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The Operational Status of the Russian Space-Based Early Warning System

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Early warning against ballistic missile attack has played a very important role in the military doctrines of the Unites States and Russia. Both countries have deployed systems of early warning satellites that could detect an attack almost immediately after the missiles were launched. These systems were vital for providing a launch on warning capability that was an important building block of their deterrence policies. With the end of the Cold War, the probability of a large-scale nuclear conflict has practically disappeared and the mission of the early warning system has become more diversified. The new missions, such as detection of accidental or unauthorized launches or countering the emerging threat of ballistic missile launches from third-world countries, becoming almost equally important, could require an early warning system of a different kind. This article analyzes the capabilities of the currently deployed Russian space based early warning system and shows that the system could not be modified to be effectively used in the post Cold War environment.

INTRODUCTION

During the Cold War, both the United States and the Soviet Union deployed early warning systems capable of detecting a ballistic missile attack. The motivation behind these deployments was to protect the nuclear forces from being destroyed by a surprise attack and therefore to discourage the adversary from striking first. In the context of deterrence policy, the early warning systems played a stabilizing role and were one of the means of ensuring retaliation. Since both countries had the early warning systems, neither one had an advantage of being able to destroy most of the adversary's nuclear forces in a preemptive strike. The capability to detect an attack allows the defending side to protect the major part of its land-based missile and strategic bomber forces

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from being destroyed by putting the bombers on airborne alert and launching the missiles out from under attack. The launch on warning option has long been a significant part of the nuclear strategies of the United States and the Soviet Union.[1] And though both countries tried to secure their strategic forces by deploying them on the relatively invulnerable submarines (the United States) or making them mobile (the Soviet Union), vulnerability of the command and control system forced the nuclear powers to develop elaborate early warning systems.

Since the flight time of an intercontinental ballistic missile is very short, the realization of launch on warning is a very challenging technical task. The United States did not have a launch on warning capability until the mid-1970s, when the DSP (Defense Support Program) early warning satellites became operational. As will be shown later, the Soviet Union acquired the capability to launch on warning only in 1982, when the Soviet system of early warning satellites was integrated into the nuclear forces command and control system.

The end of the Cold War has dramatically changed the situation. Although the United States and Russia still have large nuclear arsenals, the risk of a Cold-War-style conflict involving exchanges of massive nuclear strikes has practically disappeared. Designed and deployed during the Cold War, the U.S. and Russian early warning systems have lost their primary mission of detecting a massive ballistic missile attack. The future of the early warning systems will depend on their ability to fit into the new environment, in which the mission of detecting a massive ballistic missile attack is no longer the only mission of the system. Other missions, such as detection of an accidental or unauthorized ballistic missile launch or countering the ballistic missile threat from the third-world countries, are becoming almost equally important. This article analyzes the capabilities of the currently deployed Russian space-based system in order to understand whether the system could be effectively used in the new situation, which is characterized by decreasing tensions between the nuclear powers and the emerging threat of ballistic missile proliferation.

STRUCTURE OF THE EARLY WARNING SYSTEM

Essential to the operation of any ballistic missile early warning system are sensors that can detect enemy missiles at launch or in flight. In both the U.S. and Soviet warning systems, there are two main types of sensors: ground-based radars and space-based infrared sensors. Both the United States and the Soviet Union have deployed networks of large ground-based radars intended to detect ballistic missiles or their warheads. The main disadvantage of such radars is that their fields of view are limited by the curvature of the Earth. This limits warning time against an intercontinental ballistic missile (ICBM) attack to about 10 minutes, and the warning time might be even less against an attack by sea-launched ballistic missiles (SLBMs). To overcome this problem, the United States deployed early warning radars closer to Soviet territory: in Fylingdales, U.K.; Thule, Greenland; and in Clear, Alaska. These radars can provide up to 20 minutes warning of an attack against the United States coming from a northerly direction. In addition, four large phased-array radars located on U.S. territory complete the coverage of all other azimuthal directions, although they provide only about 10 minutes warning.[2]

The Soviet Union was not been able to deploy early warning radars beyond its national territory. In addition, the network of early warning radars in the Soviet Union never provided complete coverage of all azimuthal directions.[3] Moreover, after the disintegration of the Soviet Union, some of the radars are no longer on Russian (or even Commonwealth of Independent States) territory.[4] The future status of these radars remains unclear and there is a possibility that in the future Russia's capability to detect a ballistic missile attack with radars will be very limited.

The Soviet Union had also deployed a network of over-the-horizon (OTH) radars, which were intended to detect launches of ballistic missiles from U.S. and Chinese territory. These radars reportedly experienced serious technical problems and have been reoriented toward detecting airplanes.[5]

The other key type of early warning sensor is infrared sensors on satellites. A satellite can detect a missile almost immediately after launch by detecting the infrared radiation from its rocket plume. This means that a space-based system could provide the maximum possible warning time: about 30 minutes against ICBMs and 15 to 20 minutes against SLBMs on standard trajectories. Although this time is still quite short, in theory it is enough to pass the release codes and launch orders through the chain of command and launch vulnerable ICBMs out from under an attack or to allow bombers to escape from their airbases.

These two systems, the satellites and the radars, are intended to complement each other. They constitute a two-layer system, so that an early warning signal would come from at least two sets of detectors employing different physical principles. This is essential for providing reliable early warning while avoiding false alarms. Since the Soviet radar network was never completed, the Soviet Union was not been able to follow this principle strictly. This means that the role of the early warning satellites in the detection of an attack was even more important.

HISTORY OF THE SOVIET SPACE-BASED EARLY WARNING SYSTEM

The development of satellites that could detect missile launches from U.S. territory began in the Soviet Union in the late 1960s.[6] In 1973, the Central Committee of the Communist Party and the Military Industrial Commission approved the development and deployment of a space-based early warning system.[7] According to this plan, the system would consist of nine satellites in highly elliptical, Molniya-type orbits.[8]

Launches of the early warning satellites began in 1972 with the launch of Cosmos 520, which reportedly did not have any surveillance equipment on board but was used to work out details of station-keeping and communication with ground stations. Three more launches are believed to have been experimental—in 1973, 1974, and 1976. In 1977, the Soviet Union started the deployment of an operational early warning system. For five more years, until 1981, the system was deployed in a test configuration. Finally, in 1982 the Soviet government signed the system into operation and it was integrated into the command and control structure of the Soviet nuclear complex.[9]

The approach taken by the Soviet Union in deploying early warning satellites was different from that taken by the United States, which placed its satellites into geosynchronous orbits. The main advantage of a geostationary satellite is that such a satellite does not change its position relative to the Earth, which makes spacecraft attitude control and station-keeping procedures simpler. Such a satellite can also constantly keep a fixed covered area within its field of view, a feature which is very convenient for early warning. Molniya-type orbits do not provide such convenient observation conditions and the constellation inevitably becomes more complex.

The decision to place early warning satellites into highly elliptical orbits has usually been attributed to the Soviet Union lack of detectors and processing capabilities that would allow a satellite to look directly down and to detect missile plumes against an Earth background.[10] To avoid the problems of discrimination against the Earth background that are associated with the look-down observation geometry, Soviet satellites were designed to look at the Earth at a grazing angle, so the satellite does not see the cloud cover at all, but would see missiles against the background of cold space. However, this does not fully explain the choice of Molniya-type orbits since it is possible to arrange the same grazing-angle observation conditions with satellites in geosynchronous orbits.

It seems likely that the discrimination limitations of Soviet detectors were not the only—or even the main—reason for the choice of Molniya-type orbits. At the time the Soviet Union began to develop its space-based early warning

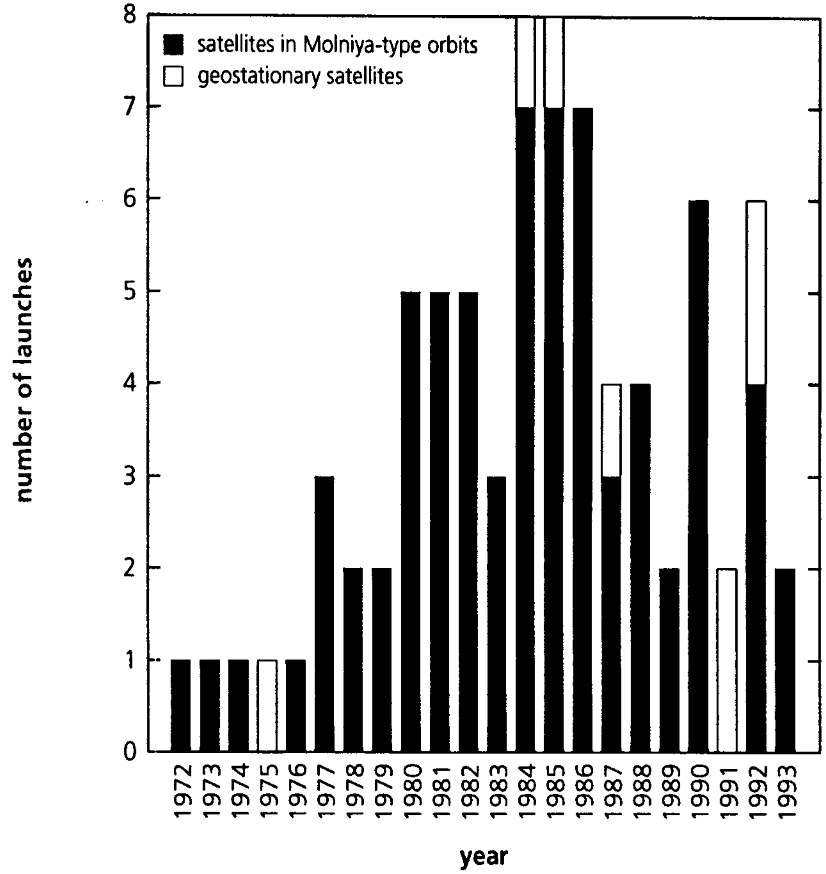

Figure 1: Early warning satellite launches (as of May 1993). The chart shows all the launches, including launch failures and failures of spacecraft shortly after launch.

system, it did not have any experience with geostationary satellites. The first Soviet geostationary satellite was launched only in March 1974, when the early warning program was already under development. On the other hand, the Molniya communication satellites had been in operation since 1965, so the choice was made in favor of the proven Molniya-type configuration.

The early warning satellites were launched from the Plesetsk, Russia, space launch site with the Molniya launcher. To maintain the operational status of the system, the Soviet Union launched up to seven satellites annually (see figure 1). The high launch rate can be partly explained by the size of the constellation (nine satellites), launch failures, and by the relatively short lifetime of the satellites (two years on average).

By 1991, however, the Soviet Union had gained enough experience in operating the satellites, and for the first time since the beginning of the program there were no launches of early warning satellites into highly elliptical orbits during that year. Our analysis shows that in 1991 all nine satellites in the constellation were operational and there was no need for replacement launches. In 1992, launches of satellites in Molniya-type orbits were resumed: four satellites were launched in 1992 and two in 1993 (as of May 1993). These launches most likely represent routine replacement activity.

In addition to the system of satellites in Molniya-type orbits, the Soviet Union was developing a new early warning system that would consist of satellites in geosynchronous orbits and could eventually replace the currently deployed system. This development was approved by the same 1973 Central Committee decision.[11] Regular launches of geostationary early warning satellites began in 1984, but as of May 1993 only eight such satellites had been launched. The new system still seems to be in the development stage and has not reached operational status yet.

EARLY WARNING SATELLITES IN MOLNIYA-TYPE ORBITS

Configuration of the System

The currently deployed constellation of Russian early warning satellites consists of nine spacecraft in highly elliptical orbits very similar to those of Molniya communication satellites: the orbits have apogees of 39,700 kilometers, perigees of 620 kilometers, and inclinations of about 63.5 degrees. A satellite in such an orbit makes exactly two revolutions per day. All satellites in the constellation are synchronized to follow the same groundtrack, and this allows them to be easily distinguished from Molniya communication satellites. Molniya satellites as a rule have apogees over Russian territory, while the apogee of a typical early warning satellite orbit occurs over Northern Africa, roughly over the point 35°N latitude and 10°E longitude. Figure 2 shows the groundtracks of the communication satellite Molniya 3-41 and the early warning satellite Cosmos 2217; these are typical of the satellites in these constellations.

Observation Geometry

A satellite can detect a missile during a powered flight by detecting radiation emitted by the rocket plume. The spectrum of this radiation is characterized

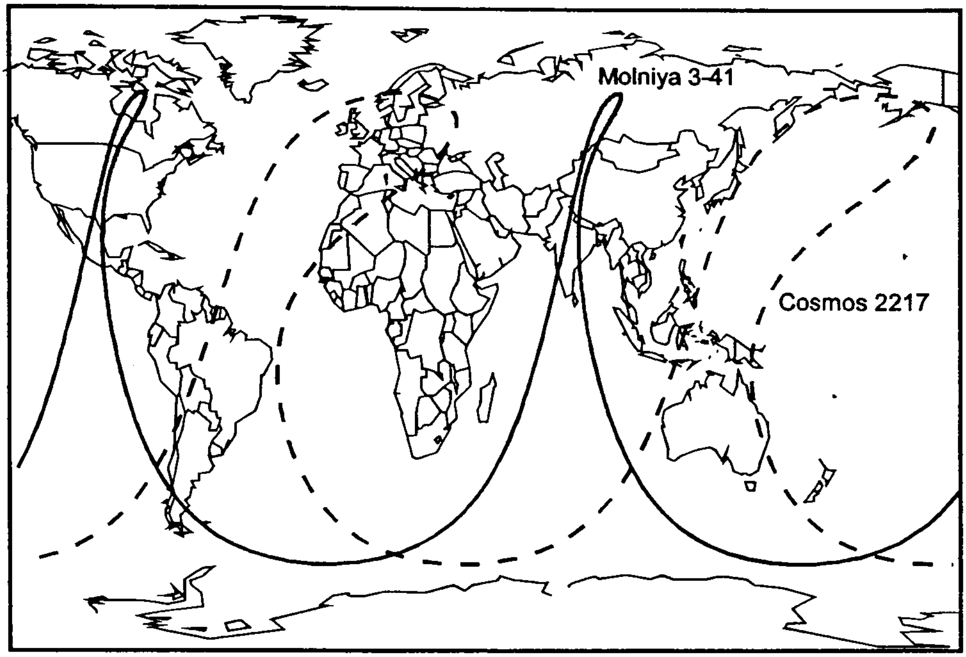

Figure 2: Groundtracks of the early warning satellite Cosmos 2217, and the communication satellite Molniya 3-41. These groundtracks are typical for both constellations.

by at least two prominent peaks—in the 2.7 and 4.5 μ regions, although there is also a significant amount of energy emitted in other parts of the spectrum.[12] Our calculations show that the amount of energy emitted by the plume is great enough so a highly sensitive detector is not required. The main detection problem is discriminating the signal from a rocket plume against the background. Successful discrimination requires a detector with small, sensitive elements and quite sophisticated signal processing techniques. However, a proper choice of observation geometry can eliminate the problem of discrimination against background.

For a satellite to avoid the clutter background problem by viewing the Earth at a grazing angle, it must be at or near the horizon as seen from the missile it is to detect. In other words, the elevation angle of the satellite as seen from the burnout point of the missile should be less than some critical angle α. If the elevation angle is greater than α, the detector would see sunlight reflected from clouds or the Earth's surface (see figure 3). The critical angle α can be found from the following simple expression:

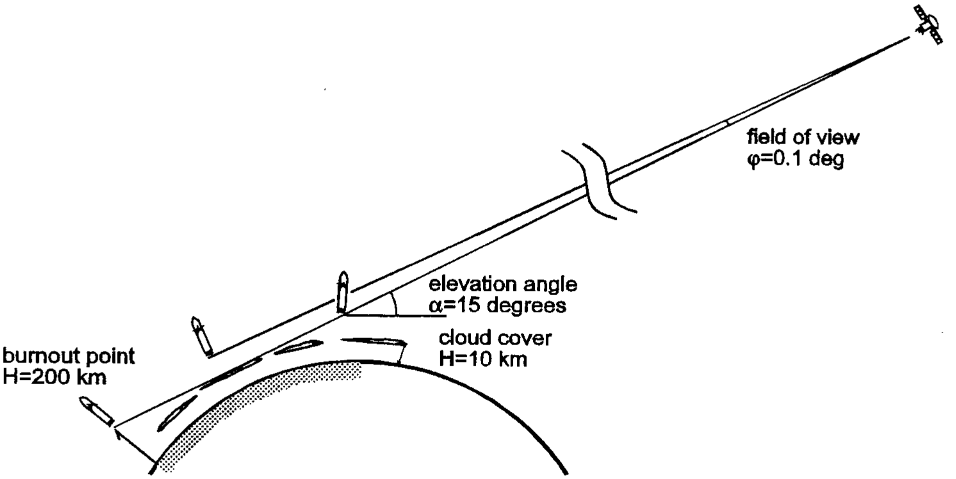

Figure 3: Observation geometry. A missile can be seen from the satellite if the elevation angle at which the satellite is seen from the burnout point is less than the critical angle α = 15 degrees. The shaded area on the Earth's surface shows the locations of launch sites that can be simultaneously covered by the satellite.

$$\cos\alpha = \frac{R_{\text{earth}} + H_{\text{clouds}}}{R_{\text{earth}} + H_{\text{burnout}}}$$

where R_{earth} = 6,378 kilometers is the radius of the Earth; H_{burnout} is the burnout altitude; and H_{clouds} is the average highest altitude of the clouds. Given that H_{clouds} is about 10 kilometers[13] and for intercontinental range missiles a typical burnout altitude is 200 to 300 kilometers, the maximum elevation angle α is about 12 to 15 degrees.

As shown in figure 3, this observation geometry allows a Soviet early warning satellite positioned at or near its apogee to detect a launch originating from any point within a strip of land that has width of about 3,000 kilometers (which corresponds to 25 degrees of arc on the Earth's surface). Moreover, there is no need to scan the field of view: since the detector is looking only at the edge of the Earth's disk, a missile launched from any point within this strip of land would be seen within a very narrow field of view—about 0.1 degree in the direction perpendicular to the edge of the Earth's disk. This makes it possible to use a linear-array detector configuration. On the other hand, the requirements on pointing accuracy are very high: to align the detector with better than 0.1 degree precision, the spacecraft must employ three-axis stabilization techniques and use a star-sighting technique to determine its attitude.[14]

The size of the field of view in the direction parallel to the edge of the

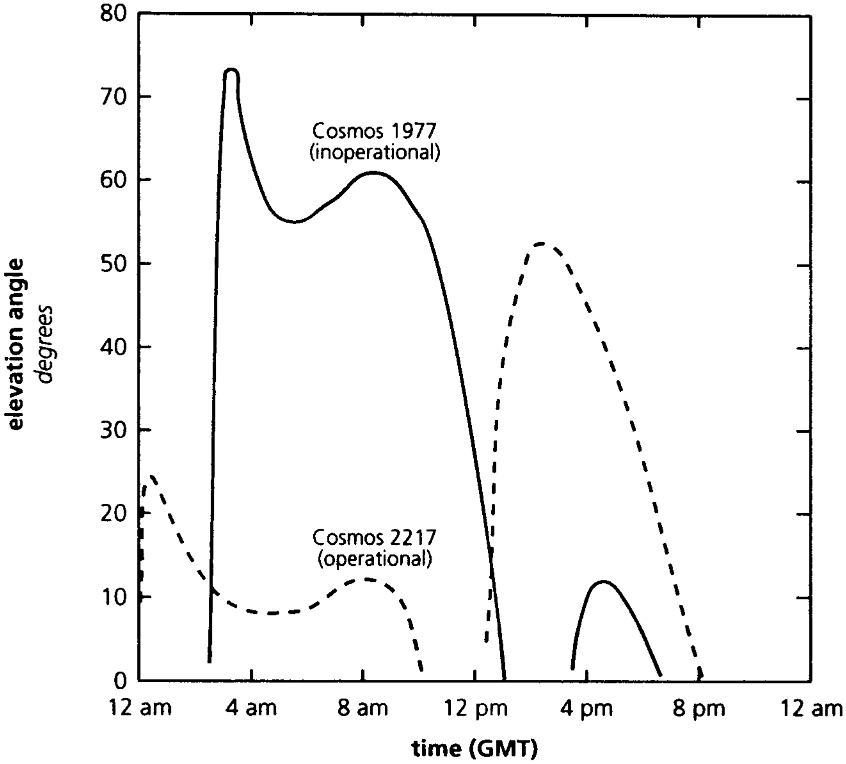

Figure 4: The elevation angle of two early warning satellites as seen from the Grand Forks missile site. If the satellite is to detect a missile launched from this site, its elevation angle must be less than 15 degrees. Cosmos 1977 is not able to see any launches from this site and most likely is not operational. Cosmos 2217 can view the missile site for about eight hours. However, during the last five hours the azimuth angle of the satellite is more than 55 degrees, so the satellite's detector could be blinded by the direct sunlight.

Earth's disk depends on the size of the detector and characteristics of the focusing optics.[15] If the telescope on board the satellite has a focal length of about one meter, a field of view of 10 degrees can be covered with an array of about 2,000 elements of 100 μ each. This seems to be a reasonable number; the detectors on the U.S. DSP satellites are arrays of 2,000 elements.[16]

Figure 4 shows the elevation angle of one of the operational satellites, Cosmos 2217, as seen from the Grand Forks missile site. As seen on the figure, the satellite is seen from Grand Forks twice during a 24 hours time interval, which reflects the fact that the satellite makes two revolutions per day. The observation conditions, however, are favorable only once a day, when the elevation angle to the satellite is less than 15 degrees for about eight hours. After that, the satellite quickly disappears below the horizon. The time available for observations, however, is substantially less than eight hours; the main factor that limits this time is direct sunlight.

Since the satellites look at U.S. missile launches from the northwest, sunset light could blind the detectors. The azimuth of sunset varies with the season and latitude. Since at latitudes of 45 to 50°N (the latitudes of the U.S. ICBM sites) the sunset azimuth is about 305 degrees in June and 235 degrees in December, a satellite would never see direct sunlight if its azimuth as seen from the covered area is less than 55 degrees.[17] Analysis of the orbital motion of the satellites shows that this factor can limit the time available for observations to about 160 to 180 minutes. However, this affects only the one or two satellites in the constellation that pass their apogees at the time of sunset.

Areas of Coverage

Figure 5 shows how the area that can be seen by one of the Russian early warning satellites changes as the satellite passes through its orbit's apogee. The orientation of the band of instantaneous coverage is constantly changing due to both the orbital motion of the satellite and the rotation of the Earth. However, there is a region where all these bands overlap. This region is constantly held within the field of view of the satellite while it passes through apogee.

Since one satellite cannot provide continuous coverage of any region, an operational system must include several satellites that follow each other at intervals of about 160 minutes. The fully operational system would, therefore, consist of nine satellites in a constellation configured so that the satellites replace each other over the same fixed point on the Earth. Such a system, with all the satellites operational, can constantly cover the area shown on figure 6. Since the satellites make two revolutions per day, there are actually two identical areas of coverage, separated by 180 degrees longitude. We can see that these areas cover all the U.S. ICBM sites and at least some of the Chinese ICBM sites.

In addition to covering the ICBM fields, the satellites can also detect launches from several space launch sites: Cape Canaveral (U.S.), Tyuratam (Baikonur, Kazakstan), Plesetsk (Russia), and Kapustin Yar (Russia). It is possible, therefore, to test the system by observing routine space launch activity. In fact, until March 1981 the constellation was positioned so that the areas of coverage were shifted westward from their current positions by 30 degrees[18] and therefore the system was not able to detect launches from U.S. ICBM fields. It seems likely that at that time the system was deployed in a test configuration and was oriented primarily toward detecting launches from the

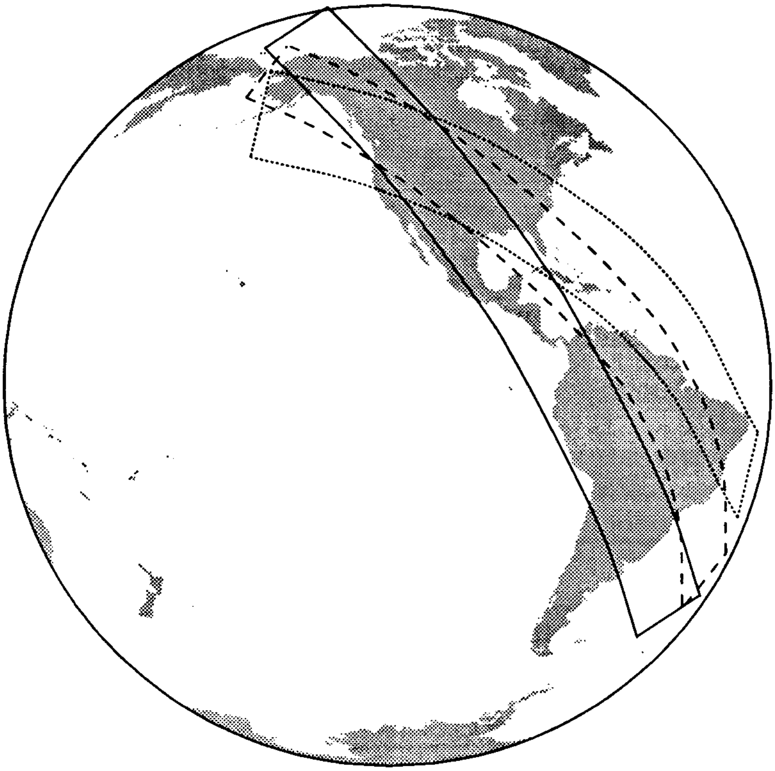

Figure 5: Area of continuous coverage is formed by overlapping areas of coverage at different times as the satellite passes through the apogee. Shown on the figure are the areas covered by the satellite when it is 80 minutes before the apogee, at the apogee, and 80 minutes after the apogee.

Soviet space launch facilities. The system became fully operational only after 1981, when the orbits were shifted to their current positions.

In the grazing-angle geometry, the area of coverage depends on the burnout altitude of a missile the satellite is to detect. The covered area shrinks very rapidly with decreasing burnout altitude, so the satellite in effect cannot detect launches of tactical missiles. The currently deployed constellation cannot, therefore, be used for detecting such launches, even if it can be restructured to point, say, to the Middle East rather that to the United States.

Operational Status

Since 1972, the Soviet Union and Russia have launched more than 70 early warning satellites. Since most of them are no longer operational we need to find some criteria that can help to distinguish between operational satellites

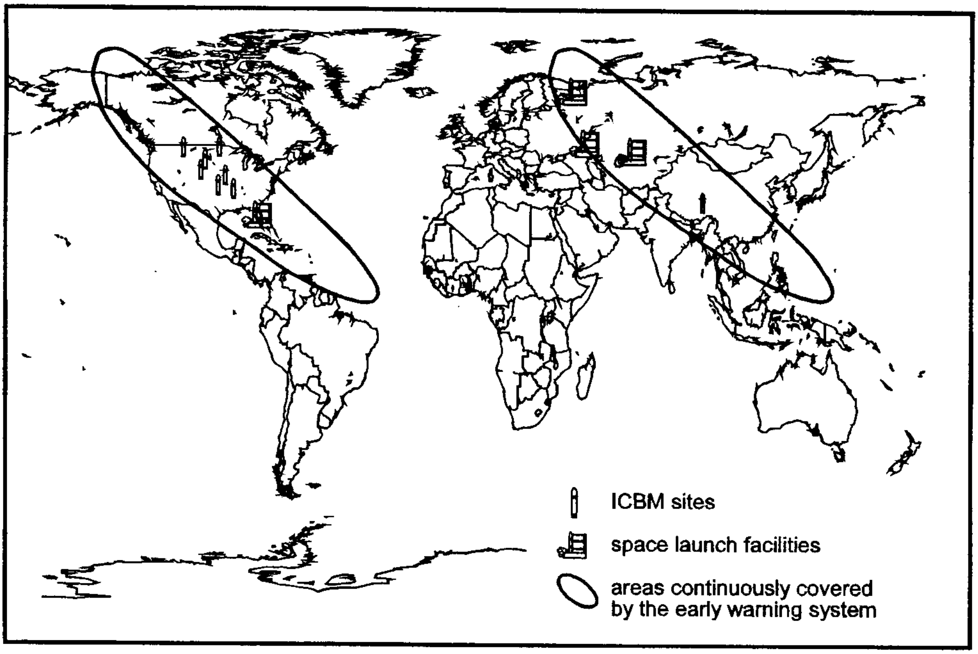

Figure 6: Areas continuously covered by the Russian space-based early warning system.

and nonoperational ones. The best criterion is the satellite's station-keeping activity. Various perturbations cause orbital parameters to change with time, and a satellite should regularly perform station-keeping maneuvers to keep its orbit within operational limits. These maneuvers are the best indicator of the operational status of a satellite: failure to perform station-keeping maneuvers means that a satellite is no longer functional.

There are several factors that result in orbital drift: the oblateness of the Earth and perturbations caused by the moon and sun's gravitational forces. For Molniya-type orbits, the main contribution to orbital drift is due to the oblateness of the Earth with the two other factors causing only minor effects. The perturbations caused by the Earth's oblateness, primarily by the second zonal harmonic, result in a gradual increase of a satellite's orbital period that leads to a westward drift of the right ascension of the ascending node of 0.13 to 0.15 degrees per day.[19] This would eventually cause a significant shift of the orbit's groundtrack and the satellite would lose the ability to view U.S. ICBM sites at a grazing angle. This is illustrated in figure 4, which shows the elevation angle of one of the satellites that stopped station-keeping, Cosmos 1977, as seen from the Grand Forks missile site: during passage through its apogee, the satellite is at elevation angles more than 15 degrees and therefore cannot

Table 1: Operational Russian early warning satellites (as of May 1993).

Slot number	Satellite (NORAD number)	Satellite launch date	Right ascension of ascending node	Last maneuver
1	Cosmos 2196 (22017)	8 Jul 1992	342	Mar 1993
	Cosmos 2001 (19796)	14 Feb 1989	338	Oct 1992
2	Cosmos 2176 (21847)	24 Jan 1992	27	Mar 1993
3	Cosmos 2241 (22594)	26 Jan 1993	70	Apr 1993
4	Cosmos 2217 (22189)	21 Oct 1992	108	Apr 1993
	Cosmos 1974 (19554)	3 Oct 1988	92	Jan 1993
5	Cosmos 2050 (20330)	23 Nov 1989	154	Mar 1993
6	Cosmos 2222 (22238)	28 Nov 1992	200	no data
7	Cosmos 2063 (20536)	27 Mar 1990	233	Mar 1993
8	Cosmos 2097 (20767)	28 Aug 1990	273	Mar 1993
9	Cosmos 2232 (22321)	26 Jan 1993	310	Feb 1993

detect missile launches from this site.

Correction of the right ascension of the ascending node is a difficult maneuver, so the satellites use a different technique to stabilize their groundtracks and keep the orbit within operational limits. The satellites are initially placed into orbits with orbital periods of about 717.5 minutes, which are slightly less than the true semi-synchronous period, 718 minutes. In the absence of the orbital perturbations, this would result in the groundtracks drifting eastward. Perturbations caused by the Earth's oblateness other than those caused by the second zonal harmonic lead to an increase of the period at a rate of about 0.008 minutes per day, slowing the eastward drift and eventually, after the period exceeds the true semi-synchronous period, reversing it.[20] Taking into account both the eastward and westward shifts, we can estimate that after about 70 to 90 days the groundtrack of a satellite returns to its initial position. At this time the satellite would maneuver to decrease its orbital period to its initial value of 717.5 minutes.

An analysis of orbital parameters of the early warning satellites allows us to determine which satellites are operational.[21] As can be seen from table 1, in

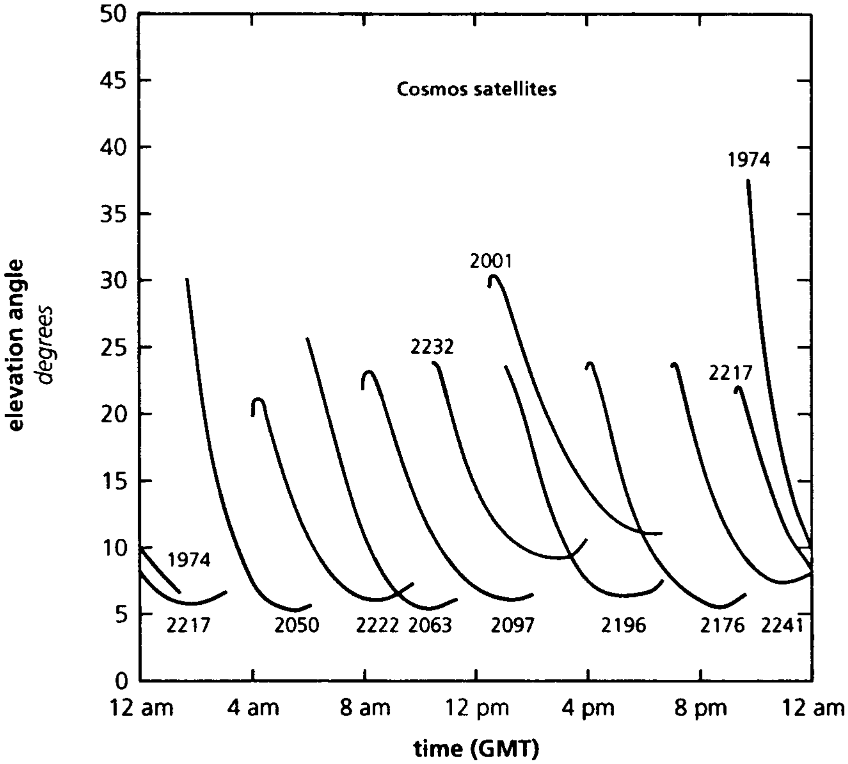

Figure 7: The elevation angle at which operational early warning satellites are seen from Grand Forks missile site during the day. A satellite is shown only if its azimuth angle as seen from the missile site is less than 55 degrees, i.e., the satellite cannot be blinded by the direct sunlight. Since a satellite can detect a missile launch if it is seen at the elevation angle less than 15 degrees, Grand Forks missile site is constantly viewed by at least one satellite.

May 1993 all the slots in the constellation were occupied by at least one operational satellite. Slots 1 and 4 contain two satellites, but as can be seen from the dates of last maneuver, Cosmos 2001 and Cosmos 1974 did not perform station-keeping maneuvers that were due in January 1993 and April 1993, respectively, and most likely are no longer operational and are drifting off their stations.

Figure 7 shows the change of the elevation angles with time of the satellites as seen from the Grand Forks missile site as they pass through one of the apogees. The figure shows that at any time of the day one of the satellites is in a position to detect a ballistic missile launched from this site. The situation at all other ICBM sites that fall within the area shown in figure 6 is similar. This means that the constellation in its current configuration, with nine satellites in orbit, can provide continuous coverage of all U.S. ICBM fields.

In fact, the system is redundant and the loss of some of the satellites would not substantially affect the system's capability. As we have seen earlier, if a satellite is not blinded by direct sunlight it can keep the covered area within its field of view for more than 160 minutes. This leads us to the conclusion that the system can operate with less than nine satellites in orbits.

GEOSTATIONARY SYSTEM

Although the Russian early warning satellites in Molniya-type orbits can provide prompt warning against an ICBM attack originating from U.S. territory, in other aspects the system has limited capabilities. First, because of the limited coverage, the system cannot provide warning against sea-based missiles. Second, it can provide very little information about the location of the launch and the direction of flight, which, in principle, could be used to determine the potential targets of an attack.

These limitations, particularly the limited area of continuous coverage, are inherent to the system design and are the result of the choice of the grazing-angle observation geometry in combination with the highly elliptical orbits of the satellites. The limitations of such a system were well understood in the Soviet Union. In 1975, the Soviet Union launched Cosmos 775, a geostationary satellite whose mission was reportedly to experiment with the look-down observation geometry. The satellite was used for about two years, but given that the next geostationary satellite was launched only in 1984, results of the experiment apparently proved unsatisfactory. Geostationary satellite launches were resumed in 1984, indicating that the development of a geostationary early warning satellites continues.

As of May 1993, there have been eight geostationary satellites that were thought to have an early warning mission.[22] The last one, Cosmos 2224, was launched in December 1992. As of May 1993, all of these satellites were in Prognoz points which the Soviet Union reserved for its geostationary satellites. Table 2 shows the longitudes of these points, which are located over the equator. It should be noted that so far the satellites have been deployed into Prognoz-1, Prognoz-2, Prognoz-3, or Prognoz-4 points. Every satellite was positioned in the Prognoz-1 point, but some were later moved to another point. Some satellites were initially deployed at another point and later moved to Prognoz-1.[23]

An assessment of the capabilities of the geostationary early warning system is more difficult than that of a system using Molniya-type satellites. While the orientation of the orbits of Molniya-type satellites reveals informa-

Table 2: Geostationary points reserved for the Prognoz series satellites.

Stationary point	Longitude
Prognoz-1	24°W
Prognoz-2	12°E
Prognoz-3	35°E
Prognoz-4	80°E
Prognoz-5	130°E
Prognoz-6	166°E
Prognoz-7	159°W

tion about the system's design, a geostationary satellite system's capability depends primarily on the capability of its detectors. From the information available it is not even clear whether the new generation early warning satellites have a real look-down capability, permitting their detectors to detect missile launches against the background of the Earth, or whether they still use the grazing-angle technique.

From the first geostationary point, Prognoz-1, a satellite can see the territory of the United States at a grazing angle which makes it possible, in principle, to use a satellite very similar, or even identical, to those launched into Molniya-type orbits. At the same time, if a new-generation satellite can effectively deal with the Earth background problem, this position can be used to detect launches of sea-based missiles from the Atlantic. In this cas, U.S. territory could be covered by a look-down satellite placed into the Prognoz-7 point, and a similar satellite at the Prognoz-4 point could detect launches from the Indian Ocean and from the Middle East region.

In any case, the small number and irregularity of geostationary satellite launches, as well as the continuing launches of Molniya-type satellites, suggest that most likely, for about a decade the Molniya-type satellites will constitute the core of the Russian space-based early warning system.

CONCLUSIONS

The capabilities of the Russian early warning system or of its space-based component should not be considered separately from the Russian military doctrine, the number and capabilities of the delivery systems, and the character of possible threats. The fact that the currently deployed system is strongly oriented toward detecting a ballistic missile attack originating from the continental U.S. and cannot provide early warning against sea-based missile launches does not mean that the system was always inadequate. This capability might have been quite sufficient in the early 1970s, when the system was in its early stages of development. At that time, U.S. sea-based ballistic missiles did not have the capability to destroy hardened silos and could not be used in a disarming first strike. Soviet land-based missile forces, which constituted the core of the Soviet strategic forces, could withstand an SLBM attack and retain the capability to inflict substantial damage. Another possible reason why the space-based early warning system was designed to detect only land-based missiles is that the detection of an SLBM attack by satellites does not substantially increase warning time over that provided by early warning radars. These considerations, as well as the technical difficulty of deploying a system with global coverage, probably led to the decision to restrict the coverage of the Soviet space-based early warning system to U.S. territory.

The counterforce capability of the U.S. SLBM force substantially increased in the 1980s with the introduction of very accurate Trident II missiles. These missiles reportedly have accuracies comparable to the accuracy of the U.S. land-based missiles, and can be effectively used against hardened silos in a first strike. Had the Cold War confrontation continued, the Soviet Union would eventually have found itself in a situation in which neither its space-based early warning system nor its network of early warning radars could guarantee the detection of an attack. Although an SLBM attack could not have destroyed most of the Soviet nuclear forces, such an attack could have seriously undermined the Soviet Union's ability to retaliate.[24] This shows that in the 1980s, the ability of the old space-based early warning system to provide a launch on warning capability was questionable only a few years after the system reached operational status. The decision to proceed with the development of the geostationary system was an attempt to correct this situation.

The Cold War confrontation, however, worked to the advantage of the old early warning system. In the early 1990s, the United States and the Soviet Union had about 10,000 strategic nuclear weapons and more than 2,000 delivery systems each. The number of weapons guaranteed that if the United

States were to launch a disarming preemptive attack, it would need to employ all its forces, including the land based missiles, to destroy the Soviet retaliatory forces. This meant that the limited capability of the Soviet space-based early system, namely its inability to detect launches of sea-based missiles, would not prevent it from detecting such an attack.

The situation will be different after the United States and Russia cut their nuclear forces according to the START Treaties. According to the START II Treaty, by 2003 both countries will eliminate all MIRVed land-based missiles, and the major part of their nuclear forces will be deployed on submarines. In the unlikely event of a nuclear conflict, the main threat to Russia would come from the ocean rather than from the continental United States. As a result, the old system of early warning satellites will very quickly lose its useful capability. As for the new missions, such as detection of accidental or unauthorized launches and monitoring the ballistic missile activity in the third world, the limited coverage of the system means that the system would be of little relevance. These new missions might require a new system, which would replace the currently deployed one. The obvious candidate for the replacement is the geostationary system now being developed in Russia. However, the question of whether this system is adequate for these new missions, as well as the old ones, remains open. It is also not clear also that Russia really needs a space-based early warning system at all.

Assessing the need for a new early warning system, the authors of an article in Russian military journal *Voennaya Mysl'* argue that such a system must

> detect launches of ballistic missiles or other signs indicating that the opposite side started a strategic attack . . . The main function of an early warning system is to discourage an adversary from striking first. If the defending side has an early warning system, striking first gives no advantage of a surprise attack and would be associated with the risk that the defender would inflict unacceptable damage in a [launched under attack] counterstrike.[25]

This way of thinking, however, implies that the main threat is associated with a surprise disarming attack. This is hardly so, even if we assume that the U.S.-Russian nuclear confrontation will return to the Cold War level. First, the disarmament steps that the United States and Russia will undertake in the framework of the START agreements are aimed at restructuring their nuclear forces in order to reduce, if not eliminate, the advantages of a first strike. The major part of the nuclear forces will be deployed on submarines and the remaining land-based missiles will have only one warhead, which makes them far less attractive targets for a first strike. Second, as far as a first strike is concerned, it might be used to disrupt the command and control system rather than to destroy the nuclear forces. In this case, increasing the capabilities of early warning systems might lead an adversary to find other ways to perform such an attack. These might be the use of long-range cruise missiles or Stealth bombers rather than ballistic missiles. Detection of these targets, though possible, is a quite different technical task, and a space-based early warning system oriented toward ballistic missile detection would be of almost no help in these cases. Third, the early warning system is only a part, though a significant one, of the nuclear forces' command and control system. The role of the rest of the command and control system in assuring retaliation should not be underestimated. It seems likely that a highly survivable command and control system with elaborated procedures for dissemination of launch orders could be more reliable and far less expensive than a system which relies on early warning.

As for other possible missions of an early warning system, namely detection of accidental or unauthorized launches, detection of tactical missile launches, and monitoring of ballistic missile development worldwide, it is very unlikely that any of these missions would justify the deployment of a complex system of satellites, communication links, and ground control stations constituting a modern early warning system.

Since Russia still has no articulated military doctrine, any conclusions about its need for an early warning would be premature. However, the role of early warning deserves an open discussion in the context of the changes brought in by the recent development in the world. It would be unwise to spend resources maintaining or deploying a system that Russia would never need.

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NOTES AND REFERENCES

1. Other options include retaliation after withstanding a first strike and a preemptive strike. The retaliation after ride-out option has not been technically feasible, since the ability of the nuclear forces and, more importantly, of the command and control system to withstand an attack and produce a retaliatory strike is quite limited. Another option—a preemptive attack—was actually denied by the development of the early warning systems on both sides. These systems, though having limited capabilities in early stages of their development, substantially reduce the probability of a successful preemptive strike. Detailed analysis of the nuclear doctrines and the role of launch on warning is beyond the scope of this article. Analysis of the role of these options in the U.S. and Soviet military doctrines, based on information about the command and control systems, can be found in Bruce Blair, *The Logic of Accidental Nuclear War* (Washington DC: The Brookings Institution, 1992).

2. These are PAVE PAWS radars, located at Cape Cod, Massachusetts; Goodfellow Air Force Base (AFB), Texas; Beale AFB, California; and Robins AFB, Georgia. PARC large phased-array radar at Grand Forks, North Dakota, which was built as a part of an ABM system, provides additional coverage of northerly directions. See John C. Toomay," Warning and Assessment Sensors," in *Managing Nuclear Operations*, Ashton B. Carter, John D. Steinbruner and Charles A. Zracket (editors) (Washington, DC: Brookings Institution, 1987) p. 311.

3. The network was about to be completed, but the last radar in the network, located at Krasnoyarsk, violated provisions of the ABM Treaty: it was not located at the periphery of national territory and was not oriented outward as required by the ABM Treaty. Construction of the radar was suspended in 1990 and the radar has now been dismantled.

4. Large phased-array radars (LPARs) on Russian territory are in Pechora, Olenegorsk (Kola Peninsula), Mishelevka (near Irkutsk). Those outside Russian territory are in Liaki (Azerbaidzhan) and Sary Shagan (Kazakhstan). One more LPAR has been under construction in Mukachevo (Ukraine), but construction was suspended in 1990 and the future of this radar remains unclear. In addition, there are 11 older Hen House radars which are located in Mishelevka and Murmansk (both in Russia), Skrunda (Latvia), Mukachevo and Sevastopol (both in Ukraine), Sary Shagan (Kazakhstan); Stephen D. Shenfield, "Dividing Up the Soviet Defense Complex: Implications for European Security," Security for Europe Project Paper no. 2, Center for Foreign Policy Development, Brown University, 1992, p. 23; John Lepingwell, "US-Russian Cooperation in Missile Defense," Radio Free Europe/Radio Liberty, Research Report no. 33, 21 August 1992.

5. A.S. Sumin, "Mezhdunarodnaya systema kontrolya vozdushnogo prostranstva" (International Airspace Monitoring System), *Voennaya Mysl'*, no. 6–7, 1992, pp. 24–27, discusses the possible employment of the Russian OTH radars for airspace monitoring. The article does not even mention the possibility of ICBM detection. The United States also built an OTH radar, but it was designed to detect airplanes.

6. Much of the information about the history of the development of the Soviet space-based early warning system is drawn from the annual reports *Soviet Year in Space* (Teledyne Brown Engineering) by Nicholas Johnson.

7. Maxim Tarasenko, *Voennye aspekty sovetskoi kosmonavtiki* (Military Aspects of the Soviet Space Program) (Moscow: Nikol, 1992), p. 80.

8. The system was designed at TsNPO "Kometa" (the Chief Designer of "Kometa" is

A.I. Savin; the Chief Designer of the early warning system is K.A. Vlasko-Vlasov), and the spacecraft were produced at Lavochkin Design Bureau (the Chief Designer is R.S. Kremnev).

9. Maxim Tarasenko, op. cit., p. 80. The 1982 exercise on launch on warning described by Blair (op. cit., p. 208) must have involved the space-based component of the early warning system.

10. Matthew Partan, "Soviet Assessment of U.S. Early Warning Technology Programs," Center for International Studies, Massachusetts Institute of Technology, Research Report no. 86-1, August 1986, pp. 52, 53.

11. Maxim Tarasenko, op. cit., pp. 80, 81.

12. Jurgen Altmann, *SDI for Europe: Technical Aspects of Anti-Tactical Ballistic Missile Defenses* (Frankfurt: Peace Research Institute Frankfurt, 1988) pp. 54–63.

13. William L. Wolfe, editor, *Handbook on Military Infrared Technology* (Washington DC: Office of Naval Research, 1965) p. 118.

14. James R. Wertz and Wiley J. Larson (editors) *Space Mission Analysis and Design* (Dordrecht: Kluwer Academic Publisher, 1991) p. 309.

15. There are at least three detectors aboard, presumably to collect information in different spectral regions. We assume that the main detector works at 2.7 μ, which corresponds to a strong emission line in rocket plume spectrum. Two other detectors probably work at 4.5 μ (another strong emission line) and in the visible part of spectrum, providing the redundancy needed to decrease the false alarm rate.

16. Bruce Gumble, "Air Force Upgrading Defenses at NORAD," *Defense Electronics*, August 1985, p. 98.

17. The azimuth angle is measured from the north.

18. Nicholas Johnson, *Soviet Year in Space, 1989*, p. 105.

19. B.S. Skrebushevsky, *Formirovanie Orbit Kosmicheskikh Apparatov* (Spacecraft Orbits Design) (Moscow: Mashinostroenie, 1990) p. 53. Right ascension of the ascending node is the angle between the vernal equinox, which is a fixed in the inertial space axis, and the ascending node, which is the point where the satellite crosses the Earth's equator passing from south to north.

20. The evolution of an orbit having a constant groundtrack is quite complex and depends on the geographical position of the ascending node; B.S. Skrebushevsky, op. cit., p. 235. The data on the evolution of the orbital periods in this paper were obtained by direct analysis of the orbital elements of the early warning satellites.

21. Orbital parameters of the satellites are distributed by NASA and can be obtained through Celestial BBS, operated by T.S. Kelso.

22. These are Cosmos 775 (launched on 8 October 1975), Cosmos-1546 (29 March 1984), Cosmos-1629 (21 February 1985), Cosmos-1894 (28 October 1987), Cosmos-2133 (14 February 1991), Cosmos-2155 (13 September 1991), Cosmos-2209 (10 September 1992), Cosmos-2224 (17 December 1992); interview with Russian space analyst.

23. Nicholas Johnson, private communication.

24. This shows that the deployment of Trident II missiles was actually a very dangerous development since it might have given the United States a real first strike capability. Had the Cold War continued, this could have seriously undermined strategic

stability.

25. General-Lieutenant V.M. Smirnov, Colonel V.F. Grin'ko, "Sistema preduprezhdeniya o raketnom napadenii: tendentsii i problemy razvitiya," (The Early Warning System: Trends and Problems of Development) *Voennaya Mysl'*, nos. 6–7, 1992, p. 15.