

Strengthening Nuclear Test Ban Monitoring and Verification: The Role of Commercial Satellite Imagery

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Cover image: Ground Zero (location of first Soviet nuclear test on 29 August 1949), former Semipalatinsk Test Site, Kazakhstan; satellite image: 18 October 2023, © Planet Labs Inc. All Rights Reserved. Reprinted by Permission.

Contents

| | |
|---|----|
| I. Executive Summary..... | 4 |
| II. Introduction..... | 5 |
| III. Methodology..... | 6 |
| IV. Test Site Activity | 7 |
| Punggye-ri, Democratic People’s Republic of Korea (DPRK) | 8 |
| Key Takeaways | 8 |
| Site Overview & Background..... | 8 |
| Observations | 10 |
| Assessment..... | 10 |
| Nevada National Security Sites, USA | 11 |
| Key Takeaways | 11 |
| Site Overview & Background..... | 11 |
| Observations | 13 |
| Assessment..... | 14 |
| Novaya Zemlya, Russian Federation | 15 |
| Key Takeaways | 15 |
| Site Overview & Background..... | 15 |
| Observations | 18 |
| Assessment..... | 21 |
| Lop Nur, People’s Republic of China | 22 |
| Key Takeaways | 22 |
| Site Overview & Background..... | 22 |
| Observations | 24 |
| Assessment..... | 26 |
| V. Conclusions | 29 |
| VI. Annexes | 29 |

I. Executive Summary

This report details key findings of four case studies that examined developments at select nuclear test sites with the use of commercially available satellite imagery and other supporting open-source information. Specifically, the report summarises findings of developments from July 2023 until March 2024 observed at the Democratic People's Republic of Korea's (DPRK) Punggye-ri test site, the United States' Nevada National Security Sites, the Russian Federation's Novaya Zemlya/Central Test Site, and the People's Republic of China's Lop Nur test site. Together, these studies sought to examine in practical ways how commercially available satellite imagery can best be used for monitoring and verification purposes, and for increasing transparency surrounding activities at test sites where little other information is available to determine the nature of specific developments.

While the four sites differ in scale, development, and their geographies, analysis of tasked and ordered satellite imagery and available open-source information suggests that all four sites are undergoing continued maintenance and intermittent modernisation activities. There have been no indications of imminent test preparations or an imminent return to a full-scale nuclear testing regime. For all sites, however, subcritical or small-scale supercritical experiments cannot be excluded, as any possible indications are less or not observable through remote sensing. The observed activities indicate that all four states aim to retain some infrastructure to resume nuclear testing, should they decide to do so.

Punggye-ri **Democratic People's Republic of Korea**

During the analysis period, observations indicated only site maintenance activities. Some minor vehicle and personnel presence and minor activity at the administrative areas and at one restored tunnel was observed. While no activities that would suggest active preparations for imminent testing were observed, it is possible that no major additional activities would be required to quickly field a test. The site is now likely in a standby mode, pending a decision by the political leadership to further restore it for improved test readiness or to actively prepare for a nuclear test.

Novaya Zemlya/Central Test Site **Russian Federation**

The Novaya Zemlya test site was also observed undergoing maintenance and modernisation. Observed activities appeared to be consistent with official statements that Russia intends to maintain test readiness. At least six horizontal tunnels appear, externally, to be in an operable condition, but no indications were identified that suggested preparations for an imminent nuclear test or a return to a full-scale nuclear testing regime.

Nevada National Security Sites **USA**

The Nevada National Security Sites (NNSS) were similarly observed undergoing maintenance and modernisation. From satellite imagery alone, it is nearly impossible to see clear indications of the difference between conventional explosives and subcritical or potential small-scale supercritical nuclear experiments when conducted in horizontal tunnels or in fully underground facilities. However, what was observed over the period analysed for this report was consistent with known U.S. policy and other sources of open-source information about activities on the site. No indications were identified suggesting preparations for an imminent nuclear test or a return to a full-scale nuclear testing regime.

Lop Nur (No. 21 Base) **People's Republic of China**

Lop Nur was observed undergoing maintenance and possible expansion. Available satellite imagery showed that Lop Nur has undergone modernisation and expansion throughout the past decade and continuing in 2023–2024. Activities observed at Lop Nur suggested that China wants to continue to maintain some test readiness capability. These activities included the construction of a new horizontal tunnel, vertical drilling activities, and potential initial excavations for another underground facility. However, the exact purpose of these activities remains unclear. No indications were identified that suggested preparations for an imminent nuclear test or a return to a full-scale nuclear testing regime.

Findings demonstrate that using commercially available satellite imagery for monitoring test site activities can increase understanding of broad trends and patterns of activities, and support official statements or raise questions about their veracity. Imagery analysis is a potent verification and monitoring tool that should ideally be leveraged as part of a more extensive toolkit, such as the CTBTO's verification regime. At the same time, there are significant limitations to relying only on remote sensing sources and methods to attempt to determine the nature of observed activities and verify compliance. Much of the observed activity remains ambiguous, with multiple alternative explanations conceivable that cannot be excluded from information drawn from available satellite images and other open-source information alone.

As such, these findings further highlight the crucial role of transparency. When states offer public information on the maintenance and usage of test sites, they can demonstrate compliance with testing moratoria. Greater levels of transparency can enable others, including other states, international organization, and civil society to independently verify compliance more accurately, significantly minimizing the risk of misunderstandings.

II. Introduction

In the past two decades, technological developments have significantly increased the availability, accessibility, and quality of satellite imagery data, and changed how and by whom imagery can be used for treaty verification purposes. While individual states have long employed national technical means to monitor others, the information has tended to remain largely classified and not shareable. Today, a growing number of international and non-governmental organisations use satellite imagery in various ways for their monitoring, reporting, and verification needs.

However, more work is needed to explore what specific opportunities and challenges remote sensing techniques present for analysing developments at nuclear test sites with their unique infrastructural properties in remote geographies. While the Comprehensive Nuclear-Test-Ban Treaty (CTBT) called on state parties to explore the use of satellite imagery as a potential future verification tool (CTBT Article IV, Paragraph 11), satellite imagery analysis has not yet been integrated as a formal part of the Comprehensive Nuclear-Test-Ban Treaty Organization's (CTBTO) verification regime. As such, it is with this view of exploring both opportunities and challenges that this project was undertaken.

This resulting report details key findings of four case studies that examined developments at select nuclear test sites with the use of commercially available satellite imagery and other supporting open-source information. Together, these studies aim to show how, in practical ways, commercially available satellite imagery can best be used for monitoring and verification purposes, and for increasing transparency surrounding activities at test sites where little other information is available to determine the nature of specific developments. Specifically, the studies focused on identifying, characterising, and monitoring observable infrastructure and human activity at a select number of nuclear test sites for the July 2023 to March 2024 time period: at the Punggye-ri test site in the Democratic People's Republic of Korea (DPRK), the Nevada National Security Sites (NNSS) in the United States, the Novaya Zemlya test site in the Russian Federation, and the Lop Nur test site in the People's Republic of China (PRC).

These sites were selected on the basis that they have been used for nuclear tests in the past and continue to be maintained for reserving a capacity to resume testing if needed or desired and for stockpile stewardship or other experimental research and development purposes, including for non-nuclear military uses. It is important to note that the four sites differ significantly in their size, the scale and scope of observable activities, how well they are funded and developed, how much is known from other open sources about past and present activities, and their geographical features. This report does not aim to compare and contrast activities at these four sites or to determine compliance with the testing moratorium. Instead, it focuses on examining the most effective ways of leveraging satellite imagery for different circumstances.

III. Methodology



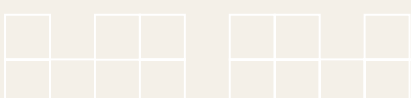
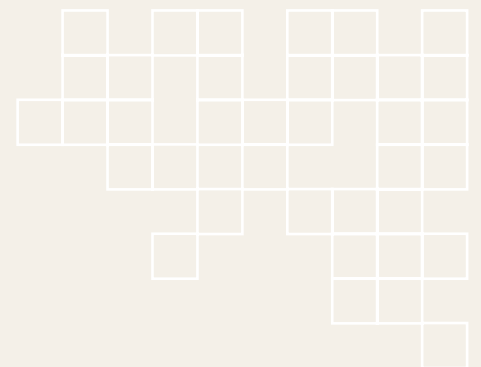
Effective satellite imagery analysis relies on supporting information to reliably identify and assess observed items and activities. The lack of transparency by most states for past and present (nuclear and non-nuclear-related) activities at nuclear test sites makes imagery analysis difficult. As such, initial project work focused on a comprehensive review of available literature, official documentation, and other openly available information on the respective test sites for:

- site familiarisation, geolocation, and mapping;
- identification of possible indicators for specific testing-related activities; and
- determination of imagery tasking requirements and parameters.

This effort then informed the collection and tasking of high-resolution optical imagery and synthetic aperture radar (SAR) data from a range of commercial providers. Images were procured primarily for the July 2023–March 2024 period, but some archive images were additionally needed for background research and reference purposes. This report uses “project period” to describe the July 2023–March 2024 period.

Specific collections include:

- High-resolution optical imagery with a resolution of 0.5m or 0.3m was prioritised to enable detailed image interpretation and detection of changes of small areas of interest (<5 square kilometres) within much larger site complexes.
- Medium-resolution optical imagery (approximately 3 meters) and lower-resolution SAR data were used for wide-area monitoring and geolocation to ensure no activity occurred at unknown locations during the project.
- High-resolution SAR acquisitions were specifically tasked for the polar night period (approximately November until February) on the Novaya Zemlya archipelago, when the lack of sunlight does not allow for any useful optical imagery collections. Most SAR acquisitions were tasked with similar parameters to allow for precise change detection between dates.





IV

Test Site Activites

Punggye-ri

Democratic People's Republic of Korea (DPRK)

Key Takeaways

The Punggye-ri nuclear test site is being maintained and test readiness has likely been restored. Some minor vehicle and personnel presence and minor activity at the administrative areas and at one restored tunnel can be observed. While no activities that would suggest active preparations for imminent testing have been observed, it is possible that no major additional activities would be required to quickly field a test. The site is likely in a standby mode, pending a decision by the political leadership to further restore it for improved test readiness or to actively prepare for a nuclear test.

Site Overview & Background

At the Punggye-ri nuclear test site, four horizontal tunnels were constructed as early as 1985¹ for six nuclear weapon tests, which were held between 2006 and 2017. The entrances to Tunnels 1, 2, 3, and 4 are commonly referred to as the East, North, South and West Portals, respectively (Images 1 and 2).

Tunnel 1 was used for the DPRK's first nuclear weapon test on 9 October 2006, and is believed to have been rendered unusable for further testing.² Tunnel 2 was used for the nuclear tests carried out on 25 May 2009, 12 February 2013, 6 January 2016, 9 September 2016, and 3 September 2017 (Image 2). Tunnel 3 and Tunnel 4 are not known to have been used before.³

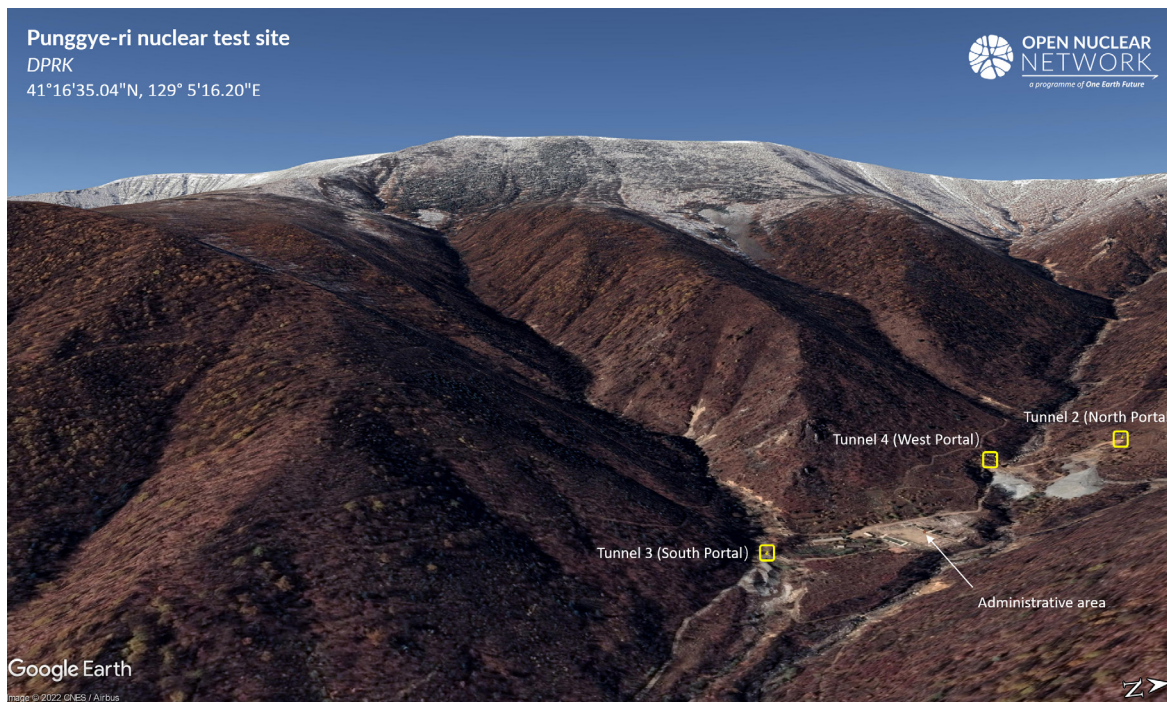


Image 1: Overview of the Punggye-ri nuclear test site. Image: Google Earth.

1. Joseph S. Bermudez Jr., Victor Cha, and Jennifer Jun, 'Punggye-ri Declassified: Birth of North Korea's Northern Nuclear Testing Site', CSIS Beyond Parallel, 23 January 2024 <<https://beyondparallel.csis.org/punggye-ri-declassified-birth-of-north-koreas-northern-nuclear-testing-site/>>.
2. Tunnel 1 was sealed and abandoned after the 2006 test, reportedly due to radioactive contamination. See: Frank V. Pabian, Joseph S. Bermudez Jr., and Jack Liu, 'More Potential Questions About the Punggye-ri Nuclear Test Site Destruction', 38 North, 8 June 2018 <<https://www.38north.org/2018/06/punggye060818/>>. In May 2018, a deputy director of the DPRK's "nuclear research institute" informed a group of journalists who visited the Punggye-ri nuclear test site to observe the demolition of the tunnels that Tunnel 1 (the East Portal) had been shut down. See: Will Ripley, Tim Schwarz, and Paul Devitt, 'North Korea Blows Up Tunnels at Punggye-ri Nuclear Test Site', CNN, 25 May 2018 <<https://edition.cnn.com/2018/05/24/asia/north-korea-nuclear-test-site-intl/index.html>>. Available satellite images since October 2009 have not provided any evidence of further activity at that location.
3. Frank Pabian, 'The Punggye-ri Nuclear Test Site: A Test Tunnel Tutorial', 38 North, 23 May 2018 <<https://www.38north.org/2018/05/punggyetunnel052318/>>.

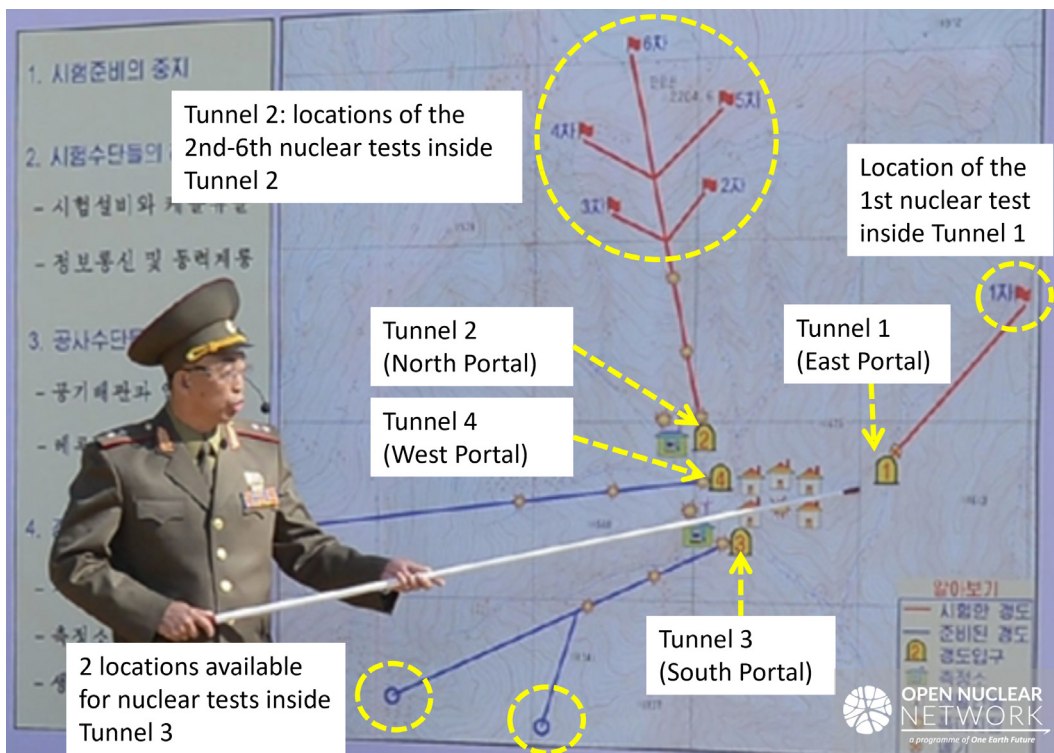


Image 2: Overview of the Punggye-ri nuclear test site. Image: KCNA.

Partial dismantlement, 2018–2022

In April 2018, the DPRK decided to suspend nuclear and ICBM testing as confidence-building measures,⁴ and in May 2018, it announced that it would dismantle the test site “to ensure transparency of discontinuance.” Foreign journalists were invited to attend the dismantlement process, which the DPRK described as entailing the collapse of all tunnels by explosion, blocking of entries, and removal of observation facilities, research institutes, and guard-unit structures. It also said that it would withdraw guards and researchers, and that the test ground would be “completely closed.”⁵

Between 2018 and the end of 2021, the test site remained largely inactive, although some maintenance work, including flood mitigation and road work, was occasionally observed from commercial satellite imagery.⁶

Restoration of Tunnel 3 since 2022

In January 2022, it was reported that the Workers’ Party of Korea’s Political Bureau decided to reconsider the confidence-building measures and “promptly examine the issue of restarting all temporarily suspended activities.”⁷ Between March and May 2022, significant activities were observed near Tunnel 3 suggesting efforts to rehabilitate the tunnel after its partial demolition.⁸ This work mostly concluded by June/July 2022, and little has changed at this area since then.⁹

Possible preparations for restoration of Tunnel 4 since 2022

Since June 2022, some minor activity was also observed in commercial satellite imagery near Tunnel 4, mainly the restoration of the road leading from the main administrative area to the demolished tunnel site. While the tunnel entrance remained visibly demolished, one or two small support installations were constructed since April 2023 and some occasional cleanup work could be observed.¹⁰

4. “3rd Plenary Meeting of 7th C.C., WPK Held in Presence of Kim Jong Un”, KCNA, 21 April 2018.

5. “Press Release of Ministry of Foreign Affairs of Democratic People’s Republic of Korea”, KCNA, 12 May 2018.

6. Joseph S. Bermudez Jr. and Victor Cha, ‘Punggye-ri Nuclear Test Site: Imagery Supports ROK and U.S. Government Reservations About Permanent Disablement’, *CSIS Beyond Parallel*, 17 October 2019 <<https://beyondparallel.csis.org/punggye-ri-nuclear-test-site-imagery-supports-rok-and-u-s-government-reservations-about-permanent-disablement/>>; Joseph S. Bermudez Jr., Victor Cha, and Jennifer Jun, ‘Punggye-ri Update: Flood Mitigation’, *CSIS Beyond Parallel*, 29 August 2022 <<https://beyondparallel.csis.org/punggye-ri-update-flood-mitigation/>>; Joseph S. Bermudez Jr., Victor Cha, and Jennifer Jun, ‘Punggye-ri Update: Continued Activity Near Tunnel No. 4’, *CSIS Beyond Parallel*, 3 October 2022 <<https://beyondparallel.csis.org/punggye-ri-update-continued-activity-near-tunnel-no-4/>>.

7. “6th Political Bureau Meeting of 8th C.C., WPK Held”, KCNA, 20 January 2022.

8. Joseph S. Bermudez Jr., Victor Cha, and Jennifer Jun, ‘Punggye-ri Update: Construction and Volleyball’, *CSIS Beyond Parallel*, 28 April 2022 <<https://beyondparallel.csis.org/punggye-ri-update-construction-and-volleyball/>>; Jenny Town, Olli Heinonen, and Jack Liu, ‘Punggye-ri Nuclear Test Site: Probable Spoil at the South Portal’, 38 North, 31 March 2022 <<https://www.38north.org/2022/03/punggye-ri-nuclear-test-site-probably-spoil-at-the-south-portal/>>; Katsuhisa Furukawa, ‘Developments at the DPRK’s Punggye-ri Nuclear Weapon Test Site since December 2021’, *Open Nuclear Network*, 28 March 2022 <<https://opennuclearnetwork.org/en/open-nuclear-network/publication/developments-dprks-punggye-ri-nuclear-test-site-between-14-24-january-2022/>>; Katsuhisa Furukawa and Jaewoo Shin, ‘Update: Developments at the DPRK’s Punggye-ri Nuclear Test Site Between 6 and 14 April 2022’, *Open Nuclear Network*, 6 April 2022 <<https://opennuclearnetwork.org/en/open-nuclear-network/publication/update-developments-dprks-punggye-ri-nuclear-test-site-between-6-14-april-2022/>>; Jaewoo Shin and Katsuhisa Furukawa, ‘Update: Developments at the DPRK’s Punggye-ri Nuclear Test Site Between 14 and 20 April 2022’, *Open Nuclear Network*, 14 April 2022 <<https://opennuclearnetwork.org/en/open-nuclear-network/publication/update-developments-dprks-punggye-ri-nuclear-test-site-between-14-20-april-2022/>>; Jaewoo Shin and Katsuhisa Furukawa, ‘Update: Developments at the DPRK’s Punggye-ri Nuclear Test Site between 14 and 20 April 2022’, *Open Nuclear Network*, 21 April 2022 <<https://opennuclearnetwork.org/en/open-nuclear-network/publication/update-developments-dprks-punggye-ri-nuclear-test-site-between-14-20-april-2022/>>.

9. ‘Application of Safeguards in the Democratic People’s Republic of Korea’ (IAEA, 25 August 2023) GOV/2023/41-GC(67)/20 <>; Joseph S. Bermudez Jr., Victor Cha, and Jennifer Jun, ‘New Activity at Punggye-ri Tunnel No. 4’, *CSIS Beyond Parallel*, 15 June 2022 <[https://www.iaea.org/sites/default/files/gc/gc67-20.pdf](https://beyondparallel.csis.org/new-activity-at-punggye-ri-tunnel-no-4/)>; Joseph S. Bermudez Jr., Victor Cha, and Jennifer Jun, ‘New Activity at Punggye-ri Tunnel No. 4’, *CSIS Beyond Parallel*, 15 June 2022 <<https://beyondparallel.csis.org/new-activity-at-punggye-ri-tunnel-no-4/>>.

10. IAEA, ‘Application of Safeguards in the Democratic People’s Republic of Korea’, Joseph S. Bermudez Jr., Victor Cha, and Jennifer Jun, ‘Punggye-ri Update: New Activity at Tunnel No. 4’, *CSIS Beyond Parallel*, 4 May 2023 <<https://beyondparallel.csis.org/punggye-ri-update-new-activity-at-tunnel-no-4/>>; Jack Liu, Olli Heinonen, and Peter Makowsky, ‘North Korea’s Punggye-ri Nuclear Test Site: No Signs of an Imminent Test’, 38 North, 11 April 2023 <<https://www.38north.org/2023/04/north-korea-punggye-ri-nuclear-test-site-no-signs-of-an-imminent-test-2/>>.



Image 3: Punggye-ri test site: Tunnel No. 3 and main administrative and support area.

Satellite images captured between July 2023 and March 2024 show only minor activities at the site. In particular, signs of vehicle traffic and personnel movements were observed around the command centre and support area, the administrative area, and near Tunnel 3 (Image 3).

Assessment

Recent activities observed at the test site do not suggest imminent preparations for a seventh nuclear test. The site is likely in standby mode, pending a decision by the political leadership to further restore it for improved test readiness or to actively prepare for a nuclear test. Observables that would be expected for an imminent test (see Figure PG-1, Annex A), such as an increase in personnel or vehicle traffic or installation of additional diagnostic or communication equipment, were not identified during the report period.

The entrance to and external supporting infrastructure for Tunnel 3 appear to be fully restored and potentially ready for at least one or two tests (assuming two separate adits as shown in the DPRK's presentation to journalists in 2018, see Image 2), should the DPRK decide to resume testing. Based on estimated tunnel length, overburden, and assumed containment limitations, 38 North estimates that such tests could have a yield of up to 50 to 120 kilotons, respectively.¹¹

As the entrance to Tunnel 4 is still in a demolished state and would require extensive work to be restored, it is not presently ready for testing. While it is believed that the 2018 entrance explosions only collapsed the entrance section,¹² at least three to four months (the time it took to similarly restore Tunnel 3 in 2022) would likely be required to re-excavate, line, and stabilise a new entrance, as well as to install necessary support buildings and other support infrastructure.

It is important to note, however, that while no test appears imminent, the DPRK could likely prepare for a test (at Tunnel 3) in a short period and do so with little additional observable activity—in particular if the DPRK were to attempt to conceal the preparations and/or the test.¹³

11. 'North Korea's Next Nuclear Test: How Big Could It Be?', *38 North*, 29 April 2022 <<https://www.38north.org/2022/04/north-koreas-next-nuclear-test-how-big-could-it-be/>>.
 12. Joseph S. Bermudez Jr., Victor Cha, and Jennifer Jun, 'Punggye-ri Update: The Waiting Game', *CSIS Beyond Parallel*, 7 November 2022 <<https://beyondparallel.csis.org/punggye-ri-update-the-waiting-game/>>.
 13. Based on analysis of satellite imagery alone, the DPRK's sixth nuclear test in 2016 came with little or no advance notice (Jack Liu, 'Is North Korea Preparing for a Fifth Nuclear Test?', *38 North*, 16 February 2016 <<https://www.38north.org/2016/02/punggye021616/>>). Further, a review of preparations of tests over the years also showed that observable preparations have been inconsistent over time, leading to challenges in detecting future tests. (While, for example, preparations for the fifth nuclear test in February 2013 were visible between as early as two to three months in advance—increase in personnel, heavy vehicle presence and traffic, communications and cabling installations, area clearing near entrance—no such activities could be clearly observed for the sixth test in 2016.) See: Jack Liu, 'The Challenge of Predicting Future North Korean Nuclear Tests', *38 North*, 1 February 2016 <<https://www.38north.org/2016/02/punggye020116/>>; David Albright and Robert Avagyan, *Monitoring Activity at Punggye-ri Nuclear Test Site* (Institute for Science and International Security, 3 February 2013) <<https://isis-online.org/isis-reports/detail/monitoring-activity-at-punggye-ri-nuclear-test-site/10#images>>; Joel S. Wit, 'The Great 2010 DPRK Nuclear Test Debate Continues: Imagery Evidence Inconclusive', *38 North*, 28 April 2015 <<https://www.38north.org/2015/04/punggye042815/>>.

Nevada National Security Sites

USA

Key Takeaways

The Nevada National Security Sites (NNSS) are being maintained and modernised. NNSS has a number of tunnels and facilities available for subcritical tests, conventional explosives tests, or other experiments for stockpile stewardship and non-proliferation monitoring, research, and development. Additionally, NNSS is undergoing continuous maintenance, with active experiments to support its test readiness programme, including subcritical and other scientific tests. Therefore, active mining is known to be used to support planned expansion for subcritical testing and additional explosive experiments in horizontal tunnels.

To help assess the use of satellite imagery for monitoring NNSS, imagery was analysed around a known chemical explosive test in one of the horizontal tunnels. The results show that it is difficult to discern regular NNSS maintenance activity from testing activity without a long period of continuous monitoring to develop a baseline of site activities. From satellite imagery alone, it is nearly impossible to see clear indications of the difference between conventional explosives and subcritical or small-scale supercritical nuclear experiments when conducted in horizontal tunnels or in fully underground facilities. However, what was observed over the project period is consistent with known U.S. policy and other sources of open-source information about activities on the site. No indications were identified that suggest preparations for an imminent nuclear test or a return to a full-scale nuclear testing regime.

Site Overview & Background

NNSS, located in the Nevada desert 105 kilometres northwest of Las Vegas, is the former atmospheric and underground nuclear test site for the United States, which is currently maintained by the Department of Energy (DOE) National Nuclear Security Administration (NNSA). In addition to the former test sites, NNSA and partner organisations run a number of scientific and diagnostic facilities at NNSS which conduct activities and experiments related to nuclear weapons stockpile stewardship, nuclear science, and nonproliferation. Full-scale nuclear testing came to an end in 1992 and the United States signed the CTBT in September 1996 (but has yet to ratify the treaty).¹⁴ In June 2023, NNSS Administrator Jill Hruby stated that the United States “fully observes the CTBT” and has “no plans” to resume nuclear explosive testing.¹⁵

In December 2023, NNSA Administrator Jill Hruby also stated: “The truth is, we have activity going on at our former test site... to do subcritical experiments for our science-based Stockpile Stewardship Program, ... conduct experiments for the nonproliferation program that helps us improve our ability to detect testing, ... [and] they [the Department of Homeland Security] wanted to test the monitors that they were putting at ports.”¹⁶

From 1997 until August 2023, NNSS conducted 33 known subcritical experiments. Recently, NNSS has been undergoing numerous modernisation and expansion efforts related to its subcritical testing infrastructure, primarily focused at the PULSE facility (formerly U1a). PULSE is an underground tunnel complex with two vertical elevator shafts and a vertical cable shaft. The bulk of the known upgrade work known from open sources is taking place underground, and therefore not highly visible from satellite imagery.¹⁷

14. 'Status of Signature and Ratification', CTBTO Preparatory Commission, n.d. <<https://www.ctbto.org/our-mission/states-signatories>>.

15. National Nuclear Security Administration, 'Remarks by NNSA Administrator Jill Hruby at the CTBT: Science and Technology Conference 2023', 19 June 2023, <<https://www.energy.gov/nnsa/articles/remarks-nnsa-administrator-jill-hruby-ctbt-science-and-technology-conference-2023>>

16. 'Managing an Arsenal Without Nuclear Testing: An Interview With Jill Hruby of the U.S. National Nuclear Security Administration', Arms Control Today, December 2023, <<https://www.armscontrol.org/act/2023-12/interviews/managing-arsenal-without-nuclear-testing-interview-jill-hruby-us-national>>

17. Nuclear Weapons: Program Management Improvements Would Benefit U.S. Efforts to Build New Experimental Capabilities (<<https://www.gao.gov/products/gao-23-105714>>).

In summary, NNSS is undergoing continuous maintenance with active experiments to support its test readiness programme, including subcritical and other scientific tests. There is also an extensive modernisation programme that includes active mining to support planned expansion at the PULSE subcritical test facility and potentially additional explosive experiments.

Observations

Numerous sites of relevance for nuclear testing were monitored during the project period, including (see Image 4):

- Area 12 Camp (staging area for tests in Area 12, including P-Tunnel)
- Control Point (former test support facility)
- Device Assembly Facility
- Drill Yard
- Heavy Equipment Yard
- JASPER and Baker Facilities (previous device assembly/disassembly facility)
- Joint Test Organization Forward Area Support Facilities (site for dormant test equipment)
- Mercury (personnel support facilities)
- Other potential tunnel openings via wide area monitoring of the mountains
- P-Tunnel (horizontal tunnel for testing)
- PULSE (underground subcritical testing facility)

The chemical explosion on 18 October 2023, announced on the day of the test, provided an opportunity to establish a use case of what a conventional explosive test conducted in a horizontal shaft would look like from satellite imagery.

The key areas of interest for observation for this test event are the P-Tunnel entrance area and Area 12 camp. Images of the two areas were gathered to look for changes from what might be post-test activities versus normal maintenance activity. Similar times of day and days of the week were gathered to account for differences in normal operating patterns.

Image 5 shows the P-Tunnel entrance area three days post-test and approximately one month post-test, both weekend days. During this period, mine carts and equipment were moved, and fewer vehicles appeared at the entrance area one month later.



Image 5: P-Tunnel entrance area.



Image 6: Area 12 Camp.

Image 6 shows the Area 12 Camp (near P-Tunnel entrance area) two days post-test and approximately two weeks post-test, both weekday afternoons. In the second image two weeks post-test, equipment and vehicles were no longer visible in the camp area.

Assessment

For the observations demonstrated above, the vehicles and equipment seen a few days after the test likely represent post-test monitoring and assessment activities. However, there was regular vehicle movement at the whole site throughout this period, which could be normal maintenance or other activity. Even with advance knowledge of the planned test from other open sources, without a strong indicator (like seeing a device being loaded into the tunnel, or another item as described in Figure NN-1, Annex B), it is difficult to make a confident assessment as to the nature of the observed activity.

The overall conclusion drawn from these observations is that it is difficult to discern maintenance activity from testing activity without a long period of continuous monitoring to establish a baseline. Additionally, from satellite imagery alone, it is nearly impossible to see clear indications of the difference between conventional explosives and subcritical or potential small-scale supercritical nuclear experiments when conducted in horizontal tunnels.

For the other NNSS facilities and areas of interest that were monitored over the course of the project, similar issues arose. Regular movement of vehicles was observed, but without establishing a pattern of life over a long time period at the same time and on the same days, it is difficult to determine what constitutes unusual vehicle movement (see Figure NN-1 in Annex B).

During the project period, no movement of heavy machinery at critical facilities was observed. Heavy machinery movement could indicate test preparations, maintenance activity, or construction related to modernisation activities (see Figure NN-1 in Annex B). However, the absence of observation of heavy machinery movement does not mean these activities are not happening. This is especially true at PULSE as the facility is nearly fully underground, thus making outside observation difficult unless the satellite takes a picture at the exact time as heavy machinery is being taken to the elevator shaft.

Novaya Zemlya

Russian Federation

Key Takeaways

Activities observed at the Novaya Zemlya nuclear test site through open-source satellite imagery are consistent with official statements that Russia intends to maintain test readiness. While maintenance and modernisation activities could be observed during the project period, with at least six horizontal tunnels that appear, externally, to be in an operable condition, no indications were identified that suggest preparations for an imminent nuclear test or a return to a full-scale nuclear testing regime. Subcritical or small-scale supercritical experiments cannot be excluded, as any possible indications would be less observable in satellite images.

Site Overview & Background

The Central Test Site of the Russian Federation (Центральный полигон Российской Федерации) is located on the Novaya Zemlya archipelago in the Arctic Ocean. This report will use “Central Test Site” to refer to the nuclear test site on Novaya Zemlya. The last nuclear test conducted there was on 24 October 1990. Russia signed the CTBT in September 1996, ratified it in June 2000, but withdrew its ratification in November 2023.²⁰ According to Russia’s Ministry of Defence, “within the framework of activities not prohibited by the Comprehensive Nuclear Test Ban Treaty, non-nuclear explosive experiments” are carried out at the Central Test Site “to maintain the reliability and safety of the nuclear arsenal.”²¹ The Central Test Site “has been kept in ready condition for the resumption of nuclear tests if such a need arises.”²² Its main tasks are “the preparation and testing of promising samples of weapons and military equipment.”²³ The 12th Main Directorate of the Russian Ministry of Defence (12 GUMO) manages the Central Test Site,²⁴ and is responsible for the implementation of the “military nuclear-technical policy of the state and nuclear support of the Armed Forces of the Russian Federation.”²⁵

Although Russia stresses that all its activities are in accordance with international agreements, according to treaty compliance reports by the U.S. Department of State, the United States believes that some of Russia’s “activities since 1996 have demonstrated a failure to adhere to the zero-yield standard, which would prohibit supercritical nuclear tests.”²⁶ Further, the United States has concerns about Russia’s adherence to its moratorium due “to the lack of transparency with regard to its nuclear testing activities.”²⁷

After conclusion of the active testing programme on Novaya Zemlya in 1990, four main active locations have been maintained on the island (Image 7):

- 1) Belushya/Belushya Guba (Белушья Губа)—the central residential and scientific headquarters of the Central Test Site (Image NZ-1, Annex C);

20. 'Country Profiles: Russian Federation', CTBTO Preparatory Commission, n.d. <<https://www.ctbto.org/our-work/country-profile?name=Russian%20Federation>>.
21. Original quote: “Currently, within the framework of activities not prohibited by the Comprehensive Nuclear Test Ban Treaty, non-nuclear explosive experiments are being conducted at the test site in order to maintain the reliability and safety of the nuclear arsenal” (“В настоящее время в рамках не запрещённой Договором о всеобъемлющем запрещении ядерных испытаний деятельности на полигоне проводятся неядерно-взрывные эксперименты в целях поддержания надёжности и безопасности ядерного арсенала.”). From: Ядерные полигоны [‘Nuclear Test Sites’] (Ministry of Defence [n.d.]) <<https://encyclopedia.mil.ru/encyclopedia/dictionary/details.htm?id=13811@morfDictionary>>.
22. ‘Novaya Zemlya Nuclear Test Site Remains Ready for Nuclear Tests, Source Says’, TASS, 21 February 2023 <<https://tass.com/defense/1579777>>.
23. ‘Russian Defence Minister General of Army Sergei Shoigu Checks Russian Grouping of Troops in Arctic Area’, (Ministry of Defence of the Russian Federation, 12 August 2023) <https://eng.mil.ru/en/news_page/country/more.htm?id=12475596@egNews>.
24. ‘В Минобороны рассказали о задачах ядерного полигона на Новой Земле’ [‘The Ministry of Defense Spoke About the Tasks of the Nuclear Test Site on Novaya Zemlya’], TV Zvezda, 6 June 2021 <<https://tvzvezda.ru/news/202166118-fZoDI.html>>.
25. Двенадцатое главное управление Министерства обороны Российской Федерации (12 ГУМО) [Twelfth Main Directorate of the Ministry of Defence of the Russian Federation (12 GUMO)], (Ministry of Defence of the Russian Federation, [n.d.]) <<https://encyclopedia.mil.ru/encyclopedia/>>
26. Adherence to and Compliance with Arms Control Nonproliferation and Disarmament Agreements and Commitments (U.S. Department of State, April 2022) <<https://www.state.gov/wp-content/uploads/2022/04/2022-Adherence-to-and-Compliance-with-Arms-Control-Nonproliferation-and-Disarmament-Agreements-and-Commitments-1.pdf>>.
27. Adherence to and Compliance with Arms Control Nonproliferation and Disarmament Agreements and Commitments (U.S. Department of State, April 2023) <<https://www.state.gov/wp-content/uploads/2024/01/APR23-2023-Treaty-Compliance-Report.pdf>>

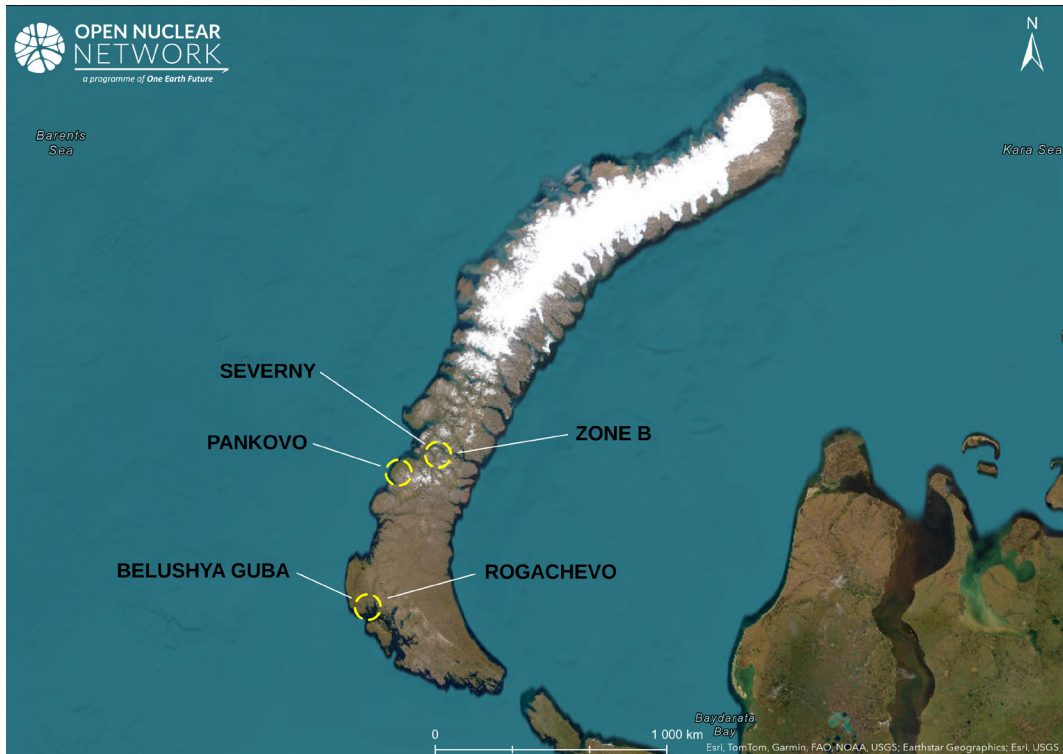


Image 7: Overview of Novaya Zemlya archipelago. Image: Esri, TomTom, Garmin, FAO, NOAA, USGS; Earthstar Geographics; Esri, USGS.

- 2) Rogachevo (Рогачево)—the main airfield (with an air defence division nearby) located approximately 10 kilometres from the Belushya Guba (Image NZ-2, Annex C);
- 3) Pankovo site (Паньково)—approximately 180 kilometres from Belushya Guba, a testing site that has been used to test the Burevestnik nuclear-powered cruise missile;²⁸ and
- 4) Severny (Северный)—approximately 200 kilometres from Belushya Guba, a settlement near which all known nuclear tests in horizontal tunnels on Novaya Zemlya have been conducted in the past.

Key changes that were observed in satellite imagery prior to July 2023 include the renovation of buildings in Severny, modernisation of a potential subcritical test site,²⁹ and replacement of at least three old tunnel entrances in Zone B.³⁰

Additionally, there are many activities on the maintenance and modernisation activities,³¹ geological exploration³² and environmental remediation,³³ nuclear waste management,³⁴ and military activities.³⁵

28. Timothy Wright, 'Russia Claims to Have Tested Nuclear-Powered Cruise Missile', IISS, 13 October 2023 <<https://www.iiss.org/online-analysis/missile-dialogue-initiative/2023/10/russia-claims-to-have-tested-nuclear-powered-cruise-missile/>>; Riley Mellen, 'Russia May Be Planning to Test a Nuclear-Powered Missile', The New York Times, 2 October 2023 <<https://www.nytimes.com/2023/10/02/video/russia-nuclear-missile.html>>.

29. 'Welcome to Novaya Zemlya! Surveying Russia's Underground Nuclear Test Site,' James Martin Center for Nonproliferation Studies, 20 December 2018 <<https://nonproliferation.org/welcome-to-novaya-zemlya-surveying-russias-underground-nuclear-test-site/>>.

30. Replacement of at least three old tunnel entrances throughout Zone B was identified by ONN with available satellite imagery.

31. Ядерные испытания. Кн. 1: Ядерные испытания в Арктике [Nuclear tests. Book 1: Nuclear Testing in the Arctic], ed. by V.N. Mikhailov, Vol.1 (Kartush, 2006) <https://elib.biblioatom.ru/text/yadernye-ispytaniya_kn1_t1_2006/p370/>; such activities can also be observed with available satellite imagery in recent years. For instance, in 2021, the Ministry of Defence announced that two residential buildings for families of contract servicemen and a preschool educational institution were built. It said that it would build 30 additional facilities "in the interests of the Central Test Site" by 2030 (Vladimir Raskhodchikov, 'В Минобороны рассказали о задачах ядерного полигона на Новой Земле' [The Ministry of Defence Spoke About the Tasks of the Nuclear Test Site on Novaya Zemlya], TV Zvezda, 6 June 2021 <<https://tvzvezda.ru/news/202166118-fZoDI.html%20>>). According to the Ministry of Defence, 424 decommissioned buildings were demolished between 2015 and 2018, sometimes with the use of explosives ('Министерство обороны очистило полигон на Новой Земле от 7000 тонн металлолома' [The Ministry of Defence Cleared the Test Site on Novaya Zemlya from 7,000 Tons of Scrap Metal] (Ministry of Defence of the Russian Federation, 22 January 2018) <https://function.mil.ru/news_page/country/more.htm?id=12159112@egNews>.) In 2015–2016 alone, 55 tons of "engineering ammunition" were delivered to Novaya Zemlya by aircraft for demolition purposes ('С архипелага Новая Земля в 2024 году вывезут около 700 тонн металлолома' [The Russian Ministry of Defence Will Remove 2 Thousand Tons of Scrap Metal from the Test Site on Novaya Zemlya], Nezavisimaya Gazeta, 27 January 2017 <https://www.ng.ru/armies/2017-01-27/100_lom270117.html>).

32. Russia is planning to develop the so-called Pavlovskoye zinc and lead mine on Novaya Zemlya. See: Atle Staalesen, 'Following Andrei Patrushev's Infrastructure Investment Comes a Major Government Development Plan for Seaports in Arkhangelsk and Novaya Zemlya', Independent Barents Observer, 2 October 2023 <<https://thebarentsobserver.com/en/industry-and-energy/2023/10/following-andrei-patrushevs-infrastructure-investment-comes-major>>.

33. Since 2014, within the framework of the environmental federal programme "Ecological cleanup of the Arctic" ("Экологическая очистка Арктики"), metal waste, other waste, and soil have been removed from Novaya Zemlya every year. See: 'С архипелага Новая Земля в 2024 году вывезут около 700 тонн металлолома' [About 700 Tons of Scrap Metal Will Be Removed from the Novaya Zemlya Archipelago in 2024], TASS, 2 November 2023 <<https://tass.ru/armiya-i-orpk/19181661>>; 'Военнослужащие 12-го Главного управления управления собрали 85 тонн металлолома на Новой Земле' [Military Personnel of the 12th Main Directorate Collected 85 Tons of Scrap Metal on Novaya Zemlya], TASS, 28 June 2022 <<https://tass.ru/obschestvo/15060479>>.

34. Nuclear waste used to be disposed of by the Soviet Union in the fjords of Novaya Zemlya and the Kara Sea. Russian scientists sometimes check the flooded nuclear waste. See: Modelling of the Radiological Impact of Radioactive Waste Dumping in the Arctic Seas: Report of the Modelling and Assessment Working Group of the International Arctic Seas Assessment Project (IASAP) (IAEA, January 2003) <https://www-pub.iaea.org/MTCD/Publications/PDF/te_1330_web.pdf>; 'На Новой Земле изучат состояние затопленных ядерных объектов' [The Condition of Flooded Nuclear Facilities Will Be Studied on Novaya Zemlya], TASS, 30 September 2023 <<https://nauka.tass.ru/nauka/18882369>>. In 2015, the Arkhangelsk Oblast's Assembly of Deputies approved the construction of a radioactive waste disposal facility on Novaya Zemlya by Rosatom. However, it is unclear if any progress has been made since then. See: 'На Новой Земле появится хранилище радиоактивных отходов "Росатома"' [Rosatom's Radioactive Waste Storage Facility Will Appear on Novaya Zemlya], TASS, 25 November 2015 <<https://tass.ru/obschestvo/2472561>>.

35. This includes the development and testing of the Burevestnik nuclear-powered cruise missile, the potential testing of the Poseidon nuclear-powered torpedo

The wide range of broader archipelago that are not directly connected to preparing for or conducting nuclear testing. These includes general site-wide activities conducted on Novaya Zemlya makes it more difficult to clearly determine the nature of observed developments, particularly those within the known areas of the Central Test Site.

Of the four main active areas, only one area is assessed as plausible for a potential resumption of nonatmospheric/contained nuclear testing—an area near the Severny settlement. During Soviet times, this area was called “Zone B” (Зона Б), where 33 nuclear tests were conducted in horizontal tunnels. The zone also has horizontal tunnels that were constructed but never used.³⁶ While active, most of the underground nuclear tests in Zone B were conducted in the August–October period, likely due to weather considerations.³⁷ No other area on Novaya Zemlya was identified with maintained tunnelling infrastructure that could support a potential resumption of nuclear testing.

From 1995 to 2000, horizontal tunnels near Severny were used for subcritical tests. According to papers written by Russian researchers about this period of subcritical testing, Russia was able to conduct five to six tests per year if needed.³⁸ According to statements by Russia’s Ministry of Defence and Russian media reports,³⁹ Russia has continued to carry out subcritical nuclear tests since then; however, the timing and regularity of these tests are unknown.

Developments in 2023–2024

Russian President Vladimir Putin, in his 21 February 2023 Presidential Address to the Federal Assembly, stated, “we know for certain that some politicians in Washington are already pondering live nuclear tests” and under given circumstances, “the Defence Ministry and Rosatom must make everything ready for Russia to conduct nuclear tests.”⁴⁰ It was stated that Russia would not resume nuclear tests as long as the United States also refrains from doing so.⁴¹ On 12 August 2023, Russian Minister of Defence Sergei Shoigu and the head of Rosatom, Alexey Likhachev, visited Novaya Zemlya.⁴² On 2 November 2023, Putin signed into law Russia’s withdrawal of its CTBT ratification to “restore parity of obligations under the CTBT,” specifically to address the “imbalance between Russia and the United States.”⁴³ However, Russia continues “to participate in the work of the Preparatory Commission of the Organization for the CTBT” and emphasises that it remains a signatory to the CTBT “with all the ensuing rights and obligations.”⁴⁴ On 14 December 2023, the Russian segment of the CTBTO’s IMS was completed.⁴⁵

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- with a nuclear warhead, and conventional military activities on and near Novaya Zemlya to increase Russia’s military presence in the Arctic zone and to improve the safety of navigation and maritime economic activity of Russia along the Northern Sea Route. See also: Thomas Nilsen, ‘New Study Reveals Comprehensive Buildup of Nuclear Missile Test-Ground at Novaya Zemlya’, *Independent Barents Observer*, 18 September 2022 <https://thebarentsobserver.com/en/security/2022/09/new-study-reveals-comprehensive-buildup-nuclear-missile-test-ground-novaya-zemlya/>; Focus 2024: *The Norwegian Intelligence Service’s Assessment of Current Security Challenges* (The Norwegian Intelligence Service, 26 January 2024) <https://www.etterretningstjenesten.no/publikasjoner/fokus/focus-english/Focus2024%20-%20EN%20-%20Web%20spread%20v4.pdf/_/attachment/inline/867233c3-e20b-4a8d-b451-95228510fccb:ecce08c192a7bdddae2034d1b1faed5ff3e31ae1/Focus2024%20-%20EN%20-%20Web%20spread%20v4.pdf>; Hans M. Kristensen, Matt Korda, Eliana Johns and Mackenzie Knight, ‘Russian Nuclear Weapons, 2024’, *Bulletin of the Atomic Scientists*, 7 March 2024, <<https://thebulletin.org/premium/>>; ‘Shoigu Checks Russian Grouping of Troops’ (Ministry of Defence of the Russian Federation); Jonas Kjellén, ‘The Russian Northern Fleet and the (Re)militarisation of the Arctic’, *Arctic Review on Law and Politics*, 13 (2022), p. 34–52, <<https://www.jstor.org/stable/48710657>>. 2024-03/russian-nuclear-weapons-2024/
36. Vitaly I. Khalturin, Tatyana G. Rautian, Paul G. Richards, and William S. Leith, ‘A Review of Nuclear Testing by the Soviet Union at Novaya Zemlya, 1955–1990’, *Science & Global Security*, 13 (2005) <<https://scienceandglobalsecurity.org/archive/sgs13khalturin.pdf>>.
37. J.R. Matzko, *Physical Environment of the Underground Nuclear Test Site on Novaya Zemlya, Russia* (U.S. Geological Survey, 1993) Open File Report 93-501 <<https://pubs.usgs.gov/of/1993/0501/report.pdf>>.
38. Vladimir Belous, ‘Ядерные испытания—возобновление неизбежно?’ [‘Nuclear Tests—Resumption Inevitable?’], *Nezavisimaya Gazeta*, 19 November 2010, <https://nvo.ng.ru/concepts/2010-11-19/10_nuclear.html>; Ядерные испытания. Кн. 1: Ядерные испытания в Арктике [Nuclear Tests. Book 1: Nuclear Testing in the Arctic], ed. by V.N. Mikhailov, Vol. 2 (Kartush—2006) <http://elib.bibliotom.ru/text/yadernye-isyptaniya_kn1_t2_2006/go,130/>; Oleg Bukharin, *Downsizing Russia’s Nuclear Warhead Production Infrastructure*, (The Nonproliferation Review, Spring 2001) <<https://www.nonproliferation.org/wp-content/uploads/npr/81bukh.pdf>>.
39. Vladimir Mukhin, ‘Ядерный зонтик для Арктики’ [‘Nuclear Umbrella for the Arctic’], *Nezavisimaya Gazeta*, 28 September 2012 <https://nvo.ng.ru/nvo/2012-09-28/1_arctic.html>; Vladimir Mukhin, ‘Эксперты: Москва испытывает атомные боеприпасы’ [‘Experts: Moscow Is Testing Atomic Weapons’], *Nezavisimaya Gazeta*, 30 May 2019 <https://www.ng.ru/politics/2019-05-30/1_7587_mukhin.html>; Anna Ershova, ‘Новая эпоха контроля над вооружениями: США на пути к стратегической неприкосновенности’ [‘A New Era of Arms Control: The United States Towards Strategic Integrity’], *International Affairs*, 29 August 2020 <<https://interaffairs.ru/news/show/27296>>.
40. Presidential Address to Federal Assembly (President of Russia, 21 February 2023) <<http://en.kremlin.ru/events/president/news/70565>>.
41. Other key officials repeated this idea several times. See: ‘If US Does Not Resume Nuclear Tests, Russia Will Not Start Them Either—Senior Diplomat’, TASS, 2 March 2023 <<https://tass.com/politics/1584021>>; ‘Директор департамента МИД РФ: США подорвали принципы договоренностей в рамках ДСНВ’ [‘Director of the Department of the Russian Foreign Ministry: The United States Undermined the Principles of the Agreements Within the Framework of the New START Treaty’], TASS, 16 October 2023 <<https://tass.ru/interviews/19019115>>. Since the end of the 1990s, the position of the Russian government has been to comply with the nuclear test moratorium commitment if the other P5 states (China, France, UK, US) do the same. For example, during the CTBT conference in 2011, Russia discussed its commitment to the nuclear test moratorium and stated that “Russia intends to further comply with this commitment, if other nuclear weapon States do likewise.” (‘Statement by the Head of Delegation of the Russian Federation, Deputy Foreign Minister Sergey A. Ryabkov, at the 7th Conference on Facilitating the Entry into Force of the Comprehensive Nuclear-Test-Ban Treaty’, 23 September 2011 <https://www.ctbto.org/sites/default/files/2022-07/russia_2011.pdf>.)
42. ‘Russian Defence Minister General of Army Sergei Shoigu checks Russian grouping of troops in Arctic area’ (Ministry of Defence of the Russian Federation, 12 August 2023) <https://eng.mil.ru/en/news_page/country/more.htm?id=12475596@egNews>.
43. ‘Law Revoking the Ratification of the Comprehensive Nuclear-Test-Ban Treaty’, (President of Russia, 2 November 2023) <<http://en.kremlin.ru/acts/news/72635>>.
44. ‘Заявление МИД России в связи с отзывом Российской Федерацией ратификации Договора о всеобъемлющем запрещении ядерных испытаний’ [‘Statement by the Russian Ministry of Foreign Affairs in Connection with the Russian Federation’s Withdrawal of Ratification of the Comprehensive Nuclear Test Ban Treaty’], (Ministry of Foreign Affairs of the Russian Federation, 3 November 2023) <https://www.mid.ru/ru/foreign_policy/news/1913392/>.
45. ‘Заявление МИД России в связи с завершением создания российского сегмента Международной системы мониторинга, предусмотренной Договором о всеобъемлющем запрещении ядерных испытаний’ [‘Statement by the Russian Ministry of Foreign Affairs in Connection with the Completion of the Creation of the Russian Segment of the International Monitoring System Provided for by the Comprehensive Nuclear Test Ban Treaty’], (Ministry of Foreign Affairs of the Russian Federation, 14 December 2023) <https://www.mid.ru/ru/foreign_policy/news/1921267/>.



Image 8: Overview of Zone B. Image: Sentinel-2 via ESRI World Imagery (ESRI, European Commission, European Space Agency, Azure).

Observations

In addition to site-wide modernisation and maintenance activities, the following activities were observed during the project period:

- Delivery and transportation of cargo on site,
- Expansion of storage facilities and construction of new ones,
- Plane movements at the Rogachev airfield (peak in August and September 2023),
- Removal of metal debris from the archipelago,
- Ship movements to Severny (peak in September 2023) and Belushya Guba (with peaks from the end of August to November 2023),
- Vehicle and helicopter movements.

Six sites (each with one or two tunnel entrances and collocated support buildings/barracks) were identified near Severny that appear, externally, to be in an operable condition that may allow for explosive testing, including a potential resumption of nuclear testing, should there be a political decision to do so (Image 8):⁴⁶

- Two sites showed an increased level of activity (“Suspected Subcritical Test Site” and “Other Active Site”);
- One site (“Maintained Site No. 1”) showed some activity (the site’s proximity to Severny—approximately 2 kilometres—would likely preclude testing beyond a very low yield); and
- Three sites (“Maintained Site No. 2,” “Maintained Site No. 3,” and “Maintained Site No. 4”) appear, externally, to be in an operable state that may allow for explosive testing but showed little or no activity.

46. Official tunnel site-specific names are unknown/incomplete. As such, this report uses the following designations for reference purposes only.

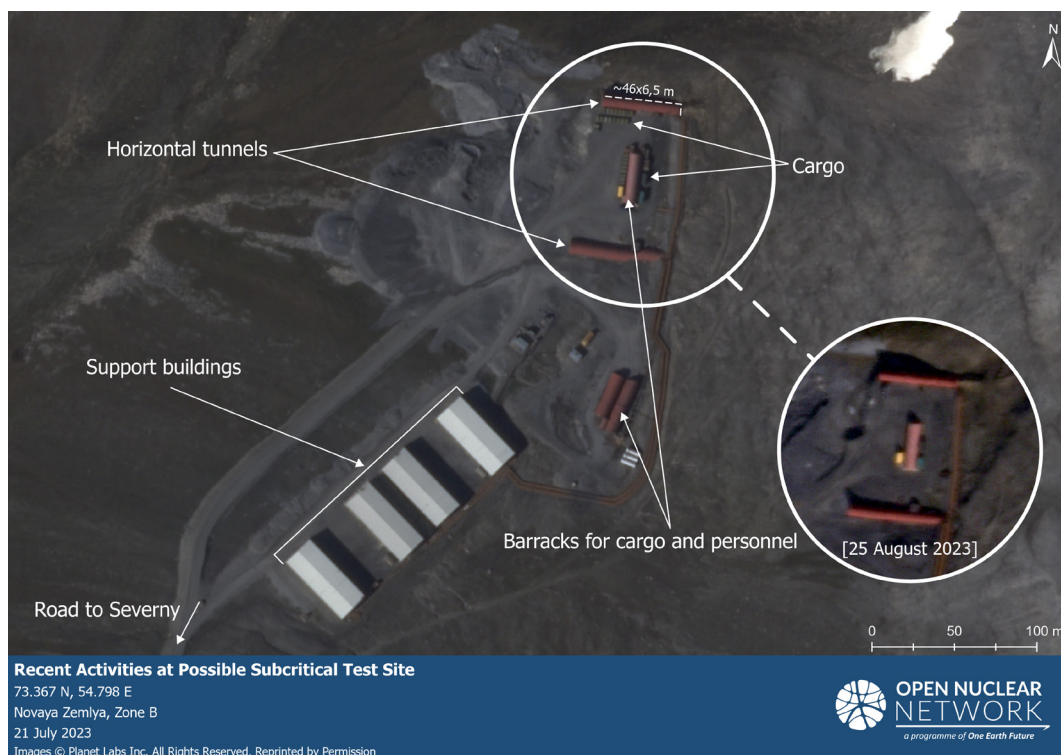


Image 9: Recent activities at the Suspected Subcritical Test Site.

Severny and horizontal tunnels

Severny

The following activities at Severny were observed during the project period:

- Building construction (see Image NZ-3 in Annex C):
 - One large building and one smaller building (possible storage facilities) nearby to the south of Severny (the main construction process appeared to conclude in September–October 2023).
 - At least two barracks in the centre of the settlement.
- Port visits by cargo ships and special vessels:
 - Large floating crane ship (PK-7500 Navy crane) in July 2023.
 - Rosatom ship used for transporting nuclear waste (Rossita) in September 2023. The Rossita visit is unique because it usually only travels between Andreeva Bay and Murmansk, transferring containers with spent fuel from the Soviet Union's submarine fleet.⁴⁷
 - Ships for transporting collected metal scraps and other waste.
- Vehicle/helicopter movements, arrival of containers and construction materials.

Horizontal tunnels

During the project period, two sites with increased levels of activity were identified.

The first site is the "Suspected Subcritical Test Site" (Image 9).⁴⁸ Movement of vehicles on the site (vehicles were spotted at least six times during the project period) and delivery of boxes/containers at two horizontal tunnels were observed (approximately 18 boxes/containers in July 2023 near the northern tunnel and approximately 15 boxes/containers near one barrack for cargo and personnel).

The site was active and visited even when snow started to cover the area from the end of September. The activity level from mid-November to January is uncertain due to the polar night complicating satellite imagery monitoring (sunlight reflectance is required for usable optical imagery collections). Available SAR collections suggest that there was no activity at the site between December and the end of January. Surface disturbances and vehicle tracks observed in one partial optical collection from 5 February 2024, a coherent pair of SAR collections between 5 February and 14 February, and images from March 2024 suggest that the site has been visited again since early February 2024 (Image NZ-4, Annex C).

47. Thomas Nilsen, 'Nuclear Waste Ship Makes Unprecedented Port Call at Novaya Zemlya,' *Independent Barents Observer*, 29 September 2023 <<https://thebarentsobserver.com/en/nuclear-safety/2023/09/nuclear-waste-ship-makes-port-call-novaya-zemlya>>.

48. 'Welcome to Novaya Zemlya! Surveying Russia's Underground Nuclear Test Site,' *James Martin Center for Nonproliferation Studies*, 20 December 2018 <<https://nonproliferation.org/welcome-to-novaya-zemlya-surveying-russias-underground-nuclear-test-site/>>; Vladimir Mukhin, 'Ядерный зонтик для Арктики' ['Nuclear Umbrella for the Arctic'], *Nezavisimaya Gazeta*, 28 December 2012.

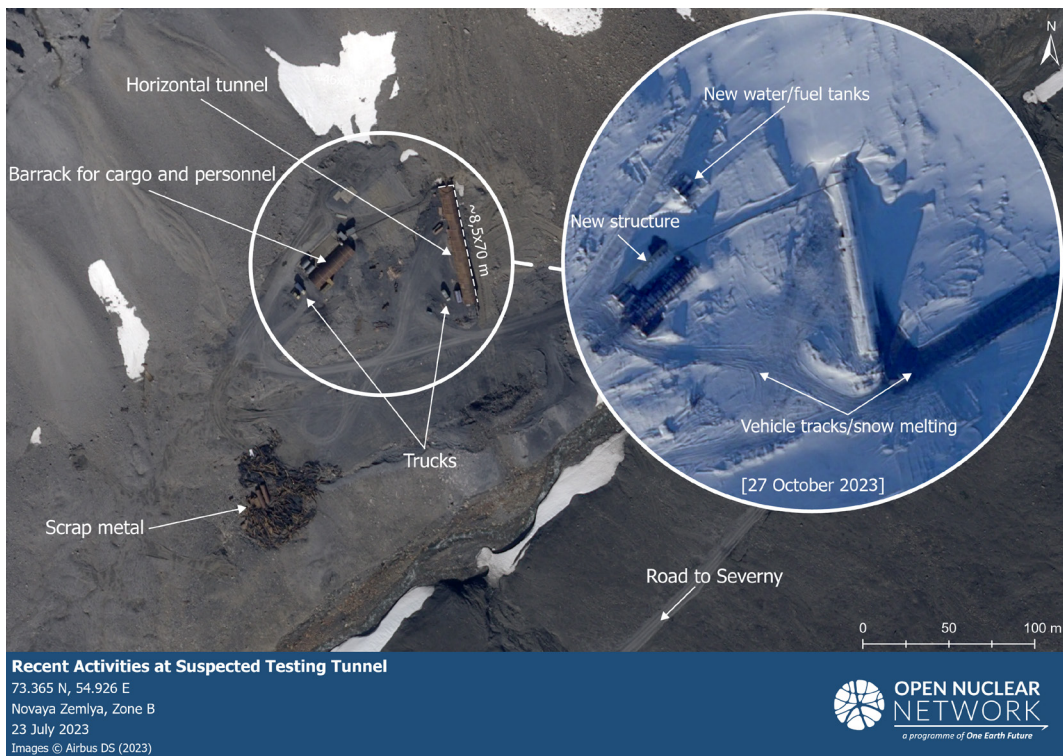


Image 10: Recent activities at suspected testing tunnel (labelled as "Active Site" in Image 8).

The "Other Active Site" comprises one horizontal tunnel entrance, a barrack/support area, fuel/water tanks, and an area for scrap metals. Mining carts have also been identified in available satellite imagery (Image 10).

The following activities were observed: delivery of boxes/containers, construction of a new barrack, movement of vehicles (including concrete mixer trucks, potentially to create a concrete foundation for the new barrack and/or for tunnel grouting, lining, or reinforcements), and the placement of new water/fuel tanks. Construction and installation activities were observed from 23 July to 15 August.

The site was active and visited even when snow started to cover the area at the end of September. The activity level after early November and during January is uncertain due to the polar night complicating satellite imagery monitoring. Available SAR collections suggest that there was no major activity at the site between November and January. However, snow melting/surface disturbances, multiple vehicle tracks and vehicles present on site were observed, suggesting that the site was regularly visited again between early February to March 2024. (Image NZ-5, Annex C).



Image 11: Other possible testing sites.

There are four additional sites that appear, externally, to be in an operable condition that may allow for explosive testing (Image 11).

“Maintained Site No. 1” (73.375° N, 54.780° E; see Image 11) has a horizontal tunnel and a cable/pipe connection with the “Suspected Subcritical Test Site.” There were fewer visible activities compared to the first two sites—only vehicle movements and surface disturbances were observed. The site was visited even when snow started to cover the area at the end of September. Given the site’s close proximity to residential areas in Severny, it is unlikely that the site would be used for a larger yield nuclear test in the future.

“Maintained Site No. 2” and “Maintained Site No. 3” were visited by vehicles at least three times between July and September 2023. However, no substantial changes were observed during the project period (e.g., no new construction or growth in excavated spoil etc.). “Maintained Site No. 4” has likely not been used for nuclear testing before.⁴⁹ No activity was observed at this site.

Another presumably unused tunnel⁵⁰ (73.239° N, 55.133° E) was possibly decommissioned in 2021, with the destruction of the sole tunnel entrance. The tunnel remained unusable during the project period, and the site appeared to be in an abandoned state (Image NZ-6 in Annex C).

Other identified Soviet-era test sites in Zone B have been observably degraded or demolished so that they are unlikely to be available for potential nuclear testing without major reconstruction works. Only one such site was visited by trucks, possibly for collection of metal debris as part of a federal environmental programme on the Ecological cleanup of the Arctic.⁵¹

Assessment

During the project period, Russia was observed maintaining and improving the Central Test Site. Observations do not suggest that the site is currently undergoing preparations for an imminent nuclear test as additional indicators should be visible, such as (Figure NZ-7 in Annex C):

- A substantial volume of newly excavated rock/ground spills,
- Heavy mining/construction machinery,
- Additional cabling installed for testing diagnostics, and
- Trailers with recording equipment near the testing area.

However, subcritical tests cannot be ruled out since related activities for such tests would likely feature fewer external indicators that could be observed with available satellite imagery. Overall, observed activities appear to be in line with Russia’s recent statements on maintaining test readiness.⁵²

It is important to note that significant uncertainties exist due to the limited number of images, the weather conditions, and difficulty in identifying specific objects without additional supporting information.⁵³ Specific observables that may be indicative of activities related to the testing programme can also be explained by unrelated activities on the site (see Figure NZ-8 in Annex C). Additionally, much of the accumulated knowledge about the Central Test Site is based on documentation and literature dating back to the past decades. Technological developments over the past 30 years have likely changed testing procedures and relevant indicators.

Monitoring and overall assessment of activity at the Central Test Site is further complicated by activities that are not related to the nuclear testing programme, such as the frequent testing of various weapon systems, the overall increase of Russia’s military presence in the broader Arctic region, general infrastructure modernisation, geological exploration, and environmental remediation activities. The broad scope of activities on and near Novaya Zemlya in recent years have made it more challenging to clearly differentiate between activities associated with the Central Test Site and other developments.

49. The tunnel is assumed to have never been used before because it is located outside of the area where the Soviet Union conducted nuclear tests in Zone B. A map of Zone B and the locations of underground nuclear tests conducted is available in the existing literature. See: Khalturin, Rautian, Richards, and Leith, ‘A Review of Nuclear Testing by the Soviet Union at Novaya Zemlya, 1955–1990’.

50. The tunnel is assumed to have never been used before because it is located outside of the area where the Soviet Union conducted nuclear tests in Zone B. A map of zone B and the locations of underground nuclear tests conducted is available in the existing literature. See: Khalturin, Rautian, Richards, and Leith, ‘A Review of Nuclear Testing by the Soviet Union at Novaya Zemlya, 1955–1990’.

51. Available satellite imagery also shows that scrap metal was collected and removed in July–August 2023; ‘Военнослужащие 12-го Главного управления собрали 85 тонн металлолома на Новой Земле’ [‘Military Personnel of the 12th Main Directorate Collected 85 Tons of Scrap Metal on Novaya Zemlya’], TASS, 28 June 2022 <<https://tass.ru/obschestvo/15060479>>.

52. ‘Presidential Address to Federal Assembly’ (President of Russia, 21 February 2023) <<http://en.kremlin.ru/events/president/news/70565>>.

53. For example, there are some objects and activities whose role at the Central Test Site is still unknown—unclear excavation works, locations resembling waste disposal/storage sites, unusual storage sites, and a site surrounded by fences but not related to nuclear test tunnels.

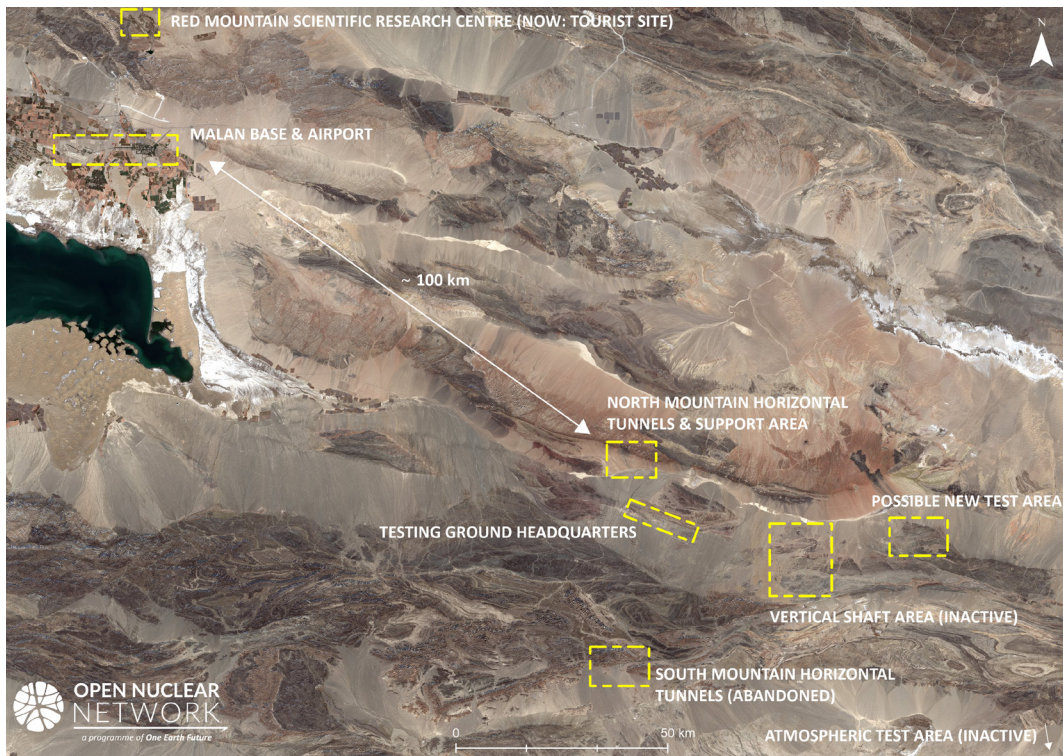


Image 12: Overview of the No. 21 Base. Image: Sentinel-2 via ESRI World Imagery (ESRI, European Commission, European Space Agency, Azure).

research activities and science experiments.⁶² The United States has publicly stated that it has compliance concerns with China's "possible preparation to operate its Lop Nur test site year-round, its use of explosive containment chambers, extensive excavation activities at Lop Nur, and lack of transparency on its nuclear testing activities," but has refrained from explicitly alleging noncompliance.⁶³

Publicly available Chinese TV reports and news articles along with interviews and short memoirs by scientists and former staff form the basis to understand the site history and activities.⁶⁴ Augmenting this information with satellite imagery can then enable the geolocation and monitoring of specific sites. In addition, foreign news outlets and nongovernmental organisations have reported on continued expansion of the site in recent years, based on open-source information, primarily satellite imagery.

From identified open sources, it is understood that the No. 21 Base once consisted of three areas (Image 13), namely the Red Mountain nuclear weapon scientific research centre (or Red Mountain base), a living area (also referred to as the Malan base, or Malan village), and a testing ground in the Lop Nur Gobi Desert.⁶⁵ Since 2021, the construction of a possible new test area has been observed east of the testing ground's vertical shaft area.⁶⁶ The Red Mountain nuclear weapon scientific research centre (Red Mountain base) was abandoned and has been remodelled into a tourist site for the general public.⁶⁷ The living area and the testing ground in Lop Nur, both active, are currently under the management of the PLA 63650 troop unit.⁶⁸

62. Bernard Sitt and Camille Grand, *Nuclear Stockpile Management: A Technical and Political Assessment* (International Commission on Nuclear Nonproliferation and Disarmament, October 2009) <https://inis.iaea.org/collection/NCLCollectionStore/_Public/48/018/48018702.pdf>. National Academies of Sciences, Engineering, and Medicine, *Technical Issues Related to the Comprehensive Nuclear Test Ban Treaty* (The National Academies Press, 2002) <<https://nap.nationalacademies.org/read/10471/chapter/6#73>>.

63. "China maintained a high level of activity at its Lop Nur nuclear weapons test site throughout 2019. China's possible preparation to operate its Lop Nur test site year-round, its use of explosive containment chambers, extensive excavation activities at Lop Nur, and lack of transparency on its nuclear testing activities—which has included frequently blocking the flow of data from its International Monitoring System (IMS) stations to the International Data Center operated by the Preparatory Commission for the Comprehensive Nuclear Test-Ban Treaty Organization—raise concerns regarding its adherence to the "zero yield" standard adhered to by the United States, the United Kingdom, and France in their respective nuclear weapons testing moratoria." See: *Executive Summary of the 2020 Adherence to and Compliance with Arms Control, Nonproliferation, and Disarmament Agreements and Commitments* (Compliance Report) (U.S. Department of State, 2020) <<https://www.state.gov/2021-adherence-to-and-compliance-with-arms-control-nonproliferation-and-disarmament-agreements-and-commitments-compliance-report/>>. "In recent years, China's possible preparation to operate its Lop Nur test site year-round and lack of transparency on its nuclear testing activities have raised concerns regarding its adherence to the U.S. "zero yield" standard adhered to by the United States, the United Kingdom, and France in their respective nuclear weapons testing moratoria. China continued work at its Lop Nur nuclear weapons test site throughout 2020." See: *2021 Adherence to and Compliance with Arms Control, Nonproliferation, and Disarmament Agreements and Commitments* (Compliance Report) (U.S. Department of State, 2021) <<https://www.state.gov/2021-adherence-to-and-compliance-with-arms-control-nonproliferation-and-disarmament-agreements-and-commitments/>>. The 2022 and 2023 Compliance Reports provided no further updates or additional information.

64. For example: 'Satellite Photos Show China's New Nuclear Test Site in Xinjiang', *Nikkei*, 15 August 2022 <<https://asia.nikkei.com/static/vdata/infographics/satellite-photos-show-chinas-new-nuclear-test-site-in-xinjiang/>>; William J. Broad, Chris Buckley, and Jonathan Corum, 'China Quietly Rebuilds Secretive Base for Nuclear Tests', *New York Times*, 9 January 2024 <<https://www.nytimes.com/interactive/2023/12/20/science/china-nuclear-tests-lop-nur.html>>.

65. '秘密核试基地马兰经历公开: 每次核试前都写下遗书' [Life at Secret Nuclear Test Base Malan Revealed: Writing a Goodbye Letter Every Time Before a Test], *Wenhui News*, 30 May 2019 <<https://wenhui.whb.cn/third/yidian/201905/30/266700.html>>.

66. For example: 'Satellite Photos Show China's New Nuclear Test Site in Xinjiang', *Nikkei*; and Broad, Buckley, and Corum, 'China Quietly Rebuilds Secretive Base for Nuclear Tests'.

67. '走进马兰红山军博园' [Introduction to Red Mountain Military Park], *Toutiao*, 19 February 2021 <https://www.toutiao.com/article/6930814093746094606/?source=seo_tt_juhe>.

68. Peter Wood, Alex Stone, and Thomas Corbett, 'Chinese Nuclear Command, Control, and Communications' (China Aerospace Studies Institute, March 2024) p. 33 <<https://www.airuniversity.af.edu/Portals/10/CASI/documents/Research/PLARF/2024-03-11%20Chinese%20Nuclear%20Command%20and%20Control.pdf>>.

Observations

Malan Base and Airport

The Malan base is under military management and serves as a patriotism education centre that accommodates group visits organized by universities and party schools.⁶⁹ Available satellite images show that the Malan base has been well maintained and modernised in the past 10 years.

The Malan airport, roughly 10 kilometres west of the Malan base, is also referred to as Malan West Village. During the active testing era, it had served to provide both air protection and logistical support to the No. 21 Base.⁷⁰ Since at least 2004, the Malan airport has become an active airbase of the People's Liberation Army Air Force (PLAAF),⁷¹ supporting the flight of bombers, large drones, and other military aircraft.⁷² There are no indications that these PLAAF activities at the airport are directly linked to any nuclear test site activities.

During the project period, fighter jets, early-warning aircraft, transport aircraft, and other PLAAF aircraft were seen in available images, as demonstrated in Image LN-1 (Annex D). The most plausible explanation for these movements at the airport is PLAAF activities, though PLAAF activities could provide cover and/or support possible airlift or monitoring missions for any potential nuclear tests. The airport has its own housing that could serve as barracks. However, considering the airport's proximity to the Malan base, it is also likely that some PLAAF personnel are being accommodated at the Malan base during their mission.

Besides the Malan airport, another airfield was built in 2016 and expanded in 2021 in the now inactive atmospheric test area.⁷³ Foreign media reports assessed that this airfield was built to support the development of China's reusable spacecraft.⁷⁴ While there is no specific information that the airfield supports the No. 21 Base, its location within the former atmospheric test area indicates it could be used to provide logistical support to the No. 21 Base, should there be a need for an additional airfield.

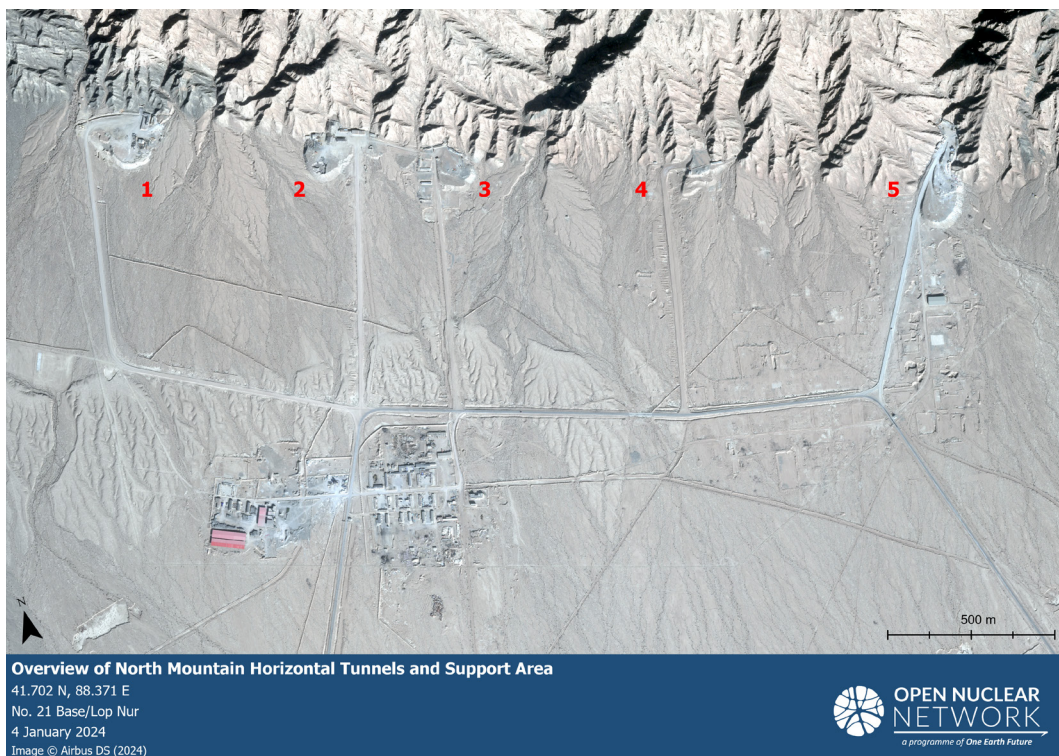


Image 13: An overview of the five horizontal tunnels and their support area at the North Mountain.

69. 清华大学工物系实践支队赴马兰基地开展活动 [Tsinghua University Engineering Physics Department Visits Malan Base], Tsinghua University, 19 August 2016 <<https://www.tsinghua.edu.cn/info/1180/55110.htm>>.

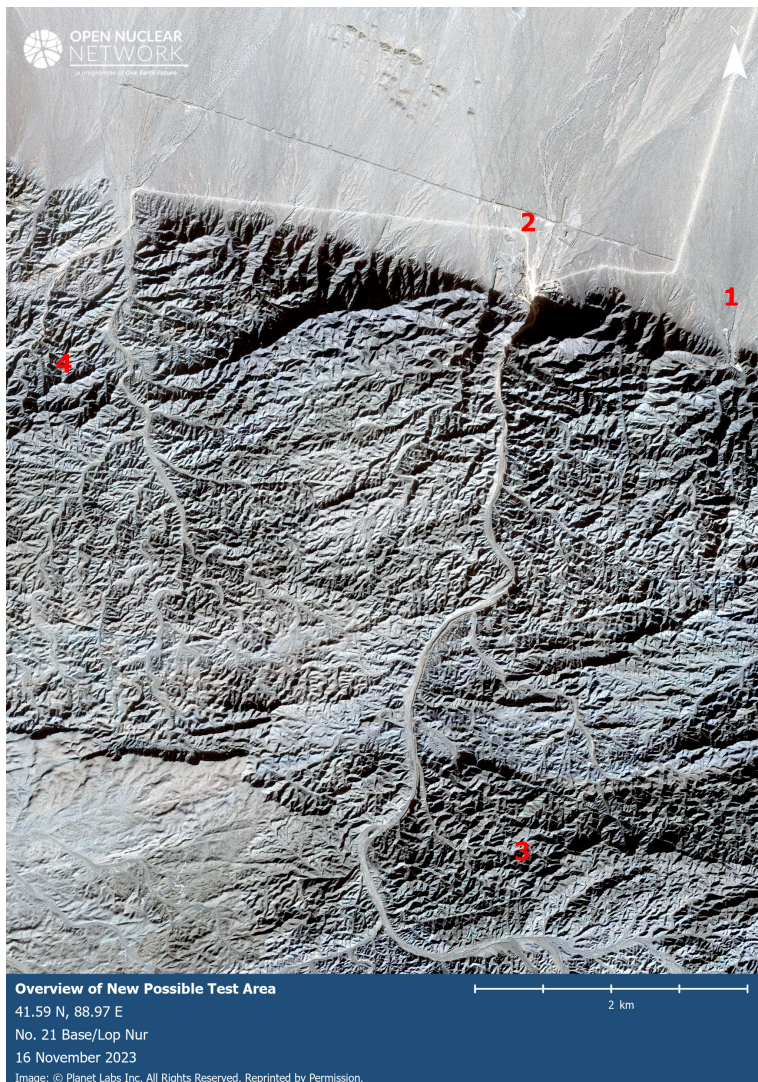
70. Zhang Zengrong, '大漠戈壁:那些在马兰基地度过的日子' [Gobi Desert: My Days at the Malan Base], js7tv, n.d., original link (<https://www.js7tv.cn/news/201705_95007.html>) invalid. Same text could be found at: <<https://www.meipian.cn/2sztgcv0>>.

71. The possibility that some of these aircraft belong to PLA navy aviation units cannot be ruled out. However, considering the No. 21 Base is far away from China's coastlines, and for simplicity in the context of the purpose of this report, these aircraft are considered to belong to the PLAAF here.

72. Tyler Rogoway, 'Flanker Fighter Appears Among Unmanned Aircraft At China's Secretive Test Base,' *The War Zone*, 2 July 2021 <<https://www.twz.com/41386/flanker-fighter-appears-among-unmanned-aircraft-at-chinas-secretive-drone-test-base>>.

73. Geoff Brumfiel, 'New Chinese Space Plane Landed At Mysterious Air Base, Evidence Suggests,' *NPR*, 9 September 2020 <<https://www.npr.org/2020/09/09/91113352/new-chinese-space-plane-landed-at-mysterious-air-base-evidence-suggests>>.

74. Geoff Brumfiel, 'Satellite Photos Show China Expanding Its Mysterious Desert Airfield,' *NPR*, 1 July 2021 <<https://www.npr.org/2021/07/01/1011806020/satellite-photos-show-china-expanding-its-mysterious-desert-airfield>>; Joseph Trevithick, 'Activity At Remote Chinese Airstrip Seen Before Spaceplane Launch,' *The War Zone*, 5 August 2022 <<https://www.twz.com/activity-at-remote-chinese-airstrip-seen-before-spaceplane-launch>>; Yvaine Ye, 'China's Mysterious Space Plane Returns to Earth,' *Nature Magazine*, 18 May 2023 <<https://www.scientificamerican.com/article/chinas-mysterious-spaceplane-returns-to-earth/>>.



North Mountain Horizontal Tunnels (North Mountain) and Support Area

While China conducted its first two known horizontal tunnel tests (1969 and 1975) in the South Mountain, starting with the third horizontal tunnel test in 1976, the North Mountain has been the only site for such tests.⁷⁵ According to official accounts, a total of four horizontal tests were conducted at the North Mountain by the end of 1988.⁷⁶ A few additional horizontal nuclear tests may have been conducted at the North Mountain site by the end of 1996.⁷⁷

Currently, there are five known horizontal tunnels (Image 14) at the North Mountain. The initial construction of the first tunnel (Number 5 in Image 14) at the North Mountain possibly started in 1972/1973.⁷⁸ The westernmost tunnel (Number 1 in Image 14) appears to have been constructed after 2000,⁷⁹ suggesting that this tunnel likely has not been used for any supercritical tests.

Between April 2023 and January 2024, the construction of three buildings with red roofs at the support area for the North Mountain horizontal test zone was observed (Image 12).

During the project period, activities were observed in available images at the Number 1, Number 2, and Number 5 Tunnels, mainly consisting of the movement of construction waste and/or construction materials and vehicles. For Tunnel Number 3 and Number 4, no clear indications of activities were observed.

Image 14: Overview of the possible new test area. The drilling rigs were found in Area 3 and Area 4

Testing Ground Headquarters

Since 2013, the testing ground headquarters has undergone notable development including the expansion and construction of two suspected high explosive storage sites.⁸⁰ The expansion of the existing suspected explosive storage sites started as early as 2013 and has included the addition of several new buildings (Figures LN-2A, LN-2B, Annex D).

Possible New Test Area

Since 2021, the most significant identified development at the No. 21 Base has been the possible new test area (Image 13), built approximately 20 kilometres east of the inactive vertical shaft area.⁸¹ This location is assessed as a possible new test area because of the observed construction for at least one possible horizontal tunnel and the presence of two possible drilling sites. It cannot be excluded that this area serves other purposes, such as geological exploration (see “Assessment” section).

75. Wang Naiyan, '我亲身经历了氢爆和三次地下核试验' [My Firsthand Experience of Hydrogen Bomb Tests and the Third Underground Nuclear Test], China Nuclear Society, 23 October 2020 <<http://hexuehuim.kechuangfu.com/site/content/7921.html>>; '1969年9月23日 中国首次进行地下核试验' [China Conducted Its First Underground Nuclear Test on 23 September 1969], China Military, 23 September 2016 <https://photo.81.cn/tsjs/2016-09/23/content_7274169.htm>; '纪念程开甲院士九十华诞' [Commemorating the 90th Birth Anniversary of Cheng Kaijia], CCTV, n.d., 27 July 2007 <<https://news.cctv.com/military/20070727/110676.shtml>>.

76. 当代中国的国防科技事业上册 [Band 1 of Defence Science of the Contemporary China], [Contemporary China Press, 1992] p. 273-274; 我亲身经历了氢爆和三次地下核试验 [My Firsthand Experience of Hydrogen Bomb Tests]; '1969年9月23日 中国首次进行地下核试验' [China Conducted Its First Underground Nuclear Test on 23 September 1969]; '纪念程开甲院士九十华诞' [Commemorating the 90th Birth Anniversary of Cheng Kaijia].

77. This is based on compilation of seismic data. For example, see: Xiaoping Yang, Robert North, Carl Romney, and Paul G. Richards, Worldwide Nuclear Explosions (Columbia University) <https://www.ideo.columbia.edu/~richards/my_papers/WW_nuclear_tests_IASPEI_HB.pdf>.

78. 纪念程开甲院士九十华诞 [Commemorating the 90th Birth Anniversary of Cheng Kaijia]; Broad, Buckley, and Corum, 'China Quietly Rebuilds Secretive Base for Nuclear Tests.'

79. Jeffrey Lewis, 'Subcritical Testing at Lop Nur,' Arms Control Wonk, 3 April 2009 <<https://www.armscontrolwonk.com/archive/202239/subcritical-testing-at-lop-nor/>>; Mark D. Fisk, 'Accurate Locations of Nuclear Explosions at the Lop Nur Test Site Using Alignment of Seismograms and IKONOS Satellite Imagery,' *Bulletin of the Seismological Society of America*, (2002) <<https://pubs.geoscienceworld.org/ssa/bssa/article-abstract/92/8/2911/102996/Accurate-Locations-of-Nuclear-Explosions-at-the?redirectedFrom=fulltext>>.

80. See also: Broad, Buckley, and Corum, 'China Quietly Rebuilds Secretive Base for Nuclear Tests.'

81. See also: Broad, Buckley, and Corum, 'China Quietly Rebuilds Secretive Base for Nuclear Tests'

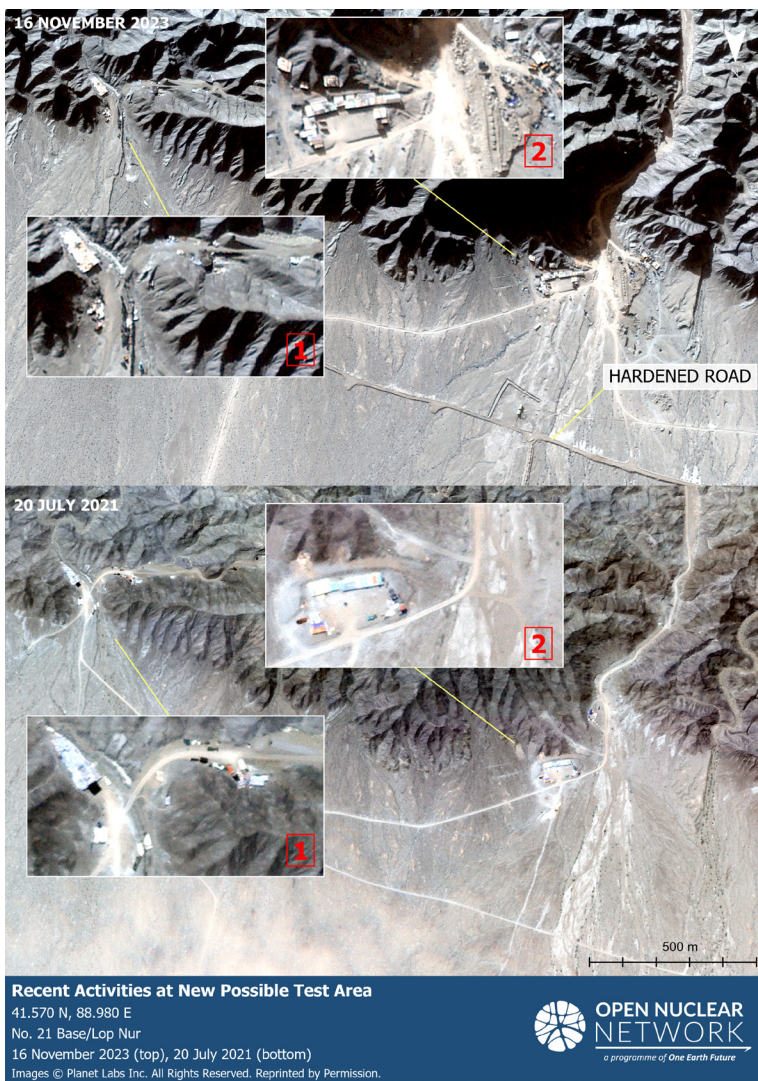


Image 15: Since 2021, construction in Area 1 and Area 2 of the possible new test area has been observed.

During the project period, some further modifications to this area were identified, including minor changes in Area 2 and on a hardened road section that connects with Area 4, mainly including the movement of vehicles, construction materials, and construction waste.

Initial construction in Area 1 can be observed as early as April 2021. Items observed at the site mainly include a possible entrance cover that may suggest the presence of a horizontal tunnel,⁸² a possible spoil pile, containers, workshop sheds, and construction materials. Minimal changes were detected during the project period in Area 1.

Initial construction in Area 2 could be observed as early as July 2021. This area, possibly having a primary supporting function for Areas 1, 3, and 4, has been expanded since and has remained active during the project period. Observed activities mainly include movement of vehicles and other objects (Image 14).

In Area 3, signs of construction for what appeared to be a tower-shaped structure could be observed as early as December 2021 (Image 15). Subsequent high-resolution images from MAXAR in August 2022 suggest that the structure was a possible drilling rig.⁸³ While there are several plausible explanations for the intended use of this rig, including some that will be discussed in the following “Assessment” section of this report, vertical drilling rigs had been used in the now inactive vertical shaft testing zone to construct vertical testing shafts (Figure LN-5, Annex D).

Signs of construction for another possible drilling rig could be observed as early as July 2021 (Figure LN-6, Annex D). However, this rig appears to have been dismantled by September 2021. As of March 2024, satellite images taken since the dismantlement no longer show this possible drilling rig (Image 15).

In August 2022, what appear to be workshop sheds or large containers were installed/moved along the road leading to Area 4. Possible construction vehicles could also be seen in images taken between July 2023 and March 2024. During the project period, the road leading to Area 4 appears to have been actively used, as movements of vehicles and possible mining trailers/carts could be observed in available images. Notably, it is possible that initial horizontal excavations have taken place at one section of this road (Image 16).

Assessment

No indications were identified that suggest preparations for an imminent nuclear test or a return to a full-scale nuclear testing regime. Subcritical or small-scale supercritical experiments cannot be excluded, as any possible indications would be less observable in satellite images.

Analysis of available satellite images suggests that maintenance and expansion in active areas have taken place throughout the past decade. The continued maintenance, modernisation, and expansion work may indicate that China aims to retain an infrastructure to resume nuclear testing, should it decide to do so.

Activities observed during the project period at the active areas of the No. 21 Base mainly include military aircraft movement and construction works. The movement observed at the active areas of the testing ground, especially

82. See also: Broad, Buckley, and Corum, ‘China Quietly Rebuilds Secretive Base for Nuclear Tests’.
83. Broad, Buckley, and Corum, ‘China Quietly Rebuilds Secretive Base for Nuclear Tests’.

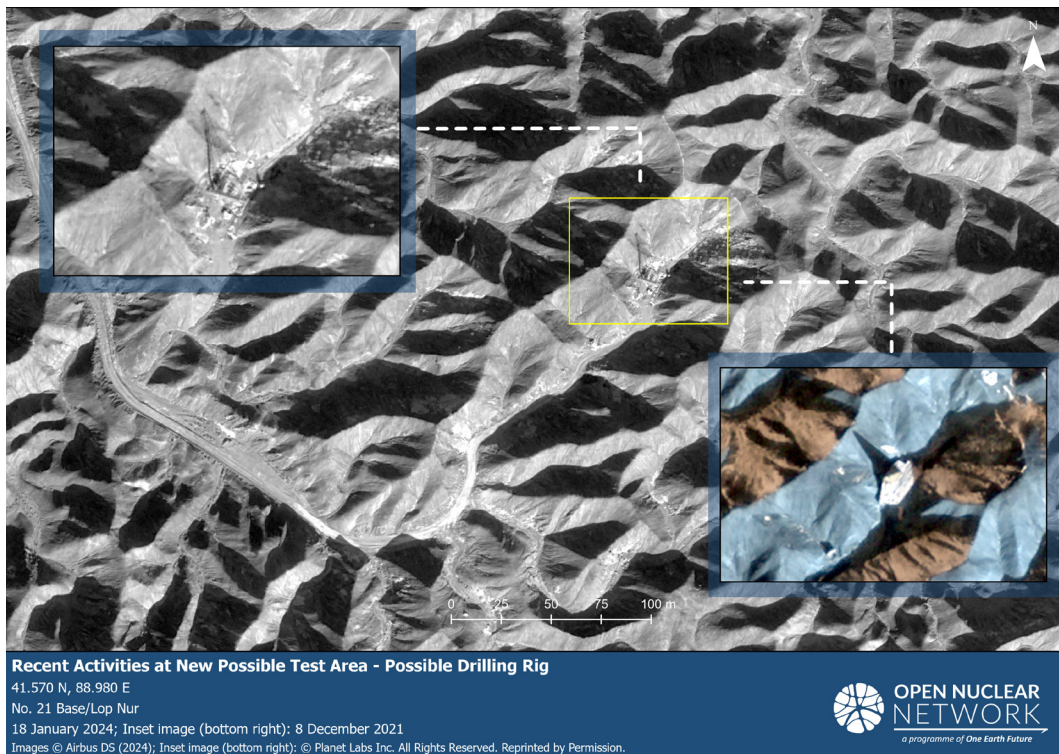


Image 16: What appears to be a vertical drilling rig in Area 3 of the possible new test area with construction starting as early as December 2021.

at the five horizontal tunnels at the North Mountain and at the possible new test area, include movement of vehicles, containers, construction waste or materials, and installation of possible workshop sheds.

The possible new test area has been the most significant development at the No. 21 Base since 2021 because of possible tunnel excavations and possible vertical drilling activities. While the construction of vertical shaft for use in sub- or supercritical testing cannot be excluded, other possible explanations of these drilling rigs (in Area 3 and 4) may include:

- Activities related to the decontamination of the nuclear testing ground;⁸⁴
- Geological evaluation/sampling for suitability of this area for future testing or research related to the design of new test beds;⁸⁵
- Geological excavations for non-test-related activity (e.g., natural resource exploration,⁸⁶ deep borehole disposal of nuclear waste⁸⁷); or
- High explosive testing site for physics experiments (e.g., to test diagnostic equipment).⁸⁸

More information is needed to ascertain the precise nature of these activities.

84. According to state media, the No. 21 Base has been conducting research works on test site decontamination since 1996. See: '中国核试验基地科学家干惊天动地事 做隐姓埋名人' [Scientists at Nuclear Test Base Accomplished Incredible Feats].

85. Any new location would need to be extensively evaluated to examine its suitability for the specific testing objective and its natural containment characteristics. Evaluation would likely focus on the specific rock type, structures and water content (while it is unknown what this process would look like in practice in China, the US had a dedicated Containment Evaluation Panel to certify the technical adequacy of any test and test location from the viewpoint of containment: *The Containment of Underground Nuclear Explosions* (U.S. Office of Technology Assessment, October 1989) OTA-EC-414, p. 35–41 <<https://www.osti.gov/opennet/servlets/purl/16087194.pdf>>. While the existing, now inactive vertical shaft area is well explored and tested, new evaluations would need to be done for this potential new area.

86. For example, Lop Nur is known for its rich natural reserves in potassium sulphate. China's largest potassium sulphate production facility is located approximately 200 kilometres southeast of the possible new test area. See: 'About Us', SDIC Xinjiang LUOBUPO Potash Co., Ltd., n.d. <<https://www.sdicbp.com/gtji/index.htm>>.

87. China has explored suitable areas for high-level waste repositories since 1985 and identified the Beishan area in Gansu Province for the first repository. Since 2011, China has continued to conduct drillings of deep boreholes in Xinjiang and Inner Mongolia to find additional suitable areas; see Ju Wang, Liang Chen, Rui Su, and Xingguang Zhao, 'The Beishan Underground Research Laboratory for Geological Disposal of High-Level Radioactive Waste in China', *Journal of Rock Mechanics and Geotechnical Engineering* 10(3), (June 2018) p. 411-414 <<https://doi.org/10.1016/j.jrmge.2018.03.002>>; 'China Begins Construction of its First Underground Research Laboratory for High Level Waste Disposal', (IAEA, 23 July 2021) <<https://www.iaea.org/newscenter/news/china-begins-construction-of-its-first-underground-research-laboratory-for-high-level-waste-disposal>>. Deep borehole disposal is considered to be a substantially more cost-effective alternative to mined repositories that also take longer to construct (e.g. *Technical Evaluation of the U.S. Department of Energy Deep Borehole Disposal Research and Development Program* (United States Nuclear Waste Technical Review Board, January 2016) <[https://www.nwtrb.gov/docs/default-source/reports/dbd_final.pdf?sfvrsn=7](https://www.nwtrb.gov/docs/default-source/reports/dbd_final.pdf?sfvrsn=7;)>; Bernt S. Aadny and Maurice B. Dusseault, *Deep Borehole Placement of Radioactive Wastes* (Norsk Nukleær Dekommissionering, 2020) <<https://www.norskdekkommissionering.no/wp-content/uploads/2020/10/Deep-Borehole-Placement-of-Radioactive-Wastes-A-Feasibility-Study-1.pdf>>; Palmer Vaughn, Bill W. Arnold, Susan J. Altman, Patrick V. Brady, and William Payton Gardner, *Site Characterization Methodology for Deep Borehole Disposal* (Sandia National Laboratories, September 2012) SAND2012-7981 <<https://energy.sandia.gov/wp-content/gallery/uploads/SAND2012-7981.pdf>>).

88. Such experiments are being conducted by, for example, the United States at the Nevada National Security Sites for improving nuclear explosion monitoring capabilities (e.g., C. M. Snelson, C. R. Bradley, W. R. Walter, T. Antoun, R. Abbott, K. Jones, V. D. Chipman, and L. Montoya, *The Source Physics Experiment (SPE) Science Plan*, (Lawrence Livermore National Laboratory, 27 June 2019) LLNL-TR-654513 < NNSA, "NNSA Conducts Experiment to Improve U.S. Ability to Detect Foreign Nuclear Explosions," 18 October 2023, available at: <https://www.energy.gov/nnsa/articles/nnsa-conducts-experiment-improve-us-ability-detect-foreign-nuclear-explosions-0>). In China, diagnostic equipment is being developed by the Northwest Nuclear Technology Research Institute (NINT) in Xi'an, Shaanxi Province; Kevin Pollpeter and Ken Allen (eds.), *The PLA as Organization v2.0*, China Aerospace Studies Institute, 2012, 256, available at: <https://apps.dtic.mil/sti/pdfs/AD1082742.pdf>; Dan Stillman, 'Inside China's Nuclear Weapons Program,' MIT Security Studies Program Seminar Series, 10 October 2001, https://web.mit.edu/SSP/seminars/wed_archives01fall/stillman.htm; J.J. Sweeney, *Report of On-Site Inspection Workshop-16*, Lawrence Livermore National Laboratory, LLNL-TR-418860, 28 October 2009, 31, available at: <https://www.osti.gov/servlets/purl/967724>.>; 'NNSA Conducts Experiment to Improve U.S. Ability to Detect Foreign Nuclear Explosions' (NNSA, 18 October 2023) <<https://www.energy.gov/nnsa/articles/nnsa-conducts-experiment-improve-us-ability-detect-foreign-nuclear-explosions-0>>. In China, diagnostic equipment is being developed by the Northwest Nuclear Technology Research Institute (NINT) in Xi'an, Shaanxi Province; *The PLA as Organization v2.0*, ed. by Kevin Pollpeter and Ken Allen (China Aerospace Studies Institute, 2012) p.256 <<https://apps.dtic.mil/sti/pdfs/AD1082742.pdf>>; Dan Stillman, 'Inside China's Nuclear Weapons Program,' MIT Security Studies Program Seminar Series, n.d., 10 October 2001 <https://web.mit.edu/SSP/seminars/wed_archives01fall/stillman.htm>; J.J. Sweeney, *Report of On-Site Inspection Workshop-16* (Lawrence Livermore National Laboratory, 28 October 2009) LLNL-TR-418860, p. 31 <<https://www.osti.gov/servlets/purl/967724>>.

In general, increases in personnel, vehicle traffic, construction material, and cargo movements at key locations may be linked to testing preparations or related activities. Much of the observed activity, however, remains ambiguous in nature with multiple alternative explanations conceivable that cannot be excluded with information drawn from available satellite images and other open-source information alone. Additionally, because of the proximity of facilities functionally unrelated to possible nuclear weapon tests at the No. 21 Base, increases in personnel and traffic, especially at the living area and airport, are likely not reliable indicators for activities that are directly linked to China's nuclear weapons programme (see also: Figure LN-7, Annex D).

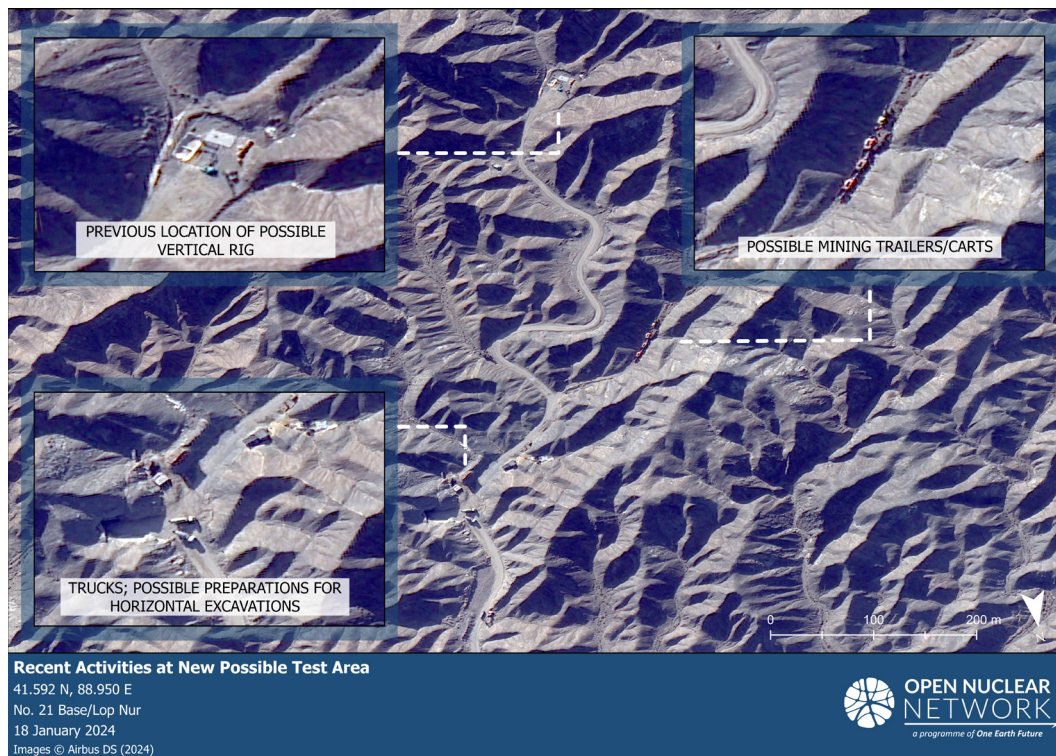


Image 17: During the project period from July 2023 to March 2024, the road leading to Area 4 appears to have been actively used, as vehicle movements and possible mining trailers/carts could be observed in available images. It is possible that new horizontal excavations have taken place in this area.

V

CONCLUSION

Some continued maintenance and intermittent modernisation can be observed at all four sites with commercial satellite imagery. The observed activities indicate that all states aim to retain some infrastructure to resume nuclear testing, should they decide to do so. However, there have been no indications observed of any imminent test preparations or a return to a full-scale nuclear testing regime. For all sites, subcritical or small-scale supercritical experiments cannot be excluded, as any possible indications are likely less observable or not observable in available satellite images.

Findings demonstrate that leveraging commercially available satellite imagery for monitoring test site activities can increase understanding of broad trends, and support official statements or raise questions about their veracity. The increasing availability, accessibility, and quality of imagery data has turned imagery analysis into a potent verification and monitoring tool that should ideally be leveraged as part of a more extensive toolkit, such as the CTBTO's verification regime.

Findings also show, however, that, given the limited availability of other relevant open-source information and limited transparency by most states about nuclear weapon programme developments, more work would be needed to better understand regular patterns of life activities at these sites. While it is possible to detect and monitor, e.g., increases in personnel, vehicle traffic, construction material, and cargo movements at key locations, such increases may also be related to regular site-wide maintenance and modernisation activities. Much of the observed activity remains ambiguous, with multiple alternative explanations that could not be excluded from information drawn from available satellite images and other open-source information alone.

As such, these findings further highlight the crucial role of transparency. When states offer public information on the maintenance and usage of test sites, they can demonstrate compliance with testing moratoria. Greater levels of transparency can enable others, including other states, international organization, and civil society to independently verify compliance more accurately, significantly minimizing the risk of misunderstandings.

VI. Annexes

| | |
|---|-----------|
| Annex A: Punggye-ri, DPRK | 30 |
| Possible Indicators for Activity at the Punggye-ri Test Site..... | 30 |
| Annex B: Nevada National Security Sites, USA | 31 |
| Possible Indicators for Activity at the Nevada National Security Sites, USA... 31 | |
| Annex C: Novaya Zemlya, Russian Federation | 32 |
| Possible Indicators for Activity at the Central Test Site..... | 35 |
| Annex D: Lop Nur, People's Republic of China | 36 |
| Possible Indicators for Activity at the No. 21/Lop Nur Test Site..... | 39 |

Annex A: Punggye-ri, DPRK

Possible Indicators for Activity at the Punggye-ri Test Site

| Activity type | | Explanation | Observability with satellite imagery | Alternative explanations |
|--|-------------------------------------|---|---|--|
| General site activities | Modernization activities | New support infrastructure in administrative areas; road improvements | 1) Changes to support infrastructure, roads etc. 2) Increased personnel and vehicle presence throughout the site | Could be active preparations for a test |
| | Maintenance activities | Flood mitigation; road improvements; snow clearing in the winter season etc. | 1) Activity at main support area and other support areas 2) Intermittent personnel and vehicle presence throughout the site | Could be active preparations for a test |
| Tunnel activities/ testing preparations | Excavation activities | Restoring tunnels/tunnel entrances that have been demolished in 2018; new excavation of tunnels or adits within existing tunnels; | Additional excavations with increased specialized vehicle activity and spoil pile changes | Regular maintenance/modernization of deteriorating tunnel infrastructure |
| | New infrastructure | New support buildings, workshops, barracks near tunnels and administrative areas | 1) construction equipment visible 2) new trailers or buildings visible 3) increased personnel and vehicle activity in the test area | In support of regular maintenance/modernization of deteriorating tunnel infrastructure |
| Testing | Test monitoring preparations | Mobile monitors are dispatched throughout the site; diagnostic cabling or pipes installed | 1) mobile monitoring vehicles observed leaving or entering 2) cabling or piping visible from shaft to external monitoring area | Training apparatus; legacy equipment; normal vehicle movement |
| | Movement of testing supplies | Preparation of the device and movement to the test area; backfilling of the tunnel or shaft; establishment of a control area where the test can be monitored at a safe distance | Possible increase in specialized vehicle presence throughout the site | Training apparatus; legacy equipment; normal vehicle movement |
| | Explosive testing | Removal of personnel and vehicles from the area | Possible increase in specialized vehicle presence throughout the site | Security incident unrelated to testing; Mine cars could be outside to be loaded/unloaded |
| Post-Testing | Environmental monitoring | Unknown | Possible presence of mobile monitoring vehicles | Regular environmental monitoring at site; incident occurred (e.g. earthquake) that necessitated increased radiological safety measures |
| | Waste disposal | Unknown | Possible increase in specialized vehicle presence throughout the site | Waste from previous test is being disposed of |

Figure PG-1: Activity indicators and expected observables.

Annex B: Nevada National Security Sites, USA

Possible Indicators for Activity at the Nevada National Security Sites, USA

| Activity type | Explanation | Observability with satellite imagery | Alternative explanations | |
|--|------------------------------|---|--|--|
| General site activities | Modernization activities | Currently in the process of upgrading the PULSE subcritical testing facility; replacement of decaying legacy infrastructure throughout the site | 1) Heavy equipment at PULSE 2) Increased activity at PULSE 3) Increased activity at the Drill Yard, Heavy Equipment Yard 4) Increased construction activity throughout the site, especially Mercury | Could be related to test preparations. |
| | Maintenance activities | Work in tunnels or vertical shafts, including excavation and environmental monitoring; maintenance of existing infrastructure, including necessary repair/refurbishment work | 1) Activity at the Drill Yard, Heavy Equipment Yard 2) Activity at tunnel entrances or craters 3) Fresh soil disturbance 4) Rock/ground spills/debris 5) Heavy equipment and vehicle movement around NNSS | Could be related to test preparations or test monitoring. |
| Tunnel activities/ testing preparations | Excavation activities | Creation of new tunnels at a number of sites around NNSS, including exploratory drilling for a suitable location | 1) Increased activity at the Drill Yard, Heavy Equipment Yard 2) Increased activity at PULSE, Climax Mine, P-Tunnel, E-Tunnel or other site in the mountains (horizontal shaft) OR in the valley (vertical shaft) 3) Fresh soil or vegetation disturbance 4) Rock/ground spills/debris near the test site 5) Heavy equipment at the test site, including drill rigs 6) Two holes being created (one main and one ventilation) in round-the-clock shifts for months | At PULSE: could be related to modernisation or subcritical testing At other sites: could be related to subcritical or high-explosives testing; regular maintenance activities |
| | New infrastructure | Trailers or instrumentation shelters will be added near the test site | 1) Construction equipment visible 2) New trailers or buildings visible 3) Increased activity in the test area 4) A diesel generator, or a concrete pad for a generator, may be present on the apron near the portal and depending on the dimensions of the drift | At PULSE: could be related to modernisation or subcritical testing At other sites: could be related to subcritical or high-explosives testing; regular maintenance activities |
| Testing | Monitoring preparations | Mobile monitors are dispatched in the surrounding areas; testing tower (vertical shaft only); diagnostic cabling or pipes established | 1) Mobile monitoring vehicles observed leaving or entering NNSS 2) Testing tower erection & emplacement (only pre-test & vertical shaft) with "Big Blue" crane 3) Cabling or piping visible from shaft to external monitoring area | Training apparatus; legacy equipment; normal vehicle movement |
| | Movement of testing supplies | Preparation of the device and movement to the test area; backfilling of the tunnel or shaft; establishment of a control area where the test can be monitored at a safe distance | 1) Increased activity at the Device Assembly Facility 2) Increased activity at the Technical Facility (would need to be modernized before it could be used; currently JASPER facility); could be assembled at Baker (next to JASPER) 3) Large trucks entering NNSS and transporting the device to the testing area ("blue-light" convoy) 4) Increased activity at the Heavy Equipment Yard 5) Increased activity at the Control Point, Joint Test Organization Forward Area Support Facilities, Mercury 6) Backfill material in piles near the site or moving into the test tunnel/shaft, including large concrete or steel plugs | Subcritical testing; inspection of devices either from the US or other arsenals; tour groups visiting; higher tempo of maintenance |
| | Explosive testing | Removal of personnel from the area is conducted; aerial surveillance is airborne near test site; helicopter unit is on standby; potential landslide and surface deformations | 1) Mine carts taken out of mine 2) Increased security (e.g. blocking off roads, temporary fencing) 3) Air traffic control & monitoring/security aircraft 4) Helicopter on the ground somewhere in or near NNSS 5) Mountain subsidence cratering and spallation, rockslides and avalanches | Security incident unrelated to testing; Mine carts could be outside to be loaded/unloaded; natural surface deformations, earthquakes |
| Post-Testing | Environmental monitoring | Mobile monitors are dispatched in the surrounding areas; aircraft take cloud samples; teams will enter the test area ~24 hours or more after the test to survey; drillback operations are conducted | 1) Mobile monitoring vehicles observed leaving or entering NNSS 2) Surveillance aircraft near the test site 3) Increased activity at test site one or more days after the test 4) "Base Station" established at site boundary 5) Drilling or heavy equipment visible 6) Potential shock-mounted equipment | Regular environmental monitoring at site; incident occurred (e.g. earthquake) that necessitated increased radiological safety measures |
| | Waste disposal | Debris and radiated equipment would need to be removed from the test area due to environmental concerns | 1) Special waste canisters delivered, transported around NNSS, left at test site to be filled 2) Burial/excavation activities at RWMS-3, RWMS-5 3) Increased activity at RWMS-3, RWMS-5 | Waste from previous test is being disposed of; subcritical testing with nuclear material also generates RW; incident occurred (e.g. earthquake) that necessitated increased radiological safety measures |

Figure NN-1: Activity indicators and expected observables.

Annex C: Novaya Zemlya, Russian Federation

Additional images of the Central Test Site

Belushya Guba



Belushya Guba

71.537 N, 52.342 E
 Novaya Zemlya, Yuzhny Island
 5 August 2023

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Image NZ-1: Belushya Guba.

Rogachevo Airfield and Air Defence Troops



Rogachevo Airfield and Air Defence Troops

71.610 N, 52.469 E
 Novaya Zemlya, Yuzhny Island
 2 September 2023

Image © Planet Labs Inc. All Rights Reserved. Reprinted by Permission



Image NZ-2: Rogachevo Airfield and Air Defence Troops

Expansion of storage facilities near Severny

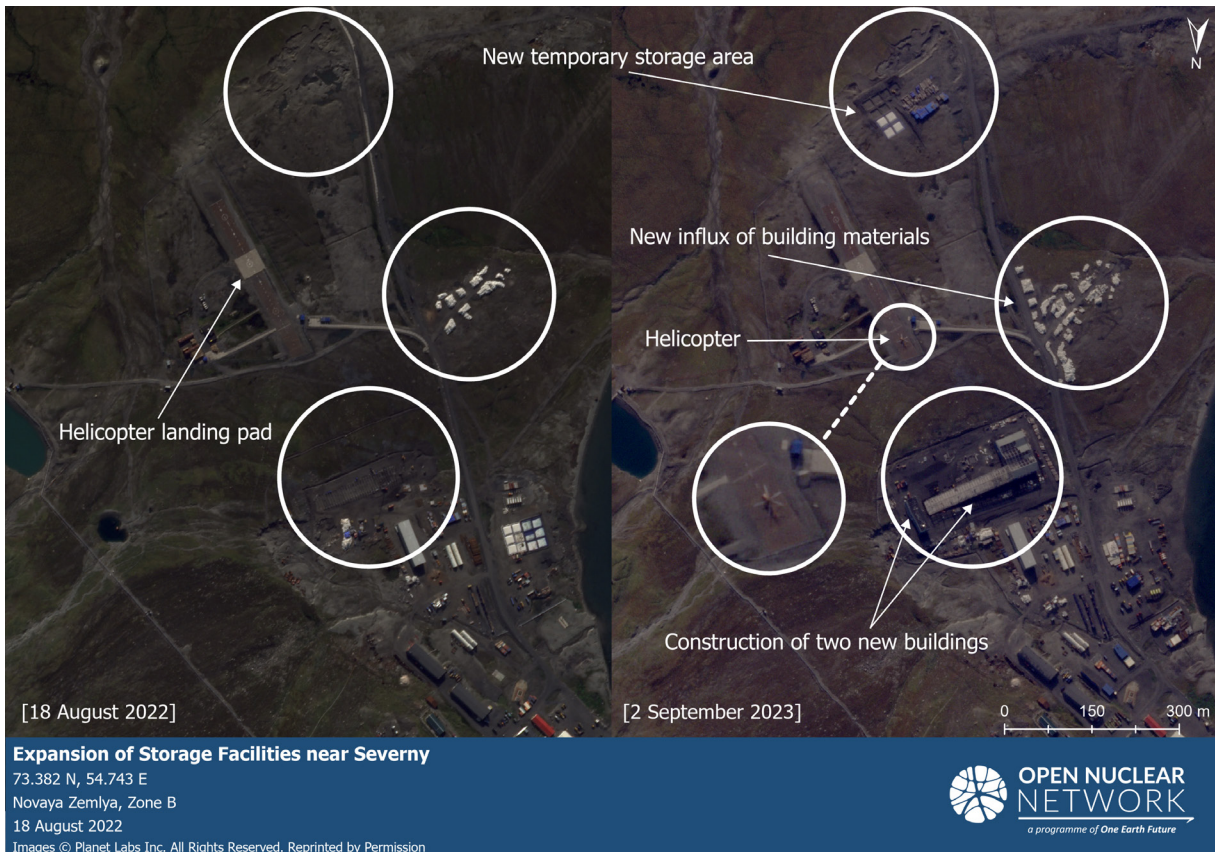


Image NZ-3: Expansion of storage facilities near Severny, arrival of building materials, and a helicopter present on the landing strip.

Suspected Subcritical Test Site in October 2023 and March 2024

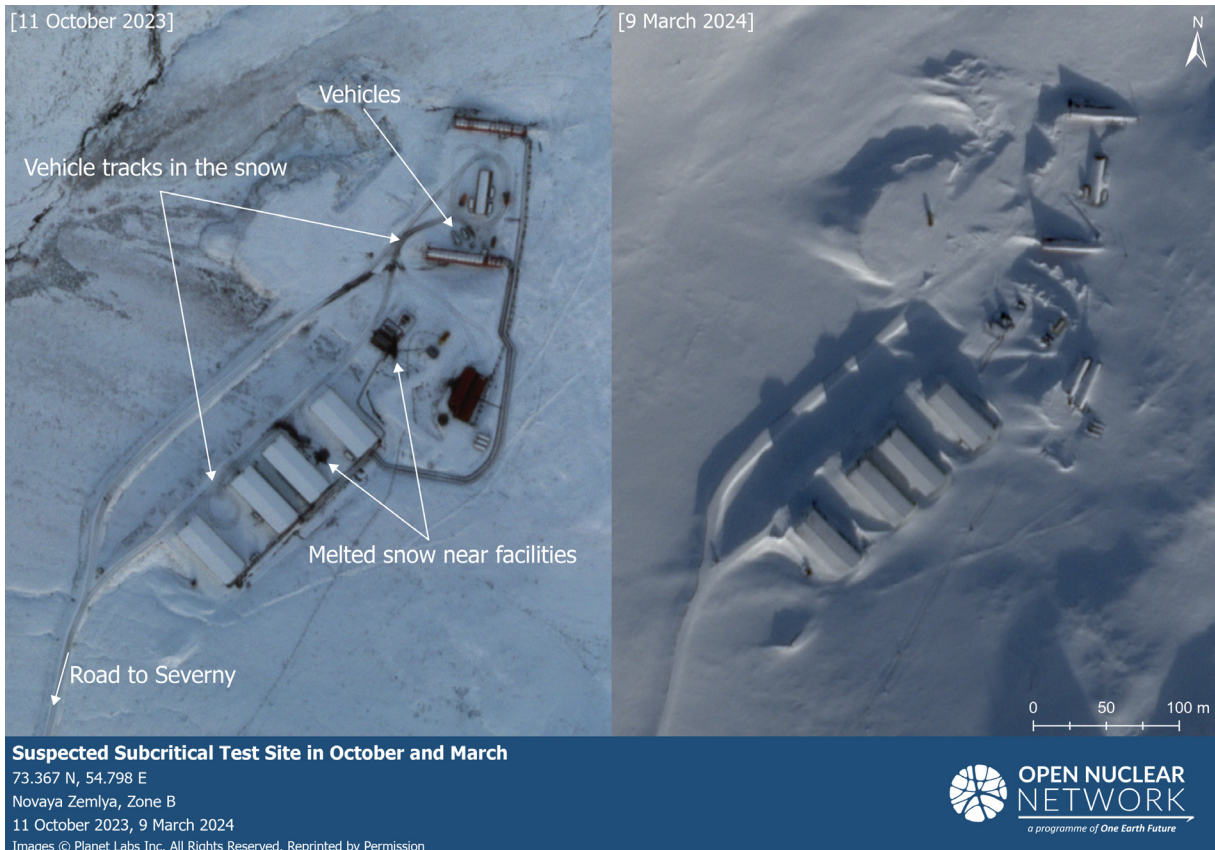


Image NZ-4: Suspected Subcritical Test Site in October 2023 and March 2024.

March activities at the "Other Active Site"



Image NZ-5: Activities at the "Other Active Site" observed in March.

Possible tunnel decommissioning



Image NZ-6: Possible tunnel decommissioning.

Possible Indicators for Activity at the Central Test Site

| Activity type | Explanation | Observability with satellite imagery | Alternative explanations | |
|--|------------------------------|--|--|--|
| General site activities | Modernization activities | Replacement of decaying legacy infrastructure throughout the site, e.g. construction of new buildings in Severny's administrative and residential area to support more supplies, equipment, and workers; upgrades to support infrastructure at tunnel sites | 1) Large trucks 2) Construction cranes 3) Other construction supplies 4) New buildings 5) Construction debris 6) Activity at tunnel sites | Could be related to test preparations. |
| | Maintenance activities | Maintenance of existing infrastructure, including necessary repair/refurbishment work, e.g. roof repairs, road resurfacing; work in tunnels, including excavation and environmental monitoring | 1) Large trucks 2) Construction cranes 3) Other construction supplies 4) Construction debris 5) Snow removal 6) Activity at tunnel sites | Could be related to test preparations or test monitoring. |
| Tunnel activities/testing preparations | Excavation activities | Additional excavation/drilling activities may be needed to create space for new test chamber, drift cavity, additional containment infrastructure, diagnostic equipment etc. | 1) Fresh soil disturbance 2) Rock/ground spills/debris near the test tunnel 3) Mining equipment and machines (bulldozer, drill rigs, shovels, etc.) | Activities that look like excavation may be related to decommissioning and closure of the tunnel. Could also be related to regular maintenance/modernization and/or subcritical/high-explosive testing requirements. |
| | New infrastructure | New temporary or permanent buildings/tunnel entrances may be needed to prepare dormant tunnel sites (e.g. buildings/barracks for equipment, on-site workers; modernized entrances to accommodate new machinery requirements etc.) | 1) Buildings/barracks 2) Tunnels 3) Construction equipment/machinery | Could be related to regular maintenance/modernization and/or subcritical/high-explosive testing requirements. |
| Testing | Monitoring preparations | Diagnostic equipment would be installed in and near the tunnel. A temporary command post would likely also be established at distance from the tunnel to control and monitor the test and for safety protocols. | 1) Trailers with recording equipment and other equipment at a distance of hundreds of meters from the tunnel (1-2 km if the slope of the mountain is steep) 2) Cabling near the tunnel 3) Command post a safe distance from the tunnel, consisting of one-story barracks with antennas and a site marked with red flags for helicopters. | Training apparatus; legacy equipment; normal vehicle movement |
| | Movement of testing supplies | Testing would require additional supplies and specialized workers to be brought to Severny and the testing tunnels. They would arrive by ships and helicopters from Belushya (headquarters) to the Severny settlement. Trucks and helicopters would then transport supplies to the tunnel sites. | 1) Increased movement of helicopters, ships, trucks at Severny 2) Backfill material in piles near the site or moving into the test tunnel/shaft, including large concrete or steel plugs 3) "Kolba" container with testing device transported and inserted in tunnel | Increased activity in Severny without increased activity directly near the tunnel could indicate preparations for the winter season, normal site activities |
| | Explosive testing | Helicopters and aircrafts with specialized radiation-sensing equipment used to monitor during and after testing; potential landslide and surface deformations | 1) Abnormal movement of dosimetrist helicopters and laboratory aircraft from the mainland to Rogachev airfield or from Rogachev to Zone B. 2) Mountain subsidence cratering and spallation, rockslides, and avalanches | Security incident unrelated to testing; natural surface deformations, earthquakes |
| Post-testing | Environmental monitoring | Additional mobile monitoring; environmental sampling; potential drillback for sampling | 1) Additional monitoring vehicles/helicopters/aircrafts and trailers with recording equipment observed 2) Excavation/drilling machinery for sampling | Regular environmental monitoring at site; incident occurred (e.g. earthquake) that necessitated increased radiological safety measures |
| | Waste disposal | Debris and radiated equipment may need to be removed from the test area | 1) Special waste canisters for transportation on or off site 2) Burial/containment activities on site or at unknown waste storage site | Waste from previous test is being disposed of; subcritical testing with nuclear material also generates RW; incident occurred (e.g. earthquake) that necessitated increased radiological safety measures |

Figure NZ-7: Activity indicators and expected observables.⁸⁹

89. Anne Pellegrino and Jeffrey Lewis, 'The Underground Nuclear Test Site at Novaya Zemlya', n.d. <<https://view.ceros.com/miis-edu/nuclear-threat-initiative-novayazemlya/p/1>>; Stuart Elbert Rawlinson, *Test Site Verification Team Optimal and Nominal Nuclear-Testing Programs* (Los Alamos National Laboratory, 9 June 2023) <<https://www.osti.gov/servlets/purl/1985003>>; Ядерные испытания. Кн. 1: Ядерные испытания в Арктике [Nuclear Tests. Book 1: Nuclear Testing in the Arctic], ed. by V.N. Mikhailov, Vol. 1 (Kartush—2006) <https://elib.biblioatom.ru/text/yadernye-ispytaniya_kn1_t1_2006/p0_o/>; Ядерные испытания СССР: Цели, общие характеристики, организация ядерных испытаний СССР, первые ядерные испытания [Nuclear Tests of the USSR: Objectives, General Characteristics, Organization of Nuclear Tests of the USSR, First Nuclear Tests], ed. by V.N. Mikhailov (Sarov, 1997) Vol. 1, RFNC-VNIIEF – <https://elib.biblioatom.ru/text/yadernye-ispytaniya-sssr_1997/p0_o/>; Курчатовский институт. История атомного проекта [Kurchatov Institute. History of the Atomic Project], ed. by G.Ya. Karmadonova, Vol. 11, (Russian Scientific Centre "Kurchatov Institute", 1997) <https://elib.biblioatom.ru/text/kiae-istoriya-atomnogo-proekta_v11_1997/p0_o/>; Johnny Skorve, *Megaton Nuclear Underground Tests and Catastrophic Events on Novaya Zemlya: A Satellite Study* (Norwegian Institute of International Affairs, January 2007) <https://www.files.ethz.ch/isn/28878/716.pdf>; Barbambia, 'Новая Земля - Технология подземных испытаний' ['Novaya Zemlya - Underground Testing Technology'], Youtube, 29 October 2019 <<https://www.youtube.com/watch?v=td8Rpr7QoQ>>.

Annex D: Lop Nur, People's Republic of China

Additional images of Lop Nur

Malan Airport



Malan Airport

42.184 N, 87.178 E
No. 21 Base/Lop Nur
9 November 2023

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Image LN-1: A particularly busy day at Malan airport in November 2023. The types of aircraft present suggest a possible PLAAF drill. Bombers, transport aircraft, and drones frequently visit this airport.

Potential explosive storage site



Testing Ground Headquarters - Possible Explosive Storage Site

41.598 N, 88.457 E
No. 21 Base/Lop Nur
4 January 2024

Image © Airbus DS (2024)



Figure LN-2A: Potential explosive storage site with multiple lightning arresters, berms, and double-layer fencing suggest that this site may be associated with the handling of explosives.

Expansion of suspected explosive storage site



Figure LN-2B: Expansion of suspected explosive storage site since as early as 2013.

Another possible explosive storage site



Figure LN-3: Another possible explosive storage site (construction started in 2021). Multiple lightning arresters, berms, bunkers, and double-layer fencing suggest that this site may be associated with the handling of explosives.

Construction of a new compound at the testing ground headquarters in 2023-2024

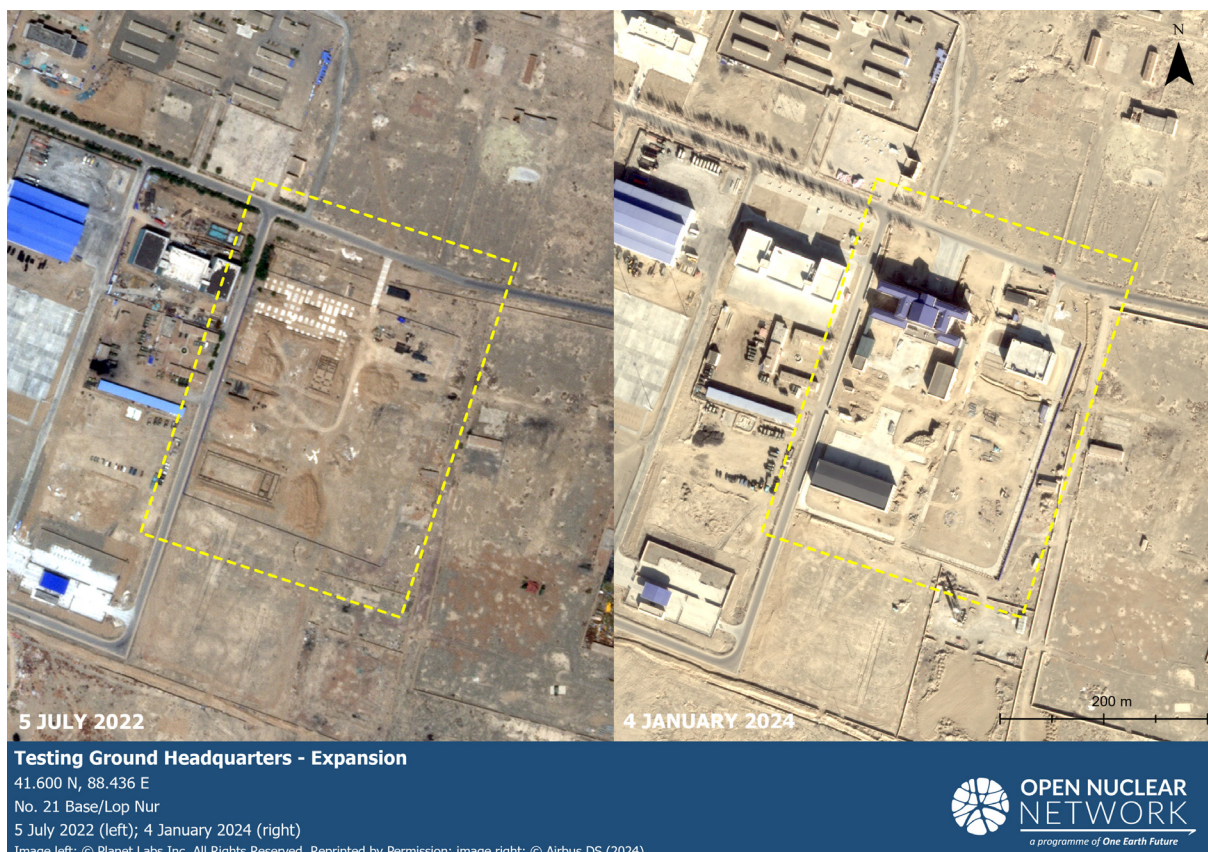


Figure LN-4: Construction of a new compound at the testing ground headquarters in 2023–2024. The purpose of this new compound is unclear.

A drilling rig used to construct a vertical shaft for a Chinese underground nuclear test



Figure LN-5: A drilling rig used to construct a vertical shaft for a Chinese underground nuclear test. Image: 81.cn⁹⁰

A possible drilling rig was installed in Area 4 of the new possible test area



Figure LN-6: A possible drilling rig was installed in Area 4 of the new possible test area (Image 12) as early as 27 July 2021 and seemed to have been dismantled by September 2021.

90. '1969年9月23日 中国首次进行地下核试验' [China Conducted Its First Underground Nuclear Test on 23 September 1969], China Military, 23 September 2016 <https://photo.81.cn/tsjs/2016-09/23/content_7274169.htm>.

Possible Indicators for Activity at the No. 21/Lop Nur Test Site

| Activity type | Explanation | Observability with satellite imagery | Alternative explanations | |
|--|-------------------------------------|--|--|--|
| Overall site activities | Modernization activities | Such as recent modernization activities: new buildings at the Malan base (living and administrative area), support area for the North Mountain, testing headquarters | 1) Construction sites 2) Constructional waste and materials, 3) Vehicles 4) Spoil pile 5) Workshop sheds or containers | Could be related to test preparations. |
| | Maintenance activities | E.g.: reconstruction or renovation of old buildings at the Malan base (living and administrative area), support area for the North Mountain, testing headquarters; road improvements throughout the site | 1) Construction sites 2) Constructional waste and materials, 3) Vehicles 4) Spoil pile 5) Workshop sheds or containers | Could be related to test preparations or test monitoring. |
| | Malan airport activities | Airport expansion and modernization, movement of PLA military aircraft; possible logistical or diagnostic support for No. 21 Base activities | 1) Different types of aircraft 2) Multiple support vehicles parked at the airport | PLAAF training and drills |
| Tunnel activities/test preparations | Excavation activities | Excavation at the existing five tunnels, and/or new excavations, e.g. at the possible new test site, including vertical drilling activities for development or improvements of test beds | 1) Spoil piles 2) Mining equipment and machines 3) Drilling towers for vertical shafts 4) Workshop sheds or containers or cargos | Training for scientists and support staff, scientific study on test site, geological exploration, sampling; for non-nuclear explosive testing, waste disposal, storage site, regular maintenance of existing tunnels |
| | New infrastructure | Workshop sheds, containers, temporary housings, towers or drilling rigs, structure at tunnel entrances; cargo deliveries close to testing site, vehicles close to tunnels and vertical shafts, cable installations, possible helicopter activities | 1) Construction sites 2) Construction waste and materials 3) Cargos and vehicles in support area and close to test site 4) Spoil pile 5) Workshop sheds or containers or cargos 6) Cabling installations | Support for non-nuclear activities on site; regular maintenance/modernisation of existing infrastructure |
| Testing | Monitoring preparations | Aircraft deployment, cabling installations, vehicles. For imminent test, may see vehicles parked near the underground test site | 1) Cable installations; 2) Removal of drilling towers for vertical shafts 3) Vehicles parked near underground test site/parked in support areas 4) Possibly helicopters; aircraft with diagnostic equipment | Training apparatus; legacy equipment; normal vehicle movement |
| | Movement of testing supplies | More vehicles in the base, especially around suspected testing sites; possible helicopter activities close to the tunnels and vertical shafts | 1) Increase vehicle presence and movement 2) Specialized cargo, including testing chamber in special container 3) Possibly helicopters for logistical support 4) Backfill material in piles near the site or moving into the test tunnel/shaft, including large concrete or steel plugs | Training for scientists and support staff, scientific study on test site; non-nuclear experiments and testing |
| | Explosive testing | Removal of personnel from the area is conducted; aerial surveillance is airborne near test site; helicopter unit is on standby; potential landslide and surface deformations | 1) Increase vehicle presence and movement 2) Increased security (e.g. blocking off roads, temporary fencing, air traffic control) 3) Mountain subsidence cratering and spallation, rockslides and avalanches | Security incident unrelated to testing; mine carts could be outside to be loaded/unloaded; natural surface deformations, earthquakes |
| Post-testing | Environmental monitoring | Additional mobile monitoring; environmental sampling; potential drillback for sampling | 1) Vehicles 2) Possible mining, drilling equipment 3) containers, workshop sheds 4) aircraft sampling activities | Regular environmental monitoring at site; incident occurred (e.g. earthquake) that necessitated increased radiological safety measures |
| | Waste disposal | Debris and radiated equipment would need to be removed from the test area due to environmental concerns | 1) Possible construction for disposal sites 2) Constructional waste and materials, 3) Vehicles 4) Spoil pile 5) Workshop sheds or containers | Waste from previous test is being disposed of; subcritical testing with nuclear material also generates RW; incident occurred (e.g. earthquake) that necessitated increased radiological safety measures |

Figure LN-7: Activity indicators and expected observables.

