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Chapter 14

"RD & PE Zvezda" JSC: A History of the Creation of Russian Spacesuits, Escape and Life Support Means for Space Vehicle and Space Station Crews*

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This paper presents a brief history of "RD & PE Zvezda" JSC, the leading Russian company in the creation of escape, survival and rescue means for crews of flying vehicles, including spacesuits and portable life support systems for cosmonauts. Since 1957, "RD & PE Zvezda" JSC has been developing the above technology for all Soviet and Russian space vehicles: from the animal capsules of the first satellites to the crew gear and onboard equipment for such programs as Vostok, Voskhod, Soyuz, Salyut, Mir, Buran, and the L-3 Lunar program.

The paper describes the history of the creation of such unique items as Gagarin's spacesuit and ejection seat (1959-1961), the first EVA spacesuit and airlock (1964-1965), the ejection seat for the Buran space shuttle (1987-1991), a family of semi-rigid Orlan-type spacesuits (that are still in operation), the cosmonaut's space maneuvering unit (1988-1990), et al. The paper also informs readers about Zvezda's development of cosmonaut prophylactic means to prevent unfavorable effects of weightlessness. The company structure, its scientific and engi-

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neering potential, and unique testing facilities, have made it possible to perform a comprehensive approach to all stages of this technology including the research, design, manufacture, development testing and scientific and engineering support of all equipment operations. Lastly, the paper briefly describes Zvezda's current activities that center on its active participation in the creation of spacesuits and related systems for the space crews of the International Space Station (ISS).

Introduction

The Research, Development & Production Enterprise (RD & PE) "Zvezda" JSC (Joint Stock Company) is the leading Russian company in the development and production of portable life support systems for pilots and cosmonauts, emergency escape and survival means for passengers and crews of flying vehicles, and aircraft in-flight refueling systems. The company was established in the former U.S.S.R. in 1952. In the past, it has gone through several names and status changes and is currently a public joint-stock firm. [Hereafter, the present name of the company will be used in this paper—Ed.]

The basis for Zvezda's creative team was formed by designers and scientists who came from the Flight Research Institute (FRI) of the Central Aero-Hydrodynamics Institute (TsAGI) as well as leading airplane experimental design offices. Key people were: N. L. Umansky, A. M. Gershkovich, E. F. Shwartsburg, I. L. Makarov, A. I. Boiko, A. S. Povitsky, V. O. Galperin and others. S. M. Alekseev, Chief of the FRI Design and Production Complex, headed the enterprise. Practically from the start of [the U.S.S.R.'s—Ed.] entry into space exploration, the company was involved in ensuring manned space mission safety and carried out these developments simultaneously with activities on an aviation theme. The first fruits were reaped in the 1950s in the space field with Zvezda's work on special life support systems for experimental animals (dogs) that were vertically launched in rockets to high altitudes for biological tests. The company likewise developed life support complexes for the orbital flight of the dog named Laika (1957), and since 1959 the company first became involved in the design and development of personal means for cosmonaut escape, rescue, survival and life support. RD & PE Zvezda's task in this field of activities was to create the equipment designed exclusively for crew protection in emergency situations that might jeopardize crew life and health, and the development of equipment to provide for cosmonaut extravehicular activity (EVA).

Since that time, RD & PE Zvezda's history has had indissoluble ties with the history of manned space flight missions. In the U.S.S.R. and later in Russia, neither manned spacecraft nor orbiting stations have managed without the items developed by Zvezda's collective body.

Spacesuits and Escape Means for "Vostok" Spacecraft Crews

The most difficult and sharp issue in the design of personal protective gear for the Vostok spacecraft crews was to predict likely emergencies a cosmonaut might encounter, and to seek ways to protect them from such emergencies. It was clear for everybody that the first manned space flight was such an enormous historic event that it was impossible to assume its failure.

One special technical challenge was the cosmonaut's escape in case of a launch pad accident. After a comprehensive analysis of this problem, it was agreed to use an ejection system. An ejection seat design concept for the Vostok spacecraft was developed in the FRI laboratory headed by G. I. Severin. RD & PE "Zvezda" were to materialize that concept.

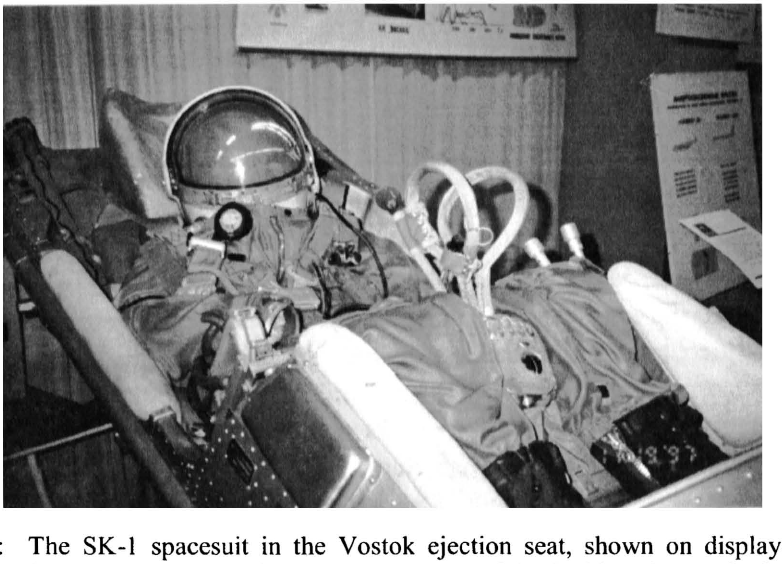

Figure 1: The SK-1 spacesuit in the Vostok ejection seat, shown on display at the Zvezda Museum outside of Moscow (Courtesy of the Smithsonian Institution).

The Vostok spacecraft pilot seat was, as a matter of fact, an independent flying vehicle that was reflected even in the ejection system's external appearance. In case of a launch pad accident, the hatch lid had to be thrown away and cosmonaut ejection from the cabin was to take place using a pyrotechnical mechanism. Then two powder rocket motors were initiated. They took the ejection seat with a cosmonaut to a safe distance by the horizontal, and simultaneously lifted it to an altitude sufficient for parachute inflation. It was necessary that parachute canopy inflation of the seat was to have a definite orientation as regards the air flow direction. In order to speed up parachute system inflation, the seat was provided with a special "gun," "the shell" of which was tether-connected to the parachute apex. As the rocket flew away from the Earth, its speed and acceleration increased rapidly. The cosmonaut was exposed to vibration and g-forces that he had to withstand. The cosmonaut needed restraint in a strictly definite posture. These tasks were also solved using the same ejection system that had the corresponding configuration and orientation in the spacecraft cabin; the ejection seat was equipped with a special restrain system.

The ejection seat was not only the emergency escape means; it was also designed for cosmonaut landing. At that time the spacecraft's "soft" landing system was not developed yet, and cosmonaut landing in the spacecraft at the parachuting rates of eight to ten meters per second was dangerous. Therefore, it was agreed that a cosmonaut should not take a risk of landing in the spacecraft. When the descending spacecraft reached five to seven km altitude, the seat with the cosmonaut in it was ejected.

Conditions of ejection from the spacecraft cabin were, in general, more favorable than those from high-speed aircraft: the incoming air flow rate was lower and there was no danger to collide with the tail assembly, etc. Therefore, using certain measures, it turned out well to reduce the loads acting on a cosmonaut to safe levels. In particular, those measures included proper selection of the seat configuration, introduction of the seat with the back to the incoming airflow, and automatic adjustment of ejection g-loads. In pro-landing ejection unlike in launch pad ejection, the seat rocket motors were not initiated. As a result, the whole ejection process went off rather gently and caused no significant troubles for the cosmonaut.

After ejection from the spacecraft, the seat with the cosmonaut in it descended using a small drogue parachute. Then the main parachute canopy inflated and the cosmonaut separated from the seat together with a backpack frame which contained the basic-up parachute and inflatable floatation means and a container which served as a seat proper and housed the survival kit.

The survival kit included an oxygen unit with a bottle that contained enough oxygen for a cosmonaut for breathing in the pressurized suit until landing. An automatic radio system for cosmonaut direction finding throughout the descent was activated during parachuting. Besides, the survival kit included a stock of food, water and survival means that could support cosmonaut survival for several days after landing or splashing down.

After the spacecraft left the dense atmosphere of Earth and separated from the launcher, the space crew entered into conditions in which their lives and health completely depended upon the spacecraft's life support systems complex. RD & PE "ZVEZDA" developed a special spacesuit. In case of cabin depressurization or irrespirable cabin air, the suit enclosure, as an additional barrier, could maintain the required pressure and composition of the atmosphere around the cosmonaut. Since the first days of [Soviet—Ed.] manned spacecraft design and development, there was a strong opposition toward utilization of IVA [Intra-Vehiclular Activity—Ed.] suits among the developers. The designers of the first stage of the Vostok protective gear development foresaw the need of an immersion suit. The opponents of the utilization of the spacesuits considered the possibility of cabin depressurization to be minimal and the depressurization-associated risk to be quite acceptable. In their opinion, there were a lot of other hazards to be prevented in the first place by using all available resources and limits. Fortunately, the resistance against the spacesuit proponents was crushed only with assistance of leading aerospace medicine specialists and Air Force authorities, following S. P. Korolov's personal intervention in the matter.

Consequently, that spacesuit that was developed was a multi-layer pressure suit connected with a pressure helmet, gloves and footwear. The spacesuit enclosure featured special joints in the areas corresponding to the shoulder, elbow, knee and ankle joints of the human body. The suit's joints maintained a certain range of mobility under the in-suit gas positive pressure and vacuum of the depressurized cabin. The spacesuit gloves also had several maniple joints in each finger. To maintain the required temperature mode, remove evaporating perspiration and exhaled carbon dioxide, the ventilation system tubing was integrated into the suit liner.

The spacesuit helmet incorporated a pressure helmet proper and visor that had a sealed connection with the helmet along the face cut. In a normal flight, the visor was up and under the helmet shell. It was automatically shut down in case of cabin depressurization. A special device made it possible to use a waste management system with the spacesuit on.

Flight and emergency ventilation systems of the spacesuit as well as the cosmonaut's oxygen supply system and spacesuit pressurization system were designed as independent (of the onboard life support system) modules located in the ejection seat. A version of the suit system combined with the spacecraft life support system (similar to the schemes adopted in U.S. manned space projects), that provided for mass advantage was also considered. But in order to provide more reliability and due to lack of time for combined system development, a self-contained version of the spacesuit life support system was adopted.

Certainly, RD & PE Zvezda cannot solely take total credit for the creation of the above system and the systems described below. A lot of other research, design and production teams took part in the work. The spacecraft developers, as well as scientists and test engineers of the Flight Research Institute named after M. Gromov, the Central Aero-Hydrodynamics Institute, the Research and Development Institute of Parachute Systems, the Oxygen Equipment Design Bureau, as well as research and test departments of the Air Force, Department of Health and many others also made contributions to the development of these systems.

Spacesuits and Escape Means for "Voskhod" and "Soyuz" Spacecraft – The First EVA Suits –

A soft landing system was realized in the Voskhod and Soyuz-type spacecraft. The main philosophy and concept of the system had been proposed by G. I. Severin, the Chief of the Flight Research Institute Laboratory. The Soyuz-type spacecraft were also fitted with a cabin emergency separation/recovery system to prepare for the case of a launch accident. Therefore, there was no longer any necessity for using the ejection system. However, new issues arose: how to accommodate several crew members in a limited volume of the cabin, and how to protect the crew members in G-loads in the acceleration phases and in the event of a total or partial failure of the soft landing system.

To solve these problems, RD & PE Zvezda specialists developed the 'Elbrus" and "Kazbek" shock-absorbing seats. While designing and testing the shock-absorbing seats, the specialists had to tackle a number of problems relating to both engineering science and physiology. An extremely limited room of the cabin was assigned for the crew seats. Therefore, one could not count on a large stroke of shock absorbers. The required safety level at emergency landing was achieved only by providing the concerted operation of the shock absorbers, cosmonaut profiled couch liners, and restraint systems. Owing to this, the cosmonaut took the strictly appointed optimum posture at landing. With ground impact, even if the G-load at the spacecraft bottom reached 100 Gs, the shock absorber would decrease the G-load for a cosmonaut by five times, and the couch line would exclude the injuries and decrease the onset rate of the load acting on the crew member. The effort to determine seat shock-absorbing characteristics and obtain final approval for the seat operation of spacecraft required a great amount of unique research and tests, including man-rated tests.

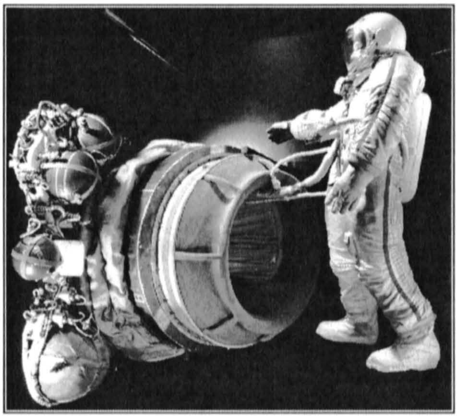

Figure 2: Aleksei Leonov's Berkut spacesuit emerges from the Volga airlock of the Voskhod spacecraft at the Smithsonian Institution's National Air and Space Museum (Courtesy of the Smithsonian Institution).

In early 1964, when the decision to perform a spacewalk outside the Voskhod-2 spacecraft was made, RD & PE Zvezda had already carried out experiments on the development of a special spacesuit for extravehicular activity. It was then that an elegant design concept, a semi-rigid-type spacesuit, was undertaken. The design concept, which was implemented later, is classical now, but we shall talk about it below. For the Voskhod-2 spacecraft mission, the design concept could not be realized yet. The reason was not only insufficient development of the design concept, but also, for the most part, there were small overall dimensions of the spacecraft's cabin that were the same as for the Vostok-like sphere. Besides, the cabin equipment was not designed for long operation in a depressurized condition. The spacecraft developers worked on several different versions of folded airlocks that turned out to be unacceptable due to their large overall dimensions and mass.

There were RD & PE Zvezda specialists who proposed a design of a folded airlock with a soft inflatable enclosure. Such a design allowed the designers to use the existing structures of the spacecraft and launch vehicle nose cone with minimum modification and to comply with the available mass limits. The proposal was finally approved at the meeting that was held at S. P. Korolov's office in April 1964. RD & PE Zvezda was entrusted with the development of the airlock, spacesuits, and systems for the first historic EVA. In the performance of that task, Zvezda's specialists relied upon Korolov's resolute support and considerable assistance in the Voskhod-2 spacecraft development under the leadership of P. V. Tsybin, Korolov's Deputy.

The early development of the airlock (called Volga) and the spacesuit (called Berkut), and other EVA support hardware, was initiated in July 1964. The activities for the creation of a system for support of the first-in-the-world EVA sortie were led by G. I. Severin, General Designer of the company, who was appointed to this position in January 1964. Many talented specialists made their creative contribution to the design of both the spacesuit and airlock designs. Among them were I. P. Abramov, S. M. Alekseyev, V. G. Galperin, A. S. Povitsky, N. L. Umansky, O. I. Smotrikov, M. N. Doudnik, A. L. Zelvinsky, V. V. Ushinin. D. B. Kuchevitsky, I. I. Derevyanko, V. I. Svertshek, B. V. Mikhailov, A. Yu. Stoklitsky, I. I. Skomorovsky, I. I.. Chistyakov; R. Kh. Sharipov and others.

The Volga airlock consisted of an upper hard portion with an egress hatch and a lower mounting ring. The upper portion and the lower ring were connected via a pressure bladder and a system of longitudinal air beams (inflatable rubber cylinders covered with strong fabric). The airlock incorporated the following: a system to fold the airlock and retain it folded under the launch vehicle nose cone in the ascent phase; a system to deploy the airlock in the orbit by pressurizing the air beams; a system to regulate the bladder pressure during airlock procedures; manual and electric controls to open and close the hatch; cosmonaut's safety and attachment elements; a back-up pressurization system for the spacesuit; lighting aids, photographic and motion-picture cameras; and a system to separate the airlock from the spacecraft after the program completion.

The Berkut spacesuit was also an intra-vehicular activity (IVA) spacesuit for the event of the Voskhod-2 spacecraft cabin depressurization during airlock operations.

Figure 3: The Sokol SK-2 spacesuit in the Kazbek-U couch from the Soyuz spacecraft, on display at the Zvezda Museum (Courtesy of the Smithsonian Institution).

In order to improve reliability and protect against the harsh space environment, the spacesuit was fitted with a double pressure bladder, a vacuum-shield thermal insulation and a sun visor. In order to prevent decompression sickness, operating barometric pressure of the space suit oxygen atmosphere was increased.

The first spacewalk objectives were narrow. That is why a simple system was used to support the cosmonaut's vital functions. The system was designed for 45-mm operation and provided pressurization and ventilation of the spacesuit with oxygen supplied from the bottles mounted in the spacesuit backpack. A redundant oxygen supply system was mounted in the airlock and attached to the spacesuit via an umbilical cord.

P. Beliayev, the Commander of the Voskhod-2 spacecraft, was wearing the spacesuit that had the same design as Leonov's so that he could come to the airlock and help Leonov, if necessary. It should be noted that development of the systems designed to support the first EVA was performed so promptly and enthusiastically that only nine months passed from the Statement of Work issued to the EVA date.

After the Voskhod-2 mission, it became feasible to realize plans for further modernization of the EVA support equipment. Lunar mission preparation, simultaneous missions of several spacecraft, and their space docking, etc., became topical issues. In the course of these missions, the participation of one spacecraft crew in rescue of the other, including the crew space transfer, could be vital. So far as is known, in January 1969, cosmonauts E. N. Khrunov and A. S. Eliseyev demonstrated the possibility of such a transfer during the Soyuz-4/Soyuz-5 spacecraft mission.

The RD & PE Zvezda's task in support of the mission was to develop the spacesuits and self-contained life support systems for a longer EVA. In addition to the EVA period prolongation (up to 2.5 hours), the project had a totally new problem. This was to provide onboard unassisted donning of the spacesuits as the cosmonauts were in their short sleeves inside the spacecraft.

A spacesuit (called "Yastreb") was similar to the Berkut spacesuit in design. The modifications performed were connected with the mission peculiarities and application of the self-contained life support system (LSS) of the so-called regeneration type. The spacesuit ventilation gas circulated around a closed loop where it was replenished with oxygen, purified from carbon dioxide, harmful impurities and water vapor, and cooled. The bottled oxygen was consumed only to compensate metabolic expenditures and leaks. For the first time in our country, a number of particular assemblies for the system were designed by enterprises co-operating with Zvezda. There were the following assemblies: oxygen equipment for 42 MPs operating pressure (undertaken by the Oxygen Equipment Design Bureau, under Orekhovo-Zuyevo); the lithium hydroxide cartridge for carbon dioxide absorption (Chemical Research Institute, Tambov); a direct current commutatorless motor that was safe to operate in pure oxygen (All-Union Research Institute of Electro Mechanics); a portable measuring complex (Design Bureau of Analytical Instrument Engineering), etc.

In order to cool and dry the circulating gas, RD & PE Zvezda designers created an evaporative heat exchanger. At that time, the provision of the proper operation of a heat exchanger under weightlessness and ultrahigh vacuum conditions was an absolutely new and complicated technical task A self-contained life support system was designed as a backpack. However, the on-ground test program revealed that it was difficult to pass through the hatches of the existing diameters (660 mm). The designers had to make an unusual decision about the backpack attachment to the cosmonaut's thighs.

The Yastreb spacesuits were ready for the mission in early 1967. But their use was put off due to the fatal accident of the Soyuz-1 spacecraft with cosmonaut V. M. Komarov aboard. The utilization of the IVA suits for the Voskhod and Soyuz missions was not foreseen. The negative attitude of spacecraft designers towards IVA suits application prevailed. The Soyuz-11 fatal accident in 1971 put a full stop to this discussion. The deaths of three cosmonauts resulting from cabin depressurization in the reentry portion of the spacecraft flight made it necessary to return to IVA spacesuit usage. It was necessary to develop the IVA spacesuit compatible with the profiled couch liner of the shock-absorbing seat. This task was fulfilled in a short period of time: in 1972 RD & PE Zvezda designed and developed the Sokol-K lower-mass IVA suit featuring a soft helmet and a sliding visor. The IVA suit operation philosophy foresaw that the cosmonauts must wear such suits only during the most critical (in terms of cabin depressurization) phases of space missions: during orbit insertion, docking/undocking and re-entry. As to the other mission phases, the IVA suits should be stored ready for utilization. Moreover, the capability of their unassisted donning/doffing in emergency should be provided. Since 1981, an updated suit version, Sokol-KV-2, has been used in Soyuz spacecraft.

Semi-Rigid Spacesuits for the Lunar Program and EVAs on the Outer Surface of Orbiting Stations

As we have already mentioned above, since 1962 RD & PE Zvezda had been working on some variants of spacesuits for lunar exploration and multiple long-duration EVAs. In the beginning, this work was carried out without fixing to any specific program. The overall goal was to draw up a concept or, as they said then, to the "face" of the working spacesuit.

After approval of the Soviet lunar expedition program, several versions of enclosure designs for the lunar spacesuit were reviewed. The designs were a traditional soft-type enclosure with a detachable backpack (leading designer S. P. Umansky) and a totally new semi-rigid type enclosure with a built-in life support system (leading designer A. Yu. Stoklitsky).

As a result of the comprehensive analysis and comparison of the mock-ups, the semi-rigid spacesuit concept was recognized to be optimal. The spacesuit made according to such a concept consisted of a hard upper torso, soft anus and a soft lower torso assembly. Donning (rather, we can call it "entering the space suit") is performed through an entry hatch located on the spacesuit back. The hatch door, at the same time, is a container to accommodate the self-contained life support system. Arranged on the hard upper torso are a visor, hatch sealing elements, and flanges to connect the arms and soft lower torso assembly.

By 1969, the lunar exploration spacesuit (called "Krechet") and EVA spacesuit (called "Orlan") had been developed and manufactured and had passed the whole test program. The life support system of the Krechet spacesuit was designed for a cosmonaut's ten-hour autonomous stay on the Moon's surface and performance with great physical efforts. The system was comprised of a gas atmosphere circulation and regeneration loop, oxygen supply and leak compensation sub-system, liquid coolant (water), circulation loop with a water cooling garment, radio communication and telemetry sub-systems, and other elements peculiar to the self-sufficient manned space vehicle, including a drinking water provision device and urine collector. However, as the Soviet lunar program was cancelled, the spacesuits were not called for.

The first EVA with the use of a semi-rigid space suit (a modification called "Orlan-D") was performed from the Salyut-6 orbiting station in 1977. Since then, these spacesuits have become orbital-based spacesuits being improved permanently and modified several times. They stayed permanently onboard the "Salyut" and "Mir" orbiting stations and provided practically all crew members with a capability to perform EVA.

The experience gained has shown that a semi-rigid type of the spacesuit is the most suitable for EVAs related to operational support of a long- term space station.

The concept of spacesuit functions (IVA and EVA) separation and rejection of their universality have been also substantiated by experience. The lightweight soft IVA spacesuits are used in the transport spacecraft, and the semi-rigid spacesuits with the built-in self-contained life support systems are optimal for multiple long activities in the open space.

The semi-rigid spacesuit has undergone several modifications since the time of its creation. The spacesuit and its sub-system design changes have been connected with the change of spacesuit specifications (change-over of the programs, extension of the crew task envelope, etc.) and the results of operations (drawbacks to be removed, cosmonauts' proposals, new design ideas, reliability and service life improvement). But the principle of orbital basing has never been changed.

Up to the present time, four modifications of the EVA spacesuits have been developed. All of these have a number of advantages that ensure their successful operation during long term missions. They include quick unassisted donning/doffing, the use of one standardized sized spacesuit for cosmonauts with various anthropometric dimensions, capability to perform spacesuit maintenance in the orbit without return to Earth, and easy changing of removable or failed elements.

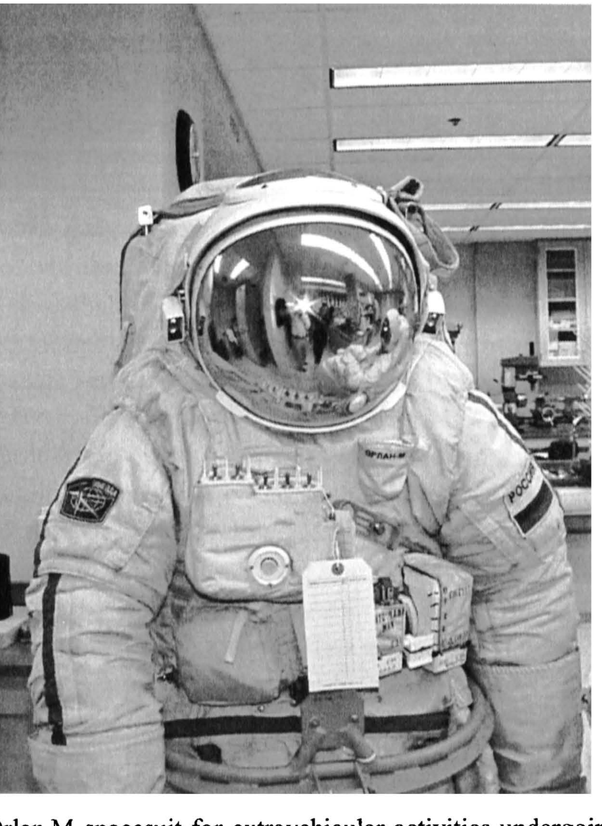

Figure 4: The Orlan-M spacesuit for extravehicular activities undergoing testing at the NASA Johnson Space Center (Photo Courtesy of NASA).

By June 1999, the cosmonauts (37 crews) used 22 Orlan type spacesuits to perform 184 man-sorties successfully with a total duration of more than 764 hours. The Orlan-M, the latest EVA spacesuit modification used in the "Mir" orbiting station, has been currently approved for operation on the International Space Station (ISS). Creation of the manned maneuvering unit (MMU) to provide a cosmonaut's movement in "supportless" space (outside the space station) became one more area of the RD & PE Zvezda's activities. The RD & PE Zvezda's designers got down to research and development of the first MMU version in the mid 60s. The MMU models were manufactured and tested in laboratory conditions. But they were never tested in space. At that time, many competent specialists considered that there is nothing to do for a man in free space and all work in space would be performed more efficiently by remote control apparatus than by a man.

In February 1990, the Mir orbiting station cosmonauts A. A. Serebrov and A. S. Victorenko tested the Zvezda-developed 21 KC unit, enabling the Orlan-DMA suited cosmonaut to move with six degrees of freedom. This unit was developed taking into account the specific features of the Orlan-DMA semi-rigid suit and its design advantages. In particular, connection of the suit to the MMU is performed by the cosmonaut himself using a central latch and two side fixing arms. The maneuvering controls are located on two rotating booms. The MMU's 32 jets operate using air that is contained in two eight-liter bottles under the pressure of 35 MPa. The leading designer for the MMU experimental model created in 60s and its final version was V. A. Frolov. The following Zvezda specialists also made valuable contributions to MMU development: E. G. Akopian, A. N. Livshits, I. I.. Chistiakov and B. Yu. Shmulder. The Rocket Space Corporation Energia developed the MMU control system.

From 1992 through 1994, RD & PE Zvezda, together with a number of Western European companies under Dornier's (Germany's) leadership, were involved in the design and development of the EVA-2000 spacesuit project pursuant to the agreement between the Russian and European space agencies. The Russian-European spacesuit was expected to be a new generation suit. It was anticipated that the Russian experience would be combined with some West-European advanced technologies to develop a baseline model of the suit for application both on national and international space stations by 2000. By 1994, an ergonomic suit mock-up, backpack packaging mock-up and separate suit components had been developed and manufactured. Technical specifications for new assemblies had been developed and proven. However, towards the end of 1994, the above-mentioned activities were ceased on an ESA initiative.

Escape and Life Support Systems for the Buran Spaceplane Crew

In the period from 1980 to 1992, the complex of escape and life support means for the Buran spaceplane crew was developed on the basis of experience gained in aviation and space developments and was qualified. The personal LSS for the "Energia"-"Buran" complex and IVA suit (called "Strizh") were designed for crew members' 12-hour stay within the pressurized suit during the mission. The crew was provided with the capability to escape from the space plane using the K-36RB ejection seats especially designed for this project.

Figure 5: The Strizh full-pressure suit was developed for the Buran program (Courtesy of Zvezda).

The Strizh IVA suit has a parachute harness integrated into the suit enclosure and a number of other specific features. The K-36RB ejection seat was designed and developed by RD & PE Zvezda on the basis of the Zvezda's unified K-36 type ejection seat that was intended for combat aircraft and became well known in the Air Force by that time. Nowadays, these ejection seats are well known all over the world and have proven to be the best in aviation, even among the leading industrial countries.

The K-36RB seat/Strizh suit system ensures crew escape from Buran-type spacecraft in case of accidents at the launch pad, and landing, as well as during flight phases at the altitudes up to 25-30 km and at speeds three times as much as sonic velocity. The seat was complemented with a survival kit that contained necessary means for a cosmonaut's search and survival to be used in contingency situations during landings or splashdowns in various climatic and geographic areas.

Prophylactic Means to Prevent Unfavorable Effects of Weightless on the Crew

Above, we talked about the protective, rescue and life support means to be used by crew members in extremely dangerous contingency situations. However, normal prolonged missions can also jeopardize crew member lives due to an adverse effect of weightlessness. The prolonged stay in weightlessness affects the locomotor system, main groups of muscles, and the cardiovascular system, and causes disorders that are not appreciable in a space station, but can result in serious consequences when crew members return to the Earth. To prevent these consequences, crew members should undergo physical exercises and take other measures every day. To improve the crew tolerance to weightlessness, the RD & PE Zvezda specialists designed and developed two types of special gear, a prophylactic lower body negative pressure suit called "Chibis" and a prophylactic muscle and bone loading suit called "Penguin."

The "Chibis" suit comprises the trousers having a carcass and sealing in the waist area so that the negative pressure generated under the suit enclosure provides for proper loading of the cardiovascular system while hydrostatic loading (caused by negative pressure differential), taken up by the soles and shoulder straps, simulates the body weight mechanically and stimulates the locomotor system.

The "Penguin" suit is comprised of a body-loading system integrated into the overalls. This system consists of a set of resilient elements that apply the load on the main muscle groups of the lower limbs and torso when performing natural movements: flexion; extension in hip, knee and ankle joints; abduction; and rotational and sideways motions of the body. Currently, utilization of the "Chibis" and "Penguin" suits in combination with other measures make it possible to minimize the negative effect of weightlessness on the cosmonaut's organism.

Conclusion

In more than 40 years of space developments "RD & PE Zvezda" JSC has developed a number of spacesuits, escape, survival and life support means for space crews that are still being successfully operated in conjunction with current spacecraft and the space station. It is not an exaggeration to say that the most brilliant milestones of Zvezda's history are its support of the first manned space mission, support of the first in the world EVA sortie, the creation of the semi-rigid orbit-based EVA space suit, the creation of the space manned maneuvering unit, and crew emergency escape means for the "Buran" space plane.

Besides the above systems, throughout the whole period of national space development, "RD & PE Zvezda" JSC has been in the development and manufacture of related systems including waste management systems, flight equipment, survival means and some other special means. The Zvezda's main tasks are:

- To provide high performance capability and efficiency of the crew in performance of their professional tasks.
- To improve crew tolerances for unfavorable effects of space mission.
- To provide absolute crew saving in emergency.

In their work, Zvezda specialists apply both state-of-the-art technologies and original design solutions that are conducive to item creation on the state-of-the-art level and even on a higher level for some parameters. "RD & PE Zvezda" is an integral complex comprising scientific engineering and test departments with a unique experimental base. A unique feature of "RD & PE Zvezda" is the complex approach to product creation, including performance of all work stages at the company facilities (from working out Statements of Work to acceptance tests).

"RD & PE Zvezda" co-operates in close contact with Russia's leading scientific and research institutes, design bureaus and production companies.

The "RD & PE Zvezda" collective body participates actively in international programs. Its products are permanent exhibits of most space exhibitions.

Currently Zvezda participates in the product development for the International Space Station and actively co-operates with corresponding NASA structures and Hamilton Standard, the leading designer of U.S. spacesuits. "RD & PE Zvezda" uses the experience gained in space programs for development of "conversion" products.

References

[1] G. I. Severin, I. P. Abramov, V. I. Svertshek, "Main phases of the EVA Spacesuit Development," paper presented at the 1995 International Astronautical Congress, paper IAA-95-IAA.10. 1.01.