History of Rocketry and Astronautics

Proceedings of the Twenty-Eighth and Twenty-Ninth History Symposia of the International Academy of Astronautics

Jerusalem, Israel, 1994
Oslo, Norway, 1995

Donald C. Elder and Christophe Rothmund,
Volume Editors

Donald C. Elder, Series Editor

AAS History Series, Volume 23

A Supplement to Advances in the Astronautical Sciences

IAA History Symposia, Volume 15

AAS Publications Office
P.O. Box 28130
San Diego, California 92198

Affiliated with the American Association for the Advancement of Science
Member of the International Astronautical Federation

First Printing 2001

ISSN 0730-3564

ISBN 0-87703-477-X (Hard Cover)
ISBN 0-87703-478-8 (Soft Cover)

Published for the American Astronautical Society
by Univelt, Incorporated, P.O. Box 28130, San Diego, California 92198

Printed and Bound in the U.S.A.

Chapter 28

The History of Space Launch Vehicle Development*

S. N. Konyukhov and V. A. Pashchenko†

Introduction

The development of space engineering in Dnepropetrovsk began with an assignment given to Michael K. Yangel to duplicate S. P. Korolev's work on the Earth artificial satellite. It was decided to develop a launch vehicle on the basis of a military missile. This shortened the terms and cost of this complex creation and operation at the expense of using industrial and launching equipment.

This kind of work was finished on March 16, 1962 with the launch of the "Cosmos-1" satellite by a new launch vehicle which was built by installing a second stage on the R-12 rocket.

An analogous idea was used in building the "Intercosmos" launch vehicle (LV). The R-14 military missile was used as the first stage in the project "Intercosmos" LV.

The "Yuzhnoye" design office developed a landing block for the lunar-landing spacecraft of the N1-L3 space system.

The R-36 military missile gave life to two space vehicles: the two-stage "Cyclone-2" LV in 1967 and the three-stage "Cyclone-3" LV in 1977. Only two crashes out of the 100 launches of "Cyclone-3" LV have made it the leader

* Presented at the Twenty-Ninth History Symposium of the International Academy of Astronautics, Oslo, Norway, 1995.

† "Yuzhnoye" Design Office, Dnepropetrovsk, Ukraine.

among launch vehicles for reliability. One of the last achievements of the "Yuzhnoye" design office is the most perfect, in terms of its design and the automatization of preparation for launch, two-stage "Zenit" launch vehicle.

"Zenit" LV is the basis for building a whole family of perspective launch vehicles of light and middle classes.

First Experience: The Motivation for the Search

The inclusion of Earth artificial satellite launches in the International Geophysical Year program in 1954 was the beginning of an open rivalry between the USA and USSR for first place in the realization of the orbital flight of a hand-made body round the Earth. The USSR was going to use a powerful multipurpose rocket R-7; the draft of a combat variant of this rocket had been finished in July 1954. This rocket consisted of one and a half stages, and it was intended to have intercontinental range with a five-ton nose cone. It could provide cosmic speed to a body of significant weight even without an additional booster stage.

Development work on this complex rocket system was very difficult, sometimes resulting in crashes.

Because of this situation, D. F. Ustinov, the Minister of Defense, asked Michael Yangel, the Main Designer of the Dnepropetrovsk OKB-586 (now known as the "Yuzhnoye" design office) at the beginning of 1957 to duplicate the work of S. P. Korolev, the Main Designer of OKB-1, and to consider the possibility of injecting a satellite into orbit using one-stage ballistic medium-range missiles, taking into account that analogous work had been performed in the USA. This assignment was not occasional, because OKE-586, which had been created from the design department of Plant N586 (now known as the "Yuzhny Machine-Building Plant"), had a staff consisting of specialists: rocketeers from the Moscow design office. They were generally young specialists, former students of the Moscow, Kharkov, and Kasan Aviation Institutes; the Moscow Higher Technical College and the Leningrad Military-Mechanical Institute; and Moscow, Dnepropetrovsk, and Saratov Universities. They were qualified and hard-working engineers. By this time, development work on the R-12 rocket, the second powerful rocket in the country (after the R-7) was being finished in OKB-586; design work on the R-15 rocket was being performed, which was intended for the newest submarines; the drafts of the continental R-14 rocket and the intercontinental R-16 rocket had been issued and submitted to the Government.

But the assigned task was very difficult to accomplish. Calculations showed that with a minimum satellite weight, one more rocket stage was needed for satellite injection into orbit. There was no liquid-propellant engine with suitable characteristics; and OKB had no experience in building rocket stages with solid propellant engines, or with the process of flight control.

Then the Soviet Union did inject the first Earth artificial satellite in the world; that's why the problem was not significant any more and the Ministry was not interested in solving this task at that time. But a lot of designers were interested in this task; enthusiasts continued their work, waiting for their time. And this time has come.

Launcher for Small Satellites is Needed

The fact is that the unique R-7 rocket with its great potential capabilities was needed in different modifications for bringing combat launching positions up to strength; for launches of satellites with animals; for launches of spacecraft to the Moon, Mars, and Venus; and for preparation of human beings for space flight. This rocket also was involved in prioritization, and that was a deficiency.

That's why there was no possibility to pick up this rocket for space exploration and for solving applied tasks from a near-Earth orbit.

At the same time the USA, which was creating space launchers on the basis of the combat rockets "Red Stone," "Thor," and "Atlas," had performed multiple injections of small research satellites of "Explorer" and "Vanguard' types.

Famous scientists of the Academy of Sciences of the USSR and M. V. Keldysh, its president, insisted on space exploration, by comparatively small satellites, which were to be equipped with automatic devices, measuring sensors and a transmission system. As a result, the program of space exploration development was determined by the solution of the Government; the first step of this program was the assigning of OKB-586 to build a launch vehicle for small satellites on the basis of the R-12 rocket.

Solutions Are Found

It was decided to make the new launcher two-staged; the diameter of the second stage was equal to the diameter of the first stage, that is of the combat rocket. The first stage was left without any changes except the upper end which was to provide rational mating of the second stage. It allowed maximum use of productive tooling, transport means and on-ground technological equipment of the test benches and the test range. The aspect of the launcher was defined by the marginal bearing capacity of the first stage on thrust and strength and by the second stage engine characteristics.

The designers were lucky while choosing the necessary engine. An original engine, the RD-119, had been designed but not used yet by that time in

OKB, where V. P. Glushko was the General Designer (now known as "Energomash"). Oxygen and unsymmetrical dimethylhydrazine were used as propellant components in this engine. Its perfect structure provided the highest level of specific impulse achieved in the country at that time: 3,450 m/sec. Its own motionless control nozzles and one motionless cruising thrust chamber provided control for the second stage on all the channels without any special control engines, and they used burned gas of the turbopump unit. The engine also generated gases for propellant tank pressurization and that's why there was no need to use additional pressurization systems. The simplest interstage connecting truss in combination with a conical heat shield, covering the first stage end, allowed the use of "hot" stages separation without positive braking of the first stage. The truss with the shield were transported by being fixed to the second stage, but the first stage length was not increased during transportation, and simultaneously it protected the second stage engine from occasional damage. This launch vehicle had a spacious faring which was opened and jettisoned during the flight. Thus, the rational design solutions allowed the building of a space launcher which was simple in operation and cheap in manufacturing; it could inject satellites with 600 kg weight into orbit.

Designers were very creative in providing for the launcher start-up. An experimental silo "Mayak-2" had been used for first launches; it had been built at the Kapustin Yar test range for development work with silo starts of combat rockets. The second stage protruded above the silo; it was serviced with the help of a special truss with grounding. One of the launching silos of the R-12 rocket was re-equipped and used for further launches at the same test range in Kapustin Yar. Only in 1967 was the complex "Raduga" with two launching pads and a mobile service tower put into operation at the "Plesetsk" test range. It allowed the changing of one satellite for another on the launch vehicle, which was in a vertical position on the launching pad.

Counting of the "Cosmos" is Opened

The Ministry of Defense (Rocket forces) used their own numbering system for Soviet combat rockets. So, the R-12 rocket had been given the designation 8K63. At that time there were no space forces in our country and OKB-586 had given the index 63S1 to designate its own space rocket. The first figures in this index showed what combat rocket was taken as a basis for the building of a launcher; S is the designation to inject satellites, and 1 is the ordinal number of a new space stage. This designation was adopted by all who used it in design documentation.

The loading of the structure and the newness of a couple of propellant components created a negative reaction during the first two launches of this new launcher. Acoustic and vibration loads in the slow movement of a heavy rocket had led to a failure of the gyroscopic instrument and to a crash of the rocket's first stage. The introduction of a special damper removed this shortcoming. But an error in the calculation of the fuel requirement led to a fuel shortage and to a premature second stage propulsion cut-off before reaching cosmic speed.

The third launch of the 63S1 rocket was successful and ended with the "Cosmos-1" satellite's injection into orbit; this was the beginning of a big program of planned space exploration by special satellites, injected by launchers of various classes. The "Cosmos-1000" satellite was injected into orbit in 1978, the "Cosmos-1500" in 1983, and the number of these satellites is steadily increasing.

Development of Direction Chosen

At the beginning of 1960s there were a number of combat medium-range and long-range missiles which were at various levels of development in OKE-586. The country's need for launch vehicles, capable to inject spacecraft into orbit for solving complex tasks, was increasing. Satellites with an enlarged amount of equipment, longer service life, and higher circular orbits were needed. The mass of the satellites was also increasing. At this stage in work our enterprise chose the direction of launcher development on the basis of combat missiles; we also chose three fundamental ways of building them:

- Without installing an additional stage
- With installing an additional stage of small weight where significant development of the body and basic rocket systems is not needed
- Installing an additional stage with optimum characteristics where power engineering is used to the fullest.

Relying on the successful experience of its first design work, OKB was ready to offer projects involving numerous launch vehicles on the basis of combat missiles of various classes, having given them designations according to the classification mentioned above: 64S2, 65S3, 66S4, and 67S5.

As a result of a comprehensive consideration of some criteria (small weight injected, deficiency of the basic rocket), not all the proposals were taken up. The building of the 65S3 launcher had been approved, and its draft had been designed by OKE on the basis of the R-14 rocket. Due to the second stage's low thrust system, this launcher could inject up to 1,500 kg into a polar orbit. As OKB had a great number of other tasks, further development of this launcher was passed to KB, which was headed by M. F. Reshetnyev, its Main Designer (this is Krasnoyarsk city). After flight testing, this launcher continued the successful injection of satellites in accordance with the "Cosmos" program. Its launching complexes for "Voskhod" had been built both in "Kapustin Yar" and in "Plesetsk."

The growth of launchers nomenclature and space tasks had caused the creation of a Central office for space means in the Ministry of Defense in 1965. This office began putting in order its "space economy" and began giving launch vehicles and satellites its own designations. Thus, the 63S1 rocket had been given the designation 11K63.

These rockets in general provided the validation of the program, which had united efforts of scientists from nine countries in the sphere of space exploration and usage. The first satellite on this program—the "Intercosmos-1"—was injected in 1969 by a 11K63 rocket.

New Launchers—the Same Principles

After building its first intercontinental R-16 rocket, OKB-586 had offered to develop a family of combat missiles of the heavy and super-heavy classes based on known components; the R-36, R-46, R-56 that could inject the weight of 5t, 15t, and 50t respectively. Each rocket was supposed to be used for space purposes; in addition, it could help in the gradual accumulation of launcher energy capabilities in the future.

The R-36 rocket had been designed, and its orbital variant, as a matter of fact, was already a space launcher, as this rocket had been injecting a nose cone into orbit. This nose cone could perform a full turn around the Earth, having started at any azimuth.

This rocket, which had been developed for ground launches with complete automatization of the minimum cycle of prelaunching preparation, later was named "Cyclone-2"; it has been in operation since 1972.

On the basis of this rocket as a way of installing an additional third stage (S5M) with a propulsion system (which was analogous to the retrorocket of the orbital nose cone), another launcher had been built. Its prototype was the 67S5, and it was named "Cyclone-3." Its operational scheme is analogous to the operational scheme of the "Cyclone-2." Beginning in 1977, "Cyclone-3" LV has performed more than 100 launches; the level of its reliability is 0.97.

The Lunar Program

The proposal on the R-46 rocket, which would carry a 50-megaton nuclear charge, was interesting neither from a space nor from a military point of view. The proposal on the R-56 rocket was interesting for the Government of the country because of the competition between the USA and USSR involving Moon exploration. The draft of this rocket was developed in 1964; its launch weight was 1,400t and it could inject about 40t into the polar orbit with a 200 km altitude. This launch vehicle was visualized in a monoblock variant, and according to the evaluation of specialized institutes, it was the optimum rocket for the realization of the programs given, including auxiliary tasks associated with Moon exploration. Without any visible causes and reasons, however, this development work was suddenly stopped later. Many specialists and scientists were disappointed about this decision.

The most important task in Moon exploration—a manned landing on the Moon and a return to the Earth—was to be performed by the N1-L3 space system as a part of a super-heavy N1 launcher and rocket lunar complex L3; the lunar-landing spacecraft LK was a part of this complex. The main organization to perform this giant project was S. P. Korolev's OKB, and other big enterprises of the rocket-space branch took part in this project as well. The pre-draft of the system had been finished by the end of 1964; it showed that the building of the lunar spacecraft was possible. This lunar spacecraft could meet the parameters required. The draft was needed, and in reply to S. P. Korolev's request M. K. Yangel, the main designer of OKB-586, agreed to continue lunar spacecraft rocket block development. The block was called "Block E."

This task was very difficult, especially the reliability of the work. If there were failures at previous stages of flight, the death of the crew could be prevented by the escape system and by correction of the flight program. But at the spacecraft's orbital departure and at the beginning of descending to the Moon, the cosmonaut's life depends completely on the proper functioning of the rocket Block E. It was to provide lunar spacecraft SC landing and to play the role of the launching pad during its ascent from the Moon. If there were any extraordinary situations during SC descent or during the stay on the Moon, then this block was to provide the expedition stoppage and SC return to the near-Moon orbit.

The total reliability of the Block E engines had to be about 0.99976. It must be taken into account that the block of engines consisted of the main one-chamber engine and reserve two-chamber engine, which used unsymmetrical dimethylhydrazine and nitrogen tetroxide.

Total guidance of Block E development was assigned to B. I. Gubanov, the Main Engineer of OKB-586; further, he was the main designer of the "Energia" launch vehicle. In the process of block development work, the tasks of starting the engines in a condition of weightlessness, and provision for the propellant components thermal conditions for long duration in space were solved, taking into account all the requirements for the mass of the structure.

After testing the electrical, thermal, aerial, dynamic models, and after firing stand testing, three flight tests of Block E as a part of the lunar SC together with the "Soyuz" launcher were conducted in 1970 and 1971. The lunar spacecraft was injected into orbit, and multiple SC maneuvers with control in the automatic mode with its own equipment had been conducted. SC work had been controlled according to the cyclogram, and in failure modes. All the tests were successful, and the lunar SC was ready for a flight as a part of the lunar complex; but in 1972 there were some failures with the N-1 launcher, and the program was stopped and closed.

A New Direction

At the beginning of the 1970s, the "Yuzhnoye" design office had performed pre-draft work of a new class of launchers on the basis of the R-36M rocket, keeping to expediency and elements proved by practice. These launchers had to be used instead of existing launchers of the light and middle classes. The two-stage rocket of the middle class consisted of two blocks being used as the first stage. Each block was the first stage of the R-36 rocket. This rocket could inject up to 10t into orbit.

This design work was not continued because by that time there were requirements on propellant components intoxity, on minimization of regions of separating parts dropping, on control engine testing without an overhaul, etc. But these launchers did not meet those requirements.

That is why our design office began working in the direction of developing a system of launchers using liquid oxygen and kerosene, according to a two-stage scheme. The stages were made as monoblocks, and the dimensions of each block were suitable for railway transportation. At the end of 1970s the "Yuzhnoye" design office offered to develop drafts of launchers of the light (11K55, 11K66), middle (11K77), and heavy (11K37) classes.

The peculiarity of these launchers is that they are built on the basis of the first stage block of the basic middle-class launcher; their launching and technical positions are unified regarding basic systems and units of technological equipment. For example, the 11K37 launcher was offered as a multi-variant launcher, adapted to the payload needed. This launcher could inject 30-60t into orbit, using a group of two, three or four basic modules as the first stage. The only variant of a launcher, which is known among specialists as "Zenit-2" and has a high level of structural and operational perfection, has been realized among the family of launchers up to the present. Besides, the basic module of the rocket was a part of four A blocks of the first stage of the super-heavy launch vehicle in the "Energia-Buran" system.

At present, LV designers at the "Yuzhnoye" design office have, as well as specialists of many other countries, some financial difficulties. But they perform design work to develop the potential of existing launchers and to build new perspective launchers on the basis of combat rockets and on the basis of a unified rocket module.