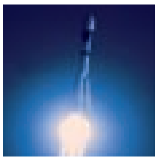
STARSEM

The Soyuz Company

SOYUZ

USER'S MANUAL

ST-GTD-SUM-01 - ISSUE 3 - REVISION 0 - APRIL 2001

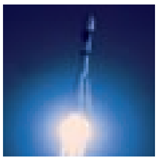


FOREWORD

Starsem is a Russian-European joint venture founded in 1996 that is charged with the commercialization of launch services using the Soyuz launch vehicle, the most frequently launched rocket in the world and the only manned vehicle offered for commercial space launches. Starsem headquarters are located in Paris, France and the Soyuz is launched from the Baikonour Cosmodrome in the Republic of Kazakhstan.

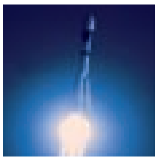
Starsem is a partnership with 50% European and 50% Russian ownership. Its shareholders are the European Aeronautic, Defence, and Space Company, EADS (35%), Arianespace (15%), the Russian Aeronautics and Space Agency, Rosaviacosmos (25%), and the Samara Space Center, TsSKB-Progress (25%).

Starsem is the sole organization entrusted to finance, market, and conduct the commercial sale of the Soyuz launch vehicle family, including future upgrades such as the Soyuz/ST.



REVISION CONTROL SHEET

Revision Date	Revision No.	Change Description
1996	Issue 1, Revision 0	New issue
June 1997	Issue 2, Revision 0	Complete update
April 2001	Issue 3, Revision 0 ST-GTD-SUM-01	Complete update General modifications that reflect successful flights in 1999-2000 and Starsem's future development plans.



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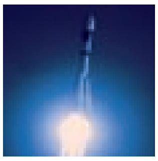

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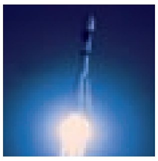
Photos : Francis Demange/Gamma, Philippe Caron/Sygma, Stephane Corvaja/ESA, Starsem.



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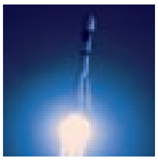

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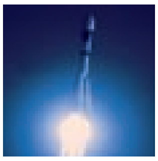

ACRONYMS, ABBREVIATIONS, AND DEFINITIONS

A		
	ACS	Attitude Control System
	AUS	Application to Use Soyuz
C		
	CAD	Computer Aided Design
	CDR	Critical Design Review
	CFRP	Carbon Fiber Reinforced Plastic
	CLA	Coupled Loads Analysis
	CoG	Center of Gravity
	COTE	Check Out Terminal Equipment
	CRR	Cosmodrome Readiness Review
E		
	EADS	European Aeronautic, Defence, and Space Company
	EGSE	Electrical Ground Support Equipment
	EMC	Electromagnetic Compatibility
	ESA	European Space Agency
F		
	FAR	Fueling Authorization Review
	FMA	Final Mission Analysis
	FMAD	Final Mission Analysis Document
	FMAR	Final Mission Analysis Review
	FQR	Final Qualification Review
G		
	GEO	Geosynchronous Equatorial Orbit
	GSE	Ground Support Equipment
	GTC	Gestion Technique Centralisée/Command and Control Center (French word)
	GTO	Geosynchronous Transfer Orbit
H		
	ha	Height of Apogee
	hp	Height of Perigee
	HPF	Hazardous Processing Facility
	HSF	Hazardous Storage Facility
I		
	ICBM	Intercontinental Ballistic Missile
	ICD	Interface Control Document
	IMU	Inertial Measurement Unit
	I/S	Interstage
L		
	LEO	Low-Earth Orbit
	LOX	Liquid Oxygen
	LV	Launch Vehicle

M		
	MEO	Medium-Earth Orbit
	MGSE	Mechanical Ground Support Equipment
	MIK	Assembly and Integration Building (Russian word)
	MMH	Monomethyl Hydrazine
	MPS	Master Program Schedule
N		
	N/A	Not Applicable
	NTO	Nitrogen Tetroxide
O		
	OA	Office Area
P		
	PDR	Preliminary Design Review
	PFM	Proto-Flight Model
	PMA	Preliminary Mission Analysis
	PMAD	Preliminary Mission Analysis Document
	PMAR	Preliminary Mission Analysis Review
	PPF	Payload Preparation Facility
	PSD	Power Spectral Density
Q		
	QSL	Quasi-Static Load
R		
	RAAN	Right Ascension of the Ascending Node
	RCR	Remote Control Room
	RF	Radio Frequency
	RMS	Root Mean Square
S		
	S/C	Spacecraft
	SOW	Statement of Work
	SPPLF	Starsem Payload Processing and Launch Facilities
	SRP	Spacecraft Readiness Panel
	SRS	Shock Response Spectrum
	SSAs	Standard Storage Areas
	SSO	Sun-Synchronous Orbit
	STM	Structural Test Model
	STVVD	Low-Flow-Rate Air-Conditioning System (Russian word)
T		
	TAA	Technical Assistance Agreement
	TM	Telemetry
	TRR	Transfer Readiness Review
U		
	UC	Upper Composite
	UCIF	Upper Composite Integration Facility
	UDMH	Unsymmetrical Dimethyl Hydrazine
V		
	VSOTR	High-Flow-Rate Air-Conditioning System (Russian word)
W		
	w.r.t.	With Reference to/With Respect to

Stack, defined as spacecraft and adapter/dispenser
Nose Module, defined as ***Stack*** and Fregat
Nose Block, defined as ***Nose Module*** and interstage
Upper Composite, defined as ***Nose Block*** and fairing

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CHAPTER

1

INTRODUCTION

1.1. PURPOSE OF THE USER'S MANUAL

This Starsem Soyuz User's Manual is intended to provide both current and potential customers with basic information on Starsem's launch services solution, which encompasses:

- the Soyuz and Soyuz/ST launch vehicles (LVs);
- payload processing and ground operations performed at the launch site;
- mission management and analysis; and
- support carried out throughout the duration of the launch contract.

The objective of the manual is to give readers sufficient information to assess the suitability of the Soyuz or Soyuz/ST LV and its associated launch services for a satellite or a spacecraft. Both vehicles are presented to provide user with the freedom to choose the launch vehicle that best balances their needs in terms of performance, mission flexibility, payload volume, and cost. For more detailed information, the reader is encouraged to contact Starsem.

1.2. DESCRIPTION OF THE USER'S MANUAL

This manual is divided into chapters that, taken together, address all areas of relevance to determining the suitability of Soyuz LVs for a spacecraft. Also described are features and technical information related to the LV and its associated launch services.

Chapter 2, entitled "Performance," gives standard reference performance data for the Soyuz and Soyuz/ST LVs and outlines the full range of missions that are accessible with these medium-class vehicles. These include 4- to 6-ton low-earth orbit (LEO) (including sun-synchronous orbit, or SSO) missions; 1.5- to 3-ton medium-earth orbit (MEO) missions; 1- to 1.5-ton escape missions; 1.8 tons to geosynchronous transfer orbit (GTO); and even 450 kg for a geosynchronous equatorial orbit (GEO) direct insertion. Standard ascent and mission profiles are described as well, and information is provided on LV constraints, injection accuracy, and separation conditions.

Chapter 3, entitled "Spacecraft Environment," discusses the key environmental conditions imposed by the LV used for dimensioning the spacecraft. In large part because of its heritage as a manned LV, Soyuz LVs impart a fairly benign mechanical environment to the spacecraft, with a maximum quasi-static load (QSL) of 5.0 g longitudinal and 1.8 g lateral, and with induced shock levels that are lower than those imparted by standard separation systems.

Chapter 4, "Spacecraft Design and Verification Requirements," lists requirements for spacecraft design, qualification, and acceptance. Both the types of tests and the required testing qualification levels and durations are defined.

Chapter 5, designated "Spacecraft Interfaces," provides information on mechanical and electrical interfaces with or around the spacecraft and its adapter/dispenser, including the interface with the Fregat upper stage and the two fairings that are used with the Soyuz and Soyuz/ST. Fairing characteristics such as usable dynamic volume and acceptable locations of access doors and radio-frequency (RF) windows are provided as well. The electrical connections between the LV and the adapter/dispenser harness are then described, as are those between the vehicle and the payload's electrical ground support system (EGSE). Finally, pyrotechnic commands and RF and telemetry (TM) system interfaces are discussed.

Chapter 6, entitled "Baikonur Cosmodrome," offers an overview of the 1158-m^2 Class 100,000 cleanroom facilities that Starsem has constructed at Baikonur, which provide users with facilities for the preparation, fueling, and integration of the payload with the LV. Baikonur's overall facilities and services are also described, including its airports, launch pads, transportation facilities, security and communications systems, and launch team accommodations.

Chapter 7, "Mission Integration and Management," discusses activities and services, both standard and optional, which are involved in the launch contract. Technical support and mission management activities are outlined, and a context is provided within which to understand the content and organization of a typical Starsem launch services contract. Baikonur launch campaign tasks and activities are explained, including Starsem documents, which coordinate spacecraft/LV preparation activities. A typical launch campaign scenario is also delineated, and launch site safety considerations are discussed.

The three appendices that follow are intended to provide additional information not included in the primary document. The first is a copy of the "Application to Use Soyuz," a user's questionnaire that is intended as a first step in the process of determining the compatibility of a spacecraft. The second appendix outlines adapters and dispensers developed by Starsem for its prior customers. The third appendix contains a more detailed history of the Soyuz LV family.

1.3. SOYUZ LAUNCH VEHICLE FAMILY HISTORY

The Soyuz/ST is the most recent in a long line of Soyuz LVs that, taken together, are acknowledged to be the most frequently launched family of rockets in the world. Vehicles in this family, which launched both the first satellite (Sputnik, 1957) and the first man (Yuri Gagarin, 1961) into space, have been credited with more than 1650 launches to date. The three-stage version known as Soyuz, introduced in 1966, has been the workhorse of the Soviet/Russian space program, achieving a high launch success rate in over 800 flights. As the primary manned LV in Russia and the former Soviet Union, the Soyuz has benefited from these exacting standards in both reliability and robustness. The addition of the flexible, restartable Fregat upper stage in 2000 allowed the Soyuz launch vehicle to reach a full range of missions (LEO, SSO, MEO, GTO, GEO, and escape). The Soyuz/ST adds increased payload volume (4.110-m fairing) and flexibility (digital control system) to this launch system, meeting both the performance and payload accommodation needs of the user.

Both the Soyuz and Soyuz/ST are launched from the Baikonur Cosmodrome in Kazakhstan, which has been leased on a long-term basis to meet the needs of Russian governmental and commercial space efforts.

Soyuz LVs continue to be mass-produced in Samara, Russia, by the Samara Space Center, whose facilities are designed to accommodate the production of up to four launchers per month. As a result of continued demand from the Russian government, international space-station activity, and Starsem's commercial orders, the Soyuz LV is in uninterrupted production at an average rate of 10 to 15 LVs per year with a capability to rapidly scale up to accommodate users' needs.

The Soyuz/ST three-stage LV represents the latest evolution of the Soyuz LV family. The Soyuz/ST uses flight-proven Soyuz components and processes and features two major upgrades:

- A larger fairing (4.110 m in diameter and 11.433 m in length) that provides Starsem customers with a worldwide standard for their spacecraft; and
- A modern avionics system based on proven Russian technology that provides flexibility in mission profile as well as digital control of the vehicle.

All upgrades will be flight-qualified before any commercial launches are conducted. A qualification flight of the Soyuz/ST is scheduled to take place in the second half of 2002.

Starsem is also considering the development of the Soyuz/ST⊕, a higher-performance version of the Soyuz/ST with an improved third-stage engine that will result in a significant increase in performance.

Table 1-1 shows a timeline of LV development leading up to the Soyuz/ST.

Table 1-1: Soyuz LV Family Evolution

1957 –	R-7A / Sputnik (Two-stage missile used to launch Sputnik payload)
1958 –	Vostok (Three-stage LV with block E as third stage)
1960 –	Molniya (Four-stage LV with block I as third stage and block L as upper stage)
1963 –	Voskhod (Three-stage LV with block I as third stage)
1966 –	Soyuz (Voskhod upgrade for launch of Soyuz manned capsule)
1973 –	Soyuz U (Unified LV for replacement of Voskhod, Soyuz)
1982 –	Soyuz U2 (Soyuz-U upgrade for use of the improved fuel “Sintin” in the second stage)
1999 –	Soyuz (with Ikar upper stage) (Soyuz U with Ikar upper stage used for Starsem commercial launches)
2000 –	Soyuz (with Fregat upper stage) (Soyuz U with Fregat upper stage used for Starsem commercial launches)
2002 –	Soyuz-ST (with Fregat upper stage)(Soyuz-U upgrade with digital control system and larger fairing for Starsem commercial launches)

1.3.1. VEHICLE RELIABILITY

Table 1-2 offers a summary of Soyuz flight history and reliability information. Reliability coefficients are presented individually for the lower three stages of the vehicle and the Fregat upper stage. This is primarily due to the large statistical database of flights with the lower three stages. There are two coefficients presented to describe the reliability:

- Design reliability is an engineering estimate of the aggregate system reliability at the design phase, calculated by taking into account the reliability of all subcomponents in the system, safety factors, redundancies, and level of quality control at the manufacturing level.
- Flight success ratio is the overall ratio of successful flights over flight attempts. It takes into account all launch system failures, regardless of corrections or modifications.

Table 1-2: Vehicle Reliability as of December 31, 2000

Component/Vehicle	Soyuz (lower 3 stages)	Fregat upper stage
First Flight	1966	2000
Number of Flights	820	4
Number of Failures	19	0
Design Reliability(%)	95.86	99.00
Flight Success Ratio(%)	97.68	100

The Soyuz and the Soyuz/ST differ primarily in their payload fairing and control systems. Both fairings use essentially the same technology (materials, manufacturing processes, separation systems) and should have nearly the same reliability. For the control system, design reliability estimates are:

- Soyuz : 0.990
- Soyuz/ST : 0.995

Taking into account its more reliable control system, it is assumed that the Soyuz/ST will maintain at least the same flight reliability as the Soyuz.

1.4. LAUNCH VEHICLE DESCRIPTION

1.4.1. GENERAL DATA

Both the Soyuz and Soyuz/ST LVs consist primarily of the following components:

- A lower composite consisting of four liquid-fueled boosters (first stage), a core (second) stage, and a third stage;
- A restartable Fregat upper stage;
- A payload fairing and interstage section; and
- A payload adapter/dispenser with separation system(s).

Depending on mission requirements, a variety of different adapters/dispensers may be used. Although the Soyuz/ST will be the latest version in the Soyuz launch family, Starsem may propose the use of the currently operational Soyuz LV with an analog control system and a 3.715-m external-diameter fairing for certain missions. The principal differences between the two vehicles are outlined in the following section, and vehicle data are provided in *Table 1-3*. The basic configurations of the Soyuz and Soyuz/ST are shown in *Figure 1-1* and *Figure 1-2*, respectively.

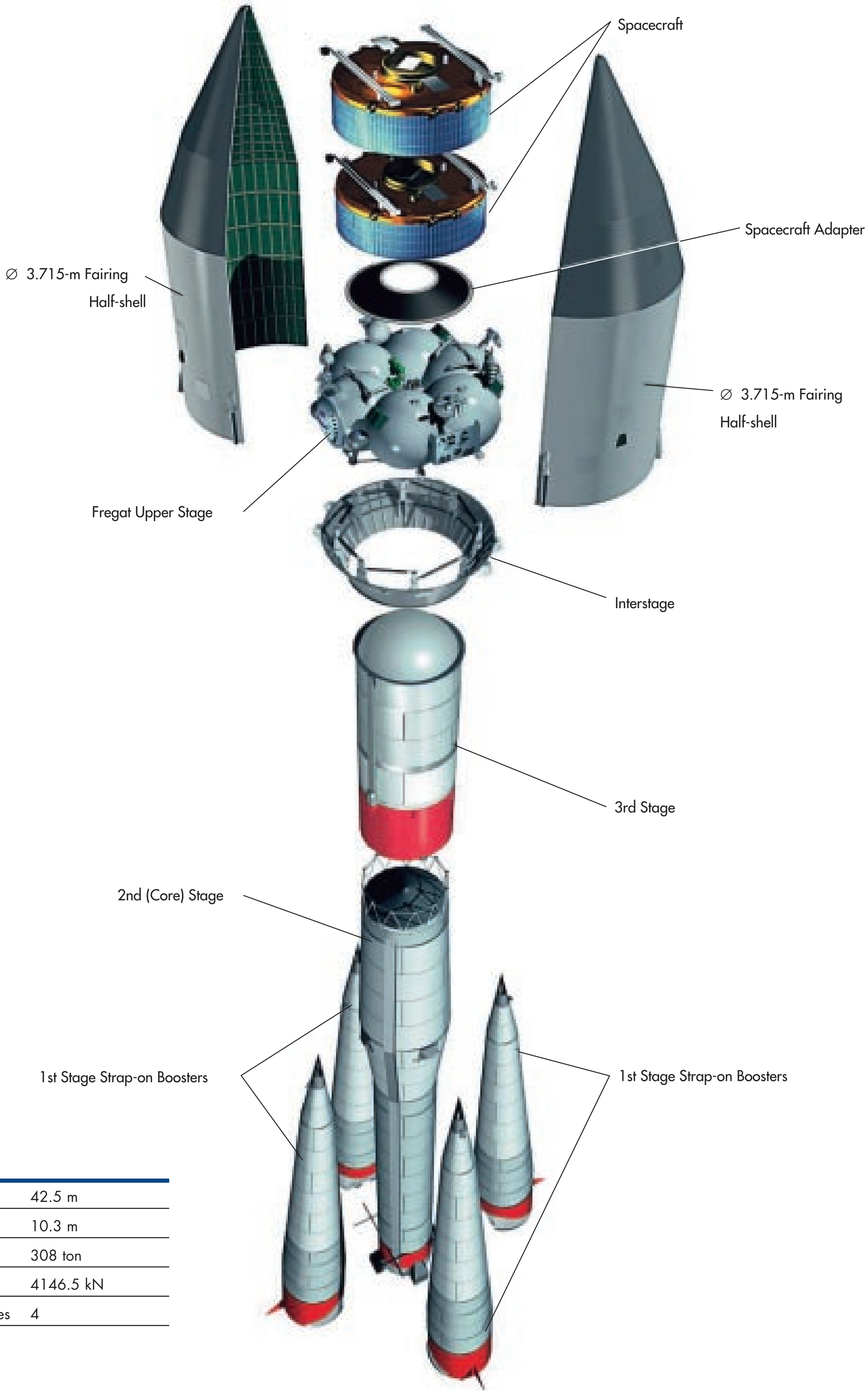
Table 1-3: Soyuz and Soyuz/ST Vehicle Data

	Booster		Core Stage		Stage 3	
	Soyuz	Soyuz/ST	Soyuz	Soyuz/ST	Soyuz	Soyuz/ST
Quantity	4		1		1	
Length (m)	19.6		27.1		6.70	
Diameter (m)	2.68		2.95		2.66	
Gross mass (metric ton)	43.4	43.4	99.5	99.4	25.2	25.3
Inert mass (metric ton)	3.80	3.82	6.55	6.45	2.41	2.47
Engine	RD-107A		RD-108A		RD-0110	
	(14D22)		(14D21)		(11D55)	
Quantity	1		1		1	
Manufacturer	AO Motorstroitel		AO Motorstroitel		Voronyezh Mechanical Factory	
Propellants	LOX*/Kerosene		LOX/Kerosene		LOX/Kerosene	
Isp - sea level (s)**	262		255		N/A	
Isp - vacuum (s)**	319		319		325	
Thrust - sea level (kN)**	838.5		792.5		N/A	
Thrust - vacuum (kN)**	1021.3		990.2		297.9	
Typical burn time (s)	118		290		240	
Restart capability	No		No		No	

*LOX = Liquid oxygen

**Includes performance of vernier thrusters

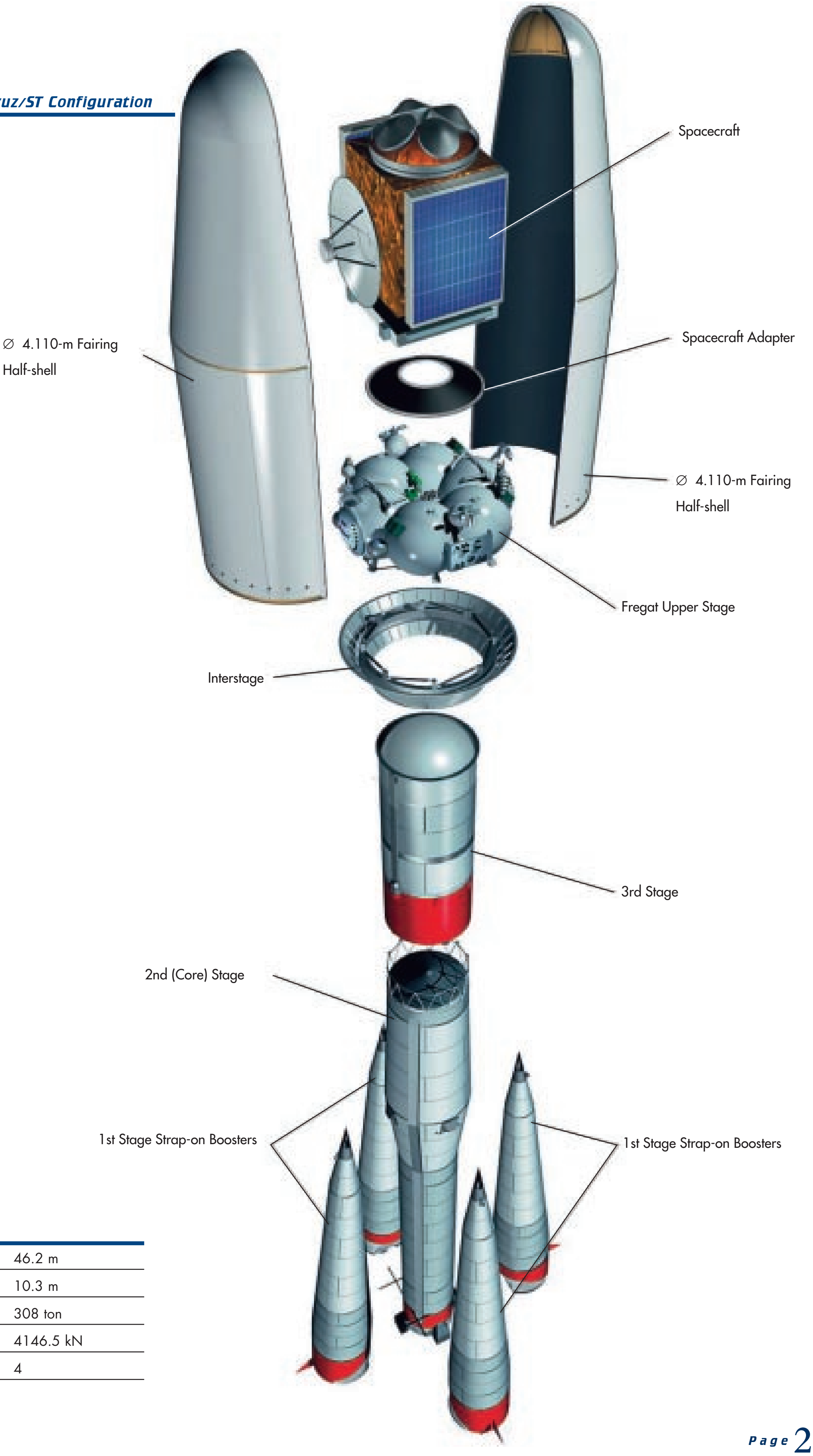
Figure 1-1: Soyuz Configuration



Soyuz

Length	42.5 m
Diameter	10.3 m
Liftoff Mass	308 ton
Liftoff Thrust	4146.5 kN
Number of Stages	4

Figure 1-2: Soyuz/ST Configuration



Soyuz/ST

Length	46.2 m
Diameter	10.3 m
Liftoff Mass	308 ton
Liftoff Thrust	4146.5 kN
Number of Stages	4

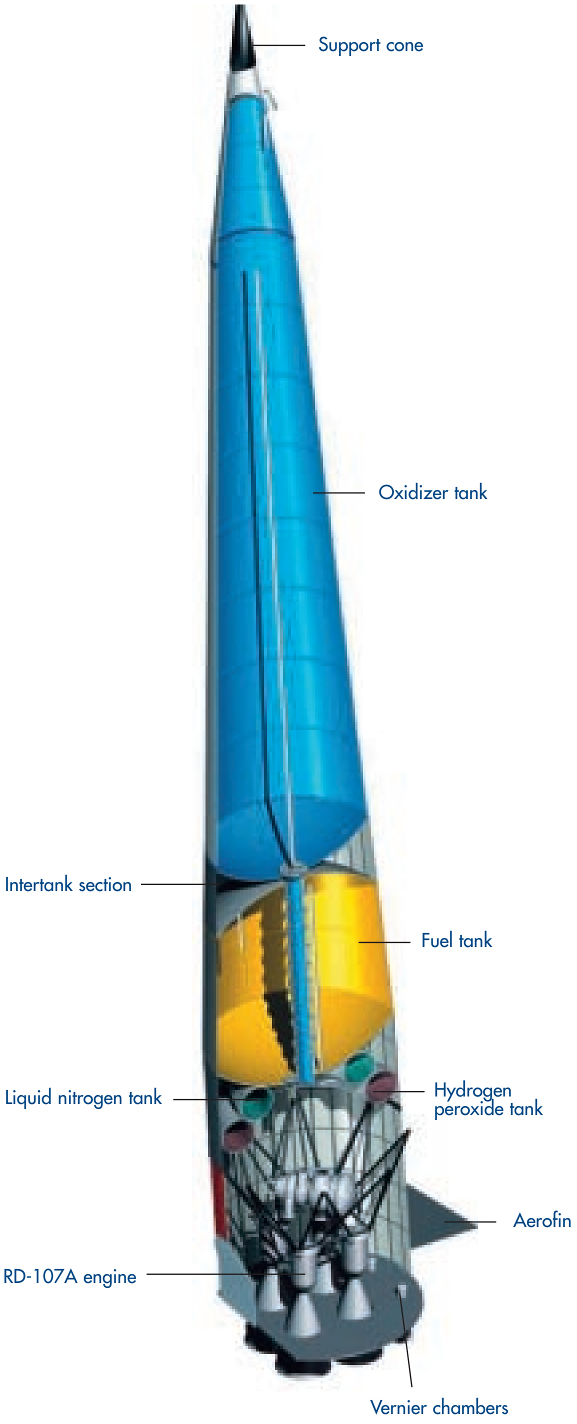
1.4.2. BOOSTERS (FIRST STAGE)

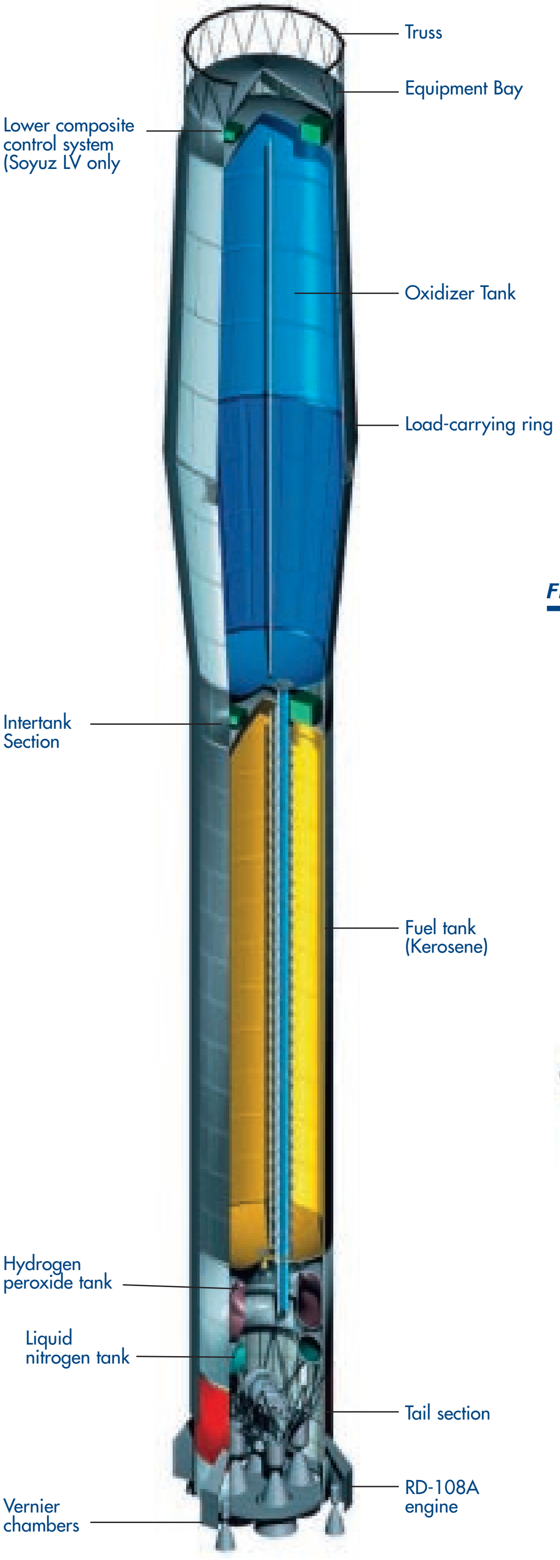
The four boosters are arranged around the central core and are tapered cylinders with the oxidizer tank in the tapered portion and the kerosene tank in the cylindrical portion (see *Figure 1-3*). As in the entire Soyuz lower composite, the RD-107A engines of the boosters are powered by nontoxic liquid oxygen – kerosene propellants. These spark-ignition engines are fed by a turbopump running off gases generated by the catalytic decomposition of H_2O_2 in a gas generator. Each RD-107A has four combustion chambers and nozzles. Liquid nitrogen is used for pressurization of the propellant tanks.

Attitude control is carried out through two movable vernier thrusters and one aerofin. Three-axis flight control is made possible through these eight engines (two per booster) and four aerofins (one per booster).

The boosters burn for 118 seconds and are then discarded. Thrust is transferred through a ball joint located at the top of the cone-shaped structure of the booster, which is attached to the central core by two rear struts.

Figure 1-3: Booster Layout and Location





1.4.3. CORE (SECOND STAGE)

The second stage is similar in construction to the booster stages, using the RD-108A engine and four vernier thrusters for three-axis flight control (see *Figure 1-4*). The core stage nominally burns for 290 seconds. The stage is shaped to accommodate the boosters, and a stiffening ring is located at the upper interface between the boosters and central core. The Soyuz/ST has a strengthened structure to handle increased loads due to the larger fairing.

The boosters and the central core are ignited on the ground. They burn at intermediate thrust levels for approximately 20 seconds before actual liftoff in order to verify their health and nominal level of operation. The core stage continues to function after booster shutdown and separation.

Figure 1-4: Core Stage Layout and Location

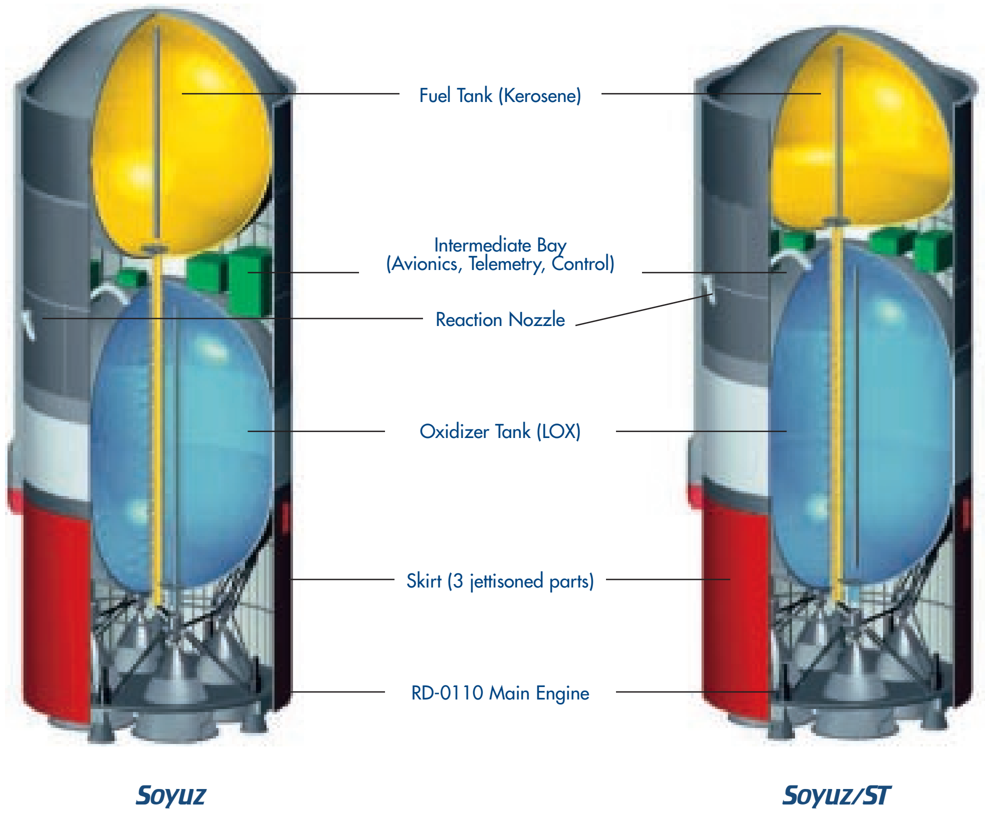
1.4.4. THIRD STAGE

Ignition of the third stage's single main engine occurs approximately 2 seconds before shutdown of the central core. The separation of the stages takes place at a predetermined velocity. After separation, the lower skirt of the third stage is jettisoned in three sections.

The third stage of the Soyuz is powered by the RD-0110 engine (see *Figure 1-5*). The LOX and kerosene tanks are modified in the Soyuz/ST version to accommodate the more powerful RD-124 engine; however, the engine is being considered only for the Soyuz/ST⊕.

The third-stage engine is powered by a single turbopump spun by gas from combustion of the main propellants in a gas generator. These combustion gases are recovered to feed four vernier thrusters that handle attitude control of the vehicle. For deorbitation and collision avoidance, a reaction nozzle is positioned on the side of the stage and vents the oxygen tank. The LOX tank is pressurized by the heating and evaporation of the oxygen, while the kerosene tank is pressurized by combustion products from the gas generator. An interstage truss structure connects the core stage with the third stage, thereby allowing for the ignition of the third stage before separation of the second. In fact, this ignition assists the separation of the second stage.

Figure 1-5: Third Stage



1.4.5. SOYUZ AVIONICS

1.4.5.1. Control System

The control system performs the following functions for flight of the first three stages of the Soyuz and Soyuz/ST:

- Attitude control/stabilization;
- Navigation and guidance; and
- Vehicle management, including health monitoring, propellant control and monitoring, and delivery of pyrotechnic commands.

The currently operational Soyuz has no inertial platform or on-board computer and uses an entirely analog control system. Separation events are calculated by comparing the integral of acceleration with a predetermined cutoff velocity. The control system in the Soyuz is located primarily in the third stage and core stage.

The Soyuz/ST introduces a digital computer and four-axis gimbaled inertial measurement unit (IMU) for improved navigation accuracy and control capability. The Soyuz/ST's control system is somewhat more centralized and is located primarily (IMU and digital computer) in the equipment bay of the third stage.

The differences in control systems lead to the following:

- The Soyuz/ST attitude control system (ACS) is more flexible and more efficient. It is capable of handling the increased aerodynamic instability generated by the larger fairing. The control laws are analog on the Soyuz and digital on the Soyuz/ST.
- The flight of the first three stages of the Soyuz/ST is more accurate than that of the Soyuz. However, the Fregat upper stage has an independent digital control system with a three-axis gimbaled IMU. This system is able to correct errors introduced by the Soyuz control system. Therefore the flight of the full four-stage vehicle (Soyuz or Soyuz/ST) typically leads to the same overall mission accuracy.
- The Soyuz/ST is able to perform in-flight roll maneuvers as well as in-plane yaw steering (dogleg) maneuvers.

1.4.5.2. Telemetry

A telemetry system with transmitter is located in the equipment bay of the third stage of the Soyuz and Soyuz/ST. In addition, health-monitoring parameters are downlinked to ground stations along the flight path. Data are transmitted from ground stations to a Flight Control Center where they are analyzed and recorded, some in real time.

1.4.5.3. Tracking

Tracking of the Soyuz is carried out using ground radar stations. With the Soyuz/ST, tracking of the launch vehicle is accomplished by using an on-board satellite navigation receiver. Position information is then relayed to the ground using the vehicle's telemetry system.

1.4.5.4. Range Safety

There is no remote safeguard system on the Soyuz or Soyuz/ST. In the case of a mission abort scenario (some parameter out of limits), the vehicle shuts down all engines and falls ballistically back to earth.

1.4.6. FREGAT UPPER STAGE

The Fregat upper stage is an autonomous and flexible stage that is designed to operate as an orbital vehicle. It extends the capability of the lower three stages of the Soyuz vehicle to provide access to a full range of orbits. The upper stage consists of six spherical tanks (four for propellant, two for avionics) arrayed in a circle, with trusses passing through the tanks providing structural support. The Fregat can be seen in *Figure 1-6*. Being a restartable upper stage (designed for up to twenty ignitions with six demonstrated during flight), it is capable of performing a wide range of missions.

In order to provide the Fregat with high initial reliability and to speed up the development process, several flight-proven subsystems and components from previous spacecraft and rockets are incorporated into the upper stage. The Fregat upper stage was flight-qualified in February 2000 and successfully flew four missions in that year. These flights corroborated the validity of both the design and its margins.

The main propulsion system is based on previously developed units for the Phobos spacecraft and uses nitrogen tetroxide (NTO) and unsymmetrical dimethyl hydrazine (UDMH) as propellants. This propulsion system was used to inject Phobos onto a Martian trajectory in 1988. Its main engine has been in operation for 30 years and has been extensively used on 27 different spacecraft as part of a variety of interplanetary missions, including those for lunar, Venus, and Mars exploration.

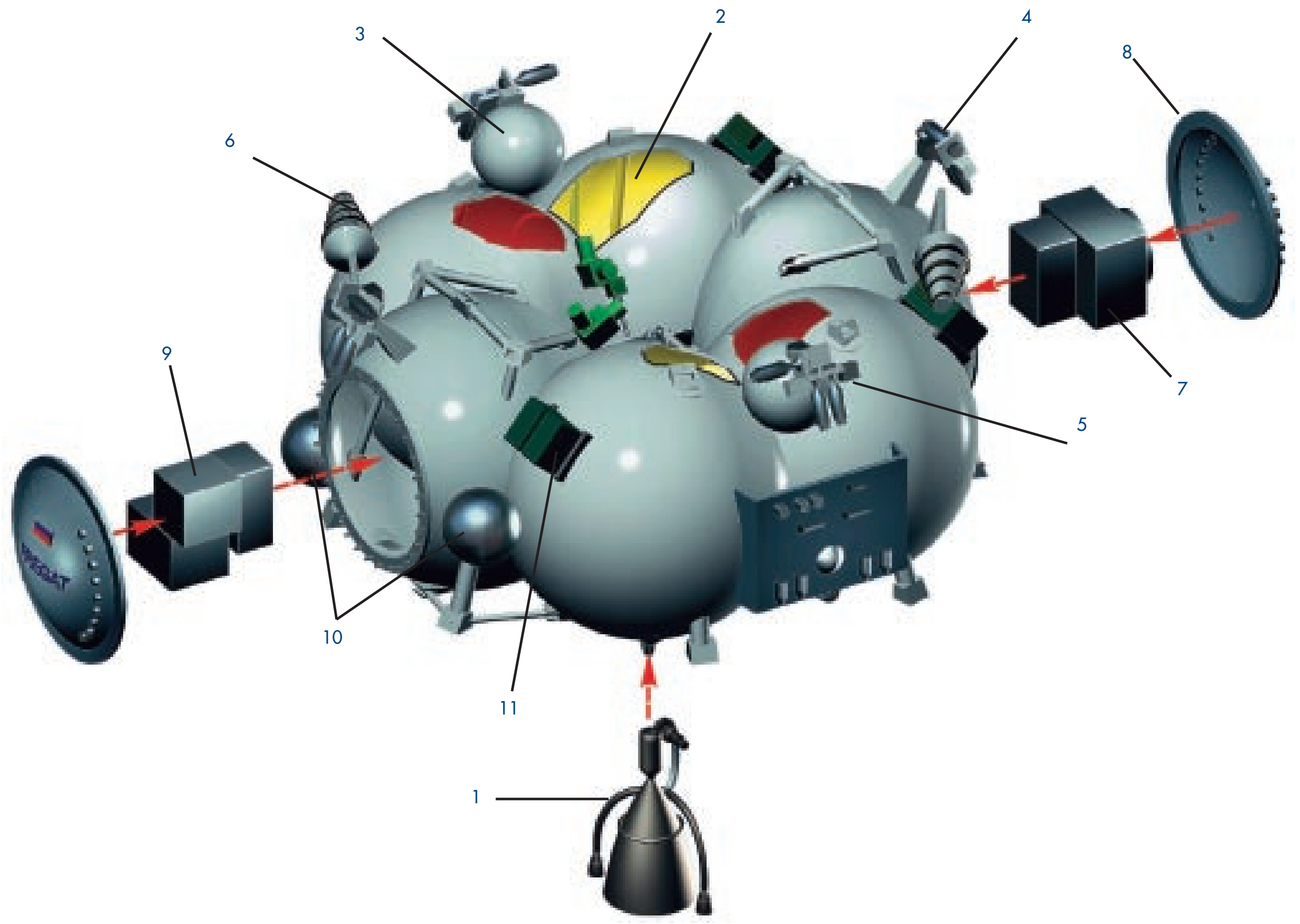
The Fregat's guidance, navigation, and control subsystems (inertial platform, on-board computers, and software) are based on units designed for military ballistic missiles and launch vehicles. The RF/TM subsystem is already in production by Russian industry for other spacecraft and LVs. As a result, it is readily available for Fregat.

NPO Lavochkine, located near Moscow, is responsible for the production of Fregat. Its facilities can accommodate the production of up to eight upper stages per year with a production time of 10 to 15 months. The same factory was used for the manufacture of the Block L upper stage, which was previously used as an upper stage for the Molniya vehicle. Key Fregat parameters are shown in *Table 1-4* and *Figure 1-6*.

Table 1-4: Fregat Upper Stage Data

Dimensions	
Height (m)	1.500
Diameter (m)	3.350
Mass	
Useful propellant mass (kg)	5350
Inert mass (kg)	1000
Main Engine	S5.92
Propellant Feed System	Pump-fed, open cycle gas generator
Manufacturer	KB Khimash
Propellants	N_2O_4/UDMH
Isp - vacuum (s)	330
Thrust (kN)	19.6
Restartable	Yes (up to 20)
Shutdown process	Command shutdown or depletion burn
Structure	
Type	6 spherical tanks supported by 8 longitudinal rods
Material	Aluminum alloy
Attitude Control	
Pitch, yaw	Translation of S5.92 engine or use of 8 ACS thrusters
Roll	4 ACS thrusters
Navigation	Inertial 3-axis platform
Stage Separation	Cumulative pressure lock / pushers
Operational Lifetime (hours)	Up to 48

Figure 1-6: Fregat Overview



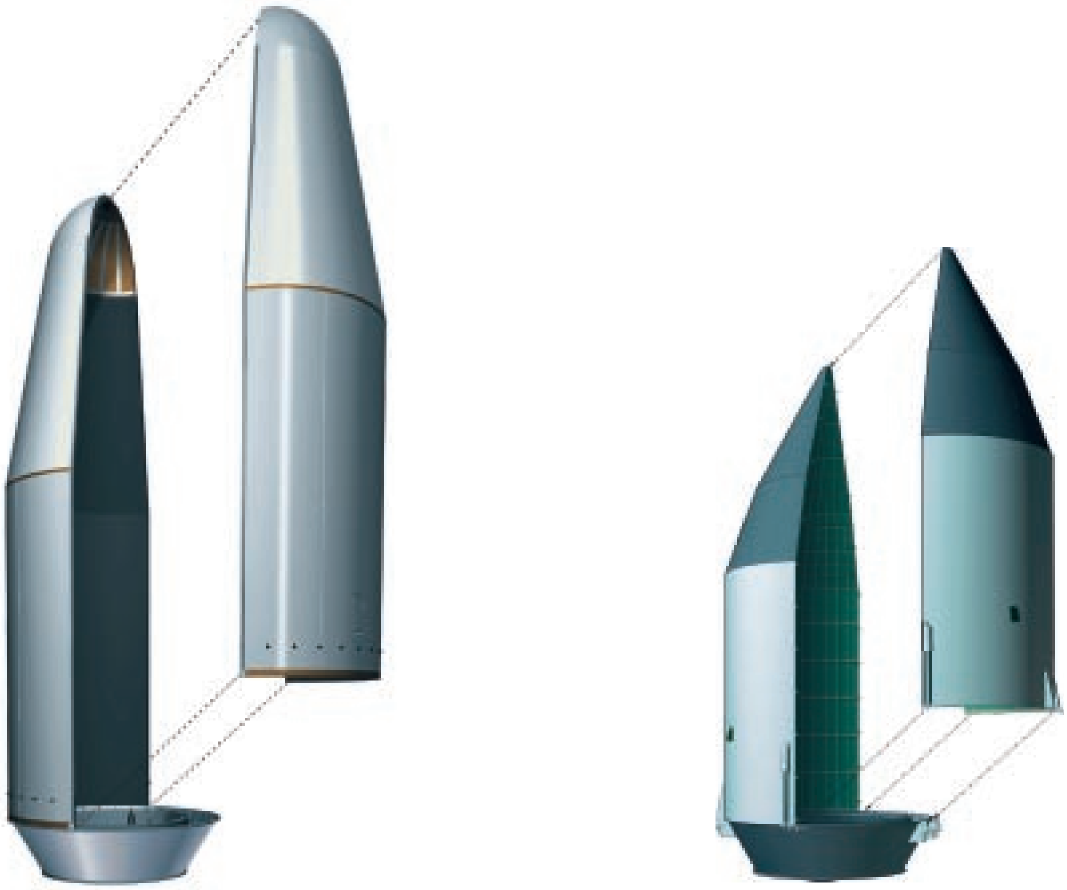
1 - S5.92 main engine
2 - fuel tanks
3 - hydrazine bottle
4 - ACS thrusters
5 - oxidizer tanks
6 - telemetry system antenna
7 - control system
8 - equipment bay cover-radiator
9 - telemetry and tracking system
10 - helium bottles
11 - chemical batteries

1.4.7. PAYLOAD FAIRINGS

Depending on payload and mission requirements, Starsem offers two payload fairings (see *Figure 1-7*):

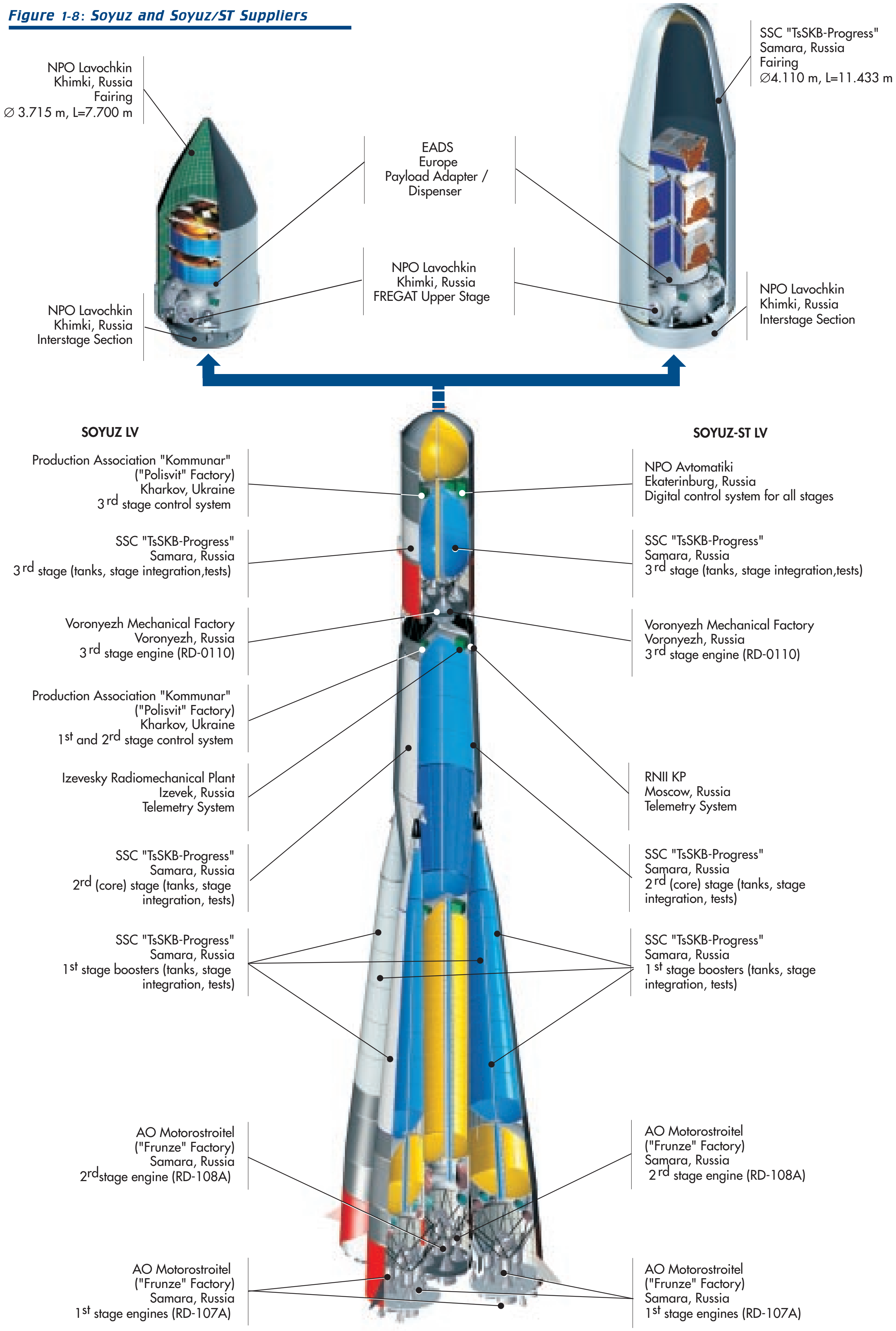
- An ST fairing with an external diameter of 4.110 m and a length of 11.433 m, developed for the Soyuz/ST program; and
- An S fairing with an external diameter of 3.715 m and a length of 7.700 m, first used in Fregat's initial flights and in the flight of the European Space Agency's (ESA's) Cluster II mission.

Figure 1-7: Payload Fairings



ST fairing **S fairing**

Figure 1-8: Soyuz and Soyuz/ST Suppliers



1.4.8. KEY SUPPLIERS

In addition to the contributions of the partners outlined above, there are several organizations that deal directly or indirectly with Starsem to provide hardware and/or services. Key Soyuz/ST suppliers are shown in *Figure 1-8*.

1.5. BAIKONUR LAUNCH SITE FACILITIES

Soyuz and Soyuz/ST LVs take off from Baikonur Cosmodrome, located in Kazakhstan (see *Figure 1-9*). The Cosmodrome is used by Soyuz for a variety of missions, including human space flights. An international agreement forged between Russia and Kazakhstan to use the Cosmodrome until 2020 ensures the long-term operation of Soyuz from the Baikonur Cosmodrome.

In order to meet Western standards for prelaunch spacecraft processing, Starsem has constructed state-of-the-art facilities with Class 100,000 (1158-m^2) cleanrooms consisting of the following:

- A Payload Processing Facility (PPF);
- A Hazardous Processing Facility (HPF); and
- An Upper Composite Integration Facility (UCIF).

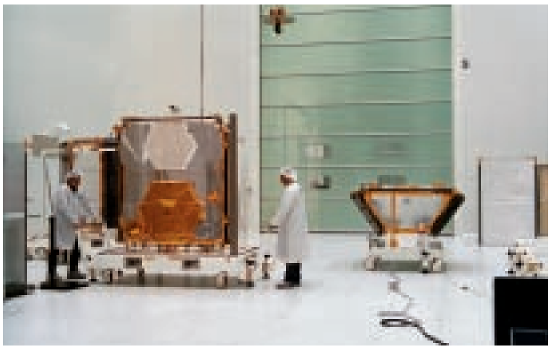
The operational capability of these facilities has been demonstrated during the prelaunch operations of Starsem's first ten flights. The launch pad and related facilities have been upgraded to provide launch capability with the Soyuz/ST launcher and to meet user requirements.

Starsem was also a partner in building the Sputnik Hotel, a facility situated close to the Cosmodrome in the city of Baikonur. This world-class, 125-room facility is available for Starsem customers and provides an optimal environment for both work and recreation. Transportation is readily available to and from the Cosmodrome.

Starsem provides all necessary support, facilities, and consumables for satellite preparation. Integration with the launcher and combined activities are carried out by a team consisting of Starsem, Rosaviacosmos, Samara Space Center, the European Aeronautic, Defence and Space Company (EADS), and Lavochkine personnel.

The launch campaign duration of typical Soyuz launches is five weeks but may be adapted to accommodate users' needs.

Figure 1-9: Baikonur Launch Site Facilities



Payload Processing Facility

Hazardous Processing Facility

Upper Composite Integration Facility

MIK 40: Soyuz and Fregat Assembly and Integration Building

Soyuz Launch pad

Sputnik Hotel

1.6. PARTNER ORGANIZATIONS

Starsem is a 50/50 joint venture between Russian and European partners that draws on some of the best-known names in the aerospace industry. Four partners have combined their organizational, managerial, and technical strengths to form Starsem:

— THE EUROPEAN AERONAUTIC, DEFENCE, AND SPACE COMPANY (EADS) (35%);
— RUSSIAN AVIATION AND SPACE AGENCY (ROSAVIACOSMOS) (25%);
— SAMARA SPACE CENTER (TsSKB-PROGRESS) (25%); AND
— ARIANESPACE (15%).

These partners have an extensive history of involvement in space operations, specifically with the Soyuz and Ariane LVs, and bring a range of experience that encompasses design, production, operations, and marketing. Representatives from the four partners are members of Starsem's administrative board, which is responsible for the overall direction of the company.

EUROPEAN AERONAUTIC, DEFENCE, AND SPACE COMPANY (EADS)

The European Aeronautic, Defence, and Space Company is a world leader in the aeronautics, space, and defense industry. Formed in 2000, it combines the strengths of Aerospatiale Matra, Daimler-Chrysler Aerospace, and CASA into a comprehensive European aerospace company. For more than 30 years EADS has played a major role in the development and production of European LVs such as Ariane.

In relation to Starsem, EADS is responsible for:

– Adapter/dispenser design, development, and production; and
– Engineering analysis and system support.

RUSSIAN AVIATION AND SPACE AGENCY (ROSAVIACOSMOS)

The Russian Aviation and Space Agency was created in February 1992 by a decree issued by the President of the Russian Federation. It is the federal agency charged with defining and implementing Russian space policy.

By regulating and coordinating the activities of more than 140 Russian space companies and organizations, Rosaviacosmos is responsible for ensuring the success of national space programs and research. It also acts as the government customer for the development of these programs and research activities, and coordinates cooperation on international programs such as the International Space Station and commercial ventures such as Starsem.

In the framework of Starsem, Rosaviacosmos is responsible for:

– Coordinating the activities of Russian organizations and suppliers;
– Maintaining a high level of contact within the Russian government;
– Baikonur facility management; and
– Arranging approval for safety issues and other legal matters.

SAMARA SPACE CENTER (TsSKB-PROGRESS)

The Samara Space Center "TsSKB-Progress," created by Russian presidential decree in 1996, combines the TsSKB Central Samara Design Bureau and the Progress production plant, each of which has been a key component of the Russian and Soviet space programs for over 40 years.

TsSKB-Progress is a world leader in the design of LVs, spacecraft, and space systems. Its origins trace back to 1959 at the start of the space age, when a branch of the Sergei Korolev's OKB-1 design bureau (now RSC Energia) was established in the city of Kuibyshev, now known as Samara.

From there, TsSKB evolved a family of LVs building off of the R-7 intercontinental ballistic missile developed by OKB-1.

In addition to years of experience building LVs, TsSKB has also built numerous earth observation and scientific satellites. TsSKB has extensive facilities for spacecraft and systems testing.

In the framework of Starsem, TsSKB is responsible for:
- Manufacturing and delivery of the Soyuz/ST LV;
- Developing and qualifying modifications to the Soyuz/ST;
- Mission analysis activities; and
- Launch preparation and launch.

ЦСКБ-ПРОГРЕСС

ARIANESPACE

Arianespace is the international leader in commercial launch services, holding more than 50% of the market for satellites launched to GTO. Since its creation in 1980 as the world's first commercial space transportation company, Arianespace has successfully performed more than 100 launches and signed contracts with approximately 50 operators/customers for more than 190 spacecraft.

Arianespace oversees the marketing, sales, production, and operation of the Ariane family of LVs. The heavy-lift Ariane 5, flight-qualified in 1998, is the latest addition to the Ariane family and will serve as Arianespace's workhorse LV well into the 21st century. Based just outside Paris in Evry, France, Arianespace has 53 European corporate shareholders.

In the framework of Starsem, Arianespace is responsible for:
- Marketing support; and
- Developing common commercial strategies.

arianespace

STARSEM'S ROLE

By blending the best of East and West, Starsem has brought the Soyuz LV family to the commercial market. A Russian-European joint venture headquartered in Paris, Starsem is the organization that is exclusively responsible for marketing and operating commercial launches on the Soyuz family LV.

Starsem's primary mission is to coordinate and manage the inputs of its various partners and suppliers and to combine those inputs with mission management and operations activities to ensure successful launch services that meet or exceed all customer requirements. Starsem adopts an end-to-end management approach from contract signature to delivery on orbit in order to ensure that the launch service is delivered with the highest level of customer satisfaction.

Since its inception in August 1996, Starsem has accomplished a number of key objectives in order to successfully bring the Soyuz LV to the commercial market. These include:

- Building 1158 m^2 of Class 100,000 payload processing facilities at the Baikonur Cosmodrome as well as a 125-room hotel for customers;
- Overseeing the development and qualification of two different upper stages for use with the Soyuz LV;
- Managing and coordinating the activities of various contractors and suppliers in Russia and Europe; and
- Carrying out 10 successful launches in 18 months from February 1999 through August 2000.

STARSEM
The Soyuz Company

1.7. STARSEM LAUNCH SERVICES

By building on the strength of its relationship with its partners and suppliers, Starsem offers its customers focused, proven launch services that include the following primary activities:

- Mission management and organization that covers all aspects of launch activities and preparation from contract signature through launch;
- Systems engineering support and analysis;
- Production, verification, and delivery of the LV and all associated hardware and equipment, including all adaptations required to meet customer requirements;
- Ground facilities and support for user activities at launch site;
- Combined operations at launch site, including LV and spacecraft integration and launch;
- Telemetry and tracking ground station support and postlaunch activities;
- Assistance and logistics support, which may include transportation and assistance with insurance, customs, and export licenses; and
- Quality assurance and safety activities.

Starsem provides the user with a single point of contact (the mission manager) for all launch service activities in order to simplify and streamline the process.

CHAPTER

2

PERFORMANCE

2.1. VEHICLE PERFORMANCE OVERVIEW

This section provides information that can be used to make preliminary performance assessments for LVs of the Soyuz family. The paragraphs that follow demonstrate these vehicles reference performance, typical accuracy, attitude orientation, and mission duration.

This chapter provides standard performance information for Soyuz/ST LVs using the Fregat upper stage and a 4.110-m external-diameter payload fairing, which provides the largest available volume for spacecraft accommodation. The currently operational Soyuz LV using the Fregat upper stage, a 3.715-m external-diameter payload fairing, and an analog control system may be optimal for some missions. Performance for this vehicle will be equivalent or marginally higher than for the Soyuz/ST for the reference missions given due to its lower aerodynamic drag and fairing mass.

Both the Soyuz and Soyuz/ST are flexible, medium-class launch vehicles that are capable of carrying out a wide variety of missions. Although initially designed for manned missions and for the delivery of satellites to low circular and elliptical orbits, a series of steady improvements such as the Fregat upper stage has enhanced the vehicle's design to allow it to reach a range of missions extending beyond low-earth orbit.

It should be noted, however, that there are other Soyuz configurations that can be used depending on the customer's mission requirements and payload dimensions. An option for LEO missions involves the use of the first three stages of the Soyuz/ST without the Fregat upper stage in a configuration similar to that used for manned space-flight missions. A three-stage version of this vehicle would be particularly well suited to circular missions up to approximately 400 km and low elliptical orbits with up to a 1500-km apogee altitude.

2.2. VEHICLE PERFORMANCE DEFINITION

LV performance is dependent on a variety of factors, including the following:

- Launch system configuration;
- Geographic location of the launch site;
- Constraints imposed by launch azimuth limitations and by the location of approved drop zones for expended elements;
- Attitude and thermal constraints; and
- Mission-specific customer requirements.

All launch vehicle calculations are based on flight validated mathematical models for the vehicle characteristics, atmosphere, gravitation field, etc. All altitude values are given with respect to an Earth radius of 6378 km.

2.2.1. LAUNCH SYSTEM CONFIGURATION

The Soyuz and Soyuz/ST LVs consists of three lower stages — boosters, core, and third stage — combined with the Fregat upper stage. Sufficient propellant reserve is assumed to reach the intended orbit with a 99.7% probability. The Fregat's fuel capacity is sufficient for deorbitation or for transfer to a safe orbit as required.

All performance values given in this chapter are expressed in terms of overall payload mass. This means that the mass of the spacecraft adapter or dispenser must be subtracted from these values to obtain the estimated separated spacecraft mass. Available payload adapters are shown in *Appendix 2*.

Performance data presented in this manual are not totally optimized in that they do not take into account any uncertainty that may arise from the specificity of the user's mission; from the technical evolution of the Soyuz/ST and the Fregat; and from margin release following the development phase. Some specific mission configuration updates may also affect performance. The data presented herein do not take into account additional telemetry provisions, Fregat electrical power supply to the spacecraft, or propellant limits for the ACS as a function of mission duration or other additional services.

2.2.2. LAUNCH PAD AND AZIMUTHS

Performance data are presented for missions launched from Soyuz launch pad 17P32-6 ("launch pad no. 6"), whose launch-pad geographic coordinates are 45.59° N and 63.33° E. This launch pad is the nominal launch pad for Starsem's commercial missions, with pad 17P32-5 ("launch pad no. 5") also available.

Launch azimuths for vehicle ascent trajectories are constrained by ground-path safety rules as well as by the limited number of authorized drop-zone locations for expended stages and other separated elements (e.g., the fairing and the tail section of the third stage). That is why the first three stages of the launch vehicle can be nominally launched only to authorized initial parking-orbit planes corresponding to authorized launch azimuths.

The currently approved launch azimuths from the Baikonur Cosmodrome are shown in *Table 2-1* and *Figure 2-1*. The initial parking-orbit inclinations that correspond to a direct injection on these azimuths are also shown.

Table 2-1: Approved Launch Azimuths from Baikonur Cosmodrome

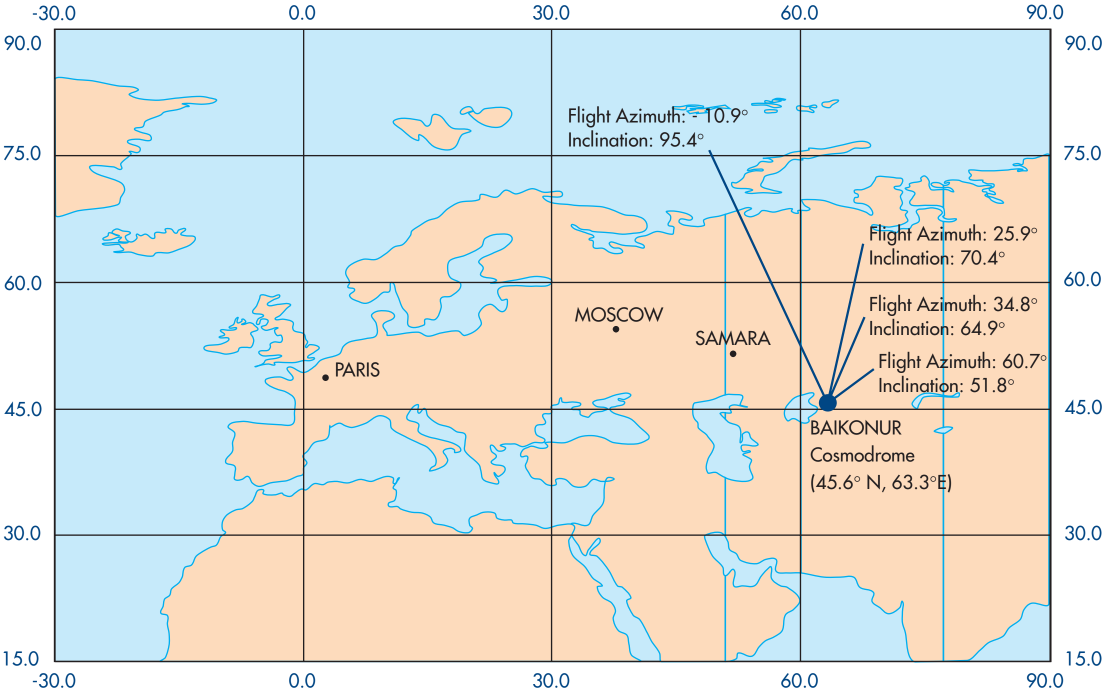
Launch Azimuth	Corresponding Reference Orbit Inclination (Direct Ascent Trajectory)
60.70	51.80
34.80	64.90
25.90	70.40
–10.90	95.40

For the Soyuz/ST LV, some changes in inclination can be carried out during third-stage flight by means of out-of-plane yaw-steering maneuvers. Although limited to ± 5 degrees relative to the nominal reference orbit inclination, this dogleg capability can provide a more efficient means of reaching the final desired orbital plane. Typically any remaining inclination change is carried out by the Fregat. In such cases, users should contact Starsem for a performance estimate and a mission-adapted profile. Performance estimates should not be made merely through linear interpolation between two performance curves.

2.2.3. ATTITUDE AND THERMAL CONSTRAINTS

For all missions, the aero-thermal flux affecting the payload at fairing jettison is less than 1135 W/m^2. Increasing this values would improve LV performance by allowing for the use of a more optimal injection profile.

Figure 2-1: Location of Baikonur Cosmodrome and Authorized Launch Azimuths



Where necessary, the Soyuz/ST launcher may provide roll maneuvers during the three-stage ascent phase to protect the payload from sun exposure. The Fregat flight is designed to accommodate preferred attitude pointing, continuous rolls, maneuvers, and orientation during coast phase to satisfy satellite thermal control, battery-charging, solar exposure, and other specified attitude or exposure requirements.

2.2.4. USER-SPECIFIED MISSION REQUIREMENTS

The user may request specific launch conditions with regard to final orbital parameters (e.g., visibility of separation point from ground stations, argument of perigee, mission duration) that may have a slight effect on performance.

2.2.5. LAUNCH WINDOWS

The launch window is defined primarily by orbit accuracy requirements (such as on right ascension of the ascending node [RAAN]) and by the ability of the launch vehicle to recover launch time error. The actual launch window of each mission and its impact on performance will be calculated as part of Starsem's mission analysis activities. No provision for launch windows was made for the performance analysis presented herein. The dispersion of any planned launch time in a nominal mission scenario is less than one second, taking into account all potential dispersions in the launch sequencing and system start/ignition processes.

2.3. TYPICAL MISSION PROFILES

A typical mission profile consists of the following three phases:

- Phase I: Ascent of the first three stages of the launch vehicle with a suborbital or direct ascent profile;
- Phase II: Orbital maneuvers of the Fregat upper stage for payload delivery to final orbit; and
- Phase III: Fregat deorbitation or orbit disposal maneuvers.

2.3.1. PHASE I - ASCENT OF THE FIRST THREE STAGES

The suborbital injection profile separates the third stage and the Fregat at less than orbital velocity, causing the third stage to fall immediately back to earth. The Fregat is then used to reach the first parking orbit.

By injecting the entire third stage into orbit along with the Fregat and payload, the direct ascent profile results in slightly lower performance in comparison to most missions. Generally, the direct ascent profile is used for escape missions with hyperbolic excess (escape) velocities greater than 5.0 km/s.

Inasmuch as the suborbital mission profile results in increased mass for most missions, most performance data presented in this chapter use this profile.

The typical three-stage suborbital ascent profile and its associated sequence of events are shown in *Figure 2-2* and *Figure 2-3*.

Jettisoning of the payload fairing can take place at different times depending on the aero-thermal flux requirements on the payload. Typically, fairing separation takes place between 155 and 200 seconds from liftoff owing to aero-thermal flux limitations.

If required, the Soyuz/ST can perform an out-of-plane yaw-steering maneuver during third-stage flight in order to change inclination from the nominal value resulting from a direct ascent on the authorized launch azimuth or to compensate for launch-time delay.

Figure 2-2: Phase I: Typical Ascent Profile

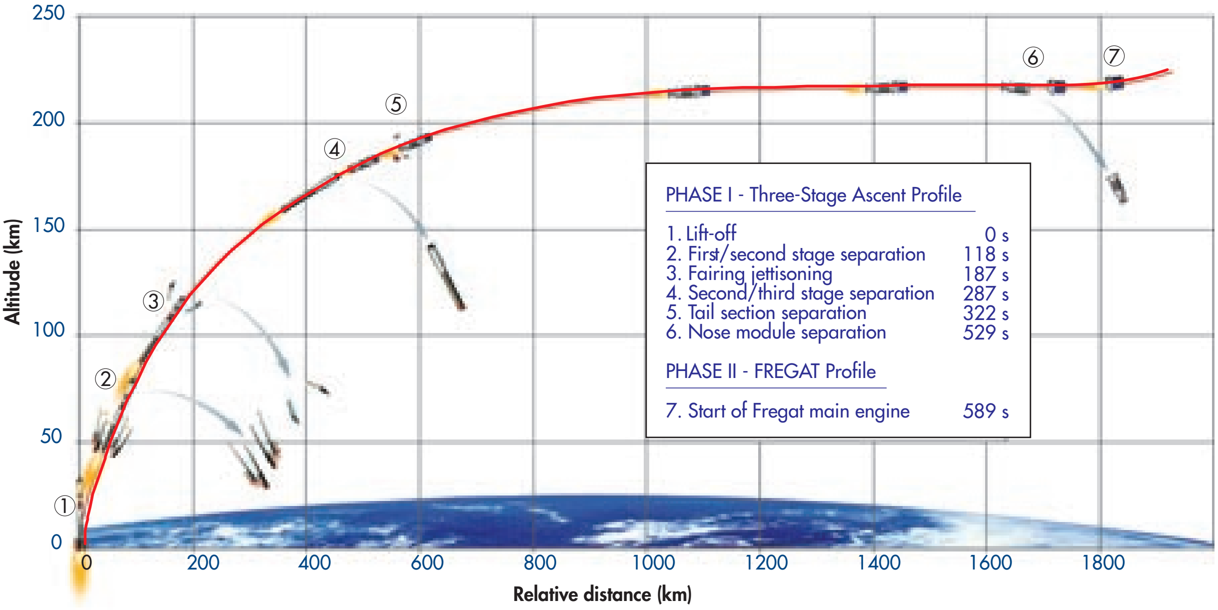
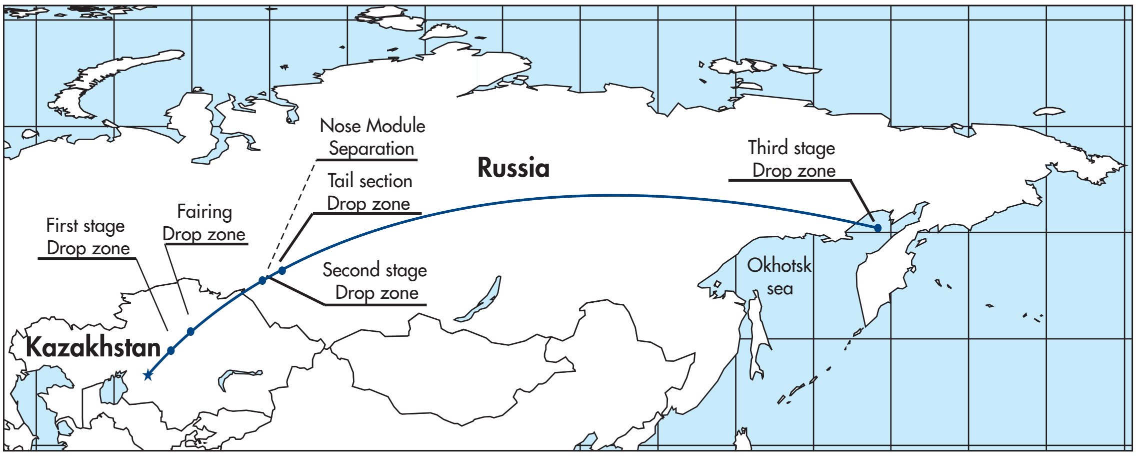


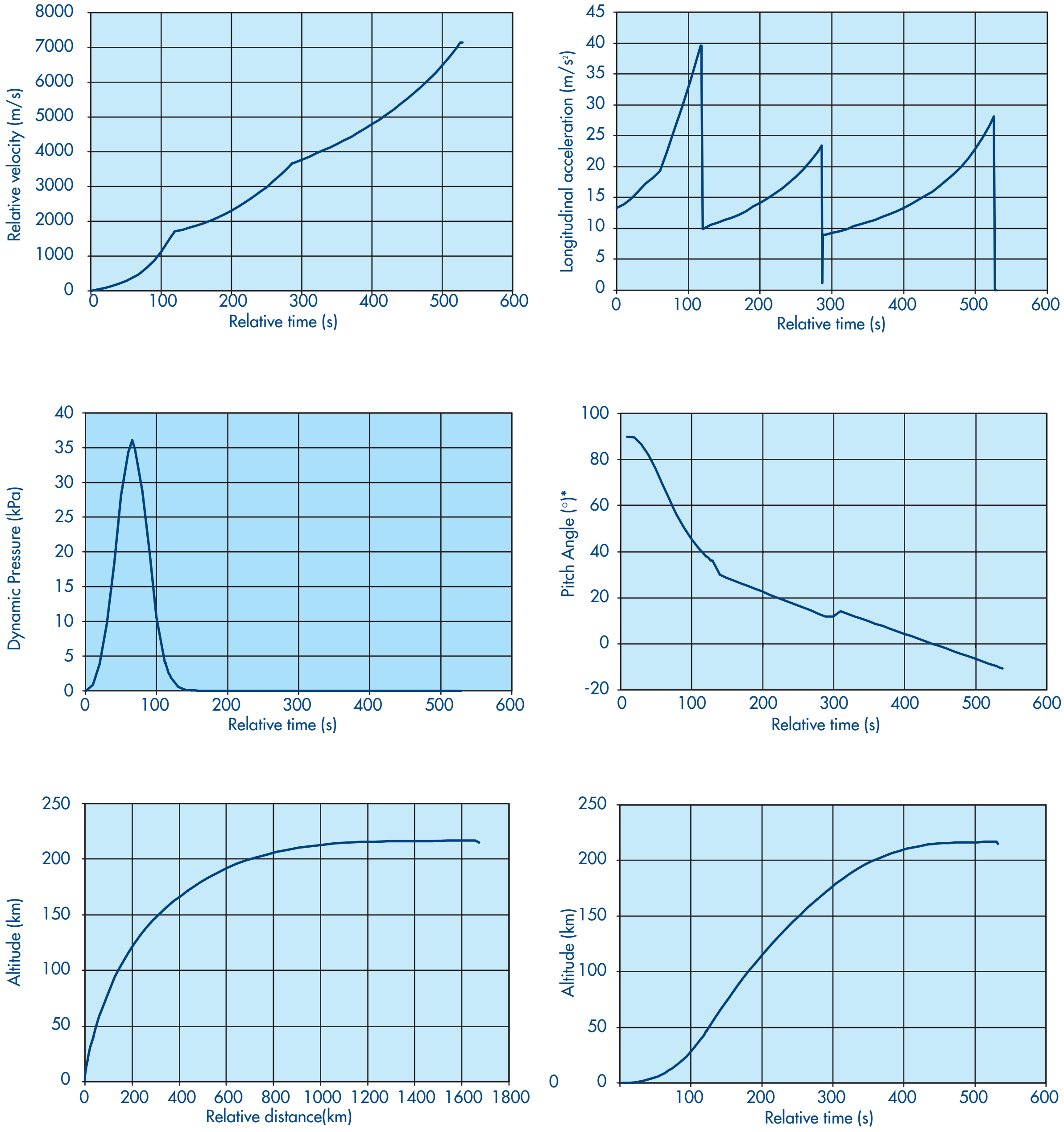
Figure 2-3: Typical Ground Track for the First Three Stages



The Fregat and its attached payload are separated approximately 520–530 seconds following liftoff. The third stage discarded from the flight path falls back to earth in an authorized third-stage drop area. A specific third-stage drop area will be allocated for each mission and in most cases will be located in the ocean. The drop area will be analyzed during the project, especially when dogleg maneuvers are to be incorporated.

Figure 2-4 shows an example of the main trajectory parameters as a function of flight time.

Figure 2-4: Example of the Flight Parameters During the Ascent Profile of the First Three Stages



* Angle is measured relative to inertial coordinate system at liftoff.

2.3.2. PHASE II - FREGAT UPPER STAGE FLIGHT PROFILE

Following the cutoff of the third stage, the restartable Fregat upper stage completes the job of delivering the payload or payloads to their final orbits. A typical Fregat flight profile is shown in *Figure 2-5* and *Figure 2-6*. This profile consists of the following events:

- The ACS thrusters start 5 seconds after separation from the third stage;
- 55 seconds later, the Fregat's main engine is started to transfer to a 200-km parking orbit; and
- Following the initial parking orbit, the Fregat is used to transfer the payload to a wide variety of orbits, providing plane change and orbit raising.

Up to 20 burns may be provided by the Fregat to reach the final orbit or to arrange the payload among different orbits.

2.3.3. PHASE III - FREGAT DEORBITATION OR ORBIT DISPOSAL MANEUVER

After spacecraft separation and following the time delay needed to provide a safe distance between the Fregat upper stage and the spacecraft, the Fregat typically conducts a deorbitation or orbit disposal maneuver. Usually, this maneuver will be carried out by an additional burn of the Fregat's ACS thrusters. Parameters of the "safe" orbit or entry into the earth's atmosphere will be chosen in accordance with international laws pertaining to space debris and will be coordinated with the user during mission analysis.

Figure 2-5: Phases II and III: Example of Fregat Upper-Stage Mission Profile

1. Soyuz launch from Baikonur Cosmodrome on authorized launch azimuth.
2. Nose module separation and first Fregat burn to reach a low-earth parking orbit with an altitude $H_{parking} \cong 200$ km
3. Fregat coast phase
4. Second Fregat burn for transfer to an intermediate transfer orbit (H_a = final orbit altitude, H_p = 200 km). During this burn, the Fregat upper stage can also provide a small change of inclination as needed
5. Fregat coast phase up to apogee of the intermediate transfer orbit
6. Third Fregat burn to raise perigee and change inclination to the desired values
7. Spacecraft separation from Fregat upper stage
8. Fourth Fregat burn for deorbitation or transfer to a safe orbit

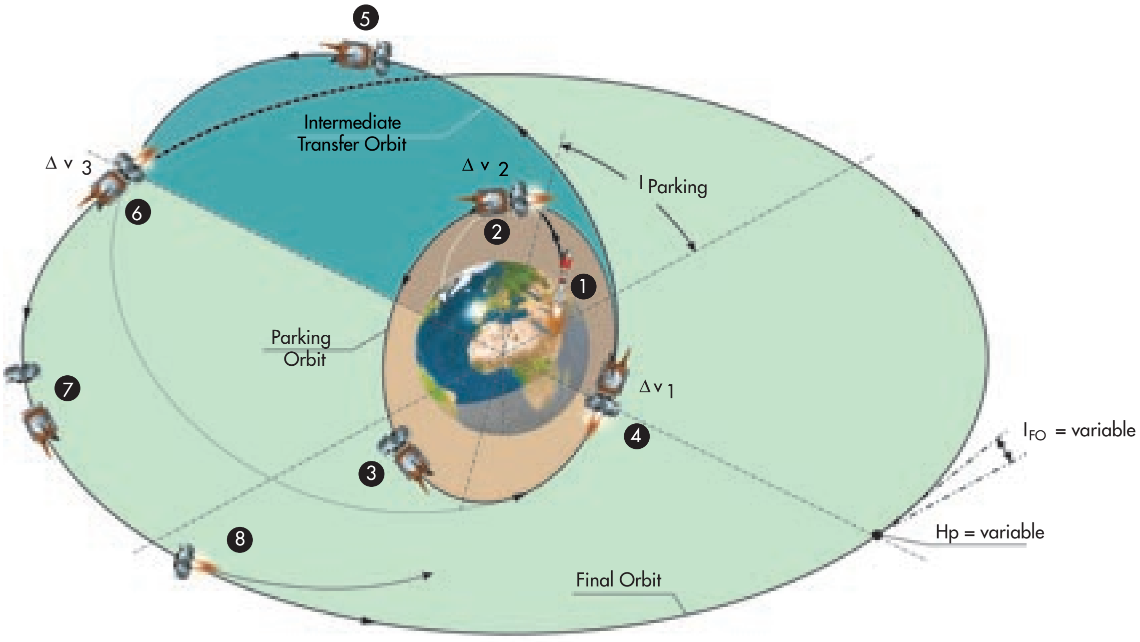


Figure 2-6: Example of Flight Ground Path for 18,000-km Elliptical Orbit with 64.9° of Inclination

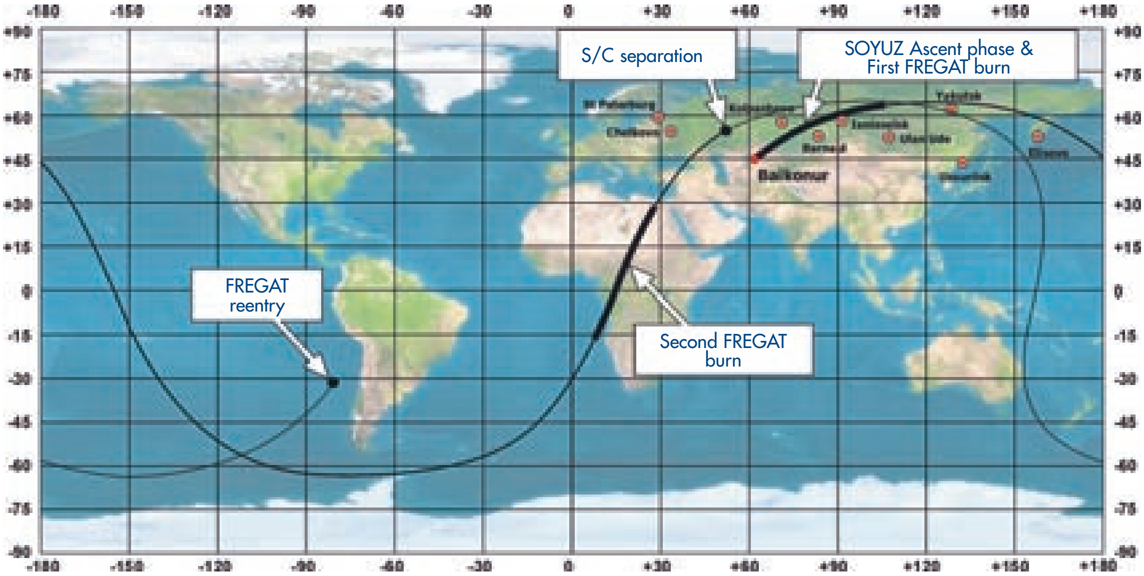
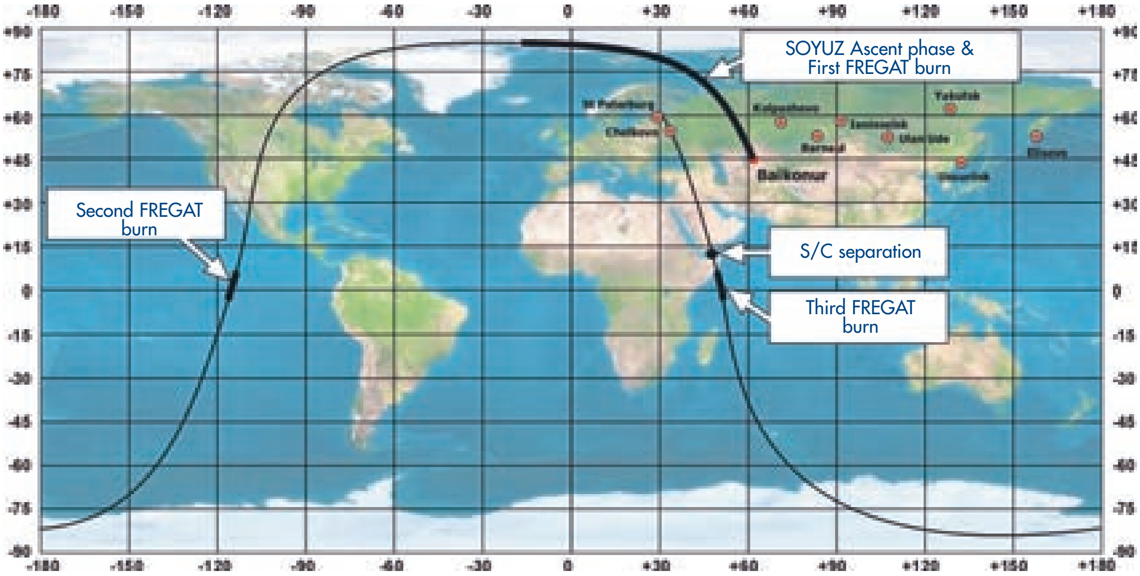


Figure 2-7: Example of Flight Ground Path for 800-km SSO



2.4. GENERAL PERFORMANCE DATA

2.4.1. CIRCULAR ORBITS

Depending on the required inclination of the final orbit and the duration of the mission, one of two slightly different Fregat flight profiles can be chosen: a three- or a two-Fregat-burn mission. The three-burn profile is chosen to optimize performance and the two-burn profile to minimize mission time.

2.4.1.1. Three-Fregat-Burn Mission

For missions requiring inclinations that differ from the reference values given in *Table 2-1,* inclination changes will be carried out using Soyuz/ST third-stage dogleg and/or Fregat upper stage maneuvers. In this case, the Fregat flight profile will include three burns:

- A first burn to transfer to a 200-km parking orbit followed by a coast phase up to the first orbital node;
- A second Fregat burn to transfer to an intermediate elliptical orbit with an altitude of apogee equal to the target value and possibly a small change of inclination; and
- A third Fregat burn for orbit circularization and change of inclination up to the target value.

2.4.1.2. Two-Fregat-Burn Mission

In some cases, it may be desirable to reduce the mission duration below that for a typical three-Fregat-burn mission profile. Some reduction in mission duration is possible in certain cases at the cost of reduced performance. For the Soyuz, this type of profile is feasible for missions with the same final orbit inclination as that of the parking orbit corresponding to the launch azimuth. The Soyuz/ST can tolerate some deviation of the inclination and change inclination during the third stage flight with a dogleg maneuver. The typical Fregat mission profile for such a scenario is as follows:

- A first burn for transfer to the intermediate elliptical orbit with an altitude of apogee equal to the target value; and
- A second Fregat burn for orbit circularization.

This mission profile decreases injection time but may affect LV performance. Performance will depend on the type and magnitude of inclination-change maneuvers and on specific mission requirements. In such cases, the user should contact Starsem for a performance estimate and for selection of the optimal mission profile.

2.4.1.3. Low Circular Orbits (400 km ≤ H_{circ} ≤ 1500 km)

Launch vehicle performance data for circular orbit missions with altitudes between 400 and 1500 km are presented in *Figure 2.8*. This information is based on a three-Fregat-burn mission profile. For an estimate of the typical impact on LV performance of a mission that requires an inclination differing from the 51.8-degree reference value, see *Figure 2-10*.

2.4.1.4. Medium Circular Orbits (1500 km ≤ H_{circ} ≤ 25,000 km)

LV performance data for circular orbit missions with altitudes between 1500 and 25,000 km are presented in *Figure 2.9*. This information is based on a three-Fregat-burn mission profile. For an estimate of the typical impact on LV performance of a mission that requires an inclination differing from the 51.8-degree reference value, see *Figure 2-10*.

2.4.1.5. Sun-Synchronous and Polar Orbits

The launch vehicle has the potential to launch spacecraft to a sun-synchronous orbit (SSO) through an intermediate orbital plane nominally inclined by 95.4 degrees. Orbit inclination can be changed by means of a dogleg maneuver of the third stage and/or via Fregat maneuvers. LV performance data for SSOs are presented in *Figure 2-11* as a function of altitude.

The same mission profile will be used for injection to polar orbit. Performance data for polar orbits are presented in *Figure 2-12*.

Figure 2-8: LV Performance for Low Circular Orbits: H_{circ} = 400–1500 km

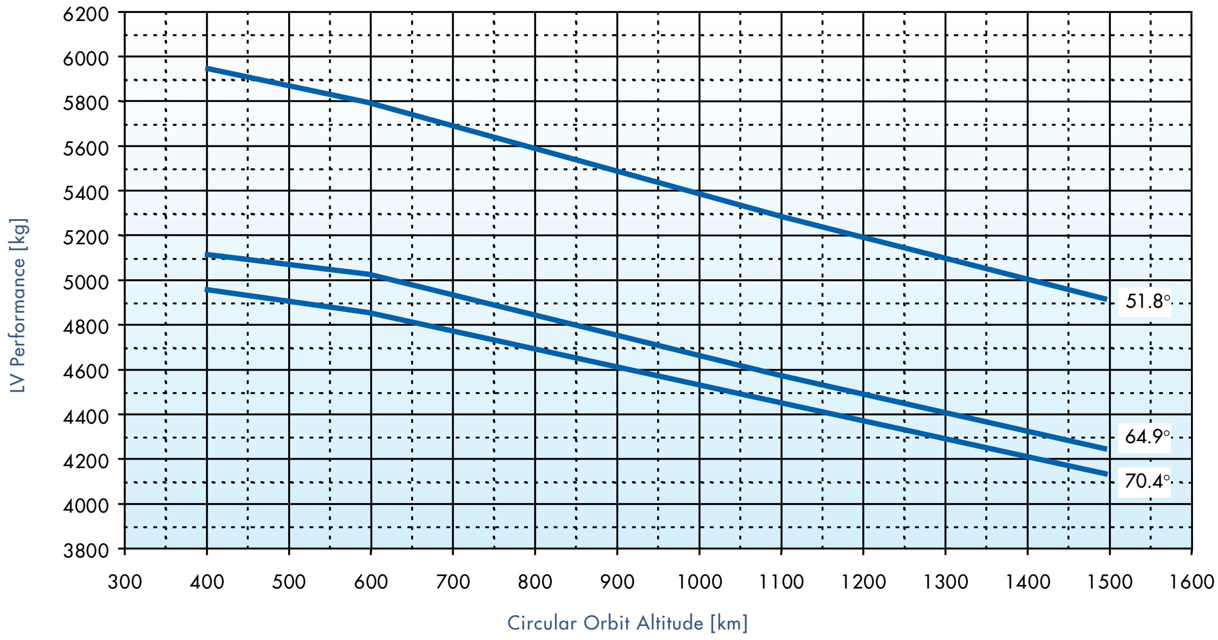


Figure 2-9: LV Performance for Medium Circular Orbits: H_{circ} = 1500–25,000 km

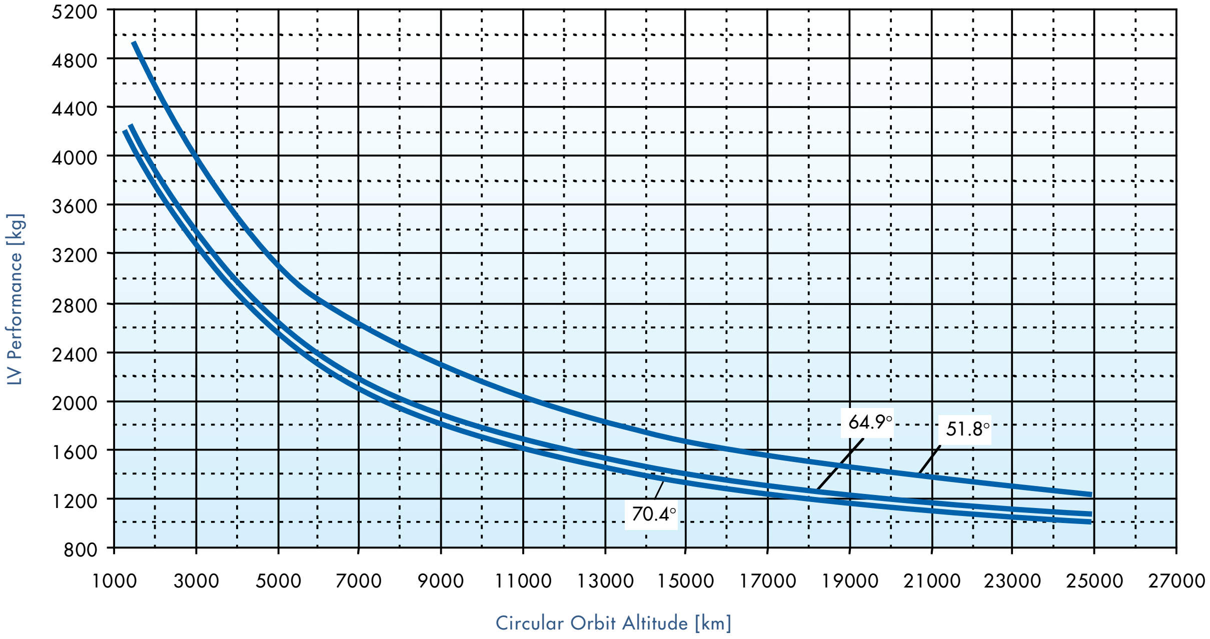


Figure 2-10: Typical Impact on LV Performance for Change of Inclination for Circular Orbits with Reference Value of 51.8 degrees

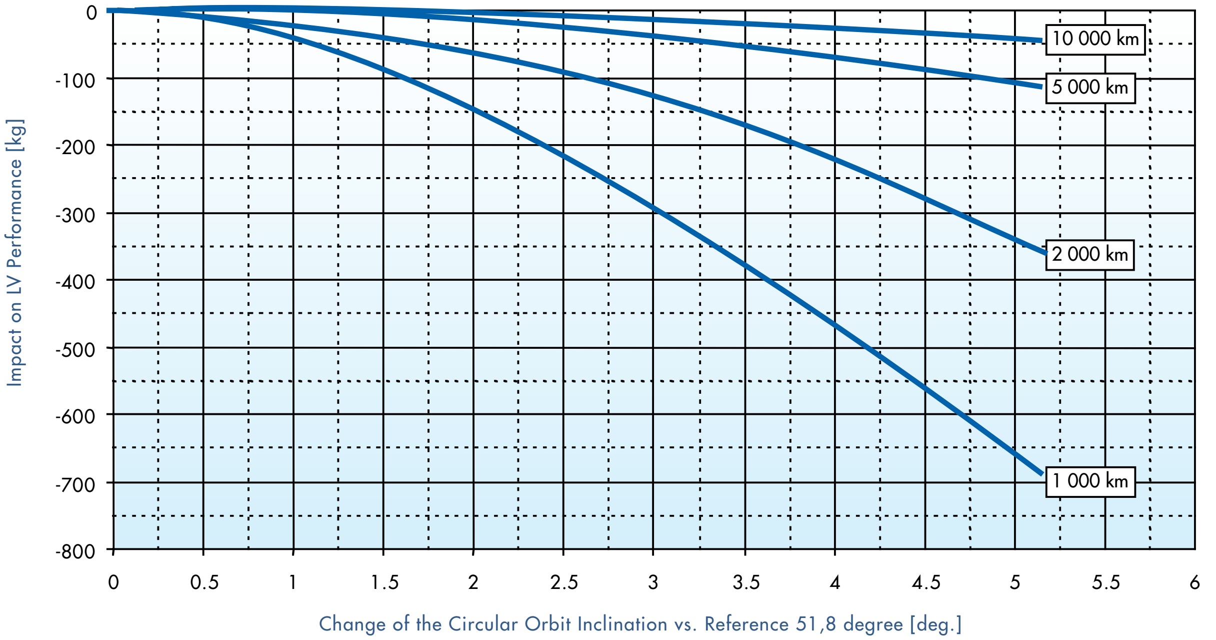


Figure 2-11: LV Performance for SSOs: H_{circ} = 400–1700 km

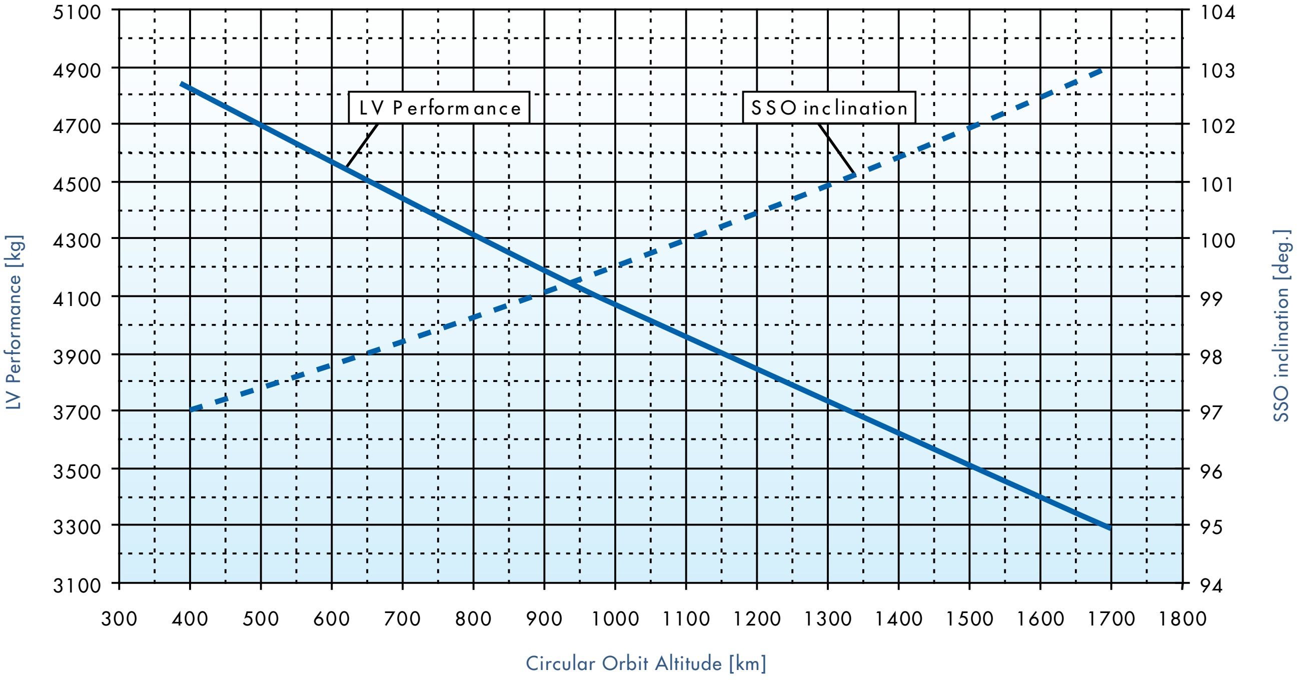
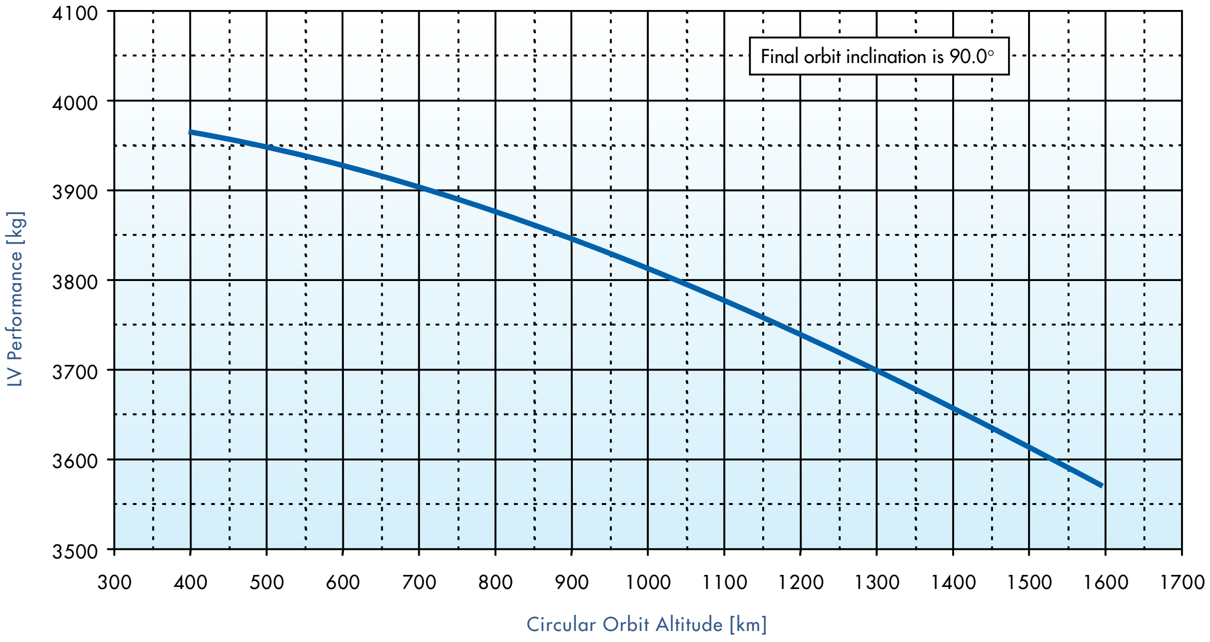


Figure 2-12: LV Performance for Polar Orbits: H_{circ} = 400 - 1600 km



2.4.2. ELLIPTICAL ORBITS

Depending on the perigee altitude and the inclination of the final orbit, two slightly different Fregat flight profiles can be chosen. These mission profiles can meet any argument-of-perigee requirements.

2.4.2.1. Three-Fregat-Burn Mission

If the inclination is close to that of the standard reference orbits, the inclination change can be carried out during the Soyuz/ST third-stage dogleg maneuver, and the desired apogee can be reached as a result of a three-Fregat burn, which would consist of the following:

- A first burn to transfer to a 200-km parking orbit followed by a coast phase up to a point corresponding to the required argument of perigee of the target elliptical orbit;
- A second Fregat burn to transfer to an intermediate elliptical orbit with an altitude of apogee equal to the target value; and
- A third Fregat burn to raise the perigee from 200 km to the required value.

If there is a need to decrease injection time, this can be carried out by changing those transfer-orbit parameters that affect LV performance. In this case, the second Fregat burn will provide a given altitude of perigee of the target orbit, and the third burn will result in the raising of the apogee to the required value.

2.4.2.2. Two-Fregat-Burn Mission

If the required altitude of perigee is in the range of 180–260 km, the mission profile is similar to the previous case but includes only two Fregat burns, and the altitude of the circular parking orbit corresponds to the required altitude of perigee.

For missions using the Soyuz or those with a final orbit inclination which is far enough from the standard reference orbits that the Soyuz/ST can not change the inclination during third stage flight, the mission profile will likely be a three-burn profile similar to that for low circular orbits. In this case, the potential to meet any argument-of-perigee requirements should be analyzed by Starsem to determine the effects of mission profile and Fregat propellant limits on the vehicle's ability to carry out the mission. Performance will depend on the type and magnitude of inclination change maneuvers as well as on specific orbit requirements. In such cases, the user should contact Starsem for a performance estimate and for selection of the optimal mission profile.

2.4.2.3. Low Elliptical Orbits (400 km $\leq H_{apogee} \leq$ 1500 km)

Performance data for altitudes of apogee in the range of 400–1500 km for the standard launch inclinations and a perigee altitude of 200 km are presented in *Figure 2-13*. This information is based on a two-Fregat-burn mission profile.

2.4.2.4. Medium Elliptical Orbits (1500 km ≤ H_{apogee} ≤ 25,000 km)

Elliptical orbits are generally used for a variety of spacecraft missions and for intermediate transfer orbits. Performance data for altitudes of apogee in the range of 1500–25,000 km for the standard launch inclinations and a perigee altitude of 200 km are presented in *Figure 2-14*. This information is based on a two-Fregat-burn mission profile.

Figure 2-13: LV Performance for Low Elliptical Orbits: H_{apogee} = 400–1500 km

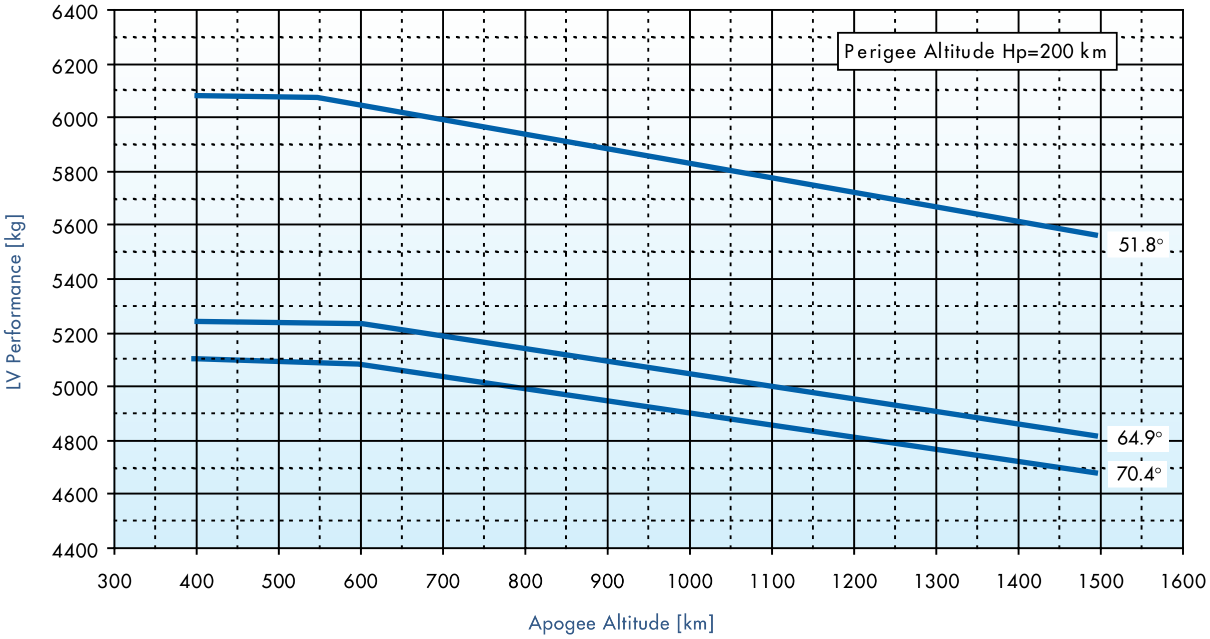
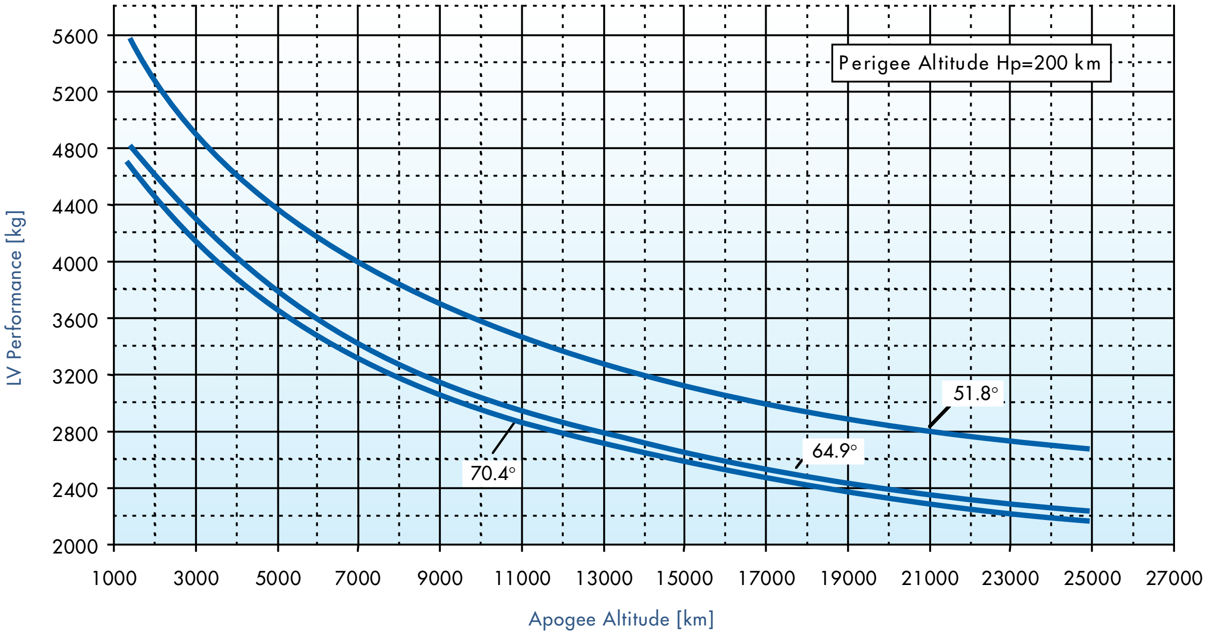


Figure 2-14: LV Performance for Medium Elliptical Orbits: H_{apogee} = 1500–25,000 km



2.4.2.5. Molniya-Type Orbits

Molniya-type orbits are highly elliptical orbits at an inclination of 63.4 degrees that are used for communications satellites and for missions that require long dwell times over specific areas. They are characterized by an argument of perigee that does not change with time ("frozen" orbits).

To reach the Molniya orbit, the Soyuz/ST is launched on an azimuth corresponding to a direct injection to a 64.9-degree parking orbit. A small inclination change to 63.4 degrees is carried out by means of a dogleg maneuver during Soyuz/ST third-stage flight. The Fregat carries out a three-burn mission profile to reach the required values of apogee and perigee for the specific target orbit.

Depending on the required mission duration, one of two slightly different Fregat flight profiles can be selected.

2.4.2.5.1. Long Mission - Spacecraft Separation at Apogee of Required Orbit

This mission profile is the same as that presented for low elliptical orbits. The spacecraft will be separated immediately after the third Fregat burn at the apogee of the required elliptical orbit. This mission profile is characterized by maximal LV performance but by longer mission duration.

2.4.2.5.2. Short Mission - Spacecraft Separation at Perigee of Required Orbit

This mission profile is similar to the typical case, but with differences in second and third Fregat burns. Specifically, it involves the following:

- A second Fregat burn to transfer to an intermediate elliptical orbit with an altitude of apogee equal to the altitude of perigee of the required final orbit (this burn will be realized at a point that is opposite to the required argument of perigee of the target elliptical orbit); and
- A third Fregat burn to reach apogees from 200 km up to the required value.

The spacecraft will immediately be separated after the third Fregat burn at the perigee of the required elliptical orbit. This mission profile is characterized by shorter mission duration but by decreased LV performance.

Performance data for Molniya orbits with an orbital period of 12 and 24 hours are presented in *Figure 2-15* and *Figure 2-16*. These data are presented as a function of perigee altitude. Apogee altitude can be calculated as:

- 12 hours orbit: H_{apogee} [km] = 40,464 – $H_{perigee}$ [km]
- 24 hours orbit: H_{apogee} [km] = 71,726 – $H_{perigee}$ [km]

2.4.2.6. High Elliptical Orbits (25,000 km ≤H_{apogee} ≤400,000 km)

The launch vehicle can inject a spacecraft to high elliptical orbits with an apogee altitude up to 400,000 km. Performance data for these orbits for the standard launch inclinations and a perigee altitude of 200 km are presented in *Figure 2-17*. This information is based on a two-Fregat-burn mission profile with an intermediate circular parking orbit.

For cases involving a higher perigee altitude and/or an inclination that varies significantly from the standard inclinations, Starsem should conduct an analysis to determine the vehicle's ability to carry out the mission.

Figure 2-15: LV Performance for a 12-Hour Molniya-Type Orbit: $H_{perigee}$ = 200–2600 km

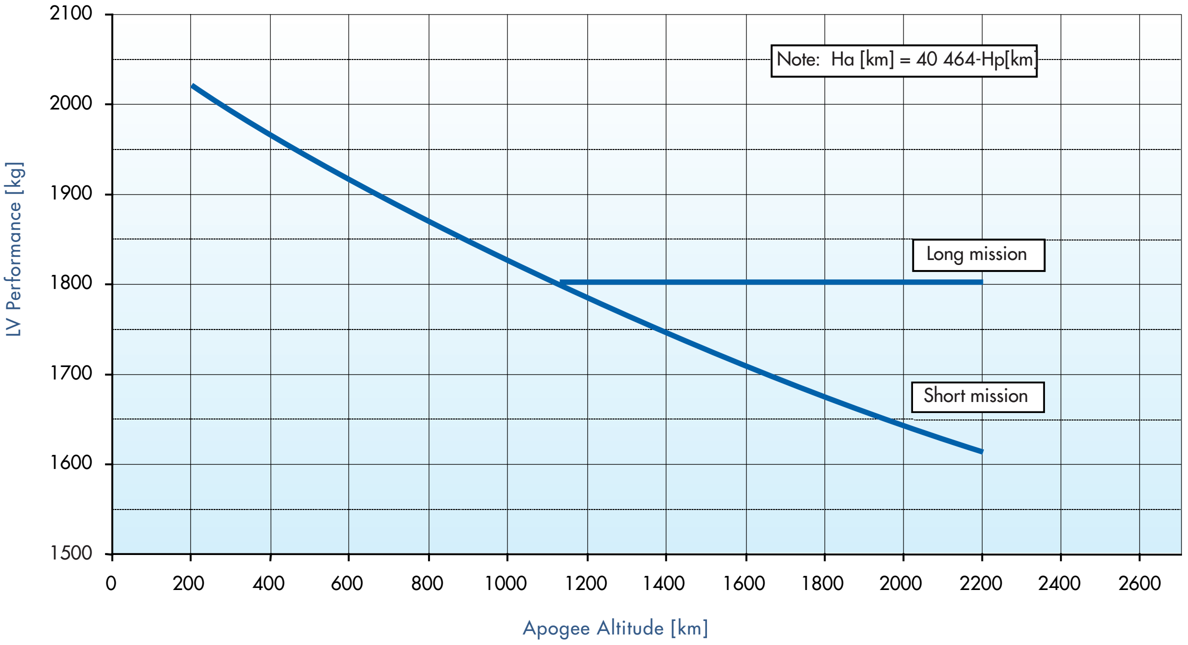


Figure 2-16: LV Performance for a 24-Hour Molniya-Type Orbit: $H_{perigee}$= 1000–20,000 km

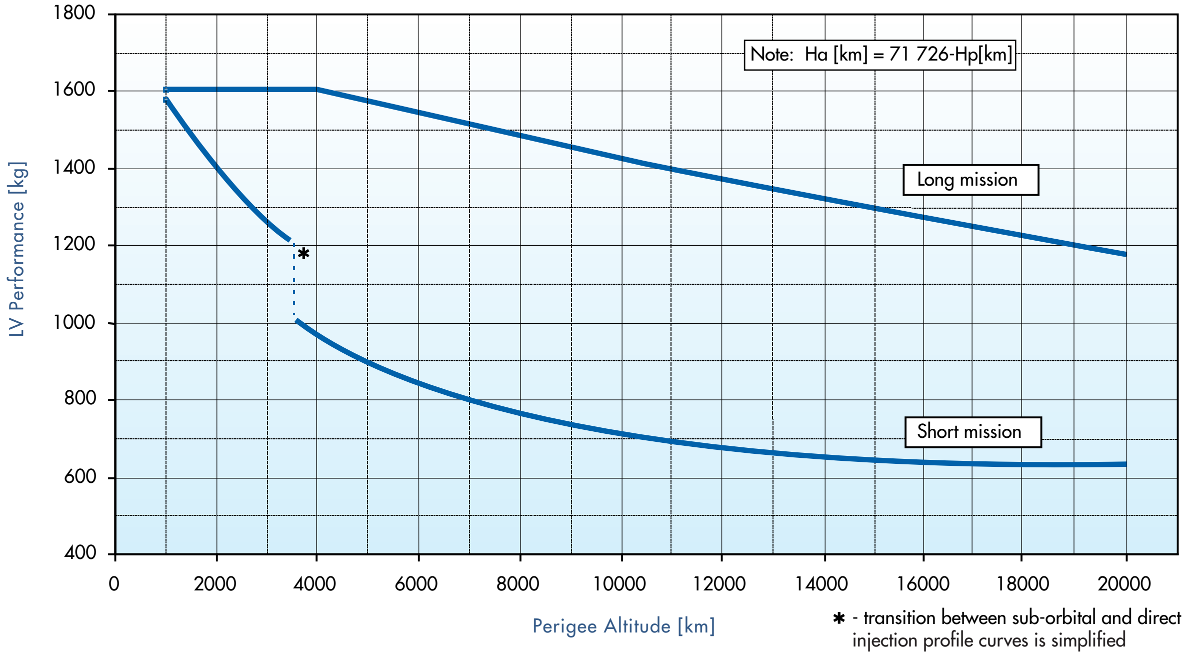
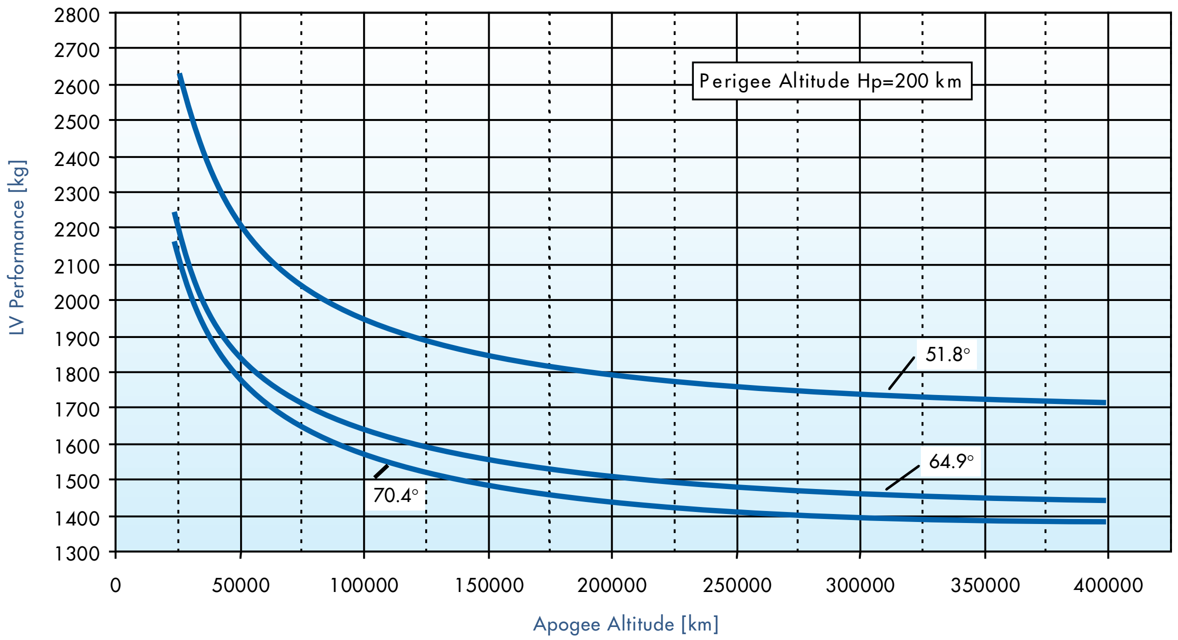


Figure 2-17: LV Performance for High Elliptical Orbit: H_{apogee} = 25,000–400,000 km



2.4.3. GEOSYNCHRONOUS TRANSFER AND GEOSTATIONARY ORBIT MISSIONS

2.4.3.1. Geosynchronous Transfer Orbit

The launch vehicle is capable of delivering a satellite to a geosynchronous transfer orbit (GTO), from which the satellite separates from the Fregat upper stage, ignites its own engine, and goes to its final destination in geosynchronous equatorial orbit (GEO).

The satellite is delivered to a GTO with a 35,786-km apogee altitude with variable orbit perigee and inclination, optimized for the delta-velocity (ΔV) contribution that will be made by the satellite to reach GEO in one high-thrust burn. This concept leads to the idea of "equivalent GTO." For example, a launch from Kourou would typically use a GTO of 200 km x 35,786 km at 7.0 degrees. Following satellite separation, the satellite would use its own on-board propulsion to deliver approximately 1500 m/sec of velocity change to the spacecraft, raising the orbit's perigee and lowering its inclination until GEO is reached. With this in mind, the Soyuz "Kourou GTO equivalent" is an orbit with a higher inclination and perigee than the standard Kourou GTO, resulting in approximately the same ΔV requirements (1500 m/s) on the satellite's propulsion system in one burn to reach GEO.

A Soyuz reference GTOs is used to make both a Kourou- and Cape Canaveral–equivalent GTOs. These transfer orbits require 1500 and 1800 m/sec ΔV, respectively, for transfer to GEO. Performance on these reference GTO missions allows the Soyuz to be better understood in the context of other LVs launches from lower latitudes, and enables the satellite manufacturer and/or operator to baseline the same propulsion system for a satellite qualified for several LVs. This mission uses a suborbital ascent profile with three Fregat burns. The optimal launch azimuth for GTO missions corresponds to a parking-orbit inclination of 51.8 degrees. The orbital parameters for Soyuz GTO are outlined in *Table 2-2*.

For certain missions with satellites using reignitable propulsion to reach GEO, alternative injection strategies such as super GTO (altitude of apogee is higher than 36,000 km) may provide a more optimized total mission than presented above for Kourou and Cape-Canaveral equivalent GTO missions. In such situations, the user is invited to contact Starsem for more information.

Table 2-2: GTO Orbital Parameters

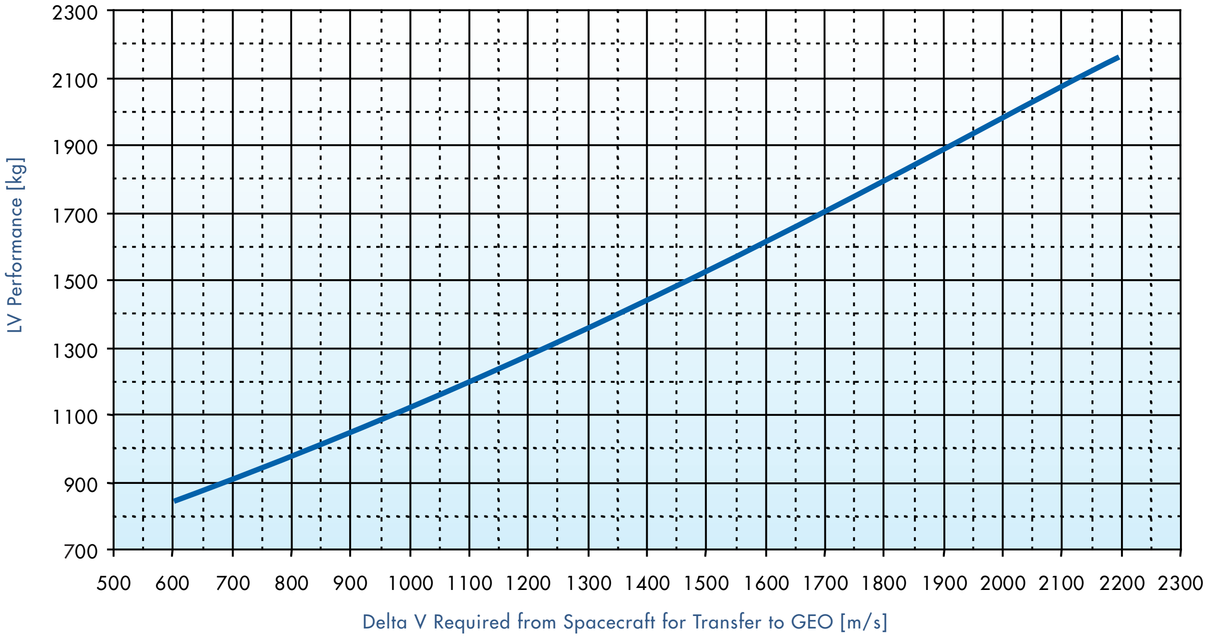
Parameters	1800 m/s for Transfer to GEO (Cape Canaveral Equivalent)	1500 m/s for Transfer to GEO (Kourou Equivalent)
Apogee altitude (km)	35,786	35,786
Perigee altitude (km)	2100	4200
Inclination (deg)	31.0	23.3
Argument of perigee (deg)	0.0 or 180.0	0.0 or 180.0

For payloads with other ΔV requirements for transfer to GEO, GTO parameters can be selected in accordance with the required ΔV. The launch vehicle performance data for a range of GTO as a function of ΔV are presented in *Table 2-3* and *Figure 2-18*.

Table 2-3: LV Performance for Geosynchronous Transfer Orbits

S/C ΔV	GTO Parameters		LV Performance
(m/sec)	Inclination (deg)	Altitude of Perigee (km)	(kg)
600	7.0	16,600	850
700	8.2	14,400	910
800	9.7	12,600	980
900	11.3	11,000	1040
1000	13.1	9600	1120
1100	15.0	8300	1190
1200	17.0	7200	1270
1300	19.0	6100	1350
1400	21.1	5100	1430
1500	23.3	4200	1500
1600	25.7	3400	1600
1800	31.0	2100	1800
2000	37.2	1300	1970
2200	43.6	600	2150

Figure 2-18: LV Performance for GTO: ΔV_{GEO} = 600–2200 m/s



2.4.3.2. Direct Geosynchronous Equatorial Orbit

With a mission profile similar to that of the GTO mission, a payload can be injected directly to GEO by means of a three-Fregat-burn mission profile. The injection scheme is the same as that presented above for the GTO mission, but with the final Fregat burn reaching the GEO parameters (orbit circularization and inclination change to 0.0 degree).

LV Performance for GEO is 450 kg.

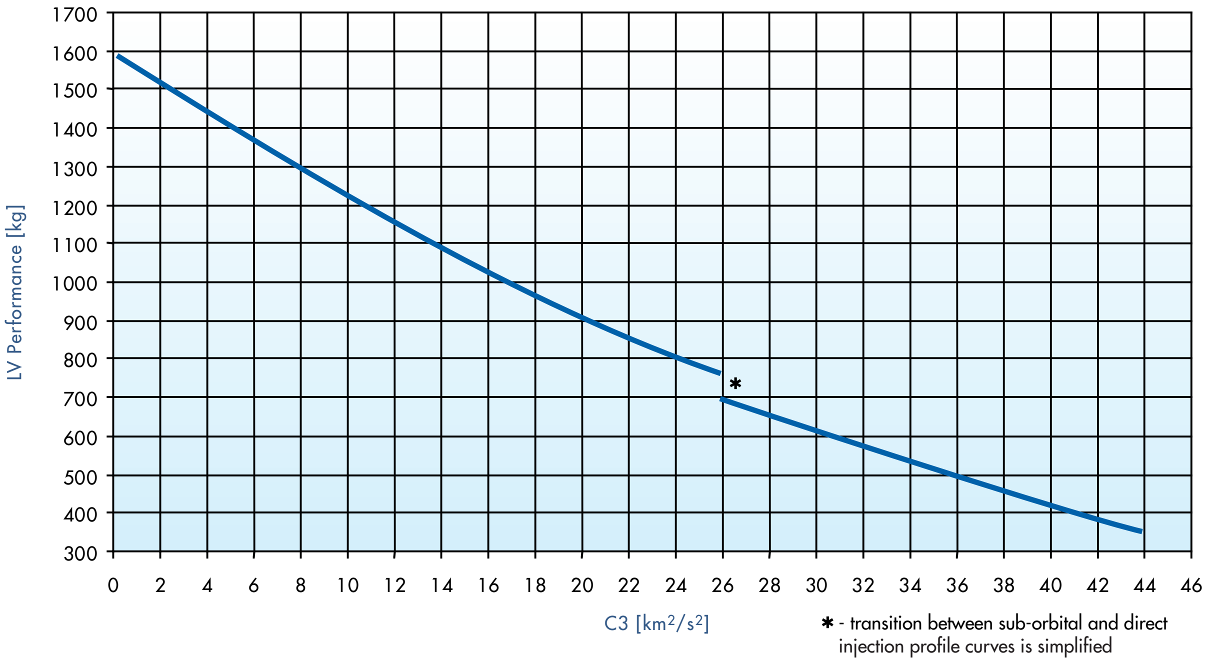
2.4.4. EARTH ESCAPE MISSIONS

Earth escape missions can be performed using a suborbital ascent profile with two Fregat burns. However, if Fregat fuel is used to circularize to the parking orbit after separation from the third stage, the propellant capacity of the Fregat becomes a constraint when trying to attain hyperbolic excess velocities in excess of 5.0 km/sec. High hyperbolic excess velocity requirements must then be traded off with the amount of fuel used in the first circularization burn of Fregat. Using the third stage to achieve higher cut-off velocities will leave more fuel in the Fregat upper stage, which will allow for the attainment of escape velocities up to 6.6 km/sec by using the direct ascent profile (see *Section 2.3*).

Taking this all into account, two approaches are taken for presenting launch vehicle performance data for earth escape missions in *Figure 2-19* as a function of the parameter C3 (square of velocity at infinity). A suborbital ascent profile is used for lower hyperbolic excess velocities (<5.0 km/s), and a direct ascent profile is used for higher ones (>5.0 km/s).

In any case, a feasibility analysis should be carried out by Starsem to determine the optimal mission profile for any spacecraft.

Figure 2-19: LV Performance for Escape Missions: [C3 = V_∞^2]



2.5. MISSION DURATION

Mission duration until separation of the spacecraft on the final orbit depends on the selected mission profile, required orbital parameters, injection accuracy, and visibility at separation conditions. Typically, critical mission events such as payload separation are carried out within the visibility zones of Russian ground stations. This allows for the receipt of near-real-time information on relevant events, orbital parameters, and separation conditions.

Actual mission duration will be determined in the course of detailed mission analysis, taking into account ground station availability and visibility. The typical durations of various missions (without the visibility constraint of spacecraft separation) are presented in *Table 2-4*.

There are several ways to reduce mission duration for a particular set of orbital requirements, including relaxation of the requirements on the final orbital parameters and separation conditions, use of mobile ground stations, and the like. If mission duration is a key issue for a spacecraft, these options will be analyzed during detailed mission analysis.

Table 2-4: Typical Mission Duration (up to Spacecraft Separation)

Mission			Altitude (km)	Mission Duration (hh:mm)
Circular orbit			SSO 800	01:00 – 01:30
			10,000	02:00 – 02:30
			20,000	03:10 – 03:40
Molniya-type orbit*	12 hrs	Short mission	1000 x 39,464	01:00 – 02:30
	24 hrs	Short mission	10,000 x 61,762	02:00 – 03:30
	24 hrs	Long mission	10,000 x 61,762	10:15 – 11:45
GTO and GEO				06:00 - 07:00
Earth escape mission**				00:15 – 01:45

* Mission duration depends on argument-of-perigee requirements.

** Mission duration depends on declination requirements.

2.6. INJECTION ACCURACY

The performance of the Fregat upper stage determines the accuracy of the four-stage Soyuz and Soyuz/ST configurations. Conservative accuracy data for such missions are presented in *Table 2-5*. Mission-specific injection accuracy will be calculated as part of mission analysis.

Table 2-5: Injection Accuracy for LV with Fregat Upper Stage

	Accuracy (3σ)		
Orbital Parameters	Circular Orbit Altitude (km)		GTO Altitude (km)
	1000	20,000	35,786 x 4,200
Semi-major axis (km)	± 10	± 60	± 70
Altitude of apogee (km)	—	—	± 120
Altitude of perigee (km)	—	—	± 20
Eccentricity	± 0.002	± 0.001	—
Inclination (ang min)	± 6	± 7	± 5
Period (sec)	± 12	± 120	± 170
Argument of perigee (ang min)	—	—	± 11
RAAN (ang min)	± 9	± 15	± 15

2.7. SEPARATION CONDITIONS

2.7.1. SPACECRAFT ORIENTATION AND TIPOFF RATES

Fregat can provide any attitude orientation required by the spacecraft and can perform separations in various modes:

- Three-axis stabilized mode, or
- Longitudinal spin-up mode.

The typical attitude accuracy values for both three-axis stabilized separation and spin separation are given assuming that the spacecraft balancing characteristics are in accordance with *Section 4.2.2* and that both adapter and spacecraft separation system (clamp band) are Starsem supplied. Spacecraft sloshing properties are not included.

If the adapter is provided by the User, Starsem should be contacted for launcher kinematic conditions before separation.

Three-Axis stabilized mode :

The attitude accuracy at 3-σ in a three-axis stabilized separation are:

- 3-axis depointing ≤ 1 deg
- Angular tipoff rates ≤ 0.3 deg/sec

Spin-up stabilized mode :

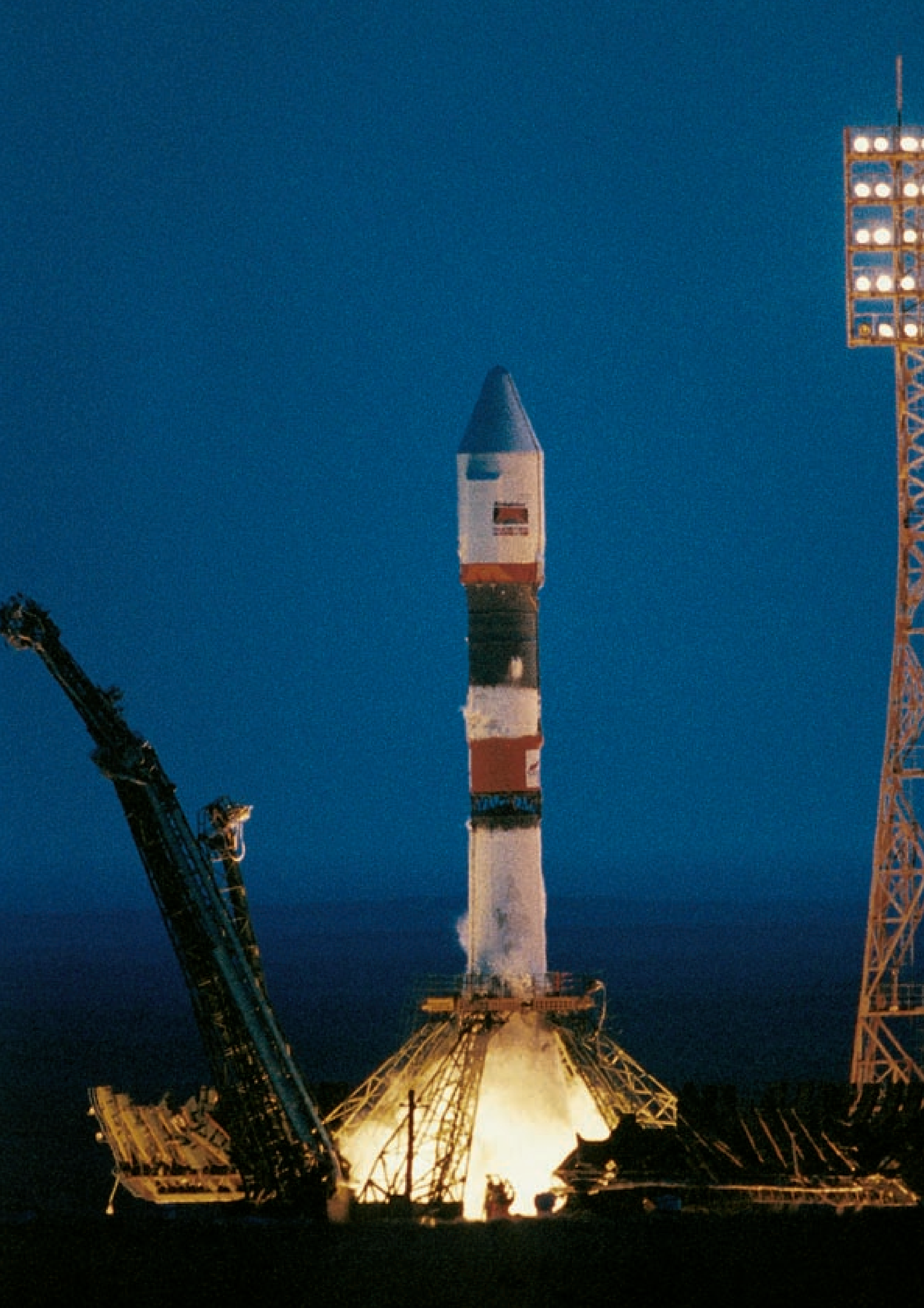
The Fregat ACS can provide a roll rate around the upper composite longitudinal axis up to 30 deg/sec, clockwise or counterclockwise. Higher spin rates are possible but shall be specifically analyzed.

The attitude accuracy at 3-σ in a 30 deg/sec spin separation with a spacecraft dynamic imbalance less than 1 degree are:

- Spin rate accuracy = ± 1 deg/s
- Transverse angular tipoff rates ≤ 0.3 deg/s
- Depointing of kinetic momentum vector ≤ 1 deg

The spacecraft attitude accuracy just after separation is highly dependent on the actual spacecraft mass properties (including uncertainties) and spin rate.

In both cases, a relative separation velocity between spacecraft and Fregat ranges from 0.3 to 1.0 m/sec.



CHAPTER

3

SPACECRAFT ENVIRONMENT

During preparation for launch (starting at MIK 112[1]) and then during flight, the spacecraft is exposed to a variety of mechanical, thermal, and electromagnetic environments. This chapter provides a description of the environment the spacecraft is intended to withstand.

All environmental data given in the following paragraphs should be considered limit loads; that is to say, the probability that they will not be exceeded is 99%.

3.1. MECHANICAL ENVIRONMENT

3.1.1. QUASI-STATIC LOADS

3.1.1.1. On Ground

Prior to the tilting of the nose block, the spacecraft is in a vertical position. During transportation and handling inside Starsem's Payload Processing and Launch Facilities, the spacecraft is subjected to QSLs that are applied at its center of gravity (CoG) and are defined as follows:

- Along the longitudinal direction: 1 g (static) ± 0.8 g (dynamic); and
- Along any lateral direction: ± 0.4 g (dynamic).

During the tilting of the nose block, mechanical loads applied to the spacecraft are negligible and in any case are not the sizing loads for the satellite's structure and equipment.

After being mated to the Fregat upper stage as well as during subsequent operations, the spacecraft is in a horizontal position. During transportation phases on the launch site, the spacecraft is subjected to QSLs that are again applied to its CoG and are defined in *Table 3-1*.

Table 3-1: Maximum QSL During Transfers

Load Case	QSL (g)					
	Lateral			Longitudinal		
	Static	Dynamic	Total	Static	Dynamic	Total
Transport	1.0	± 0.55	+1.55/+0.45	0.0	± 0.30	± 0.30

Note:

- The minus signs indicate compression along the longitudinal axis and the plus signs tension.
- Longitudinal and lateral QSL act simultaneously.
- Lateral loads along the axis (δ) are oriented to the Earth — that is, at 45 degrees from the LV axes, as presented in Figure 3-1.
- These QSL values are the maximum expected values for a spacecraft complying with the characteristic frequency requirements given in Chapter 4.

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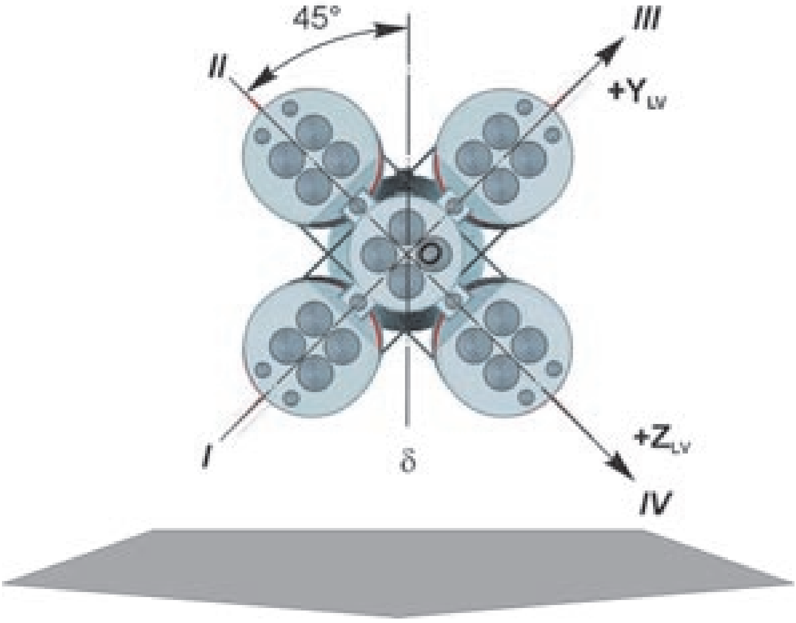
[1] The transportation of the spacecraft from Yubileiny Airport to MIK 112 is addressed in Chapter 6 (to be considered as input data for the container design).

Figure 3-1: Coordinate System for the Transportation Case



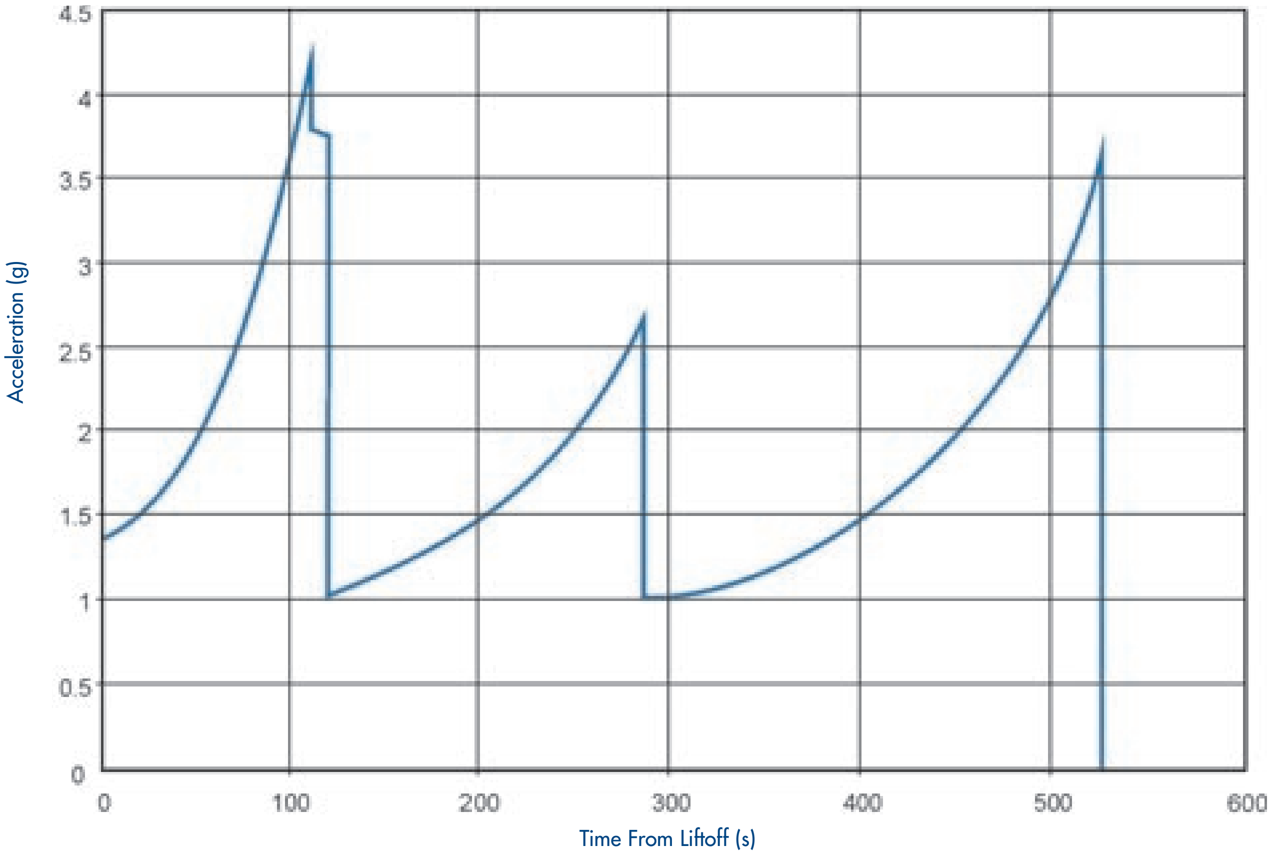
3.1.1.2. In Flight

During flight, the spacecraft is subject to static and dynamic loads. Such excitations may be of aerodynamic origin (e.g., wind, gusts, or buffeting at transonic velocity) or due to the propulsion systems (e.g., longitudinal acceleration, thrust buildup or tail-off transients, or structure-propulsion interaction).

Figure 3-2 shows a typical longitudinal static acceleration-time history for the LV during its ascent flight. The highest longitudinal acceleration occurs just before the first-stage cutoff and does not exceed 4.3 g.

The peak lateral static acceleration may be up to 0.4 g at maximum dynamic pressure and takes into account the effect of wind and gust encountered in this phase.

Figure 3-2: Typical Longitudinal Steady-State Static Acceleration (First through Third Stage Flight)



During liftoff and flight, low-frequency dynamics and steady-state accelerations combine to produce QSLs. QSLs are defined at the spacecraft's CoG and apply to its main structure sizing (see *Table 3-2*).

Table 3-2: Maximum QSL During Flight

Load Event	QSL (g) (+ = tension; – = compression)					
	Lateral			Longitudinal		
	Static	Dynamic	Total	Static	Dynamic	Total
1 Liftoff	±0.2	±1.6	±1.8	–1.0	±0.6	from –1.6 to –0.4
2 Flight with maximum dynamic pressure (Q_{max})	±0.4	±0.6	±1.0	–2.2	±0.4	from –2.6 to –1.8
3 First-stage flight with maximal acceleration	±0.1	±0.4	±0.5	–4.3	±0.7	from –5.0 to –3.6
4 Separation between first and second stages	±0.2	±0.8	±1.0	from –4.1 to –1.0	from 0.0 to ±0.3	from –4.1 to –0.7
5 Second-stage flight	±0.1	±0.7	±0.8	from –2.6 to –1.0	from ±0.3 to ±1.2	from –3.8 to –0.7
6 Separation between second and third stages	± 0.2	± 0.6	± 0.8	from –2.6 to –0.2	from 0.0 to ±1.5	from –2.6 to +1.3
7 Beginning of third-stage flight	± 0.2	± 0.5	± 0.7	–1.2	±1.5	from –2.7 to +0.3
8 First-stage engine cutoff	± 0.1	± 0.2	± 0.3	from –3.7 to 0.0	From 0.0 to ±1.5	from –3.7 to +1.5

Note:

- The minus signs indicate compression along the longitudinal axis and the plus signs tension.
- Longitudinal and lateral QSL act simultaneously.
- These QSL values are the maximum expected values for a spacecraft complying with the characteristic frequency requirements given in Chapter 4.

3.1.2. SINE-EQUIVALENT DYNAMICS

3.1.2.1. On Ground

During all transportation phases on the launch site — after the spacecraft stack has been mated to the Fregat — the sine-equivalent excitation at the spacecraft base does not exceed the levels given in *Table 3-3* and *Table 3-4*.

Table 3-3: Transfer from the UCIF to the MIK

Frequency Band (Hz)	Sine-Equivalent Amplitude (g)		
	X-Axis	Y-Axis	Z-Axis
1 – 2	—	—	0.02
2 – 5	—	—	0.03
5 – 10	0.1	0.06	0.01
10 – 20	0.04	0.07	0.05
20 – 30	—	0.03	0.01
30 – 60	0.03	0.03	0.04

Table 3-4: Transfer from the MIK to the Launch Pad

Frequency Band (Hz)	Sine-Equivalent Amplitude (g)		
	X Axis	Y Axis	Z Axis
1 – 2	—	0.06	0.05
2 – 5	—	0.1	0.05
5 – 10	0.3	0.1	0.05
10 – 20	—	0.18	0.1
20 – 30	—	0.05	0.1
30 – 60	—	—	—

The durations of these transfers are as follows:

- Up to 6 hours between the UCIF and MIK 40; and
- Up to 1 hour between MIK 40 and the launch pad.

In the event of an aborted launch, a return to the initial configuration, and relaunch, these durations shall be multiplied by a factor of 3.

3.1.2.2. In Flight

Several sinusoidal excitations derived from controlled POGO instabilities and continuous atmospheric turbulence may affect the launcher during its flight (primarily the atmospheric flight).

Transient phases such as:

- engine ignition and cutoff sequences,
- swiveling of vernier thrusters,
- firing of attitude control thrusters, and
- wind gradient and gust

may also excite the LV's structural modes.

The envelope sinusoidal (or sine-equivalent) vibrational levels at the spacecraft base do not exceed the values given in *Table 3-5* in the longitudinal direction or those given in *Table 3-6* in the lateral one.

Longitudinal and lateral vibrations apply simultaneously.

Table 3-5: Longitudinal Sine Excitation at Spacecraft Base

Frequency Band (Hz)	Sine Amplitude (g)
5 – 10	0.5
10 – 30	1.0
30 – 60	0.6
60 – 100	0.3

Table 3-6: Lateral Sine Excitation at Spacecraft Base

Frequency Band (Hz)	Sine Amplitude (g)
1 – 5	0.3
5 – 30	0.8
30 – 60	0.6
60 – 100	0.2

3.1.3. RANDOM VIBRATIONS

Random vibrations at the spacecraft base are generated by propulsion system operation and by the adjacent structure's vibro-acoustic response. Maximum excitation levels are obtained during the first-stage flight. Assuming that the acoustic environment is the driving factor, spacecraft compliance verification with respect to the random environment will consider only the acoustic excitation under the fairing.

Acceleration power spectral density (PSD) and root mean square (RMS) vibration levels (σ_{Σ}) are given in *Table 3-7* .

Table 3-7: Random Vibrations at Spacecraft Base

Frequency Band (Hz)	Spectral Density (10^{-3} g^2/Hz)
20 – 50	5
50 – 100	5 – 10
100 – 200	10 – 25
200 – 500	25
500 – 1000	25 – 10
1000 – 2000	10 – 5
Overall (g)	5.0

3.1.4. ACOUSTICS

3.1.4.1. On Ground

The noise level generated by the venting system does not exceed 95 dB.

3.1.4.2. In Flight

Acoustic pressure fluctuations under the fairing are generated by engine operation (plume radiation and impingement on the pad during liftoff) and by unsteady aerodynamic phenomena during atmospheric flight (i.e., shock waves and turbulence inside the boundary layer), which are transmitted through the upper composite structures.

The envelope spectrum of the noise induced inside the fairing during flight is shown in *Table 3-8*. It corresponds to a space-averaged level within the volume allocated to the spacecraft stack, as defined in *Chapter 5*.

It is assessed that the sound field under the fairing is diffuse.

Table 3-8: Acoustic Noise Spectrum Under the Fairing

Octave Center Frequency (Hz)	Flight Limit Level (dB) (reference: 0 dB = 2 x 10^{-5} Pa)	
	ST-Type Fairing	S-Type Fairing
31.5	125	122
63	132	131
125	134	132
250	136	135
500	134	134
1000	125	125
2000	121	121
RMS (20 – 2828 Hz)	141	140

This maximum environment is applied during a period of approximately 60 seconds: 15 seconds for liftoff and 45 seconds for atmospheric flight.

Outside of liftoff and maximum dynamic pressure phases, acoustic levels are substantially lower than the values indicated above.

3.1.5. SHOCK

The spacecraft is subject to shock primarily during stage separations, during fairing jettisoning, and during the operation of its own separation device.

The envelope acceleration shock response spectrum (SRS) at the spacecraft base (computed with a Q-factor of 10) is presented in *Table 3-9* and *Table 3-10*. These levels are exerted simultaneously in axial and radial directions.

Table 3-9: Shock Response Spectra at Stage Separations, Fairing Jettisoning, and Spacecraft Separation

Flight Event	Frequency (Hz)	
	100 – 1000	1000 – 5000
	SRS (Q = 10) (g)	
Fairing separation, upper-stage separation	15 – 350	350
Spacecraft separation (Ariane-standard clamp bands)	See Table 3-10	

Table 3-10: Shock Response Spectra for Ariane-Standard Clampband Separation Systems

Frequency (Hz)	Spacecraft Adapter Interface Diameter				
	Ø 937		Ø 1194	Ø 1666	Ø 1920
	Band Tension	Band Tension	Band Tension	Band Tension	Band Tension
	≤ 18.3 kN	≤ 27.7 kN (type B)	≤ 28.2 kN	≤ 32 kN	≤ 35 kN
	SRS (Q = 10) (g)				
100	20	20	20	20	20
600	421	416	1700	1125	1700
800	686	678	2190	2150	2300
1500	2000	1965	3858	2520	4447
2000	2000	3200	5000	2707	6012
3250	2000	3620	5000	3060	10,000
5550	2000	4147	5000	3500	10,000
8000	2000	4550	5000	3500	10,000
10,000	2000	4550	5000	3500	10,000

3.1.6. STATIC PRESSURE UNDER THE FAIRING

3.1.6.1. On Ground

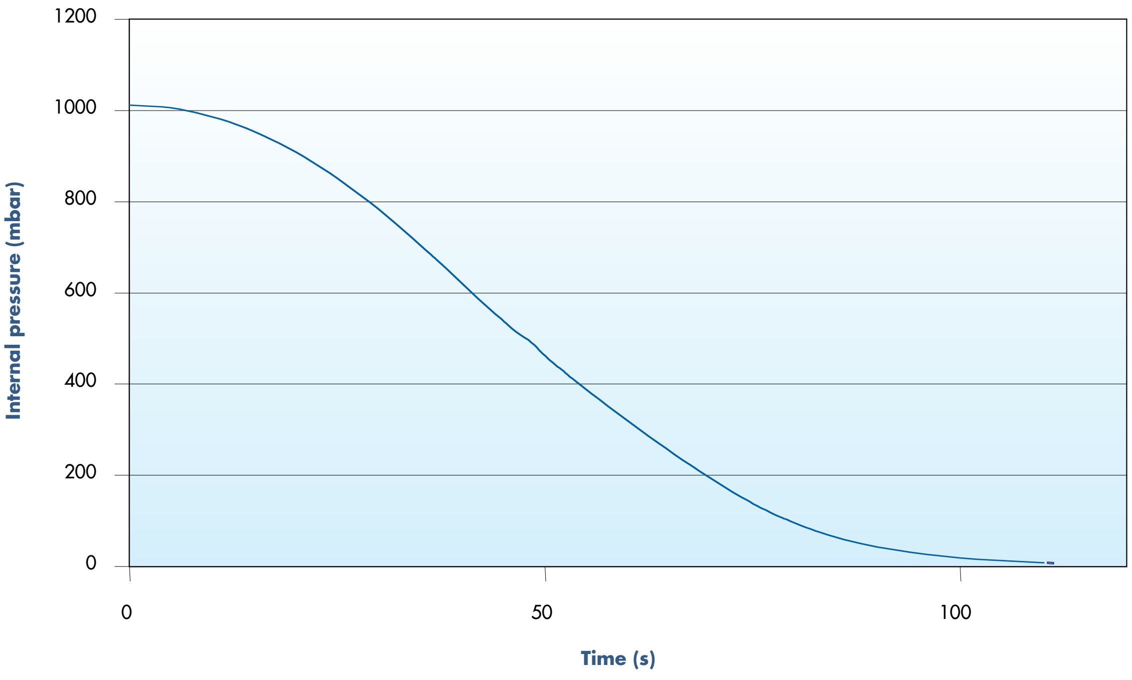
Before and after encapsulation, the air velocity around the spacecraft due to the ventilation system is lower than 5 m/sec.

3.1.6.2. In Flight

A typical static pressure evolution curve under the fairing is shown in *Figure 3-3* . The depressurization rate does not exceed 25 mbar/sec.

The differential pressure between the pressure under the fairing and external pressure, at the instant of the fairing jettisoning, is lower than 2 mbars.

Figure 3-3: Typical Pressure Variation Under the Fairing



3.2. THERMAL ENVIRONMENT

3.2.1. PRELAUNCH ENVIRONMENT

The environment that the spacecraft experiences both during its preparation and once it is encapsulated under the fairing is controlled in terms of temperature, relative humidity, cleanliness, and contamination (see *Chapter 6*).

3.2.1.1. Facility Environments

The thermal environment within Starsem's facilities is summarized in *Table 3-11*.

Table 3-11: Thermal Environment in Starsem's Facilities

Location	Temperature	Relative Humidity	Cleanliness
PPF cleanroom	Any specified between +17°C and +23°C Accuracy: ± 1°C	Any specified between 30% and 60% Accuracy: ± 10%	100,000
HPF cleanroom			
UCIF cleanroom			

3.2.1.2. Temperature Under the Fairing

The fairing cavity is vented both during transfer of the upper composite (regardless of whether it is integrated to the LV) and during the standby phase on the launch pad except during the erection of the LV on the pad. Air-conditioning characteristics are described in *Table 3-12* .

Table 3-12: Air Conditioning Under the Fairing

Phase		Temperature	Relative Humidity(not controlled)	Flow	Duration
Operations in MIK 112			No venting		4 h
Transfer from MIK 112 to MIK 40		10 °C ≤ T ≤ 25°C	5% ≤ r ≤ 60%	≤ 6000 m^3/h	6 h
Operations in MIK 40		10 °C ≤ T ≤ 25°C	5% ≤ r ≤ 60%	≤ 6000 m^3/h	3 days*
Transfer to the pad		10 °C ≤ T ≤ 25°C	5% ≤ r ≤ 60%	≤ 6000 m^3/h	1 h
LV erection			No venting		2 h
Standby	"VSOTR" venting	Any specified between 10°C and 25°C** Accuracy: ± 2°C	5% ≤ r ≤ 60%	≤ 6000 m^3/h	3 days
on the pad	"STVVD" venting		Dew point: –55°C	≤ 1600 m^3/h	45 min

Note:

* In the MIK 40, the air conditioning system is switched on only when the air temperature around the spacecraft is about to go out of the specified range.

** The air temperature shall be agreed on with Starsem on a case-by-case basis in order to take into account the Fregat's constraints. The air temperature also depends on the spacecraft's heat dissipation.

During LV erection, venting systems are disconnected. However, the air temperature in the fairing cavity does not vary significantly during this period by virtue of thermal inertia and the use (depending on the season) of a thermoelectric cover wrapped around the fairing. This cover maintains the surface temperature at about 20°C. The thermal behavior of the upper composite, including the ground phase with venting, is analyzed within the framework of the mission analysis.

In the event of an aborted launch, the "STVVD" venting system is operated again within a few minutes until the "VSOTR" venting system is reconnected (1 hour and 45 minutes at a maximum).

3.2.2. LAUNCH ENVIRONMENT

3.2.2.1. Thermal Conditions Under the Fairing

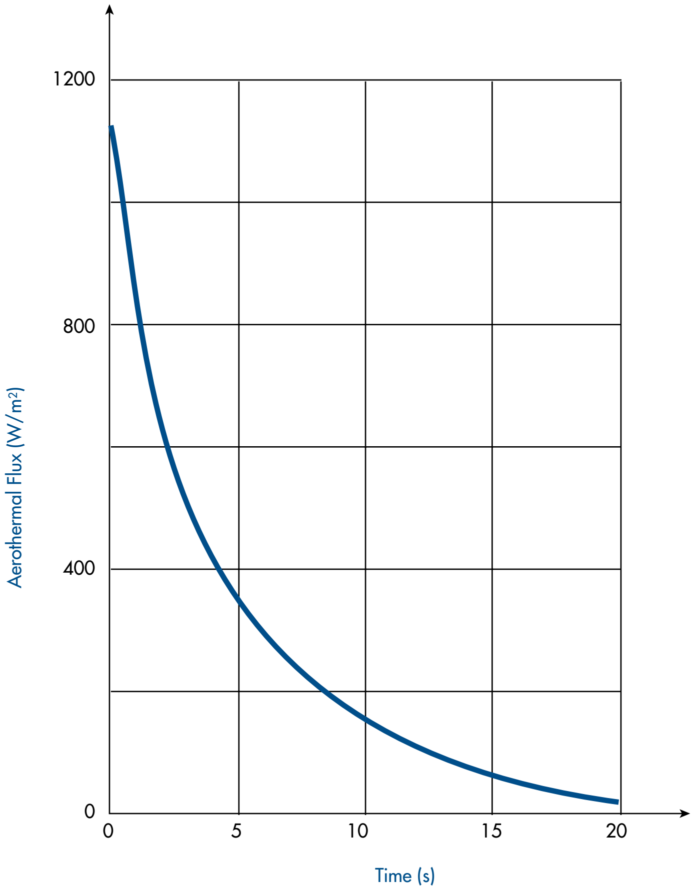
The thermal flux density radiated by the fairing does not exceed 800 W/m^2 at any point.

3.2.2.2. Thermal Conditions After Fairing Jettisoning

Nominally, fairing jettisoning occurs when the aerothermal flux drops below 1135 W/m^2 (this flux is determined as $\Phi = {}^1\!/_2\,\rho V^3$, corresponding to free molecular flow conditions on a flat plate normal to the free stream and based on the atmospheric model). The fairing jettisoning time can be adjusted to meet specific requirements or to improve LV performance.

Typically the aerothermal flux varies from 1135 W/m^2 to less than 200 W/m^2 within 20 seconds after the fairing jettisoning, as presented in *Figure 3-4* .

Figure 3-4: Aerothermal Flux Decay After Fairing Jettisoning



Following injection into the parking orbit, the thermal behavior of the spacecraft is influenced primarily by solar radiation, albedo, and Earth infrared radiation. During coast periods, the LV can be oriented to meet specific sun angle requirements. A slow roll ("barbecue mode") can also be provided to limit orbital heating and cooling.

3.2.2.3. Thermal Flux Reflected from Separated Stages

No thermal flux coming from separated stages need be considered.

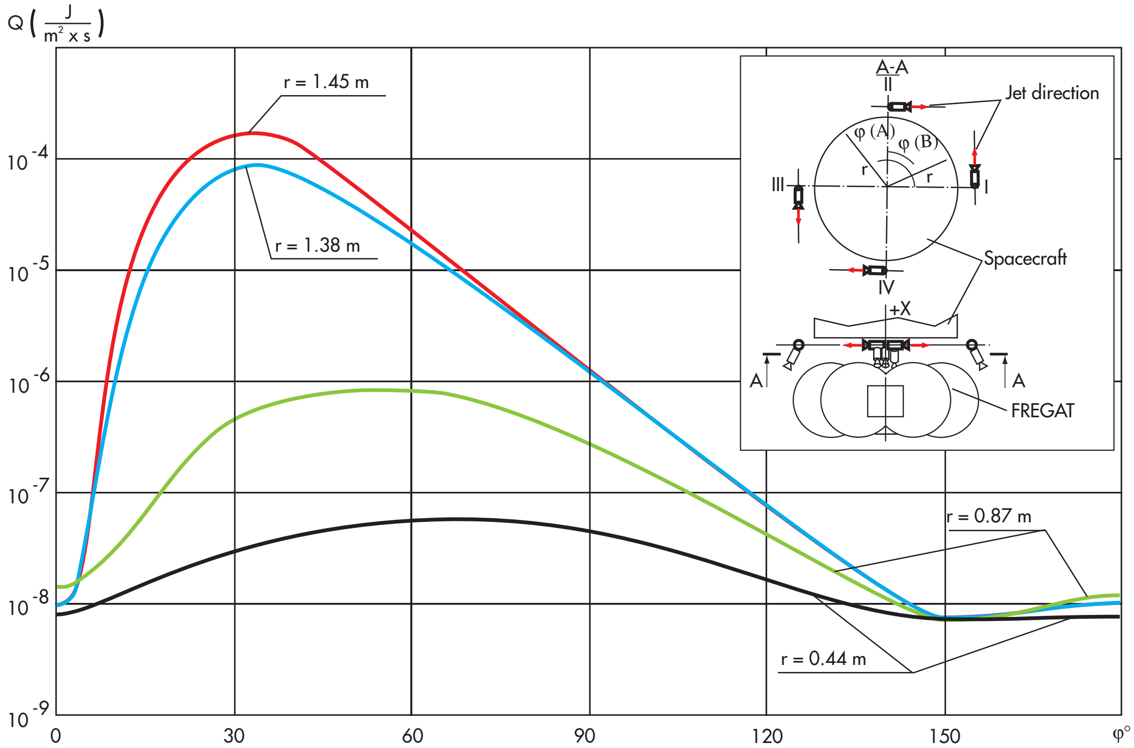
3.2.2.4. Thermal Flux Radiated from Fregat's Attitude Control System

Because the Fregat attitude control thrusters are located in the vicinity of the spacecraft, they may generate a heat flux that must be taken into account if sensitive equipment is located on the bottom surface of the spacecraft.

The heat flow distribution along the spacecraft bottom surface is given in *Figure 3-5*, where

r = the distance from the spacecraft x axis;
φ = the angle counted from the plane where the simultaneously operating thrusters are located;
φ(A) = angle φ corresponding to the operation of the thrusters located in the I-III plane; and
φ(B) = angle φ corresponding to the operation of the thrusters located in the II-IV plane.

Figure 3-5: Heat Flow Distribution Along the Spacecraft Bottom Surface



3.3. CLEANLINESS AND CONTAMINATION

3.3.1. CLEANLINESS

The following standard practices ensure that spacecraft cleanliness conditions are met:

- Precautions are taken and a clean environment is provided during the production, test, and delivery of all upper-composite components (upper stage, interstage section, fairing, and adapter) to prevent contamination and accumulation of dust. The LV materials are selected to not generate significant organic deposit during all ground phases of the launch preparation.
- All spacecraft operations are carried out in controlled Class 100,000 cleanrooms.
- Prior to the encapsulation of the spacecraft, the upper stages and fairing are cleaned, and their cleanliness is checked. All handling equipment is cleanroom compatible, and they are cleaned and inspected before their entry in the facilities.
- Once encapsulated, the upper composite will be hermetically closed (for the standby phase) or a Class 100,000 air-conditioning of the fairing will be provided (during transfer and standby on the launch pad).

3.3.2. CONTAMINATION

During all spacecraft ground activities from spacecraft delivery to launch site up to liftoff, the maximum organic nonvolatile deposit on the spacecraft surface will not exceed 2 $mg/m^2/week$. The organic contamination in facilities and under the fairing is controlled.

The LV materials are selected to limit spacecraft contamination during flight. The nonvolatile organic deposit on the spacecraft surface generated by the materials outgassing does not exceed 2 mg/m^2.

The LV systems are designed to preclude in-flight contamination of the spacecraft. The LVs pyrotechnic devices used by the LV for fairing jettison and spacecraft separation have sealed gas chambers and do not release contamination to the outside environment.

The nonvolatile organic deposit on the spacecraft surface generated by the Fregat's attitude control thruster plume does not exceed 2 mg/m^2 for 90 minutes mission duration with spin maneuver.

The nonvolatile organic contamination generated during ground operations and flight is cumulative.

3.4. ELECTROMAGNETIC ENVIRONMENT

3.4.1 RF MEANS OF LV LOWER THREE STAGES

The basic RF characteristics of the LV lower three stages of the Soyuz/ST and Soyuz transmission and reception equipment are given in *Table 3-13* :

Table 3-13: RF Characteristics of Third-Stage Soyuz Transmitters and Receivers

		Frequency (MHz)	Power (W)	Power (dBW)	Antenna (Number)
SOYUZ /ST	Transmitter:				
	Standard TM	638	10	—	2
	"RTSTs" System	627*	10	—	1
	Additional TM	247.3 ± 2.56	13	—	1
	"SKUT" System**	1002.5 ± 2.56	13	—	2
	Receiver:				
	Tracking "NAP" System	1595 ± 25	—	- 164	2
	Satellite Navigation System "SSN"	1595 ± 20	—	- 165	2
SOYUZ	Transmitter:				
	II Stage TM System	192 ± 0.576	120	—	1
	III Stage TM System	248 ± 0.744	120	—	2
	Additional TM	203.3 ± 0.1	10	—	1
	"SKUT" System**	1002 ± 1.75	10	—	1

Note:

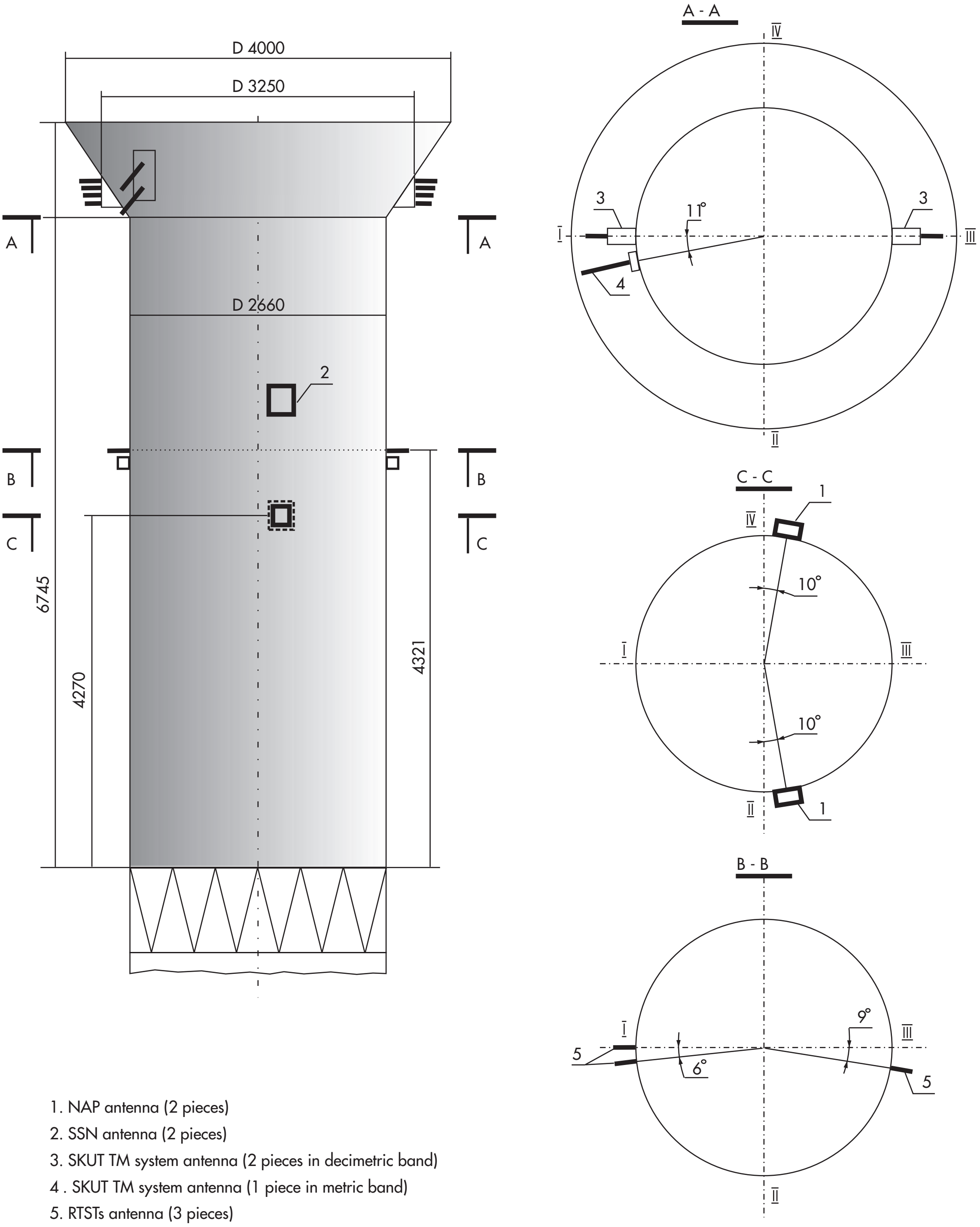
* It is characterized by a 3-second transmission delay in comparison with the first channel.

** The optional telemetry system will be installed as needed for a specified measurement plan.

For the Soyuz/ST, the tracking information of NAP system is relayed to the ground stations using the telemetry system.
The tracking of the Soyuz is carried out using ground radar stations.

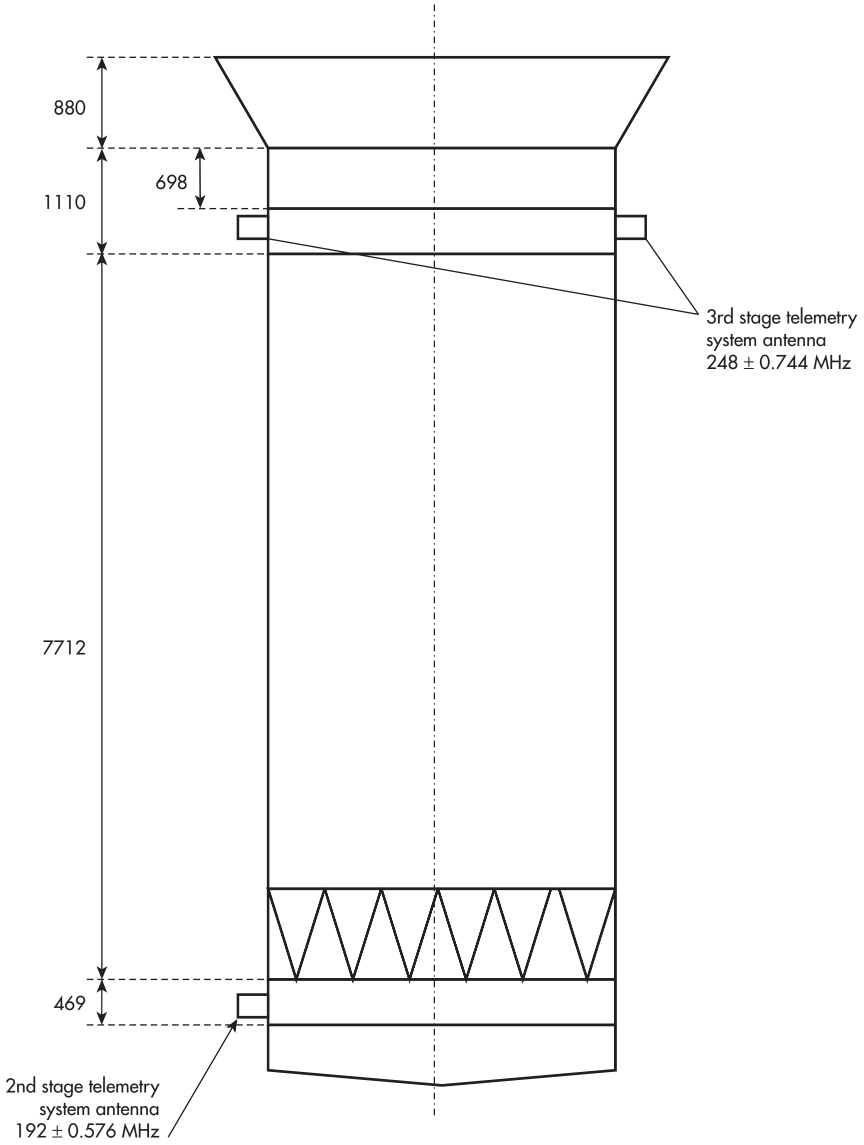
The locations of the antennas are shown in Figure 3-6 for the Soyuz/ST and in Figure 3-7 for the Soyuz.

Figure 3-6: Third-Stage Soyuz/ST – Location of Antennas



1. NAP antenna (2 pieces)
2. SSN antenna (2 pieces)
3. SKUT TM system antenna (2 pieces in decimetric band)
4 . SKUT TM system antenna (1 piece in metric band)
5. RTSTs antenna (3 pieces)

Figure 3-7: Third-Stage Soyuz – Location of Antennas



3.4.2 FREGAT RF MEANS

The basic RF characteristics of the Fregat transmission and reception equipment are given in *Table 3-14*.

Table 3-14: RF Characteristics of the Fregat Transmitters and Receivers

Equipment	Frequency (MHz)	Power (W)	Power (dBW)	Antenna (Number)
Transmitter:				
Tracking RDM	2805 ± 11	0.075 / 100*****	—	1
Tracking PPU	3410 ± 0.125	3	—	2
Telemetry TMC-M4*	643 ± 0.31	7	—	1
		14	—	2
Telemetry TMC-M6**	633 ± 0.565	7	—	1
Receiver:				
Tracking RDM***	2725 ± 14	—	- 126	1
Tracking PPU****	5754.9 ± 0.3	—	- 146	2
Satellite Navigation System "SSN"	1600 ± 0.001	—	- 167	1

Note:

* The TMC-M4 system comprises one transmitter and three antennas:

- One antenna, equipped with a reflector and located on the interstage section below the Fregat, operates as long as the Fregat is not separated from the third stage; and
- Two antennas, located on the top of the Fregat, operate after Fregat separation.

** The TMC-M6 system, which comprises one transmitter and one antenna equipped with a reflector, operates up to Fregat separation. The equipment within this subsystem is located on the interstage section below the Fregat

*** The RDM system is switched "on" 20 minutes before the launch and is functional for a range up to 8000 km. It comprises one transmitter, one receiver, and two antennas. Each antenna ensures both transmission and reception.

**** The PPU system is designed for a range between 1000 and 45,000 km, and is switched "on" during flight when the Fregat reaches an altitude higher than 1000 km. It comprises one transmitter and one receiver, each associated at one antenna.

***** Average power 0.075 W; for a 0.7-μs impulse: 100 W

The interstage section and the Fregat antenna locations are shown in *Figure 3-8* and *Figure 3-9*.

Figure 3-8: Interstage Section – Antenna Locations

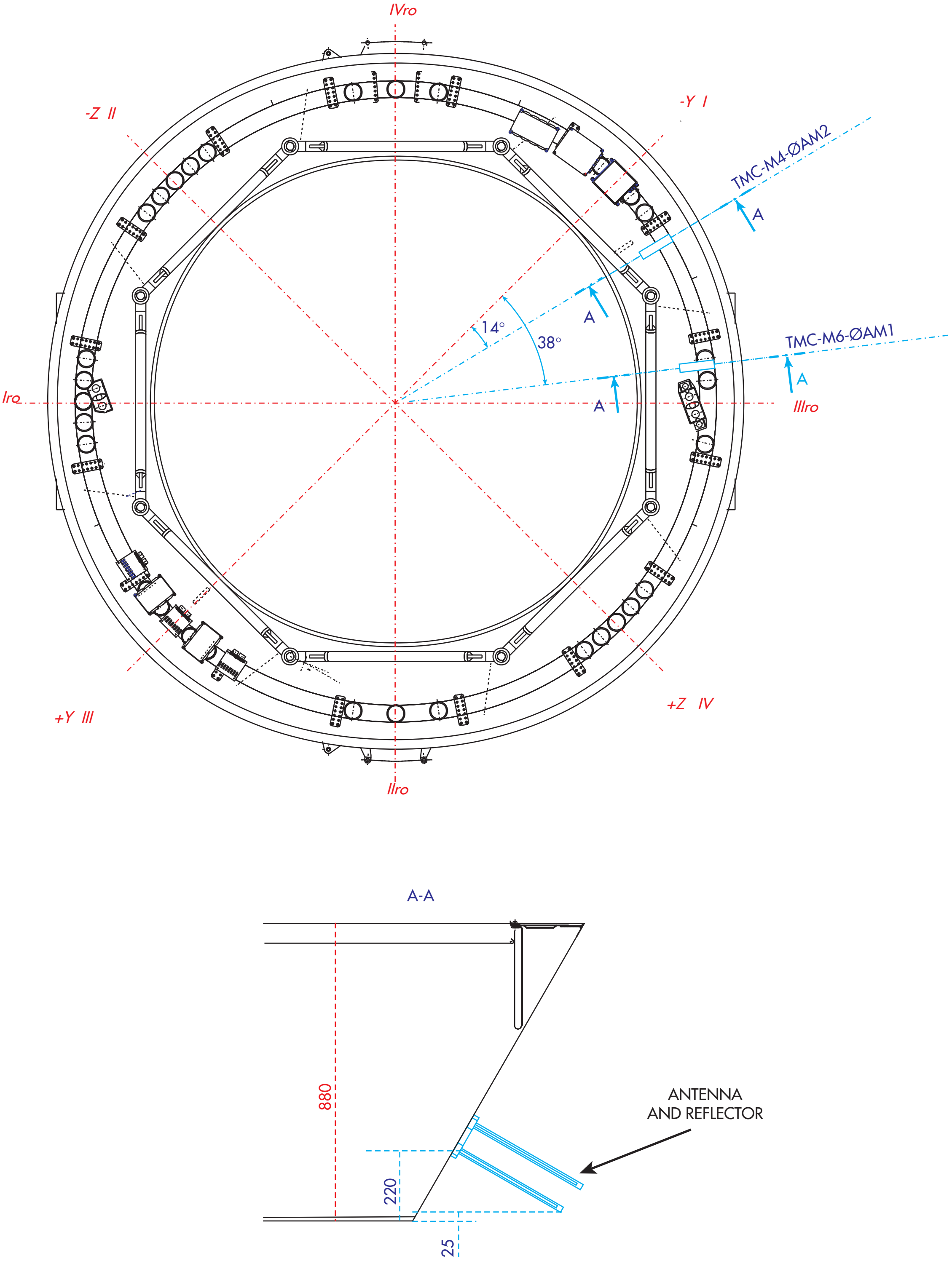


Figure 3-9: Fregat – Antenna Locations

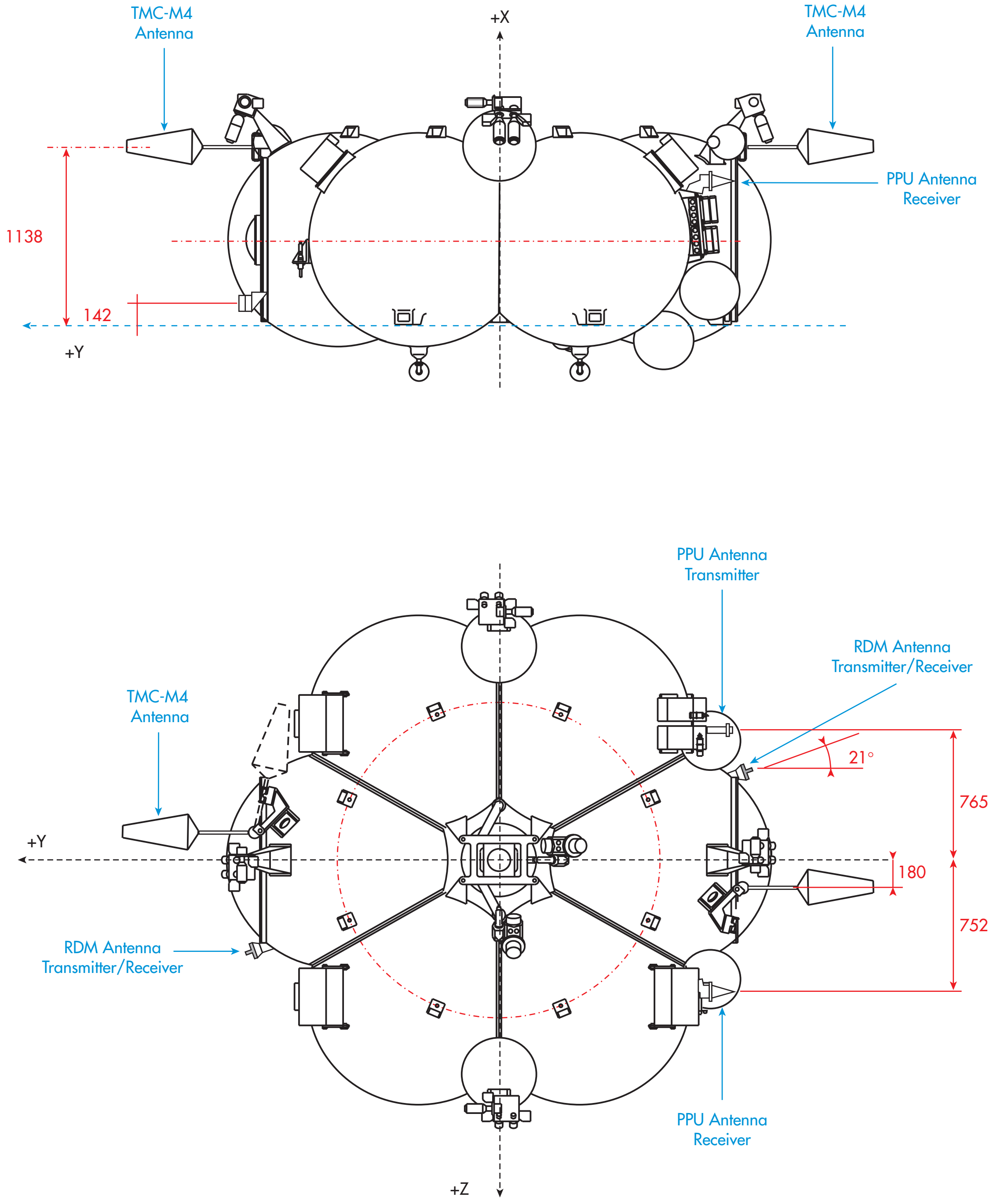
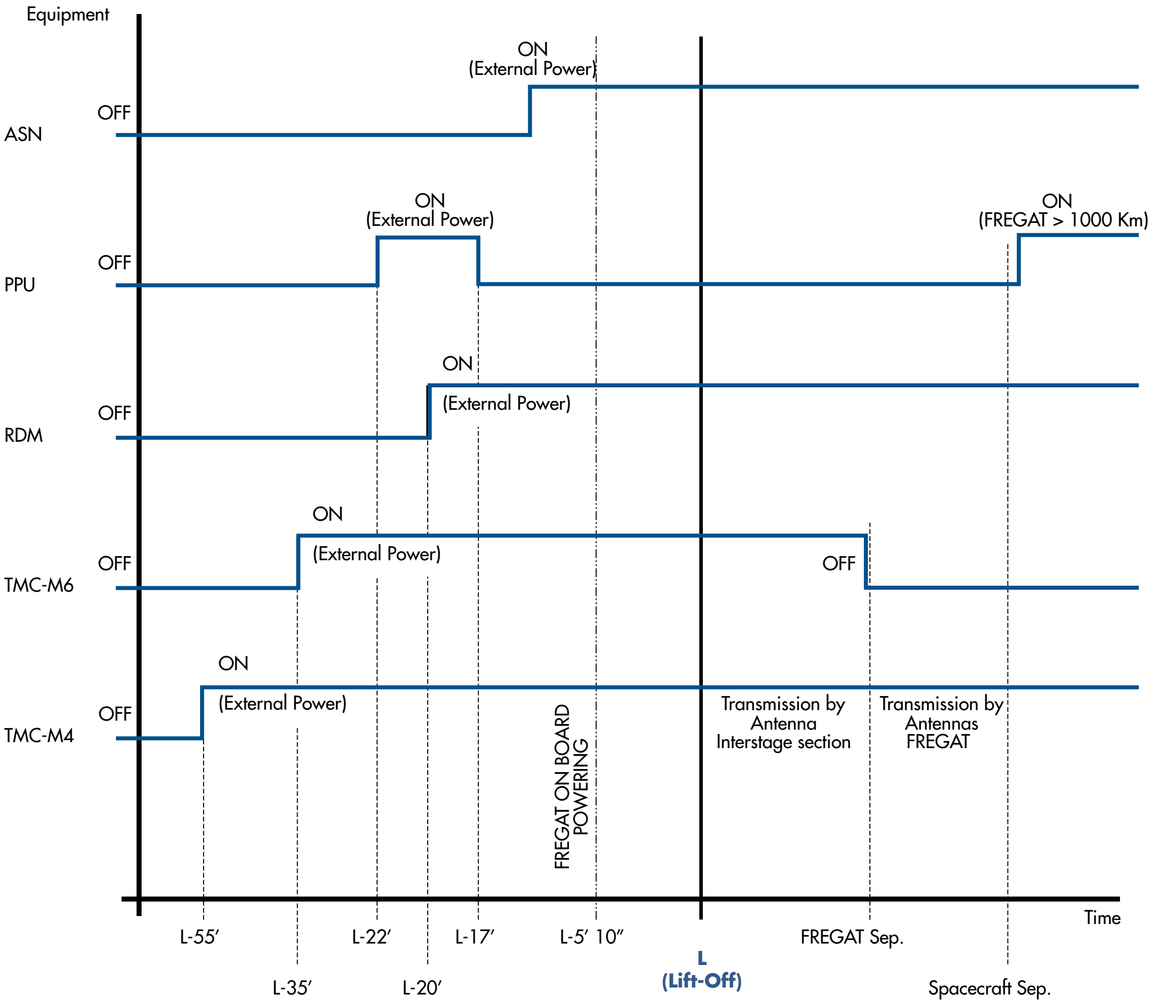


Figure 3-10 shows a typical Fregat RF equipment power "on-off" sequence during countdown and flight. The Fregat tracking and TM transmitters are switched "off" during no- visibility zones from the ground stations.

Figure 3-10: Fregat RF Equipment Power "On-Off" Sequence



3.4.3 LV AND LAUNCH BASE RADIATED EMISSIONS

This chapter describes the RF emission spectra for the Soyuz/ST and the Soyuz.

3.4.1.1. RF Emission Spectra for Soyuz/ST

The LV and ground facility RF emission spectra are presented in *Figure 3-11* and in *Table 3-15*. The spacecraft susceptibility shall comply with these levels.

Figure 3-11: LV and Launch Base Emission Spectra (Soyuz/ST Configuration)

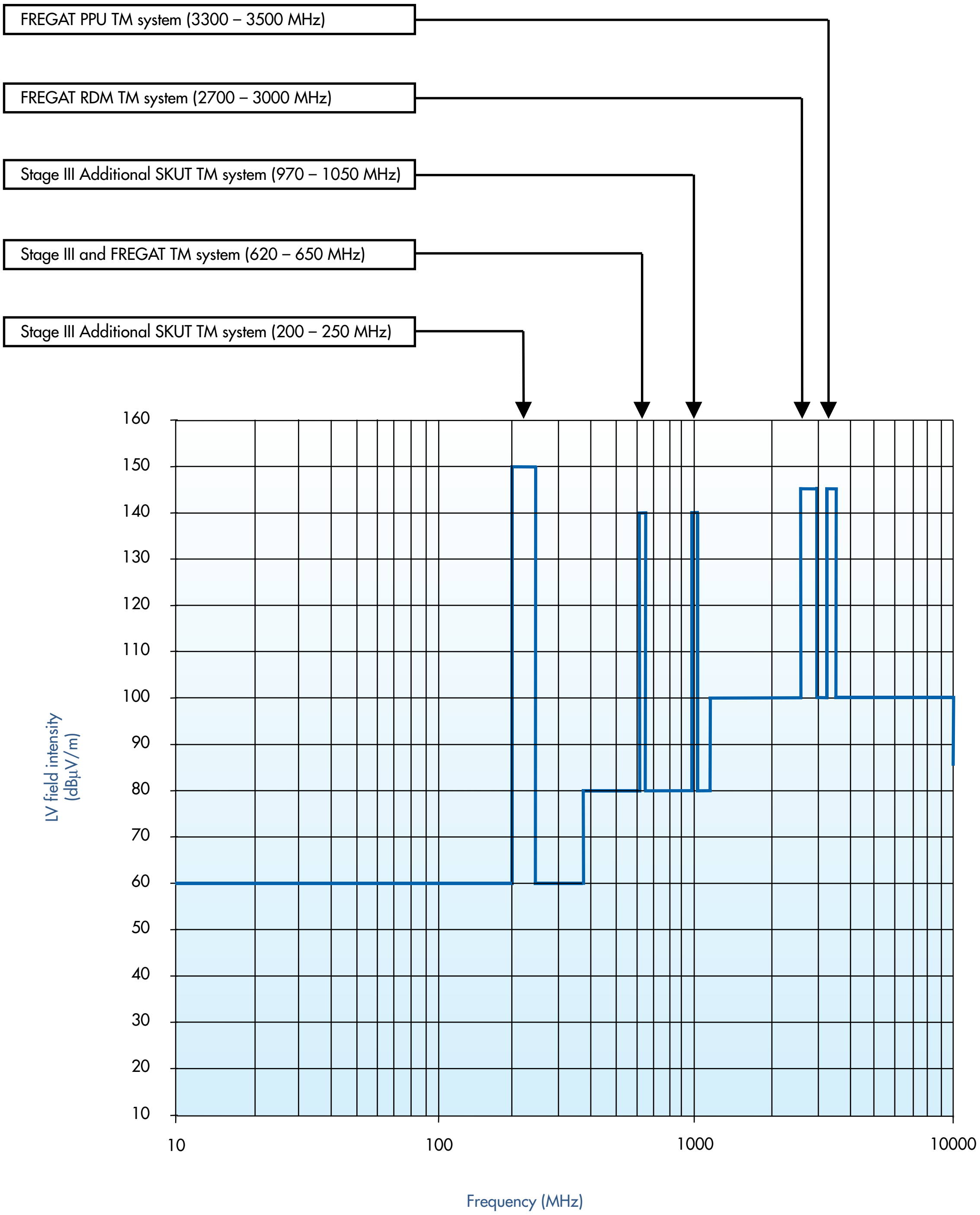


Table 3-15: LV and Launch Base Emission Spectra (Soyuz/ST Configuration)

Frequency Band (MHz)	LV Field Intensity (dBµV/m)
0.014 – 200	60
200 – 250	150
250 – 380	60
380 – 620	80
620 – 650	140
650 – 970	80
970 – 1050	140
1050 – 1250	80
1250 – 2700	100
2700 – 3000	145
3000 – 3300	100
3300 – 3500	145
3500 – 10,000	100
> 10,000	85

These levels are measured at the Fregat–adapter interface.

The range electromagnetic environment of the Baikonur Cosmodrome is monitored and checked during flight preparation.

3.4.1.2. RF Emission Spectra for Soyuz

The LV and ground facility RF emission spectra are presented in *Figure 3-12* and in *Table 3-16*. The spacecraft susceptibility shall comply with these levels.

Figure 3-12: LV and Launch Base Emission Spectra (Soyuz Configuration)

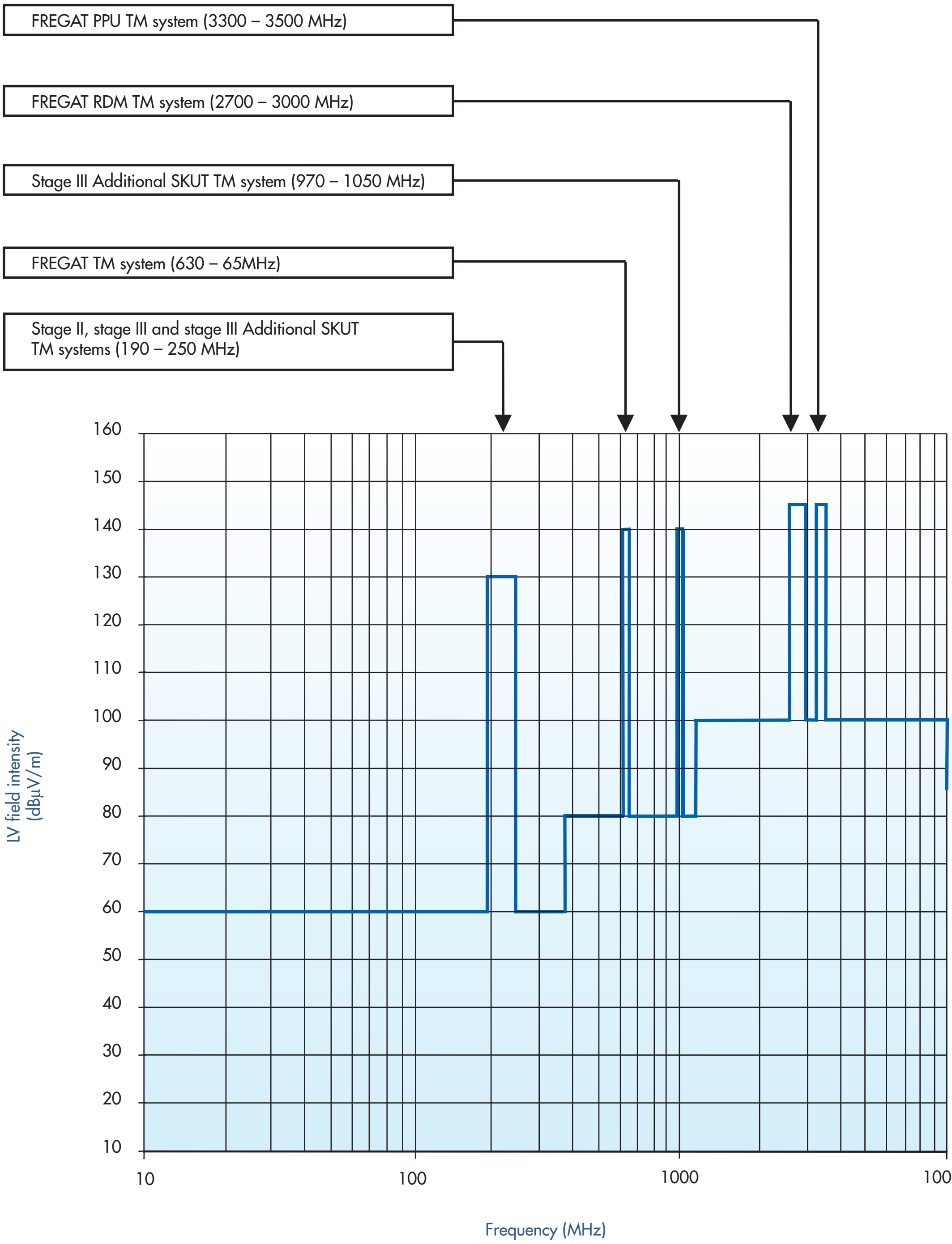


Table 3-16: LV and Launch Base Emission Spectra (Soyuz Configuration)

Frequency Band (MHz)	LV Field Intensity (dBμV/m)
0.014 – 190	60
190 – 250	130
250 – 380	60
380 – 630	80
630 – 650	140
650 – 970	80
970 – 1050	140
1050 – 1250	80
1250 – 2700	100
2700 – 3000	145
3000 – 3300	100
3300 – 3500	145
3500 – 10,000	100
> 10,000	85

These levels are measured at the Fregat–adapter interface.

The range electromagnetic environment of the Baikonur Cosmodrome is monitored and checked during flight preparation.

3.4.4 LV RADIATED SUSCEPTIBILITY LIMITS

LV susceptibility is given in *Figure 3-13*. In particular, the spacecraft should avoid significant radiation in the frequency bandwidths of the LV receivers, given in *Table 3-17*.

Figure 3-13: LV Radiated Susceptibility Limit

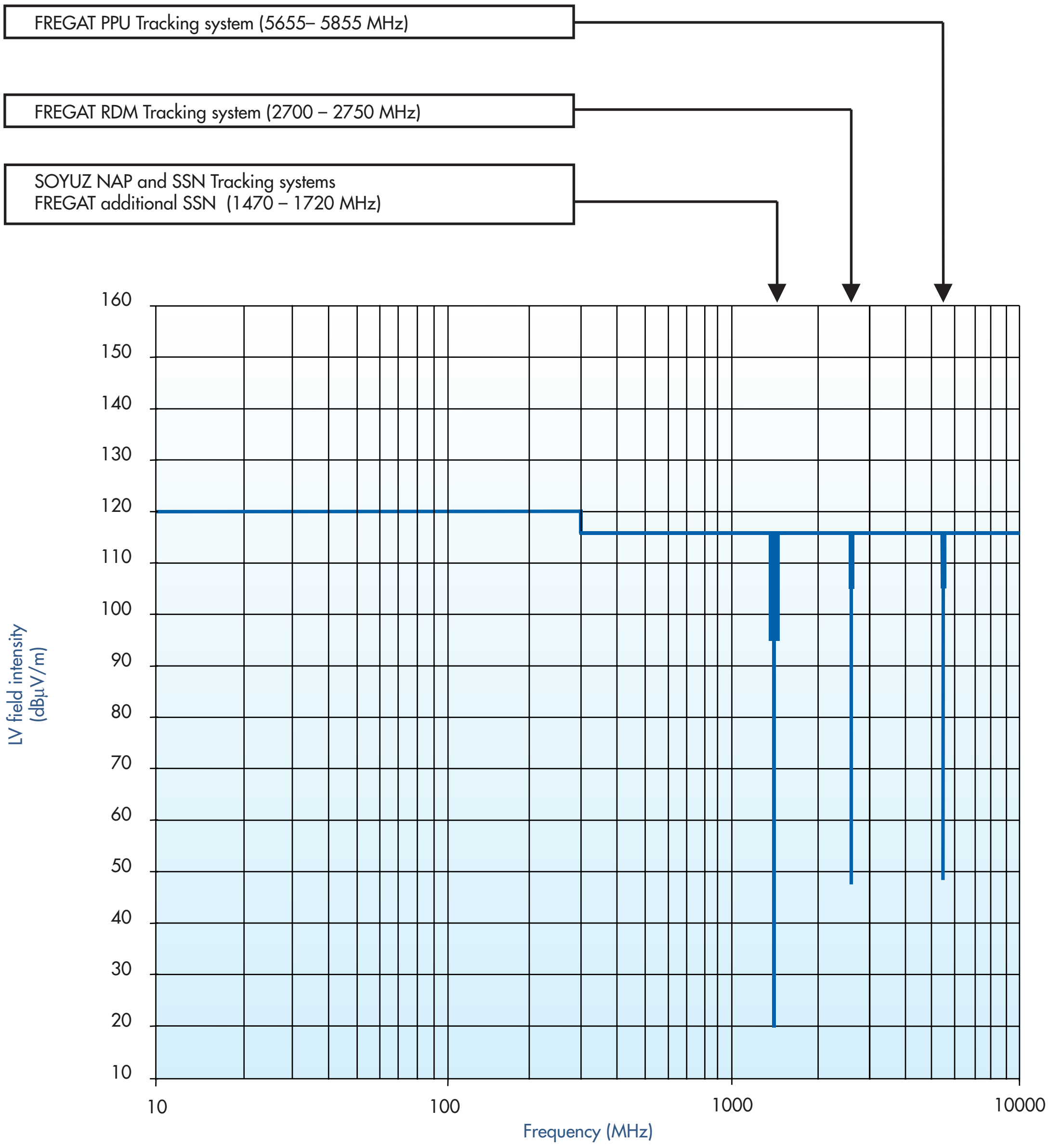


Table 3-17: LV Radiated Susceptibility Limit

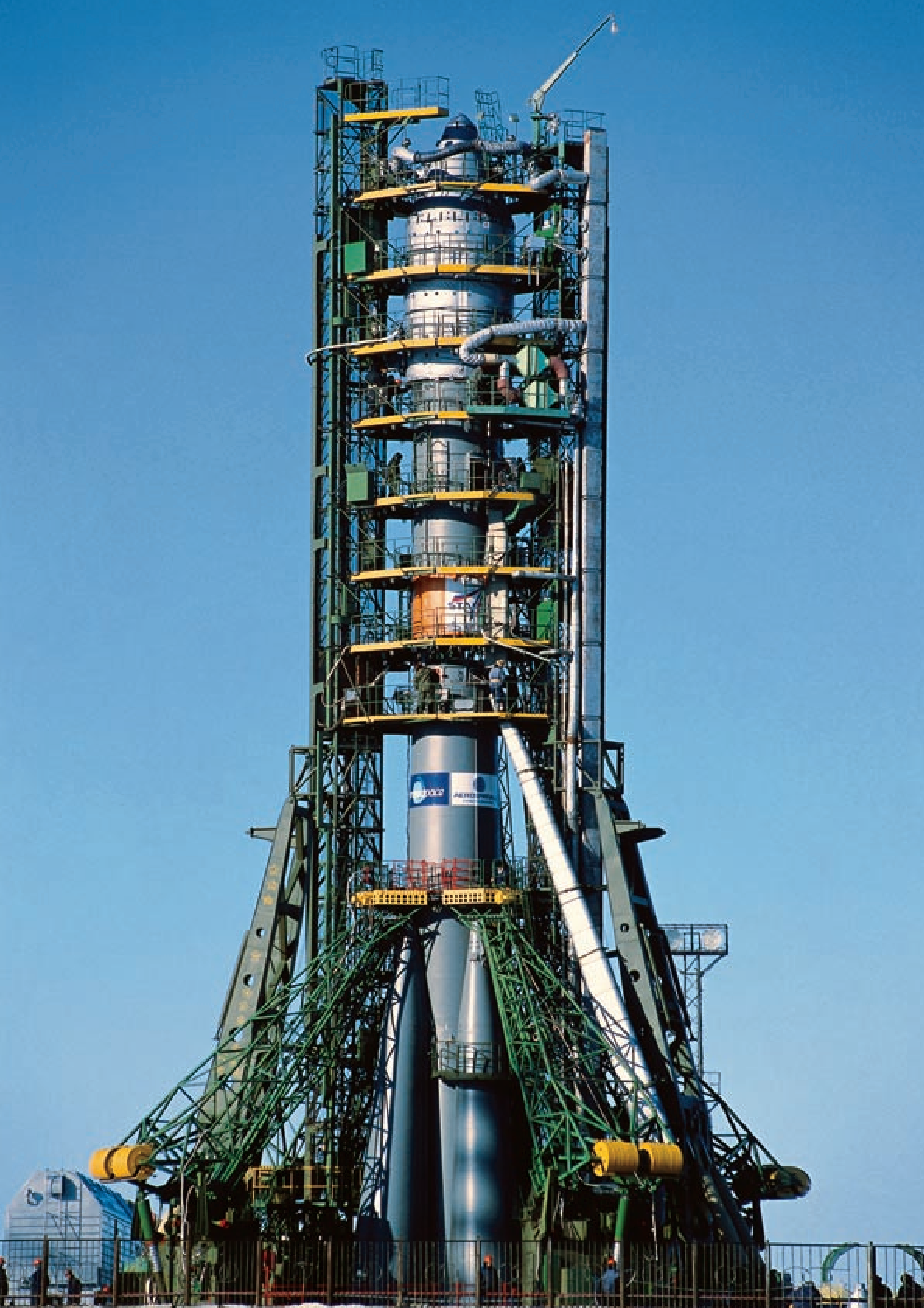
Frequency Band(MHz)	LV Field Intensity (dBµV/m)
0.014 – 300 and 300 – 10,000	120 and 116
1470 – 1720	95
1566 – 1623	20
2700 – 2750	105
2716 – 2734	47
5655 – 5855	105
5745 – 5765	48

Nominally, the spacecraft transmitters are not switched “on” during all ground operations and flight phases (except during test phase in MIK 112). The spacecraft transmission can start 20 seconds after spacecraft separation. It is also assumed, that during flight there is no uploading command to the spacecraft.

The potential for the spacecraft to emit during the countdown phase, during the flight phase, or at spacecraft separation will be analyzed by Starsem on a case-by-case basis.

3.4.5 MAGNETIC FIELD

Regarding magnetic induction, during handling and operations the spacecraft is not exposed to a magnetic field of more than 300 µT for direct current, measured at 1 m from the spacecraft surface.



CHAPTER

4

SPACECRAFT DESIGN AND VERIFICATION REQUIREMENTS

4.1. INTRODUCTION AND REFERENCE AXES

This chapter details the design and dimensioning data that shall be taken into account by any user intending to launch a spacecraft compatible with the Soyuz or Soyuz/ST LV.

Figure 4-1 shows the three-stage vehicle and the Fregat upper-stage coordinate systems.

It is preferable that the spacecraft and adapter reference frames be parallel to the LV coordinate system and have the same positive direction. However, any spacecraft axis system can be accommodated if the relationship with the LV system is clearly defined.

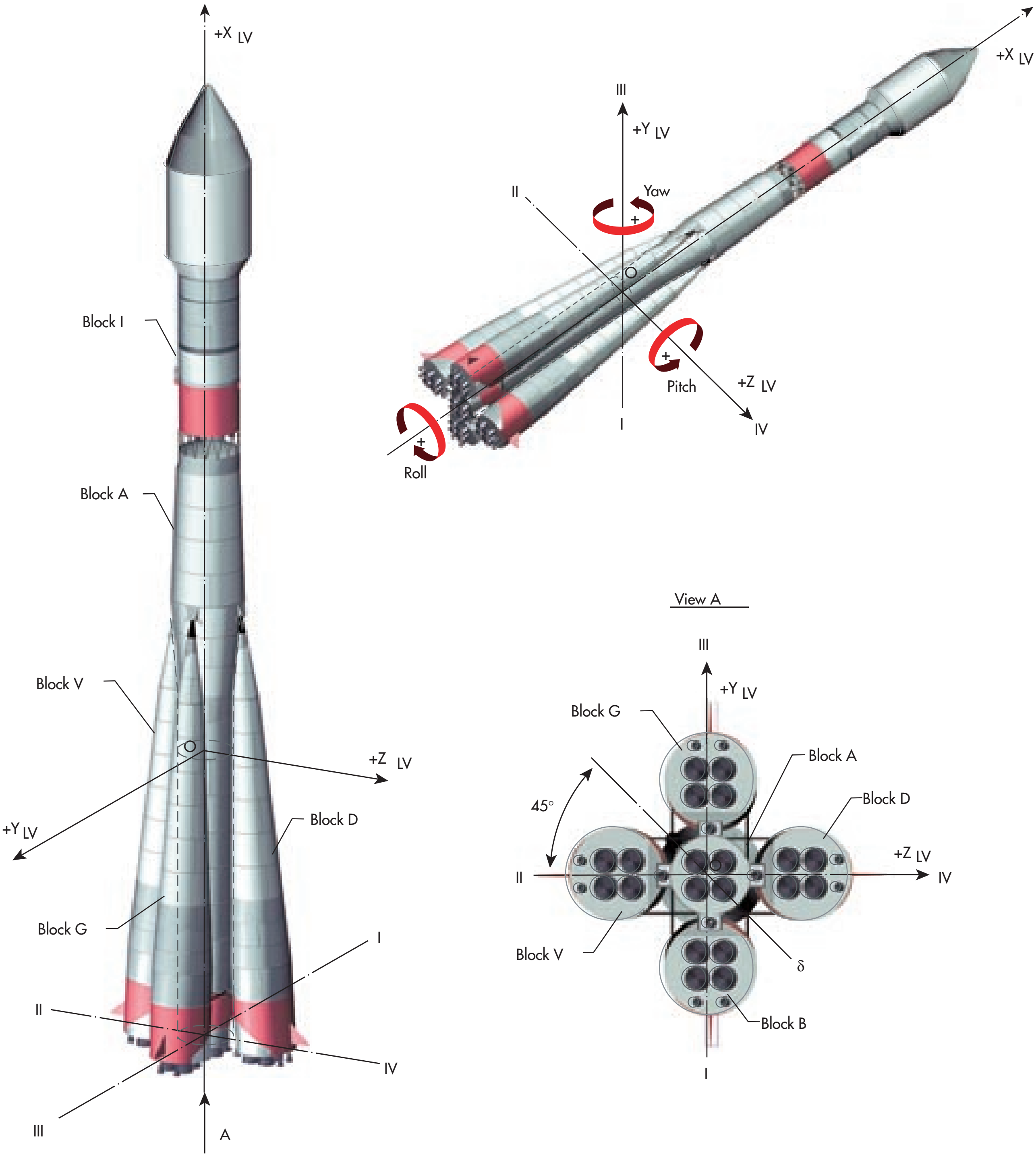
4.2. DESIGN REQUIREMENTS

4.2.1. SAFETY REQUIREMENTS

Safety requirements that the spacecraft's designer must take into account are outlined in *Chapter 7*.

Figure 4-1: Soyuz/ST Reference Axes

Body-fixed axes	X,Y,Z
Direction to the ground during transportation	δ



4.2.2. MASS PROPERTIES

4.2.2.1. Static Imbalance

The spacecraft CoG offset (static imbalance) should not exceed 15 mm. A higher offset can be accommodated but must be compensated on the launcher side and must therefore be analyzed by Starsem.

4.2.2.2. Dynamic Imbalance

There is no predefined requirement for spacecraft dynamic balancing with respect to ensuring proper operation of the LV. However, these data have a direct effect on spacecraft separation. In its mission analysis, Starsem will therefore assess the attitude and motion of the spacecraft after separation taking such characteristics into account.

4.2.3. SPACECRAFT ALLOCATED VOLUME

The spacecraft should comply with the allocated volume defined in *Chapter 5*.

4.2.4. FREQUENCY REQUIREMENTS

To prevent dynamic coupling with fundamental modes of the LV, the adapter/dispenser and the spacecraft should be designed with a structural stiffness which ensures:

- That the fundamental frequencies of the spacecraft are not less than
  - 15 Hz in lateral and
  - 35 Hz in longitudinal; and
- That the fundamental frequencies of the spacecraft stack (spacecraft + adapter/dispenser) are not less than
  - 12 Hz in lateral and
  - 27 Hz in longitudinal.

These frequency values apply either to a spacecraft or to a spacecraft stack hard-mounted at its interface with the LV.

The envelope QSLs given in *Chapter 3* are consistent with these requirements. Starsem will examine the potential relaxation of these requirements at the system level.

4.2.5. MECHANICAL LOADS

4.2.5.1. Static Loads

During flight, low-frequency dynamic and steady-state accelerations combine to produce the quasi-static g-loads.

The QSL reflects the mechanical fluxes (Φ) at the interface between the spacecraft and the adapter (or dispenser):

$$\Phi_{longi} = M_{sat}.QSL_{longi}.g/(\pi.D_{I/F})$$

$$\Phi_{lat} = 4.M_{sat}.QSL_{lat}.g.X_{sat}/(\pi.D_{I/F}^2)$$

$$\Phi_{tot} = \Phi_{longi} + \Phi_{lat}$$

where Msat is the spacecraft mass, X_{sat} its CoG position with reference to its separation plane, and $D_{I/F}$ the interface diameter.

The spacecraft main structure shall withstand the most severe load combination that can be encountered at any instant of the mission (ground and flight operations). *Chapter 3* outlines the most critical flight events and corresponding longitudinal and transverse QSLs relative to the spacecraft center of gravity when using the Soyuz/ST launcher.

The structural design must take into account the safety coefficients defined in *Section 4.3.2*.

4.2.5.2. Dynamic Loads

The secondary structures and flexible elements (e.g., solar panels, antennas, and propellant tanks) must be designed to withstand the dynamic environment described in *Chapter 3* and must take into account the safety factors defined in *Section 4.3.2*.

4.3. SPACECRAFT VERIFICATION REQUIREMENTS

4.3.1. VERIFICATION LOGIC

The spacecraft authority shall demonstrate that the spacecraft structure is capable of withstanding the Soyuz/ST ground and flight environments.

Spacecraft structural capability shall be proven by means of relevant tests. The following classification corresponds to current practice:

- The structural test model (STM) approach consists of:
  - Static, sine, acoustic, and shock qualification tests on the STM; and
  - Sine and acoustic proto-flight tests (i.e., qualification-level and acceptance duration/sweep rate) and shock test on the first flight model.
- The proto-flight model (PFM) approach encompasses:
  - Static qualification by heritage; and
  - Sine and acoustic proto-flight tests (i.e., qualification-level and acceptance duration/sweep rate) and shock test on the first flight model.

For subsequent flight models (recurrent spacecraft), sine, acoustic, and shock acceptance tests shall be conducted.

Note that the mechanical environment test plan for spacecraft qualification and acceptance shall be reviewed by Starsem prior to the implementation of the first test.

4.3.2. SAFETY FACTORS

Spacecraft qualification and acceptance test levels are determined by increasing the flight limit levels — which are presented in *Chapter 3* with a 99% probability of not being exceeded — by the factors given in *Table 4-1*.

Table 4-1: Qualification and Acceptance Factors

		Acceptance Factor	Qualification Factor
QSL:	In-flight	N/A	1.3
	Ground operations and transportation	N/A	1.5
Sine vibrations:			
	In flight	1.0	1.3
	Ground operations and transportation	1.0	1.5
Acoustics		1.0	1.41 (or +3 dB)
Shock		See Section 4.3.3.5	

Note:

For metallic structures, the safety factors to be considered with respect to yielding are 1.1 and 1.15 for flight and ground QSL, respectively.

4.3.3. QUALIFICATION AND ACCEPTANCE TESTS

4.3.3.1. Static Load Tests

Static load tests (in the case of an STM approach) are performed by the customer to demonstrate the design integrity of the primary structural elements of the spacecraft platform. Test loads are based on worst-case conditions — i.e., on events that induce the maximum mechanical fluxes into the main structure, derived from the table of maximum QSLs (see *Chapter 3*) by using the spacecraft mass properties. The qualification factors given in *Section 4.3.2* shall be considered.

Qualification testing may be accomplished either through a static test or on a centrifuge.

4.3.3.2. Sinusoidal Vibration Tests

The spacecraft qualification test consists of one sweep through the specified frequency range and along each axis.

The sweep rate to consider is:

- 0.5 octave/mn for the qualification test; and
- 1.0 octave/mn for the acceptance test.

Flight limit amplitudes are specified in *Chapter 3* and are applied successively on each axis. The tolerance on sine amplitude applied during the test is ± 10%.

A notching procedure may be agreed on the basis of the latest coupled loads analysis (CLA) available at the time of the tests.

4.3.3.3. Random Vibration Tests

No random vibration test is required at the spacecraft level given that an acoustic qualification test is performed.

4.3.3.4. Acoustic Tests

Acoustic testing is accomplished in a reverberant chamber. The volume of the chamber with respect to that of the spacecraft shall be sufficient so that the applied acoustic field is diffuse.

The test duration is as follows:

- 120 seconds for the qualification test; and
- 60 seconds for the acceptance test.

The flight limit spectrum to consider is provided in *Chapter 3* and is specified in octave bands.

Tolerances on the octave-band level are as follows:

- –2/+4 dB for the 31.5-Hz octave band; and
- –1/+3 dB for octave bands from 63 Hz to 2000 Hz

4.3.3.5. Shock Tests

The qualification of the spacecraft's ability to withstand the separation shock generated by the LV shall be based on one of the two following methods:

- Method Number One: A qualification test and analytic demonstration are carried out successively.

  1. A clamp-band release test is conducted with the tension of the belt set as close as possible to its maximum value, during which interface levels and equipment base levels are measured. This test can be performed on the STM, on the PFM, or on the first flight model provided that the spacecraft structure close to the interface as well as the equipment locations and associated supports are equivalent to those of the flight model. The release test is performed twice.
  2. An analytic demonstration of the qualification of each piece of equipment is conducted. This analytic demonstration is performed as follows:
     - The release shocks generated at the spacecraft's interface and measured during the two above-mentioned tests are compared to the release-shock-specified envelope. The difference derived from the above comparison is then considered to extrapolate the measured equipment base levels to the maximum levels that can actually be observed during clamp-band release.
     - These extrapolated shock levels are then increased by a safety factor of +3 dB and are compared to each piece of equipment qualification status. Note that each unit qualification status can be obtained from environmental qualification tests other than shock tests by using equivalent rules (e.g., from sine or random vibration tests).
- Method Number Two: An analysis is conducted on the basis of multiple previous clamp-band release tests (i.e., on a comprehensive shock database).

The acceptance test consists of performing clamp-band release under nominal conditions (nominal tension of the band, etc.). This single release test is usually performed at the end of the mechanical fit-check (see *Section 4.3.4.1*).

4.3.4. INTERFACE TESTS

Prior to the initiation of the launch campaign, the following interface checks shall be performed. Specific LV hardware for these tests is provided by Starsem.

4.3.4.1. Mechanical Fit Check

The spacecraft flight model shall pass a mechanical fit check to confirm that its dimensional and mating parameters meet all relevant requirements as well as to verify operational accessibility. This test is usually performed at the customer's facility, with Starsem providing the adapter.

4.3.4.2. Electrical Fit Check

Functional interfaces between the spacecraft and the Fregat upper stage (power supply, TM monitoring, commands, etc.) shall be checked prior to the beginning of the launch campaign. The customer shall provide an adequate spacecraft electrical interface simulator to be used in the launcher authority's facilities to perform these tests.

Transit line validation between the spacecraft and the customer's EGSE are usually performed in the UCIF of the Baikonur Cosmodrome at the beginning of the launch campaign, before mating the spacecraft on the Fregat.

Electromagnetic compatibility (EMC) tests are not required but can be carried out in the event of a specific user requirement.

CHAPTER

5

SPACECRAFT INTERFACES

5.1. MECHANICAL INTERFACE

The spacecraft stack is mated to the Fregat upper stage. The mechanical junction between the spacecraft and the launcher is provided by a dedicated structure called an adapter (when it addresses a single interface) or a dispenser (when it addresses multiple interfaces). The adapter/dispenser is also used:

- To route the electrical harness that provides the electrical link between the spacecraft and the launcher (see *Section 5.3*);
- To accommodate all sensors that will be used to monitor the spacecraft flight environment (see *Section 5.3*); and
- To separate the satellite(s) on their required orbit(s) upon order(s) sent by the launcher.

These structures and their associated equipment, which are provided by Starsem as part of its launch services agreement, can either be obtained off the shelf from among those already developed for other programs or be designed to address specific user needs (especially in the case of dispensers). In some situations, the user may wish to assume responsibility for these structures. In such cases, the customer shall send an appropriate request to Starsem.

In either case, the user's satellite-handling interface shall be designed in such a way that it can be used with the mechanical ground support equipment (MGSE) available in Starsem's Payload Processing and Launch Facilities after the adapter has been mated to its lower interface.

Among the standard off-the-shelf devices described in Appendix 2, Starsem proposes that its users use two adapters:

- Adapter 1194-SF (whose mass is lower than 110 kg)
- Adapter 937-SF (whose mass is lower than 50 kg).

An adapter compliant with the Ariane-standard 1666-V interface (Adapter 1666-SF, whose mass is lower than 100 kg) is also being developed and will be available by the end of 2002. The launch services agreement additionally provides for the development, manufacture, and testing of a mission-specific adapter/dispenser should user requirements so dictate.

5.2. PAYLOAD FAIRINGS

The Soyuz family offers the following range of fairings:

- Type ST (Ø4.110 m, length 11.433 m — see *Section 5.2.4*); and
- Type S (Ø3.715 m, length 7.700 m — see *Section 5.2.5*).

5.2.1. PAYLOAD ALLOCATED VOLUME

The spacecraft-stack allocated volume represents the area under the fairing that is available to the stack adapter/dispenser and spacecraft (including all extreme points). All tolerances attributable to the manufacture and assembly of the various parts of the spacecraft stack shall be accounted for when its compatibility with this envelope is addressed. This implies that all tolerances attributable to the manufacture of the fairing and intermediate bay, as well as all displacements of both fairing and spacecraft stack due to ground and flight loads, are already taken into account to arrive at the above-mentioned volume.

In the event of local protrusions located slightly outside the above-mentioned envelope, Starsem and the user can conduct a joint analysis in order to arrive at the most suitable layout.

5.2.2. SPACECRAFT ACCESSIBILITY

Users can access the spacecraft for physical operations up to 10 hours before liftoff by removing specially designed access doors. The allowable dimensions and locations of these doors (as well as those of the radio-transparent windows) vary with the fairing selected.

Doors can be installed in all parts of the fairing except in areas close to the separation plane and in the vicinity of its interface with the intermediate bay.

5.2.3. SPECIAL VEHICLE INSIGNIA

A special vehicle insignia corresponding to the customer's logo can be placed on the cylindrical section of the fairing. The dimensions, colors, and location of each such insignia shall be determined for each mission.

Stickers with the mission symbol shall be made of any material conforming to the following requirements:

- The sticker material shall be nontoxic and shall have technological and chemical characteristics that render it resistant to operational temperatures ranging from –45°C to +100°C;
- The sticker material must be resistant to self-ignition in an environment of gaseous and liquid oxygen characterized by a temperature of –182°C; and
- The sticker material must demonstrate good technological compatibility with and fixation on surfaces painted with alkyd-epoxy and acrylic enamels.

5.2.4. FAIRING TYPE ST

The type ST fairing (see *Figure 5-1* and *Figure 5-2*) consists of a two-half-shell carbon-fiber reinforced plastic (CFRP) structure.

A 20-mm-thick thermal cover made of polyurethane foam with a protective liner is applied to the internal surface of the cylindrical part of the fairing. Acoustic blankets may be used if necessary, but the spacecraft-stack allocated volume does not take such blankets into account.

On a case-by-case basis, radio-transparent windows may be installed in areas agreed on by Starsem and the user. Up to two access doors per half-fairing may also be installed in areas agreed on by Starsem and the user.

Figure 5-1: Fairing Type ST: External Dimensions

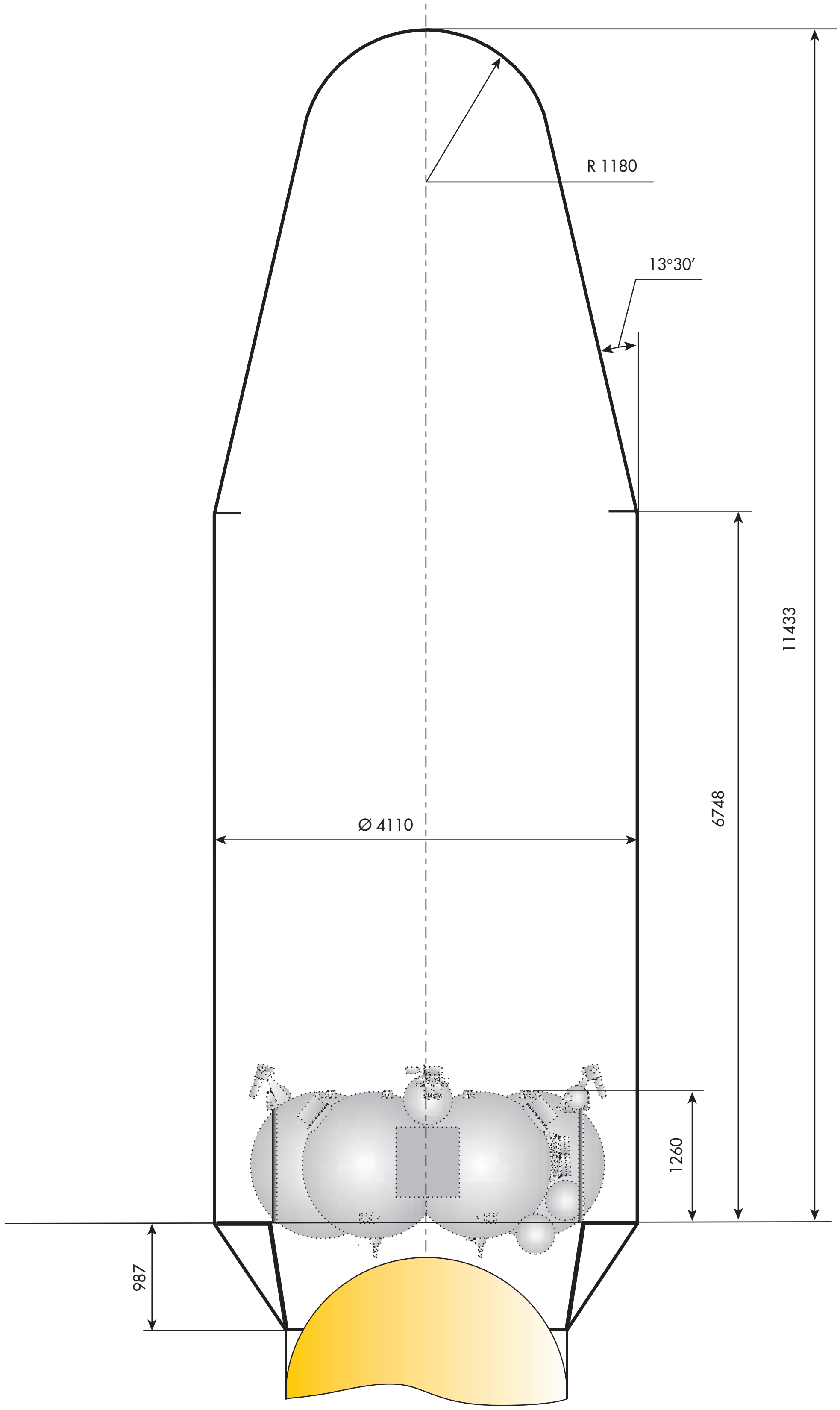
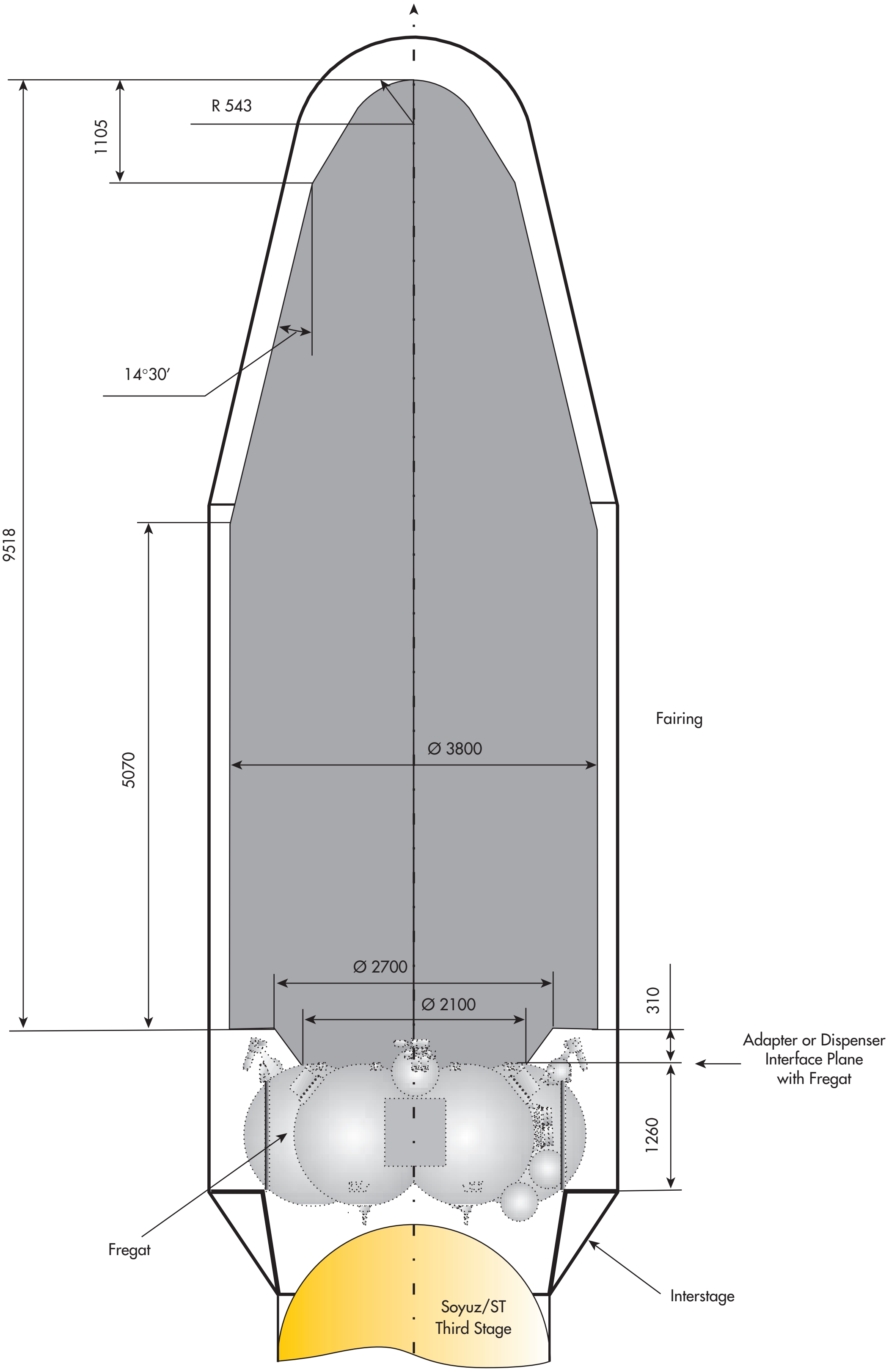


Figure 5-2: Fairing Type ST: Spacecraft-Stack Allocated Volume



5.2.5. FAIRING TYPE S

The type S fairing (see *Figure 5-3* and *Figure 5-4*) consists of a two-half-shell aluminum structure.

A 20-mm-thick thermal cover made of polyurethane foam with a protective liner is applied to all areas of the inner surface of the fairing except the spherical cap and part of the cone. Acoustic blankets may be used if necessary, but the spacecraft-stack allocated volume does not take these blankets into account.

The provision of access doors and radio-transparent windows will be agreed on by Starsem and the user on a case-by-case basis.

Figure 5-3: Fairing Type S: External Dimensions

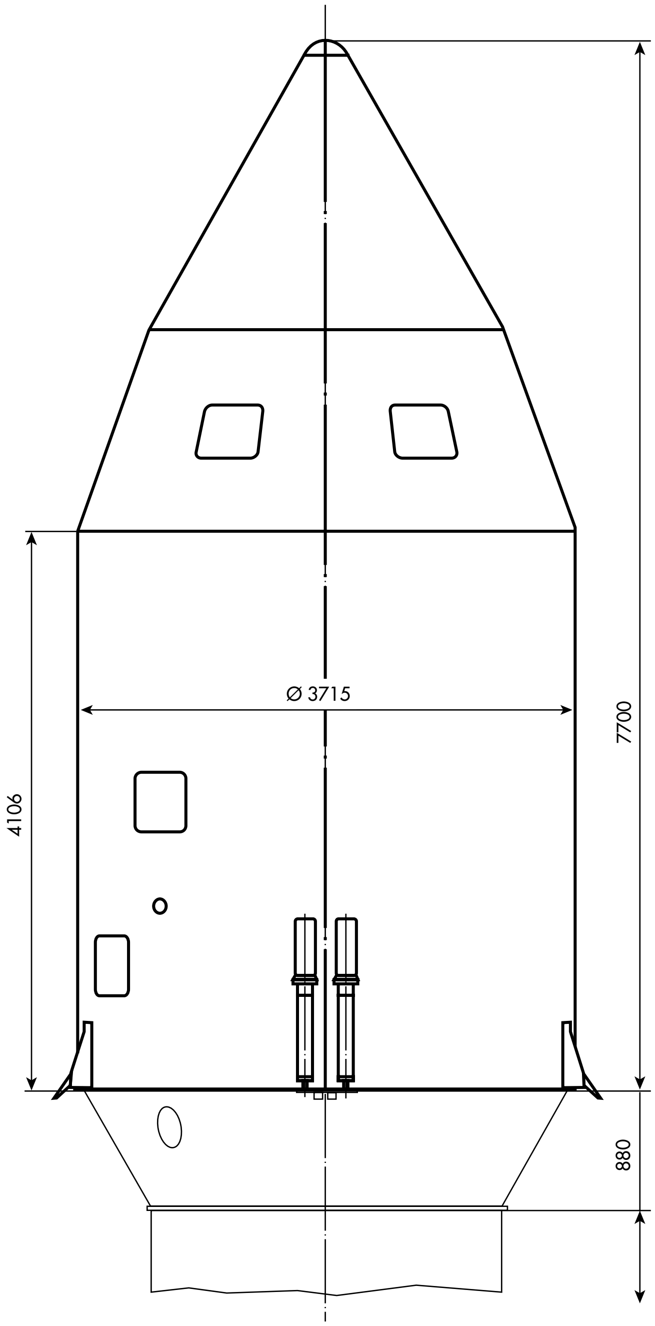
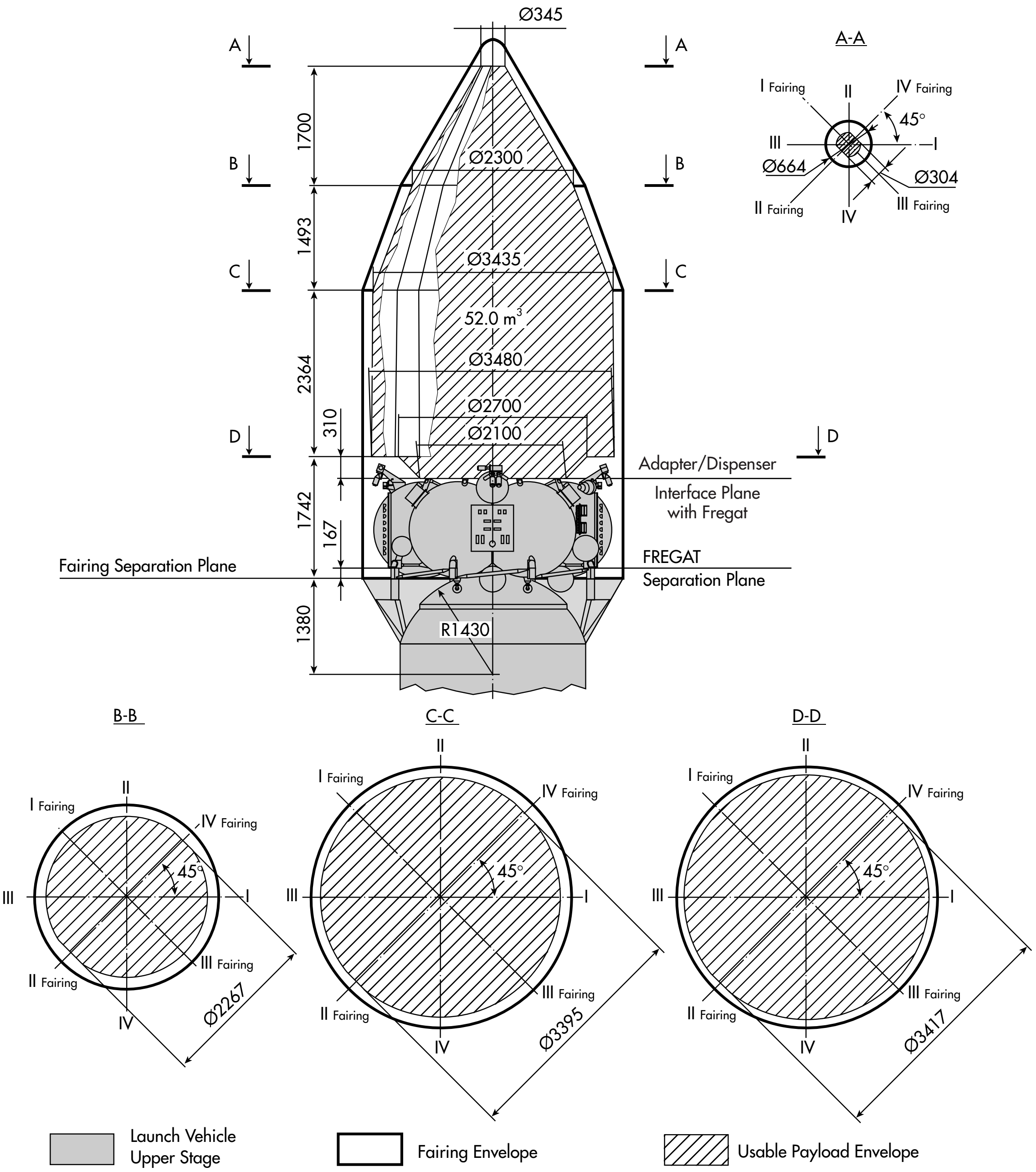


Figure 5-4: Fairing Type S: Spacecraft-Stack Allocated Volume



5.3. ELECTRICAL INTERFACES

This section defines the electrical interfaces between the spacecraft, LV, and first level EGSE located below the launch pad in the catacombs (see *Section 6.2.3.2.2*). Standard and optional configurations are outlined both while the vehicle is on the launch pad and during the various phases of launch preparation.

5.3.1. STANDARD LAUNCH PAD CONFIGURATION

5.3.1.1. Spacecraft to EGSE Umbilical Lines

This subsystem refers to the electrical lines between the spacecraft and the EGSE (see *Figure 5-5*). For connections between the catacomb EGSE and other locations (bunker, MIK 112) see *Section 6.3.3*.

5.3.1.1.1. Line Definition

Lines between the catacombs and the spacecraft pass through:

- The LV umbilical connector SHO1, located on the interstage section of the Fregat. An 86-pin connector is allocated to the spacecraft electrical ground links at this interface. The umbilical connector SHO1 is jettisoned 2 minutes and 35 seconds before liftoff.
- The LV last-instant connector R15, located at the base of the first stage. At this interface, six pins are allocated to the spacecraft for a specific electrical function. This function relates to the spacecraft "switch OFF power" command, which permits the safety configuration to be reinstituted in the event of a launch abort.

5.3.1.1.2. Line Composition

The spacecraft-to-catacomb wiring consists of permanent and customized sections. The permanent sections have the same configuration for each launch, and consist of the following segments: *Table 5-1* illustrates these segments.

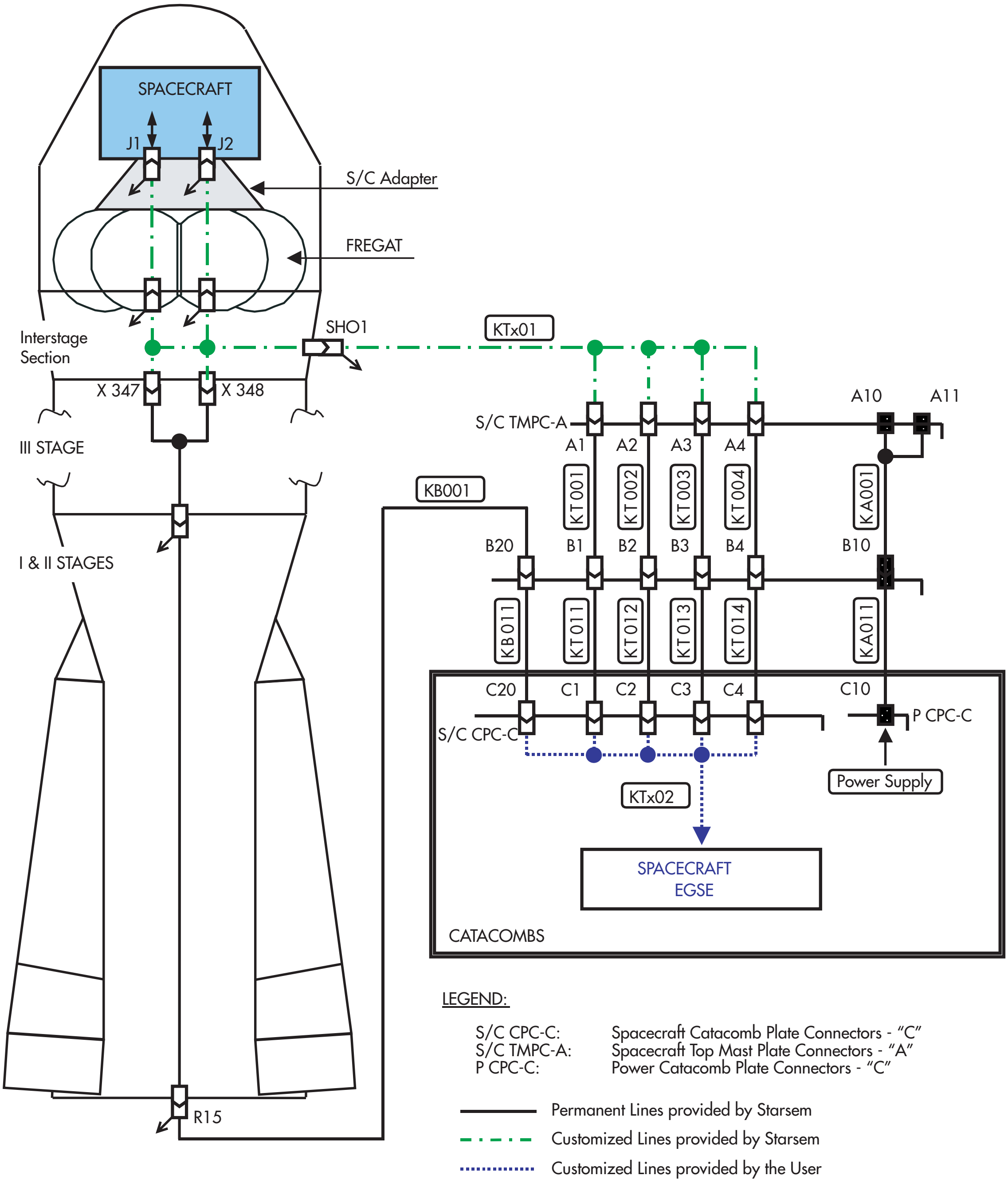
- Those between catacomb connectors C1, C2, C3, and C4 and the connectors A1, A2, A3, and A4 at the top of the mast. This segment is 100 meters long and composed of four harnesses.
- Those between the catacomb connector C20 and the Fregat interstage section connectors X347 and X348. This segment is 180 meters long, and its harness is composed of six shielded wires with a 1.5 mm^2 cross section.

The customized section is configured for each mission. It consists of the following segments:

- Those between the spacecraft interface (J1 and J2), and connectors A1; A2; A3; and A4 at the top of the mast. Two 37-pin connectors* make up the nominal spacecraft interface. These connectors are of the DBAS 70 37 OSN and DBAS 70 37 OSY type. For each connector, the user will reserve three pins: one for shielding and two for spacecraft telemetry separation as described in *Section 5.3.1.2.2*. Starsem will provide the spacecraft connector for the flight model and the harnesses for this segment.
- Those between catacomb connectors C1, C2, C3, and C4 and the user EGSE in the catacombs. The user will provide the harness for this segment. Starsem will provide all Russian connectors.

*One or two 61-pin DBAS-type connectors can be accepted at the spacecraft interface.

Figure 5-5: Electrical Connection Between Spacecraft and EGSE: Launch Pad Standard Configuration



5.3.1.1.3. Electrical Characteristics

The ground lines are configured to support a permanent current of up to 10 A by wires. A large number of available lines (28 twisted shielded pairs) allows for custom adaptation to spacecraft requirements and also allows lines to be wired in parallel, thus minimizing voltage losses in the ground harnesses.

The LV harnesses shall not carry permanent currents in excess of 4 A by wire. The voltage shall be less than 125 V.

To meet prelaunch electrical constraints, 60 seconds prior to the jettisoning of the umbilical mast and last-instant connectors, all spacecraft EGSE electrical interface circuits shall be designed to ensure no current flow greater 100 mA across the connector interfaces.

5.3.1.1.4. Power Supply Available On Launch Tower

One additional line, reserved for providing power (e.g., 220 V) for user EGSE (e.g., the spacecraft simulator), runs between the catacombs (connector C10) and the top of the mast (connectors A10 and A11). This line, which consists of harnesses KA001 and KA011, can be used during validation and launch operations. A description of these lines and their interfaces is given in *Table 5-2*.

Table 5-1: Catacomb Interface Connectors for Spacecraft Ground Umbilical Line.

Harness Connector Designation	Connector Location (adapting plate #)	Connector Type	Spacecraft Ground Umbilical Electrical Signals	Type of Wire Available
KT011/C1	SC CPC-C	OSS 50Z	Spacecraft power and remote control	14 twisted shielded pairs with a cross section of 2.5 mm^2
KT012/C2	SC CPC-C	OSS 50Z	Spacecraft power and remote control	14 twisted shielded pairs with across section of 2.5 mm^2
KT013/C3	SC CPC-C	OS2RMD 32G	Spacecraft check and monitoring	10 twisted shielded pairs with a cross section of 1.0 mm^2 4 twisted shielded pairs with a cross section of 0.20 mm^2 and with low capacitance (< 12 nF for 100 m)
KT014/C4	SC CPC-C	OS2PMD 45G	Spacecraft check and monitoring	16 twisted shielded pairs with a cross section of 0.20 mm^2 and with a specific impedance (75 ± 5 Ω)
KB011/C20	SC CPC-C	OS2RMD 32G	Spacecraft remote control and check	6 shielded wires with a cross section of 1.5 mm^2

Table 5-2: Power Supply Line on Launch Tower.

Harness/ Connector Designation	Connector Location (adapting plate #	Connector Type	Electrical Signals	Type of Wire Available
KA011/C10	P CPC-C	2RMD 7	Main power line	3 single shielded wires with a cross section of 8 mm^2.
KA001/A10 KA001/A11	P TMPC-A	2RMD 7	Main power line	3 shielded wires with cross section of 8 mm^2 for A10. 3 shielded wires with a cross section of 1.5 mm^2 for A11.

5.3.1.2. Spacecraft Separation Straps

Two different types of straps can exit at the spacecraft interface. The main electrical characteristics of these straps are:

Strap "open": $R \leq 1\ \Omega$
Strap "closed": $R \geq 100\ k\Omega$

5.3.1.2.1. Strap on the Launch Vehicle Side

The LV will provide continuity loops for use by the spacecraft as defined by the spacecraft umbilical connectors.

5.3.1.2.2. Strap on the Spacecraft Side

The spacecraft is required to provide continuity loops for separation monitoring by the Fregat telemetry system TMC-M4. Each spacecraft separation connector must provide one loop.

5.3.2. ADDITIONAL OPTIONAL SERVICES

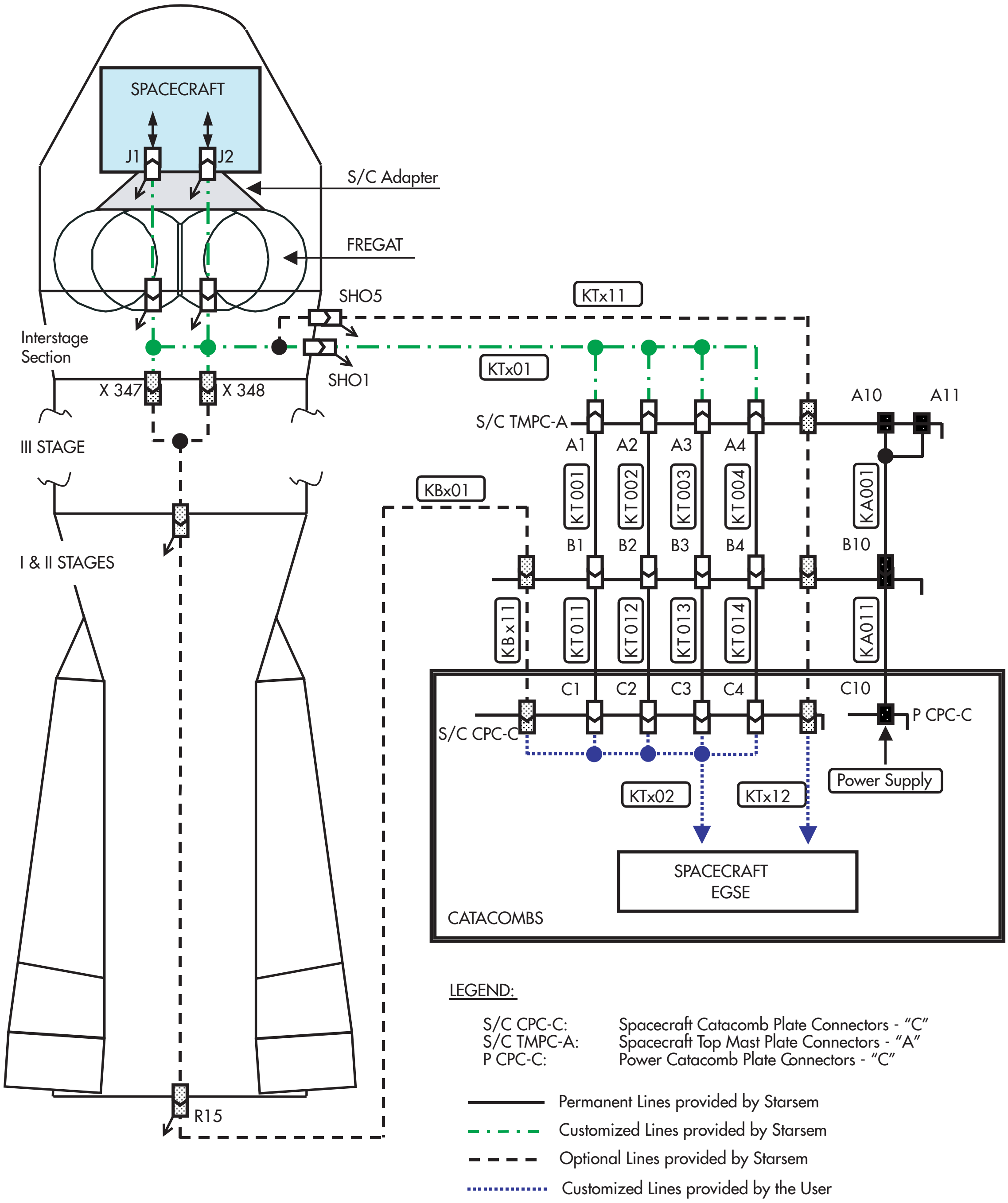
This chapter describes additional optional services that may be made available to the user and gives the relevant electrical characteristics of each. To meet specific requirements, Starsem will study the type and number of links with the spacecraft designer on a case-by-case basis.

5.3.2.1. Spacecraft to Electrical Ground Equipment Umbilical Lines

Two extensions may be used for mission-specific needs (see *Figure 5-6*):

- In the first case, another umbilical connector may be added to the Fregat interstage section. This connector, referred to as SHO5, offers the same service as connector SHO1. To establish this extension, Starsem will provide a new set of harnesses between the spacecraft and the catacombs.
- The second extension concerns the transit lines through the last-instant connector of the launcher. Four specific lines may be provided to permit monitoring of spacecraft telemetry data by the EGSE up to the time of liftoff.

Figure 5-6: Electrical Connection Between Spacecraft and EGSE: Launch Pad Optional Configuration



5.3.2.2. Services Provided by the Launch Vehicle to the Spacecraft

The following electrical functions can be provided at the spacecraft/adapter interface:

5.3.2.2.1. Electrical Command

This function allows for commands to be sent to the spacecraft from the Fregat.

The main electrical characteristics are:

Input voltage: 28 V ± 4 V
Input current: ≤ 0.5 A
Number: 8
Impulse duration n x (32 ± 0.15) ms (with n: $1 < n < 6$)

These commands are redundant and are monitored by the Fregat telemetry system.

5.3.2.2.2. Open/Closed Loop Command

This function is used for initiating spacecraft flight commands. The information is sent through the opening or closing of a relay contact which is part of the Fregat electrical equipment (yes- or no-type information).

The main electrical characteristics are:

Loop closed: $R \leq 1\ \Omega$
Loop open: $R \geq 100\ k\Omega$
Voltage: ≤ 32 V
Current: ≤ 0.5 A

During flight, these commands are monitored by the Fregat telemetry system.

5.3.2.2.3. Pyrotechnic Command

Pyrotechnic commands are available for operations of the spacecraft internal pyrotechnic system other than LV orders for spacecraft separation. The electrical diagram is presented in *Figure 5-7*.

The main electrical characteristics are:

Minimal current: 4.1 A
Nominal current: 5 A
Impulse duration: 32 msec ± 0.15 msec
Nominal battery voltage: 27 V

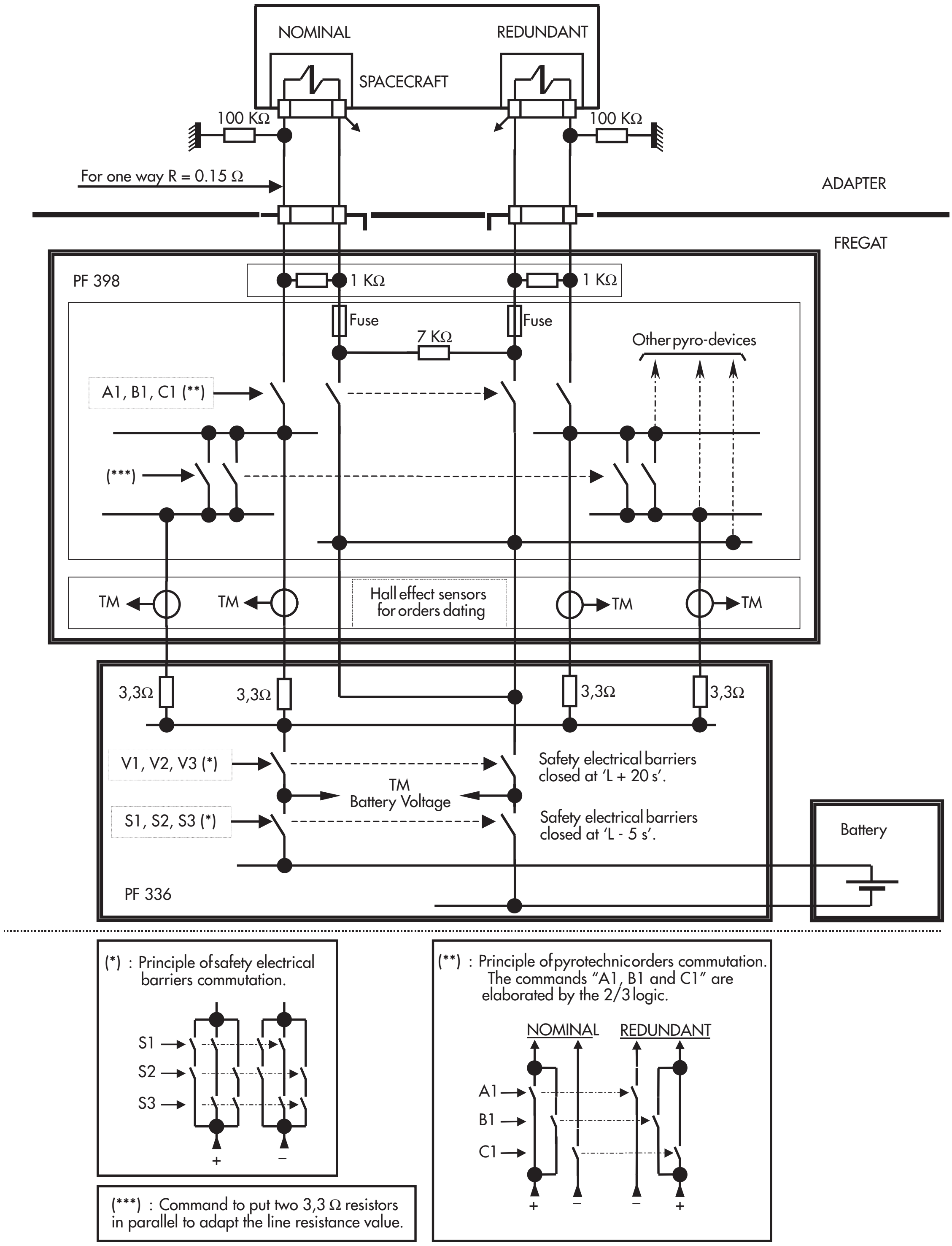
This subsystem is compatible with the Western initiator 1 A / 1 W / 5 min, with a resistance of the bridge wire equal to 1.05 Ω ± 0.15 Ω. The one-way circuit line resistance between the Fregat/adapter interface and the spacecraft initiator must be less than 0.150 Ω.

The redundant pyrotechnic order is given by the Fregat control system at the same time as the nominal one.

To ensure safety during ground operations, two electrical barriers are installed in the Fregat electrical line of the pyrotechnic circuits. The first barrier is closed 5 seconds before liftoff, and the second is closed 20 seconds after liftoff.

During flight, the pyrotechnic orders are monitored by the Fregat telemetry system.

Figure 5-7: Pyrotechnic Command – Electrical Diagram



5.3.2.2.4. Power supply

An independent power supply, without regulation, can be dedicated to the spacecraft through specific lines.

The main characteristics are:

Input voltage:	28 V ± 2 V
Nominal current:	1.5 A
Capacity:	120 Ah

5.3.2.2.5. Spacecraft Telemetry Monitoring

It is possible to ensure the transmission of spacecraft telemetry data with the Fregat telemetry subsystem TMC-M4.

The main characteristics are:

Analog low-frequency signals:	0–6 V
Status contacts with output resistance:	≤ 1 kΩ in the closed state ≥ 100 kΩ in the open state

5.3.2.3. Spacecraft Radio Communications

A direct RF link from the spacecraft antenna can be provided with a modification of the fairing. The following configurations are possible:

- Use of radio-transparent windows and a repeater on the launch pad mast.
- Installation of a passive repeater under the fairing and linking of that repeater to the spacecraft EGSE until liftoff. This option allows users to check the spacecraft RF transmission on the launch pad during countdown.

5.3.3. INTERMEDIATE INTERFACE CONFIGURATION

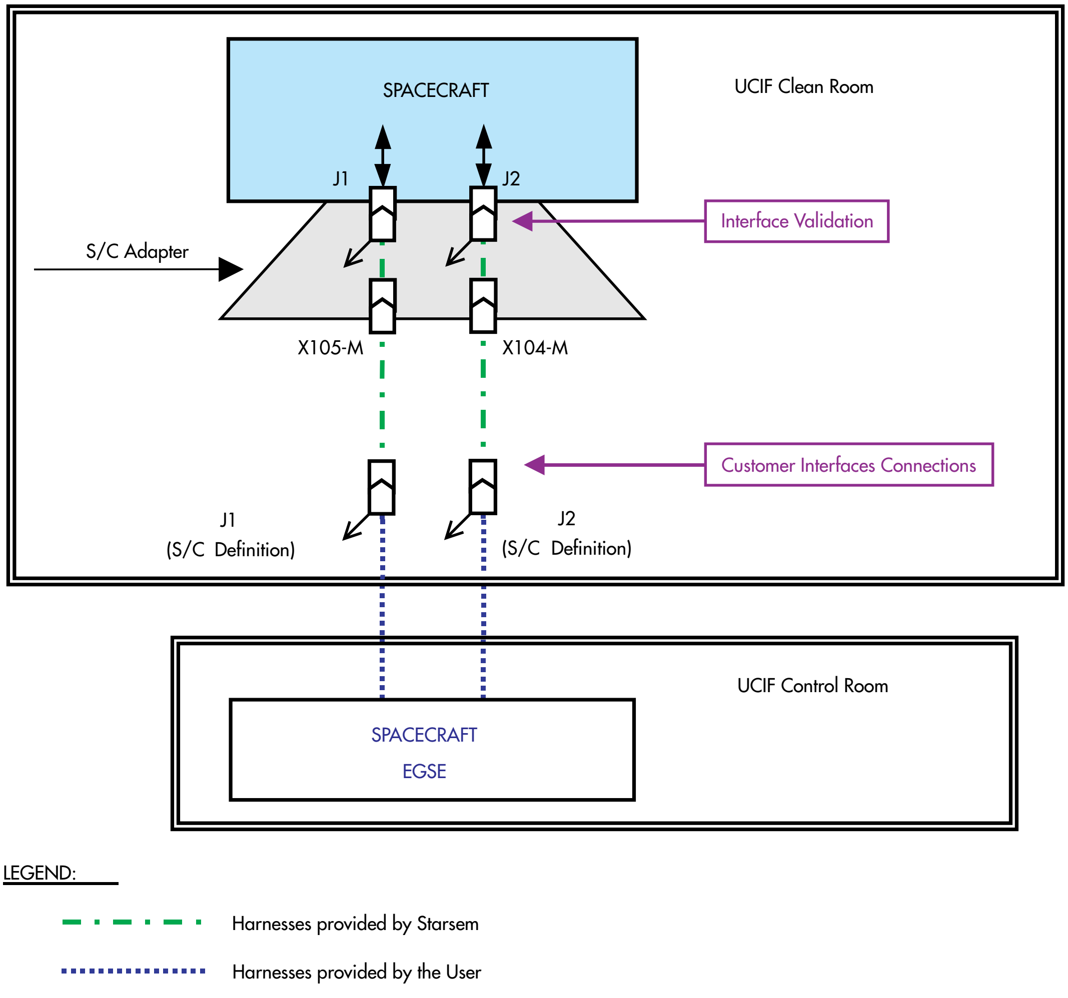
This chapter outlines spacecraft umbilical-lines interface validation for various configurations. It indicates the electrical interface with the user for these different phases.

5.3.3.1. Spacecraft Mating onto Adapter

This validation which takes place in the UCIF, checks the correct connection between the spacecraft and the adapter (see *Figure 5-8*).

Starsem provides ground harnesses conforming to the spacecraft electrical interface definition in order to allow a direct connection to the spacecraft EGSE ground cables. This configuration permits the user to use the same EGSE ground cables that are used during the spacecraft autonomous functional tests.

Figure 5-8: Electrical Interface Validation After Spacecraft Mating onto Adapter



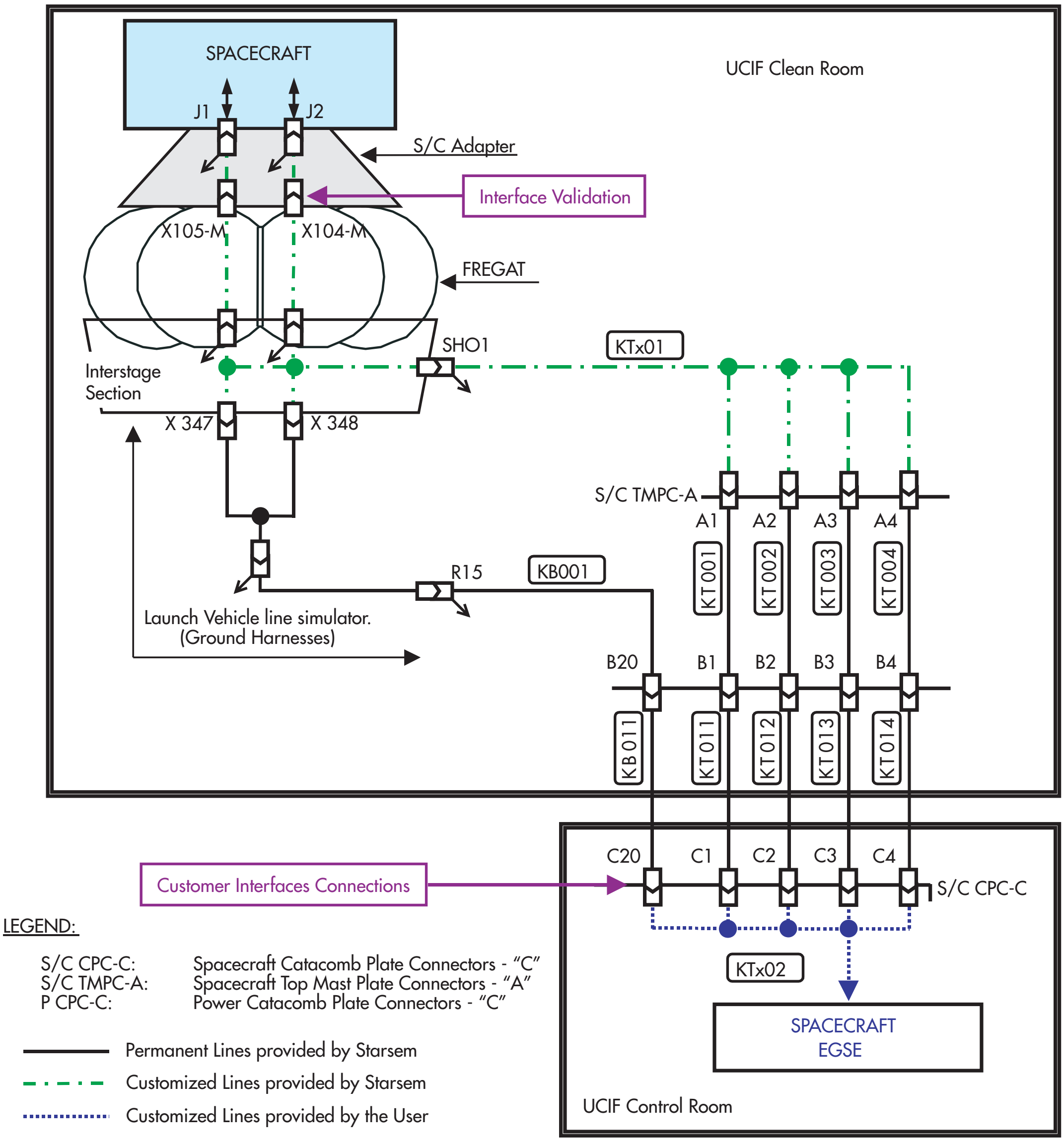
5.3.3.2. Spacecraft Stack Mating onto Fregat

This validation process takes place in the UCIF. The purpose of these operations is to validate the connection integrity of the spacecraft umbilical lines between the adapter and the Fregat.

Starsem installs a dedicated set of spacecraft umbilical harnesses in the same configuration as those at the launch pad. In this phase users can use EGSE harnesses configured for launch pad operations as described in *Section 5.3.1.1.2*

The electrical diagram in *Figure 5-9* presents this configuration.

Figure 5-9: Electrical Interface Validation After Stack Mating onto Fregat



S/C CPC-C: Spacecraft Catacomb Plate Connectors - "C"
S/C TMPC-A: Spacecraft Top Mast Plate Connectors - "A"
P CPC-C: Power Catacomb Plate Connectors - "C"

▬	Permanent Lines provided by Starsem
- · - ·	Customized Lines provided by Starsem
······	Customized Lines provided by the User

5.3.3.3. Launch Vehicle Final Integration

The final integration and validation of the LV takes place in MIK-40.

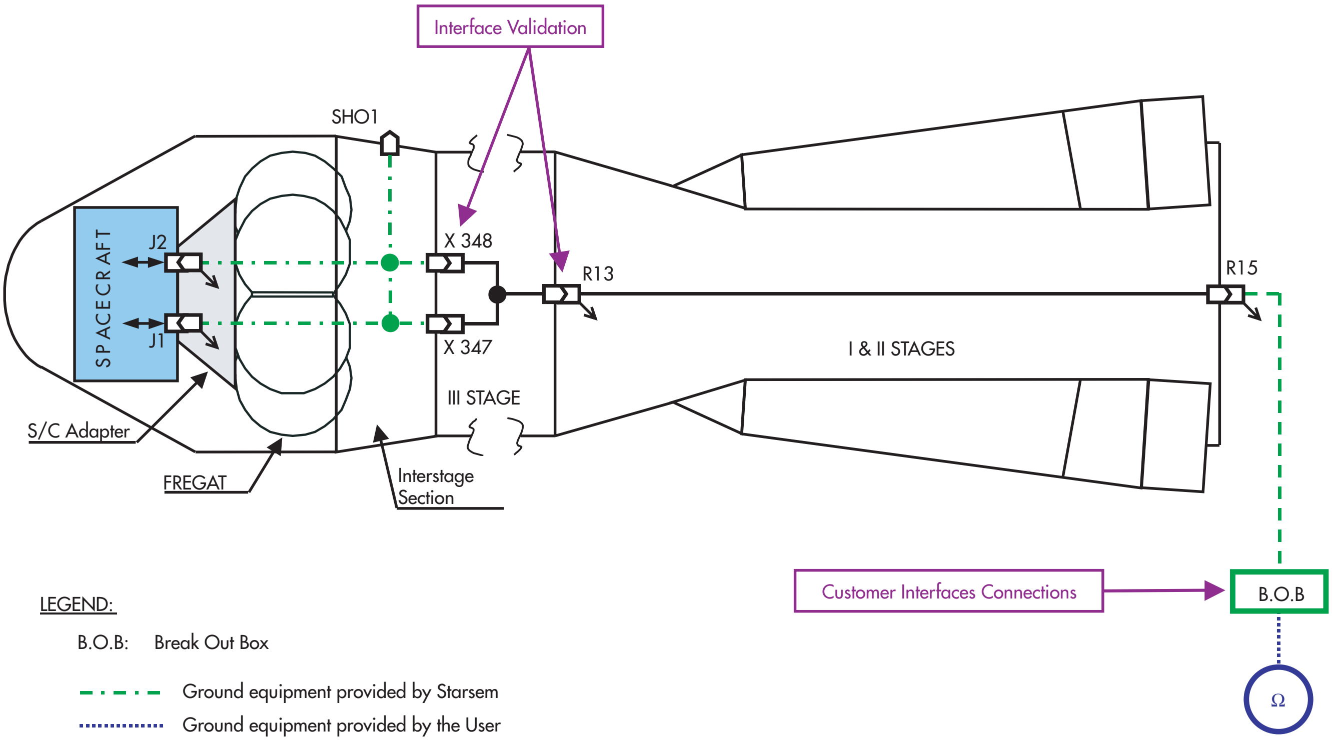
In this phase, it is not necessary to reverify the spacecraft umbilical lines connected through the umbilical connector. This configuration of electrical connections remains identical to that used during validation activities in the UCIF (i.e., no new connection).

For the spacecraft last instant lines connected through R15, Starsem provides a specific break-out box to allow an electrical cold check. This operation confirms the correct connection of these lines through the LV (see *Figure 5-10*).

The user provides the ohmmeter.

Note: If the user wishes to perform any functional tests on the spacecraft at this time, this will be studied by Starsem on a case-by-case basis.

Figure 5-10: Electrical Interface Validation After LV Final Integration



5.3.4. ELECTRICAL CONTINUITY INTERFACE

5.3.4.1. Bonding

The electrical continuity resistance between the spacecraft and the adapter shall be lower than 10 mΩ, with a current of 10 mA. This electrical continuity is ensured through direct contact between the two bodies.

The electrical continuity between the adapter and the Fregat is ensured through direct contact between the two bodies. The corresponding resistance shall be lower than 2 mΩ, with a current of 10 mA.

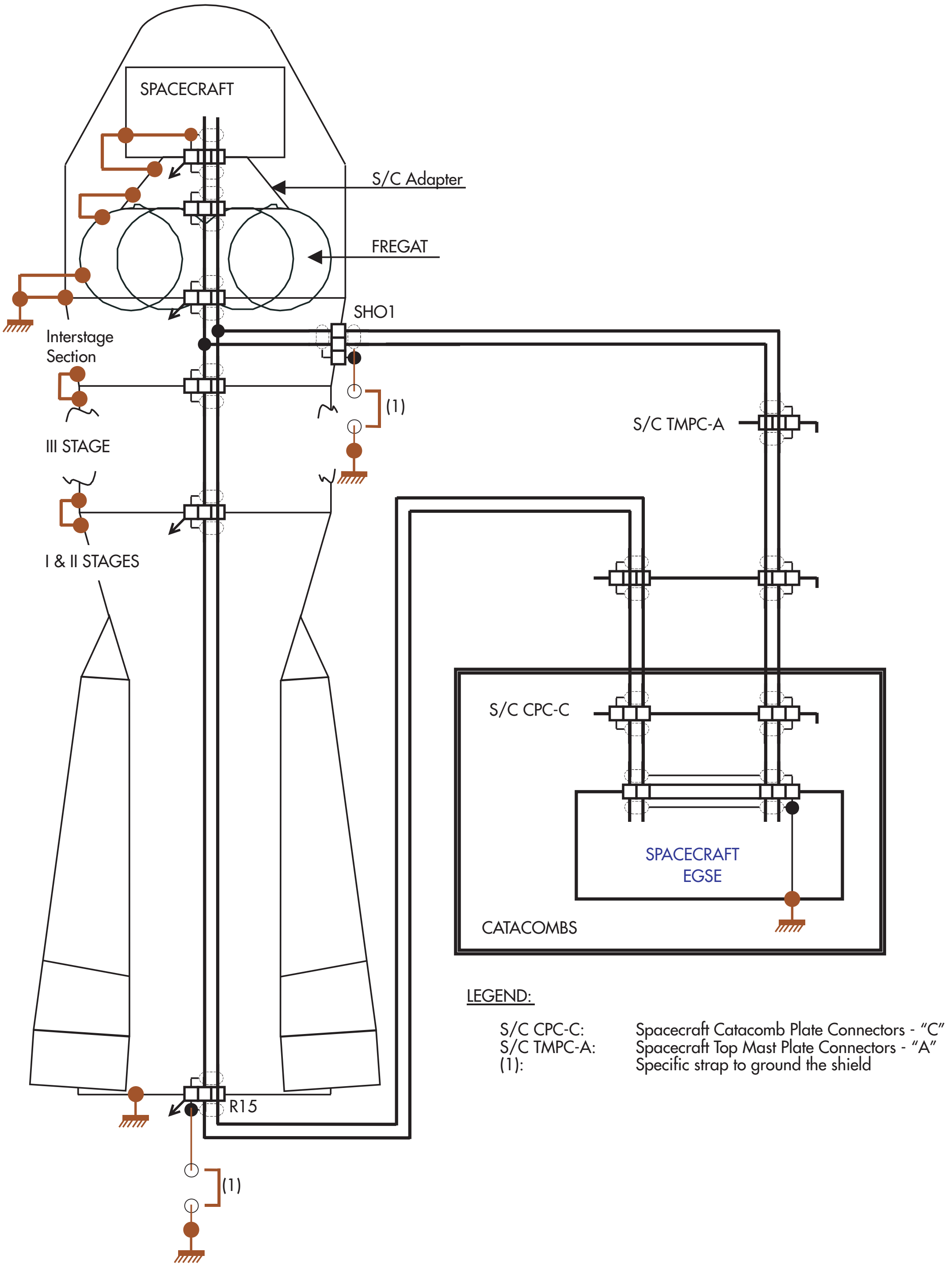
The LV has a "ground" base point connected to the ground circuit during tests and launch preparation. The LV body to earth cable terminal and earth cable terminal to earth circuit bus has a resistance lower than 200 mΩ.

5.3.4.2. Shielding

The umbilical shield links are grounded at both ends of the lines (the spacecraft on one side and EGSE on the other). If the user desires it is also possible to connect to ground at the umbilical mast connector SHO1 and the last-instant connectors R15. The spacecraft umbilical grounding network diagram is described in Figure 5-11.

For each LV and ground harnesses connector, two pins are reserved to ensure continuity of the shielding.

Figure 5-11: Spacecraft Umbilical Grounding Network Diagram



LEGEND:

S/C CPC-C:	Spacecraft Catacomb Plate Connectors - "C"
S/C TMPC-A:	Spacecraft Top Mast Plate Connectors - "A"
(1):	Specific strap to ground the shield


CLUSTER

CHAPTER

6

BAIKONUR COSMODROME

6.1. INTRODUCTION

This chapter describes Starsem's payload processing and launch facilities in Baikonur, which allow users to perform all necessary operations from the arrival of the spacecraft and its associated ground support equipment (GSE) up to the launch of the vehicle.

Baikonur Cosmodrome is located in the Republic of Kazakhstan (see Figure 6-1). The site is approximately 2100 km to the southeast of Moscow, between 45° and 46° north latitude and 63° east longitude. It is accessible by air (Krainy and Yubileiny Airports), by rail (Tyuratam Railway Station), and by road. Typically there are two regular flights per week between Moscow and Baikonur (Krainy Airport). Flight duration is approximately three hours. Charter flights may be organized upon request.

Baikonur time is GMT + 5 hours in winter and GMT + 6 hours in summer. The climate is of the continental type (semiarid zone), averaging –9°C in winter, +19°C in spring, +27°C in summer, and +8°C in autumn with a low level of humidity.

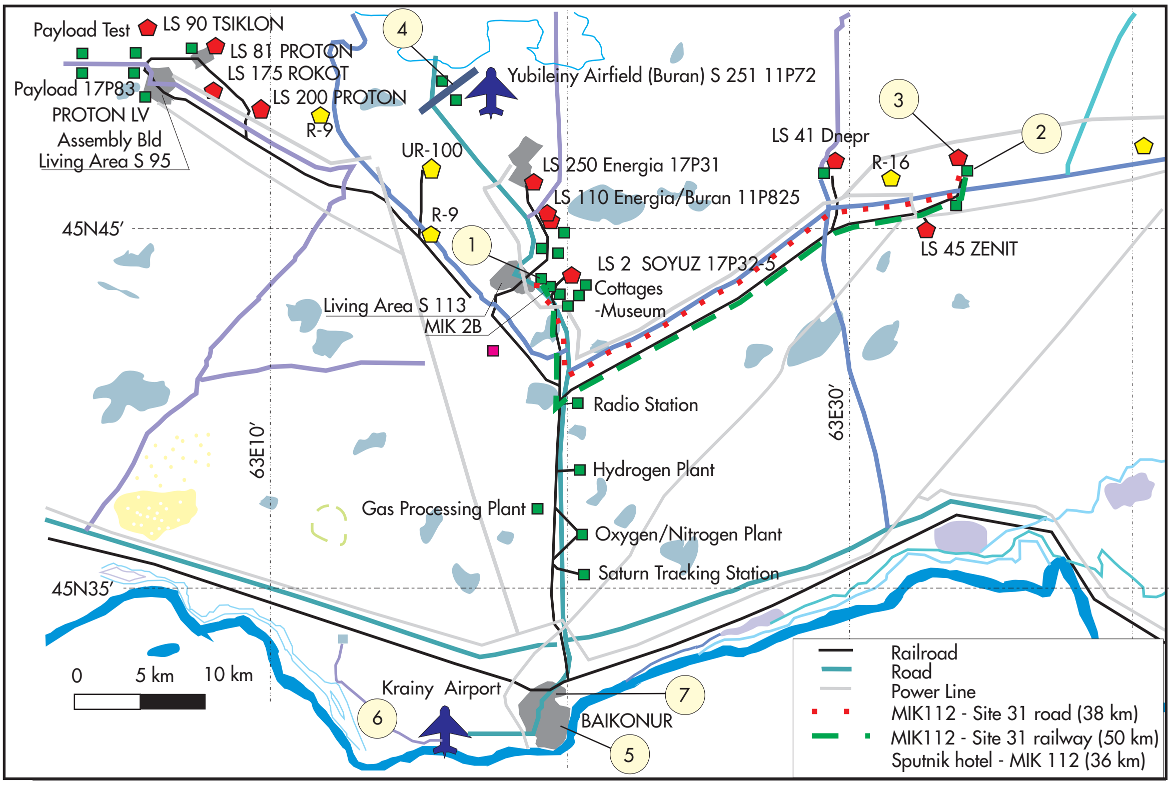
Baikonur is the oldest space launch complex in the world, with a history dating back to 1957. With several operational launch pads, the Cosmodrome remains one of the most active launch complexes in the world. A map of the Cosmodrome is shown in *Figure 6-2*.

The city of Baikonur is located on the bank of the Syr Darya River. The two primary working areas used during Starsem launch campaigns are Site 112 and Site 31, which are 35 km and 50 km away from the city of Baikonur respectively. Under Russian regulation and a dual administration (Russian and Kazakh), Baikonur is home to some 55,000 people. Its infrastructure includes a broad network of service and facilities, including two hospitals, a central market, shops, museums, a stadium, and parks.

Sputnik Hotel, located in the city, offers Western-standard services with 120 comfortable rooms and 5 suites.

Figure 6-1: Map of Russia

Figure 6-2: Baikonur Cosmodrome



1 Site 112 – STARSEM Payload Processing Facilities
2 Site 31 – MIK40: Launch vehicle assembly hall
3 Site 31 – Launch Pad # 6 and associated facilities

4 Yubileiny airport
5 Baikonur city
6 Krainy airport

7 Sputnik hotel

6.2. STARSEM PAYLOAD PROCESSING AND LAUNCH FACILITIES: GENERAL PRESENTATION

Starsem has adapted, modified, developed, and built dedicated facilities within Baikonur Cosmodrome that allow commercial users to provide Western-standard services for all phases of spacecraft preparation. All Starsem facilities are concentrated in two areas, thereby facilitating user activities and operations processing.

Besides the services offered by the two Baikonur airports (see *Section 6.2.1*), Starsem operates the following facilities that are collectively known as Starsem Payload Processing and Launch Facilities (SPPLF):

- Site 112 (see *Figure 6-3*), which consists of:
  - The Payload Processing Facility (PPF);
  - The Hazardous Processing Facility (HPF);
  - The Upper Composite Integration Facility (UCIF);
  - Standard Storage Areas (SSAs);
  - The Office Area (OA);
  - The Hazardous Storage Facility (HSF);
  - The Remote Control Room (RCR) in the OA; and
  - A restaurant.
- Site 31 (see *Figure 6-4*), which includes:
  - MIK 40: the Fregat and Soyuz technical complex;
  - Launch pad: the launch table, catacomb, Fregat bunker, customer bunker, and LV bunker; and
  - Building 51: offices and canteen.

For environmental conditions and for power, data link, crane, and communications characteristics, refer to *Section 6.3*.

The Class 100,000 cleanrooms (PPF, HPF, UCIF) used for spacecraft activities were built by Starsem in 1998 according to state-of-the-art Western standards. All already-existing Soyuz facilities were upgraded according the same standard.

A detailed presentation of the SPPLF is given in the SPPLF user's manual.

Figure 6-3: Site 112 Layout

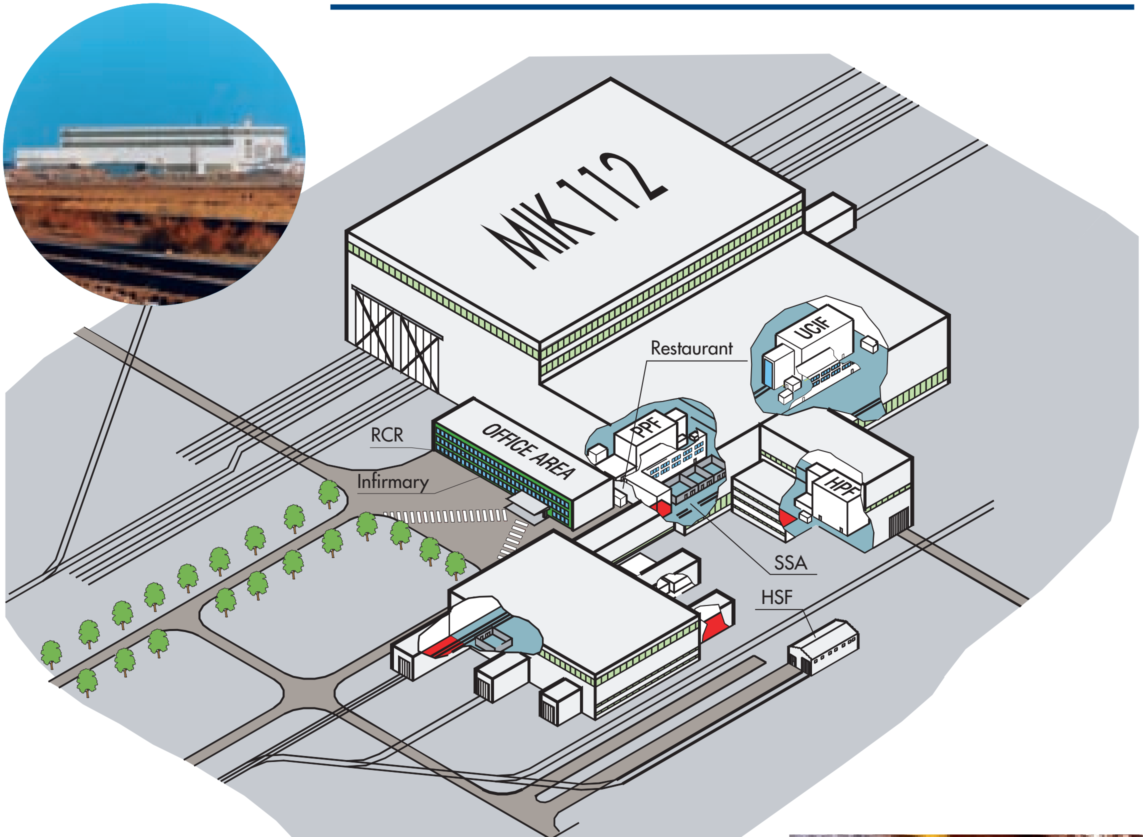
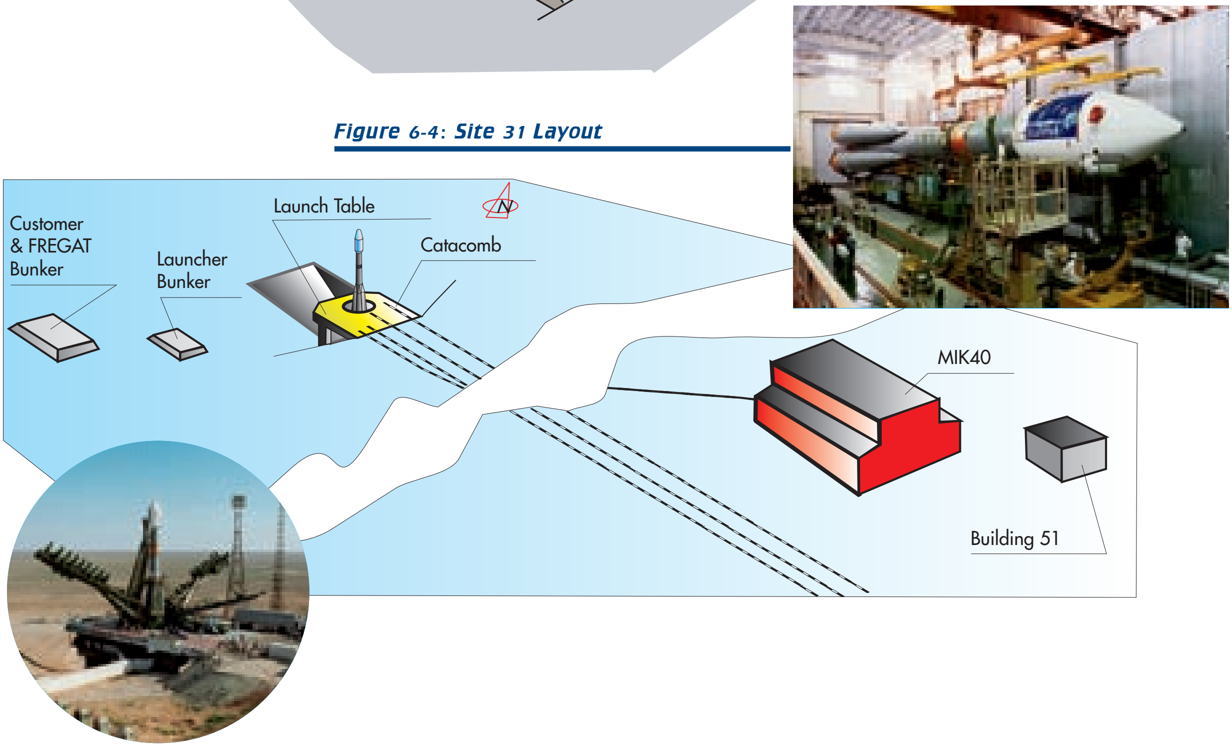


Figure 6-4: Site 31 Layout



6.2.1. AIRPORTS

6.2.1.1. Krainy Airport

Krainy Airport (see *Figure 6-2*) is situated 6 km from Baikonur. It can accommodate midsize aircraft for passenger travel between Baikonur and Moscow.

6.2.1.2. Yubileiny Airport

Yubileiny Airport (see *Figure 6-2*) is located within Baikonur Cosmodrome. This site, which was previously used for the Buran space shuttle landing, handles aircraft of all classes for both freight and charter flights. The aircraft offloading area is located approximately 50 meters from the railway loading area. The airport is connected to MIK 112 by rail and road. The distance between the airport and MIK 112 is approximately 20 km.

6.2.2. SITE 112

Site 112, which includes MIK 112, the largest building within Baikonur Cosmodrome (see *Figure 6-3*), houses Starsem's new cleanrooms. Access routes to Site 112 allow for either truck or rail-car delivery of payload and GSE (e.g., spacecraft transport containers, GSE containers, and propellant drums). Internal routes are designed to transfer payload and GSE between the preparation rooms.

Starsem's command-and-control center ("Gestion Technique Centralisée"[GTC]) in the MIK 112 OA allows for the monitoring of facility environmental parameters.

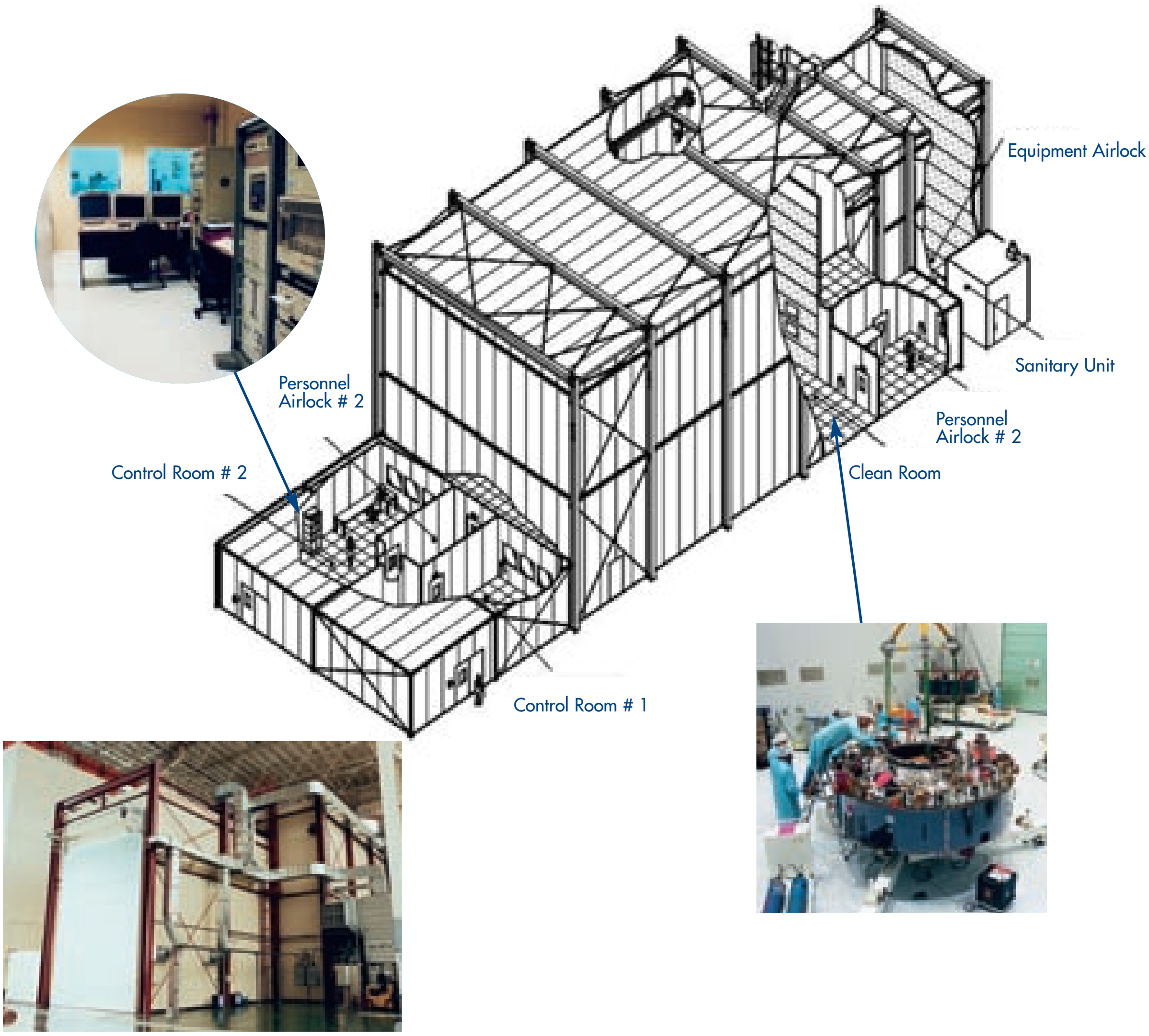
Starsem technicians are on duty 24 hours a day, seven days per week. They are capable of taking corrective action in the event of any deviation from the functions provided by the facilities (conditioning, power supply, detectors, etc.). They are also tasked with alerting Starsem management if any critical issues arise. If such issues have a potential impact on the spacecraft, the user will be appropriately advised.

6.2.2.1. Payload Processing Facility (PPF)

The PPF (see *Figure 6-5*), which is located in MIK 112 (see *Figure 6-3*), is composed of:

- One 286-m^2 cleanroom dedicated to the performance of spacecraft autonomous processing;
- Two control rooms measuring 70 m^2 each;
- Two personnel airlocks measuring 20 m^2 and 17 m^2; and
- One equipment airlock measuring 75 m^2.

Figure 6-5: PPF Building Perspective



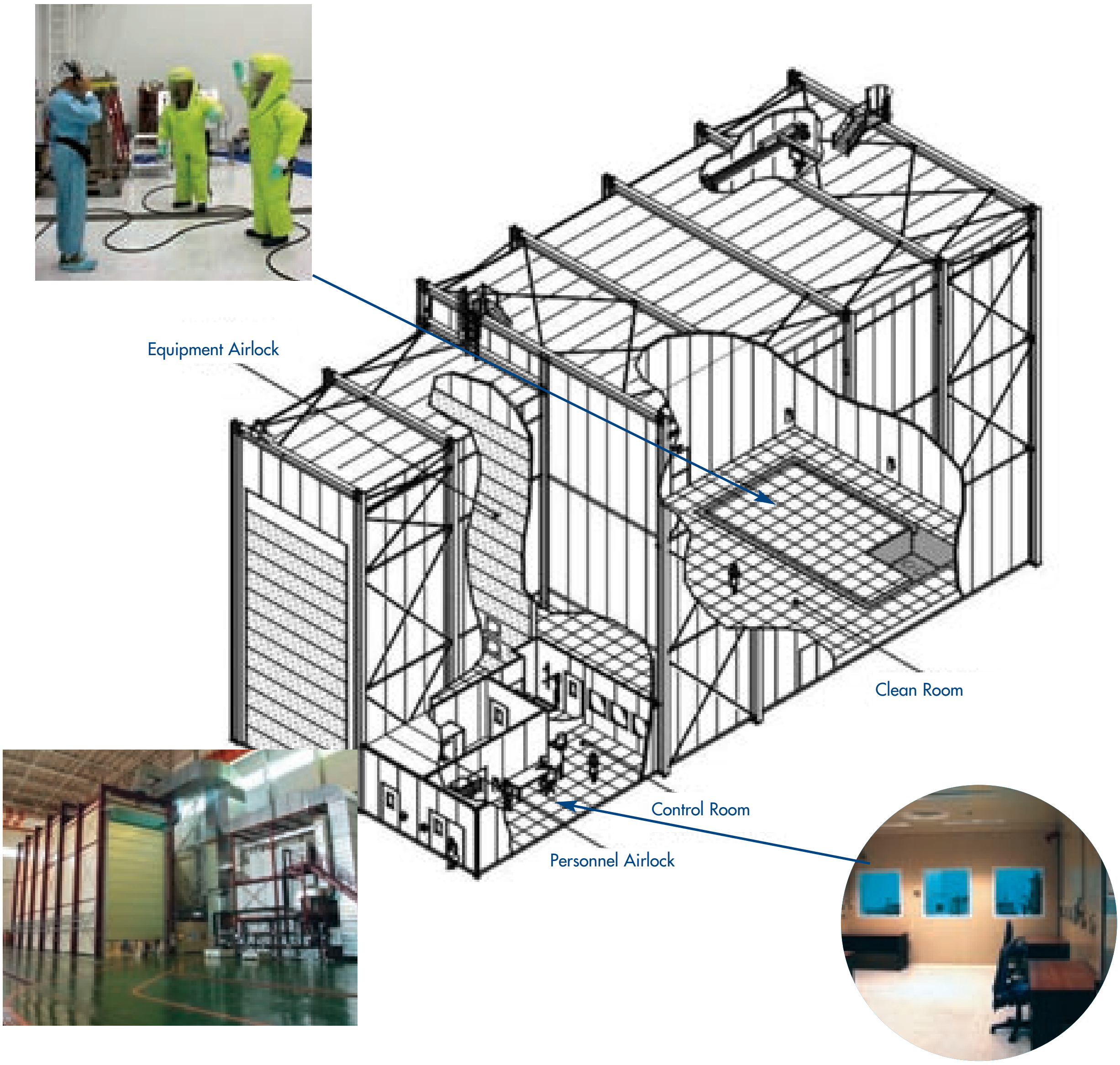
6.2.2.2. Hazardous Processing Facility (HPF)

The HPF (see *Figure 6-6*), which is located in MIK 112 (see *Figure 6-3*), is composed of:

- One 285-m^2 cleanroom dedicated to the performance of hazardous operations such as propellant filling (monomethyl hydrazine/nitrogen tetroxide [MMH/NTO] propulsion systems) and pressurization;
- One 42-m^2 control room for nonhazardous operations;
- One personnel airlock measuring 23 m^2; and
- One equipment airlock measuring 73 m^2.

Specific operations can be remotely controlled from the RCR (see *Section 6.2.2.4*), which is equipped with a dedicated data package (TV, intercom, environmental data, spacecraft status, etc.).

Figure 6-6: HPF Building Perspective

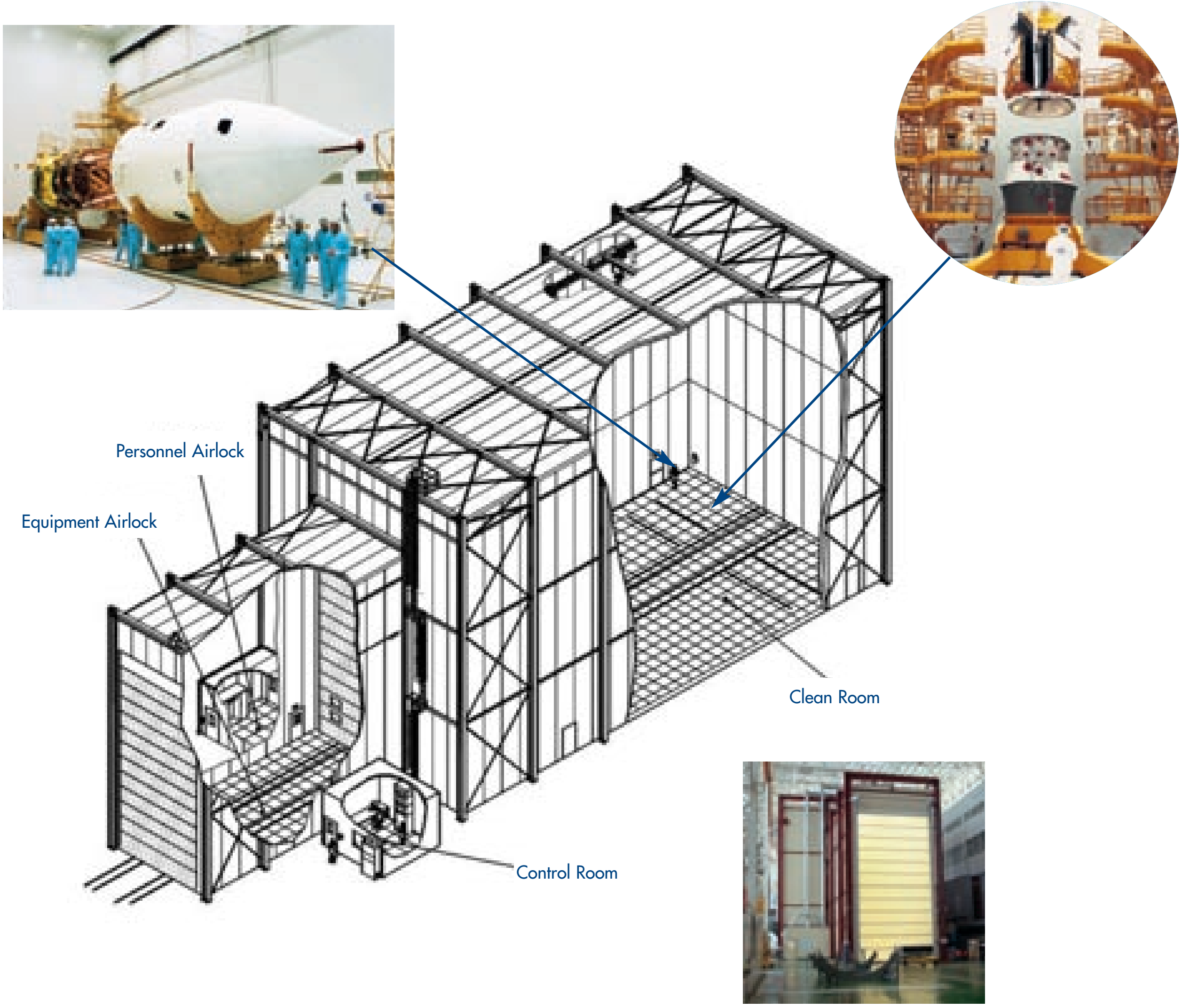


6.2.2.3. Upper Composite Integration Facility (UCIF)

The UCIF (see Figure 6-7), which is located in MIK 112 (see Figure 6-3), is composed of:

- One 587-m^2 cleanroom dedicated to performing upper-composite activities (e.g., adapter/dispenser preparation for spacecraft mating, spacecraft mating to the adapter/dispenser, spacecraft + adapter/dispenser integration on the Fregat upper stage, and fairing installation);
- One 22-m^2 control room for nonhazardous operations;
- One personnel airlock measuring 26 m^2; and
- One equipment airlock measuring 101 m^2.

Figure 6-7: UCIF Building Perspective



Specific operations can be carried out in the UCIF with the support team located in the RCR (see *Section 6.2.2.4*).

6.2.2.4. Remote Control Room (RCR)

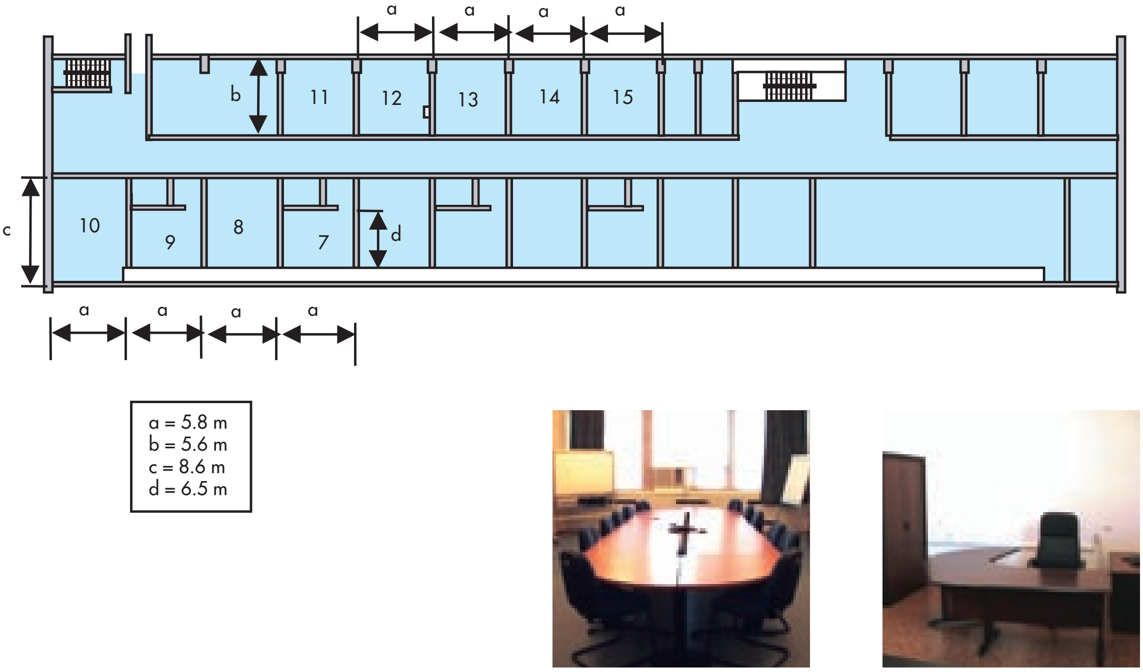
The RCR is located on the second floor of the office area (see Figure 6-8, Room 12). With a surface area of 30 m^2, the RCR is equipped with TV monitors from the HPF and UCIF video cameras. A dedicated intercom is also available, allowing direct communication with fixed and mobile headsets worn by operators within the facilities. Power supply and environmental condition parameters from cleanrooms as well as filling station status are also monitored in the RCR through a computer connected with the GTC.

6.2.2.5. Office Area (OA)

The OA (see *Figure 6-8*) is a three-story administrative building at Site 112 that houses various Cosmodrome entities, Starsem, users' offices, and service rooms. Seven offices on the second floor (7, 8, 9, 10, 13, 14, and 15), each designed to accommodate from four to eight people, are available for the user. One high-speed copy machine is also available for use. Additional offices can be provided.

A Starsem Western-standard restaurant is located near the offices (see *Figure 6-3*).

Figure 6-8: Office Area



6.2.2.6. Hazardous Storage Facility (HSF)

The HSF is a dedicated facility designed for the storage of liquid propellant in tanks or drums, all of which are under safety constraints. The surface area available is approximately 160 m^2 for fuel and 150 m^2 for oxidizer and includes leak detection, fire detection, and protection systems.

6.2.3. SITE 31

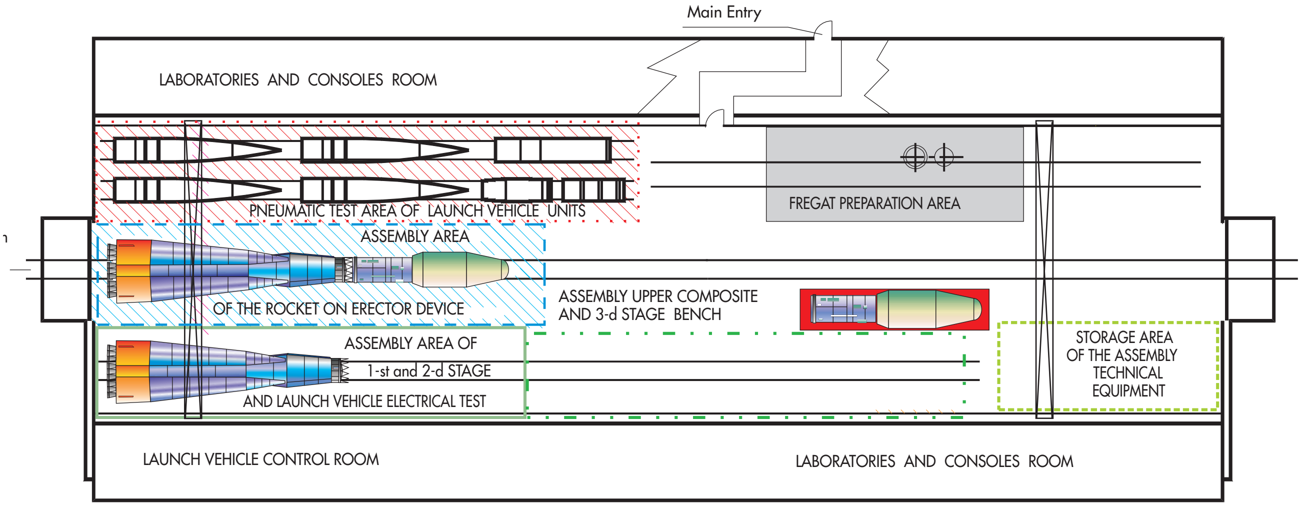
Site 31 (see *Figure 6-4*) is a dedicated area designed for LV preparation and launch activities. It is connected to MIK 112 by both rail and road.

6.2.3.1. MIK 40

MIK 40 (see *Figure 6-9*) is the main building for LV preparation and control, Fregat upper-stage preparation, and upper-composite integration to the LV.

A dedicated surface area is provided for the user and related equipment. Spacecraft operations in this building are typically limited to pyrotechnic circuit arming, purging, and verification of connections to the LV.

Figure 6-9: MIK 40 Layout



6.2.3.2. Launch Pad

Launch pad no. 6 at the Baikonur Cosmodrome (see *Figure 6-4*) is used for Soyuz LV preparation and launch. The launch table, catacomb, and customer bunker are the main facilities used on the launch pad.

6.2.3.2.1. Launch table

The launch table (see *Figure 6-4* and *Figure 6-10*) includes all equipment, servicing towers, and access platforms necessary to support LV preparation and launch.

Ground/board connection is performed at the Fregat interstage section.

Access to the upper composite is provided by two lifts measuring 110 x 110 x 190 cm. The servicing platform varies in width from 0.5 to 1.2 m around the LV.

On the launch pad, the ventilation under the fairing is provided by two complementary systems:

A high-flow-rate air-conditioning system (VSOTR) until L – 45 minutes; and

A low-flow-rate air-conditioning system (STVVD) between L – 45 minutes and 45 seconds before liftoff.

Environmental characteristics are given in *Chapter 3*.

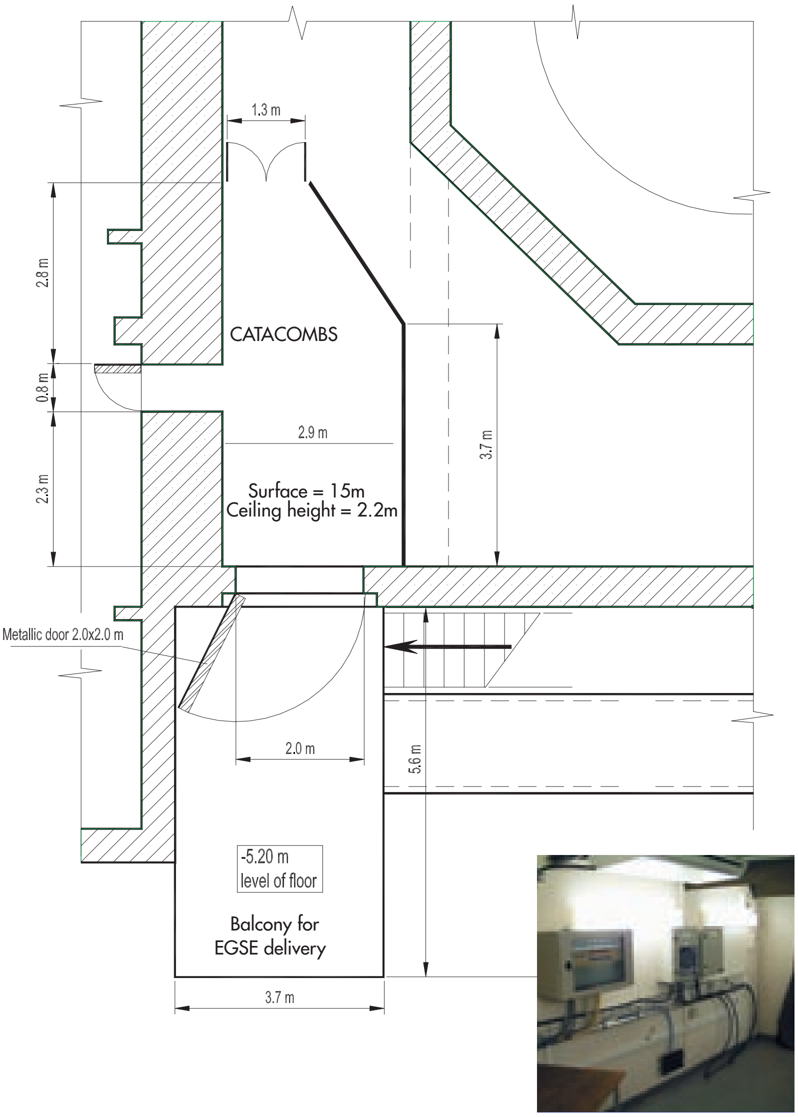
Figure 6-10: Launch Table and Servicing Platforms

6.2.3.2.2. Catacombs

The catacombs (see *Figure 6-11*), which are located under the launch table (see *Figure 6-4*), measure approximately 15 m^2 and have a minimum height of 2.2 m. The catacombs protect the spacecraft EGSE (e.g., Check-out terminal equipment, or COTE) from the environment generated by the launch. This facility is in the "unmanned area" during launch final countdown. The acoustic level inside the catacomb during launch does not exceed 130 dB.

An umbilical harness along the launch mast allows for the connection of user EGSE to flight hardware for spacecraft monitoring and preparation for launch (see *Section 5.3* of *Chapter 5*, Electrical Interfaces).

Figure 6-11: Catacombs Layout



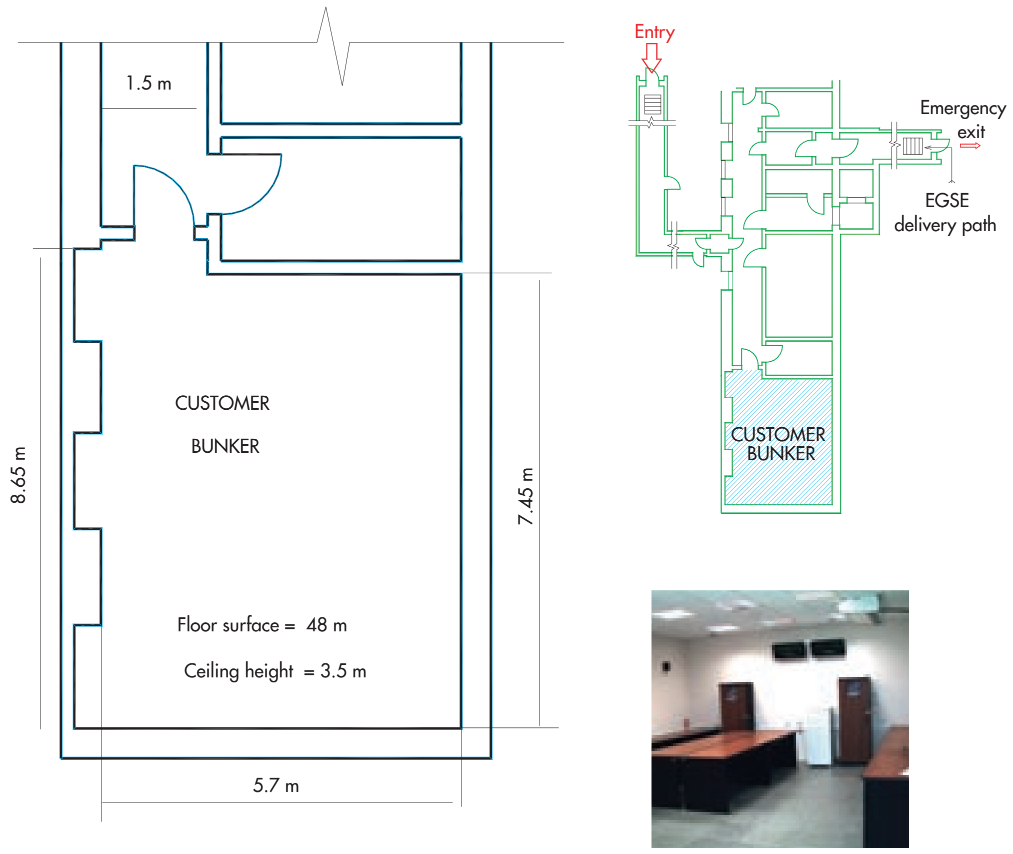
6.2.3.2.3. Customer Bunker

The customer bunker (see *Figure 6-4* and *Figure 6-12*), which is located underground, uses an existing room in one launch pad blockhouse and protects user personnel and EGSE from the environment generated by the LV. The user's EGSE can be arranged to form a control room dedicated to spacecraft processing and monitoring. Alternatively, these personnel and the EGSE may elect to stay in the PPF for such activities.

The spacecraft launch manager or his representative shall be present in the customer bunker during prelaunch and launch activities. Through the operational communications network and dedicated intercom, these individuals remain in contact with Starsem's operations manager throughout all launch pad activities. Through a specific spacecraft readiness panel (SRP) provided by Starsem, they deliver spacecraft readiness and, if necessary, abort commands.

Two videos are available for launch pad monitoring.

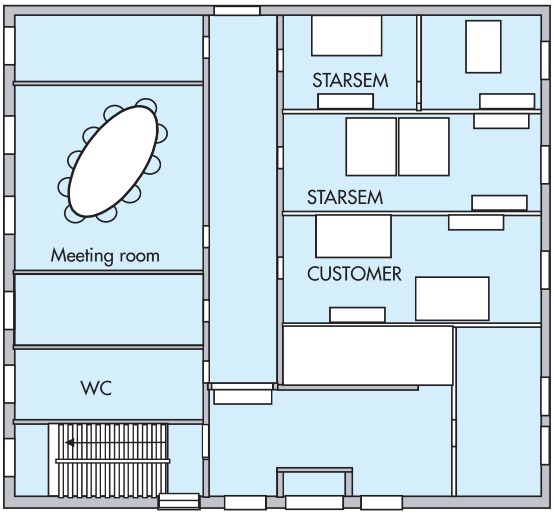
Figure 6-12: Customer Bunker Layout



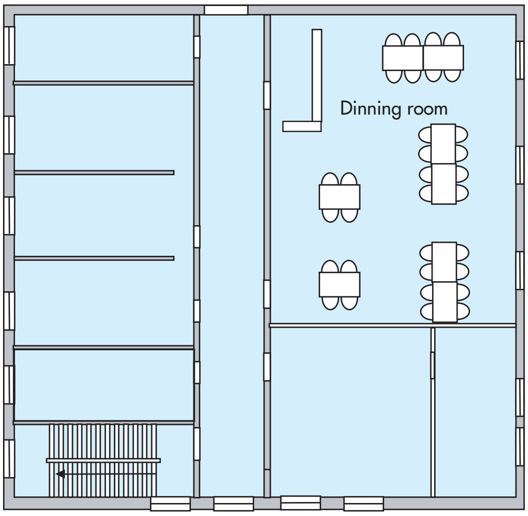
6.2.3.3. Offices in Site 31

One office is available for users in Building 51 (see *Figure 6-13*). The meeting room is dedicated to users and Starsem. A dining room located on the second floor is used during activities in Site 31. This room is converted to a meeting room for the Transfer Readiness Review (TRR).

Figure 6-13: Offices and Dining Room in Building 51 – Site 31



First floor



Second floor

6.3. STARSEM PAYLOAD PROCESSING AND LAUNCH FACILITIES: GENERAL CHARACTERISTICS

6.3.1. ENVIRONMENTAL CONDITIONS

6.3.1.1. Climatic Conditions

The relevant extreme climatic conditions in Baikonur are:

Temperature : –40°C < T < +50°C
Relative Humidity: 10% < r < 100%

6.3.1.2. Environment and Cleanliness of Facilities

Data related to the environment and cleanliness of the various working areas are given in *Table 6-1*.

Table 6-1: Environment and Cleanliness of Facilities

Designation	Particle Cleanliness	Organic Cleanliness	Temperature	Relative Humidity
PPF/HPF/UCIF	100,000*	ESA standard**	17°C < set point < 23°C Accuracy ± 1°C	30%< set point <60% Accuracy ± 10 %
MIK and SSA	N/A	N/A	15°C < T < 30°C	20% < r < 80%
Customer bunker and catacomb	N/A	N/A	15°C < T < 25°C	20% < r < 80%
HSF	N/A	N/A	10°C < T < 40°C	10% < r < 90%
Offices and RCR	N/A	N/A	18°C < T < 28°C	10% < r < 90%

*According to Federal Standard 209.

**ESA PSS-01-705 issue 1 and ESA PSS-01-201 issue 1.

6.3.1.3. Mechanical Environment

During ground activities, most flight hardware transfers are done by railway.
QSLs for container transfers by train (e.g., to and from Yubileyny Airport and MIK 112) are as follows:

- Longitudinal (direction of motion): ± 1g
- Vertical (with respect to the earth): 1g ± 1g
- Transverse: ± 0.4g

Details on the mechanical environment of the spacecraft when it is removed from its container are given in *Chapter 3*.

6.3.1.4. Electromagnetic Environment

The electromagnetic environment in the Cosmodrome is described in *Chapter 3*. The environment is monitored during upper-composite and LV transfers and as well as on the launch pad.

6.3.2. POWER SUPPLY

The PPF, HPF, UCIF, RCR, customer bunker, and catacomb are equipped with an uninterrupted power supply whose main characteristics are described in *Table 6-2*.

Table 6-2: Power Available in Facilities

Category	Category II: Diesel Generators Short Break: 5 min	No Break: Category III
Tolerance	220 V – 5% + 10%	400 V ± 2% (3 phases + neutral)
	50 Hz ± 2 %	50 Hz ± 1 %
Power in Site 112: PPF, HPF, UCIF, and RCR	80 kW	60 kW
Power in launch pad #6: customer bunker and catacomb	20 kW	20 kW

Note: Total available power for customer use is Cat II + Cat III.

A public network (220 V/50 Hz) is available in all SPPLF.

6.3.3. COMMUNICATIONS NETWORK

6.3.3.1. Local Communications

Phone and fax network:

Each office and room in the SPPLF is equipped with phones that are connected both with each other and with the city of Baikonur. Starsem also provides fax machines.

Data network:

The characteristics of the existing wired network are given in *Table 6-3*.

Table 6-3: Data Link Characteristics

Location	Types of Lines	Interface
PPF/ HPF	Optical bus 12 fibers	Adaptable
	Twisted shielded pairs,	Threaded or RJ45
	4 x coax 50 Ω	BNC
PPF/UCIF	Optical bus 12 fibers	Adaptable
	Twisted shielded pairs	Threaded or RJ45
	16 Twisted shielded pairs (75Ω)	BNC
	4 x coax 50 Ω	BNC
PPF/RCR	Twisted shielded pairs	Threaded or RJ45
HPF/RCR	Twisted shielded three conductors	Threaded or RJ45
Bunker/Catacomb	Optical bus 12 fibers	Adaptable
	Twisted shielded pairs	Threaded or RJ45
	16 Twisted shielded pairs (75Ω)	BNC
	4 x coax 50 Ω	BNC
PPF/Bunker	Rf link (microwave station)	X21

Between PPF Site 112 and catacomb Site 31, a redundant RF microwave network with a rate of 1 Mbps is available.

VHF system:

The Cosmodrome is equipped with a VHF network that allows individual handsets to be used for the following communications:

- Conference calls;
- Point-to-point connections; and
- Direct access to the cosmodrome network.

Intercom system:

An independent communications system is available for specific operations such as filling activities, launch pad validation, and launch countdown. This system is based on a specific Starsem network that allows full-duplex conversations between fixed stations in various facilities and six mobile (wireless) UHF kits working in the neighborhood of the UHF fixed stations.

TV network:

The facilities in MIK 112 are equipped with an internal closed-circuit TV network for monitoring, security, and safety activities.

6.3.3.2. International Communications

Access to international communications is provided through an existing cosmodrome network (fax and phones only). The user has the option to rent channels from satellite operators (Eutelsat, Intelsat, Gorizont, etc.) for phone, fax, data, e-mail, Internet, and videoconference communication between Baikonur Cosmodrome and spacecraft control centers anywhere in the world.

6.3.4. TRANSPORTATION AND HANDLING

For all intersite transportation (e.g., transportation to and from Yubileyny Airport and Site 112), spacecraft containers and their associated GSE are placed on open railway platforms under protective covers. The trains' power supply is available for containers' autonomous conditioning system if necessary. A thermostatic wagon with the following characteristics can also be provided:

Maximum capacity: 16 tons
Dimensions: 15 x 3.6 x 3.5 m
Temperature: $15^\circ C < T < 25^\circ C$
Relative Humidity: $10\% < r < 60\%$

A transfer container is available for spacecraft transfers between the PPF, HPF, and UCIF within MIK 112. This container ensures transportation with low mechanical loads and maintains environments equivalent to those of cleanrooms.

Smooth traveling cranes and trolleys are available for spacecraft and GSE transfers inside the PPF, HPF, UCIF, MIK 112, and MIK 40. The capacity of the traveling cranes is 10 tons inside the PPF, HPF, and UCIF and up to 50 tons inside MIK 112 and MIK 40.

6.3.5. FLUIDS AND GASES

Starsem provides standard fluids and gases to support user launch campaign operations. Most such fluids and gases are provided and certified in accordance with Russian standards that are equivalent to Western ones.

A variety of distribution networks are available in the facilities (e.g., industrial water and compressed air). Breathable-air and distilled-water networks are available in the HPF for hazardous operations.

Users typically deliver propellant directly to Baikonur Cosmodrome. Alternatively, a user may opt to deliver propellant to Saint Petersburg harbor, at which point Starsem assumes responsibility for its transportation to Baikonur by train. Starsem may also procure and deliver Western propellant as well as specific fluids and gases to Baikonur.

6.4. LOGISTICS

6.4.1. VISAS AND ACCESS AUTHORIZATION

Starsem will support the user in obtaining entry visas to Russia, including Baikonur Cosmodrome, by providing letters of invitation.

Starsem will provide all user representatives access to the Cosmodrome as well as badges to SPPLF.

6.4.2. SECURITY

Starsem and Cosmodrome authorities maintain strict security measures that are compliant with the most rigorous Western requirements (e.g., the Technical Assistance Agreement, or TAA). Access to the cosmodrome is restricted at the road entrance, and each area is guarded by the Cosmodrome Security.

In Site 112, three levels of security are implemented:

- The first level is situated at the entrance to the building and allows access to office areas.
- The second level is situated at the entrance of MIK 112, where the PPF, HPF, UCIF, and SSAs are located. Starsem issues specific badges with Cosmodrome authority approval.
- The third level is at the door of each cleanroom. Magnetic badges permit access to this facility. Starsem can program badges on a daily basis when so requested. Additional measures (e.g., locks and/or guards) can be added at the user's request.

The cleanrooms and the SSAs are monitored at all times by a video system. Any activity taking place inside these facilities may be recorded if requested.

Any external guards certified by the user may monitor the spacecraft 24 hours a day, including during transportation.

Security procedures can be adapted to the specific requirements of the user.

6.4.3. DAILY SCHEDULE

The standard workweek is six days, Monday through Saturday. Workdays begin at 7:30 a.m., when workers leave the hotel for the Cosmodrome, and end at 6:30 p.m. with the return trip to the hotel. Additional working time or other daily/weekly schedules can be arranged on a case-by-case basis.

6.4.4. PERSONNEL TRANSPORTATION

Starsem provides the following vehicles for personnel transportation as part of scheduled daily work support:

- Two vans with five seats each;
- Two vans with nine seats each; and
- Two buses with 49 seats each.

All vehicles are equipped with air-conditioning systems. If necessary, additional vehicles (e.g., VIP transportation) may be rented in Baikonur. Upon request, and preferably one day in advance, Starsem can provide transportation to meet atypical user needs, including night shifts.

6.4.5. CUSTOMS CLEARANCE

Starsem will support the user in obtaining customs clearances at all ports of entry and exit as required for the transport of spacecraft and associated GSE.

By following Russian rexportation customs procedures and benefiting from international agreements between Russia and Kazakhstan concerning the Baikonur Cosmodrome no customs duties should be imposed on the spacecraft, GSE, or other associated equipment used in the launch campaign. However, administrative fees may be associated with customs clearance in Russia, and these fees are the responsibility of the user. Any customs or export/licensing processes (export license authorization) in the user's country of origin (e.g., Europe) for equipment and propellants are the responsibility of the user. The user will also be responsible for providing all associated packing lists and invoices.

6.4.6. MEDICAL CARE

There is a system in place at the Cosmodrome and in the city of Baikonur that provides all necessary services and equipment for medical care in accordance with an agreement between Starsem and the Baikonur military hospital. If the user so requests, special arrangements can be made with a variety of international medical organizations outside the existing service.

A Russian infirmary located at Site 112 is fully equipped to give medical support. A nurse employed at this site is capable of handling any injuries that might arise. An ambulance and a physician from this hospital are present at the Cosmodrome throughout the campaign.

6.4.7. HOTEL AND FOOD

The Sputnik Hotel (see *Figure 6-14*), located in the city of Baikonur, offers 120 comfortable rooms and 5 suites, one restaurant, a bar club, a fitness center, a conference room, offices, a swimming pool, a sauna, a game room, a hairdresser, mountain bikes, and a variety of other amenities.

Lunch is served at the Cosmodrome in the Starsem restaurant in Site 112 as well as in a dedicated canteen in Building 51, near launch pad no. 6 and MIK 40. This service is part of the support provided by the hotel.

The Sputnik Hotel also has the capability to provide five days' worth of purified water, electricity, and air conditioning in the event of a disruption in the local networks.

Figure 6-14: Sputnik Hotel

6.4.8. TRAINING COURSE

Starsem will provide all training courses for program-specific needs (e.g., safety, propellant team, crane operations, Baikonur-specific constraints for forklift operations, and communication means).

6.4.9. SAFETY

Safety support is provided in accordance with operations analysis throughout the campaign. Safety management rules and submissions are defined in *Chapter 7*.

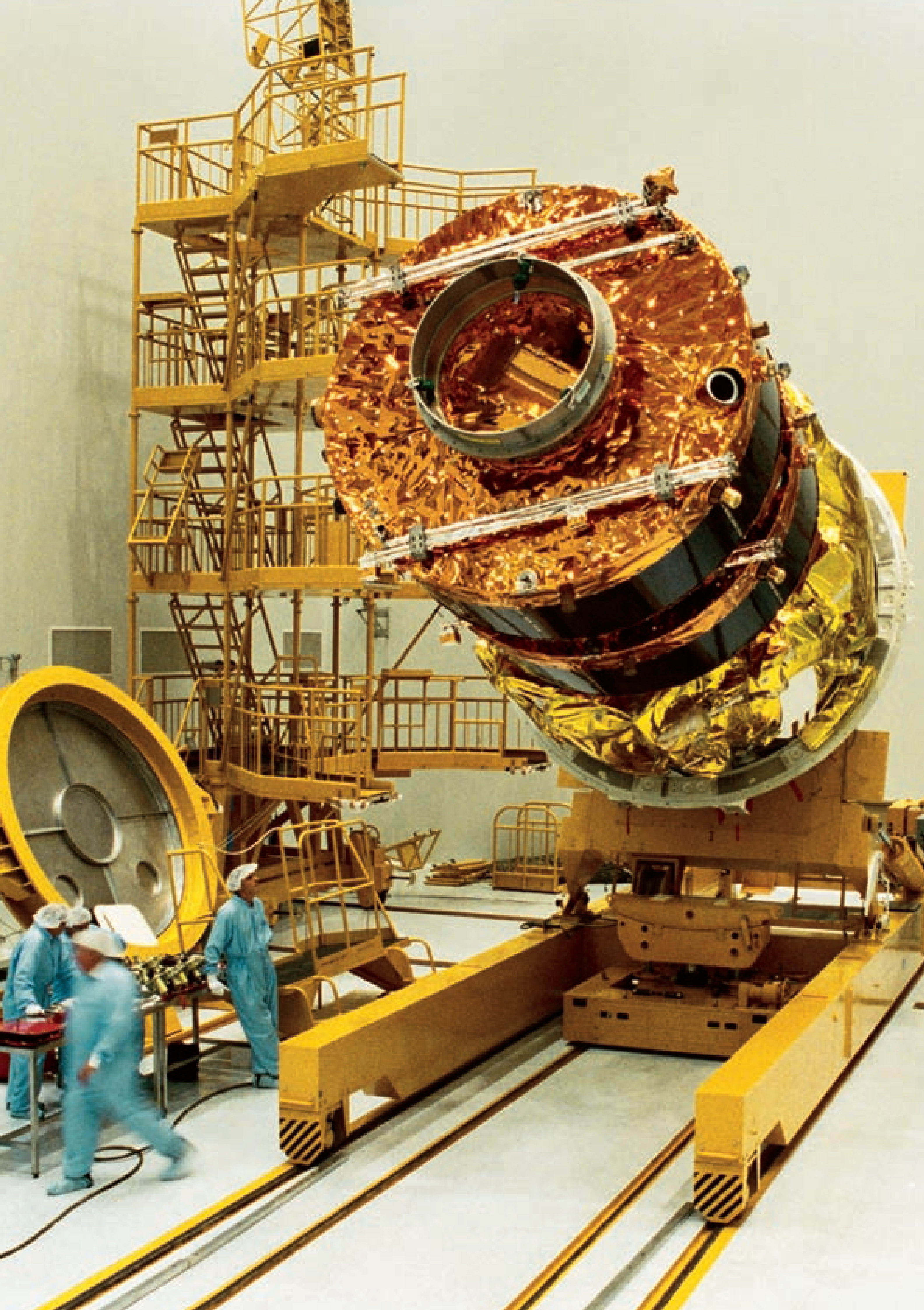
During hazardous operations, a specific safety organization is activated (officers, equipment, fire brigade, etc.).

6.4.10. VIP ACCOMMODATION

During launch, Starsem provides a viewing site 1 km from the launch pad for witnessing of the final chronology and launch.

During the Fregat orbital phase, Starsem provides a meeting room in Building 51 (see *Figure 6-13*) that accommodates up to 10 user VIPs and offers with the following capabilities:

- Display of simulated Fregat flight data during orbital flight;
- An open line with the Fregat upper-stage flight control center; and
- Access to the international phone network (two lines)



CHAPTER 7

MISSION INTEGRATION AND MANAGEMENT

This chapter describes Starsem's approach toward the integration and management of a nonrecurring mission. It comprises seven topics:

- Starsem's overall organization for mission management;
- Definition of the Mission Master Schedule;
- Systems engineering support, which consists of interface management, mission analysis, spacecraft development verification, and postlaunch analysis;
- LV procurement and hardware/software development/adaptation;
- Launch campaign management;
- Safety; and
- Quality assurance.

The contractual commitments between Starsem and the user are defined in the Launch Services Agreement (LSA) and its two annexes, the Statement of Work (SOW), and the Interface Control Document (ICD). Based on the Application to Use Soyuz (AUS) filled out by the user, the SOW identifies the task and deliveries of the parties, and the ICD (see *Section 7.3*) defines the technical interfaces.

The template for the AUS is presented in *Appendix 1*.

7.1. STARSEM ORGANIZATION FOR MISSION MANAGEMENT

To provide the user with efficient mission integration, Starsem provides a single point of contact between the user and Starsem. A Mission Manager appointed for every mission is responsible to the user for all aspects of the mission (technical, financial, and schedule). He is supported by Starsem's technical and contractual staff as well as by Starsem's industrial partners.

For every mission, Starsem issues a dedicated management and quality plan that defines:

- Starsem's organization in relation to the mission;
- The industrial organization of the launch service; and
- The application of Starsem's Quality Manual procedures and regulations to the mission.

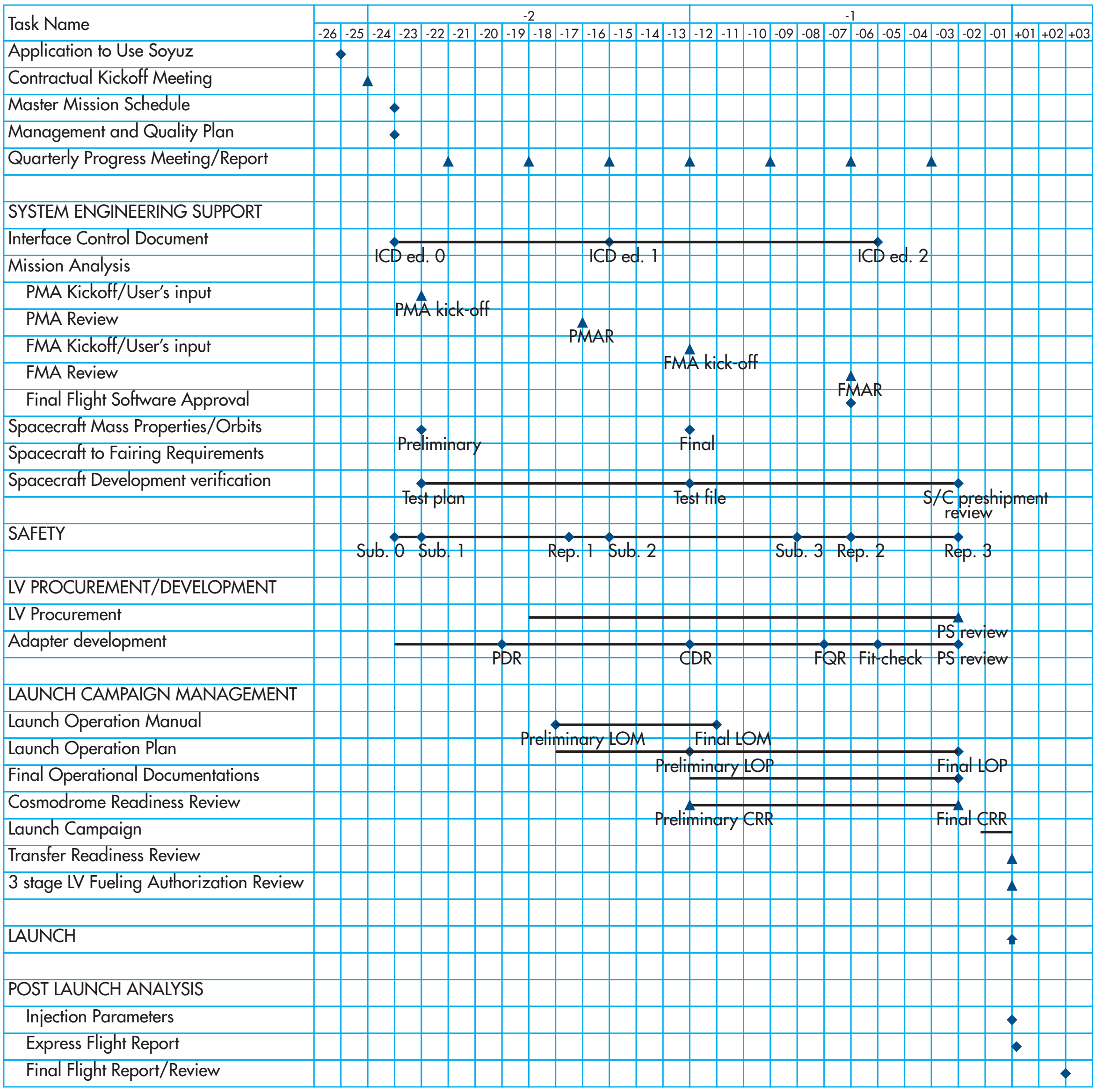
The Mission Manager organizes and manages all contractual reviews and meetings according with the Mission Master Schedule. Starsem and the user will meet as often as necessary to allow for the satisfactory and timely execution of all mission activities. In addition to these meetings, Starsem will conduct Quarterly Progress Meetings that will address mission status, highlight key technical issues and critical points, verify the status of actions, and update the Mission Master Schedule.

7.2. MISSION MASTER SCHEDULE

Starsem will establish a Mission Master Schedule in compliance with the launch dates specified in the LSA. The Mission Master Schedule reflects the time line of the main tasks defined in *Sections 7.3.* to *7.7.* The Mission Master Schedule and its updates are approved by the user.

A typical master schedule for nonrecurring missions is provided in *Figure 7-1*.`

Figure 7-1: Typical Mission Master Schedule



Note: Typically approximately 28 months are needed for specific dispenser development beginning at contract kickoff and ending with dispenser delivery.

7.3. SYSTEMS ENGINEERING SUPPORT

7.3.1. INTERFACE MANAGEMENT

The technical interface management is based on the ICD, which is prepared by Starsem and signed as an annex of the LSA (Edition 0). This document gathers spacecraft and spacecraft mission parameters, outlines the definition of all interfaces between the launch system (LV, operations, and ground facilities) and spacecraft, and illustrates their compatibility.

Nominally, two major updates of the ICD are provided in the course of the mission:

- An update after preliminary mission analysis review (Edition 1); and
- An update after final mission analysis review (Edition 2).

Once approved by both Starsem and the user, this document is maintained under configuration control until launch. In the event of a contradiction, the document takes precedence over all other technical documents.

7.3.2. MISSION ANALYSIS

To design the LV mission and demonstrate the compatibility of the spacecraft with the LV environment, Starsem typically provides the following analyses:

- Trajectory, performance, and injection accuracy analysis;
- Spacecraft separation and collision avoidance analysis;
- Coupled loads analysis (CLA);
- Spacecraft upper-composite clearance analysis;
- Thermal analysis;
- Cleanliness and contamination analysis; and
- Electromagnetic compatibility analysis.

Mission analysis is generally organized into two phases, each linked to spacecraft development milestones and to the availability of spacecraft input data. These phases are:

- Preliminary Mission Analysis (PMA); and
- Final Mission Analysis (FMA).

Each analysis begins with a kickoff meeting. At the completion of each phase, a review designated the Preliminary Mission Analysis Review (PMAR) and the Final Mission Analysis Review (FMAR), respectively, will be held under the joint responsibility of Starsem and the user. The duration of each phase is approximately six months, and the FMAR should be completed no later than four months from the beginning of the launch campaign.

7.3.3. PRELIMINARY MISSION ANALYSIS (PMA)

The purposes of the PMA are as follows:

- To describe the compliance between the LV and the spacecraft;
- To identify all open points in terms of mission definition that shall be closed during the FMA; and
- To evaluate the environment seen by the spacecraft to enable the user to properly qualify it for the LV environment.

The output of the PMA will be used to define the adaptation of the mission, flight, and ground hardware and software or to adjust the spacecraft design or qualification program as needed. Based on the results of the PMAR, the ICD will be updated and reissued as Edition 1.

7.3.3.1. Preliminary Trajectory, Performance, and Injection Accuracy Analysis

The preliminary trajectory, performance, and injection accuracy analysis comprises:

- Definition of the preliminary reference trajectory or set of trajectories if they depend on the launch date and/or LV and spacecraft tracking data;
- Definition of flight sequences up to separation command and deorbitation of the upper stage;
- Evaluation of nominal performance and margins with regard to spacecraft mass and propellant reserves and preliminary assessment of launch mass budget;
- Evaluation of orbit accuracy; and
- Compliance with attitude requirements during flight, if any, and evaluation of attitude accuracy at separation command.

The preliminary trajectory analysis is also used to assess the number of flight programs that will be necessary to ensure compliance throughout the entire launch period.

7.3.3.2. Preliminary Spacecraft Separation and Collision Avoidance Analysis

The preliminary spacecraft separation and collision avoidance analysis comprises:

- Definition of the separation device and the sequence of events;
- Evaluation of the relative velocity between the spacecraft and the LV;
- Clearance evaluation during spacecraft separation; and
- Short- and long-term noncollision prospects after spacecraft separation.

7.3.3.3. Preliminary Coupled Loads Analysis (CLA)

The preliminary CLA allows the user to verify the ground and flight limit loads applicable to the spacecraft with respect to the environment described in *Chapter 3*. It uses a preliminary spacecraft dynamic model provided by the user according to standards specified by Starsem. The preliminary CLA:

- Performs the modal analysis of the LV and its payload, with the outputs used to adjust, if necessary, the parameters of the LV stabilization loop;
- Describes the dynamic responses of the spacecraft for the most severe load cases generated by the LV;
- Provides, at the spacecraft-adapter interface and at nodes selected by the user, the time history of forces, accelerations, and, in the latter case, deflections, enabling the user to update the QSL and sinusoidal vibration environment (see *Tables 3.1* to *3.6*);
- Provides inputs to analyze requests for notching during spacecraft qualification sinusoidal vibration tests; and
- Provides inputs for the launcher measurement plan.

The results of the CLA allow the user to verify the validity of payload dimensioning and to adjust the qualification test plan should this prove necessary.

7.3.3.4. Preliminary Clearance Analysis

A preliminary clearance analysis at the upper composite/spacecraft level is conducted for the most severe cases of the mission to verify the spacecraft accommodation concept. This analysis takes into account:

- Manufacturing and assembly tolerances for the launcher and the spacecraft;
- An estimate of fairing deflection under aerodynamic loads;
- An estimate of upper-composite deflections under QSLs; and
- An estimate of the motion and deflections of the two fairing halves during fairing jettisoning.

The clearance analysis during spacecraft separation is addressed in *Section 7.3.3.2*.

7.3.3.5. Preliminary Thermal Analysis

The preliminary thermal analysis is used to demonstrate spacecraft thermal compatibility throughout the mission, to identify potential areas of concern, and to propose solutions to any problems and concerns that have been identified. This analysis covers both ground operations and flight, especially after fairing jettisoning.

A spacecraft thermal model provided by the user in accordance with Starsem's specifications is used as input for this analysis.

7.3.3.6. Preliminary Cleanliness and Contamination Analysis

The purpose of this analysis is to estimate the various sources of contamination (e.g., outgassing, ACS plume impingement) and to verify compliance with relevant requirements. In cases of specific user requirements, adaptive measures will be implemented. This analysis covers the period from spacecraft delivery to the Cosmodrome up to spacecraft separation.

7.3.3.7. Preliminary Electromagnetic Compatibility Analysis

This study allows Starsem to check the compatibility between the frequencies used by the LV, the ground stations, and the spacecraft during launch operations and flight. The analysis is intended to verify that the spacecraft-generated electromagnetic field is compatible with LV susceptibility levels and vice versa as defined in *Chapter 3* of this manual. The results of the analysis allow users to verify the validity of spacecraft dimensioning and to adjust their qualification test plan should this prove necessary. It also provides inputs to assist in the analysis of requests for notching during spacecraft qualification.

7.3.4. FINAL MISSION ANALYSIS (FMA)

The purpose of the FMA is:

- To fix the mission baseline (launch dates, orbit parameters, spacecraft mass, centering, and inertia properties, attitude during the flight, and LV capabilities) and to validate all data used for the launch trajectory (or set of trajectories) and flight program generation; and
- To demonstrate mission compliance with all spacecraft requirements.

Once the FMA's results have been accepted by the user, the mission is considered frozen. The ICD will be updated and reissued as Edition 2.

7.3.4.1. Final Trajectory, Performance, and Injection Accuracy Analysis

The final trajectory analysis defines and fixes:

- The nominal trajectory or set of trajectories for confirmed launch dates and flight sequences;
- The tracking and ground station visibility plan;
- All vehicle and spacecraft data used to generate the launch trajectory or set of launch trajectories, such as LV mass breakdown, margins with respect to propellant reserves, and spacecraft properties;
- The parameters of the launch trajectory (or set of trajectories) used to generate the flight program;
- Injection orbit accuracy prediction; and
- Specific spacecraft attitude during flight, if any, and attitude accuracy at separation command.

7.3.4.2. Final Spacecraft Separation and Collision Avoidance Analysis

The final spacecraft separation and collision avoidance analysis repeats and confirms the preliminary analysis for the latest configuration data, taking into account:

- The last estimate of spacecraft and LV properties;
- The last estimate of attitude and angular velocities at separation command; and
- Experimental data concerning the separation device.

7.3.4.3. Final CLA

The final CLA updates the preliminary analysis, taking into account the latest model of the spacecraft validated by tests. It provides:

- For the most severe load cases, the final estimate of the forces and accelerations at the interfaces between the adapter and spacecraft and of forces, accelerations, and deflections at selected spacecraft nodes; and
- The final modal model of the LV with the spacecraft, which will be used to verify the stability of the LV control loop.

7.3.4.4. Final Clearance Analysis

The final spacecraft/upper-composite clearance analysis updates the preliminary clearance analysis, taking into account:

- The results of the final CLA;
- Any significant update of payload volume; and
- The results of the spacecraft–adapter/dispenser fit check if available.

7.3.4.5. Final Thermal Analysis

The final thermal analysis takes into account the final thermal model provided by the user. For ground operations, it provides a time history of the temperature at nodes selected by the user and the parameters of air ventilation around the spacecraft. During flight and after fairing jettisoning, it provides a time history of the temperature at critical nodes, taking into account the real attitudes of the LV during the entire launch phase.

7.3.4.6. Final Cleanliness and Contamination Analysis

The final cleanliness and contamination analysis updates the preliminary one, taking into account the results of the actions, if any, taken at the end of the preliminary analysis. Inputs for Cosmodrome operations will be addressed.

7.3.4.7. Final Electromagnetic Compatibility Analysis

The final electromagnetic compatibility analysis updates the preliminary study, taking into account the final launch configuration and final flight sequences.

7.3.5. SPACECRAFT DEVELOPMENT VERIFICATION

7.3.5.1. Spacecraft Design Compatibility

Starsem will support the user in demonstrating that the spacecraft design is able to withstand the LV environment. Toward that goal, Starsem will require the following reports for review and approval:

- ***A spacecraft environment test plan*** correlated with requirements described in *Chapter 4*. Users shall provide a spacecraft environmental test plan to describe their approach to qualification and acceptance tests. This plan is intended to outline the user's overall test philosophy along with an overview of the system-level environmental testing that will be performed to demonstrate the adequacy of the spacecraft for ground and flight loads (e.g., static loads, vibration, acoustics, shock). The test plan shall include test objectives and success criteria, test specimen configuration, general test methods, and a schedule. It shall not include detailed test procedures.
- ***A spacecraft environment test file*** comprising theoretical analysis and test results. Following the system-level structural load and dynamic environment testing, a test file documenting the results shall be provided to Starsem. This file should summarize the testing performed to verify the adequacy of the spacecraft structure for flight and ground loads. For structural systems not verified by test, a structural loads analysis report documenting the analyses performed and resulting margins of safety shall be provided to Starsem.

Starsem wishes to attend the spacecraft qualification and acceptance reviews concerning the structural integrity of the spacecraft and interfaces with the LV.

7.3.5.2. Spacecraft Preshipment Review

The preshipment review, held before shipment of the spacecraft to Baikonur, is organized by the user and attended by Starsem. Starsem's objectives are to verify the last spacecraft data and production files with respect to the ICD. This review makes use of three main inputs:

- Spacecraft readiness;
- Cosmodrome readiness, which is assessed at the Cosmodrome Readiness Review four weeks before the projected start of the launch campaign; and
- LV readiness, which is assessed at the Spacecraft Readiness Review and is based on the current production or operations status. (The preshipment reviews authorizing the shipment of the launcher elements to Baikonur may occur before or after the Spacecraft Preshipment Review, depending on the spacecraft campaign duration.)

7.3.6. POSTLAUNCH ANALYSIS

7.3.6.1. Injection Parameters

During flight, Starsem provides the user with confirmation of spacecraft physical separation:

- In real time if the separation occurs in visibility of the Russian ground-tracking and telemetry stations; and
- At the beginning of subsequent TM transmission session from Fregat if separation occurs outside of visibility zones.

The state vector (velocity, position, attitude) estimate of Fregat just prior to spacecraft separation is provided within 60 minutes after the beginning of TM transmission from Fregat.

7.3.6.2. Express Flight Report

Starsem provides the user with an Express Flight Report within seven days after launch. This report will include flight event sequences, an evaluation of LV performance, and injection orbit and accuracy parameters with regard to requirements.

7.3.6.3. Final Flight Report and Postflight Review

Starsem provides the user with a Final Flight Report within 60 days after launch. This report will include flight event sequences, LV performance, injection orbit and accuracy, separation attitude and rates, records for ground and flight environment, and on-board system status during flight. The specific Postflight Review will be organized as requested.

7.3.6.4. Launch Mission Failure Analysis

In the event that the launch mission is not completely successful, Starsem will perform an immediate and comprehensive failure investigation. The results, corrective actions, and recommendations of this investigation will be presented to the user at the earliest possible opportunity.

7.4. LAUNCH VEHICLE PROCUREMENT AND HARDWARE/SOFTWARE DEVELOPMENT/ADAPTATION

As part of its launch services, Starsem procures the following flight items:

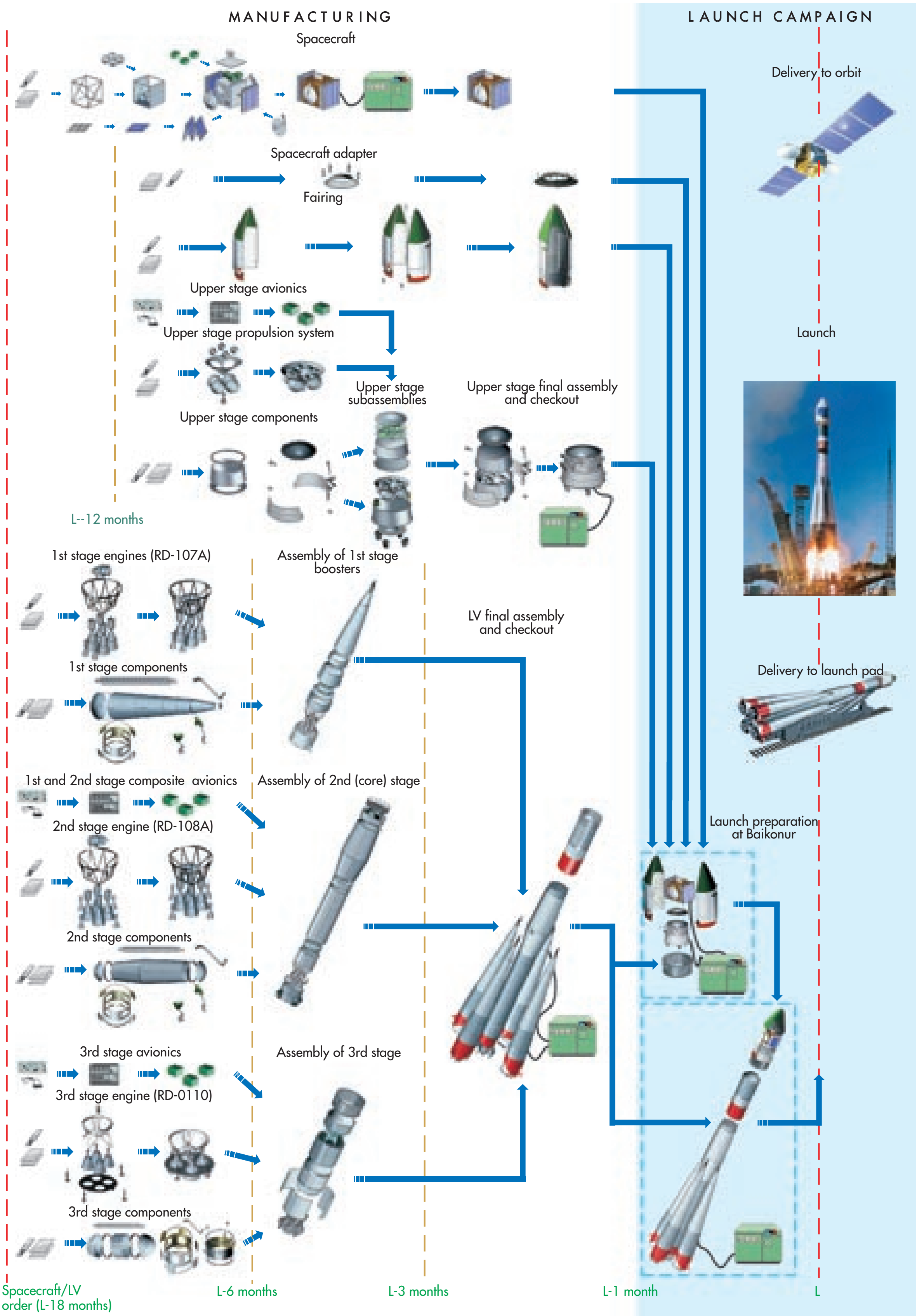
- One three-stage launch vehicle and Fregat upper stage;
- Dedicated flight programs;
- One customized fairing with adjusted radio-transparent windows and access doors; and
- One adapter/dispenser with separation system, umbilical harnesses, and instrumentation.

If any components of the LV need to be modified (due to specific mission requests, the output of mission analysis, etc.), modifications, in terms of specification, definition, and justification, will be implemented in accordance with standard quality rules. The user will be involved in this process.

Starsem will ensure that standard development procedures will be applied to all newly developed hardware such as the adapter/dispenser. Toward that goal, Starsem will invite the user to participate in the preliminary design review (PDR), critical design review (CDR), and flight qualification review (FQR).

Before shipment to the launch site, every recurrent "level one" component of the LV (Soyuz three-stage vehicle, Fregat, nose fairing, adapter or dispenser) will be submitted to a preshipment review. During these reviews, all changes, nonconformities, and waivers encountered during production and acceptance tests will be presented and justified. The reviews are Starsem's responsibility, and the user is invited to attend.

Figure 7-2: Production Cycle



7.5. LAUNCH CAMPAIGN

7.5.1. INTRODUCTION

The launch campaign formally begins with the delivery in Baikonur of the spacecraft and its associated GSE and concludes with GSE shipment after launch. Prior to the launch campaign, the preparation phase takes place, during which time all operational documentation is issued and the facilities' compliance with users' needs is verified. The Spacecraft Preshipment Review (see *Section 7.3.5.2*) authorizes the shipment of the spacecraft to Baikonur

During the campaign, Starsem provides support for all spacecraft autonomous activities and manages all LV and combined operations. Starsem's launch campaign organization and facilities offer significant flexibility for spacecraft preparation and launch. The typical launch campaign duration is approximately five weeks but can be adjusted to meet users' needs. The typical launch rate is one every four weeks, but this can also be adjusted on a case-by-case basis. The configuration of the separated facilities within MIK 112 allows two spacecraft programs to be managed in parallel.

Starsem's Launch Campaign Manager serves as the user's interface for all activities conducted during the launch campaign at the Baikonur Cosmodrome. He or she bears overall responsibility as well as legal responsibility for the campaign. The Launch Campaign Manager reports to Starsem management (a hierarchical link) and to the Mission Manager (an operational link) and is appointed six months prior to the Cosmodrome Readiness Review.

7.5.2. LAUNCH CAMPAIGN PREPARATION AND SUPPORT DOCUMENTATION

During the launch campaign preparation phase, Starsem issues the following documentation based on the user's launch operations manual:

- An operations plan;
- An operations master schedule;
- Master procedures; and
- A countdown manual.

The preparation phase is formally brought to a close by the Cosmodrome Readiness Review.

7.5.2.1. Operations Plan

Based on the customer launch operations manual and on the ICD, Starsem shall issue an operations plan that will outline all information relevant to launch campaign preparation, to include:

- An operations scenario from spacecraft delivery through launch pad activities;
- A description of all operations (both autonomous and combined) related to the preparation of the spacecraft for launch and to LV activities interfacing with the spacecraft;
- A list of all reviews and significant milestones and their associated dates, sequenced with operations;
- Identification of all nonreversible spacecraft and LV activities;
- Identification of all hazardous operations involving the spacecraft and/or LV activities along with associated actions (restrictions, personnel training, etc.); and
- A list of all relevant master procedures.

7.5.2.2. Operations Master Schedule

Based on the operations plan, Starsem shall prepare an operations master schedule to serve as the reference plan for campaign processing, to include:

- All operations and reviews identified in the operations plan;
- All constraints on the above-mentioned operations;
- A reference for each operation to the relevant master procedure and associated responsibilities; and
- Critical path and contingency information.

Where necessary, this document will be updated during the campaign to reflect the true status of the work.

7.5.2.3. Master Procedures

In a multicultural background, the master procedures, which are bilingual documents (English and Russian), ensure that the activities associated with on-site processing operations are properly coordinated. Based on the operations plan, Starsem shall prepare master procedures that include:

- Identification of related operations with reference to the working operations procedure;
- A comprehensive description of all activities performed in the context of each master procedure;
- A description of the required sequence of the above-mentioned activities;
- Identification of the above-mentioned activities' associated responsibilities;
- Identification of all required support and GSE from Starsem and from the user that are not identified in the working operations procedure; and
- Identification of all constraints on both Starsem and user activities.

7.5.2.4. Countdown Manual

Based on the customer's launch operations manual, Starsem, in coordination with the user, shall establish a countdown manual that gathers all information relevant to countdown processing, to include:

- A detailed countdown sequence flow, including all communication exchanges (instruction, readiness status, progress status, parameters, etc.) performed on launch day;
- Go/No-Go criteria;
- The communications network configuration;
- A list of all authorities who will interface with the customer, including launch team members' names and functions; and
- The launch abort sequence.

7.5.2.5. Cosmodrome Readiness Review (CRR)

The Cosmodrome Readiness Review, conducted in Baikonur Cosmodrome as part of Starsem's responsibilities, is a prerequisite for the delivery of spacecraft and associated GSE to Baikonur. A preliminary review is performed at least one year before launch in order to identify all open issues.

The Cosmodrome Readiness Review addresses the following main points:

- The readiness of Baikonur Cosmodrome facilities to support all planned activities, particularly specific customer requests, communication and data transmission, safety support, and logistics;
- The approval of the operational documentation;
- The approval of Starsem's and the customer's organization within the framework of the launch campaign, particularly organizational charts, the presentation of each function, individuals involved and their presence on site, and workday planning;
- The delivery of the safety regulations compliance certificate (end of safety submission phase three); and
- The approval of the logistics and public relations plan.

The review may comprise an overall visit and audit of Cosmodrome facilities.

7.5.3. KEY MILESTONES AND LAUNCH CAMPAIGN REVIEWS

In addition to a daily coordination meeting held between Starsem and the user, key milestones and formal reviews are carried out.

7.5.3.1. Key Milestones During Launch Campaign

During autonomous operations on the LV and on the spacecraft as well as during combined operations, key milestones are defined in order to monitor and control the progress of the launch campaign. At each key milestone, a certificate is issued to authorize the next operation. The main key milestones are as follows:

Key milestones related to facilities readiness:

- PPF readiness before user activities in the PPF;
- HPF readiness before user activities in the HPF;
- UCIF readiness before user activities in the UCIF;
- Transfer wagon readiness before upper-composite transfer from MIK 112 to MIK 40;
- MIK 40 readiness before LV final integration;
- Transfer wagon readiness before LV transfer from MIK 40 to the launch pad;
- Launch pad readiness before launch pad preparation; and
- Launch pad readiness before LV transfer to the launch pad.

Key milestones related to hardware readiness:

- Spacecraft readiness before hazardous activities (certificate provided by the user);
- Spacecraft readiness before filling (certificate provided by the user);
- Spacecraft readiness before combined operations (certificate provided by the user);
- Adapter readiness before spacecraft mating;
- Stack (spacecraft and adapter) readiness before mating on the Fregat;
- Fregat readiness before the stack is mated to it;
- Fairing readiness before encapsulation;
- Nose module readiness before fairing encapsulation;
- Upper Composite readiness before transfer from MIK 112 to MIK 40;
- Upper Composite readiness before integration on the LV; and
- Soyuz three-stage readiness before Upper Composite integration.

7.5.3.2. Transfer Readiness Review (TRR)

A Transfer Readiness Review is held before the transportation of the fully integrated LV to the launch pad, usually the day before rollout. The purpose of the review is to authorize the transfer of the LV to the launch pad and to authorize final launch preparation. This review is held in two successive sessions.

- The first session is organized and cochaired by Starsem and the user and is intended to provide a detailed presentation on the status of the mission.
- The second session is organized and led by the Rosaviacosmos Authority (Russian State Commission) and is cochaired by Starsem and the user; it is intended to provide formal authorization for transfer and start the final launch preparation.

The review covers:

- Launch data and a review of the FMAR conclusions;
- A synthesis of previous launch campaign operations;
- Any nonconformities and waivers encountered during the launch campaign;
- A report on the readiness of the spacecraft, GSE, and user communications network;
- A report on the readiness of the LV;
- A report on the readiness of Cosmodrome facilities (launch pad, communications and tracking network, weather forecast, EMC status, general support services);
- An overview and organizational description of launch pad activities; and
- A review of logistics and public relations activities.

7.5.3.3. 3-Stage LV Fueling Authorization Review (FAR).

A Fueling Authorization Review is held 4 hours and 20 minutes before launch to authorize the filling of the lower 3 stages of the LV and to pursue the final countdown and launch. This review is organized and led by the Rosaviacosmos Authority (Russian State Commission) and is cochaired by Starsem and the user. The following points will be addressed during this review:

- Flight hardware nonconformities and waivers encountered during pad activities;
- A report on the readiness of the LV;
- A report on the readiness of the range facilities (launch pad, communications and tracking network, weather forecast, EMC status, general support services); and
- A report on the readiness of the spacecraft, user's GSE, and spacecraft communications network and control center

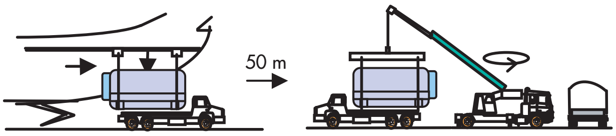
7.5.4. TYPICAL LAUNCH CAMPAIGN

7.5.4.1. Launch Campaign Scenario

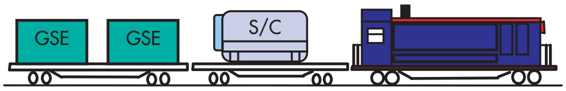
Figure 7-3 describes the events that comprise a typical launch campaign.

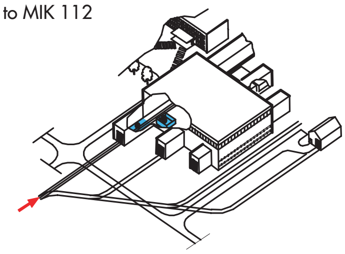
Figure 7-3: Typical Launch Campaign Scenario

1 Arrival at Yubileiny airport

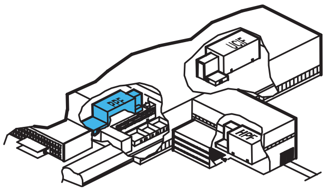


2 Yubileiny airport activities
Preparation for transfer to MIK 112

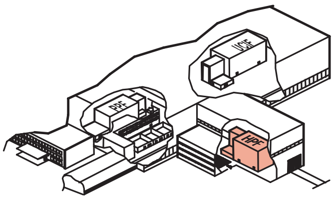




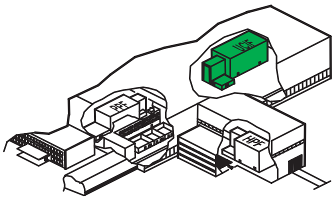
3 Containers transfer to MIK 112



4 Spacecraft autonomous preparation
PPF HPF - UCIF



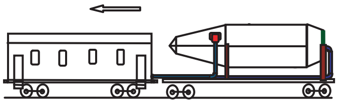
5 Spacecraft filling (HPF)



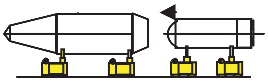
6 Upper Composite integration (UCIF)

Spacecraft Autonomous Processing

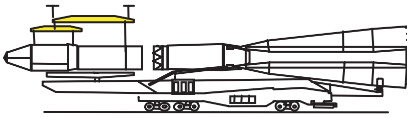
Combined Operations



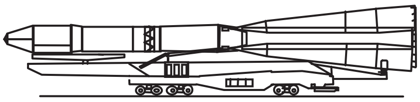
7 Upper Composite transfer to
MIK 40



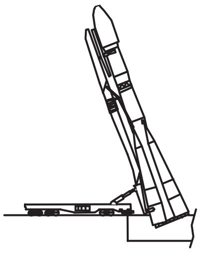
8 Upper Composite integration
with LV third stage



9 Launch Vehicle final integration



10 Launch Vehicle transfer to Launch Pad



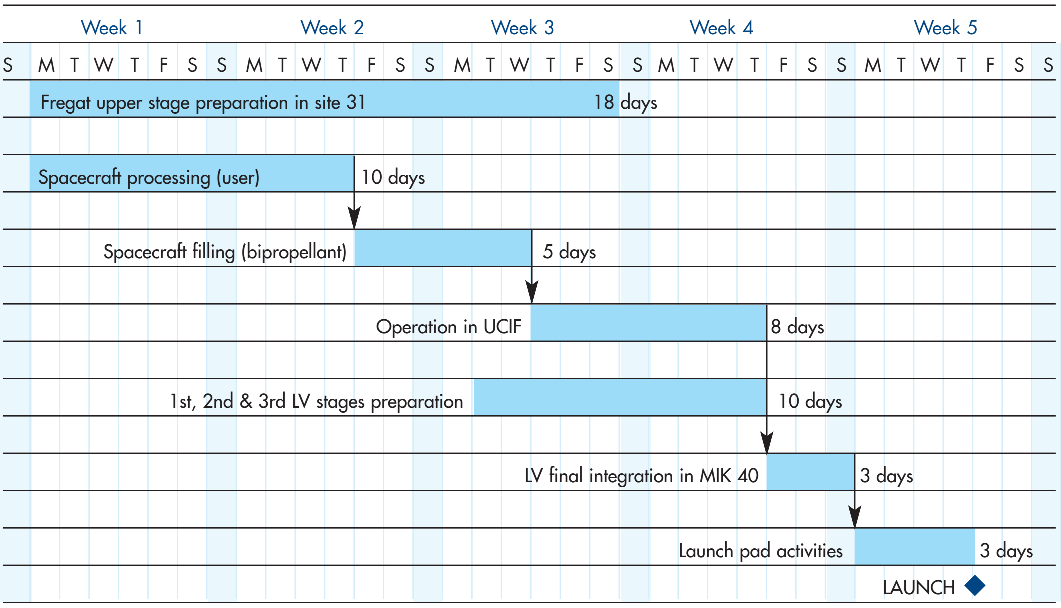
11 Launch Vehicle set-up
on Launch Pad

12 - Preparation & Launch

7.5.4.2. Launch Campaign Time Line

A typical launch campaign time line is shown in *Figure 7-4*. Typical launch campaign duration is five weeks.

Figure 7-4: Typical Launch Campaign Time Line



7.5.4.3. Spacecraft Processing

7.5.4.3.1. Spacecraft and GSE Transport (Steps 1, 2, and 3)

The spacecraft and its associated GSE arrive at the Baikonur Cosmodrome at Yubileyny Airport. Unloading and handling activities, which are carried out with Starsem support, are performed by means of the aircraft with the aid of Starsem equipment. Starsem can provide transport service for the delivery of the spacecraft and its associated GSE to Baikonur.

The spacecraft and GSE are transferred by train or by road from the airport to MIK 112, where they are unloaded, dispatched, and stored in dedicated areas. The duration of this transfer is approximately five hours by train at 10 km/h. Upon their arrival in Baikonur, the propellant drums are stored in the HSF.

7.5.4.3.2. Spacecraft Preparation (Step 4)

Autonomous operations and checks of the spacecraft are carried out either in the PPF or in the HPF or UCIF. These activities include:

- Installation of the spacecraft checkout equipment, connection to the Starsem PPF, and validation;
- Removal of the spacecraft from containers and deployment in cleanrooms;
- Spacecraft assembly and functional tests;
- Spacecraft transfer between Starsem PPFs; and
- Battery charging.

The duration of such activities varies with the nature of the payload and its associated tests.

7.5.4.3.3. Spacecraft Filling (Step 5)

Spacecraft filling (see *Figure 7-5*) is performed in the HPF. Dedicated milestones will authorize the beginning of filling operations. Typical flow activities will then be performed, to include:

- Supply, infrastructure support, and determination of spacecraft readiness for filling operations;
- Setup of spacecraft filling equipment and associated verification;
- Setup of propellant transfer tanks;
- Filling of the spacecraft with propellants and pressurization; and
- Transfer of the spacecraft to the UCIF.

Hazardous operations management and control are carried out from the Remote Control Room. The activities conducted in the PPF and HPF are carried out by the user with Starsem's support. Starsem ensures safety in all such activities.

Figure 7-5: Filling Activities

7.5.4.4. Launch Vehicle Processing

7.5.4.4.1. Preparation of the Lower Three Stages of the Launch Vehicle

The four strap-on boosters (Soyuz first stage), the central core in two parts (second stage), and the Soyuz third stage are unloaded from the train and installed on integration trolleys. The second stage is assembled, and the four boosters are then attached to the central core. Autonomous and combined tests are performed on the first, second, and third Soyuz stages. These activities are conducted in parallel with the spacecraft activities in MIK 112.

7.5.4.4.2. Fregat Upper-Stage Preparation

The Fregat upper stage is unloaded from the train and installed on its stand inside MIK 40, where the following operations are performed:

- Fregat autonomous verification;
- Fit check of the adapter/dispenser (mechanical and electrical) with the Fregat; and
- Filling of the Fregat at the Site 31 filling station and transfer to the UCIF in MIK 112.

These activities are performed in parallel with spacecraft autonomous activities.

7.5.4.4.3. Fairing Processing

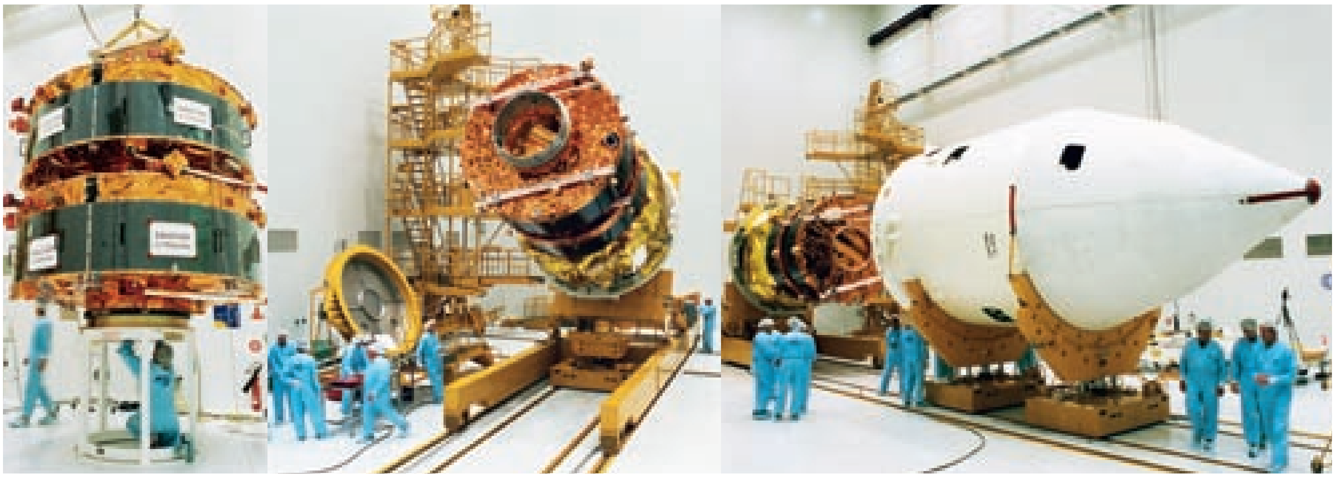
After the fairing is unloaded from the train, it is installed with its protective cover on a dedicated stand inside MIK 112 in standby configuration for the beginning of encapsulation activities in the UCIF.

7.5.4.5. Operations in the UCIF (step 6)

The UCIF is the "rendezvous" point for the spacecraft, the adapter/dispenser, the Fregat upper stage, and the fairing with its adapter. The following activities are typically performed in the UCIF (see *Figure 7-6*):

- Adapter/dispenser verification before spacecraft mating;
- Final preparation of the spacecraft;
- Mating of the spacecraft onto the adapter/dispenser (spacecraft stack) and associated verification;
- Delivery of the Fregat upper stage and preparation for receipt of the spacecraft stack;
- Integration of the spacecraft stack on the Fregat and associated verification;
- Encapsulation, which consists of:
    - Assembly of two half-fairings into one piece in the horizontal position;
    - Tilting of the Fregat, with its interstage section and its spacecraft stack, into the horizontal position;
    - Alignment of the fairing and the Fregat, interstage section, and spacecraft stack;
    - Horizontal translation of the fairing on railway trolleys, enveloping the spacecraft stack and the Fregat;
    - Completion and verification of separation-system installation and encapsulation; and
- Upper-composite preparation and transfer to the Launch Vehicle Assembly and Integration Building, MIK 40, in the horizontal position. For this transfer, the upper composite is installed on a designated transfer wagon. The ventilation under the fairing is provided by a dedicated air-conditioning system installed on a mobile wagon in the transfer train. Environmental characteristics are given in *Chapter 3*.

Figure 7-6: UCIF Activities



7.5.4.6. Launch Pad Preparation Activities

The setup of spacecraft EGSE and the verification of the launch pad ground segment are performed as early as possible in the campaign. A countdown chronology rehearsal based on the launch countdown should be conducted as well to allow staff to familiarize themselves with nominal and abort procedures.

7.5.4.7. Final LV integration in MIK 40 (steps 7, 8, and 9)

After its arrival in MIK 40, the upper composite is placed on an assembling trolley in front of the launcher third stage. The upper composite is then mated with the launcher third stage (see *Figure 7-7*).

The first- and second-stage assembly is transferred onto the transport and erection wagon for final integration of the LV. The assembled upper composite and the third stage are then mated with the first- and second-stage assembly onto the transport and erection wagon.

For LV transfer to the launch pad, the ventilation under the fairing is provided by a dedicated air-conditioning regulation system installed on a mobile wagon in the transfer train. Relevant environmental characteristics are given in *Chapter 3*.

A Transfer Readiness Review is organized at the end of LV preparation, usually one day before rollout.

Figure 7-7: Final LV Integration

7.5.4.8. Launch Pad Activities

7.5.4.8.1. Typical Nominal Flowchart

A typical flowchart of launch pad activities is described below.

First day on launch pad (see *Figure 7-8*):

- LV transfer from MIK 40 to the launch pad;
- LV erection into the vertical position;
- LV connection to the launch pad (umbilical, ventilation, filling pipes, etc.);
- Spacecraft preparation and checkout;
- Three-stage LV countdown rehearsal; and
- Activation of LV and Fregat TM systems for full RF compatibility verification.

Second day on launch pad:

- LV filling preparation;
- Upper-composite launch countdown rehearsal; and
- Other spacecraft activities if needed.

Third day on launch pad (countdown chronology):

- LV preparation for launch;
- LV propellant filling operations; and
- Final countdown.

Figure 7-8: Launch Vehicle Transfer and Setup on Launch Pad.

7.5.4.8.2. Launch Countdown

Table 7-1 shows major events in the countdown chronology on launch day.

Table 7-1: Launch Countdown Chronology

Time Before Liftoff	3-Stage LV Status	Fregat Upper Stage Status	Spacecraft Status
08:00:00	Communications network verification	Communications network verification	Communications network verification Spacecraft launch preparation
07:30:00	Beginning of 3-stage LV preparation	Fregat and GSE verifications	
06:30:00	3-stage LV TM verification	Fregat TM verification	
05:35:00	Control system verification		
05:10:00		Beginning of Fregat launch readiness setting	
04:25:00	3-stage LV readiness for fueling	Fregat readiness for 3-stage LV fueling.	Spacecraft readiness for 3-stage LV fueling
04:20:00	FAR before 3-stage LV fueling		
04:05:00	Initation of 3-stage LV fueling		
01:20:00	Completion of 3-stage LV fueling		
00:55:00		Fregat TM "on"	
00:45:00		Low-flow-rate air-conditioning system "on" (STVVD) / high-flow-rate air-conditioning system "off" (VSOTR)	
00:30:00	Service platform removal		
00:15:00	LV TM "on"		Spacecraft switching to onboard power supply
00:10:20		Fregat status "ready"	Spacecraft status "ready"
00:05:20	3-stage LV status "ready"		
00:05:10	N_2 purge of propellant feedlines	Fregat transfer to onboard power	
00:03:20	End of propellant ventilation and filling of feedlines		
00:02:35	Tank pressurization	Fregat umbilical connector drop-off	Spacecraft umbilical connector drop-off
00:00:45	3-stage LV transfer to onboard power supply	Low-flow-rate air-conditioning system "off" (STVVD)	
00:00:20	Launch command		
00:00:17	Engine Ignition		
00:00:15	Preliminary thrust level		
00:00:07	Intermediate thrust level		
00:00:03	Full thrust level		
00:00:00	LIFTOFF		

The launch window varies with the spacecraft mission profile.
Hold can be managed in accordance with the spacecraft launch window.

7.5.4.8.3. Launch Postponement

Three different situations must be considered for launch postponement, depending on the decision time:

- **Decision before LV fueling (L – 4 hours, 20 minutes):** The new launch date can be scheduled within ten days following LV installation on the pad.
- **Decision after beginning of fueling sequence (L – 4 hours, 20 minutes) and before the Launch command:** The new launch date can be rescheduled within 24 hours of the first launch attempt:
  - In the event of a launch abort after upper-composite umbilical dropoff (L – 2 minutes, 35 seconds), reconnection will occur within 1 hour and 30 minutes. The last instant connector (limited number of links between EGSE and spacecraft) remains connected until LV liftoff (for details, see *Section 5.3.1*).
  - In the event of an abort after L – 45 minutes, the ventilation under the fairing (low-flow-rate air-conditioning system [STVVD]) is maintained or turned back on within 2 minutes (when abort occurs within the last minute before liftoff). The high-flow-rate air-conditioning system (VSOTR) is reconnected a maximum of 1 hour and 45 minutes after abort.
- **Decision after launch command:** The launcher must be removed from the pad for refurbishment. After the spacecraft is set into a safe mode, LV removal operations are executed in the reverse order of the scenario used for setup.

Following L – 10 minutes 20 seconds, a spacecraft non-readiness status signal manually sent by the user (by turning of key on the Spacecraft Readiness Panel located in the Customer Bunker) will automatically stop the countdown sequence. The user can stop the final countdown sequence until L – 20 seconds. Spacecraft readiness is established by the user's Launch Director or his/her representative, taking into account spacecraft status as monitored through the umbilical and through reports from satellite control centers in accordance with the criteria described in the customer launch operations manual.

7.5.4.8.4. Go/No-Go Criteria

Go/No-Go criteria are based on the verification and readiness of the flight hardware, on the availability and readiness of the ground segment, and on meteorological constraints.

Starsem is responsible for LV readiness and for authorization for launch. This depends on the flight hardware readiness criteria provided by the Soyuz console as well as on automatic verification procedures carried out during countdown and visual launcher inspection with a periscope. Ground segment readiness is also reported (range services, tracking and communications network, safety activity on the Baikonur Cosmodrome and in the drop areas).

The launch will be aborted or postponed in the event of the following meteorological conditions:

- Thunderstorm;
- Air temperature out of the range of –40° to +50° C;
- For the following wind velocity and velocity gradient constraints:
  - Wind at ground level (10 m): if it exceeds 15 m/sec at launch time; or
  - Wind at 6- to 16-km altitude: if it exceeds 40–50 m/sec with a gradient higher than 15 m/s per km.

The Baikonur meteorological service continuously monitors the launch site weather and provides all necessary forecasts.

7.5.4.9. Cosmodrome Postlaunch Activity

The postlaunch process by which user GSE is packaged and removed from the cleanroom and associated offices is planned within five working days after launch. Shipment is planned within 10 days after launch. At least two months in advance, the user shall provide a full shipping list of GSE to be returned. This scenario can be arranged on a case-by-case basis.

7.6. SAFETY

7.6.1. GENERAL

Starsem is responsible for the implementation of safety regulations and for ensuring that these regulations are observed. All transportation and ground activities that involve spacecraft and GSE hazardous systems require the approval of Starsem's Safety Manager. In order to obtain this approval, users must demonstrate that their hazardous equipment and its utilization comply with Starsem's safety regulations.

The following documents specify the safety requirements applicable to Starsem facilities and Soyuz LV users and extend the definitions provided hereafter:

- RDS-001. safety regulations - Starsem launch services at Baikonur - General rules; and
- RDS-002. safety regulations - Starsem launch services at Baikonur - Specific Rules - Spacecraft.

Safety demonstration is accomplished in a number of steps through the submission of documents defining and describing hazardous elements and their processing. Submission documents are prepared by the user and are sent to Starsem. At each step and with Cosmodrome authority support, Starsem then verifies the compliance of spacecraft hazardous systems and processing with Starsem safety regulations.

7.6.2. SAFETY SUBMISSION

The user must provide a specific safety submission that is divided into different numbers of phases depending on the project. The following time schedule for formal safety submissions shows the requested deadlines working backwards from launch date L.

Table 7-1: Safety Submission Time Schedule

Typical Schedule	Safety Submissions
Before contract signature	Phase 0 preliminary submission
Contract signature	Phase 1 submission of the design of the spacecraft and description of hazardous systems
PMAR (see Section 7.3.3)	End of Phase 1 submission
As soon as available	Phase 2 submission of the hardware definition and the validation plan for all the identified hazardous systems of the spacecraft. The qualification and acceptance documentation showing compliance with the validation plan should be provided. Preliminary spacecraft operations procedures at Cosmodrome should also be provided.
FMAR (see Section 7.3.4)	End of Phase 2 submission
CRR - 6 months	Phase 3 submission of the final description of operational procedures with spacecraft hazardous systems
CRR (see Section 7.5.2)	Issuance of Safety Regulation Compliance Certificate

* Note: Dedicated meetings between Starsem's safety manager and the user are recommended after Starsem's response to submission phases to address the open safety submission sheet.

Each step will be studied by Starsem's safety manager and will be formally approved. Final spacecraft safety compliance will be stated in a Safety Regulation Compliance Certificate approved both by Starsem and by the user.

Phases 1 and 2 can be combined depending on the design status of the systems.

7.7. QUALITY ASSURANCE

Starsem quality rules and procedures are defined in the company's Quality Manual, which is compliant with the ISO 9001:2000 standard. The application of the Quality Manual to each subcontractor is described in the dedicated Starsem Product Assurance Requirements Applicable to Contractors document. Major subcontractors are certified in accordance with state and industry standards that comply with international requirements of the ISO 9001:2000 standard. Their quality system is proven by the number of flights accomplished and by the long evolutionary history of the launch system. It should be noted that the same quality rules are applied to the three-stage Soyuz as for manned flights.

The application of the Quality Manual to each dedicated mission is described in the Management and Quality Plan.

7.8. REVIEW AND DOCUMENTATION CHECKLIST

7.8.1. DOCUMENTATION PROVIDED BY STARSEM

No.	Title	Section	Delivery Dates in Months	User's Approval
1	Preliminary Mission Master Schedule	7.2.	To +1	Yes
	Mission Master Schedule Updates	7.2.	Quarterly	Yes
2	Mission Management and Quality Plan	7.1.	To+1	—
3	Quarterly Progress Report	7.1.	Quarterly	—
4	ICD Version #0	7.3.1.	To	Yes
	ICD Version #1	7.3.1.	To+9	Yes
	ICD Version #2	7.3.1.	L - 5	Yes
5	Preliminary Mission Analysis Document (PMAD)	7.3.3.	To+8	—
	Final Mission Analysis Document (FMAD)	7.3.4.	L - 6	—
6	Safety Phase 1 Reply	7.6.2.	To+6	—
	Safety Phase 2 Reply	7.6.2.	L - 6	—
	Safety Phase 3 Reply	7.6.2.	L - 2	—
7	Preliminary Operation Plan	7.5.2.1	To+12	Yes
	Final Operation Plan	7.5.2.1	L - 2	Yes
8	Operations Master Schedule	7.5.2.2	L - 2	Yes
9	Master Procedures	7.5.2.3	L - 2	Yes
10	Countdown Manual	7.5.2.4	L - 2	Yes
11	Injection Parameters	7.3.6.1	Injection +1 hour	—
12	Express Flight Report	7.3.6.2	L+7 days	—
13	Final Flight Report	7.3.6.3	L + 2	—

Note: To = Contractual Kickoff Meeting L = Liftoff

7.8.2. DOCUMENTATION PROVIDED BY THE USER

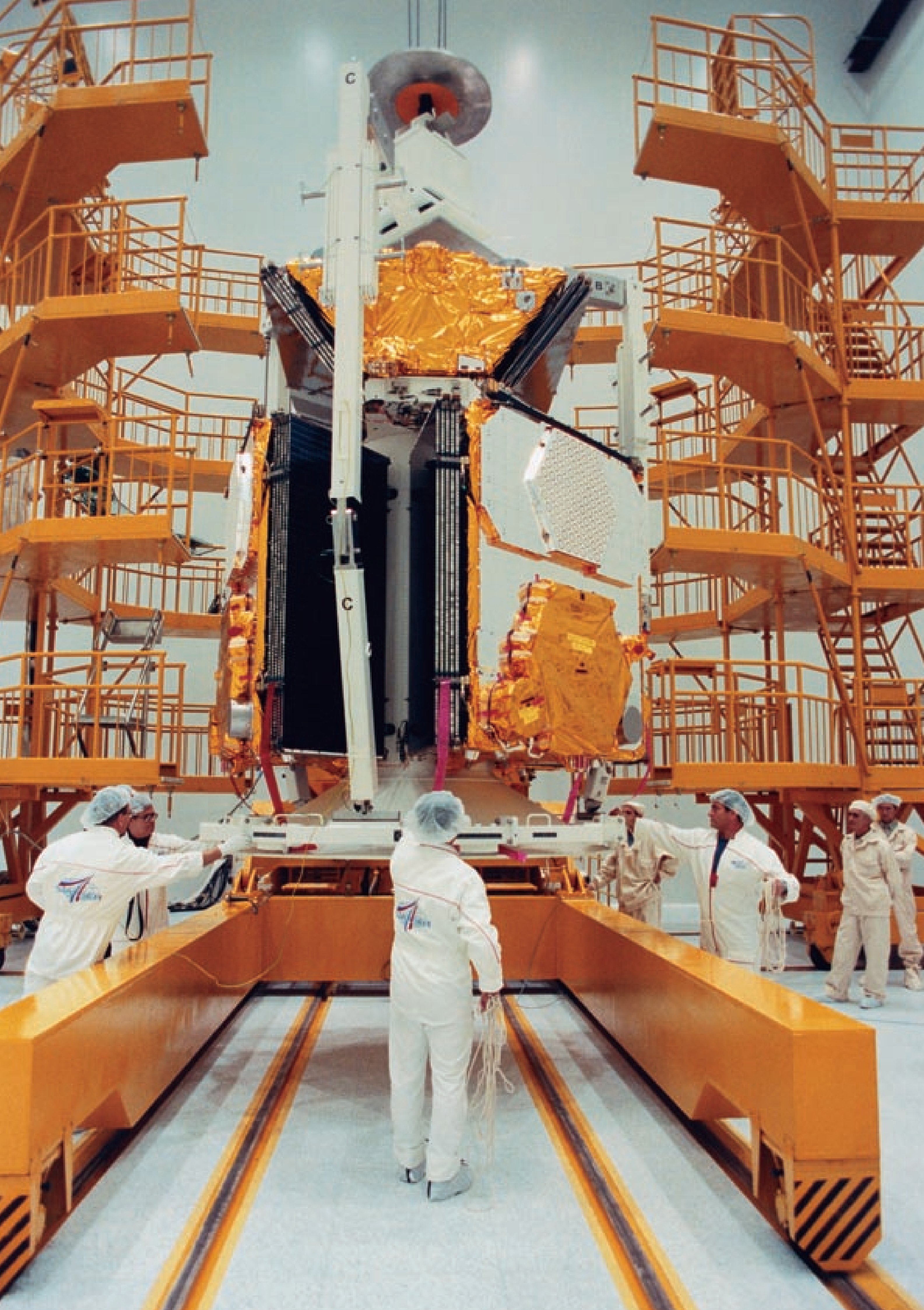
No.	Title	Section	Delivery Dates in Months	Starsem's Approval
1	Application to Use Soyuz	App. 1	To -1	—
2	Preliminary Spacecraft Mass Properties	7.3.3.	To +1	—
	Final Spacecraft Mass Properties	7.3.4.	L - 12	—
3	Spacecraft Environment Test Plan	7.3.5.	To +1	Yes
4	Spacecraft Environment Test File	7.3.5.	L - 12	Yes
5	Preliminary Spacecraft Dynamic Model	7.3.3.	To +1	—
	Final Spacecraft Dynamic Model	7.3.4.	L - 12	—
6	Preliminary Spacecraft Thermal Model	7.3.3.	To +1	—
	Final Spacecraft Thermal Model	7.3.4.	L - 12	—
7	Preliminary Spacecraft CAD Model	7.3.3.	To +1	—
	Final Spacecraft CAD Model	7.3.4.	L - 12	—
8	Preliminary Orbit Specification	7.3.3.	To +1	—
	Final Orbit Specification	7.3.4.	L - 12	—
9	Spacecraft Radio System Inputs for EMC	7.3.3.	To +1	—
10	Spacecraft to Fairing Requirements (Windows, Insignia)	5.2.	L - 15	—
11	Safety Submission Phase #0	7.6.2.	To	Yes
	Safety Submission Phase #1	7.6.2.	To +1	Yes
	Safety Submission Phase #2	7.6.2.	L - 15	Yes
	Safety Submission Phase #3	7.6.2.	L - 8	Yes
12	Preliminary Launch Operation Manual	7.5.2	To +6	—
	Final Launch Operation Manual	7.5.2	L - 11	—

Note: To = Contractual Kickoff Meeting L = Liftoff

7.8.3. MEETINGS AND REVIEWS LIST

No.	Title	Section	Dates in Months	Organized by
1	Contractual Kickoff Meeting	7.2.	To	Starsem
2	Quarterly Progress Meetings	7.1.	Quarterly	Starsem
3	Preliminary Mission Analysis Kickoff Meeting	7.3.3	To +1	Starsem
	Preliminary Mission Analysis Review	7.3.3	To+8	Starsem
4	ICD Edition 1 Signature Review	7.3.1.	To+9	Starsem
5	Final Mission Analysis Kickoff Meeting	7.3.4.	L - 12	Starsem
	Final Mission Analysis Review	7.3.4.	L - 6	Starsem
6	ICD Edition 2 Signature Review	7.3.1.	L - 5	Starsem
7	Spacecraft Qualification Review	7.3.5.	As defined	User
	Spacecraft Acceptance Review	7.3.5.	As defined	User
	Spacecraft Preshipment Review	7.3.5.	L - 2	User
8	Adapter Preliminary Design Review	7.4.	To +6	Starsem
	Adapter Critical Design Review	7.4.	L - 12	Starsem
	Adapter Qualification Review	7.4.	L - 8	Starsem
	Adapter Preshipment Review	7.4.	L - 2	Starsem
9	LV Preshipment Review	7.4.	L - 2	Starsem
10	Preliminary Cosmodrome Readiness Review	7.5.2.5	L - 12	Starsem
	Final Cosmodrome Readiness Review	7.5.2.5	L - 2	Starsem
11	Transfer Readiness Review	7.5.3.2	L - 4 days	Starsem
12	LV Filling Authorization Review	7.5.3.3	L	Starsem
13	Postflight Review	7.3.6.3	L+2	Starsem

Note: To = Contractual Kickoff Meeting L = Liftoff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APPENDIX

1

APPLICATION TO USE SOYUZ

A 1.1. BRIEF SPACECRAFT DESCRIPTION AND MISSION SUMMARY

MANUFACTURED BY	MODEL
MASS	DIMENSIONS
Total mass at liftoff: kg	Base and height stowed for launch:
CoG location:	m
XG= m YG= m ZG= m	Container size: m

ORBIT DESCRIPTION	Separation orbit	Spacecraft final orbit (if different)
Perigee altitude:	± km	± km
Apogee altitude:	± km	± km
Semimajor axis:	± km	± km
Eccentricity:	±	±
Inclination:	± deg	± deg
Argument of perigee:	± deg	± deg
RAAN:	± deg	± deg
Minimum altitude requirements for coast phase / parking orbit	km	

LAUNCH WINDOW(S) REQUIREMENTS:

Targeted launch period:

Solar aspect angle, eclipse:

SUBSYSTEMS: brief description of propulsion (solid/liquid), attitude control, battery types, etc.

MISSION SUMMARY: characterization of the payload

ΔV to provide by spacecraft to reach final orbit: m/sec

Spacecraft injection time limitation (if any): h

Ground station visibility requirements:

Maximum aerothermal flux: W/m^2

SPECIAL REQUIREMENTS: purging, cleanliness, etc.

Include a 3D-view drawing of the spacecraft in stowed configuration with an exploded view and exact locations of main equipment with coordinate system. Preferably, a 3D model should be supplied.

A 1.2. MANEUVER REQUIREMENTS AND DESCRIPTION

A 1.2.1. ATTITUDE CONTROL DURING FLIGHT

Any particular constraint that the spacecraft faces leading up to injection in the separation orbit should be indicated.

A 1.2.2. SEPARATION CONDITIONS

A 1.2.2.1. Separation attitude

The desired direction of the spacecraft longitudinal axis is to be indicated.

A 1.2.2.2. Separation mode and conditions

Indicate spinning or three-axis stabilization (tip-off rates, depointing, etc., including limits).

A 1.2.3. SEQUENCE OF EVENTS AFTER SEPARATION UNTIL FINAL ORBIT

Describe main maneuvers from separation until final orbit, including apogee firing schedule.

A 1.3. SPACECRAFT CHARACTERISTICS

A 1.3.1. MASS ALIGNMENT INERTIA AND FUNDAMENTAL MODES

The data required here are for the spacecraft during injection. The CoG coordinates should be given in spacecraft axes with the origin of the axes at the separation plane; the coefficients of the inertia matrix should be given as well. For each parameter, a tolerance should be given. Also indicated will be:

- The maximum dynamic imbalance in degrees (if applicable); and
- The fundamental modes (lateral, longitudinal).

A 1.3.2. PROPELLANT/PRESSURANT CHARACTERISTICS

Also indicated will be:

- The propellant type;
- The position of the CoG and the volume of each tank;
- The propellant mass in each tank, fill fraction, propellant density, and pulsation/effective masses (slosh model);
- The pressurant gas type and mass in each of the propellant tanks; and
- The pressurant gas mass in each pressurant tank.

A 1.4. MECHANICAL INTERFACE

A 1.4.1. SPACECRAFT–ADAPTER INTERFACE

A 1.4.1.1. Interface Geometry

Provide a drawing with detailed dimensions and nominal tolerances showing:

- The spacecraft interface ring;
- The area allocated for spring actuators and pushers;
- Umbilical connector locations and supports;
- The area allocated for separation sensors (if any);
- Equipment in close proximity to the separation clamp band (superinsulation, plume shields, thrusters); and
- The energy of separation and the energy released in the umbilical connectors (for distancing analysis).

A 1.4.1.2. Interface Material Description

For each spacecraft mating surface in contact with the Soyuz adapter and clamp band, indicate material, roughness, flatness, surface coating, rigidity (frame only), inertia and surface (frame only), and grounding.

A 1.4.2. SPACECRAFT ACCESSIBILITY REQUIREMENTS THROUGH FAIRING

Indicate items on the spacecraft to which access and RF windows are required through the fairing, and give their exact locations in spacecraft coordinates.

A 1.5. ELECTRICAL INTERFACES

Provide the following:

- A spacecraft and EGSE entrance circuit description and diagram as well as a definition of umbilical connectors and links (indicate voltage and current during launch preparation as well as at plug extraction if any);
- A block diagram showing line functions on the spacecraft side and the EGSE side;
- Data link requirements on ground (RF band and data network);
- A description of additional links used after spacecraft mating on the LV;
- The location of the spacecraft ground potential reference on the spacecraft interface frame; and
- Electrical link requirements (data, power, etc.) during flight between the LV and spacecraft.

A 1.6. RADIOELECTRICAL INTERFACES

Provide the following:

- Spacecraft transmit and receive systems (telemetry and command) — for each, give the function, band, carrier frequency (MHz), bandwidth around the carrier frequency (–3dB and –60 dB), carrier modulation and polarization, local oscillator frequencies, emitted power, and timeline of operation;
- Antenna diagrams and location;
- Spacecraft emission spectrum and susceptibility levels;
- Satellite ground station network — indicate the geographic location (latitude, longitude, and altitude) and the radio-electrical horizon for TM and telecommand; and
- Spacecraft visibility requirements from ground stations.

A 1.7. ENVIRONMENTAL CHARACTERISTICS

Provide the following:

- Thermal and humidity requirements (including limits) of environment during launch preparation and flight phase;
- Dissipated power under the fairing during ground operations and flight phase;
- Contamination characteristics and constraints; and
- Purging requirements (if any).

A 1.8. OPERATIONAL REQUIREMENTS

Provide the following:

- Spacecraft limitations with regard to horizontal handling;
- A main operations list and description (including launch pad activities) and estimated timing (with hazardous operation identification);
- Power requirements (voltage, amps, phases, frequency, standard or no break category) for spacecraft ground equipment;
- Facility equipment requirements;
- Environmental requirements (T, relative humidity, cleanliness) for all ground operations (cleanrooms and under fairing);
- RF and hard-line link requirements;
- Telecommunications requirements (telephone, facsimile, data lines, time code, telex, etc.);
- Transportation requirements (with dimensions and weights of any of nonstandard containers)
- A definition of the spacecraft container and associated handling device (constraints);
- A definition of the spacecraft lifting device;
- A definition of spacecraft GSE (dimensions and interfaces required);
- Hazardous item storage requirements (propellants and pyrotechnic devices);
- Fluid and propellant requirements (quality and quantity, analysis to be performed, safety garments); and
- Miscellaneous — e.g., estimating packing list, technical support equipment, and hotel and transportation requirements.

A 1.9. SPACECRAFT DEVELOPMENT PLAN

Provide the following:

- Spacecraft test plan: define the qualification policy, vibrations, acoustics, shocks, protoflight or qualification model;
- Requirements for test equipment (adapters, clamp-band volume simulator, etc.);
- Tests on the customer's premises; and
- Test at the range.

A 1.10. HAZARDOUS SYSTEM DESCRIPTION

The user should prepare a file containing all the documents necessary to detail his plans with respect to hazardous systems. The user must respond to all questions on the hazardous-items checklist given in the document "Starsem Safety Regulations."

APPENDIX

2

OFF-THE-SHELF ADAPTERS/DISPENSERS

A 2.1. ADAPTER 1194-SF

Adapter 1194-SF was developed by EADS Launch Vehicles within the framework of the Cluster II launch services program and is currently flight-proven on the Soyuz LV (three successul flights were performed in 2000). The adapter is an aluminum monolithic structure that takes the form of a truncated cone with a diameter of 1194 mm at the level of the spacecraft separation plane (see *Figure A 2 - 1* to *Figure A 2 - 5*). Its minimal height (230 mm) enables users to save as much space as possible in the volume under the fairing allocated to the spacecraft itself.

Adapter 1194-SF is equipped with a Saab 1194A separation system (a standard Ariane device). The spacecraft installed on top of the adapter is secured by a clamp band consisting of an iron strip that holds in place a series of clamps hooked onto the spacecraft and adapter interfacing frames (see *Figure A 2 - 5*). At separation, the band is severed in two places by a bolt cutter mounted on the adapter, with all pieces remaining captive to the adapter. The release shock spectrum at the spacecraft/adapter interface is indicated in *Figure A 2 - 6*. The spacecraft is then forced away from the launcher by 4–12 spring actuators (4 in the case of the Cluster II mission) that are also part of the adapter and that bear on the spacecraft rear frame (see *Figure A 2 - 7*). In this way, the relative velocity between the spacecraft and the launcher can be adjusted to mission requirements. Once the clamp band has been installed and the springs have been released, each actuator applies a maximum force of 1200 N on the spacecraft rear frame with a ±24 N tolerance. Note that the clamp band tension does not exceed 30,100 N at any time, including dispersions due to temperature variations on ground and in flight. This ensures that no gapping or sliding occurs between the spacecraft and adapter interfacing frames during all phases of the mission.

The angular positioning of the spacecraft with respect to the adapter is ensured by the alignment of engraved marks on the interfacing frames at a specified location to be agreed on with the user.

Adapter 1194-SF is equipped with a set of sensors that are designed to monitor the spacecraft environment. Standard equipment includes two three-axis acceleration sensors as well as one three-axis high-frequency vibration sensor. All sensor outputs are processed by the Fregat telemetry system (TMC-M6).

Adapter 1194-SF also holds the electrical harness that is necessary for umbilical links as well as for separation orders and telemetry data transmission from and to the Fregat. This harness will be tailored to user needs, with its design depending on the required links between the spacecraft and the launcher (see *Section 5.3*).

Adapter 1194-SF can be used with spacecraft whose mass and CoG are below the curve provided in *Figure A 2 - 8*. Its mass depends on the equipment mounted for the specific application in consideration but in all cases remains lower than 110 kg.

Figure A 2 - 1: Adapter 1194-SF on Its Integration Support Inside the Upper Composite Integration Facility

Figure A 2 - 2: Adapter 1194-SF General Dimensions

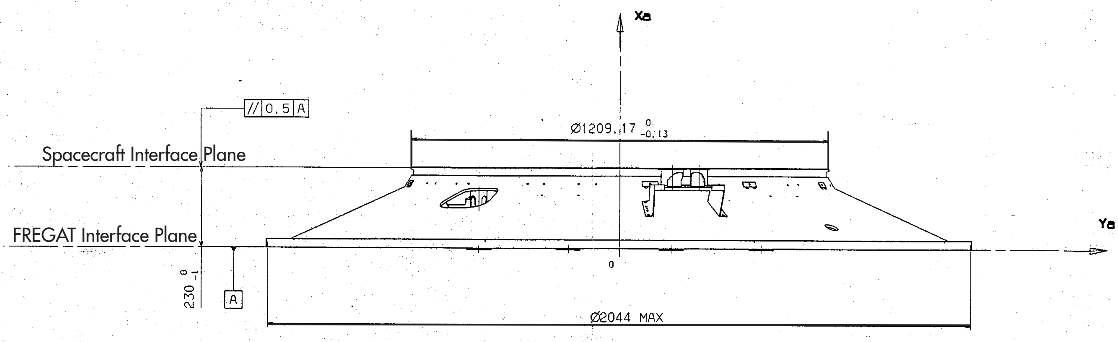
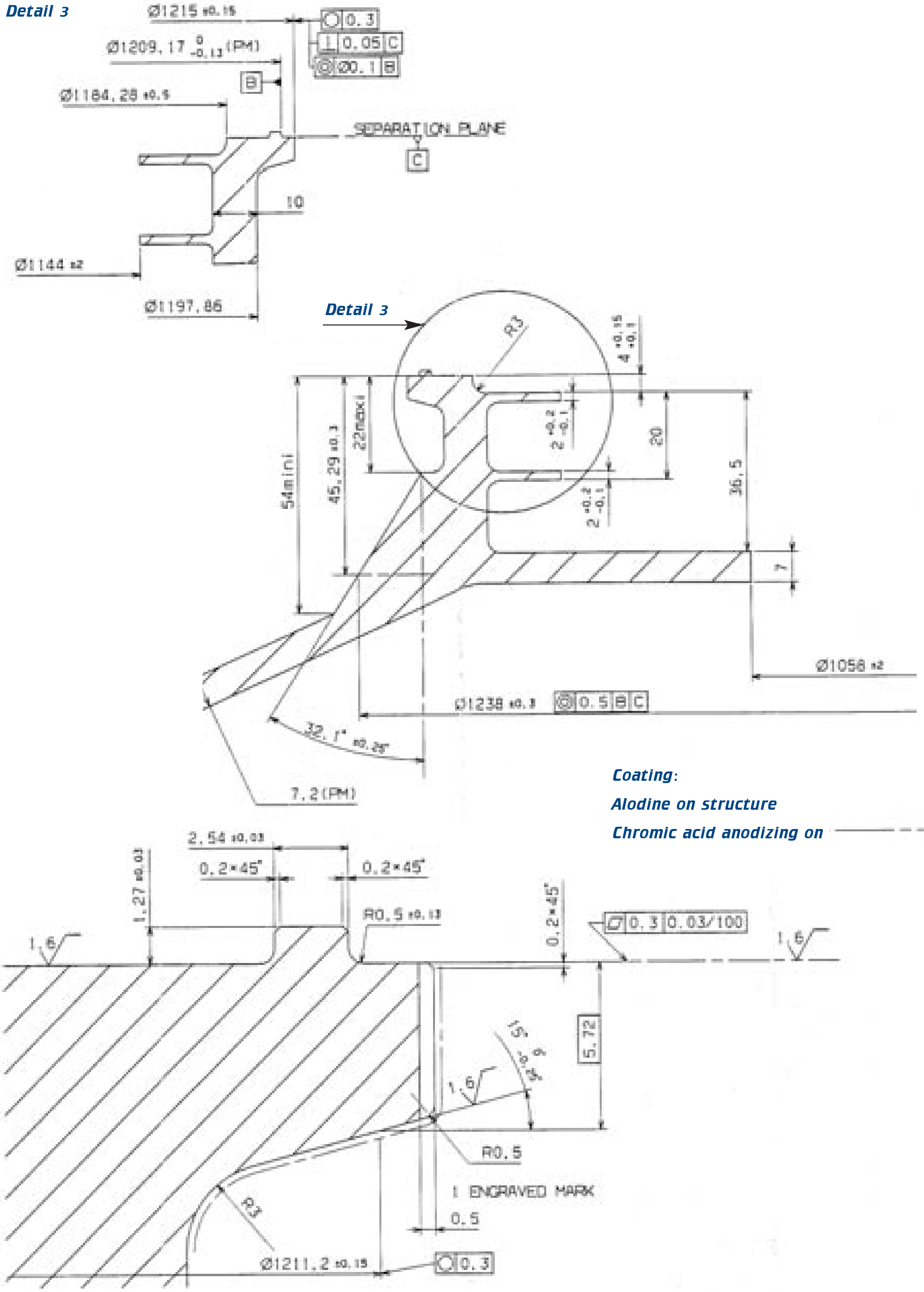


Figure A 2 - 3 : Adapter 1194-SF/Spacecraft Mechanical Interface (Adapter Side)

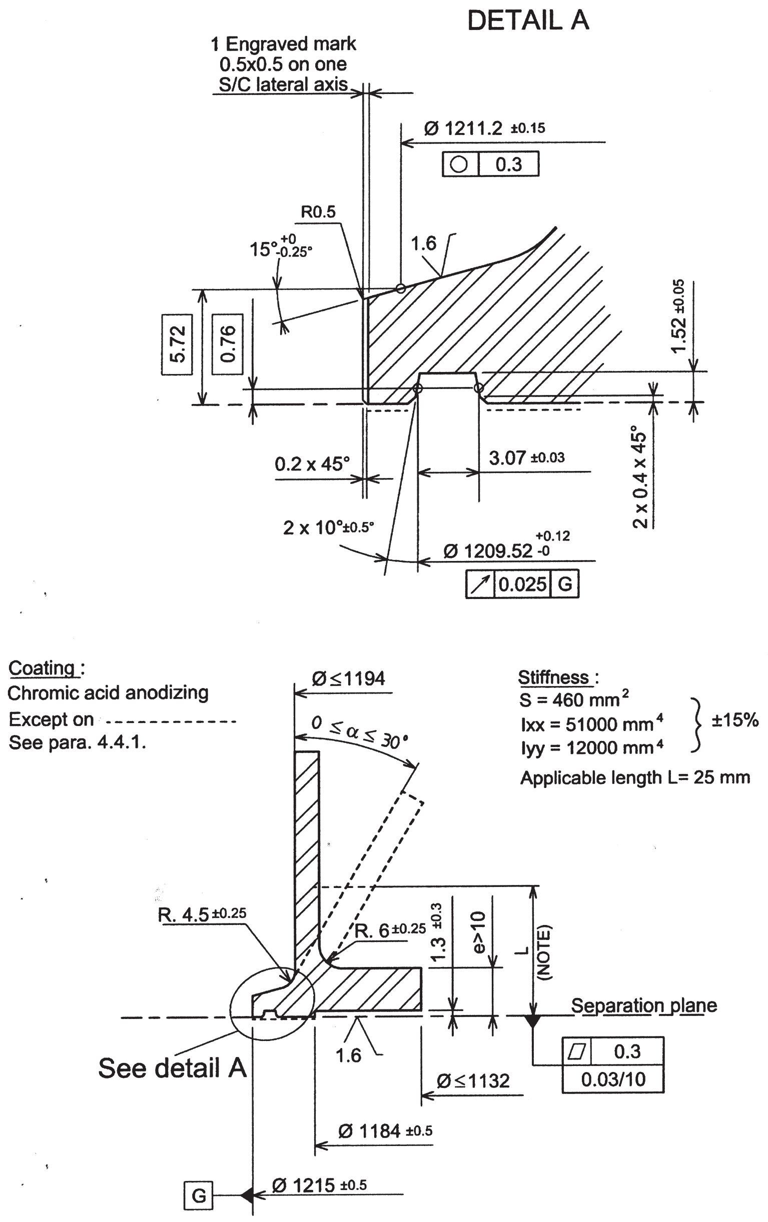


Coating:

Alodine on structure

Chromic acid anodizing on

Figure A 2 - 4: Adapter 1194-SF/Spacecraft Mechanical Interface Requirements (Spacecraft Side)



Coating :
Chromic acid anodizing
Except on - - - - - - - - - - - -
See para. 4.4.1.

Stiffness :
S = 460 mm²
Ixx = 51000 mm⁴ } ±15%
Iyy = 12000 mm⁴
Applicable length L= 25 mm

Figure A 2 - 5: Clamp Band Saab 1194A Installed on Equipped Adapter 1194-SF

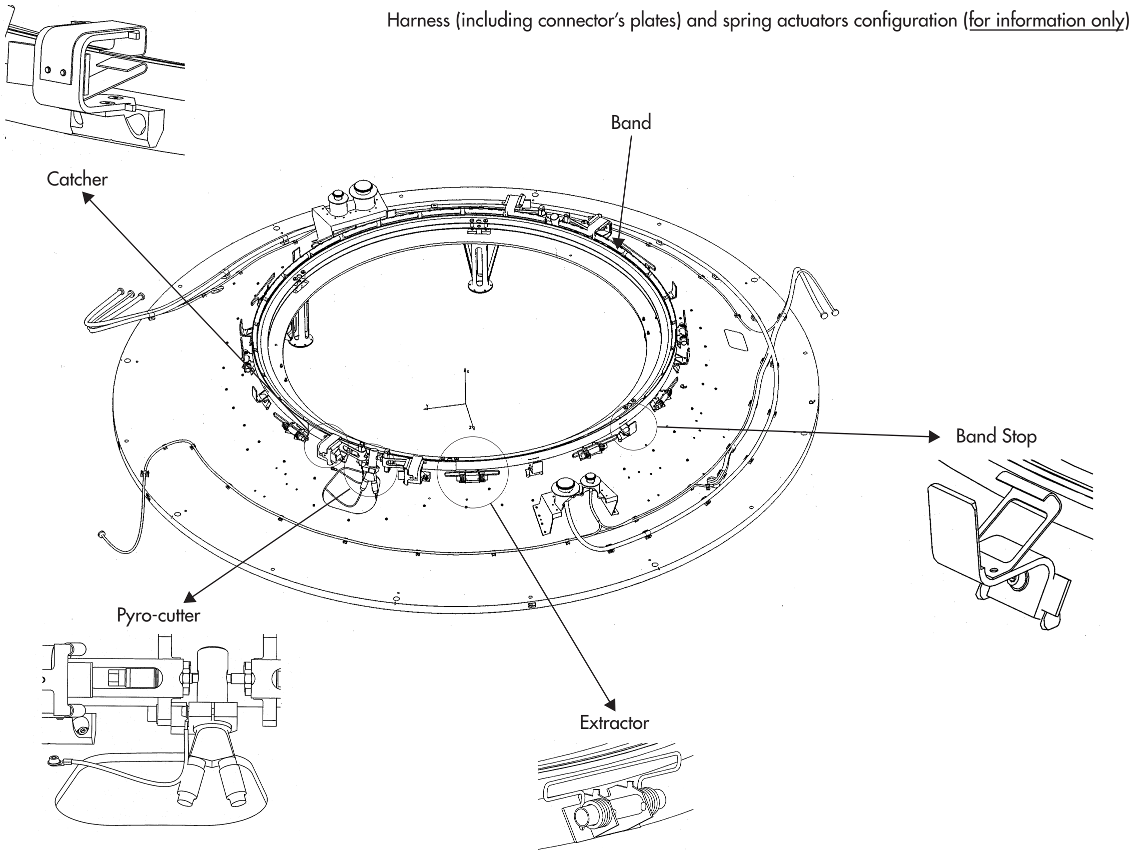


Figure A 2 - 6: Clamp Band Saab 1194A Release Shock Spectrum at Adapter 1194-SF/Spacecraft Interface

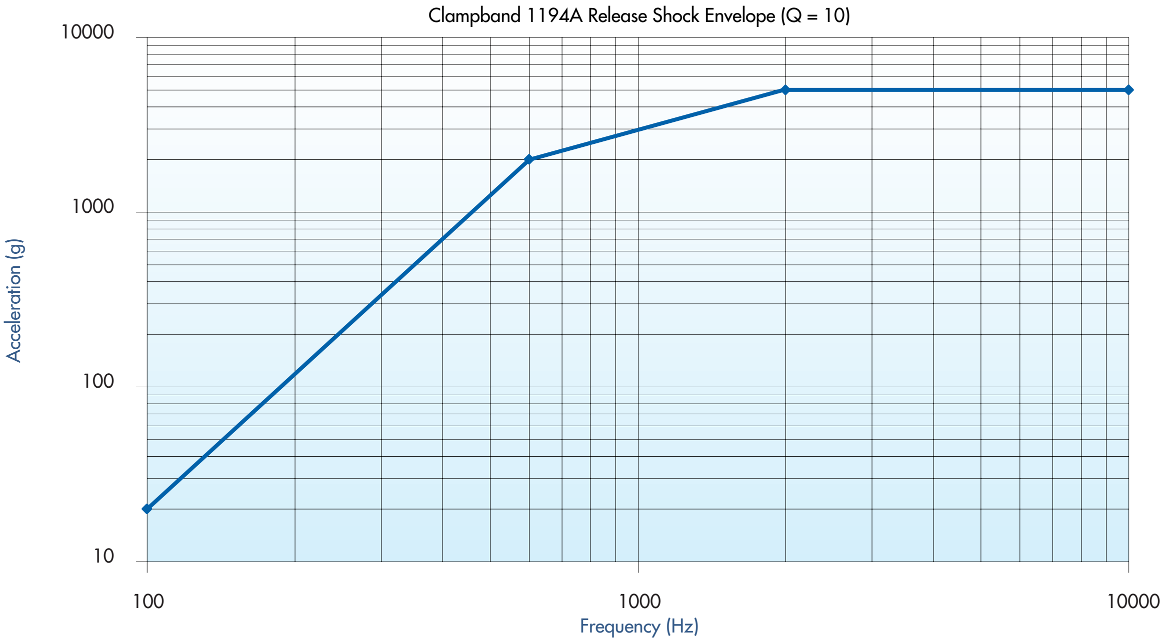


Figure A 2 - 7: Spring Actuator Design

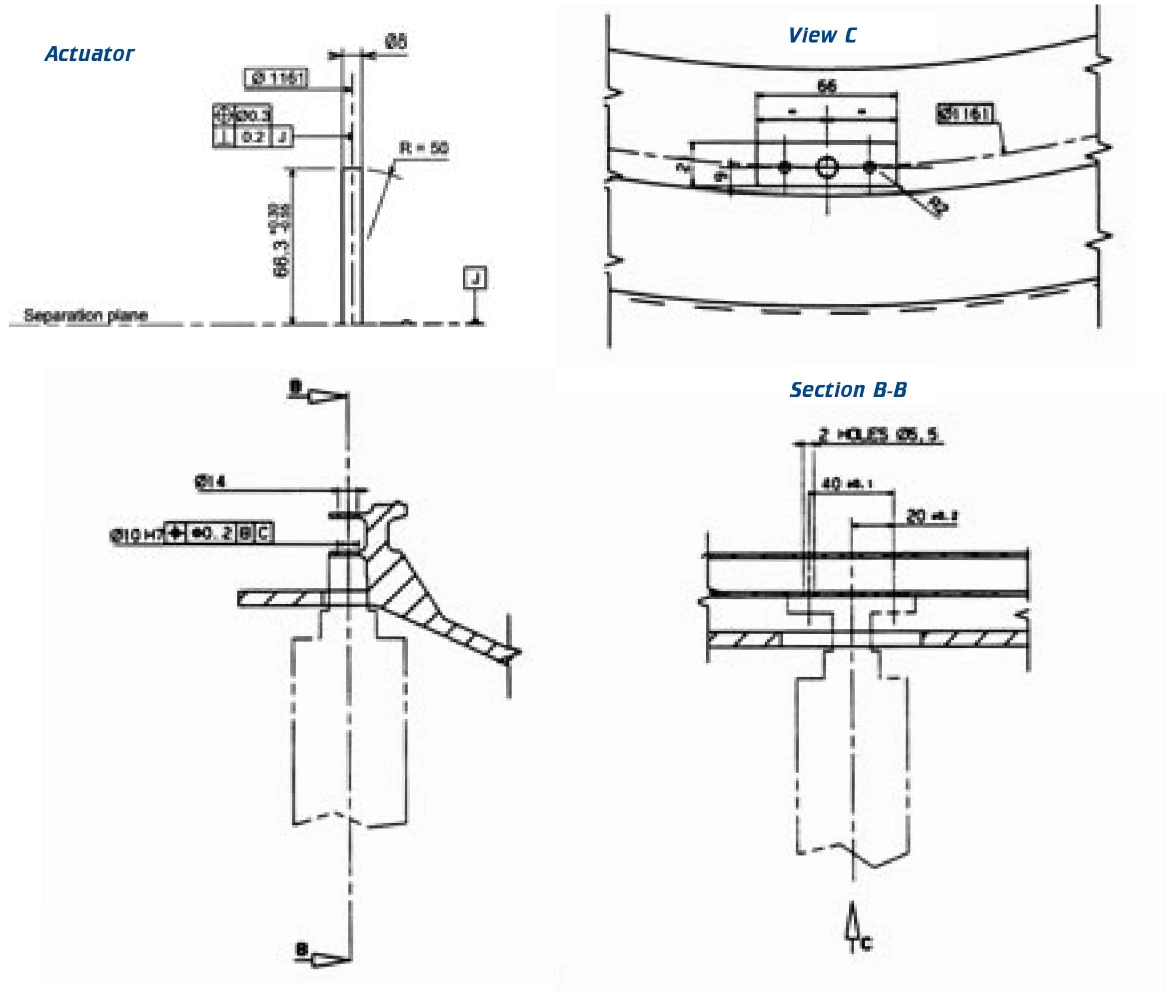
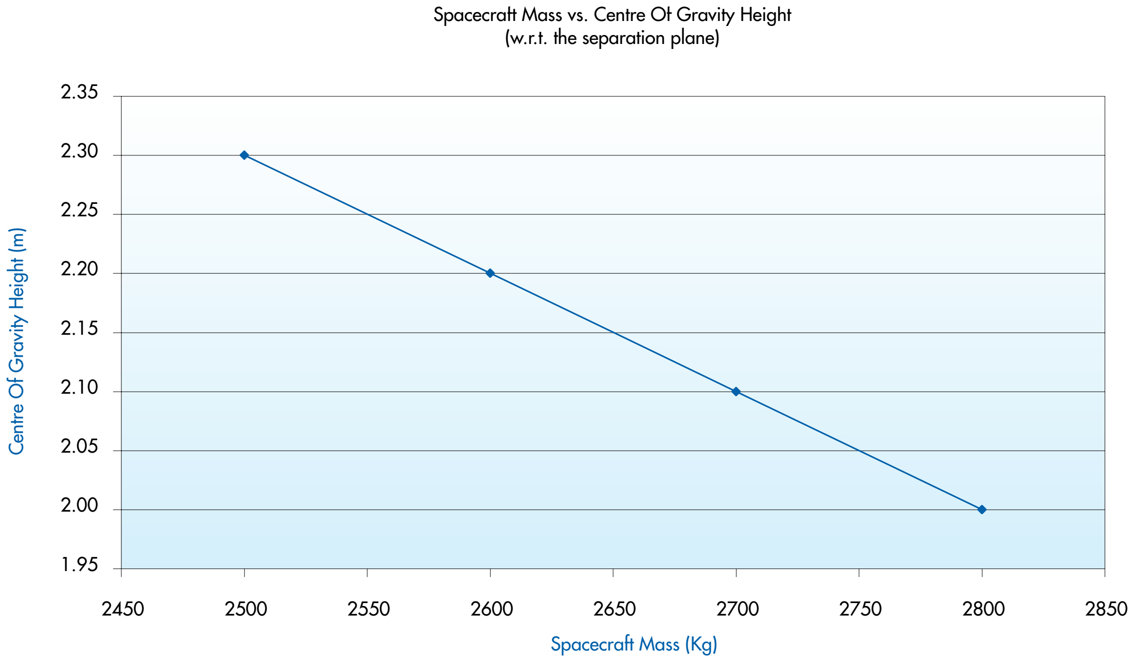


Figure A 2 - 8: Limit Loads for Adapter 1194-SF



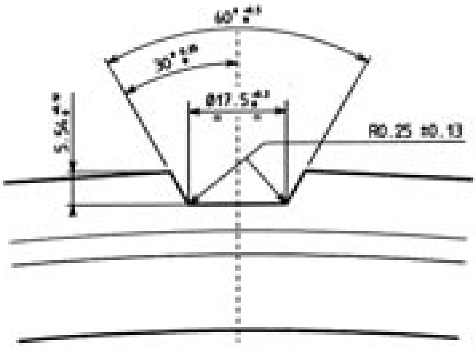
A 2.2. ADAPTER 937-SF

Adapter 937-SF is currently being developed by CASA within the framework of the Mars Express launch services program and should be qualified for ground and flight operations on the Soyuz LV by mid-2001. It is a composite structure that takes the form of a truncated cone with a diameter of 937 mm at the level of the spacecraft separation plane (see *Figure A 2 - 9*). The upper ring that interfaces with the spacecraft and the eight-foot area that interfaces with the Fregat brackets are made of aluminum alloys, whereas the conical part is a classical sandwich with CFRP skins and an aluminum-honeycomb core.

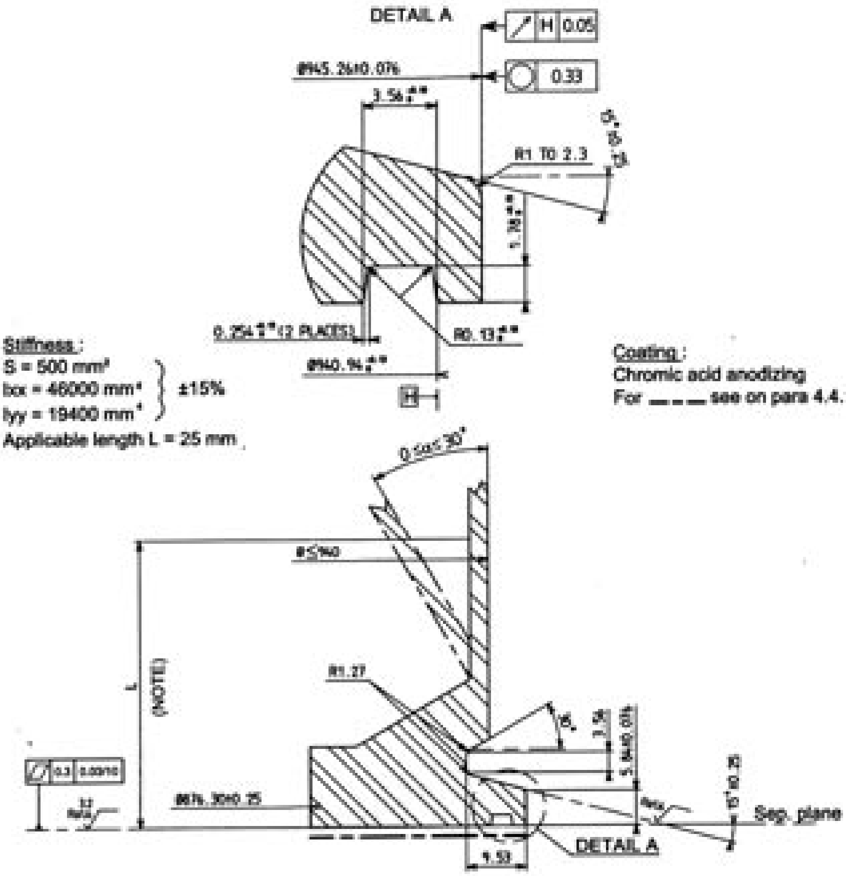
Adapter 937-SF is equipped with a Saab 937B separation system (a standard Ariane device). Its principles are similar to those outlined for the Saab 1194A separation system. The release shock spectrum at the spacecraft/adapter interface is indicated in *Figure A 2 - 10*.

Up-to-date information about Adapter 937-SF will be made available on request in the course of its development. Its present estimated mass is lower than 45 kg.

Figure A 2 - 9: Adapter 937-SF/Spacecraft Mechanical Interface Requirements (Spacecraft Side)



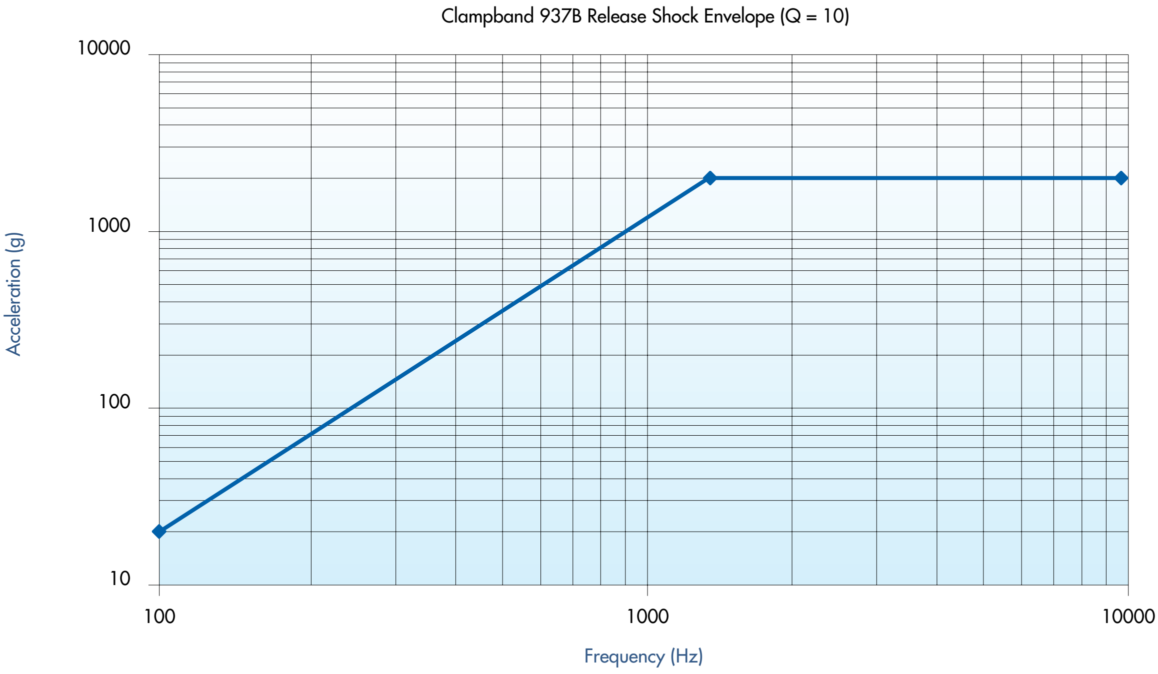
Keyway Detail (Not Mandatory)



Stiffness :
S = 500 mm^2
Ixx = 46000 mm^4 } ±15%
Iyy = 19400 mm^4 }
Applicable length L = 25 mm

Coating :
Chromic acid anodizing
For — — — see on para 4.4.1.

Figure A 2 - 10: Clamp Band Saab 937B Release Shock Spectrum at Adapter 937-SF/Spacecraft Interface



A 2.3. GLOBALSTAR DISPENSER

Dispensers are specific interface structures that are devoted to satellite constellation deployment and that allow for the handling and separation of at least two spacecraft per launch. In as much as mission requirements and constraints differ significantly from one constellation to another, such structures are generally mission-specific and thus cannot be considered off-the-shelf devices. Consequently, the information provided below with regard to the Globalstar dispenser is intended mainly to present Starsem's ability to manage the development, qualification, and recurrent manufacture of this type of structure. Such experience would obviously be of benefit to other satellite constellation programs, as most of the principles involved — especially those related to the handling and separation system — are valid for any application.

The Globalstar (GLS) dispenser was developed by EADS Launch Vehicles within the framework of the Globalstar launch services agreement and was successfully flown six times on the Soyuz Ikar launcher in 1999. It is an aluminum structure that is capable of handling four 450-kg satellites and of providing these satellites with the required separation impulse once in orbit. It consists of the following (see *Figure A 2 - 11* through *A2 - 13*):

- A conical part that interfaces with the Ikar upper frame;
- A cylindrical part that interfaces with three of the four spacecraft; and
- . A top plate that interfaces with the fourth spacecraft.

Each spacecraft has four contact points with the dispenser. These points are located at the corners of a 598 mm x 1650 mm rectangle. The separation subsystem thus consists of four assemblies, each comprising four pyro bolts, four spring actuators, and two microswitches. The release shock spectrum at the spacecraft/adapter interface is indicated in *Figure A 2 - 14*.

The Globalstar dispenser is equipped with a set of sensors that are designed to monitor the spacecraft mechanical environment, thereby enabling users to verify the compliance of acoustic pressure, QSLs, and sine and random vibrations against the levels indicated in the Interface Control Document. All sensor outputs are processed by the Ikar telemetry system.

The Globalstar dispenser also holds the electrical harness that is necessary for umbilical links as well as for separation orders and telemetry data transmission from and to the Ikar. This harness was tailored to Globalstar's needs and includes the transmission of spacecraft battery temperature and voltage up to separation. The Globalstar dispenser mass is 391 kg.

Figure A 2 - 11: GLS Dispenser on Its Integration Stand Prior to Spacecraft Mating

(Hazardous Processing Facility)

Figure A 2 - 12: GLS Stack (Dispenser + Four Satellites) During Transportation with the Cluster Handling Tool

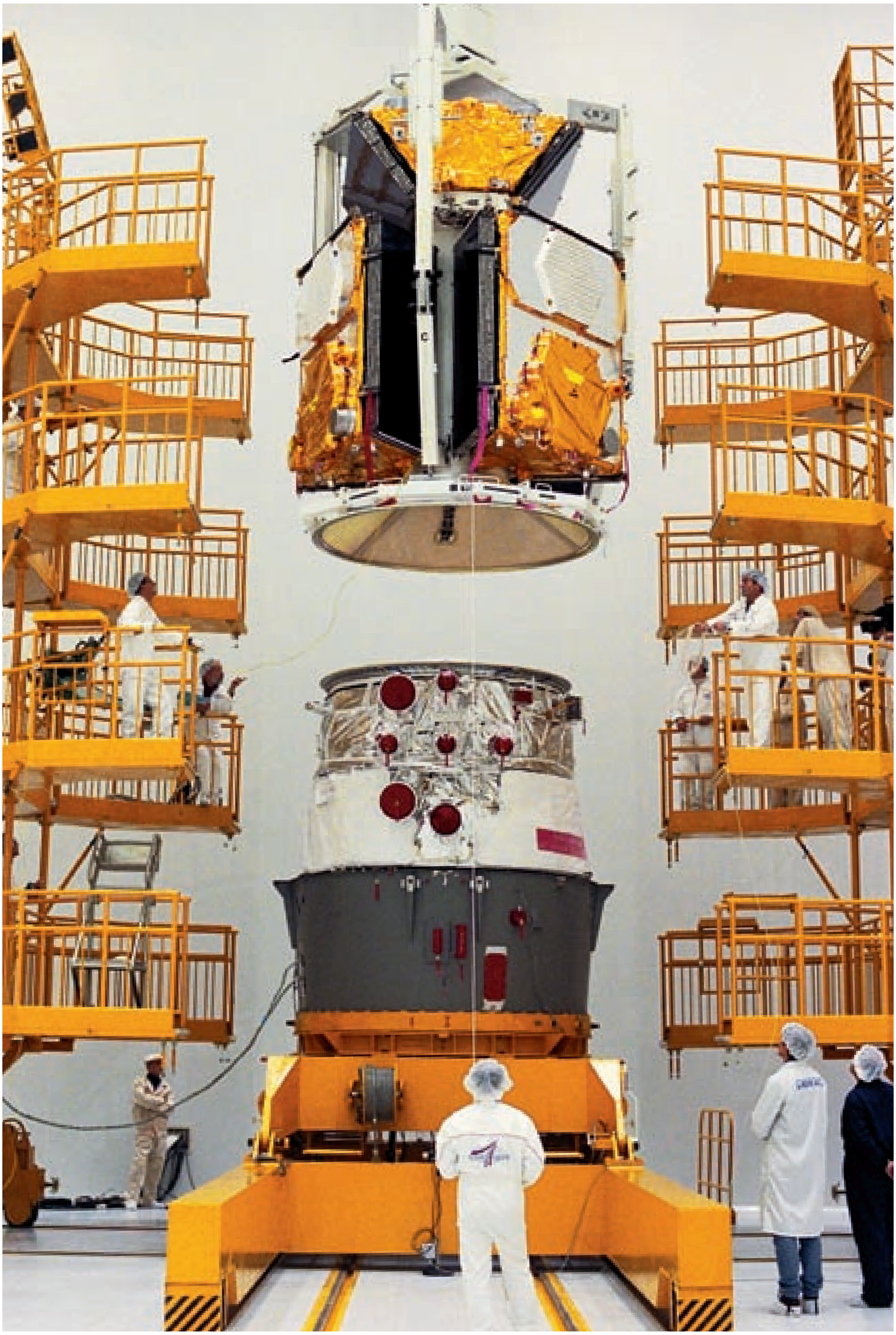


Figure A 2 - 13: GLS Dispenser General View

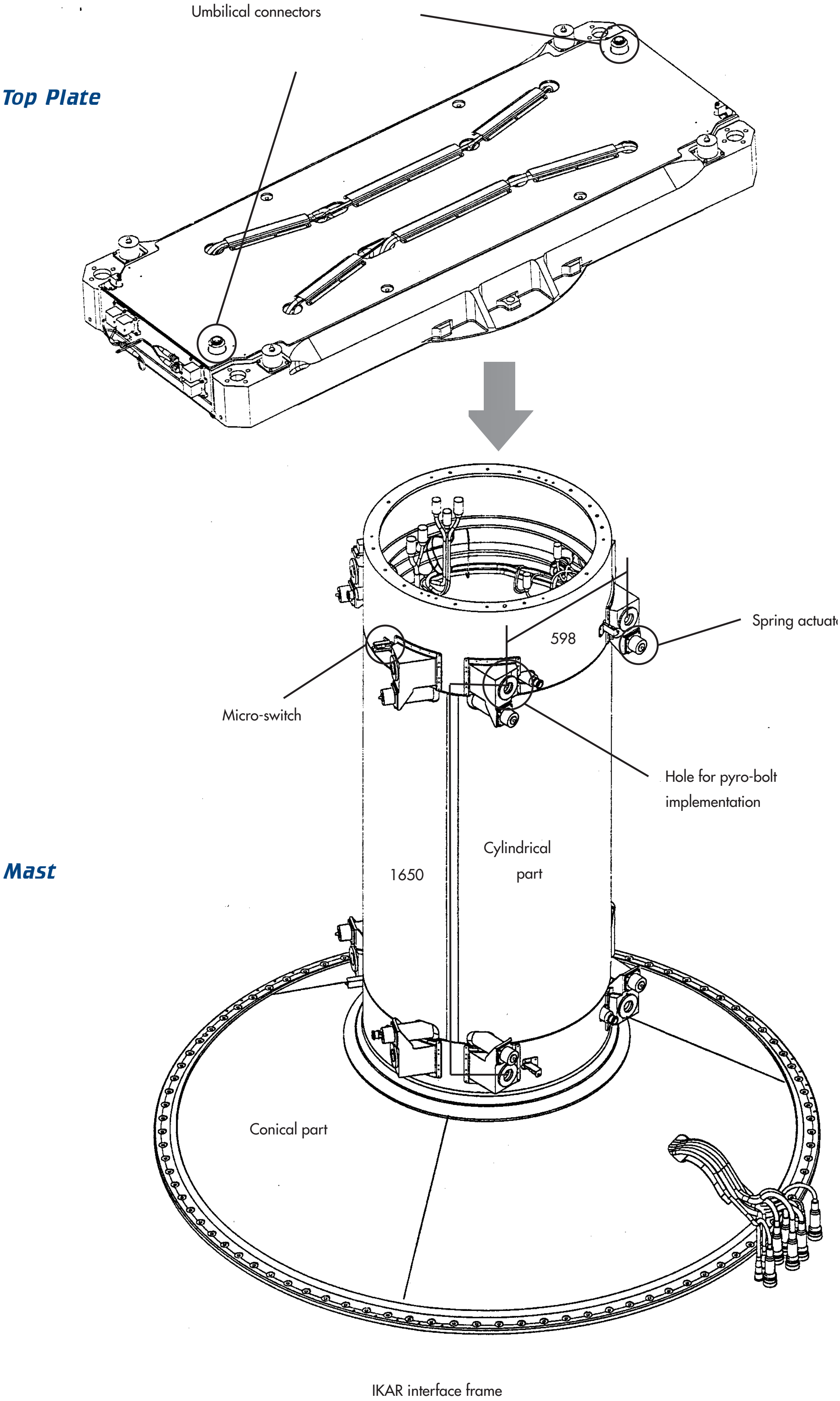
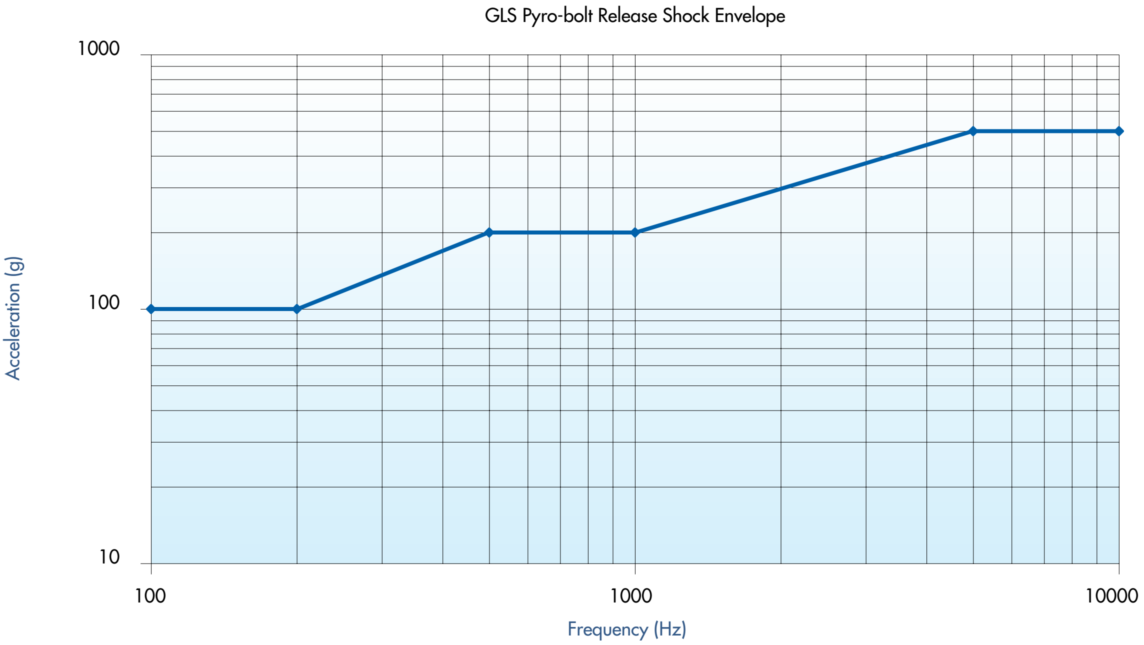


Figure A 2 - 14: GLS Dispenser Pyro-Bolt Release Shock Spectrum at Dispenser/Spacecraft Interface

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APPENDIX

3

LAUNCH VEHICLE HISTORY / RECORD

A 3.1. SOYUZ FAMILY OF LAUNCH VEHICLES

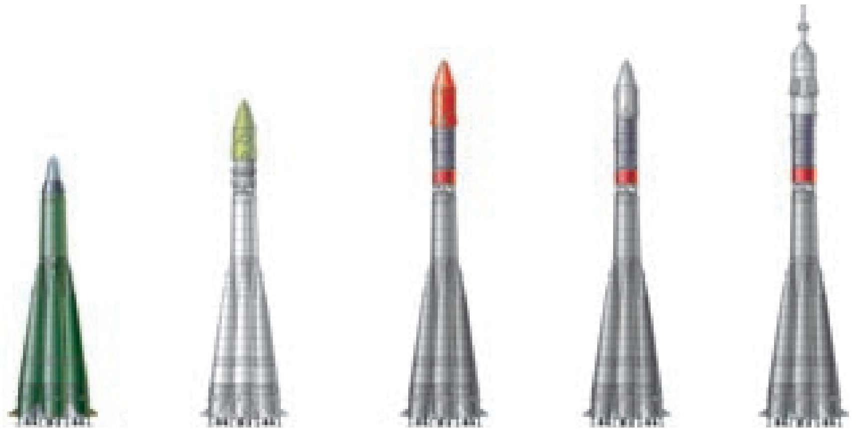
The two-stage R-7A intercontinental ballistic missile (ICBM) laid the groundwork for an evolutionary series of launch vehicles that would eventually launch the world's first satellite (Sputnik, 1957) and man (Yuri Gagarin, 1961) into space. Originally developed by Sergei Korolev's OKB-1 design bureau (now RSC Energia) in Kaliningrad, the R-7A was the first in a series of vehicles that, taken together, have logged more than 1654 flights, and in addition to the Soyuz, includes: Sputnik, Vostok, Molniya, and Voskhod. Since the R-7A was developed between 1953 and 1957, some ten different versions have been built in this family.

Production of the R-7A was moved to the Progress Aviation Factory in Samara, Russia, now the production facility of TsSKB-Progress, beginning in 1959. Over time, complete responsibility for the family would pass from Kaliningrad to Samara, with the design facilities at Samara transforming from a subsidiary of OKB-1 to an independent entity (TsSKB) in 1974. Since then, TsSKB and the Progress factory have been in charge of design, development, and production of vehicles in this family and their future derivatives. They were combined into one entity, TsSKB-Progress, in 1996.

Vehicles in this family have followed a conservative evolutionary path of development, and have been in continuous and uninterrupted production and flight for more than 40 years. Owing to this development philosophy, such vehicles have achieved a high launch rate as well as a high degree of reliability.

Table A3 - 1 shows a chronology of the most significant versions in this launch vehicle family.

Table A3 - 1: Soyuz (R-7) Family Evolution

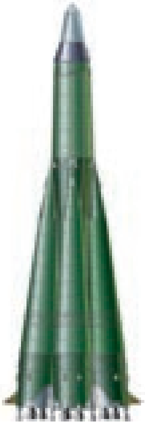


General view

Designation	R-7A / Sputnik	Vostok	Molniya	Voskhod	Soyuz
First launch	1957	1958	1960	1963	1966
1st Stage	Blocks B,V,G,D	Blocks B,V,G,D	Blocks B,V,G,D	Blocks B,V,G,D	Blocks B,V,G,D
2nd Stage	Block A	Block A	Block A	Block A	Block A
3rd Stage	—	Block E	Block I (w/o control system)	Block I	Block I
4th Stage	—	—	Block L	—	—
Status	Out of production	Out of production	Out of Production	Out of production	Out of production

General view

Designation	Soyuz U	Soyuz U2	Soyuz U(Ikar)	Soyuz U (Fregat)	Soyuz/ST(Fregat)
First launch	1973	1982	1999	2000	2002
1st Stage	Blocks B,V,G,D	Blocks B,V,G,D	Blocks B,V,G,D	Blocks B,V,G,D	Blocks B,V,G,D
2nd Stage	Block A	Block A(sintin-fuel)	Block A	Block A	Block A
3rd Stage	Block I	Block I	Block I	Block I	Enhanced Block I (with digital control system)
4th Stage	—	—	Ikar	Fregat	Fregat
Status	Operational	Out of production	Operational	Operational	Under Development



R-7A / SPUTNIK

1957-1960

(8K71, 8A91)

Used to launch the world's first artificial satellite in 1957, the Sputnik LV was a modified version of the R-7A ICBM and was designed for injection of a payload of up to 1.5 tons. The vehicle consists of just four strap-on boosters and a central core, and is considered a two-stage LV.

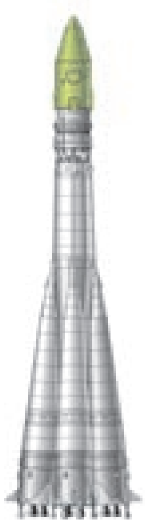
This vehicle launched the first three Sputnik satellites in 1957 and 1958. Soon after these missions, this two-stage LV was no longer used owing to the desire to launch larger payloads.

VOSTOK

1958-1991

(8K74, 8K72, 8A92, 11A50, 8A92M)

In order to launch heavier payloads and more complex missions, the Vostok LV added a third stage to the R-7A / Sputnik LV alone. The Vostok LV essentially uses the same four strap-on boosters as the R-7A / Sputnik launch vehicle and adds a LOX/Kerosene fueled third stage (Block E) designed by the OKB-1 design bureau.

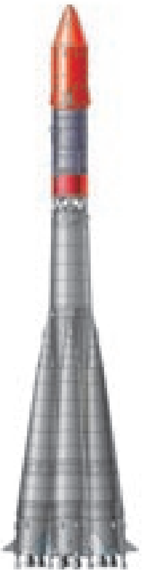


In 1959, the Vostok successfully launched the first unmanned spacecraft (Lunnik) to the moon and to achieve earth escape velocity. In 1961, the Vostok LV was also used to launch the first man (Yuri Gagarin). Owing to its limited payload capacity, the Vostok was not used for manned missions for very long, but remained operational until 1991. From 1962 to 1969, this LV was used to launch the first generation of earth observation satellites. From 1966 to 1983 it was used for meteorological and communications satellites. From 1984 to 1991, the vehicle was used less frequently for the launching of remote sensing satellites to SSO, including the Indian IRS 1A and 1B spacecraft.

MOLNIYA

1960-1999

(8K78, 8K78M)



The Molniya is a four-stage LV that replaces the Block E third stage of Vostok with a significantly more powerful LOX/kerosene Block I third stage, and adds a LOX/Kerosene nonrestartable fourth stage. This Block L fourth stage is adapted specifically for ignition in a vacuum, having been used to launch Soviet interplanetary probes before a four-stage version of the Proton LV was introduced in 1964.

From 1960 to 1964, the Molniya LV launched the following interplanetary probes: Luna-4 through 14, Mars-1, Venera-1 through 8, and Zond-1 through 3.

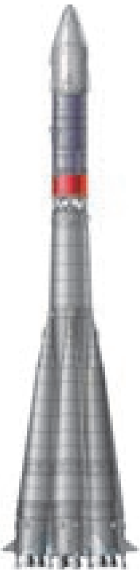
From 1964 to 1999, the Molniya was used to launch Molniya communication satellites, Prognoz science satellites, military satellites, and Earth remote sensing satellites, all on highly elliptical orbits.

The introduction in 2000 of the Fregat upper stage will lead to the phasing out of the Block L stage used with Molniya, due in part to the advantages of the Fregat's restartable main engine.

VOSKHOD

1963-1976

(11A59, 11A57)



The Voskhod LV is essentially the first 3 stages of the Molniya vehicle. It was able to launch heavier payloads to LEO than the Vostok, and became the Soviet Union's workhorse launch vehicle of the late 1960's and early 1970's.

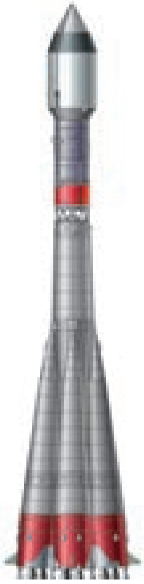
This vehicle was first launched in 1963 to launch the Zenit series of observation satellites. From 1964 to 1966, it was also used to launch the Voskhod series of three-crew-member manned spacecraft.

SOYUZ
1966-Present
(11A511, 11A511L, 11A511M, 11A511U, 11A511U2, 11A511U/Ikar, 11A511U/Fregat)

The Soyuz LV was developed from Voskhod for the purpose of launching the manned Soyuz spacecraft. Initially, modifications were made to the intermediate bay of Voskhod, and a new fairing was designed with an emergency crew escape system.

Several improvements were made on the vehicle's design during the 1960's and early 1970's, cumulating in 1973 with the introduction of the Soyuz U (11A511U) in 1973, which unified and standardized the improvements that had been made over the previous eight years. The Soyuz U incorporated performance enhancements in the booster and core engines, and improved ground test equipment. This version is by far the most frequently flown, and makes up the first three stages of the Soyuz vehicle that Starsem markets for commercial use with the Fregat upper stage.

The Soyuz U2 (11A511U2) was introduced in 1982 and used synthetic kerosene ("Sintin") in the core stage to provide higher performance. The Soyuz U2 was flown 70 times, all successfully from 1982 through 1995. This vehicle was then discontinued owing to the end of production of its Sintin fuel.



In 1999, Starsem added a restartable upper stage (Ikar) based on the Kometa satellite bus to the lower three-stages of the Soyuz U. This LV configuration allowed the Soyuz to reach circular orbits above 500 km, and was used for six flights to deploy half (24 satellites) of the Globalstar constellation.

In 2000, the Soyuz began flying the Fregat upper stage, developed by NPO Lavochkin. This upper stage is based on components used on Phobos and other interplanetary missions and also features a control system based on that used on other Russian LVs. It has a larger propellant capacity then the Ikar stage, and is also restartable.

This upper stage was launched four times in 2000, delivering ESA's Cluster II science satellites to orbit.

A 3.2. LAUNCH RECORD (1957 - 2000)

Vehicles based on the R-7 ICBM have been launched 1654 times through December 31, 2000. A breakdown of these launch attempts by vehicle class is shown in *Table A3 - 2*.

Table A3 - 2: Record of Soyuz (R-7) Launch Vehicle Family

Year	LaunchAttempts	Failures	R-7A / Sputnik		Vostok		Molniya		Voskhod		Soyuz	
	(L)	(F)	L	F	L	F	L	F	L	F	L	F
1957	6	2	6	2								
1958	11	8	8	5	3	3						
1959	20	4	15	3	5	1						
1960	17	6	1	0	14	4	2	2				
1961	16	2			14	2	2	0				
1962	15	2			9	1	6	1				
1963	19	3			13	2	4	1	2	0		
1964	28	4			14	0	8	4	6	0		
1965	37	3			13	1	12	2	12	0		
1966	40	4			15	1	9	1	14	1	2	1
1967	40	3			9	0	7	0	20	3	4	0
1968	42	2			2	0	6	1	29	1	5	0
1969	44	1			3	1	4	0	32	0	5	0
1970	44	1			5	0	7	0	30	1	2	0
1971	44	4			5	0	3	0	31	4	5	0
1972	48	1			5	0	11	0	29	1	3	0
1973	54	1			3	0	10	0	32	1	9	0
1974	52	3			6	0	7	0	24	2	15	1*
1975	59	1			6	0	12	0	28	0	13	1
1976	55	1			5	0	11	0	12	0	27	1
1977	56	2			7	0	10	0			39	2
1978	59	0			5	0	9	0			45	0
1979	62	2			8	0	7	0			47	2
1980	64	1			7	1	12	0			45	0
1981	62	1			6	0	14	0			42	1
1982	61	2			5	0	11	0			45	2
1983	58	1			4	0	11	0			43	1
1984	55	0					11	0			44	0
1985	57	0			1	0	16	0			40	0
1986	51	1					14	0			37	1
1987	48	1					4	0			44	1
1988	58	3			2	0	11	0			45	(2+1*)
1989	44	0					6	0			38	0
1990	44	2					12	0			32	2
1991	30	0			1	0	5	0			24	0
1992	32	0					8	0			24	0
1993	25	0					8	0			17	0
1994	18	0					3	0			15	0
1995	16	0					4	0			12	0
1996	12	2					3	0			9	2
1997	13	0					3	0			10	0
1998	11	0					3	0			8	0
1999	14	0					2	0			12	0
2000	13	0									13	0
Totals	1654	74	30	10	195	17	308	12	301	14	820	21

* Failure due to payload and not counted in flight success ratio (*Section 1.3.1*)

A 3.3. DETAILED LAUNCH RECORD 1996 - 2000

Through December 31, 2000, Soyuz family launch vehicles had carried out 58 straight launches (47 Soyuz U, 11 Molniya) since the last failure of a Soyuz U in 1996. Table A3 - 3 shows a detailed log of all launches since 1996.

Table A3 - 3: Record of Soyuz (R-7) Launch Vehicle Family (1996 - 2000)

Date	Launch Site	Launch Vehicle	Manned / Unmanned	Payload Flight Number	Success	Failure	LV Family Flight Number	Soyuz Flight Number
Feb. 21, 96	Baikonur	Soyuz U	Manned	Soyuz TM-23	X		1592	769
Mar. 15, 96	Plesetsk	Soyuz U	Unmanned	Kosmos-2331	X		1593	770
May. 05, 96	Baikonur	Soyuz U	Unmanned	Progress M-31	X		1594	771
May. 14, 96	Baikonur	Soyuz U	Unmanned	Kosmos		X	1595	772
Jun. 20, 96	Plesetsk	Soyuz U	Unmanned	Yantar-4K2		X	1596	773
Jun. 31, 96	Baikonur	Soyuz U	Unmanned	Progress M-32	X		1597	774
Aug. 15, 96	Plesetsk	Molniya	Unmanned	Molniya-1T	X		1598	
Aug. 17, 96	Baikonur	Soyuz U	Manned	Soyuz TM-24	X		1599	775
Aug. 29, 96	Plesetsk	Molniya	Unmanned	Prognoz-M2	X		1600	
Oct. 24, 96	Plesetsk	Molniya	Unmanned	Molniya-3	X		1601	
Nov. 20, 96	Baikonur	Soyuz U	Unmanned	Progress M-33	X		1602	776
Dec. 24, 96	Plesetsk	Soyuz U	Unmanned	Bion-11	X		1603	777
Feb. 10, 97	Baikonur	Soyuz U	Manned	Soyuz TM-25	X		1604	778
Apr. 06, 97	Baikonur	Soyuz U	Unmanned	Progress M-34	X		1605	779
Apr. 09, 97	Plesetsk	Molniya	Unmanned	Kosmos-2340	X		1606	
May 14, 97	Plesetsk	Molniya	Unmanned	Kosmos-2342	X		1607	
May 15, 97	Baikonur	Soyuz U	Unmanned	Kosmos-2343	X		1608	780
Jul. 05, 97	Baikonur	Soyuz U	Unmanned	Progress M-35	X		1609	781
Aug. 05, 97	Baikonur	Soyuz U	Manned	Soyuz TM-26	X		1610	782
Sep. 25, 97	Plesetsk	Molniya	Unmanned	Molniya-1T	X		1611	
Oct. 05, 97	Baikonur	Soyuz U	Unmanned	Progress M-36	X		1612	783
Oct. 09, 97	Plesetsk	Soyuz U	Unmanned	Foton-11	X		1613	784
Nov. 18, 97	Plesetsk	Soyuz U	Unmanned	Resurs-F1M	X		1614	785
Dec. 15, 97	Plesetsk	Soyuz U	Unmanned	Kosmos-2348	X		1615	786
Dec. 20, 97	Baikonur	Soyuz U	Unmanned	Progress M-37	X		1616	787
Jan. 29, 98	Baikonur	Soyuz U	Manned	Soyuz TM-27	X		1617	788
Feb. 17, 98	Baikonur	Soyuz U	Unmanned	Kosmos-2349	X		1618	789
Mar. 15, 98	Baikonur	Soyuz U	Unmanned	Progress M-38	X		1619	790
May 07, 98	Plesetsk	Molniya	Unmanned	Kosmos-2351	X		1620	
May 15, 98	Baikonur	Soyuz U	Unmanned	Progress M-39	X		1621	791
Jun. 24, 98	Plesetsk	Soyuz U	Unmanned	Kosmos-2358	X		1622	792
Jun. 25, 98	Baikonur	Soyuz U	Unmanned	Kosmos-2359	X		1623	793
Jul. 01, 98	Plesetsk	Molniya	Unmanned	Molniya-3	X		1624	
Aug. 13, 98	Baikonur	Soyuz U	Manned	Soyuz TM-28	X		1625	794
Sep. 29, 98	Plesetsk	Molniya	Unmanned	Molniya-1T	X		1626	
Oct. 25, 98	Baikonur	Soyuz U	Unmanned	Progress M-40	X		1627	795

Date	Launch Site	Launch Vehicle	Manned / Unmanned	Payload Flight Number	Success	Failure	LV Family Flight Number	Soyuz Flight Number
Feb. 09, 99	Baikonur	Soyuz U (Ikar)	Unmanned	Globalstar FM36, 23, 38, 40	X		1628	796
Feb. 20, 99	Baikonur	Soyuz U	Manned	Soyuz TM-29	X		1629	797
Mar. 15, 99	Baikonur	Soyuz U (Ikar)	Unmanned	Globalstar FM22, 41, 46, 37	X		1630	798
Apr. 02, 99	Baikonur	Soyuz U	Unmanned	Progress M-41	X		1631	799
Apr. 15, 99	Baikonur	Soyuz U (Ikar)	Unmanned	Globalstar FM19, 42, 44, 45	X		1632	800
Jul. 08, 99	Plesetsk	Molniya	Unmanned	Molniya-3	X		1633	
Jul. 16, 99	Baikonur	Soyuz U	Unmanned	Progress M-42	X		1634	801
Aug. 18, 99	Plesetsk	Soyuz U	Unmanned	Kosmos-2365	X		1635	802
Sep. 09, 99	Plesetsk	Soyuz U	Unmanned	Foton-12	X		1636	803
Sep. 22, 99	Baikonur	Soyuz U (Ikar)	Unmanned	Globalstar FM33, 50, 55, 58	X		1637	804
Sep. 28, 99	Plesetsk	Soyuz U	Unmanned	Resurs-F1M	X		1638	805
Oct. 18, 99	Baikonur	Soyuz U (Ikar)	Unmanned	Globalstar FM31, 56, 57, 59	X		1639	806
Nov. 22, 99	Baikonur	Soyuz U (Ikar)	Unmanned	Globalstar FM29, 34, 39, 61	X		1640	807
Dec. 27, 99	Plesetsk	Molniya	Unmanned	Kosmos-2368	X		1641	
Jan. 02, 00	Baikonur	Soyuz U	Unmanned	Progress M1-1	X		1642	808
Feb. 09, 00	Baikonur	Soyuz U (Fregat)	Unmanned	IRDT	X		1643	809
Mar. 20, 00	Baikonur	Soyuz U (Fregat)	Unmanned	DUMSAT	X		1644	810
Apr. 04, 00	Baikonur	Soyuz U	Manned	Soyuz TM-30	X		1645	811
Apr. 25, 00	Baikonur	Soyuz U	Unmanned	Progress M1-2	X		1646	812
May 03,00	Baikonur	Soyuz U	Unmanned	Kosmos-2370	X		1647	813
Jul. 16, 00	Baikonur	Soyuz U (Fregat)	Unmanned	Cluster-II FM6, 7 (Samba, Salsa)	X		1648	814
Aug. 06, 00	Baikonur	Soyuz U	Unmanned	Progress M1-3	X		1649	815
Aug. 09,00	Baikonur	Soyuz U (Fregat)	Unmanned	Cluster-II FM5, 8 (Rumba, Tango)	X		1650	816
Sep. 29, 00	Baikonur	Soyuz U	Unmanned	Kosmos-2373	X		1651	817
Oct. 17, 00	Baikonur	Soyuz U	Unmanned	Progress M-43	X		1652	818
Oct. 31, 00	Baikonur	Soyuz U	Manned	Soyuz TM-31	X		1653	819
Nov. 16, 00	Baikonur	Soyuz U	Unmanned	Progress M1-4	X		1654	820

The two failures listed in 1996 (May 14 and June 20) were due to a manufacturing defect with the fairing release mechanism. Since the fairings for the two flights were manufactured in a batch, the same defect was repeated on both fairings. The cause was identified, other fairings in the batch were repaired, and corrective actions were taken to ensure that this defect was not repeated. These failures were the only two in 195 Soyuz family launches, going back to 1990. Since these failures, Soyuz family LVs have been launched sucessfully 58 consecutive times through December 31, 2000.