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Transformation of the Soviet Space Program after the Cold War

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Changes in the management of the space program and the operational status of various systems in the former Soviet Union are examined with particular emphasis on defense-related space systems. After the break-up of the Soviet Union, Russia assumed general responsibility for the entire scope of Soviet space activity. Space program management was re-organized to separate military and civilian activities. Russia is committed to maintaining military space capabilities, however, its top priority is now the conversion of military space technology for civilian uses, including global environmental problems.

INTRODUCTION

Space systems are now crucial for global security both from military and environmental standpoints. Early in the space age, development of space-based systems was driven primarily by the desire of competing superpowers to carry out effective strategic reconnaissance. Later, civilian applications, such as satellite communications, weather forecasts, and global environmental monitoring, became progressively more important.

Beginning in the late 1960s, the number of Soviet space launches by far surpassed the combined launch rate of all other countries in the world (see figure 1). The Soviet Union and the United States were the only countries in the world which pursued the entire spectrum of space research and applications, scientific, commercial, and military. The breakup of the U.S.S.R. raises questions about the fate of the entire spectrum of its space activities. The paper first reviews the capabilities and management structure of the Soviet space program. The paper then surveys organizational changes in the management

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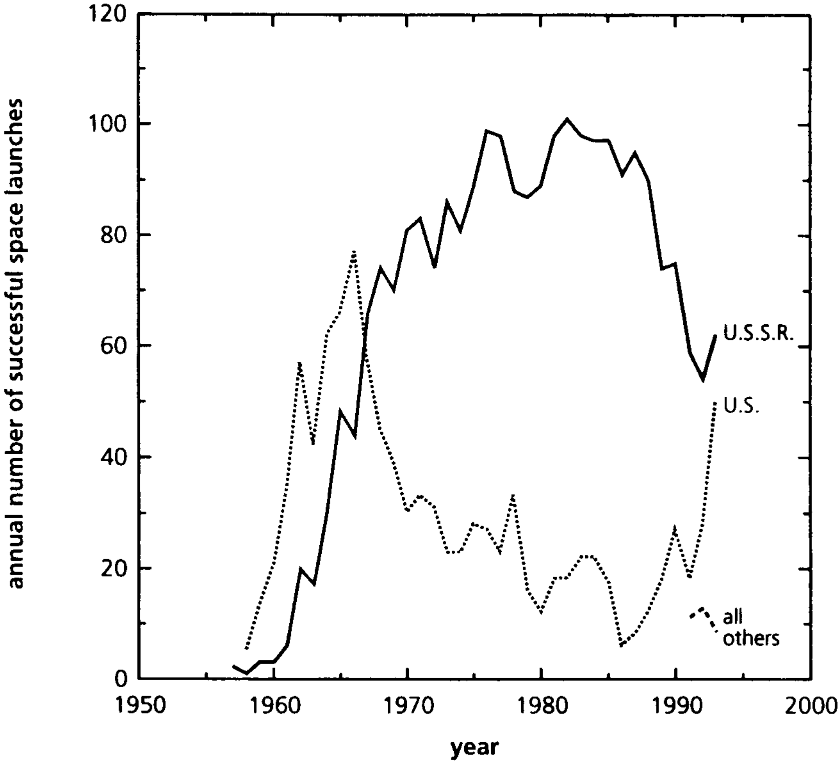

Figure 1: Annual number of successful space launches worldwide. Launch failures are not included because of incomplete data on Soviet launches. Number of launches in 1993 is estimated.

of the space program after the break-up of the U.S.S.R. Next, we describe the current operational status of Soviet space systems. The last section of the paper describes newly emerging opportunities to use Russia's extensive space capabilities, including hitherto dedicated military systems, for various civil applications.

BACKGROUND

Soviet Space Capabilities

The Soviet space program began with ICBM development in the 1950s. Since missile and space capabilities were considered vital for Cold War competition with the United States, the rocket and space programs enjoyed unstinting

Figure 2: Rocket test ranges and major rocket production facilities.

support from the supreme Soviet leadership. Under this commitment, the Soviet Union developed a powerful rocket and space industry, versatile R&D facilities, and an extensive infrastructure to support both missile testing and space operations (see figure 2). Major rocket production facilities were established in Moscow, Dniepropetrovsk, Samara, Miass, and Omsk. Several hundred enterprises with a cumulative workforce of more than one million people directly participated in the Soviet missile and space programs. The operations support infrastructure included a number of rocket test ranges and a network of tracking, telemetry and control stations spread across the U.S.S.R. Rocket test ranges included:

- Kapustin Yar in the Astrakhan' region, established in 1946 for the first LRBM testing. From 1961 until 1987 it was also used by IRBM-derived satellite launch vehicles;

- Tyuratam in the Kzyl-Orda region of Kazakhstan, built for the first Soviet ICBM testing. Since 1957, it has been used extensively for space launches;
- Plesetsk in the Arkhangelsk region, a refurbished ICBM deployment area, which became the busiest space launch site.

In addition, there were about 10 ground control stations in the U.S.S.R. and a number of ship-borne stations to extend tracking, telemetry and control capabilities in the absence of overseas bases. The key spacecraft control facility was established in Golitsyno near Moscow. Several mission control centers for particular spacecraft were located in and around Moscow. The best known of those was the manned mission Control Center (TsUP) in Kaliningrad.

Space Program Management

The author's reconstruction of the organizational structure of the Soviet space program on the eve of the break-up of the U.S.S.R. is schematically depicted in figure 3. The structure differs only marginally from that established in the mid-1960s. The main difference in the structure compared to that of any Western country is that it represents a strict pyramid, with supreme authority held by top level Communist Party officials.

In the Soviet Union all executive decisions concerning the space program were adopted by joint decrees of the Central Committee of the Communist Party of the Soviet Union (CPSU) and the U.S.S.R. Council of Ministers. The legislative branch of power, formally represented by the Supreme Soviet of the U.S.S.R., had no influence on the actual decision-making and merely rubber-stamped documents prepared by the Central Committee. The Central Committee of the CPSU (with the Politburo at its head) was in fact the supreme body, governing all military and space activities in the U.S.S.R

A second important characteristic of the Soviet space program was that, unlike the United States, there was no clear separation of military and civilian space activities. The responsibility for implementation of all space projects, as well as for missile programs, belonged to the so-called Ministry of General Machine-Building (MOM).[1] It was one of nine military industrial ministries supervised by the Military Industrial Commission of the U.S.S.R. Council of Ministers (VPK) and the Defense Division of the Central Committee of the CPSU. An overwhelming majority of subcontracts for development and supply of related hardware circulated within these defense industrial ministries. Their common subordination to the VPK allowed for easier cooperation than with other sectors of the economy. However, a large amount of basic research was performed in the institute of the Academy of Sciences, contracted

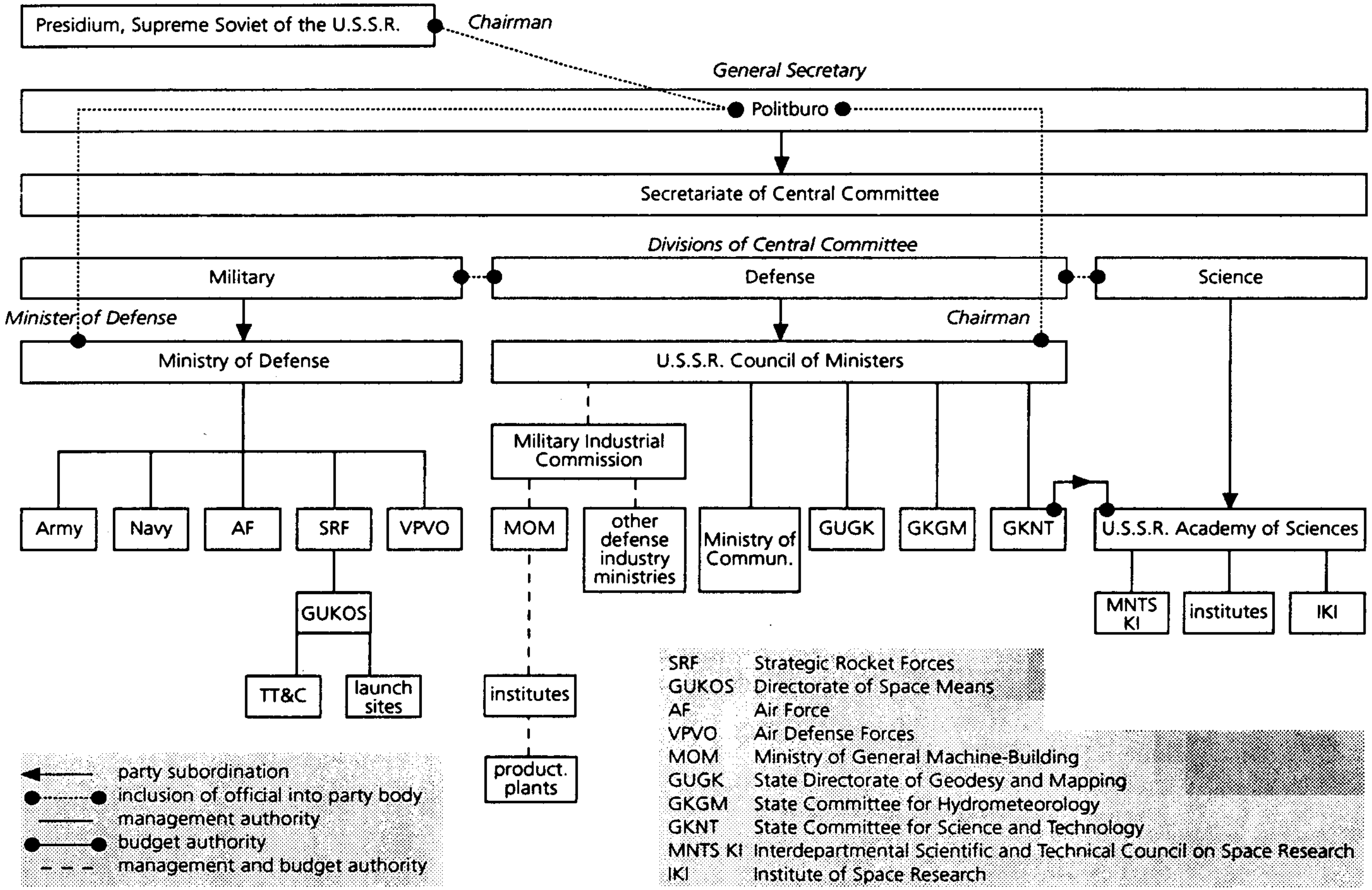

Figure 3: Space activity management in the U.S.S.R. from the mid-1960s to the mid-1980s.

by the enterprises of the military-industrial complex. The body responsible for procurement of spacecraft and launch vehicles was the so-called Directorate of Space Means of the Ministry of Defense (UNKS). However, the "procuring" military branch did not actually appropriate funds to finance industrial research and development or purchase hardware. Money went directly from the government to contractors, via the MOM or other ministry of the military-industrial complex. This allowed the government to hide the majority of military spending in the budgets of industrial ministries.

As a by-product of this approach, the military services got only an advisory vote in development and procurement. Therefore, the Space Forces, in most cases, had to accept whatever the manufacturer could supply. UNKS, earlier known as TsUKOS and then GUKOS, was formed in 1964 from subdivisions of the Strategic Rocket Forces, responsible for space, rather than missile operations. UNKS was responsible for pre-launch ground testing and actual launch and in-orbit control of all Soviet spacecraft, both military and civilian.

Unlike the U.S. Air Force, the Soviet Air Force had only marginal involvement in space activities. The Air Force was responsible for cosmonaut selection and training and for search and rescue operations. Other military branches acted as an end users of operational space systems. The exception was the Air Defense Forces (VPVO), which controlled the early warning satellite system and the anti-satellite system. VPVO had their own network of control and tracking stations for this purpose.

Civilian agencies, including the Ministry of Communications, the State Committee for Geodesy and Mapping (GUGK), the State Committee for Hydrometeorology (GKGM), used the space systems which were developed by MOM and deployed and operated by the Space Forces. Scientific missions were accomplished in a similar manner, with the Institute of Space Research (IKI) (or other Institutes of the Academy of Sciences) supplying the scientific instrumentation and MOM enterprises providing the spacecraft and mission integration. The Interdepartmental Scientific Technical Council on Space Research under the President of the Academy of Sciences (MNTS KI) was supposed to provide space expertise and balance interests of the science and industry. In practice, research and civil applications got the lowest priority, being dependent both on industry and the Ministry of Defense.

The hierarchical management system was reasonably suited to completing clearly defined tasks. This ability was demonstrated by spectacular breakthroughs in space technology from the late 1950s to early 1960s. However, the strictness of the system and lack of feedback and independent assessments goals and tasks as the strategic and civilian environment changed. Because of these features of the general state management system, the Soviet space activities were focused too narrowly on keeping a military parity with the United States and/or on projects, considered politically beneficial by the supreme state leadership.

CHANGES IN SPACE PROGRAM MANAGEMENT

At the end of Perestroika, in 1989–1990, some modest changes were introduced at the top level of the state management structure. The intent was to replace Party direction with a formal administrative structure. In 1990, Mikhail Gorbachev, the General Secretary of the CPSU, became the legitimate head of the country—the President of the U.S.S.R. The newly established Security Council and the Presidential Council took over some Politburo functions. However, general principles of management remained essentially unchanged until the very last days of the unified Soviet Union.

Changes in the military industrial complex and in the space program were essentially limited to budget cuts and the conversion of industrial capacities for consumer goods production, which were ordered from above in 1988–1989. For example, in 1991 the budget for military space research and development was slashed by 35 percent from the 1990 figure. The allocations for procurement were cut by 26 percent.[2] These changes undermined the welfare of the military industrial complex and eventually became one of the reasons for the attempted coup in August 1991. The coup was headed by representatives of this complex, including the former Minister of General Machine-Building, Oleg Baklanov. The failure of the coup determined the fate of the U.S.S.R. and all Soviet management structures. By the end of 1991, the Soviet Union was dissolved and all the Soviet properties were divided among the republics.

During the earlier fight for independence most leaders of the republics criticized the U.S.S.R. space program as a waste of money. Russian President Boris Yeltsin himself demanded the suspension of space programs for six to eight years when he opposed Gorbachev. In the debates of 1990–1991 on the future of the Soviet Union, state and military leaders of the U.S.S.R. emphasized that no single republic, not even Russia, would be able to maintain the space program of the entire U.S.S.R. For these reasons, many observers speculated that, with the break-up of the U.S.S.R., the space program would be suspended or at least drastically scaled down.

After the Commonwealth of Independent States (C.I.S.) was created, it seemed, that the space program of the U.S.S.R. would be replaced by a joint effort of member states, much like the European Space Agency. The Agreement on Space Exploration, signed by the C.I.S. member states in Minsk on 30

December 1991, stated that space programs would be implemented jointly. The agreement called for "proportional financing" and envisioned establishing an Inter-State Council on Space. However, friction between C.I.S. members prevented them from forming workable relationships even in more general areas, such as economic and financial policy. Sharing the armed forces and military assets of the U.S.S.R. was also a matter of constant dispute for the C.I.S. members.

In December 1991, the Space Forces of the former U.S.S.R. were initially included in the Joint Armed Forces (J.A.F.) of the C.I.S. and given the global mission of joint space activities. However, disputes about the composition of the JAF continued throughout 1992, mostly because of disagreements between Russia and Ukraine. The lack of consensus about the J.A.F. resulted in growing problems with supply to disputed military units and made it difficult to carry out their duties. For this reason, Russia established its own Ministry of Defense on 16 March 1992. An increasing number of units, initially to be included in the JAF, were transferred to Russian authority. In August 1992, the Directorate of Space Means was also formally incorporated into the Russian Ministry of Defense and became the Space Forces of the Russian Federation. This last step concluded the process of concentrating the Soviet space program under the auspices of Russia. It also resulted in Ukraine switching off communications between the space tracking stations on its territory and the rest of the network in September 1992.

A substantial portion of the space-related industrial potential and support infrastructure remains outside Russia, particularly in Ukraine and Kazakhstan. Ukraine possesses the Yuznoe Design Bureau and Yuzhny Machine-Building plant at Dniepropetrovsk, which produced the SS-18 and SS-24 ICBMs, as well as Tsiklon and Zenit medium lift space launch vehicles. Furthermore, the development and production of rocket guidance systems is concentrated in Khar'kov. Two tracking, telemetry and control stations, which greatly extended total network coverage to the South and West, are located in Evpatoria (Crimea) and Dunayevtsy. Kazakhstan has Baikonur Cosmodrome, which hosts all Soviet launches to a geostationary orbit, and all manned and interplanetary missions. Sary-Shagan, the sole ABM test site, is also located in Kazakhstan. However, the inherited space-related capabilities in Kazakhstan and Ukraine (and lesser facilities in other republics) are not comprehensive enough to enable the former republics to continue any part of the Soviet space activities or to build independent space programs, at least for the time being. According to different estimates, Russia possesses 75 percent of "space related properties" (measured by their economic value) and 90 percent of the space industry enterprises.[3] Russia, therefore, has become the sole successor of the Soviet space program.

As soon as the U.S.S.R. was dissolved, the new Russian Ministry of Industries was established to take over responsibility for all industrial enterprises situated in Russia.[4] Within this ministry, the Department of General Machine-Building took over the enterprises of the former Ministry of General Machine-Building. These included 13 production associations, 13 scientific and production associations, 20 scientific research institutes, 21 design bureaus, three scientific technological centers, 53 separate enterprises, and 214 "structural units." Total employment in this branch in 1992 was roughly 800,000 people.

The change of title was accompanied by a change of approach to managing the state-owned industry. The supervising ministry no longer dictates to industry exactly what they must develop. Enterprises have to bid for contracts from the procuring authorities, e.g., the Ministry of Defense. The Ministry of Defense received its own budget for weapons procurement (including military satellites and space launch vehicles) for the first time in 1991. Another major change in space program management occurred in February 1992, when President Yeltsin established the Russian Space Agency (RKA) for implementing national space policy and developing space systems for scientific and civil applications. In so doing, responsibilities for civil and military space activity were split between the RKA and the Ministry of Defense, which gave the civilian space program a chance to develop apart from the military program. The shift towards organizational forms accepted in the West also included incorporating the legislative branch into the decision-making process.

In Russia, the budgeting process has become more common than it used to be in the U.S.S.R. Now the President submits a budget to the Parliament, which either accepts it or returns with corrections. The Supreme Soviet of the Russian Federation had two principal committees to supervise space activities. The Committee on Defense controlled military space programs, which were budgeted through the Ministry of Defense budget. The Commission on Transport, Communications and Space supervised the civilian space program, financed mostly through the Russian Space Agency. Despite the dissolution of the Supreme Soviet in September 1993, this general approach will apparently remain in a new parliament.

In August 1993, the Russian space program acquired a more legitimate mandate with the adoption of the Law on Space Activities in the Russian Federation. This law was endorsed by President Yeltsin and is not likely to be challenged in the aftermath of Yeltsin's confrontation with the Supreme Soviet. The legislation declares that space activity in Russia shall be:

- Dominated by the practical needs of the society;
- Performed on a competitive basis;
- Open to the public;
- Subjected to the independent review.

The new military space doctrine states, that military space activity in Russia is intended to:

- Provide support to ground operations;
- Monitor compliance with international agreements;
- Provide warning of attack;
- Deter potential aggression.

The changes mark a remarkable shift of priorities from competition with the United States to satisfying Russia's own needs.

CURRENT STATUS OF OPERATIONAL SPACE SYSTEMS

Throughout the 1980s the pace of Soviet space launches slowly diminished from roughly 100 to 90 per year (see figure 1). A sharper drop occurred in 1989–1990, and in 1991 (the year the U.S.S.R. broke up) the launch rate dropped to 59 successful launches, the lowest in 25 years. However, this decline does not reflect any change in commitment to space activity. The initial decline in the 1980s was caused by the phase out of several obsolete systems and their replacement with longer-lasting satellites. The drop in 1989–1991 was caused by economic problems, and later aggravated by political turmoil. However, as soon as budgeting and management problems were resolved by transferring the space program to Russia, the decline in space activity stopped.

At the end of 1992, the launch pace returned to the level of the late 1980s. In fact, the Space Forces planned as many as 90 launches for 1992.[5] The actual figure turned out to be 55, 21 of which were carried out in the last quarter of the year.[6] The commitment of the state to space projects should not be measured only by the launch rate, but also by the diversity of satellite constellations that are being kept functional. Russia now keeps more than 20 operational satellite systems. These include essentially all the systems that existed before the break-up of the U.S.S.R. (see table 1). The Russian leadership

Table 1: Russian operational satellite systems.

System	Function	Orbit[a] Apogee/ Perigee[b]	Inclination	Constell- ation size	Annual replace- ments
		km	*degrees*		
(ASAT)	satellite interception			—	—
(4th generation)	photo. reconn.	350/175	62.8–70	1	6
(5th generation)	photo. reconn.	280/240	64.8	1–2	1–2
(6th generation)	photo. reconn.	350/175	64.8	1	1
Kometa	mapping	310/210	70	1	1
Resurs F	remote sensing	260/230	82.6	1	3–4
(3rd generation)	elec. intell.	650	82.6	6	1–2
(4th generation)	elec. intell.	850	71	4	2
	ocean reconn.	44/415	65	3 (6)	1–2
1st echelon	early warning	40,000/600	63	9	4-5
2nd echelon	early warning	geosynchronous		1–2 (7)	1
Molniya-1	communicat.	40,000	63	8	3
Molniya-3	communicat.	600		8	2–3
(LEO octets)	communicat.	1,400	74	~20	1 × 8
(LEO sextets)	communicat.	1,500	82.6	~20	2 × 6
(LEO singlets)	communicat.	800	74	3	1
Ekran M	communicat.	geosynchronous		2	1
Gorizont	communicat.	geosynchronous		10	3
Raduga		geosynchronous		6?	2
Geizer	data relay	geosynchronous		2?	1
Luch	data relay	geosynchronous		2?	1
Tsikada	navigation	1,000	83	4	1
Parus		1,000	83	6	4
Uragan/GLONASS		19,150	64.8	12 (24)	6 (2X3)
Musson	geodetic	1,200	73.6 82.6	1–2	1
Meteor-3	meteorology	1,200	82.6	2–3	1
Foton	microgravity	410–200	62.8	1	1
Bion	space biology	410–200	62.8	1	1/2
Total orbital constellation				**~140**	

a. Geosynchronous orbit has a height of about 35,800 kilometers and an orbital period of 1,436 minutes.
b. Values of apogees and perigees are rounded. For spacecraft operating in circular orbits orbit height is provided in the apogee/perigee column.

admits that economic reality and a new political environment demand a radical change in space program priorities and a reconstruction of space activities. However, a decision was made to maintain all aspects of the former Soviet space program. The aim was to preserve the industrial and scientific potential until new political and economic arrangements could be worked out to optimize the space program and make the reorientation to new tasks as painless as possible.

In 1993, more decisive action was taken. A number of space systems, which were at different stages of development, were cancelled or put on hold. This allowed Russia to allocate more funds for maintaining operational systems and to concentrate R&D efforts on systems which promised tangible benefits quickly. The most notable cancellation was the Energia-Buran heavy launcher/re-usable spacecraft program, the single most expensive project in the Soviet space programs.[6] At least 17 R&D programs were canceled; 15 programs were downsized to the research and experiment phase; and 38 were delayed for two to four years.[7]

Budgetary constraints also caused some constellations to be maintained at minimum levels, i.e., orbital lifetimes were extended and replacements were delayed. Nevertheless, at the end of 1992 the total constellation of operational Russian spacecraft consisted of about 140 satellites, more than the year before.[8] By the year 2000, Russia expects to maintain 160 to 180 spacecraft, representing about 30 satellite systems for scientific, economic, and military purposes.[9] However, these projections are based on the assumption that the Russian economy will recover from the current crisis. Moreover, many currently operational systems rely on Ukrainian-built launchers and/or launch sites located in Kazakhstan. This makes their long-term future unclear and heavily dependent on the political developments within the C.I.S. Table 1 summarizes all currently operational space systems and specifies their general functions.

The following discussion focuses on military-related systems in more detail.[10] These systems can be subdivided, as shown in figure 4, into:

- Space weapons;
- Space surveillance and intelligence systems;
- Support systems;
- Scientific systems.

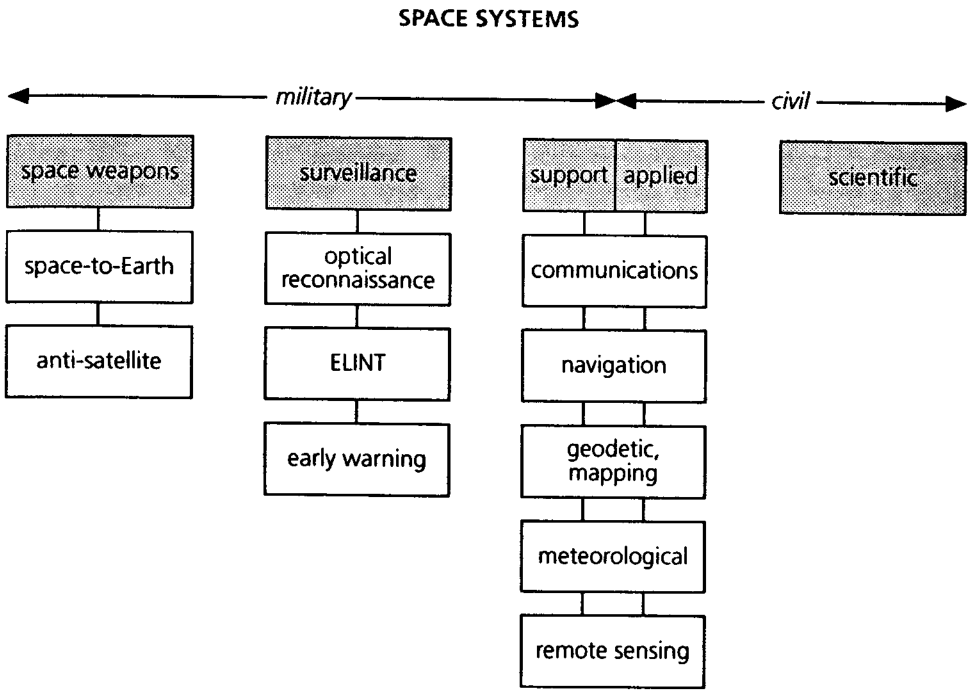

Figure 4: Classification of space systems by missions performed.

Space Weapons

Space striking systems or space weapons are intended for striking targets in outer space (anti-satellite weapons), or hitting targets on the ground from the outer space (space-based striking weapons) In the 1960s and early 1970s, the U.S.S.R. developed an anti-satellite system to be used against satellites in low Earth orbit (LEO). The system used the SS-9 heavy ICBM as a launcher. The satellite interceptor, weighing several tons, would be inserted into orbit, co-planar to its target. After an approach maneuver, it would destroy the target with a conventional shrapnel explosion. The system was commissioned in 1976. Operational testing continued until June 1982. The orbit heights, where interception was tested, varied from 150 to 1,700 kilometers.[11] Despite the absence of test launches after 1982, there was no official declaration about decommissioning the system, and it may still be in service.

Space Surveillance

Space surveillance and intelligence systems provide a unique opportunity to monitor an adversary's activities anywhere around the globe. This is an important means of preventing a surprise attack. Space surveillance also contributes to arms control verification. Depending on the particular mission and physical principles involved, there are different kinds of space surveillance: optical reconnaissance, electronic intelligence, and missile-attack early warning.

Optical Reconnaissance

Optical reconnaissance satellites provide visual imagery for strategic reconnaissance purposes, e.g., estimating an adversary's capability, monitoring military activity, and target locating. Four types of optical reconnaissance satellites are now operational—two types, designed for high-resolution ("close-look") reconnaissance, one for lower-resolution area survey missions, and one for precise topographic mapping. The close-look photoreconnaissance satellites, classified as "fourth generation" by Western observers, have been operating since 1974. They operate in elliptical orbits with apogees of about 350 kilometers and perigees of about 175 kilometers, with the perigee adjusted to be above areas of particular interest for greater resolution. Their current lifetime of two months ensures a continuous presence of a high-resolution satellite in orbit with six to seven launches per year.

Lower-resolution surveillance of wider areas is provided by the so-called fifth generation satellites. They operate in a more circular orbit with perigees of from 220 to 240 and apogees of 250 to 280 kilometers. Their operational lifetime is eight to nine months. Keeping one in orbit at all times requires one or two launches per year. The distinctive feature of fifth generation satellites is that they reportedly use optico-electronic, rather than photographic imaging techniques. This provides an image of the scene directly in digital form, which can be relayed by radio channel to a ground station in real or close to real time.

The latest type of high-resolution optical reconnaissance satellite is apparently in an early stage of operation. Five sixth generation satellites have been launched since 1989, roughly one every year. Their orbits and lifetimes are the same as those of their fourth generation predecessors. However, at the end of the mission they are destroyed in orbit rather than recovered. This system is apparently intended to eventually replace older fourth generation satellites.

The last operational optical imaging satellite is known in the West as a "fourth generation mapping satellite." In fact, this is a special type of spacecraft called Kometa. Kometas have been used since 1981 and launched once a year for missions lasting about 45 days. Kometa is the only operational reconnaissance spacecraft for which some data about the imaging apparatus are available. It possesses two optical systems—a panoramic camera with two-meter ground resolution and a dedicated topographic camera to make snapshots with 10-meter resolution and cross-hairs for photogrammetric processing.

In 1992–1993, older Zenit-class photoreconnaissance satellites (known in the West as third generation) were finally phased out. However, the same satellite bus, based on the late 1950s design, continues to be used for short-duration recoverable remote sensing satellites of the Resurs F-1 and Resurs F-2 series. All operational optical reconnaissance satellites weigh about seven metric tons and are launched by Soyuz launchers, known in the West as the A-2 or SL-4. Inclination of their orbits (which equals 64.8 degrees for fifth and sixth generation satellites, 70 degrees for Kometas and 62.8 to 70.4 and for fourth generation satellites) does not provide truly global coverage. However, all ground-based military-related installations are located under 65 degrees latitude and are covered by Russian reconnaissance satellites tracks.

Electronic Intelligence

Electronic intelligence, or ELINT, embraces a wide class of activities dealing with the interception of electromagnetic waves emitted by radars, communication devices, etc. It is the most classified segment of military space activities. Signal interception permits a country to locate and study the performances of an adversary's radar systems and monitor communications that could indicate a build-up in military preparations.

The current Russian space-borne ELINT system consists of two separate constellations. One is composed of six satellites in circular Earth orbits at 650 kilometer altitude with an inclination of 82.6 degrees. The current version of the system has been in operation since 1983 and, on average, has two replacement launches per year. The satellites, which apparently weigh 1.5 to two tonnes, are launched from Plesetsk by the Tsiklon (F-2 or SL-14) launchers. The latest ELINT constellation employs substantially heavier satellites inserted into orbit by the new Zenit launcher (J-1 or SL-16). This constellation is expected to include four spacecraft in orbit with a height of 850 kilometers and inclination of 71 degrees. However, the deployment of the system, which began in 1984, has been plagued by launch-vehicle problems. The system appeared to be fully deployed only in 1993. Although their orbits are not strictly polar, ELINT satellites provide the capability to listen to radio signals from pole to pole. The major potential problem with the Russian ELINT satellite program is that they are apparently manufactured in Ukraine.

Ocean Surveillance

A specific kind of electronic intelligence is tracking of naval vessels by their radio signals. An ocean surveillance system was one of the top priorities of the Soviet military because of heavy reliance of the United States on naval force-projection groups. This made the system very dangerous in the eyes of U.S. Naval officials, since the system was capable not only of tracking vessels, but also of relaying the data to the Soviet naval attack forces for targeting. Electronic Ocean Reconnaissance Satellites (EORSATS) are launched by the ICBM-derived F-1 (SL-11) booster and operate in low Earth orbits at heights of 415 to 450 kilometers. The orbital inclination of 65 degrees ensures that EORSATS cover all world waterways. The satellites feature a precise orbit-keeping system for steady coverage of high seas. Since the early 1980s, two satellites have usually operated simultaneously to allow successive observation of the same area after a short interval. After expanding the system from two or three operational satellites to five in 1990, launches stopped in 1991, and the system apparently was allowed to deteriorate. Western observers interpreted this as a sign of Soviet re-evaluation of the threat from Western fleets. However, in March 1993 launches resumed, and in September the number of operational satellites had reached four.

Early Warning

The Early Warning Ballistic Missile Attack Warning System (SPRN) is intended to provide timely warning of launches of potentially hostile ICBMs. SPRN consists of two basic types of spacecraft. Both use infra-red sensors to detect exhaust from an ICBM. The first echelon of the system, fully operational since 1982, consists of nine satellites in highly elliptical orbits. With an orbital period of nearly 12 hours, satellites keep their ground track stabilized in a way that allows them to observe launches of the U.S. ICBMs from their apogees. Orbits are positioned to allow ICBMs launched from bases in the central part of the United States to be seen clearly above the Earth's disc against the cold background of space.

The second echelon employs satellites in a geostationary orbit (GEO). Geostationary positioning gives better coverage of the desired region with a smaller number of satellites. Currently the second echelon occupies only two slots in GEO, but is expected to expand to up to seven slots to provide global coverage eventually.

Support Systems

Communications Satellites

Communications satellites provide command and control links, which ensure global management of armed forces and exchange of relevant information. Space communications are represented by a wide variety of systems, shown in table 1. The geostationary Raduga and Gorizont satellites are used for direct global communication. Molniya satellites, placed into inclined highly elliptical orbits, allow for communications with high-latitude areas. The geostationary Geizer satellites are used for data transmission. Three different constellations of light satellites in low orbits provide store/dump message relay services.

Navigation

Two generations of satellite navigation systems are currently in use. First generation systems are similar to the U.S. Navy Transit system. The U.S.S.R. has deployed two systems of this class. One, called Parus, is fully dedicated to military users, while another, called Tsikada, is accessible to the Soviet trade and fishing fleets. Both systems employ satellites in nearly polar circular orbits 1,000 kilometers high with 83 degrees inclination. They provide naval and trade vessels with the opportunity to determine their positions within one or two hours anywhere at the globe. Doppler-shift measurement technique, used by the systems, allows for positioning accuracy of up to 80 to 100 meters. Satellites, weighing about 800 kilograms, are launched from the Plesetsk Cosmodrome by Kosmos (C-1 or SL-8) boosters.

The second generation system (known as GLONASS in the West, but named Uragan by the Russian military) is similar to the U.S. Navstar Global Positioning System. When fully deployed it will allow continuous determination of three-dimensional coordinates within dozens of meters and velocities within fractions of a meter per second. Operational deployment started in 1989 and has now resulted in a constellation of 15 satellites; 24 makes a complete system. An Uragan/GLONASS satellite weighs about 1,400 kilograms. These satellites are launched by a Proton (D-1-e or SL-12) launcher three at a time into high circular orbits of 19,150 kilometers.

Meteorological Satellites

Meteorological satellites (meteostats) provide global and local meteorological data, vital for any military mission planning. The current Russian meteorology satellite constellation consists of three Meteor 3 spacecraft, orbiting the

Earth at a height of 1,200 kilometers. Several older Meteor 2 satellites continue to operate in lower 950 kilometer orbits. In addition to this low orbit system, an introduction of a new geostationary meteosat is expected in 1994. The Electro spacecraft would enhance capabilities for continuous global weather monitoring.

Geodetic Satellites

Satellite geodesy is intended for precise measurements of the Earth's gravity field, which allows for better targeting of strategic weapons. The Soviet Union used two types of satellites for this purpose. Low-orbiting Musson satellites have been launched since 1981. They are equipped with flash light and a Doppler transmitter, which reportedly can determine the position of reference points on the Earth within 15 meters. Two passive Etalon satellites, launched in 1989 with Uragan navsats, are covered with laser retroreflectors. Laser tracking could provide positioning accuracy within small fractions of a meter.

OPPORTUNITIES TO USE RUSSIAN MILITARY SPACE CAPABILITIES FOR CIVIL APPLICATIONS

Many military space systems have civil applications. For example, the same space launch services are used for civilian and military payloads. As noted above, they are even handled by the same ground teams and launch crews.

Communications, navigation, and weather data are equally necessary for civilians and military operations. As a matter of fact, the Soviet meteorological satellites and some navigation satellites have already been utilized by both military and civilian users. Recently, the term "dual-use systems" was coined as an official way of referring to these system. However, "dual use" still usually means that one of the two consumers has a predominant position. In the Soviet case it was naturally the military. In recent years, when government supplies ran short, enterprises became desperate to raise funds on their own. Some relaxation of military security took place and new opportunities to contact potential customers outside the country appeared. This resulted in an unprecedented flow of proposals made to Western businesses by the Russian space industry. The space industry proposed commercial applications of even the most classified dedicated military systems (see table 2).

Table 2: Proposals for civil applications of ex-Soviet military space systems.

System	Original purpose	Proposed application	Promoted by
Sokol	strategic command relay	global commercial communications	NPO Elas
Gonets	clandestine communications	global message relay	a/o SMALLSAT
Kometa	photoreconnaissance, mapping	remote sensing mapping	Sovinform-sputnik
	ocean surveillance	bus for environmental monitoring	KB Arsenal
	early warning	global ozone, atmosphere monitoring	TsNPO Kometa
	satellite interceptor	"space debris collection"	TsNPO Kometa NPO mashino-stroeniya

Launch Services

The extensive launch support infrastructure was the first to be offered to foreign customers for commercial use. Efforts in this direction started as early as the mid-1980s, but met with little success. The Soviets had six types of operational launchers with payload capacities from 1.3 to 20 tonnes to low earth orbit. The launch facilities were able to carry out as many as 100 launches per year, threatened to overwhelm the lucrative satellite launch market. This market is now estimated at 12 to 15 launches per year, primarily to geosynchronous orbits. For this reason, Western launch vehicle manufacturers strongly oppose Russia's entrance into the international space launch market. Until now only one Western-made satellite was approved to be launched by the Russian Proton launcher. A Russian-American agreement, signed in the summer of 1993, allows Russia to launch no more than eight satellites to GEO until the end of the year 2000.[12] This problem emphasizes the importance of possible applications for Russian-built systems, which do not need international approval to be launched.

The military support systems, which, as noted above, have inherent dual-use capabilities, became the first to find practical civilian applications.

Communications Systems

The Soviet system of strategic communications is already being used for commercial communications. The capacity of Geizer satellites, which provided command relay to mobile strategic forces, is now used by the Sokol joint Russian-American company. The company leases out these communication channels and Russian-made Very Small Aperture Terminals (VSATs). This system for secure and clandestine communications, initially developed to relay messages from intelligence agents worldwide, is now used to test commercial communications systems. Two pilot Gonets satellites were launched in July 1992 in a cluster with their regular military counterparts to demonstrate the system's capabilities. The first committed client for the Gonets system is the Healthnet international medical e-mail service.

Earth Observation Satellites

Photoreconnaissance satellites were probably the first military space system reconfigured for civilian applications. As early as 1975, specialized Fram satellites, designed on the basis of Zenit recoverable spacecraft, were employed. Now they have been replaced by more capable Resurs F-1 and Resurs F-2 spacecraft. In 1987, the imagery from Resurs F, with ground resolution of up to five meters, became commercially available worldwide. Before then the best resolution available for commercial users was 30 meters from the U.S. Landsat and 10 meters from French SPOT satellites.

In 1992, representatives of the industry agreed with the Russian intelligence community and the government on the declassification of satellite imagery with ground resolution of two meters. The imagery, produced by Kometa satellites, is now also commercially available. There was discussion of releasing even more detailed imagery, with ground resolution of up to one meter. This would apparently imply conversion of yet another type of dedicated reconnaissance satellites into peaceful applications. These systems are already operational, and their civil application needs only political commitment and a data distribution network.[13] The same is applicable also to the proposal from TsNPO Kometa—the main contractor for missile and space defense systems development—which suggested that the Russian early warning satellite system be employed for global environmental monitoring. The system could distribute its resources between monitoring missile sites and measuring the concentrations of carbon and nitrogen oxides in the atmosphere. Expected installation of longer-wave infra-red sensors on follow-on early warning satellites would further expand the system.

Another Russian proposals for conversion of dedicated military space systems needs significant hardware upgrades. In 1992, KB Arsenal of Saint Petersburg, which manufactures ocean surveillance satellites, proposed to use them as buses for an environmental monitoring platform. Up to 700 kilograms of equipment could be installed on the available buses. The precise attitude control system of EORSAT would enable pinpointing of Earth observation instruments. Its ability to keep the ground track highly stable would be valuable for cyclic monitoring of Earth's regions. NPO Mashinostroenia of Reutov, Moscow Region, offers a complete Almaz 1B orbital station with a powerful synthetic aperture radar and other Earth observation instruments. The basic design is that of the Almaz reconnaissance radar imaging satellite, similar to the American Lacrosse.

The most amazing proposal came from designers of the Soviet anti-satellite system. NPO Mashinostroenia and TsNPO Kometa suggested that the (ASAT-derived) system could be used "for monitoring compliance with the Outer Space Treaty and solving the problem of space debris." The latter means that a system developed on the basis of existing co-orbital ASAT, could approach and capture large pieces of space debris and either de-orbit them or boost the debris to a safe orbit. "Monitoring compliance with the Outer Space Treaty" apparently implies using the same system in a fly-by inspection mode. This idea seems vague and would hardly add much to capabilities of the ground-based space surveillance networks employed by the U.S. and Russia (while it would certainly add much to concerns about an ASAT threat).

The feasibility of some of these proposals needs more detailed analysis. The purpose of this paper is simply to outline a set of opportunities available at this time. It is worth noting that the window of favorable opportunities will not necessarily last long. For Russian industry, the first effort to contact Western (primarily American) aerospace business proved disappointing. Contrary to Russian expectations, Americans were not in a hurry to purchase Russian hardware and technologies or to invest in sizable joint ventures. It is understandable, because since the end of the Cold War governmental funding to space industries has been shrinking worldwide. However, the lack of response to the new openness of the ex-Soviet industry sent a message that Western companies "come only to steal technology." Losing hope for immediate cooperation, the industry pressed the Russian government to resume domestic funding for military developments. The current economic environment in Russia threatens to destroy the unique technological capabilities of the space industry. In 1992, the average salary in the space industry was nearly half the average in other industries. During that year, the Russian missile and space industry lost about 80,000 employees, including 10 percent of its production work force and 30 percent of its research staff.[14] This trend adds to social tension and to weapons technology proliferation concerns.

For all the above reasons, opportunities to use Russian space capabilities should receive serious consideration as soon as possible. The author would suggest that the most viable way would not be direct purchases of Russian or other Soviet hardware and technologies, but rather the establishment of joint ventures between Russian and Western enterprises. This would both stabilize the internal situation and divert Russia from aligning with anti-Western regimes.

There are already several examples of this kind of cooperation. In October 1992, Pratt and Whitney formed a joint venture with NPO Energomash, the leading manufacturer of large liquid rocket engines. In December 1992, Lockheed allied with the Khrunichev plant to market Russian Proton launchers. A 1993 Russian-American agreement on cooperation in space station development is also a very positive move towards merging the space activities of both countries and, hopefully, the number of joint ventures in the space industry will grow.

CONCLUSIONS

With the break-up of the U.S.S.R., Russia gradually assumed full responsibility for the entire Soviet space program. However, the management structure of the program is changing. Military and civil space activities are being separated, and the legislative branch is participating in space policy-making. Despite economic problems, Russia continues to maintain all operational space systems inherited from the U.S.S.R. As long as Russia remains a sound military power, the military will continue to rely heavily on space systems, and space program will retain a high priority.

At the same time, in a new political environment efforts are being made to shift the priorities in the national space program from military to civil applications. Conversion and diversification are already underway for some military systems. They are now being used for civil needs, such as remote sensing, mapping and environmental monitoring. The current situation in the Russian space industry provides a unique opportunity to employ its potential to solve global problems with international cooperation. This opportunity should be seized immediately, before it is lost.

NOTES AND REFERENCES

1. The vague name was intentionally invented for "reasons of secrecy." Similarly, the nuclear weapons industry was under the "Ministry of Medium Machine-Building."

2. Lt. Gen. Yuri Gusev, testimony at the hearings on the Russian space policy, Supreme Soviet of the Russian Federation, 10 November 1992.

3. *Nezavisimaya Gazeta*, 25 September 1991, p. 6; *Komsomol'skaya Pravda*, 8 October 1991, p. 2.

4. At the end of 1992 the Ministry of Industries was disbanded and replaced by the Committee on Defense Branches of Industry.

5. Including one launch failure.

6. Yuri Koptev, interview with the POSTFACTUM agency, April 1993.

7. Lt. Gen. Yuri Gusev, testimony at the hearings on the Russian space policy.

8. Yuri Koptev, interview with Moscow Radio, 4 January 1993. See also *Space News*, 11–17 January 1993, p. 11.

9. "Space Program of the Russian Federation up to the Year 2000," (draft) Russian Space Agency, 1992.

10. The explanations of particular Soviet/Russian space systems are based on the author's book *Military Aspects of the Soviet Cosmonautics*, published in 1992 (in Russian) and on updates for it's second edition, to be published in 1993. For this reason numerous quotations from the original sources are omitted from this section.

11. Nicholas L. Johnson, *The Soviet Military Strategy in Space*, 1987. However, Russian capabilities for geostationary launches are not as overwhelming as one might imagine when comparing cumulative launch rates. Russia now as the only launch vehicle (the Proton) capable of launching to GEO. After 199, Russia could develop with Ukraine a Zenit-3 GEO-capable launcher. Currently, the annual launch rate of Protons is only seven or eight, and Zenit launches total no more than four.

12. *Aviation Week & Space Technology*, 24 May 1993; *Space News*, 24–30 May 1993, p. 4.

13. This is a low-investment business, and the issue of sharing resources is a difficult one. Military duties and commercial operations must be balanced carefully.

14. Supreme Soviet of the Russian Federation, hearings on Space Policy, 10 November 1992.