Cluster Launches of Small Satellites on Dnepr Launch Vehicle

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September 26, 2000 marked the launch of Dnepr launch vehicle (converted SS-18 ICBM) with a group of small spacecraft. The rocket was launched from a silo located on Baikonur Cosmodrome. Five spacecraft were injected into a 650 km circular orbit inclined 65 degrees – MegSat-1 and UniSat (Italy), SaudiSat-1A and 1B (Saudi Arabia), and TiungSat-1 (Malaysia). For the purposes of rational use of the SS-18s being eliminated under the START treaty, an International Space Company Kosmotras was established in 1997 by the decision of the governments of Russia and Ukraine, which incorporated rocket and space industry enterprises of both countries. The Dnepr launch vehicle is 34.3 meters in length, 3 meters in diameter and its launch weight is 211 metric tons. It is equipped with liquid propellant engines. The Dnepr Program is one of the major conversion programs. The basis of the Dnepr Program is formed by all SS-18 assets available in Russia and silo launchers at Baikonur Cosmodrome. The SS-18 system has more than 20 years of successful launch history with the last Dnepr launch being 159th one. The last rocket launched differed from the standard SS-18 by its modified control system and flight program. An Encapsulated Payload Module (EPM) containing five spacecraft mounted on individual adapters was installed under its fairing. The use of EPM allows for the integration of all satellites with the launch vehicle adapter and their electrical checks in a separate clean room, with subsequent transportation of the hermetically sealed EPM to the Space Head Module Processing Facility for installation into the Space Head Module. Consecutive separation of the satellites in the course of the third stage motor operation (throttled-back operation mode) ensured their deployment into individual orbits. The September 26, 2000 Dnepr launch was the second one under the Dnepr Program. It was the next step of the program evolution – mastering the so-called "cluster" launches of spacecraft owned by different customers. Small satellites are expected to take a greater share among other payloads planned for launch in the near future. Small satellite builders always face a challenging task of finding a suitable launch opportunity. Basically, their payloads are piggy-back launched, while ISC Kosmotras offers them dedicated Dnepr launches, where a group of small spacecraft is launched as a primary payload.

1. Dnepr Program Basis

Dnepr is the name of the program that provides for establishment and operation of the Dnepr Space Launch System based on the SS-18 heavy intercontinental ballistic missiles (ICBMs) being eliminated; yet it is one of the largest conversion programs.

The SS-18 is the world's most powerful ICBM, which possesses high performance characteristics and reliability.

In accordance with the Russian – US treaties on reduction of strategic offensive arms (known as START treaties), the SS-18 ICBMs are subject to elimination. The START treaties allow for elimination of these missiles by orbital launch of spacecraft.

International Space Company (ISC) Kosmotras was established in 1997 by the decisions of the Russian and Ukrainian governmental bodies. ISC Kosmotras incorporates a number of Russian and Ukrainian aerospace companies, which developed the SS-18 system and are now involved in supervising its operation and conversion.

ISC Kosmotras activities on Dnepr Space Launch System are governed by the decrees of the Russian and Ukrainian Governments.

Dnepr Program implementation is based on the following main principles:

- use of available SS-18s;
- use of proven technology of SS-18 decommissioning and their subsequent processing for launch;
- availability of active launch site (4 silo launchers) and ground infrastructure (including clean room facilities for spacecraft processing) at Baikonur Cosmodrome.
- use of flight trajectories with designated drop zones;
- receipt and processing of launch vehicle telemetry data by available ground stations.

These principles make it possible to significantly reduce Dnepr Program costs and offer competitive prices for launch services.

2. Dnepr Program Team

The following companies and agencies participate in the Dnepr Program:

Russia: Russian Aviation and Space Agency, Russian Ministry of Defense, JSC ASKOND (Moscow), JSC Rosobschemash (Moscow), Central Scientific and Research Institute of Machine Building, etc.

Ukraine: National Space Agency of Ukraine, State Desing Bureau Yuzhnoye (Dnepropetrovsk) – Dnepr Program technical team leader, Production Association Yuzhniy Machine Building Plant (Dnepropetrovsk), etc.

Also, Dnepr team members are Aerospace Committee of the Ministry of Energy and Mineral Resources of the Republic of Kazakhstan and the US ATK Thiokol Propulsion as marketing agent on the Western market.

3. Organization of Activities under Dnepr Program

ISC Kosmotras establishes contacts with potential customers, signs launch contracts, organizes work and cooperation of the Dnepr team members in Russia, Ukraine and Kazakhstan, interacts with national space agencies of these countries and Russian Ministry of Defense.

Dnepr Program marketing is performed by ISC Kosmotras with the support of the US ATK Thiokol Propulsion.

4. Dnepr-1 LV Main Data

The SS-18 ICBM possesses high reliability (reliability index is 0.97) confirmed by 159 launches during more than 20 years.

Dnepr-1 LV uses proven SS-18 design and is a three-stage liquid propellant rocket of 3 meter diameter, 34.3 meter length and launch weight of 211 metric tons. Propellant components for all stages are amyl and heptyl.

Dnepr LV is silo-launched using a so called steam eject type launch. This type of launch facilitates pre-launch processing, allows to maintain required humidity and temperature conditions of the launch vehicle and spacecraft and makes it possible to conduct launches around the year under virtually any weather conditions. The level of sound pressure is quite acceptable for spacecraft authority and does not exceed 140 dB.

Dnepr-1 LV is capable of delivering spacecraft weighing up to 500 kg into 800 km orbits and spacecraft weighing up to 3,500 kg into 300 km orbits, with the orbit inclinations of 50.5, 65 and 97.8 (sun-synchronous orbit) degrees.

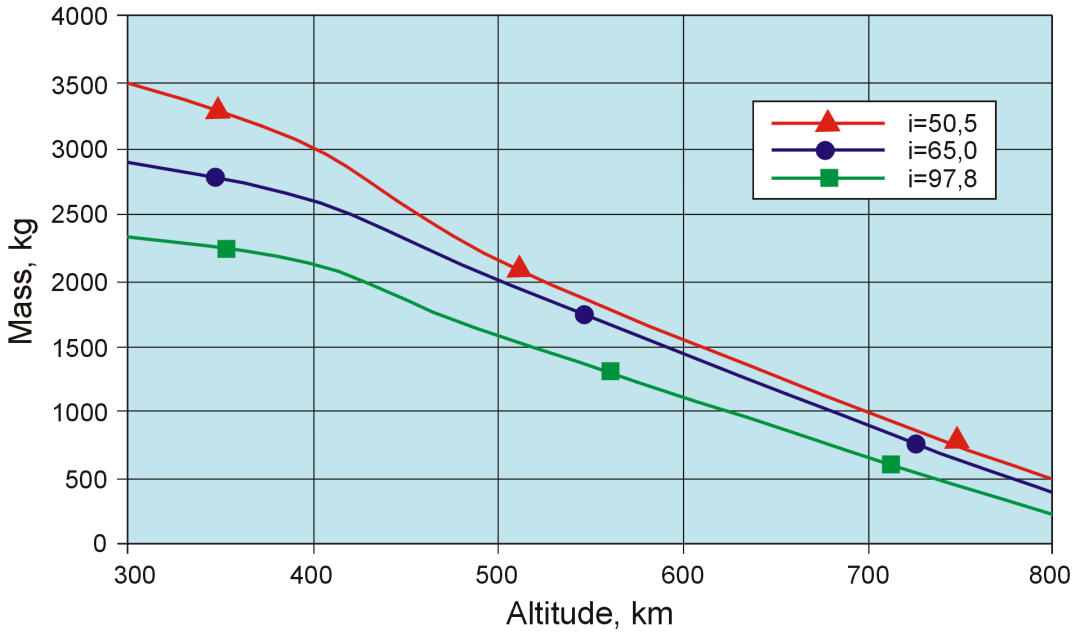
Injection accuracy is $\pm$ 4 km for altitude, $\pm$ 2.4 angular min for inclination, $\pm$ 3 angular min for right ascension of ascending node. Maximum longitudinal acceleration is 7.5 and maximum lateral acceleration is 0.8.

Dnepr performance curves and payload envelope are shown in Figure 1.

5. Program for Cluster Launches of Small Spacecraft on Dnepr LV.

Taking into account the availability of a large number of SS-18s to be eliminated and thus an opportunity of relatively inexpensive launches, ISC Kosmotras, in addition to launches of single large spacecraft, has adopted a program of

Dnepr-1 Performance Curves for Circular Orbits



Dnepr-1 Payload Envelope

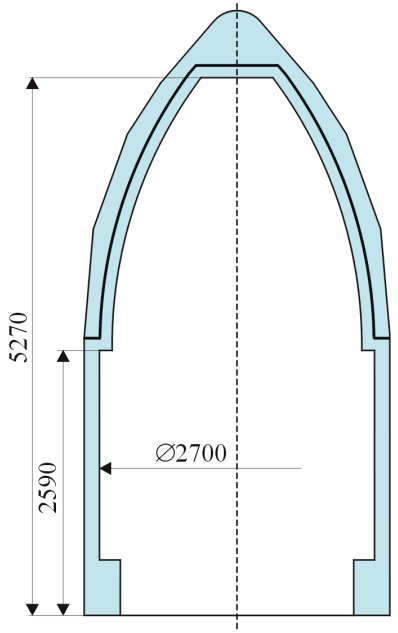


Fig.1 Performance Curves and Payload Envelope.

cluster (consolidated) launches of small and micro satellites for universities, governmental and commercial entities.

In proposing this program, ISC Kosmotras proceeds from understanding the prospects of small satellite technology for practical space exploration (the trend of building smaller satellites, broader range of missions applicable for small satellites, more countries and companies possessing satellite technology).

Small and micro satellite builders seek for regular and relatively inexpensive launch opportunities, and ISC Kosmotras assumes that a cluster launch may be more attractive for them than a piggyback one.

Normally, one rocket delivers either a group of similar spacecraft, or a primary satellite and a piggyback payload.

With the cluster launch, all payloads are primary, and not piggyback. Another possible option is when a primary passenger is determined, who pays a greater (as compared to other passengers) portion of the launch price.

In one cluster launch, a group of several completely different spacecraft is deployed (from 2 to 8). ISC Kosmotras plans to have several cluster launches per year during the period 2001 – 2007.

Groups of spacecraft for a cluster launch are selected in such a way so that the orbit is acceptable for all spacecraft in a particular

group. The spacecraft for a cluster launch should have a passive electrical interface, i.e. no electrical links between the spacecraft and launch vehicle.

The launch price is contingent on the satellite integration requirements and can be within the range of $10,000 – 12,000 per kg.

Mission profile for a group of small spacecraft is shown in Figure 2.

Consecutive separation of satellites during the 3rd stage motors operation (so called throttled-back operation) using a ”drag” scheme, provides high accuracy of injection (shown in Figure 2).

It should be noted that the separation systems used on Dnepr LV are not equipped with any pushers, which ensures minimum impact on the spacecraft during its separation from the LV.

6. Configuration of Payload Envelope

An Encapsulated Payload Module (EPM) accommodating spacecraft on their individual adapters is installed under the LV fairing. The use of EPM allows to conduct the integration of all satellites with the LV adapter and their electrical checks inside the clean room facility, with subsequent transportation of the hermetically sealed EPM to the Space Head Module processing facility.

The shape and design of EPM may vary depending on the number of spacecraft, their dimensions and configuration.

Two payload envelope configurations are possible – one tier and two tiers (see Figure 3 and 4).

ISC Kosmotras ensures fabrication of adapter and separation system. Currently, proven separation systems and three types of flight-tested adapters are available:

- for spacecraft under 20 kg (used for SaudiSat and UniSat);
- for spacecraft weighing 60 – 100 kg- (used for MegSat, TiungSat);
- for spacecraft weighing 300 – 600 kg (used for UoSAT-12).

Figure 5 shows platform with 5 spacecraft being processed for Dnepr launch # 2.

***Figure 5**. Platform with 5 spacecraft (Dnepr launch # 2)*

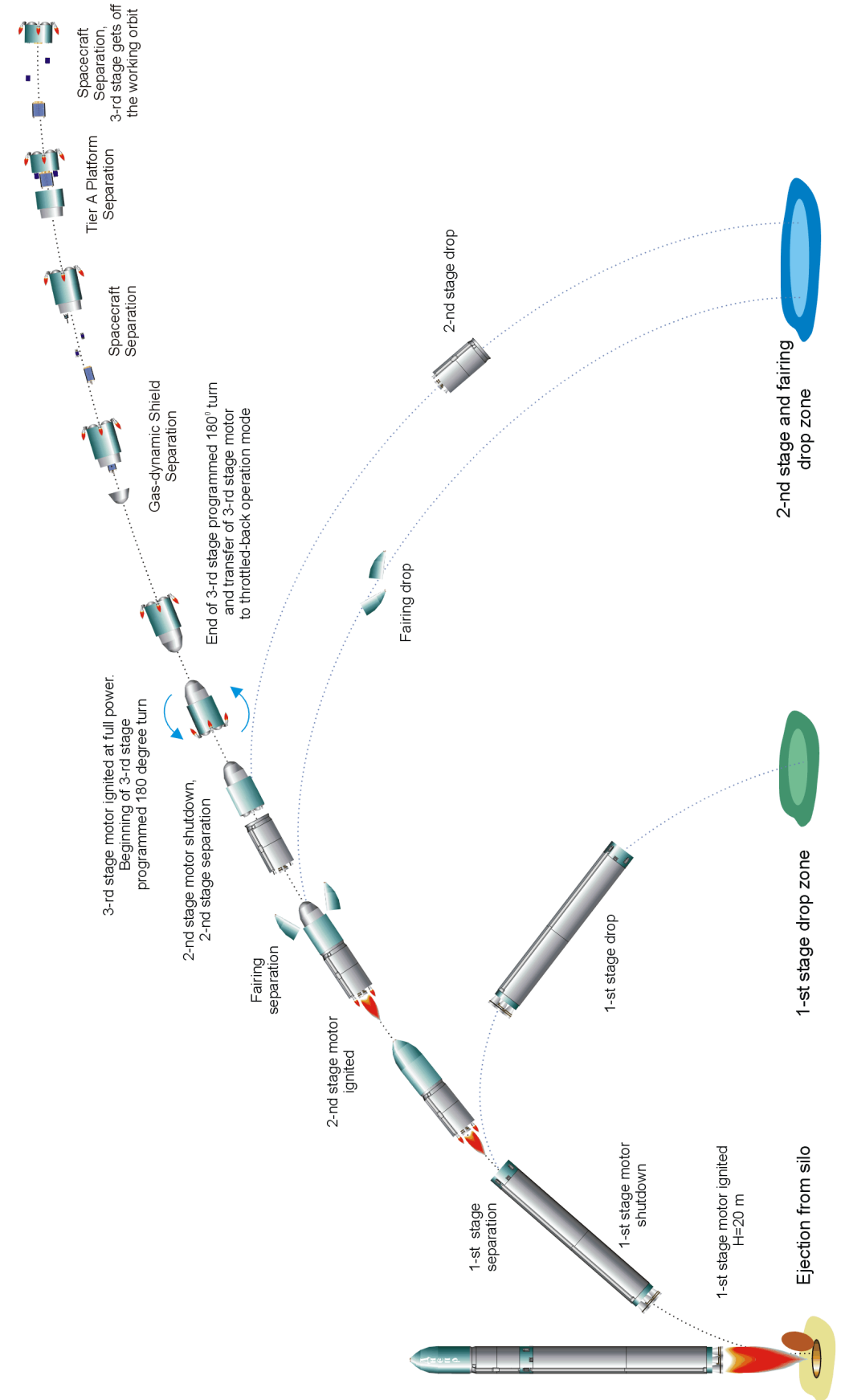
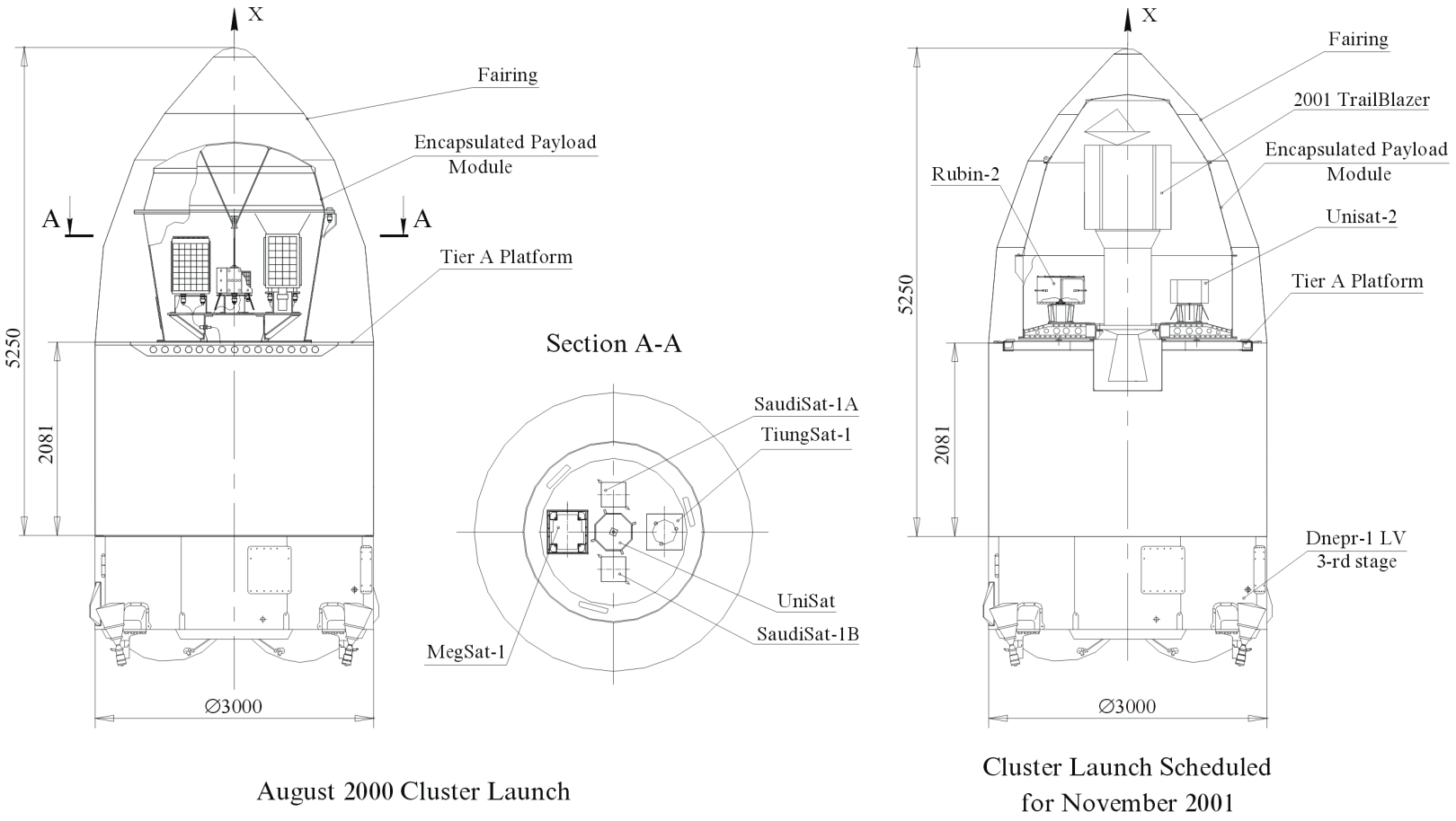


Fig.2 Mission Profile for a Group of Small Spacecraft.



August 2000 Cluster Launch

Cluster Launch Scheduled
for November 2001

Fig.3 Spacecraft Layout for 2000 and 2001 Dnepr-1 Cluster Launches.

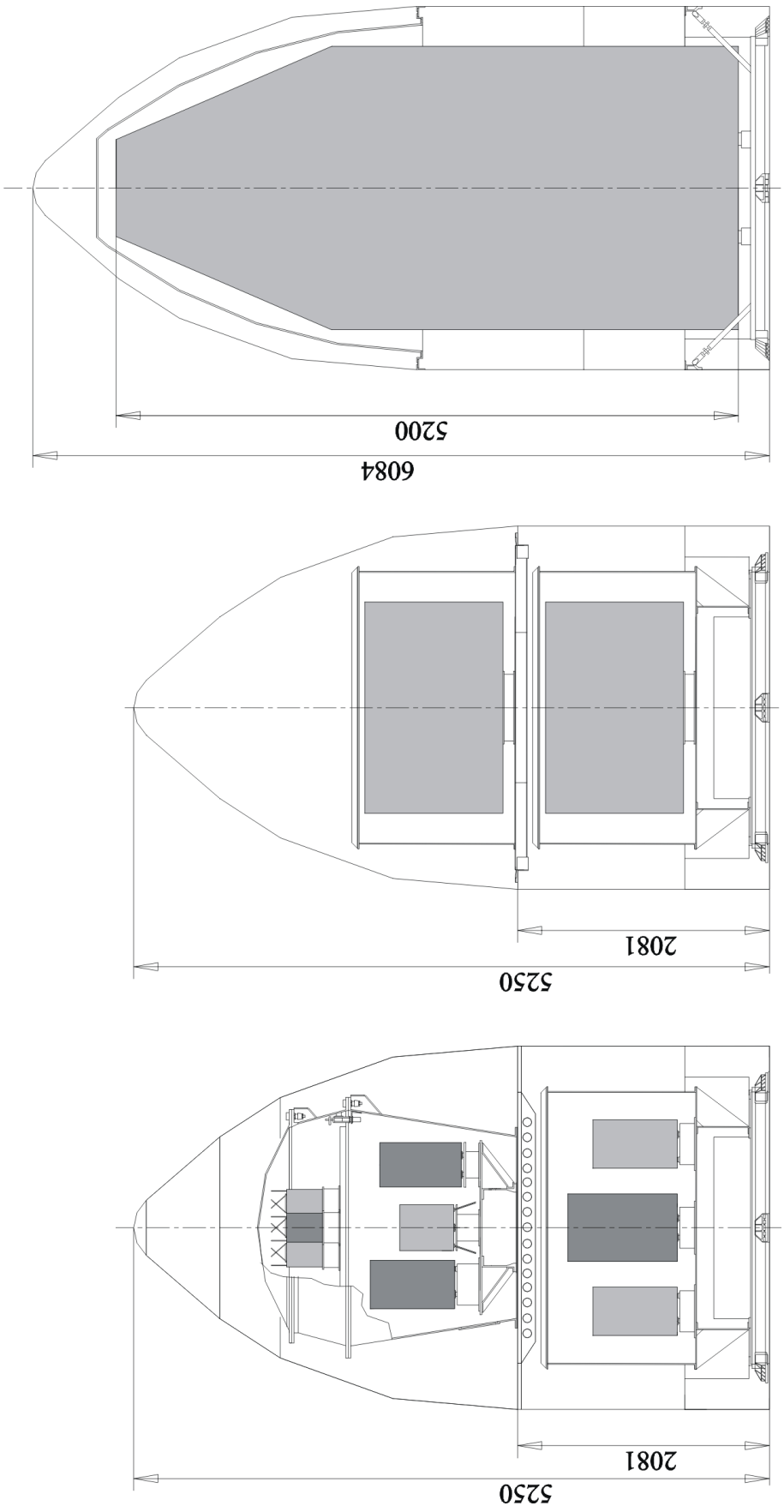


Fig.4 Variants of Payload Layout Within Dnepr-1 Payload Envelope

At Baikonur Cosmodrome, spacecraft are processed for launch by customers' specialists.

Available clean room facilities provide 100,000 class cleanliness (US 209E Standard). If necessary, 30,000 class cleanliness can be reached.

7. Dnepr LV Launches (Performed and Planned)

Two Dnepr launches have deployed 6 satellites in orbit

7.1 *1st Dnepr Launch, 21 April 1999*

One spacecraft was injected into a 650 km circular orbit inclined 65 degrees.

Spacecraft	Mass, kg	Owner	Mission
UoSat-12	325	SSTL, UK	Earth observation, data transmission, technology demonstration, education

7.2 *2nd Dnepr Launch (Cluster), 26 September 2000*

Five spacecraft belonging to different customers were injected into a 650 km circular orbit inclined 65 degrees.

Spacecraft	Mass, kg	Owner	Mission
MegSat-1	55	MegSat s.P.a., Italy	Environment monitoring, data transmission, scientific experiments, education
UniSat	10	University "La Sapienza", Rome, Italy	Science and education
SaudiSat-1A and SaudiSat-1B	2 x10	Space Research Institute, Saudi Arabia	Science and education (first national satellites)
TuingSat-1	60	ATSB, Malaysia	Remote sensing (first national satellite)

7.3 3rd Dnepr Launch (Cluster) Scheduled for November – December 2001

Three spacecraft are planned to be launched into a circular 650 km orbit inclined 65 degrees.

Spacecraft	Mass, kg	Owner	Mission
UniSat-2	10	University "La Sapienza", Rome, Italy	Science and education
Rubin-2	20	OHB System, Germany	Technology experiment
2001 TrailBlazer	420	TransOrbital, USA	Flight to the Moon (mapping and video filming of lunar

			surface, delivery of business souvenirs to lunar surface)

8. Planned Activities

As a new approach, which enhances the potential of the Dnepr Program and expands capabilities of our customers, we should name the use of Dnepr LV for launches of spacecraft equipped with apogee solid motors as boosters. Such a combination allows for delivery of spacecraft weighing up to 700 kg into high elliptical orbits with the apogee of up to 40,000 km, of spacecraft weighing up to 500 kg into geostationary orbits using lunar-assist maneuver, and also into high circular orbits. One or two solid motors will be used for injection. Mission profile with the use of a solid motor is shown in Figure 6.

Our company step by step expands the range of proposals to potential customers. For example, the 1st Dnepr launch deployed one spacecraft, the 2nd one was cluster and one of the spacecraft on the 3rd cluster launch scheduled for the end of 2001 will be equipped with an apogee solid motor and will be injected into a trans-lunar trajectory.

9. Conclusion

Dnepr Program opens up new opportunities in terms of reducing costs associated with the use of small satellites operating on orbits with relatively low altitudes, which is of great importance for educational establishments, new rapidly developing companies and countries.

We are convinced (and doing our best for it) that converted ICBMs, the most powerful of which is Dnepr, should bring maximum benefit to humanity during their second “lifecycle”.

Dnepr Program is open for cooperation and ISC Kosmotras invites all potential customers for mutually beneficial contacts.

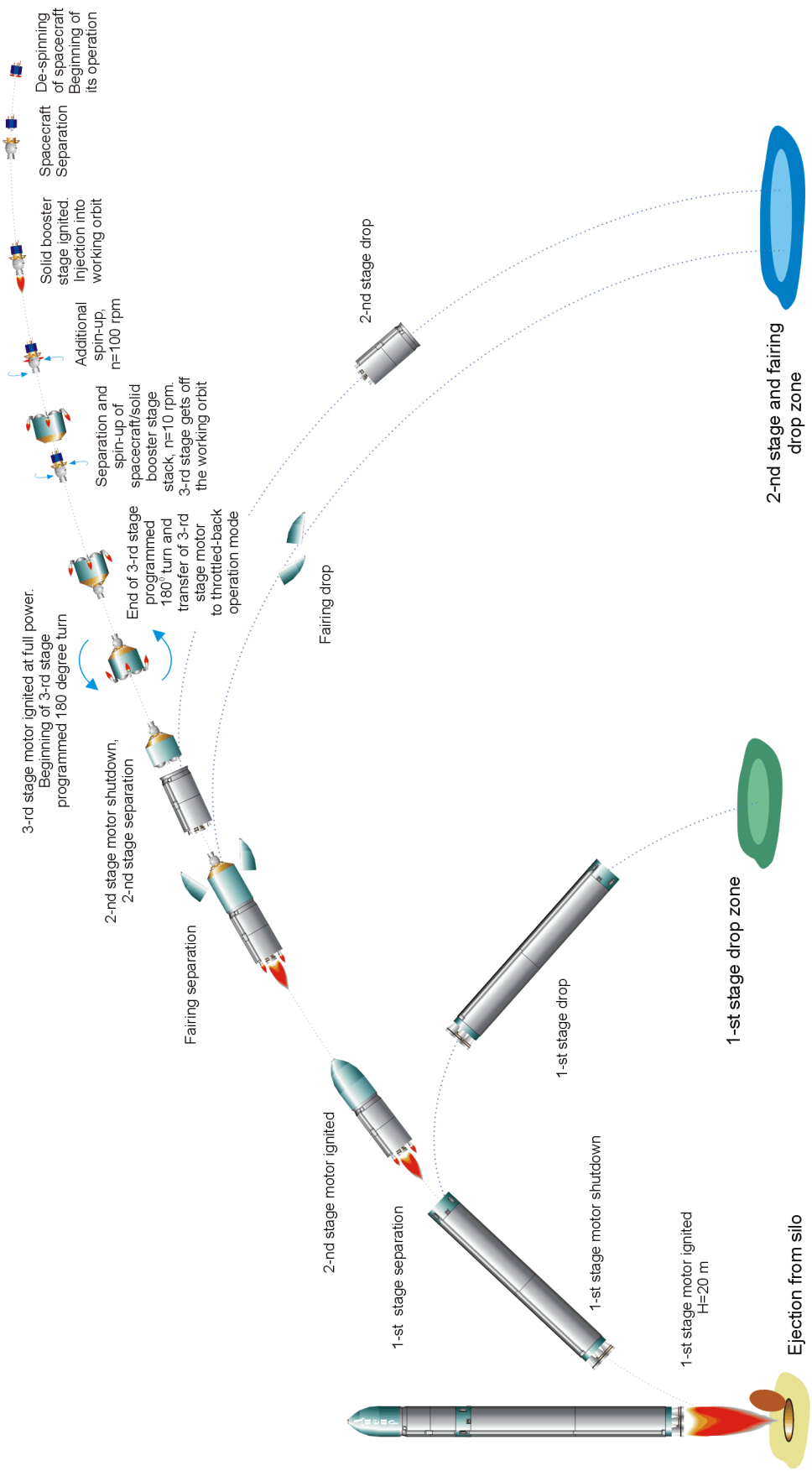


Fig.6 Mission Profile of Dnepr LV with a Spacecraft Equipped with a Solid Booster Stage.

Information on Authors

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