SRP SC "TsSKB-Progress": Trends and Future Prospects

A.N.Kirilin*, R.N.Akhmetov* and S.I.Tkachenko*

** State Research and Production Space Center "TsSKB-Progress", Russia,*
(tel. : 246-955-1361; e-mail csdb@samtel.ru)

Abstract. The report highlights the main trends on development of the State Research and Production Space Center "TsSKB-Progress" in the sphere of rocketry, space exploration and spin-off manufacturing. Here results of international co-operation of the company, are presented.

Keywords: launch vehicle, satellite, designing, manufacturing, testing, operation

1. INTRODUCTION

State Research and Production Space Center "TsSKB-Progress" is the core of the aerospace cluster of Samara Region (Russian Federation). The company is aimed at building of the leading product, namely development, manufacturing and operation of (Kirilin, 2006):

- light, middle and heavy launch vehicles;
- high-resolution remote sensing and mapping satellites;
- satellites for scientific research and technology improvement.

Besides, manufacturing is diversified by:

- aeronautical engineering (trainers, short-haul airliners and passenger airplanes);
- building of hardware for oil survey and natural gas liquefaction;
- Manufacturing of Aqualine boats etc.

2. LAUNCH VEHICLE

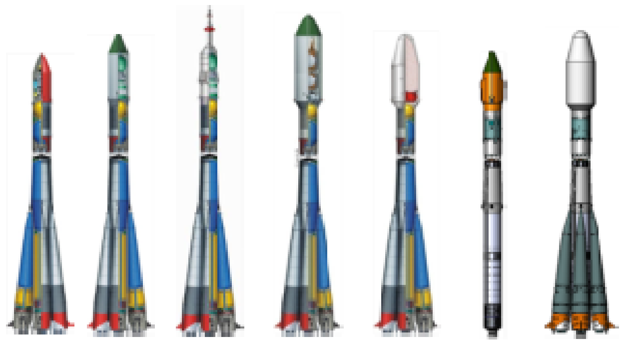
For 50 years the space center has been producing and operating a number of middle- class launch vehicles by request of Roskosmos, Ministry of Defense and on commercial basis. By May 9, 2009 nine modifications of the R-7 family middle-class vehicles designed in Samara were credited with 1743 launches.

Launch vehicles of Molniya, Soyuz-U, Soyuz-FG, Soyuz-2, Soyuz-ST types are given in Fig. 1. At present they are manufactured by Customer request. Besides, there are shown Soyuz-1, Soyuz-2-3 launch vehicles currently being under development. State Research and Production Space Center "TsSKB-Progress" takes up monopolistic market position in providing manned flights. From the first Gagarin launch in 1961 till 30.04.09, launch vehicles built in Samara put into orbit 134 manned spacecraft of Vostok, Voskhod and Soyuz type and 123 cargo ship.

Launches of carriers supporting ISS operation over the period from 2004 to April 2009 are given in Table 1.

Currently our efforts are focused upon Soyuz-ST launch vehicle tailored for launches from the spaceport in French Guiana. The launch vehicle is a modification of Russian Soyuz-2-1a and Soyuz-2-1b launch vehicles designed by SRP SC "TsSKB-progress" which is adapted to tropical conditions.

Even during trial operation (3 launches of Soyuz-2-1a and 2 launches of Soyuz-2-1b) of this modern launchers with increased carrying capacity and equipped with the digital control system (designed by NPO-A, Ekaterinburg) there were placed into orbit two ESA satellites – Metop and Corot.



Molniya Soyuz-U Soyuz-FG Soyuz-2 Soyuz-ST Soyuz-1 Soyuz 2-3

Fig. 1. Launch vehicles designed by State Research and Production Space Center "TsSKB-Progress".

Table 1. Launches made by "TsSKB-Progress" within ISS operation program

Year	Manned spacecraft of 11F732 type	Cargo ship of 11F615A55 type	Total number of launches
2004	2	4	6
2005	2	4	6
2006	2	3	5
2007	2	4	6
2008	2	4	6
2009	1	1	2
Total	11	20	31

On November 7, 2003 there was signed an Agreement between the Russian Federation Government and the French Republic Government on long-term co-operation in the sphere of building and implementation of Soyuz-

ST launch vehicle in the European spaceport in French Guiana.

Construction of a Launch Facility and Processing Facility near equator (spaceport in Kourou) with the purpose of launching adapted Soyuz-ST carriers will ensure Soyuz-2 type launch vehicles with Fregat Upper Stage with additional payloads impossible to be launched from Baikonur cosmodrome.

2009 is a year of completion installation and commissioning of the Launch and Processing Facilities on the Kourou spaceport. These facilities as well as the launch vehicle are built in conformity with international requirements on safety of launches and their performance under tropical climate conditions.

For the first time in the history there will be used the launcher servicing mobile gantry (Fig. 2), lightning protection system and a number of other specially designed systems.

Soyuz-ST maiden flight from Kourou spaceport is set for December 2009.

Fig. 2. Mobile gantry intended for Soyuz-ST servicing

The aspect of international co-operation in the sphere of launch vehicles will be incomplete without the following.

The initial phase (1981-1995) of international co-operation in the sphere of space exploration is based on intergovernmental agreements. Then there were launched a French Rosot satellite (together with a Soviet spacecraft), a Bulgarian Bulgaria-1300 satellite and three Indian remote sensing satellites.

In the 90s the mutually advantageous co-operation on commercial basis became the new aim. The first success was in 1999 with the launch of 24 American Globalstar communications satellites by means of six Soyuz-U launch vehicles with Ikar upper stage specially developed by TsSKB-Progress in short time (1.5 year). In recent 5 years Soyuz launch vehicle has successfully done 9 launches with foreign payload aboard. To date 43 foreign satellites have been placed into orbit. The history of foreign satellite injection into orbit by launch vehicles of State Research and Production Space Center "TsSKB-Progress" design is given in Table 2.

The company improves lifting capacity of middle-class launch vehicles and designs a launch vehicle of light class. Soyuz-1 light-class launch vehicle is intended for high-efficiency orbital injection of small satellites strengthening its positions on the space systems market in recent years.

Unique characteristic of Soyuz-1 launch vehicle is a legendary "lunar" the NK 33 engine used in it, which was designed by Kuznetsov SNTK as long ago as in the 1970s.

Successful tests carried out in 2008 prove the reliability and quality of these engines that is also confirmed by the fact that the United States of America purchased a lot of NK 33 engines for their new launchers.

General view of the NK 33-1 engine with gimbal mount specially designed for Soyuz-1 is given in Fig. 3. Engine has the following parameters: nominal thrust near the Earth – 1511.2 kN, in vacuum – 1681.8 kN; specific thrust near the Earth – 2949.8 m/s, in vacuum – 3250.9 m/s; engine mass without fuel – 1715 kg; component mass ratio – 2.6; engine control range – from 118 to 55 % of nominal. One of the main advantages of Soyuz-1 is a possibility to use for its launch Soyuz-2 launch facility with the minimal modification. Structural potential of Soyuz-2 phase 1b (Fig.4) is planned to be used not only for light-class launch vehicles, but also for Soyuz-2-3 middle-class launchers with increased lifting characteristics, see Tab.3.

Table 2. History of foreign satellites launches carried out by launch vehicles of "TsSKB-Progress" design

Year	Launcher	Number of launches	Satellite number, type and country of origin
1981	Vostok	1	One Bulgaria-1300 scientific research satellite, Bulgaria
1988	Vostok	1	One IRS-1A Earth remote sensing satellite, India
1991	Vostok	1	One IRS-1B Earth remote sensing satellite, India
1995	Molniya-M	1	One IRS-1C Earth remote sensing satellite, India
1999	Soyuz-U with Ikar upper stage	6	Twenty-four GLOBALSTAR communications satellites, USA, middle-earth orbit
2000	Soyuz-U with Fregat upper stage	2	Four CLUSTER space exploration satellites, ESA, high-elliptical orbit
2003	Soyuz-FG with Fregat upper stage	2	One MARS-EXPRESS satellite, ESA, exploration of Mars One AMOS-2 communication satellite, Israel, geo-transitional orbit
2005	Soyuz-FG with Fregat upper stage	3	One GALAXY-14 communication satellite, USA, geo-transitional orbit One VENUS-EXPRESS satellite, ESA, exploration of Venus One GALILEO-1 test satellite of navigation system, ESA
2006	Soyuz 2-1a with Fregat upper stage	1	One METOP weather satellite, EUMETSAT, sun-synchronous orbit
2006	Soyuz 2-1b with Fregat upper stage	1	One COROT satellite, CNES, astronomical telescope
2007	Soyuz-FG with Fregat upper stage	2	Eight GLOBALSTAR communications satellites, USA One RADARSAT-2 Earth remote sensing satellite, CSA
2008	Soyuz-FG with Fregat upper stage	1	One GALILEO-2 test satellite of navigation system, ESA

3. VOSTOCHNY COSMODROME

By results of open contest held in March of this year by Roscosmos on the subject "Building of a new-generation middle-class space launch facility with increased lifting capacity at Vostochny cosmodrome: draft design project" SRP SC "TsSKB-Progress" was selected as the leading participant.

Within this project the company carries out studies on substantiation of general characteristics, technical and technological solutions on middle-class space launch facility with increased capacity for launching of different types of satellites. General view and technical characteristics of this launch vehicle with RD180 engines designed by Energomash JSC (Moscow) at first stage and RD0146 engines designed by KBHA JSC (Voronezh) at second stage are given in Fig. 5 and Table 4. Provision of conditions for a manned flight program development is meanwhile a foreground task.

"TsSKB-Progress" suggestions on the variants of launchers to be used at Vostochny cosmodrome with RD180 engine at first stage and launching and mating facility are given in Fig. 6.

Necessary to admit that the company with its engineering know-how, machining, testing equipment and facilities is practically ready to start designing launchers with oxyhydrogen engines, increased diameter of midship and principally new control system.

4. THE PAYLOAD INJECTION

In recent years the interest of Customers has enhanced to the injection of small satellites into orbit as a piggyback payload. Launch vehicle technical characteristics analysis showed the possibility to accommodate payload in intermediate bays (IB) of assembly-protective units (APU) providing interface between spacecraft and launcher. In addition the scope of orbits available for insertion corresponds to launch vehicle operational orbits. In the majority of cases these are near-circular orbits with 300 km of altitude and 51.8º - 98º of inclination. Small satellite life span with account of insertion orbit altitude and aerodynamic characteristic makes up to 10 days. Launches are carried out from Baikonur and Plesetsk cosmodromes.

Accommodation of small satellites is possible in several types of intermediate bays designed and manufactured by SRP SC "TsSKB-Progress" and used in Soyuz and Soyuz-2 types of launchers. A type of the IB is meant for accommodation of scientific research satellites (Resurs-P, Foton-M, Bion-M types); type of IB – for Progress M/M1 cargo ship (design of Energiya RKK).
Intermediate bay of A type is planned to be used for launches of Resurs-P, Foton-M, Bion-M beginning from 2010 year. Intermediate bay of B type is used in Progress M/M1 launches to ISS on a regular basis within manned flight program (no less than 4 launches in a year).

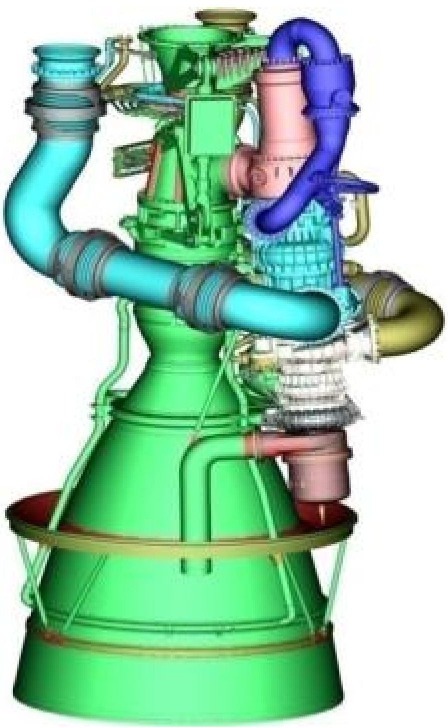


Fig. 3. NK-33-1 engine

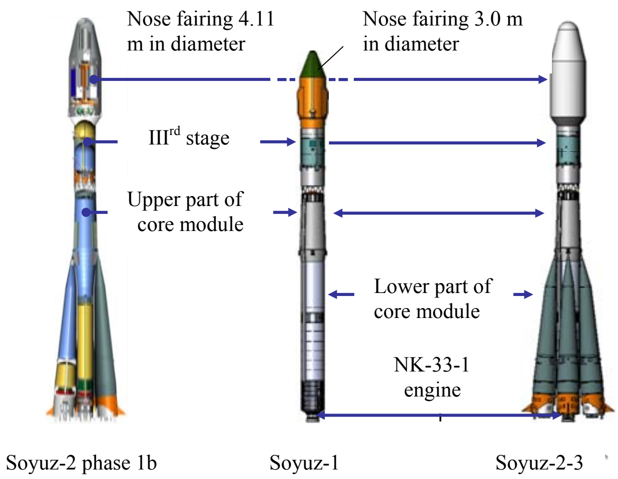


Fig. 4. Use of structural potential of Soyuz-2 phase 1b launch vehicle

Table 3. Soyuz-2-3 launch vehicle capacity

Cosmodrome	Circular orbit (mean altitude 200 km)	Geo-transitional orbit (Fregat upper stage)
Baikonur	10 000 kg (inclination 51,8°)	2500 kg
Kourou	10 700 kg (inclination 5,3°)	4000 kg

Fig. 5. Middle-class launch vehicle with increased lifting capacity with RD180 engines at first stage and RD0146 at second stage

Table 4. RD-180 engine characteristics

Mass at lift-off, kg	673000
Number of stages	2
Fuel components: - oxidizer - I stage fuel - II stage fuel	 oxygen RG-1 naphthyl hydrogen
Operational margin, kg - of I stage - of II stage	 3 x 180000 46500
I stage engines:	3 x RD180
Engine thrust (80 % of nominal), kN: - in vacuum - on Earth	 3 x 3321.5 3 x 2996
Specific thrust, m/s: - in vacuum - on Earth	 3308 2984
II stage engines:	4 x RDO146
Engine thrust, kN: - in vacuum	 4 x 100
Specific thrust, m/s: - in vacuum	 4540.5
Length of LV with fairing, m	61.1
Minimal diameter, m	11.6
Payload mass at GSO, kg	4000
Payload mass at open orbit, kg	23800

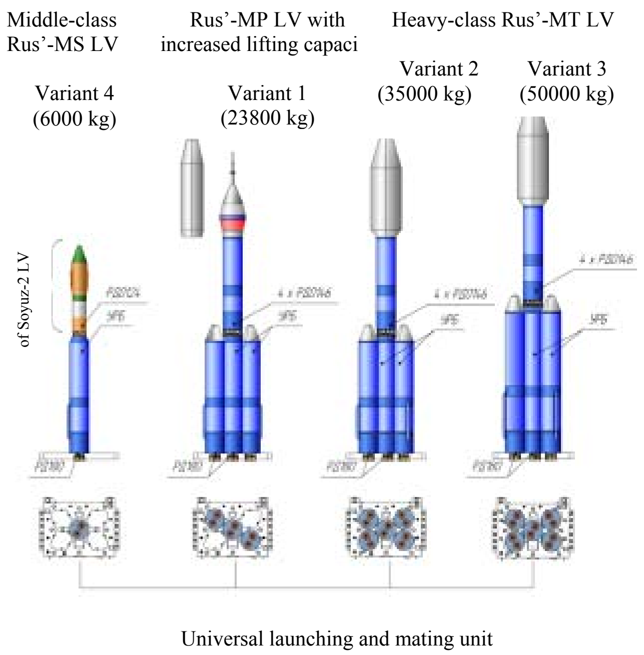


Fig. 6. Variants of launchers to be used at Vostochny cosmodrome with RD180 engine at first stage.

As an example, in Fig. 7 there are given possible accommodation places of 12 picosatellites with mass up to 1.0 kg in intermediate bay of the 17C13A type.

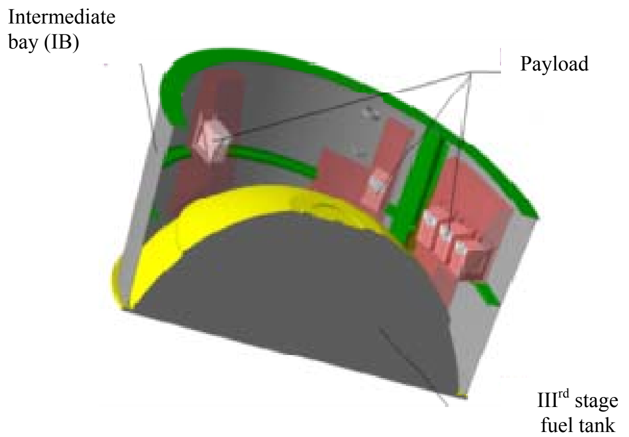


Fig. 7 Small satellite hardware possible accommodation zones in intermediate bay of B type.

5. EARTH REMOTE SENSING SPACECRAFT

The company has designed and manufactured 15 kinds of observation satellites since 1963. These are such well-known series of satellites as Zenit, Yantar, Orlets and Kometa assigned for the defense of the country and needs of the national economy.

Let's set our choice on Resurs-DK1, an optoelectronic satellite, which has already been successfully operating on orbit nearly for 3 years (Fig.8).

Satellite fulfills specific range of the Earth remote sensing actual tasks. From the beginning of operation satellite with ground resolution of no less than 1 m took more than 50 m km^2 of the Earth surface images. A picture of Samara city made by Resurs-DK satellite is given in Fig. 9.

Resurs-DK is equipped with well-developed onboard control facility including:

- modern motion control system;
- navigation satellite system operating both in GPS and GLONASS navigational fields;
- highly-efficient onboard programmable computer system.

Resurs-DK1 provides azimuthal stereophotography and survey of ground with required quality, operability and productivity (Akhmetov, R., 2008).

Imagery data are acquired and processed by the Earth on-line monitoring centre (NTsOMZ) in Russian space instrument engineering research institute.

At present time specialists of the company are working hard on designing Resurs-P satellite (Fig. 10) having technical characteristics (Table 5) higher than Resurs-DK1 and its foreign prototypes have.

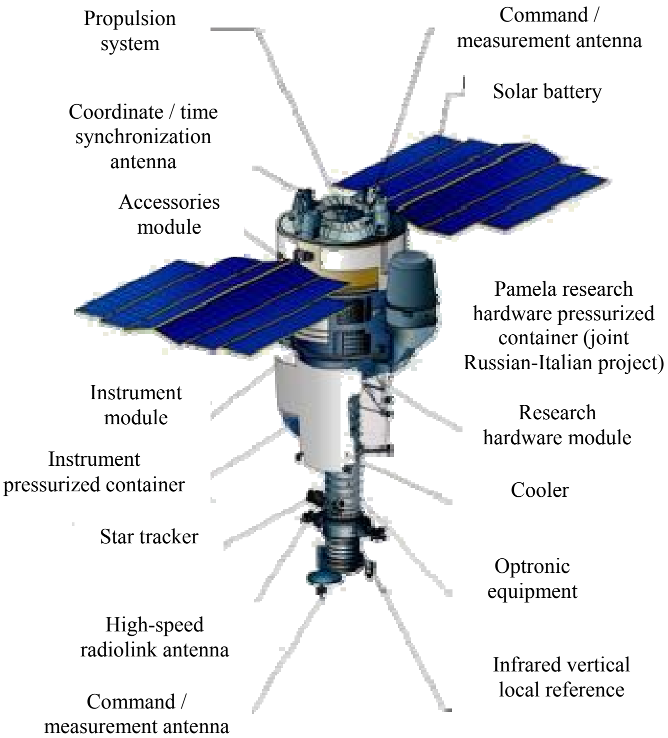
In order to expand the network of local centers of remote sensing data reception Samara data acquisition and processing center (TsPOI) has been certified and put into service on the territory of our company. The center receives and processes (Raschyupkin, 2008) remote sensing data obtained from Resurs-DK1 satellite as well as from satellites of foreign manufacture by local consumers requests. Currently, a special-purpose program "Analysis of space activity results in the interests of development of socioeconomic sector of Samara region in 2009-2010" is implemented.

One of the important aspects of this program is the development of Earth remote sensing innovation techniques and realization of program "Earth remote sensing data accessing and its usage by agricultural sector of Samara region and Srednevolzhsky area". Within the framework of international cooperation data from Resurs-DK satellite are received by the centers in Toulouse and Yerevan.

Important task of the "TsSKB-Progress" is to increase and improve quality of the Earth observations from space. t should be noted that owing to considerable mass, volume and power potential, Pamela, a unique Italian-Russian scientific hardware have been accommodated together with Resurs-DK1 satellite.

The hardware aimed at precise measuring of cosmic rays composition and behaviour in near-Earth space. Obtained results analysis helps to solve some fundamental problems in a sphere of cosmology.

It should be noted that owing to considerable mass, volume and power potential, Pamela, a unique Italian-Russian scientific hardware has been accommodated together with Resurs-DK1 satellite. The hardware aimed at precise measuring of cosmic rays composition and behaviour in near-Earth space. Obtained results analysis helps to solve some fundamental problems in a sphere of cosmology.



. 8. Resurs-DK1 satellite.

6. THE RESEARCH AND TECHNOLOGY SPACECRAFT

Designed by TsSKB-Progress, spacecraft of scientific purpose is a subject of intensive work and international cooperation.

Foreign scientific hardware was first installed onboard of the spacecraft in 1989. It was French hardware, named SEFA, which was accommodated onboard of Foton-5 spacecraft.

Experience gained at designing and operation of 11 Bion and 15 Foton spacecrafts helps to create considerably new Bion-M and Foton-M spacecraft with uprated characteristics allowing to enlarge the sphere of scientific research.

On September, 2007 22 scientific programs and 109 experiments were carried out onboard of Foton-M3 spacecraft (Fig. 11, Table 6), structure of which provides extremely low microgravity level (up to10^{-7}g).

Next launches of Bion-M1 and Bion-M2 will be in 2012 and 2014, respectively.

Fig. 9 Samara city, view from space

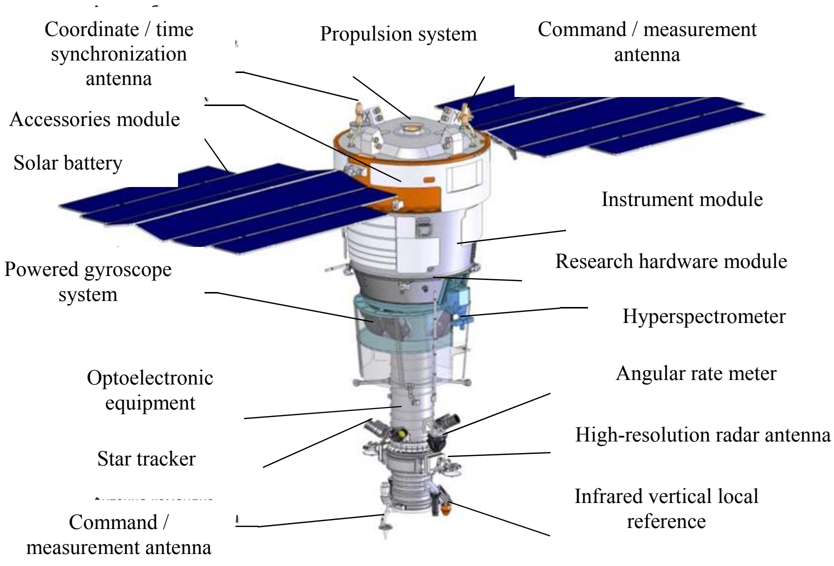


Fig. 10. Resurs-P satellite

Table 5. Resurs-P and Resurs-DK1 specification

Characteristic	Specification	
	Resurs-DK1	Resurs-P
Operational orbit - type - altitude, km - inclination, degree	 Elliptical 361 × 604 70	 Near-circular (SSO) 475 to 480 97.28
Ground resolution in nadir, m - in panchromatic range - in narrow spectral ranges	H=350 km 1 2-3	H=475 km 1 3-4
Bandwidth in nadir, km	28.3 (H=350 km)	38 (H = 475 km)
Swath width	448 (H=350 km)	950 (H= 475 km)
Spectral ranges, μm - panchromatic - narrow spectral ranges	0.58 ÷ 0.8 Green (0.5 ÷ 0.6); Red (0.6 ÷ 0.7; 0.7 ÷ 0.8)	0.58÷0.8; Blue (0.45÷0.52); Green (0.52÷ 0.61); Red (0.61÷0.68; 0.72 ÷ 0.8); Red + near infrared (0.8 ÷ 0.9)
Number of spectral ranges	4	6
Number of spectral ranges taken simultaneously	1 ÷ 3	1 ÷ 6
Hyperspectral survey	Not available	Available
Sensing interval, days	6	3
Maximum output per day in a mode of strip mapping with a data compression of 1 bit per sampling, m square km	1	1*
Rate of data transmission to receiving station, hour	From on-line to 13	From on-line to 12
Mean square error of image binding, m	-	No worse than 30
Life span time, years	3	5
*If space system consists of less than 4 stationary data reception centers and in case of lack of satellite radio visibility zones intersection		

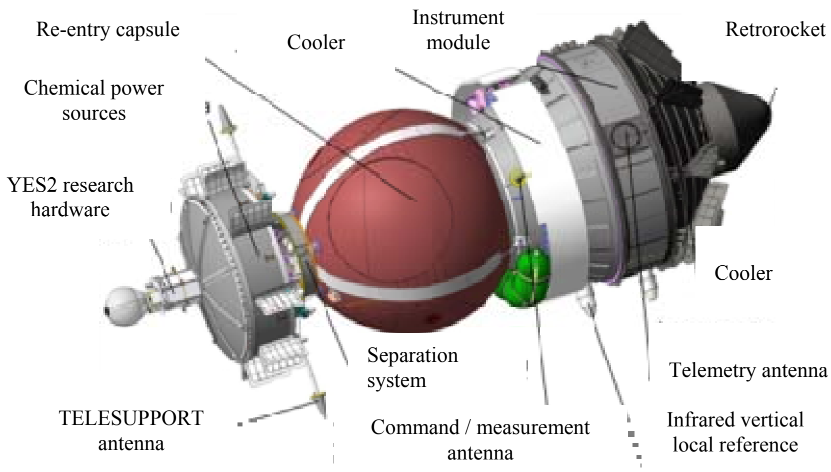


Fig. 11. Foton-M3 spacecraft.

Table 6. General specification

Characteristic	Value
Operation orbit: - maximal altitude, km - minimal altitude, km - inclination, degree	 304 262 63
Spacecraft mass, kg	6535
Research hardware mass, kg	700
Number of research hardware installed	27
Average power consumption per day, W	800
Microacceleration level, g	$10^{-6} – 10^{-7}$
Life span, days	12
Launcher	Soyuz
Cosmodrome	Baikonur

Scientific-purpose small satellites are planned to be placed as a piggyback payload on the spacecraft mentioned above, scientific hardware to be installed onboard of it is being built in international cooperation. In particular, MKA-TUS small satellite (consumer – Russian Academy of Science) and AIST small satellite (designed by a group of students, postgraduates and scientists of Samara Aerospace University) is to installed on Bion-M1.

Intensive adoption of the state-of-the-art technologies by TsSKB-Progress allows to improve the skills in aerospace engineering. Among them, information technologies and product end-to-end design and manufacturing technology are emphasized (Kirilin, 2008).

In order to put on the market challenging aerospace cluster products being under development now the company substantially improves its testing and manufacturing capabilities. A unique test-bench facility as well as a number of state-of-the-art manufacturing equipment presents innovation policy of "TsSKB-Progress".

Alongside with the execution of space industry orders SRP SC "TsSKB-Progress" extends sphere of its activity. The most significant trend is development of aircraft industry products.

At the present time the design and manufacturing of training passenger airplane named Rysachok has been started up, this plane is going to be a substitution for AN-2 airplane. General specification of this light-class airplane designed on the basis of CALS-technologies is given at Fig 13 and Table 9.

Development of new projects including consumer's goods leads to the necessity of mainline production modernization and adoption of high-precision 3D-models-oriented machining centers. Manufacturing systems are united by information network with the company's hardware and software intended for design documentation development.

Samara space center has put into service high-technological machining equipment such as laser material sheeting facility which is widely used in manufacturing of shell-structured products applicable at aerospace industry. SRP SC "TsSKB-Progress" takes advantages of the equipment for high-precision casting of complex parts and technology of a number of specialized coatings deposition.

One of the most important trends of the company development is an extension of radio-electronics production. Besides traditional well-proven technology and manufacturing process applied in launchers and spacecrafts manufacturing the company also designs and develops principally new radio-electronics systems.

In addition to aerospace products center aims at building of equipment for oil survey and natural gas liquefaction, Aqualine boats manufacturing as well as medical equipment production. Extension of these spheres of activity is based on the use of so-called double technology.

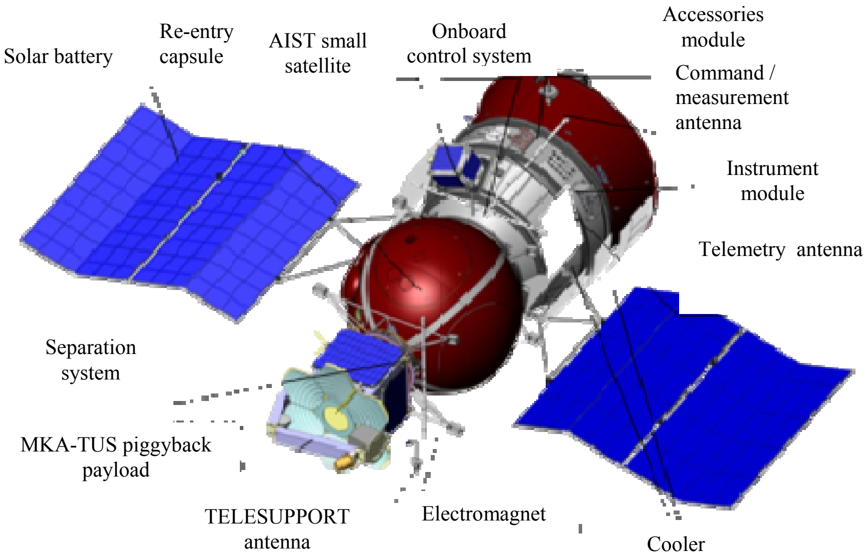
Table 7. List of ESA research hardware onboard of Foton-M3

Research hardware	Purpose
BIOBOX	Programmable incubator containing experiments on cell biology
SCCO	Experiments on multicomponent mixtures of crude oil
TELESUPPORT	Allows to monitor scientific hardware and transmit data to the ESA ground control stations
GRADFLEX	Research in the sphere of fluid physics
eERISTO/ eOSTEO	Biological incubators for bone tissue research
DIMAC	Direct measurement Micro-Accelerometer
AQUAHAB	Biological experiments in aquatic medium
GRANADA	Experiments on growing of protein crystals
FREQBONE	Experiment to test influence of low frequency low amplitude vibration on bone samples
BIOPAN	Experiment allows to expose bioobjects to harsh space environment
STONE	Research of changes in stone samples taking place in result of meteoritic fall
KBTS14	Experiments on growing semiconductive material crystals
VIBROKON-M	Research of controlled vibration influence on heat transmission in liquid phase
BIOKONT-M	Microorganisms vital activity research
KONTUR-L	Gerbilles vital functions research
TEPLO	Experiment on heat transmission by heat pipes
BIOKON	Biological experiments (agreement between TsSKB-Progress and Kayser-Italia)
DATA LOGGER	Humidity, temperature, shock and vibration measurements inside the re-entry capsule at all operational phases (joint use of results)
YES 2	Experiment demonstrates a possibility of returning FOTINO small capsule by means of a tether system

7. CONCLUSION

The main aspects of State Research and Production Space Center “TsSKB-Progress” development:

- holding the lead in the sphere of reliable launchers manufacturing to realize manned flight program of the world’s cosmonautics;
- continuous improvement of multipurpose middle-class launch vehicles;
- design and manufacturing of competitive light and heavy-class launch vehicles; competitiveness extension of high-resolution remote sensing and mapping satellites at the markets of the foreign countries;
- design and manufacturing of a new world leading product in the spheres of aeronautical engineering, oil survey, natural gas liquefaction and consumer’s goods; intensive adoption of innovation techniques of double application;
- improvement of complicated aerospace systems designing, manufacturing, testing and operation methods and facilities.



Transmission of scientific data is provided:

- by telemetry channel to the Russian ground stations
- by means of TELESUPPORT to the ground station in Sweden
- by "soft" landing of re-entry capsule

Fig. 12 The Bion-M spacecraft

Table 8. General specification

Characteristic	Value
Operation orbit: - near-circular with mean altitude, km - inclination, degree	 400-450 64.9
Spacecraft mass, kg	6400-6840
Mass of research hardware installed: - inside the re-entry capsule, kg - outside the re-entry capsule, kg	 650-850 250
Average power consumption per day: - support hardware, W - research hardware, W	 550 450
Life span, days	45
Launcher	Soyuz-2 phase 1a, 1b
Cosmodrome	Baikonur

Table 9 Rysachok airplane general characteristics

Parameter	Value
Weight-carrying capacity, kg	1570
Length of cargo compartment, m	4.40
Width of cargo compartment, m	1.50
Height of cargo compartment, m	1.56
Overall dimensions of cargo compartment port (inner), length × height, m	1.8 ×1.4
Cruising speed, km/h	250-400
Distance of flight with full tanks at H=3 km, km	2000
Maximal flight duration, hour	9.5

REFERENCES

Akhmetov, R., Anshakov, G., Manturov, A., Mostovoy, Y., Semerikov, A., Ustalov, Y. (2008). Modern Earth remote sensing satellite angular motion independent programmed control. *Aerospace courier,* (6), 20-22. In Russian.

Kirilin, A.N., Akhmetov, R.N., Fomin, G.E. (2006). Design products of SRP SC "TsSKB-Progress". *Polyot,* (1), 83-86. In Russian.

Kirilin, A.N., Akhmetov, R.N., Sollogub, A.V. (2008). Enterprise database generation for rocket-space products design. *Polyot,* (8), 71-78. In Russian.

Raschyupkin, A.V. (2008) Image data process technology ensuring quality of aerospace inventions. *Poliot,* (11), 42-47. In Russian.

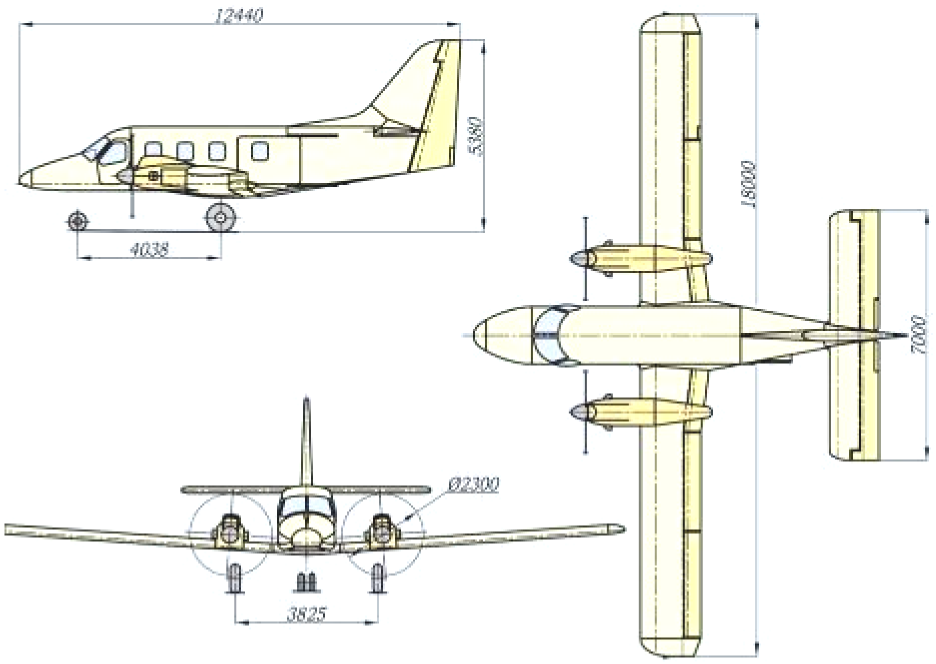


Fig. 13. General characteristics of light-class twin-engine Rysachok airplane