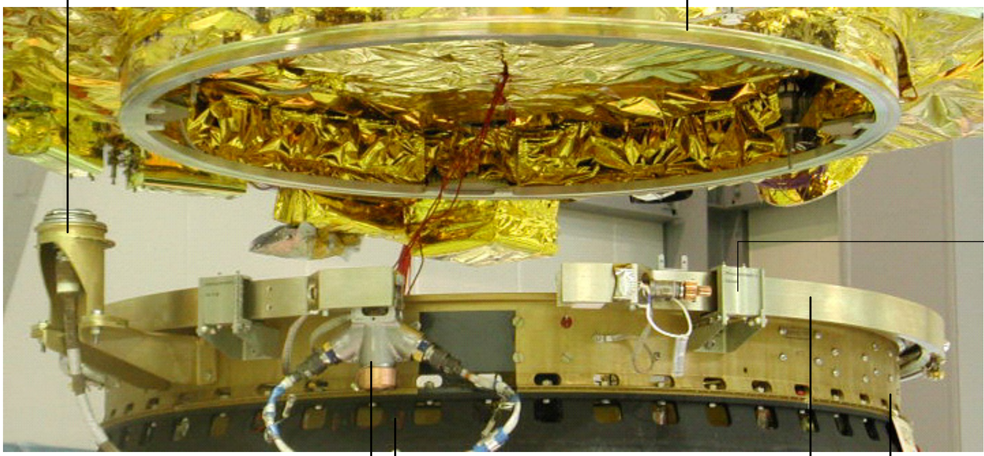


Figure 4-4 CASA CRSS Clamp Ring Separation System installation with KSRC pyrolock.

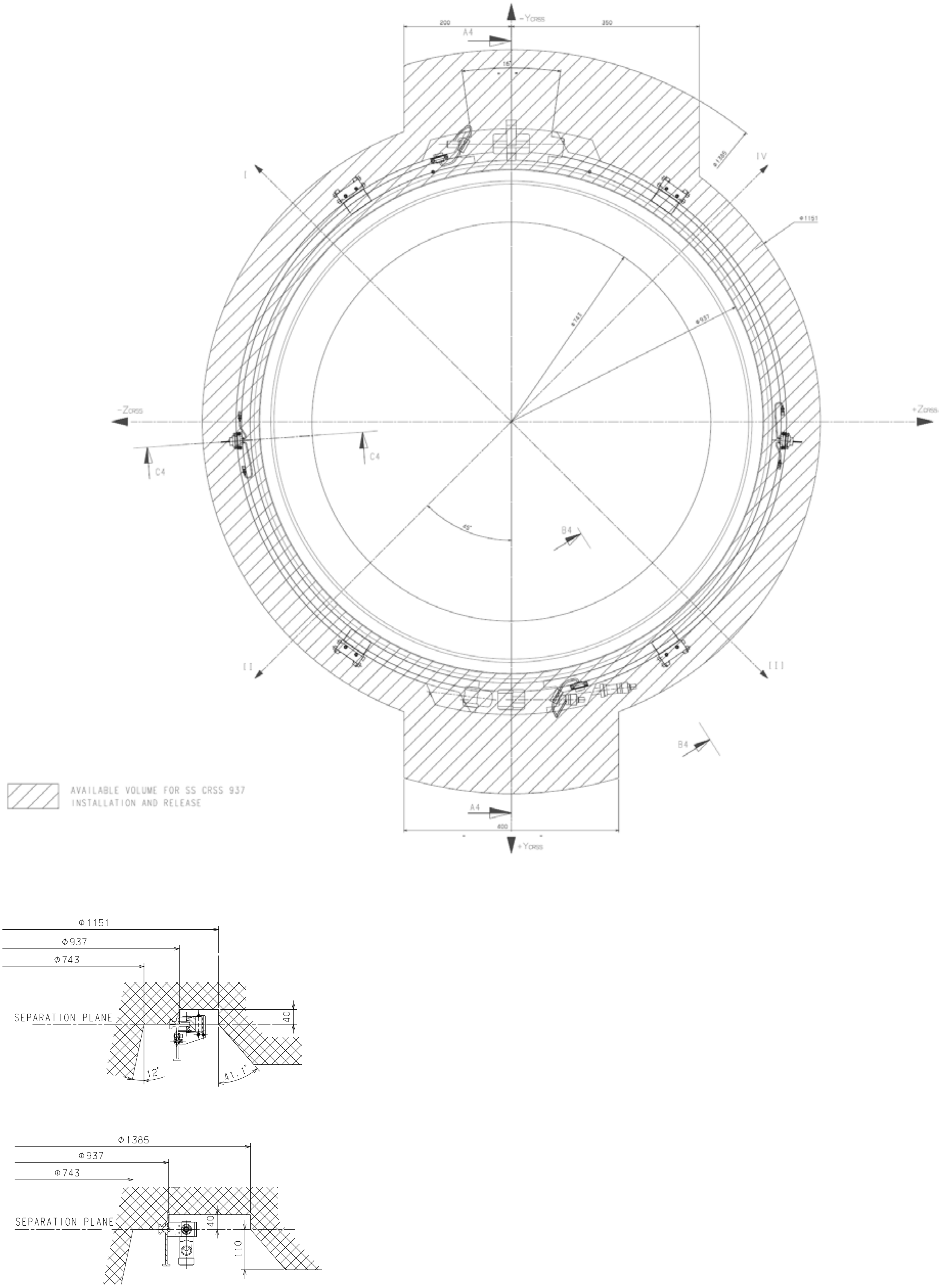


Figure 4-5 Stay-out zones (hatched) for the standard interface diameter of 937 mm.

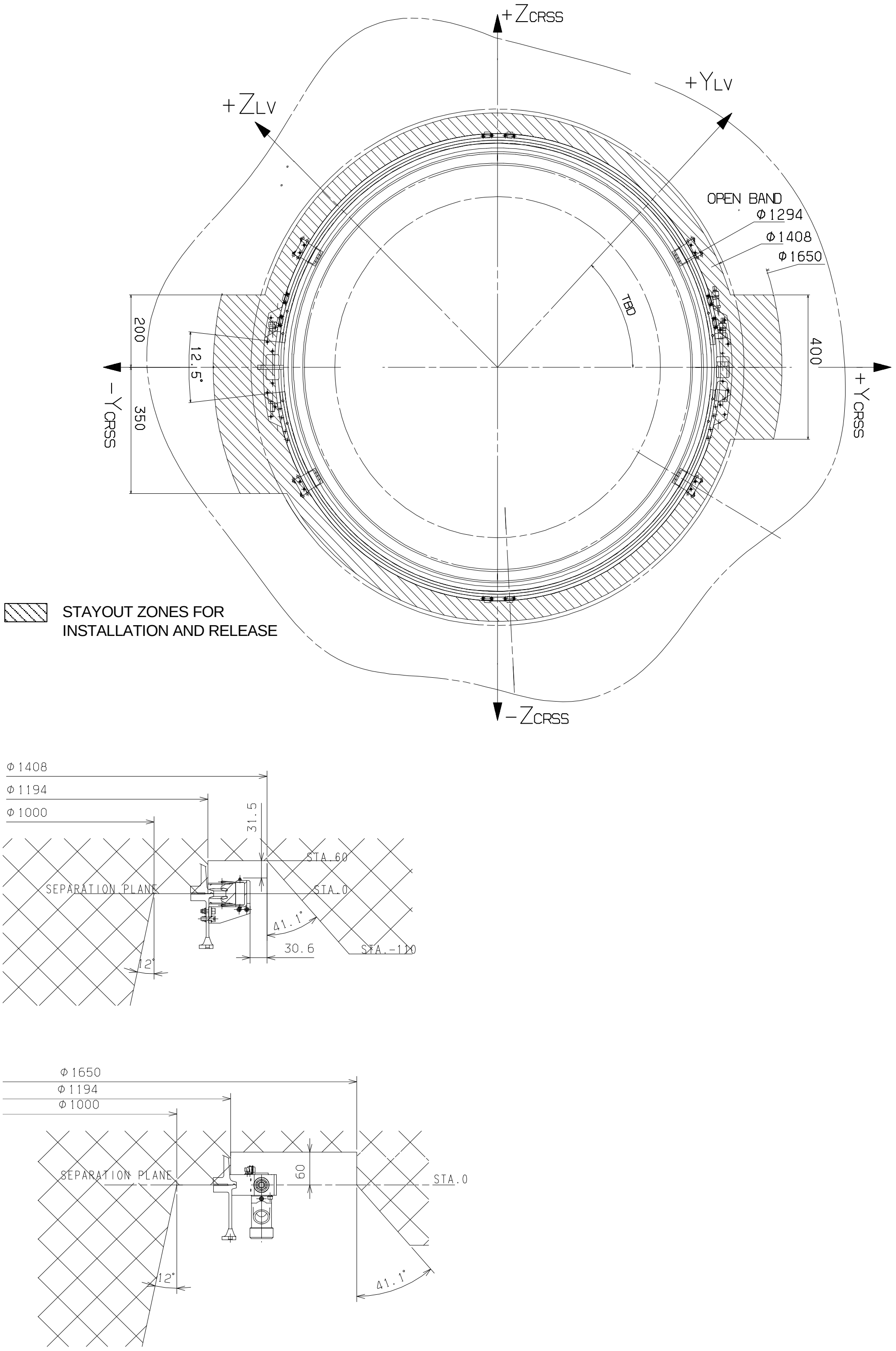


Figure 4-6 Stay-out zones (hatched) for the standard interface diameter of 1194 mm.

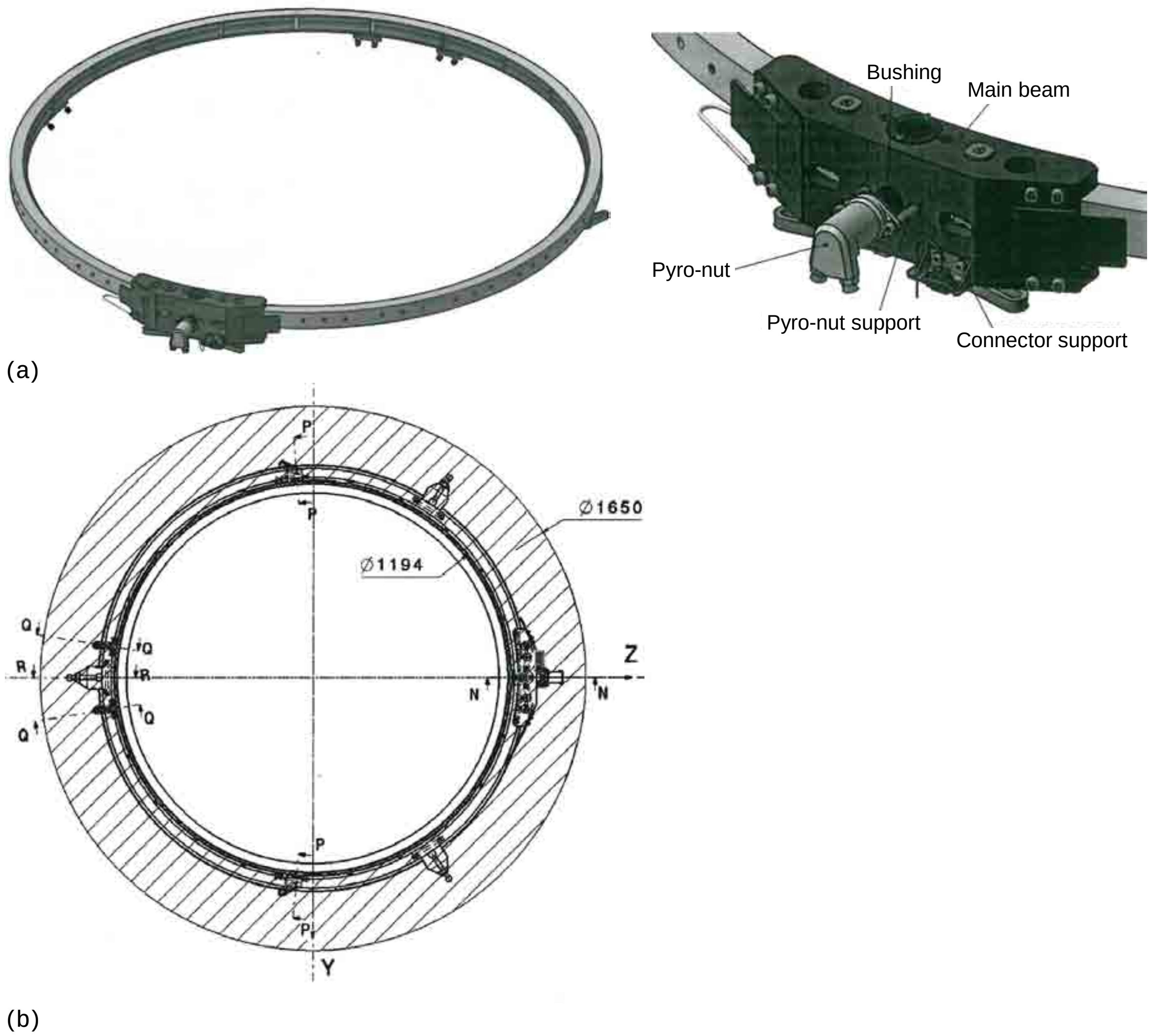


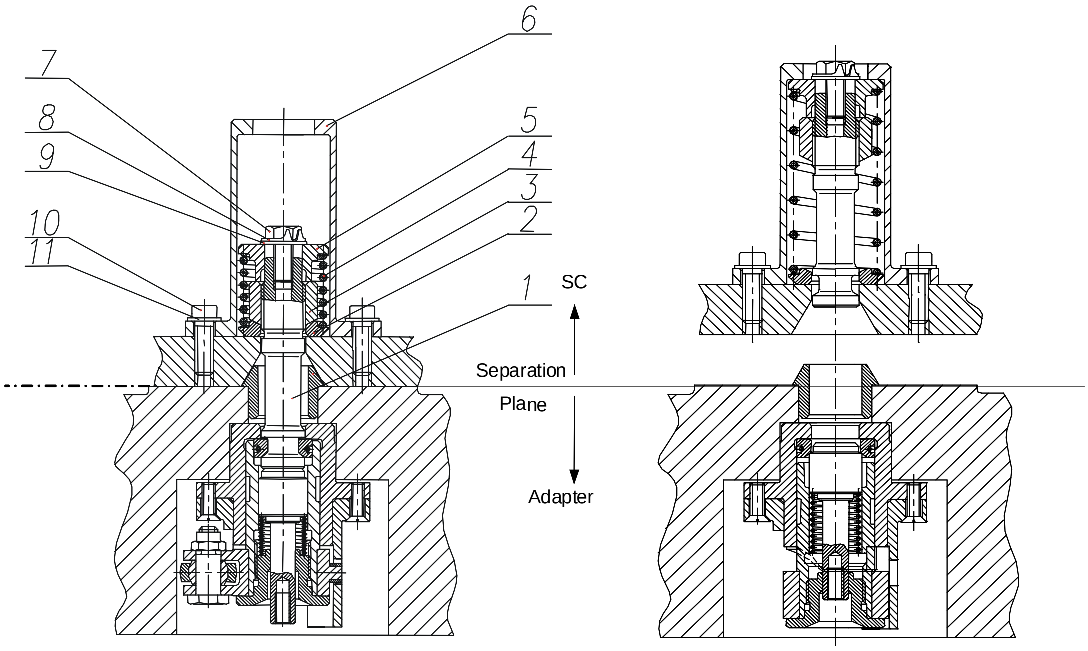
Figure 4-7 **Optional CASA LPSS Launcher Payload Separation System, (a) general view, (b) stay-out zones (hatched) for the standard interface diameter of 1194 mm.**

4.1.4.2 Mechanical Lock Systems

The Mechanical Lock System (MLS) is offered by EUROCKOT for use with spacecraft that are attached to the launch vehicle at discrete points rather than via a ring as in a standard clamp band system. Such mechanically driven point attachment systems are particularly advantageous when deploying several satellites during a single launch.

The MLS, which is shown in Figure 4-8, has successfully performed more than 25 in-flight separations, not only with *Rockot* but also with the *Proton* launch vehicle. It fastens the satellites to the launch vehicle payload adapter or dispenser via three or four point mechanical attachments at the base of each satellite. The number of attachment points depends on the satellite shape and mass. The spacecraft are released by the firing of a single pyrodriver located in the payload adapter system.

This actuates a mechanical drive to unlock the attachment points. The mechanical shock is not exerted directly on the spacecraft interfaces, but on the elements of the mechanical drive, thereby significantly attenuating the pyrotechnic shock levels experienced by the spacecraft. All components of the MLS are contained and no part will be released.



Note: The indicated parts remain on the spacecraft after separation: 1,7,10 = Bolt, 2,8,9,11 = Washer, 3 = Screw-nut, 4 = Spring, 5 =Support, 6 = Bolt Retainer.

Figure 4-8 Cut-away detail of the Mechanical Lock System.

4.1.4.3 Minisatellite Separation System

Eurockot also offers a KSRC separation system for minisatellites. An overview and design details are shown in Figure 4-9. All the components of the separation system are mounted on the housing of this system. The upper ring of the separation system is attached to the spacecraft lower bottom by bolts. The spring pushers interface either directly with the spacecraft structure or with the spacecraft adapter.

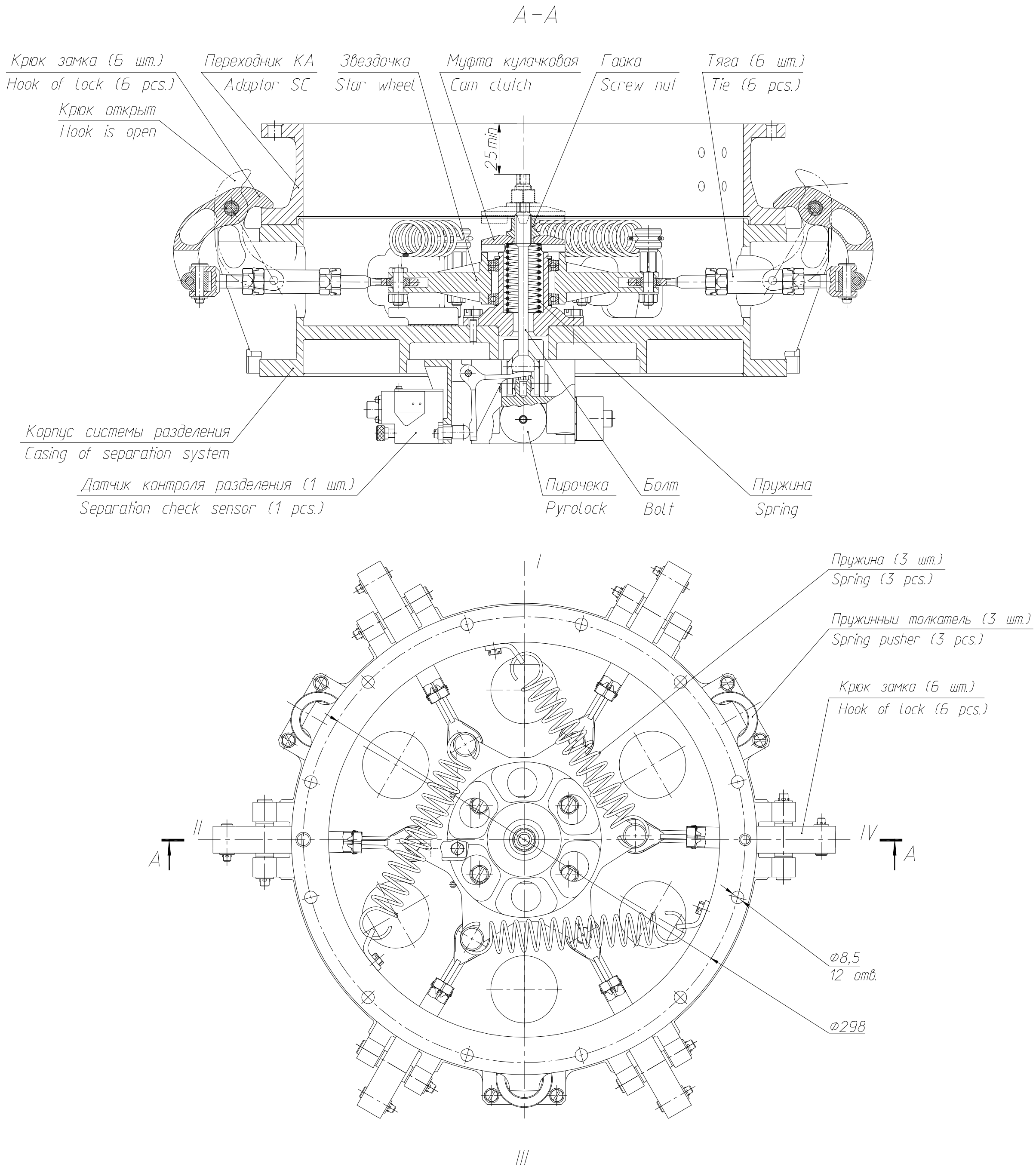


Figure 4-9 Minisatellite separation system.

4.1.5 Payload Adapters

Payload adapter and dispenser systems, which are the structures supporting the chosen separation system, are described in this section.

The payload adapter also accommodates the spring loaded pushers, separation monitoring switches, and umbilical connectors which are components of the separation system (section 4.1.4).

4.1.5.1 Clamp Band Separation System Adapters

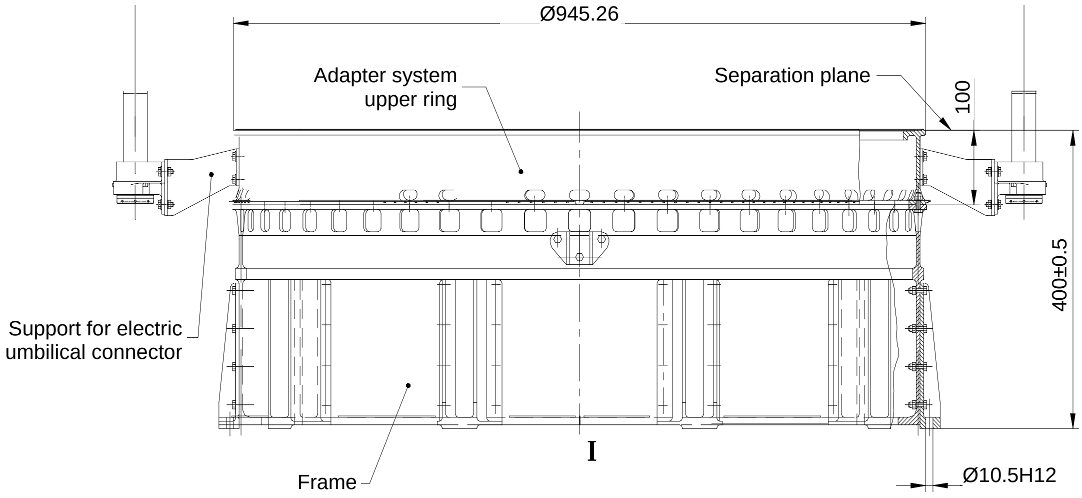
Adapter systems compatible with classical Marmon-type V-shaped clamp band separation systems are offered by EUROCKOT. Such payload adapter types are flight-proven and can be offered in two sizes, 937 mm and 1194 mm. As an option, also other clamp band sizes can be adapted for *Rockot/Breeze-KM* if required.

The payload adapters have the shape of either a cone or a cylinder and are offered as either aluminium or carbon fibre structures or a combination of both. The payload adapter is bolted to the top of the equipment bay of the *Breeze-KM* upper stage. The forward face of the payload adapter is machined into a ring with predefined dimensions according to the requirements of the clamp band separation system chosen. The payload adapter may also be split into a lower part which interfaces to the upper stage and the LV interface ring that interfaces the clamp band and the spacecraft. The spacecraft interface ring is pressed on top of this surface against to the adapter by adequate tensioning of the clamp band.

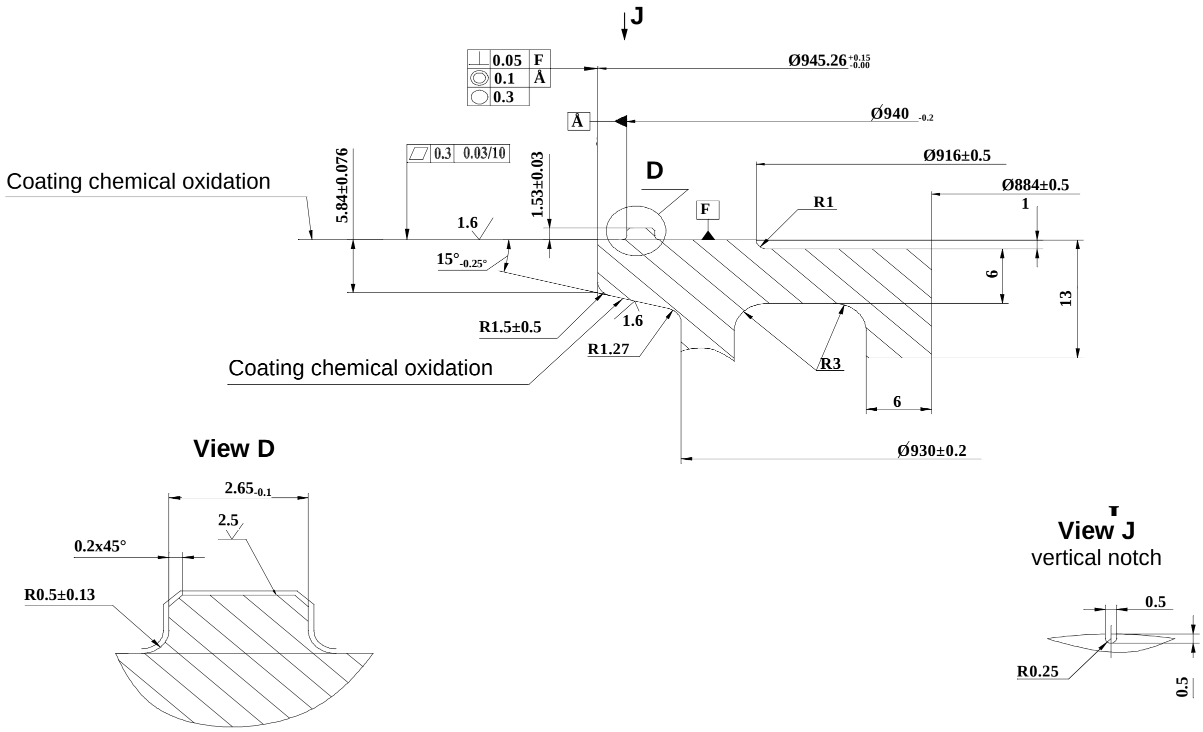
The upper part of the adapter allows for the accommodation of electrical connectors to the spacecraft via support brackets. The bracket position can be varied on a case-by-case basis, each bracket also allows ± 4 mm horizontal and ± 2 mm vertical adjustment for fine tuning. The lower part of the adapter allows for positioning of separation system components and sensors. Figure 4-10 depicts a flight qualified cylindrical aluminium payload adapter with 400 mm height together with interface details. This cylindrical adapter type is currently in modification for the 1194 mm clamp band. Figure 4-11 shows a conical shaped adapter with an 1194 mm interface ring diameter specially developed for the Kompsat-2 spacecraft interface. In the majority of cases the payload adapter consists of two parts, namely an upper part and a lower part bolted together. The upper part provides the launch vehicle interface ring and is manufactured from aluminium alloy. The lower part of the adapter which interfaces to the launch vehicle can be made from a carbon fibre or aluminium structure. A distinctive feature of these adapter designs is that, while the height of the lower part may vary for different payloads, the payload adapter interface remains unchanged. Finally, Figure 4-12 shows a conical payload adapter with an extended length for the CRSS 937 SRF clamp band.

Two spacecraft on top of each other can be launched on *Rockot/Breeze-KM* using Multi-Satellite Dispenser systems (MSD). An example of two base mounted satellites with clamp band separation systems designed for the SMOS/Proba-2 mission (2009) is shown in Figure 4-13. The smaller spacecraft is transported underneath the conical payload adapter of the larger spacecraft and attached with the minisatellite separation system (Figure 4-9).

The spacecraft ring interfacing with the clamp band and adapter on the launch vehicle side is generally designed by the Customer. While the spacecraft ring interface dimensions are fix, the cross section is selected by the Customer, who is responsible for the structural integrity of the spacecraft ring. EUROCKOT will check together with KSRC and EADS CASA Espacio that the cross section of the ring is still enough to ensure the correct function of the interface. Therefore, the Customer shall provide the spacecraft design concept to EUROCKOT for verification before releasing the design to manufacturing. Details for the EADS CASA CRSS 937 and 1194 SRF clamp band separation system, the launch vehicle adapter and the spacecraft interface ring are given in the latest issue of EUROCKOT specification ESPE-0018.

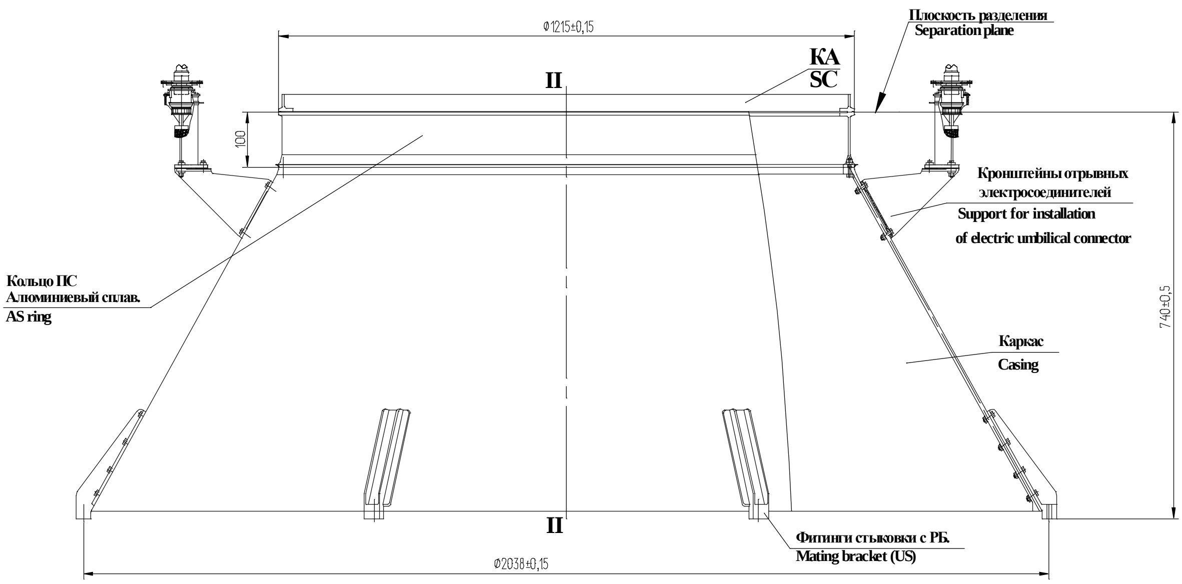


(a)

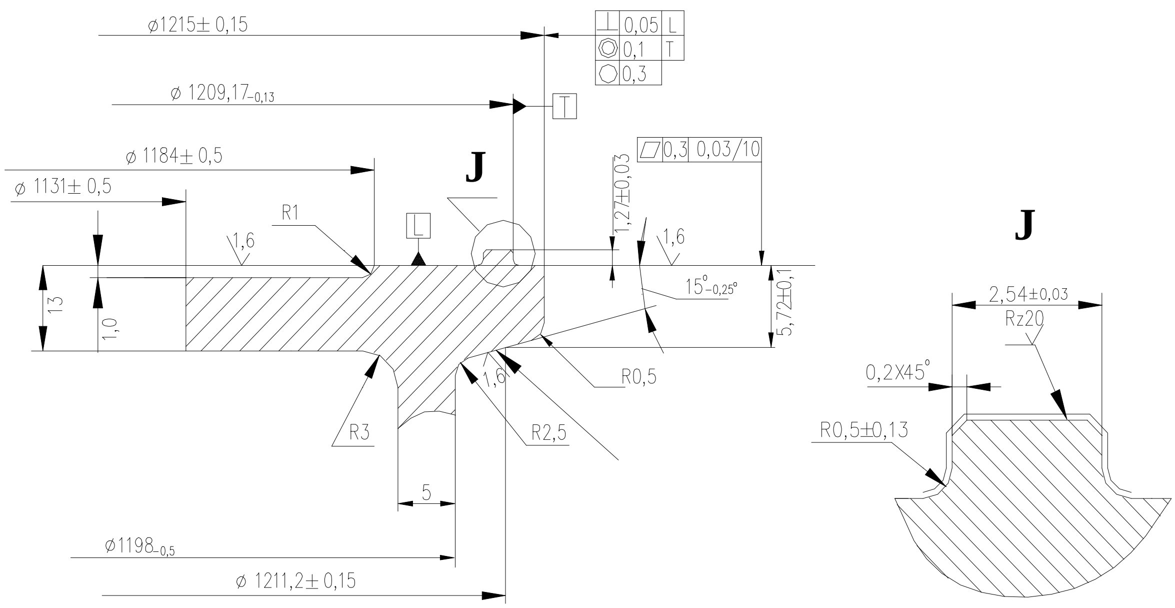


(b)

Figure 4-10 **CASA 937 SRF clamp band cylindrical payload adapter. (a) Side view. (b) Launch vehicle interface ring detail.**



(a)



(b)

Figure 4-11 CASA CRSS 1194 SRF clamp band conical payload adapter system (Kompsat-2). (a) Side view. (b) Launch vehicle interface ring, detail.

Figure 4-12 Elongated conical payload adapter for the CASA CRSS 937 SRF clamp band.

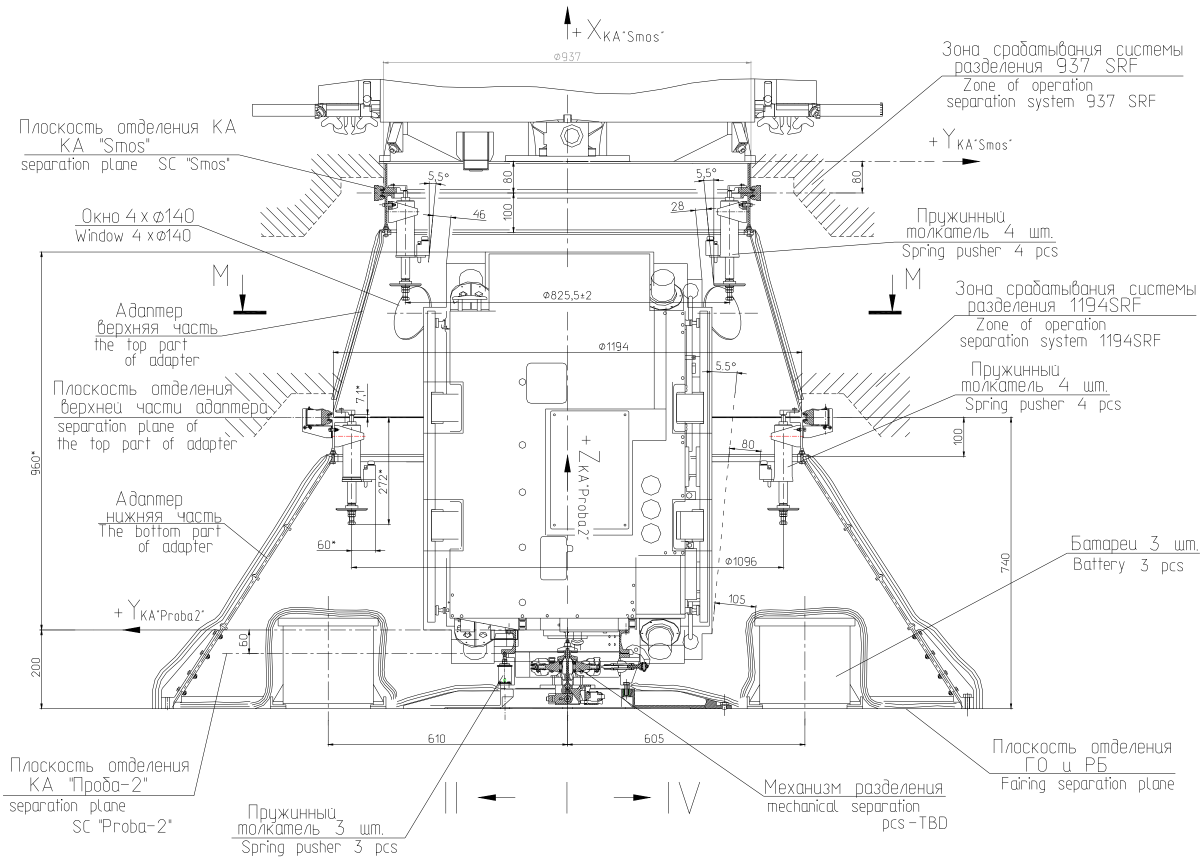


Figure 4-13 Example of base-mounted multiple satellite dispenser system for two spacecraft (SMOS/Proba-2).

4.1.5.2 Mechanical Lock System Payload Adapters

Payload adapters designed for use with the MLS separation system are individually configured to suit the particular spacecraft design. This customisation allows extremely lightweight and low height adapters to be realized. EUROCKOT and KSRC have designed, manufactured and successfully flown over two dozen systems of this kind for commercial Customers. These adapters are also well suited for multiple satellite accommodation.

The mass and height of the adapter depend on the final arrangement, i.e. dimensions of the spacecraft and number of attachment points. Spacecraft interface brackets that stay on the spacecraft after separation will have a mass of approximately 2 to 10 kg depending on mass and geometry of the spacecraft (Figure 4-8). Adapter heights as low as 100 mm can be realized.

An example of a single satellite adapter using the mechanical lock system is shown in Figure 4-14. It incorporates the mechanical lock separation components including pyro-actuator, rods, spring pushers, connectors and bonding provisions. The satellite is fastened to the launch vehicle payload adapter via four or three mechanical locks using four or three brackets at the base of each satellite. The number of attachment points depends on the satellite shape and mass. Separation is achieved by igniting the pyro-actuator which in turn rotates the mechanical locks via the mechanism rods releasing the spacecraft adapter frame. The spacecraft is then pushed away by spring pushers. Shock is not exerted directly on the spacecraft interfaces but on the parts of the mechanical drive, thus significantly attenuating the pyrotechnic shock levels at the spacecraft.

EUROCKOT is able to provide customised payload adapter and dispenser systems for multi satellite deployment upon Customer request. EUROCKOT and its parent company KSRC have significant experience in the design, manufacture and qualification of these systems. Figure 4-15 shows an example of a side-mounted multiple satellite dispenser. This particular system was designed and qualified for the NASA-DLR GRACE mission. The riveted aluminium structure incorporates the mechanical lock system described and allows two spacecraft to be accommodated side-mounted. Figure 4-16 depicts the multiple satellite dispenser developed for the ESA SWARM mission with the capability to attach and release three base-mounted spacecraft.

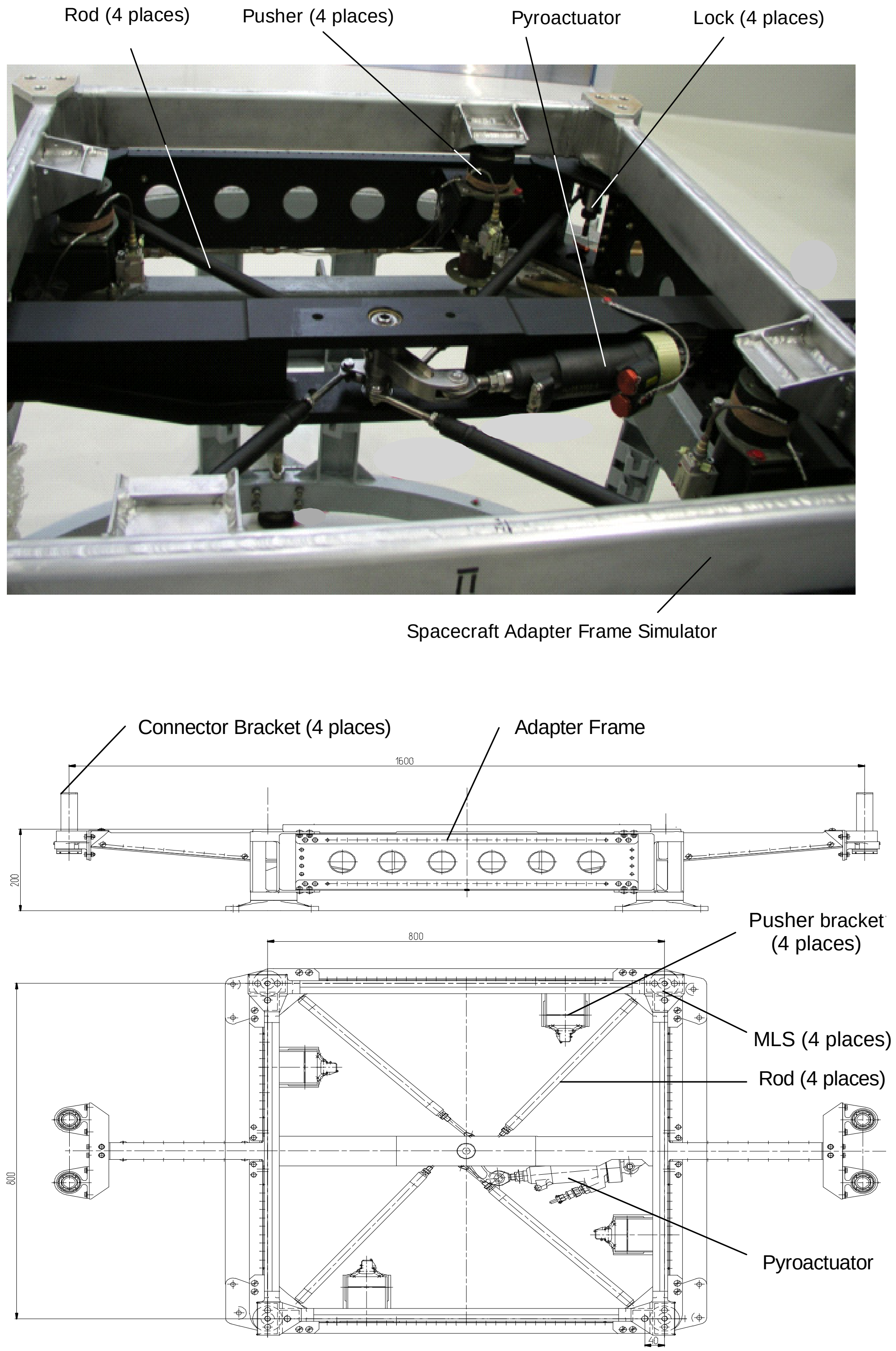


Figure 4-14 Example of an MLS adapter system for single satellite accommodation.

Figure 4-15 **Example of side-mounted multiple satellite dispenser system for two spacecraft (GRACE), only one spacecraft attached.**

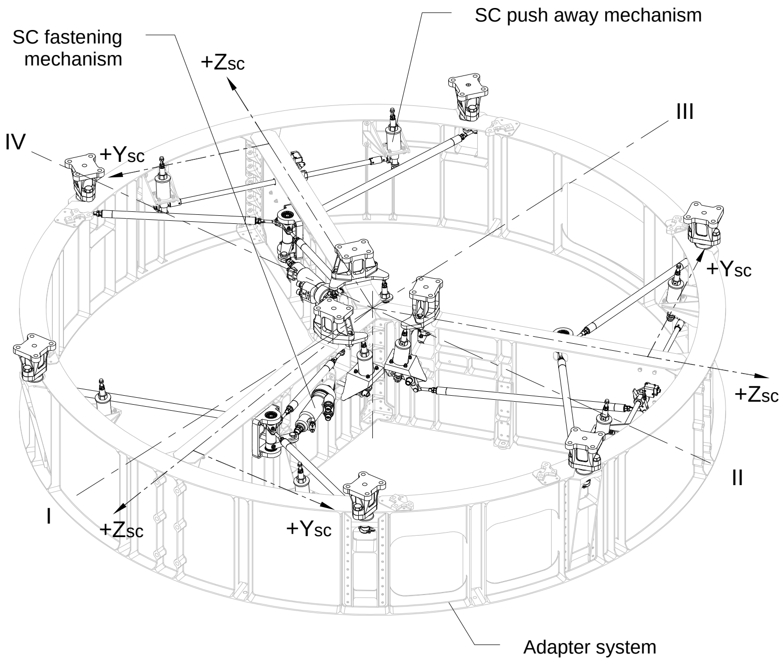


Figure 4-16 **Example of side-mounted multiple satellite dispenser system for three spacecraft (SWARM)**

4.2 Electrical Interfaces

This section describes the interfaces employed to provide electrical links between the spacecraft's umbilical connectors and the Customer's EGSE for spacecraft use. The electrical interfaces include the launch vehicle to spacecraft on-board electrical interfaces, EGSE interfaces, and telemetry/command links.

4.2.1 On-board Interfaces

The on-board electrical interfaces provide links from the spacecraft's umbilical connectors via the ground cable network to the spacecraft EGSE, including power circuits, checkout and control circuits, and telemetry and command links. Examples of the umbilical connector brackets that can usually be accommodated on the payload adapter are illustrated in Figure 4-17 and Figure 4-18. The brackets may vary in design depending on their location on the spacecraft and electrical connector types.

4.2.1.1 Umbilical Connectors

As a baseline EUROCKOT proposes the use of four 50-pin Russian connectors type OS RS50BATV. The connectors are mounted on the payload adapter by means of suitable brackets. Wires up to AWG 22 size with a cross section of 0.35 mm^2 can be accommodated by the OS RS50BATV connectors. The maximum permissible cross section area of the accommodated wire is 0.5 mm^2 on the condition that it is used via a pin and not more than 20 pins are used on the contact region connector perimeter. The number of connectors and number of pins per connector can be selected according to the Customer's needs. Hence, the spacecraft connector configuration shown in is only an example. Because of the potential impacts on the separation dynamics, alternative connector types have to be mutually agreed with EUROCKOT.

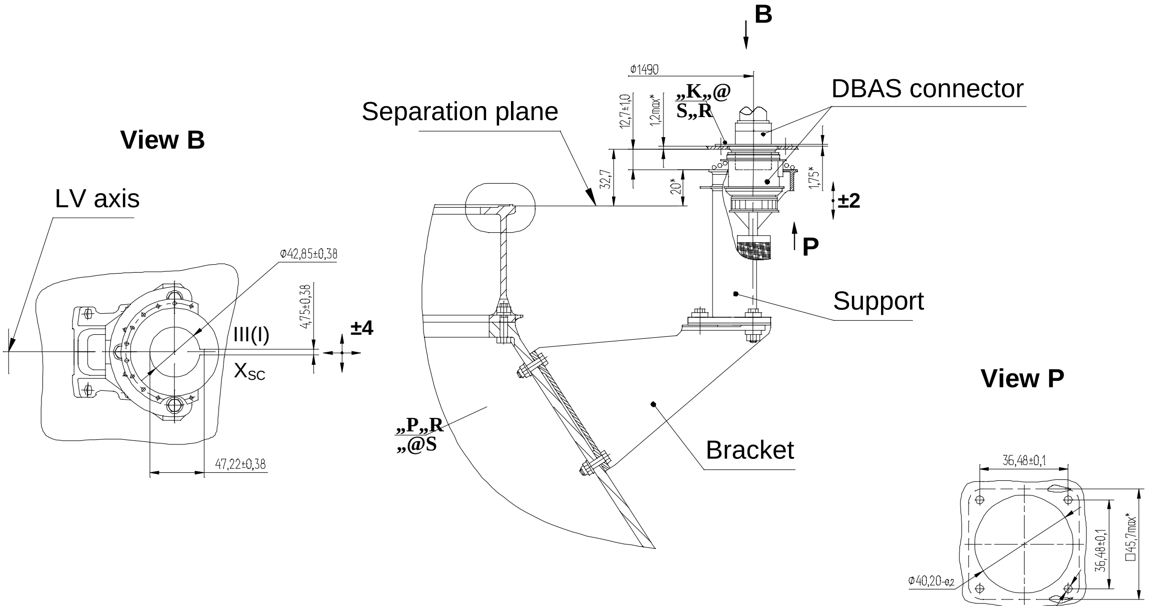
4.2.1.2 Separation Verification

The spacecraft manufacturer has to provide spacecraft separation monitoring circuits as jumpers in each of the spacecraft umbilical connectors for use by the launch vehicle telemetry. Separation monitoring circuits as jumpers on Launch Vehicle side are provided to be used by Spacecraft telemetry.

4.2.1.3 Interface Electrical Constraints

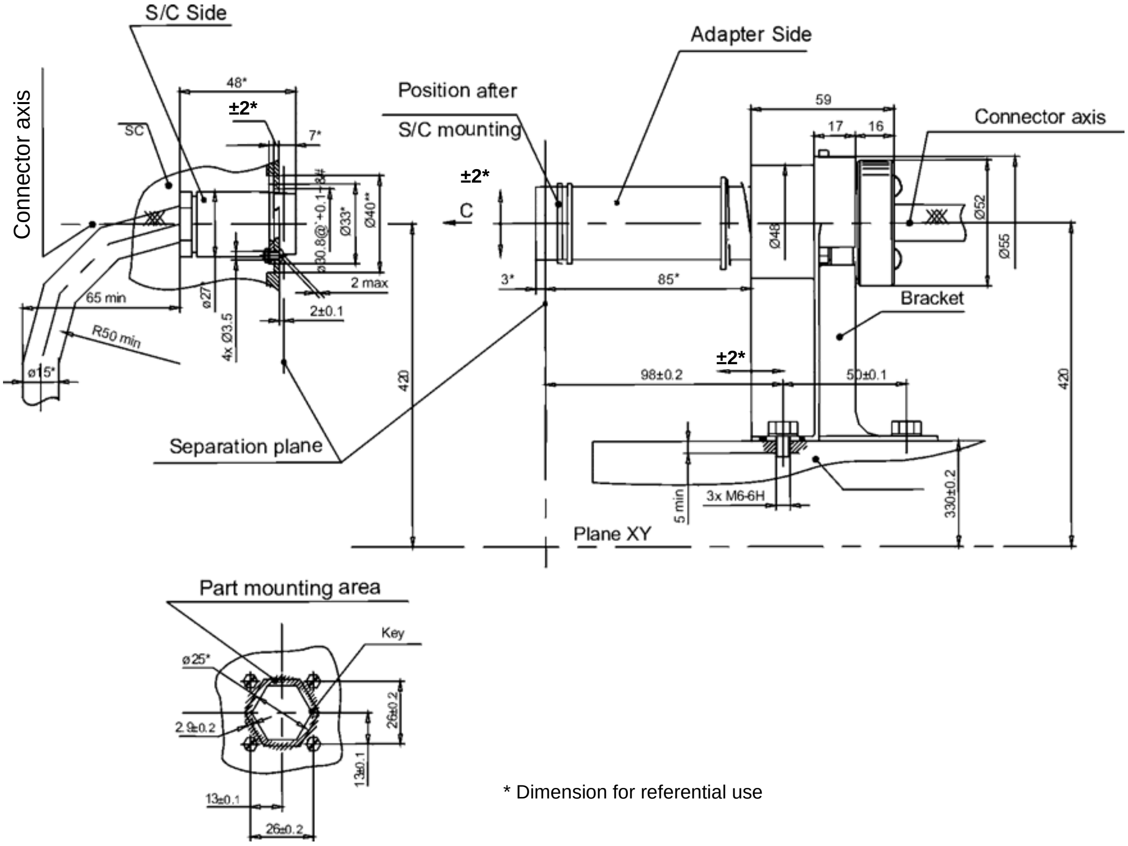
The following restrictions on the spacecraft to launch vehicle electrical interfaces will apply:

- The maximum voltage on the spacecraft umbilical connectors must not exceed 100 V. At lift-off, the transit cable must be de-energised both on the spacecraft and EGSE side, except for the separation jumpers.
- The EGSE provided by the spacecraft contractor must be designed to inhibit voltages above 100 V.
- GSE power through the spacecraft umbilical connectors must be switched off automatically if the nominal operating current is exceeded by 50% over a 0.2 s period. The EGSE supplied by the Customer must be designed so that it will cause automatic switch-off if the nominal operating current of the spacecraft lines exceeds 100% over a 0.1 s period.
- Not later than 20 s before spacecraft separation the current at spacecraft to launch vehicle interface should be limited to 100 mA, except for the separation jumpers.



* Dimension for referential use

Figure 4-17 **Typical example of an umbilical connector bracket used in combination with a 1194 mm clamp band.**



* Dimension for referential use

Figure 4-18 **Umbilical connector OSRS50BATV.**

4.2.1.4 Umbilical Harness Configuration and Specifications

The standard *Rockot* umbilical harnesses is schematically shown in Figure 4-19. Four spacecraft umbilical connectors 801 to 804 may accommodate up to 200 transit lines. Any telemetry channel for the monitoring of the spacecraft interface environment will share this budget of lines with the spacecraft. These lines lead to the connectors 811 and 813 of type OS 9R102 (OC 9P102) with 102 pins each. These connectors are mounted on the payload adapter / *Breeze-KM* interface. Telemetry circuits from the umbilical connectors 801 through 804 are routed into connector 840 and from there to the upper stage telemetry. From connectors 811 and 813 the circuits are routed into connectors ShR10 and ShR11 with 102 pins each on the *Breeze-KM* umbilical plate to the ground interface. The launch container plate accommodates electrical connectors of type OS RRM47 with 102 pins each.

The circuitry of the payload adapter harness from the spacecraft umbilical connectors 801 through 804 to connectors 811 and 813 is developed on the basis of the Customer’s input data and is payload-specific. Table 4-1 shows the pin allocation requirements. It is however limited by the capacities of the harness of the *Breeze-KM* that is specified in Table 4-2. The harness length from the spacecraft umbilical connectors 801 to 804 to connectors 811 and 813 depends on the payload adapter design.

The harness beyond the connectors 811 and 813 down to the spacecraft EGSE in Undertable Room 7 is standardised transit wiring via the upper stage and the stationary column. The wires are symmetrically distributed between the two umbilical cables. Wires of type MC-15-11-0.35 are used. The maximum operating voltage is 100 V on the spacecraft umbilical connectors, the maximum operating current is 1.5 A per transit wire. All transit wires have a 0.35 mm^2 cross-section. The total length of the on-board transit lines from connectors 811 and 813 on the *Breeze-KM* pressurised equipment bay to connectors ShR010 and ShR011 on the container plate is less than 18 m.

Neglecting the resistance of the payload harness, the resistance of the on-board cable network from spacecraft connectors 801 through 804 to the connectors on the plate of the launch container ShR010 and ShR011 is not more than 1 Ohm. The shields of the twisted pairs and single shielded wires are isolated from the cable jackets and launch vehicle connector shells and terminated at the appropriate electrical connector pins.

The insulation resistance of the transit lines should be at least 10 MOhm.

A high reliability is ensured by:

- Highly reliable components operated in a derated mode
- Verified service life margins as to operating time, storage time and number of actuations
- Verified robustness and environmental resistance margins

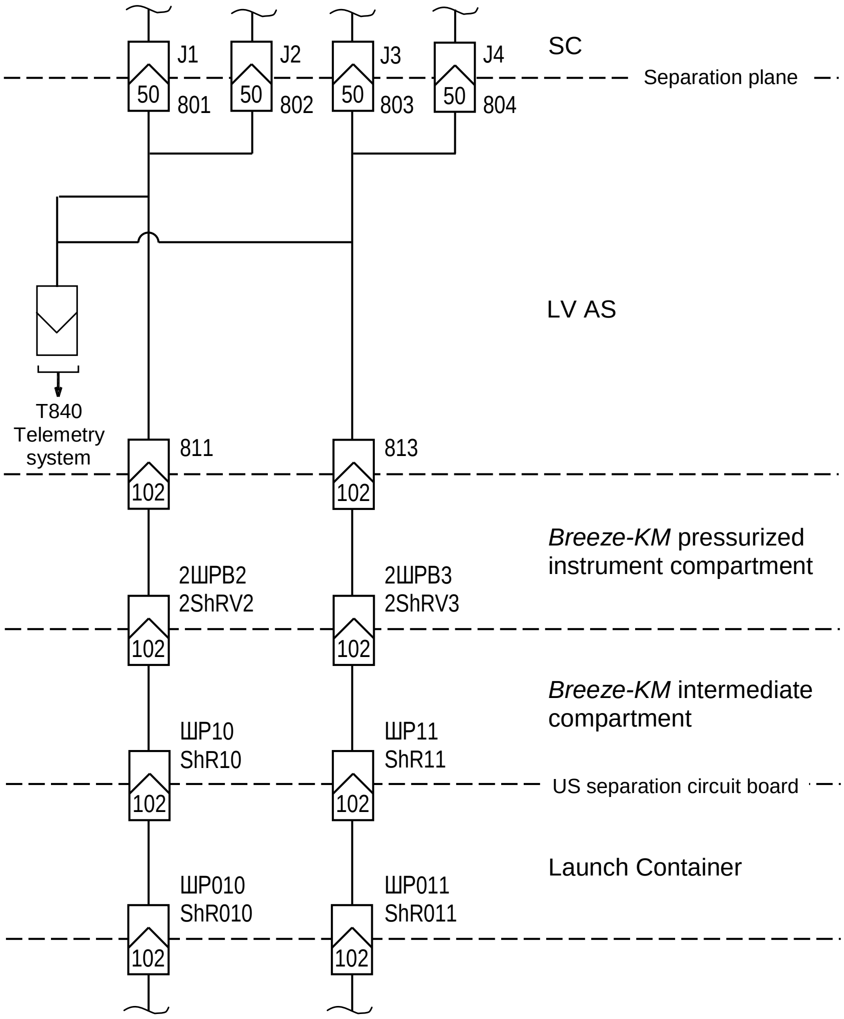


Figure 4-19 ***Rockot*** **umbilical harness diagram.**

Pin No.	Signal designation or type	Max. voltage, V	Max. current, A	Max. Resistance, Ohm	Line start (Source)	Line end	Specific require-ments	Powered or signal
	example of table to be filled in by the Customer during the mission integration process							

1. In the column “Specific requirements” please specify:
   - Single, non shielded wire twisted shielded pair.
   - With what umbilical electrical connector pin does it combine to make twisted shielded pair?
   - For jumpers on the spacecraft or launcher side side, with what umbilical electrical connector pin does it combine to make a jumper?
2. The resistance values specified by the Customer apply from the spacecraft to umbilical connectors through the Customer EGSE in Undertable Room 7.

Table 4-1 **Pin allocation of umbilical connectors.**

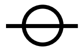
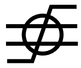
Transit wire type	Quantity	Total transit wires	Wire cross section, mm^2 Flight harness	Ground harness	Note
Single, no shield	100	100	0.35	2.5	
Single shielded	30	30	0.35	1.5	
Twisted shielded pairs	34	68	0.35	2.5	
Shield	2	2	0.35	>1.5	
Total:		200			

Table 4-2 Ground wiring capacities.

4.2.1.5 Matchmate / Electrical Checkout

The Matchmate and electrical checkout between the spacecraft interface and the payload adapter is strongly recommended and should preferably be conducted at the spacecraft manufacturer's facility.

4.2.1.6 Spacecraft Electrical Interface Input Data Requirements

For the purpose of *Rockot* mission adaptation, the Customer shall provide input data containing specifications for each transit wire line per umbilical connector, as shown in Table 4-1.

4.2.2 Ground Electrical Interface

The ground wiring is designed to interface between the launch vehicle on-board harness and the spacecraft EGSE located in Undertable Room 7.

The ground wiring will only be used to support payload electrical testing or other operations involving the spacecraft EGSE, as well as upper composite integration and mating with the launch vehicle at the processing facility.

Serving as an electrical extension of the launch vehicle on-board harness (and Figure 4-20), the ground wiring is consistent with all electrical characteristics as applicable to the spacecraft on-board equipment lines. The ground wiring length is approximately 65 m from electrical connectors ShR010 and ShR011 to electrical connectors X1-1, X2-1, X3-1, X4-1. The total number of ground wires to support the spacecraft on-board equipment and the spacecraft EGSE is 200. The configuration of the ground harness is identical to the harness installed on the *Breeze-KM* (Table 4-2).

The ground wiring can be terminated with any electrical connector as required for the spacecraft EGSE interface in Under-table Room 7.

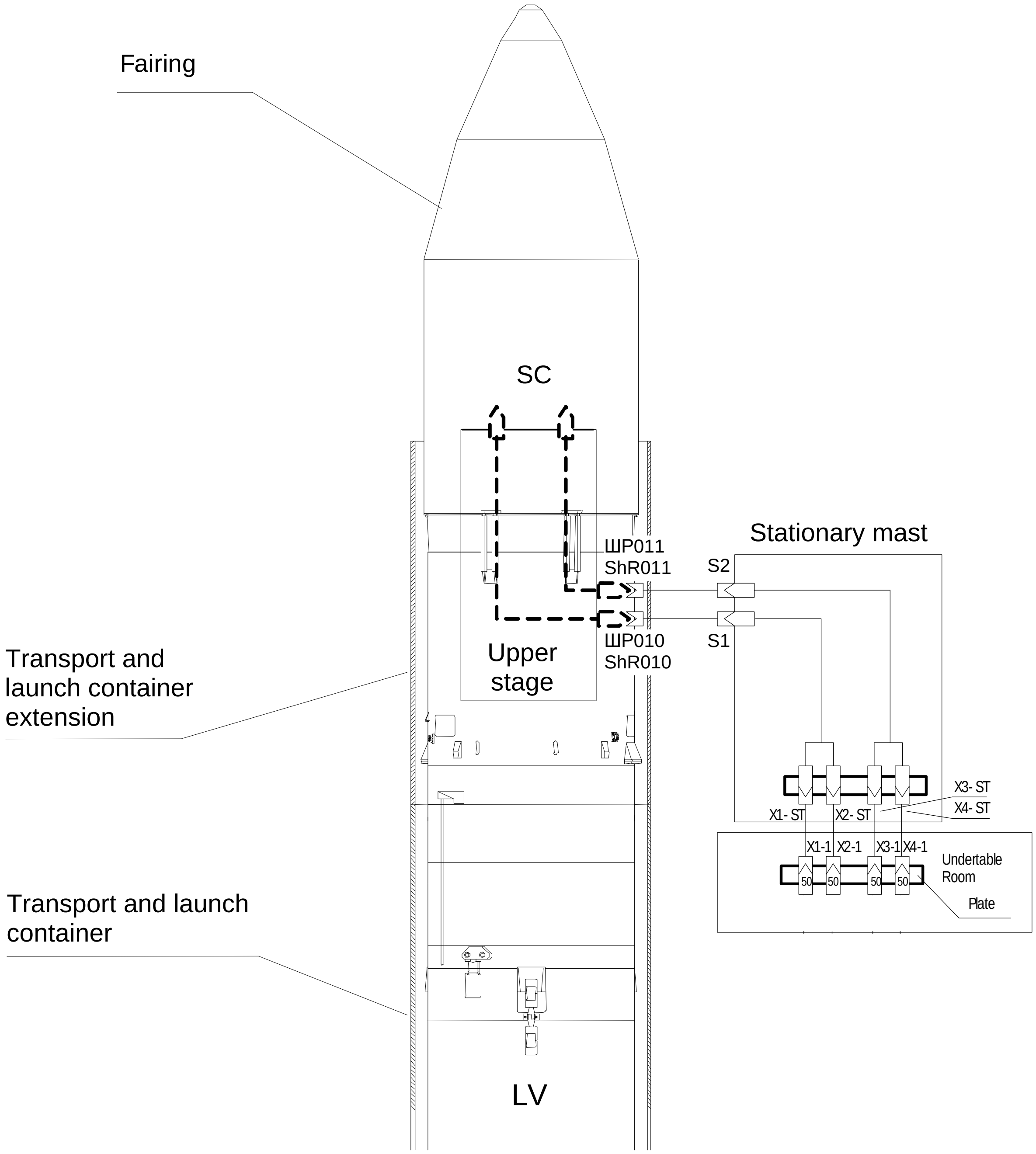


Figure 4-20 Launch site ground wiring diagram.

4.2.3 Payload Grounding and Bonding

A passive approach is employed to protect the upper composite from hazardous static build-up. This approach includes bonding, creation of conductive surfaces, and grounding of the upper composite. The goal of the three techniques is

- to reduce the voltage potential between any two structural elements to a safe level,
- to ensure more effective cable shielding in order to eliminate any electrostatic discharge (ESD) risk for the personnel, and
- to reduce the voltage difference between the upper composite or any of its components and the ground to zero.

The upper composite is designed

- to have no outer surface areas with voltage drops equal to the threshold beyond which a hazardous electrostatic discharge becomes possible,
- to ensure reliable electrical bonding of all metal elements of the structure so that a common reference, or a common electrical mass will be created,
- to ensure that any charge that may build up on an outer conductive surface of a dielectric component will leak a way to the common reference, and
- to enable grounding of the upper composite during integration, testing, fuelling, and transportation.

The usage of conductive coatings on the mating surfaces of the spacecraft and the adapter system should be as defined below:

- Alodine 1200 conductive coating on the spacecraft side
- SECO electro conductive oxidizing on the adapter system side
- The transient resistance should not exceed 10 mOhm.

The upper composite ESD control is implemented by:

- the use of external surface materials with a volume resistivity of less than 10^5 Ohm · m,
- coating non-conductive materials with conductive layers to be bonded to the metal structure,
- the use of a conductive film, foil, grid or fabric to create a conductive outer surface in a dielectric,
- bonding each spacecraft to the dispenser/adapter by means of two umbilical straps,
- bonding any upper composite component with at least two points separated by the maximum possible distance, and
- electrically interconnecting all layers of each multi layer insulation blanket by bonding each blanket to the metal structure.

To prevent ESD, shield braiding and transit cable connector bodies should be connected to the launch vehicle.

On the pad, the upper composite is grounded via the launch vehicle metal structure. For this purpose, the spacecraft is connected to the adapter or dispenser via bonding straps or a conductive coating applied on the spacecraft and adapter mating surfaces. The adapter system in turn is connected to the upper stage / launch vehicle via bonding straps. Two detachable bonding straps or a conductive coating is applied to the spacecraft and adapter system mating surfaces to ensure adequate electrical contact between the spacecraft and the dispenser.

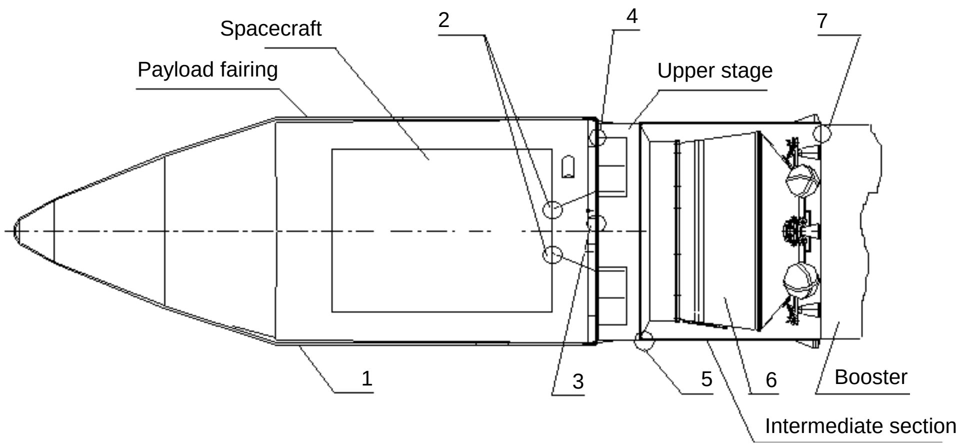
For this purpose, the spacecraft is required to have an "earth" reference point close to the separation plane, on which a bonding strap can be mounted. The contact resistance at the bonding points is required to be less than 3×10^{-3} Ohm.

A grounding point is envisaged at the upper composite for grounding the upper composite in the course of manufacturing, processing, handling and transportation.

The resistance across the interface at any bonding or grounding point must not exceed 2×10^{-3} Ohm.

Upper composite ESD control is achieved as shown in the bonding / grounding schematic in Table 4-3.

The upper composite will be protected from direct lightning hits by the launch facility lightning protection system.



Components to be bonded	Recommended bonding technique	Number of bonding points	Comments
1 Payload fairing	Continuous conductive coating		Entire surface
2 Spacecraft/Adapter	Detachable straps	2	
3 Dispenser/equipment bay	Non-detachable straps	2	
4 PLF halves/upper stage	Detachable straps	2	
5 Intermediate section / upper stage	Detachable straps	2	
6 Upper stage	Continuous conductive coating		Entire surface
7 Intermediate section / booster stack	Non-detachable straps	4	

Table 4-3 Bonding / grounding schematic drawing; example of a dispenser configuration.

4.2.4 Payload Auxiliary Power Supply

4.2.4.1 Ground Auxiliary Power Supply

An uninterruptible power supply (UPS) is provided for the spacecraft EGSE. Please refer to Chapter 10 for further details.

4.2.4.2 In-flight Power Supply

At launch and in flight up to payload deployment, the payload can be supplied with power from the batteries of the upper stage as an optional service. The payload can be supplied with:

- Power (non-stabilised) with 24 to 30 VDC (voltage spikes of +/- 3 V might be encountered within this range), in duration of up to 50 ms
- Maximum power supply 15 Ah for 7 hours with not more than 5 A

4.2.4.3 Optional Services

For a customer-supplied separation system power supply can be provided as an option, with the following characteristics:

- Voltage: 28 VDC
- Current: pulse of 10 A and 30 ms duration for up to 10 pulses

4.2.5 Separation Ignition Command

Discrete sequencing commands, generated by the *Rockot* on-board computer, are available to the payload during the payload injection phase.

The number of command lines provided for the payload, as well as the signal characteristics, will be defined in detail in the Interface Control Document. Discrete lines are provided through the same type of interface connector as used for the payload auxiliary power lines.

The pyrotechnic command for spacecraft separation is a standard provision.

4.2.6 Payload Telemetry Support

The *Rockot* on-board telemetry system comprises a low rate telemetry device TA1 and a high rate telemetry device TA2. TA1 can operate up to end of *Breeze-KM* operation in three modes:

- DT: Direct transmission
- REC: Data record
- REP: Data replay

REC is used for the flight phases without visibility to downlink the data in the subsequent visibility phase in the REP mode. The total storage capacity of TA1 is 64 Mbit.

The following channels in the TA1 system are assigned to the payload:

- 24 event channels with 1 bit
- 20 analogue channels with 8 bit resolution
- 10 temperature channels with 8 bit resolution

The maximum data sampling and downlink data rates depend on each other and on the operating mode as listed in Table 4-4 and Table 4-5.

TA1 also registers and transmits the status signals of the payload separation. The separation signals are generated by the LV separation detection devices.

TA2 operates up to the second stage separation in a direct downlink transmission mode with a maximum data transmission rate of 320 kBit/s. The following channels are assigned for payload needs:

- Three channels, each with 8000 Hz sampling rate
- Five channels, each with 500 Hz sampling rate

TA1 and TA2 can provide channels for the data acquisition from the payload adapter or dispenser re-allocated within the overall limits as specified above.

Operating mode	Data transmission rate, kBit/s	Sampling rate, Hz			Time of mode realization
		event channels	analogue channels	temperature channels	
DT 1	256	50	50	0.4	on LC, in flight
DT 2	32	6.25	6.25	0.05	after SC separation
REC 1	256	50	50	0.4	in flight
REC 2	32	6.25	6.25	0.05	in flight
REC 3	4	0.78	0.78	0.006	in flight
REP 1	256	as recorded in REC 1-3			in flight
REP 2	32	as recorded in REC 1-3			in flight

Table 4-4 Operational parameters of the telemetry system TA1.

Operating mode	Data transmission rate, kBit/s	Time of mode realization
DT	320	in flight until second stage separation

Table 4-5 Operational parameters of the telemetry system TA2.

Chapter 5 Spacecraft Environmental Conditions

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5 Spacecraft Environmental Conditions

This section describes the environment to which the spacecraft is exposed during the launch site operations and its transport into orbit with the *Rockot* launcher as well as accelerations occurring during ground transportation and handling.

5.1 Mechanical Environment

5.1.1 General

During flight, the payload is subjected to static and dynamic loads induced by the launch vehicle. Such excitation may be of aerodynamic origin, especially wind and gusts, buffeting in the transonic flight regime, or may be due to loading induced by the operation of the propulsion systems due to longitudinal acceleration, thrust build-up or tail-off transients, structure-propulsion coupling, attitude control operation, etc.

The various types of mechanical environment experienced by the payload are described in the following paragraphs. Typical data are given for sine, random and shock environments. If not explicitly stated, all mechanical loads are defined as maximum operational loads. They are estimated with 90% confidence and their levels will not be exceeded in 99% of all flights. For different dispenser types, dedicated environments have to be defined on a case-by-case basis.

For the launch vehicle and payload coordinate system refer to Figure 5-1.

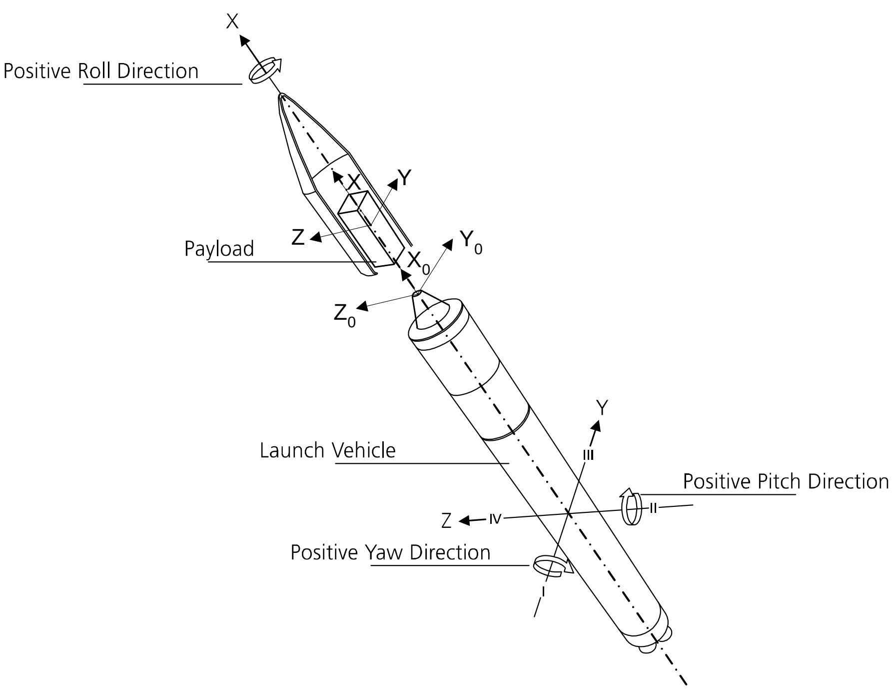

Figure 5-1 Launch vehicle and payload coordinate system.

The spacecraft coordinate system without index may be selected with the origin at the CoM of the spacecraft or in the attachment plane and with axes parallel to the launch vehicle coordinate system, if the satellite is clocked orthogonally. The orbital block coordinate system with the index "O" is a useful tool for the definition of the loads and performance of the coupled loads analysis (CLA). Its origin lies in the *Breeze-KM* / payload adapter interface plane. The *Y* and *Z* axes concur with the launch vehicle stabilisation axes III and IV respectively.

5.1.2 Quasi-Static Accelerations

During ascent, the payload will experience dynamic loads generated by

- the operating launch vehicle propulsion unit,
- the aerodynamic forces appearing as the launch vehicle traverses dense atmospheric layers, and
- the operating launch vehicle navigation system.

The low-frequency or quasi-static component of dynamic loading, which is the frequency component below 100 Hz is used as the dimensioning factor when selecting technical solutions aimed at ensuring adequate strengths of the payload and adapter system structures.

Figure 5-2 and Figure 5-3 show typical low-frequency spacecraft interface accelerations during powered flight of stages 1 and 2. Payload accelerations during powered flight of the upper stage are much smaller and, thus, of no concern for the structure’s load capability.

Quasi-static loads experienced by the spacecraft are largely determined by the spacecraft mass and stiffness properties. The loads given in Table 5-1 can be used as preliminary dimensioning inputs to the design of the spacecraft. These loads are the worst-case limit loads that do not necessarily apply to any spacecraft. Instead, they are obtained for an average spacecraft and shall be subject to updates by a dedicated CLA for each particular mission.

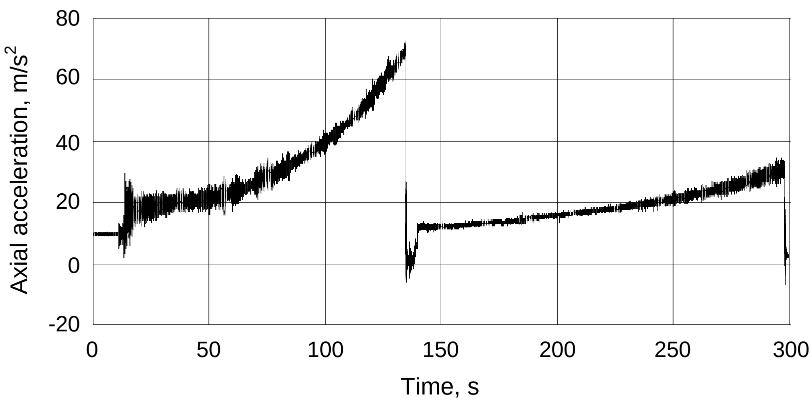

Figure 5-2 Typical axial payload interface acceleration.

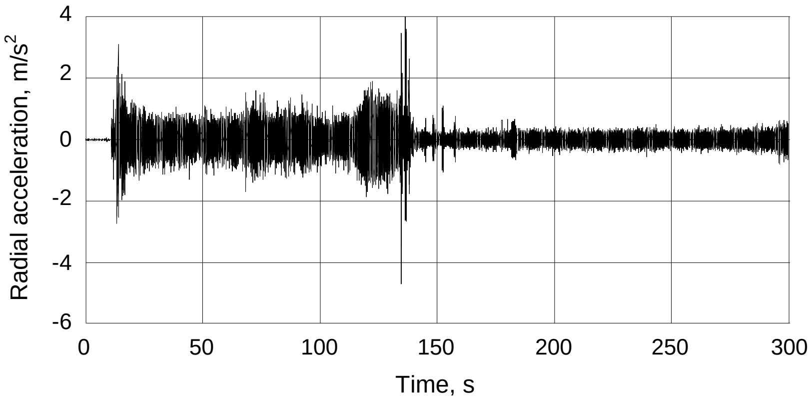

Figure 5-3 Typical radial payload interface acceleration.

Seq.	Event	axial, g		radial, g
		max	min	
1	Lift-off	+ 3.6	0	± 0.7
2	Worst-case dynamic pressure q_{max}	+ 2.8	+ 2.4	± 0.9
3	Peak stage 1 thrust P_{max}	+ 8.0	+ 6.2	± 0.5
4	Worst-case axial stage 1 structural acceleration n_{Xmax}	+ 8.1	+ 6.3	± 0.5
5	Stage 1 shutdown	+ 8.1	– 1.5	± 0.7
6	Stage 2 powered flight	+ 3.0	0	± 0.4
7	Upper stage powered flight	+ 1.6	0	± 0.4

Note:
1) "+" means compression, "-" means tension
2) Axial and radial loads may exist simultaneously.

Table 5-1 Quasi-static loads experienced by an average payload during ascent.

5.1.3 Low Frequency Vibration

The low frequency longitudinal and lateral vibration environment spectra experienced at the spacecraft separation plane are presented in Table 5-2 and Figure 5-4 respectively.

Frequency, Hz	Acceleration, g	
	Longitudinal	Lateral
5 - 10	0.8	0.5
10 - 20	0.8 - 1.2	0.5
20 - 40	1.2 - 0.8	0.5
40 - 100	0.8	0.5

Table 5-2 Low frequency vibration environment.

These values are subject to revision after the performance of a CLA with a dedicated structural mathematical model of the spacecraft.

A notching to design loads can be allowed based on controller data at the adapter interface to the spacecraft or at the interface to *Breeze-KM* whichever is more critical.

For test approaches and factors please refer to chapter 6.

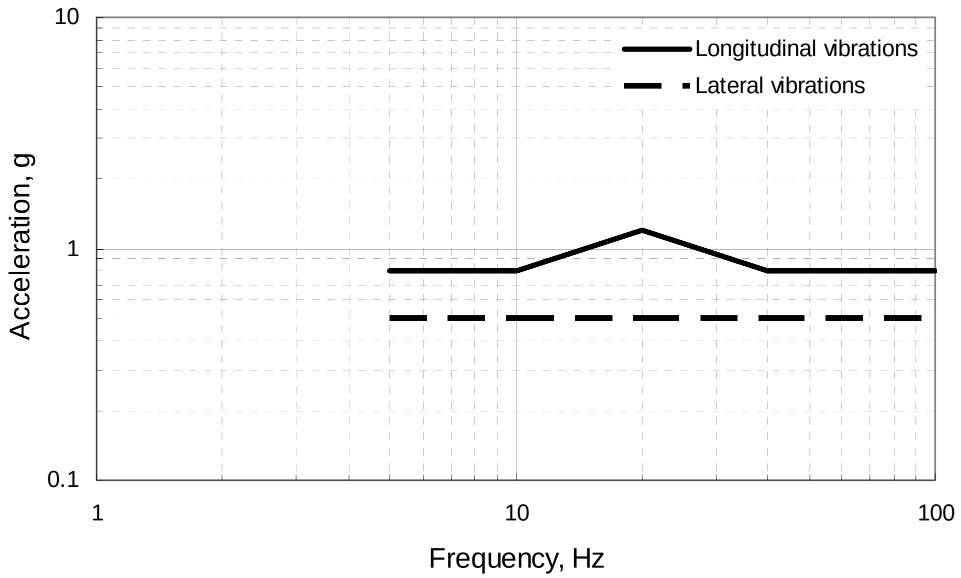

Figure 5-4 Low frequency vibration environment at the separation plane.

5.1.4 Acoustic Noise

The spacecraft is exposed to an acoustic environment throughout the boost phase of flight until the vehicle is out of the atmosphere. Acoustic noise is generated by engine noise, buffeting and boundary layer noise. The level is highest at lift-off (137.9 dB OASPL) and in the transonic phase (135 dB OASPL) with a RMS reference pressure of 2×10^{-5} Pa = 0 dB. Noise is substantially lower outside these periods.

The composite noise spectrum at lift-off is given in Figure 5-5 and Table 5-3. The given spectra reflect the guaranteed upper limit, including the worst case fill factor for spacecraft within the payload fairing. The composite duration is 10 seconds.

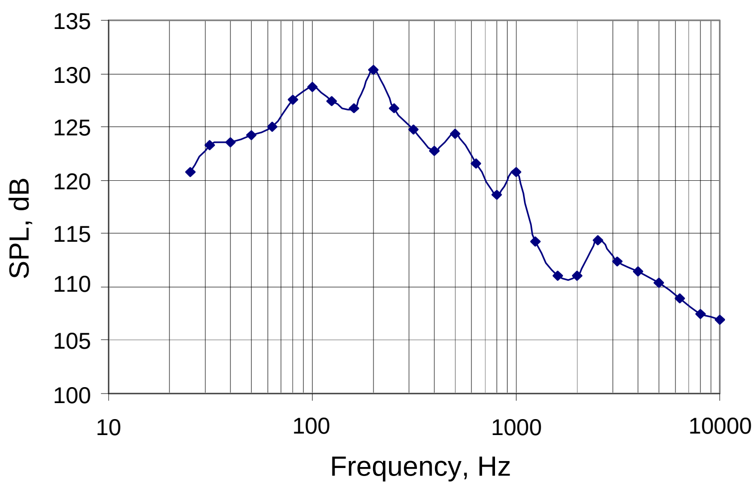

Figure 5-5 Composite noise spectrum under the *Rockot* payload fairing during flight given in 1/3 octave band referenced to 2×10^{-5} Pa RMS.

1/3 octave band centre frequency, Hz	Sound pressure level, dB
25	120.7
31.5	123.3
40	123.5
50	124.2
63.5	125.0
80	127.4
100	128.7
125	127.4
160	126.8
200	130.4
250	126.7
315	124.7
400	122.8
500	124.4
630	121.5
800	118.6
1000	120.7
1250	114.3
1600	111.1
2000	111.1
2500	114.4
3150	112.4
4000	111.4
5000	110.4
6300	108.9
8000	107.4
10000	106.9
OASPL	137.9

Note:
- The acoustic loads are referenced to the RMS acoustic pressure of 2×10^{-5} Pa
- Test duration and factors are defined in chapter 6
- Composite duration is 10 seconds

Table 5-3 Composite noise spectrum under the fairing during flight.

5.1.5 Random Vibration

Random vibration is mainly generated by the acoustic noise field under the payload fairing and is also transmitted via the launcher structure. Random accelerations excited by the launch vehicle engines can be neglected for spacecraft design. The random vibration depends on specific payload configuration, e.g. fill factor, payload adapter, payload surfaces. Therefore a generic random vibration environment is not defined here. In the case of small compact satellites it may be more convenient to perform a random vibration test. In this particular case, the customer is asked to contact EUROCKOT directly for definition of the appropriate random vibration test levels.

5.1.6 Shock

The spacecraft is subjected to a shock environment during separation of the fairing and launch vehicle components as well as spacecraft separation.

The shock levels at the spacecraft separation plane experienced during the separation from the *Breeze-KM* upper stage are associated with the separation system selected (section 4.2).

The shock levels are also dependent on the pre-tension of the bolts for the MLS system or the pre-tension of the band for the clamp band systems. Pre-tensions are determined according to the spacecraft and interface characteristics such as spacecraft CoM and interface diameter in relation to the separation system following qualified standards. Table 5-4 and Figure 5-6 show the shock specifications for the fairing separation as well as the MLS and EADS CASA clamp band systems with typical pre-tensions.

For detailed information for other sizes, special pre-tensions and low shock systems, please contact EUROCKOT.

Shock loads are defined as worst value applicable to all three axes and they act simultaneously. For clamp band systems the shock loads are measured in radial, tangential directions to the clamp band and normal to the separation plane. Please note that the second stage separation shock levels are lower than the specifications given here, thus not to be considered in the shock environment.

Frequency, Hz	Acceleration, g (SRS, Q=10)				
	Fairing Separation**	Mechanical Lock System*	CASA CRSS 937 SRF*	CASA CRSS 1194	Small satellite separation system
100	50	50	80	80	40
700	700	800	1000	1000	400
1000	1000	2000	1800	1800	600
1500	1000	2000	2800	2800	
2000	1000		2800	2800	1500
4000	1000	4000	2800	2800	
5000	1000	4000			
6000	1000				1800
10000	1000	2000			1800

* Shock values for separation systems are measured 40 mm above the separation plane.

** Fairing separation shock is defined at the base of the payload adapter. Hence, for taller payload adapters shock at the spacecraft to adapter interface plane will be lower.

Table 5-4 Typical shock environment for diverse separation systems.

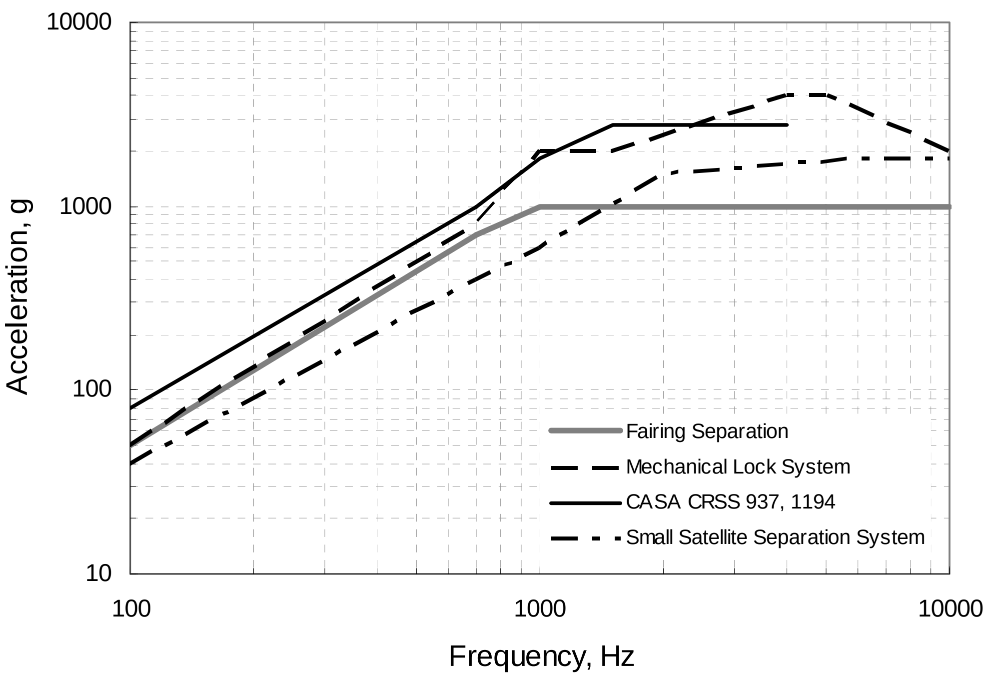

Figure 5-6 Typical shock environment for diverse separation systems.

5.1.7 Loads during Ground Operations

This section presents the ground loads the spacecraft or its container is subjected to on the EUROCKOT standard ground transportation route from the port-of-entry Archangel Talagi Airport to Plesetsk Cosmodrome by lorry and railway. The right-handed co-ordinate systems used for the different ground operations are defined in Figure 5-7and Figure 5-8. All loads that are specified in this section are 3 sigma values with 90% confidence. The accelerations during the transportation are defined for wind velocities less than 20 m/s.

Section 5.1.7.1 provides the maximum handling loads to be expected on the spacecraft container. Section 5.1.7.2 contains the loads given for spacecraft container transportation with a railway wagon as per the co-ordinate definitions in Figure 5-7. Similarly, section 5.1.7.3 provides loads for short duration truck transport from the Archangel airport to the railhead in Plesetsk and within the Cosmodrome, if applicable. Finally, section 5.1.7.4 provides the loads on the spacecraft during railway transportation to the launch pad as part of the *Rockot* launch vehicle upper composite. The specific measurement plan and positions of the instrumentation (Figure 5-7, Figure 5-8) can be customised for each customer's individual project.

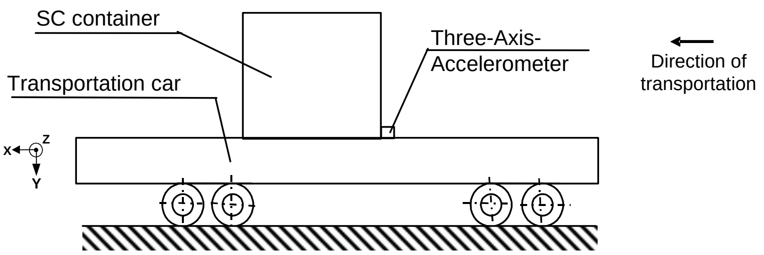

Figure 5-7 Transportation of the spacecraft in the spacecraft container.

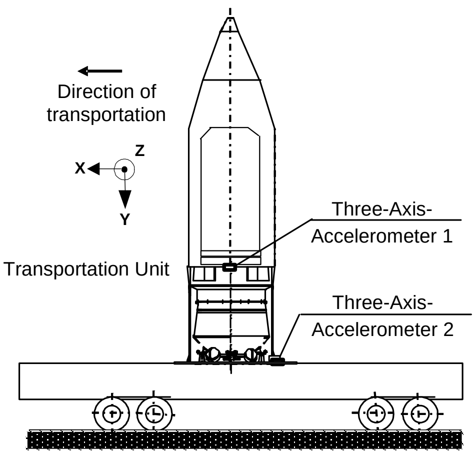

Figure 5-8 Spacecraft transportation as part of the upper composite.

5.1.7.1 Handling Loads During Ground Operations

The maximum handling loads acting at the spacecraft CoM during the ground operations, e. g. hoisting, are presented in Table 5-5. While the gravity acceleration acts continuously in the vertical direction, other operational loads may act simultaneously along the other directions.

Quasi-static loads		
Vertical direction	Lateral directions	Safety factor
1±0.5	±0.3	1.5

Table 5-5 Maximum handling loads.

5.1.7.2 Spacecraft Container Railway Transportation Loads

The location of the accelerometers and the co-ordinate system for the load measurement during the spacecraft container transport by railway are defined in Figure 5-7. The loads for railway transportation from Archangel to Plesetsk are defined in Table 5-6, Table 5-7 and Figure 5-9.

Direction	Amplitude, g	Impulse duration, s	Number of loads
X	1.0	0.16 - 0.035	100
Y	1.0		
Z	0.5		

Note: The impulse form can either be a triangle or half-sine.

Table 5-6 Shock loads during autonomous railway transportation.

Fre-quency, Hz	Power spectral density, g²/Hz direction		
	X	Y	Z
2	1.5E-4	7.5E-4	6.0E-4
4	8.0E-4	1.0E-2	8.0E-4
8	3.0E-3	1.0E-2	1.0E-3
10	1.0E-3	1.0E-2	3.0E-3
14	8.0E-4	3.0E-3	1.0E-3
20	8.0E-4	1.0E-3	1.0E-3
25	8.0E-4	8.0E-4	1.0E-3
30	8.0E-4	1.5E-3	1.0E-3
35	1.2E-3	8.0E-4	1.0E-3
40	4.0E-4	6.0E-4	1,5E-4
45	4.0E-4	4.3E-4	1.5E-4
50	4.0E-4	2.8E-4	1.5E-4
Time, min	420	420	420

Table 5-7 Random vibration power spectrum acting at spacecraft container base during autonomous railway transportation.

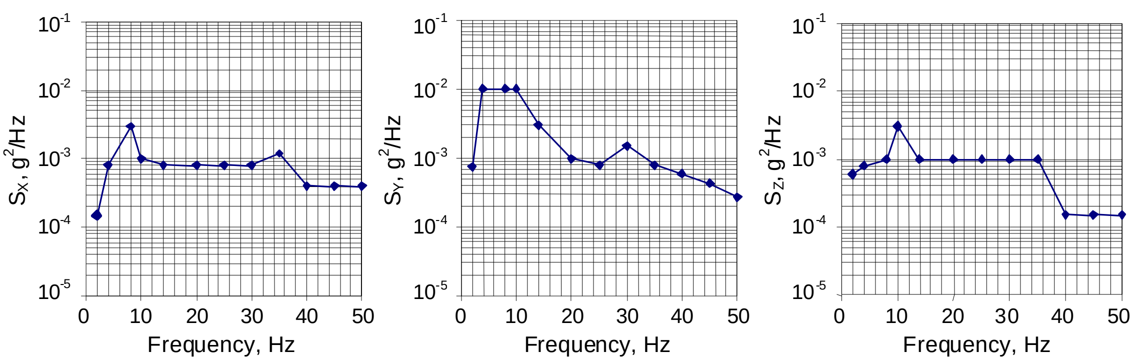

Figure 5-9 Random vibration power spectrum acting at spacecraft container base during autonomous railway transportation.

5.1.7.3 Roadway Autonomous Transportation in Archangel and Plesetsk Cosmodrome

The quasi-static acceleration loads for the short duration roadway transportation in Archangel are defined Table 5-8, and Figure 5-10. The random vibration loads are defined in Table 5-9. These spectra apply also to the short road transportation at the launch site in the Plesetsk Cosmodrome. The reference coordinate system definition given in Figure 5-7 also applies to the roadway autonomous transportation.

Quasi-static accelerations, g			Safety factor
X	Y	Z	
±1.0	1±1.0	±0.5	1.5

Note: For transportation regimes the loads are applied according to the coordinate system of the transportation system. The loads may apply at the same time on axes X, Y and Z.

Table 5-8 Quasi-static accelerations for autonomous roadway transportation at wind velocities ≤ 20 m/s.

Frequency, Hz	Power spectral density, g^2 Hz direction		
	X	Y	Z
2	5.0E-5	7.0E-4	4.0E-4
4	1.2E-4	3.0E-3	5.5E-4
8	3.0E-4	3.0E-3	7.0E-4
10	3.0E-4	3.0E-3	7.0E-4
14	3.0E-4	3.0E-3	7.0E-4
20	1.0E-4	4.0E-4	3.0E-4
25	4.0E-5	1.5E-4	1.0E-4
30	1,3E-5	5.0E-5	4,5E-5
35	6.0E-6	2.0E-5	2.0E-5
40	3.0E-6	1.0E-5	1.0E-5
45	2.0E-6	6.0E-6	6.0E-6
50	1.0E-6	3.2E-6	3.2E-5
Time, min	10	10	10

Table 5-9 Random vibration power spectrum for autonomous roadway transportation.

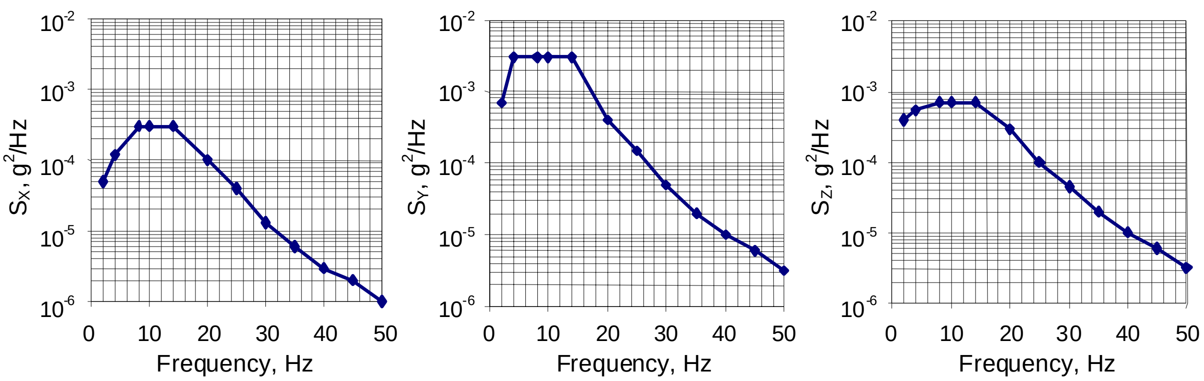

Figure 5-10 Random vibration spectrum for autonomous roadway transportation.

5.1.7.4 Loads during Transport in Upper Composite

The location of the accelerometers and the co-ordinate system for spacecraft transport within the upper composite are defined in Figure 5-8. The upper composite is transported over a distance of 7 km at 3 to 5 km/h. The corresponding loads are defined in Table 5-10, Table 5-11 and Figure 5-11. The loads may act simultaneously in the respective axes.

Quasi-static accelerations ,g			Safety factor
X	Y	Z	
±1.0	1±0.5	±0.3	1.5

Table 5-10 **Accelerations during upper composite transportation at wind velocities ≤ 20 m/s.**

Frequency, Hz	Power spectral density, g^2 /Hz direction		
	X	Y	Z
2	6.0E-5	6.0E-5	1.2E-4
4	2.0E-4	1.0E-4	1.5E-4
8	4.5E-4	5.0E-4	2.0E-4
10	1.5E-4	5.0E-4	3.0E-4
14	1.2E-4	5.0E-4	1.0E-4
20	1.2E-4	1.5E-4	1.0E-4
25	1.2E-4	1.2E-4	1.0E-4
30	1.2E-4	1.5E-4	1.0E-4
35	2.0E-4	1.1E-4	1.0E-4
40	1.5E-4	1.0E-4	3.7E-5
45	1.0E-4	8.3E-5	3.7E-5
50	1.0E-4	7.5E-5	3.7E-5
Time, min	18	18	18

Table 5-11 **Random vibration power spectrum acting on the spacecraft during upper composite transportation**

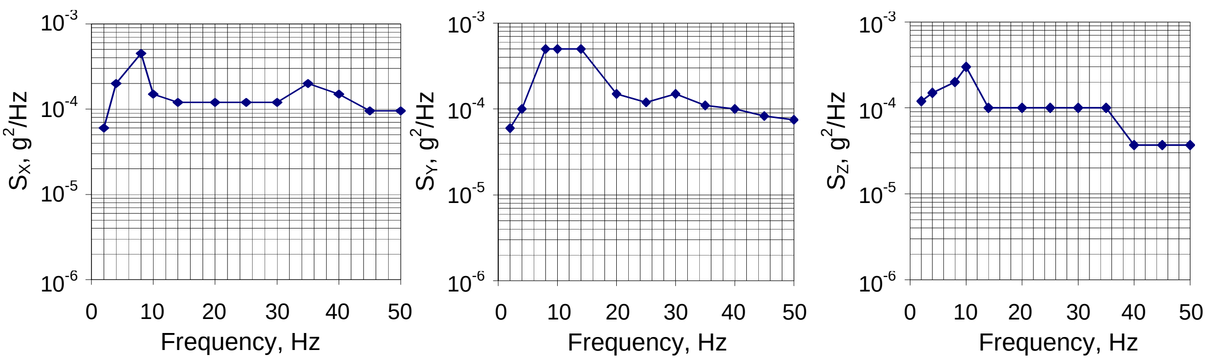

Figure 5-11 **Random vibration power spectrum acting on the spacecraft during upper composite transportation.**

5.2 Thermal Environment

This section describes the thermal environment of the spacecraft before and after launch. For the definition of the spacecraft thermal environment, three phases of the mission are considered:

- The spacecraft preparation phase within the preparation buildings,
- transportation to the launch pad, when the spacecraft is encapsulated inside the fairing, and
- the in-flight environment phase after mating the upper composite with the launch vehicle.

5.2.1 Environmental Conditions in the Integration Facility

The payload is processed in clean rooms of the integration facility MIK. The clean rooms are compliant with ISO Standard 14644-1 Class 8 (former FED-STD-209 Class 100,000) with a regulated temperature of 18 to 25 °C and relative humidity between 30 and 60%. EUROCKOT can also provide ISO Class 7 cleanliness (former Class 10,000) as an optional service.

5.2.2 Pre-Launch Temperature Control within the Fairing

After encapsulation and upper composite integration, conditioned air to the fairing is supplied either by a mobile thermal conditioning system on a railcar or a stationary thermal conditioning system at the launch pad. A removable thermal cover is installed on the outer fairing surface for the duration of the upper composite transportation from the integration facility to the launch site, the upper composite lifting into the service tower, and the upper composite installation on the booster unit. A supplementary spacecraft battery air conditioning system can be provided as an optional service.

The upper composite air conditioning configuration during transportation from the integration facility to the launch pad and while at the launch pad is shown in Figure 5-12 and Figure 5-13.

The basic performance data of the mobile air conditioning system, the characteristics of the air supplied by the upper composite stationary air conditioning system, and the characteristics of the air supplied by the optional spacecraft battery air conditioning system are shown in Table 5-12.

The mobile and stationary air conditioning systems are compatible with ISO Class 8 cleanliness, ISO Class 7 can be provided as an optional service. The mean air velocity induced by the thermal conditioning system within the fairing does not exceed 3 m/s.

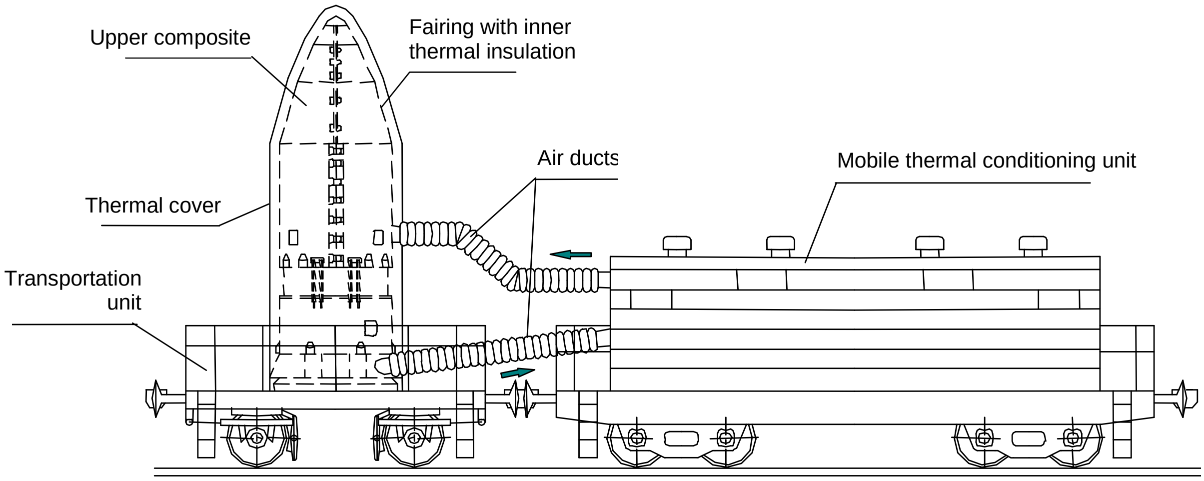

Figure 5-12 Thermal conditioning of the upper composite during transportation.

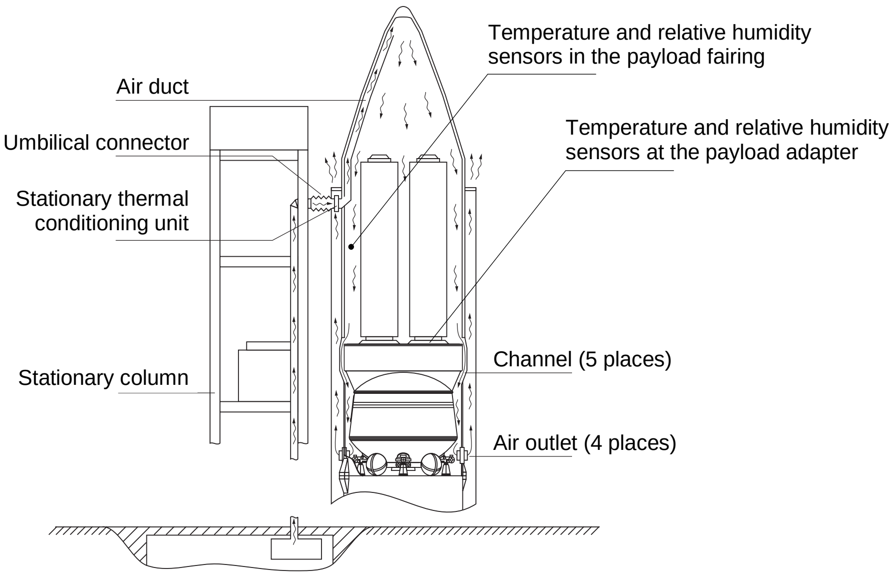

Figure 5-13 Thermal conditioning of the upper composite at the launch pad.

The air temperature inside the fairing is between 10 and 25°C during active temperature control, and between 5 and 30°C when no active temperature control is provided. These ranges will be updated on the basis of thermal analysis results. The thermal analysis will be performed by means of the spacecraft thermal and geometric mathematical models to be provided by the Customer. The adapter hardware temperature, fairing inside air temperature and humidity will be measured and recorded by the ground measurement system during the upper composite transportation en route to the launch pad and during processing on the launch pad (Table 5-13).

Parameter	Mobile thermal conditioning unit	Stationary thermal conditioning unit	SC batteries system (optional service)
Temperature of supplied air, °C	10..25 (adjustable)	10..25 (adjustable)	7…20 (adjustable)
Dew point of supplied air, °C			≤ -20
Relative humidity of supplied air, %	30* - 60	≤ 30	
Air flow rate, m^3/h	≥ 4,000	≥ 4,000	200
Static overpressure inside payload fairing, Pa	2,000	2,000	12,000
Cleanliness of supplied air	ISO Class 8 (ISO Class 7 optional)	ISO Class 8 (ISO Class 7 optional)	ISO Class 8

* Optionally, a relative humidity of less than 30% can be maintained.

Table 5-12 Air conditioning systems performance data.

Parameter	Number of sensors	Measurement range	Measurement accuracy
Fairing internal air temperature within approx. 3 m of fairing separation plane	2	- 40 … 80°C	± 0.7°C
Fairing internal air humidity within approx. 3 m of fairing separation plane	2	5 … 90 %	± 3 %
Adapter hardware temperature at 1/2 adapter height	2	- 40… 80°C	± 0.7°C

Table 5-13 Ranges of measured parameters under the payload fairing.

Air conditioning of the upper composite is provided up to approximately 30 seconds before lift-off and is restarted in about 1 minute in case of a launch abort. The total number of thermal conditioning interruptions is four:

- Upper composite lifting into the service tower
- Upper composite installation on the booster unit
- Stiffness ring removal
- Installation of LTC extension

The duration of each interruption period does not exceed 1 hour. In these periods the required thermal status of the upper composite is maintained due to the thermal inertia of the thermal cover, the fairing and the upper composite itself as well as due to the heat resistance of both the thermal cover and the fairing internal thermal blanket. This will be verified by thermal analyses carried out for each phase of ground processing.

5.2.3 In-flight Temperature under the Fairing

The payload fairing protects the payload during the ascent to a nominal altitude of about 120 km.

The in-flight adapter hardware temperature lies within the range -50°C to +40°C range without considering the payload-induced environment. During the ascent, the net flux density radiated by the fairing does not exceed 500 W/m^2 at any point.

Since the upper stage employs an internal temperature control system to keep the temperature of the equipment bay that directly interfaces the payload below 50°C, no induced heat load from here is to be expected. After the fairing has been jettisoned, the payload is exposed to the Free Molecular Heating (FMH) flux (section 5.2.5), solar radiation and terrestrial infrared.

5.2.4 Aerothermal Flux at Fairing Jettisoning

The time for jettisoning the fairing is determined to ensure that the aero-thermal flux of 1135 W/m^2 will not be exceeded. This flux is calculated as free molecular heating acting on a plane surface perpendicular to the velocity direction.

5.2.5 Heat Impact during Coasting Phase

After the fairing has been jettisoned, the spacecraft is exposed to solar radiation flux, terrestrial albedo and terrestrial infrared radiation. The nominal orientation of the upper composite during the coasting phase is described in chapter 3.4. The heat impact to the spacecraft during the coasting phase is determined during the dedicated mission analysis. Within the requirements of the upper stage, the mission profile takes into account the spacecraft thermal requirements.

5.3 Fairing Static Pressure during the Ascent

The payload compartment is vented during boosted flight. The payload compartment pressure and the depressurisation rate are a function of fairing design and flight trajectory. The nominal predicted pressure decrease profile for the *Rockot* payload fairing is shown in Figure 5-14. The maximum depressurisation rate will not exceed 4 kPa/s. The static pressure within the fairing is measured during flight and transmitted to the ground using the on-board telemetry system.

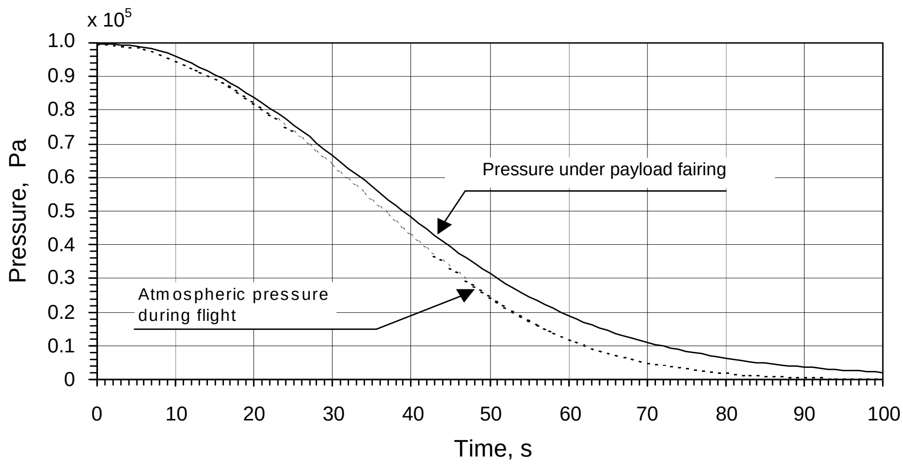

Figure 5-14 Variation of fairing inner static pressure during ascent.

5.4 Contamination and Cleanliness

The pyrotechnic systems used for stage, fairing and payload separation are leak proof and do not cause any organic contamination or debris. Several pyrotechnic device operations occur during the *Rockot/Breeze-KM* flight. In all cases, contamination of the spacecraft is avoided either by hermetically closed containment of the pyro charge or via the geometry of the plume relative to the payload. For payloads that are sensitive to organic contamination, a dedicated contamination analysis will be performed. The implementation of the required measures is to be negotiated and will be defined in a contamination control plan. All non-metallic materials in the upper composite are selected according to the Russian GOST standard, which specifies the use of materials with acceptable outgassing properties. ISO Standard 14644-1 Class 8 air cleanliness is provided and continuously monitored in the payload preparation rooms and inside the fairing until lift-off.

5.5 Electromagnetic Environment

5.5.1 Launch Vehicle Electro-Magnetic Emissions

The launch vehicle is equipped with the following transmission and reception systems:

- Two telemetry systems with transmitters and antennas, one in the interstage and one in the second stage
- A telemetry system with two transmitters and antennas in the *Breeze-KM* stage
- A transponder tracking system with a transmit-receive antenna.

During on-ground testing and during flight, the transmission systems create electric and magnetic fields. Their characteristics are presented in Table 5-14 and Figure 5-15 that define also the necessary immunity of the spacecraft against the launch vehicle and cosmodrome emissions during all operations. In all frequency portions not explicitly described in Table 5-14 the electrical field intensity is 90 dBµV/m.

Radio transmitter	Emission frequency, MHz	Max. antenna emissive power, dBWt	Calculated level of electrical field intensity in adapter plane, dBμV/m	
			with fairing	without fairing
Telemetry 1	120 - 130	12.3	107	119
Telemetry 2	1030 - 1050	10.0	105	117
Telemetry 3	1015 -1025	7.8	100	112
Telemetry 4	1015 - 1025	7.8	100	112
Tracking	2700 - 3000	20.0 (pulsed mode)	107	119

Table 5-14 Launch vehicle and cosmodrome electromagnetic emissions.

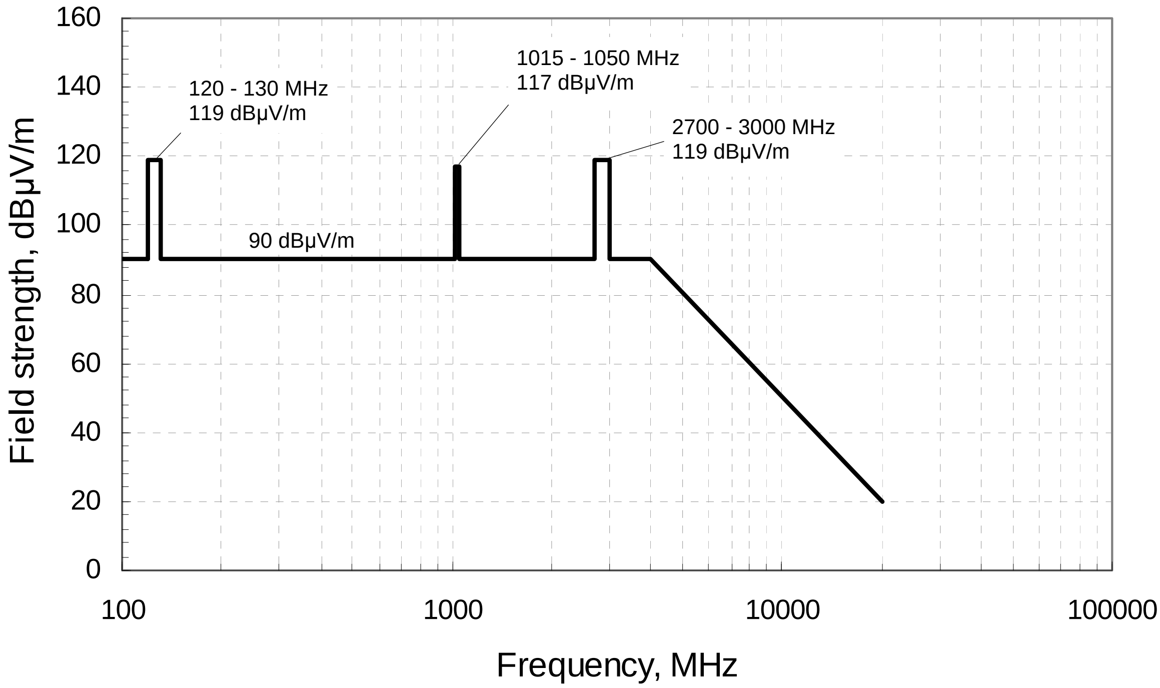

Figure 5-15 Field strength of launch vehicle and cosmodrome electromagnetic emissions in the adapter plane without payload fairing.

5.5.2 Spacecraft Electro-Magnetic Emissions

In order to avoid electromagnetic interference with the launch vehicle, the spacecraft radio frequency emission during all operations should not exceed the levels defined in Table 5-15 and Figure 5-16.

To ensure electromagnetic compatibility (EMC) between the launch vehicle and the spacecraft, a frequency plan is prepared for each launch. The Customer shall supply all data needed to support appropriate EMC analyses.

Frequency band, MHz	Allowable field strength, dBµV/m
120 - 130	80
1015 - 1050	80
2700 - 2900	70

Table 5-15 Allowable spacecraft emissions at Plesetsk Cosmodrome.

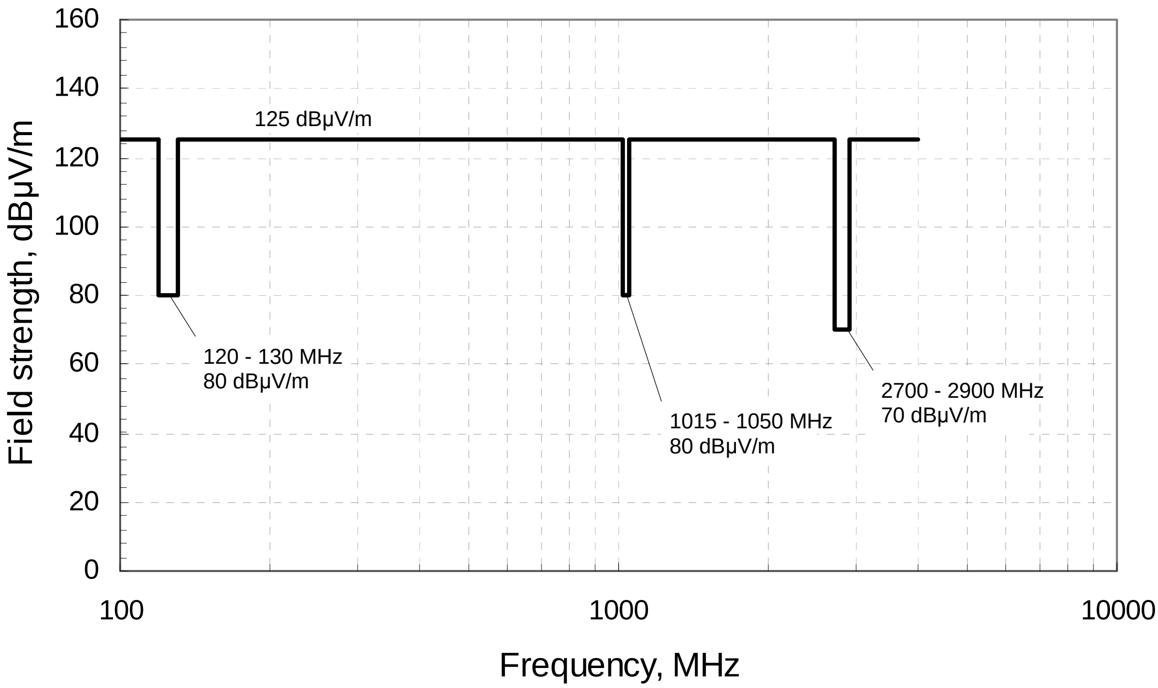

Figure 5-16 Allowable spacecraft emissions at Plesetsk Cosmodrome.

Chapter 6 Spacecraft Design and Verification Requirements

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6 Spacecraft Design and Verification Requirements

This chapter defines the spacecraft design and verification requirements that have to be taken into account in preparation of a launch on *Rockot/Breeze-KM*. Any deviation from these requirements has to be mutually agreed.

6.1 Safety Requirements

The Customer is required to design and operate the spacecraft in accordance with the launch site safety regulations described in chapter 9. It must be assured by appropriate means (mechanical ground support equipment design, operational procedures) that constraints related to ground operations do not become design drivers for the flight hardware.

6.1.1 Selection of Payload Materials

Properties as well as types of materials and components used for the spacecraft design must be based on recognised standards agreed by the launcher authority.

6.2 Design Characteristics

6.2.1 Mass Properties

The spacecraft mass properties shall be defined according to the following accuracies to enable dynamic analyses to be undertaken as part of the overall spacecraft to commence vehicle preliminary mission analyses. The mass shall be specified with an accuracy of better than ±2.5 %, the mass moment of inertia better than ±10 %. The CoM shall be specified with an accuracy of 50 mm along the launch vehicle longitudinal axis and within a circle of 30 mm radius around the launch vehicle longitudinal axis.

For spacecraft using liquid propellant the dynamics of the liquid shall be specified by means of a proper sloshing model at different acceleration levels.

6.2.2 Centre of Mass Constraints

The *Rockot* launch vehicle is capable of supporting a large variation of the CoM position along its *X*-axis. However, the dependency of the lateral accelerations on the CoM position may limit its position on the *X*-axis.

The total displacement of the composite CoM of the spacecraft or a combination of multiple spacecraft and the *Breeze-KM* must stay within a radius of 30 mm around the launch vehicle longitudinal axis. This imbalance directly affects the controllability of the upper stage and thus the spacecraft angular velocities at separation

6.2.3 Structural Integrity

6.2.3.1 Factors of Safety

The minimum factors of safety to be taken into account for structural dimensioning are:

- Yield load: $j \geq 1.1$
- Ultimate load: $j \geq 1.25$

The factors of safety apply to combinations of simultaneously acting mechanical and thermal limit loads.

Figure 6-1 Typical limit load factors for initial dimensioning of secondary structures and equipment brackets.

6.2.3.2 Dimensioning Loads

Structural dimensioning must take into account critical combinations of simultaneously acting load types.

Generic design accelerations for spacecraft primary structure dimensioning are compiled in chapter 5.1.2.

Secondary structures and equipment brackets must be dimensioned taking into account local responses to the combined effect of simultaneously acting low frequency transient and high frequency random vibrations. Typical mass-dependent combined load factors *n* are presented in Figure 6-1 as a design guideline. For dimensioning, limit load factors have to be applied

- at equipment / unit CoM,
- in the worst case spatial direction with respect to resulting stresses and reactions.

Limit load factors cover equipment / unit responses due to quasi-static and low-frequency transient and random accelerations encountered during lift-off and ascent.

6.2.4 Stiffness

To avoid dynamic coupling between the low-frequency launch vehicle and payload modes, the payload minimum natural frequency f_0 is required to be:

- Lateral (*Y-Z* plane): $f_0 \geq 15$ Hz
- Axial (*X*): $f_0 \geq 33$ Hz

Note: Resonance requirements are related to spacecraft modes with significant effective mass of $m_{eff} \geq 70\%$. The minimum natural frequency values are targets for design, if existing spacecraft are not compliant, the given requirement can be relaxed based on CLA results. For heavy spacecraft, additional coordination with EUROCKOT is required to ensure that the structural modes of the integrated spacecraft/ adapter stack do not decrease below critical limits.

6.2.5 Overflux

Overflux refers to disturbances of the axial line load at the interface of the adjacent mating structures. These local disturbances are caused by structural discontinuities such as stringers, cut-outs, etc.

Overflux requirements apply to clamp adapters only and will be specified on a case-by-case basis.

6.3 Spacecraft Mechanical Qualification and Acceptance Tests

The Customer shall demonstrate that the spacecraft structure complies with the required design characteristics as defined in Chapter 6.3, taking into account the environmental conditions stated in chapter 5.

Additionally, spacecraft mathematical models submitted to the launcher authority for performance of final coupled analyses and flight mechanics analyses must be verified by tests.

A typical qualification/acceptance test matrix is shown in Table 6-2. The spacecraft verification plan finally selected needs to be approved by the launcher authority.

6.3.1 Static Load Test

On the basis of dimensioning loads given in chapter 6.2.3.2, EUROCKOT defines critical load cases to which the spacecraft structure will be subjected. The structure must successfully pass static load tests up to:

- Qualification model: ultimate load (1.25 times limit loads)
- Protoflight model: yield load (1.1 times limit load)

For a realistic simulation of the load introduction, the spacecraft must be attached to a flight representative adapter or separation system during the static test.

6.3.2 Sinusoidal Vibration Test

The inputs at the spacecraft adapter interface are shown in Table 5-2, and the test factors in Table 6-1.

A permission for notching of sine test levels at critical resonances may be requested from EUROCKOT in order not to exceed the spacecraft flight responses predicted by coupled load analysis.

	Acceptance	Qualification
Test factors	1	1.25
Sweep rates (one sweep per axis)	4 oct/min	2 oct/min

Table 6-1 Sinusoidal vibration loads.

6.3.3 Random Vibration Test

Random vibration test is recommended only for small satellites of 100 kg mass or less and for satellites with small dimensions. The vibration loads for this purpose will be specified on a case-by-case basis, see chapter 5.1.5.

For larger spacecraft, EUROCKOT recommends to perform an acoustic test to accurately reflect the in-flight random environments experienced. Since the vibration level depends on the dynamic properties of the payload adapter structure, this test should be performed with the spacecraft attached to a flight-like payload adapter (not hard mounted) to accurately represent the flight configuration.

A permission for notching of random vibration test levels at critical resonances may be requested from the launcher authority in order not to exceed local responses measured during an acoustic noise test or determined by an acoustic response analysis.

Test Hardware	Required Tests									
	Static Chap. 6.3.1		Sinusoidal Chap. 6.3.2		Random Chap. 6.3.3		Acoustic Chap. 6.3.4		Shock Chap. 6.3.5	
	Q	A	Q	A	Q	A	Q	A	Q	A
Prototype Philosophy: Qualification Model Flight Model	X		X	X	X 1)	X 1)	X	X	X	X 2)
Protoflight Philosophy: Protoflight Model	X		X		X 1)		X		X 2)	

1) alternatively for small satellites
2) optionally

Table 6-2 Typical mechanical verification test matrix for qualification (Q) and acceptance (A) of the spacecraft.

6.3.4 Acoustic Noise Test

The acoustic noise spectrum as defined in chapter 5.1.4 must be used as the test input with the factors and durations of Table 6-3 applied.

	Acceptance	Qualification	Protoflight Qualification
Test factor for acoustic pressure	Per SC designer's national standard		
Exposure duration, s	60	120	60

Table 6-3 Acoustic noise spectrum.

The requested test duration takes into account a scatter factor significantly greater than four.

6.3.5 Shock Test

Shock tests of complete spacecraft must be conducted by firing of the planned separation system. For predicted shock response spectra, see Chapter 5.1.6.

6.4 Interface Tests

Depending on the specific mission the following set of compatibility tests may have to be performed:

- The Matchmate test, also referred to as Fit-check test for verification of electrical and mechanical interfaces of the spacecraft to the adapter and separation system. This test is performed preferably with flight units and can be combined with a functional test of the separation system. This test is mandatory for each mission.

- If necessary, volume compatibility test with fairing and adapter. A satellite dummy simulating the spacecraft static envelope will be used for this purpose

Additionally, the following test have to be performed in case of necessity:

- Thermal tests
- EMC tests
- Dedicated electrical interface tests when non-standard interfaces are used

Chapter 7 Mission Management

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7 Mission Management

7.1 Mission Management Overview

Mission management is conceived by EUROCKOT to fulfil all the Customer's requirements to the greatest possible extent by undertaking the following activities:

- Management and planning of the entire mission integration process
- Definition and control of all payload/ launch vehicle interfaces
- Performance of mission design and mission analyses
- Provision of the launch vehicle with appropriate interfaces including the payload adapter and separation system
- Transport of the customer's spacecraft and support equipment from the Russian port-of-entry to EUROCKOT's facilities at the launch site
- Provision of appropriate payload preparation facilities within EUROCKOT's facilities at the launch site
- Management and performance of pre-launch operations and launch
- Performance of trajectory tracking and payload telemetry data reception, as required

7.2 Organisation and Responsibilities

EUROCKOT is responsible to the Customer for all commercial and technical activities within the launch contract. EUROCKOT implements this contract as the single prime contractor towards the Customer and as the Customer's sole industrial partner for all aspects of the law. EUROCKOT is a company governed by German law and offers all the legal safeguards provided by a Western company.

As a constituent company of EUROCKOT, Khrunichev State Research and Production Space Center (KSRC) of Russia provides the launch vehicle as well as the launch services and launch operations support through a sub-contract to the Russian Space Forces.

EUROCKOT's other parent company Astrium which is located next door to EUROCKOT, offers support in engineering and commercial areas as necessary. The distribution of the relevant activities among EUROCKOT, KSRC and Astrium is depicted in Figure 7-1.

For mission management, EUROCKOT uses a scheme (Figure 7-2) which has proven extremely successful in the past. Customers conclude a Launch Services Agreement (LSA) directly with EUROCKOT, who provides the single point of focus for the Customer through a designated Mission Manager. The Mission Manager is responsible for the management of all the launch service tasks. The Mission Manager has full programme authority and is responsible for all coordination required to implement the launch contract. The Mission Manager is responsible for ensuring that all payload launch requirements are met and is in continuous contact with the Customer from contract signature up to launch.

At the launch site, he/she acts as the day-to-day intermediary between the Customer and the launch site authorities for the purpose of satisfying the Customer's requirements. This includes responsibility for launch operations planning, procedures and launch execution. The launch decision is the responsibility of a Management Group consisting of the EUROCKOT Mission Manager and representatives of KSRC, the Customer and the launch site authorities.

The Mission Manager acts as part of a team of experienced programme managers, mission managers and engineers who make up the nucleus of the EUROCKOT technical team. The Mission Manager reports to the Technical Director and the CEO. Within each individual project, the Mission Manager is supported by another member of the technical team, thereby ensuring common standards and practices within EUROCKOT as well as providing personnel redundancy. He/she is supported by other members of the EUROCKOT team to fulfil contractual obligations including the contracts and finance team which is responsible for all contractual, commercial and financial matters and the sales team for public relations activities.

Within EUROCKOT, the Mission Manager represents the interests of the Customer, towards the Customer he represents the interests of EUROCKOT. The structure of the mission management organisation and its relationship to the Customer and KSRC is shown in Figure 7-2.

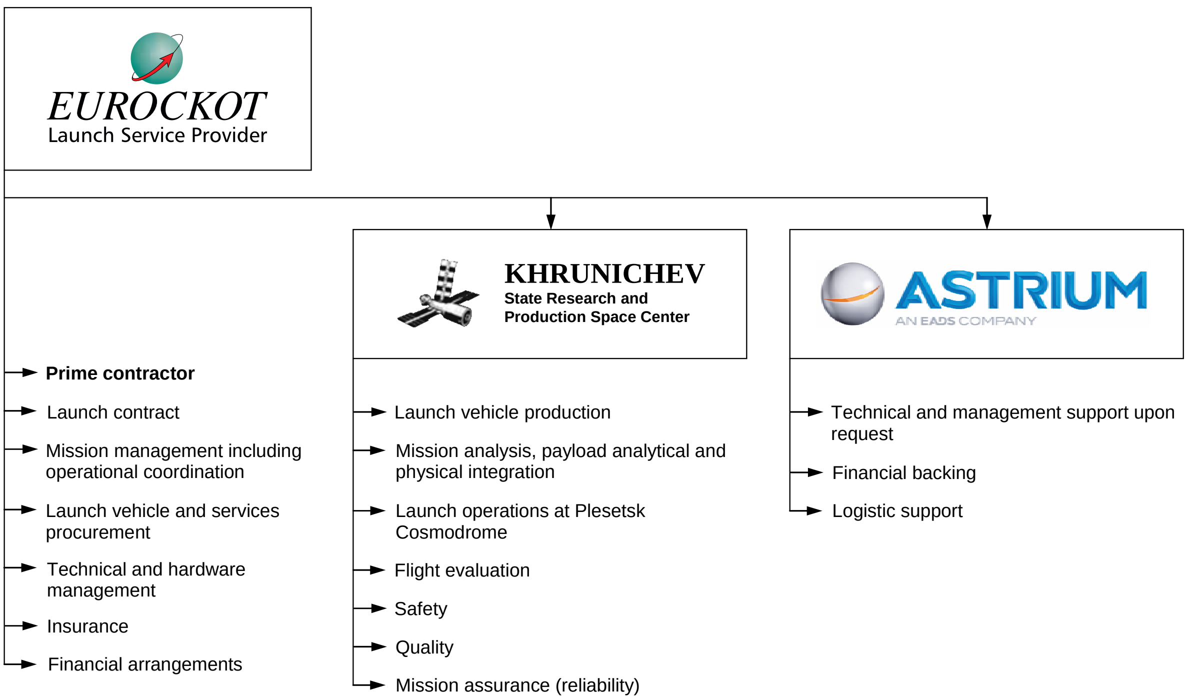

Figure 7-1 Industrial organisation of EUROCKOT and its major subcontractors.

7.2.1 EUROCKOT Mission Responsibilities

EUROCKOT will manage all mission-related activities from first preliminary estimations before launch contract signature through post-launch evaluation and review with the emphasis on Customer satisfaction.

7.2.1.1 Mission Integration

EUROCKOT's mission integration responsibility includes the definition and control of the spacecraft to launch vehicle interfaces as well as the performance of the mission design and mission analyses (Chapter 8). Initially a draft Interface Control Document (ICD) which contains the requirements and design solutions for the interfaces is established at the start of the mission integration phase. This is based upon customer responses to the questionnaire "SC Initial Data Requirements for the *Rockot* launch vehicle", ESPE-0022, as well as the Interface or Technical Requirements Document (IRD) which forms part of the technical annexes of the launch contract. This ICD is agreed and signed by all parties including EUROCKOT, Khrunichev, the Customer and the Spacecraft developer. Preliminary mission design and mission analyses are then performed versus the requirements contained within the ICD and presented in the Interface Preliminary Design Review (PDR) for customer review and approval. After the PDR the ICD is updated and put under formal configuration control, with EUROCKOT responsible for maintenance and updating of this document. When the spacecraft design matures and the final spacecraft data is known the final mission design and mission analyses are then performed versus the requirements contained within the ICD and presented in the Interface Critical Design Review (CDR) for customer review and approval.

The ICD is maintained under formal configuration control until launch. This document also includes relevant technical specifications relating to payload preparation facilities at the range.

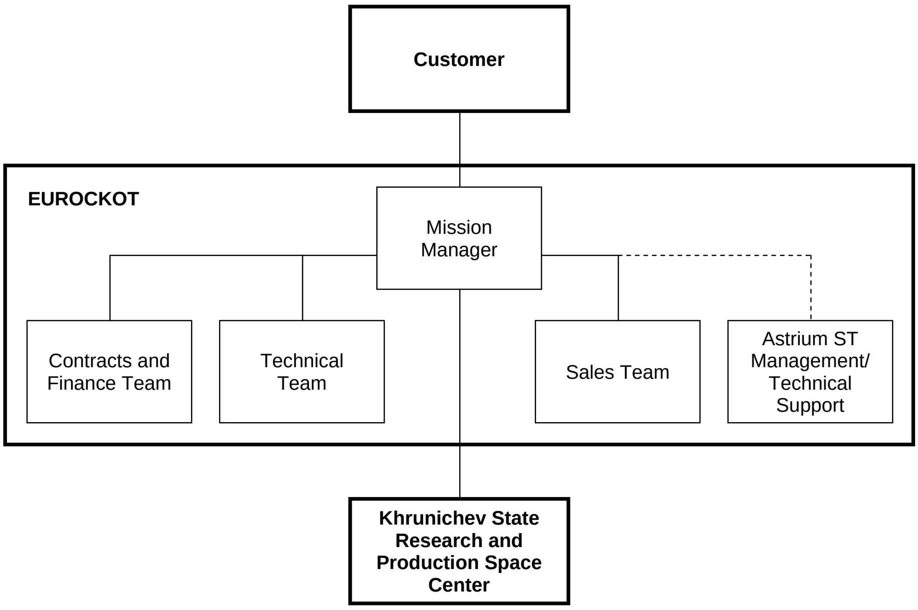

Figure 7-2 EUROCKOT mission management organisation.

7.2.1.2 Interface Design, Qualification and Verification

The design of the interfaces between the launch vehicle upper stage and the spacecraft, i. e. the payload adapter, attachment and separation system, is one of the first activities to be started after technical kick-off. In the majority of cases, a mission-specific payload adapter design is used, due to the fact that even for similar designs there can still be small but significant differences between designs, e. g. connector type and layout, spring pusher location and forces, clamp band pre-tension, adapter geometry and height as well as different spacecraft mass properties etc. Hence, in the cases where qualification by similarity is not applicable, a design and qualification process will be undertaken to cover these differences.

7.2.1.2.1 Design of the Payload Adapter

Compliance of the design with the Customer requirements stated in the ICD and with the environmental constraints is demonstrated in the PDR and CDR. A successful CDR signifies the payload adapter design approval and the go-ahead for manufacturing. If, on the other hand, design changes are necessary because of the CDR, this go-ahead is given when these design changes are successfully completed.

However, owing to time constraints, the procurement of long lead items and initiation of piece part manufacturing can start earlier. Like the necessary effort for qualification, this depends mainly on the degree of individuality of the payload adapter for each mission. Ideally, qualification and flight units are produced together. On the basis of the existence of a fully qualified launch vehicle including the *Breeze-KM* upper stage and payload fairing, only the mission-specific interface has to be verified. Depending on the degree of individuality of the payload adapter requested to fulfil specific spacecraft designs, a qualification test program will be set up.

7.2.1.2.2 Payload Adapter Qualification Test at KSRC

The qualification programme of the payload adapter will typically consist of some of the following test steps:

- Static tests
- Dynamic tests
- Spacecraft separation tests
- Fit-check with payload adapter or optionally, in case of low clearances to the payload fairing, a volume fit-check with the fairing

The tests are performed at the premises of KSRC in Moscow, Russia. The tests are performed using a *Breeze-KM* upper stage mechanical interface simulator together with a spacecraft Mass Frequency Simulator model (MFS). The MFS is a high fidelity reproduction of the spacecraft flight model electro-mechanical interfaces and also reproduces the major mass and dynamic properties of the spacecraft including its lowest natural frequencies. In case of low clearances between the spacecraft and payload fairing, an additional volume fit check, using a spacecraft volume simulator can also be undertaken as an option.

The necessity and extent of each test depend mainly on spacecraft mass and stiffness properties, and geometrical interfaces environment sensitivities.

To further verify correct attachment interface and integration feasibility, two additional means to confirm interface compatibility can be undertaken and are described in the following paragraphs.

7.2.1.2.3 Fit Check of FM Spacecraft with FM Payload Adapter

A fit check, preferably using the flight model spacecraft and the flight model payload adapter or an identical model thereof, is performed at the spacecraft manufacturer's premises demonstrating that the mating and separation of mechanical and electrical joints comply with the ICD requirements. Depending on the customer's specific requirements, a separation test involving ignition of the separation system pyrotechnics can be undertaken to verify shock levels at the spacecraft interface.

7.2.1.2.4 Master Gauge Interface Verification

A master gauge / drill template, produced by either the spacecraft contractor or EUROCKOT, ensures that the correct positions of the fixing points are achieved not only by compliance with the interface drawings but also by using the identical tool for applying them on the test and flight hardware. This is generally used for point attachment systems to ensure correct positioning of the interface points on the spacecraft for the separation system.

7.2.1.3 Configuration Control

Programme-specific configuration control and data management procedures begin immediately upon contract signature with EUROCKOT and cover all documents and data exchanged with the Customer. These documents are defined in chapter 7.3. The overall programme configuration control of the launch vehicle and launch service is an extension of the KSRC Quality and Mission Assurance Plan. Data management is an integral part of this plan. A unique programme configuration control plan is prepared. This plan shows:

- Responsibilities for configuration management in each organisation
- Documentation subject to configuration management
- Change orders issued
- Orders processed
- Constitution of the joint change board

7.2.1.4 Launch Vehicle Procurement

EUROCKOT monitors the launch vehicle production progress according to the mission integration schedule, approves launch vehicle acceptance and is responsible for the specification and provision of the launch vehicle to spacecraft interfaces and, if applicable, adaptation of the fairing.

7.2.1.5 Spacecraft Preparation and Launch Operations

EUROCKOT defines the launch operations for the launch site through the establishment of a Joint Operations Plan (JOP) for all joint activities with the customer. This includes all activities which involve support from EUROCKOT and KSRC at the launch site, for example launch site support activities including fuelling support as well as combined operations of the launch vehicle and spacecraft. The plan defines the launch site organisation, joint operations, facilities, operational support, electrical check-out as well as launch day activities including go/no-go criteria. The Spacecraft Operation Plan (SOP) (section 7.2.2) provided by the Customer provides the inputs for this plan and will be adhered to. The JOP is the working document used by EUROCKOT, the Customer, and KSRC and its subcontractors to manage the launch campaign.

7.2.1.6 Post-Launch Activities

State vectors of the upper stage at burn-out and of the satellite separation event will be provided as preliminary data approximately 60 minutes after separation. Two months after launch, EUROCKOT provides a Launch Evaluation Report (LER), showing the performance achieved and the behaviour of the launch vehicle. This report is based on processed launch vehicle telemetry and tracking data as well as on spacecraft orbit data provided by the Customer.

7.2.1.7 Quality and Mission Assurance

At KSRC, the Deputy Director for Quality Assurance, reporting directly to the General Director, ensures and supervises compliance with all relevant requirements. Quality audits and procedures maintain rigorous adherence to all elements in the factory and launch site operations. Incoming materials and subcontractors are certified, continuously reviewed and inspected.

A system of procedures which has proven its efficiency in the past assures detailed analysis of discrepancies as well as related dispositions and verification of their execution.

7.2.1.8 Safety Provisions

EUROCKOT will provide the single focal point for all system and range safety matters. The Customer will provide the necessary data as described in chapters 9 and 12 to enable EUROCKOT to obtain spacecraft safety approval for the launch campaign.

7.2.1.9 Risk Management

Risk management by EUROCKOT covers the following risk in particular:

Political Risk: The EUROCKOT programme is part of the German-Russian space cooperation agreement, backed by high level guarantees from the German and Russian Governments, explicitly including the Russian Space Agency and the Space Forces.

Commercial Risk: Astrium is financially backing all required funding.

Technical Risk: The *Rockot* launch vehicle is fully operational. The first two stages undergo extensive tests (DPA / test firing) on a yearly basis. The commercial *Rockot* configuration, including *Breeze-KM* and the large payload fairing, was successfully flight-qualified for the first time in May 2000. The co-production of *Breeze-KM* for *Rockot* and *Breeze-M* for *Proton* ensures programme continuity at KSRC.

Launch Risk: Launchers which are held in stock for rapid replenishment ensure short reaction launches in the case of satellite problems and immediate re-launch in the case of launch failure after completion of a failure investigation. In the unlikely event of a launch failure, a contingency plan previously reviewed and tailored to the specific mission would control the total process providing a failure action list from data review through anomaly identification and the setting up of analysis and review boards up to final explanation and corrective action dispositions.

Almost 1500 launches from Plesetsk combined with the *Proton* experience of KSRC and the *Ariane* experience of Astrium further reduce technical risks for the Customer.

7.2.1.10 Technology Transfer and Security

EUROCKOT is committed to meeting government and Customer requirements concerning technology transfer issues and the physical security of the spacecraft, its support equipment and associated documentation during the mission integration process and the launch campaign. For this purpose, the mission integration process and launch site activities conducted by EUROCKOT, for instance all technical interchange meetings (TIM), data transfer from the spacecraft contractor, e. g. drawings and mathematical models, and activities at the launch site will be governed by a specific document generated for PDR and updated for CDR.

For the majority of spacecraft contractors, this document will be based to a large extent on United States requirements issued by the Office of the Secretary of the Defense Technology Security Administration (DTSA).

For spacecraft coming under DTSA jurisdiction, special measures will be taken to meet these requirements. In the case of technology transfer issues, it is recommended that a Technical Assistance Agreement (TAA) with DTSA is concluded very early on in the programme to allow for technical interchanges between the spacecraft contractor and the launch service companies, e.g. EUROCKOT, KSRC and their subcontractors. Physical security of the spacecraft, of its associated support hardware and of documentation at the launch site is assured by physical barriers such as controlled entry doors, round-the-clock surveillance of the hardware by security guards and agreed procedures.

7.2.2 Customer Mission Responsibilities

The Customer is required to designate a Payload Mission Manager who will be the single point of contact for the Mission Manager at EUROCKOT. Early in the contract implementation process, the Customer is requested to provide responses to the questionnaire "SC Initial Data Requirements for the Rockot Launch Vehicle", ESPE0022" which covers:

- Required mission characteristics
- Spacecraft characteristics (dimensional, electrical, thermal, environmental, etc.)
- Spacecraft launch preparations requirements

Early in the mission analysis process, the Customer submits a payload development and test plan to meet the *Rockot/Breeze-*

KM environmental conditions. Additionally, the Customer shall provide several spacecraft software models, especially for integrated structural and thermal analyses (chapter 8 and section 12.2). During the mission design and mission analysis process, the Customer is requested to submit environment test results (section 12.4). The Customer attends the preliminary and final mission analysis reviews which are undertaken as part of the Launch Vehicle Preliminary and Critical Design Review.

As an input to the setup of the Joint Operations Plan (JOP), the Customer will issue the Spacecraft Operations Plan (SOP). For the operational activities at the range, the Customer will provide procedures for the various operations on the spacecraft for safety examination by the range authority (see Section 12.5).

A safety review based on three safety submissions (phases I, II and III) and the spacecraft safety certificate provided by the Customer or spacecraft contractor must also be completed during the launch preparation phase. A phase I safety submission is expected at the start of the contract phase. For details, see chapter 9 and section 12.3.

Hardware models which have to be provided, especially a spacecraft mass frequency simulator model and, if necessary, the volume fit-check dummy are described in sections 7.2.1.2 and 12.7. In general, all items to be provided by the Customer such as documents, software and hardware models are summarised in chapter 12.

7.3 Reviews and Documentation

Within each phase of the launch service implementation there are various activities and milestones planned to enable successful fulfilment of the contract. These activities include regular meetings with the customer and spacecraft contractor and also the generation of documents and analyses for review and approval. The activities are coordinated by the EUROCKOT Mission Manager at the start of the contract.

Typically EUROCKOT tries to distribute meetings approximately evenly between the customer, spacecraft contractor and EUROCKOT / KSRC sites. Generally, to have easy access to specialists, the main mission design and mission analysis reviews, the Preliminary Design Review (PDR) and the Critical Design Review (CDR) are held at KSRC's premises in Moscow. Other technical interchange meetings and reviews can be held at other locations including the customer site depending on the specific purpose. A summary of reviews and their typical allocation within the mission schedule is given in Table 7-1.

The aim is, where possible, to combine some of these meetings and reviews in order to optimise the time and cost involved for all parties. An overall summary of documents to be supplied by EUROCKOT and the Customer, as well as their typical release dates is given in section 7.4.

Meetings / reviews schedule	Date
Contract signature meeting	L - 24 months
Technical kick-off meeting/ IRD review	L - 24 months
Launch vehicle to spacecraft system requirements review + ICD outline	L - 22 months
ICD review (draft issue)	L - 21 months
Launch Vehicle to Spacecraft Preliminary Design Review incorporating the preliminary mission design and analyses	L - 18 months
ICD review (issue 1)	L- 12 months
Spacecraft Operations Plan/ Joint Operations Plan review	As necessary, combined with other meetings
Technical interchange meetings	As necessary, combined with other meetings
Safety reviews (phases I, II and III)	As necessary, combined with other meetings
Launch Vehicle to Spacecraft Critical Design Review incorporating the final mission design and analyses	L - 12 months
ICD review (issue 2)	L - 11 months
Design qualification review	L - 5 months
ICD review (final issue, if applicable)	L - 5 months
Shipment Readiness Review	To be agreed
Launch Readiness Review (LRR)/ State Commission	L - 3 days
Launch Evaluation Review meeting	L + 2 months

Table 7-1 Typical launch services reviews and meetings.

7.3.1 EUROCKOT Documents

The main documents to be established by EUROCKOT are summarised below:

7.3.1.1 Interface Control Document

Interface Control Document	L - 21 to 5 months

The ICD is the document that guarantees the technical definition and control of all interfaces between the launch system and the payload to both the spacecraft Customer and to EUROCKOT. In addition, the ICD is intended to establish the operational requirements for a launch campaign. The document will be updated regularly with inputs from the Customer and updated by the EUROCKOT Mission Manager in agreement with all parties. The ICD is a living document, being constantly updated to reflect the latest status of the launch services. A typical ICD structure is depicted in Table 7-2.

1 Introduction
2 Mission Requirements
3 Mechanical and Electrical Interfaces
4 Mechanical Loads and Environments
4.1 Flight Loads
4.2 Ground Loads
4.3 Thermal
4.4 Cleanliness
4.5 EMC
5 Preparation Facilities
5.1 General Requirements
5.2 Communication
6 Verification Matrix

Table 7-2 Typical ICD structure.

7.3.1.2 Preliminary Design Review Data Package

Preliminary Design Review Data Package	L-19 months

The results of the preliminary mission design and the analyses are documented in the preliminary design review data package. This includes:

- Payload accommodation design including mission-specific equipment and interfaces
- Trajectory and mission sequence
- Spacecraft separation analysis
- Ground and flight thermal environment
- Dynamic Coupled Loads Analysis
- Cleanliness
- Measurement system
- Telemetry
- Radio frequency compatibility
- Electrical
- Pre-launch support and operations
- Reliability
- Social services
- Communication infrastructure
- Security
- Transportation

7.3.1.3 Critical Design Review Data Package

Critical Design Review Data Package	L - 13 months

The results of the final mission design and analyses are documented in the critical design review data package. This includes:

- Payload accommodation design including mission-specific equipment and interfaces
- Trajectory and mission sequence
- Spacecraft separation analysis

- Ground and flight thermal environment
- Dynamic coupled loads analysis / loads
- Cleanliness
- Measurement system
- Telemetry
- Radio frequency compatibility
- Electrical
- Pre-launch support and operations
- Reliability
- Social services
- Communication infrastructure
- Security
- Transportation

7.3.1.4 Joint Operations Plan

Joint Operations Plan	L - 13 months

The JOP covers all joint operations involving EUROCKOT, Khrunichev including subcontractors and the Customer, such as joint activities where launch site support is needed like spacecraft fuelling as well as combined operations of the launch vehicle and spacecraft from the beginning of encapsulation to lift-off. The JOP also includes the agreed go/ no-go criteria for launch.

Note: Specific spacecraft operations are the responsibility of the Customer and to be included in the SOP.

7.3.1.5 Safety Reply

Safety Reply, Phases I; II; III	L – 17; 11; 4 months

The EUROCKOT safety reply contains:

- Assessment of customer safety submissions
- Description of spacecraft systems and classification of hazardous systems
- Development of list of hazards and reports on analysis of these hazards
- Verification of spacecraft design compliance with the standards of either the country of origin or agency
- Safety constraints tailored to dedicated spacecraft
- Verification of spacecraft design compliance with EUROCKOT Safety Handbook EHB0004 and establishment of reports on non-compliance with these provisions
- Specific verification guidelines are given in chapter 9

7.3.1.6 Launch Evaluation Report

Launch Evaluation Report	L + 2 months

The launch evaluation report provides:

- Launch vehicle performance based on telemetry and tracking data
- Launch vehicle behaviour
- Launch vehicle / spacecraft interface aspects including launch environment

7.3.2 Customer Documents

The documents to be provided by the Customer are described in detail in chapter 12 and summarised in Table 7-3.

Documents to be provided	Date (typically)	
	Preliminary	Final
Interface Requirements Document (IRD)	L - 24 months	
Safety Submission (Phase I, II, III)	I: L-18 months II: L-12 months	III: L- 6 months
SC Safety Certificate	L – 12 months	III: L – 5 months
SC Flight Readiness Certificate	L – 6 months	L – 5 months
Flight Readiness Data Package	L – 6 months	L – 5 months
Spacecraft Mechanical Environment Test Plan	L - 16 months	
Spacecraft Dynamic Model (Preliminary)	L - 23 months	L - 11 months
Spacecraft Thermal Model (Preliminary)	L - 23 months	L - 11 months
Response to Questionnaire: Input to Mission Design and Mission Analysis	L - 23 months	L - 11 months
Spacecraft Operations Plan	L - 17 months	
Spacecraft Mechanical Environment Qualification Test Results	L - 6 months	
Final Spacecraft Mass Properties	L - 7 days	
Orbital Tracking Operation Report	L + 2 weeks	

Table 7-3 Documents to be supplied by the Customer.

7.4 Overall Mission Schedule

The overall mission planning is designed to provide the Customer with a reasonably minimum lead time of 24 months from contract signature to launch, while still allowing for thorough technical preparation, in particular through mission analysis. If a repeat launch for a similar spacecraft and comparable orbit characteristics is requested by the Customer, lead times of 15 months should be achievable and would be the subject of specific agreements.

The mission schedule of a typical mission with a 24 month lead time is depicted in Table 7-4. Nevertheless, the mission-specific schedule will be established during the mission kick-off meeting. It will address in particular the spacecraft development and qualification schedule as well as other Customer requirements. If the results of the preliminary mission analysis are required for spacecraft development and qualification earlier than indicated in this section, a project begin earlier than L-24 months can easily be implemented. The schedule of the launch campaign is described in chapter 10.

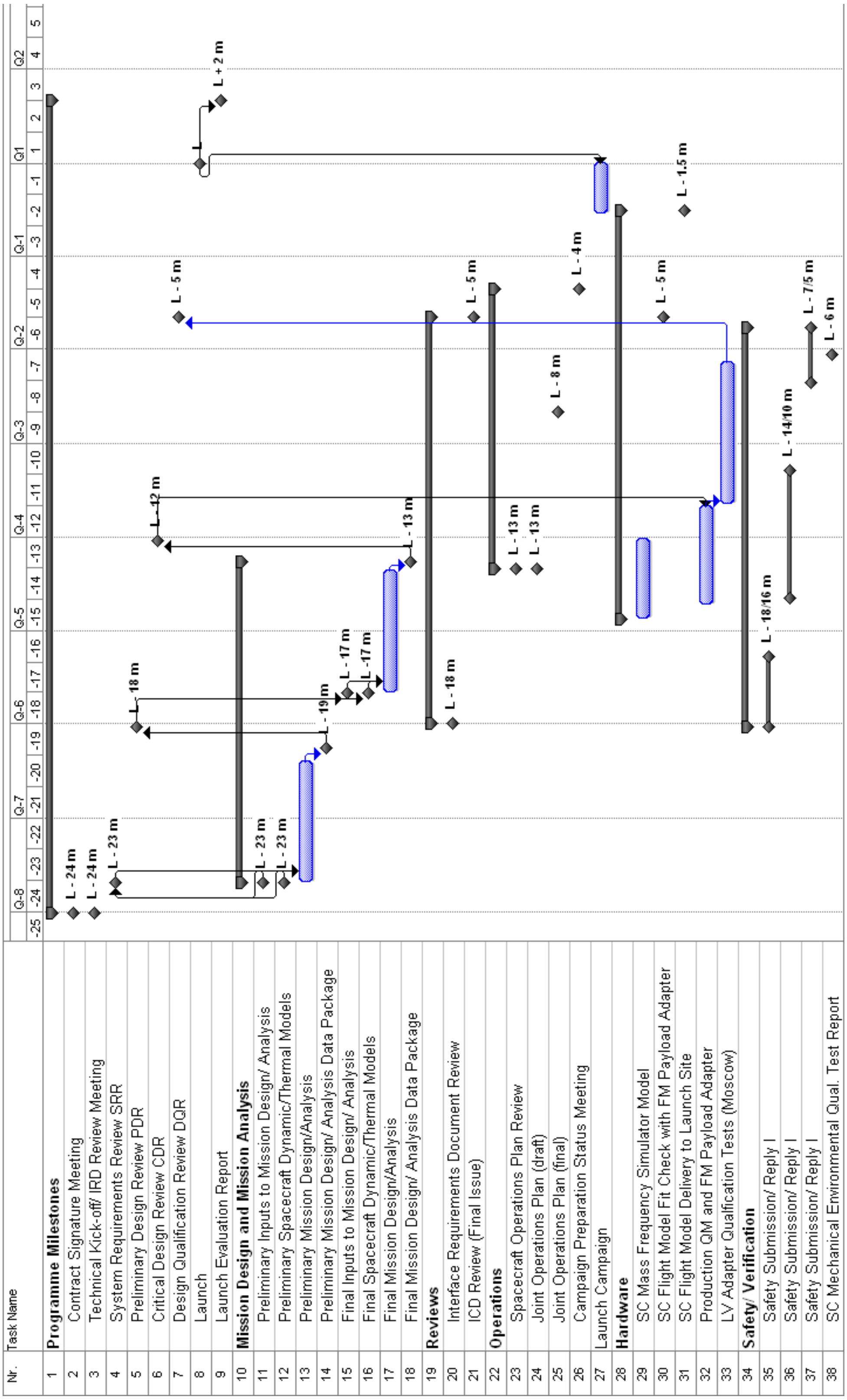

Table 7-4 Typical mission schedule.

Chapter 8 Mission Design and Mission Analysis

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8 Mission Design and Mission Analysis

8.1 General

Consistent with the dedication to provide the highest standards and a successful launch of the customer spacecraft, EUROCKOT strives to conduct a thorough, detailed and transparent mission design and analysis process for the Customer. This is evidenced by the extensive and detailed data packages provided to the customer during the review process, as described later in this chapter.

Within the framework of mission integration activities, mission design and mission analyses are conducted to ensure that the customer's mission objectives can be achieved, e. g. reliable spacecraft injection into the required orbit in the correct attitude, provision of facilities meeting the Customer's requirements,. The design and analyses are conducted on the basis of inputs from the Customer (chapter 12) and the compatibility checked versus the Interface Control Document requirements. They are undertaken in two phases:

- Preliminary mission design and analysis. This uses preliminary input data from the customer to confirm the basic design and mission scenarios to the customer. The data package is reviewed in the launch vehicle to spacecraft Preliminary Design Review (PDR). Following a successful PDR, the input data and mission aspects are studied and refined, leading to an update of the Interface Control Document and to an update in the input data from the customer.
- Final mission design and analysis. This uses final input data from the customer to finalise and freeze the actual design for the launch campaign and flight. The data package is reviewed in the launch vehicle to spacecraft Critical Design Review (CDR). Following successful conclusion of the CDR the design for flight is formally released.

The contents and tasks undertaken for the preliminary and final mission design and analyses are identical and differ only in the updated input data. The results of the design and analyses are presented in the form of books. An overview of the data package structure is provided in Table 8-1 below.

Each book contains the structure as shown in Table 8-2. The contents of the individual books are summarised in the next sections.

Book	Content
Book 1	Overall Description of *Rockot* Launch Vehicle Integration to Spacecraft
Book 2	Design Data Package Structure - for internal KSRC use only. Not provided to the customer.
Book 3	Input Data (ICD based) - for internal KSRC use only. Not provided to the customer.
Book 4	Trajectory and Mission Sequence
Book 5	Spacecraft Separation Dynamics
Book 6, part 1	Thermal Analysis: Ground Processing
Book 6, part 2	Thermal Analysis: Flight
Book 7	Coupled Loads Analysis
Book 8	Spacecraft Cleanliness Control
Book 9, part 1	Measurement System
Book 9, part 2	Launch Information Telemetry and Navigation Ballistic Support
Book 10	Spacecraft Electromagnetic Compatibility with the Launch Vehicle and Launch Site
Book 11	Onboard Electrical Interface of Spacecraft and Launch Vehicle
Book 12	Ground Electrical Cabling, Power Supply and Interfaces with Spacecraft GSE
Book 13	Intentionally left blank
Book 14, part 1	Launch Base Operations: Operations Flow
Book 14, part 2	Launch Base Operations: Facilities and GSE (except fuelling support)
Book 14, part 3	Launch Base Operations: SC Fuelling Support Activities and Facilities
Book 15, part 1	Reliability
Book 15, part 2	ILV Components Quality Assurance
Book 16	Social Services (Hotel, Intra launch site transportation etc)
Book 17	Communications Support
Book 18	Security
Book 19	Transportation of SC and Ground Support Equipment to Launch Site Facilities

Table 8-1 Data package structure.

Section Titles	Contents
Requirements Verification Matrix	• Per ICD and contract requirements
Results	• Summarized results of analyses and design work • Demonstration that ICD requirements are met
Conclusions	• Outstanding problems • Requirements remaining to be met • Actions to meet requirements
Detailed Data	• Description of techniques used for the analyses • Input data • Miscellaneous

Table 8-2 Data package book content.

8.2 Overall Description of Spacecraft to Rockot Launch Vehicle Integration (Book 1)

This book provides a top level description of the measures taken to integrate the customer's satellite to the *Rockot/Breeze-KM* launch vehicle. It introduces the launch vehicle and its major systems as well as covering in particular detail the mission-specific equipment in the upper composite, such as the payload adapter and separation system. The accommodation of the payload is described accompanied by detailed clearance analyses, the fairing venting analysis, fairing jettison analysis, as well as measures for electrostatic discharge control.

8.3 Trajectory and Mission Sequence (Book 4)

This book describes the mission timeline in detail starting from the countdown sequence to separation and upper stage orbit removal/ de-orbiting.

In order to perform these analyses, the Customer is requested to submit the following detailed data in addition to the data contained within the launch services contract. This includes:

- spacecraft orbital parameters including required injection accuracy,
- constraints on the upper composite / payload orientation during the coast phase portion of the flight such as those required for thermal manoeuvres,
- orientation of the spacecraft at the moment of separation, and
- launch window constraints from the spacecraft side.

The trajectory analysis provides a description of the launch vehicle during stage 1, stage 2 and upper stage flight phases. This includes velocity, altitude, dynamic pressure, flight angle and position of the launcher, burn times and a summary of the manoeuvres of the upper stage, a detailed launch event time line and trajectory description, orbital ground-track as well mission-specific analyses, e.g. upper stage orientation angle to the sun, for the customer.

The resulting trajectory is then used as input data for various analyses such as orbit dispersion, loads, thermal, separation sequence and telemetry/ ground station coverage.

The results of the Critical Design Review provide the final flight data including:

- The flight event sequence for the on-board computer
- The guidance parameters for the on-board computer

8.4 Dynamics of Spacecraft Separation (Book 5)

This particular study provides a detailed assessment of the spacecraft dynamics after separation from the upper stage. This includes calculation of the separation velocity of the spacecraft relative to the upper stage and the angular velocities of the spacecraft after separation. A Monte-Carlo type analysis is used to provide a statistical basis for the results taking into account the uncertainties of the interface characteristics, e. g. variations in spring pusher force and connector disconnection force characteristics. Thus, the analysis provides a confirmation of the interface design to meet the Customer's velocity and tip-off rate requirements. The results also provide a confirmation of the overall separation strategy including collision free separation for both near and long term scenarios.

The final mission analysis repeats and confirms the studies performed during the preliminary analysis for the latest configuration data taking into account the actual *Rockot/Breeze-KM* and payload parameters. Thus it enables EUROCKOT to

- define the data to be used by the on-board computer for the orbital phase (manoeuvres, sequence)
- predict the clearance between the separated elements in orbital flight to verify collision avoidance including *Breeze-KM* orbit removal.

8.5 Thermal Environment (Book 6, parts 1 and 2)

The thermal environment study is implemented to show thermal compatibility throughout the mission. Book 6 part 1 covers the ground operations phase whereas book 6 part 2 covers the launch and ascent phase up to separation. The Customer provides a thermal model of the spacecraft containing:

- Description of the thermal nodes (heat capacities, mass type, etc.)
- Internal thermal couplings of nodes (conductive, radiative and convective)·
- Heat dissipation for all applicable modes of operation during the mission phases covered
- Interface descriptions (areas of contact, conductive and/or radiative properties)
- Thermal requirements for the environment to be maintained during integration, launch and flight

The detailed requirements of the spacecraft thermal model to be provided by the Customer are summarised in the EUROCKOT specification ESPE-0009. The preliminary thermal analysis must prove compatibility of thermal requirements and environmental conditions during the following phases or identify areas of concern where modifications have to be agreed upon for those phases:

- Operations within integration facilities
- Transportation to the launch pad
- Spacecraft integration on the *Rockot* launch vehicle
- Integrated phase until launch
- Ascent
- Aerothermal heating after fairing separation
- Coast phase

The final analysis will update the thermal compatibility study for all actual launch vehicle and spacecraft parameters.

8.6 Dynamic Coupled Loads Analysis (Book 7)

The goal of the coupled loads analysis (CLA) is to evaluate the limit levels and the frequency response of low-frequency dynamic loading of the payload below 100 Hz as part of the Integrated Launch Vehicle (ILV) in the key ascent events.

The CLA includes as many simulation runs as are required for each specific launch vehicle to spacecraft integration project phase:

In the launch vehicle to spacecraft compatibility study phase, it shall be established whether the ILV mechanical environment is compatible with the payload requirements.

In the PDR phase,

- preliminary levels of payload dynamic loads shall be evaluated,
- requirements for the adapter system shall be finalised and
- acceptable notching levels shall be determined, if required.

In the CDR phase,

- the system-level test conditions for the adapter system and the separation system shall be finalised,
- payload dynamic loads during ascent shall be predicted and
- dynamic displacements and sufficient clearance to payload fairing shall be verified.

More then one CLA simulation run may be required in any single project phase. This is particularly true for the launch vehicle to spacecraft compatibility analysis. A new updated payload model will usually be used in each successive CLA simulation run.

This analysis is based on a spacecraft dynamic model submitted by the customer as specified in detail in EUROCKOT specification ESPE-0008.

The payload experiences the worst-case dynamic loads during stage 1 flight including the worst-case dynamic pressure environment that results from aerodynamic disturbances and lasts about 60 s. Loads experienced during powered flight of either stage 2 or upper stage are much lower and are therefore of no interest in terms of payload load capability.

Thus, three major events are considered in the CLA:

- Lift-off
- Worst-case dynamic pressure q_{max}
- Stage 1 shutdown

Axial dynamic loading of the structure results from transient processes in the propulsion unit and can be predicted with a fairly high accuracy. This is evidenced by telemetry obtained in earlier missions. As for radial loads, these are caused by random phenomena such as thrust differences between cluster engines at lift-off or shutdown, the ground wind direction and speed at the time the ILV leaves the transportation and launch container, and the wind direction and speed at the time the dynamic pressure attains its peak level. Therefore, the CLA is carried out for two mutually orthogonal directions of radial disturbance when studying the above key events. These directions are usually selected to run in payload orientation planes.

The CLA time interval for each simulated event shall be long enough to ensure a reliable prediction of load levels under study.

After a description of the calculation method and the covered load cases for each event and each radial disturbance direction, the CLA Report includes

- a table of maximum CoG accelerations for each spacecraft,
- a table of maximum interface loads fo each spacecraft,
- tables of maximum values of the quantities generated by recovery matrices, and
- acceleration time histories and CoG shock spectra for each spacecraft.

The summary results in this report include summary tables of maximum CoG accelerations and interface loads for the events investigated. For a payload having a clampband interface, the maximum interface line loads and the clampband tensioning specifications are provided.

Attached to the CLA Report are ASCII files containing

- tables included in the CLA Report and specifying the maximum CoG accelerations, the maximum interface loads and the maximum values of the quantities generated by recovery matrices, and
- time variations of Craig—Bampton accelerations and displacements for each payload spacecraft.

The appendices to the CLA Report may also include supplementary data such as

- time histories of the quantities specified by the Customer,
- shock spectra of the pre-specified quantities, and
- any other data as agreed upon with EUROCKOT.

8.7 Spacecraft Cleanliness Control (Book 8)

This study provides an assessment of how the cleanliness requirements for the customer's spacecraft are implemented including methods, standards and measurement methods. The following items are covered:

- Particle cleanliness referring to the concentration of the particles in the air within the clean rooms and the payload fairing. Also the particle concentration for surfaces located close to spacecraft such as the payload fairing.
- Organic contamination (optional) considering the concentration of the organic compounds in the air within the clean rooms and the payload fairing. Also the organic compound concentration for surfaces located close to spacecraft such as the payload fairing.
- Consideration and mitigation of the outgassing and offgassing by spacecraft dispenser and payload fairing

- Consideration and mitigation of potential pyrotechnic contamination from the fairing and separation system
- Consideration and mitigation of plume contamination by retro-rockets during second stage separation as well as *Breeze-KM* thrusters during orbit or attitude manoeuvres especially during collision avoidance manoeuvres after separation.

The standard cleanliness analysis is performed in two phases. The preliminary contamination analysis must prove that accumulated contamination can be kept within the specified limits or identify areas of concern where improvements have to be agreed. The final analysis will confirm contamination compatibility for all actual launch vehicle and spacecraft parameters.

8.8 Measurement System (Book 9)

This book provides a detailed overview of the measurement system which covers both the ground and the flight operations of the *Rockot* launch system.

The ground measurement facilities, which make up part of the overall measurement system, support the acquisition of data required during ground operations. The flight measurement system has two main functions, to provide tracking of the launch vehicle during ascent within visibility of the ground stations and to downlink important telemetry information from the vehicle during the whole flight.

The tracking system of the *Rockot* launcher which uses ground radar stations and an on-board transponder is described in some detail.

The measurement system description is mainly concerned with the capabilities of this system and measurements undertaken on ground and in flight. Among other things, a list of the parameters measured by the ground measurement facilities is provided. This list includes temperature, humidity and loads during the ground operations. For the flight phase, the parameters monitored include pressure, temperatures, loads as well as separation confirmation signals. This thorough characterisation of parameters during ground operations and launch allows EUROCKOT to provide an extensive and thorough post launch evaluation giving the Customer full visibility as to whether the ICD requirements have been met and to provide lessons learned for future missions.

8.9 Electromagnetic Compatibility Study (Book 10)

The preliminary electromagnetic compatibility (EMC) study allows EUROCKOT to check the compatibility between frequencies and their harmonics used by the launch vehicle, the ground stations and the spacecraft during launch operations and flight. This study is based upon the spacecraft frequency plan including intermediate frequencies from 14 kHz to at least 20 GHz which has to be provided by the Customer. It also considers the impact of radiated emission caused by spacecraft or launch vehicle on RF communication capabilities.

The Customer is also requested to submit parameters of radio-telemetric equipment operating simultaneously with the *Rockot* transmission and reception systems during ground preparation, in flight and immediately after spacecraft deployment before the *Rockot/Breeze-KM* transmission and reception systems are switched off. The Customer also shall provide limits for emissions and susceptibility regarding radiated disturbances. In case of conflict, the study will include an analysis of possible solutions related either to the launch vehicle or to the spacecraft.

The final EMC study considers the actual configuration of the launch vehicle and spacecraft. The study involves the examination of possible spurious emission frequencies and the susceptible frequencies of the receivers.

8.10 Onboard Electrical Interface of Spacecraft and Launch Vehicle (Book 11)

This book covers in detail the configuration of the ground electrical cabling designed to provide interfaces between the Customer's electrical ground support equipment (EGSE) on the one hand, and the spacecraft at the integration facility and the launch site on the other. The extent of and procedures for electrical check-outs of the ground cabling are specified. The available power supply systems are described together with the types, quantities and the locations of outlets for connecting the Customer's EGSE at the integration facility or the launch site.

8.11 Ground Electrical Cabling, Power Supply and Interfaces with Spacecraft GSE (Book 12)

This book covers in detail the design solutions for the ground electrical cabling and interfaces of the Customer's ground support equipment (GSE) as well as a summary of the available power supplies for customer equipment. Specifically, this describes cables and harnessing in the Undertable Room 7, where the Customer's GSE is located, as well as the test steps and check-out procedures used to verify the correct installation and functioning of these circuits. Furthermore, a detailed description of the available power supplies including uninterruptible power supplies is given.

8.12 Launch Base Operations Support (Book 14 part 1, 2, 3)

Book 14 provides a summary of the agreed services necessary to support the Customer launch site operations as provided from the EUROCKOT / KSRC side. This covers the responsibilities and support as well as the agreed processing schedule in such areas as spacecraft transportation within the launch site, off-loading operations of the Customer spacecraft container and equipment at the facility, support for standalone spacecraft processing, ground operations support including support equipment such as boom lift, access platforms, fork lift etc. as well as safety aspects including definition of hazardous operations, crane operations, spacecraft fuelling support services and equipment. A successful conclusion of these aspects in the critical design review leads to the establishment and release of the Joint Operations Plan which then becomes the working document at the launch site.

8.13 Reliability (Book 15, part 1)

This book provides an overview of the measures to ensure quality and reliability of the launch process according to Russian Federation standards. Specifically this provides a description of the qualify assurance process used at KSRC including the procedures, practices and testing methods used to verify this. Furthermore theoretical reliability figures for various *Rockot/ Breeze-KM* subsystems are established to provide an overall reliability figure for the complete *Rockot/Breeze-KM* launch system. Finally, a summary of the complete licensing process including the Customer inputs and responsibilities is given.

8.14 ILV Components Quality Assurance (Book 15, part 2)

This book describes the quality management system, namely, responsibilities, the system's documentation, personnel training and continuous improvement. The plan of measures to implement the ILV quality requirements is presented.

The existing KSRC quality assurance procedures are described in detail including the respective manuals, operation guidelines and quality inspection procedures.

It is emphasised that the Customer will be enabled to track all life cycle phases of each procedure envisaged by the Quality Management System.

8.15 Social services (Book 16)

This book provides a summary of an important but often overlooked part of the launch campaign, i. e. the comfort and welfare of customer and contractor personnel during their stay at the launch site. This book describes the city infrastructure, personnel transportation services available within the launch site, the hotel and amenities such as laundry services, satellite television, medical services, dining facilities etc. Therefore, the customer has the possibility to express their agreement with these arrangements or to discuss other arrangements and services, e. g. special dietary requests like Asian food, at the preliminary and critical design reviews.

8.16 Communications support (Book 17)

This book reflects the services and infrastructure available to support the Customer's communications requirements. This includes a description of the available telephone and facsimile services, internet access via LAN or direct dial-up, mobile communications through walkie-talkies, intra-launch site high data rate communications such as fibre optic and microwave transmission as well as the provision of a multitude of satellite television channels in the hotel. Furthermore, a thorough description of the communications channels and back-up services available at the *Rockot* Mission Control Centre is given.

8.17 Security (Book 18)

This book provides a description of the jointly agreed security plan between the customer and EUROCKOT/KSRC and the launch site authorities. This aspect can be particularly important when dealing with customers with technology sensitive payloads wherein their national governments impose high security requirements on spacecraft and equipment. EUROCKOT and KSRC have gained extensive experience in this area especially in meeting the strict standards imposed for the launching of payloads from the USA, wherein round the clock surveillance and restricted access must be ensured around the satellite and equipment.

8.18 Transportation from Port-of-Entry to the Launch Site Facilities (Book 19)

This book provides a thorough description of the agreed transportation plan for the customer spacecraft and equipment from its arrival at the Russian port-of-entry Archangel Talagi airport to EUROCKOT's facilities in Plesetsk Cosmodrome. This includes definition of the transportation timeline, definition of cargo and containers to be transported, customs clearance, paperwork requirements and specific responsibilities, the transportation route and timing, interfaces to transport equipment, such as lorries, rail wagons and lifting devices, contingency planning for off nominal situations, e.g. delays as well as shipping returnable equipment after conclusion of the launch etc. It also provides an overview of the available transportation methods for personnel intending to travel to the launch site. The review of this book during the preliminary and critical design review allows the customer sufficient time to fine tune this important aspect of the launch campaign such that a smooth and successful transportation of the spacecraft and its equipment is assured.

Chapter 9 Safety

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9 Safety

9.1 Introduction

EUROCKOT is responsible for ensuring the compliance of the spacecraft, ground support equipment and launch site operations with the requirements of the standards of the Russian Federation and of countries where the spacecraft and support equipment are developed. For more detailed information refer to the EUROCKOT Safety Handbook EHB-0004. The purpose of these regulations is to ensure the safety of the environment, population, service personnel, ground equipment and facilities and the *Rockot/Breeze-KM* launch vehicle.

It is the responsibility of the Customer and the spacecraft designer to ensure compliance with the safety requirements in the design of the spacecraft, ground support equipment and applicable processes. KSRC will review each submission and issue an assessment report that will be subject to approval by EUROCKOT. A spacecraft safety certificate and a safety data package approved by EUROCKOT are pre-requisites for obtaining a launch licence from KSRC.

9.2 Submission Procedure

To ensure early identification of the constraints of the safety requirements upon the spacecraft, support equipment design and operations, the safety submissions are split into three phases with the initial phase I undertaken as soon as possible after contract signature. This allows the spacecraft contractor and Customer sufficient time to take into account design constraints and measures necessary to meet the regulations and reduce the impact of costly design changes late in the project. Figure 9-1 provides a schematic view of the submissions process.

It should be noted that the phased safety submission procedure described in the following sections is a generic description for a spacecraft under development. For existing spacecraft designs, the safety submission process can be streamlined.

9.2.1 Phase I Safety Submission

The spacecraft designer or Customer prepares a file containing all planning documents for hazardous systems. The file shall contain a description of the hazardous systems and a reply to a hazardous items check list supplied by EUROCKOT. A detailed check list of potential hazardous items can be found in the EUROCKOT Safety Handbook EHB-0004.

The document shall cover all safety-related activities such as component choice, safety and warning devices, risk analysis for catastrophic events and in general all data enabling the risk level to be evaluated.

EUROCKOT will study this submission, classify the hazardous systems described and declare any special requirements imposed by the Flight/Ground Safety departments. EUROCKOT will compile a list of potential sources of hazards in accordance with the list provided in EHB-0004. Based on this list, EUROCKOT will compile a list of reports on SC/GSE hazard analyses.

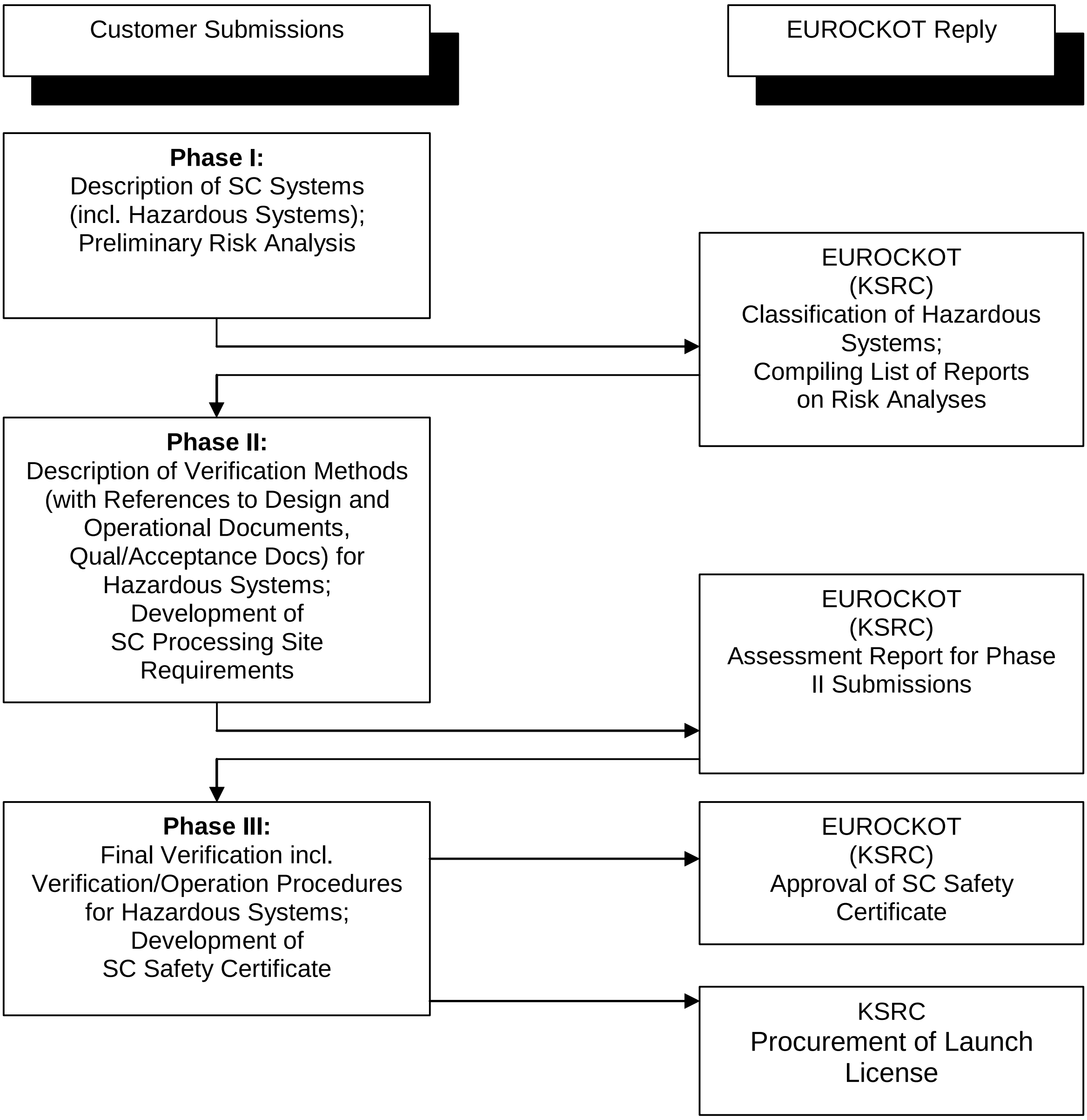

Figure 9-1 Safety submissions and assessment.

9.2.2 Phase II Safety Submission

The spacecraft designer or Customer shall submit the hazardous systems manufacturing, qualification and acceptance documentation as soon as it becomes available. It must satisfy the requirements laid down by EUROCKOT at the end of phase I. This documentation states the requirements for spacecraft integration facility equipment and operations to be used during the launch campaign and all other documents required by EUROCKOT during phase I and phase II submissions. It also defines the policy for checking and operating all systems classified as hazardous.

EUROCKOT checks that the documentation supplied in phase II complies with the requirements specified in phase I, states its intentions concerning verification of systems classified as hazardous and defines the draft procedure to be applied during spacecraft activities.

Phase II hazard analysis reports established by the Customer shall describe with sufficient degree of detail:

- Hazard prevention measures
- Methods of verification of hazard prevention measures with references to drawings, manuals, etc.
- National or agency safety standards with which the spacecraft complies

9.2.3 Phase III Safety Submission

The final safety submission must result in a statement accompanied by a data package encompassing the complete results arising from phases I and II including EUROCKOT's replies to the submissions. In addition, the spacecraft designer or Customer shall submit the final verification plan and operations procedures for systems described as hazardous.

9.3 Safety Submission Contents and Requirements

A detailed description of the format, contents and requirements for the safety submissions is given in the EUROCKOT Safety Handbook EHB-0004. As a minimum, the format and data described below must be presented at the safety review of phase III, but no later than six months prior to launch. The final statement shall take into account the responses from EUROCKOT to the safety submissions made in phases I and II.

9.3.1 Release of Safety Statements

The safety statement (safety certificate) is the official document from the spacecraft designer or Customer and is signed by responsible officers of the spacecraft designer or Customer, e. g. by the Project Manager/Chief Designer of Spacecraft, Department Manager.

9.3.2 Final Date for Submission

The final safety statement shall be submitted to EUROCKOT not later than five months before the spacecraft launch.

9.3.3 Applicability

A safety statement shall be presented for the following phases of operation:

- Operations with spacecraft and ground support equipment at the technical complex and launch complex
- Flight of the spacecraft as a part of the launch vehicle from moment of launch up to the spacecraft separation from the third stage.

9.3.4 Identification of Statements

Each safety statement is prepared in separate lists and must include the following information:

- Safety statement name and its designation number
- Name of the company which presented this statement
- Name and post of the person who is responsible for it
- Date of submission

The format of this safety statement is contained within annex 2 of the EUROCKOT Safety Handbook EHB0004.

9.3.5 Spacecraft Safety Data Package Contents

The data package which confirms the operational safety of the spacecraft and its support equipment shall be attached to the safety statement. The package of data on safety concerning the spacecraft operation shall include data as described in Sections 9.3.6 and 9.3.7.

9.3.6 Hazardous Systems

Please refer to the EUROCKOT Safety Handbook EHB-0004 for a more detailed list and description of hazardous systems.

9.3.7 Guidelines for Safety Analyses

Analyses must be undertaken concerning the safety of the spacecraft and the support equipment during the following phases of operation:

- Operations with the spacecraft and support equipment at the technical complex and launch complex
- During the flight of the spacecraft as a part of the launch vehicle, beginning with the moment of launch up to spacecraft separation from the upper stage.

9.3.7.1 Overall Assessment of Risk and Severity

The results of the safety analyses of the spacecraft and the support equipment and operations at the technical and launch complex are used to assess the overall safety of pre-launch operations.

The results of the safety analyses on the spacecraft during flight up to separation from the launch vehicle third stage are used to assess the overall safety of the flight phase of *Rockot/Breeze-KM*.

The safety of such phases is determined by the severity of the hazard impact classified with a severity of either catastrophic or critical.

- Catastrophic severity is defined as the total loss of the launch vehicle and/or spacecraft, ground facilities and/or support equipment. and/or severe injury or loss of life to service personnel and/or severe damage to the environment and population.

- Critical severity is defined as a partial launch failure, aborted launch because of the launch vehicle and/or, the spacecraft and/or support equipment failure and non-fatal injury to service personnel.

In flight:

- Catastrophic severity is defined as the loss of the launch vehicle and/or the spacecraft.
- Critical severity is defined as an incomplete achievement of the mission goal, i. e. reduced mission effectiveness.

9.3.7.2 Probability of Hazards

The potential threat of a hazard must be evaluated qualitatively by classification of the probabilities of such events occurring into categories ranging from “High” to “Remote”.

9.3.7.3 Prevention of Hazards

In the safety analyses of the spacecraft and support equipment, measures concerning prevention of hazards via the spacecraft design, technology and operational barriers must be shown.

The requirements for spacecraft safety must include the following:

- Design characteristics. Safety of spacecraft and support equipment via design measures and material characteristics such as:
  - Strength coefficients
  - Sealings/couplings structure and quality of umbilical connectors
  - Design and layout of the cable network insulation
- Inhibits. Safety inhibits of spacecraft and support equipment, concerning inadvertent operation of systems:
  - Inadvertent operation leading to a catastrophic failure must be inhibited by at least three independent mechanical or electrical inhibits.
  - Inadvertent operation leading to a critical failure must be inhibited by at least two independent mechanical or electrical inhibits.

9.3.7.4 Reference Documents

In the results of the analysis of the spacecraft or support equipment, there should be references to design and operational documentation, to procedures on equipment and system level, to existing statistics for previous spacecraft/equipment, or to verification by similarity. In analyses of emergency cases in which the spacecraft or equipment endangers the launch or technical complex or the launch vehicle during flight, any documents used as references in the assessment must be mentioned. In the event of any of the above mentioned documents having classified status and being unable to be released, a non-classified version of the document should be provided.

9.4 Non-compliance with Safety Requirements / Waivers

EUROCKOT and KSRC shall identify the non-compliances, if any, of the spacecraft and its GSE with the safety provisions of EHB-0004 as early as possible. The Customer shall document any non-compliance in form of a report on spacecraft non-compliance with the safety provisions of EHB-0004 and submit this report to EUROCKOT and to KSRC safety experts for review and provision of their recommendations. These recommendations shall be taken into account and implemented prior to spacecraft safety certification. The non-compliance reports shall demonstrate that a particular provision or provisions in EHB-0004 cannot be complied with and yet the respective operational and/or managerial measures introduced in connection with the non-compliance or non-compliances under review will minimize the risk of the associated hazards. Each report shall be signed by the spacecraft designer's executives whose positions are higher than those of the signatories to the hazard reports.

The spacecraft safety statement shall be signed at a higher managerial level if the spacecraft fails to comply with one or more provisions in EHB-0004.

9.5 Summary

It must be shown as a result of the safety submissions described above that the spacecraft and its support equipment have been subjected to analyses and tests which confirm their compatibility with the *Rockot/Breeze-KM* launch system for all phases from launch preparation, through the launch and ascent phase and up to spacecraft separation. The final safety submission (phase III) shall be presented to EUROCKOT not later than five months prior to launch for approval.

It should be noted that EUROCKOT will work actively with and assist the spacecraft contractor or Customer to help them meet the safety regulations. For this purpose, EUROCKOT will interact with the Customer very early on in the mission integration process (phase I submission) to ensure that no surprises occur at a late date.

Chapter 10 Plesetsk Cosmodrome

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10 Plesetsk Cosmodrome

10.1 General Description

The *Rockot* Plesetsk launch site is located at 62.7° N latitude and 40.3° E longitude, about 800 km north-east of Moscow and 200 km south of Archangel (Figure 10-1).

The Plesetsk Cosmodrome was founded in 1963 as a test range for launchers. Since 1967 several international programmes with the participation of France, Germany, Great Britain and the USA have been launched from Plesetsk. Plesetsk Cosmodrome conducted over one third of all launches in the world with a total number of over 1500, including launches for some 30 Western and Asian satellites. Plesetsk Cosmodrome covers an area of 1752 km² and includes the non-civilian Pero Airport and a railway station, the town of Mirny, LOX and LN2 plant, ground tracking stations, integration and technical facilities and launch pads. The main layout of the Cosmodrome is shown in Figure 10-2.

The facilities used for the *Rockot* launch are:

- The launch complex comprising:
  - Ground support facilities including service tower, stationary mast, air conditioning system, fuelling system for stage 1 and stage 2, and equipment for launch preparation
  - Payload EGSE rooms in the under-table area
- Mission control centre (MCC) in Mirny, which provides:
  - Accommodation for the Customer during launch
  - Customer console seating
  - Countdown
  - Data display and transmission of launch information
  - Operational communications
  - Room for VIP/Catering
- Integration facility MIK with
  - General hall for offloading/ loading, container cleaning and storage
  - Clean room bay with upper composite integration room and processing room for spacecraft integration, testing and for spacecraft fuelling
  - Administrative area with offices and monitoring room
  - EGSE and fuelling control rooms
  - Capability for environmentally controlled spacecraft battery storage
- Helicopter landing pad
- Fuelling facility for the *Breeze-KM* upper stage.
- Airport
- Hotel *Rockot* in Mirny

All the facilities used for the *Rockot* launch are linked by rail and road. The *Rockot* dedicated launch pad is adjacent and the helicopter landing pad is in the vicinity of the MIK (Figure 10-2).

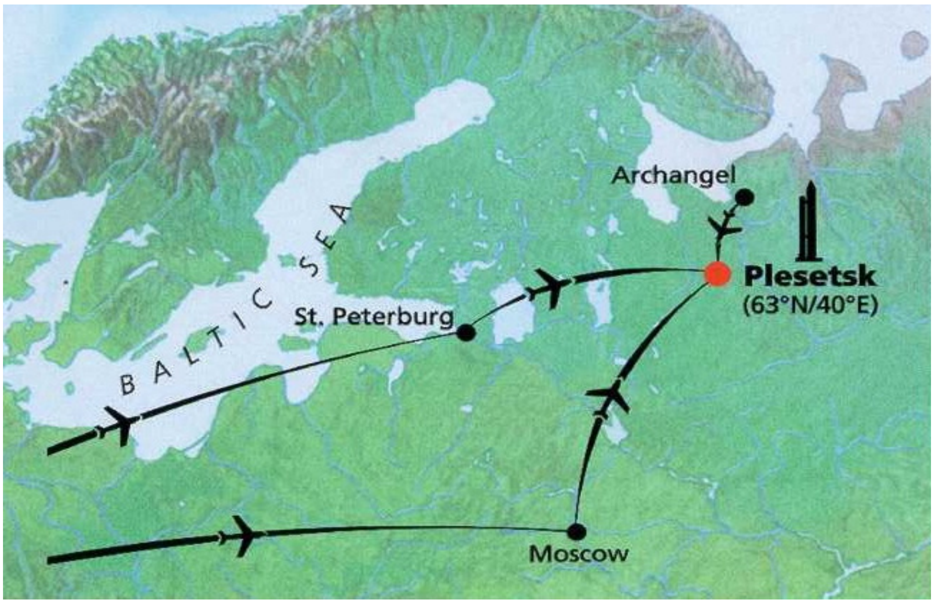

Figure 10-1 Geographical location of the Plesetsk Cosmodrome.

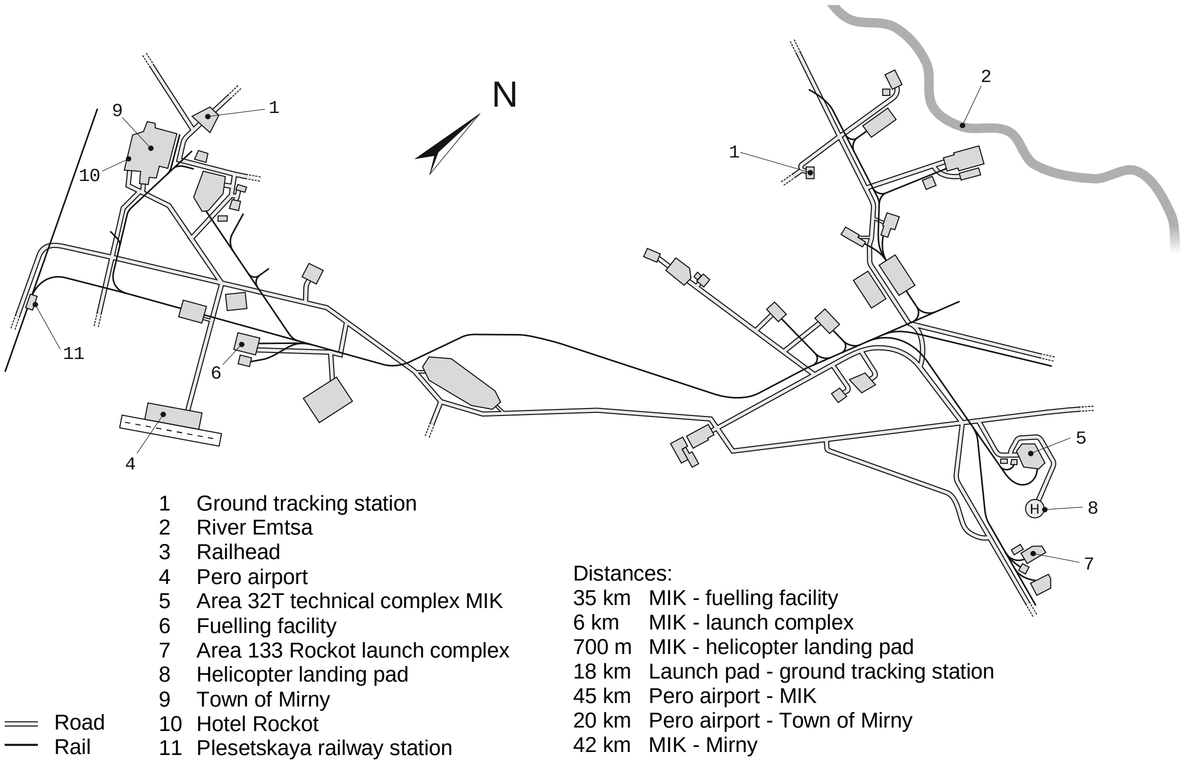

Figure 10-2 Plesetsk Cosmodrome layout.

10.1.1 Climatic Conditions

The climatic conditions in Plesetsk are continental, with the following characteristics:

- Minimum winter air temperature -38°C
- Maximum summer air temperature +33°C
- Average annual precipitation amount 398 mm

10.2 Logistics

The main goal of the logistics items described in the following is to provide an overview of how the transportation, especially of the spacecraft and related equipment as well as customer personnel to Plesetsk Cosmodrome can be performed. The transport logistics described herein are all qualified and operational and have been used by all EUROCKOT Customer's to date. Although not explicitly described, an identical but reverse transportation route will be used for return of spacecraft equipment and personnel after conclusion of the launch campaign.

10.2.1 Spacecraft and Hardware Transport

As a baseline, EUROCKOT's transportation responsibilities begin upon off-loading of the Customer spacecraft and equipment at the Russian port-of-entry, Talagi airport in Archangel. EUROCKOT supported by KSRC and its Russian subcontractors will provide a team and equipment to conduct off-loading and transfer activities from the aircraft all the way to EUROCKOT's processing facilities in Plesetsk Cosmodrome.

The Customer will also be fully supported by EUROCKOT and KSRC during the customs clearance process at the port-of-entry.

Table 10-1 gives an overview of the characteristics of Archangel Talagi and other airports potentially used. Archangel Talagi is able to handle the largest Russian cargo aircraft, the AN-124, which is generally the workhorse of the space industry for large transports (Figure 1-4). This port-of-entry is usually used by Customers for the import of their spacecraft and equipment to the Russian Federation.

The spacecraft and equipment transport to the EUROCKOT facilities is described below. An approximate timeline for a Customer from Asia is provided as an example for preliminary planning purposes. Aircraft arriving directly from Europe and the USA will have different arrival times due to their different time zones.

- Day one morning: arrival of the transport aircraft (e. g. AN-124) at the Russian port-of-entry Talagi airport in Archangel.
- Day one morning: off-loading and customs clearance in Talagi.
- Day one noon: loading of equipment onto EUROCKOT / KSRC supplied lorries and transfer at low speed to railhead over an approximate distance of 10 km (Figure 1-5).
- Day one afternoon to early evening: transfer and securing of spacecraft and equipment from lorries to railway wagons (Figure 1-6, Figure 1-7).
- Day one evening: departure of railway wagons to Plesetsk train station with a

travel distance of approximately 200 km. As the public railway system is used on this route, the transportation is conducted during the night in order to allow low travel speeds.

- Day two morning: arrival of train at Plesetsk train station and transfer to internal cosmodrome railway network.
- Day two morning: transfer on the cosmodrome internal rail network to the EUROCKOT processing facilities and subsequent off-loading of equipment (Figure 1-8).

An optional transportation path for spacecraft fitting into a standard 20 foot container or smaller is to fly to Pero airport at Plesetsk Cosmodrome using an IL-76 after an intermediate customs stop in Archangel Talagi airport.

Parameters	Sheremetyevo/ Domodedovo Moscow	Pulkovo, St. Petersburg	Talagi, Archangel	Pero, Plesetsk Cosmodrome*
Status of airport	International	International	International	Non-civilian
Runway length	3699 m 3794 m	3780 m	2500 m	2000 m
Surface solidity, PCN	No constraints	No constraints	44	11
Types of aircraft to be accommodated	All types	All types	AN-124, restrictions may apply to some other wide body aircraft types	IL-76, AN-72, AN-12, AN-24, YAK-42, Yak-40
Landing category	III A	II	II	I
Role of airport for spacecraft shipping	Port of entry back-up	Port of entry back-up	Nominal Port of entry	For small spacecraft only

* Pero Airport of Plesetsk Cosmodrome is operated and controlled by the Russian Space Forces (RSF) and can process civilian aircraft only if cleared by the Russian Ministry of Defence (MOD) general staff and possibly subject to special navigator availability on board.

Table 10-1 Characteristics of airports for shipping of spacecraft containers, related GSE and personnel transfer.

10.2.2 Transportation Requirements

The basic transportation requirements for spacecraft and related equipment are described in detail in the Customer's response to the spacecraft questionnaire data sheet (chapter 12), sent at the beginning of the project to customers and reviewed during the spacecraft to launch vehicle preliminary and critical design reviews. These requirements are transferred to the Joint Operations Plan. The requirements shall cover the following at least:

- Container handling and storage requirements
- Number, dimensions, weight, centre of mass, and material of all containers

- Container grounding requirements
- Necessity of immediate container transfer or possibility of intermediate storage upon arrival
- List of hazardous materials and their international codes
- Maximum allowable duration for interruption of container power supply and maximum/minimum allowable ambient temperatures during periods of cargo transhipment

10.2.3 Transport Environments

The spacecraft and its equipment will be subjected to mechanical and thermal environments during their transportation by air and on the ground as well as during ground handling. In section 5, the worst case transportation and handling loads are described. Electrical power can be supplied to the Customer for environmental control if the spacecraft container does not have its own power. Additionally, the results of transportation load measurements for rail and road transport are included.

10.2.3.1 Environmentally Controlled Transport of Spacecraft during Launch Campaign

For the transport of spacecraft as part of the launch vehicle upper composite from the payload processing facility (MIK) to the launch pad, a mobile thermal conditioning system is available (Figure 1-26).

In order to maintain the required temperature, moisture and cleanliness conditions under the fairing in the vicinity of the spacecraft, the thermal conditioning unit is connected to the upper composite after its assembly and reloading on the transportation unit. The characteristics of conditioned air can be taken from chapter 5.2.3.

10.2.4 Spacecraft Team Transport to Plesetsk Cosmodrome

Customer personnel transfer from the Russian port-of-entry to Plesetsk Cosmodrome, as well as the transfer from hotel to launch site facilities, will be arranged and supported by EUROCKOT/ KSRC. Upon request, quotes for air / rail transportation fees will be provided.

For entry to Russia, EUROCKOT will support the Customer's team in all necessary formalities for customs clearance and in the obtaining of visas for the spacecraft team. The entry to Russia and departure from Russia will also be assisted by EUROCKOT.

Normally, the spacecraft team will arrive at Sheremetyevo or Domodedovo International Airport, Moscow. The ongoing possibilities of transfer to Plesetsk Cosmodrome are described in the following chapters.

10.2.4.1 Charter Aircraft

Pero Airport at Plesetsk Cosmodrome has limitations on the aircraft size to be accommodated (Table 10-2). For the transport of the Customer's personnel, a YAK-40 aircraft will normally be used. The YAK-40 can be provided in an economy class configuration with 22 seats or in a configuration with 5 business class seats and 10 seats of economy class. The flight duration from Moscow to Plesetsk is approximately 2 hours.

10.2.4.2 Scheduled Flights

The nearest airport to Plesetsk Cosmodrome for scheduled flights is to Talagi airport in Archangel. The flight route Moscow - Archangel with a flight duration of approximately 1 hour 50 minutes is a regular scheduled route. EUROCKOT can arrange a special transfer from the airport to Plesetsk Cosmodrome by car taking approximately 5 hours.

10.2.4.3 Rail Transfer to Plesetsk Cosmodrome

A convenient alternative and non-weather constrained option for travelling to Plesetsk is by rail. The rail transfer from Moscow to Plesetskaya, which is 3 km south of Mirny, is via overnight train and takes 18 hours. This transportation route is especially suitable and cost-effective for transportation of small groups of personnel to and from the launch site. Please note that the overall travel time for the customer to the launch site from their foreign facilities is not much longer than via other routes. The travellers sleep in the train rather than staying overnight in Moscow and arrive the next day, as they would if they flew by charter aircraft. The sleeping compartments are of good standard and are comfortable and clean. Booking of sleeping compartments in the train can be arranged through EUROCKOT as well as a transfer to a domestic airport or railway station in Moscow.

If customers arrive by plane in Archangel, a transfer to Plesetsk can also be arranged by train taking approximately 5 hours.

The transfer from Plesetskaya station to Hotel *Rockot* in Mirny, which is located in the military restricted area of the Cosmodrome will be organised by EUROCKOT.

10.2.5 Customer Team Transport at the Launch Site

At the launch site, buses, minivans and, if necessary, lorries will be made available to transport the management team, technical support and security personnel to the work area during spacecraft processing and launch operations according to the daily working schedule. The distance between Hotel *Rockot*, where the Customer is accommodated, and the technical complex is 42 km. The transfer time by bus is approximately 45 minutes.

10.3 Communications

Reliable and independent national and international communication services are provided by the telecommunication system installed in Plesetsk Cosmodrome. All positions in the processing facility MIK, launch pad, mission control centre (MCC) and Hotel *Rockot* are interconnected by microwave or fiber-optic lines that are connected to international lines through Moscow via satellite (Figure 10-3). The following types of optional telecommunication services are available upon request:

- Local and international direct dial (IDD) phone lines
- Data lines
- LAN
- Mobile radios (IDD)
- CCTV
- Inmarsat

- Internet access and mail server
- Various types of telecommunications support at the MCC (Section 10.4.4)
- Entertainment TV in the hotel

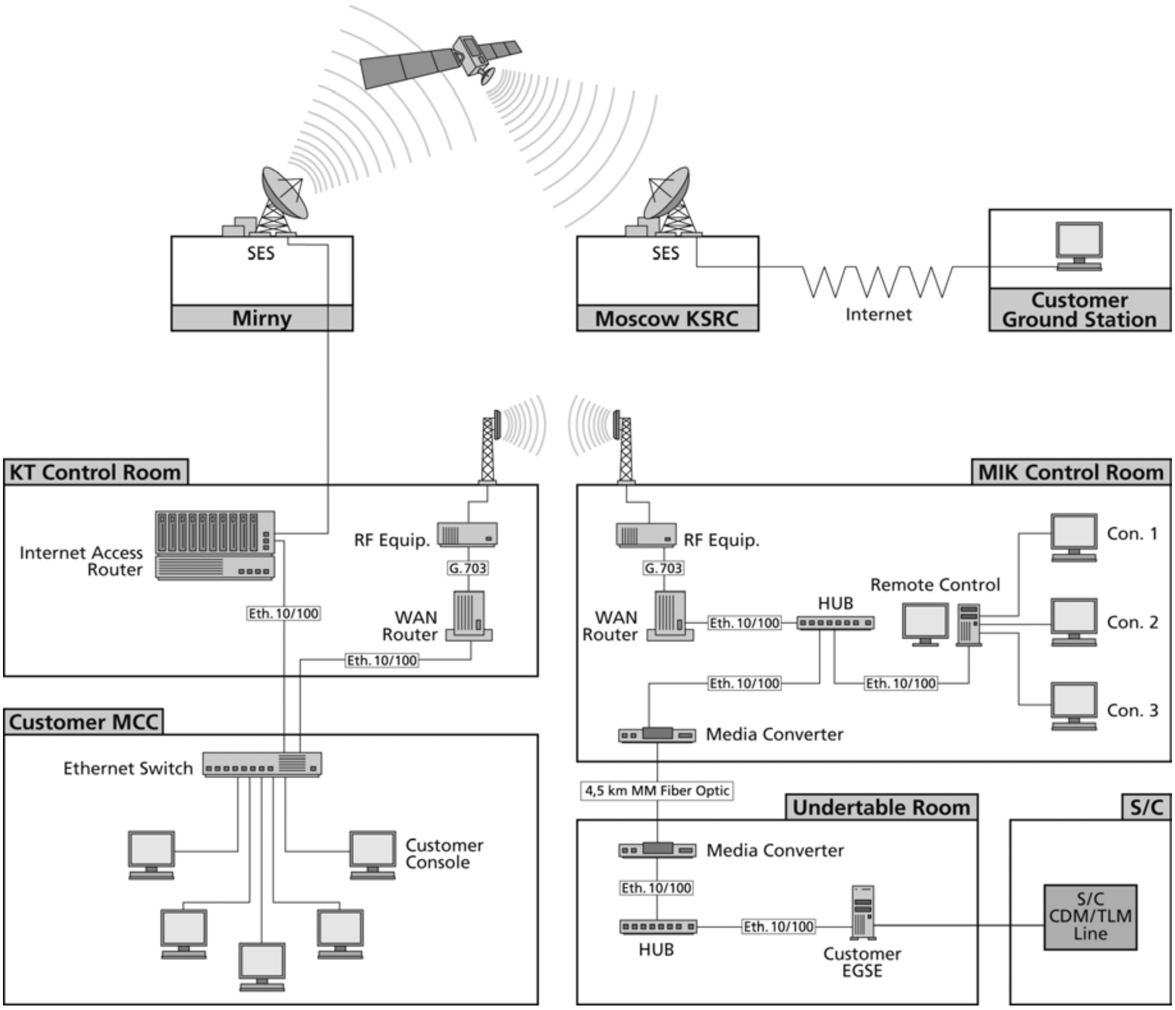

Figure 10-3 Communications links.

10.3.1 Phone Lines

The national and international phone lines support links between launch site facilities, the Mission Control Centre and the hotel. International calls can be placed from any phone line. Multi-purpose RJ 45 jacks are used to connect either digital or analogue phones. Access to mobile radios is possible within the phone network.

10.3.2 Data Lines

In order to support data transmission at the launch site, inter-area data lines connecting the integration facility MIK, the launch complex and the hotel as well as international data lines are available. The launch site inter-area data lines comprise:

- Analogue interface for modem-based transmissions at up to 19.2 kbps
- ISDN interfaces for data rates of up to 128 kbps
- V.35 interfaces for data rates of up to 64 kbps
- Data transmission over a multi-mode fibre optic cable between the Undertable Room 7 and the integration facility
- LAN cable network in the MIK and Hotel *Rockot* with RJ45 interface. To interconnect the MIK LAN segment and hotel LAN segment into a network, a 2048 kbps channel is provided that runs through the MCC.
- Dial-up access to Internet and a mail server of up to 30 users at a time with V.90 protocol (56 kbps) from any analogue phone interface
- For access to Internet from the customer's LAN, a network infrastructure using Ethernet data lines is provided. Internet access from MIK and/or *Rockot* Hotel via dedicated lines to Moscow ISP makes use of a satellite channel with 64 Kbps to 2048 Kbps data rate.
- For spacecraft check-out while on the launch pad an Ethernet data exchange channel between the MIK and the launch pad can be provided. The Customer's EGSE LAN segment in the MIK and on the launch pad can communicate via media converters with Ethernet protocol operating through multimode fibre optic lines with a data rate of up to 10 MBits/s.

10.3.3 Mobile Radios

Mobile radio links will be available at the MIK, at the launch site, in the Customer accommodation area and also along the routes interconnecting any two of these locations. The mobile radio system operates in half duplex mode and supports either conference sessions or point-to-point links, with mobile radio access to or from the launch-base phone network being possible. The required quantity of calling groups will be pre-programmed in each portable radio in use by the Customer.

10.3.4 CCTV

Security video monitoring services will be provided at the integration facility and the launch complex. The system enables monitoring of the spacecraft and the Customer's GSE with the image sent to the Customer's rooms, taped and/or played back. The following video support is available at the launch site:

- Explosion-proof video cameras available in all clean rooms with the camera outputs delivered to the Customer's office
- Video monitors available in the Customer's office. Each video camera can be remotely controlled, i. e. panned, tilted, focused and/or zoomed from this office
- Video taping capabilities
- Video cameras available in the Undertable Room 7 to monitor the Customer's GSE. The outputs from these cameras

will be sent to the Customer offices in the MIK.

10.3.5 Entertainment TV

Four different TV channels in English, German and/or other languages upon request are available in each room of the *Rockot* Hotel used by the Customer's staff.

10.4 Ground Facilities

The facilities available to the customer for their spacecraft processing and launch campaign activities are described below.

EUROCKOT's facilities at the launch site have been specially designed and constructed to enable convenient implementation of customer security measures. For instance many of the facilities can be placed under the sole control of the Customer and, therefore, under his security control. For these areas, the Customer can implement access control procedures in accordance with Customer state governmental regulations. Within the MIK, the Customer has its closed dedicated area under its sole security control. Within this dedicated area the Customer can move without escort. This closed dedicated area contains:

- A spacecraft processing area for conducting autonomous spacecraft operations and spacecraft fuelling
- EGSE rooms for support equipment installation
- Change rooms, shower and rest rooms as well as an air shower
- Emergency exits with emergency showers and eye wash facility
- Office area

Access to the Customer area on the first and second floor of MIK can be gained via a separate entrance with staircase or escorted via the general MIK entrance. An additional staircase in the Customer's office area allows direct access to the foyer of the Customer's changing rooms. Entrance to the spacecraft processing area and EGSE rooms, as well as to the upper composite integration area in the case of joint operations, is possible without contact with military controlled areas.

At the launch complex, the Undertable Room 7 is dedicated to and under the security control of the Customer.

Video observation of the clean room area as well as the Undertable Room 7 can be performed from the Customer's security office. During launch, the separate mission control centre is used.

10.4.1 The Integration Facility MIK

The integration facility MIK (Figure 1-8, Figure 10-4), internally designated building 130 in area 32T, is located in the south-eastern part of the Cosmodrome at a distance of 6 km from the EUROCKOT launch complex and 42 km away from the town of Mirny. The spacecraft container and related equipment can be directly delivered to the MIK by helicopter. A helicopter landing pad is located in the vicinity of the MIK.

The integration facility is intended for acceptance, storage, assembly and checking of boosters, *Breeze-KM* and fairing, acceptance of spacecraft, spacecraft operations and assembly of the upper composite. It comprises:

- General Hall with common work area
- Clean room bay, certified cleanliness ISO Class 8 with
  - hardware air-lock (54 m²) and personnel air-lock (101V)
  - clean room for the upper composite encapsulation (101B, 146 m²)
  - clean room for the spacecraft processing and fuelling (101A, 180 m²)
- Two EGSE rooms (111 and 111A)
- Administrative area with Customer offices and rooms for remote control

Customers requiring clean room cleanliness conditions better than the given standard should contact EUROCKOT for further information. Fuelling of spacecraft can take place on a fuelling platform in Room 101A within the closed clean area described above. This platform with an area of 9150 × 7620 mm contains a system for containment and drainage of minor spills smaller than 1 litre of hydrazine propellants. The spacecraft will be placed on a special-purpose 3000 × 3000 mm support adapter. Room 111A can be used as a fuelling control room. A viewing window between these rooms enables visual contact.

EUROCKOT can optionally provide a fuelling service performed by an experienced and qualified team.

The clean room bay is equipped with an oxygen content control system and a hydrazine monitoring system. Critical values will automatically initiate alarm by acoustic and visual means. Fire protection in the integration facility is provided not only in the usual way but also by a water deluge system on the walls and by water curtains on the doors of the clean room bay.

The floor in the MIK is made of anti-static and electrically conductive linoleum.

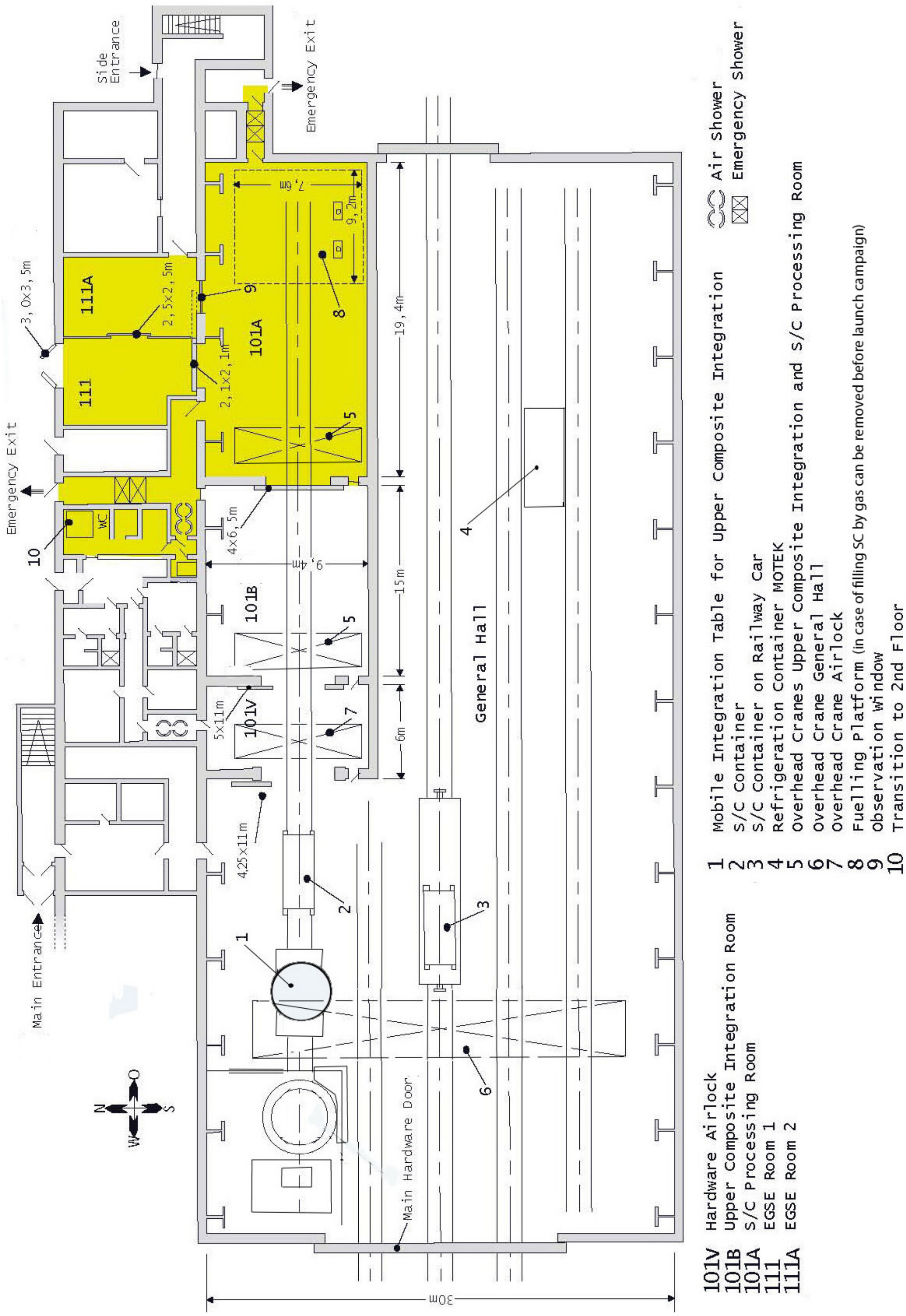

Figure 10-4 **Layout of the integration facility MIK.**

10.4.1.1 General Hall

The common work area (Figure 10-4) with 500 m² in the general hall of the MIK is dedicated for ground support equipment unloading, unpacking/ packing and short-time storage, booster preparation, autonomous checks of *Breeze-KM* and fairing, and electrical checks of the upper composite. For lifting operations, an overhead travelling crane with 30 tonnes lifting capacity is installed. The general hall is not environmentally controlled but can be kept at reasonable temperatures.

10.4.1.2 Clean Room Bay

The spacecraft processing as well as upper composite integration and encapsulation will take place in the closed clean area of the MIK (Figure 1-14) which is certified to cleanliness ISO Class 8. The particular parameters of environmental control can be taken from Section 5.2.2. Higher cleanliness levels can be provided as an option.

10.4.1.2.1 Airlock

The airlock (room 101V) located at the beginning of the clean room bay has a floor area of 54 m² (9.4 m wide and 6 m long). An overview of the equipment of the airlock is given below. The final cleaning of the spacecraft container and associated equipment will be done here.

Equipment of the airlock:

- Explosion-proof cameras for remote control
- Explosion-proof phones
- Wall mounts for 120 V 60 Hz and 380 / 220 V 50 Hz power supply
- 2 t overhead crane
- Sensors, acoustic and visual warning devices of oxygen control system
- Sensors, acoustic and visual warning devices of hydrazine/ oxidiser control system
- Particle counter
- Grounding terminals
- Emergency lighting
- Fire protection system
- The size of the door leading from the general hall to the airlock is 4.25 m wide x 11 m high

10.4.1.2.2 Upper Composite Integration Area

The upper composite integration area has an area of 146 m² and is located between the airlock and the spacecraft processing area. The upper composite integration area is intended for the mating of the spacecraft with *Breeze-KM* and assembling of the upper composite (Figure 10-5). The equipment of the upper composite integration area is stated below. The upper composite integration area is accessible for the Customer’s personnel from the clean room changing area under the Customer's security control after they have passed through the air shower.

The facility has two main doors for movement of spacecraft and equipment. The door to the airlock is 5 m wide x 11 m high, while the door to the spacecraft processing area is 4 m wide x 6.5 m high.

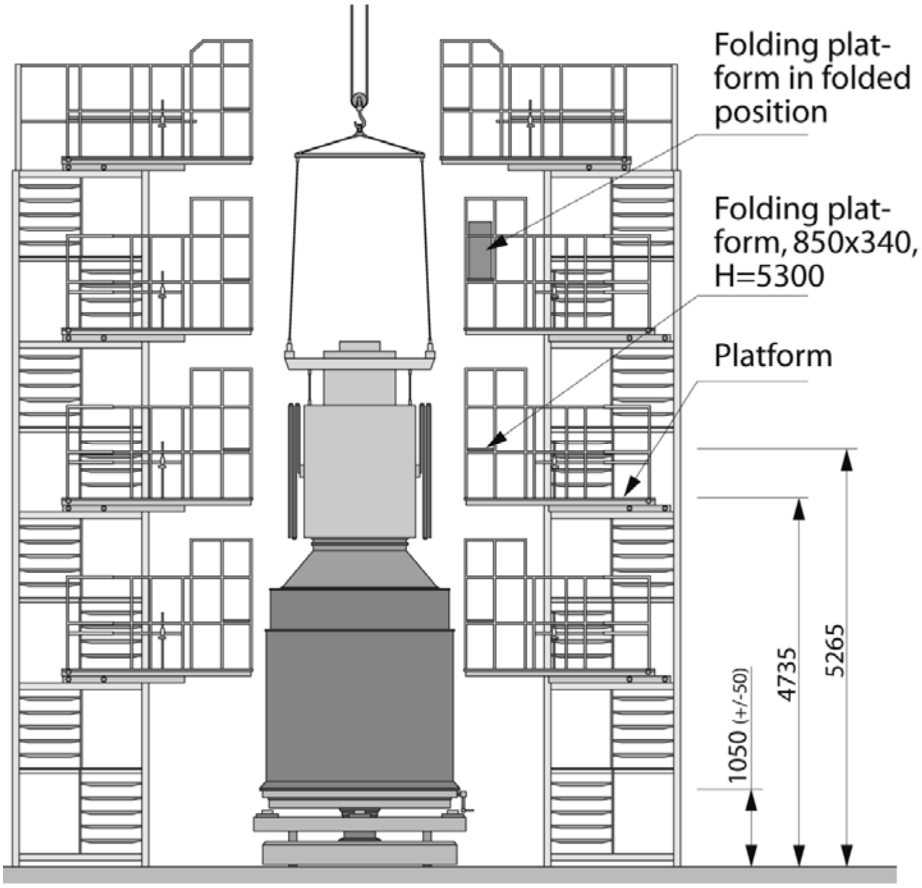

Figure 10-5 Assembly stand with platforms in upper composite integration room.

The upper composite integration room is equipped with:

- Explosion-proof cameras for remote control
- Explosion-proof phones
- LAN-drops
- Wall mounts for single and three phase 208/120 V 60 Hz and 380/220 V 50 Hz power supply
- 10 t overhead crane
- Assembly stand shown in Figure 10-5
- Emergency exit with emergency shower and eye wash facility
- Sensors, acoustic and visual warning devices of oxygen control system
- Sensors, acoustic and visual warning devices of hydrazine/ oxidizer control system
- Particle counter
- Grounding terminals
- Emergency lighting
- Fire protection system

10.4.1.2.3 Spacecraft Processing Area

The spacecraft processing area (room 101A), placed under Customer security control, covers a total area of 180 m². This area of the clean room bay is intended for spacecraft processing and comprises a 90 m² work area and a spacecraft fuelling area with 90 m². The spacecraft processing area is accessible for the Customer's personnel through a separate entrance from the clean room changing area under the Customer's security control after they have passed through the air shower. Two emergency exits are installed in the north and the east of the processing area, each comprising two showers and one eyewash facility. All operations in this spacecraft processing area can be monitored and recorded. Additionally, an explosion-proof window provides a view from EGSE room 111A which can be used as a fuelling control room, (section 10.4.1.3).

The facility's main door for movement of spacecraft and equipment from the upper composite integration area is 4 m wide x 6.5 m high.

For spacecraft fuelling operations, EUROCKOT can provide a removable fuelling platform (Figure 10-6) with a system for containment and drainage of minor spills of not more than 1 litre and a spacecrafft support adapter. This fuelling platform will be located in the spacecraft processing area. The fuelling platform is further designed to accommodate the fuelling equipment and propellant containers.

The provision of industrial-grade compressed air and technical water to wash out spillage as well as a blast shield to support operations involving high-pressure gases are standard services.

A rescue team will be on duty throughout the fuelling operations. This team will include a fire engine, an ambulance and a medevac car each fully manned.

Equipment of the spacecraft processing room:

- Explosion-proof cameras for remote control
- Explosion-proof phones
- LAN-drops
- Wall mounts for 208/120 V 60 Hz and 380/220 V 50 Hz power supply
- 10 t overhead crane
- Removable fuelling platform with a spillage containment and drainage collection system
- Two emergency exits with emergency showers and eye wash facilities
- Sensors, acoustic and optic warning devices of oxygen control system
- Sensors, acoustic and visual warning devices of hydrazine / oxidizer control system
- Particle counter
- Grounding terminals
- Emergency lighting
- Fire protection/extinguishing system
- Industrial-grade compressed air supply
- Industrial-grade water supply to wash down spillages
- Blast shield to support operations involving high-pressure gases

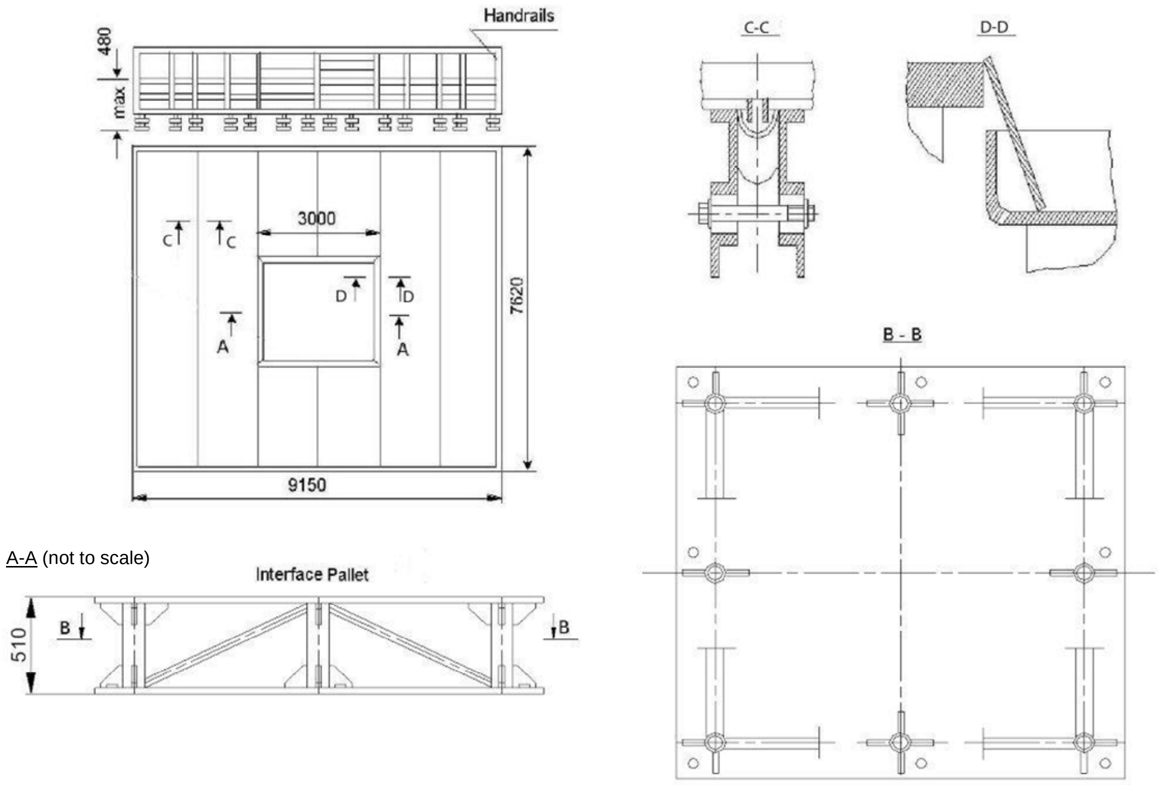

Figure 10-6 Scheme of removable fuelling platform.

10.4.1.3 EGSE Rooms

Adjacent to the clean area, an EGSE room with an overall floor area of 100 m^2 is located. A wire-mesh bulkhead with a 2.5 m wide × 2.5 m high sliding door subdivides this room into room 111 with 60 m^2 and room 111A with 40 m^2.

These rooms can be used for accommodation of the electrical equipment and fuelling equipment and can accommodate stations tooled up to support spacecraft processing.

The Customer's personnel can access room 111A from the office area on the second floor.

Room 111A is equipped with a viewing window to observe operations in the spacecraft processing area. If fuelling of the spacecraft is performed in the spacecraft processing area, room 111A can be used as a fuelling control room.

Room 111 has a door 3 m wide x 3.5 m high to transfer hardware from outside the building.

There is a 2.1 m wide x 2.1 m high door between room 111 and the spacecraft processing area. This door can be opened for the time the GSE is being set up. However, it will be airtight sealed during clean operations.

If the spacecraft battery stored in room 111 needs cooling, the MOTEK battery cool cabin built around a 20 foot sea shipping container can be provided upon request.

Equipment of EGSE rooms:

- Cameras for remote control
- Monitors (optional)
- Phones
- LAN-drops
- Wall mounts for 208/120 V 60 Hz and 380/220 V 50 Hz power supply
- Ground terminals
- Emergency lighting
- Common fire protection system
- Optional optical and/or RF link terminals to the SC and/or Customer's EGSE at the Launch Pad.

10.4.1.4 Customer's Office Area

The Customer's offices are located on the 2nd floor of the integration facility extension in the vicinity of EUROCKOT and KSRC offices (Figure 10-7). The second floor is above the EGSE rooms and clean room changing area. Access to the Customer's office area is provided via the common MIK entrance or by a separate staircase. The entrances to the Customer's office area corridor are secured by lockable doors.

The administrative area for the Customer comprises seven offices (4 x 41 m² and 3 x 20 m²) dedicated to sole Customer use (Figure 10-5). All rooms are equipped with heating, smoke detectors and fire extinguishing systems and have a telephone / fax capability, LAN- drops and a 60 Hz and 50 Hz power supply. Room 210 of the Customer's office area provides direct access to the changing rooms of the clean area by stairs. Room 209 provides video monitoring capabilities for the TV cameras which are installed in the processing area for security and safety needs.

Office equipment such as fax devices, electronic data processing system and computer monitors, copy machines, overhead projectors etc. are available upon request.

10.4.1.5 Handling and Hoisting Equipment in MIK

The main handling and hoisting equipment in MIK comprises:

- Boom lift
- Fork lift
- Rail car
- Trolley for adapter with spacecraft
- Mobile integration table
- Upper composite assembly stand

10.4.1.6 Power Supply of MIK

Uninterrupted power is supplied in all Customer dedicated areas in the MIK, airlock and Upper Composite integration hall with 208/120 V at 60 Hz and 380/220V at 50 Hz.

The 208/120 V, 60 Hz Power Supply System (PSS) is a self-contained power supply system set incorporating two diesel-generators and two uninterruptible power sources (UPS). The PSS specifications are listed in Table 10-2.

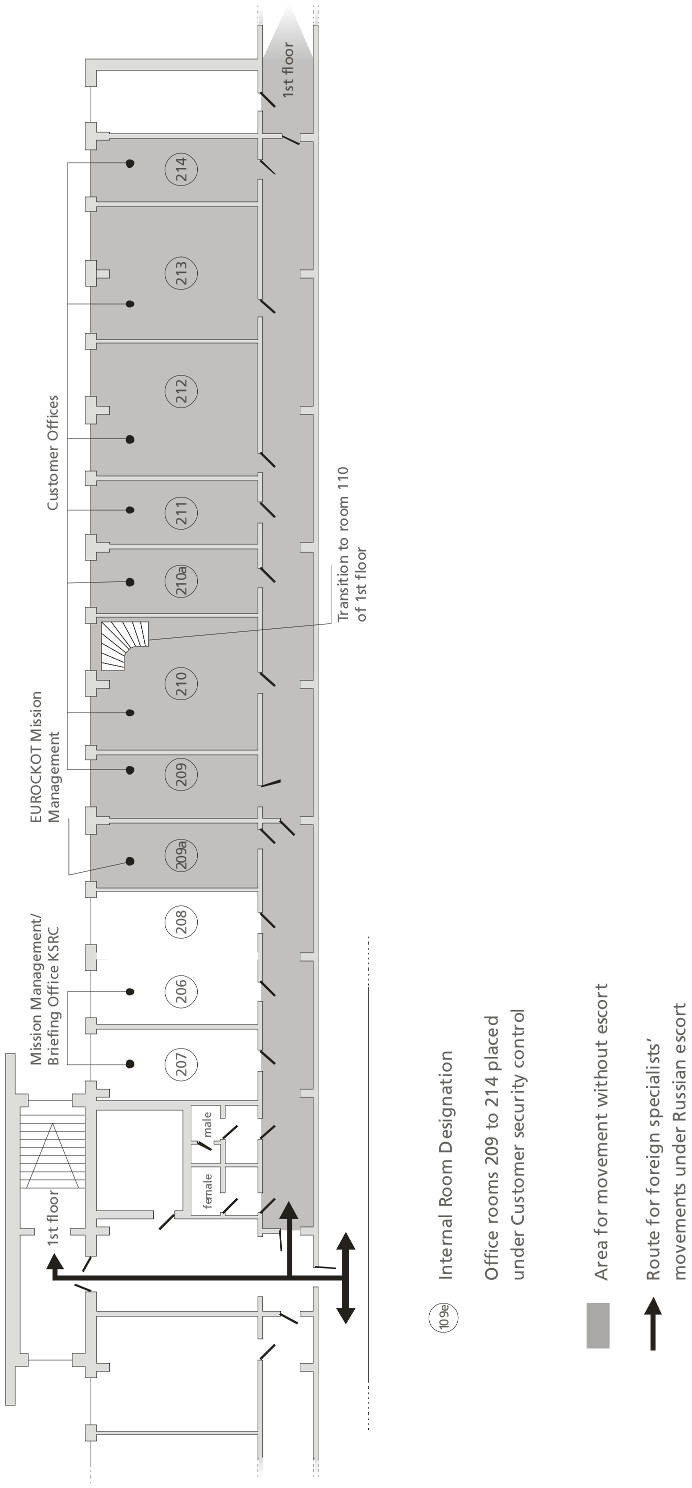

Figure 10-7 Customer office area in MIK.

The power supply system can operate non-stop for 30 days before it is turned off for maintenance work. In the case of failure of either a diesel generator (DG) or an uninterruptible power source (UPS), the other DG or UPS will run at rated 100% power output. The uninterruptible power source includes built-in battery-supported converters providing 100 kW power for not less than 10 minutes.

50 Hz UPS power is also provided in the EGSE rooms as single or three phase power supply to a total maximum rate of 30 kVA. The specification of the 50 Hz UPS power supply system is given in Table 10-3.

Item	Description
Rated power output	100 kV·A (cos φ = 0.8)
Power change under load (power consumers)	From 0 to 100% of the rated output
Line/phase output voltage	208/120 V
Voltage waveform	Continuous sinewave
Current frequency	60 Hz
Stable output voltage variation	±1%, continuous with the load increasing from 0 to 100% and falling back to 0
Overload capacity at power output of	110% ≤ 20 min 125% ≤ 10 min 150% ≤ 1 min 200% ≤ 1 s
Stable output frequency deviation	±0.1 %
Total harmonic distortion factor	< 3% in static conditions < 5% in dynamic conditions
Storage battery capacity	At least 10 min
Voltage regulator response time	< 5 ms
Radio interference level	Below "N" as per VDE 0875
Efficiency at rated load	> 90%
Protection to DIN 40050 Standard	1P21
Duration of system operation	Continuous and uninterrupted for up to 30 days
Type of system of current-carrying conductors	Three-phase, five-wire (A, B, C – phases, N – neutral wire, PE – protective earth wire)

Table 10-2 Specification of 208/120 V 60 Hz AC processing facility power supply system.

Item	Description
Rated power output	30 kV·A (cos $\varphi = 0.7$)
Power change under load (power consumers)	From 0 to 100 % of the rated output
Line/phase output voltage	380/220V
Voltage waveform	Continuous sinewave
Current frequency	50 Hz
Output voltage variation with continuous load variation	±1% within period from 0 to 100 % and falling back to 0
Output voltage variation with stepwise load variation	±5% within period from 0 to 100 % and falling back to 0
Stable output frequency deviation	±0.1%, continuous
Storage battery capacity	At least 10 min
Efficiency at rated load	> 90 %
Duration of system operation	Continuous and uninterrupted for up to 30 days
Capacity of storage battery	Not less than 10 minutes
Type of system of current-carrying conductors	Three-phase, five-wire (A, B, C – phases, N – neutral wire, PE – protective earth wire)

Table 10-3 Specification of 380/220 V 50 Hz AC processing facility uninterrupted power supply system.

10.4.2 The *Rockot* Launch Complex

The launch complex as shown in Figure 10-8 is dedicated to *Rockot* launches exclusively for use by EUROCKOT. In the course of rebuilding and renovating work for all *Rockot* dedicated facilities in the years 1999 and 2000, the *Rockot* launch complex underwent a complete renewal, so that today all equipment is state-of-the-art.

The *Rockot* Launch Complex is situated in the north-east area of Plesetsk Cosmodrome, at a distance of 6 km from the MIK. The railroad ends directly in front of the launch table for loading and unloading the booster stages and upper composite. A site plan of the *Rockot* launch complex is shown in Figure 10-8.

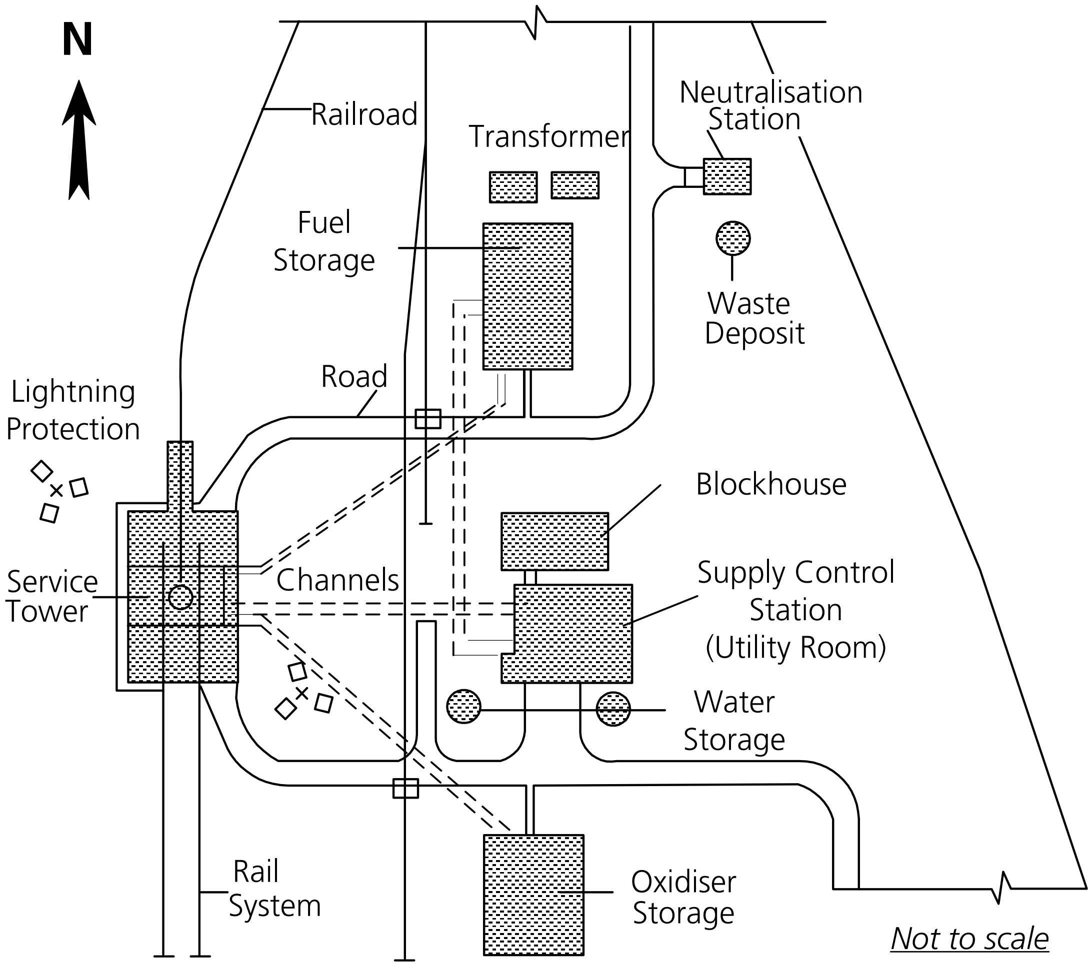

Figure 10-8 Launch complex for *Rockot*.

10.4.2.1 Launch Pad

The launch pad includes a launch table with launch equipment and a stationary mast, surrounded by the mobile service tower during launch vehicle processing (Figure 10-9).

The launch table is equipped with retractable supports for the alignment of the launch vehicle and with metal gas deflectors. The surface around the launch table is covered with reinforced concrete.

The mobile service tower is designed for vertical integration of the Upper Composite with the *Rockot* booster. In the closed gate position, the service tower encloses the *Rockot* to allow all-weather operations. The service tower is equipped with a lift and working platforms at several levels to provide access to the launch vehicle service areas. A special adapter frame serves for the transportation and launch container (TLC) erection, whereas an overhead travelling crane ensures zero impact mating of the upper composite with stage 2 of the *Rockot* booster unit.

Retraction of the mobile service tower occurs approximately 10 minutes before lift-off. At lift-off, the distance between the rolled-back service tower and the stationary column with *Rockot* in the TLC is approximately 50 m (Figure 1-23).

The stationary column is designed to fasten and hold the booster unit in the TLC at the moment of launch. Electrical cables, air ducts and fluid lines to the launch vehicle are maintained via the stationary column. The stationary column also accommodates the ground control equipment devices, the launch vehicle azimuth positioning system and the remote control system.

10.4.2.2 Undertable Rooms

Undertable rooms contain the launch vehicle EGSE and pre-launch processing equipment, the fuelling system for booster stage 1 and stage 2 and the payload air conditioning system. For the Customer's use, one undertable room, designated as Undertable Room 7 with an area of 26 m^2 is provided (Figure 10-10). This Undertable Room 7, containing the equipment stated below, is dedicated for the accommodation of the spacecraft on-board battery trickle charging equipment and other items at the launch pad. Access to the undertable rooms is possible except during launch vehicle fuelling operations, during final countdown and launch. Monitoring equipment for the spacecraft parameters can be situated in room 213/111A of the Customer office area in the MIK. The Undertable Room 7 is linked to room 213/111A via a fibre optic cable. The Customer shall provide the equipment for connecting the fibres.

The harness length from the Undertable Room 7 to the spacecraft umbilical connectors is approximately 80 metres.

The equipment of the Undertable Room 7 includes:

- Camera for remote control monitoring due to security reasons
- Phones
- Wall mounts for 208/120 V 60 Hz and 380/220 V 50 Hz power supply
- Fibre optic cable access

10.4.2.3 Power Supply of Launch Complex

The launch complex has its own independent UPS system. Power of 208/120 V at 60 Hz with nominal output power of 100kVA and 380/220V at 50 Hz with 10 kVA is supplied in the Undertable Room 7.

The launch complex power supply system is similar to that of the MIK (section 10.4.1.6). The only difference is the rated output power of 380/220V at 50 Hz equal to 10 kV·A.

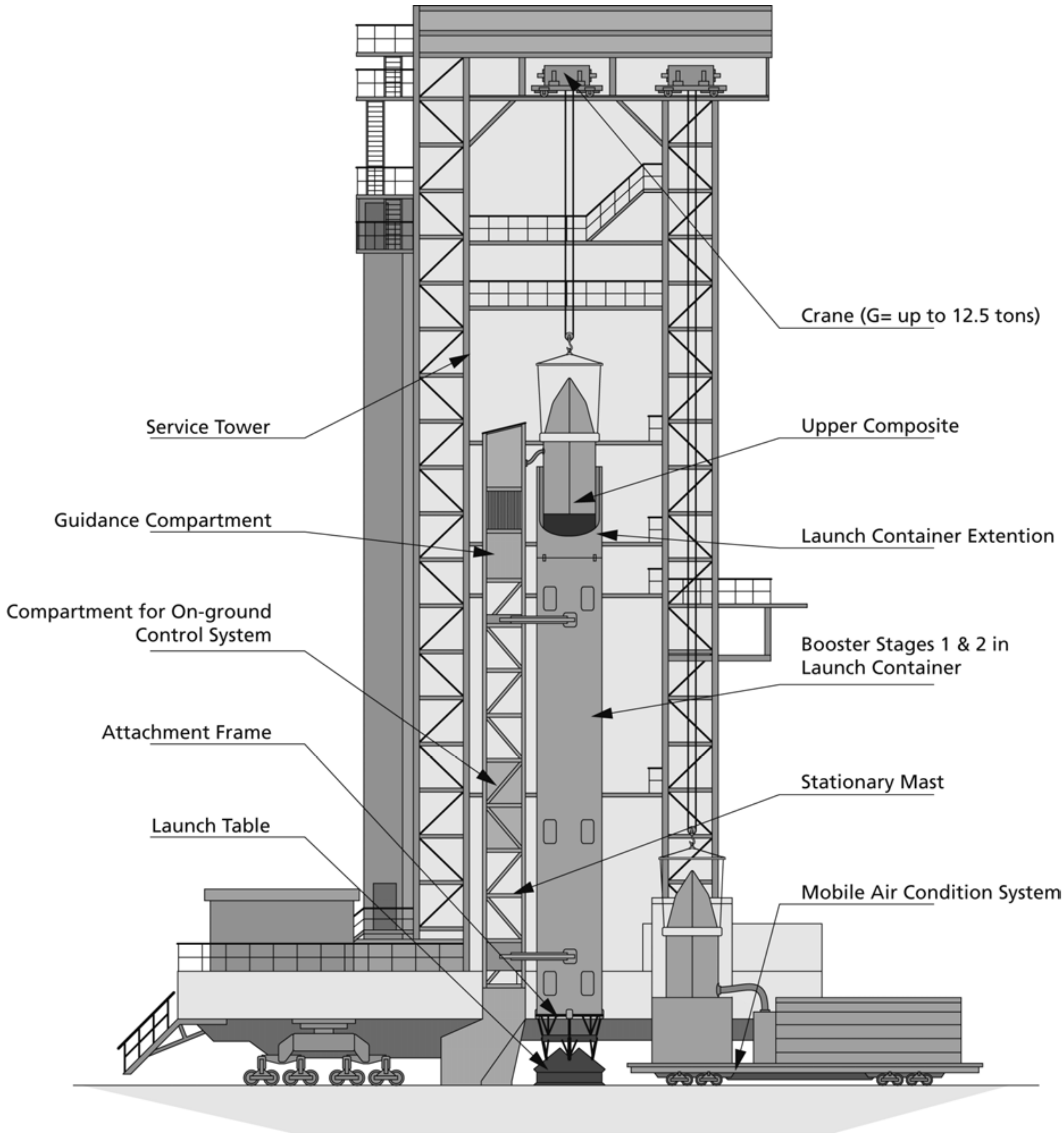

Figure 10-9 *Rockot* launch pad.

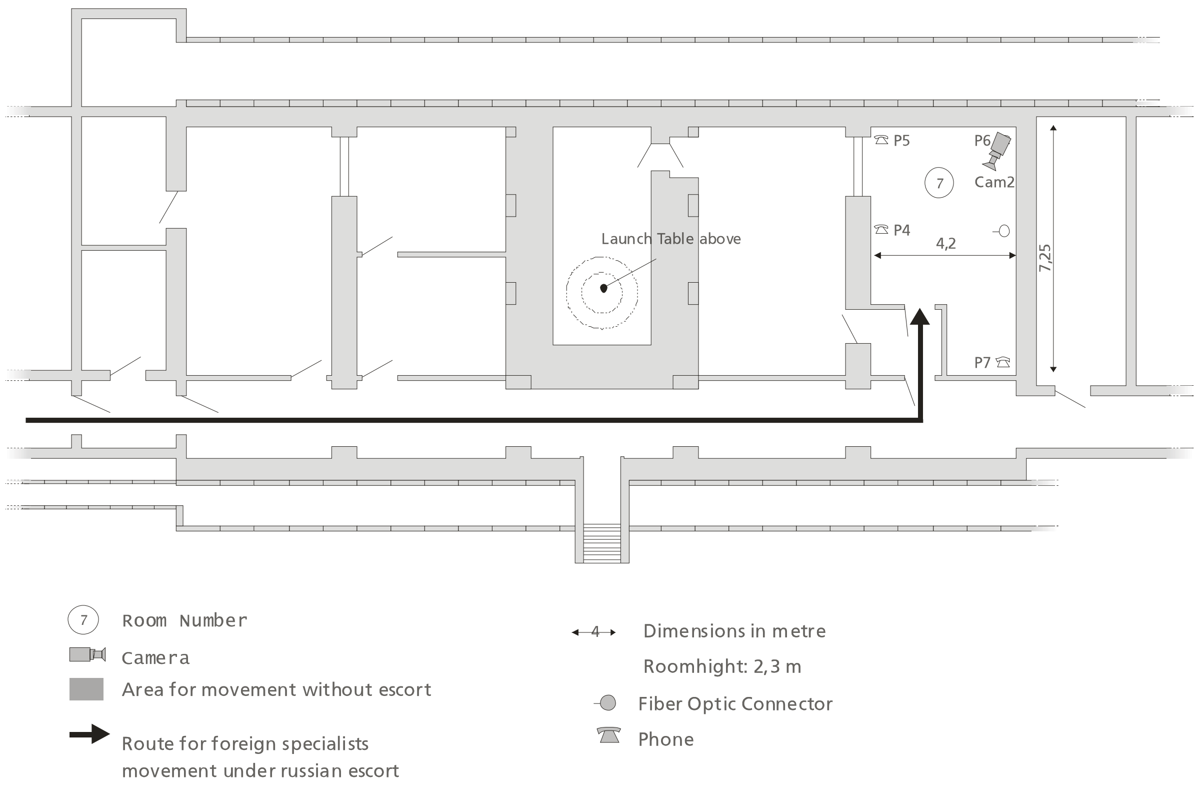

Figure 10-10 Undertable Room 7 for Customer's use.

10.4.2.4 Air Conditioning of the Spacecraft at the Launch Pad

After encapsulation, air conditioning of the payload is provided during transportation of the upper composite to the pad and up to 30 seconds before lift-off. Depending on the fairing design, purging of the spacecraft batteries can also be performed, if required. Interruption of the payload air conditioning occurs only for periods of no longer than one hour each.

At the launch pad, the stationary air conditioning equipment is located under the launch table and the air duct passes through the stationary mast. The air duct and the air inlet of the fairing are connected via a flexible tube.

The air conditioning lines will only be disconnected during lift-off. In the case of a launch cancellation the air conditioning system will be switched on again within 1 minute. The air conditioning system for the spacecraft and spacecraft batteries is compatible with ISO Class 8 cleanliness or optionally ISO Class 7 (chapter 5). EUROCKOT will provide periodic monitoring of air temperature, humidity and flow of fairing air with a minimum interval of 15 minutes during the time the spacecraft is on the launch pad.

10.4.3 The Mission Control Centre

The Mission Control Centre (Figure 1-26), located in the town of Mirny at a distance of approximately 40 km from the launch pad, provides:

- Local, interurban and international telephone communications with the capability of telephone conferencing
- Video and audio reporting from the launch site in real time
- Countdown information
- Transmission and receive of the formats in electronic and fax form
- Operational communications with launch support services including backup communications, Inmarsat and public GSM
- Display and transmission of launch information in real time
- Go/ no-go system for the spacecraft operator as well as go/ no-go display panel and launch vehicle status.

The following data can be displayed on large size wall panels:

- CoG motions of stages 1 and 2, the upper stage and the fairing during powered flight in the ascent phase, ranging data, key flight events such as staging and jettisoning of the fairing, major telemetry data down link and tip-off angles.
- Sub-orbital unit track on an earth map accompanied by the display of ranging data, key flight events such as upper stage burns, major telemetry data down link timelines for ground telemetry stations, and predicted or actual orbit parameters
- Computer-generated presentation of spacecraft motion about its CoG, with the viewing angle and solar exposure. In this mode, staging events are displayed and several upper stage performance quantities are presented in numerical form
- 3D motion of the item's CoG against the earth background and several orbit parameters in numerical form
- Generalised state vector including geodetic predicted position as well as actual orbit parameters, and the predicted as well as telemetered *Breeze-KM* engine performance
- Live launch coverage

The MCC is equipped with hardware and software which allows integration of any other information, coming e. g. from other monitoring facilities during and after spacecraft injection, into the set of data displayed. In addition, processed flight data can be compressed and sent to any remote user to be decompressed and displayed.

10.5 Launch Campaign

10.5.1 Responsibilities and Operational Organisation

EUROCKOT / KSRC is responsible for the preparation of the launch vehicle and combined operations. The Russian Space Forces execute *Rockot/Breeze-KM* operations including launch as subcontractors to EUROCKOT / KSRC.

EUROCKOT/KSRC will conduct the installation of the Customer's spacecraft on the adapter. Additional support shall be mutually agreed between EUROCKOT / KSRC and the Customer. The spacecraft preparation will be performed under the responsibility of the Customer and its launch site team.

During the launch campaign, a core of the EUROCKOT team responsible for the specific Customer mission will be present at the range as day-to-day intermediaries between Customer, KSRC and the range authority to coordinate the spacecraft launch site support requirements as well as to accompany the Customer's launch site team in all matters. The EUROCKOT team is supported by a KSRC team at the range. Both teams ensure undisturbed execution of all necessary operations until launch and the fulfilment of spacecraft support requirements in accordance with the launch site requirements.

10.5.2 Planning

Spacecraft launch site operations and the relevant requirements will be specified in the Spacecraft Operations Plan (SOP) as well as the responses to the spacecraft questionnaire from EUROCKOT. These Customer-generated documents should address all operational and logistical support requirements.

All spacecraft activities and technical facilities will be controlled at the launch site according to Joint Operations Plan (JOP) jointly established with EUROCKOT.

The JOP gives an overview of the spacecraft operations and joint operations to be conducted at the launch site, and defines ground rules for all involved parties at the range. The JOP is established to define the equipment and support needed at the launch site for both spacecraft and joint operations in order to ensure undisturbed working conditions for the Customer. Due to the parallel processing of spacecraft and launcher up to the joint operations prior to launch, these activities have to be coordinated to ensure the availability of necessary equipment and support personnel and the accessibility of facilities, taking into account the security and safety matters of all parties involved.

During the launch campaign, a daily schedule meeting will be held with the participation of all parties involved, Customer, EUROCKOT/KSRC and attendees from the Russian Space Forces . The goal of this meeting is to

- communicate the status of the work
- identify issues that require immediate attention
- define the schedule and coordinate operations for the next day with a view to the support personnel needed, access to facilities, transportation needs, lunch times,
- coordinate future joint operations and
- adapt the launch campaign schedule, if necessary.

10.5.3 Procedures and Logbook of Works

Every process will have an approved procedure. These procedures will identify the necessary equipment, personnel, documentation and facility requirements in detail to complete the process. The related launch site procedures will be carried out under consideration of safety and security regulations of the Russian Government and the Customer state government. All procedures for joint operations have to be signed off by the Customer and EUROCKOT / KSRC.

All joint operations will be documented in a logbook. The joint working steps are documented in Russian and English language and have to be signed off by all parties upon completion of the work.

10.5.4 Training / Briefings

Training and briefings for the spacecraft operations team will be performed before the start of the spacecraft operations. Such training and briefings comprise:

- Familiarisation with emergency evacuation procedures and all alarms
- Communications equipment operations
- Security requirements and briefings
- Training to operate launch site specific equipment

10.5.5 Security and Access Control

The security requirements for Plesetsk will be defined in the joint launch site security plan. This document considers the requirements from the Russian side as well as the requirements of the Customer state government.

10.5.6 Safety

The safety regulations (chapter 9) define the rules applicable to all operations and the constraints to be observed in the definition and performance of launch vehicle and spacecraft operations.

10.5.7 Launch Campaign Operations

The launch campaign operations, especially the spacecraft operations described in the following, serve the purposes of orientation. For a programme, the duration of a launch campaign will be tailored to the Customer's requirements. A final and detailed Launch Operations Schedule which includes a statement of the precise duration of all operations, will be established after definition of the Joint Operations Plan (JOP) together with the Customer.

A typical Customer launch campaign from the arrival of the spacecraft and related equipment at the Cosmodrome until launch will last approximately 28 days (Figure 10-11), up to three days needed for post-launch activities have to be added. A complete launch campaign, which also takes the launch vehicle operations into account, consists of three major parts:

- Launch vehicle stand-alone operations, duration 16 days
- Spacecraft operations, duration depending on Customer needs, average duration 14 days
- Combined operations, duration 14 days

The spacecraft and its support equipment will arrive on day L-29 at the Russian port-of-entry, accordingly the spacecraft reception team will usually arrive there earlier to prepare for the delivery and the ongoing transport to the launch site.

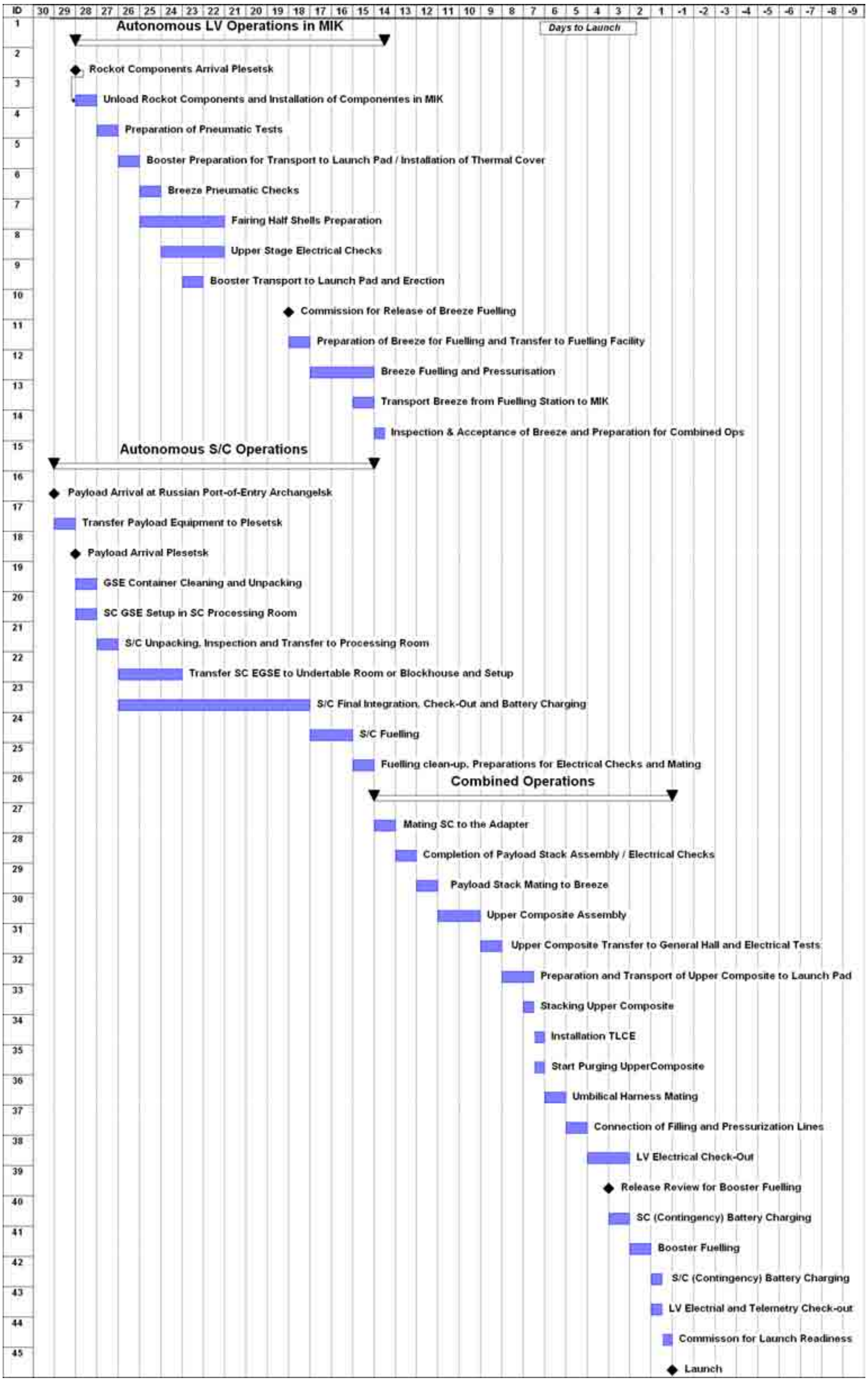

Figure 10-11 Schedule of operations.

The combined operations start on day L-14 usually with mating the spacecraft to the launch vehicle adapter.

The launch vehicle processing is performed in parallel with the space vehicle processing. The major launch vehicle processing, spacecraft operations and combined launch vehicle / spacecraft tasks are summarised in the operations schedule (Figure 10-12).

10.5.7.1 Launch Vehicle Operations in MIK and at Launch Complex

The stand-alone launch vehicle operations at the launch site typically start on day L-28 with the arrival of the *Rockot* components at the MIK processing facility and end on day L-14 with the start of combined operations.

Before the components of the upper composite are prepared for spacecraft integration and assembly, an electrical *Breeze-KM* / booster interface check-out is performed at the launch pad. For this purpose, the upper composite will be assembled, transported to the launch pad and stacked on the second stage. All operations dedicated to the electrical *Breeze-KM* / booster interface check-out activities are similar to the launch operations, but do not include the fuelling of the upper stage and are performed without the spacecraft.

The main launch vehicle stand-alone operations up to the start of the combined operations are shown in Figure 10-12 and the sequence in Figure 10-13.

10.5.7.2 Spacecraft Operations

The spacecraft operations at the launch site nominally start on day L-19 with the arrival of the spacecraft and spacecraft GSE container.

The spacecraft autonomous operations are conducted in the spacecraft processing area of the clean room bay of MIK.

The order of spacecraft fuelling and mating the spacecraft to the adapter may be changed depending on mission specific preferences.

10.5.7.3 Combined Operations in MIK

The combined operations of launch vehicle and spacecraft in MIK nominally start on day L-14 with mating the spacecraft to the adapter to configure the payload stack. The stack integration is usually be performed in the spacecraft processing area (room 101A). All upper composite operations, i. e. spacecraft / *Breeze-KM* and fairing assembly, are performed in vertical orientation.

The independent preparations of all upper composite components are completed when the payload stack is transferred from the spacecraft processing area to the upper composite integration area of the clean room bay on a dedicated dolly. The prepared and fuelled *Breeze-KM* is assembled on the mobile integration table and the fairing is separated into halves. The specific combined operations tasks are shown in Figure 10-12 and Figure 10-13.

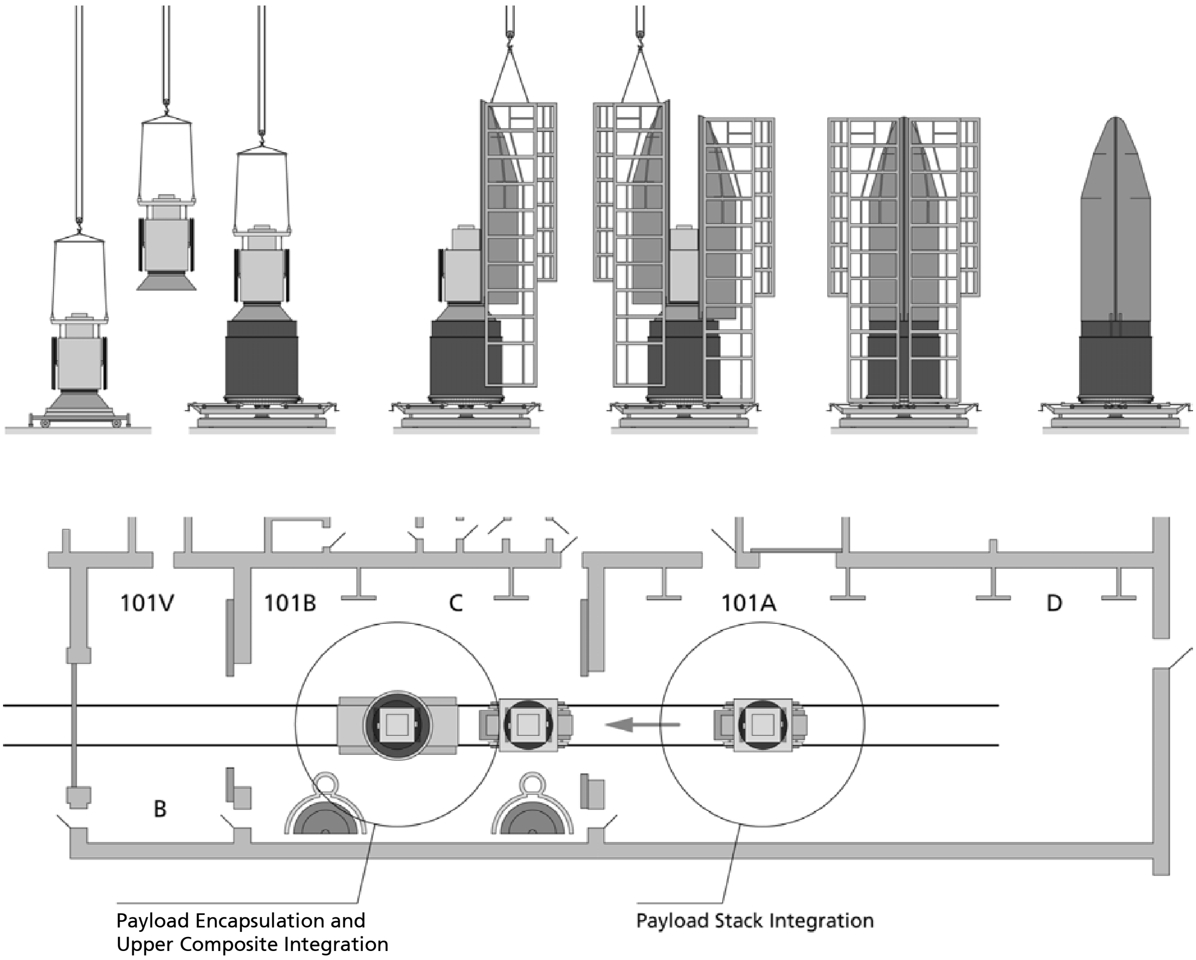

Figure 10-12 Flow of combined operations in MIK.

10.5.7.4 Combined Operations at the Launch Pad

The upper composite with the spacecraft arrives at the launch pad on day L-7 for mating. The air conditioning of the space-craft will be stopped four times for short periods during ILV integration with each shut-down period lasting no more than one hour. Air conditioning is interrupted for the first time when the Upper Composite is being lifted into the service tower. During ongoing Upper Composite preparations for mating, the air conditioning system is activated. The air conditioning is interrupted for the second time during Upper Composite installation onto the booster. The third interruption takes place when the stiffening ring is removed and the fourth shut-down occurs when the transport launch container extension is installed on the transport launch container. The tasks performed at the launch pad, such as *Rockot* booster erection and mating of the upper composite are shown in Figure 1-20 to 1-23 and schematically in Figure 10-13.

A Launch Readiness Review (LRR) on day L-3 the so-called "State Commission". gives permission for booster fuelling.

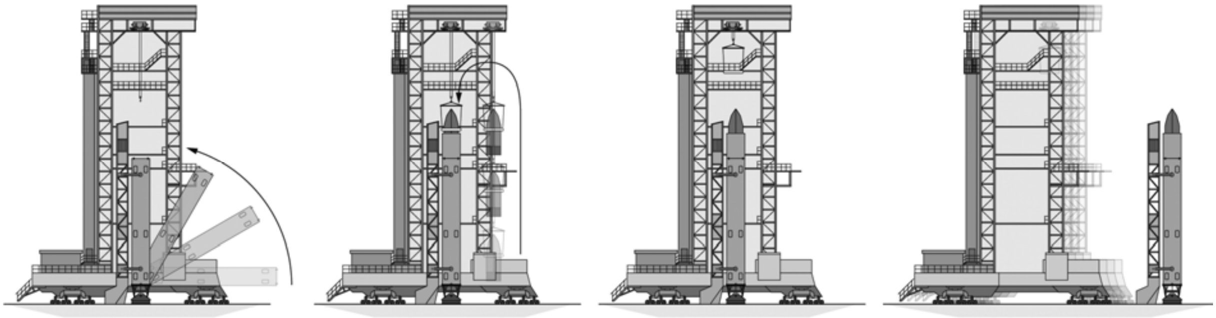

Figure 10-13 Launch pad operations.

10.5.8 Launch Day

After the performance of all electrical check-out operations and the telemetry readiness check carried out on the launch day, the State Commission decides about the launch and the start of the count-down. The constitution of the management envisioned on the launch day, as well as their role during countdown, will be defined in the JOP. The chairman of the commission will decide on the readiness for launch after readiness report of all participated parties:

- Weather conditions
- Launch pad status
- Launch vehicle ground tracking stations
- Launch vehicle ground measurements
- Spacecraft status
- Communications network
- Launch conditions (launch window, GO / NO-GO criteria, launch abort)
- Launch vehicle status

The Launch Operations Leader conducts the launch according to the criteria that will be defined in the JOP. The previous launch decision may be affected at any time during the final count-down by modifications or anomalies of the launch configuration. All the modifications of the previous launch configuration must be reported in real time to the Operations Leader.

The Launch Operations Leader observes the GO / NO-GO criteria and holds the count-down, if necessary.

About 10 minutes before launch the service tower is withdrawn, whereas the air conditioning for the spacecraft will continue until 30 seconds before launch. Mechanical access to the payload after encapsulation is not planned as a standard service. However, access via umbilical connectors will be provided during any operation phase after encapsulation, e. g. for battery trickle charging and communication.

All operations, boundary conditions, communication links and other relevant information are prepared, agreed and documented in the Launch Operation Schedule (LOS), the guiding document for the launch day.

10.5.9 Abort Re-Cycle/ Return-to-Base Operation

In the case where the launch has to be postponed, the Launch Operations Leader requests an agreement from the various management representatives.

If the count-down is held on the scheduled launch day inside the launch window without any malfunctions of the launch vehicle or spacecraft systems, the launch will be postponed at least by one hour required for launch systems readiness and at the most by 48 hours, for SSO launches usually by one day. During this delay, the launch vehicle can remain filled on the launch table, assuming the environmental temperature is within the allowable range.

In the case of launch delay, thermal conditioning for the upper composite is provided. The thermal conditioning system will be switched on one minute after launch cancellation.

If any malfunction is detected that could not be solved in-situ, related either to the launch vehicle or to the spacecraft systems, the booster will be defueled and the upper composite will be removed from the booster unit and transported back to MIK. All defects and failures on the spacecraft are repaired within the spacecraft processing area, whereas all defects and failures of *Breeze-KM* are repaired in the upper composite integration area of the clean room bay. After repair and check-out are finished, the upper composite will be integrated and transported back to the launch pad, re-integrated on top of the booster unit, and the launch preparation cycle will begin again. The booster unit remains at the pad during this process.

10.6 Accommodation and Leisure Activities

Customers will be accommodated in the Hotel *Rockot* in the town of Mirny (Figure 1-35). Mirny is the Cosmodrome's main supporting town and has a well-developed social infrastructure.

The international standard Hotel *Rockot* was refurbished in 1999 in order to satisfy all needs of EUROCKOT Customers. The common areas of the hotel comprise a meeting room, TV lounge that can be arranged as a fitness room as well as a bar and restaurant.

Each hotel room contains a bathroom, a desk, refrigerator, telephone, TV set able to receive Russian, local and satellite TV programs and LAN outlet. The telephone link may also be used for dial-up to a local internet server and e-mail account. In total there are 39 guest rooms available.

One guest room on the second floor can be used as a Customer office. A LAN patch panel leading to each room and a 64 kbps modem interface to PBX are terminated in the entrance area of this room. The hotel LAN is connected to the processing area LAN.

For the safety of the guests, the hotel has a fire alarm system. Each room is equipped with fire detectors and there are smoke detectors on the corridors. In the event of an alarm, an audible alert will be sounded in the lobby area and on each floor. Fire hoses, plumbing and emergency exits are installed on each floor.

In the immediate vicinity of the hotel there are two stadiums, tennis, volleyball and basketball courts, and an indoor athletics complex accommodating a swimming pool, a gym and a fitness centre. Trips to wildlife areas or historic places, sightseeing, sports events and games, jogging and use of the athletic complex facilities and sauna can also be arranged.

10.7 Medical Care

A well-equipped military hospital can treat up to 200 patients. The medical team is trained to the highest standard available in Russia. Ambulances are available. Companies offering rapid medical evacuation services to Western Europe can be arranged upon request.

Chapter 11 Baikonur Cosmodrome

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11 Baikonur Cosmodrome

The modification of KSRC dedicated facilities at Baikonur Cosmodrome for EUROCKOT launches is possible but currently not being pursued. Although *Rockot* launches have occurred in the past from Baikonur Cosmodrome, it is currently no longer operational for *Rockot* launches. Activation of the site for *Rockot/Breeze-KM* requires upgrades and modifications to existing facilities. A decision for site activation will be made on a case-by-case basis should the need arise.

Generally, the extent and quality of the EUROCKOT facilities and services at Baikonur will at least be similar to those in the Plesetsk Cosmodrome, and in some respects even better.

Baikonur is particularly suited for serving inclinations in the 50° range, since these cannot be efficiently reached from Plesetsk due to its northerly latitude.

Chapter 12 Items to be Delivered by the Customer

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12 Items to be Delivered by the Customer

This chapter summarises and describes the main software (documents, data and software-models) and hardware (flight units, dummies and ground equipment) which shall be supplied by the Customer as a minimum. The times and destinations for shipments are also described. Delivery times and destinations of additional items which the Customer wants to use, e. g. mission insignias for the launch vehicle or container-external surfaces, are to be agreed on in the first two mission preparation phases. Wherever possible, submission of data in electronic format is preferred by EUROCKOT in order to improve shipment times and accessibility of the data.

Table 12-1 provides a summary of all documents to be supplied by the Customer during the various mission phases. Further explanations regarding their definition can be found in the following sections.

Documents to be provided	Date (typically)	
	Preliminary	Final
Interface Requirements Document (IRD)	L - 24 months	
Safety submission (Phase I, II, III)	I: L-18 months II: L-12 months	III: L- 6 months
Spacecraft mechanical environment test plan	L - 16 months	
Spacecraft dynamic model (Preliminary)	L - 23 months	L - 11 months
Spacecraft thermal model (Preliminary)	L - 23 months	L - 11 months
Response to questionnaire: Input to Mission Design and Mission Analysis	L - 23 months	L - 11 months
Launch license documentation		L - 10 months
Spacecraft Operations Plan	L - 17 months	
Spacecraft mechanical environment qualification test results	L - 6 months	
Technical readiness documentation: SC technical readiness certificate, SC readiness package for launch campaign operations within the integration facility, launch pad and launch	L - 6 months	L - 3 months
Final customs documentation		SC shipment - 1 month
Final spacecraft mass properties	L - 7 days	
Orbital Tracking Operation Report	L + 2 weeks	

Table 12-1 Summary of documents to be supplied by the Customer.

12.1 General Documents

12.1.1 Interface Requirements Document

Interface Requirements Document	L-24 months

The Interface Requirements Document (IRD) will be the technical baseline document for the first mission phase as long as no Interface Control Document has been established and agreed. The IRD will be created by the Customer and is generally one of the parts of the technical annexes of the launch services contract. EUROCKOT can supply a generic IRD template for customers to use, if required.

With this document, the Customer will also describe the mission and spacecraft characteristics as already defined. This focuses on mass properties, interface dimensions, and mission and orbit characteristics in particular. Within the outline provided by EUROCKOT, all chapters which have to be completed with information for contract signature will be marked.

Figure 12-1 shows the typical table of contents for this. Nevertheless, modifications according to dedicated demands of the mission can be implemented on the basis of joint agreements.

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1.3 Project Summary

2 APPLICABLE DOCUMENTS
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2.2 Customer Documents
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3.3 INTERFACE REQUIREMENTS
- 3.3.1 Mass Properties
- 3.3.2 Mechanical Interfaces
  - 3.3.2.1 Static Envelope and Clearances
  - 3.3.2.2 Satellite to Launch Vehicle Interface
  - 3.3.2.3 Satellite Stiffness
- 3.3.3 Electrical Interfaces
- 3.3.4 RF Link (if applicable)

3.4 LAUNCH SITE OPERATIONAL REQUIREMENTS
- 3.4.1 Transportation
- 3.4.2 Payload Processing Facility
- 3.4.3 Launch Pad

3.5 MECHANICAL ENVIRONMENTS
- 3.5.1 Static Loads
- 3.5.2 Low Frequency Vibration
- 3.5.3 Acoustic Noise
- 3.5.4 Separation Shock

APPENDICES AND DRAWINGS

Figure 12-1 Interface Requirements Document table of contents.

12.1.2 Orbit Tracking Operation Report

Orbit Tracking Operation Report	L+2 weeks

In order to confirm *Rockot* performance with regard to orbit injection accuracy, the Customer is requested to submit spacecraft tracking data after third stage burnout before and subsequent to separation as far as such data are available. This must include a complete set of orbital parameters and their estimation accuracy.

12.2 Input to Mission Design and Mission Analysis

12.2.1 Response to Questionnaire

Response to Questionnaire: Input to Mission Design and Mission Analysis	
Preliminary:	L-23 months
Final:	L-11 months

In addition to the dynamic and thermal models for coupled loads and thermal analyses, EUROCKOT requires additional input data and information to adequately perform the preliminary and final mission design and analyses. It should be noted that some of this data will probably be contained within the customer supplied IRD and the resulting ICD that is established. However, all the required data is repeated here for completeness.

- Flight programme specification including
  - Required injection orbit and allowable errors
  - Requirements (if any) of spacecraft attitude to the sun during coast phases of upper stage
  - Manoeuvres during upper stage coast phase, e.g. thermal manoeuvres.
  - Separation attitude of spacecraft
  - Requirements to the launch vehicle after separation, e.g. collision avoidance manoeuvres, constraints on thrusters operations etc.
  - Requirements to the launch window and allowable launch window duration (if not specified by other parameters)
- Spacecraft characteristics
  - Payload designation
  - Dimensions of spacecraft stowed in launch configuration and when deployed
  - Mass and inertial characteristics of dry and fuelled spacecraft
  - Propellant characteristic, viscosity, density etc.
  - Fuel sloshing analysis inputs (if applicable)
  - Thermal model
  - Dynamic model
- Ground and launch environments
  - Quasi-static and dynamic loads in flight
  - Transportation loads
  - Separation shock loads
  - Acoustic loads
  - Ground temperature / humidity constraints
  - Flight temperature constraints / fairing internal surface temperature constraints

  - Spacecraft cleanliness requirements, i. e. particles, surface cleanliness, organics (if applicable)
  - Pressure / venting constraints within payload fairing
  - Free molecular heating rate constraints after payload fairing jettison.
  - RF/ EMI constraints
- Spacecraft Interfaces
  - Spacecraft coordinate system and reference to launcher coordinate system
  - Spacecraft static envelope (stowed, in launch configuration), critical points of spacecraft envelope relative to fairing.
  - Preferences for spacecraft location and clocking within payload fairing
  - Flight mechanical interfaces, including spacecraft to launcher interface flanges / points.
  - Ground mechanical interfaces, e. g. to handling dolly, fuelling platform etc.
  - Electrical interfaces including quantity, type and location of umbilical connectors
  - Umbilical connector separation force
  - Content and parameters of umbilical lines for flight
  - Electrical interfaces for ground operations
  - Telemetry parameters to be recorded during flight
  - Grounding and bonding requirements
  - Injection orbit data reporting formats
- Launch site requirements
  - Spacecraft transportation provisions
  - Processing area requirements
  - Spacecraft fuelling area requirements
  - Personnel accommodation office in facilities / hotel requirements
  - Technical support requirements at launch base
  - Communication requirements, e.g. LAN interfaces, internet access, mobile walkie-talkies etc.
  - Spacecraft ground support equipment quantity / size etc.
  - Required consumables (gases etc.)
  - Security requirements
- Campaign schedule/ operations
- Drawings of spacecraft handling units and transport containers
- Requirements for installation
- Points for hoisting and fixing
- Requirements for the separation system
- Data on the payload elements which have to be jettisoned or deployed
- Pyrotechnic devices and related constraints
- Orbital parameters for the payload
- Requirements for injection accuracy and payload orientation prior to its deployment
- Acceptable range for thermal environments during the payload injection phase
- Requirements for protection of optical surfaces

- Thermal control requirements
- Parameters of payload / ground support equipment interfaces
- Characteristics of the payload telemetry and telecommand system and other RF systems
- Payload and related GSE input data:
  - Allowable thermal conditioning interruptions for the payload, batteries and propellant containers
  - Payload processing cycle duration in integration facility and at launch pad
  - Payload ambient temperature, humidity and contamination control requirements during operations
  - Spacecraft battery charging/trickle charging cycles in integration facility and at launch pad.

12.2.2 Spacecraft Dynamic Model

Spacecraft Dynamic Model		
	Preliminary	L-23 months
	Final	L-11 months

As described in section 8.4, structural compatibility will be demonstrated with preliminary and final CLA. Customer inputs, in particular structural models of the spacecraft, are requested for both preliminary and final CLA steps.

The spacecraft mathematical models must be provided by the Customer in the form of stiffness matrices and masses of non-fixed structures, mathematically reduced to a Craig-Bampton model. For detailed descriptions, refer to section 8.4.1 and to EUROCKOT document ESPE-0008.

Other presentations of the mathematical models, e. g. a spring mass model, are to be agreed with EUROCKOT.

12.2.3 Thermal Model

Thermal Model	Preliminary	L-23 months
	Final	L-11 months

Section 8.5 describes which thermal environment studies are required to verify thermal compatibility through out the mission. This study will be implemented using a thermal model provided by the Customer. As this study covers the period from integration of the payload onto the dispenser within the integration facility, up to spacecraft separation, the Customer has to provide the following:

- A thermal model of the spacecraft containing
  - a description of the thermal nodes (heat capacities, mass type, etc.)
  - internal thermal couplings of nodes (conductive, radiative and convective)
  - heat dissipation for all applicable modes of operation during the covered mission phases
- interface descriptions (areas of contact, conductive and/or radiative properties)
- thermal requirements for the environment to be fulfilled during integration, launch and flight

For detailed descriptions, refer to section 8.5 and EUROCKOT document ESPE-0009.

12.3 Safety

Safety Submissions	Step 1	L-18 months
	Step 2	L-12 months
	Step 3	L-6 months

During the mission phases, safety submissions have to be provided by the Customer in three steps. The content and format of the data to be supplied are described in more detail in chapter 9 and in the EUROCKOT Safety Handbook EHB-0004.

Generally, all areas generating risks for personal safety such as pressurised systems, explosives (propellants, pyrotechnical devices, etc.), radioactive material, RF sources and toxic substances have to be covered, as well as safety-relevant operations to be performed during ground preparations. It has to be proven with all available information, how risks to people involved can be minimised to acceptable levels, which safety factors have been applied and how they have been or will be verified, and which precautions are envisaged.

SC Technical Readiness Documentation	
Preliminary	L-6 months
Final	L-3 months

Spacecraft Technical Readiness Documentation submitted by the Customer should include:

- The spacecraft technical readiness certificate for launch campaign operations within the integration facility, on the launch pad and for launch. This certificate ensures that the spacecraft is designed and checked in compliance with the ability to take all environmental loads, specified in ICD, and is ready for launch campaign operations at Plesetsk Cosmodrome and for launch on the *Rockot/Breeze-KM* launch vehicle.

The spacecraft readiness data package providing information necessary to justify spacecraft readiness for ground operations and flight certificate.

12.4 Payload Environmental Test Documents

Spacecraft Mechanical Environment Qualification Test Report	L-6 months

After the performing of structural qualification, test results shall be submitted to EUROCKOT for a review of compliance with the structural model supplied for the coupled loads analysis. If any discrepancies regarding loads, strength or stiffness were identified during qualification testing, corrective actions have to be agreed on.

Certainly, just as for the acceptance test results below, the extent to be provided is subject to mutual agreements as far as proprietary or technology export issues are involved.

12.5 Operations Documents for Spacecraft

For the organisation of work within the integration facility and on the launch pad, the following documents are required:

Spacecraft Operations Plan	L-17 months

The purpose of the SOP is to define the activities to be performed on the spacecraft during the launch campaign and the relevant support and facilities required at the range. The document shall also be forwarded to EUROCKOT to establish the launch campaign Joint Operations Plan (JOP) which is agreed between cosmodrome authorities, EUROCKOT, KSRC and the Customer. The JOP is further discussed in chapter 7. An outline version of a typical SOP document is given in Figure 12-2.

For spacecraft shipment and customs clearance the customer has to prepare and deliver the final pro-forma invoice accompanied by the detailed packing list of the spacecraft shipment not later than one month prior to the spacecraft shipment. Information about hazardous materials in internationally accepted formats also have to be provided, if applicable.

1. Introduction
2. Applicable Documents
3. General
4. Operations/ Baseline Schedule including
- Test plan, day-by-day planning
- Preparations and check-out to be carried out in the integration facility
- Assembly of the payload with the upper stage
- Payload fuelling procedure SC
- Payload control and monitoring on the launch pad
- Warning regarding handling
- Launch constraints
- Launch window
- Equipment associated with spacecraft
- Electrical wiring requirements
- Installations (buildings etc.)
- Logistics

Figure 12-2 Spacecraft Operations Plan table of contents.

12.6 Contractual / Higher Level Documents

As well as technical documents other inputs will be requested from the Customer for obtaining the launch license.

- An End User Certificate that briefly describes the intended purpose of the mission, end user and the instrumentation of the spacecraft is to be provided 10 months prior the launch.
- The Customer is also responsible for obtaining the export license and the appropriate approval for use of radio frequencies in the intended orbit in a timely manner.

12.7 Models, GSE

As a minimum, two hardware models have to be available for testing (for more details refer to section 7.2.1.2.

Mass Frequency Simulator	L-12 months

A spacecraft model simulating at least mechanical interfaces, mass and CoG position has to be provided by the Customer. It also has to be mutually agreed how far and with which tolerances, MoIs and stiffness characteristics have to be simulated. As a baseline, the main natural frequencies should be simulated.

Fit Check/Dummy (TBC)	L-12 months

In case of very low geometrical clearance between the spacecraft and the payload fairing, an advanced mock-up model similar to the flight unit regarding geometrical and mechanical interfaces has to be supplied for testing at KSRC's premises in Moscow. The fit of overall dimensions with the accommodation envelope (upper stage cover, dispenser, adapter and fairing) would be verified during this test. If it is obvious that there are no clearance issues regarding the fairing, a fairing fit check and a spacecraft geometrical model are not required. Potentially, the fit check dummy could be provided in the form of the mass frequency simulator and geometric adapter mentioned above.

Flight Unit for Matchmate Test	L-5 months

The Matchmate test with the launch vehicle adapter flight unit and the spacecraft flight unit shall be performed at the facilities of the spacecraft manufacturer in order to prove mechanical, electrical and operational compliance of this interface. A time slot as well as personal and technical resources have to be provided by the Customer and/or spacecraft manufacturer of the flight unit.

Master Gauge / Drill Templates	L-18 months

For point attachment interfaces it has to be mutually agreed whether and by whom tools will be provided to enable precision positioning of attachment/fixing points at the spacecraft and the dispenser. This will not be necessary, if the same degree of precision can be achieved by fulfilling drawing requirements only or if a clamp band separation system is used.

Others

Shipments of other items which the Customer requires for ground operations (e. g. unit testers for integration facilities and launch pad, pathfinder spacecraft or containers, special transportation and handling equipment, fuelling equipment as well as personal safety equipment and fuel itself) as well as their storage and application are matters for dedicated arrangements between the Customer, EUROCKOT and the range operation organisations.

12.8 Hardware, Software and Document Time Schedule

A summary of all hardware, software and documents to be provided by the Customer is shown in Figure 12-3.

Generally, EUROCKOT is open to agreements on any modification imposed by special mission requirements if it is possible to consider it within the overall schedule.

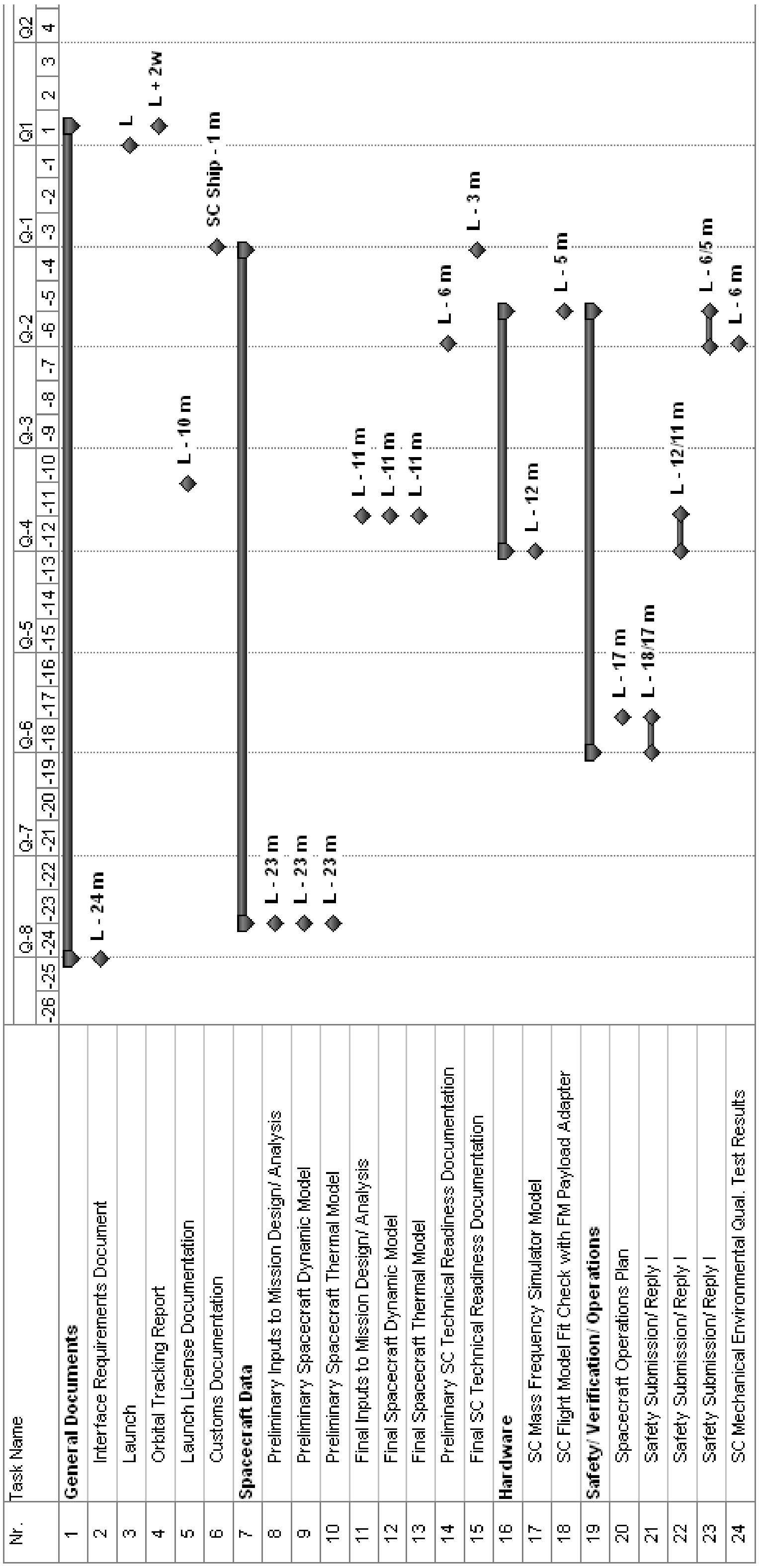

Figure 12-3 Dates of the Customer's documents, software and hardware supply.