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Reducing a Common Danger
Improving Russia's Early-Warning System

by Geoffrey Forden

Executive Summary

During the past 20 years the world has survived at least four false alerts for nuclear war. Each time, space-based early-warning systems played a major role. In three of the four false alerts, two involving U.S. forces and one Russian forces, reliable space-based sensors assured leaders that they were not under attack when other systems indicated that nuclear annihilation was imminent. In the fourth, in 1983, a relatively new Soviet satellite system falsely indicated that the United States was launching a nuclear attack. All four cases show the importance of both sides' having reliable space-based early-warning systems.

Because of that need, Russia's continuing economic difficulties pose a clear and increasing danger to itself, the world at large, and the United States in particular. Russia no longer has the working fleet of early-warning satellites that reassured its leaders that they were not under attack during the most recent false alert—in 1995 when a scientific research rocket launched from Norway was, for a short time, mistaken for a U.S. nuclear launch. With decaying satellites, the possibility exists that, if a false alert occurs again, Russia might launch its nuclear-tipped missiles.

The Bush administration could help Russia obtain and maintain an effective, economic, and reliable space-based early-warning system in both the short and the long term. Such assistance would improve U.S. security by helping to prevent Russia from mistakenly launching a nuclear attack. The primary measure initiated by the Clinton administration—the Joint Data Exchange Center—is inherently ineffective because the Russians may not believe U.S. early-warning data. Instead, U.S. assistance should be focused on helping Russia to improve its own space-based system. Only then will the Russians have confidence that no U.S. launches have occurred.

Joint early-warning centers can, however, have a stabilizing influence on the tensions among China, India, and Pakistan. New nuclear states run a substantial risk that their nuclear weapons may accidentally explode, perhaps triggering an inadvertent nuclear war. In that case, joint centers—supplying information from the sensors of nations not involved in the conflict (Russia and the United States)—might prevent a tragic accident from escalating into a regional nuclear war.

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Reductions in its military budget have prevented Russia from launching replacements for its early-warning satellites as they age and die.

Introduction

Six years ago, on January 25, 1995, the world lived through what some observers have called the most dangerous moments of the nuclear missile age.[1] Russian radars in Latvia and Lithuania detected a powerful rocket somewhere over the North Sea. The missile's trajectory must have set off all the alarm bells in the Russian nuclear command-and-control center. The missile was following the same trajectory that a U.S. Trident missile would take to mask a massive U.S. nuclear first strike by knocking out Russian detection systems with a high-altitude nuclear airburst. Fortunately, Russian commanders had access to a constellation of early-warning satellites that showed that no U.S. intercontinental ballistic missiles (ICBMs) had been launched from the continental United States. In reality, what was detected was a harmless scientific rocket launched from Norway. That early-warning capability may very well have prevented nuclear annihilation. Unfortunately, if another benign event sets off the nuclear alarm, the Russians no longer have that fleet of satellites to reassure them.

The Clinton administration acknowledged the dangers the shortfalls in Russia's early-warning system pose for the United States, but the administration's opening of a joint early-warning center in Moscow has failed to provide Russia the confidence it needs to not launch a nuclear attack in error. Ukraine, Belarus, and Kazakhstan pose no such dangers because they gave up the nuclear weapons on their soil after the Cold War ended.

Consider what would hypothetically happen if the same false alarm were to occur today: Just after dawn, the single surviving Russian early-warning radar covering Europe and the North Atlantic detects a powerful rocket launched from somewhere off the Norwegian coast. The missile is heading away from Russia toward the polar region, but it has a speed and an altitude similar to those of a Trident missile. Furthermore, several objects have separated from the missile at approximately the same altitude and speed that a Trident would drop its expended first stage and nose cone. Russia has, of course, monitored Trident test flights and incorporated those characteristics into its computer programs. Those programs now project the future course of the missile to see if it represents a possible threat.

Although definitely heading away from Russia, the missile is heading along the same flight corridor that incoming missiles launched from U.S. ICBM fields would take. If the missile is a Trident, it could explode a nuclear warhead in the upper atmosphere—blinding Russia's early-warning and tracking radars. In the parlance of nuclear war, that is a precursor attack. At the start of an actual nuclear war, such a precursor attack would prevent Russia from knowing which of its nuclear forces were being targeted in the initial attack and which U.S. missiles had been launched. Lacking those vital bits of information, Russia could end up holding in reserve missiles that are targeted by the incoming wave of U.S. warheads. Therefore, if Russia believes that a precursor attack has been launched, a strong incentive exists for it to launch its missiles as soon as possible.

Thus, distinguishing a precursor nuclear attack from harmless events is paramount. Yet the same reductions in Russia's military budget that may have contributed to the sinking of the submarine *Kursk* have prevented Russia from launching replacements for its early-warning satellites as they age and die. Russia has had to prioritize its military spending, and such warning systems—in today's climate where the chance of nuclear war with the United States is believed to be considerably reduced—have been given a very low priority. Only two of the fleet of nine early-warning satellites that existed in 1995 are functioning now. For long periods each day, Russia does not know whether or not the United States has launched its land-based ICBMs. Furthermore, the breakup of the Soviet Union has placed most of Russia's early-warning radars on what is now foreign soil. The Latvians—for a variety of reasons, including a need to demonstrate national sovereignty—

dynamited the early-warning radar on their territory in September 1999. That action left in Russia's coverage a gap that Trident missiles can fly through undetected until they explode over Moscow. If U.S.-Russian relations continue to worsen, the United States could be attacked because of those deficiencies in Russia's early-warning system.

With many of its strategic early-warning systems out of commission, Russia is left in the dark except for information from the joint early-warning center in Moscow. Today Russian commanders would need to call a Russian officer manning that center and ask him to look over the shoulder of his American counterpart to see whether the American's computer screen showed any missile launches. But the data shown on the U.S. computer screen—transmitted on a dedicated telephone line directly from the U.S. early-warning center in Cheyenne Mountain—have already been filtered to prevent them from indicating any possible vulnerability in the U.S. early-warning system. The data could just as easily be altered to mask any U.S. ICBM launches.

Would U.S. computer screens showing no evidence of a massive U.S. first strike be enough to convince Russian leaders that they were not under attack? We can only hope so. But there are measures the United States could take that would allow Russia access to reliable early-warning information entirely under its own control. First, the United States might pay for the launch of early-warning satellites that Russia has constructed but apparently cannot afford to put into space.

Another possibility would be for the United States to cooperate with Russia in developing the next generation of early-warning satellites. New sensors developed and tested during the joint research project could allow Russia to deploy far fewer satellites that had much broader coverage than does the current constellation. The Clinton administration, after years of trying to tie that joint venture explicitly to Russian concessions on the Anti–Ballistic Missile Treaty, finally removed that restriction and let the project begin.

Both of those measures involve some sort of financial aid to Russia's military, freeing scarce resources Russia could then use for other military programs that the United States would find undesirable. However, it appears that Russia is not devoting any resources to improving its strategic early-warning systems. If U.S. aid could be directed solely to improving Russia's early-warning system, the money would strengthen U.S. security in much the same way as does U.S. financing of the Cooperative Threat Reduction program (U.S. assistance in securing or dismantling Russian nuclear weapons that could be stolen or sold to terrorists or "rogue" states).

A Brief History of Avoiding Unintended Nuclear Wars

The Cuban missile crisis is the best-known example of narrowly avoiding nuclear war. However, there are at least four other less well-known incidents in which the superpowers geared up for nuclear annihilation. Those incidents differed from the Cuban missile crisis in a significant way: they occurred when either U.S. or Soviet or Russian leaders had to respond to false alarms from nuclear warning systems that malfunctioned or misinterpreted benign events.

All four incidents were very brief, probably lasting less than 10 minutes each. Professional military officers managed most of them. Those officers had to decide whether or not to recommend launching a "retaliatory" strike before possibly losing their own nuclear forces to apparent surpise nuclear first strikes. In three of the four incidents, the decision not to respond to the alarm was made when space-based early-warning sensors failed to show signs of massive nuclear attacks. The fourth incident was caused by an inadequate early-warning satellite system that was fooled into thinking that reflected sunlight was the flames from a handful of ICBMs.

As the brief history of those four incidents makes clear, space-based early-warning systems played a major role in avoiding nuclear

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war. During the 1980s, a few specialized articles in the media hinted at the presence of those systems. However, it was only during the Gulf War that the American public truly became aware of U.S. capability to detect missile launches using space-based assets. During that crisis, U.S. Defense Support Program satellites, first orbited in 1970, detected the launch of every Iraqi Scud missile. The satellites made the detections from their orbits by "seeing" the infrared light that the missiles' motors gave off during powered flight. The warning of launches was transmitted to Patriot air defense missile batteries in Israel and Saudi Arabia to support attempts to shoot down the incoming warheads. The association with the fighting of conventional war has obscured the more important strategic role those systems have played: reassuring leaders of the United States and Russia that they were not under nuclear attack. A review of the four nuclear crises will better highlight that role.

The Training Tape Incident

Shortly before 9 a.m. on November 9, 1979, the computers at North American Aerospace Defense Command's Cheyenne Mountain site, the Pentagon's National Military Command Center, and the Alternate National Military Command Center in Fort Ritchie, Maryland, all showed what the United States feared most—a massive Soviet nuclear strike aimed at destroying the U.S. command system and nuclear forces. A threat assessment conference, involving senior officers at all three command posts, was convened immediately. Launch control centers for Minuteman missiles, buried deep below the prairie grass in the American West, received preliminary warning that the United States was under a massive nuclear attack.

The alert did not stop with the U.S. ICBM force. The entire continental air defense interceptor force was put on alert, and at least 10 fighters took off. Furthermore, the National Emergency Airborne Command Post, the president's "doomsday plane," was also launched, but without the president on board.[2] It was later determined that a realistic training tape had been inadvertently inserted into the computer running the nation's early-warning programs.

However, within minutes of the original alert, the officers had reviewed the raw data from the DSP satellites and checked with the early-warning radars ringing the country. The radars were capable of spotting missiles launched from submarines close to the U.S. shores and ICBM warheads that had traveled far enough along their trajectories to rise above the curvature of the earth. The DSP satellites were capable of detecting the launches of Soviet missiles almost anywhere on the earth's surface. Neither system showed any signs that the country was under attack, so the alert was canceled.

The Computer Chip Incident

On June 3, 1980, less than a year after the incident involving the training tape, U.S. command posts received another warning that the Soviet Union had launched a nuclear strike.[3] As in the earlier episode, launch crews for Minuteman missiles were given preliminary launch warnings, and bomber crews manned their aircraft. This time, however, the displays did not present a recognizable or even a consistent attack pattern as they had during the training tape episode. Instead, the displays showed a seemingly random number of attacking missiles. The displays would show that two missiles had been launched, then zero missiles, and then 200 missiles. Furthermore, the numbers of attacking missiles displayed in the different command posts did not always agree.

Although many officers did not take this event as seriously as the incident of the previous November, the threat assessment conference still convened to evaluate the possibility that the attack was real. Again the committee reviewed the raw data from the early-warning systems and found that no missiles had been launched. Later investigations showed that a single computer chip failure had caused random numbers of attacking missiles to be displayed.

The Autumn Equinox Incident

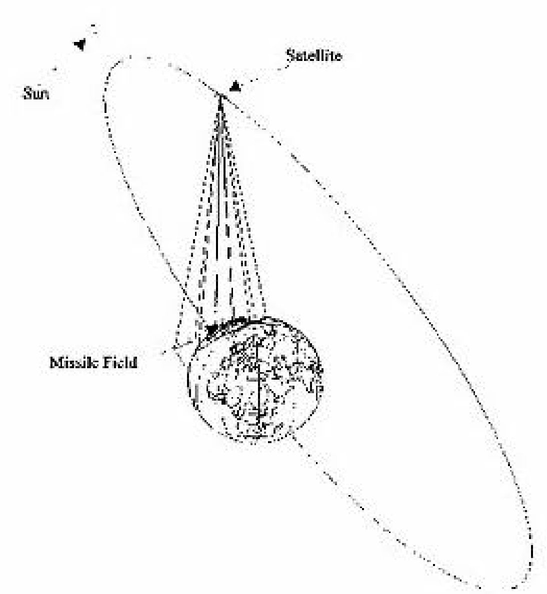
On September 26, 1983, the newly inaugurated Soviet early-warning satellite system caused a nuclear false alarm. Like the United States, the Soviet Union realized the importance of monitoring the actual launch of ICBMs. However, the Soviets chose a different method of spotting missile launches. Instead of looking down on the entire earth's surface the way U.S. DSP satellites do, Soviet satellites looked at the edge of the earth—thus reducing the chance that naturally occurring phenomena would look like missile launches. Missiles, when they had risen 5 or 10 miles, would appear silhouetted against the black background of space. Furthermore, when the edge of the earth is viewed, light reflected from clouds or snow banks has to pass through a considerable amount of the atmosphere. That view reduces the chances that clouds and snow may cause false alarms.

A satellite has to be in a unique position to view a recently launched missile silhouetted against the black of space. To get that view, the Soviet Union picked a special type of orbit that it had used for its communications satellites. Those orbits, known as Molnyia orbits, come very close to the earth in the Southern Hemisphere but extend nearly a tenth of the distance to the moon as the satellite passes over the Northern Hemisphere. From that position high above northern Europe, the Soviet Union's Oko (or Eye) early-warning satellites spend a large fraction of their time viewing the continental U.S. missile fields at just the right glancing angle. However, shortly after midnight Moscow time on September 26, 1983, the sun, the satellite, and U.S. missile fields all lined up in such a way as to maximize the sunlight reflected from high-altitude clouds (Figure 1).

Whether that effect was a totally unexpected phenomenon is hard to know. That may have been the first time this rare alignment had occurred since the system became operational the previous year. Press interviews with Lt. Col. Stanislav Petrov, the offi-

That Norwegian scientific rocket incident caused a dangerous moment in the nuclear age.

Figure 1
A Russian Oko Early-Warning Satellite's Hypothesized View of the U.S. Missile Fields at the Time of the Autumn Equinox Incident



Source: The satellite's position was determined using orbital parameters supplied by the National Aeronautics and Space Administration.

cer in charge of Serpukhov-15, the secret bunker from which the Soviet Union monitored its early-warning satellites, indicated that the new system reported the launch of several missiles from the U.S. continental missile fields.[4] Petrov had been told repeatedly that the United States would launch a massive nuclear strike designed to overwhelm Soviet forces in a single strike.

Why did that false alarm fail to trigger a nuclear war? Perhaps the Russian command did not want to start a war on the basis of data from a new and unique system. On the other hand, if the sun glint had caused the system to report hundreds of missile launches, then the Soviet Union might have mistakenly launched its missiles. Petrov said that he refused to pass the alert to his superiors because "when people start a war, they don't start it with only five missiles. You can do little damage with just five missiles."[5]

The Norwegian Rocket Incident

Early on the morning of January 25, 1995, Norwegian scientists and their American colleagues launched the largest sounding rocket ever from Andoya Island off the coast of Norway. Designed to study the northern lights, the rocket followed a trajectory to nearly 1,500 kilometers altitude but away from the Russian Federation (Figure 2). As discussed above, the flight appeared similar to one that a U.S. Trident missile would take to blind Russian radars by detonating a nuclear warhead high in the atmosphere.

That scientific rocket caused a dangerous moment in the nuclear age. Russia was poised, for a few moments at least, to launch a full-scale nuclear attack on the United States. In fact, President Boris Yeltsin stated the next day that he had activated his "nuclear football"—a device that allows the Russian president to communicate with his top military advisers and review the situation online—for the first time.

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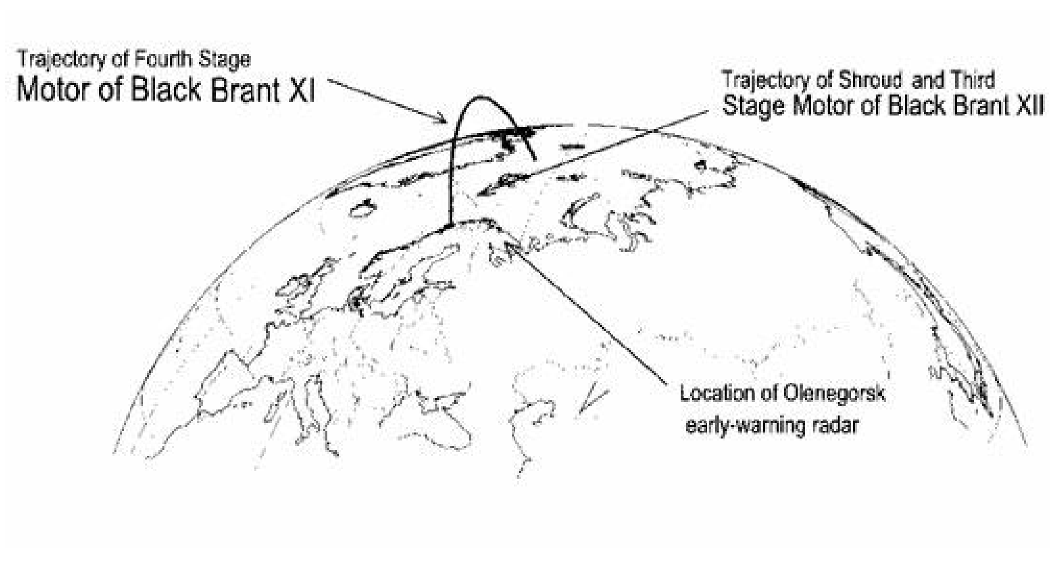
However, we can be fairly confident that Yeltsin's football showed that Russia was not under attack and that the Russian early-

Figure 2
Trajectory of the Black Brant XII Sounding Rocket, Which Set Off the Norwegian Missile Incident



Source: Author's calculations of the trajectory from radar tracking information supplied by the National Aeronautics and Space Administration.

warning system was functioning perfectly. In addition to the string of radars surrounding the border of the former Soviet Union, Russia had inherited a complete fleet of early-warning satellites that, even by 1995, still maintained continuous 24-hour coverage of the U.S. continental missile fields. In the early 1990s Russia had still managed to launch replacement satellites for its early-warning system as the previous ones died out—thereby retaining continuous coverage. Because of those satellites, Yeltsin's display must have shown that no massive attack was lurking just below the horizon.

Reliable Early-Warning Coverage Benefits Both Countries

The danger posed by those incidents was not the unauthorized or accidental launch of a handful of nuclear-tipped missiles but the possibility that either country might misinterpret a benign event—a computer training tape mistakenly inserted into an operational computer or sunlight glinting off clouds during a rare lineup of the sun, earth, and satellite—and decide to launch a full-scale nuclear attack.

Each incident caused officials to take steps to solve a specific problem. After the training tape incident, the U.S. Department of Defense constructed a separate facility to train operators so that a training tape could not again be inserted into the computer running the nation's early-warning system. Apparently, the Soviet Union launched a new fleet of early-warning satellites in geostationary orbit simply to provide a second angle from which to view U.S. missile fields. That expensive and redundant system ensured that at least one satellite could search for missile launches free from sun glint.

After three of the four incidents, the U.S. government maintained that steps were taken that would prevent any future false alarms. However, it had to wait only seven months after the first incident (the computer tape incident) to see that complex organizations, relying on even more complex machinery, can find new and unexpected ways to fail. In fact, a comprehensive study of nuclear accidents has shown convincing historical evidence that, despite measures taken to prevent them, such accidents are inevitable.[6]

The most recent example of solving the "last problem" was the Clinton administration's initiative to share early-warning data with Russia. The jointly manned center has been presented by the American side as a solution to the decline of Russia's early-warning facilities. Russians familiar with the negotiations, however, maintain that the center has no military significance. That view is underscored by the choice of the site for the center: an old schoolhouse nearly an hour away from downtown Moscow. In fact, U.S. Department of Defense officials familiar with the Joint Data Exchange Center admit that, even if the center had been active during the Norwegian rocket incident, its only effect would have been to facilitate the launch notification issued before the NASA launch.

Any assistance the United States provides must increase Russia's confidence in the validity of its own early-warning systems. The JDEC fails that test. Russia would never believe that the United States would pass along launch indications if a U.S. nuclear attack had been launched. However, to determine what U.S. assistance would actually help improve the Russian early-warning system, an understanding of the system itself is needed.

Despite measures taken to prevent them, accidents are inevitable.

An Overview of the Russian Early-Warning System

As they raced for primacy in ballistic missiles, both sides of the Cold War sought reliable, long-range early-warning systems. Prior to the missile age, the Soviet Union's ground-based air defense radars, with ranges of around 550 kilometers, provided sufficient warning of the relatively slow-moving strategic bombers deployed by both sides in the 1950s. Those radars were capable of giving several hours warning of

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incoming bombers but could give only one or two minutes warning of incoming ballistic missiles—if the radars saw the missiles at all. The next decades saw both countries make rapid improvements in the range and resolution of radars and undertake expensive programs to increase their numbers. But, ultimately, both the United States and the Soviet Union turned to space-based sensors to give the maximum amount of warning time.

Soviet Early-Warning Radars

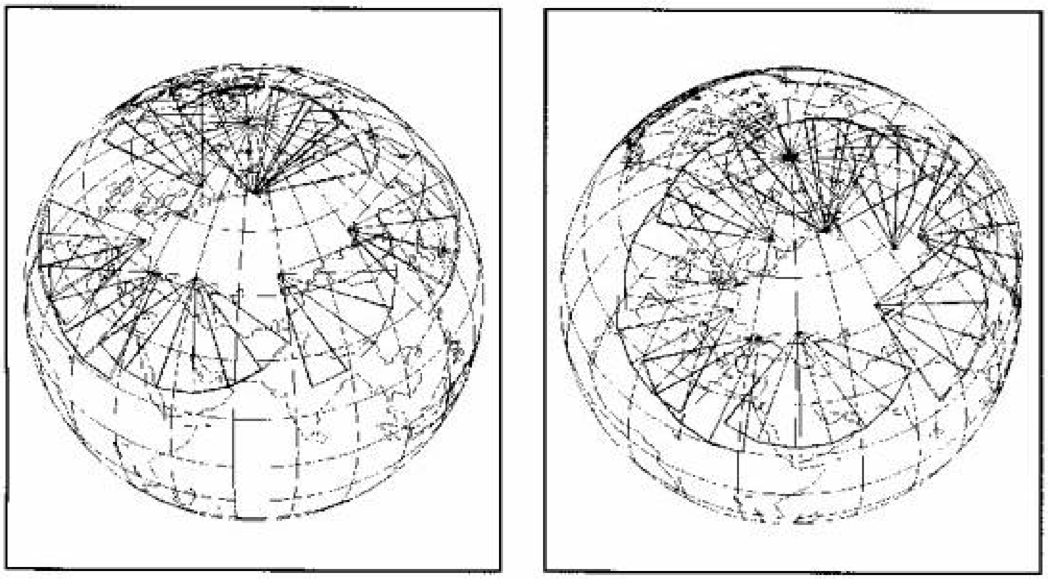
In 1957 the West first became aware of the Soviet Union's long-range radars when a U2 spy plane photographed the Sary Shagan missile test range in Kazakhstan.[7] The radar facility photographed on that flight was the prototype for the "Hen House" radar, which had a range of 6,000 kilometers. (The West referred to this system as Hen House presumably because the long buildings that supported the antennas were reminiscent of chicken coops.) By 1964 the Soviet Union had added four more Hen House radars—two looking toward China and the Pacific and two scanning the attack corridors of U.S. ICBMs and submarine-launched ballistic missiles (SLBMs). Those systems could spot SLBMs soon after launch but would have to wait until the warhead from an ICBM appeared above the horizon. That time period could be anywhere from 10 to 15 minutes—vital decisionmaking time that either country lost when using that type of radar from within its own borders. In 1960 the United States started positioning its radars—the Ballistic Missile Early-Warning Systems—in Canada, Greenland, and England, an option not available to the Soviet Union.

Both sides launched high-priority research and development projects to try to increase their warning time of missile launches. One avenue for extending the range of radars is to use special radio frequencies that bend around the earth's surface.[8] That type of radar is known as "over-the-horizon" radar. In 1971, when it opened a facility in Belarus, the Soviet Union started operating its first over-the-horizon radar aimed at the U.S. ICBM fields. Such radars sacrifice the ability to measure distances accurately and are more susceptible than regular radars to atmospheric disturbances such as the northern lights. In 1973, to try to compensate for those deficiencies, the Soviets constructed a second over-the-horizon radar on the eastern edge of their country. They obviously hoped that one or the other radar could always look around the electronic noise associated with the polar region. However, by 1990 that system proved inadequate and the Soviet Union abandoned over-the-horizon radar for long-range missile surveillance.

By then, the Soviet Union had already started to move its warning systems into space. However, the Soviets still had a use for powerful strategic radars. But by 1978 the Soviets were more interested in the resolution of the radars and were willing to sacrifice distance for improved tracking ability. In that year they started to replace the aging Hen House radars with a newer design. Those high-resolution tracking radars became known in the West as Pechora-type radars—named after the Russian town near which the first one appeared.

Pechora-type radars operate in a range of the radio spectrum ideal for detecting and tracking incoming warheads. An unintended consequence of that choice of radio frequency is that the radars are unusually susceptible to being blinded by nuclear bombs exploded high in the upper atmosphere—the "precursor" attack that must have been a principal concern during the Norwegian rocket incident in 1995. But the improved tracking capability of those radars, which the Soviet Union intended to install in a ring around the country, has two important applications. First, it can be used for ballistic missile defense. In fact, the United States protested vigorously when the Soviet Union started to construct a Pechora-type radar in Krasnoyarsk province. The Krasnoyarsk site was a considerable distance inside Soviet borders—a clear violation of the 1972 ABM treaty. The other nine Pechora-type radars were constructed on the periphery of the Soviet Union and were permissible under the ABM treaty. The original planned coverage of the Soviet Union's Pechora-type radars and the actual cov-

Figure 3
Planned and Actual Coverage of the Soviet Union's Pechora-Type Radar Stations



Source: Theodore Postol, Massachusetts Institute of Technology, personal communication.

erage today are shown in Figure 3.

Second, the improved tracking capabilities of the Pechora-type radars gave the Soviets the ability to assess an actual attack. That assessment involves projecting the paths of the incoming warheads toward their intended targets and backtracking the missiles' flight to their launch silos. Such projecting allows military commanders to know which of their own nuclear missiles are in danger from the first wave of incoming warheads. Backtracking the incoming warheads could, in principle, allow the Soviets to re-aim warheads previously aimed at now-empty U.S. silos. Thus the Soviets could avoid wasting missiles on those silos. However, even Pechora-type radars would not be very accurate at backtracking the warheads because of uncertainties in missile maneuvers below the radar's horizon.

The Soviets' chain of Pechora-type radars was never completed. Protests by the United States had the effect of halting the construction of the Krasnoyarsk radar. In fact, since the fall of communism, Russian leaders have admitted that its construction was a violation of the ABM treaty.

Adding to Russia's problems with early warning, several of the Pechora-type radars that were constructed on the periphery of the Soviet Union are now situated in the newly independent states. That situation has been a source of conflict been the Russian Federation and those new nations. In fact, Latvia dynamited the early-warning radar facilities on its territory on September 1, 1998—creating a second large gap in Russia's radar fence. Russia must worry that the gap could serve as a new attack corridor for U.S. Trident II missiles. The gap also contributes to the imperative to respond quickly to perceived threats.

Early-Warning Systems Move into Space

The atmospheric difficulties encountered by the over-the-horizon radars helped drive both countries to investigate space-based systems. For instance, in 1970 the United States abandoned its over-the-horizon radar efforts when it started to deploy geostationary early-warning satellites. Those DSP satellites were actually the second generation of U.S. space-based missile detection systems. The United States first attempted in 1960 to orbit an infrared-sensitive missile launch detection satellite, named the Missile Detection and Alarm System. Those satellites in low orbit reportedly used infrared-sensitive television-

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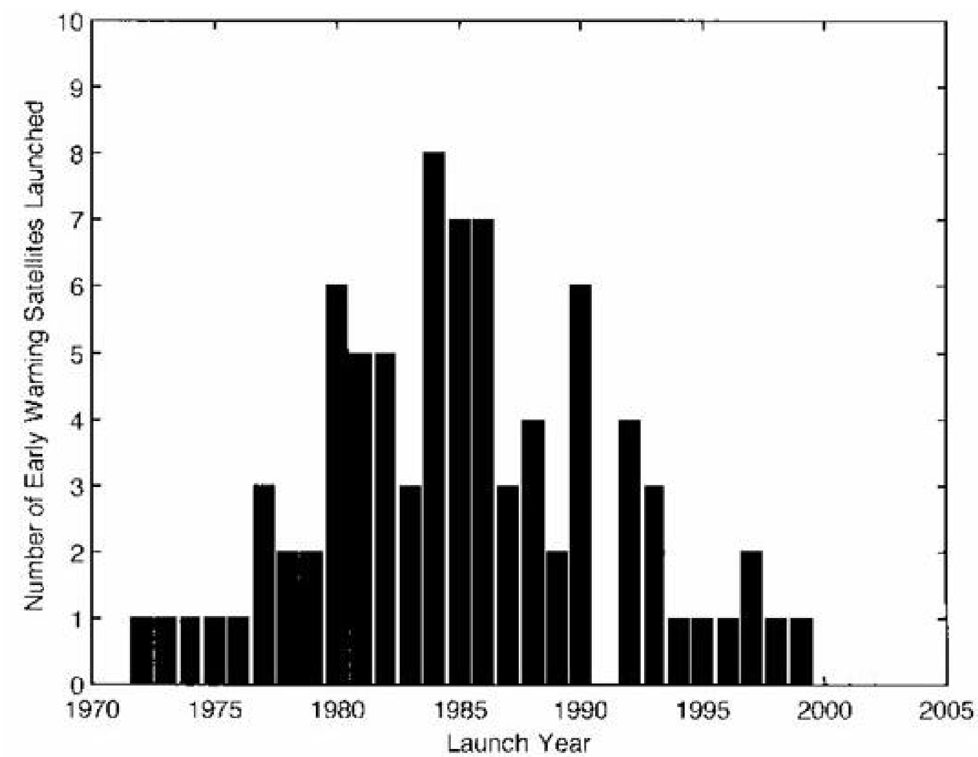
style cameras. However, because those cameras had very serious difficulties distinguishing actual missile launches from naturally occurring phenomena, the program was abandoned in 1962.

In the 1970s the Soviet Union also started research on space-based early-warning satellites. Initial efforts were focused both on television-style cameras similar to the failed MIDAS satellites and on primitive solid-state detectors along the lines of those used in the DSP program. However, the Soviet television-style detectors were abandoned before the system was operationally deployed. But producing space-qualified, solid-state detectors requires a number of well-developed high-tech industries, such as producers of high-purity silicon wafers and high-precision photolithography, and proficient microassembly industries. At the time, the Soviet Union was struggling with all those processes. Russian expatriates familiar with the Soviet early-warning satellite programs have stated that the solid-state sensors tested on those early flights were about 50 pixels long. In contrast, some experts believe that the first U.S. DSP satellites had infrared sensors nearly 1,000 pixels long.

Those relative detector sizes have had an extraordinary effect on how each country has used its satellites and on their ultimate capabilities. With detectors 1,000 pixels long, the United States was able to scan the earth's entire visible surface from geostationary orbit and segment it into squares one kilometer on a side. Thus, the system had to distinguish the light of a missile's plume only from the light reflected from clouds, ice, or snow in one square kilometer. If the Soviets had tried to view the entire surface of the earth, they would have needed to distinguish

Figure 4
Satellites Launched into Highly Elliptical Orbit



Source: Paul Podvig, Moscow Institute of Physics and Technology, personal communication.

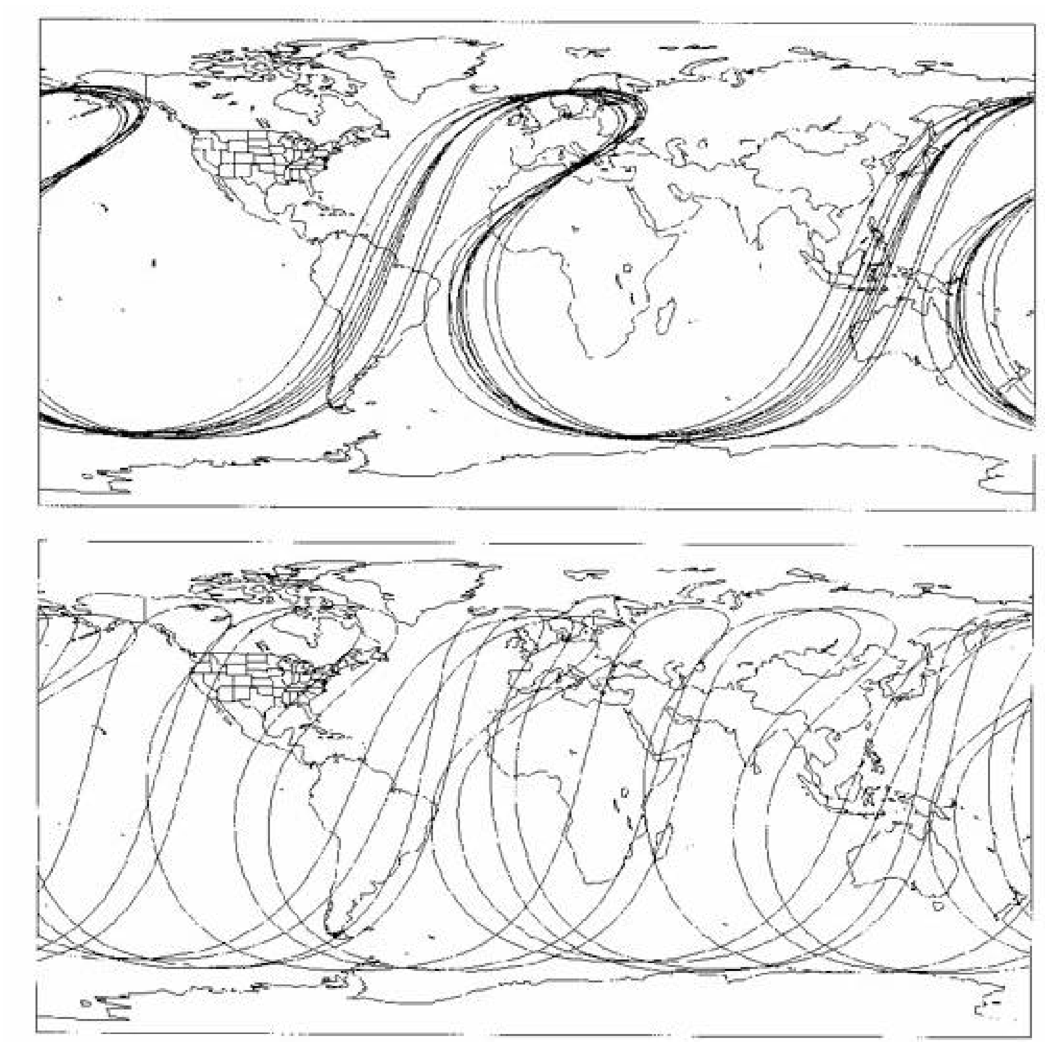
Note: The first three launches are believed to have been satellites without operational sensors.

the missile's plume from light reflected from more than 14,000 square kilometers of clouds—clearly a more difficult problem.

Faced with that problem, the Soviet Union traded global coverage, with a high chance of false alarms, for very limited coverage of highly sensitive areas—the U.S. continental missile fields—with a significantly reduced chance of false alarms. (Of course, the autumn equinox incident discussed above showed that there was still room for error.) To accomplish that objective, the Soviets positioned their satellites in so-called Molnyia orbits so that they viewed the areas of interest at a glancing angle. Thus, a U.S. missile would appear to be silhouetted

The autumn equinox incident showed that there was still room for error.

Figure 5
Orbits of Russia's Early-Warning Satellites in 1995 (top) and Today (bottom)



Source: The author calculated these ground traces using orbital parameters supplied by the National Aeronautics and Space Administration.

Since 1995 the constellation of Russian early-warning satellites has deteriorated significantly.

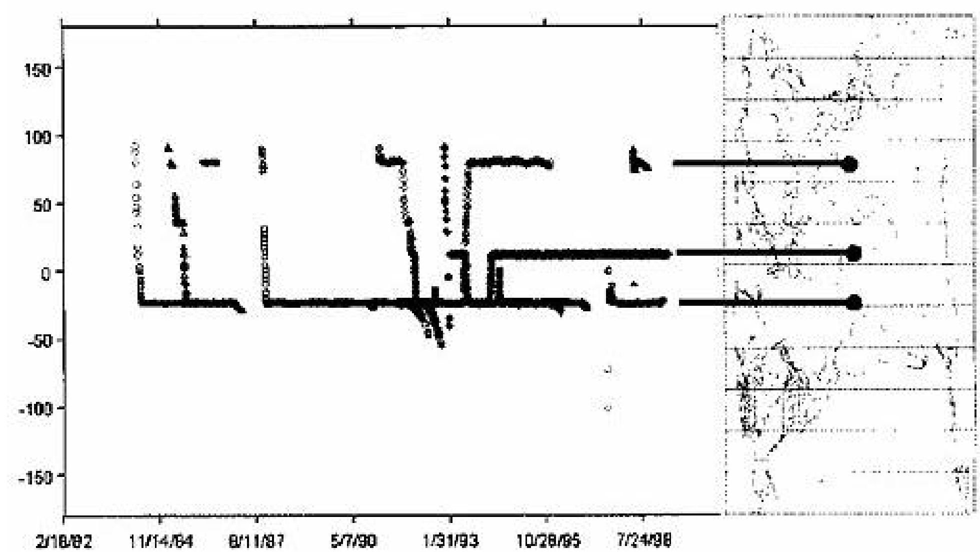
against the black background of space.

Pioneered by the Soviets, the Molnyia orbit is a highly elongated trajectory with a point closest to the earth just 2,000 kilometers over the Southern Hemisphere. But the orbit's highest point—where a satellite spends most of its time—is more than 36,000 kilometers above northern Europe. Soviet communication satellites, by contrast, had their highest points over the Soviet Union to facilitate ground-to-satellite-to-ground communications.

In 1984 the launches of early-warning satellites into those highly elliptical orbits reached a peak of eight in one year (Figure 4). A modest decrease in numbers of launches per year subsequently occurred. However, in 1995 the Soviets were still managing to maintain nine working satellites in orbit. Presumably, an increase in satellite lifetime meant that fewer launches were needed. Russian scientists working on this project have indicated that that type of satellite now has a lifetime of around three years.

Since 1995, however, the constellation of Russian early-warning satellites has deteriorated significantly. Russia had a full complement of those satellites during the 1995 Norwegian rocket incident. Since then, Russia has not replaced satellites often enough to maintain complete 24-hour coverage. In fact, assuming every satellite—even those that have drifted far from their optimal orbits—is still working, Russian coverage has dropped to less than 17 hours per day. In reality, the coverage is probably considerably less. After all, Russia, and the Soviet Union before it, went to considerable effort to almost daily realign their early-warning satellites into a very precise formation to maintain the best surveillance of U.S. nuclear forces. Today, the satellites have been allowed

Figure 6
History of Russia's Geostationary Early-Warning Satellites' Longitude



Source: The author derived this plot from orbital parameters supplied by the National Aeronautics and Space Administration.

Note: The Soviets, and then the Russians, occasionally moved satellites. They did this most often to keep the position over the mid-Atlantic occupied. When a satellite stops actively keeping station, it is removed from this plot.

to drift far from those optimal orbits, presumably because they no longer function. (See Figure 5, which shows the orbits of Russia's early-warning satellites in 1995 and today.)

Early-Warning Satellites in Geostationary Orbit

The Soviet Union was very aware of the advantages of putting sensors in geostationary orbit. Such orbits are so high that satellites in them take 24 hours to circle the earth—appearing fixed over the same spot on the earth's surface. Placing an early-warning satellite over the mid-Atlantic would allow a single satellite to constantly observe U.S. continental missile fields at a glancing angle—as opposed to the nine satellites the Soviet Union planned for the highly elliptical orbits previously discussed.

Reportedly, the Soviet Union first tested an early-warning satellite in geostationary orbit in 1975. However, that Soviet satellite lasted only a few months and then drifted off orbit because of the natural perturbations in the earth's gravitational field.

When the Soviets launched another satellite in 1984, they again placed it over the mid-Atlantic. In fact, that position was the Soviet Union's, and is now the Russian Federation's, highest priority position. The Russians have kept this slot nearly continuously occupied since that time. Furthermore, they have moved working early-warning satellites from other slots to the one over the mid-Atlantic when the satellite occupying that slot failed. (See Figure 6 for evidence of that movement.)

"Slots" in geostationary orbits are regulated by the International Telecommunications Union. Otherwise, radio interference would occur between satellites if they were too close together and used the same radio frequencies. Also, command signals might be sent to the wrong satellite. To avoid that problem, geostationary satellites are spread out in space. Furthermore, radio frequency bands are allocated to different purposes—from civilian communications to astrophysics research to military uses. The Soviet Union claimed eight slots for early-warning purposes, but it has not used them all. An analysis by Theodore Postol of the Massachusetts Institute of Technology showed that all of those slots were situated so that satellites in them could view important regions, such as Western Europe, China, or the United States, at glancing angles.[9] None of them is directly over the United States—indicating that the Soviets did not give a high priority to looking directly down on the earth's surface.

Did Technology Drive Doctrine, or Did Doctrine Drive Technology?

Why did the Soviet Union, and now Russia, place such a high priority on geostationary satellites over the mid-Atlantic when they had another fleet of early-warning satellites also viewing the United States? The timing of the first operational launch of a satellite into geostationary orbit gives an important clue. The first launch was just a year after the autumn equinox incident—when sunlight reflecting off high-altitude clouds caused a false alarm. A reasonable inference is that the Soviet early-warning establishment was concerned about repeats of such an incident and decided to place a satellite in an orbit that provided a view of the U.S. missile fields from a totally different angle. Sunlight could affect only one of the two satellite constellations at any given time. That might explain why the Russians have kept such an expensive duplicate system running. This theory is bolstered by reports in the West that the first Soviet early-warning satellite in geostationary orbit had exactly the same design as the ones already in highly elliptical orbits.

There have been reports that a second generation of early-warning satellites, designed to be capable of looking down on the surface of the earth, is now being launched into orbit. However, conversations with Russian space scientists familiar with those satellites indicate that the satellites have only a very restricted view. In fact, some Western analyses have estimated that a single new-generation satellite might be able to view an area only the size of the North Atlantic. In discussions with the author, the Russian scientists maintained that

If another false alarm occurs, Russia will be less confident that it is not under attack.

the satellites do not have to view the entire earth's surface. Instead, they state that Russian doctrine is to view only those areas from which the Russians believe a U.S. missile might be launched.

Those areas of interest include the continental United States and parts of the Pacific and Atlantic known to be Trident submarine patrol areas. However, Trident submarines are capable of launching attacks on Moscow and elsewhere in Russia almost as soon as they leave port. That capability makes the needed surveillance area far wider than the area the Russian early-warning satellites can view at any given time.

The doctrine of expecting only massive nuclear attacks, which would include attacks by U.S. land-based ICBMs, was possibly valid during much of the Cold War. However, the doctrine is becoming increasingly untenable as submarine-launched missiles make up a large fraction of U.S. nuclear forces. Under the START II framework, the number of U.S. land-based warheads will decline because multiple warheads on land-based missiles have been eliminated. Furthermore, U.S. improvements in conventional precision-guided weapons also reduce the need for the United States to launch its ICBMs during a nuclear attack.

If another false alarm occurs, all those factors will make Russia less confident that it is not under attack.

The history of nuclear false alerts shows that either Russia or the United States can be tricked by a benign event into suspecting that the other nation has launched a nuclear attack.

Potential U.S. Assistance for the Russian Early-Warning System

The history of nuclear false alerts shows that either Russia or the United States can be tricked by a benign event into suspecting that the other nation has launched a nuclear attack. So far, global space-based missile surveillance systems have boosted the confidence of military leaders that they were not under attack. Without that confidence, they might have mistakenly recommended starting a nuclear war. Therefore, the common interest of both the United States and Russia is to ensure that the other has access to reliable early-warning information.

Today Russia's early-warning system is falling apart. The system provides far less than 24-hour coverage of the continental U.S. missile fields. If some benign event triggers a Russian nuclear alert, Russia's leaders will not have the same confidence that they had during the 1995 Norwegian rocket incident that a real attack is not under way. During some possible future period of tension between the United States and Russia, they might launch a nuclear attack if an equally benign event caused them to go on alert. In fact, the expansion of NATO and U.S. plans to deploy national missile defense systems has ratcheted tensions higher than they were in 1995. It is possible that just helping the Russians overcome their early-warning problems might ease tensions somewhat.

A number of alternatives are available for improving Russia's access to early-warning information. Economic difficulties that Russia has faced over the last decade prevent it from having a reliable early-warning system. Short-term solutions should focus on overcoming those financial difficulties. However, technological difficulties drove the Soviet Union, and now Russia, to choose methods that reduced false alarms at the price of limiting coverage. The choices the Soviet Union made in overcoming those technological shortcomings have produced a system that is inefficient and expensive to maintain and lacks global coverage. Because global coverage will become increasingly important, long-term solutions should focus on technological cooperation that produces cost-effective systems to provide such coverage.

Joint Data Exchange Centers Do Not Address the Problem

During a presidential summit in September 1998, the Clinton administration initiated cooperation with the Russian government on a program of shared early warning. The program that has evolved, however, does not address Russia's need for reliable early-warning information. Instead, the program provides a room in which filtered early-warning data from both countries' warning systems can be displayed on computer screens. Members of the Russian team can look over the shoulders of their American counterparts to see what is being shown on U.S. computer screens. The U.S. participants can do the same to see what is on the Russian computer screens. Because Russia would not have confidence that an attack was not under way during periods of tension, that method of cooperation is the least satisfactory.

As noted earlier, the Russians believe that the joint center has no direct military value. More important, the JDEC does not have a direct input into Russia's command-and-control system.

Pay for Launching Russia's Existing Satellites

Russia has undergone at least a decade of financial difficulties. Some economic analysts argue that Russia is functioning in a "virtual economy." The only companies making a profit are those that can sell natural resources for hard cash to foreign buyers.[11] Internal economies are run on a barter system, and most businesses avoid paying taxes whenever they can. The reduced tax base has produced shrinking military budgets and an obvious reordering of priorities in military programs. For instance, during the recent crisis surrounding the sinking of the *Kursk* submarine, it became known that Russia had phased out its submarine rescue operations. Also, some analysts suspect that reduced operating funds led directly or indirectly to the sinking itself.

The Russian early-warning system has also suffered during this prolonged economic crisis. The fleet of early-warning satellites has been allowed to fall far below the number needed to maintain complete 24-hour coverage. According to Russian space scientists, six completed early-warning satellites sit on the ground waiting for launch into space. The scientists note that the Russian government cannot afford to launch those satellites because many other military programs have higher priority.

The U.S. government could pay for the launching of those satellites. The launch services for five additional satellites—the minimum needed to give Russia 24-hour coverage of the continental U.S. missile fields—would cost roughly $160 million.[12] This option has the advantage of using Russia's own satellites—in which Russia has complete confidence. Also, no risk exists of revealing any information about the U.S. early-warning system that the U.S. government might consider sensitive.

Unfortunately, this option does not address Russia's long-term early-warning problem. Russia's existing satellites—even if they are launched and do reestablish 24-hour coverage—can only detect missiles launched from a small part of the earth's surface. In the future, as a larger fraction of the U.S. nuclear force is deployed on submarines, Russia will need a more global system.

Also, some observers might consider it inappropriate for the United States to fund a Russian military project. They could argue that Russia has enough resources to launch those satellites if only a higher priority were assigned to doing so. Furthermore, as evidence that enough resources exist, they could point to the continuing development of advanced Russian ICBMs, such as the SS-27. The Casey Institute of the Center for Security Policy insists that no U.S. tax dollars be made available to Russia as long as it is modernizing its strategic forces.[13]

However, the advantage to the United States of improving Russia's access to early-warning information—reducing the likelihood of an inadvertent nuclear war—outweighs any assistance it might give to Russia's war-fighting capabilities. The satellite systems in question simply do not have the precision tracking needed to make a quantitative difference in a nuclear war. (This is precisely the reason that helping to rebuild Russia's early-warning radar fence is not recommended.)

The United States has an interest in Russia's having complete 24-hour coverage regardless of whether Russia makes concessions on the ABM treaty.

The benefits to the United States of Russia's having a complete ground-based radar system do not justify the costs.

The Clinton administration also appeared reluctant to provide financial assistance for launching Russia's existing satellites. After the Congressional Budget Office's second report to Sen. Tom Daschle (D-S.D.) outlining that option, the Clinton administration did offer to pay for the launch of those satellites. When the administration did so, it made U.S. financial assistance contingent on Russia's acceptance of modifications of the ABM treaty. Russia, however, has demonstrated that other projects have a higher priority than continuous early warning. Russia is unlikely to decide to reverse its objections to the U.S. national missile defense simply to get those satellites launched. On the other hand, the United States has an interest in Russia's having complete 24-hour coverage regardless of whether Russia makes concessions on the ABM treaty.

Assistance for Long-Term Improvement

Future Russian early-warning systems must both be cost effective and provide global coverage. Those requirements suggest a system of three geostationary satellites, each of which is capable of scanning the entire visible surface of the earth from its orbit. Each satellite, however, must also avoid being blinded or tricked by reflected sunlight—the reason for Russia's expensive and seemingly redundant early-warning satellite fleets.

U.S. assistance to Russia's future early-warning system should focus on two aspects. First, we should continue our joint research effort with Russia—known as the Russian-American Observation Satellites project. RAMOS has had a long and stormy history. The program started out in 1992 as an effort to engage Russia in missile defense research—a goal to which it continues to contribute. But some of the research also has significant implications for reducing the costs of Russia's early-warning system.

One goal of RAMOS is to test a new way of filtering out reflected sunlight. If that line of inquiry is fruitful, as many scientists believe it will be, Russia and the United States will be able to deploy satellites that are no longer sensitive to reflected light, so the Russians will no longer need early-warning satellites in highly elliptical orbits. Instead, a single satellite in geostationary orbit over the Atlantic would give them all the ability that 10 do today. Relying on three such satellites would result in global coverage, considerable cost savings, and presumably allow Russia to better maintain its own satellites.

About $340 million would be needed to complete the RAMOS project. However, the United States gets considerably more than just the vital improvement in Russia's early-warning system. The research being done by RAMOS could directly contribute to improvements in the troubled Space-Based Infrared System—a low-satellite program that is a component of the U.S. national missile defense system. Furthermore, Russia has agreed to launch some tactical missiles for RAMOS satellites to observe; those observations should provide valuable data that the United States can use for its theater missile defenses.

After several years of tying U.S. assistance on RAMOS to Russian concessions on the ABM treaty, the Clinton administration wisely decided to remove that requirement. Unfortunately, the administration viewed the project as little more than foreign aid. RAMOS can contribute significantly to alleviating the common danger only if its scientific results are fully exploited. But scientific exploitation funds for the RAMOS program have been cut drastically. The funding is less than a sixth of what a previous space-based sensor research program spent on science-related activities. For instance, millions were spent on collecting data during a preliminary RAMOS aircraft experiment, but no money has been allocated for analyzing those data. If the trend continues, the United States will have squandered hundreds of millions of dollars for RAMOS and an excellent chance to improve its own long-term security.

A second way to help Russia's next-generation early-warning system would be to allow Russia to import sensors and other components for its satellites from the West. Those components do not need to be state of the art. In 1970 the United States was able to scan the earth's surface with large, solid-state infrared detectors that were sensitive enough. Since then, U.S. satellites have progressed to more sophisticated technologies. Nevertheless, Russia would still benefit from importing a limited number of sensors with older technology. But to allow such sales, Western export control laws would have to be modified to permit the transfer of that technology.

Russia already has the scientific and technological know-how to manufacture those older components. What the Russians lack is the industrial base needed to make space-qualified components. Western exports of the components would not increase Russia's manufacturing capabilities, which might then be used for other less-desirable military purposes. Instead, allowing Russia to import a limited number of solid-state detectors and space-qualified computers would merely bypass Russia's decaying industrial base. In other words, both of the suggested avenues of assistance are basically financial assistance.

Why We Should Not Help Rebuild Russia's Radars

Some observers might argue that the United States should assist Russia in rebuilding its ground-based early-warning radar systems. That perimeter of radars has an increasing number of gaps and will probably deteriorate further if more of the newly independent states decide they will no longer host a Russian presence on their soil. Although proponents of U.S. assistance for such an undertaking could argue that the aid would provide additional confidence that Russia was not under attack, the benefits to the United States of Russia'a having a complete ground-based radar system do not justify the costs.

Completing the radar system would provide Russia with a marginal increase in confidence that no nuclear attack was under way, but it would not give the global coverage needed to justify U.S. assistance in the long term. Nor would it provide the narrowly focused coverage of U.S. ICBM fields needed in the short term. Finally, the Russian radar systems have too much of a war-fighting capability to warrant U.S. assistance.

Instead, the Bush administration should assist Russia in launching its existing early-warning satellites in order to fill Russia's short-term early-warning gap. Also, the United States should engage Russia in developing a next-generation early-warning satellite, one that would be more cost-effective to operate. These steps would improve U.S. security by reducing the chances of an inadvertent nuclear war without significantly improving Russia's nuclear war-fighting abilities.

Multilateral Shared Early Warning

The Clinton proposals to include additional countries in the JDEC either focused on countries with early-warning technologies or were general proposals to include any country in the world. But international agreements should be entered into only when they solve real problems. Including most third-party countries would not solve any security problems either they or the United States face. However, the unique geographical, political, and nuclear status of China, India, and Pakistan means that they could benefit from shared early-warning information. Such sharing would add to U.S.-Russian bilateral nuclear stability as well.

China, India, and Pakistan, the most recent nations to acknowledge the acquisition of nuclear weapons, are too close to each other for early warning to be meaningful in their war-fighting plans. For instance, it would take about six minutes for a Scud-type missile to fly the 425 miles between Islamabad and New Delhi—about the time the Pentagon's threat assessment conferences took during the false alarms of 1979 and 1980. In fact, real-time early warning

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The United States has a vital interest in helping Russia maintain an early-warning system that covers the entire globe.

might prove destabilizing. If any of those countries decided to adopt a policy of launching its weapons on warning of an attack, it would not have enough time to properly consider and eliminate the inevitable false alarms.

Surveillance of other nations' missiles, however, can give those nations confidence that they are not being attacked (as it does the United States and Russia)—especially when an accidental detonation of one of its own nuclear weapons occurs.[14]

India and Pakistan are relative newcomers to the problems associated with owning nuclear weapons. It is realistic for the three nuclear powers in the region, and in fact all countries of the world, to worry that one or the other country's nuclear weapons are not sufficiently safe to be continuously deployed for extended periods of time. The nearly 60 years of U.S. nuclear weapons management has shown that deploying nuclear weapons is a dangerous undertaking. There have been a number of accidents that have strained the safety features on U.S. nuclear weapons and U.S. command and control to the limit. That no nuclear explosions occurred and that the accidents involving command and control did not cause an inadvertent nuclear war do not dispel the danger. Those incidents should make the world more aware of the dangers posed by deployed nuclear weapons.

The cause of an accidental nuclear explosion would not have to be design problems, though those too are possible. (It is known, for instance, that Iraq's designs for nuclear weapons would have proved very unstable. Some UN arms inspectors stated that if the weapon had been constructed it could have exploded if it had been hit by a bullet or even dropped off a table.)[15] Perhaps even more likely are accidents associated with deployment. For instance, the United States has had airplanes carrying nuclear weapons crash or accidentally drop them. Such accidents severely stress any weapons safety features. In at least two accidents associated with B-52s, the conventional high explosives—used to initiate the nuclear explosion—detonated. It is possible, and some observers might argue, even likely, that a partial nuclear explosion could result. And in the heat of the moment, it might not be obvious that a subkiloton accident was not a several kiloton attack.

Of course, either India or Pakistan, and certainly China, might object that its own nuclear weapons were safe. But each country cannot be sure that all the nuclear weapons in the other countries in the region are safely deployed. For instance, if a nuclear explosion occurs in Pakistan, India's vital security interest requires that Pakistan realize that an accidental detonation has occurred on its soil and was not the result of an Indian nuclear attack. Otherwise, Pakistan might mistakenly launch a "retaliatory" strike on India. China's interests are also served by India's knowing that a nuclear explosion on Indian territory was not the result of an attack. Similarly, Pakistan is well served if India knows that it was not attacked.

Russia and the United States could mitigate this danger on the Asian subcontinent by jointly providing missile surveillance information to joint centers in all three countries. The joint centers would not have to routinely provide raw data, which might reveal sensitive information about early-warning technology. Instead they could normally provide the type of analyzed information the JDEC plans to exchange between Russia and the United States. Only after an accidental nuclear explosion, as explained below, would a limited amount of raw data have to be provided.

Establishing confidence in the information provided is still key to the success of this measure, and that is harder than it might appear. For instance, any of those countries might argue that, in the case of an actual nuclear attack, both Russia and the United States have an interest in not providing confirmation. Instead, they would argue, it would be in the U.S. and Russian interests to try to slow down the escalation by not showing a missile attack in the hopes that the countries could reach an agreement before an all-out nuclear war.

However, if the United States judges that the dangers of an inadvertent nuclear war in the region are greater than those of confirming an unprovoked attack, it must accept the responsibility of providing valid data even in the advent of a real nuclear war. Fortunately, there are technical means that could provide the countries with the reassurances they need. One possible approach would involve granting India, China, and Pakistan access to raw data in the event of an actual nuclear explosion. The data coming down from the satellite could be encrypted with codes that the three countries created to validate the data's authenticity. Because of the need to show raw data to the countries in the region, the JDEC will not be enough. Hence the dedicated satellite.

How would those joint centers improve U.S.-Russian nuclear stability? The centers in regional nations could be used to build confidence in U.S. and Russian missile identification software without revealing sensitive information about the algorithms that either country uses to identify the other's missiles. In the original collaboration, U.S. and Russian space scientists working on RAMOS exchanged satellite images but carefully avoided exchanging algorithms for identifying missiles. A follow-on experiment could use the information derived from the current experiment to build a single, advanced-technology early-warning geostationary satellite that would be positioned over the Indian Ocean. (That satellite could have a field of view restricted to China, India, and Pakistan and would not provide the United States with additional early-warning information on Russia's missile fields.) In the new experiment, the two teams of scientists—each with close ties to their own country's early-warning establishments but independent of them—could jointly develop software that would recognize Indian, Chinese, and Pakistani missiles.

Building and launching such a geostationary satellite should cost about $240 million—assuming the program, as the current RAMOS experiment does, uses Western sensor technology and Russian launch services. Costs to operate the satellite should run about $12 million each year. Providing dedicated landlines for communication from a joint U.S.-Russian downlink and satellite control center in Far Eastern Russia to the three centers—one each in China, Pakistan, and India—might cost about $1 million each year.

Conclusion

Almost inevitably, some future benign event will be misinterpreted by Russian military leaders as a possible nuclear attack—especially if the incident happens during a period of increased political tension with the United States. When that happens, early-warning systems can play a vital role in preventing escalation into a nuclear holocaust. Therefore, Russia's deteriorating early-warning system poses a real threat to U.S. security.

The United States has a vital interest in helping Russia maintain an early-warning system that covers the entire globe. Such a system could provide Russia with the confidence that no attacks have been launched. U.S. assistance, however, should be narrowly focused on solving real problems.

The Bush administration could take a series of phased steps to help Russia build up its own space-based early-warning systems. Concentrating on assistance that emphasizes systems built and operated by Russians ensures that they will have confidence in the early-warning information. Furthermore, the steps outlined in this paper do not risk revealing information about current or future U.S. early-warning systems.

Washington should not help to rebuild Russia's radar fence, which could pose a security threat to the United States, but should work, with Russia, toward a system for sharing early-warning information with India, Pakistan, and China. Such a system would not only guard against false alerts in those newly nuclear countries; it would also promote U.S.-Russian bilateral nuclear stability.

Concentrating on assistance that emphasizes systems built and operated by Russians ensures that they will have confidence in the early-warning information.

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