2. Russian Military Space Capabilities

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Russia is one of the few countries that maintain extensive space industry and carry on a number of military-related space programs. In many aspects the Russian civilian and military space program is comparable to that of the United States, although sometimes in intent rather than in actual capabilities. In any event, the expertise that the Russian space program has makes it a very important player in any future space-related developments.

It should be noted, however, that the existing Russian capabilities in space should be assessed with caution, since the core of the existing Russian space program was developed during the Soviet times. Although Russia has managed to maintain some parts of the Soviet program successfully, some have been neglected, so not everything that existed in the Soviet Union still exists today. Some important components of the industrial and organizational infrastructure are no longer capable of supporting development of space systems.

This article gives an overview of military-related Russian space programs from the point of view of their ability to contribute to developments of space-based weapons or space-based systems that are usually considered in the context of weaponization of space.

Anti-satellite systems

The Soviet Union was the only country that developed and operationally deployed an anti-satellites system (ASAT), designed to attack satellites on low Earth orbits (LEO). The United States also worked on its own ASAT systems during the cold war, but abandoned its projects on the early stages of development.

The development of the Soviet ASAT system began as early as the early 1960s. The first test flights of maneuverable spacecraft were performed in 1963-1964 as part of the ASAT development program. After a series of organizational changes, the development was assigned to the TsNII Kometa design bureau in 1964. The space launcher used in the system was a modified R-36 (SS-9) missile, developed by OKB-586 design bureau (now Yuzhnoye Design Bureau). Design of the interceptor spacecraft was assigned to the Lavochkin Design Bureau. In addition to the space launcher and interceptor spacecraft, the system included a network of space surveillance radars and the command and control center.

The first tests of the system were conducted in 1968. During later tests the system demonstrated its capability to destroy satellites on low orbits with altitudes of up to 1000 km. During test intercepts the developers tested different intercept geometries and onboard sensors and proximity fuses (infrared and radar).

The system was accepted for service and commissioned for active duty in 1979. The launchers-modified R-36 (SS-9) or R-36M (SS-18) missiles-were deployed at the Baykonur test site. Test intercepts continued until 1982. In November 1983, however, the Soviet leadership announced a unilateral moratorium on further ASAT tests. The tests have never resumed.

The exact status of the ASAT system deployed in Baykonur is unclear, but it is most likely that it is no longer operational. There were reports that the system underwent a modernization in 1991, but since it was done without flight tests it is highly unlikely that this modernization involved any significant upgrades. Significant parts of the space surveillance network that is an integral part of the system, have been lost during the break up of the Soviet Union. Although Russia has not formally announced that the system is decommissioned, the current structure of the Russian Space Forces does not include any units that could operate the system, which almost certainly means it is no longer functional.

The Soviet Union also did some work on other ASAT technologies, such as space-based lasers or space-based kinetic weapons, but these never went beyond research stage.

The ability of the Russian space industry to embark on a serious ASAT development effort seems highly questionable. First of all, Russia has lost both the military and industrial organizational infrastructure that was responsible for research and development in the area of anti-satellite or space-based weapons.

On the military side, the anti-satellite research and development programs were managed by the Air Defense Forces, which used to be a separate service in the Soviet armed forces. This service, however, was disbanded during the military reform of 1997. The units that supported operations of missile defense and anti-satellite systems, space surveillance and early warning networks were subordinated to the Strategic Rocket Forces. In 2000, however, these systems were removed from the Strategic Rocket Forces and brought under command of a new branch of armed forces-Space Forces. The status of this new branch within the armed forces, however, makes it difficult for it to initiate any major research and development effort.

The changes in the defense industry have been much more serious. While Russia has managed to keep most of its space industry intact, this does not apply to the companies that were involved in the development of anti-satellite systems. In the Soviet Union, that development was managed by the Ministry of Radio Industry, not by the Ministry of General Machine Building, which was responsible for the space program. In the early 1990s, as old Soviet defense ministries were being abolished, the key space industry enterprises were transferred to the Russian Space Agency (now Russian Aviation and Space Agency, Rosaviakosmos), which helped them maintain their viability. The Ministry of Radio Industry enterprises and design bureaus were moved to the Ministry of Economics together with other defense companies and have been largely neglected. As a result of these transformations, Russia now does not have an agency that would be capable of supporting development program in the area of anti-satellite systems or space-based weapons.

Other military space-based systems

Military uses of space are not limited by anti-satellite capabilities or by space-based weapons that could attack targets on the ground or in flight. There are a number of systems that could play a very important role in supporting military operations on various stages of a conflict and therefore can constitute a significant military asset. Among those are imaging, reconnaissance, signal intelligence, navigation, and communication satellites and systems. Denying an adversary access to capabilities of this kind is one of the arguments often made in favor of development of anti-satellite capability, whether space- or ground-based.

The attention to Russia's capability to develop and deploy systems of this kind is not necessarily linked to the possibility of a military conflict between the United States and Russia, the prospect of which is extremely remote. Rather, it is likely that Russia would play a role in developing these capabilities worldwide by either advancing the relevant technologies to the open market or even by supplying parts and components to the interested parties. Since most of the technologies involved have legitimate civilian applications, controlling this process would be very difficult.

An analysis of the capabilities that exist today in Russia would help determine whether Russia could contribute into proliferation of military significant space-based capabilities, which are often used to justify the work on ASAT or space-based weapons.

Imaging satellites

Russia is operating several types of photo-reconnaissance satellites, which vary in their capabilities and missions-from wide area cartography to detailed hotography of specific areas of interest. Most of these satellites operate on low orbits with apogees from 170 to 350 km and use film to deliver images to the ground. Earlier versions of photo-reconnaissance satellites had to reenter to deliver their images, which limited their lifetime and made timely transmission of data impossible. More recent satellites are equipped with multiple reentry capsules that are used to deliver exposed film.

Satellites of the Neman type (known also as fifth-generation satellites) use radio relay link to transmit images electronically either directly to the Earth or via geosynchronous relay satellites. Resolution provided by the LEO satellites is unknown, but it quite likely that photo-reconnaissance satellites of the latest generation can provide resolution of better than 1 meter. In the recent years the Military Space Forces were launching one or two imagery satellite of these types a year. Given their limited lifetime, this means that Russia has not been able to provide continuous presence of its optical reconnaissance satellites in orbit.

In 1997 Russia launched the first in what seems to be a completely new series of imaging satellites. The satellite, known as Arkon-1, was launched into an elliptical orbit with perigee of about 1500 km. The satellite was reported to provide optical resolution of about one meter and apparently transmitted its images electronically. The satellite suffered malfunction after only four months of operations. The second launch of a satellite of this type was conducted in July 2002. The second satellite appears to be operational.

It is unclear to what extent Russia will be able to contribute to the emerging market for high-resolution optical imagery. It is very unlikely that the film-based satellites of old generations could provide response times necessary to compete with the satellite imagery available today. Russia has announced plans to sell images obtained by the new Arkon satellites, but it is yet to demonstrate that the quality of this images and delivery times are adequate.

Signal intelligence

Another space-based system with considerable military applications that has been supported in working conditions in the recent years is the ocean reconnaissance system, known as EORSAT or US-PM (another ocean reconnaissance system, RORSAT, which involved nuclear-powered satellites, was discontinued in

1988). The EORSAT system includes satellites that can track naval vessels based on their radio communications, radar emissions etc. The satellites are deployed on circular orbits with altitudes of about 400 km. Full constellation seems to include three or four satellites. Until 1997 Russia had been launching one or two satellites of this type every year, but after 1997 there was only one launch in 2001.

It is not clear if Russian military intend to keep the system operational. It was initially developed to track positions of U.S. military ships and to provide Soviet fleet with targeting information. While it may still provide this capability, the system was developed in the late 1960s-early 1970s and therefore may need a major upgrade.

The family of signal intelligence systems also includes a heavy Tselina-2 satellite, which was developed in the late 1970s-early 1980s. These satellites are deployed on relatively high circular orbits (altitude about 850 km). The most recent launch of this type of satellite was conducted in February 2000. From the point of view of the Russian military, the main problem with this system is that its spacecraft are produced in Ukraine.

There have been reports that a new system, which will replace the current two in functionality is under development, but the details are scarce.

Navigation satellites

There are two major military navigation systems that are currently in use in Russia. The first one is known as Tsiklon or Parus, includes satellites on circular orbits with altitudes of about 1000 km. The accuracy provided by this system is about 100 m. This system was initially developed as a military system, but later was widely used for navigation by the Soviet (and now Russian) civilian ships. In the recent years Russia has been launching about one satellite a year, which was probably enough to keep the system operational, although maybe in the minimum configuration.

Another navigation system, known as Glonass or Uragan, is the Soviet/Russian analog of the U.S. Navstar/GPS system. Like its U.S. counterpart, it includes satellites deployed on semi-synchronous circular orbits with altitudes of 20000 km.

There are also differences in configuration-the Russian system includes 24 satellite deployed in three orbital planes (as opposed to four orbital planes for GPS). The accuracy provided by the Glonass system is comparable to that of GPS.

Deployment of Glonass satellites began in 1982, but the system has not reached initial operational capability until 1989. After the breakup of the Soviet Union the system has suffered from mismanagement and inadequate funding. The Russian government has tried several times to commercialize the system, but they were unsuccessful. As a result, the system is being kept in operation, but the number of working satellites is rarely higher than ten. Consequently, the ability of the system to provide accurate navigation information is very limited. Despite of the existing problems, Russia seems determined to continue operations of the Glonass system and is launching about tree satellites a year to replenish the constellation. It is currently working on a new modification of Glonass satellite, known as Glonass-M, which is expected to be ready for deployment in 2004.

Conclusion

As we can see, although Russia continues to support its military space program, the scale of that effort is just enough to maintain the programs that are most important. In addition to the systems described above, Russia invests significant effort into its early-warning and military communication satellites. Neither of these systems, however, is related to space-based weapons or anti-satellite capability. Russia does seem to preserve the basic industrial infrastructure that theoretically would allow it to develop and eventually deploy these kind of weapons, but that infrastructure has been steadily deteriorating in the recent years and it is extremely unlikely that Russia will be able to undertake any serious development effort in the area of space weapons or ASAT.

As for other space-based military capabilities-imagery, signal intelligence, navigation-that might potentially play important role in a military conflict, the existing systems do not seem to provide Russia with capabilities that would significantly improve performance of its military. Besides, Russia has yet to demonstrate its ability to integrate space-based systems into military operations.

Another problem that Russia is facing is that the existing industrial and organizational infrastructure that supported development of space systems was formed in the Soviet Union. It is being adapted to the new economic realities, but this process is going rather slowly and it is yet unclear if this adaptation will be successful and Russia will be able to undertake large-scale research and development projects.

3. The Capabilities of North Korean Ballistic Missiles

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In this paper I describe what is believed to be known about the current state of development of North Korean ballistic missiles, and their capabilities for launching objects into space.

Introduction

One way that a missile can be used to attack a satellite is by direct ascent, in which case the missile flies up to the altitude of the satellite and attempts to intercept it. A useful rule of thumb is that if a missile is launched vertically with a given burn-out speed, the maximum altitude it can reach is roughly one-half of the maximum range it can reach with the same burnout speed. This is exact in the case of a flat earth, and therefore holds for short-range missiles, but it continues to be approximately true for missiles of intercontinental range as well. This means that a 300-km range Scud missile can carry the same payload to roughly 150 km altitude, and that an intercontinental missile with a range of 10,000 kilometers could lift a similar payload to roughly 5,000 km.

If a missile is to be used to place an object in orbit, such as a satellite, a co-orbital ASAT, or a debris cloud to be used as an ASAT, this requires significantly more capability than the direct ascent case, since the missile must lift the object to the proper altitude and give it sufficient speed at that altitude to inject it into orbit (roughly 7-8 km/s for LEO).

This means that a short-range missile can reach low-lying satellites in low-earth orbit in direct ascent mode, but cannot put an object into orbit. An

ICBM in direct ascent mode could reach satellites at altitudes of several thousand kilometers, but could not reach satellites in synchronous or semi-synchronous orbits. An ICBM can place a lightweight satellite into low-earth orbit; the mass of the satellite will depend on the capability of the ICBM as well as the altitude and inclination of the orbit.

North Korean missiles

Scud derivatives

By 1985, North Korea was producing a version of the Soviet Scud-B: the Scud Mod-B, called the Hwasong-5 in North Korea. This one-stage missile has a range of roughly 300 kilometers with a one-ton warhead, or about 500 kilometers with a 300 kg payload.

It has a steel body that is slightly over 11 meters long and 0.88 meters in diameter, and with fuel has a mass of nearly six tons. The missile uses storable liquid fuel. Its accuracy is relatively low: the CEP is reported to be roughly a kilometer.[32] A significant fraction of the CEP results from atmospheric forces during reentry, so this number is not directly relevant to understanding the capability of the guidance system to target a point in space. Using modern guidance technologies could clearly improve the performance of the guidance and control system significantly.

By 1989, North Korea is believed to have started building a longer range version of the Scud Mod-B, called the Scud Mod-C or Hwasong-6, which can reach 500 kilometers. This range may have resulted from reducing the payload from 1,000 to 700-800 kilograms and lengthening the fuel tanks to carry more fuel,[33] although some sources state that the additional range increase resulted from reducing the weight of the missile body by using a special stainless steel purchased from the Soviet Union.[34] The CEP of the Mod-C is probably 1 to 2 kilometers.[35]

A key question is the level of North Korea's foreign technical assistance and how important that was to the progress of its program. Soviet assistance at this stage is believed by some to have essentially non-existent due to political problems between the countries.[36] Others, however, have argued that the rapid pace of missile development in North Korea and the high success rate of the testing programs suggest very significant assistance, likely from the Soviet Union and later Russia.[37] Some North Korean engineers are believed to have received training in China, but China is not known to have been directly involved in the development of these Scud versions.

Nodong

The longest range missile North Korea has successfully flight tested and deployed is the Nodong missile, which is believed to have a range of 1,300 kilometers with a payload of about 700 kilograms.

The Nodong appears to be essentially a scaled-up Scud missile, using similar or identical liquid propellants with a larger engine that can produce roughly four times the thrust of North Korea's previous engines. The missile is single stage, with a length of roughly 16 meters, a diameter of 1.3 meters, and a mass of about 16 tons. Estimates of the accuracy suggest a CEP of several kilometers, but this could be considerably larger if the warhead spirals or tumbles during reentry.[38]

North Korea is believed to have had foreign assistance-possibly very considerable-in the development of this missile, with key assistance coming from Russian missile designers.[39] For example, press reports from late 1992 state that two planeloads of Russian missile engineers were stopped as they were preparing to travel to Pyongyang, suggesting that there were significant contacts between engineers in the two countries.[40]

Taepo Dong-1

The only test of a missile with range longer than the Nodong occurred in August 1998, with the unsuccessful launch of the three-stage Taepo Dong-1 (TD-1) missile (called the Paektusan-1 in North Korea). Western analysts originally expected the TD-1 to be a two-stage ballistic missile, consisting of a modified Nodong missile as the first stage and a Scud Mod-C as the second stage. Such a combination was estimated to have a range of 1,500-2,000 kilometers with a one-ton payload.

However, the TD-1 launched in August 1998 was a three-stage missile that appears to have been specifically designed to launch a satellite rather than to deliver a payload as a ballistic missile. The first stage is a modified Nodong missile. The second stage engine, however, appears to have been designed to have a long burn time at relatively low thrust.[41] Such performance would not be expected for a ballistic missile, but would allow the third stage to reach a high altitude before it fired its engine and attempted to put the satellite in orbit. The third stage consisted of a small solid-fuel rocket motor that carried a small satellite with a mass of probably a few tens of kilograms. The satellite, named Kwangmyongsong, apparently carried a small transmitter that was intended to broadcast political songs to make its presence known, similar to the first Chinese satellite in April 1970, which played "The East is Red."

The satellite launch was not successful due to a failure of the missile's third stage, but did demonstrate for the first time North Korea's technical capability to launch missiles with multiple stages, since the second and third stages both successfully separated from the previous stage. Moreover, the third stage reached a high enough speed by the time it failed that debris from its breakup reportedly traveled some 4,000 kilometers. What caused the failure of the third stage is not known.

The mass of the TD-1 is estimated to be 20 to 25 tons.

The origin and technical details of the third stage are not known. North Korea is not known to have previously built solid-fuel engines, although it would not be surprising to learn that it was developing a capability to do so. Both Pakistan and Iran have built small, solid-fuel rocket motors for short-range missiles, so the engine used in this stage may have been come from one of these countries.

The TD-1 was fired nearly due east, which maximizes the speed that the missile can get from the rotation of the earth; this trajectory would have led to an orbit with an inclination of about 41 degrees. North Korea claimed that the satellite went into a highly elliptical orbit with a perogee of 219 km and an apogee of 6970 km, which may have been the trajectory they were attempting to attain. Such a trajectory would require the booster to give the satellite a speed of 9 km/s at perogee.

While the TD-1 may have reached near-orbital speeds in the 1998 test, it apparently did so with a very small payload and would have significantly reduced capability with a larger payload. Estimates suggest that if it were used as a ballistic missile, it might be able to deliver a small payload of 100 to 200 kilograms as far as the continental United States. A space-launch vehicle would have an advantage over a ballistic missile that it would not require a reentry heat-shield, which would increase the amount of this mass available for usable payload.

Taepo Dong 2

The largest missile under development by North Korea is the Taepo Dong 2 (TD-2). It has never been flight tested and its development status is the subject of controversy. US National Intelligence Estimates have stated since 1998 that it is believed ready for flight testing, although others experts are skeptical.

While the TD-2 uses components from North Korea's previous missiles, it is significantly different from any missile North Korea has built or tested. It is expected to use the same engines as the Nodong and the same propellant. However, it would require a large, new first stage that is expected to use a cluster of four Nodong engines, which increases the complexity of the missile. This stage would be roughly equivalent in size and capability to the Chinese DF-3 missile, and by itself would be considerably more capable than any missile North Korea has tested.

The second stage is expected to use a single Nodong engine, modified to be used at high altitudes. Rather than using a Nodong missile body for the second stage as is often shown in illustrations, North Korea is more likely to build a stage that is shorter and larger diameter than the Nodong, since that configuration can reduce the structural mass of the stage, which is crucial for attaining the high speeds needed for to reach long ranges.

The TD-2 missile would be significantly larger than the TD-1, with a maximum diameter (2.4 meters) nearly twice that of the TD-1 (1.3 meters). It would be four times as massive as the TD-1 (75 to 80 tonnes) and would generate greater thrust, so that the mechanical stresses on the body would be more severe than on previous missiles. As noted above, keeping the structural mass low is crucial to achieving long ranges, so that making the structure sufficiently strong to accommodate these much larger stresses while keeping the mass low is a difficult engineering problem. In addition, most discussions of the TD-2 assume that it will include a third stage, which is required for the long ranges usually attributed to it, but North Korea has not successfully launched such a stage.

As a result, while there do not appear to be fundamental technical barriers to building a missile of this type, it would present North Korea with a number of demanding engineering problems.

The potential range of the TD-2 is controversial, and official estimates have increased significantly over the past few years.

In particular, for the two-stage TD-2, the 1998 National Intelligence Estimate (NIE) projected that this missile would have a range of 4,000 to 6,000 kilometers, without specifying a payload. The 1999 NIE increased the range estimate, saying it could carry a several-hundred-kilogram payload to Alaska and Hawaii (7,500 km) and a lighter payload to the western half of the United States (10,000 km). By the 2001 NIE, the estimate was 10,000 km for a several-hundred-kilogram payload. [43]

Similarly, estimates for a three-stage TD-2 have also increased with time. Assuming that the TD-2 might carry a third stage similar to that used in the 1998 TD-1 test, the 1999 NIE estimated that a three-stage TD-2 "could deliver a several-hundred kilogram payload anywhere in the United States," which implies a range of 11,000 to 12,000 km. By December 2001, the NIE estimated the range at 15,000 km, which would be sufficient to allow it to reach all of North America.

The NIEs do not specify what "several hundred kilograms" means, but presumably it is meant to include a first generation nuclear weapon and heat shield, which is often estimated to be roughly 500 kilograms. A larger payload would reduce the range of the missile, so the payload estimate is important for the range estimates. For example, a missile of the size of a TD-2 that could carry a 500-kilogram payload 11,000 km could reach only 8,000 kilometers with a 1,000-kilogram payload.

These official range estimates appear to assume that the technology used in the TD-2 is significantly better than that used in the TD-1. My projections of the TD-2 range assuming the level of technology used in the 1998 TD-1 launch give estimates of 6,000 to 7,000 kilometers for a 500-kg payload for a two-stage TD-2.[44] This two-stage estimate appears to roughly agree with the 1998 NIE estimate. These same assumptions lead to a range of roughly 9,000 kilometers with a 500-kilogram payload for a three-stage TD-2.

The longer NIE estimates appear to assume that the TD-2 body is made of significantly lighter materials, and that the engines provide higher thrust, than was observed in the TD-1 launch. For example, North Korea might have switched to making missile bodies out of aluminum magnesium, rather than steel, which would result in a significant weight savings. These assumptions may be correct, but, it is not known publicly whether they are based on specific evidence or simply reflect an expectation that North Korea would be able to improve its design over time.

It is worth noting that the TD-2 missile, while considerably larger than any of North Korea's current missiles, is significantly smaller than the DF-5 ICBM that China developed to deliver its nuclear weapons. The DF-5 has a maximum diameter of 3.35 meters and a mass of 183 tonnes, compared to a diameter of 2.4 meters and a mass of 75 to 80 tonnes assumed for the TD-2.[45]

Future developments

North Korea continues to observe a self-imposed moratorium on flight testing of all long-range ballistic missiles, which it announced in 1999 and has extended several times. This fact is highly significant, since without flight testing North Korea cannot develop an operational missile. Moreover, flight testing is easily observed by US satellites, so this limit on its missile development is readily verifiable. Ground testing of engines has apparently continued during the moratorium.

North Korea says it will maintain the moratorium on long-range missile tests as long as the United States continues missile talks. It has recently threatened to end its moratorium, in response to US refusals to take part in bilateral negotiations, and to Japan's launch of its first two reconnaissance satellites in March 2003.

The underlying reason that North Korea has maintained the test moratorium for nearly five years is not known. It is possible that despite early rapid progress in developing short-range missiles, the program has encountered technical difficulties in recent years in developing long-range systems. Short-range missiles are much simpler and less technically demanding systems than are long-range systems, and considerable information is available about missiles such as the Scud. It is also possible that North Korea's early progress was due to significant foreign assistance and that that level of assistance is no longer available.

On the other hand, there is a general sense that the development of new missiles has been restricted for political reasons, and reflects an interest by North Korea in trading limits on its program for economic assistance and security guarantees.

The history of its missile development program suggests that given time and resources, North Korea will be able to develop missiles with increasing range if it decides to do so. How long successfully demonstrating such missiles might take is unclear, especially since the level and quality of foreign assistance is not known.

Space-launch Capabilities of North Korean Missiles

Based on information from the August 1998 launch, it appears that the TD-1, if the third stage could be made to work successfully, could place a few tens of kilograms into low-earth orbit.

To put the space-launch capabilities of the TD-2 into perspective, it is useful to compare it to the three-stage Chinese CZ-1 space-launch vehicle. The first two stages of this missile were based on the Chinese DF-4 ballistic missile, which is similar in size to the TD-2, having a maximum radius of 2.25 m and a liftoff mass of roughly 80 tonnes. The DF-4 is reported to have a range of 4,750 km with a 2,200 kg payload;[46] this corresponds to a range of about 8,000 km with a 1,000 kg payload, or 10,000-11,000 km for a 500 kg payload. This range capability is comparable to the 2001 NIE estimate for the 2-stage TD-2, but considerably longer than the earlier NIE estimates. The body of the DF-4 is made from aluminum-magnesium alloy,[47] and this may be what later NIE estimates assume for the TD-2. The CZ-1 uses a solid-fuel third stage motor.

The CZ-1 was used to launch China's first satellite in April 1970. It is reported to be able to place 300 kg into a 200-300 km circular orbit, and is not capable of putting a satellite into a geo-transfer orbit.

In the 1990s, China produced an improved version of the CZ-1, the CZ-1D, with improved engines. This vehicle is said to be able to place 700-800 kg into a 300 km circular orbit for inclinations between 28.5 and 70 degrees, and 200 kg into a geo-transfer orbit at 28.5 degree inclination.