



Space Launch System

DNEPR

User's Guide





This User's Guide contains technical data, the use of which is mandatory for:

- evaluation of spacecraft/Dnepr-1 launch vehicle compatibility; and
- preparation of all technical and operational documentation regarding a spacecraft launch on Dnepr-1 launch vehicle.

All questions on the issues associated with the operation of the Dnepr Space Launch System that were not addressed in this User's Guide should be sent to the address below:

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Current information relating to the Dnepr Space Launch System, activities of International Space Company Kosmotras, performed and planned launches of Dnepr launch vehicle can be found on ISC Kosmotras web-site:

<http://www.kosmotras.ru>

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Table of Contents

1. Introduction	10
2. International Space Company Kosmotras	12
2.1 ISC Kosmotras Permits and Authorities	12
2.2 Dnepr Program Management. Dnepr Team and Responsibilities	12
3. Purpose, Composition and Principal Characteristics of Dnepr Space Launch System	15
4. Dnepr-1 Launch Vehicle	17
4.1 General Description	17
4.2 Spacecraft Injection Accuracy	22
4.3 Launch Vehicle Axes Definition	22
4.4 Space Head Module	24
4.4.1 Space Head Module Design	24
4.4.2 Payload Envelope	26
4.5 Launch Vehicle Flight Reliability	30
5. Baikonur Cosmodrome	31
6. Dnepr SLS Ground Infrastructure	35
6.1 Elements and General Diagram of Ground Infrastructure	35
6.2 SC and SHM Processing Facility	35
6.3 Spacecraft Fuelling Station	39
6.4 Launch Complex	40
7. Baikonur Operations Flow	42
7.1 Preparation of LV for Integration with SHM	43
7.2 Independent SC Processing	43
7.3 Preparation of SHM for Mating with SC	44
7.4 SC / SHM Integration	44
7.5 Transportation of SHM Containing SC by Transporter Erector to the Silo Launcher	45
7.6 SHM/LV Integration and LV Preparation for Launch	46
7.7 Pre-launch Operations and LV Launch	47
8. SC/LV Interfaces	49



8.1 Mechanical Interface	49
8.2 Electrical Interface	51
9. Spacecraft Environments	54
9.1 Stiffness Criteria (Frequency Requirements)	54
9.2 Quasi-static and Dynamic Loads	54
9.3 Vibration Loads	54
9.4 Shock Loads	57
9.5 Acoustic Loads	57
9.6 Temperature and Humidity Conditions and Thermal Effect on Spacecraft	58
9.7 Pressure Underneath LV Fairing	59
9.8 Gas-dynamic Effect on Spacecraft	59
9.9 SC/LV Electromagnetic Compatibility	60
9.10 Spacecraft Tests Required to Meet Dnepr LV Launch Services Requirements	62
10. Ground Qualification Tests	62
11. Telemetry and Tracking	64
12. Analysis of Flight Results	65
13. Range Safety	66
14. Transportation of Spacecraft and Associated Equipment. Customs Clearance	69
14.1 Transportation of Dummy Spacecraft to Ukraine for Ground Testing	69
14.2 Transportation of Spacecraft and Associated Equipment to Baikonur Cosmodrome	69
15. Principles of Pricing Policy and Contractual Relations	75
16. Design and Technical Documents to Be Submitted by Spacecraft Authority	73
17. Documents to Be Submitted to ISC Kosmotras by Spacecraft Authority	75
18. Launch Campaign Schedule	76



List of Figures

Figure. 1-1	Dnepr-1 Lifts off from Baikonur Cosmodrome. September 26,2000	11
Figure 2.2-1	Dnepr Program Operations Diagram	14
Figure 4.1-1	Dnepr-1 General View	18
Figure 4.1-2	SS-18 1 st and 2 nd Stages Inside TLC	18
Figure 4.1-3	Dnepr-1 Performance Curves for Circular Orbits	19
Figure 4.1-4	Mission Profile of Dnepr-1 LV Carrying a Large Spacecraft	20
Figure 4.1-5	Mission Profile of Dnepr-1 LV with a Group of Spacecraft	21
Figure 4.3-1	Launch Vehicle Major Axes	23
Figure 4.4.1-1	SHM Configuration 1 – Standard Length	25
Figure 4.4.1-2	SHM Configuration 2 – Standard Length	25
Figure 4.4.1-3	SHM Configuration 1 – Extended by 850 mm	25
Figure 4.4.1-4	SHM with 2-tier Layout	25
Figure 4.4.2-1	Payload Envelope Available within SHM Configuration 1 with Standard Adapter and GDS	27
Figure 4.4.2-2	Payload Envelope Available within SHM Configuration 2 with Standard Adapter and EPM	28
Figure 4.4.2-3	Payload Envelope Available within SHM Configuration 1 Extended by 850 mm with Standard Adapter and GDS	29
Figure 5-1	Yubileiniy Airfield	31
Figure 5-2	Syrdarya River	31
Figure 5-3	Cosmodrome Residential Area – Town of Baikonur	31
Figure 5-4	Kosmonavt Hotel	32
Figure 5-5	Baikonur Hotel	32
Figure 5-6	Facilities of Sputnik Hotel	32
Figure 6.1-1	Dnepr SLS at Baikonur Cosmodrome	35
Figure 6.2-1	Layout of AITB, Site 42	36
Figure 6.2-2	Layout of AITB, Site 31	37
Figure 6.4-1	Dnepr Launch Complex Facilities (Sites 106 and 109)	40
Figure 6.4-2	Transporter Erector	41
Figure 7-1	Spacecraft Processing and Launch Schedule	42



Figure 7.1-1	Loading of TLC Containing LV 1 st and 2 nd Stages into Silo Launcher	43
Figure 7.2-1	Off-loading of Spacecraft Container from the Plane	43
Figure 7.2-2	Spacecraft Processing	44
Figure 7.4-1	SHM Integration	45
Figure 7.5-1	SHM Loading into Transporter Erector	45
Figure 7.6-1	SHM/LV Integration Inside Silo Launcher	46
Figure 7.6-2	SHM Loading into Silo Launcher	47
Figure 7.7-1	Dnepr LV Liftoff	48
Figure 8.1-1	Typical Design of Spacecraft/Standard Adapter Attachment Point	50
Figure 8.2-1	Schematics of SC/SC COE Transit Electrical Links	52
Figure 9.7-1	Pressure Change Rate inside Payload Envelope	59
Figure 11-1	Tracking Station	64
Figure 12-1	Flight Data Processing Center	65
Figure 18-1	Launch Campaign Schedule	76



List of Tables

Table 4.1-1	Dnepr-1 Main Characteristics	18
Table 4.2-1	Spacecraft Injection Accuracy	22
Table 5-1	Typical Routes of Transportation at Baikonur Cosmodrome	33
Table 6.2-1	Characteristics of Area A, B and C, AITB at Site 31	38
Table 9.2-1	Accelerations at SC/LV Interface during Transportation	55
Table 9.2-2	Maximum Quasi-static and Dynamic Accelerations at SC/LV Interface	55
Table 9.3-1	Amplitude of Harmonic Oscillations at SC/LV Interface. Longitudinal Axis (X)	56
Table 9.3-2	Amplitude of Harmonic Oscillations at SC/LV Interface. Lateral Axes (Y, Z)	56
Table 9.3-3	Spectral Density of Vibro-accelerations at SC/LV Interface	56
Table 9.4-1	Shock Spectrum at Spacecraft Attachment Points	57
Table 9.5-1	Acoustic Loads	58
Table 9.8-1	Maximum Values of 3 rd Stage Motor Plume Parameters Affecting Spacecraft	60
Table 9.9-1	Maximum Residual Levels of RF Emissions	61
Table 9.9-2	Maximum Levels of Electromagnetic Emissions	61



Abbreviations

AITB	-	Assembly, Integration and Test Building
COE	-	Checkout Equipment
ECOE	-	Electrical Checkout Equipment
EPM	-	Encapsulated Payload Module
FSUE	-	Federal State Unitary Enterprise
GDS	-	Gas-dynamic Shield
GPE	-	Ground Processing Equipment
GPS	-	Global Positioning System
ICBM	-	Intercontinental Ballistic Missile
ICD	-	Interface Control Document
ISC	-	International Space Company
LCC	-	Launch Control Center
LSA	-	Launch Services Agreement
LSS	-	Launch Services Specifications
LV	-	Launch Vehicle
MoD	-	Ministry of Defense
MoU	-	Memorandum of Understanding
NSAU	-	National Space Agency of Ukraine
RASA	-	Russian Aviation and Space Agency
SC	-	Spacecraft
SDB	-	State Design Bureau
SHM	-	Space Head Module
SLS	-	Space Launch System
TLC	-	Transport and Launch Canister
UHV	-	Ultra High Frequency



1. Introduction

Dnepr Space Launch System (SLS) is designed for expedient high accuracy injection of various single or multiple spacecraft (SC) weighing up to 3.7 metric tons into 300 – 900 km low earth orbits inclined 50.5, 64.5, 87.3 or 98 degrees.

The core of the Dnepr SLS is the world's most powerful intercontinental ballistic missile (ICBM) SS-18 or Satan, which possesses high performance characteristics and mission reliability confirmed through 159 launches (including 2 launches under the Dnepr Program).

The SS-18's design and invariance of its control system allowed for creating, on its basis, a high-performance Dnepr launch vehicle (LV) equipped with a space head module (SHM), which meets modern requirements for SC injection means.

The actual availability of a considerable number of missiles (about 150) that have a long operational life, of ground infrastructure at Baikonur Cosmodrome that comprises processing facilities and launch complex, drop zones and ground data processing complex, as well as of a team of the companies that developed the Dnepr SLS, ensures stable provision of launch services.

Dnepr Program implementation is exercised in full compliance with the provisions of the treaties on reduction and limitation of the strategic offensive arms (START Treaties).

As a first practical step in the Dnepr Program implementation, ISC Kosmotras jointly with the Russian Ministry of Defense prepared and launched the British Surrey Satellite Technology Limited UoSAT-12 satellite on a modified SS-18 (Dnepr-1) rocket on April 21, 1999.

The following step of the Dnepr Program evolution is mastering cluster launches of satellites belonging to different customers. September 26, 2000 marked the Dnepr launch with five spacecraft: MegSat-1 (MegSat s.P.a., Italy), UniSat (La Sapienza University, Rome, Italy), SaudisSat-1A and 1B (Space Research Institute, Saudi Arabia) and TiungSat-1 (ATSB, Malaysia).

The User's Guide contains information on basic characteristics, performance, initial data for spacecraft integration with the launch vehicle as well as spacecraft environments within the Dnepr SLS that will facilitate the preliminary evaluation of feasibility to utilize the Dnepr SLS for the launch of a specific spacecraft.

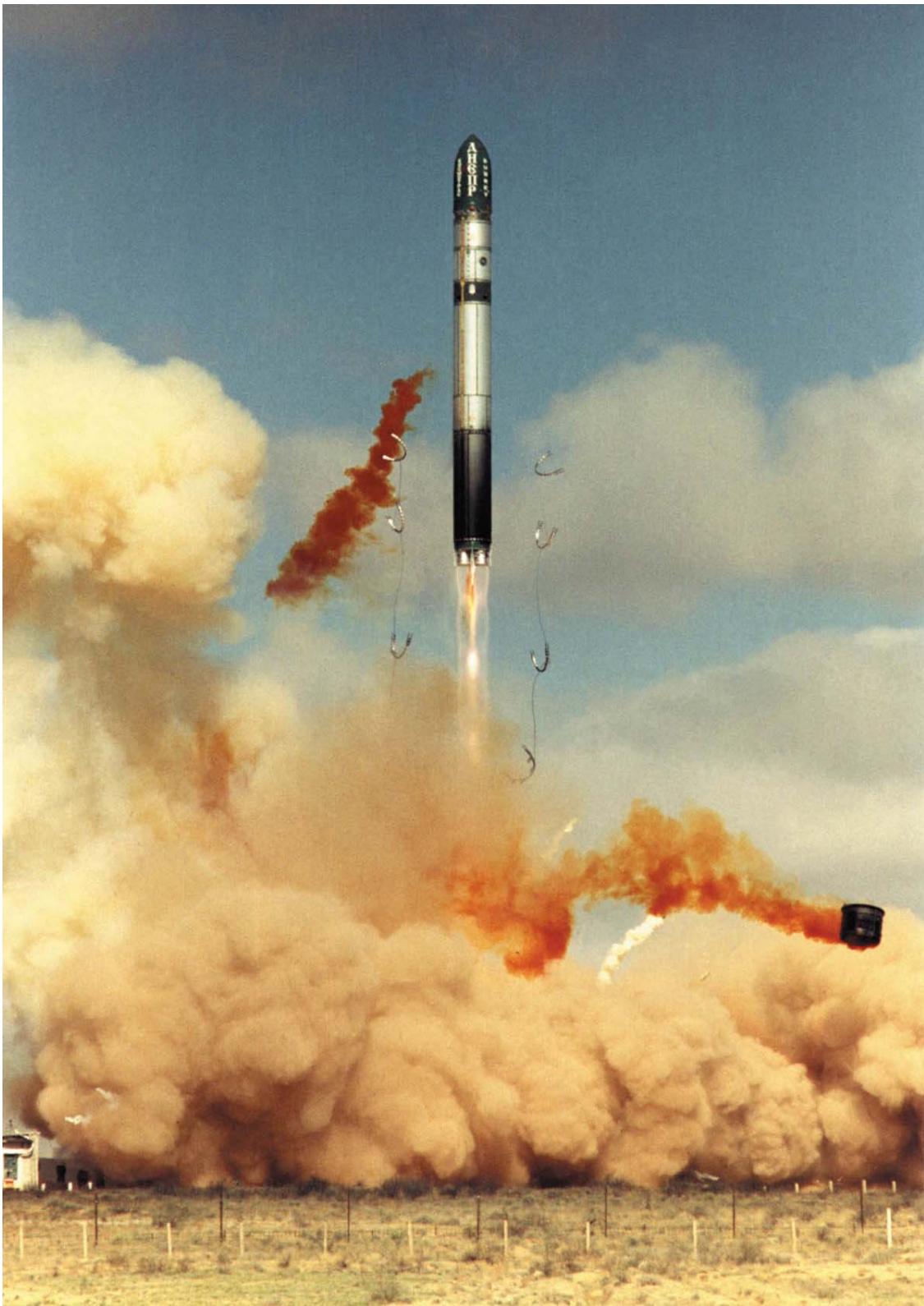


Figure. 1-1 Dnepr-1 Lifts off from Baikonur Cosmodrome. September 26, 2000



2. International Space Company Kosmotras

2.1 ISC Kosmotras Permits and Authorities

International Space Company (ISC) Kosmotras (a joint stock company) was established in 1997 by aerospace agencies of Russia and Ukraine.

ISC Kosmotras performs the development and commercial operation of the Dnepr SLS in accordance with the Russian Government Decree # 1156 "On Creation of Dnepr Space Launch System" dated October 5, 1998 and Ukrainian Cabinet of Ministers decree # 1246 "On Measures Regarding the Establishment of ISC Kosmotras" dated November 6, 1997.

The activities on Dnepr SLS were recognized in the joint statement of the Russian and Ukrainian presidents issued on May 31, 1997, and on February 27, 1998 were incorporated into the Program of Cooperation between Russia and Ukraine in the field of research and exploitation of outer space for peaceful purposes, and into the Russian Federal Space Program and National Space Program of Ukraine.

In the joint statement of the Russian and Ukrainian presidents on cooperation in the field of rocket and space technology dated 12th February 2001, the expansion of commercial application of Dnepr launch vehicle was quoted as top priority for long term cooperation of the two countries in the field of space related activities.

In the Program of Cooperation between the Russian Aviation and Space Agency and National Space Agency of Ukraine in

the field of research and exploitation of outer space for peaceful purposes for 2001, which is an integral part of the long term cooperation program between Russia and Ukraine for 1998 - 2007, the Program of development and operation of the Dnepr Space Launch System was called as one of the priority projects for 2001.

2.2 Dnepr Program Management. Dnepr Team and Responsibilities

The top management body of ISC Kosmotras is its Board of Directors composed of the members from Russia, Ukraine and the Republic of Kazakhstan - heads of companies incorporated in ISC Kosmotras, officials of governmental entities, as well as leading specialists of the program.

Direct Dnepr Program management is exercised by ISC Kosmotras principal office located in Moscow, Russia.

Given below are Dnepr team members:

Russia

- Russian Aviation and Space Agency (Moscow) - state support and supervision, provision of facilities and services at Baikonur Cosmodrome;
- Russian Ministry of Defense – allocation of SS-18 assets to be converted into Dnepr-1 launch vehicles, SS-18 storage and Dnepr-1 standard launch operations;
- Joint Stock Company ASKOND (Moscow) – primary entity for Dnepr Program management;



- ❑ Joint Stock Company Rosobschemash Corporation (Moscow) - coordination of SS-18 elimination programs;
- ❑ FSUE Design Bureau of Special Machine Building (St. Petersburg) - primary entity for maintenance of launch complex and processing facilities;
- ❑ FSUE Central Scientific and Research Institute of Machine Building (Moscow) - scientific and technical support of the program;
- ❑ FSUE Scientific and Production Association "IMPULSE" (St. Petersburg) - development and upgrade of launch control and support equipment;
- ❑ State Enterprise Moscow Electrical and Mechanical Equipment Plant (Moscow) - modification of launch vehicle control system instrumentation;

Ukraine

- ❑ National Space Agency of Ukraine (Kiev) - state support and supervision;
- ❑ State Design Bureau (SDB) Yuzhnoye (Dnepropetrovsk) - primary design and development organization for the launch vehicle and the entire Dnepr SLS;
- ❑ State Enterprise "Production Association Yuzniy Machine Building Plant" (Dnepropetrovsk) - primary manufacturing entity;
- ❑ Scientific and Production Enterprise KHARTRON-ARKOS (Kharkov) - primary entity for launch vehicle control system;

Republic of Kazakhstan

- ❑ Aerospace Committee of the Ministry of Energy and Mineral Resources - state support and supervision;
- ❑ State Enterprise "INFRAKOS" (Baikonur) - participation in Dnepr Program activities at Baikonur Cosmodrome;
- ❑ State Enterprise "INFRAKOS-EKOS", a subsidiary of "INFRAKOS" (Alma-Aty) - ecological support of the program.

Additionally, ISC Kosmotras, on a contract basis, uses services of partners located outside of Russia and Ukraine for Dnepr Program marketing.

Figure 2.2-1 shows the Dnepr Program operations structure. ISC Kosmotras principal office maintains contacts with launch customers, conducts preliminary evaluation of launch services provision opportunities, concludes contracts with customers, organizes their fulfillment by companies – subcontractors from Russia, Ukraine and Kazakhstan, works in cooperation with the Russian Ministry of Defense, Russian Aviation and Space Agency, National Space Agency of the Ukraine and National Aerospace Committee of the Republic of Kazakhstan, as well as with other governmental agencies of these countries.

In August 1999 ISC Kosmotras established an ISC Kosmotras subsidiary that is located in the city of Kiev, Ukraine. It is licensed by the NSAU to conduct space related activities. Its primary mission is to participate in the process of establishing favorable conditions for promotion of Dnepr launch services to the market.

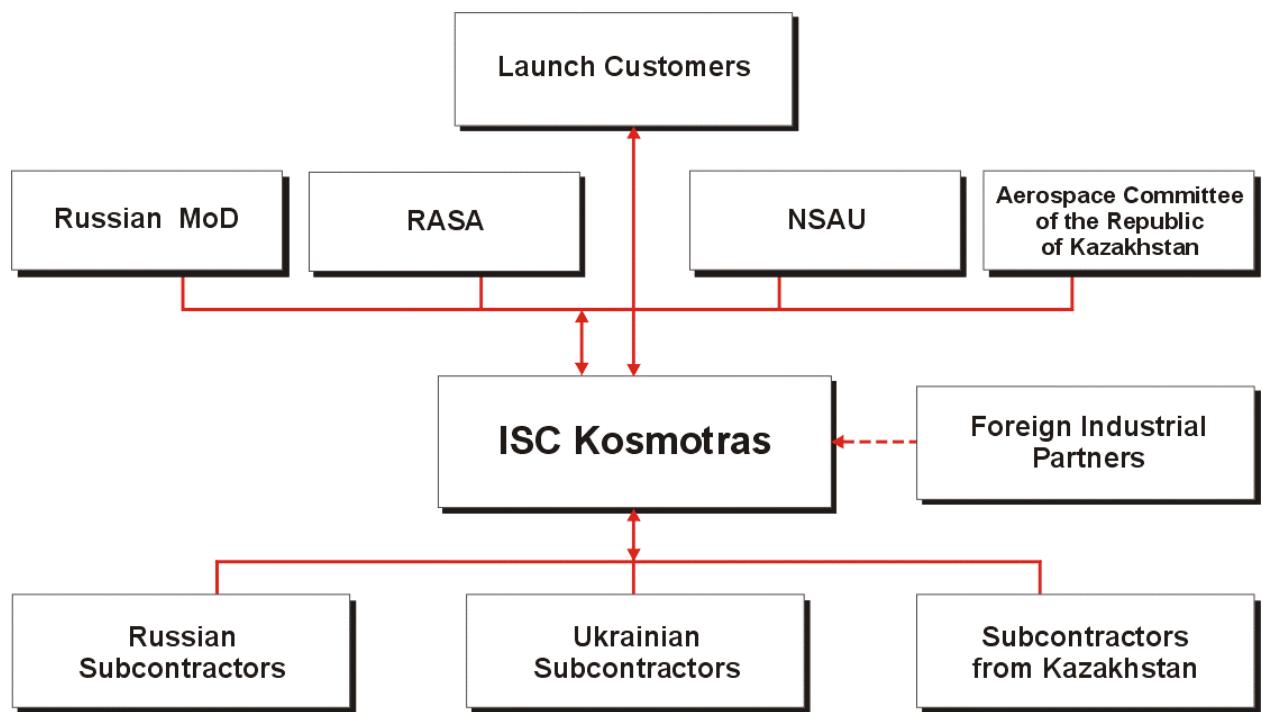


Figure 2.2-1 Dnepr Program Operations Diagram



3. Purpose, Composition and Principal Characteristics of Dnepr Space Launch System

Dnepr SLS is designed for expedient, high-accuracy injection of various single or multiple spacecraft weighing up to 3.7 metric tons into low-earth orbits inclined 50.5, 64.5, 87.3 or 98 degrees.

Dnepr SLS is developed on the basis of the SS-18 missile system, which is being decommissioned in the process of reduction and elimination of strategic offensive arms. In the course of the development of the system, the following major principles are being followed:

- maximum heritage with previously developed and proven systems and units;
- utilization of proven work technologies; and
- utilization of LV standard flight trajectories and their associated drop zones.

Dnepr SLS consists of the following elements:

- launch vehicle with the space head module;
- launch complex with the launch control center;
- launch vehicle, spacecraft and space head module processing facilities; and
- set of data collection and processing means.

Dnepr LV is based on the SS-18 ICBM modified in order to ensure optimal spacecraft integration and injection with the minimum costs incurred.

Launch complex is a combination of technologically and functionally interrelated systems, components, facilities and service lines required to maintain the readiness status of the launch vehicle, and to prepare and execute its launch.

LV processing facility incorporates special structures and mobile processing equipment required to prepare the LV for launch.

SC and SHM processing facility is designed to perform the following operations:

- acceptance, temporary storage and processing of the spacecraft; and
- assembly and processing of the space head module consisting of the spacecraft, adapter, intermediate section, gas-dynamic shield and LV fairing.

Available telemetry posts are used for receiving telemetry data during injection into orbit and for taking trajectory measurements.

If the spacecraft is launched southward (87.3, 98 degrees inclination), telemetry posts located along the flight path on the territory of foreign countries may be used in order to ensure stable coverage.

The sequence of ground telemetry post operation (including mobile telemetry assets) is contingent on the injection pattern of a specific spacecraft.



Depending on the spacecraft launch program requirements 1 to 3 silo launchers can be used, which are capable of up to 25 launches per year (if the personnel work in one shift).

The launch vehicle inside its launch canister, when fuelled and placed inside the silo launcher, can be on stand-by awaiting integration with the SHM and SC for an unlimited period of time throughout its operational life.



4. Dnepr-1 Launch Vehicle

4.1 General Description

Dnepr-1 launch vehicle with a space head module is a basic modification of the liquid-fuelled SS-18 ICBM with a three-stage-plus-SHM in-line configuration.

General view of the launch vehicle with the space head module is shown in Figures 4.1-1 and 4.1-2.

The LV first and second stages are standard SS-18 elements and used without modification.

First stage propulsion unit features four single-chamber motors, while the second stage propulsion unit is composed of a main single-chamber motor and a four-chamber thruster.

The LV third stage is a modified standard SS-18 third stage equipped with a liquid propellant, two-mode propulsion unit that operates based on a "drag" scheme. Modifications involve only the control system in order to provide optimal flight software and electrical links with the spacecraft.

SHM is attached to the third stage upper end. SHM consists of a spacecraft, intermediate section, adapter, either gas-dynamic shield (GDS), or Encapsulated Payload Module (EPM), protective membrane and SS-18's standard fairing.

Dnepr LV features a standard inertial high-precision computer-based control system.

The LV telemetry system ensures transmission of telemetric data from the LV up to SC separation (including the moment of separation) from the LV.

The LV safety system ensures flight abort of the first and second stages in case of an emergency (loss of flight stability). This system is based on the safety system used for flight testing of the SS-18 ICBM.

Dnepr LV is steam ejected from its transport and launch canister to a height of approximately 20 meters above the ground by means of activation of the black powder gas generator. The first stage propulsion unit is ignited upon the rocket ejection from the launch canister.

Separation of stages and fairing follows the proven SS-18 procedures. Spacecraft separation from the third stage is done by the third stage taking away from the spacecraft by means of throttled-back operation of its motor. Prior to the spacecraft separation, the gas dynamic shield or EPM cover is jettisoned.

Principal characteristics of Dnepr-1 LV with a single-tier space head module are given in Table 4.1-1.

Dnepr-1 LV performance curves are presented in Figure 4.1.3.

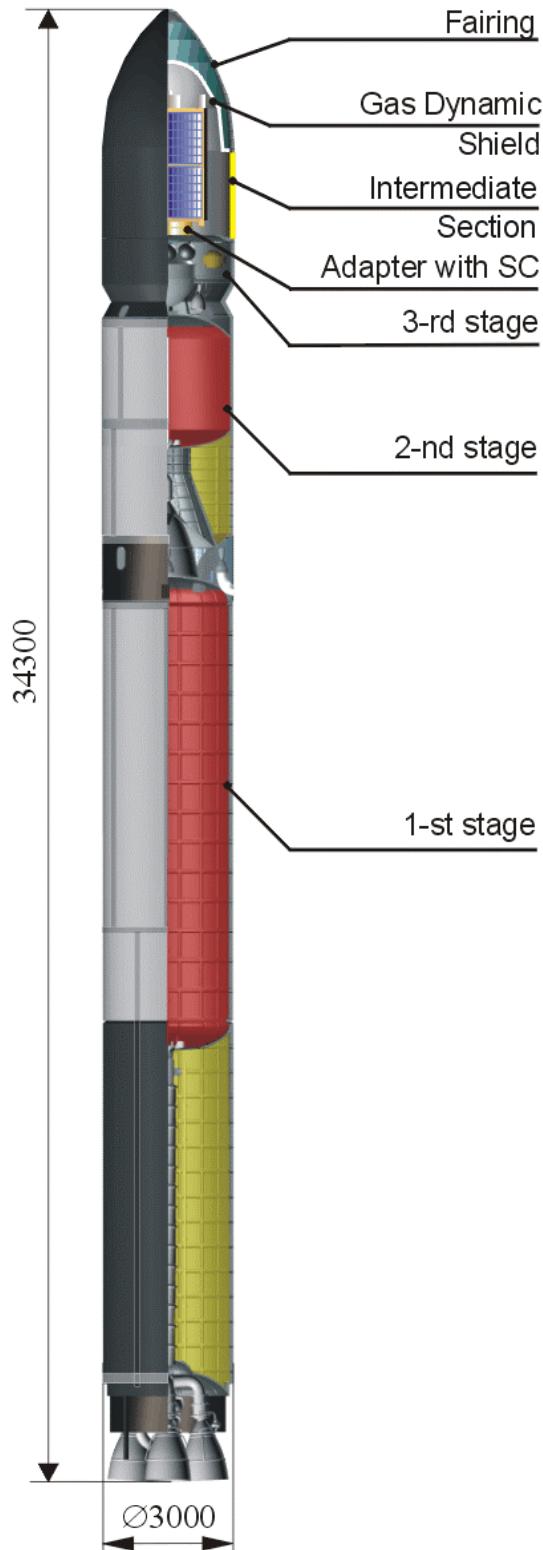


Figure 4.1-1 Dnepr-1 General View

Table 4.1-1 Dnepr-1 Main Characteristics

Liftoff mass (with the spacecraft mass of 2000 kg), kg	
1 st stage	208900
2 nd stage	47380
3 rd stage	6266
Thrust in vacuum, tons	
1 st stage	461.2
2 nd stage	77.5
3 rd stage (primary mode/throttled back operation mode)	1.9/0.8
Propellant components for all stages	
Oxidizer	Amyl
Fuel	Heptyl
Effective propellant capacity, kg	
1 st stage	147900
2 nd stage	36740
3 rd stage	1910
Flight reliability	0.97
SC injection accuracy (Orbit altitude $H_{cir} = 300$ km)	
for orbit altitude, km	± 4.0
period of revolution, sec.	± 3.0
for inclination, degrees	± 0.04
for ascending node right ascension, degrees	± 0.05
Orbit Inclination, degrees	50.5°; 64.5°; 87.3°; 98°



Figure 4.1-2 SS-18 1st and 2nd Stages Inside TLC

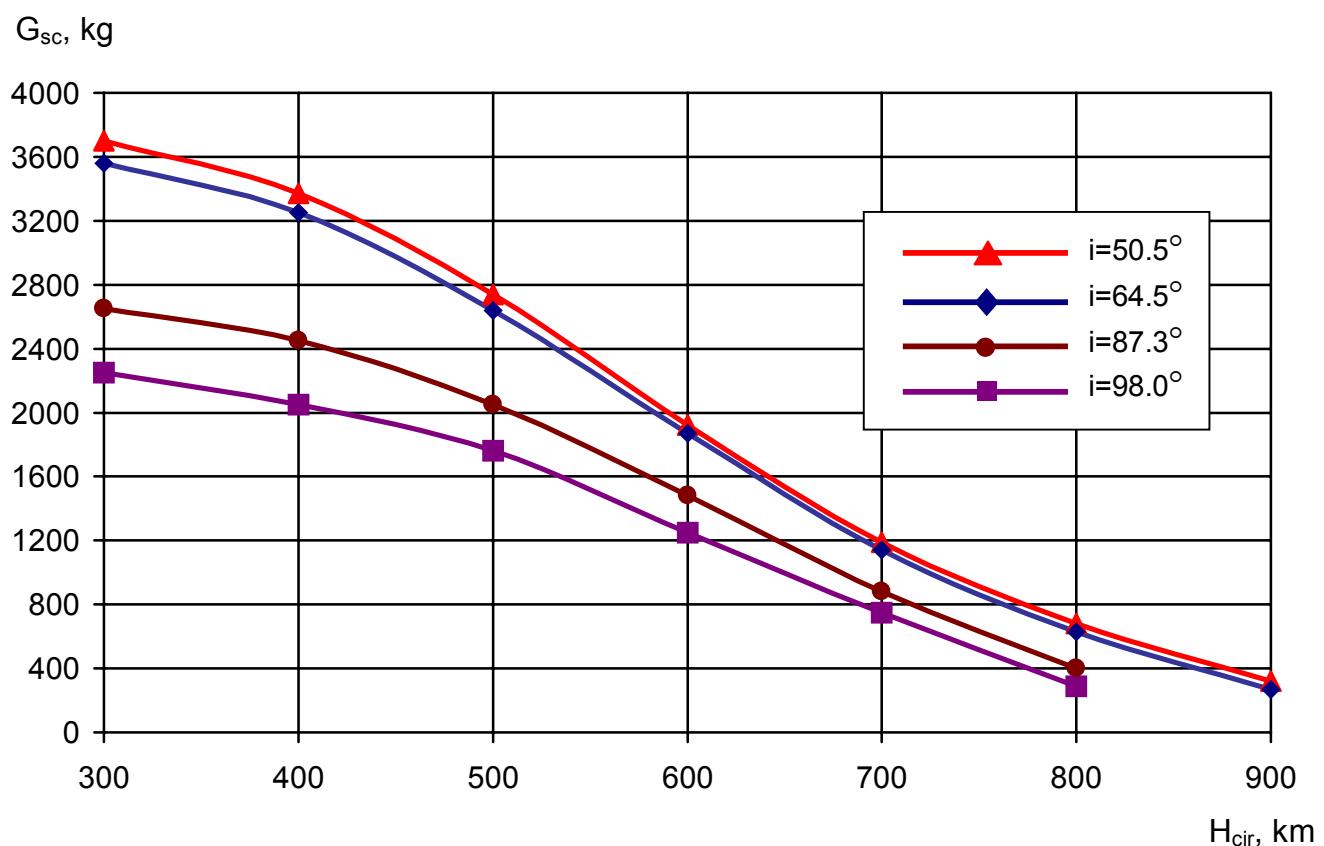


Figure 4.1-3 Dnepr-1 Performance Curves for Circular Orbits

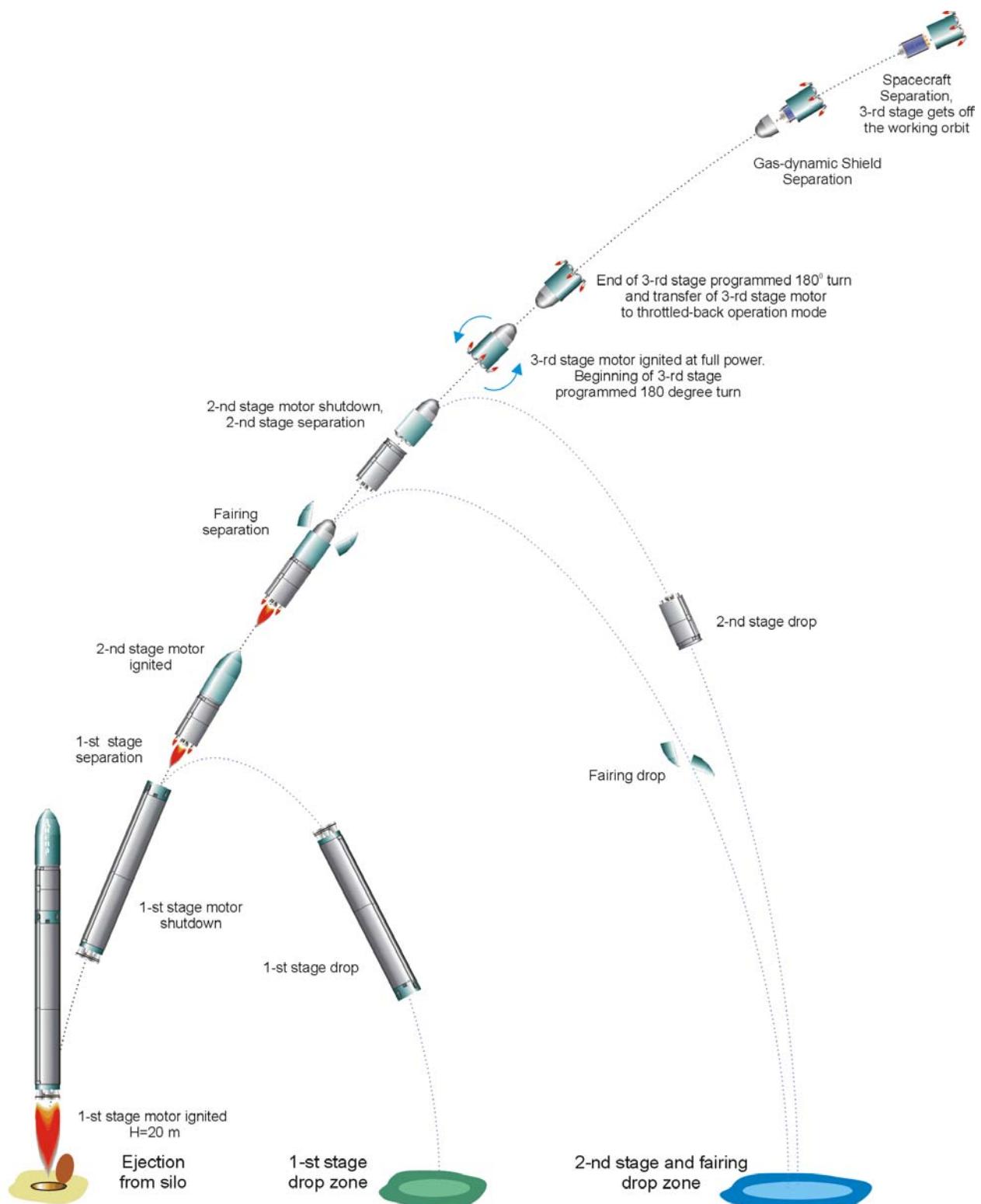


Figure 4.1-4 Mission Profile of Dnepr-1 LV Carrying a Large Spacecraft

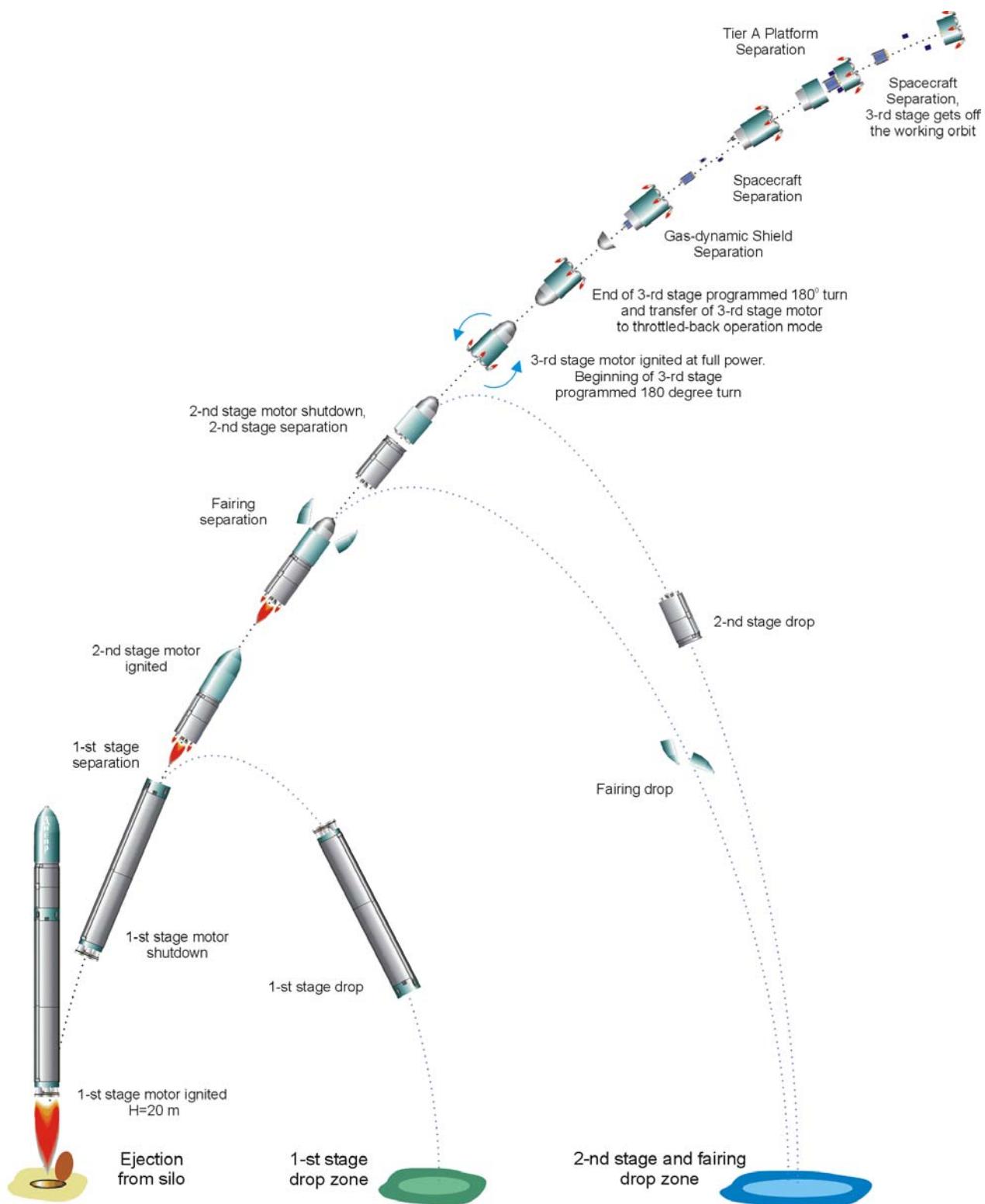


Figure 4.1-5 Mission Profile of Dnepr-1 LV with a Group of Spacecraft



4.2 Spacecraft Injection Accuracy

In spacecraft mission profile to a circular orbit without application of yaw maneuver, the maximum deviations (with probability $P=0.993$) of orbital parameters from nominal values at the moment of spacecraft separation do not exceed the values given in Table 4.2-1 below.

In case of multiple spacecraft injection, the orbit is calculated for each spacecraft, and the injection accuracy of a specific spacecraft may be specified.

The data contained herein is of general character. For each specific flight, the composition and values of monitored parameters may be specified subject to launch mission and associated modifications of 3rd stage control system operation pattern, required orbit parameters, payload mass (number of spacecraft being inserted), separated element drop zones, etc.

4.3 Launch Vehicle Axes Definition

The Launch Vehicle pitch and yaw planes as well as its rotation axes are defined by the LV center line as its longitudinal axis and by mutually perpendicular I-III and II-IV axes (see Figure 4.3.1):

- the pitch plane is defined by the LV longitudinal axis and I-III axis.

I-III axis is positioned in such a way that the I-direction of the axis is pointing away from the launch site (lift-off point), whereas III-direction is pointing to the launch site;

- the yaw plane is defined by the LV longitudinal axis and II-IV axis.

The LV angular displacements are determined (relative to an observer looking forward from the LV aft section) as follows:

- the LV makes pitch rotation around II-IV axis. The pitch positive movement displaces the LV nose section in the upward direction (towards direction III of I-III axis);
- the LV makes yaw rotation around I-III axis. The yaw positive movement displaces the LV nose section in the left-hand direction (towards direction II of II-IV axis);
- the LV makes roll rotation around the longitudinal axis. The roll positive movement turns the LV clockwise (from direction I of I-III axis to direction II of II-IV axis).

Positive directions of the pitch, yaw and roll rotation are shown by arrows in Fig. 4-3.1.

Table 4.2-1 Spacecraft Injection Accuracy

Orbital Parameter	Typical circular orbits		
	H=300 km, i=98°	H=600 km, i=98°	H=900 km, i=65°
Altitude, km	±4.0	±5.5	±10.0
Period of revolution, sec.	±3.0	±4.0	±6.5
Inclination, deg.	±0.040	±0.045	±0.050
Right ascension of the ascending node, deg.	±0.050	±0.060	±0.070

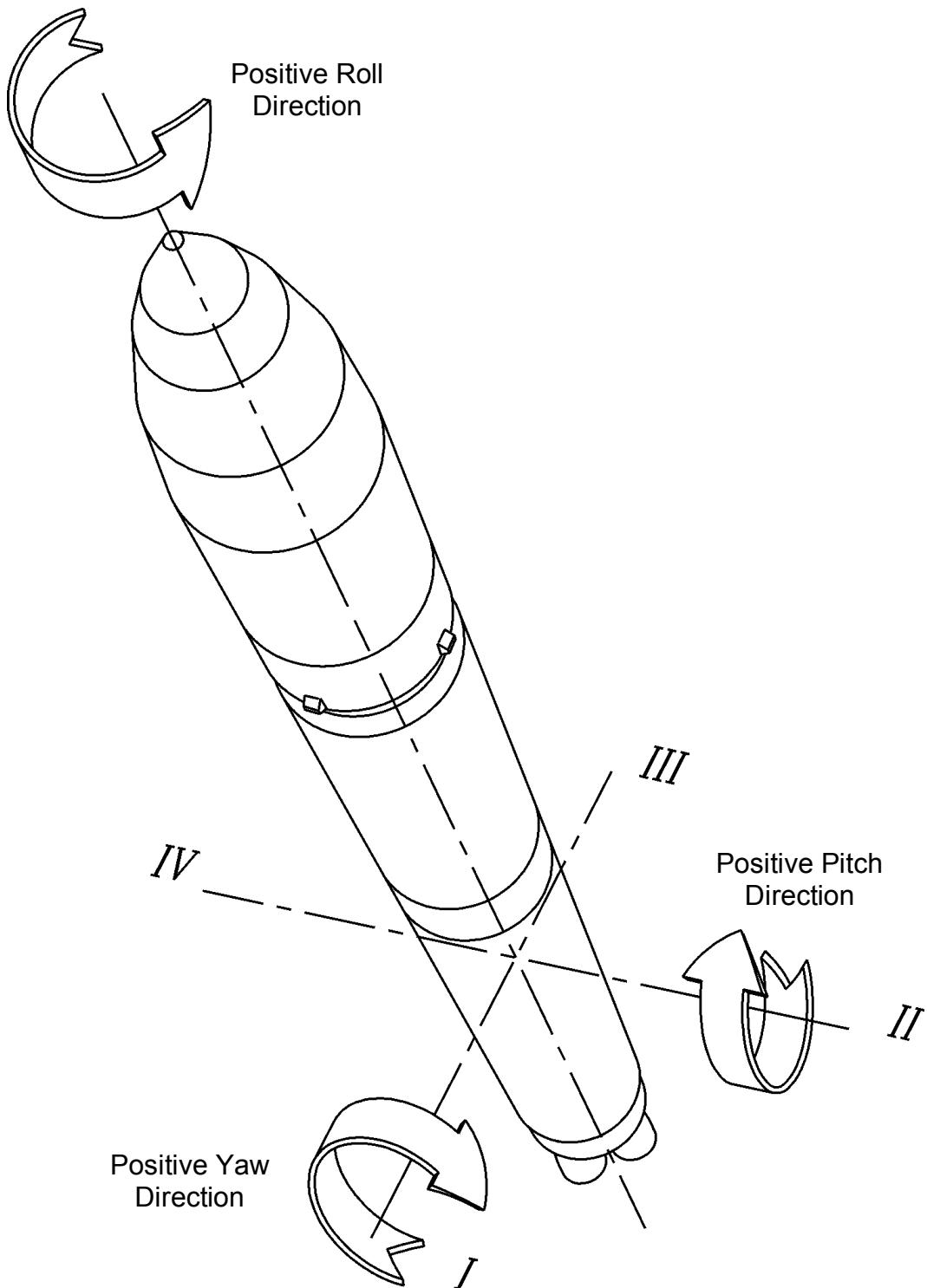


Figure 4.3-1 Launch Vehicle Major Axes

4.4 Space Head Module

4.4.1 Space Head Module Design

The spacecraft is installed inside the SHM. The SHM is composed of the fairing, cylindrical intermediate section, adapter, protective membrane, GDS or EPM.

Fairing is a four-cone structure that has a longitudinal joint along stabilization axes I and III, which divides the fairing into two half-shells (sections) that are tied together by 28 pyro-devices. The fairing is installed atop the cylindrical intermediate section and attached to it by means of 8 pyro-devices. Upon the fairing separation command, the half-shell and fairing/intermediate section attachment pyros are activated, the half-shells are hinged by means of spring pushers installed at the bottom end of the fairing and, upon reaching a certain angle of turn, are separated from the intermediate section.

Intermediate section is a cylindrical part that has a length of 2080 mm (standard size) and diameter of 3000 mm and incorporates two platforms – A (on upper extreme ring frame of which, the fairing is installed) and B (the bottom extreme ring frame of which is attached to the 3rd stage). Both platforms are interconnected by 6 pyro-devices. The length of intermediate section can be extended by 850 – 2000 mm to incorporate a bigger spacecraft.

Adapter is a newly developed conical structure. Attached to the adapter upper flange are the spacecraft and a special protective membrane that isolates the payload envelope from the control and telemetry system instrumentation

compartment located under the adapter. The adapter bottom flange sits on the lower extreme ring frame of the platform B.

In necessary, an additional adapter (or several adapters) that is already integrated with the spacecraft, may be placed on the standard adapter.

SHM is available in two configurations:

Configuration 1 – a newly developed intermediate section with GDS;

Configuration 2 – an intermediate section consisting of standard platforms A and B plus EPM.

Both configurations of SHM use the standard fairing and a newly developed adapter.

For SC protection against the 3rd stage motor plume, the Configuration 1 utilizes the GDS that is attached to the Platform A upper ring frame and separated prior to the SC release.

For the above purpose, the Configuration 2 uses the EPM, the cover of which is separated prior to the spacecraft release, i.e. similarly to the GDS.

Layout schematics of the standard length SHM (both with GDS, and EPM) is shown in Figure 4.4.1.1 and 4.4.1.2 respectively.

Layout schematic of SHM Configuration 1, the length of which is extended by 850 mm, is shown in Figure 4.4.1.3.

SHM design allows for multi-tier spacecraft layout. One of the options for such layout is shown in Figure 4.4.1.4.

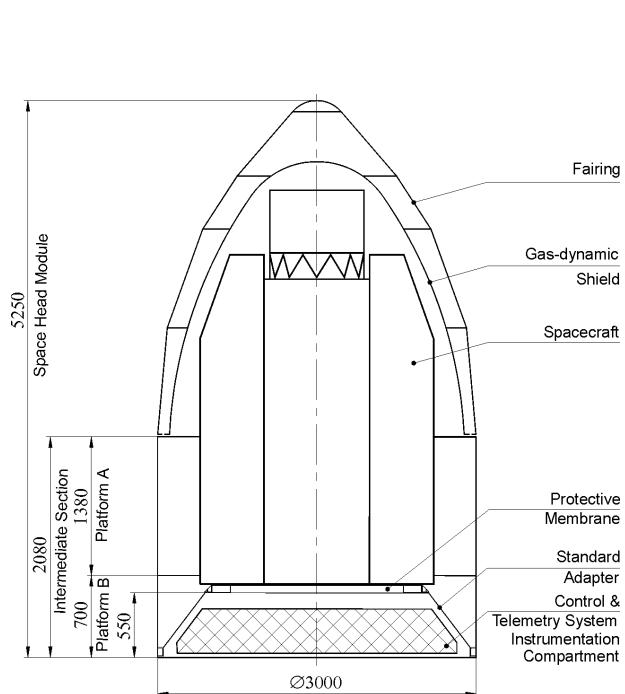


Figure 4.4.1-1 SHM Configuration 1 –
Standard Length

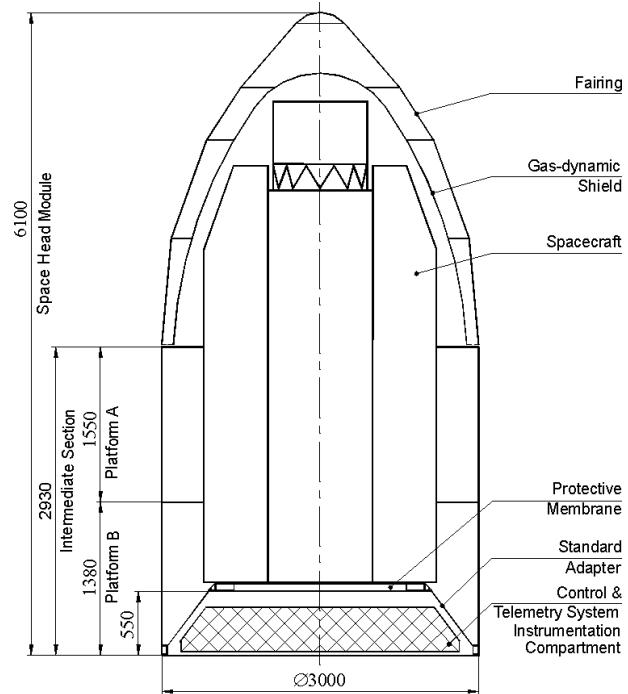


Figure 4.4.1-3 SHM Configuration 1 –
Extended by 850 mm

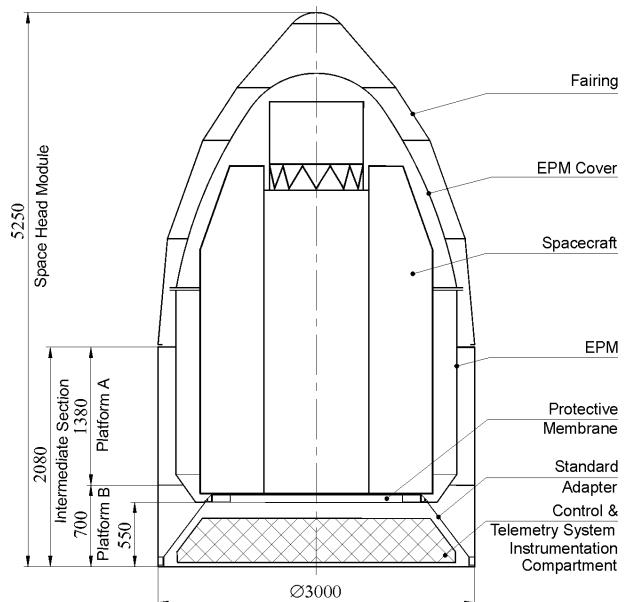


Figure 4.4.1-2 SHM Configuration 2 –
Standard Length

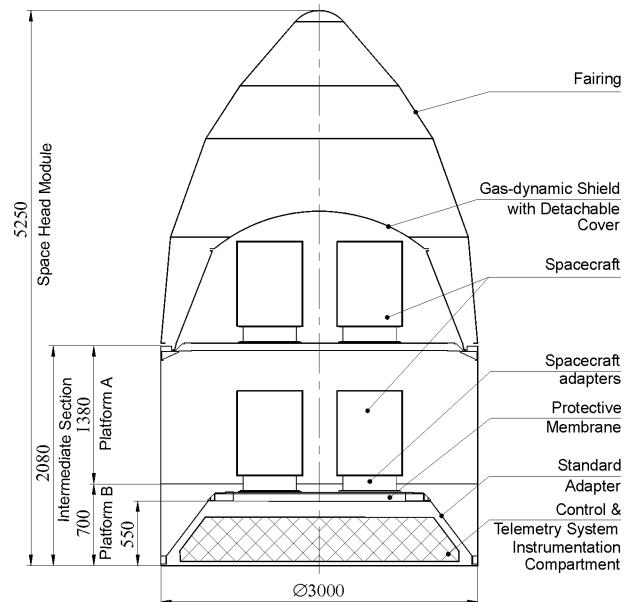


Figure 4.4.1-4 SHM with 2-tier Layout



4.4.2 Payload Envelope

Payload envelope is a volume within the SHM, which is designed for accommodation of spacecraft.

Spacecraft dimensions (including all of its protruding elements) must fit within the specified payload envelope, given all possible deviations and displacements from the nominal position during the ground testing and in flight.

The size of payload envelope within the standard SHM (length – 5250 mm) and

adapter ($H = 550$ mm) is shown in Figures 4.4.2.1 and 4.4.2.2 (i.e. for SHM Configuration 1 with GDS and SHM Configuration 2 with EPM respectively).

Figure 4.4.2.3 shows the size of payload envelope within the SHM extended by 850 mm (maximum possible extension of the SHM length is 2000 mm).

When designing the interface between the launch vehicle and a specific spacecraft, the size and configuration of the payload envelope may be specified.

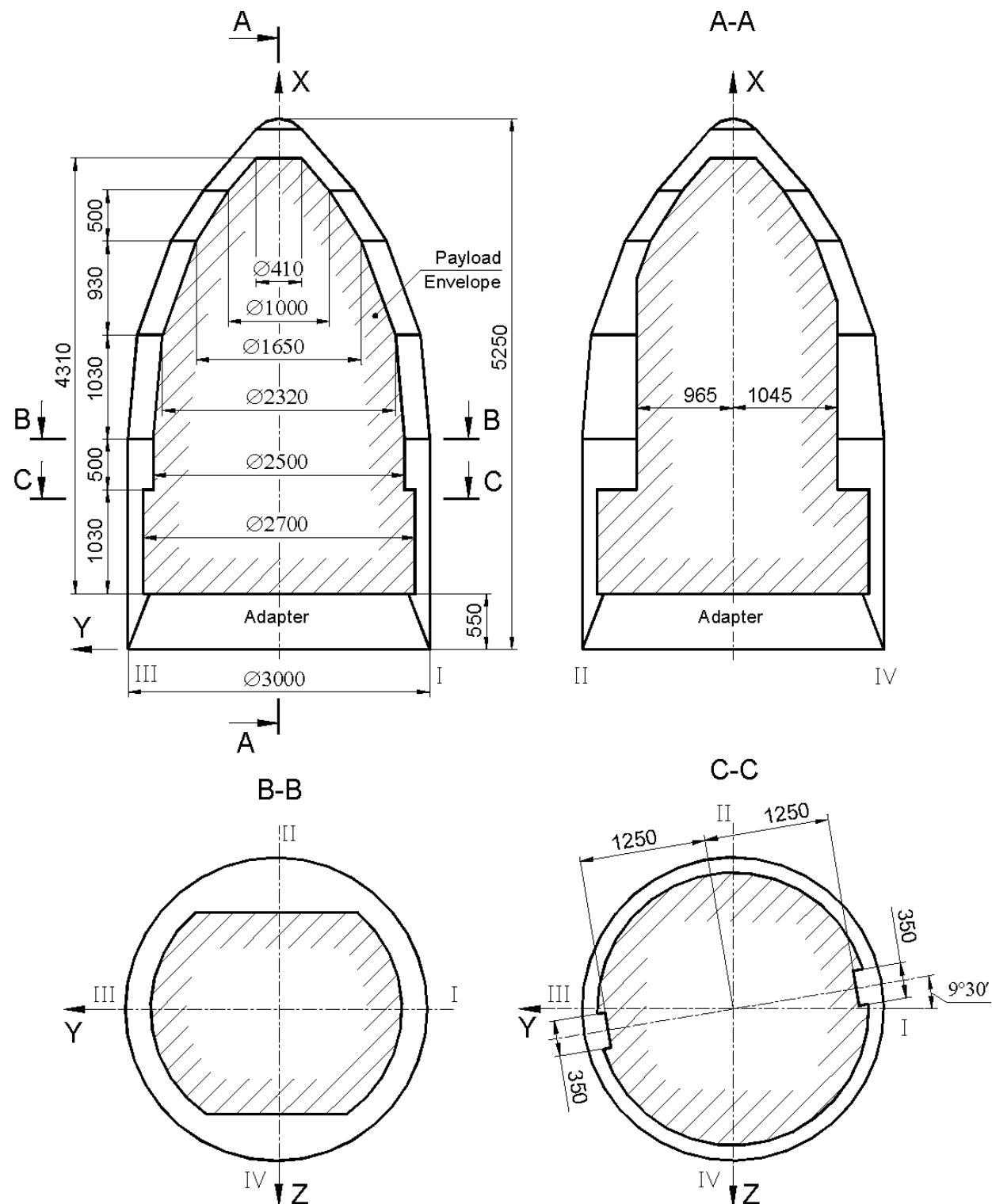


Figure 4.4.2-1 Payload Envelope Available within SHM Configuration 1 with Standard Adapter and GDS

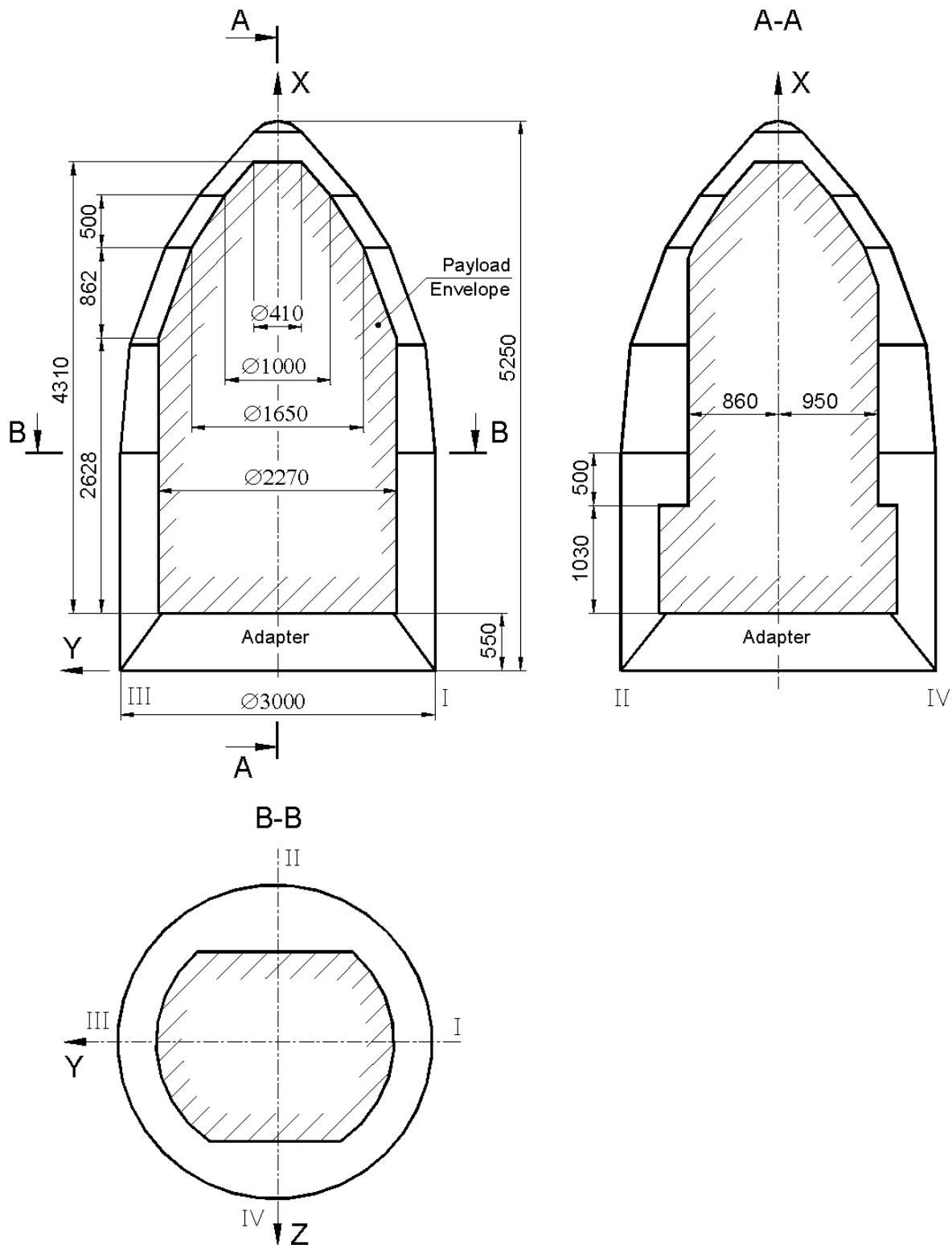


Figure 4.4.2-2 Payload Envelope Available within SHM Configuration 2 with Standard Adapter and EPM

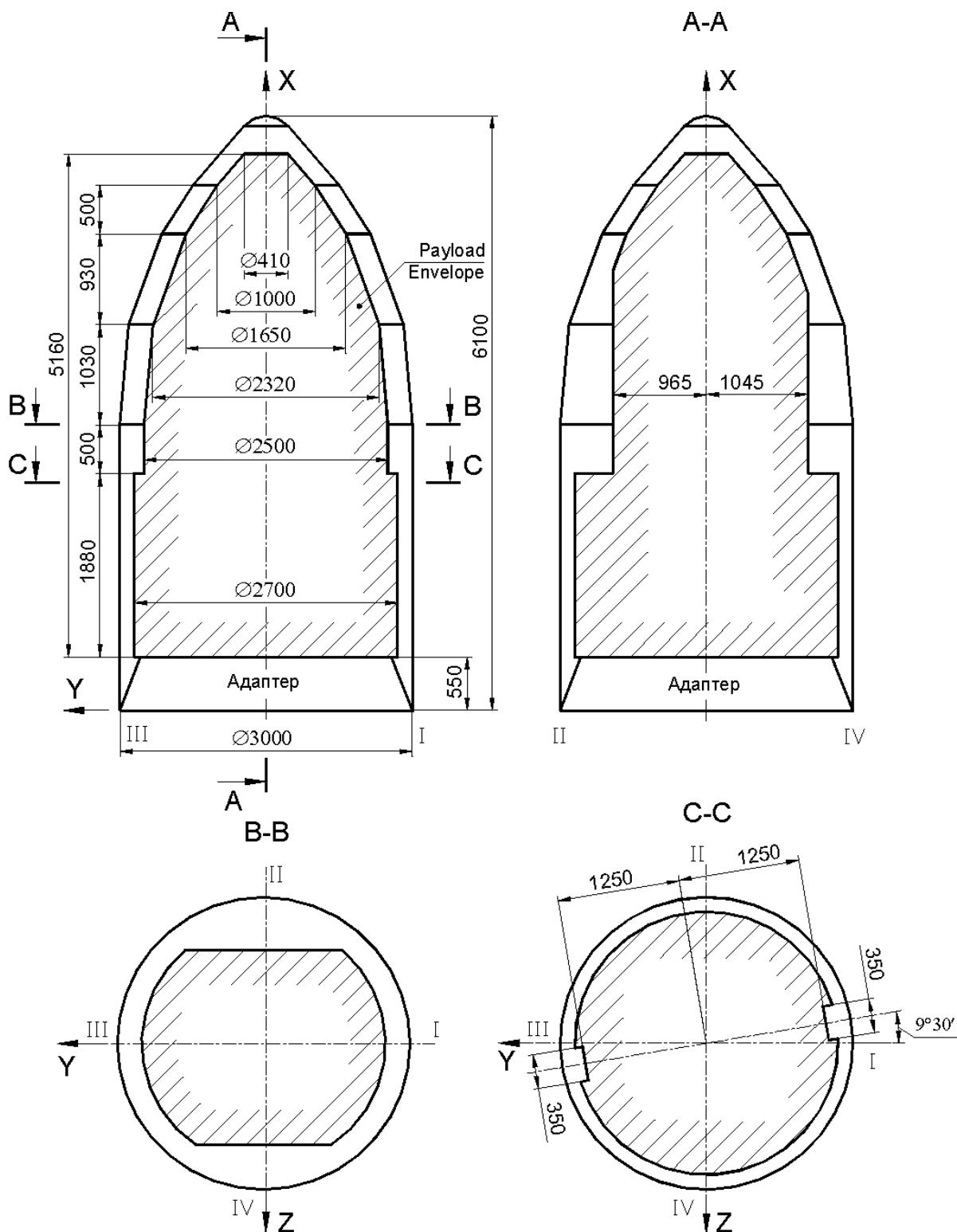


Figure 4.4.2-3 Payload Envelope Available within SHM Configuration 1 Extended by 850 mm with Standard Adapter and GDS



4.5 Launch Vehicle Flight Reliability

SS-18 in its basic configuration has been in operation since mid-70s. Throughout the entire period of its operation, a number of measures have been taken to maintain the technical condition of the rockets, launch and processing equipment. These measures include the following:

- Regular inspections of the operability of the systems, units and equipment;
- Scheduled (routine) maintenance;
- Replacement of faulty units, modules and components; and
- Periodical checks of the readiness of all systems, units and equipment for the performance of their basic functions.

The effectiveness and adequacy of the above measures have been demonstrated by the successful launches of the rockets with the different storage periods at various times during the SS-18 operational life.

In order to monitor the actual degree of the launch vehicle reliability, the leading institutes of the Russian Ministry of Defense and Russian Aviation and Space Agency, as well as State Design Bureau Yuzhnoye as the principal developer of the system, conduct annual independent evaluation of the reliability data values, of their compliance with the established requirements and also develop programs of work necessary to ensure the required

level of reliability. The implementation of this work ensures and allows to maintain the high level of the rocket reliability throughout the entire period of its operation. Currently, the mission reliability factor for the rocket is 0.97, which has been established through a great number of successful launches.

The total of 159 launches of the SS-18 were carried out as of October 2001 with only 4 of the launches encountering malfunctions or anomalies of certain systems. The causes of the failures have been unequivocally established. They were due to isolated manufacturing defects. Based on the analysis of these defects, certain measures were taken to enhance rocket fabrication quality and ensure full compliance with engineering documentation during fabrication. The effectiveness of the measures taken was proved through subsequent successful launches. No similar recurring malfunctions were encountered. 8 SS-18 launches have been conducted from 1990 to 2000, all of them successfully accomplished their mission.

The conversion of the SS-18 into Dnepr-1 launch vehicle requires minor design modifications associated with the spacecraft integration with the launch vehicle and spacecraft separation process. The modified components undergo vigorous ground testing that enables to maintain the achieved mission reliability level. The above-mentioned 8 launches included two launches in Dnepr-1 configuration that were performed in 1999 – 2000.

5. Baikonur Cosmodrome

Dnepr SLS operates from Baikonur Cosmodrome, one of the largest spaceports in the world.

Baikonur Cosmodrome is located in Kazakhstan east of the Aral Sea (63° E and 46° N) in the semiarid zone with sharply continental climate. Typical for this area are hot dry summers and frosty winters with strong winds and little precipitation. In summer, the temperature can rise up to plus 45°C and in winter, it can drop to minus 40°C. Yearly average temperature is approximately plus 13°C.

The Cosmodrome is located sufficiently far away from the large centers of population. This fact ensures safety of the launches and facilitates the task of creating buffer areas, which are used as launch vehicle stage drop zones. Another advantage of the Cosmodrome location is the fact that typical for this location is a great deal of clear days on a yearly basis.

The residential area of the Cosmodrome is the town of Baikonur located on the right bank of the Syrdarya River. Directly adjacent to the town are the village of Tyuratam and the railway station of the same name. Two Baikonur airports are connected with the city of Moscow by regular flights.



Figure 5-1 Yubileiniy Airfield



Figure 5-2 Syrdarya River



Figure 5-3 Cosmodrome Residential Area – Town of Baikonur

These airports are equipped to accommodate any types of cargo and passenger planes.

The town has the following facilities: a movie theatre, a stadium, a swimming

pool, TV center, medical facilities, cafes and restaurants as well as international telephone, telex and facsimile services. Baikonur visitors can stay at several hotels that offer single and double rooms.

Accommodations are offered for spacecraft processing specialists and launch guests at Sputnik, Baikonur and Kosmonavt hotels located in the northern part of the town.

All Russian and foreign cosmonauts stay at Kosmonavt hotel during preparation for space flight.

The rooms have air conditioning, a television set, a refrigerator and a bath room. Deluxe accommodations, in addition



Figure 5-4 Kosmonavt Hotel



Figure 5-5 Baikonur Hotel

to the above-mentioned facilities, have a bed room and a private office. The cost of accommodation is \$30 – 80 per day at Baikonur and Kosmonavt hotels and \$220 – 250 per day at Sputnik hotel.



Figure 5-6 Facilities of Sputnik Hotel



ATMs and exchange offices are available in Baikonur for currency exchange and cash withdrawal. Both Russian and Kazakhstan currencies are accepted. Most payments are made by cash.

The Cosmodrome is connected with other cities and countries by air, rail and road transportation. There is an extensive network of motor and railroads on the territory of the Cosmodrome.

The town provides centralized water (hot and cold) and 220V/50Hz power supply.

The basic accommodation for the customer's personnel is assumed to be Kosmonavt hotel.

Table 5.1 shows typical routes of transportation at Baikonur Cosmodrome.

Table 5-1 Typical Routes of Transportation at Baikonur Cosmodrome

Krainiy Airport	Kosmonavt Hotel	6 km
Yubileiniy Airport	Kosmonavt Hotel	55 km
Tyuratam Railway Station	Kosmonavt Hotel	3 km
Kosmonavt Hotel	Launch Site	45 km
Kosmonavt Hotel	Facility 31, SC Fuelling Facility	60 km
Kosmonavt Hotel	Facility 42, AITB	55 km

Minivans and sedan cars are available for transportation of personnel. The presence of local escorts to accompany transport vehicles is a must.

Accommodation for VIPs is available at 5-star Sputnik hotel. Police escorts can be

arranged for VIP transportation.

During spacecraft preparation for launch at S/C processing facility and launch complex, the Customer can be provided with the following telecommunication services:

- local/international telephone/facsimile communication;
- internal technological and public address system between work sites at processing facility premises (intercom);
- mobile radio and radiotelephone communication;
- communication channels to transmit UTC and pre-launch countdown signals;
- access to the Internet, etc.

Dnepr SLS telecommunication system is integrated into the single distributed information network of the Baikonur Cosmodrome based on the ISDN principles by wire cable and radio relay communication channels network. This network covers the premises and facilities of the launch complex (Sites 103, 106, 109, 111/2), S/C processing facility (Sites 31, 42) and other Cosmodrome facilities.

International communications are provided by a satellite segment based on the Intelsat and Inmarsat type ground stations with direct access to the Moscow telephone network.

The mobile communication is provided by the trunking radio stations covering the complete Cosmodrome area, the GSM-900 cellular communication is provided at the most of the cosmodrome and adjacent town areas.



A fully equipped military hospital is located near the Kosmonavt hotel. Its personnel has the required qualification and experience. First medical aid is available at work premises and sites.

Upon customer's request, medical personnel and equipment can be placed on stand-by at spacecraft processing facility and in emergency circumstances, the patient may be evacuated to a European medical facility.

6. Dnepr SLS Ground Infrastructure

6.1 Elements and General Diagram of Ground Infrastructure

The Dnepr SLS ground infrastructure includes the following facilities:

- ❑ SC and SHM Processing Facilities;
- ❑ SC Fuelling Station;
- ❑ Launch complex;
- ❑ LV Processing Facility;
- ❑ Fueling station for storage, preparation and discharge of rocket propellant components;

Figure 6.1-1 shows infrastructure facilities at Baikonur Cosmodrome, which are used by ISC Kosmotras for Dnepr launch campaigns.

6.2 SC and SHM Processing Facility

SC and SHM processing facility is designed to perform the following operations:

- ❑ Receiving, temporary storage and processing of the spacecraft, including, if necessary, its filling with compressed gases and propellant components; and
- ❑ Assembly and processing of the space head module (consisting of spacecraft, adapter and launch vehicle fairing).

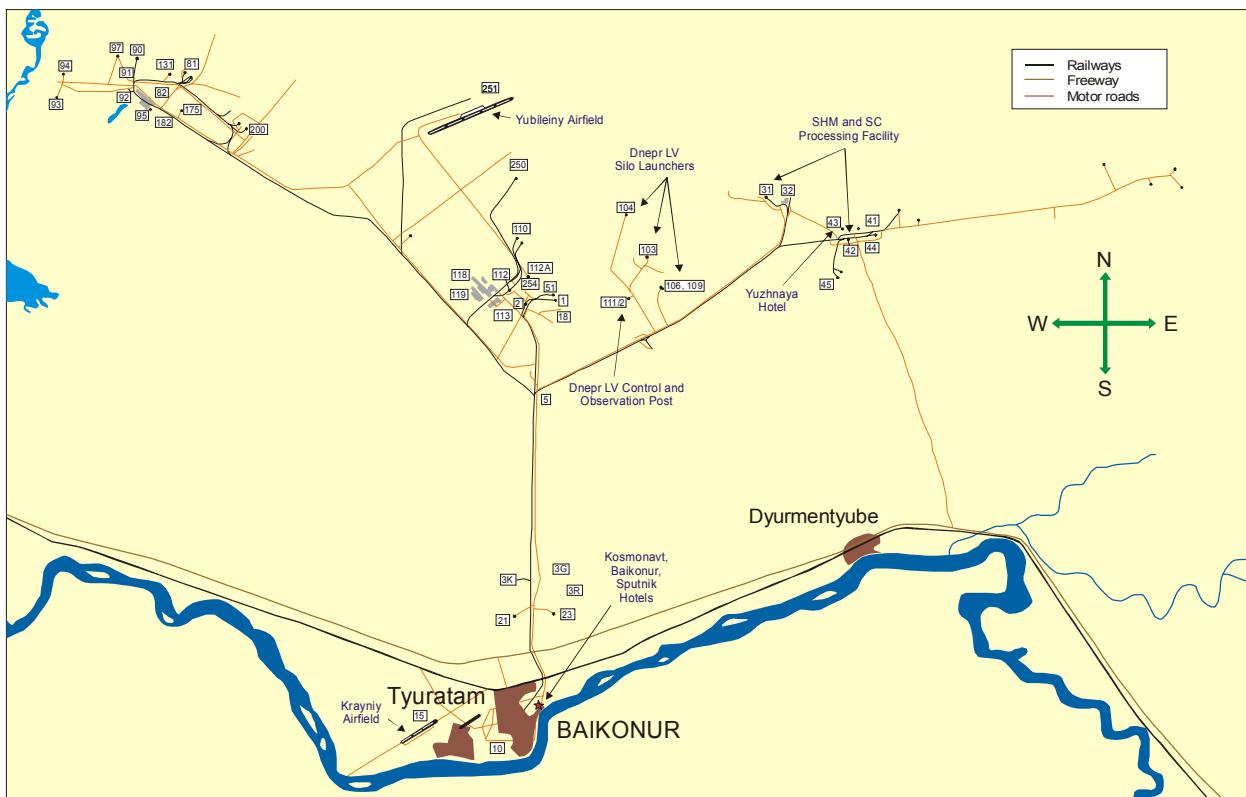


Figure 6.1-1 Dnepr SLS at Baikonur Cosmodrome

Containers with the spacecraft and spacecraft ground processing equipment (GPE) can arrive Baikonur via two airports - Yubileiniy and Krainiy as well as via TyuraTam railway station.

If a spacecraft needs to be kept in certain temperature conditions, it will arrive at Yubileiniy airport, from where it will be transported to SC and SHM processing facilities by special environmentally controlled railcars for subsequent operations.

If there is no strict temperature requirement, the spacecraft and SC GPE will be transported by road vehicles or general purpose railcars.

Two airports (Yubileiniy and Krainiy) are capable of receiving all passenger and cargo airplanes, including heavy ones (An-

124 and Boeing 747) and possess all necessary ground support equipment for handling operations.

Directly adjacent to Yubileiniy airport is a rail line that can be used for transportation of spacecraft and SC GPE to SC and SHM processing facility.

Depending on spacecraft processing requirements, its weight and dimensional characteristics and the cost of operation, ISC Kosmotras offers customers assembly, integration and test buildings (AITB) for spacecraft processing at Site 42 and/or Site 31.

If necessary, other AITBs available at Baikonur Cosmodrome may be used for spacecraft processing.

Premises and equipment located inside

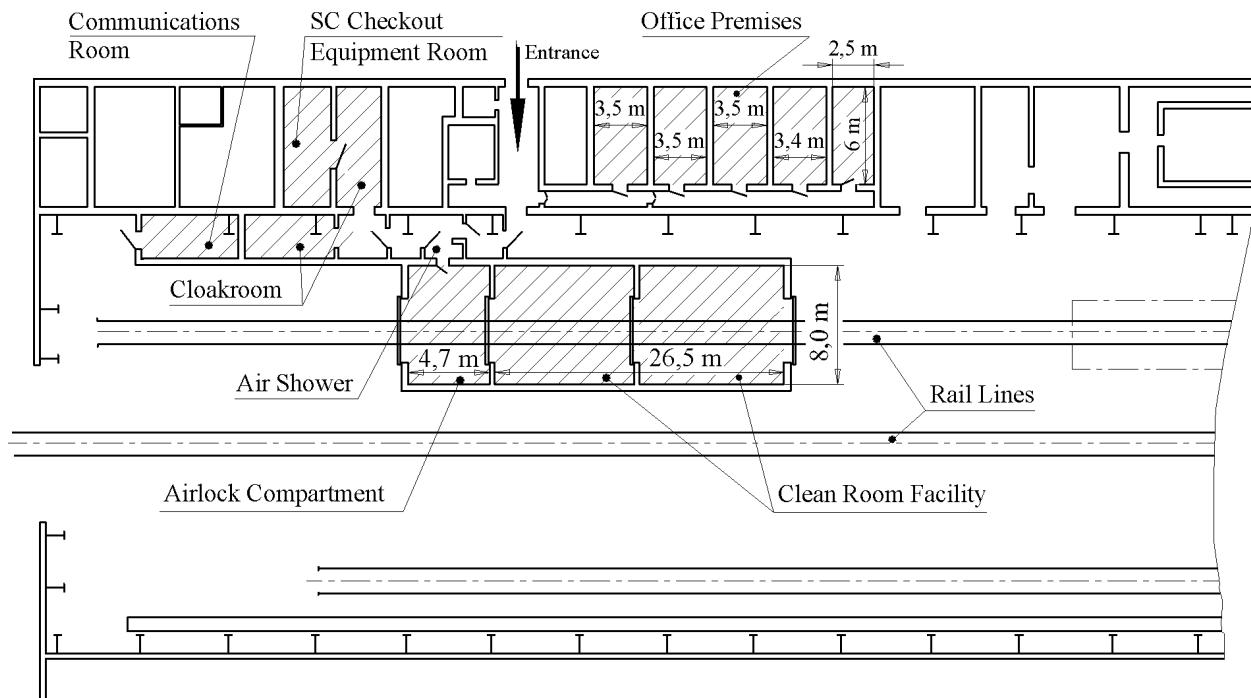


Figure 6.2-1 Layout of AITB, Site 42

the Zenith LV AITB were used for spacecraft processing in the course of first two Dnepr launch campaigns (Site 42). A layout of AITB, Site 42 is shown in Figure 6.2-1. Technical data for clean room facility (primary place for spacecraft processing and assembly of EPM) and other AITB premises is given below.

Clean room facility located inside the AITB is divided into two clean rooms with the aggregate floor area of 212 sq. meters and an airlock compartment of 32.6 sq. meters. Telphers with lifting capacity of 1000 kgf are available in the airlock compartment and the two clean rooms. Maximum height to the telpher hook is 8.2 meters. The sizes of the airlock compartment gate, the gate between clean rooms and the gate opposite the airlock compartment are 5.2x6.3 m, 5.2x8.2 m and 5.2x6.3 m respectively. The temperature inside the clean room facility is maintained within the range of 21.1°C - 26.7°C with the relative humidity being 30-60%. Cleanliness class is 100,000 (US FED-STD-209E). Clean

room facility has an anti-static floor, a low-impedance grounding contour (up to 4 ohms) and 12V/220V AC 50 Hz electric outlets. Illumination of airlock compartment is 300 lux and of clean rooms is 500 lux.

Spacecraft checkout equipment (COE) room has the aggregate floor area of 53 sq. meters (29 sq. meters and 24 sq. meters).

The AITB has office premises for personnel involved in spacecraft processing and assembly (4 rooms, 21 m² each), which are equipped with required communications means.

The AITB is equipped with the following utilities: uninterrupted power supply (with the same characteristics as both in Russia and the US), heating, air conditioning and ventilation, water supply, sewer, security and fire alarms, and various communication systems.

Near the clean room facility, there is a

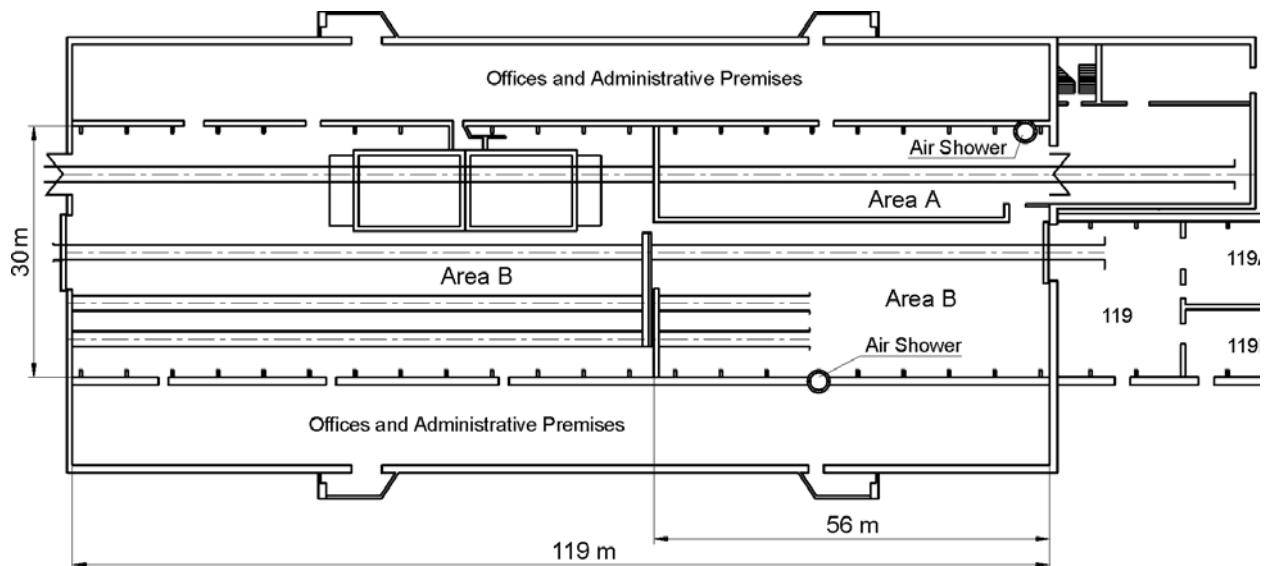


Figure 6.2-2 Layout of AITB, Site 31

place where the SHM or EPM is assembled and loaded into the transporter erector.

If the weight and dimensions of the spacecraft do not allow to use the AITB at site 42 or the spacecraft filling with propellant is required during its processing, ISC Kosmotras offers to use the AITB and fuelling station located at Site 32, shown in Figure 6.2-2.

This AITB consists of three areas A, B and C.

- Area A is designed for integration of EPM and for electrical checks of spacecraft as part of the EPM. To maintain the required cleanliness conditions during operations, the Area A is equipped with "air shower";
- Area B is designed for the spacecraft processing and assembly of SHM;
- Area C is designed for receiving and temporary storage of shipping containers with SC and SC GPE, of SHM platforms (SC adapters) and launch vehicle fairing, as well as for

handling operations including the loading of the integrated SHM into the transporter erector for transportation to the silo launcher.

Main characteristics of areas A, B and C are given in Table 6.2-1 below.

Facility 40D within the Area B consists of hall 119, 119A and 119B, the area of which is 240, 100 and 100 m² respectively. Hall 119 will incorporate the spacecraft, hall 119A will host spacecraft COE, and hall 119B will be for mechanical equipment, devices and consumables.

Hall 119 is equipped with compressed gas filling system, including filling with Nitrogen. This Nitrogen will be supplied under the pressure of 40 MPa (standard OCT 92-1577-78) and have the following parameters:

- nitrogen content – no less than 99.95%;
- oxygen content – no more than 0.05%;
- water vapor – 0.004%.

Table 6.2-1 Characteristics of Area A, B and C, AITB at Site 31

Area	A		B	C
	Characteristics			
Dimensions	Length 56.0 m Width 11.5 m		Length 56.0 m Width 18.5 m	Length 63.0 m Width 30.0 m
Cleanliness Class (US standard 209E)	100,000, if necessary 30,000		100,000, if necessary 30,000	-
Height to Crane Hook	13.8 m		13.8 m	13.8 m
Crane Lifting Capacity	10 and 50 tons		10 and 50 tons	10 and 50 tons
Temperature	18-25°C		18-25°C	18-25°C
Relative Humidity at 20 °C	30-60%		30-60%	-



Hall 119 has the following power supply system:

- 120 V 20 A 50 Hz;
- 208 V 30 A 50 Hz;
- 15 kWt 50 Hz.

Hall 119 is equipped with video cameras.

The personnel directly involved in spacecraft processing operations at Halls 119, 119A and 119B enter area B through air showers located at both ends of the AITB and separating “clean” and “not clean” areas. The personnel not completely involved in operations with the spacecraft, who operate communications means or computers are located in office premises of the “not clean” area. To support operations with the spacecraft in “clean” area, the office premises are connected with hall 119 by the required number of cables run through hermetically sealed inlets.

Work place for the SHM integration, processing and checks is also set up in area B.

The AITB is equipped with the following utilities: uninterrupted power supply (with the same characteristics as both in Russia and the US), heating, air conditioning and ventilation, water supply, sewer, security and fire alarms, and various communication systems.

6.3 Spacecraft Fuelling Station

SC fueling station is located in close vicinity to the AITB and is used for filling spacecraft with liquid propellant and gases.

Fuelling station is equipped with following systems:

- oxidizer filling system;
- fuel filling system;
- fuelling remote control system;
- system for collection and incineration of propellant vapors and sewage;
- fuelling equipment neutralization system;
- temperature and humidity control system;
- vacuumization system;
- gas control system;
- fire fighting system;
- set of scales.

Depending of the SC fuelling requirements, the propellant components undergo necessary processing:

- filtration through 20 or 5 micron filters;
- providing required temperature and humidity of propellant;
- saturation with nitrogen or helium; and
- degassing.

The fueling station is a heated 97-m long and 41-m wide building. The building is divided into three sections: section No. 1 – filling with fuel, section No. 2 - filling with compressed gas, and section No. 3 – filling with oxidizer.

The external doorways and openings between the sections have hermetic seals – rolling hermetic doors 5.5 meters long and 7 meters high. The sections are equipped with 15-ton capacity bridge cranes. For the purposes of transportation, there is a rail line running through the filling rooms. The temperature in the filling rooms is kept at +5°C to +35°C. Filling rooms are equipped with “clean tents”, which provide the cleanliness class 100,000 in accordance with US Federal Standard 209 A.

6.4 Launch Complex

Launch complex is a combination of service facilities, systems and lines, which ensure accomplishing of the following tasks:

- Achieving launch readiness status for the Dnepr LV and SC;
- Continuous and periodical automated remote control of LV, SC and silo launcher equipment parameters; and
- LV launch.

The launch complex includes:

- silo launchers;
- launch control center (LCC);
- standard internal power supply system;
- communication and control cable lines running between sites;



Figure 6.4-1 Dnepr Launch Complex Facilities (Sites 106 and 109)

- roads and technical facilities available between sites.

If active electrical interface is used or the Customer needs to monitor the SC status up to launch, the underground Facility 25 can be used for accommodation of the SC COE. This facility is located in the close vicinity of the silo launcher and is connected with it by a 80 m utility tunnel. Facility 25 is a reinforced concrete structure consisting of a number of rooms. In particular, a 67 m² room (5.7 by 11.8 m and 2.4 m high) will be available for the Customer's COE.

Facility 25 has a 220/380V 3-phase 15 kWt power supply system. Required temperature (+ 15 - +25°C) is maintained by electric heaters.

Facility 25 can be equipped with various communications means to communicate with the LCC and other services both at Baikonur Cosmodrome and outside of it, as required by the Customer. ISDN line (64kbit/sec.) can be made available for Facility 25, if necessary.

In addition to that, the Customer may be offered a so-called customer monitoring post, located near the LCC at a distance of about 7 km from the launch site and Facility 25. These premises may accommodate customer's personnel, who monitor the SC parameters up to the launch. If the parameters being monitored differ from the nominal values, the Customer will have an opportunity to suspend the pre-launch sequence no later than 3 minutes prior to launch in order to save the spacecraft.



Figure 6.4-2 Transporter Erector

A transporter erector, equipped with a

system that allows to maintain certain temperature and humidity conditions, is used for transportation of the SHM containing the SC from AITB to the silo launcher for integration with the launch vehicle.

The launch of the LV and control over the launch command execution are carried out via wire communications by the remote control system, the equipment of which is located at the LCC.

If the launch is cancelled or postponed, or it is necessary to detach the SHM from the launch vehicle, the operations are conducted in a sequence reverse to the SHM/LV integration sequence.

In case of spacecraft on-board equipment malfunction, or if it is necessary to re-check the spacecraft at the SC processing facility, operations of its delivery to the processing facility (Site 42 or 31) are performed in a reverse sequence of SC integration with the SHM.

7. Baikonur Operations Flow

Spacecraft and launch vehicle preparation operations are divided into several stages, which may overlap depending on the spacecraft preparation requirements:

- ❑ preparation of LV for integration with SHM;
- ❑ SC processing;
- ❑ preparation of SHM for mating with the SC;

- ❑ SC / SHM integration;
- ❑ transportation of SHM containing SC by transporter erector to the silo launcher;
- ❑ SHM/LV integration and LV preparation for launch;
- ❑ pre-launch operations and LV launch.

Figure 7-1 shows work schedule for preparation and launch of a SC by Dnepr-1 LV (all dates are tentative).

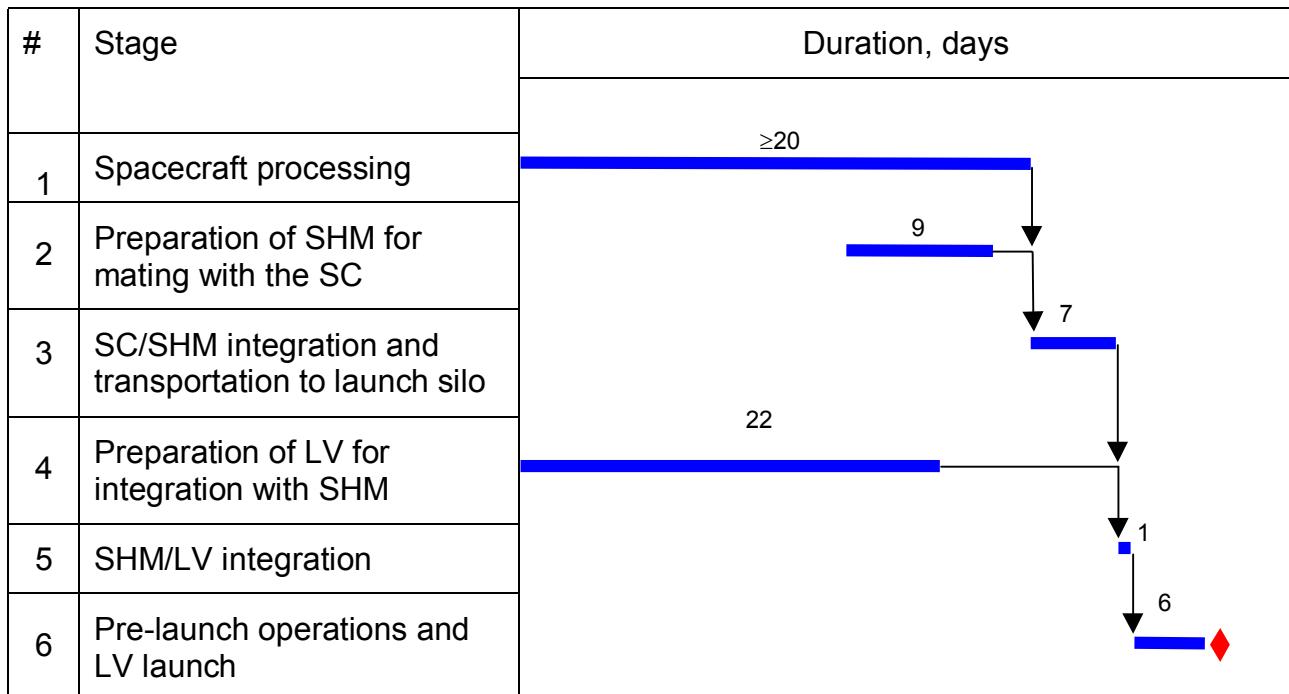


Figure 7-1 Spacecraft Processing and Launch Schedule

7.1 Preparation of LV for Integration with SHM

LV preparation for integration with the SHM is done as follows:

- ❑ installation of the launch vehicle transport and launch canister containing the 1st and 2nd stages into the silo launcher;
- ❑ equipping 3rd stage with telemetry system;
- ❑ filling of 3rd stage with propellant;
- ❑ mating 3rd stage and LV inside the silo;
- ❑ set-up of work place for SC checks in Facility 25 (if active electrical interface is used);
- ❑ checkout of the launch vehicle with the electrical equivalent of the SHM, check of SC/work place-Facility 25 line; and
- ❑ fueling of stages 1 and 2 with propellant components.



Figure 7.1-1 Loading of TLC Containing LV 1st and 2nd Stages into Silo Launcher

Duration of LV preparation for integration with SHM is about 21 days. The fueled LV can await integration with the SHM inside the silo for an unlimited period of time (within its operational life).

7.2 SC Processing

Containers with the spacecraft and its ground processing equipment (GPE) arrive Baikonur by air or by rail, in accordance with the launch campaign schedule agreed between the Customer and ISC Kosmotras, normally, no less than 20 days prior to launch.

Container off-loading is done by lifting gear of the airplane, by road cranes or forklifts using pull ropes, cross-arms, pallets and other Customer's devices.

Arrived containers with the spacecraft and GPE will be delivered to the SC/SHM processing facility for subsequent operations by road or rail, on common carrier rail flatcars in shrouded condition to protect from direct impact of precipitation.



Figure 7.2-1 Off-loading of Spacecraft Container from the Plane

If necessary, the containers can be transported from Yubileiniy airport on special environmentally controlled railcars. At customer's request, the ground transport loads (g-loads, accelerations, temperature) can be controlled during transportation and the results made available to the customer.

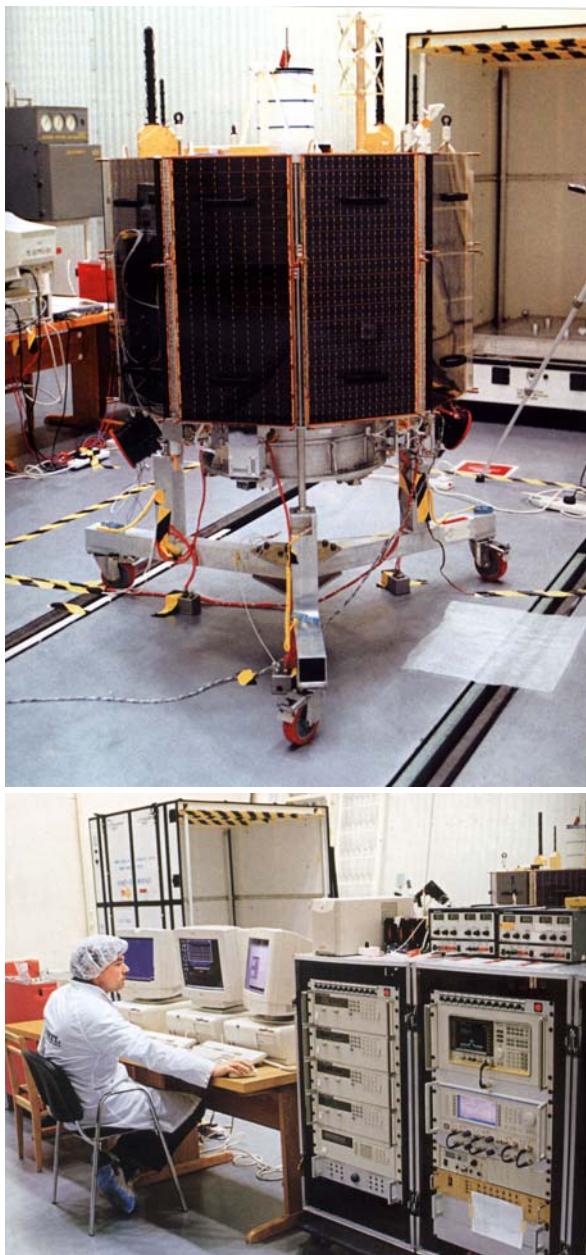


Figure 7.2-2 Spacecraft Processing

At SC and SHM processing facility, the containers with the spacecraft and GPE are off-loaded inside the AITB. GPE is deployed at designated work places and the spacecraft is brought into the clean room (clean room inside AITB at Site 42 or Area B inside AITB at Site 31).

Spacecraft processing is done based on the spacecraft authority requirements, including its filling with propellant components and gases at the fuelling station, if necessary. To ensure the required temperature environment during the spacecraft transportation from the AITB to the fuelling station, the spacecraft is delivered to the fuelling station inside its container on a special environmentally controlled railcar.

The customer may use its own propellant (hydrazine).

7.3 Preparation of SHM for Mating with SC

Upon completion of the spacecraft processing (if processing is done at Site 42), the SHM or EPM is delivered to the AITB by a special road vehicle.

Upon delivery, the SHM is off-loaded and the fairing is detached.

The SHM or EPM is brought inside the clean room by a special rail trolley. Adapter(s) is prepared for mating with the spacecraft. Spacecraft adapter(s) may be detached from SHM or EPM and placed on special supports.

7.4 SC / SHM Integration

Counterparts of separation mechanisms are mounted on the spacecraft.

Spacecraft are mounted on adapters manually or by telphers available at clean room; spacecraft electrical checks and battery charging (if necessary) are conducted. Then the spacecraft with their adapters attached are mated with the SHM or EPM.

Final assembly of SHM or EPM is carried out. SHM or EPM is then taken out of the clean room by a rail trolley. Fairing is attached to the SHM.

SHM or EPM is loaded into a special road vehicle and transported to the AITB at Site 31 for SHM final assembly, its electrical checks and preparation for integration with the launch vehicle.

If the spacecraft is processed at Site 31,



Figure 7.4-1 SHM Integration

the assembly of the SHM (with or without EPM) is conducted at the Area B of the AITB at Site 31 following the same sequence as for the Site 42, except for the transportation of the SHM (EPM) between sites.

7.5 Transportation of SHM Containing SC by Transporter Erector to the Silo Launcher

Assembled and processed SHM is loaded into the transporter-erector and delivered to the launch complex. During the transportation, the required temperature and humidity conditions are maintained around the spacecraft by means of transporter erector climate control system. SHM delivery time to the launch complex does not exceed 3 hours.



Figure 7.5-1 SHM Loading into Transporter Erector

7.6 SHM/LV Integration and LV Preparation for Launch

Upon arrival at the launch complex, the SHM, by means of transporter erector, is mated with the LV installed inside the silo. SHM/LV mating time does not exceed 3 hours.

Electrical checks of the LV with SHM, data analysis, final launch preparation operations are performed. Time period from the completion of SHM/LV mating to launch does not exceed 6 days.

If necessary, during LV preparation for launch, continuous (periodical) monitoring of the spacecraft from Facility 25 can be organized. Monitoring stops 30-40 minutes prior to launch since all personnel must be evacuated from danger zone to the vicinity of the LCC. 24-hour stand-by duty can be organized at the launch complex to support operations with the spacecraft COE.

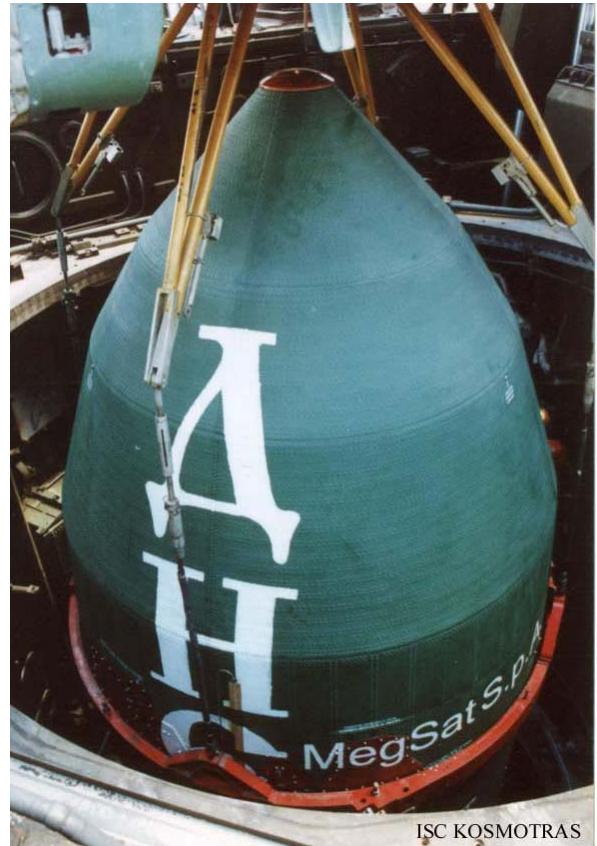


Figure 7.6-1 SHM/LV Integration Inside Silo Launcher

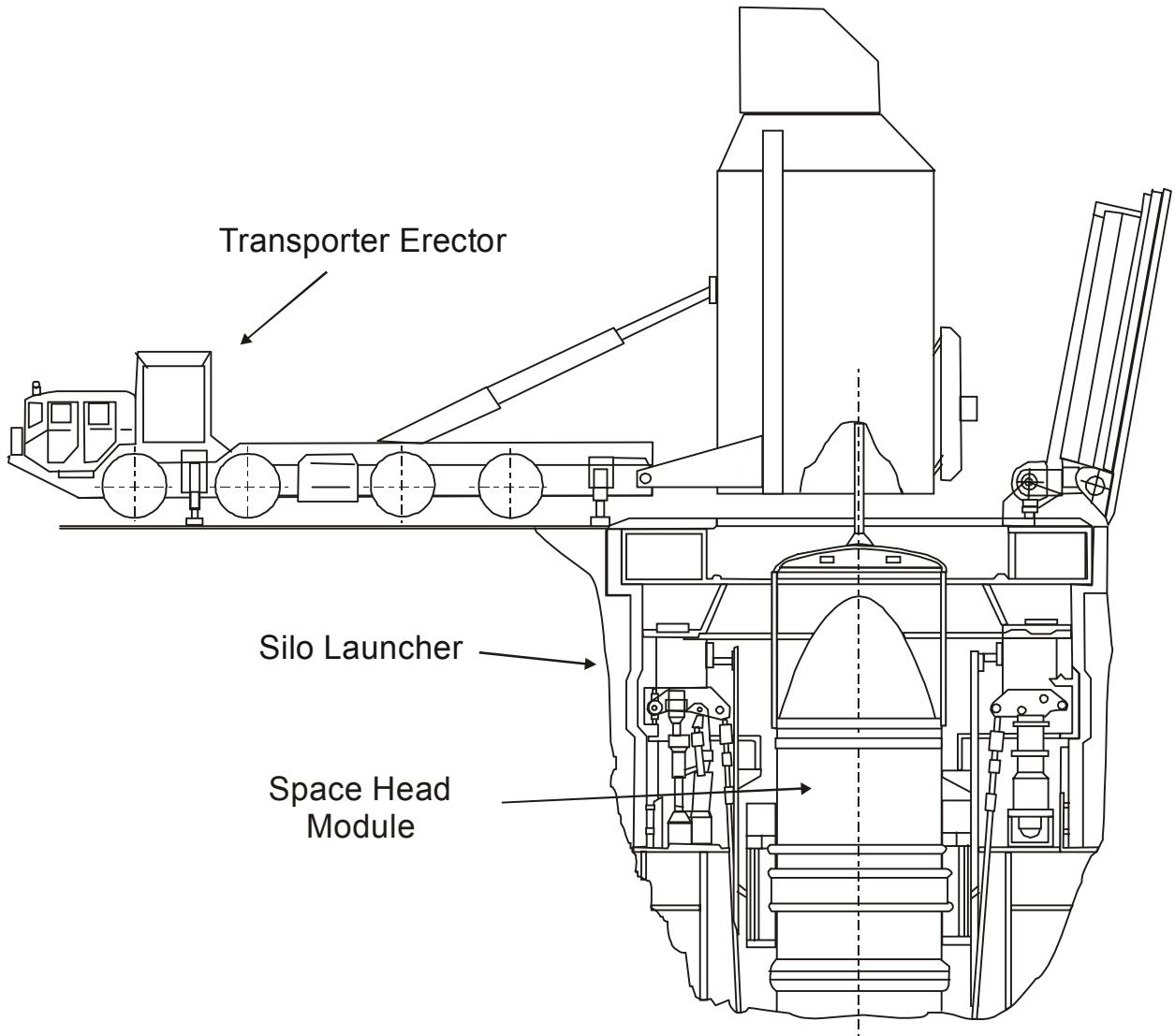


Figure 7.6-2 SHM Loading into Silo Launcher

7.7 Pre-launch Operations and LV Launch

The LV launch is conducted from the LCC (Site 111/2). The launch command is issued at the pre-determined moment of time, and the following operations are performed prior to the launch command issuance:

- ❑ final operations are conducted at the LCC (3 hours);
- ❑ 2 hours prior to launch, the preparation of the telemetry system ground equipment begins;

- ❑ 1.5 hours prior to launch the silo door is opened and mobile equipment in the vicinity of silo is evacuated;
- ❑ 1 hour prior to launch, the on-board telemetry system is activated (for about 10 minutes) and the telemetry data receipt by the ground stations is verified;
- ❑ 20 minutes prior to launch, the on-board telemetry system is activated again and the personnel are evacuated;
- ❑ 3 minutes before launch by a command from the launch control post, the on-board telemetry system starts getting power from the LV on-board power supply system, the ground stations start receiving, recording and processing the actual pre-launch and flight telemetry;
- ❑ LV is launched.

After the launch, the launch crew and telemetry system crew return to the silo launcher and conduct final operations with the telemetry system checkout equipment and examination of the silo launcher.



Figure 7.7-1 Dnepr LV Liftoff

8. SC/LV Interfaces

8.1 Mechanical Interface

Spacecraft is attached to the launch vehicle adapter by means of pyro-devices. The number and type of pyro-devices is contingent on a number of parameters (spacecraft weight, the diameter on which the attachment points are located, etc.) and is agreed upon with the customer for the specific spacecraft.

For some types of spacecraft, the adapters that were used in previous launches, can be applied. They include adapters for 10-20 kg spacecraft, 50-70 kg spacecraft and 300-400 kg spacecraft. These adapters can serve as prototypes for the development of new ones.

Typical design of the spacecraft/standard adapter attachment point is shown in Figure 8.1-1.

To verify the spacecraft separation from the Space Head Module, separation switches mounted on the adapter are used.

To disconnect electrical connectors that ensure the LV/SC electrical links, separation mechanisms are used, which are activated prior to the operation of the separation system.

Pyro-devices, separation switches and mechanisms used, have undergone all necessary ground and flight testing and are highly reliable.

Separation system activation equipment and cables are installed on the Space Head Module and adapter in compliance with all operational requirements, which precludes any damage to or collision with the elements being separated and

satisfies high reliability requirements of electrical command relay that was confirmed by ground and flight testing.

If necessary, and subject to mutual agreement, the adapter can be supplied to the spacecraft authority by ISC Kosmotras and SDB Yuzhnoye for fit-check testing.

It should be noted that the separation systems used for SC/Dnepr-1 LV separation have no spring pushers, since the spacecraft separation is done by taking away the upper stage from the spacecraft by means of the upper stage motor throttled-back operation, which ensures minimum disturbances on the spacecraft during separation.

Angular stabilization errors of the launch vehicle 3rd stage with the Space Head Module at the moment of issuing the spacecraft separation command, do not exceed:

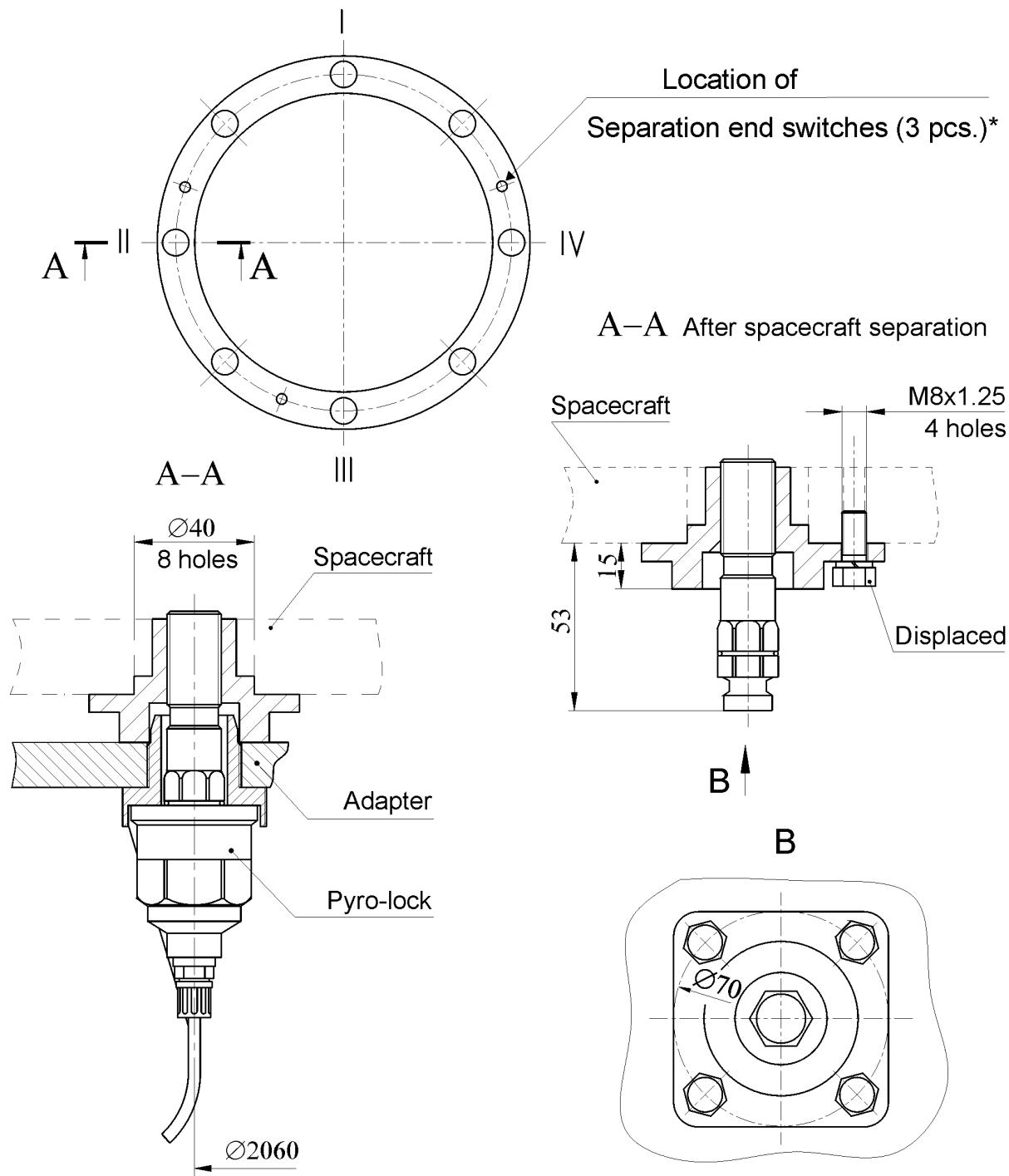
- ± 1.5 degrees for angles of pitch, yaw and roll; and
- ± 0.5 degrees per second for rates of pitch, yaw and roll.

Spacecraft disturbances due to process of separation are dependant on the inertial characteristics of the spacecraft and the 3rd stage with the Space Head Module (including the spacecraft), on the type, number, location and characteristics of the spacecraft/space head module attachment joints. Spacecraft (with the weight exceeding 300 kg) angular rates after separation due to stabilization errors and disturbances induced by the separation process are as follows:

$$\begin{aligned}\omega_x &< 2.0 \text{ degrees per second;} \\ \omega_y &< 3.0 \text{ degrees per second;} \\ \omega_z &< 3.0 \text{ degrees per second.}\end{aligned}$$

Analysis of the relative motion of the spacecraft being separated and SHM elements confirms the spacecraft

separation safety, i.e. indicates no collision among the spacecraft themselves and with the SHM elements.



* - 20 by 20 mm seats, where separation switches will rest, should be available on the spacecraft.

Figure 8.1-1 Typical Design of Spacecraft/Standard Adapter Attachment Point

8.2 Electrical Interface

Two types of SC/LV electrical interface are possible when launching a spacecraft on Dnepr-1 LV:

- ❑ Passive electrical interface – no electrical connections between LV and SC. No power is supplied to the spacecraft during ascent. Upon spacecraft separation, its separation switch is activated and its power supply system turns on. The LV has spacecraft separation sensors which, upon separation, generate a telemetry signal that is transmitted to the ground; and
- ❑ Active electrical interface – electrical connections available between SC and LV that are used prior to (SC-SHM-LV-TLC-SC COE) and during launch (SC-SHM-LV) as well as during injection into orbit (SC-SHM).

The type of the electrical interface is agreed upon between the Customer and ISC Kosmotras. The above interface types differ by their complexity and cost of their technical realization.

SC/LV electrical links ensure the following:

- ❑ transmission, if necessary, of telemetry data on the status of the SC on-board systems during ascent as well as during electrical checks of the SC integrated with the LV inside the silo launcher;
- ❑ issuance of commands by the LV control system to the SC on-board instrumentation during ascent as well as during electrical checks of the SC integrated with the LV inside the silo launcher;

- ❑ supply of power for SC battery charging, maintaining required temperature and humidity conditions of the SC bus and for the SC command and control interface, prior to launch when the SC is integrated with the LV inside the silo launcher.

Existing through circuits of the LV control system and TLC that can maintain about 20 various transmission lines are used for LV/SC and LV/SC checkout equipment electrical links. Diagram of Spacecraft/Spacecraft ground equipment links is shown in Figure 8.2-1.

Through circuits run via umbilical connectors on the LV frame, which are ruptured prior to launch – 3.5 seconds before LV starts moving inside the TLC. Spacecraft ground equipment is connected to the LV and TLC through circuits by means of additional connectors mounted on the TLC and cables running from the silo to Facility 25.

A 32-pin electrical connector (ГШР8) is available at LV/SHM interface, the pins of which have 0.75 mm^2 wires running from a 3-pin electrical connector (ШР8) that is installed at ground/LV side connector board and allows to pass the total amperage of up to 50 A. On the SHM, between the ГШР8 connector and two spacecraft umbilical connectors, a new cable will be run for battery charging and maintaining the spacecraft on-board equipment required temperature and humidity conditions.

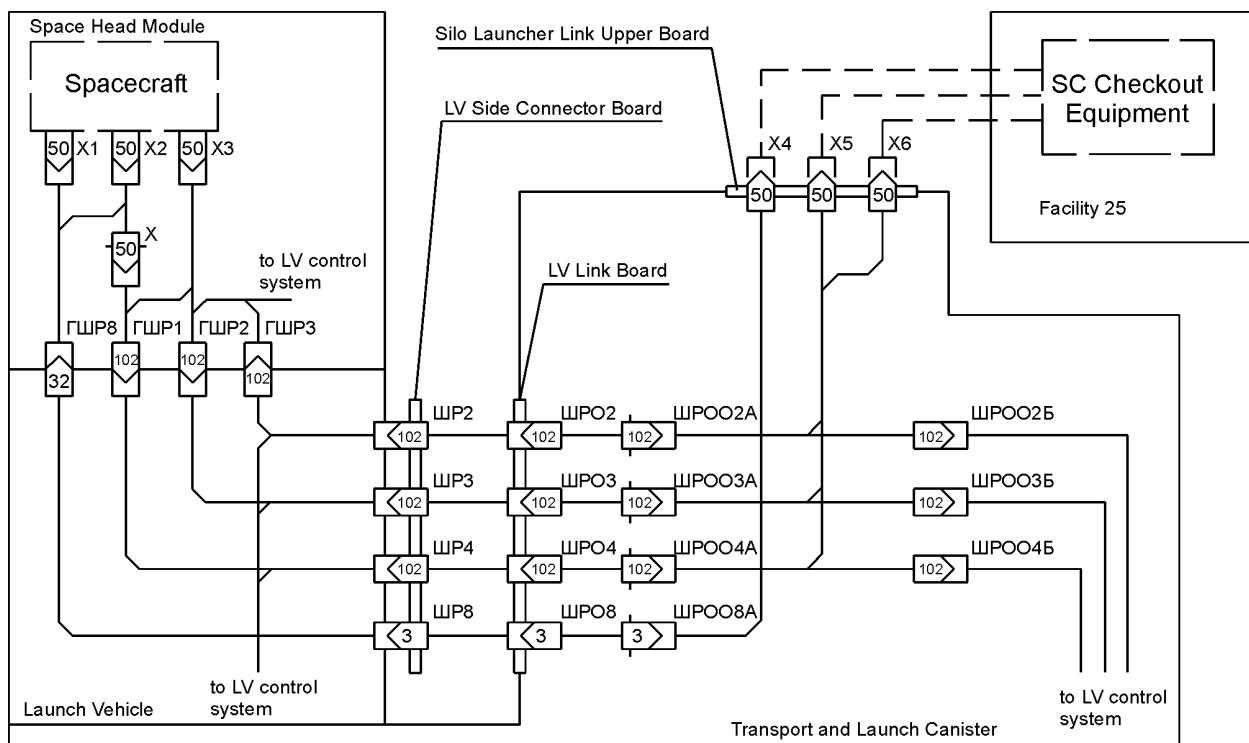
In addition to that, LV/SHM interface has three more 102-pin electrical connectors (ГШР1, ГШР2, ГШР3), some pins of which have 0.2 mm^2 and 0.35 mm^2 wires for through circuits running from electrical

connectors (ШР2, ШР3, ШР4) installed at the side connector board. These circuits (about 65 of them) can be used for spacecraft/ground equipment link. For this purpose, a new cable will be run from the specified connectors to the third umbilical connector of the spacecraft.

If the characteristics (wire cross-section, shielding, etc.) of the above-mentioned standard LV electrical links are not sufficient to ensure the required electrical interface with the SC, an additional cable may be inserted into the electrical connectors (ШР2, ШР3, ШР4) of the side connector board. At the LV/SHM joint, the output connectors of this additional cable will be mated with the SHM cables that service the Spacecraft.

It is desirable to install on the spacecraft several hermetically sealed subminiature plug connectors used on SS-18 (standard designation ОС РС 50ГБАТ ВЛО.364.046 ТУ), the pins of which are soldered with 0.12 – 0.35 mm² wires. The plug weight is 38 grams (with the case) and 20 grams (without the case). Maximum amperage is 75 A. This connector can withstand low pressure (down to 10⁻⁶ mm of Mercury) and pressure difference of up to 1 atmosphere. This connector has a standard SS-18 no-impact disconnection device.

All electrical connectors used in through circuits are standard proven devices successfully tested by a great number of SS-18 launches. Other types of umbilical



X,X1,X2,X3 - ОСРС series connectors
X4,X5,X6, - 2РМД series connectors

X1-X4 distance - 5,3 m
X4- SC checkout equipment distance - 80.0 m

Figure 8.2-1 Schematics of SC/SC COE Transit Electrical Links

connectors can be installed on the Spacecraft. Their counterparts are to be provided to ISC Kosmotras for fabrication of the appropriate SHM cables.

When the SC is injected into the required orbit, the LV control system, if necessary, issues a reference command to the SC instrumentation. Upon 0.1 second following the issuance of the command, the electrical connectors with SC are disconnected and 0.5 second after the issuance of the command, the SC/LV separation occurs.

If active electrical interface is used or it is necessary to monitor the SC status up to the moment of launch, the SC COE can be installed in underground Facility 25 located in close vicinity of the silo launcher.

During electrical checks of the SC integrated with LV inside the silo, the following parameters of SC/LV interface are monitored:

- connection of cables running from LV to SC and ground equipment;
- issuance of signal “INITIAL STATUS OF LV CONTROL SYSTEM”;
- resistance of power lines supplying signals from the LV control system to the SC instrumentation; and
- issuance of reference signals from the LV control system to the SC instrumentation.

The list of commands (signals) required for maintaining interface with the LV control system during LV preparation for launch, launch and flight, as well as sequence and parameters of such interface, types of connectors and number and characteristics of electrical links are agreed upon between ISC Kosmotras and the spacecraft authority.

9. Spacecraft Environments

9.1 Stiffness Criteria (Frequency Requirements)

The spacecraft should be designed with a structural stiffness, which ensures that the values of fundamental frequency of the spacecraft, hard mounted at the separation plane, are not less than:

- 20 Hz in the longitudinal axis; and
- 10 Hz in the lateral axis.

If it is not possible to comply with the above requirements, SDB Yuzhnoye will carry out an additional analysis of the LV dynamic characteristics and loads that will take into account the spacecraft fundamental frequencies.

9.2 Quasi-static and Dynamic Loads

Tables 9.2-1 and 9.2-2 contain quasi-static and dynamic components of accelerations that act on the SC/LV interface during the ground handling, launch and in-flight.

Spacecraft dimensioning and testing must take into account safety factors, which are defined by the spacecraft authority, but should be no less than the values given below:

- 2.0 for ground handling;
- 1.5 during launch while LV is moving inside the TLC;
- 1.3 during launch after the LV exits from the TLC;

- 1.3 during the LV flight.

The spacecraft should remain operable after the effect of the above accelerations.

9.3 Vibration Loads

Described below are vibrations acting on the Spacecraft attachment points during the LV flight. Two types of vibrations are as follows:

- Harmonic oscillations; and
- Random vibrations.

The harmonic oscillations are characterized by the amplitude of vibro-accelerations and frequency. The parameters of harmonic oscillations are given in Tables 9.3-1 and 9.3-2.

The random vibrations are characterized by spectral density of vibro-accelerations and the duration of influence. The random vibration parameters are given in Table 9.3-3.

The random vibrations are spatial with approximately equal intensity of vibro-accelerations in each of the three randomly selected mutually perpendicular directions.

The values of amplitude and spectral densities are given in the extreme octave points. The change of these values within the limits of each octave is linear in the logarithm frequency scale.



Table 9.2-1 Accelerations at SC/LV Interface during Transportation

Load Source	Acceleration		
	Longitudinal (X)	Lateral (y)	Lateral (z)
SHM Transportation	±0.4	-1.0±0.7	±0.5

Table 9.2-2 Maximum Quasi-static and Dynamic Accelerations at SC/LV Interface

Load Source	Acceleration	
	Longitudinal (X)	Lateral (y, z)
LV movement inside TLC	2.5±0.7	±0.3
After LV exit from TLC	±1.0	±0.8
1 st stage burn:		
Maximum dynamic head	3.0±0.5	0.5±0.5
Maximum longitudinal acceleration	7.5±0.5	0.1±0.5
2 nd stage burn – maximum longitudinal acceleration	7.8±0.5	0.2
3 rd stage burn	-0.3...-0.5	0.25

Notes to Tables 9.2-1 and 9.2-2:

- Lateral accelerations may act in any direction, simultaneously with longitudinal ones;
- The above values are inclusive of gravity force component;
- Dynamic accelerations are preceded by "±" symbol;
- The above values are correct for the spacecraft complying with the fundamental frequency requirements contained in paragraph 9.1.



Table 9.3-1 Amplitude of Harmonic Oscillations at SC/LV Interface. Longitudinal Axis (X)

Frequency sub-band, Hz	5-10	10-15	15-20
Amplitude, g	0.5	0.6	0.5
Duration, sec.	10	30	60

Table 9.3-2 Amplitude of Harmonic Oscillations at SC/LV Interface. Lateral Axes (Y, Z)

Frequency sub-band, Hz	2-5	5-10	10-15
Amplitude, g	0.2-0.5	0.5	0.5-1.0
Duration, sec.	100	100	100

Table 9.3-3 Spectral Density of Vibro-accelerations at SC/LV Interface

Frequency sub-band, Hz	Load Source	
	Liftoff, LV flight segment where M=1, q_{\max}	1 st stage burn (except for LV flight segment where M=1, q_{\max}), 2 nd stage burn, 3 rd stage burn
Spectral Density, g ² /Hz		
20-40	0.007	0.007
40-80	0.007	0.007
80-160	0.007-0.022	0.007
160-320	0.022-0.035	0.007-0.009
320-640	0.035	0.009
640-1280	0.035-0.017	0.009-0.0045
1280-2000	0.017-0.005	0.0045
Root Mean Square Value, σ , g	6.5	3.6
Duration, sec.	35	831

9.4 Shock Loads

Shock loads are wide-band, fading processes and are characterized by the shock spectrum and the duration of action.

The activation of the separation pyro-devices is a source of the vibro-pulse loads at the spacecraft attachment points (the duration of shock process is up to 0.1 sec). The shock spectrum values are given in Table 9.4-1. They are accurate for the Q=10 and for each of the three randomly selected mutually perpendicular directions. The change of the shock spectrum values versus frequency within each sub-band is linear (in the logarithm frequency scale and shock spectrum values).

9.5 Acoustic Loads

The sources of acoustic loads are:

- 1st stage motor burn;
- frame surface pressure fluctuations in the turbulent boundary layer.

The acoustic loads are characterized by the duration of action, integral level of the sound pressure within the frequency band of 20-8,000 Hz, and the levels of sound pressure within the octave frequency band with the mean geometric frequencies of 31.5; 63; 125;...; 2,000; 4,000; 8,000 Hz.

Table 9.4-1 Shock Spectrum at Spacecraft Attachment Points

Load Source	Frequency subband, Hz							Number of shock impacts
	30-50	50-100	100-200	200-500	500-1000	1000-2000	2000-5000	
Shock Spectrum Values, g								
Separation of fairing, 3 rd stage and neighboring spacecraft	5-10	10-25	25-100	100-350	350-1000	1000	1000	*
Separation of SC	5-10	10-25	25-100	100-350	350-1000	1000	1000-3000	1

Note: * - number of shock impacts is contingent on a number of spacecraft installed in the SHM.



Table 9.5-1 Acoustic Loads

Mean Geometric Frequency of Octave Frequency band, Hz	Level of Sound Pressure, dB
31.5	125
63	132
125	135
250	134
500	132
1000	129
2000	126
4000	121
8000	115
Integral Level of Sound Pressure, dB	140
Duration, sec.	35

9.6 Temperature and Humidity Conditions and Thermal Effect on Spacecraft

During operations with the spacecraft at SC processing facility, the air temperature around the spacecraft is maintained within 21 - 27°C, with relative humidity of not more than 60%.

During SC/SHM integration at AITB, the air temperature is maintained within 5 - 35°C, with relative humidity of not more than 80%.

When transporting the SHM to SHM processing facility and to the launch silo, the temperature inside the Transporter-Erector is within 10-25°C with relative humidity of no more than 80%.

During operations with the SHM at SHM processing facility, the air temperature around the spacecraft is maintained within 5 - 35°C, with relative humidity of not more than 80%.

When loading the Space Head Module into the launch silo and mating it with the LV, the SHM is affected by the temperature within 0-45°C during the time period of no more than 30 minutes and with the temperature within 5 - 35°C during the time period of no more than 5.5 hours, with the relative humidity being no more than 80%.

When the SHM is inside the silo, the temperature inside the silo is within the range of 5 - 25°C with the possible short-term increase of up to 35°C and relative humidity is of no more than 80%, and the temperature around the spacecraft is

within the range of 5 - 30°C with the relative humidity being no more than 70%.

Spacecraft heat emission while on the LV inside the silo and in-flight were not taken into account.

Thermal flux acting on the spacecraft from the inner surface of gas-dynamic shield will not exceed 1,000 Wt/m².

9.7 Pressure Underneath LV Fairing

Pressure change inside the fairing envelope during the ascent phase is given in Figure 9.7-1.

The maximum rate of in-flight pressure change inside the fairing envelope does not exceed 0.035 kgf/(cm² per sec.), except for transonic phase of flight where

a short term (2-3 seconds) increase up to 0.035 kgf/(cm² per sec.) is possible.

Data contained in this section may be specified for each specific mission.

9.8 Gas-dynamic Effect on Spacecraft

Following separation from the Space Head Module the spacecraft encounters a short term impact (several seconds) of the 3rd stage motor plume.

All combustion products (composed of: N₂ – 28%, H₂ – 27%, H₂O – 21%, CO₂ – 18%, CO – 6%) are in gaseous state; solid or liquid phases are not present.

Parameters of the 3rd stage motor plume affecting the spacecraft are given in Table 9.8-1.

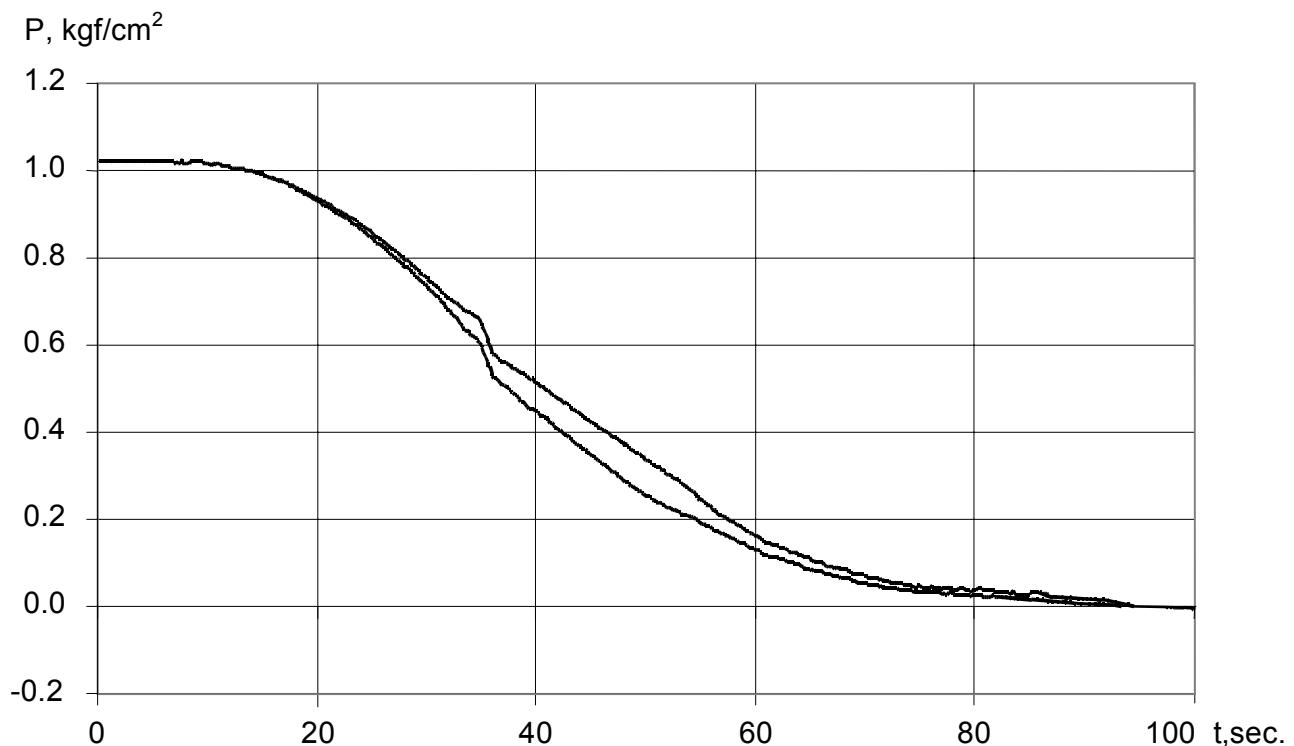


Figure 9.7-1 Pressure Change Rate inside Payload Envelope

Spacecraft surface contamination due to sedimentation of solid or liquid particles does not occur, since they are not present among the 3rd stage motor combustion products.

Spacecraft surface contamination due to H₂O vapor condensation does not occur, since the maximum gas pressure on the spacecraft surface (stagnation pressure) is significantly (dozens of times) lower than H₂O saturated vapor pressure at the spacecraft surface temperature, which, at this moment, normally exceeds 273⁰K.

3rd stage motor plume impact on the spacecraft is insignificant. Integral thermal flux on the spacecraft surface during separation will not exceed 5 Wt per hour/m². Actual heating of 1 mm thickness spacecraft shell made of AMg-6 alloy is 2-4⁰.

3rd stage motor plume may cause light disturbances of the spacecraft motion. Torque may be induced that is dependant on the spacecraft position with respect to the X axis of the launch vehicle and spacecraft inertia characteristics.

Data on the spacecraft launched by Dnepr-1 LV and history of their subsequent operation confirm the absence of 3rd stage motor plume impact on spacecraft operability, including the spacecraft equipped with high resolution optics.

9.9 SC/LV Electromagnetic Compatibility

The engineering solution to use EPM or gas-dynamic shield provides for about 30 dB noise shielding within the frequency range of 10 kHz – 30 GHz. Apart from that, up to about 275th second of flight, the LV fairing provides for additional 10 – 20 dB noise shielding within the frequency range of 10 kHz – 1000 MHz.

Maximum residual levels of LV on-board system (radioelectronics) RF emissions that penetrate the EMP (GDS) and have effect on the spacecraft during the active phase of LV flight prior to and after the EMP cover (GDS) separation, are given in Table 9.9-1.

Table 9.8-1 Maximum Values of 3rd Stage Motor Plume Parameters Affecting Spacecraft

x, m	0	1.8	3.3	4.5	6	7.5	9	15	20	30	50
t, sec.	0	1.2	1.6	1.9	2.2	2.5	2.7	3.5	4.0	4.9	6.3
P ₀ , kgf/m ²	0.2	6.27	4.7	7.3	11	8.2	6.6	3.2	1.84	0.84	0.3
P, kgf/m ²	0.05	0.048	0.034	0.025	0.017	0.012	0.0095	0.0038	0.002	0.00077	0.00023
T, K	254	252	238	226	213	200	193	165	149	127	104
V, m/sec.	3670	3671	3680	3687	3696	3704	3709	3726	3736	3750	3764

Where: x - distance (along X axis) from EPM attachment plane;

P₀ - gas stagnation pressure;

P, T, V - pressure, temperature and velocity respectively of undisturbed gas flow.



Maximum levels of industrial noise induced by LV control system equipment that affect the spacecraft during active phase of LV flight within the frequency range of 10 kHz – 1 GHz, will not exceed 5.6 mV prior to and 35 mV after the EMP cover (GDS) separation.

Maximum levels of electromagnetic emissions (radio and industrial noise) for LV on-board systems are given in Table 9.9-2.

Maximum levels of electromagnetic emissions generated by spacecraft and

Table 9.9-1 Maximum Residual Levels of RF Emissions

Frequency Band	Electromagnetic Field Strength, V/m	
	Prior to EPM (GDS) Cover Drop	After EPM (GDS) Cover Drop
10 kHz – 140.4 MHz	$1.4 \cdot 10^{-2}$	$2.2 \cdot 10^{-2}$
140.4 – 144.4 MHz	0.43	6.9
144.4 – 1000.5 MHz	$1.4 \cdot 10^{-2}$	$2.2 \cdot 10^{-2}$
1000.5 – 1004.5 MHz	0.38	6
1004.5 – 2500 MHz	$1.4 \cdot 10^{-2}$	$2.2 \cdot 10^{-2}$
2500 – 2855 MHz	$5.4 \cdot 10^{-2}$	0.12
2855 – 2865 MHz	1.2	19
2865 – 30000 MHz	$5.4 \cdot 10^{-2}$	0.12

Table 9.9-2 Maximum Levels of Electromagnetic Emissions

Frequency Band	Electromagnetic Field Strength
10 kHz – 125 MHz	70 mV/m
125 – 250 MHz	10 V/m
250 – 1000 MHz	70 mV/m
1000 – 1050 MHz	10 V/m
1050 – 1570 MHz	70 mV/m
1570 – 1620 MHz	10 μ V /m
1620 – 2750 MHz	70 mV/m
2750 – 2900 MHz	50 V/m
2900 – 7500 MHz	70 mV/m
7500 – 7600 MHz	10 V/m
7600 – 30000 MHz	70 mV/m



spacecraft electric checkout equipment (ECOE) at the SC/LV and LV/spacecraft ECOE interfaces (at a distance of 1 m from spacecraft and its ECOE), from the beginning of SC/LV integration and until spacecraft separation from LV plus 1 minute, must be 10 dB less than the values given in Table 9.9-2.

During preparation and launch of spacecraft that has active electrical interface with LV, the spacecraft instrumentation is also affected, along the electrical circuits of SC/LV interface, by electromagnetic interference with the levels of up to 100 dB/ μ V within the frequency range of 30 Hz – 100 MHz for feed and control circuits, and up to 60 dB/ μ V within the frequency range of 30 Hz – 30 GHz – for data circuits.

Instrumentation of SC, in case of active electrical interface, should not generate electromagnetic emissions in the electric circuits of the SC/LV interface over 60 dB/ μ V within the frequency range of 30 Hz – 100 MHz – for feed and control circuits, and over 40 dB/ μ V within the frequency range of 30 Hz – 30 GHz – for data circuits.

Density of electromagnetic fields generated by Cosmodrome electronic equipment at processing facilities and routes of transportation of SC, SHM and LV do not exceed 10 V/m for frequency range 10 kHz –30 GHz, except for the frequency range of 1570 - 1620 MHz, where maximum allowable level of external electromagnetic interference is 30 mV/m (for active or shut radio receivers of spacecraft). This is similar to both European and US standards.

Coordination of efforts to ensure electromagnetic compatibility of SC, LV and range systems at all stages of SC/LV integration is done under a special EMC procedure for a specific mission that is developed at the preliminary integration phase.

9.10 Spacecraft Tests Required to Meet Dnepr LV Launch Services Requirements

The customer shall demonstrate that the spacecraft meets the requirements detailed in the entire section 9 of this User's Guide, by means of analyses and ground tests.

For spacecraft qualification and acceptance, sinusoidal, shock and random tests are mandatory.

A test plan established by the spacecraft authority describing the tests, which are executed on the spacecraft, shall be provided to SDB Yuzhnoye.

After completion of the tests, the test results report shall be submitted to SDB Yuzhnoye.

10. Ground Qualification Tests

To verify the ability to integrate the spacecraft with the Dnepr launch vehicle and to confirm the operability of spacecraft/launch vehicle mechanical and electrical interfaces, a ground qualification test program may be provided that includes spacecraft fit-check testing, vibration testing of spacecraft and SHM structural elements and spacecraft separation system tests.

The objective of qualification testing is to confirm the following:

-
- ❑ operations with spacecraft provided for by spacecraft authority are easy to handle by personnel and ensure no-collision integration with launch vehicle;
 - ❑ engineering solutions to protect the spacecraft from damage are sufficient;
 - ❑ vibration strength at spacecraft attachment points is sufficient to withstand loads on the spacecraft during LV launch and flight;
 - ❑ separation system remains operable following the impact of vibration loads;
 - ❑ complete separation along spacecraft/adapter joints is achieved;
 - ❑ motion parameters of the spacecraft

being separated meet the requirements and shock loads that act upon activation of spacecraft separation pyros are within the allowable limits.

Qualification tests are performed at SDB Yuzhnoye facilities with participation of spacecraft authority specialists. The scope of qualification testing is to be agreed upon with the spacecraft authority.

Necessary process related equipment and spacecraft dummies with actual mechanical and electrical interfaces to be furnished by spacecraft authority are used for qualification testing. Based on the results of qualification testing, an acceptance certificate authorizing the launch of a specific spacecraft on Dnepr LV is released.

11. Telemetry and Tracking

Telemetry system is based on LV on-board radio telemetric system with data capacity of 512 Kbit/sec., which allows to register both slowly and rapidly changing parameters.

During spacecraft injection, a number of physical process parameters are registered, which determine the proper functioning of the LV systems and units, characterize the LV/SC separation process as well as measure dynamic and heat impact on the spacecraft during its orbital injection. For this purpose, the LV on-board telemetry system is equipped with initial signal transformers and normalizers.

Data capacity of the LV telemetry system allows, if necessary, for recording information supplied by the spacecraft on-board instrumentation within the broad sampling frequency range of 25 Hz – 8 kHz and output voltage of 0-6 V.

Specific requirements for telemetry reading and interface will be defined during SC/LV integration concept work.

Pre-launch checks of the LV on-board telemetry system are carried out by means of available standard ground checkout equipment.

Motion parameters of the LV center of gravity are determined by GPS system, which transmits obtained data through telemetry channels.

When launching spacecraft on Dnepr LV from Baikonur eastward (orbit inclinations 50.5 and 64.5 degrees), the telemetry data transmitted from LV through two channels (to ensure appropriate transmission reliability) is registered by Baikonur ground tracking stations and ground tracking stations of Russian Federation located along the LV flight trajectory.

When launching spacecraft from Baikonur southward (orbit inclinations 87.3 and 98.0 degrees), the telemetry data is subsequently registered by a mobile ground tracking station located in Oman near the town of Salalah. This ground station relays to Baikonur data collection and processing center a certain amount of telemetry data in real-time scale, including the parameters of spacecraft initial motion.



Figure 11-1 Tracking Station

12. Analysis of Flight Results

Analyses of all LV system functioning, of the loads the spacecraft encountered during injection are carried out based on the results of the telemetry measurements taken during the LV pre-launch preparation and flight.

The scope of analyses required is determined jointly with the customer in the process of approval of the statement of work for the spacecraft launch.

The analysis of the flight results is carried out in the following way:

- ❑ real-time telemetry data on a limited number of LV system status parameters (command issuance and execution, propulsion unit operation and LV flight stabilization);
- ❑ determination of spacecraft separation event (10 minutes after the separation);
- ❑ determination of spacecraft actual separation time (1.5 hours after the spacecraft separation event);

- ❑ preliminary data on spacecraft initial motion parameters (2 hours after spacecraft separation);
- ❑ full set of data on spacecraft orbital parameters (1 day after spacecraft separation);
- ❑ comprehensive analysis of all the data received in order to evaluate the LV system and sub-system functioning, to get their quantitative values, to assess spacecraft injection environments and to determine the probable reasons of malfunctions if there were any (1 month after launch).



Figure 12-1 Flight Data Processing Center



13. Range Safety

ISC Kosmotras possesses certain expertise and proven safety procedures, both organizational and technical, for launch campaigns. All works and operations are conducted in strict accordance with approved plans and documents.

Our company guarantees that the Customer's representatives have full control over the access to the spacecraft, as far as it is technically feasible. Joint operations of Customer's and Provider's specialists are conducted in compliance with the approved procedures. Following the completion of operations in clean room facility (SC/adapter integration, assembly of EPM), the EPM cover attachment points are sealed by Customer's representatives, this fact is registered in a special certificate and recorded by video and photography. Following this procedure, the direct access to the spacecraft becomes impossible. If necessary, visual and remote monitoring of the EPM (gas dynamic shield, in case of a large spacecraft) and the entire space head module seal points can be arranged.

For all operations with the spacecraft, safety procedures are worked out, planned and followed with regard to the following hazards listed below:

- ❑ electrical hazards;
- ❑ explosion hazards;
- ❑ fire hazards;
- ❑ UHF emission hazards;
- ❑ biological hazards;

- ❑ effect of chemicals and pollutants;
- ❑ mechanical impact;
- ❑ weather, thermal and light effects;
- ❑ space debris;
- ❑ personnel mishaps and equipment failure;
- ❑ acts of God (earthquakes, hurricanes, showers).

ISC Kosmotras is responsible for ensuring safety during work with spacecraft, ground support equipment at all stages of spacecraft preparation for launch, in full compliance with the standards and requirements of the Russian Federation and spacecraft authority.

Spacecraft authority is responsible for compliance with the specific safety requirements during development, fabrication and operation of the spacecraft and ground support equipment, as well as during its personnel stay at the Cosmodrome.

Spacecraft authority submits to ISC Kosmotras the documents that describe:

- ❑ hazardous systems and operations of the spacecraft and its support equipment;
- ❑ results of hazardous systems and elements testing; and
- ❑ results of spacecraft tests for vibrations and flight loads.



ISC Kosmotras reviews these documents and has the right to issue its comments for each of such safety documents.

If necessary, ISC Kosmotras is prepared to develop, together with the spacecraft authority, and sign a comprehensive document that governs the safety procedures and requirements for a specific spacecraft.

The following safety precautions are taken during operations with spacecraft (tentative list):

General:

- all equipment used for operations with the spacecraft, space head module and launch vehicle is certified as per the effective standards for the period of time sufficient to successfully complete all operations;
- required temperature and humidity conditions are maintained throughout all stages of operation;
- only authorized personnel have access to the spacecraft processing area;
- uninterrupted power supply is guaranteed during spacecraft integration and checkout;
- required speed limits are complied with during spacecraft and ground support equipment transportation;
- three levels of supervision are ensured for the control of critical and most hazardous operations with the space head module and launch vehicle.

During handling:

- Container off-loading is done by lifting gear of the airplane, by road cranes or forklifts using pull ropes, cross-arms, pallets or other gear of the spacecraft authority;
- Spacecraft offloading is conducted in strict accordance with operational documents;
- Only authorized personnel are allowed on operations site. Operations site must be sufficiently lit up and, if possible, fenced off;
- During offloading, spacecraft must be tied by means of halyards to prevent rocking.

During transportation:

- Arrived containers with the spacecraft and ground support equipment will be delivered to the processing facility for subsequent operations by road or rail, on common carrier rail flatcars in shrouded condition to protect from direct impact of precipitation;
- If necessary, the containers can be transported from Yubileiniy airport on special environmentally controlled railcars;
- At the request of the spacecraft authority, the ground transport loads (g-loads, accelerations, temperature) can be controlled during transportation and the results made available to the spacecraft authority.

During operations at spacecraft and space head module processing facility:

- spark-proof tools must be used. The personnel working with the spacecraft

-
- must have special gear for static electricity elimination;
- Checkout equipment must be grounded and resistance of bonding connection must be checked;
 - Personnel must be warned prior to supplying power or pressure to the spacecraft systems;
 - Personnel must be warned prior to activating on-board transmitting units;
 - When integrating the spacecraft elements covered with thermal insulation, the personnel must wear respirators and cotton gloves. Upon completion of work, the clothes must be de-dusted and open skin washed with water and soap;
 - Personnel must wear special clothes and soft shoes, and comply with operational documentation requirements.
- Safety during the operations with the space head module, space head module/launch vehicle integration and checkout, is ensured through exercising the technical, organizational and design measures listed below:
- launch vehicle checkout sequence is fully automated that precludes emergencies due to operator's errors;
 - prior to operations with the launch vehicle, the following checks are performed to avoid improper electrical connection with actuators and damage to the launch vehicle on-board equipment and cable network: availability of electrical connection in circuits, absence of power line bridging and connection with the launch vehicle frame, insulation resistance, initial condition of equipment, proper mating of connectors, integrity of pyro-device fuse heads, in order to prevent improper supply of power to actuators and avoid damage to the launch vehicle on-board equipment and harness;
 - use of connectors with different configuration and cables of different length to avoid improper connection;
 - use of 30 V power line from the short circuit protected ground power sources to the launch vehicle on-board equipment;
 - use of such on-board equipment design that provides for proper grounding to avoid accumulation of static electricity on launch vehicle and space head module frame;
 - monitoring that the power supplied to the pyro-devices and launch vehicle frame during the checks of launch vehicle and space head module, has the proper parameters.

Safety during operations with the space head module, its integration with the launch vehicle and checks of the launch vehicle integrated with the space head module, is ensured through the application of the procedures provided for in the operational documentation and compliance with the Russian Federation requirements "OTT 1.1.10 -90, OTT 11.1.4 -88, part 6, GOST B 20.39.308 - 76. Effectiveness of these procedures was confirmed by the results of the fit-check and bench testing conducted at SDB Yuzhnoye facilities and by the successful launches in 1999 and 2000.

14. Transportation of Spacecraft and Associated Equipment. Customs Clearance

Spacecraft authority ensures the delivery of dummy spacecraft and associated equipment to Ukraine for ground testing and of spacecraft and associated equipment to Baikonur Cosmodrome, and obtains their customs clearance.

All operations with the spacecraft, equipment and dummy spacecraft are divided into 4 stages:

1. Transportation of dummy spacecraft and associated equipment to Ukraine for ground testing (Customer's country – SDB Yuzhnoye, Dnepropetrovsk, Ukraine) and their subsequent return, upon completion of ground testing, to customer's country;
2. Customs clearance of dummy spacecraft and equipment upon entry into Ukraine (SDB Yuzhnoye, Dnepropetrovsk). Customs clearance of dummy spacecraft and equipment upon exit from Ukraine;
3. Transportation of spacecraft and associated equipment to the launch site (Customer's country – Russia, Moscow – Baikonur Cosmodrome, Kazakhstan). Return of associated equipment to customer's country after launch;
4. Customs clearance of spacecraft and associated equipment upon entry into Russia (Moscow) and Kazakhstan (Baikonur Cosmodrome). Customs clearance of associated equipment upon exit from Kazakhstan (Baikonur Cosmodrome) and Russia (Moscow)

after launch en-route to customer's country.

To accomplish stages 1, 3 and 4, ISC Kosmotras can recommend to conclude a contract with a Russian customs clearance and transportation broker company specializing in space related area to ensure import of space related equipment into Ukraine, Russia and Kazakhstan (Baikonur Cosmodrome).

Accomplishment of Stage 2 can be organized by SDB Yuzhnoye.

14.1 Transportation of Dummy Spacecraft to Ukraine for Ground Testing

To ensure the entry of the dummy spacecraft and associated equipment into Ukraine for ground testing, it will be necessary for customer to conclude a formal contract with SDB Yuzhnoye. Based on this contract, dummy spacecraft will enter Ukraine. Transportation of the dummy spacecraft to Ukraine and their customs clearance may be entrusted to a Russian transportation and customs clearance company on a separate contract, or done by the dummy spacecraft owner independently. Upon completion of ground testing, the dummy spacecraft and associated equipment will be returned to the customer. Since this is a temporary import regime, the customs duties will be minimum.

14.2 Transportation of Spacecraft and Associated Equipment to Baikonur Cosmodrome

The most appropriate and proven scenario of transportation of spacecraft and equipment is the following:

-
- ❑ Customer concludes a direct contract with a Russian transportation and customs clearance broker company that delivers the spacecraft and equipment by regular or charter flight to Moscow, Russia (Sheremet'yevo-2 International Airport);
 - ❑ At Sheremet'yevo-2 the broker company obtains customs clearance for the spacecraft and equipment and then ships them by air to Baikonur;
 - ❑ Upon arrival at a Baikonur airfield, the broker company obtains Kazakhstan customs clearance for the spacecraft and equipment;
 - ❑ Then the spacecraft and equipment are

transported to the spacecraft processing facility. Reloading and transportation of the spacecraft and equipment at Baikonur is supported by ISC Kosmotras;

- ❑ Return of the associated equipment after launch is done in reverse sequence.

Duration of transportation from Europe is no more than 2 days.

During the performance of all the above-mentioned stages, ISC Kosmotras verifies the proper conduct of transportation and customs clearance in Russia, Kazakhstan (Baikonur Cosmodrome) and Ukraine.



15. Principles of Pricing Policy and Contractual Relations

ISC Kosmotras is a primary contractor responsible for all technical and organizational issues associated with the customer's payload launch.

Dnepr-1 LV is created on the basis of the converted SS-18 ICBM by minor modifications. At present, a sufficient number of SS-18s on storage is available. This fact is reflected in the price structure, which does not have the "cost of LV fabrication" component, and therefore makes it possible to offer customers lower level of launch services price than that of other launch services providers. The lower price of launch services, reliability and proofness of all Dnepr SLS systems make a very attractive combination for potential customers.

Dnepr-1 launch services price is contingent on the following factors:

- orbit parameters (type, altitude, inclination);
- weight and dimensions of spacecraft, spacecraft layout diagram;
- type of interface;
- spacecraft processing requirements (filling with propellant, high cleanliness requirements, etc.);
- type of launch: dedicated or cluster (consolidated), single or multiple (under a program of launches).

To launch a spacecraft on Dnepr-1 LV, customer and ISC Kosmotras conclude a Launch Services Agreement (LSA). LSA

for launch of a large spacecraft is concluded no less than 18 months prior to the planned launch date. LSA for launch of a small spacecraft may be concluded 10 months prior to the planned launch date.

The LSA consists of the following:

- Main part;
- Annex 1 – Launch Services Specifications;
- Annex 2 – Logistical Support of Work;
- Annex 3 – Organizational Issues.

All annexes should be agreed upon by the parties before the contract signature.

The following services to be rendered by ISC Kosmotras are normally included into the contract price:

- spacecraft adaptation to launch vehicle, including necessary interfaces, development, manufacturing and testing of LV flight adapter and other necessary equipment;
- provision of facilities and required conditions for spacecraft processing and offices for customer's personnel at the Cosmodrome;
- launch of spacecraft into the required orbit and supply of information on spacecraft separation from LV, on orbital parameters at the moment of separation;
- third party liability insurance;
- performance of and payment for the transportation of the spacecraft and



equipment from a Baikonur Cosmodrome airport to the spacecraft processing facility, and for the transportation of the equipment back to that airport.

Under the LSA, project managers are appointed by the customer and ISC Kosmotras. They are responsible for organizational and coordination efforts throughout the effective period of the LSA.

16. Design and Technical Documents to Be Submitted by Spacecraft Authority

To evaluate the possibility of using Dnepr Space Launch System for launch of a specific spacecraft as well as to prepare the materials for spacecraft/Dnepr SLS interface, the spacecraft authority shall submit the following materials:

- 1) Line and dimensional drawings of spacecraft (including its adapter);
- 2) Spacecraft envelope drawing (The envelope where the spacecraft and adapter are placed taking into account all protruding elements and possible deviations from the nominal position due to errors during its manufacturing and balancing as well as deformations during its joint operation with the LV with respect to the plane of the adapter interface with the LV. The axis of the spacecraft envelope will be a perpendicular to the plane of the adapter interface with the LV drawn from the center of the circumference on which the attachment holes are located);
- 3) Detailed drawing of the spacecraft (adapter) interface with the LV;
- 4) Detailed drawing of the spacecraft interface with adapter denoting the elements of the separation system (separation mechanisms, guiding pins, attachment elements, etc.) and their characteristics with tolerances and deviations). The drawing that shows the area of spacecraft structural elements penetration into the adapter denoting structural gaps and "dangerous" points;
- 5) The list of connection lines to the adapter describing their characteristics (the number and type of connection lines, their location, disconnection force and travel with tolerances and deviations);
- 6) The diagram showing the location of the separation telemetry sensors at the spacecraft/adapter interface and their characteristics (disconnection force and travel with tolerances and deviations);
- 7) Mass, Center of Gravity and inertia characteristics of the spacecraft, adapter as well as the spacecraft/adapter assembly with tolerances and deviations for all variants and modifications of the spacecraft, and also the distribution of weight and linear moment of inertia along the length of the spacecraft/adapter assembly;
- 8) Stiffness characteristics of the spacecraft (the change of bending rigidity EJ, longitudinal rigidity EF, and torsion rigidity GJp along the length of the spacecraft/adapter assembly);
- 9) Data on spacecraft structural elements separated in flight, requirements and constraints regarding the separation time;
- 10) Parameters of the initial orbit in the injection point: inclination, apogee and perigee altitude with respect to earth mean radius ($R_m = 6,371$ km), argument of perigee latitude, ascending node longitude;
- 11) Injection accuracy requirements;



- | | | |
|-----|--|---|
| 12) | Spacecraft longitudinal load constraints; | processing facility and the launch complex in case of launch cancellation; |
| 13) | Constraints for dynamic pressure at the moment of fairing separation; | 23) Initial data for accommodation of the spacecraft associated equipment at processing facility and launch complex premises; |
| 14) | Spacecraft injection time constraints; | 24) Spacecraft temperature and humidity control requirements at processing facility and launch complex; |
| 15) | The number, type and electric characteristics of the spacecraft separation system pyros; | 25) Initial data for spacecraft injection timeline; |
| 16) | The list of the LV control system commands used by spacecraft, type and electric characteristics of the load on the LV control system circuits from the spacecraft; | 26) The list operations conducted on spacecraft during the phase of its joint flight with the LV; |
| 17) | The diagram of interface of the spacecraft on-board equipment and the LV control system: <ul style="list-style-type: none">□ diagram of the spacecraft separation system pyro connection;□ diagram of receiving commands from the LV control system;□ diagram of connectors along the LV-spacecraft (adapter) joint; | 27) The list of telemetry and trajectory measurement devices and radio frequencies used on-board the spacecraft as well as sequence of their operation; |
| 18) | The list and characteristics of the spacecraft links with ground equipment; | 28) Requirements to telemetry readings to be taken at the spacecraft (type and number of sensors, signal characteristics, registration time etc.); |
| 19) | Schedule of processing the spacecraft at the launch complex specifying the exchange signals with the LV control systems proposed by the spacecraft authority; | 29) Documents confirming the completion of the spacecraft tests for static and dynamic loads with the level of loading exceeding the actual loads acting on the spacecraft during its flight with LV. |
| 20) | Spacecraft processing flow chart; | |
| 21) | Safety requirements for spacecraft operation with the LV; | |
| 22) | Materials describing the volume of work with the spacecraft at the | |
- The above list of documents may be amended and specified during joint work for detailed integration of the spacecraft and the Dnepr LV.

17. Documents to Be Submitted to ISC Kosmotras by Spacecraft Authority

- Spacecraft mission nature and principal specifications;
- Spacecraft safety document to include information on fire-safety and explosion proofness;
- Spacecraft nuclear safety document (in case of presence on-board spacecraft of nuclear power unit or radiation sources);
- Statement that the spacecraft will not be for military purposes from the appropriate government organization (e.g., the national space agency) in the country where ownership of the spacecraft will reside after it is placed into orbit;
- Written statement from the appropriate government organization (e.g., the national space agency) in the country where ownership of the spacecraft will reside after it is placed into orbit stating that the spacecraft to be launched by the Russian Launch Vehicle will be registered in the national register of space objects;
- List of equipment temporarily imported by Customer for the launch, to be supplied to launch services Provider;
- Document on spacecraft radio frequency bands and maximum levels of UHF emission;
- Document from the owner of the spacecraft on its insurance aspects; and
- Spacecraft launch clearance document (after spacecraft integration to the launch vehicle payload module). This document shall be signed at Baikonur by Customer's authorized representatives and presented to launch services Provider at the point of Change of Custody to clear the spacecraft for launch.



18. Launch Campaign Schedule

Figure 18-1 shows a launch campaign schedule for a large spacecraft.

In case of a cluster launch, the time period between the contract signature and launch date may be reduced.

#	Milestone	Quarter							
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1	Signature of MoU between ISC Kosmotras and launch customer	◆							
2	Project feasibility study	■							
3	Contract signature		◆						
4	ICD release		■	■					
5	Release of documentation for additional hardware			■	■	■			
6	Fabrication of necessary hardware				■	■	■		
7	Fit-check					■			
8	Ground tests of payload module containing spacecraft dummies					■			
9	Delivery of launch vehicle, hardware and equipment to Baikonur					■	■		
10	Preparation and processing at Baikonur					■	■		
11	LV launch						◆		
12	Preparation and release of launch result analysis data							■	

Figure 18-1 Launch Campaign Schedule