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Security Tech Brief

May 2022: Burevestnik

SSC-X-9 Skyfall, KY-30, 9M730(?)

by Felix Lemmer

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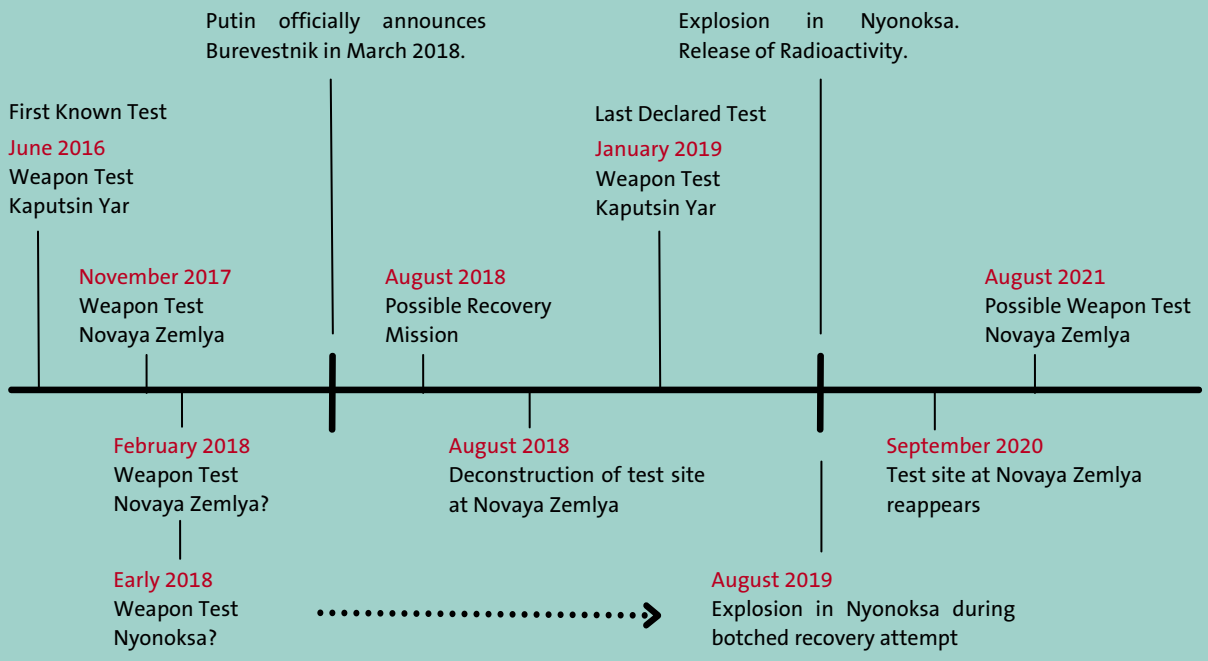
- Burevestnik is a ground-launched nuclear-armed cruise missile, powered by a nuclear reactor and currently in development by the Russian military. If deployed, the system would be the world's first nuclear-powered missile. Experts doubt that the system will be deployed any time soon with estimates ranging from later this decade to never.
- Burevestnik's nuclear power source would give the missile practically unlimited range, creating a cruise missile - i.e. hard to intercept - with an intercontinental capability.
- According to U.S. intelligence sources, Burevestnik has been tested at least thirteen times with little success. In August 2019, an explosion at a testing range killed five scientists and led to the release of radioactivity. The U.S. later linked the explosion to Burevestnik's development. The program might have been halted after the last declared test in January 2019 although analysts observed activity at testing sites in 2020 and 2021.

Timeline of Burevestnik's development:



Testing sites:

1: Kapustin Yar testing site

2: Pankovo (Novaya Zemlya) testing site

3: (Suspected) Nyonoksa testing site

What is Burevestnik?

In March 2018, Russian President Putin unveiled five new nuclear-delivery systems during a speech before the Russian Federal Assembly. One of them was a "completely new type of weapon" – a nuclear-powered and nuclear-armed cruise missile that has an "unlimited range, unpredictable trajectory" and is impossible to intercept by missile defense systems.[1] A corresponding video aired during the speech showed a missile test, followed by the computer-animated path the missile could take: dodging terrain, weaving in between missile defense systems, and flying around the tip of South America before appearing to fly towards the U.S. West Coast.[2] According to Putin, initial tests had been successful and, following a public poll, the missile was named 'Burevestnik'. Given the technological challenges and dangers associated with placing a nuclear reactor in a missile, the system's announcement has been met with skepticism. Why would Russia build such a system and what makes Burevestnik stand out?

Firstly, Burevestnik is a cruise missile, which in short means that it is less vulnerable to missile defense systems. Ballistic missiles are rocket-powered. They follow predictably arced flight paths until they run out of fuel, and essentially fall on their intended target. Cruise missiles remain propelled throughout their flight, which makes them maneuverable and their flight paths unpredictable. They can fly low to the ground to evade ground-based radar systems and can be guided using satellites or infrared detectors. Cruise missiles are not new. Nazi Germany deployed the world's first cruise missile in 1944. Secondly, Burevestnik will carry a nuclear warhead. Most nuclear-weapon states deploy such cruise missiles. Thirdly, Burevestnik is nuclear-powered. This is the missile's distinctive feature since no state has ever fielded a nuclear-powered missile. Such a system offers the advantages of a cruise missile – manoeuvrability, low altitude and low probability of interception – and adds an intercontinental capability. Fuel-powered cruise missiles such as the U.S. Tomahawk have a range of up to 2500 kilometres. Burevestnik's range is virtually unlimited. It could fly for days, attack from unexpected directions, evade missile defences and remain undetected – in theory. In practice, most experts consider Burevestnik to be the most difficult 'superweapon' to develop and doubt that it will be fielded soon.[3]

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[1] Vladimir Putin, "Presidential Address to the Federal Assembly" (March 01, 2018), http://en.kremlin.ru/events/president/news/56957; Beside Burevestnik, Putin introduced four other nuclear-capable weapon systems (sometimes dubbed 'superweapons') in his March 2018 address to the Federal Assembly: the hypersonic glide vehicle *Avangard*, the air-launched ballistic missile *Kinzhal*, the nuclear-powered and nuclear-armed torpedo *Poseidon* and the intercontinental ballistic missile *Sarmat*. Samuel Bendett et al., *Advanced Military Technology in Russia*: *Capabilities and Implications* (London: Chatham House, 2021), https://www.chathamhouse.org/sites/default/files/2021-09/2021-09-23-advanced-military-technology-in-russia-bendett-et-al.pdf, 23–34.

[2] Russian Ministry of Defence, *Крылатая Ракета Неограниченной Дальности С ЯЭУ [Unlimited-Range Cruise Missile with Nuclear Power Plant]* (2018), https://www.youtube.com/watch?v=Xr7alYwCznQ.

[3] Edward Geist and Dara Massicot, "Understanding Putin's Nuclear "Superweapons"," *SAIS Review of International Affairs* 39, no. 2 (2019): 106, https://doi.org/10.1353/sais.2019.0019; Amy Mackinnon and Lara Seligman, "Is Russia's Doomsday Missile Fake News?," *Foreign Policy*, August 22, 2019, https://foreignpolicy.com/2019/08/22/is-russias-doomsday-missile-fake-news-putin-hypersonic-nuclear-cruise-moscow-kremlin/.

Would a nuclear-powered missile work?

In theory, nuclear propulsion for aircraft or missiles is simple. Similar to a jet engine, the air is taken in at the front of the weapon, compressed, heated up, and then shot out of the back, thereby generating thrust. In a standard jet engine, the compressed air is mixed with fuel and ignited to create the necessary heat. A nuclear engine replaces the fuel with the heat generated by a nuclear reactor. By replacing the finite fuel with almost limitless nuclear energy, a much longer flight would be possible. Much like a nuclear-powered submarine whose range is limited only by the food it carries, a nuclear-powered aircraft could stay airborne for days or until the pilot's water supply is depleted. A nuclear-powered missile has even fewer limits, theoretically being able to fly as long as the air is available, and the reactor is working. Yet, no state has overcome the practical difficulties of such engines.

This is not for lack of trying. In the 1950s, the U.S. military attempted to develop a nuclear-powered cruise missile called SLAM (supersonic low altitude missile) that – in theory – could have flown in circles above the Pacific until receiving an order to attack.[4] It could have then descended on the Soviet Union at three times the speed of sound while carrying multiple hydrogen bombs. SLAM could have ejected these bombs over various widely spread targets before crashing into its final destination.[5] In practice, the U.S. government cancelled the missile before its first flight test for reasons that likely also plague Burevestnik's development. There were (at least) two major obstacles. First, designing a nuclear reactor that could withstand extremely high temperatures without being too heavy or too large to become airborne is difficult. Second, finding a way to flight-test the system safely is a challenge.

U.S. scientists did develop a working nuclear ramjet engine.[6] Although tests on the ground proved successful, radiation was a major problem. The reactor had no shielding to contain radiation, as that would have made the already locomotive-sized engine even larger. The engine used a direct-cycle approach: air was channeled directly through the reactor core to heat it up making the exhaust highly radioactive.[7] Designed as a low-flying missile, SLAM would have been "deafening, flattening, broiling and irradiating" not only to Soviets, but also anyone in allied countries who happened to be in the path

[4] Barton C. Hacker, "Whoever Heard of Nuclear Ramjets? Project Pluto, 1957—1964," *Icon* 1 (1995), http://www.jstor.org/stable/23786203; Gregg Herken, "The Flying Crowbar," *Air & Space Magazine* 5, no. 1 (April/May 1990), http://www.merkle.com/pluto/pluto.html.

[5] Kyle Mizokami, "Why the U.S. Abandoned Nuclear-Powered Missiles More Than 50 Years Ago," *Popular Mechanics*, August 13, 2019, https://www.popularmechanics.com/military/research/a28690053/russia-nuclear-powered-missile-skyfall/.

[6] Herken, "The Flying Crowbar." A ramjet engine works by ramming high-speed air through a special chamber to compress the air, then heat it before shoot the air out at the back, creating thrust to propel the missile forward. A ramjet only works if the air passing though the engine is fast enough. They usually require at least supersonic speed to function. Ramjets using fuel to heat the passing air are a key feature of modern hypersonic weapon systems.

[7] Edd Gent, "Was Deadly Explosion Off the Arctic Coast the Result of a Nuclear-Powered Russian Weapon?," *Live Science*, August 16, 2019, https://www.livescience.com/russia-explosion-nuclear-powered-weapon.html.

of the missile before ever dropping its nuclear payload.[8] What if scientists lost control during a flight test and this system continued to fly across the U.S. as an "airborne Frankenstein, a flying Chernobyl"?[9] In 1964, the US military determined there was no military need for the system and ended the project.[10] While nuclear reactor technology has advanced since the 1960s and the Russian nuclear complex has experience in developing unique nuclear-powered systems, there are still engineering challenges to be overcome before Burevestnik can be realized.[11] The difficulty of testing also remains: any flight test likely ends with a damaged reactor emitting radiation. Crash proofing the reactor would probably make the system too heavy to fly.[12]

As for Burestvenik, little is known about its technical details. From a 2018 Russian MOD video supposedly showing Burevestnik prototypes, it might be inferred that the missile is designed for subsonic flight – below the speed of sound.[13] Other experts echo this.[14] In 2020, the U.K. chief of defence intelligence also stated that Burevestnik would travel at subsonic speeds.[15] This rules out a ramjet engine, which requires supersonic speeds to function. Burevestnik might instead rely on a nuclear-powered jet turbine. This engine takes in air at the front of the missile and compresses it. The nuclear reactor then heats the air and shoots it out of the back, driving a turbine on the way out.[16] That turbine only starts to operate once the passing air is fast enough. According to U.S. intelligence sources, Burevestnik needs an external gasoline-fuelled rocket to bring the system to operating speed.[17] Burevestnik could use a closed-cycle approach in which the air does not come in direct contact with the reactor but is heated indirectly through a heat exchanger, which reduces the radioactive exhaust.[18] This approach, while more difficult to develop than the open-cycle approach, would also allow a more compact reactor.[19]

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[8] Noise levels on the ground below the missile would have been almost as high as rocket taking off to space. See: Gregg Herken, "Russia's Mysterious 'New' Nuclear Weapons Aren't Really New," *The Washington Post*, August 15, 2019, https://www.washingtonpost.com/outlook/2019/08/15/russias-mysterious-new-nuclear-weapons-arent-really-new/.

[9] Herken, "The Flying Crowbar."

[10] *The New York Times,* "U.S. Quietly Kills Its Atom Missile," July 13, 1964, https://www.nytimes.com/1964/07/13/archives/us-quietly-kills-its-atom-missile-project-pluto-canceled-after.html.

[11] The Russian nuclear complex for example operates the world's only nuclear-powered ice-breaker fleet, a nuclear-powered cargo vessel and a floating nuclear power plant. See: Thomas Nilsen, "Nuclear Reactors in Arctic Russia" (Barents Observer, 2019), https://www.nito.no/contentassets/d05c8ba243a4477da9c0227be62d1d12/atomnotat-barents-observer.pdf.

[12] Michael Spencer, "Nuclear-Engine Air Power Case Study: Russian SSC-X-9 Skyfall," in *Nuclear Engine Air Power*, 61-91, 67; David Burningham et al., "Nuclear Engine Air Power" (Air Power Development Centre / Department of Defence, Canberra, Australia, 2020), https://airpower.airforce.gov.au/sites/default/files/2021-03/BPAF02_Nuclear-Engine-Air-Power.pdf.

[13] Spencer, "Nuclear-Engine Air Power Case Study: Russian SSC-X-9 Skyfall," 67; Alexei Ramm, "Без Ограничений По Дальности [No Range Limit]," *Izvestia*, March 2, 2018, https://iz.ru/715211/aleksei-ramm/bez-ogranichenii-po-dalnosti; Vitaly Orlov, "Песня О «Буревестнике» [The Song of the Burevestnik]," *VPK*, March 8, 2021, https://vpk-news.ru/articles/61174; For the video see: Russian Ministry of Defence, *Крылатая Ракета С Ядерным Двигателем «Буревестник» [Nuclear-Powered Burevestnik Cruise Missile]* (2018), https://www.youtube.com/watch?v=okS76WHh6FI&t=1s.

[14] Jill Hruby, "Russia's New Nuclear Weapon Delivery Systems: An Open-Source Technical Review" (Nuclear Threat Initiative (NTI), Washington D.C., 2019), 34; Hanna Notte et al., "Russia's Novel Weapons Systems: Military Innovation in the Post-Soviet Period," *Nonproliferation Review*, 2021, 11, https://doi.org/10.1080/10736700.2021.1946271; Michael Kofman, "Mystery Explosion at Nenoksa Test Site: It's Probably Not Burevestnik," *Russia Military Analysis (Blog)*, August 15, 2019, https://russianmilitaryanalysis.wordpress.com/2019/08/15/mystery-explosion-at-nenoksa-test-site-its-probably-not-burevestnik/.

[15] Dominic Nicholls, "Russian Nuclear-Powered Cruise Missile Could 'Circle the Globe for Years'," *The Telegraph*, September 13, 2020, https://www.telegraph.co.uk/news/2020/09/13/russia-has-nuclear-powered-cruise-missile-could-circle-globe/.

[16] Spencer, "Nuclear-Engine Air Power Case Study: Russian SSC-X-9 Skyfall," 76.

[17] Amanda Macias, "Russia Is Preparing to Search for a Nuclear-Powered Missile That Was Lost at Sea Months Ago After a Failed Test," *CNBC*, August 21, 2018, https://www.cnbc.com/2018/08/https://www.cnbc.com/2018/08/21/russias-nuclear-powered-missile-that-putin-claimed-had-infinite-range-is-currently-lost-at-sea.html.

[18] Gent, "Was Deadly Explosion Off the Arctic Coast the Result of a Nuclear-Powered Russian Weapon?."

[19] Carolyn C. James, "The Politics of Extravagance: The Aircraft Nuclear Propulsion Project," *Naval War College Review* 53, no. 2 (2000): 163–64, http://www.jstor.org/stable/44638305. Soviet scientists might have had some success developing an indirect-cycle reactor. See: https://twitter.com/sovietologist/status/1161856783205294080.

Why try to develop it and where is the system now?

Burevestnik's primary task appears to be addressing U.S. missile defence systems. Development reportedly began months after the U.S. government withdrew from the Anti-Ballistic Missile Treaty in 2001.[20] Russian media have described Burevestnik as a retaliatory weapon that acts in concert with Poseidon, the nuclear-powered torpedo. Even if a nuclear attack has decimated Russia's nuclear arsenal, Poseidon and Burevestnik could still retaliate: Poseidon could circumvent missile defences by travelling underwater and Burevestnik could attack from the south, thereby avoiding the north-facing U.S. missile defence systems.[21] Theoretically, Burevestnik could be launched just before a crisis escalated. Less vulnerable in the air, it could fly in circles, waiting for an order to strike if Russia were attacked and reinforcing the message that Russia will be able to retaliate no matter what.[22] Burevestnik's development could also be nuclear "chest-thumping", demonstrating Russian technological superiority, or it could be a bargaining chip, traded away for concessions at arms control negotiations.[23]

Compared to the other supposed superweapons, little is known about Burevestnik. For example, in a 2021 *Izvestia* article reviewing the new weapons, Burevestnik only appears in a single paragraph stating that tests are ongoing without further details.[24] Additionally, there is no clear deployment date. Some refer to 2025; others say that it is still a long way off.[25] While Putin claimed that work was underway on Burevestnik in 2021, Defense Minister Shoigu did not mention Burevestnik in his end of year remarks in 2020 or 2021.[26] According to a 2019 U.S. intelligence report, Burevestnik might enter service in 2025, contradicting earlier reports that indicated at least another decade.[27] In March 2022, the director of the U.S. Defence Intelligence Agency stated that Russia might deploy Burevestnik later this decade.[28]

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[20] Известия, "Опубликованы Кадры Крылатой Ракеты Неограниченной Дальности «Буревестник» [Footage of the Burevestnik Unlimited Range Cruise Missile Has Been Published]," *Izvestia*, July 19, 2018, accessed February 22, 2022.461Z, https://iz.ru/768533/2018-07-19/opublikovany-kadry-krylatoi-rakety-neogranichennoi-dalnosti-burevestnik.

[21] Alexei Leonkov, "Ядерный "Буревестник": Новая Крылатая Ракета Станет "Оружием Возмездия" [Nuclear Burevestnik: New Cruise Missile to Become 'Weapon of Retaliation']," *Rossiyskaya Gazeta*, July 18, 2019, https://rg.ru/2019/07/18/iadernyj-burevestnik-novaia-krylataia-raketa-stanet-oruzhiem-vozmezdiia.html; Notte et al., "Russia's novel weapons systems: military innovation in the post-Soviet period," 14.

[22] Ramm, "Без ограничений по дальности [No range limit]"; A similar concept of operations has been associated with Poseidon, but experts doubt that Poseidon could operate as an autonomous underwater vehicle (AUV), roaming the oceans on its own before receiving an order to attack. Rather than an AUV, Poseidon appears to be a long-range nuclear-armed torpedo. See: H. I. Sutton, "Poseidon Torpedo," *Covert Shores (Blog)*, February 22, 2019, http://www.hisutton.com/Poseidon_Torpedo.html.

[23] Will Bedingfield, "The Staggering Power of Russia's New Top-Secret Nuclear Rocket," *Wired*, August 14, 2019, https://www.wired.co.uk/article/russia-explosion-nuclear-rocket-physics; Douglas Barrie and Henry Boyd, "Burevestnik: US Intelligence and Russia's 'Unique' Cruise Missile," *IISS*, February 5, 2021, https://www.iiss.org/blogs/military-balance/2021/02/burevestnik-russia-cruise-missile; Ryan Kuhns, "The Nuclear-Powered Cruise Missile: Insights into Russian Strategic Logic," *Next Generation Nuclear Network (CSIS)*, June 15, 2018, https://nuclearnetwork.csis.org/nuclear-powered-cruise-missile-insights-russian-strategic-logic/.

[24] Anton Lavrov, "Гиперзвуки Боя: Новое Супероружие Проверят В Полевых Условиях [Battle Hypersonics: New Superweapons to Be Tested in the Field]," *Izvestia*, July 1, 2021, https://iz.ru/1186581/anton-lavrov-anna-cherepanova/giperzvuki-boia-novoe-superoruzhie-proveriat-v-polevykh-usloviiakh.

[25] Pavel Ivanov, "«Буревестник» Знает, Куда Летит [Burevestnik Knows Where It's Going]," *VPK*, September 16, 2019, https://vpk-news.ru/articles/52488; Dmitry Kornev, "«Посейдон» В Помощь: Начинаются Испытания Стратегического Оружия РФ ["Poseidon" to the Rescue: Russian Strategic Weapons Testing Begins]," *Izvestia*, February 7, 2021, https://iz.ru/1121208/dmitrii-kornev/poseidon-v-pomoshch-nachinaiutsia-ispytaniia-strategicheskogo-oruzhiia-rf.

[26] Vladimir Putin, "Presidential Address to the Federal Assembly" (April 21, 2021), http://en.kremlin.ru/events/president/news/65418; Hans M. Kristensen and Matt Korda, "Russian Nuclear Weapons, 2022," *Bulletin of the Atomic Scientists* 78, no. 2 (2022): 107, https://doi.org/10.1080/00963402.2022.2038907.

[27] Amanda Macias, "Russian Nuclear Missile with 'Unlimited' Range to Be Ready by 2025, US Intelligence Says," *CNBC*, September 11, 2019, https://www.cnbc.com/2019/09/11/russian-nuclear-missile-with-unlimited-range-to-be-ready-by-2025-us-intel.html.

[28] See the DIA's director's statement here: https://armedservices.house.gov/?a=Files.Serve&File_id=5FA65E01-08C0-4B83-9713-7516A0BC4D62. Burevestnik also featured in the 2021 U.S. Air Force's National Air and Space Intelligence Centre's (NASIC) report on Ballistic and Cruise Missile Threats.

Has the Russian military tested Burevestnik?

Flight-testing a nuclear-powered missile means crashing a nuclear reactor. During SLAM's development, possible solutions included tying the system to a tether or testing it above an ocean.[29] In Russia, three sites have been associated with Burevestnik's testing: Kaputsin Yar, near the Kazakh border, Pankovo on the archipelago of Novaya Zemlya in the Arctic Ocean and possibly Nyonoksa, eighty kilometres from Arkhangelsk. The first and last reported tests in June 2016 and February 2019 took place in Kaputsin Yar, where component tests are reportedly carried out using conventional surrogates for the reactor.[30] Flight tests with a nuclear reactor are likely to take place in Pankovo, the most isolated test site. The status of Nyonoksa is less clear: while seemingly too close to human settlements to test with a nuclear reactor, the location is likely to have been the launch site of the Burevestnik that was damaged during a botched recovery effort in 2019. Possibly, parallel tests will be carried out in at different sites.[31] According to U.S. intelligence, Burevestnik has been tested at least 13 times with little to no success.[32]

In his March 2018 speech, Putin referred to a successful test of Burevestnik in late 2017. Analysts geolocated the launch site from a video aired during Putin's speech to Pankovo.[33] U.S. intelligence sources told *CNBC* that the Russian military carried out four flight tests between November 2017 and February 2018.[34] Of these four, only one was at least partially successful.[35] During this test in November 2017, Burevestnik flew for about two minutes and 22 miles before losing control and crashing into the Barents Sea. The other three tests were less successful, with the shortest lasting only four seconds.[36] While a U.S. intelligence assessment claims that all components were successfully used in the November test, Pentagon officials said that they observed two tests and "both times [the nuclear reactor] didn't light".[37] CNBC's sources echo that the reactor did not initiate and add that the Kremlin ordered the tests against the concerns of the program's engineers.[38] Norwegian intelligence saw two failed tests and could not confirm that the tested missiles used a nuclear-propulsion system.[39]

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[29] Herken, "The Flying Crowbar."

[30] Ivanov, "«Буревестник» знает, куда летит [Burevestnik knows where it's going]"; Ankit Panda, "Russia Conducts Test of Nuclear-Powered Cruise Missile," *The Diplomat*, February 6, 2019, https://thediplomat.com/2019/02/russia-conducts-test-of-nuclear-powered-cruise-missile/.

[31] Ivanov, "«Буревестник» знает, куда летит [Burevestnik knows where it's going]."

[32] Panda, "Russia Conducts Test of Nuclear-Powered Cruise Missile."

[33] Jeffrey Lewis, "A Mysterious Explosion Took Place in Russia. What Really Happened?," *Foreign Policy*, August 12, 2019, https://foreignpolicy.com/2019/08/12/russia-mysterious-explosion-arctic-putin-chernobyl/.

[34] Macias, "Russia is preparing to search for a nuclear-powered missile that was lost at sea months ago after a failed test"; Ankit Panda, "Russia Readies Recovery Effort for Nuclear-Powered Cruise Missile, Lost at Sea in 2017," *The Diplomat*, August 23, 2018, https://thediplomat.com/2018/08/russia-readies-recovery-effort-for-nuclear-powered-cruise-missile-lost-at-sea-in-2017/.

[35] Panda, "Russia Conducts Test of Nuclear-Powered Cruise Missile."

[36] Macias, "Russia is preparing to search for a nuclear-powered missile that was lost at sea months ago after a failed test."

[37] Panda, "Russia Readies Recovery Effort for Nuclear-Powered Cruise Missile, Lost at Sea in 2017"; Bill Gertz, "Pentagon: Russia Tested Nuclear-Powered Cruise Missile Twice," *Washington Free Beacon*, April 4, 2018, https://freebeacon.com/national-security/pentagon-russia-tested-nuclear-powered-cruise-missile-twice/.

[38] Macias, "Russia is preparing to search for a nuclear-powered missile that was lost at sea months ago after a failed test."

[39] Thomas Nilsen, "«There Is No Reason for Any State to Have a Nuclear-Powered Missile»," *The Barents Observer*, August 23, 2018, https://thebarentsobserver.com/en/security/2018/08/there-no-reason-any-state-have-nuclear-powered-missile.

In August 2018, U.S. intelligence sources suggested that the Russian military launched a naval operation including a vessel to handle radioactive material to recover a Burevestnik that crashed during a test in November 2017.[40] At around the same time, satellite images suggested that the Russian military was deconstructing the launch site at Pankovo.[41] The last known test took place on January 29, 2019 in Kaputsin Yar. It is unclear whether this was a flight test. A source in the Russian missile producing industry told TASS that the nuclear reactor unit was tested successfully in January, but U.S. government sources deemed the test only partially successful.[42] Other U.S. sources were more sceptical, telling CNBC that no test had been successful thus far, and that the missile would be too expensive to develop.[43]

On August 8, 2019, an explosion occurred at a naval test range near the village of Nyonoksa that killed at least five scientists working for Rosatom. After the explosion, radiation levels in nearby cities increased but seem to have stayed below harmful levels. The following chaotic and at times contradictory response by Russian authorities fuelled speculations of a cover up.[44] Suspicion soon fell on a failed Burevestnik test.[45] Two weeks after the accident, Putin described the killed scientists as national heroes who died during the test of a "promising" weapon system, a framing which changed to "unparalleled" weapon at an awards ceremony for the scientists in November.[46] However, some doubts remained.[47] Potentially, another system was at fault but the Russian leadership deemed it beneficial to frame the accident as part of the effort to develop Burevestnik rather than admit to a less spectacular component test.[48] In October 2019, the U.S. government determined that the incident was not caused by a test of Burevestnik but instead by an attempt to recover such a missile from a previous test.[49] The radiation was caused by an explosion on one of the ships trying to recover the missile damaging the missile's nuclear core.[50]

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[40] Macias, "Russia is preparing to search for a nuclear-powered missile that was lost at sea months ago after a failed test."

[41] Geoff Brumfiel, "Russia's Nuclear Cruise Missile Is Struggling to Take Off, Imagery Suggests," *NPR*, September 25, 2018, https://www.npr.org/2018/09/25/649646815/russias-nuclear-cruise-missile-is-struggling-to-take-off-imagery-suggests.

[42] *TASS,* "Tests of Burevestnik Nuclear Powered Cruise Missile Successfully Completed, Says Source," February 16, 2019, https://tass.com/defense/1045012; Panda, "Russia Conducts Test of Nuclear-Powered Cruise Missile."

[43] Amanda Macias, "Vladimir Putin's so-Called Missile with Unlimited Range Is Too Expensive for the Kremlin – and Has yet to Fly Farther Than 22 Miles," *CNBC*, March 22, 2019, https://www.cnbc.com/2019/03/22/putins-missile-with-unlimited-range-is-too-expensive-and-hasnt-flown-more-than-22-miles.html.

[44] For a helpful overview see: John Krzyzaniak, "The Nenoksa Accident: A Timeline of Confusing and Conflicting Reports," *Bulletin of the Atomic Scientists*, August 23, 2019, https://thebulletin.org/2019/08/the-nenoksa-accident-a-timeline-of-confusing-and-conflicting-reports/; Speculation only increased after four radiation-monitoring stations coincidentally stopped transmitting data right after the accident, see: Andrew E. Kramer, "Radiation Sensors Went Out in Russia. Official Explanations Changed," *New York Times*, August 20, 2019, https://www.nytimes.com/2019/08/20/world/europe/radiation-russia-nuclear-accident.html.

[45] Jonathan Landay, "U.S.-Based Experts Suspect Russia Blast Involved Nuclear-Powered Missile," *Reuters*, August 10, 2019, https://www.reuters.com/article/us-russia-blast-usa/u-s-based-experts-suspect-russia-blast-involved-nuclear-powered-missile-idUSKCN1UZ2H5.

[46] Georgi Kantchev and Michael R. Gordon, "Putin Says Weapons Test Was Behind Deadly Blast," *Wall Street Journal*, August 21, 2019, https://www.wsj.com/articles/putin-says-weapons-test-was-behind-deadly-blast-11566423312; *The Moscow Times,* "Putin Says 'Unparalleled' Weapons Tested at Deadly Nuclear Accident Site," November 22, 2019, https://www.themoscowtimes.com/2019/11/22/food-mama-moscow-family-restaurant-a68258.

[47] Kofman, "Mystery explosion at Nenoksa test site: it's probably not Burevestnik"; Pavel Luzin, "I Don't Believe a Missile Is to Blame for Russia's Deadly 'Nuclear' Explosion," *The Moscow Times*, August 14, 2019, https://www.themoscowtimes.com/2019/08/14/i-dont-believe-a-missile-is-to-blame-for-russias-deadly-nuclear-explosion-a66849.

[48] John R. Haines, "What Happened at the Severodvinsk Naval Testing Range?," *Foreign Policy Research Institute*, August 19, 2019, https://www.fpri.org/article/2019/08/what-happened-at-the-severodvinsk-naval-testing-range-thoughts-on-the-severodvinsk-radioactive-release-and-when-it-happened-here/.

[49] Mike Eckel, "U.S. Concludes White Sea Radiation Explosion Came During Russian Nuclear-Missile Recovery," *Radio Free Europe*, October 12, 2019, https://www.rferl.org/a/u-s-concludes-white-sea-radiation-explosion-came-during-russian-nuclear-missile-recovery/30213494.html. This confirmation came in the form of a statement by the U.S. Deputy Assistant Secretary of State Thomas G. DiNanno at a United Nations committee. See the statement here: http://statements.unmeetings.org/media2/21998264/united-states.pdf .

[50] Amanda Macias, "US Intel Report Says Mysterious Russian Explosion Was Triggered by Recovery Mission of Nuclear-Powered Missile, Not a Test," *CNBC*, August 29, 2019, https://www.cnbc.com/2019/08/29/intel-says-russian-explosion-was-not-from-nuclear-powered-missile-test.html.

If Burevestnik had been involved, where could have it been fired from? The U.S. government stated that the test in question occurred in early 2018. At that time, testing was believed to be taking place in Pankovo, but it seems unlikely that a missile fired from there made it to the White Sea. Nyonoksa is a more likely suspect, although that would mean that the Russian military was testing a nuclear-powered missile close to human settlements. Satellite images suggested that the set-up used to test Burevestnik at Pankovo had appeared in Nyonoksa around May 2019.[51] It is not clear whether that set-up was already present in Nyonoksa in early 2018, when the test supposedly took place. While the site at Pankovo was dismantled around August 2018, by September 2020, the launch site had reappeared and U.S. officials told *CNN* that Russia was preparing to test an advanced missile.[52] Analysts observed more activity at Pankovo a year later, possibly indicating a test occurred between August 2021 and September 2021, and U.S. officials told *CNN* that they were aware of a possible Burevestnik test.[53] However, there has been no confirmation that a test took place.

Concern about radioactivity

Given Burevestnik's small size (possibly half a meter in diameter), the reactor will have little to no shielding, therein creating risks for anyone near an active Burevestnik.[54] Flight-testing the system will also lead to some release of radioactivity and Burevestnik has been (loosely) associated with several spikes in radioactivity in Northern Europe. However, the only spike that has been linked directly to Burevestnik followed the botched recovery attempt in August 2019. Some links have since also been ruled out.[55] Other connections, particularly involving the radioactive isotope Iodine-131, remain unexplained. Iodine-131 is a nuclear fission product with a half-life of eight days, which means its detection might offer clues as to when the release occurred. Norwegian authorities are particularly worried since the Russian military appears to be testing both its experimental nuclear-powered systems – Poseidon and Burevestnik – in the Barents Sea. [56]

[51] Lewis, "A Mysterious Explosion Took Place in Russia. What Really Happened?."

[52] Jeffrey Lewis, "Burevestnik Testing to Resume," *Arms Control Wonk*, October 20, 2020, https://www.armscontrolwonk.com/archive/1210186/burevestnik-testing-to-resume/; Zachary Cohen, "Satellite Images Indicate Russia Is Preparing to Resume Testing Its Nuclear-Powered Cruise Missile," *CNN*, October 20, 2020, https://edition.cnn.com/2020/10/20/politics/russia-nuclear-powered-cruise-missile-test-satellite-images/index.html.

[53] Zachary Cohen, "New Satellite Images Show Russia May Be Preparing to Test Nuclear Powered 'Skyfall' Missile," *CNN*, August 19, 2021, https://edition.cnn.com/2021/08/18/politics/russia-skyfall-missile-test-satellite-images/index.html.

[54] Thomas Nilsen, "Nuclear-Powered Missile Crashed in Barents Sea, Intelligence Report Allegedly Claims," *The Barents Observer*, August 22, 2018, https://thebarentsobserver.com/en/security/2018/08/nuclear-powered-missile-crashed-barents-sea-intelligence-report-allegedly-claims.

[55] The detection of the radioactive isotope Ruthenium-106 over several European countries in October 2017 does not appear to be linked to Burevestnik but has instead been traced to the Mayak reprocessing plant in the Southern Urals near Yekaterinburg. See: Timo Hopp et al., "Non-Natural Ruthenium Isotope Ratios of the Undeclared 2017 Atmospheric Release Consistent with Civilian Nuclear Activities," *Nature communications* 11, no. 1 (2020); O. Masson et al., "Airborne Concentrations and Chemical Considerations of Radioactive Ruthenium from an Undeclared Major Nuclear Release in 2017," *Proceedings of the National Academy of Sciences of the United States of America* 116, no. 34 (2019).

[56] Nick P. Walsh, "Russia Is Amassing Unprecedented Military Might in the Arctic," *CNN*, April 5, 2021, https://edition.cnn.com/2021/04/05/europe/russia-arctic-nato-military-intl-cmd/index.html.

Early 2018

Small amounts of the radioactive isotope Iodine-131 were measured in Finland and Norway in January and February 2018.[57] After Putin announced Burevestnik in March 2018, there was some discussion about whether Russian tests of Burevestnik could explain these spikes in Iodine-131.[58]

According to U.S. intelligence sources, four tests of Burevestnik took place between November 2017 and February 2018 in Pankovo and possibly Nyonoksa.

June 2020

Several radioactive isotopes were detected in Norway, Sweden and Finland. Dutch authorities determined that the radionuclides originated in Western Russia. Iodine-131 was detected further north, possibly indicating a source in Northern Russia.[59] Russian authorities denied that its nuclear power plants were to blame.[60] Suspicion fell on Poseidon or Burevestnik.[61] Then-Special Presidential Envoy for Arms Control Marshall Billingslea called upon Russia to shelve these "terrible concepts" citing the spike in radiation.[62]

August 2021

Norwegian authorities detected small levels of Iodine-131 between August 2 and August 9.[63] In that week, the U.S. Air Force's "nuke sniffer" plane, equipped to monitor radiation levels, flew missions in the Baltic Sea.[64]

After satellite images revealed increased activity at Pankovo in August 2021, U.S. officials told CNN that the Russian military might be about to test Burevestnik.

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[57] Thomas Nilsen, "Traces of Radioactive Iodine Is in the Air," *The Barents Observer*, February 26, 2018, https://thebarentsobserver.com/en/ecology/2018/02/traces-radioactive-iodine-air.

[58] Thomas Nilsen, "Is Putin's New Nuclear Systems Source of Mysterious Radioactivity in the Air?," *The Barents Observer*, March 3, 2018, https://thebarentsobserver.com/en/ecology/2018/03/putins-new-nuclear-systems-source-mysterious-radioactivity-air; *Bellona,* "Are Putin's Threatened Missiles Already Polluting Europe with Radioactivity? Maybe," March 7, 2018, https://bellona.org/news/nuclear-issues/2018-03-are-putins-threatened-missiles-already-polluting-europe-with-radioactivity-maybe.

[59] Thomas Nilsen, "Radioactivity Is Blowing in the Air," *The Barents Observer*, June 26, 2020, https://thebarentsobserver.com/en/ecology/2020/06/various-reactor-related-isotopes-measured-over-scandinavia-and-svalbard.

[60] Jari Tanner, "Radioactivity Hike Seen in Northern Europe; Source Unknown," *Associated Press*, June 27, 2020, https://apnews.com/article/science-russia-finland-international-news-europe-16ce7ced2b5b98974e0cc4437b14bf44.

[61] H. I. Sutton, "Russia's New Super Weapons May Be Cause of Radiation Leak," *Forbes*, July 1, 2020, https://www.forbes.com/sites/hisutton/2020/07/01/russias-new-super-weapons-may-be-cause-of-radiation-leak/?sh=274092c45f8c.

[62] *The Moscow Times,* "Trump Nominee to Russia: Abandon 'Flying Chernobyl' Nuclear Missile," July 22, 2020, https://www.themoscowtimes.com/2020/07/22/trump-nominee-to-russia-abandon-flying-chernobyl-nuclear-missile-a70951.

[63] Thomas Nilsen, "Russia Readies Burevestnik Testing at Novaya Zemlya," *The Barents Observer*, August 19, 2021, https://thebarentsobserver.com/en/security/2021/08/russia-readies-burevestnik-testing-novaya-zemlya.

[64] Joseph Trevithick, "Curious Mission Flown over the Baltic Sea by U.S. Air Force Nuke Sniffing Plane," *The Drive*, August 6, 2021, https://www.thedrive.com/the-war-zone/41850/curious-mission-flown-over-the-baltic-sea-by-u-s-air-force-nuke-sniffing-plane; The plane's (WC-135 Constant Phoenix) missions usually revolve around detecting North Korean nuclear tests but it has flown several missions in Europe since 2017. It was for example deployed to the U.K. in February 2022. A Russian "military-diplomatic" source told the Russian newspaper *Gazeta.ru* that the plane was redeployed to look for a Burevestnik test during the 2022 strategic exercise *Grom*. There has been no indication that Burevestnik was tested during this exercise. Viktor Sokirko, "«Супернюхач» Из США Начал Охоту За Российской Ракетой «Буревестник» ["US "Super Sniffer" Launches Hunt for Russia's Burevestnik Missile]," *Gazeta.ru*, February 7, 2022, https://www.gazeta.ru/army/2022/02/07/14506351.shtml?updated.

Recommended Further Reading

On Burevestnik:

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1. Hanna Notte, Sarah Bidgood, Nikolai Sokov, Michael Duitsman & William Potter (2021) Russia’s novel weapons systems: military innovation in the post-Soviet period, The Nonproliferation Review. https://www.tandfonline.com/doi/full/10.1080/10736700.2021.1946271

2. Geist, Edward, and Dara Massicot. “Understanding Putin's Nuclear "Superweapons".” SAIS Review of International Affairs 39, no. 2 (2019): 103–17. https://muse.jhu.edu/article/751650

3. Bendett, Samuel, Mathieu Boulègue, Richard Connolly, Margarita Konaev, Pavel Podvig, and Katarzyna Zysk. Advanced Military Technology in Russia: Capabilities and Implications. Research paper / Russia and Eurasia Programme. London: Chatham House, 2021. https://www.chathamhouse.org/sites/default/files/2021-09/2021-09-23-advanced-military-technology-in-russia-bendett-et-al.pdf.

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