AIR LAUNCH AEROSPACE INTERNATIONAL PROJECT

A. Karpov, R. Ivanov, M. Kovalevsky,
Air Launch Aerospace Corporation, Russia

Keywords: *launch vehicle (LV), carrier aircraft (CA), satellite, spaceport, space*

Abstract

A concept of the Air Launch International Aerospace Project is described hereunder. The Project goal is to develop the LV available at the world launch market to put lightweight satellites in space. The Project is based on the idea of air launch from the serial cargo An-124-100 Ruslan modified into heavy CA. The Air Launch spaceport is under development on the equator to enable satellite (Spacecraft – SC) launches into any near-earth orbits including geotransfer (GTO) and geostationary (GEO) orbits, as well as translunar and interplanetary escape trajectories. Environmentally friendly Russian space launch vehicle (SLV) technologies, proven and tested to high reliability under piloted and lunar programs are used for the Project. Aeronautical and rocket-and-space companies from Russia, Ukraine, Indonesia and Germany participate in the Air Launch Project development.

1 Introduction

High cost of launch vehicles comparable to the cost of satellites is an essential boundary for many countries of the world that restricts their use of space for the purpose to launch their own communication and telecommunication, remote sensing and scientific research satellites, as well as to meet other challenges for economic development.

Therefore countries with their own space launch vehicle technologies have long contributed to the improvement of launch vehicles: reduced their costs, increased payload capability, extended application areas, improved launch operationability, as well as launch safety.

The present paper provides some results of the commercial Air Launch Project, which is a joint effort of the Russian, Ukrainian, Indonesian and Germany aeronautical and rocket-and-space companies, implemented at the initiative of the Russian Air Launch Aerospace Corporation for the purpose to develop a new air launch system with improved performance characteristics. This system ensures launches of lightweight satellites to low orbits (LEO) (up to 2,000 km), medium orbits (MEO) (10,000-20,000 km), GTO, GEO, as well as translunar and interplanetary escape trajectories, using a 100-ton LV.

2 Air Launch Project Concept

The Project stipulates ejection of the LV with the LV-based satellites at an altitude of 10 to 11 km from the modified serial cargo An-124-100 Ruslan, the heaviest aircraft in the world, used as a flying launch pad.

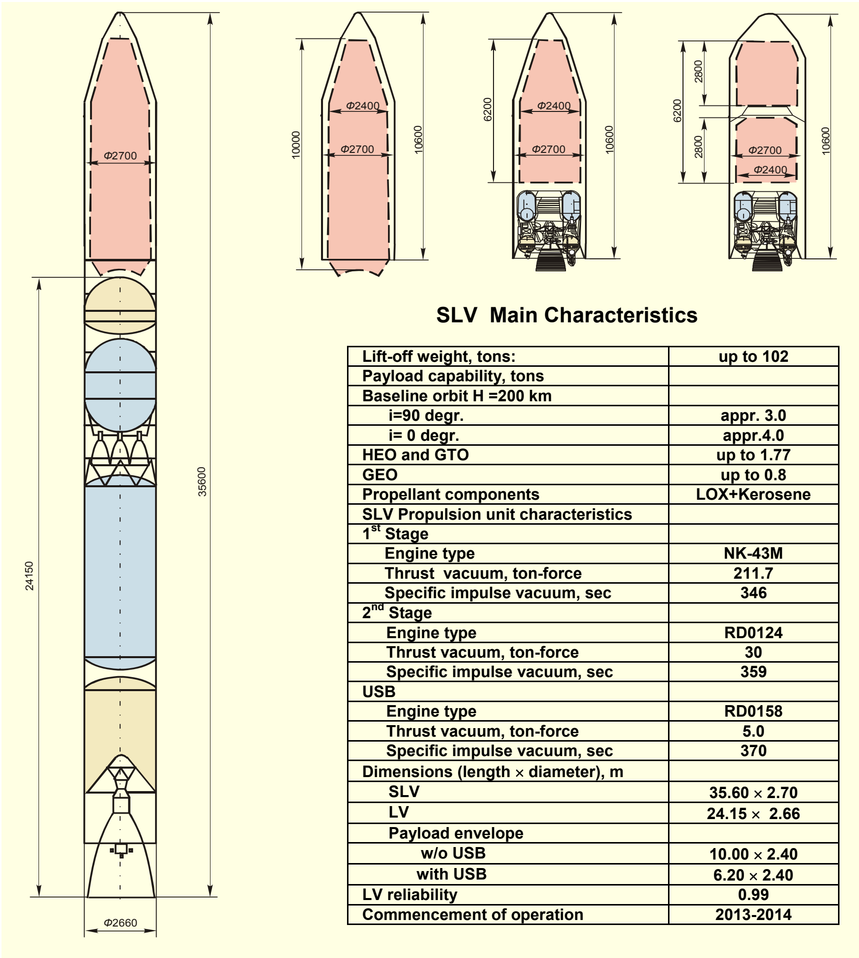
To provide favourable conditions for the LV ejection and initial phase of the LV flight, the CA performs a special pull-up maneuver to parabolic trajectory, which ensures near-zero gravity conditions within 6-10 seconds, while the LV normal load factor does not exceed 0.1 to 0.3 points. It enables to increase the LV ejected mass into 2 to 2.5 times compared to the usual level flight ejection and accordingly increase its payload capability. At the moment when the CA reaches maximum flight path angle during pull-up maneuver (pitch-up angle of appr. 20 degrees), the LV is ejected from the CA, using a special transporting and launching container (TLC) with a pneumatic ejection unit (with hot-gas pressurized accumulator).

The ejection process time does not exceed 3 seconds, while longitudinal load factor does not exceed 1.5 points.

For the development of the Air Launch two-stage Polyot LV (Figure 1) advanced space launch vehicle technologies are used, designed in Russia on the basis of the modified Soyuz LV, which proved high reliability and safety. equipped with the upper stage booster (USB), which is an advanced modification of Molnya LV "L" USB.

Russian space launch technologies used in the Project ensure the Air Launch minimal development costs and terms, as well as its best performance characteristics.

To reach the LV maximum payload capability



Lift-off weight, tons:	up to 102
Payload capability, tons	
Baseline orbit H =200 km	
i=90 degr.	appr. 3.0
i= 0 degr.	appr.4.0
HEO and GTO	up to 1.77
GEO	up to 0.8
Propellant components	LOX+Kerosene
SLV Propulsion unit characteristics	
1st Stage	
Engine type	NK-43M
Thrust vacuum, ton-force	211.7
Specific impulse vacuum, sec	346
2nd Stage	
Engine type	RD0124
Thrust vacuum, ton-force	30
Specific impulse vacuum, sec	359
USB	
Engine type	RD0158
Thrust vacuum, ton-force	5.0
Specific impulse vacuum, sec	370
Dimensions (length × diameter), m	
SLV	35.60 × 2.70
LV	24.15 × 2.66
Payload envelope	
w/o USB	10.00 × 2.40
with USB	6.20 × 2.40
LV reliability	0.99
Commencement of operation	2013-2014

Fig. 1. Polyot Launch Vehicle

For the fist stage of Polyot LV modified liquid propellant engine NK-43 (NK-33-1) is used, designed for the lunar N-1 LV and proved to 0.998 degree of reliability, while for the second stage - the third stage of Soyuz-2 LV with advanced RD-0124 liquid propellant engine. Polyot LV utilizes pollution-free propellant components (liquid oxygen + kerosene).

For the purpose to put satellites in different high orbits and escape trajectories, the LV is to GTO and GEO, spaceport for the Air Launch System is constructed on the equatorial island of Biak (Figure 2), Indonesia on the basis of Frans Kaisiepo Airfield (Figures 3, 4) with the required CA, LV, USB and satellite operations facilities and systems, as well as prelaunch operations and launch control facilities, including Mission Control Center.

Fig. 2. Frans Kaisiepo Launch Airfield (Biak Island, Indonesia)

Fig. 3. General View of Frans Kaisiepo Airfield on the Biak Island

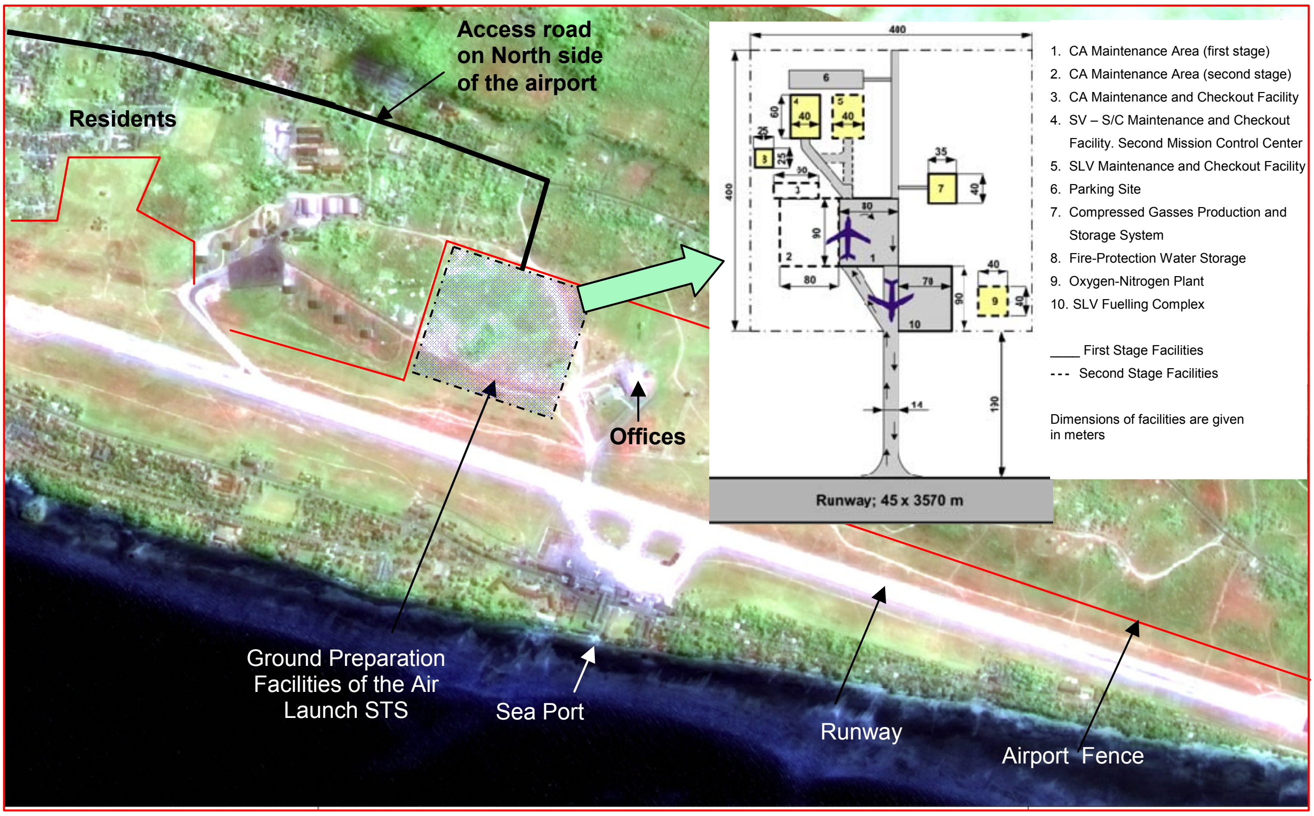


Fig. 4. Air Launch System Spaceport

3 Air Launch System Operation Concept

Figure 5 presents the Air Launch System operation stages, which start with loading of the LV with USB, placed within TLC and subjected to a complete testing cycle, into the CA cargo compartment at Bezymyanka Airfield, located in Samara (Russia) near the Progress manufacturing plant.

After the delivery of the LV and USB to the spaceport in Indonesia, integration of the LV with the satellite, which has been preliminary delivered to the spaceport and passed the required preflight tests, will be performed, as well as installation of necessary components and propellants loading. The satellite may be mounted on the LV at the Maintenance and Checkout Facility, built at the spaceport, or directly inside the CA.

After completion of the launch system assembly, its preflight tests and filling of the CA, LV, USB with propellants and gases, the CA flight to the selected launch area, execution of the preflight pull-up maneuver, the LV ejection from the CA, followed by the LV first and second stages ignition and USB flight, as well as satellite release on a baseline orbit will be performed.

At the present time a possibility to develop the Payload Pre-Integration Center in Germany at Munich Airfield is studied. In this case satellites will be prepared at the Pre-Integration Center and assembled with the LV, after it has been delivered from Russia to Germany by the CA. After checkout and tests of the assembled launch system, a number of operations for placing the satellite into intended orbit will be executed, such as flight to the spaceport on the Biak Island, prelaunch operations and processing, flight to the launch area, etc.

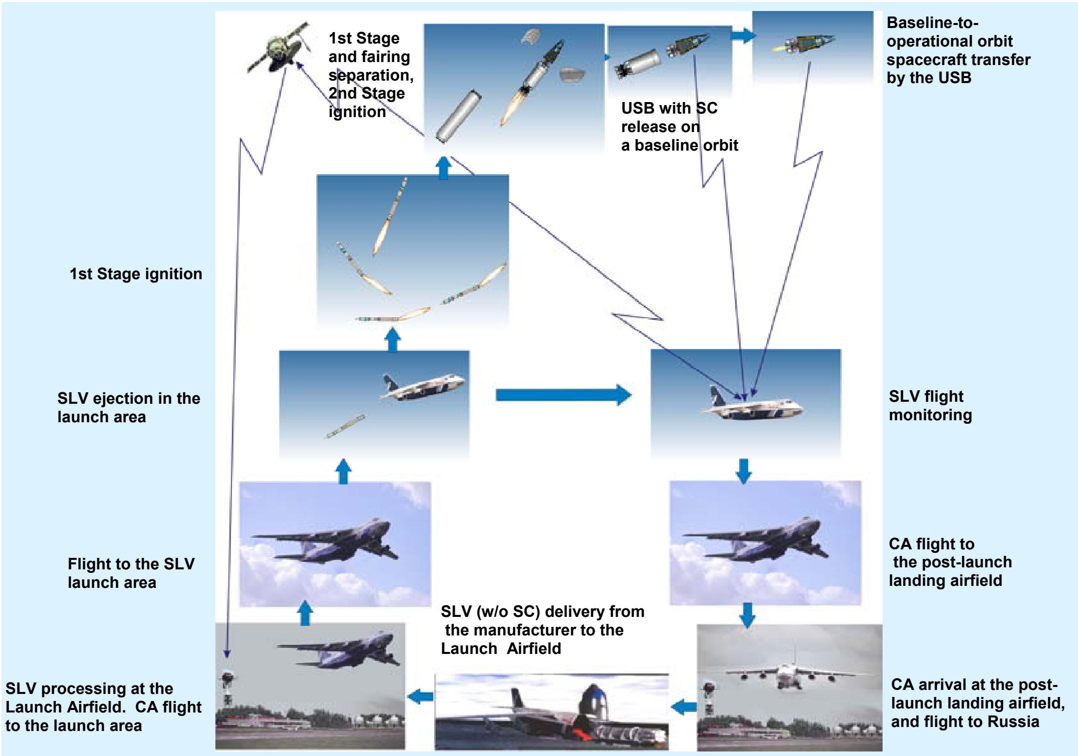


Fig. 5. Air Launch System Operation

4 Flight Route

The Air Launch Flight Route (Figure 6) ensures launches into near-earth orbits with any inclination, using the CA flight with fuelled LV and satellite, total weight of which is appr. 100 tons to the launch area, located at a distance of up to 4,500 … 5,000 km from the Biak spaceport. At this the launch area for the specified flight will be selected depending on

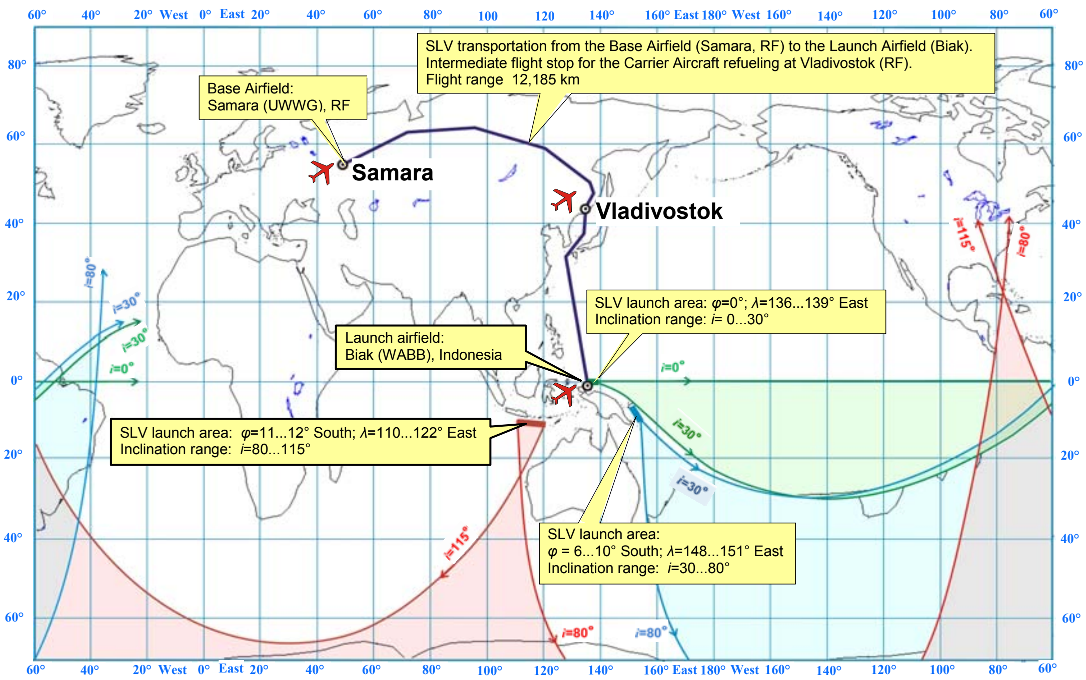


Fig. 6. Air Launch Flight Route

the calculated orbit inclination, location of flight route and impact areas for the detachable LV components over the ocean with limited navigation, as well as the necessity to land the CA at the nearest airfields, capable to land An-124-100 Ruslan aircraft, after the LV has been launched.

Figure hereunder shows three launch areas as an example, located at a distance of 150 to 2,500 km from the Biak Airfield for launches from equatorial orbits to orbits with inclinations of 115 degrees and more.

The Air Launch applicable range of orbit inclinations ensures insertion of all types of lightweight satellites available at the world launch market within the range of their payload capacity.

Satellites launched, the CA lands at the Biak Airfield for launches to orbits with inclinations of 0 to 30 degrees, at Port Moresby Airport in Papua New Guinea for launches to orbits with inclinations of 30 to 80 degrees and at Java and Timor Islands Airfields in Indonesia for launches to orbits with inclinations of 80 to 115 and more degrees.

5 Air Launch Payload Capabilities

Figure 7 presents Air Launch payload capabilities.

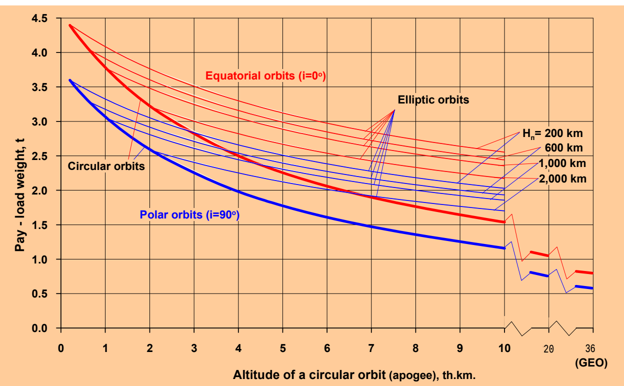


Fig. 7. Air Launch Payload Capabilities

It indicates that Polyot LV is capable to launch satellites of up to 3.5 tons in mass to low polar orbits, up to 4.5 tons - to low equatorial orbits, up to 0.85 ton - to Glonass and Galileo-type navigation systems orbits, up to 0.8 ton - to GEO. Provided satellites are equipped with apogee propellant engine, which ensures transfer of a satellite from GTO to GEO, it will allow Polyot LV to put satellites of up to 1 ton in GEO. The Air Launch System will ensure launches of 1 to 1.2 tons spacecrafts to translunar orbits and escape trajectories.

The Air Launch System demonstrates such payload capabilities owning to the air launch of the LV at an altitude of 10 to 11 km.

Figure 8 presents benefits of the LV air launching over conventional ground launching: possibility of utilization of high-altitude nozzle in the LV first-stage liquid engine, selection of optimum trajectory owing to the exclusion of the initial vertical flight path, necessary for the ground launch, use of the CA initial velocity for the LV, aerodynamic and gravity characteristic velocity losses reduction at the orbit ejection, for the LV will overcome less than 1/3 of atmospheric resistance with launch of the LV at an altitude of 10 to 11 km. Further, when selecting flight route over the world ocean, optimum impact areas may be selected for the detachable LV components without payload capability decrease to orbit.

Total payload capability of the air-launched LV is 1.5 times larger than that of analogous ground-launched LV.

Location of the Air Launch spaceport in immediate proximity to the equator, in latitude appr. 1 degree South (Figure 2), is a significant benefit.

It enables launches to GEO with lesser characteristic velocity loss compared to launches from the Russian Plesetsk and Baikonur spaceports, into 1200 m/s and 900 m/s, respectively.

Figure 9 presents comparative performance capabilities of the ground based lightweight LVs and those of the Air Launch System to launch GEO satellites from

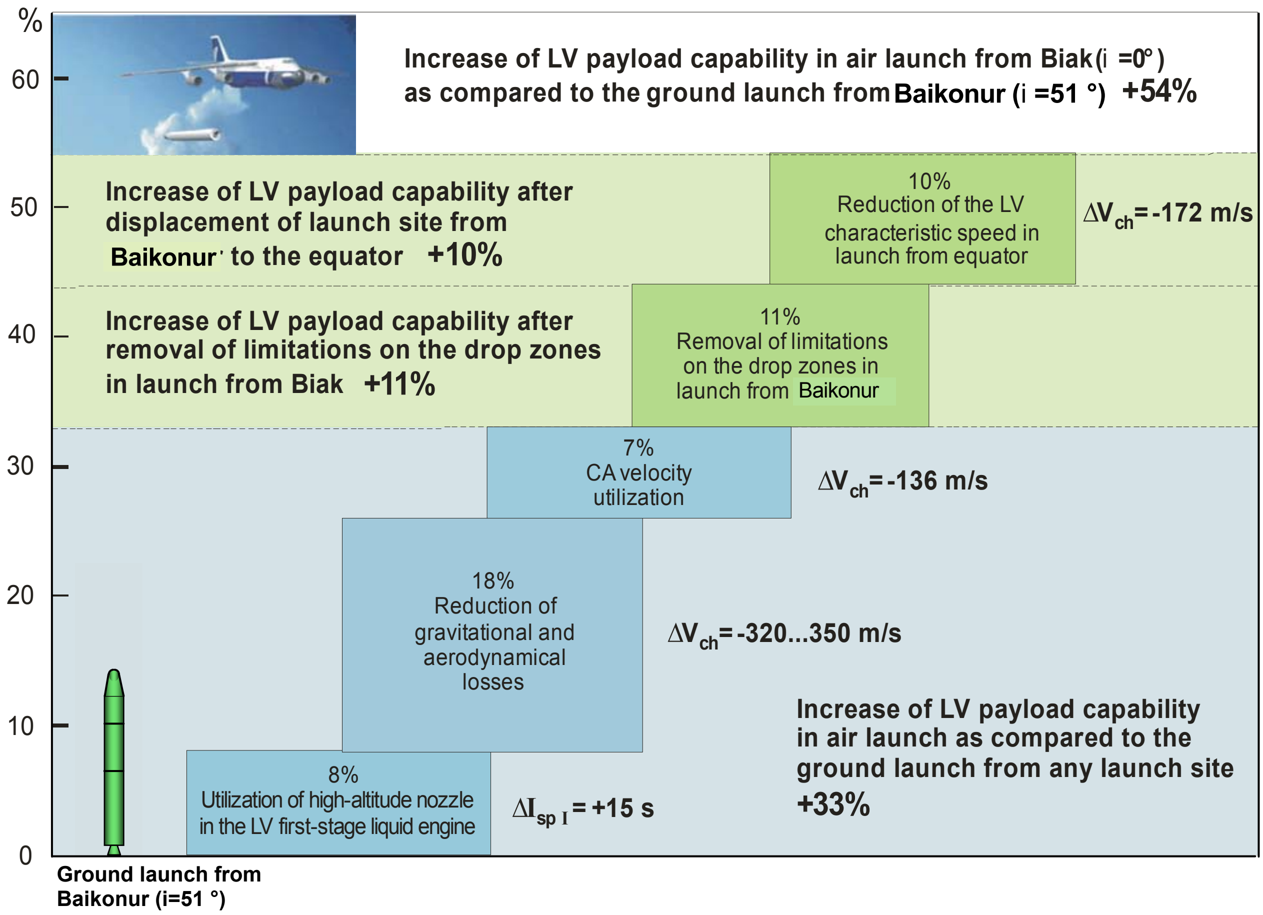


Fig. 8. Comparative Payload Capabilities of Ground- and Air-Launched LVs to 200 km-altitude Low Near-Earth Orbit

the Russian spaceports and from the equator and clearly demonstrates the benefits of the Air Launch System.

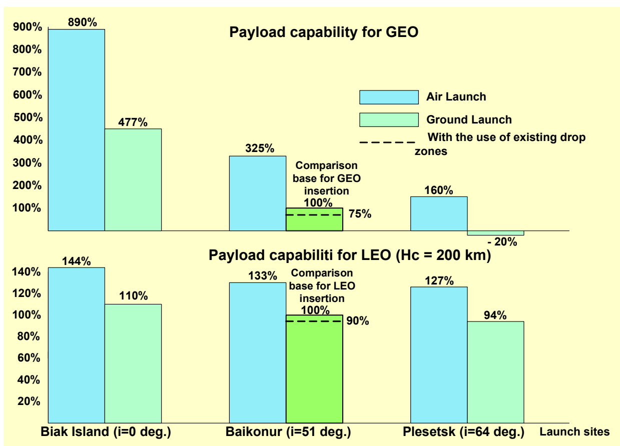


Fig. 9. Comparative Performance Capabilities of Air- and Ground-Launched Launch Vehicles to LEO and GEO

6 Reliability, Safety

Special attention for the development of the Air Launch Aerospace System is paid to the assurance of its high reliability and safety. As said above, most important System components, such as: CA, LV, USB, as well as ground launch preparation and mission control facilities are developed on the basis of high-reliability and well-proven aviation and SLV technologies.

All CA flight modes, including pull-up maneuver, shall be executed within the range of operational An-124-100 Ruslan aircraft performance characteristics and do not exceed airworthiness standards for this aircraft.

The ejection of the LV with a satellite from the CA, using a transporting and launching container with a pneumatic ejection unit, is based on a great number of launches of ground- and sea - based operational ballistic missiles, implemented in Russia and other countries, having rocket weapons. This ejection method practically does not depend on various atmospheric and aerodynamic disturbances, which could otherwise affect the ejection, and ensures optimal reliability compared to other methods, using parachutes.

In total, the Air Launch System LV and USB use three main engines, which are potentially most hazardous sources of failures and emergency situations for all SLV systems. Using minimum number of high-reliable main engines (one for each SLV unit) ensures high reliability insertion of satellites into space by the Air Launch System, which is estimated at 0.99 degree.

The Air Launch System developers pay significant attention to the safety of the CA crew, the LV and satellite operators onboard the CA.

In case of non-studied situations or abort of a planned launch during flight to the launch area of the CA with the LV and the LV-based satellite, the following operations shall be executed: overboard dumping of liquid oxygen from the LV tanks into atmosphere, kerosene transferring to the reserve CA tank and landing of the CA with dry LV at the airfields, which ensure the crew, LV and satellite safety, as well as re-ignition capability (first safety level).

In case of the second failure during flight to the launch area (second non-studied situation), excluding the LV propellant overboard dumping, the CA crew may perform unscheduled ejection of the LV without insertion of the satellite into space, in which case the LV and the satellite will be lost, the CA with a crew and operators will land at the projected airfields (second safety level).

The third safety level of the crew and operators, when it is impossible to dump propellant and perform unscheduled ejection of the LV, is the escape of the crew and operators from the CA, using personal equipment and parachutes, provided in a military An-124 Ruslan aircraft.

To ensure safety of the CA, as well as its crew and operators safety, the CA first stage engine shall be ignited after the LV moving away from the CA at a safe distance (appr. 250 m), resulting from the propellant explosion simulation in case of emergency disintegration of the above-mentioned engine and the LV at an altitude of 10 to 11 km. The Air Launch System environmental safety is ensured by utilization of pollution-free propellant «liquid oxygen + kerosene».

7 Air Launch System at the World Launch Market

The Air Launch Aerospace System in the judgment of its developers will have a great run at the world launch market due to its attractive consumer properties: high reliability of well-proven Russian SLV technologies, application universality for the insertion to any near-earth orbits and escape trajectories, environmental safety, as well as moderate launch prices for lightweight satellites.

Figures 10 and 11 present payload cost factors (launch cost of 1 kg) for launches to low

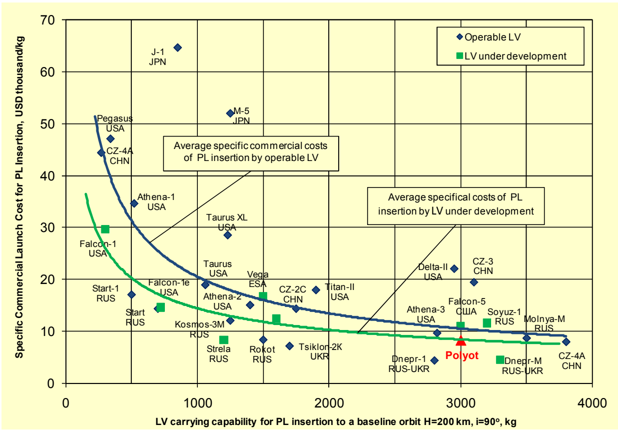


Fig. 10. Payload Cost Factor for Low Reference Orbit H=200 km, i=90°

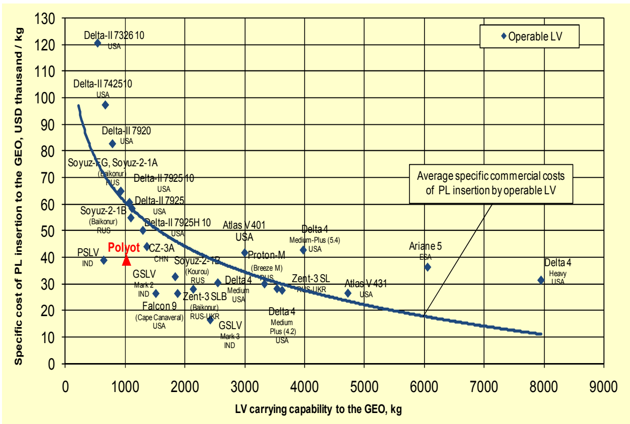


Fig. 11. Payload Cost Factor for GEO (for the transfer from GTO to GEO using satellite engine)

near-earth obits and GEO, respectively.

Diagrams on these figures indicate that the Air Launch System has the smallest payload cost factor and is next best to that of the conversion launch vehicles, modified versions of operational ballistic missiles.

Analysis of the World Launch Market for up to 2018, published in 2009 by Euroconsult, showed that the Air Launch System is capable to launch practically all types of lightweight satellites (Figure 12) to low near-earth orbits, as well as Russian and European Glonass and Galileo-type navigation systems satellites to medium orbits, spacecrafts of up to 1 ton in mass – to GEO and escape trajectories.

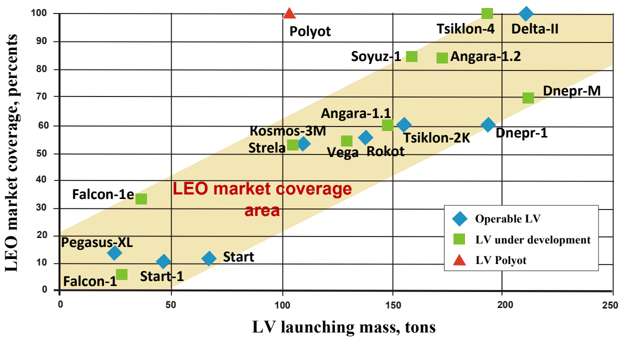


Fig. 12. Operational and Developed Lightweight LVs LEO Market Share for Payload Delivery (percent market share)

8 International Cooperation on the Project

The Air Launch Project is implemented in cooperation with a great number of aeronautical and rocket-and-space Russian, Ukrainian, Indonesian and Germany companies.

Russian Air Launch Aerospace Corporation and State Rocket Center named after Academician V.P. Makeev undertook the principal function upon the Project: the Project general technical conceptual design, development of the Air Launch SLV components, their ground and flight test and experimental checkout, as well as final flight tests of the system with the insertion of payload or spacecraft models into space.

Ukrainian Antonov company is a developer of the CA, built on the basis of the heavy cargo An-124-100 Ruslan aircraft, which will be modified at the Russian aeronautical Aviastar-SP plant.

Spaceport construction works in Indonesia at the Frans Kaisiepo Airfield (Biak Island) will be executed by the Air Launch Centra Nusa, which is a joint Russian-Indonesian venture company. Air Launch Centra Nusa will also participate as a launch operator for providing launch services at the territory of Indonesia.

It is projected that Germany companies, developers and operators of different spacecrafts will construct the European Pre-Integration Center and the Air Launch System in Germany.

Coordination works upon the Air Launch Project in these countries will be carried out by the Air Launch Aerospace Corporation.

9 Conclusion

The innovative Air Launch Aerospace Project presented in the paper is developed with the purpose to expand opportunities for the space exploration in the interests of economy development and raising of living standard of people all over the world.

10 Contact Author Email Address

airlaunch@airlaunch.ru

Copyright Statement

The authors confirm that they, and/or their company or organization, hold copyright on all of the original material included in this paper. The authors also confirm that they have obtained permission, from the copyright holder of any third party material included in this paper, to publish it as part of their paper. The authors confirm that they give permission, or have obtained permission from the copyright holder of this paper, for the publication and distribution of this paper as part of the ICAS2010 proceedings or as individual off-prints from the proceedings.