THE MARKET FOR LAUNCHING SMALL SATELLITE IN RUSSIA, ITS PRESENT SITUATION AND LIKELY FUTURE TRENDS

Gerry Webb, Eugene Motorny, Nina Pestmal, Oleg Sokolov
Commercial Space Technologies Ltd.

Abstract

For 15 years, CST has successfully brokered and managed launch solutions for small satellites using vehicles developed in the former Soviet Union (FSU). About 15 satellites have been launched so far and CST is working on solutions for at least this number again. 5 different vehicles have been employed for dedicated, ride share and piggy-back launch methods.

CST has pioneered many new options, being the first to arrange a launch on Dnepr and the first to arrange sun-synchronous orbits (SSOs) for Cosmos and Dnepr. New opportunities and arrangements are being continually assessed, particularly new launcher developments, for their likely impact on the market. Influences from outside FSU countries, such as the introduction of the Space-X 'Falcon' launcher, are also taken into account.

This paper considers the situation now and how it may develop over the next 5 years and in the longer term. Many factors are at play which will influence the outcome of this development. The most important which are assessed in the paper are: Russian government plans; Russian economic factors; outside competitions from launchers in the rest of the world; the life expectancy of the 'mainstay' missiles on which the Dnepr, Rockot and Strela are based and the price of its extension; new entries into the market such as Angara and Air Launch. The situation is, as always, complex and while CST's perspective is based on long term and broad experience only likely scenarios can be presented. Nevertheless it is hoped that the paper will be of some help to small satellite builders.

Introduction

In order to assess the present situation for launching small satellites using the Russian market and to make an attempt to forecast the further development of this situation over the nearest five years, it is first necessary to list those launch systems that are currently available in this market and to estimate their potential for a continuation of operation for this period and beyond it. Then an estimation has to be done with regard to these launch systems that are in development at the present time, with especial attention to those which would substitute for certain currently operated systems that should be removed from operation by this period's end. Equally, attention has to be paid to new capabilities that could be provided by certain newly developed launch systems.

It is necessary to remark that the below-presented information and its analysis is relevant to that small class of launch systems that is intended for the dedicated or rideshare launches of small satellites. Although CST has a significant experience of small satellite launches as piggy-backs on heavier Russian and Ukrainian launchers, an examination of the current and future Russian middle and heavy class of launch vehicles is beyond this paper's frame due to its limited volume.

The current Russian inventory of small launch vehicles numbers as much as six types of launchers of which two have also one additional option. The launch vehicles are: the Cosmos-3M", "Rockot", "Start-1" (with the "Start" option), "Volna", "Shtil-1" (with the "Shtil-2.1" option) and "Strela". All the listed launch vehicles are either in current operation, or are ready for operation i.e. an order for the launch any corresponding payload by them could be made at any time. This list of the Russia-built launchers can be supplemented with the "Dnepr" that, although having a Ukraine-located developer which is providing a technological supervision of the "Dnepr" operation, is being operated by the Russian-Ukrainian "Kosmotras" Joint Venture, while all the basic missiles from which the "Dnepr is being converted are Russia's property. All the listed launch vehicles are available for commercial missions for foreign customers.

In contrast with the "Dnepr", the Ukraine-built "Cyclone" can be not included into the list. Despite this launch vehicle (in two options, "Cyclone-2" and "Cyclone-3") continues to be used from time to time for Russian national missions, its commercial operation is offered by the its Ukrainian developer ("Yuzhnoye" NPO) True, the recently launched "Cyclone-2K" project foresaw the use of this launcher's newly upgraded option for commercial operation through a Russian operator, but the realization of this project has actually been halted, mostly due to an absence of demand for the "Cyclone's" level of payload capability.

The general information on the listed launch vehicles is presented in **Table 1**. The information, in more detail, can be found in the CST report [1] or in the CST reports that were dedicated to particular launch vehicles (some of which are referenced below).

Table 1

GENERAL INFORMATION ON THE CURRENT SMALL LAUNCH VEHICLES THAT ARE SUPPLIED IN RUSSIAN MARKET OF LAUNCH SERVICES

Launch vehicle	Developer (by its current appellation)/manufacturer	Year of maiden launch	Launch mass, tons	Propellant	Number of stages	Max. payload capability, kg (orbit)	Type of launch facility	Launch site	Operator	Estimated launch price, US$ mln	Notes
Cosmos-3M	"Yuzhnoye" NPO/"Polyot" PO	1964	109	Liquid (nitric acid+UDMH)	2	1400 (circ. H=180km, i=65deg.)	Surface	Plesetsk, Kapustin Yar	Puskovye Uslugi, Rosoboron-export	8-10	-
Rockot	Khrunichev	1994	107	Liquid (NT+UDMH)	3	1900 (circ. H=200km, i=63deg.)	Surface	Plesetsk	Eurockot	12-15	-
Dnepr	"Yuzhnoye" NPO	1999	211	Liquid (NT+UDMH)	3 (+Post-Boost Stage)	4500 (circ. H=200km, i=46.2deg.)	Silo	Baikonur, Yasny	Kosmotras	Around 10	-
Start-1	MIT/Votkinsk Machinebuilding Plant	1993	47	Solid	4	420 (circ. H=300km, I=90deg.)	Surface, mobile or transportable	Svobobny, Plesetsk	Puskovye Uslugi	8	-
Start	MIT/Votkinsk Machinebuilding Plant	1995	60	Solid	5	645 (circ. H=300km, I=90deg.)	Surface, transportable	Plesetsk	Puskovye Uslugi	10	No launches since 1995
Volna	Makeev SRC	1995 (sub-orbital)	35.3	Liquid (NT+UDMH)	2	100-130 (circ. H=200km, i=0-25deg.)	Submarine	Barents Sea	Makeev SRC	Less than 1.0	Was used for sub-orbital missions only

Shtil-1	Makeev SRC	1998	46	Liquid (NT+UDMH)	3	430 circ. H=200km, i=0-25deg.)	Submarine	Barents Sea	Makeev SRC	Less than 1.0	-
Shtil-2.1	Makeev SRC	Presumably, 2007	46+	Liquid (NT+UDMH)	3	450 (circ. H=200km, i=0-25deg.)	Submarine	Barents Sea	Makeev SRC	1-3	The maden launch is planned for 2007
Strela	NPO M	2003	105	Liquid (NT+UDMH)	2 (+Post-Boost Stage)	1400 (circ. H=200km, I=65deg.)	Silo	Baikonur	NPO M	Around 10	No launches since 2003

This impressive inventory of small launchers is servicing all national missions and a number of foreign customers. However, all of these launchers are using hardware of which a significant share is not newly manufactured any more. This circumstance defines a limited term for the current Russian small launch vehicle inventory's further operation.

Almost all of the launchers are converted ballistic missiles and are being manufactured by adapting the basic missile for the space transportation purpose to a lesser or greater degree. The basic missiles that have to be converted, although being in current military operation, had their production halted many years ago (there is a single exclusion for the "Shtil" family). Another exclusion is the "Cosmos-3M".

The "Cosmos-3M" launch vehicle

The "Cosmos-3M" is one of most demanded Russian small launchers. Although this launch vehicle is the oldest in the inventory, it has a performance that is at the level of modern requirements and its reliability is very high (no failure since 2000). These features allowed it to be announced, a few years ago, as the "best small launch vehicle in the world". The 'Cosmos-3M" is shown in **Figure 1**. This launcher was built in the "Polyot" Production Association (PO), Omsk, Siberia for more than 20 years especially as a space launch vehicle without any use of converted ballistic missile hardware.

However, this serial production was halted after the former Soviet Union (FSU) collapsed for various reasons and has not been restored despite numerous projects for this restoration. Currently, the "Cosmos-3Ms" are being built using pieces of the earlier manufactured components, the guaranteed lifetimes of which have already expired. The Russian space/missile industry has a vast experience of guaranteed lifetime prolongation for missiles and launch vehicles, as well as for their main components (this experience and corresponding methods were described in the CST report [2]). However, the stocks of the "Cosmos-3M's" components, even with expired lifetimes, are near to their complete consumption at the present time. By the Russian specialists' estimation, the "Cosmos" operation could be continued with a rate of 1-2 launches per a year no longer than for two-three more years.

As is mentioned above, the "Polyot" PO had numerous plans and projects for the "Cosmos" production restoration. A certain support for this initiative was even found in Russian and foreign business circles. However, these plans and projects have been finally buried after the entering of this company into the Khrunichev-led holding, where the role of manufacturing modules for the "Angara" family of launch vehicles (see below) is foreseen for "Polyot".

The “Rockot” launch vehicle

The “Rockot” launch vehicle (**Figure 2**), that is being successfully operated by the Russian-German “Eurockot” Joint Venture for mostly foreign missions on a commercial basis, is being manufactured by the Khrunichev State Research and Production Space Center by a conversion of the SS-19 (RS-19) intercontinental ballistic missiles (ICBMs). The conversion is mostly a substitution of the missile’s post-boost stage (PBS) with the newly developed “Breeze-K” space-purpose upper stage (it is available currently in two options, “Breeze-KM” and “Breeze-KS”). Besides, in contrast with the silo-launched SS-19, the “Rockot” is being launched from a surface launch facility at the Plesetsk spaceport (this launch facility had been formerly one of three “Cosmos-3M” launch facilities, and that was transferred and reconstructed especially for the “Rockot” operation).

Khrunichev has a well-mastered serial production of the “Breeze” upper stages while units of the SS-19’s mated first/second stages (the so called “Booster Units”) are being purchased from the Russian Strategic Rocket Troops (RVSN). As a rule, these are booster units of the missiles that have been in military operation until they have almost expired their guaranteed lifetimes (with repeated prolongations, see [2]). Therefore, Khrunichev has a potential to be provided with the hardware that is necessary for the “Rockot” production until the time when the last SS-19 will be removed from the military operation.

Meanwhile, this time is not so far. Although the number of the SS-19s that are currently in military operation exceeds a hundred, their production was terminated in 1986. Even if one would consider that the confirmed reliability of the FSU-built ballistic missiles and the verified efficiency of the currently used methods for their lifetime prolongation would allow provide a continuation of the SS-19s operation for a long time, this repeatedly prolonged lifetime will not exceed 25-30 years. This means that the “Rockot” operation would be terminated after four years in the worst case and after nine years in the best case. The same future awaits the “Dnepr”.

The “Dnepr “ launch vehicle

The “Dnepr “ launch vehicle (**Figure 3**) was converted from the SS-18 (RS-20) heavy ICBM in a simpler way than the “Rockot” (the substitution of the SS-18’s PBS with an especially developed space-purpose upper stage has not been carried out at the current time, although this upper stage is in the process of development by the “Yuzhnoye” NPO). Besides, it is being launched from standard SS-18 launch silos that are located in the Baikonur spaceport and in the former ICBM base “Yasny”, Orenburg Region of Russia.

The “Dnepr” is being used for the cluster launches of small satellites (a number of which has been contracted through CST) and is widely offered into the world’s market of launch services. However, its further operation is limited by time, probably still more strictly than for the “Rockot”. The SS-18 production was halted in the late eighties, while the prolongation of the guaranteed lifetime for this heavy ICBM is, apparently, a more complicated process than for the SS-19. Therefore, it would be reasonable to suppose that the limit of this prolongation would be around 25 years and the “Dnepr” will provide its farewell launch in 2012-2014. (As for the “Rockot”, there are not any apprehensions that the available stocks of the basic missiles would be spent before this term since the number of SS-18s that are currently in military operation is about hundred pieces.)

The “Start” launch vehicle family

The “Start” launch vehicles are seemed to be in a better position from this point of view since they are being converted from the “Topol” ICBMs, the production of which was terminated around ten years ago. Of two options of the “Start” family, the four-stage “Start-1” and five-stage “Start” (both are shown in **Figure 4**), the “Start-1” only is being currently operated with a low rate of launches (not more than one launch per year). The more powerful “Start” has not been launched any more after its unsuccessful maiden launch in 1995 but it is being offered by this family’s operator in parallel with the “Start-1”. Both of these options use stages of the “Topol” ICBMs that continue to be in a military operation by the RVSN in a significant number.

Beginning from 1997 and up to the present time, the “Start-1” has been launched from the Svobodny spaceport in the Russian Far East. However, recently, the Russian Space Troops that were the Svobodny’s prime operator announced officially that the operation of this spaceport should be interrupted for an uncertain time. Nevertheless, this circumstance will not influence the “Start” further operation: firstly, the Plesetsk spaceport has all the necessary facilities for the “Start” family of launchers (the first launches of both the “Start-1” and “Start” were realized from there) and, secondly, the “Start-1” has a unique capability to be launched from almost all the suitable spots of the globe. This capability is provided by its mobile launch device which is based on a heavy wheeled road transport vehicle. In combination with the launcher’s solid propellant type that does not require fuelling before launch (and corresponding fuelling facilities as well), this feature of the “Start-1” provides the launcher not only with the capability to be independent from fixed launch sites but also with the capability to realize the “responsive access” concept i.e. to provide an urgent launch of any already prepared payload on the customer’s request (this capability of the “Start-1” was described and estimated in details in the CST report [3]).

However, the use of solid propellant in the “Start” launch vehicles has a negative influence on the prospects for a continuation of these launchers in operation for a long time. The matter is that a prolongation of initially set guaranteed lifetimes for liquid-propellant and solid-propellant basic missiles depends on different factors. While the possibility of this prolongation for liquid-propellant missiles is defined by the condition of the missile’s structure and equipment after the preceding storage (even if the fuelled missile has been stored in its launch silo), the condition of solid propellant charges in solid-propellant missiles is a decisive factor for the definition of the possibility to prolong these missiles’ guaranteed lifetime. Meanwhile, the current solid propellants are significantly more susceptible to environmental influence than the components of the missile’s structure and equipment. Besides, these components could be replaced with spares while the replacement of current solid-propellant ballistic missile case-bonded propellant charges is impossible – it would be simpler and cheaper to manufacture a new missile or its stage.

For this reason, the “Start” launcher family has also a limited term of operation that is, apparently, around 15 years after a termination of the basic “Topol” ICBM production. True, the “Topol” was replaced in production with its improved derivative, “Topol-M” but this missile differed significantly from its predecessor and the use of this missile as a basic design for conversion into the “Start’s” following version would require serious development work. Meanwhile, the Moscow Institute of Thermal Technology (MIT) which was the prime developer of both the “Topol”, “Topol-M” and “Start” family has not provided any information on the development of space launch vehicle on the “Topol-M” basis. This might mean that the “Start’s” operation would be finished by 2015 in the most optimistic case. (Until that time, the number of the available “Topol” missiles for conversion into “Start” launchers will be sufficient for the provision of the “Start’s” operation, especially taking into consideration its low rate of launches.)

The “Volna” and “Shtil” SLBM-based launch vehicles

The “Volna” and “Shtil-1” small launch vehicles are being converted from submarine-launched ballistic missiles (SLBMs) RSM-50 and RSM-54 correspondingly by their prime developer, “Makeev State Rocket Center (SRC), Miass, Ural. The distinctive feature of these launchers is that they are being launched from the Russian North Navy’s submarines, as a rule, during the training cruises of these submarines. This feature provides an opportunity to set very low launch prices since the operation of the submarine (as a “floating launch site”) is paid by the Navy while a share of the launch vehicle’s cost is paid for by the Navy as well since its launch is considered by the Navy as a training launch of an SLBM. However, simultaneously, this feature creates serious difficulties in servicing commercial customers: the terms of launches are bound to the Navy's plans for the training cruises, representatives of the customer do not have an access to the submarine board and, therefore, cannot participate in their payload pre-launch preparation, the volume of the payload accommodation zone is strongly restricted since the shape and dimensions of the launcher's nose fairing cannot be changed because of the consideration of the launcher accommodation in the submarine's launching tube (the SRC is trying to eliminate the last shortcoming in the "Shtil-2.1" option).

Of course, these difficulties could be eliminated if these launch vehicles were launched from a fixed surface land-based launch facility. This facility exists in the Nenoksa SLBM test range, Arkhangelsk Region but it has not been used for a number of years and all projects of its restoration are far from a realization.

The "Volna" launch vehicle has not, apparently, any prospects for the continuation of its operation beyond the nearest several years. Besides the fact that the production of its basic RSM-50 SLBM was terminated many years ago and all the remaining missiles have guaranteed lifetimes near to complete expiration, this launcher has very limited capabilities (see **Table 1**). Actually, it can only provide sub-orbital missions since the "Volna" can just inject a very small payload into low-Earth orbit from near-equator areas, while Russian submarines of the corresponding type are not carrying out training cruises to this region of the World's Ocean.

The "Shtil" is in a significantly better situation. As was announced officially a few years ago, the production of its basic RSM-54 SLBM was renewed and, therefore, the "Shtil's" operation would be provided with an availability of these basic missiles for 15-20 years at least. The Makeev SRC developed a range of the "Shtil" options that is shown in **Figure 5** and was described in the CST report [4]. The currently operated "Shtil-1" is a "pure" submarine-launched launch vehicle (i.e. its operation does not require any adaptation of the submarine for space launch provision) while the "Shtil-2" and "Shtil-3" options are intended for launches from a fixed surface launch facility in the Nenoksa test range. As mentioned above, the prospects for this test range are quite unclear and, therefore, the realization of these last two options is in doubt.

The "Shtil-2.1" option is a certain compromise between the "Shtil-1" and the "Shtil-2/3". Keeping the concept of launch from a submarine, this launcher has an upgraded nose part that allows the accommodation of a payload in a larger volume under a newly introduced nose fairing. This introduction of the additional nose fairing, although not such a long one, requires a replacement of the submarine's launching tube's lid with an especially developed one (the details of both the "Shtil-2.1's" design and its accommodation in the submarine were described in [5]).

A first "Shtil-2.1" was being prepared for a launch of the South African Republic's ZA-002 small satellite in this year (this launch was agreed with the Makeev SRC through CST). However, the necessity to carry out this launch from the Barents (or Norway) Sea in a direction of the North Pole (i.e. the U.S.A.) that was stipulated with a provision of the required orbit has led to the appearance of serious problem. This problem is relevant to the receiving of special permission for this launch of the SLBM (since the converted launch vehicles continue to be their basic missiles from an international-legal point of view) from the Russian state bodies (that have to agree this launch with the U.S. state bodies). This permission has not yet been received at the moment of this paper preparation.

Apparently, the further operation of the “Shtil-1” and “Shtil-2.1” launch vehicles would be complicated from time to time with similar problems that are initiated both by their basing on an SLBM that is in military operation and by the necessity to launch them only from submarines and from near-polar seas only. Besides, the above-mentioned difficulties that are relevant to launches from submarines will remain valid as well. At the same time, one should not forget that all of these features allow the provision of these launches in combination with the Navy’s training campaigns and, thanks to this, allow the launch prices to be kept at a low level.

With this combination of the positive and negative features, it is possible to suppose that the “Shtil-2.1” and even the “Shtil-1” would remain in operation for a long time (no less than 15 years) but their operation would be limited to servicing those relatively rare missions that would be realized in the conditions of the described restrictions.

The “Strela” launch vehicle

The last in the Russian current inventory list is the “Strela” that was developed by the Research and Production Association of Machinebuilding (NPO M), Reutov, Moscow Region on the basis of the same SS-19 (RS-18) ICBM as for the “Rockot”. Actually, the “Strela” is a simplified option of the “Rockot” in which the SS-19’s PBS is not substituted with a newly developed upper stage of space purpose. This significantly less degree of conversion from the basic SS-19 ICBM results in both a lower payload capability and launch price (that was preliminarily announced by the NPO M after the “Strela’s” maiden launch) in comparison with the “Rockot”.

Due to this lower degree of conversion, the “Strela” can be launched from the SS-19’s standard launch silos. Despite a few of these silos being in the Baikonur spaceport (the “Strela’s” maiden launch was carried out from one of them), NPO M began to construct such silos in the Svobodny spaceport in order to provide an operation of its launcher from Russian territory. This launch silo was almost ready when the Russia’s Space Troops announced the foregoing termination of that spaceport operation. Currently, NPO M intends to deploy the “Strela” in full-scale operation from Baikonur again. Besides, there will be, apparently, the possibility to use the SS-19's launch silos ICBM bases when the number of the SS-19s in military operation will be gradually decreased (as was done for "Dnepr").

After the successful maiden launch of the "Strela" in 2003, no other launch has been carried out to the present. Probably, this delay of the ready launcher's full-scale operation could be explained by the circumstance that this launcher was intended, in a first turn, for launches of the "Condor"-type small satellites that were developed by the NPO M itself. The "Strela" had launched a dummy of this satellite in its maiden (demonstration) launch (this launch is shown in **Figure 6**) but the manufacturing of even the first example of this type of satellite has not been completed till the present time. (A description of NPO M's policy in regard of its development can be found in the CST report [6]).

Beyond the delayed use of the "Strela" for launches of the NPO M's satellites, a commercial operation of this launcher could be begun at any moment if the corresponding order for a launch will be received (it is necessary to note that the NPO M does not make significant efforts in the marketing of its launcher). However, if this operation will be begun, it will have the same limitation in time as for the "Rockot" since both of the launchers are consuming SS-19 ICBMs as their basic components. (The parallel consumption of the same missiles for conversion into two types of launchers will not lead to shortage of the launchers since the number of available missiles exceeds significantly any forecasts of demand for both the launchers.) So, a termination of the "Strela's" operation would be expected around 2015 (by averaging the figures for the SS-19 lifetime).

It can therefore be concluded that the current inventory of Russian small launch vehicles could provide launches of small satellites until approximately 2015. Exclusions are the "Cosmos-3M" and the "Volna" the operation of which would be terminated within the nearest two-four years and the "Shtil" (most probably, in the "Shtil-2.1" options) which would continue beyond this term.

From the above conclusion the question arises as to which new small launch vehicles would arise in the Russian launch vehicle inventory in order to substitute for those launchers that should disappear?

Over the past fifteen years, numerous projects for small launch vehicles, both on the basis of ballistic missiles and new developments, were stated in the FSU countries and certain of them were led up to the level that allowed begin their realization. However, only a few of the launchers that were based on ballistic missiles were realized (these launchers are included into the list of the current inventory and are assessed above), while not one of the newly developed (i.e. non-converted) launcher projects has been realized. Meanwhile, a "natural selection" among these latter projects took place and three projects that are either in a process of realization, or have chances to be realized within the nearest five years remain as candidates for the renewal of the current inventory of Russian small launch vehicles.

These projects include both “traditional” launch vehicles (i.e. those launchers that have to be launched from fixed surface launch sites) and launchers that have to be launched from a carrier aircraft in the air. Since the last sort of project foresees a serious reconstruction of the basic aircraft in order to combine them with the launchers, it can be reasonable to call these projects’ resulting products as “launch systems”. So, the list of the candidates for the current inventory renewal includes the “Angara-1” launch vehicle family, the “Air Launch” launch system with the “Polyot” launch vehicle and the “Ishim” launch system. The general information on these launch vehicles and systems is presented in **Table 2.**

Table 2

GENERAL INFORMATION ON THE LAUNCH VEHICLES AND SYSTEMS THAT ARE CANDIDATES FOR THE RENEWAL OF THE RUSSIAN INVENTORY OF SMALL LAUNCHERS

Launch vehicle (system)	**Developer**	**Planned year of first launch**	**Launch mass, tons**	**Payload capability, tons (orbit)**	**Propellant**	**Launch site or basic airfield**	**Operator**	**Supposed launch price, US$ mln**	**Status of development**
Angara-1.1	Khrunichev	2010	145	2.0(circ. H=200km, i=63deg.)	Liquid	Plesetsk	ILS	20 (?)	Final on-ground testing, launch site in construction
Angara-1.2	Khrunichev	2012(?)	167	3.5(circ. H=200km, i=63deg.)	Liquid	Plesetsk	ILS	25 (?)	The same as for Angara-1.1 but second stage in development
Polyot (Air Launch)	Makeev SRC	2010	102	3.0 (circ. H=200km, i=90deg.) 1.65(GTO) 0.8 (GEO)	Liquid	Khorol, Biak Island	Air Launch AC	20-27	Completion of design development, carrier aircraft were purchased
Ishim	MIT/MiG	?(2-3years after develop-ment resum-ption)	10.3	0.16(circ. H=300km, i=46deg.)	Solid	Baikonur (Yubileiny)	Kazkosmos	3-5	Completion of engineering project, further development is suspended

The “Angara-1” launch vehicle family

The “Angara-1.1” and “Angara-1.2” small launch vehicles are being created in the frame of the “Angara” launch vehicle family development that has been carried out by Khrunichev since 1994 on state order. The family includes both of these small launchers as well as launchers of middle class (“Angara-3”) and of heavy class (“Angara-5”). All the launchers of the family are assembled from two types of “Unified Rocket Modules”, URM-1 for the lower stages and URM-2 for the top stages. The difference between the “Angara-1.1” and the “Angara-1.2” which both use the URM-1 as their first stage is that the “Angara-1.1” uses the “Rockot’s” “Breeze-KM” upper stage as its second stage while the URM-2 has to be a second stage of the “Angara-1.2” (the design arrangements of both of the launchers and of the URM-1 are shown in **Figure 7**, while their designs and performances are described in detail in the CST report [7]).

Thanks to this unification with the “Rockot” by its top stage, the “Angara-1.1” would be a direct substitution of the “Rockot” with almost the same payload capability and even with the same launch range, Plesetsk. However, all of the “Angara” family of launch vehicles have to be launched from a new launch facility that is in the process of construction at the current time. This construction is currently planned to be completed by 2010, upon which the maiden launch of the “Angara-1.2” is scheduled. Meanwhile, this launcher itself is almost ready for the beginning of flight testing: the URM-1’s main component, the RD-191 rocket engine is successfully passing its on-ground tests while Khrunichev has prepared the production line for the URM-1s in its plant in Moscow. True, this production line will be transferred to the “Polyot” PO (Omsk, Siberia) that has recently entered the Khrunichev-led holdings, but this planned transfer would scarcely delay the maiden launch of “Angara-1.1” since, firstly, Khrunichev has sufficient time for this transfer and, secondly, the first launchers of this type would be assembled from hardware that will have been manufactured in the Khrunichev plant.

Although the small “Angara-1.1” by itself is not the primary interest of the state customers (Russia’s Federal Space Agency and MoD) since they are mostly interested in the heavy “Angara-5”, the planned foregoing beginning of the “Angara-1.1” launches will have a great importance for the further realization of the whole “Angara” programme. These launches will allow the verification of two key components of the family’s main hardware - the launch facility and the URM-1 module. This importance gives some grounds to assume that the “Angara-1.1” maiden launch will be carried out by the planned time and that this launcher would substitute both the “Rockot” and “Strela” when their basic SS-19 ICBMs will became useless for conversion.

Thanks to the use of the more powerful URM-2 second stage, the “Angara-1.2” will have almost twice as much payload capability as the “Angara-1.1”. By this index, “Angara-1.2” is near to the “Dnepr” (if the “Dnepr” could use its power potential completely). Although this URM-2 module is a key component for the whole “Angara” programme as well, its readiness for the beginning of flight testing is less than for the URM-1. Thus, the URM-2 production has not yet begun even for technological examples (probably, this production would be established in the “Polyot” PO directly). However, the URM-2’s most important component, the RD-0124 rocket engine was already tested in a spaceflight (in its initial option in the “Soyuz-2” launch vehicle’s composition). Taking into consideration the time that would be required for the production establishment and for the unavoidable on-ground testing of this stage, it is possible to suppose that the “Angara-1.2” first launch would be carried out about two years later than for the “Angara-1.1”. Even despite this delay, the “Angara-1.2” would have time to substitute for the “Dnepr” for launches on a commercial basis when the “Dnepr’s” operation will be finally terminated due to a complete expiration of the available SS-18 ICBMs’ guaranteed lifetimes.

Talking about the substitution of the ballistic missile-based small launch vehicles by their newly developed (non-converted) successors for the provision of launch services on a commercial basis, it is necessary to remember that the new launch vehicles will have launch prices that will exceed the current converted launchers’ launch prices. This is unavoidable since the opportunity to purchase the basic ballistic missiles at very low prices for their conversion into the small space launchers will disappear simultaneously with these too powerful missiles. Well, perhaps the future disappearance of this opportunity would not be a too high payment for the complete destruction of these former Cold War monsters.

The “Air Launch” launch system

In contrast with the state-ordered “Angara”, the “Air Launch” project has been developed, already over a range of years by a group of Russian space and aviation companies at their own expense. These companies have jointly established the “Air Launch Aerospace Corporation” that is managing the development of the launch system and would be its commercial operator when the system will begin to provide its launch services.

The “Air Launch” system is featured, accordingly to the project, by the dropping of the relatively large liquid-propellant “Polyot” launch vehicle (102 tons of launch mass comparable with the current “Cosmos” or “Rockot”) from the “Ruslan” (An-124) super-heavy cargo airplane, with a following starting of the launch vehicle in the air (the concept and profile of the “Air Launch” system’s mission to a launch of the “Polyot” launch vehicle is shown in **Figure 8**).

The “Polyot” launch vehicle is being developed by the Makeev SRC. This launcher has a two-stage design that can be additionally equipped with an especially developed upper stage (the design arrangement of the “Polyot” is shown in **Figure 9**).

A more complete description of both the “Air Launch” system and its “Polyot” launcher can be found in a CST report [1]. As it was noted in this report and other sources, certain technical solutions that were laid down in the “Air Launch” project as well as organizational items of the project realization have raised numerous questions and doubts from both Russian and foreign experts (see, for example, [8]). However, the most important problem, by these experts’ opinion was the “Air Launch” system’s prospects to find a demand in the world’s market of launch service that would justify the investments into the project development and realization (US$ 150-160 mln by an announcement of the “Air Launch AC” itself). As is mentioned above with regard to the halted “Cyclone-2K” project, launch vehicles with a payload capability of around three tons (into low-Earth orbits) are not much in demand and any prospects for a change of this situation in a future are not foreseen.

Nevertheless, the “Air Launch” developers found a suitable niche for their launch system. Using a distinctive feature of air-launched systems, the capability to provide a launch by any azimuth and, therefore, to inject payloads into orbits with any inclination without a turn of the orbit’s plane, the “Air Launch” system will be able to inject small satellites into geostationary transfer orbits (GTOs) and even to insert cetain small satellites of less mass directly into the geostationary orbit (GEO) as shown in Table 2.

The realization of these missions will require, most probably, the establishment of the system’s operation from a near-equatorial basic airfield since a range of the “Ruslan” carrier airplane would not allow provide launches of the “Polyot” in a near-equatorial area if the system will be operated from the Khorol air field in Russian territory. (This airfield, which is in Russian Far East is also considered to be a basic one for the “Air Launch" but, apparently, would be used for low-orbital mission provision.) In order to solve this problem, the “Air Launch AC” achieved an agreement with the Indonesian government for the use of an airfield on the Biak Island and the government even promised its own investment into the construction of this airfield.

The opportunity to inject small satellites into GTOs and GEO in dedicated launches at relatively low launch prices would really bring commercial success to the “Air Launch AC’s” business since a number of small geostationary satellite projects are being developed at the current time. However, it is necessary for the achievement of this success that the “Air Launch

AC’ will realize its project and also maintain the launch system’s announced performance (including payload capability) and launch price range.

According to available information, numerous on-ground experiments and tests with scale models were carried out during recent times for the verification of the technical solutions that had been laid down into the launch system’s project. The launcher’s key components (main rocket engines, avionics, etc.) have to be adopted from those that are available as products of the Russian space industry. A few of the “Ruslan” airplanes were already transferred from the Russia’s Air Force to the ‘Air Launch AC” especially for their use as carrier aircraft. With these preconditions, the “Air Launch AC” has some real chances to realize its project by the beginning of the next decade if the necessary funding will be provided.

In the case of the project's realization, the “Air Launch” system would be capable, therefore, of not only substituting the currently operated “Cyclone” and “Dnepr” but supplementing the future Russian launch vehicle inventory with a new potential for the launches of geostationary small satellites in dedicated missions.

The “Ishim” launch system

The “Ishim” project is not so well known as the “Air Launch”. Its sufficiently complete description was contained in [3] and it is reasonable to repeat it here in a shortened form.

This project was derived from the earlier development of the MiG-31 heavy fighter-based launch system which had been ready for tests before the FSU collapse. Its renewed project was proposed by the MiG aviation company in 1998.

However, this project found neither state support, nor commercial customers at that time. The project was changed again by a replacement of the earlier two-stage launch vehicle with another solid-propellant launcher to be developed by the Moscow Institute for Thermal Technology (MIT), the developer of the “Start” launch vehicle family. The MIT also became the prime developer of the project.

The project was presented to Prime Minister of the Kazakhstan Republic on March 2005. Kazakhstan was searching for potential directions for the country’s future space activity. The MIT/MiG project promised the opportunity to create a national launch system within a short time. A contract for this project development/realisation was signed by the Kazakhstan’s government with the MIT in late 2005.

An additional argument for this contract signing was that Kazakhstan had inherited two MiG-31D aircraft after the FSU collapse. These aircraft were especially up-graded for the role of carrier aircraft for the above-mentioned earlier launch system. The contracted project received the ‘Ishim’ appellation (’Ishim’ is the name of one of the rivers in Kazakhstan). The total cost of the contract was about US$ 144 mln. Flight tests of the ‘Ishim’ launch system should have been begun in 2007.

The MiG-31D should be up-graded into the MiG-31I option, a model of which with a suspended launch vehicle was shown in February 2006 at the ‘Asian Aerospace 2006’ Airshow in Singapore (this model is shown in **Figure 10**). Besides this air-launch component, the ‘Ishim’ launch system should include the on-ground facilities for the preparation of the launch vehicles and their payloads and a flying command/tracking station-aircraft to be developed on the basis of the IL-76MD cargo airplane.

Despite the “Ishim’s” three-stage solid-propellant launch vehicle being proposed by the MIT to be developed on the basis of the modern “Start” launcher’s technologies, it could not provide a significant payload capability, since the take-off mass of the carrier aircraft was limited (no more than 50 tons). As a result, the launch vehicle had to have a launch mass of 10.3 tons. Being launched from the MiG-31I at an altitude of 15-18 km with a speed of 2120-2230 km/h, this launch vehicle would inject a payload with a mass of no more than160 kg into low-Earth orbit.

Although the ‘Ishim’ launch system would provide a broad range of orbit inclinations including polar and equatorial, this range would only be realized if the system was based on the territories of foreign countries (the MiG-31I’s range to the launch point has to be 600 km).

Due to the use of a solid-propellant launch vehicle which will not require a long time for its on-ground preparation and which would be stored in a number of almost ready examples near to the used airfield, as well as, thanks to the use of the carrier aircraft on the basis of a fighter (for which a short-time for inter-flight maintenance is a typical feature), the “Ishim” launch system would provide a meeting of the requirements for “responsive access” realisation.

Although the expected launch price for the ‘Ishim’ was not announced, there were grounds to suppose that this price would be at the level of US$ 3-5 mln. This means that the specific launch price would exceed significantly the values that would provide competitiveness of the launch system in the world’s market of launch services, even for the provision of dedicated missions for individual small satellite launches. Besides, these satellites’ masses should not exceed 160 kg!

Probably, this negative forecast for the “Ishim” commercial operation became one of the main reasons on which the Kazakstan’ government made a decision for a temporary termination of the project final development in the early 2007. True, as it was underlined in the decision, the project development was not halted but suspended until a time when "more exact commercial grounding" would be possible for the project. Besides, the mentions about a not so accurate development of the project by the MIT in certain details were contained there as well.

At the same time, the MIT's experts have said that the project would be realized within 2-3 years if the necessary funding will be provided.

The nearest future should expose the will of Kazakhstan to continue its support of the "Ishim" project realization (a sign of this forthcoming continuation would be an order for the analisys of the project's commercial prospects from an independent expert company), or the project would be realized for Russia's own needs (for example, for a provision of a national "responsive access"), or the project will be finally terminated.

CONCLUSIONS

On the basis of the information that is presented in this paper, the following conclusions can be done:

1. Russia’s current inventory of small launch vehicles provides a range of services for the launches of various classes of small satellites at relatively low launch prices. All the inventory’s launchers, excluding “Cosmos-3M”, are being manufactured from ballistic missiles for which the guaranteed lifetimes are near to expiration

2. All of the types of the basic ballistic missiles that are being converted into small launch vehicles were removed from production many years ago and their remaining stocks have guaranteed lifetimes that would not be prolonged beyond the term of around 2015. Therefore, the operation of almost all the current Russia’s small launch vehicles would be terminated around this time.

3. The “Angara” launch vehicle family that is being currently realized on a state order includes two options of the “Angara-1” small launch vehicle. These launchers, which could be put into operation by 2015 would substitute for almost all of the current launch vehicles.

4. The “Air Launch” project that is being developed on a private basis would provide, in the case of its realization, a new sort of launch service – an injection of small satellites into GTOs and GEO in dedicated launches at relatively low launch prices.

5. The CST company, using its large experience in working with Russian space industry, is ready to assist any customers of small satellite launches in contracting Russian launch vehicles of both current and future inventories.

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FIGURES 1-10

Fig 1. The “Cosmos-3M” small launch vehicle at the moment of its take-off

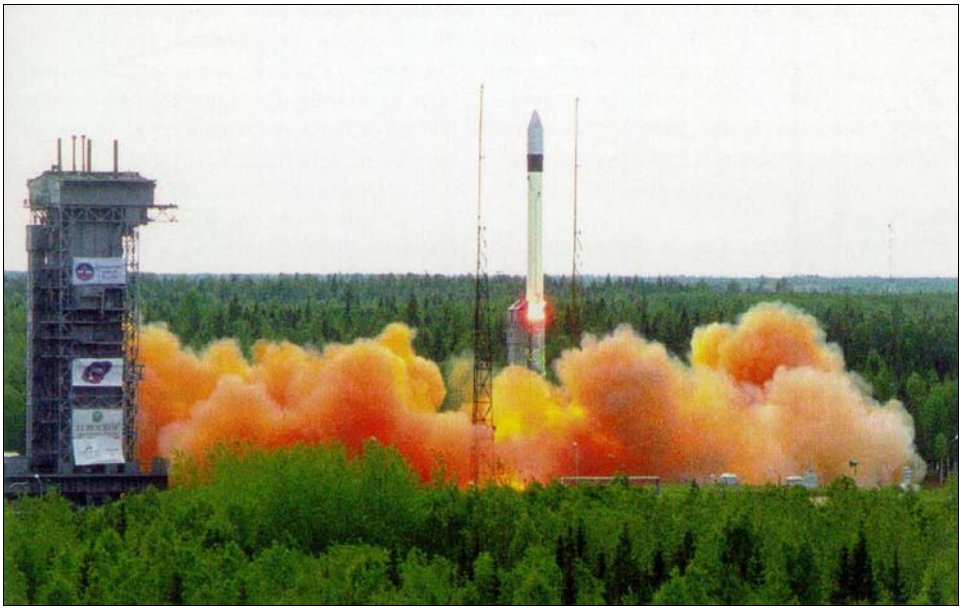

Fig. 2. Launch of the “Rockot” converted small launch vehicle from Plesetsk

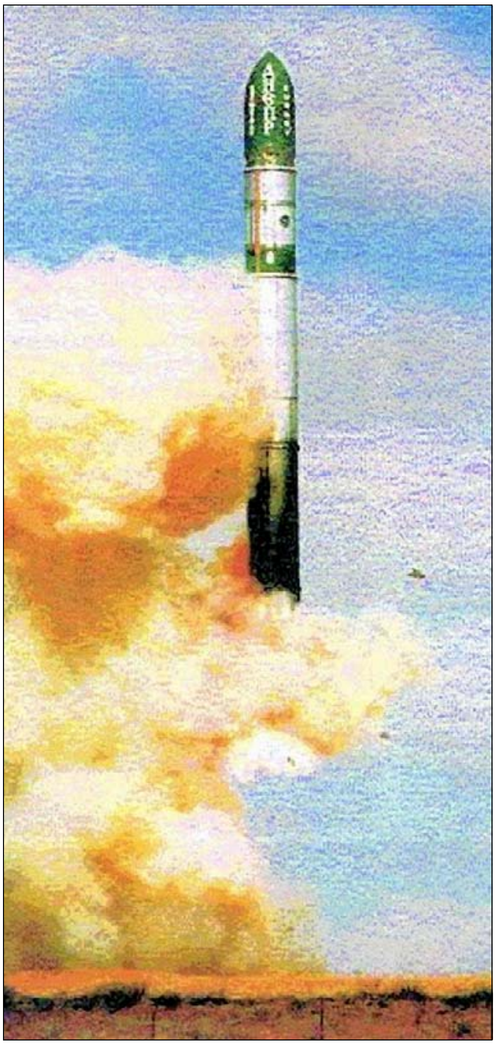

Fig 3. The “Dnepr” launcher at the moment of launch from Baikonur

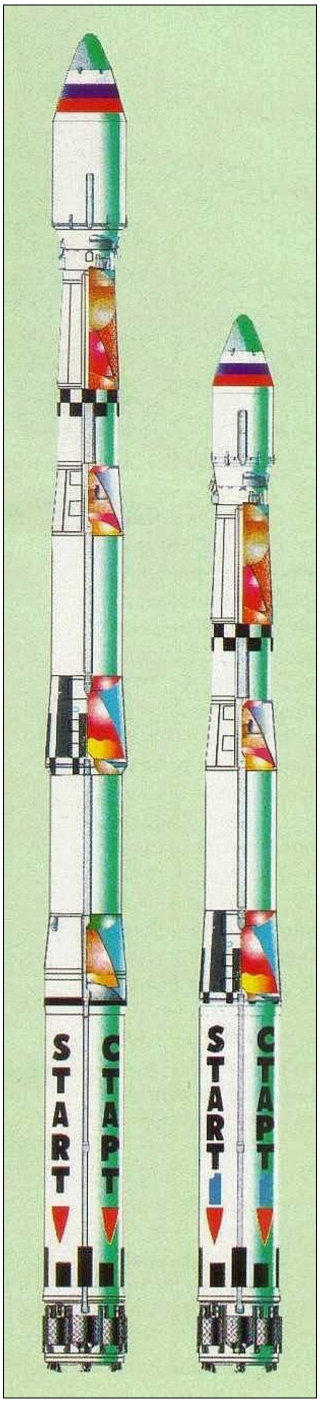

Fig. 4. The “Start” (left) and “Start-1” launch vehicles

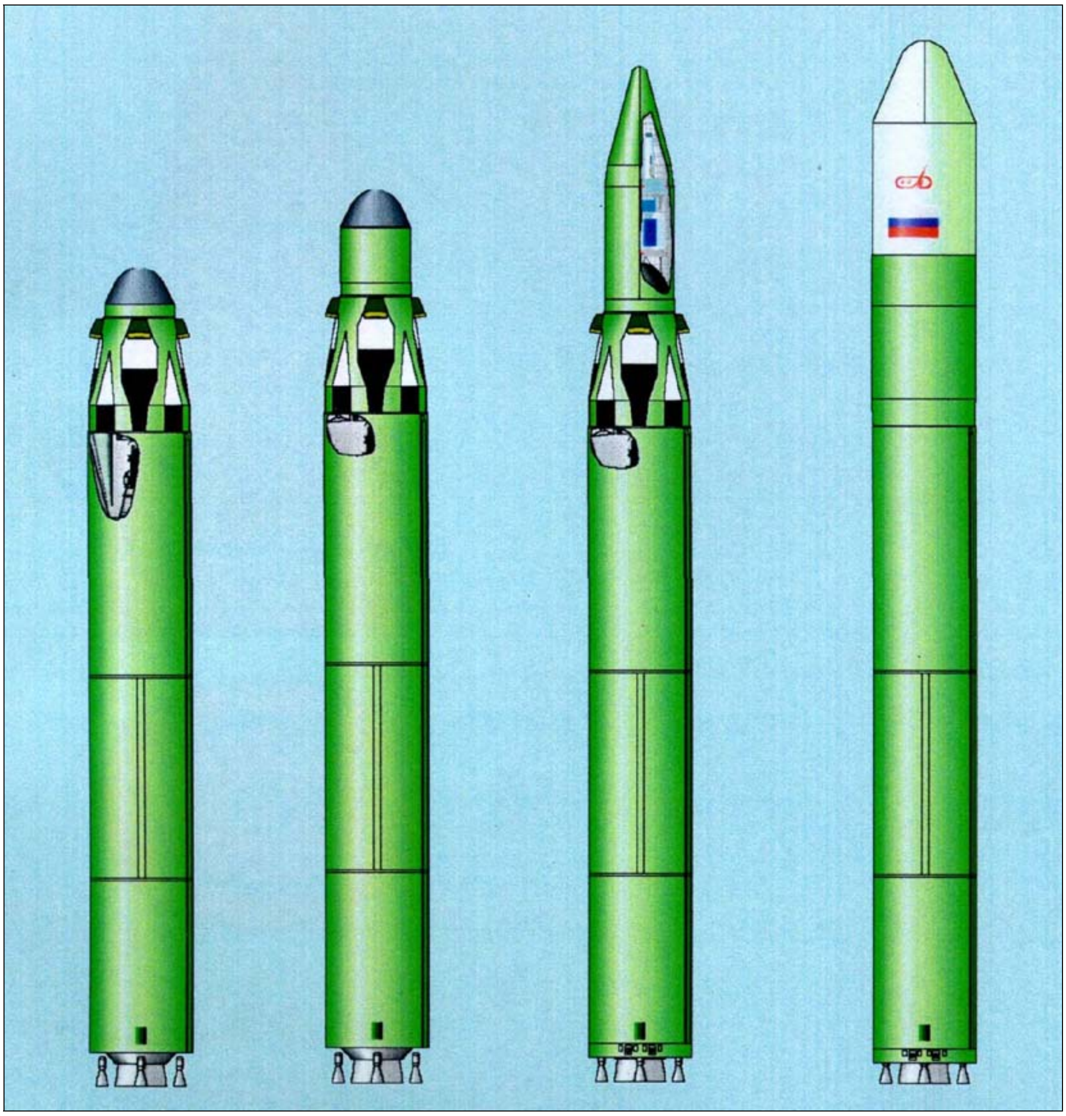

Fig. 5. The “Shtil” family of launch vehicles converted from the RSM-54 SLBM, from left to right: “Shtil-1”, “Shtil-2.1”, “Shtil-2”, “Shtil-3”

Fig. 6. The first demonstration launch of the “Strela” launch vehicle with a dummy of the ‘Condor’ spacecraft

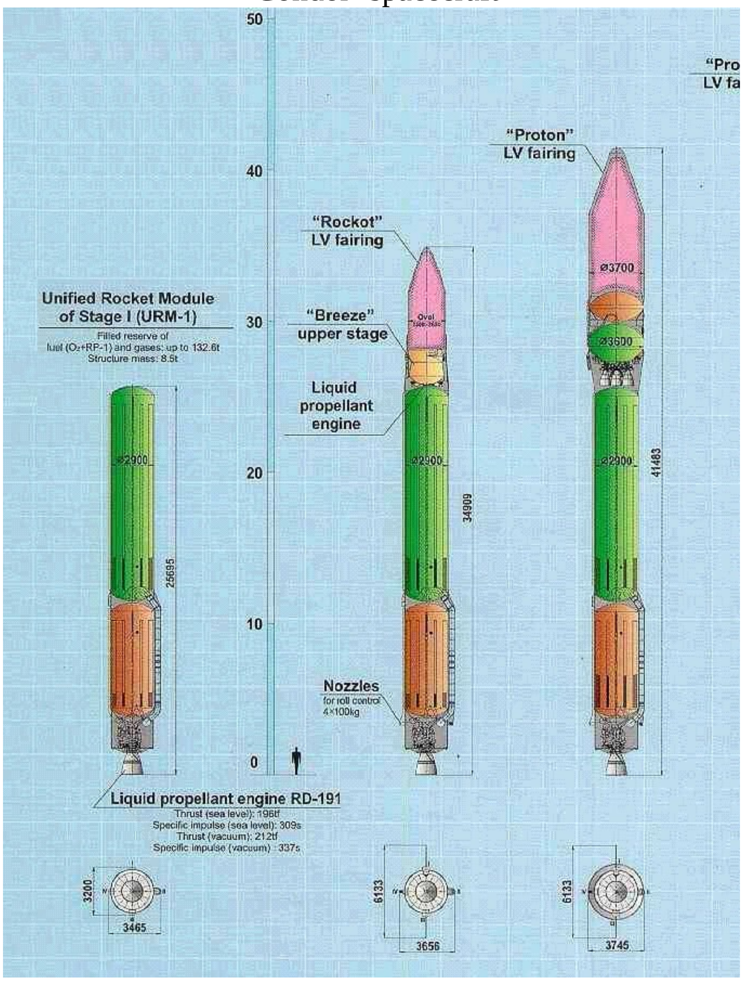

Fig. 7. Designs of the URM-1 module, “Angara-1.1” and “Angara-1.2” launch vehicles (left to right).

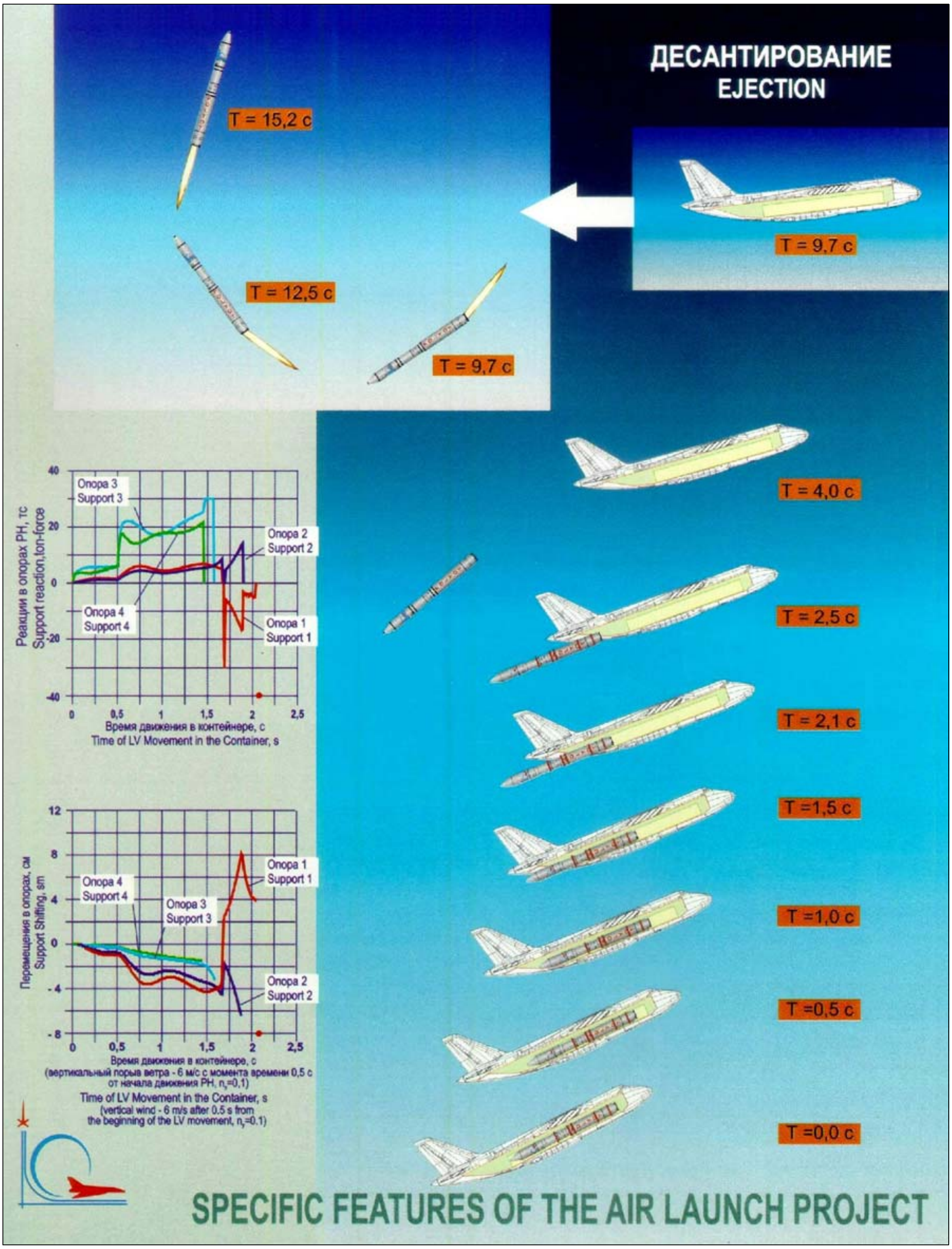

Fig. 8. The “Air Launch” system’s concept of the ‘Polyot’ launcher ejection from the “Ruslan” carrier airplane with its following launch in the air

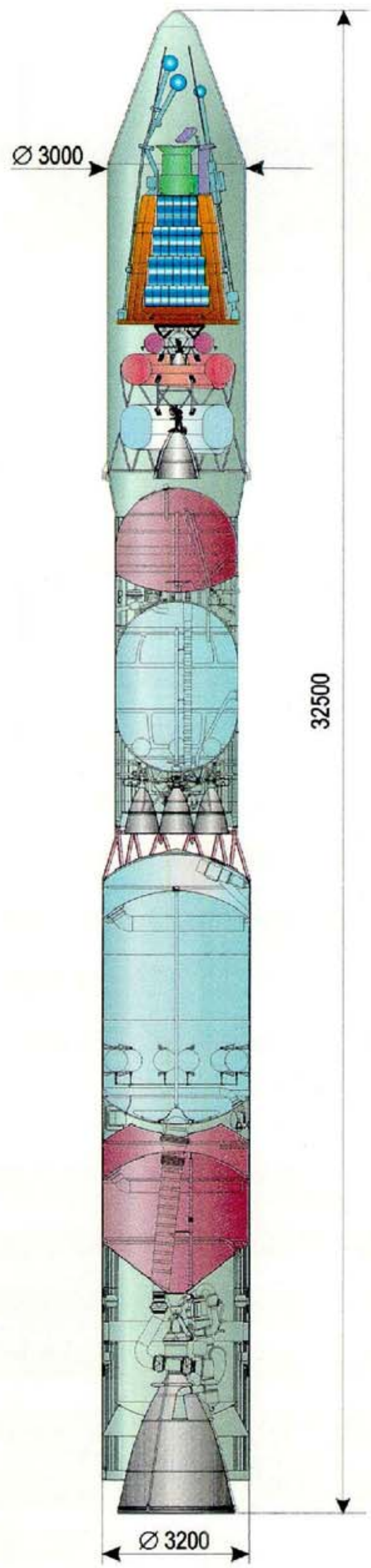

Fig. 9. The Polyot" launch vehicle's design arrangrment

Fig. 10**.** A model of the ‘Ishim’ launch system’s MiG-31I carrier aircraft with a suspended launch vehicle