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The Nuclear Triad: Alternatives from the Days Gone By and Possible Futures

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The first atomic bomb was designed almost eight decades ago. Since then, the nuclear factor has become one of the game-changers in international relations. The possession of nuclear weapons has become especially important in modern times, as discussions of the fatal destructiveness the use of atomic weapons for all mankind have reintensified. There is increasing speculation on this topic in the international arena. Nevertheless, there is no doubt that all nuclear-weapon states, whether officially recognized or de facto possessing, are aware of nuclear-associated risks and approach the nuclear factor with full responsibility. What is the future of nuclear weapons? Today, this issue is arising more and more often, attracting the attention of the international community.

The full text of the working paper is available on RIAC's website. You can download it or leave a comment via this direct link—**russiancouncil.ru/paper68**

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Introduction

Nuclear weapons have been around for a little over three-quarters of a century and have come a long way in terms of technical improvements to both the warheads themselves and the means of delivery. The need to devise the strategic nuclear forces born of their combination led to a major push for scientific and technological progress in many fields—physics, chemistry, cybernetics, engineering, and contributed to the development of aviation, nuclear power and rocketry, and, through the latter, to space exploration.

At the same time, nuclear weapons were the first human creation that literally and directly threatened the existence of civilization. Even considering that many Cold War-era forecasts and concepts of the U.S. and Soviet Union were intentionally pessimistic and exaggerated, a global nuclear war at the peak of the accumulated arsenal would have resulted in an unprecedented and unimaginable cataclysm. It might not have wiped out humanity, but it would certainly have taken many decades or even centuries to recover.

However, it was the timely realization and correct understanding by the military and political leadership of the great powers of the threat of such an outcome (or, at least, the threat of unprecedented casualties for their countries) that made it possible to break out of the seemingly unbreakable cycle of world wars of the twentieth century. Despite the sharpest contradictions, the capitalist and communist economic, political and ideological systems were not locked in mortal combat, and that’s probably a credit to Atom.

Therein lies the uniqueness of nuclear weapons—their destructive power and previously unimaginable reach and irresistibility, combined with their strategic means of delivery, have had a decisive influence on politics by their very existence. For this reason, even minor technical decisions can have far-reaching political and strategic consequences.

This influence remains even now. The articles included in this working paper began to be prepared and partially published on the website of the Russian International Affairs Council (RIAC) long before the escalation of the Ukrainian conflict and, more importantly in this topic, the sharp deterioration of Russia-West relations. The major military powers crisis instantly reintroduced the nuclear issue to the front pages of the media and the speeches of the politico-military establishment. The ongoing shaping of the U.S.-Chinese confrontation, which in military and strategic terms is already close to the state of the U.S.-Soviet Cold War, also has a nuclear dimension in large part.

Against this background, it seems useful to look at the main accumulated problems of the components of strategic nuclear forces and possible ways of solving them during a period of radical renewal—for the first time in decades in the United States, and at a new level in China. One cannot begin a conversation about the future of strategic nuclear forces without briefly considering the most striking alternatives in their development. This will show that the current shape of the nuclear triad is not axiomatic, and that small decisions in this area made in the past sometimes have a meaningful impact on our world to this day.

The nuclear triad: alternatives from the days gone by

Alternative Military-Technical History

The Strategic Arms Reduction Treaty, commonly known as START I, recently marked its 30th anniversary. It came to be the first in a series of nuclear treaties followed by START II, SORT and the New START. The longevity of the arms control regime is not the only reason to single out this landmark date, with one of the other considerations being that the all-familiar strategic nuclear triad, having emerged in the early 1960s, has been under the START framework nearly a half years of its existence. This presents us with a wonderful occasion to throw a glance at the steps that brought us to the triad as we know it as well as speculate about its future.

In the first part of the story, we set out to prove that the way the system of strategic deterrence is organized today was never preordained, which means it could have been completely different. This idea is spot-on today, when the system's design is undergoing changes yet again.

Exploring the Prehistory

The three pillars of the modern strategic nuclear triad—consisting of long-range strategic bombers (LRCMs) chiefly equipped with long-range cruise missiles, land-based intercontinental ballistic missiles (ICBMs) mounted in secure silos, launch tubes or on road-mobile launchers (RMLs), and submarines capable of deploying submarine-launched ballistic missiles (SLBMs)—seem to be a completely natural outcome of our advances in engineering. All nuclear-weapon states possess at least one component of this "package." Nuclear superpowers, such as the United States, Russia and China, have all the three components (the United States, however, lacks the RMLs), while smaller nuclear states have only some of them. The arsenal of the United Kingdom, for instance, is limited to SLBMs, while that of India includes land-based missiles, mostly of medium range,[1] as well as SLBMs. To some degree, all nuclear powers aspire to emulate the "gold standard" as it set by the United States and the Soviet Union in the course of the nuclear arms race. Some of these attempts seem almost comical, such as when North Korea was keen to rub its success in the face of the United States by naming their first SLBM after the first such missile deployed by the U.S. Navy.[2]

1 For obvious geographic reasons, missiles with an effective range below 5000 km would be enough for India as a strategic weapon of deterrence against China, its most serious potential adversary. Agni-V, the first missile that likely falls within the classic U.S.-Soviet definition of an ICBM, has only recently started to enter service, with the number of missiles deployed being fairly small.

2 The name spells "Pukkuksong" (북극성) to be rendered as the Polar Star—the first U.S. SLBM was named Polaris, a corresponding derivative from Latin conventional for the English language.

However, the triad's inception was not immediate. Naturally enough, bombers were the first-choice nuclear delivery vehicles as the first nuclear devices were so large and heavy that the idea of them fitting into something like a large-caliber projectile any time soon was totally unthinkable. Besides, only heavy aircraft could at that time offer the capability of delivering nuclear weapons across many thousands of kilometers, which was the ultimate requirement in the stand-off between the United States and the Soviet Union.

Not so obvious were the next steps in the evolution of nuclear weapons. It took some time and consideration for the military aviation to choose cruise missiles as the primary penetrator of air defense. In the U.S. Air Force, for example, the long-lived AGM-28 "Hound Dog" missile was originally fielded as a provisional solution, while the hopes were put on small air-launched ballistic missiles. The GAM-87 "Skybolt" was designed to become precisely such a missile, allowing B-52 bombers carrying them to strike four targets within a range of up to 2000 km.[3] At the same time, the USSR was designing an air-launched modification of the R-13 (SS-N-4 Sark) SLBM; unlike the U.S., however, where the similar project progressed to the phase of flight trials, the Soviet endeavor remained "on paper" only.[4] To make up for this, the "Raduga" Kh-20 (AS-3 Kangaroo), a Soviet equivalent of the "Hound Dog", paired with the TU-95K strategic bomber, saw initial fielding as early as 1959, the same year as did the "Hound Dog".

The U.S. Navy took its time to arrive at submarines as the first-choice strategic weapon, since it was aircraft carriers that were originally designated as the means of delivering strategic nuclear weapons. This task simply required equipping the carriers with airplanes with the necessary flight range and weapon payload. As a stop-gap, the Navy intended to launch the Lockheed P-2 Neptune, originally designed as a land-based patrol aircraft, from larger aircraft carriers. Equipped with jet assisted take-off rocket boosters, these aircraft had a very long flight range but were extremely inconvenient for flight deck operations—putting them in the hangar bay was impossible and meant that they could not land back on the carrier after a strike. Apparently, the Navy felt great nostalgia for the successful Doolittle Raid of 1942, when land-based B-25 bombers took off from an aircraft carrier for an air strike on Japan to ultimately land in China and the Soviet Far East. The first special Heavy Attack Squadron commenced deck training flights in 1949, followed by operational deployment with live bombs in 1951.[5] Powered by two piston engines, the North American AJ "Savage" was specifically designed to carry atomic bombs; however, having a much smaller flight range, it could "barely cope" with the Navy's nuclear strike mission in the first half of the 1950s.

Of course, this was nothing but a stop-gap measure, and it was the *United States* class carrier that was destined to become the real "strategic aircraft carrier." The heavy bomber carriers were huge, almost as big as modern *Nimitz* class

[3] All the B-52H modifications of the B-52 bomber currently in service in the United States were manufactured throughout 1961–1962 specifically to carry this missile.

[4] Kardashev M. A. Prohibited Strategic Weapons. Novoye Vremya, 2019. P. 101.

[5] Tommy H. Thomason. Strike from the Sea: U.S. Navy Attack Aircraft from Skyraider to Super Hornet 1948—Present. Specialty Press, 2009. P. 46–54.

warships, with a superstructure-free deck; they were intended as a fitting reply of the U.S. Navy to the long-range bomber armadas being constructed by the U.S. Air Force. The latter, however, proved more effective as they "bombed" these "supercarriers" in the corridors of power to see the program terminated soon after the keel-laying of the first of five ships in 1949. Admittedly, developments in the jet aviation soon let the Navy build effective carrier-based bombers suited to service on the existing aircraft carriers—in the second half of the 1950s, the Douglas A3D "Skywarrior" and the North American A-5 "Vigilante" could be used to carry nuclear weapons, being rather well-suited to the demands at that time.

The U.S. Navy had other, somewhat more "out-of-the-box", ideas. For example, 1949 saw the concept of the Seaplane Striking Force, a fleet of long-range bomber hydroplanes that were to use support ships at sea or larger hydroplanes—rather than stage airfields—for refueling[6] Full-scale production of the Martin P6M "SeaMaster" started as early as 1959; however, shortly before the aircraft was ready for fielding, the program was terminated due to budget cuts. Around the same time, the Soviet Union released a limited batch of Be-10 "Mallow" turbojet-powered hydroplanes. It was smaller than the P6M and was later redesigned as the Be-10N, equipped with K-12 nuclear-loaded anti-shipping missiles. The concept behind the Be-10N was reminiscent [7]of that of the U.S. aircraft, although it reflected an additional interest in the ability to destroy the enemy's carrier groups. As for the "creative" projects carried out by the Soviet Navy, we have to mention the T-15 super-heavy nuclear torpedo that was originally intended as the primary "means of delivery" for the USSR's first nuclear-powered submarines under Project 627. Quite contrary the myth that emerged from Andrei Sakharov's memoirs, the Soviet Union far from abandoned the project because the Soviet Navy servicemen suddenly found themselves under a pang of conscience, thus refusing to use the weapon of mass destruction; rather, it was on account of the torpedo being extremely impractical: consider how the "humane" Soviet admirals somehow succeeded in promptly arming the Navy with nuclear missiles at around the same time.

What is more, it was only a matter of years before missile-armed strategic surface combatants could have appeared. The United States was serious about equipping World War II battleships with ballistic missiles, such as the nuclear-tipped PGM-19 "Jupiter". The USS *Long Beach*, a nuclear-powered guided-missile cruiser, was built in the late 1950s with deck space to accommodate the mounting of the long-range nuclear-capable SSM-N-8 "Regulus" cruise missiles and was later re-equipped to harbor four launch tubes for the UGM-27 "Polaris", the U.S. Navy's first SLBM. In the end, after the cruiser's commissioning, additional antiaircraft weapons were installed instead.

In the early 1960s, NATO launched a program to set up the alliance's "joint" naval nuclear forces with surface ships carrying the UGM-27 "Polaris" missiles. The

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6 Tommy H. Thomason. Strike from the Sea: U.S. Navy Attack Aircraft from Skyraider to Super Hornet 1948—Present. Specialty Press, 2009. P. 73.

7 K-12 missile // A Space for Sky. Aviation Encyclopedia. URL: http://www.airwar.ru/weapon/pkr/k12.html

idea was[8] to build missile-carrying ships from transport vessels that would look almost identical to civilian vessels, at least from a distance. The concept was eventually tested on *Giuseppe Garibaldi*, an Italian light cruiser, whose rebuilding included four launchers for the "Polaris" missiles. The operational tests having concluded, the U.S. never provided the missiles, though. Nor were the "missile-carrying transport vessels" ever built, since the Multilateral Force was never adopted for political reasons, such as a tougher France under Charles de Gaulle, the deteriorating public attitude towards nuclear weapons in the wake of the Cuban Missile Crisis and the transition of the two superpowers to the policy of non-proliferation.

The Soviet Union also had programs to mount ballistic missiles on surface ships, with the closest Soviet equivalents to the MLF could be the "Scorpion" ships (projects 909 and 1111) that would be disguised as transport and hydrographic survey vessels.[9] They were supposed to accommodate eight UR-100M (SS-11 "Sego") or R-29 "Vysota" missiles. The projects were in the works in 1963–1965; had they actually been constructed, the country's armed forces could have fielded these ships around the same time with the full-scale fielding of the *Yankee* class (Project 667A "Navaga") nuclear-powered submarines. The ships would obviously have been a lot cheaper and easier to operate than the nuclear submarines as well as quite capable of engaging targets on the U.S. soil from sheltered waters washing the Soviet Union, a capability submarines did not acquire until the mid-1970s.

In addition to the idea of converting surface vessels into guided-missile warships, both the United States and the Soviet Union were intending to build long-life missile-hosting submersible platforms or seabed launchers. At the early stage, however, this was prevented by the insufficient range of SLBMs[10] as well as by the inherent for the 1950–1960s difficulties of constructing a remote-controlled ultra-reliable unmanned missile system. Later, the interest in such a system dwindled, and February 1971 saw the signing of the Seabed Arms Control Treaty that prohibited the deployment of any such systems outside territorial waters.[11]

Referring to the periods before and after, we will be talking about "creative endeavors" of the Navy and the Air Forces, the two principal operators of strategic nuclear weapons both in the United States and the Soviet Union—the USSR, though, also had a separate service branch known as Strategic Missile Forces (the RVSN in Russian). This brings us to the brief observation that the Army (i.e., the land forces) was sidelined from any strategic missions in both countries, only receiving plenty of tactical WMDs. We also have to mention Project Iceworm, impressive in its scale, which allowed the U.S. Army to initiate[12] in 1959 the

[8] Multilateral Force (MLF) // GlobalSecurity.org. URL: https://www.globalsecurity.org/wmd/systems/mlf.htm

[9] Kardashev M. A. Prohibited Strategic Weapons. Novoye Vremya, 2019. P. 26–28.

[10] The platforms would have to be deployed on the high seas rather than in coastal waters, which would produce a constant headache in terms of ensuring their security.

[11] Official title: Treaty on the Prohibition of the Emplacement of Nuclear Weapons and Other Weapons of Mass Destruction on the Seabed and the Ocean Floor and in the Subsoil Thereof.

[12] Camp Century // Atomic Heritage Foundation. 19.07.2018. URL: https://www.atomicheritage.org/history/camp-century

construction of an underground—to be more precise, an under-glacier—military base in Greenland. The United States only managed to get the Danish government to agree in general terms on a permit to build some military facilities on the island in the interests of "NATO's security", choosing not to tell Denmark about the plans to deploy 600 nuclear-tipped "Iceman" missiles (a new moniker for the existing "Minuteman") with an effective range of some 5,300 km on the island. The huge project, known as Camp Century, was supposed to be three times bigger than continental Denmark, heated by a nuclear reactor that had already been installed and even launched, with some 11,000 personnel permanently stationed on site under the massive ice sheet. At the time of construction, Camp Century was publicized as a "research facility."

The intent behind the project was to provide the U.S. Army with its own means of nuclear deterrence. Subject to the division of responsibility with the Air Force, the Army was not entitled for the ICBMs, which is why they chose such an exotic approach to acquiring a reliable and politically convenient method of "reaching" most of the Soviet Union's territory. The U.S. Army was looking into giving an "alliance-wide" status to the facility in order to set all political considerations aside. In the end, Mother Nature forced the project to be shut down once the Greenland ice sheet was discovered to be constantly moving, making it impossible to build any permanent tunnels in the ice. Construction activities were discontinued in 1963, the reactor was removed from the island, while an expedition that was sent to the site several years later confirmed that the secrets of Project Iceworm had been buried in the depth of the ice sheet. It was only many decades later—when papers on the program were finally declassified—that the public learned about its true essence.

Cruise Missiles: The First Shot

At the dawn of the automotive industry, electric cars were quite a serious competition for gasoline-powered cars. By the same token, cruise missiles went head-to-head with ballistic missiles in the early years of military rocket and missile engineering. While the usefulness of cruise missiles in strategic aviation is rather obvious, you may be surprised to learn that the first nuclear-capable warships were equipped with land-attack cruise missiles and that intercontinental cruise missiles were accepted into service almost concurrently with ballistic missiles.

In the U.S. Navy, the nuclear missile era began with the SSM-N-8 "Regulus" cruise missile. Engineers from Vought, the missile's manufacturer, managed to build a fairly ordinary vehicle in terms of its specifications for delivering nuclear and, later on, thermonuclear weapons (with device yield up to 2 megatons)—basically, the missile was as good as an unmanned subsonic jet with a range of 960 km to be used as a universal, simple and reliable means of delivery. The missile was found ready for service on surface ships in 1955, and the first ever nuclear-carrying warship, USS *Hancock* (CV-19), was deployed on combat patrol in December 1955 near the coast of China, when the relations between continental China and

Taiwan were experiencing yet another setback.[13] In total, “Regulus” missiles were mounted[14] on four heavy cruisers, ten aircraft carriers and five submarines (on combat duty since 1956), including one nuclear-propelled submarine that took part in combat patrols with the missiles starting in March 1960 to become the first nuclear-capable submarine on military duty.

On the outset, the Soviet Union had a much stronger bias in favor of cruise missiles for the Navy. Although ballistic missile submarines left a bigger imprint on the popular military-technical history—while not always for good reasons: the tragic K-19 nuclear submarine incident was so high-profile that Hollywood made a film starring Harrison Ford under the same name—they were not at the core of the Navy’s nuclear forces until the mid-1960s. The Chelomei Design Bureau succeeded in building an effective cruise missile known as P-5 “Pyatyorka” (SS-N-3C “Shaddock”), intended against large surface targets. It had a smaller range that its American counterpart (maximum 600–650 km), but it flew on autopilot to pre-set coordinates and had a faster cruise speed.[15] On the other hand, it fell far below in the device yield, carrying first 200 and later 650 kilotons. To put these missiles into service, the Soviet Union modernized twelve old submarines (projects 644 and 665) and constructed twenty-one new ones (projects 651 and 659). Shipyards started commissioning these submarines for the Soviet Navy in 1960, and 1963 saw the first of the 29 nuclear-powered cruise missile Project 675 submarines enter service.

Soviet cruise missile submarines were objectively superior to the ballistic submarines of that time. Apart from the very first *Whiskey* class (Project 644) submarines, cruise missile submarines carried four to six missiles (the *Echo-II* class even carried eight P-6 “Shaddock” anti-ship cruise missiles!), while the twenty-three *Golf* class (Project 629) submarines—commissioned at around the same time—were only armed with three R-13 “Sark” ballistic missiles that had an engagement range similar to the P-5 “Shaddock” cruise missile. Admittedly, ballistic missiles were at the time almost impossible to intercept; however, low-flying high velocity aerial targets were hard to kill just as well, especially in the case of a surprise attack.

Surprise attacks were a must, since both missiles could only be launched from the sea surface, and it was not until the mid-1960s that the Soviet Union started upgrading its *Golf* class submarines to carry the R-21 (SS-N-5 “Sark/Serb”) missiles to be launched from a submerged submarine, while the more powerful *Yankee* class (Project 667A) submarines that were closer to the U.S. counterparts in their characteristics were only fielded by the late 1960s. Before

[13] Bill Yenne. The Complete History of U.S. Cruise Missiles: From Kettering’s 1920s’ Bug & 1950’s Snark to Today’s Tomahawk. Specialty Press, 2018. P. 60–68.

[14] From Our Archive: Regulus I on board USS Hancock // U.S. Naval Institute. June 2006. URL: https://www.usni.org/magazines/proceedings/2006/june/our-archive-regulus-i-board-uss-hancock

[15] This could be regarded as an advantage, as the “Regulus” had a radio-command guidance system. Without some extra tricks (such as command ships positioned closer to the target, since more submarines were equipped with command and control systems than with missiles; missile guidance from airplanes that was being tested), it limited the engagement range to only 415 km. In this case, a somewhat higher precision is cold comfort, because we are talking about potential target deviation in both cases being at least a couple of kilometers.

that, cruise missile submarines were the USSR's key component of nuclear deterrence at sea—simply given the number of nuclear warheads they could potentially deliver.

On the ground, cruise missiles were also evolving in parallel with ballistic missiles in the 1950s, chiefly in the tactical domain. In 1954, the United States started deploying their Martin TM-61 (MGM-1) "Matador" cruise missiles in West Germany, followed by deployments in the Far East (South Korea and Taiwan) in 1958.[16] The "Matador" had a decent engagement range (over 1,000 km), but their ability to kill targets away from the battle line was limited by the need for radio control during flight, a problem similar to the "Regulus". This shortcoming was removed in the U.S. Air Force's next land-based cruise missile, the TM-76 (MGM-13) "Mace", equipped either with inertial or ATRAN terrain-matching radar navigation system. Despite the extremely primitive method of analogue operation, the ATRAN could still be regarded as the "forefather" of the navigation systems of today. Unlike the "Matador", which was chiefly fielded in secure shielded launchers, requiring some 28 vehicles in its field battery, the "Mace" was already a fairly mobile system that could be launched from a special transporter-erector-launcher (a Teracruzer), only requiring one support vehicle in addition to the Teracruzer.[17] Deployment of the new missiles began in 1959 in West Germany and South Korea, later they appeared in Okinawa in 1961. Their engagement range was increased to 2,400 km (the inertial-guidance modification had an 850-km range in the low-flying mode). By the way, the news that American missile forces operators received a misleading launch command during the Cuban Missile Crisis caused[18] extensive public discussion in 2015 and, in fact, featured the 873d Tactical Missile Squadron stationed in Okinawa.[19]

Around the same dates, on an island off the American continent, Soviet land-based cruise missiles were readied for a retaliatory strike. Along with nuclear intermediate-range ballistic missiles and bombs, the Soviet Union had the FKR-1 (SSC-2a "Salish") land-based cruise missiles delivered to Cuba as part of Operation Anadyr. Unlike, say, all the R-14 "Chusovaya" (SS-5 "Skean") intermediate-range ballistic missiles and most of the smaller R-12 "Dvina" (SS-4 "Sandal") theater missiles, these were ready-assembled and had their nuclear warheads in place. However, their 125-km range would have been insufficient to launch an effective strike on the U.S. soil, and they could only have been used to destroy the Guantanamo Bay Naval Base or staging grounds of the U.S. assault landing forces.

Still, the Soviet Union was designing a number of more impressive cruise

[16] Bill Yenne. The Complete History of U.S. Cruise Missiles: From Kettering's 1920s' Bug & 1950's Snark to Today's Tomahawk. Specialty Press, 2018. P. 43–50.

[17] Ibid. P. 53.

[18] The Okinawa missiles of October // Bulletin of the Atomic Scientists. 25.10.2015.
URL: https://thebulletin.org/2015/10/the-okinawa-missiles-of-october/

[19] It should be mentioned that the veteran's story–the entire narrative is based on an interview with just one man–drew a serious rebuke from experts and other missile force operators, including the veteran's contemporaries. However, since then, no substantial evidence has been published to support or refute the fact that somebody gave a misleading command, and the details of this story (for example, when the narrator took his pistol and threatened to kill any of his fellow officers if they tried to execute the command) can be explained by the narrator's appetite for drama.

missiles, the most famous of which was the “Burya” (La-350) project[20]. The USSR carried out 19 test launches over 1957–1960, of which seven could be deemed successful or partly successful. They demonstrated an engagement range of 6,500 km at a more than three times the speed of sound—still, the design specification required the range to be increased up to 7,500–8,500 km. By the late 1960s, the program, which was proving increasingly promising, was shut down by the country’s political leadership due to the progress with the R-7 “Semyorka” (SS-6 “Sapwood”) missile.

The supersonic SM-64 “Navaho” intercontinental cruise missile tested in 1956–1958 came to be “Burya”’s American “sister.”[21] Notably, however, it was far less successful than “Burya”, with no successful launches and a maximum demonstrated range of a mere 1,730 km.[22] Still, it was the United States that had the Northrop SM-62 “Snark”, the only combat-ready intercontinental cruise missile, on standby duty. The U.S. Air Force first received them in 1959 to deploy the missiles in the north-east of Maine, near the Canadian border.[23] In March 1960, the first “Snarks” were placed on regular standby 15-minute alert duty (a total of 30 batch-produced missiles were eventually placed on combat duty).[24] Unlike “Burya” or “Navaho”, the missile never boasted an impressive speed or flight altitude, but its flight performance was on par with an average bomber of the time, with near-sonic speed and a 15-km altitude ceiling. Its engagement range, though, was above 10,000 km, enabling it to engage targets on the Soviet soil with a 3.8 megaton warhead—directly from the missile field, albeit with a depressingly poor precision as the circular probable error exceeded 30 km for long-range launches. By the time the missile was placed on standby duty, however, Soviet air defense systems had been capable of effective interception of such targets, meaning the missile only had a good chance of successful strike if the air defense command and control system had been destroyed by prior attacks by the time the Snark approached the country’s borders. The problem consisted in the lengthy design process. The first air trials began in December 1950—had the missile been completed by the middle of the decade, it could have become a sound alternative to bombers carrying dumb bombs, as well as to the ICBMs that were still waiting to be deployed. This is why the “Snarks” were removed from standby duty as early as June 1961.

Initiated in 1957 to be shut down already in 1964, Project Pluto, a U.S. Air Force program to build a SLAM cruise missile with a nuclear-powered ramjet engine, is

[20] La-350 «Storm» supersonic cruise missile or Object-350 // Military Russia. 26.11.2013. URL: http://militaryrussia.ru/blog/topic-767.html

[21] The programme was terminated in the summer of 1957, but some of the missiles produced were later used for research trials and to test certain engineering solutions. The experience of building the “Navaho” missile proved useful for a quick design of the AGM-38 “Hound Dog” air-launched cruise missile.

[22] Bill Yenne. The Complete History of U.S. Cruise Missiles: From Kettering’s 1920s’ Bug & 1950’s Snark to Today’s Tomahawk. Specialty Press, 2018. P. 77.

[23] Ibid. P. 80–89.

[24] The approach to the standby duty of these missiles offer an interesting insight into how U.S. defence officials viewed the potential for nuclear war at the time: a total of five missiles were stored in each reinforced hangar with a launcher; the first missile was ready for launch within 15 minutes of receiving the launch command, the second one 15 minutes later, the third four hours after the command, the fourth within three days, and the fifth within five days (apparently, the last two missiles were kept disassembled).

also worthy of our attention. The project team built a demo engine that was tested on the ground. For obvious reasons, the program sparked additional interest after the recent disclosure of information about the Russian program aiming to design the "Burevestnik" nuclear-capable cruise missile of an unlimited range. Still, even though little is known about the "Burevestnik", we can say for sure that it has little semblance to SLAM as the former is relatively small and, as suggested by the airframe design, unable to gain high speed, although using, as we may discover from the previews, a reactor to bypass air defense regions.

Contrary to that, SLAM was supposed to be a 30-ton ultra-fast—up to Mach 4.2 at high elevation and 3.5 at ultra-low elevation—unmanned bomber-missile carrying up to 26 nuclear bombs to be dropped along the flight path.[25] A large nuclear-powered ramjet engine would be the only way for it to demonstrate the stated flight performance in an intercontinental flight (with spare operational range). Indeed, even if we forget about the propulsion system, it is highly doubtful that anyone would have succeeded in designing and building such an aircraft in the 1960s—at the very least, due to the issues with aerodynamic heating and the control and navigation systems. By the way, Project Pluto's greatest contribution came as a breakthrough in the design of navigation systems as the United States simultaneously sought to design a navigation system whose principle would later be employed in the BGM-109 "Tomahawk" land-attack subsonic missile and other cruise missiles.[26]

"Civilization is the End of Culture, its Sear and Yellow"

The creative freedoms enjoyed by defense engineers in the 1950s waned with breakthroughs in two areas: the development of ICBMs, which were quickly associated with the emerging field of astronautics; and the development of the first effective SLBMs, most notably the American UGM-27 "Polaris".

The Soviet and American ICBM programs were marching in lockstep. On August 21, 1957, the USSR conducted the first-ever completely successful ICBM launch, when a prototype of the R-7 (SS-6 "Sapwood") missile delivered[27] a dummy warhead 5,600 km from the launch site. It took the Americans until December 17 of that year to respond with a completely successful launch of the SM-65 "Atlas" prototype, but they were the first to have such a missile fully meet the needs of the military. In September 1959, the first "Atlas" missiles entered combat duty. The Soviet Union placed its R-7 on standby duty in January 1960.[28] This seeming contradiction gives both sides the reason to claim primacy in constructing the first ICBM. Rapid evolution of the ICBMs ensued, and the technology captured

[25] Despite what the media commonly suggest, the exhaust produced by its nuclear engine was not a weapon as such, and its effects were expected to be fairly mild.

[26] Yenne, The Complete History of U.S. Cruise Missiles. P. 89.

[27] Р-7 / 8К71, Р-7А / 8К74 - SS-6 SAPWOOD // Military Russia. 09.04.2022. URL: http://militaryrussia.ru/blog/topic-750.html

[28] The design of the Soviet missile, unlike the American one, did not make it possible to keep a number of missiles on permanent launch alert. As for the "Atlas", the engineers managed to achieve permanent readiness of one of three missiles during the very first deployments.

the minds of the military and the political leadership in both countries to receive top priority. They were brought to the baseline operational condition before intercontinental cruise missiles, which is the reason why programs like “Burya” and “Navaho” were soon terminated. The potential benefits of such an approach highlighting cruise missiles was not obvious at the time.

An even more intensive “clean-up” of cruise missile projects was driven by the unprecedented success of the UGM-27 “Polaris” submarine-launched ballistic missile: in virtually no time (approximately four years), engineers from Lockheed could build a solid-fueled missile whose overall performance was way ahead of its time and that was perfectly suited to submarine service. In July 1960, USS *George Washington* (SSBN-598) conducted the first missile launch from a submerged submarine, with the submarine taking part in its first combat patrol mission with a full load of 16 missiles as soon as November 15, 1960. To field these missiles, the United States built 41 SSBNs of five different classes before 1967, which served as the primary naval component of the U.S. strategic nuclear forces until the early 1980s, when the *Ohio* class submarines started to enter service.

In the Soviet Union, the first *Yankee* class (Project 667A) submarines with equivalent weapon systems were not delivered to the Navy until late 1967. Like before, these were armed with liquid-fueled missiles as the USSR was for a long time lagging behind in the development of solid-fueled missiles. The country’s first high-volume solid-propellant SLBM was the R-39 (SS-N-20 “Sturgeon”) that would appear in the 1980s, and its weight and size required that the USSR design and build the world’s largest submarines, the *Typhoon* class (Project 941 “Akula”).

The “Polaris” caused such a stir in the United States that the U.S. Navy attempted to get the matters of strategic deterrence exclusively transferred to its remit. The only way the U.S. Air Force managed to hold its grounds was through reasoning that ICBMs would be a cheaper solution (especially as far as “the cost of number of devices on permanent duty” goes, as it is a mere one out of three to four submarines at best that is carrying out the combat patrol mission at any given time), and they would see an easier increase in their throw weight and accuracy as well as a higher operational flexibility. This, as well as the potential of ICBMs being used in counter-force strikes, fit well into the “flexible response” strategy that was formulated by the newly elected John F. Kennedy and his administration.

Still, budget constraints left many programs overboard. The Navy had to give up on long-range carrier-based bombers and hydroplanes and on equipping surface ships with ballistic missiles; cruise missiles were soon decommissioned. The Air Force faced certain challenges with testing the Douglas GAM-87 “Skybolt”, an air-launched ballistic missile, on its early stages and failed to obtain the required funding to whip the missile into shape. The situation with “Skybolt” even triggered a “diplomatic crisis”, since the missile was developed in cooperation with United Kingdom as a projected weapon for their long-range bombers. J.F. Kennedy resolved the conflict by concluding what is known as the Nassau Agreement in

December 1962, whereby the United States committed to lend assistance to its key ally in building SSBNs as well as supply the UK with "Polaris" SLBMs. This agreement clearly came to define the future of Britain's strategic nuclear forces—until this day, they are made up of submarines built with the aid of the United States and carry U.S. missiles,[29] while prospective SSBNs of both countries will have an identical design of the missile bay.

By virtue of the 'national selection', three means of nuclear deterrence asserted themselves as most promising in the early 1960s: land-based ICBMs for the most intensive, powerful and accurate strikes; SLBMs as the most resilient weapon for guaranteed countervalue attacks; and long-range bombers primarily armed with cruise missiles as the most flexible striking element. In terms of deployment, ICBMs quickly shifted from reinforced bunkers to sheltered underground silo launchers.

However, as early as 1958, the U.S. Air Force launched a program to build rail-mobile systems (missile trains) carrying solid-propellant "Minuteman" missiles as a cheaper yet mobile and robust alternative to the Navy's "Polaris".[30] The program was terminated in December 1961, as the United States ultimately opted for deploying missiles in silos—this was cheaper, allowing to produce more missiles for the same price, and could guarantee greater accuracy and faster command-to-launch time.[31] These aspects were of higher priority to the United States, whose strategic forces were mostly built for counter-strikes, although later they would repeatedly return to mobile missile systems. In the early 1990s, the end of the Cold War would be the only thing that prevented the deployment of a missile train carrying heavy LGM-118 "Peacekeeper" ICBMs and a wheel-mounted mobile ground missile system (MGMS) carrying light MGM-134 "Midgetman" ICBMs.

The Soviet Union attached more priority to retaliation strikes—such as when the command to launch missiles is only given after confirmed nuclear blasts on its soil—which explains why Moscow focused more on the survivability of the ground component of its strategic nuclear forces, being far more skeptical about the reliability of SSBNs as compared to the United States on account of the obvious imbalance in the capabilities of the Navies and basing systems. Endeavors to design a mobile ground-based system resulted in the siting of the world's first mobile ground complex, the RT-21 "Temp-2S" (SS-16 "Sinner"), in 1976. Designed at a time of détente, the system was produced on a small scale for political reasons, but the engineering experience helped the USSR build the RSD-10 "Pioneer" (SS-20 "Saber") and the RT-2PM "Topol" (SS-25 "Sickle") systems later on. It is safe to say that today's RS-24 "Yars" (SS-29) is the direct descendent of the "Temp-2S". A missile train with the RT-23 "Molodets" (SS-24 "Scalpel") heavy missile was placed on full combat alert in 1987; it was

[29] What is more, the United Kingdom even chose not to buy the modern "Trident" SLBMs. Instead, they have agreed on a pool of these missiles within the U.S. arsenal, so British submarines travel to the United States to reload.

[30] Steven Pomeroy, An Untaken Road: Strategy, Technology, and the Hidden History of America's Mobile ICBMs (Naval Institute Press, 2016). P. 66–69.

[31] Ibid. P. 98–99.

produced on a small scale and removed from service in the early 2000s once the guaranteed service life of the missiles, as well as that of their silo-based modifications, expired.

Decision-makers found the triad's configuration as it shaped up in early 1960s to be optimal, which rendered its further development fairly conservative, with quixotic ideas being typically left to paper. The only brand-new types of strategic delivery systems that entered service in the 1980s—apart from the Soviet mobile ground missile systems—were the compact low-altitude cruise missiles. Strategic aviation and submarine forces soon began to convert to such missiles, and while this clearly was a substantial leap in capabilities, with one missile bomber now capable of attacking as many as twenty targets from a safe distance, this was more of an evolution of the missiles from the early 1960s. In fact, this could have happened sooner had more thought and attention been given to this field.

Payload of both ground-based and sea-launched ballistic missiles evolved as well, mainly through miniaturizing the warheads and improving their accuracy. Besides, improved accuracy made it possible to reduce their yield so that today's warheads are usually ten times "weaker" than they were in the early 1960s. Until recently, the biggest revolutionary breakthrough had been the emergence of the multiple independently targetable reentry vehicle (MIRV). Other potential breakthroughs, including a conversion to fractionally orbital—the Soviet Union had a small number of these on pilot duty—and guided reentry vehicles, eventually fell through.

However, we are now nearing the end of "the stagnation era" in the history of the nuclear triad, which has long been held back by the conservatism of its customers, the arms control agenda and a reluctance to trigger a new nuclear arms race. Discussing the challenges that the classic triad faces today, in the wake of technological progress, is a matter for another article.

For now, let me just cite the reason why this account of technological innovations made over half a century ago has been so long. The vivid examples have been provided to demonstrate how advances in weaponry are not pre-determined; rather, they are often sporadic and depend on trivial things. When it comes to strategic nuclear weapons, however, any progress is intertwined not only with the military posture but with global politics and the emerging global landscape as well. There is no arguing that nuclear warheads peacefully resting in armories and missile silos weighed with the decisions made by the U.S. and Soviet leadership no less than party fellows, public opinion polls and pronouncements of foreign leaders.

Bearing all these examples in mind, what could the triad's alternative history have been?

— Had the United States failed to design the "Polaris" so quickly and effectively, many other systems would likely have received funding. The Navy would have had to keep developing carrier-borne aviation for strategic strike missions, while resource shuffling would—with all probability—have made it less effective in local conflicts, such as the upcoming Vietnam War. The evolution of cruise missiles would probably have allowed for effective attacks on coastal targets, although the Navy would overall have retained a secondary role. Sooner or later, an effective SLBM would inevitably have been designed; though, by this time, its "alternatives" could have found their niches to gain some foothold. Carrier strike groups with long-range hydroplane missile bombers could thus have been a rather realistic scenario.

— The U.S. Air Force could have had the opportunity to tune up their air-launched intermediate-range ballistic missiles, which would quite likely have made the situation a lot more aggressive and tense as the Soviet leadership—subsequently, the American leadership as well, since the USSR would have tried to build an equivalent of its own—would have had to find themselves under constant fear that an attack on Moscow could only be a matter of minutes, with another aggravating factor being the virtual impossibility of getting Soviet fighter jets to patrol the airspace of Norway, unlike the case of anti-submarine warfare.

— Had the GAM-87 "Skybolt" been successful, the UK would presumedly be far less reliant on the U.S. for its nuclear policy, as getting Britain's strategic nuclear forces incorporated into NATO's "joint" forces was part of the Nassau Agreement. Without the argument that submarines would guarantee retaliation while not "attracting" enemy missiles to targets on the British Isles, the anti-nuclear movement in the UK could have forced the government into decommissioning all nuclear weapons in the country once the Cold War ended.[32]

— Had the Cuban Missile Crisis never happened and had the American administration retained its interest in proliferating U.S.-made nuclear weapons among its allies, then Russia'ы Foreign Ministry would now be ranting about NATO Joint Nuclear Missions being a group of allied ships with nuclear missiles onboard making occasional patrol missions rather than a hundred tactical aviation bombs that essentially make no sense from the military perspective. Alternatively, Joint Nuclear Operations could feature some outdated trains roaming across Europe armed with intermediate-range missiles.[33] Otherwise, Greenland could have become what would today be regarded as NATO's nuclear stronghold with a multinational garrison charged with operating the U.S. missiles.

— An emergence of full-fledged multinational nuclear forces under the auspices of NATO would have inevitably disabled the non-proliferation regime as we know it today. One of the basic tenets of today's geopolitics could have been impossible for the sole reason that one man, Charles de Gaulle, had had better relations with the United States or if Greenland's ice sheet had a different nature. These are all

[32] Britain's last air-borne nuclear weapon, the WE.177 tactical bomb, was removed from service in 1998, with the last U.S. nuclear weapons withdrawn in 2006. It may well be that the United Kingdom is the only nuclear state whose arsenal features only one type of nuclear weapons.

[33] In April 1960, the United States proposed deploying in Europe a missile train with a hundred "Polaris" missiles that was well-suited for the purpose as one of the potential scenarios for NATO's joint nuclear forces. Charles de Gaulle supported this plan provided that a third of the missiles would be handed over to France as the sole and independent operator. The United States expressed no interest in this counter-proposal. Zinchenko A. V. France's Nuclear Policy. URSS, 2010. P. 110–111.

fairly random variables in the equation whose outcome (self-evidently?) tells us how many nuclear states we have in the world.

— Designers of intercontinental cruise missiles could have seen more successes and luck, while the designers of ballistic missiles would have experienced more setbacks. Had "Burya" been ready for deployment well before the R-7 (SS-6 "Sapwood"), chances are that Soviet leaders would have initiated the construction of the missile in case of a dire need. The same applies to the United States. Effective ICBMs would eventually have been built, but it would have taken longer with less funding. In addition to altering the approach to nuclear exchange at an early stage, it would have affected space programs that basically lived on defense left-overs early in their history.

— The United States may well have preferred mobility over strength to commence building missile trains in the early 1960s. They came very close to this, even establishing the would-be strategic railway missile wings.[34] How would the U.S. nuclear posture have changed if the triad's ground component relied on a smaller number of missiles that would, in turn, be more fail-safe? The United States could then have had its posture revolve less around counter attacks, rather leaning more towards retaliation. In this case, missile trains may well have been coupled with unexpected consequences—for example, the United States could have had a much better railway infrastructure today as rail support efforts were considered to be one of the "pros" in favor of the mobile solution. This would have been similar to the Soviet Union where many thousand kilometers of track were renovated for an extremely limited missile train program. This is a sort of a "butterfly effect" that we are dealing with here: in the early 1960s, a group of generals and political leaders decided that "the more missiles, the merrier" but, fast forward to the 2020s, the United States, being among the world's most well-off nations, has no high-speed rail line at all.

There are many such scenarios, but it is more important to look to the future, based on past experience and an understanding of its non-predeterminism.

[34] Steven Pomeroy. An Untaken Road: Strategy, Technology, and the Hidden History of America's Mobile ICBMs. Naval Institute Press, 2016. P. 99.

Nuclear weapons: today and possible futures

Transformations of the Nuclear Triad

In the previous section, we took a brief look at[35] possible alternatives for the evolution of strategic nuclear forces at the dawn of the nuclear era in the 1950–60s. Following a period of "creative experimentation," the nuclear triad had more or less settled in its classic form, and it has since survived to the present day without any fundamental changes. But this is bound to end very soon.

Certainly, to say that the nuclear triad has not changed after its full deployment in the early 1960s would be an oversimplification. The "form factor", so to speak, had been well defined for strategic delivery vehicles, but the capabilities of the internals had been substantially changing throughout the Cold War, both in the Soviet Union and in the United States, with subsequent developments in Russia and China on later stages, and with the U.S. is now reactivating programs to modernize its triad.

The 1970s saw a proliferation of new type of payloads for intercontinental ballistic missiles (ICBMs), namely called a multiple independently targetable reentry vehicle (MIRV). The development of miniaturized thermonuclear warheads, missile and electronic technology converged into a system that instead of hitting a target with a single warhead could send on a prescribed course a post-boost dispenser stage, commonly known as a MIRV bus, which provided a platform complete with its own engines and a highly accurate control system that could release, at the exact pre-computed time, a bundle of warheads, without propulsion of their own, guided along accurate pathways to engage separate targets. Therefore, one MIRV-carrying missile was capable of striking a dozen targets located hundreds and thousands kilometers away from each other. MIRVs were preceded by simpler but fewer manufactured multiple re-entry vehicles (MRVs) that could propel 2 or 3 warheads with a preset deviation from a central aim point—not so flexible as MIRVs but good enough for taking care of large area targets in countervalue attacks (i. e. against cities). Under the Russian classification, first MIRV-equipped ICBMs are considered 3rd generation systems of that type, whereas, for example, modern mass-produced "*Yars*es" belong to the 5th generation.

Along with land-based missiles, MRVs / MIRVs were fitted onto submarine-launched ballistic missiles (SLBM) that had long been viewed as counterforce weapons due to their lower accuracy—a limitation which has, apparently, been overcome only in the recent decades. The high survivability of their launch platforms—nuclear-powered submarines (SSBN or PLARB[36]in the Russian terminology)—contributed to their reputation of the "weapon of assured

[35] Alexander Yermakov. The Nuclear Triad: Alternatives from the Days Gone By // Russian International Affairs Council (RIAC). 31.08.2021. URL: https://russiancouncil.ru/analytics-and-comments/analytics/yadernaya-triada-alternativy-proshlogo/

[36] Under Soviet and Russian classifications, this type of submarines, apart from the earliest models, has been traditionally designated as RPKSN (literally, Strategic Purpose Underwater Missile Cruiser). A more generic designation, commonly used to describe non-Russian submarines, is PLARB, which translates as Nuclear Submarine with Ballistic Missiles and corresponds to SSBN in the US Navy classification.

retaliation." That became a particularly fitting description when SLBMs' range was extended to intercontinental distances, from the mid-1970s in the USSR (R-29 / SS-N-8 Sawfly) and from the late 1970s in the United States (UGM-96 Trident I). Now, there was no need for nuclear submarines to penetrate antisubmarine barriers on their way to potential launch areas as they could comfortably patrol their own secure waters in the near maritime zone (200–500 miles from the coastline), though it has always been tempting, especially for Americans with their advantageous alliance geography, to keep some of the submarines "at a pistol shot".

Another approach taken by the USSR to bolster the survivability of its strategic delivery vehicles in case of the enemy's counterforce attack was to use road-mobile transporter-erector-launchers (TELs), or mobile ICBMs. The rationale was that mobile platforms dispersed in the period of threat across a wide deployment area (which in Russia often has the benefit of forest canopy cover that hinders detection even from space and to some extent cushions the effects of nuclear explosion) would require the attacking party to use up radically more warheads to assure their destruction. The first unit entering operational service in 1976 was RS-14 Temp-2C, a limited number of which were produced. Its direct descendants include the TEL truck carrying the RSD-10 *Pioneer* medium range missile and the modern systems well known to anyone with the slightest interest in weaponry: RS-12M *Topol*, RS-12M2 *Topol*-M, and the RS-24 *Yars* family (note that a significant number of *Topol* and *Yars* missiles are deployed in underground missile silos). Largely inspired by the Soviet and Russian school of thought, China, too, is now busy developing its own TEL fleet to address survivability concerns regarding its strategic nuclear forces (SNF). Beijing's first fully mobile ICBM platform was DF-31A, which first came into service in the late 2000s. A couple of years ago, China also fielded heavier MIRV-armed DF-41 missiles. North Korea has its mobile ICBM program as well, although its systems with large liquid-fuel missiles have limited mobility that merely allows them to drive out of their underground shelter into the open to fire off from a level ground nearby.

Notably, no other nuclear power, including the United States, has so far developed its own ICBM-capable TEL system. The closest the U.S. came to having their mobile platform was the MGM-134 *Midgetman*, a project aborted in 1992 for obvious reasons after one successful test launch. Its conceptual design and actual construction are very different from the classic design of Soviet, Russian and Chinese missile trucks (with their massive tubular missile container atop of a heavy-duty multi-wheeled chassis). It will be discussed later, along with its Soviet quasi-equivalent, the *Courier* system.

A derivative mobile concept is an ICBM launch system mounted on railway cars or on rail-mobile ICBM platforms. Such systems were also deployed exclusively by the USSR/Russia with heavy solid-fuel RT-23 *Molodets* (SS-24 *Scalpel*) missiles from 1987 till the end of the missiles' service life in the early 2000s. The United States considered creating a rail-based *Minuteman* ICBM as early as the 1960s (for details, see the previous article[37]), but its best and nearly completed effort by

[37] The Nuclear Triad: Alternatives from the Days Gone By // Russian International Affairs Council (RIAC). 03.09.2021. URL: https://russiancouncil.ru/en/analytics-and-comments/analytics/the-nuclear-triad-alternatives-from-the-days-gone-by/

the end of the Cold War was the *Peacekeeper* Rail Garrison program (designed to carry the LGM-118 *Peacekeeper* missile), which had to be scrapped much like the *Midgetman*.

The 1980s brought a revolutionary transformation for the triad's airborne leg when gravity bombs and bulky cruise missiles, as the primary nuclear armament, were replaced by small-size hard-to-detect high-precision cruise missiles, the American AGM-86B ALCM and the Soviet Kh-55 (AS-15 *Kent*), featuring the kind of designs we are more accustomed to seeing today. In addition to the much smaller size and weight allowing for several-fold bigger carried weapon loads, the new cruise missiles offered high accuracy targeting from an impressive range (over 2000 km). The new comers brought the cutting edge back to the triad's air-force component, which had steadily been slipping into obsolescence. At the same time, missiles with similar performance specifications were adopted by the navies, with submarine fleets being the first in line. Nuclear *Tomahawks* and *Granats* (SS-N-21 *Sampson*) were installed on both multipurpose and the less numerous special purpose submarines carrying land-attack cruise missiles (LACM),[38] enabling both types of submarines to attack both coastal as well as remote inland targets with high precision and almost undetected. Incidentally, provided that the USSR had developed such submarines ahead of the United States,[39] it is rather odd to hear the statements made more than once by the Russian leadership about "the unfairness of the INF Treaty that fails to account for sea-based cruise missiles." However, this fuzzy status of being halfway between strategic and conventional weapons proved to be quite a hassle, stalling the development of nuclear weapons of this class for political reasons. Under the "Presidential initiatives" of Bush, Gorbachev and Yeltsin, the two governments agreed not to arm vessels on patrol duty with non-strategic nuclear weapons. In the early 2010s, the United States retired its remaining nuclear-capable *Tomahawks* altogether. The feeble attempt made by the Trump Administration to launch a replacement project has ended with [40]the shutdown of the SLCM-N program this year.[41] There is a widespread view that Russian *Kalibr* missiles are indeed existent and deployed in nuclear configuration, but the lack of data regarding their number, basing modes and role in the military doctrine leave much room for speculation.

The modern edition of the nuclear triad is a long-established system, and when today's generals at Russia's Strategic Missile Forces, U.S. Air Force, France's *Force de dissuasion* or China's PLARF were just starting their careers as lieutenants, it was not so different, and even some hardware were the same. Nevertheless, with advancing science and technology (including improvements

[38] S-10 Granat system with a KS-122 (3M-10) subsonic small land-attack cruise missile (LACM), not to be confused with P-700 Granit naval anti-ship hypersonic cruise missile. Granat is the direct precursor of the modern Kalibr missile system.

[39] Shortly before its dissolution, the USSR had modernized four 667AT Grusha SSBNs (previously designated as the 667A Navaga project), each armed with 32 strategic cruise missiles, well above the maximum missile capacity of American submarines until the 2000s, when four Ohio SSBNs were converted to SSGNs with an extended capacity to carry 154 cruise missiles.

[40] Biden Administration Kills Trump-Era Nuclear Cruise Missile Program // Breaking Defense. Valerie Insinna. 28.03.2022. URL: https://breakingdefense.com/2022/03/biden-administration-kills-trump-era-nuclear-cruise-missile-program/

[41] Biden administration kills Trump-era nuclear cruise missile program // Breaking DEFENSE. 28.03.2022. URL: https://breakingdefense.com/2022/03/biden-administration-kills-trump-era-nuclear-cruise-missile-program/

in other types of weapons) and rising military and political tensions between major powers, business as usual is not an option. Following below is a brief and inevitably superficial outline of the key challenges facing each of the SNF triad components and their potential solutions.

The Land Component: Challenge of Vulnerability

In the modern world, the land-based strategic nuclear capability only includes missiles installed in hardened underground silos and on transporter-erector-launchers (TELs), remaining an integral part of the arsenals maintained by the three top nuclear powers out of the "Legitimate Five" (the United States, Russia, and China) and by all the four "illegal" nuclear weapon states (Israel, India, Pakistan, and North Korea).

Underground silos offer a host of benefits: fewer restrictions on size and weight when it comes to missile design, higher accuracy thanks to the pre-established coordinates of launch points, relatively simple and inexpensive construction, maintenance and operation, the shortest command-to-launch time (as fast as several minutes to flash down the entire chain of command when on high alert), and representing the biggest share of the warhead inventory constantly available to launch at short notice.

With all the mesmerizingly superior merits, their high vulnerability has been "the Sword of Damocles" hanging over the land-based forces from their inception. Early ICBMs were installed on open pads—not unlike the familiar launch sites for space rockets (in fact, both space and military delivery vehicles in those times were often modifications of the same designs)—but it quickly became obvious that such facilities were highly exposed even to enemy's low-accuracy ICBMs, especially considering the high nuclear yields that were the common remedy of the day for poor accuracy. Nuclear early-warning systems and reaction spans were inadequate for protecting ICBMS by counter launch. Once it became operationally possible, missiles were stored in hardened underground silos which, given their widely scattered locations, required a near-bull's-eye hit to destroy and, as a consequence, preferably two warheads aimed at each silo.

The concept got less reliable with the advent of MIRV-armed ICBMs. The attacker, using missiles with three or more submunitions, had good chances to wipe out all the silos without spending all of its warheads, which is the definition of a successful counterforce strike when the attacking party is left with considerably more delivery vehicles and warheads than its adversary, allowing the attacker to blackmail the disarmed country with further strikes against cities using the remaining firepower.

In very simple terms, the key objective of the SNF survival strategy is to ensure that your adversary is compelled to spend much, ideally severalfold, more delivery vehicles and warheads to destroy the smaller number of your weapons. As a result of such first counterforce strike, the attacked country is set to emerge with prevailing nuclear forces. In this approach, preemptive strikes make no sense and classic strategic stability[42] is easy to maintain. Note that inadequate SNF survivability of one side is as dangerous for other sides as it is for itself—in a spiraling crisis, an international actor that feels vulnerable may lose the nerve, attacking first out of fear, to remain defenseless.

Responding to the deployment of the opponent's MIRVed ICBMs, the Soviet Union opted for mobile platforms, wheeled-chassis and rail-mobile ballistic missile systems. Their mobility and camouflage prevent the adversary from obtaining reliable positioning data, and their destruction requires barraging the enemy with a severalfold bigger number of warheads. However, the advancement of space surveillance technology along with data processing and control systems (including machine learning and big data technologies already proven in civilian applications) could, even in the short term, severely compromise the classic mobile ICBM concept, which is essentially built around "juggernauts" like *Topol*, *Yars* or DF-41.

This is not a matter of visibility. While KN-11 KENNEN satellites could detect strategic missile trucks way back in the Soviet era, data transmission and processing still incurred substantial lags in reaction, and the few available satellites, equipped with sufficient detection capability, could only track narrow strips of land across the enormous Soviet territory. So, continuous monitoring of all mobile ICBMs in all operational areas was out of question, and the several-hours-old positioning information is practically useless for targeting. Another important factor to remember was that the side with mobile ICBMs would have been sure to employ a range of camouflage and concealment methods in the period of threat (not the mere camouflage netting thrown over parked vehicles, but, for instance, various aerosols with special properties) as well as to know satellite passing times in advance.

Today, the situation is totally different. Apart from the obvious change in data processing speeds, a fundamental transformation has occurred in space: the "eyes" have not become much sharper, but vastly more numerous, which is even a bigger threat to survivability of mobile platforms. The revolutionized space launch market[43] and the progress in microelectronics empowered even private operators to shoot entire constellations of satellites into orbit, providing remote sensing services. For example, Planet Labs has over 200 satellites in orbit[44]—most of them, of course, providing low-resolution imagery of circa 3 meters/pixel, but its fleet also includes about 20 SkySats capturing ground data at 50 cm/pixel. Maxar, on the other hand, operates a few WorldView satellites that can provide imaging data on par with military-grade systems in terms of resolution (as high as 30 cm/pixel). These are just two Western firms out of a legion that are certainly willing to cooperate with the Pentagon. The latter is also building the new National

[42] Strategic stability is a balance of relations and strategic forces between two nuclear powers that eliminates incentives for either of the sides to launch the first nuclear strike.

[43] Yermakov Alexander. America's «New Space». Seizing the Airhead on Battlefields of Tomorrow // Russian International Affairs Council. 30.12.2019.
URL: https://russiancouncil.ru/analytics-and-comments/analytics/novyy-etap-militarizatsii-kosmosa/

[44] Chester Gillmore. Planet To Launch 44 SuperDove Satellites On SpaceX's Falcon 9 Rocket // Planet Labs. 12.01.2022
URL: https://www.planet.com/pulse/planet-to-launch-44-superdove-satellites-on-spacexs-falcon-9-rocket/

Defense Space Architecture (NDSA), an unprecedented constellation of many hundreds, expanding in the future to thousands, of small coordinated satellites with diverse functionality, including surveillance. In this context, the current decade is probably the last when the United States is still unable to threaten the states, which rely on classic mobile ICBMs, with its capability to continuously monitor the positions of missile trucks of the opponent. Besides, this threat could potentially be augmented with hypersonic high-precision conventional missiles.

Surely, more advanced camouflage, active countermeasures to disable satellite optics with laser systems like the directed-energy weapon *Peresvet*—here, shooting satellites down could also be helpful—but there is a danger of being drawn into a self-obsessed wild goose chase after the ever-eluding survivability of classic mobile ICMB systems while completely forgetting that mobility is only a means to an end. A method that has its flipside: mobility has always come at a price, both in terms of money (mobile systems are way more expensive to produce and even more so to operate) and in terms of readiness as the land-based ICBM fleet inevitably has a smaller share of launch-ready missiles as compared to underground silos as well as a longer reaction span.

In a situation where classic ICBM TELs are losing their primary advantage, there are two obvious solutions. Number one would be to scrap them altogether, putting focus on silo-based options (even Russia has never given up silos that are now used to store most *Topol*-M's and a considerable number of *Yars* ICMBs, let alone heavier vehicles). In this case, the progress of space reconnaissance technology would no longer make any difference (in this particular application), whereas the following silo-specific strengths could be leveraged to boost survivability:

Far better protection against a nuclear explosion or a high-precision conventional strike. In fact, destroying a silo requires a direct hit by a small to medium yield nuclear warhead or a super-surgical strike with a high-precision long-range conventional missile, while it has to be specifically designed to penetrate such targets. Legacy silos are increasingly hardened up thanks to the smaller new-generation missiles that free up more room inside for added reinforcement.

Significant ease of setting up launch site missile defense both to impede targeting (with a combination of jamming, aerosols and decoys) and intercept high-precision conventional missiles or even ballistic missile warheads using short-range active missile defense systems. The task is much simplified because the aim point coordinates are known in advance, and no warhead can destroy a silo if activated at considerable altitudes. Hypersonic gliders are even more vulnerable on the terminal flightpath than the faster and smaller warheads of standard ICBMs.

Lower cost (money and man-hours) of manufacturing, deployment and operation, and a much higher, nearly absolute, share of the missile inventory continuously available on high alert. No "headaches" associated with extensive counter-sabotage measures (counter-mine, air defense, etc.) to protect TEL batteries marshalled into columns. More reliable and simple communications and control management.

Zero threat of losing most of the arsenal at home bases as a result of an enemy's sudden attack, unless mobile ICBMs have been moved to dispersed positions in advance, and no need to mobilize all strategic missile battalions into the "field" (a tactic best avoided, as it can fuel escalation).

The shortest command-to-launch time; the best way for a missile to survive an enemy strike is to get launched first.

With easy-to-provide defense capability and a bigger share of ready-to-launch inventory, underground ICBM silos may offer a somewhat better survivability performance than the classic road-mobile systems, as these are easy to detect and are relatively vulnerable. This may not be the case, however, with regard to mobile platforms of a conceptually different type.

Faster or Deeper

To get some tentative insight of possible alternatives for the future evolution of mobile ICBMs, it would make sense to look back at some projects dating back to the Cold War. Many of them are still around, like hypersonic gliders that originated from the R&D programs of that time. Unlike Soviet projects, on which we have relatively scarce data to go by, we know significantly more about American efforts. For the subject in question, it would be best to consider a program to develop a mobile land platform for the small MGM-134A *Midgetman* and discussions of platform options for the LGM-118A *Peacekeeper* (also known as MX).[45]

The former is an interesting case of an essentially different mobile design compared to the Soviet missile truck family that had evolved into a classic concept adopted by China and North Korea. Americans planned to use a specially designed lightweight single-warhead ICBM with a launch weight of only 13.6 tonnes (for comparison, *Minuteman-III* weighs 36 tonnes while the weight of *Yars* is about 46 tonnes[46]). With corresponding throw-weight sacrifices, the small ICBM could be fitted onto a relatively compact Hard Mobile Launcher (HML) that, due to its geometry and robust construction, was good at surviving the effects of nuclear weapons. For additional protection, shortly before an expected attack, the HML truck could lower its body onto the ground, partially ploughing itself into the soil. Although this would be a far cry from the security of an underground silo, the truck was able to withstand an explosion of a medium-yield MIRV warhead at a distance of 1–1.5 km (wherever possible, of course, the HML crew would also take advantage of rugged topography, etc.).[47] This is a fairly long distance to dash, but—given the smaller missile weight—the HML should have been able to drive at 45–60 km/h on unsurfaced roads.

[45] As an example, see the declassified MX Missile Basing Report (September 1981). URL: https://ota.fas.org/reports/8116.pdf

[46] Russia's Defense Ministry Briefs on Zircon Mass Deliveries // Zvezda. 29.01.2021. URL: https://tvzvezda.ru/news/20211291445-7B75N.html

[47] According to available data, HML strength was assumed to withstand at least 30 psi, equivalent to a 300 kiloton blast at a distance of about 1.3 km. Increasing the yield would be ineffective in this case, e.g. assured HML destruction at 2 km will require over 1.2 megatons, another good illustration showing that MIRV is a more effective solution for most targets.

With a *Midgetman* HML randomly based in a deployment area (or with at least more than 15 minutes warning time for garrison-based HMLs in garages on high alert), the attacker, even knowing its location at launch time, would have had to barrage the area with a disproportionate number of warheads for an assured target kill.[48] Today, however, the "dash to disperse" tactic, which used to be preferred over "moving shelters", has been undermined by the increased threat of hypersonic terminal-homing missiles or externally-guided munitions (for example, with satellites providing targeting data).

Another, more radical, option is to go completely underground, dramatically reducing the effectiveness of surveillance. During the early development of the MX ICBM basing plans, the principal option was the random basing by moving mobile launch platforms between twenty three shelters/launch sites via underground tunnels (Multiple Protective Shelter, MPS concept) connected by a 24-kilometer loop, nicknamed the "racetrack."[49] In peacetime, and especially so at a time of threat, transporters were supposed to keep Soviet reconnaissance teams busy by continually reshuffling the MX launchers and decoys between shelters, thus presenting multiple aim points, all of which would have to be targeted in case of a strike. A different concept proposed a little earlier was that of a buried trench or missile subway 1.5 meters deep using self-propelled unmanned missile launch vehicles.[50] Each missile would run in a twenty-kilometer-long tube, moving randomly between fully concealed potential launch points spaced at every half-mile where missiles could be launched after erecting the container right from under the ground. Each flight (group) of missiles was to be controlled by a mobile launch control center with a two-person crew. Considering that the trench system would be hardened, tortuous and fitted with blast-restraining plugs, the attacker, even knowing the trench layout, would have to blow up a vast area to hit all the missiles.

U.S.-designed underground projects of the 1970–1980s never made it off paper, largely because of prohibitive costs,[51] and the projects of rail-mobile *Peacekeeper* and land-mobile *Midgetman* HML that had just moved into execution, were terminated after the collapse of the Soviet Union. Sure enough, the Soviet Union had also been pondering further development of mobile ICBM platforms. Today, we know much less about those conceptual designs, and among the projects that progressed all the way to the "hardware" phase, the most intriguing was what would be the Soviet answer to the *Midgetman*—the RSS-40 Courier with a lightweight ICBM[52].

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[48] According to the report (see below), with HMLs randomly based across the deployment area and at least a 15 minute warning, the attacker will have to spend eight 0.5 megaton warheads per each mobile Midgetman; also note that the estimate does not explicitly account for the time to process surveillance and transmit targeting data. Art Hobson, "The ICBM Basing Question," Science & Global Security 2, (1991). P. 153–198.
URL: https://scienceandglobalsecurity.org/archive/sgs02hobson.pdf

[49] Steven Pomeroy, An Untaken Road: Strategy, Technology, and the Hidden History of America's Mobile ICBMs, (Naval Institute Press, 2016). P. 171–174.

[50] Ibid. P. 157–160.

[51] Curiously, one of the biggest headaches for the United States government was the need to buy up huge tracts of land (as a single plot) from private landowners, a ridiculous situation from other countries' perspective. Even for the existing silos, the government had reduced the purchased land patches to the bare minimum so that now these strategic facilities are literally surrounded by local farmers' grazing cattle.

[52] RSS-40 Courier (SS-X-26) // Military Russia. 01.04.2016. URL: http://militaryrussia.ru/blog/topic-442.html

Options considered at the early stage of the project included deployment in standard cargo containers mounted on box-truck chassis.[53] In a period of threat, RSS-40 trucks would be randomly run on public roads, with their survivability enhanced by camouflage. This approach has its downside (the need to manage security on patrol routes and exposure of civilian infrastructure to potential nuclear attacks), especially in the modern world and with new surveillance and data handling technology, but it could hold some potential as an improved version of "dispersing mobile launchers."

The shifting military and technical environment as well as the revving-up global arms race will call for revolutionary changes across all the SNF components to ensure survivability of national strategic forces. The "demand" for such breakthroughs on the part of the political and military leadership of all nuclear-armed powers will be relentlessly on the rise in the near future. The U.S. harbors plan to first deploy their upcoming LGM-35A *Sentinel* ICBM, developed under the Ground Based Strategic Deterrent (GBSD) program, in existing silos, but they do not rule out adding mobile options in the future. Similarly, time will show what new Russian systems, Kedr[54] and Osina[55], are going to be like. What is known so far is the continued silo and mobile basing configurations, but the latter will not necessarily follow the usual design. China has commenced operational deployment of its DF-41 ICBMs on mobile launchers and is believed to be constructing several "missile fields" simultaneously consisting of several hundred silo facilities.

[53] Note that as the project moved forward the missile weight and dimensions increased and absolutely required a special chassis design (though much more compact than Topol carriers). It does not mean, however, that the missile dimensions couldn't have been reduced with further system evolution.

[54] Russia To Design New Mobile Missile System // TASS. 17.12.2021. URL: https://tass.ru/armiya-i-opk/13223385

[55] Designing New 15-P-182 Strategic Missile System, Part of Osina-RV Development Phase // Livejournal. 15.06.2021. URL: https://bmpd.livejournal.com/4331641.html

Nuclear future: underwater and in the skies

The Air Component: Searching for Ways to Justify its Existence

Heavy aircraft served as the first carriers of nuclear weapons, free-falling bombs, and for a long time, they remained the principal carriers. As time went by, bombs were first supplemented and then virtually supplanted by missiles, particularly after today's long-range cruise missiles (LRCM) appeared in both in long-range and in small-scale. However, despite new weapons, missile bombers still had several problems that resulted in only the USA and Russia (and to some extent China with its program for designing a new bomber, which likely has lesser priority than developing ICBMs and nuclear submarines) keeping them in service.

The main problem is their low survivability compared to other components of the SNF triad. In the times of peace, large aircraft with highest requirements for land-based infrastructure are concentrated in several air bases, while under threat they can be distributed between several other potentially ready air bases, but they will still constitute a small number of targets vulnerable to the adversary's nuclear strike. Potentially, when under most danger, they can be switched to airborne alert mode (during Operation Chrome Dome in 1960–1968, the USA even attempted to make airborne alert a regular practice[56]), but in the long-term, this practice will rather do more harm since personnel fatigue and increasing need for aircraft maintenance will begin to reduce the overall number of combat-ready aircraft. A less harsh option is keeping part of the aircraft fleet on the ground in a high (five- or fifteen-minute) stand-by readiness to be airborne. With a properly working missile warning system (MWS) and rapidly transmitted commands, aircraft on stand-by can be saved from the strike. Unlike an ICBM, an aircraft can always be brought back after take-off, so this element of a retaliatory counter-strike can be largely automated with very little human factor involved. These are, however, no more than palliative solutions.

On the other hand, if conventional warfare preceded the nuclear one, we cannot rule out the possibility of strategic aviation having suffered major losses at the conventional stage. Unlike missile-carrying submarines and ICBMs, strategic aviation is not only fully "dual-purpose," its highest capabilities are precisely for non-nuclear conflicts and using these capabilities (or depriving the adversary of a chance of use them) could be very tempting. These capabilities in and of themselves will legitimize strikes against strategic aviation, while attacks of purely nuclear components of the SNF or the MWS are likely to be taken "very hard" by the opponent who will deduce that their nuclear retaliatory strike potential is being taken out.

However, although this potential of using strategic aviation conventionally has been described as its flaw, it also constitutes its greatest advantage. Capabilities

[56] Five bombers with nuclear bombs were lost in that operation. It concluded only after another crash on January 21, 1968, that caused major local nuclear pollution in Greenland.

to project force and deliver non-nuclear strikes at intercontinental ranges are unique, and only a large high-sea navy could match them (such a navy is a costly affair that needs to be deployed in advance).

In 1991, at the start of Operation Desert Storm, the USA demonstrated its capability[57], and repeatedly delivered as a "standard operation mode" strikes at targets at the other end of the world, with American aircraft taking off from their home airfields. Previously, when fighting for the Falkland Islands during Operation Black Buck, the UK's Vulcan strategic bombers delivered strikes against important Argentinian targets taking off from remote Ascension Island; the 16-hour raid was a record at the time. Russia's missile aircraft in Syria were deployed in far simpler conditions (strictly speaking, they could launch cruise missiles immediately after takeoff), but in order to demonstrate their potential, on November 17, 2015, Tu-160 and Tu-95MS [58]skirted all of Europe "counterclockwise" and launched strikes from the Mediterranean Sea using long-range cruise missiles; the aircraft were airborne for nearly 16.5 hours.

Prospects for subsequent development of bomber aviation appear to lie in further increasing flight range and creating new weapons; it would produce fundamentally new capabilities for the aviation's function as a component of the nuclear triad as well. That, however, will also demand fundamentally, almost radically new solutions.

As mentioned above, the main problem is heightened missile carrier vulnerability both during strikes and while on airborne alert. The first problem was partially resolved by LRCMs: back at the turn of the 1980s–1990s, their range was about 3,000–3,500 kilometers (we should always keep in mind that we are talking about the most efficient direct flight; in reality, the range will be slightly shorter). We mean Soviet-made Kh-55SM (which was developed by merely installing additional tanks on Kh-55 and it is still in service) and America's AGM-129A ACM (which was taken out of service in 2012 to economize resources). Later, already after the collapse of the USSR, Russia developed what is currently the world's most advanced LRCM, Kh-102[59] with the approximate range of about 5,000 kilometers. China massively arms its missile carriers with CJ-20 missiles ranging from 2,000 to around 2,500 kilometers. For actors whose objective is nuclear deterrence directed at Washington, the situation is complicated by geography (the USA's principal regions are covered by Alaska and Canada), the American systems of alliances, and its deployed navy; yet the existing LRCMs already provide for launch lines that are relatively safe for carriers. Nonetheless, the problem of vulnerability remains for LRCMs themselves as they existed at the end of the Cold War relying on their low visibility and breaking through air defenses in NOE flight. Developing air-based radars and network-centric target assignment systems prospectively makes them increasingly vulnerable:

[57] This is a raid of seven B-52G bombers that attacked targets in Iraq on January 16–17 with 35 AGM-86C cruise missiles. Curiously, that was almost the entire stock of non-nuclear air-launched long-range cruise missiles the US had at the time.

[58] Meeting with the leadership of the Ministry of Defense on the actions of the Russian Armed Forces in Syria // President of Russia.. 20.11.2015. URL: http://www.kremlin.ru/events/president/news/50737

[59] Media tends to mention its non-nuclear version Kh-101 far more often, but this article focuses on nuclear weapons.

fighter aircraft with powerful radars (one could do even without long-range radar detection aircraft) detecting a low-flying cruise missile and automatically sending target assignment to SAMS already is a reality drilled at exercises[60]. Since strategic aviation numbers are being cut, there is no hope of air defenses being broken by large number of missiles.

Although "classical" LRCMs will remain relevant due to the good range-to-weight and size ratio, they are not a good fit for the role of a "silver bullet." Quite likely, the future of weapons for strategic aviation lies in aero-ballistic missiles making a comeback at a new technological level; following today's trends, they will inevitably be called "hypersonic." Courtesy of politicians, this term has come to mean many things now. Here, I mean aircraft-launched missiles that use a boost stage with a regular jet engine and gain speed and altitude up to uppermost levels of the atmosphere and even beyond. Further on, a small-scale boost-glide missile without an engine continues on a guided flight; the missile can use its own aerodynamics and guided flight option for gliding or "ricocheting" off the uppermost level of the atmosphere to achieve a longer flight range or to maneuver in order to avoid the adversary's air defenses or missile defense, and to better lock on target at the final stage of the flight. In addition to "boost glides" described above, high-speed cruise missiles flying in relatively dense atmospheric level using a scramjet also count as hypersonic, but in the foreseeable future they will have a worse range-to-weight and size ratio compared to boost glides, and they will be more suitable for handling tactical objectives.

A strategic missile carrier with heavy missiles breaking through air defense or missile defense due to its flight characteristics will constitute a return to a track that had been abandoned when small-scale sub-sonic LRCMs became widespread. For instance, Tu-160 had been developed for heavy hypersonic Kh-90 missiles, while the US even reached test stage for their GAM-87 Skybolt ALBM in the early 1960s[61]. British Vulcan bombers were initially intended to carry two missiles with the range of up to 1,800 kilometers, while American B-52H were supposed to carry four, and then eight such missiles[62], which would have become a major problem (for instance, Moscow could have been struck within a few minutes with a launch from Scandinavia's air space).

Nonetheless, missiles will solve only one problem from among those listed for the SNF's air component: they will increase the likelihood of successfully delivering the payload to the target during an attack. The second problem, that of missile carriers' very low survivability, remains. Ensuring their capability of being constantly on airborne alert at least in a period of threat is the only efficient way of improving it. It is, however, difficult to achieve for today's platforms: turnaround servicing time for today's missile carriers will be comparable to, or even longer than is allowed with regular 24–36 hours in the air. Additionally, both aircraft and crews will rapidly become overextended, and it will be a recipe for accidents.

[60] F-35, SM-6 Participate in Navy Cruise Missile Defense Test // Missile Threat 28.09.2016. URL: https://missilethreat.csis.org/f-35-sm-6-participate-navy-cruise-missile-defense-test/

[61] Ironically, the first and only successful launch after five failures took place the day after the program was shut down.

[62] Scott Lowther Boeing B-47 Stratojet & B-52 Stratofortress—Origins and Evolution—Tempest Books, 2021. P. 273–278.

Although in real combat conditions there had been bombing raids that lasted for 48 hours for crews (and for 72 hours for aircraft[63]), but it meant straining both to the limit and required lengthy preliminary preparations and subsequent rest. Operating the entire fleet in this mode for several weeks will inevitably result in a rapid onset of "natural wastage." Of course, keeping very small part of the fleet airborne is possible: in the 1960s, the US Air Force for a long time performed permanent airborne alert missions on a regular basis, but comparing their fleet of many hundreds of aircraft with today's fleets, then proportionately it equates one aircraft, or two tops, being on airborne alert.

The solution lies in decreasing the turnaround servicing time and in simultaneously increasing flight duration. It could be achieved by developing strategic drones or optionally piloted modifications of manned missile carriers. There is no radical solution that could be used on existing platforms: there can be only superficial decreases in their turnaround servicing time (new aircraft, despite local problems, demonstrate the same trends) and superficial improvements in conditions for their crews. New platforms, however, will certainly be developed with a view to handling these problems: from the outset, America's new prospective B-21A Raider bomber was intended to have an optionally piloted version, while a separate unmanned bomber and fighter program is being discussed[64]. Today's large drones are initially intended long-range flights and they truly work miracles in this area. For instance, a small group of RQ-4 Global Hawks deployed in Sicily routinely goes on 24-hour-long missions to the Mediterranean, and it has been doing so for years. There are no reasons to think that Russia's PAK DA billed as sub-sonic stealth "flying wing" will not have such capabilities. The use of air-launched drone wingmen that will help break through air defense, detect adversaries, and wage air combat is also likely.

Of course, the image of an unmanned nuclear bomber is very uncomfortable psychologically (what if it "takes something wild into its head"), but no one cares about ICBMs being unmanned and about it being impossible to stop an ICBM once it has been launched. It still appears better to reserve unmanned flights for conventional conflicts, while crews would be present in the cockpits of optionally piloted aircraft on nuclear airborne alert; these crews will be free from errors stemming from fatigue, and they will be comfortable enough to remain on duty for about 48 hours. If, for instance, a dozen aircraft carrying several efficient aero-ballistic missiles each could be kept airborne in a period of threat, it could be an interesting alternative to a SSBN as a super-robust component of the triad.

[63] When delivering strikes against Afghanistan in the fall of 2001, B-2A took off in the US, crossed the Pacific Ocean, skirted Asia, delivered their strikes, and then landed on Diego Garcia Island in the Indian Ocean to change their crews and return to the US. The "base" crew flew for up to 44 hours but given that during their Diego Garcia landing aircraft did not kill their engines and power, they only rapidly refueled. The aircraft's mission was essentially over 70 hours long.

[64] Details Emerge on New Unmanned Long-Range Bomber and Fighter Projects // Air Force Magazine. 03.03.2022. URL: https://www.airforcemag.com/details-emerge-on-new-unmanned-long-range-bomber-and-fighter-projects/

The Naval Component: Shaky Resting on the Laurels?

Is there a need for such an alternative to SSBNs? This type of the SNF is the most wide-spread, and every nuclear power is developing or building prospective SSBNs:

- Russia is developing and building several Borei-class submarines;
- The US has launched construction of its first new Columbia-class missile submarine;[65]
- China is actively building the naval component of its SNF: 094-class submarines are already nearly world-class and can be put on combat standby duty, while prospective 096-class submarines should be capable of going on full-fledged combat standby duty;
- France has announced designing[66] prospective submarines under the SNLE 3G program; these submarines should replace the relatively new Triomphant-class submarines;
- The UK started working on Dreadnought-class submarines partially aligned with the US' Columbia-class submarines;
- Israel's Dolphin-class non-nuclear submarines are believed to be carrying Popeye Turbo long-range cruise missiles with nuclear warheads, while Dakar-class submarines[67] currently being built will probably carry ballistic missiles;
- India is building several Arihant-class submarines; those currently in service are rather primitive, but they are being further developed;
- Pakistan is planning to arm Agosta-class submarines with long-range cruise missiles Babur-3 (or they have already done so), and to do the same with China-built newer Hangor-class submarines;
- Even North Korea has a rather impressive program for testin several types of SLBMs, although it might be having difficulties with building submarines.

Why is there such unanimity and why are they so popular? Submarines are seen as platforms with highest survivability guaranteeing a retaliatory strike, and that makes them particularly effective as nuclear deterrent via scare tactic threatening a countervalue attack (colloquially known as "attacking cities"). Some states keep at least one submarine at sea at all times for that purpose, a policy known as "continuous at sea deterrent," or CASD. This is the policy that the US, the UK, and France have maintained for decades; there are reports that China started using this policy as well. Other states use periodic patrolling and are ready to deploy

[65] Keel Laying Ceremony Held for First Columbia-Class Ballistic Missile Submarine // US Navy. 04.06.2022. URL: https://www.navy.mil/Press-Office/News-Stories/Article/3052900/keel-laying-ceremony-held-for-first-columbia-class--ballistic-missile-submarine/

[66] Quatre nouveaux sous-marins nucléaires lanceurs d'engins pour la France en 2035 // Ouest-France. 19.02.2021. URL: https://www.ouest-france.fr/politique/defense/de-nouveaux-sous-marins-pour-la-force-oceanique-strategique-en-2035-7160150

[67] Our First Look At Israel's New Dakar Class Submarine Reveals A Very Peculiar Feature // The War Zone. 20.01.2022. URL: https://www.thedrive.com/the-war-zone/43951/our-first-look-at-israels-new-dakar-class-submarine-reveals-a-very-peculiar-feature

submarines at sea at a period of threat. Additionally, SSBNs are convenient for launching a sudden attack at smaller distances with short approach time, although it involves additional risks for many states (not every state has a large system of alliances and friendly seas).

Today, it is virtually impossible to reliably destroy a SSBN on combat patrolling especially if it operates in protected “bulwarks” of its county’s coastal seas (this luxury has become accessible with acquiring SLBMs with sufficient range). Of course, the “bulwark” can be subjected to a massive air-surface-submarine “storm,” but it is comparable to attacking the adversary’s ICBM UMS and MWS at a conventional warfare stage, which may produce an undesirable response, and that is putting it mildly. An alternative may lie in covert penetration, tracking, and attacking an SSBN upon command with one’s own hunter submarine, but during a period of threat, the adversary’s anti-submarine defense will be focused as much as possible on combating this threat, so this becomes an almost suicidal scenario.

However, the nature of threats may change soon. Light unmanned underwater craft are being widely used by navies throughout the world for auxiliary tasks (mostly clearing mines and checking underwater objects). There are now experiments with using rather large, multi-purpose craft capable of long-term self-contained navigation (the USA’s recently launched[68] Orca is an example). They are still far behind full-fledged submarines in their performance and combat capabilities, but, drawing parallels with aircraft, they will be rapidly catching up. A hypothetical highly specialized combat hunter drone (or a “kamikaze”) could soon have the necessary hydrodynamic and acoustic characteristics; difficulties will lie rather in operating them and in detecting targets, but these problems could probably be resolved, too. Such drones may either qualitatively increase onslaught on “bulwarks,” or may be preliminarily deployed there, preferably stealthily, at great depths, becoming an extra headache. We can rather confidently suppose that within a couple of decades, underwater drones will become real enemies for submarines, and this is a short time for shipbuilding programs and naval ships’ service time.

This problem has been definitely admitted, and when the US discussed the number of launch tubes at new Columbia-class missile carriers, potential drop in the survivability of the SNF’s underwater component was prospectively mentioned as a reason not to put too many nuclear “eggs into one basket” (in the sense of advocating fewer launch tubes compared to existing Ohio-class missile carriers), while a hypothetical mobile version of the prospective land-based ICBM LGM-35 Sentinel (GBSD program) should be “kept in mind” in case of “a breakthrough in anti-submarine warfare.”[69]

[68] U.S. Navy’s Orca XLUUV Christened and Launced // CAST. 08.05.2022.
URL: https://bmpd.livejournal.com/4522719.html

[69] «Pursuant to the 2018 NPR, a mobile variant of the GBSD is not currently required to ensure deterrence, but changes in adversary technology (e.g., a breakthrough in anti-submarine warfare), doctrine, and nuclear force posture may require the United States to reassess this determination in the future» STATEMENT OF ADMINISTRATION POLICY H.R. 2,500—National Defense Authorization Act for Fiscal Year 2020 // trumpwhitehouse.archives.gov 09.07.2019.
URL: https://trumpwhitehouse.archives.gov/wp-content/uploads/2019/07/SAP_HR-2500.pdf

However, an underwater drone may be both a problem and an opportunity. Squadrons of underwater drones will secure SSBNs flanking custom-made multi-purpose submarines, clearing mines, or may even serve as new delivery vehicles for nuclear payloads, primarily sub-strategic ones, but possibly strategic ones as well. Naturally, the first thing that comes to mind here is Russia's Poseidon; the media stubbornly call it a "nuclear torpedo," but it essentially is an underwater drone with nuclear propulsion, which means it likely has extremely high autonomous navigation capabilities, range, high hydrodynamic characteristics, and energy. Taken together, these characteristics open the way for a multitude of uses where "Sakharov's torpedo" (that, in fact, has nothing to do with Sakharov) with its notorious "tsunami following a hundred-megaton explosion"[70]looks like an alternative delivery vehicle that, although far from being the most useful and efficient one, still would do the job and whose potential would primarily lie in the fact that it ignores anti-missile defense systems as a matter of principle.

In addition to new underwater craft being developed, SSBNs will inevitably be influenced by missile progress that applies to them as well as to land-based vehicles. The ability of multi-purpose submarines to get close to their target makes them a particularly interesting platform for hypersonic cruise missiles with boost glide warheads. Along with small-scale nuclear cruise missiles, this will allow a large part of the submarine fleet to regain their quasi-strategic capabilities.

The peaceful lethargic sleep of the satellite's digital intelligence system was interrupted by a signal from the planet. Instead of another request for a diagnostic check-up to which the satellite usually responded with a short impulse transmitted over long cables of long-wave dishes which also served as radiators, this time the satellite received the command it, and others like it, had been born for, and had been waiting for eight years on standby duty at the remote orbit, close to the orbit of the planet's satellite.

Having many times verified the message's super-complex encoding, the computer analyzed target lists, checked the planet's position against its own orbital positioning. Once one of several trajectories was selected, a cruise stage detached from the satellite's body and emitted a short and clearly verified impulse to brake using chemical engines. It was risky as the enemy's patrol interceptor satellites were on the prowl out there but braking with electric propulsion engines that the satellite normally used to maintain and change its orbital position would take too long, and that was even more dangerous.

The cruise stage started its three-day flight to the planet. Without the satellite's miniature reactor, it had to be saving power, using only its batteries. There were other reasons for that, too, primarily minimizing its infrared emissions. The stage controlled its trajectory using signals from near-earth navigation systems, yet halfway, the services available to it ceased transmitting their signals, and it had to rely solely on its optical sensors, gyroscopes, and high-precision clock.

[70] I would like to take this opportunity to say that scientific calculations and tests debunked the ideas of waves washing away half the continent that are so popular in television and internet folklore; in fact, possible destruction would be limited to a few kilometers.

Potentially, it could become inconvenient at the final stage of the flight, but the digital intelligence did not have the capacity to be grouchy. Instead, it noted the loss of friendly navigation services as another confirmation that the order had been correct.

In addition to producing minimal heat emissions, the cruise stage naturally was small and had radio-absorbent skin. For most of the flight, it was almost entirely safe, but the final dozens of minutes were dangerous. The computer identified space-scanning radars "skimming" the station, but they were incapable of detecting the miniature space alien. Nearly approaching, the frequency and power of emissions received by sensors change rapidly, emissions become constant. Target locked, the enemy's missile defense and anti-space defense are in the target acquisition mode! Too late, the stage will now most certainly make it. Seeing as there is now no need to hide, the cruise stage deploys rapidly inflating decoys, passive ECM, and active transmitters. A flare on optical sensors tells it one of the decoys is destroyed. It is too late, it has made it at a speed far above the warheads of intra-planetary ballistic missiles, it burst into the atmosphere at a nearly right angle, straining its protective coating almost to the limit. There were still the close-quarter defensive layers of the "regular" missile defense, but there were none around the target, and the speed was so mind-boggling the cruise stage computer ignored their threat with almost human contempt.

If its creators had enabled it to feel triumphant and proud, this is what the digital pilot of the remote outer space deep retaliation system would have felt as it used the altimeter to set off thermonuclear charge.

This looks like an excerpt from another sci-fi TV show, but from time to time, snippets of such ideas filter into expert discussions. Deploying nuclear strike weapons at high orbits or even in the cislunar space is very different from the commonly discussed low-orbit deployment. It eliminates the key negative aspects of low-orbit nuclear deployment: on the one hand, the highest provocativeness, potential threat of a quick-launch strike, while on the other hand, impossibility to promptly deliver a retaliatory or counterstrike (satellites usually fly over the same point on the planet with large intervals), which makes it necessary to deploy a huge group of which only a small part will be able to attack simultaneously. While the group is waiting for the right position, the adversary may destroy a major chunk of it using anti-space defense. Therefore, low-orbit deployment is ideal for the initial decapitation attack, the vanguard of the main attack, but it has little use for retaliation: this is a nightmare combination for strategic stability.

High-orbit systems, on the contrary, are good for it: using weapons that take one, two, or three days to reach their target is risky for the first strike, the attack may be detected. On the other hand, small-scale space platforms specifically designed to be highly autonomous and to have minimal infrared emissions and radar visibility can have high survivability; we have to keep in mind that we are talking space size that is thousands of times deeper than the ocean, the atmosphere, and the actively exploited near-earth space.

Another possible reproach is that this is the way for humanity to embark on militarizing even deeper into outer space areas than the near-earth orbit that has been extensively exploited by militaries, but it is too late: the US Space Force has already proclaimed the cislunar space a new "high ground" they believe critically important to dominate[71]. Several programs for building patrol spacecraft intended to monitor the activities of potential adversaries have already been launched to explore the new domain. Although they are primarily concerned with exploring the Moon, scenarios (like the one above) have most likely occurred to heirs of those people who had intended to deploy ICBM launch vehicles on the Moon ("I" in that abbreviation probably standing for "interplanetary").

Naturally, the 1967 Outer Space Treaty precludes deploying nuclear weapons in outer space, but how reliable are such treaties in our day and age? They are, as always, likely to be reliable for as long as they do not stand in the way of their signatories' interests. We have few key agreements left over from the Cold War, and how is a bomb by the moon different from strategic missile defense?

On the one hand, the prospect (purely futuristic, maybe my far-fetched invention, if you please) of nuclear race going far beyond Earth is rather grim, smacks of fatalism, and brings to mind thoughts of humanity never learning and never improving. On the other hand, it is possible that, around sixty years ago, militaristic motives would be conducive to purely peaceful progress. After all, the first satellites, first cosmonauts and astronauts also essentially flew rapidly re-fitted ballistic missiles that had been designed for entirely different cargo.

[71] State of the space industrial base 2020. A Time for Action to Sustain US Economic & Military Leadership in Space // CSIS. July 2020. URL: http://aerospace.csis.org/wp-content/uploads/2020/07/State-of-the-Space-Industrial-Base-2020-Report_July-2020_FINAL.pdf

Conclusion

Apparently, the period of calm, the new interbellum between the Cold Wars of the nuclear superpowers is drawing to a close. In some countries, such as the United States, this is discussed openly and loudly—»renewed great power competition,» plans and the inevitability of acute, i. a. nuclear, military rivalry with Beijing and, to a lesser extent, Moscow.

The modernization of strategic nuclear forces is coming to the forefront and will again, as before, have a major bearing on political decisions.

In the coming decades, will Russia be able to remain in the top nuclear league in terms of quantity and quality of nuclear forces and capabilities?

Will the United States be able to implement its decades-long postponed program to modernize its strategic arsenals, even though some sectors of the nuclear military complex have been reduced to complete degradation?

Will China fully enter the first nuclear league, will it get a nuclear shield and a sword worthy of a superpower—an economic superpower and the one in the field of conventional armed forces—will it equal its overseas opponent?

How many more countries would see the need to acquire their own nuclear weapons to ensure national security and meet the desired status? Will there be wars between them, will the nuclear taboo, which in the twentieth century was based on the responsible behavior of a small number of major powers who reasonably believed that using nuclear weapons against each other would have unacceptable consequences for all mankind, be broken?

There is no definite answer to these questions today, but in the 21st century nuclear weapons will definitely continue to play an important role and the most basic knowledge about these weapons can be useful to those interested in international politics.

One can only hope that, as before, its role will be that of peacemaker rather than destroyer.

About the author

Alexander S. Yermakov is a military observer and expert of the Russian International Affairs Council (RIAC). Since 2013, he regularly contributes analytical pieces and review articles on military topics to print publications ("National Defense", "Independent Military Review", "New Defense Order", "Arms Export", "Profile", "Valdai") and online outlets ("Lenta.ru", "Eurasia. Expert", "Izvestia", "Valdai", "Expert", etc.). In 2018, at the suggestion of the Center for Analysis of Strategies and Technologies, he was part of the author group working on the collected volume "Thundering Sky. Aviation in Modern Conflicts»" (ISBN 978-5-9909882-2-4), penning a chapter on the U.S. war in Afghanistan. He also participated in the Ogarkov Readings conference (report "Generational Conflict and the Future of Combat Aviation»", devoted to the problems of developing multi-purpose fighters of 4/5 generations in Russia and abroad). Scientific interests: modern and post-war aviation; militarization of space; missile technology; nuclear weapons; strategic stability; international agreements in the field of arms control.

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