Harnessing transparency potential for missile non-proliferation

HCoC Research Papers
No. 9

December 2021

Katarzyna Kubiak

Information is key for non-proliferation efforts. But the times when information was the exclusive purview of governments are over.

Affordable, commercial and open-source monitoring capabilities empower states and societies alike, while challenging the ability of governments to preserve secrecy. Technological democratisation means that information is practically becoming a public good. And it allows for unprecedented transparency.

This paper explores how transparency affects missile-related activities, how growing access to technologies increases transparency and what further opportunities and challenges it creates for HCoC.

HCoC
The Hague Code of Conduct

DISCLAIMER

This document has been produced with the financial assistance of the European Union. The contents of this document are the sole responsibility of the Fondation pour la Recherche Stratégique and can under no circumstances be regarded as reflecting the position of the European Union.

CONTENTS

Room for manœuvre[1]

One way to slow down the proliferation of weapons of mass destruction (WMDs) is by restraining their means of delivery, such as missiles, rockets or drones. Ballistic missiles remain the most prominent means of transporting WMDs because of their speed and reach. In the past 50 years, Soviet Scud missile technology has spread to at least 13 countries and several non-state actors, and the trend is growing[2]. Hindering indigenous development as well as access to entire delivery systems and to the knowledge, technology and resources necessary to develop and produce them can prevent or decelerate the spread of missile technology.[3]

To ensure that states neither covertly develop nor expand their missile arsenals, some of them apply voluntary transparency measures. This promotes mutual trust. They do so through the Hague Code of Conduct (HCoC), a political missile control instrument setting norms for missile-related transparency.

143 HCoC signatories have committed to a set of rules. They accept that benefiting from space should not lead to proliferation, and that transparency on ballistic missiles and space launch vehicles should generate trust in other actors' intentions. States pledge to curb proliferation domestically and internationally. To assure fellow signatories that they are abiding by these rules and to avoid any misunderstanding, they shall inform others ahead of a ballistic missile or space launch vehicle launch (pre-launch notifications) and submit an annual declaration on their ballistic missile and space launch activities.

But their commitment goes well beyond these well-defined tangible deliverables. HCoC also encourages state parties to pursue its goals by international, multilateral, bilateral and national endeavours and to engage in cooperative although not explicitly specified measures among themselves.

Given the changing international technological and political environment, the HCoC requires constant adaptation to keep up to speed. Yet because modernising such a regime is a sensitive and lengthy political process,[4] member states might be interested in looking for additional avenues to live up to their commitments. This article explores how HCoC signatories could harness technology -enabled transparency as one way of using its room for manoeuvre.

1. The following individuals were consulted as part of this project: Aaron Arnold, Jo Beadsworth, Lars Ceranna, Nick Godwin, Melissa Hanham, Hans M. Kristensen, Jeffrey Lewis, Andreas Persbo, Jaewoo Shin, James Stepworth, Carlo Trezza, David True, Thomas van Matre, Tianran Xu and a German diplomat familiar with the subject matter. I am grateful for their time and insights. The report does not reflect their positions or opinions, and any mistakes in the document should not be attributed to them.

2. Xu Tianran and Melissa Hanham, 'The Next 50 Years of Missile Proliferation,' *Open Nuclear Network*, 15 February 2021, https://www.oneearthfuture.org/file/1834/download?token=1fOY_Mks.

. 3. Jürgen Scheffran, 'Dual Use of Missiles and Space Technologies,' in Götz Neuneck and Otfried Ischebeck (eds.), *Missile Proliferation, Missile Defense, and Arms Control,* Nomos, January 1993, pp. 49-68. .

4. Nikolai Sokov, 'The Hague Code of Conduct: Multivector Expansion,' *Middlebury Institute of International Studies at Monterey*, 10 October 2019, https://nonproliferation.org/the-hague-code-of-conduct-multivector-expansion/.

Relevance of transparency

With more technologies available to a broader public and more organisations involved in missile-related search and monitoring activities, increased transparency seems unavoidable. In consequence, states will find it increasingly difficult to hide or lie about their missile programmes.

At the same time, objective evidence and trust in information are necessary for policymakers to establish well-informed political strategies and — at least in democratic societies — for the public to understand them and have a basis on which to judge their merit.

There are many reasons why transparency matters and many examples of where more of it could help missile non-proliferation efforts:

Publicly sharing evidence can help substantiate accusations. Data generated by so-called national means of monitoring and verification is often classified as sensitive or confidential, mainly out of the fear that it might reveal too much about the sophistication of these means. This makes it hard if not impossible to share it with other governments, not to mention the public. The United States' accusations of a Russian violation of the Intermediate-Range Nuclear Forces (INF) Treaty are a case in point.[5] It took several years before Washington shared sufficient evidence to persuade NATO allies to support its allegations that Russia had developed and tested a missile against INF Treaty obligations.[6] The Dutch government claimed to have independently confirmed the Russian violation,[7] but there is no information specifying its data or methods of analysis. To this day, the public has seen no evidence and relies upon the United States' claims and decisions among NATO governments.[8] Research institutes, think tanks or individuals known for missile activity monitoring did not issue any evidence on that matter. Therefore, building 'shadow monitoring' capacities worldwide could help generating publicly shareable, traceable and thus credible evidence.[9]

Substantiating claims. Governments make claims on the missile activities of other states, often without supporting evidence.

5. US Department of State, '2014 Report on Adherence to and Compliance with Arms Control, Nonproliferation, and Disarmament Agreements and Commitments,' July 2014, https://2009-2017.state.gov/t/avc/rls/rpt/2014/230047.htm; Gen. Paul Selva, Testimony before the House Armed Services Committee, 8 March 2017, https://armedservices.house.gov/legislation/hearings/military-assessment-nuclear-deterrence-requirements; Gen. John E. Hyten, Testimony before the Senate Committee on Armed Services, 20 March 2018, https://docs.house.gov/meetings/AS/AS00/20170308/105640/HHRG-115-AS00-Wstate-SelvaUSAFP-20170308.pdf.

6. NATO, 'Statement on the Intermediate-Range Nuclear Forces (INF) Treaty,' 4 December 2018, https://www.nato.int/cps/en/natohq/official_texts_161122.htm.

7. Hans de Vreij, 'Kabinet: Rusland schendt INF-verdrag,' *Hans de Vreij's Blog*, 27 November 2018, https://hansdevreij.com/2018/11/27/kabinet-rusland-schendt-inf-verdrag/.

8. NATO, 'Statement on the Intermediate-Range Nuclear Forces (INF) Treaty,' op. cit.

9. Aaron Stein, 'Open Source Verification in Arms Control,' *Arms Control Wonk*, 5 November 2014, 31'00', https://www.armscontrolwonk.com/archive/5022/open-source-verification/.

For example, after leaving their official postings, former US Secretary of State Mike Pompeo and former Under Secretary of State for Arms Control and International Security Affairs Marshall Billingslea claimed that China conducts between 100 and 200 ballistic missile launches a year.[10] But there is no evidence substantiating these claims. Another example are assertions that China is building up its nuclear weapons arsenal. Yet only recent satellite imagery-based revelations about the construction of 16 missile silos in the Jilantai training area,[11] 110 missile silos in eastern Xinjiang province (Hami),[12] 120 missile silos in the desert of Gansu province (Yumen)[13] and some 30 missile silos in Hanggin Banner (Ordos City) [14] have provided some evidence to back this suspicion.

Transparency forces governments to react to disclosures. When in the 1980s independent researchers disclosed the locations of US nuclear weapons in Europe, European nuclear-sharing states had to position themselves. Refusing to address these issues would have been politically

Figure 1: Credits: Planet Labs Inc. / Analysis: MIIS James Martin Center for Nonproliferation Studies

10. Michael R. Pompeo and Marshall Billingslea, 'China's Nuclear Build-Up Should Worry the West,' *Newsweek*, 4 January 2021, https://www.newsweek.com/chinas-nuclear-madness-opinion-1558342 .

11. Hans Kristensen, 'China's Expanding Missile Training Area: More Silos, Tunnels, and Support Facilities,' *Federation of American Scientists*, 24 February 2021, https://fas.org/blogs/security/2021/02/plarf-jilantai-expansion/; Hans Kristensen, 'New Missile Silo And DF-41 Launchers Seen In Chinese Nuclear Missile Training Area,' *Federation of American Scientists*, 3 September 2019, https://fas.org/blogs/security/2019/09/china-silo-df41/ .

12. Matt Korda and Hans Kristensen, 'China Is Building A Second Nuclear Missile Silo Field,' *Federation of American Scientists*, 26 July 2021, https://fas.org/blogs/security/2021/07/china-is-building-a-second-nuclear-missile-silo-field/; William J. Broad and David E. Sanger, 'A 2nd New Nuclear Missile Base for China, and Many Questions About Strategy,' *The New York Times*, 26 July 2021, https://www.nytimes.com/2021/07/26/us/politics/china-nuclear-weapons.html.

. 13. Joby Warrick, 'China Is Building More Than 100 New Missile Silos in Its Western Desert, Analysts Say,' *The Washington Post*, 30 June 2021, https://www.washingtonpost.com/national-security/china-nuclear-missile-silos/2021/06/30/0fa8debc-d9c2-11eb-bb9e-70fda8c37057_story.html.

14. Rod Lee, 'PLA Likely Begins Construction of an Intercontinental Ballistic Missile Silo Site near Hanggin Banner,' Air University, China Aerospace Studies Institute, 12 August 2021, https://www.airuniversity.af.edu/CASI/Display/Article/2729781/pla-likely-begins-construction-of-an-intercontinental-ballistic-missile-silo-si/.

awkward. While accusations do not equal transparency and while the US government's statements on a Russian violation of the INF Treaty did not provide transparent evidence, they pressured Moscow to acknowledge the existence of a new missile and sparked a conversation.[15]

Transparency holds decision-makers accountable. Transparency has a distinct role in democratic societies where the government is subject to public scrutiny or concerned with its reputation. If a state does not want to display transparency, it will likely engage in a game of cat and mouse by limiting access to information to its citizens and the international community. For example, after the missile attack on the US Ain al-Asad airbase in Iraq in January 2020, the US government initially denied any serious damage to the soldiers or the base.[16] Satellite imagery footage analysed by the scientific community proved this was not the case and forced decision-makers to unveil the extent of the damage.[17] Another example was the shoot-down of Ukraine International Airlines Flight 752 in January 2020 by two Iranian surface-to-air missiles. While the Iranian government initially denied responsibility, investigation by Western intelligence agencies and civil society actors pushed the Iranian government into admission and led to a domestic investigation.[18]

Transparency in disputed territories. A concerning situation that requires transparency is when a state has de facto no control over parts of its territory.[19] This poses a range of political, legal, military and security challenges to the state with formal control, especially if the annexed or breakaway regions are considered breeding grounds for malicious activities. One example is the shoot-down of Malaysia Airlines Flight 17 in July 2014 by a Russian-made Buk missile as it flew over the Donetsk area of Ukraine – a territory controlled by Russian-backed separatists.[20]

15. Ministry of Defence of the Russian Federation, 'Russian Defence Ministry Briefs Military Attaches with Presentation of 9M729 Missile of Iskander-M Complex,' 23 January 2019, https://eng.mil.ru/en/news_page/country/more.htm?id=12213705@egNews .

16. C. Todd Lopez, 'Chairman: Defensive Measures Prevented Casualties in Iranian Attack,' *DOD News*, US Department of Defense, 8 January 2020, https://www.defense.gov/Explore/News/Article/Article/2052919/chairman-defensive-measures-prevented-casualties-in-iranian-attack/; Remarks by President Trump on Iran, The White House, 8 January 2020, https://trumpwhitehouse.archives.gov/briefings-statements/remarks-president-trump-iran/.

17. Dr Jeffrey Lewis Twitter Account, 2 March 2021, https://twitter.com/ArmsControlWonk/status/1366804542898249737.

18. 'Iran Plane Crash: Demands for Justice after Admission Jet Was Shot Down,' *BBC*, 11 January 2020, https://www.bbc.com/news/world-middle-east-51077788; 'Iran's Final Report Blames Air Defence Operator Error for Ukraine Plane Crash,' *Reuters*, 17 March 2021, https://www.reuters.com/article/us-iran-crash-ukraine-idUSKBN2B92CL; cf. Government of Canada, 'The Downing of Ukraine International Airlines Flight 752: Factual Analysis,' 24 June 2021, https://www.international.gc.ca/gac-amc/publications/flight-vol-ps752/factual_analysis-analyse_faits.aspx?lang=eng .

19. Chen Kane, 'Safeguards and Verification in Inaccessible Territories,' *CNS Occasional Paper*, No. 39, October 2018, https://www.nonproliferation.org/wp-content/uploads/2018/10/op-39-safeguards-and-verification-in-inaccessible-territories.pdf .

20. Dutch Safety Board, 'Crash of Malaysia Airlines

Transparency as a precondition to shared disclosure. One cannot expect one's counterpart to put their cards on the table without doing so oneself. This was a premise that led President Barack Obama and President Joe Biden to disclose the size of the US nuclear arsenal in 2010[21] and 2021.[22] HCoC materialises this assumption with its notifications and reporting processes.

Empowerment. Access to affordable, commercial or open-source monitoring capabilities can empower states that do not possess sophisticated and expensive national technical means such as space-based sensors. The ability to undertake independent, possibly even collaborative, monitoring opens up new avenues to actively participate in non-proliferation efforts and lessens the reliance on foreign data or intelligence provision.

Overlooking a crowded space. The substantial overlap between technology used to deliver satellites into space and that used to deliver WMDs brings new challenges[23] as the missile industry grows. What was once a costly, government-driven, oligopolistic space industry has gradually evolved into a booming marketplace for small to medium-sized private space companies. This development creates more avenues for proliferation and may require closer monitoring, oversight and transparency.

These are only some examples of why and where transparency matters in the domain of missile-related activities. Now the question is how technological democratisation could generate transparency and serve HCoC's purpose.

Generating transparency

Non-proliferation starts with information. States need to be aware of missile developments elsewhere in order to design non-proliferation strategies. Observing the missile activities of other states over time – known as monitoring – is key. And it can occur 'even if there is no rule to verify compliance against.'[24] To investigate missile activities or verify a piece of trigger information, states need to collect, structure and analyse data.

Because constant monitoring of the entire world is currently technologically impossible, those undertaking monitoring need to carefully decide where, when and what to look for. The triggers for investigating specific missile activities are diverse. They include governments'

Flight MH17,' The Hague, October 2015, https://www.onderzoeksraad.nl/en/media/attachment/2018/7/10/debcd724fe7breport_mh17_crash.pdf.

21. Hans Kristensen, 'United States Discloses Size of Nuclear Weapons Stockpile,' *Federation of American Scientists*, 3 May 2010, https://fas.org/blogs/security/2010/05/stockpilenumber/.

22. US State Department, 'Fact Sheet: Transparency in the U.S. Nuclear Weapons Stockpile,' 5 October 2021, https://www.state.gov/wp-content/uploads/2021/10/Fact-Sheet_Unclass_2021_final-v2-002.pdf.

23. Thomas Hajnoczi, 'Upcoming Chair's Introduction,' *Missile Technology Control Regime Newsletter*, 2020, p. 5, https://mtcr.info/wordpress/wp-content/uploads/2020/09/MTCR-newsletter-final-.pdf .

24. Andreas Persbo, 'Verification: Theory, Practice and Technologies,' Lecture, Kings College London, 17 March 2017, slide 10, https://www.vertic.org/media/assets/Presentations/KCL_lecture_verification.pdf .

announcements or statements about their missile programmes; other governments' official or non-official claims, intelligence sharing or leaks about another state's missile programmes; rumours, claims or imagery sharing on social media;[25] export and financial data; but also triggers as simple as individuals' curiosity or the testing of newly developed or acquired algorithms for finding patterns. Moreover, if an actor is suspected of or known for missile activities, monitoring preparations for tests and missile launches is important for maintaining situational awareness.

Monitoring activities are a corollary of military and intelligence activities. And so, for many years, only states with appropriate technological know-how and financial and human resources could undertake such activities. Yet with the democratisation of knowledge and technology access, and the advent of new technologies, this is changing rapidly.

Data collection via satellite imagery

Space observation technology is not new. Yet alternative business models, growing supply and mass demand have made commercial satellite imagery increasingly available, affordable and lucrative. In the 1960s, space observation technology was reserved for the military. Scientific research access was only allowed in 1972 and public access in 1986.[26] Using commercial imagery for security analysis dates back to 1987 when the Norwegian Institute of International Affairs studied Soviet military and nuclear facilities on the Kola Peninsula.[27] A lot has changed since then.

With 4,550 satellites currently orbiting Earth,[28] of which around 1007 serve earth observation purposes,[29] there is a growing amount of diverse satellite imagery technology available. Optical or visible light photography requires sunlight; it does not see through clouds but provides imagery with comparably good resolution. Infrared or thermal sensors detect heat energy emitted by objects and identify shapes if their surface temperature is different from that of the surrounding area. Their advantage is that they can see through dense atmospheric conditions. Multispectral and hyperspectral imagery (which can capture up to 20 and 100 bands of light wavelengths respectively)[30] can determine the chemical-physical composition of objects.[31] Active sensors (Synthetic Aperture

25. Geoff Brumfiel, 'Trump Tweets Sensitive Surveillance Image Of Iran,' *NPR*, 30 August 2019, https://www.npr.org/2019/08/30/755994591/president-trump-tweets-sensitive-surveillance-image-of-iran.

26. Laurence Nardon, 'Satellite Imagery Control: An American Dilemma,' *Ifri*, March 2002, https://www.ifri.org/sites/default/files/atoms/files/imageriesatellitaireln0302.pdf.

27. Johnny Skorve and Tomas Ries, 'Investigating Kola: A Study of Military Bases Using Satellite Photography,' *Norwegian Institute of International Affairs*, Brassey's, 1987.

28. UCS Satellite Database, Union of Concerned Scientists, updated 1 September 2021, https://www.ucsusa.org/resources/satellite-database; cf. Observing Systems Capability Analysis and Review Tool, List of all Satellites, World Meteorological Organization, accessed 23 September 2021, https://space.oscar.wmo.int/satellites/.

29. Ibid.

30. NATO Research and Technology Organization, 'Survey of Hyperspectral and Multispectral Imaging Technologies,' *RTO Technical Report*, May 2007, https://apps.dtic.mil/dtic/tr/fulltext/u2/a473675.pdf.

31. 'Going Hyperspectral,' European Space Agency,

Radar,[32] LIDAR) are independent of sunlight, overclouding or fog, can see through certain materials (e.g., fibreglass roofs)[33] and offer 'exceptional fidelity'.[34]

Space observation technology allows for search and monitoring. It can generate data to investigate a wide range of unique signals related to missile development, testing, launching and transporting. These include:

- Building structures.
- Roads with gentle slopes and turns that lead to and from these warehouses that allow the manoeuvring of special vehicles and heavy transporters capable of carrying rocket stages and other parts.
- Road trafficking patterns (tracks created by heavy vehicles), especially at night.
- Missile silos.[35]
- Gantry towers and their movement.
- Missile motor tests, day and night.
- Burn scars from missile launches.[36]

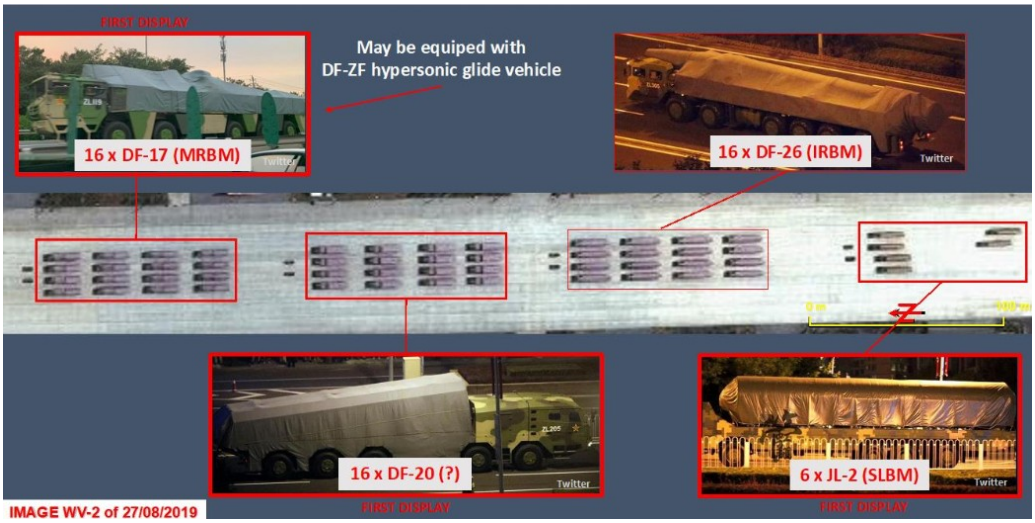

Figure 2: Identification of ballistic missiles displayed during the rehearsal of the military parade for the 70th anniversary of the PRC, 2019. Credits : Geo4i / FRS

30 March 2010, https://www.esa.int/Applications/Observing_the_Earth/Proba-1/Going_hyperspectral.

32. Capella Space website, accessed 20 June 2021, https://www.capellaspace.com/.

33. Melissa Hanham and Jeffrey Lewis, 'Remote Sensing Analysis for Arms Control and Disarmament Verification,' *Federation of American Scientists*, accessed October 2021, https://fas.org/wp-content/uploads/media/Remote-Sensing-Analysis-for-Arms-Control-and-Disarmament-Verification.pdf.

34. Jeffrey Lewis, Melissa Hanham, Joshua Pollack, Catherine Dill and Raymond Wang, 'Open-Source Monitoring of Uranium Mining and Milling for Nuclear Nonproliferation Applications,' *CNS Occasional Paper*, No. 34, December 2017, p. 5, www.nonproliferation.org/wp-content/uploads/2017/12/op34-open-source-monitoring-of-uranium-mining-and-milling-for-nuclear-nonproliferation-applications.pdf.

35. Joby Warrick, op. cit.

36. Melissa Hanham and Jeffrey Lewis, op. cit.

- Missile performance dimensions (propellant type and size, warhead size, warhead load).
- Missile test ranges.

Open-source signature databases or libraries, like the United States Geological Survey Spectral Library[37] or NASA's ECOSTRESS Spectral Library,[38] compile the spectral reflectance of thousands of materials and facilitate satellite imagery analysis.

Remote sensing technology has some limitations that determine its usability for monitoring missile activities. Apart from some specific exceptions mentioned above, it cannot provide insight into physically covert activities. Depending on the technology, weather conditions can influence what one can see. The physical limits at which satellites can operate also mean that 'after somewhere around 11 to 9 centimetres [resolution], things get wonky.'[39] Depending on the number of satellites operating on one orbit, data may not be available 24/7 for one spot. For example, with a resolution of 31 cm, WorldView-3 satellites have the sharpest view commercially available but fly at any given point on Earth only every two weeks. Planet, which provides imagery from roughly 200 satellites, can deliver data for one spot daily. The Argentinian company Satellogic, which leads in providing multi- and hyperspectral data, captures the entire surface of the Earth in several months with a resolution of 25 metres.[40] Yet with a growing number of satellites in space, the availability of data from all corners of the world will increase.

Some states require by law that satellite imagery providers blur individual locations, undertake shutter control or interrupt sales of imagery.[41] Yet blurry patches on satellite imagery only reveal the precise location of significant military facilities and often arouse a curiosity to explore their potential function.[42] Wikipedia even hosts an entry listing blurred satellite imagery locations.[43] However, the more international the supply, the less governmental interference on image availability will make sense, as non-obfuscated imagery will be available from a range of different providers. For example, for some time, the Dutch Volkel Air Base,[44] which stations US nuclear weapons, was blurred on Google Maps and Bing Maps,[45]

37. USGS Spectral Library, US Department of the Interior, https://www.usgs.gov/labs/spec-lab/capabilities/spectral-library.

38. ECOSTRESS Spectral Library, NASA, https://speclib.jpl.nasa.gov/library.

39. Geoff Brumfiel, op. cit.

40. Conversation with Thomas Van Matre, Vice President Global Business Development, Satellogic, 4 June 2021.

41. Laurence Nardon, op. cit.

42. Matt Korda, 'Widespread Blurring of Satellite Images Reveals Secret Facilities,' *Federation of American Scientists*, 10 December 2018, https://fas.org/blogs/security/2018/12/widespread-blurring-of-satellite-images-reveals-secret-facilities/.

43. Wikipedia, 'List of Satellite Map Images with Missing or Unclear Data,' December 2019, https://en.wikipedia.org/wiki/List_of_satellite_map_images_with_missing_or_unclear_data .

44. 'US Nuclear Bombs "based in Netherlands" – ex-Dutch PM Lubbers,' *BBC*, 10 June 2013, https://www.bbc.com/news/world-europe-22840880.

45. Hans Kristensen, 'Nukes in Europe: Secrecy Under Siege,' *Federation of American Scientists*, 13 June 2013, https://fas.org/blogs/security/2013/06/secrecyundersiege/.

46. Yandex, Volkel Air Base, accessed 20 August

but was visible on Yandex Maps.[46]

Another obstacle to overcome is ensuring

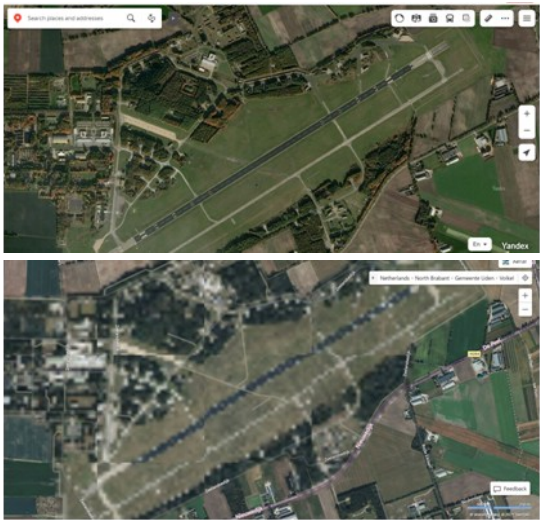

Figure 2: Comparison of Volkel Air Base open-access satellite imagery - Bing and Yandex Maps (August 2021)

that imagery data is not hacked or altered, so as to vouchsafe its authenticity. While technically, 'authenticity or attribution is typically derived from the images' metadata, in a public-facing scenario attribution and authenticity is governed by the licensing agreement between the vendor and the entity exposing the imagery to the public.'[47] Invisible digital image watermarking could further 'ensure tamper-resistance', authentication, content verification and integration of satellite images.[48] The idea behind this is to embed identification information into the original image in such a way that it cannot be removed by an unauthorised person. However, existing technologies require making trade-offs between a watermark's robustness, imperceptibility and capacity,[49] and in the realm of remote sensing this remains a capability of the future.[50]

Next to imagery from space, planes and drones are also used for monitoring purposes. The Open Skies Treaty, with 1,517 actual overflights in the OSCE area between 2002 and 2019, showed the value of such transparency measures despite developments in space observation technology.[51] Yet aerial vehicle imagery

2021, https://yandex.eu/maps/org/volkel_air_base/176481856215/?l=sat&ll=5.717849%2C51.657898&mode=search&sctx=ZAAAAAgCEAAaKAoSCfFmDd5XtSVAEXmxMEROl0hAEhIJAAAAAICNX0ARIZXL6y2fSEAoCjgAQHZIAWoCdWFwAJ0BzcxMPaABAKgBAL0BjH2sS%2BoBAPIBAPgBAIICG1ZvbGtlbCBBaXIgQmFzZSBuZXRoZXJsYW5kc4oCAA%3D%3D&sll=5.717849%2C51.657898&sspn=0.034161%2C0.012198&text=Volkel%20Air%20Base%20netherlands&z=15 .

47. Conversation with Thomas Van Matre, Vice President Global Business Development, Satellogic, 2 July 2021.

48. Hai Tao, Li Chongmin, Jasni Mohamad Zain and Ahmed N. Abdalla, 'Robust Image Watermarking Theories and Techniques: A Review,' *Journal of Applied Research and Technology*, Vol. 12, No. 1, 2014, p. 122-138 .

49. Mahbuba Begum and Mohammad Shorif Uddin, 'Digital Image Watermarking Techniques: A Review,' *Information*, Vol. 11, No. 2, 2020, https://www.mdpi.com/2078-2489/11/2/110/htm#B1-information-11-00110.

50. Suraj M. Somani, Krishna Mohan Buddhiraju, Deepak V. Choksi, Parvatham Venkatachalam and Tanzima Habib, 'Robust Watermarking of Satellite Images Using Texture-based LSB-DWT Method,' *Proc. SPIE 9880, Multispectral, Hyperspectral, and Ultraspectral Remote Sensing Technology, Techniques and Applications VI*, 98801X, 30 April 2016 .

51. Alexander Graef and Moritz Kütt, 'Visualizing the Open Skies Treaty,' last updated 27 April 2020, https://openskies.flights.

requires a state to agree to be overflown, and this may not necessarily be possible when investigating covert missile activities. Companies like Airbus are already working on high-altitude drones.[52] With no international agreement on the vertical extent of sovereign airspace,[53] they could possibly be considered by some states as operating outside national boundaries. Legal aspects aside, states will most likely assess the application of planes and drones to monitor covert missile activities in light of the monitored side's capacity to shoot them down.

Infrasound ballistic missile launch detection

A long-distance, more accessible and less expensive post-factum monitoring method involves the use of infrasound.[54] When a missile is launched or re-enters the atmosphere, it emits waves between 0.1–1Hz (liquid fuel)[55] and 1–2Hz (solid fuel).[56] Under certain environmental conditions, it can travel unhindered thousands of kilometres through the Earth's atmosphere and cannot be jammed by humans. Infrasound makes it possible to discern the location of a missile launch, its trajectory and, to a limited extent, the type of missile used.[57] While it cannot be used for early warning, it can support the monitoring of compliance with a missile test and launch agreement.

The ability to determine a missile launch through infrasound depends on the missile characteristics, atmospheric conditions, local noise conditions, direction of the measurement and density of the measurement network. Long-range infrasound is 'generated by the supersonic shock cone of a rocket at high altitude, as opposed to being generated at or near the launch site by plume exhaust or plume interaction with the ground.'[58] Depending on the missile characteristics, its theoretical detection distance varies. For example, the infrasound signature from a Russian space-launch Proton rocket can travel up to 6,300 km, from the Indian strategic missile Agni II up to 675 km, and from the tactical ballistic Scud-B missile up to 130 km.[59] Temperature and wind structure between the signal source and the receiver also influence

52. 'Zephyr,' Airbus, accessed 30 July 2021, https://www.airbus.com/defence/uav/zephyr.html#zephyr .

53. 'Where Is Space?', National Environmental Satellite, Data, and Information Service, 22 February 2016, https://www.nesdis.noaa.gov/content/where-space.

54. Infrasound is a sound wave in a frequency that a human cannot hear.

55. Bharath Gopalaswamy, 'Observing Missile Launches Using Infrasound Technology,' VERTIC, *Trust & Verify*, No. 127, October-December 2009, p. 1.

56. George Kashack, William L. Donn and Uri Fehr, 'Long-Range Infrasound from Rockets,' *The Journal of the Acoustical Society of America*, Vol. 48, 1970, pp. 12-20; Nambath K. Balachandran and William L. Donn, 'Characteristics of Infrasonic Signals from Rockets,' *Geophysical Journal International*, Vol. 26, No. 1-4, December 1971, pp. 135–148 .

57. Bharath Gopalaswamy, op. cit.; cf. Kaleb E. Smith, Mitchell L. Solomon, Kaylen J. Bryan, Anthony O. Smith and Adrian M. Peter, 'Near-Field Infrasound Classification of Rocket Launch Signatures,' *Proc. SPIE 10629, Chemical, Biological, Radiological, Nuclear, and Explosives (CBRNE) Sensing XIX*, 106291F, 23 May 2018 .

58. Bharath Gopalaswamy, op. cit.

59. Ibid. p. 2; cf. Stephen M. Tenney, John M. Noble, Rodney W. Whitaker and Douglas O. ReVelle, 'Acoustic/Infrasonic Rocket Engine Signatures,' *Proc. SPIE 5090, Unattended Ground Sensor Technologies and Applications V,* 18 September 2003, pp. 30-41.

Figure 3: Infrasound stations of the International Monitoring System of the CTBTO. Credits: CTBTO

infrasound propagation. Natural phenomena such as wind (especially jet streams), lightning, bolides and other natural and man-made background noise further determine the detection threshold of a launch. For example, in winter an infrasound station in Germany receives signatures from the west and in the summer from the east.[60] As such, the higher the density of measurement stations, the better the chance of capturing a signal.

States can either collect infrasound data from national infrasound networks or use data from the International Monitoring System. Out of the 185 members and signatories to the Comprehensive Test Ban Treaty (CTBT) eligible for 24/7/365 access to data from 53 out of the 60 planned infrasound stations around the world, over 1,200 users in 120 states utilise it.[61] This includes access for scientists and researchers with legitimate scientific projects.[62] While CTBT's monitoring system aims primarily at monitoring nuclear explosions, it also registers a variety of non-nuclear events. As such, its data can be used for purposes such as disaster warning, civil aviation monitoring, research on climate change, whale singing or missile tracking, to name but a few.[63] The data is available with an average delay of 5–10 minutes from real-

60. See Nambath K. Balachandran and William L. Donn, 'On the Propagation of Infrasound from Rockets: Effects of Winds,' *The Journal of the Acoustical Society of America*, Vol. 50, No. 397, 1971; William L. Donn, Nambath K. Balachandran and David Rind, 'Tidal Wind Control of Long-Range Rocket Infrasound,' *Journal of Geophysical Research*, Vol. 80, No. 12, 'Oceans,' 20 April 1975, pp. 1662-1664.

61. 'Overview of the Verification Regime,' CTBTO, accessed 15 April 2021, https://www.ctbto.org/verification-regime/background/overview-of-the-verification-regime/.

62. Virtual Data Exploitation Centre, Comprehensive Nuclear-Test-Ban Treaty Organization, https://www.ctbto.org/specials/vdec/.

63. 'Spin-Offs for Disaster Warning and Science,' CTBTO, accessed 14 September 2021, https://www.ctbto.org/verification-regime/spin-offs-for-disaster-warning-and-science/.

time. The missing infrasound data (gaps when stations are down) provision from the International Monitoring System is low and averages 2%.[64] To ensure that every state can acquire, process and analyse such data, the European Union funded development and training of the free, open-source NDC-in-a-BOX software package.

There are a couple of ways to further universalise infrasound as a monitoring method. An open-source database of missile launches and re-entry signatures at specific test and launch locations could increase state and non-state event monitoring capability and the ability to discern different missiles from other occurrences, like a meteorite hit.[65] An example is the infrasound signature database of '1001 rocket launches for space missions between early 2009 and mid-2020 recorded at globally distributed IMS infrasound arrays' collected by the German Federal Institute for Geosciences and Natural Resources.[66] Machine learning promises better software modelling, more realistic depicturing of the spread of signals, increased detection accuracy, lower false alarm rates and improved detection rates. Given that wireless air pressure sensors cost as much as 200 EUR–2,500 USD today,[67] citizen science and scientific activism could aid in increasing the density of infrasound measurement networks.

Data processing and analysis

There are three main challenges in processing and analysing data from satellites or the Internet. First, the data volumes are extremely high. Second, the processing, analysis and curating of data requires a highly specialised workforce that is still not widely available on the market. Third, wading through high volumes of data is laborious, time-consuming and often dull. Artificial intelligence (AI) and semi-automated techniques could help overcome these challenges.

Today, a satellite sends its remote sensing image data to a ground data centre where scientists and machines extract the information needed and prepare it for the customer. To handle large amounts of data retrieved in space, companies have started to equip satellites with onboard computers that can run algorithms. This allows in-orbit or 'at the edge' data processing – that is, on the satellite itself – which means less data transfer, faster transmission[68] and possibly reduced operational costs.

Tip-and-cue procedures enable a satellite to 'capture additional imagery or to task

64. Conversation with Lars Ceranna, Scientific Director, Federal Seismological Survey, Nuclear-Test Ban, Federal Institute for Geosciences and Natural Resources, 30 March 2021.

65. Lassina Zerbo Twitter, 14 April 2021, https://twitter.com/SinaZerbo/status/1382238744300957696; cf. Lassina Zerbo Twitter, 9 May 2021, https://twitter.com/SinaZerbo/status/1391356201972207621.

66. Christoph Pilger, Patrick Hupe, Peter Gaebler, Lars Ceranna, '1001 Rocket Launches for Space Missions and Their Infrasonic Signature, Geophysical Research Letters, 28 April 2021, https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2020GL092262.

67. Raspberry Boom Atmospheric Infrasound Monitor, Raspberry Shake, accessed 28 May 2021, https://raspberryshake.org/products/raspberry-boom/; Sensirion, https://www.sensirion.com/; Bharath Gopalaswamy, op. cit, p. 4.

68. 'Intuition-1, Processing of Hyperspectral Images in Orbit,' KP LABS, accessed 29 June 2021, https://www.kplabs.pl/processing-of-hyperspectral-images-in-orbit-intuition-1/.

another satellite – or even a drone in the sky below – to acquire more data over the area of interest.'[69] An algorithm can also detect specific signatures when a satellite is focusing on a particular geolocation and trigger a notification to the ground station/ customer.

Satellite imagery can provide increased value when combined with in-house image processing and machine learning algorithms. At the analysis stage, an algorithm can process through massive volumes of data looking for specific signatures. AI information analysis already supports humans in recognising objects, understanding hidden relationships, detecting change or recognising and mapping patterns, especially in high-noise, low-signal information environments. Software is also able to discover sites not previously recorded in open sources.[70] And if in-house capacity is unavailable, one can reach out to the market. Entities like the James Martin Center for Nonproliferation Studies (CNS) or the University of Missouri have used open-source software companies to identify patterns in satellite imagery and Chinese surface-to-air missile sites, respectively.[71] 3D modelling technology makes it possible to extrapolate 2D pictures into 3D models that help to identify shared design patterns.[72] Machine learning could also involve comparing data from the United Nations Register of Objects Launched into Outer Space with press releases and satellite imagery.

Plenty of off-the-shelf Internet research tools allow keyword or hashtag monitoring and tracking, geolocation detection, semantic analysis, sentiment analysis, trend analysis, etc. For example, reverse image search software makes it possible to identify people and locations,[73] and, as a result, to recognise missile transports or suspicious military activity. It is possible to geolocate individuals and search for undiscovered sites by tracking human activity using heatmaps (e.g., Strava, Garmin, Snapchat).[74] Geolocation of photographic or video imagery is possible by calculating the position of shadows and the sun.[75] If images provide possible trigger information,

69. 'Processing Collected Satellite Image and Data in Orbit,' GIM International, 17 December 2020, https://www.gim-international.com/content/news/processing-collected-satellite-image-and-data-in-orbit.

70. Richard A. Marcum, Curt H. Davis, Grant J. Scott and Tyler W. Nivin, 'Rapid Broad Area Search and Detection of Chinese Surface-to-Air Missile Sites Using Deep Convolutional Neural Networks,' *Journal of Applied Remote Sensing*, Vol. 11, No. 4, October 2017, https://www.spiedigitallibrary.org/journals/journal-of-applied-remote-sensing/volume-11/issue-04/042614/Rapid-broad-area-search-and-detection-of-Chinese-surface-to/10.1117/1.JRS.11.042614.full?SSO=1.

71. Jeff-rey Lewis, Melissa Hanham, Joshua Pollack, Catherine Dill and Raymond Wang, op. cit., pp. 4-5; Richard A. Marcum, Curt H. Davis, Grant J. Scott, and Tyler W. Nivin, op. cit.

72. Aaron Stein, op. cit.; See the 3D Missile Model Collection, *NTI*, 22 April 2015, https://www.nti.org/analysis/articles/overview-of-the-3d-missile-model-collection.

73. Aric Toler, 'Guide To Using Reverse Image Search For Investigations,' *Bellingcat*, 26 December 2019, https://www.bellingcat.com/resources/how-tos/2019/12/26/guide-to-using-reverse-image-search-for-investigations/.

74. Logan Williams, 'Geofenced Searches on Twitter: A Case Study Detailing South Asia's Covid Crisis,' Bellingcat, 19 May 2021, https://www.bellingcat.com/resources/2021/05/19/geofenced-searches-on-twitter-a-case-study-detailing-south-asias-covid-crisis/.

75. Youri van der Weide, 'Using the Sun and the Shadows for Geolocation,' *Bellingcat*, 3 December

software can reveal if and what type of altering changes have been made to a digital file.[76]

Today's technology makes it possible to monitor the web for trigger information, evaluate the authenticity of information, track scientists and military forces, monitor scientific developments and trends, etc. However, while computers will shoulder the burden of human analysts, it is humans that will need to ask the right questions, know where to look and make sense of the data.

Fusing data, methods and sources

Next to greater availability of and access to data and improved processing and analysis techniques, fusing different data sources with different analytical tools is what is opening new avenues for the monitoring of missile activities today.

Building evidence on missile activities involves analysing many different sources, including press photography, satellite imagery, seismic data, isotope data, weather data, social media, organisational or individual activities online, etc. It entails analysing scientific journals to track the careers of individual scientists, monitoring suspected organisations in order to search for information on specific topics, analysing networks, investigating corporate information and financial streams. Analysts also try to obtain and analyse other sources of information, e.g., car air filters to determine if they carry radioactive elements.[77]

Human beings are often the weakest link in any given system, so unsurprisingly many investigations include an analysis of social media accounts. For example, Jeffrey Lewis and Catherine Dill discovered a Chinese attempt to construct an underground nuclear reactor during the 1960s and 1970s using a retired Chinese professor's memoirs and pictures on social media.[78] On another occasion, Jeffrey Lewis located the Chinese Korla Missile Test Complex, whose existence the Chinese did not acknowledge, by cross-referencing information from satellite images with Wikileaks, press accounts and selfies posted on social media by Chinese military unit alumni.[79]

At the same time, finding information does not necessarily mean acquiring hardly accessible or costly data. A recent Bellingcat investigation found that US soldiers deployed in Europe used publicly accessible flashcard learning apps that revealed 'a multitude of sensitive security protocols about US nuclear weapons and the bases at which they are stored.'[80] While this case

2020, https://www.bellingcat.com/resources/2020/12/03/using-the-sun-and-the-shadows-for-geolocation/.

76. Nathalie Hof, 'Photo Expert: "A Manipulated Image Is Not Necessarily a Lie",' *TIME*, 1 June 2015, https://time.com/3897858/photo-expert-a-manipulated-image-is-not-necessarily-a-lie/.

77. Elizabeth Gibney, 'How Nuclear Scientists Are Decoding Russia's Mystery Explosion,' *Nature*, 30 August 2019, https://www.nature.com/articles/d41586-019-02574-9.

78. Jeffrey Lewis, 'The Untold Story of China's Forgotten Underground Nuclear Reactor,' *Foreign Policy*, 8 July 2014, https://foreignpolicy.com/2014/07/08/the-untold-story-of-chinas-forgotten-underground-nuclear-reactor/.

79. Jeffrey Lewis, 'Korla Missile Test Complex,' *Arms Control Wonk*, 14 August 2014, https://www.armscontrolwonk.com/archive/207415/korla-missile-test-complex/; Aaron Stein, op. cit.

80. Foeke Postma, 'US Soldiers Expose Nuclear Weapons Secrets Via Flashcard Apps,' Bellingcat, 28 May 2021, https://www.bellingcat.com/

clearly shows security gaps, it also illustrates the breadth of sources from which one can obtain sensitive information.

How we organise monitoring activities matters

In the past, the best data was secret. Today, the challenge is less to find the needle in a haystack, but rather that you have an entire haystack of needles that you need to structure in order to figure out what you want to find.

So far, the discovery of what seems like several ICBM missile silo fields under construction in China prompted Adm. Charles Richard, commander of USSTRATCOM, to say 'if you enjoy looking at commercial satellite imagery, can you keep looking? Normally we pay people to do it.'[81] But governments could consider more rigorously how they could benefit from the democratisation of monitoring activities that allows almost anybody to contribute.

As yet, most of the public revelations on missile activities seem to be an unsolicited outcome of individual scientific or journalistic curiosity. The James Martin Center for Nonproliferation Studies, Johns Hopkins University, the Federation of American Scientists, 38 North, the Institute for Science and International Security, the Verification Research, Training and Information Centre (VERTIC), Bellingcat and the Open Nuclear Network are self-mobilising entities that monitor and investigate non-proliferation events independently. They mainly represent academia, non-profit organisations and media platforms that bring together expert communities. But these tools can also be used by official international organisations. A governmental example is the International Atomic Energy Agency. The international nuclear watchdog in charge of ensuring compliance with the Non-Proliferation Treaty, uses geospatial tools and other safeguards-relevant open-source information.[82]

One can only imagine how much and what type of information could be found by undertaking similar research on a larger scale, with a broader geographical scope and in a systematic fashion. Some intelligence services may already be doing such work. But as curious analysts will not disappear and can generate publicly shareable information, one question is if and how governments will utilise this opportunity to their advantage.

Societal verification, public technical means (PTM),[83] citizens' media,[84] citizens'

news/2021/05/28/us-soldiers-expose-nuclear-weapons-secrets-via-flashcard-apps/.

81. US Strategic Command, 'Space and Missile Defense Symposium Speech,' 12 August 2021, Huntsville, https://www.stratcom.mil/Media/Speeches/Article/2742875/space-and-missile-defense-symposium/.

82. 'Information Collection and Evaluation,' IAEA, accessed 15 May 2021, https://www.iaea.org/topics/information-collection-and-evaluation/.

83. Kelsey L. Hartigan and Corey Hinderstein, 'The Opportunities and Limits of Societal Verification,' *Nuclear Threat Initiative*, July 2013.

84. Doug Naquin, Central Intelligence Retirees' Association Luncheon Remarks, 3 October 2007.

reporting, inspection by the people[85] and social monitoring[86] are not novel concepts. They broadly refer to the supplementary involvement of civil society for monitoring compliance with and implementation of international treaties and agreements.[87] This can range from non-expert support,[88] passive data collection,[89] societal observation,[90] deploying monitoring tools on private property and providing information on 'how to use homemade or personally purchased equipment to collect data for public distribution'[91] to expert analysis and evaluation.

But what about soliciting know-how from enthusiasts not associated with prestigious organisations? Individuals around the world knowingly or unknowingly share monitoring -relevant data through social media,[92] 'outside enthusiasts catalogue lists of interesting findings on individual user blogs or aggregator websites'[93] and whistle-blowers raise awareness among authorities about the breach of non-proliferation rules.[94] Are there ways to streamline such dispersed activities? While crowdsourcing problem solving (like DARPA's Red Balloon Challenge[95] or Shredder Challenge[96]) has proved its effectiveness despite some

Figure x: Red Balloon Challenge, where users had to locate 10 red weather balloon across the continental United States. Credits: DARPA

85. Lewis Bohn, Memorandum of 12 January 1956 to the RAND Corporation (not published); reproduced in Lewis Bohn, 'Tecniche d'ispezione non material,' in Donald G. Brennan (ed.), *Controlli degli armamenti, disarmo e sicurezza nazionale*, New York/Milan, 1961, p. 466; Seymour Melman, 'General Report,' in Seymour Melmon (ed.), *Inspection for Disarmament*, Columbia University Press, New York, 1958, p. 38; Grenville Clark and Louis Sohn (eds.), *World Peace Through World Law*, Harvard University Press, Cambridge, Massachusetts, 2nd ed., 1962, p. 264.

86. Dieter Deiseroth, 'Societal Verification: Wave of the Future?,' *Verification Yearbook 2000*, pp. 265-280.

87. Zoe N. Gastelum, 'Societal Verification for Nuclear Nonproliferation and Arms Control,' *Sandia Nattional Laboratories*, March 2013, p. 1.; Dieter Deiseroth, op. cit.

88. Ibid.

89. Thomas Lorenz and Yana Feldman, 'The Efficacy of Social Media as a Research Tool and Information Source for Safeguards Verification,' *Information Analysis Technologies, Techniques and Methods for Safeguards, Nonproliferation and Arms Control Verification Workshop*, Workshop Proceedings, Portland, 12-14 May 2014; Kelsey L. Hartigan and Corey Hinderstein, op. cit., p. 4.

90. Zoe N. Gastelum, op. cit.

91. Ibid.

92. See for example Jeffrey Lewis, 'The Untold Story,' op. cit.

93. 'Innovating Verification: New Tools & New Actors to Reduce Nuclear Risks. Redefining Societal Verification,' *NTI*, July 2014, p. 20, https://media.nti.org/pdfs/WG2_Redefining_Societal_Verification_FINAL.pdf.

94. See for example Dieter Deiseroth, op. cit.

95. DARPA, 'Red Balloon Challenge,' accessed July 2021, https://www.darpa.mil/about-us/timeline/network-challenge.

96. DARPA, 'Shredder Challenge,' accessed July 2021, https://archive.darpa.mil/shredderchallenge/.

limitations,[97] there is no systematic data on how it could be used for search and monitoring in the non-proliferation context.[98]

There are two rare exceptions in the missile community. The Open Nuclear Network's software platform Datayo aimed to test a curated crowd's ability to process and analyse raw data sets. It provided data that is too expensive for individuals or small NGOs to acquire and allowed a group of chosen experts and enthusiasts 'to analyse many kinds of open-source information and talk about it with people around the world.'[99] Another example is the Arms Control Wonk Slack Channel.[100] On occasion, its members mobilise themselves to solve missile-related puzzles, such as tracking down details of the Ukraine International Airlines Flight 752 shoot-down.[101] But sustaining such initiatives is a tall order, as Datayo exemplifies. The challenges include establishing a system of incentives to keep people engaged, handling licence tools, permissions and export control restrictions related to tools or data for a global crowd of users to work on. On top of this, such initiatives suffer from financial uncertainty and/or inconsistency.

At the same time, evidence generated through civil society can be reliable because one can verify the credibility of open-source information and of the source itself.[102] This does not mean that every amateur analysis is correct, but that everybody can prove or disprove its reliability. Acclaimed expert hubs like the Arms Control Wonk Slack Channel or the Datayo community could help determine the credibility of such sources or information in the public domain.

Societal monitoring can both reduce the burden on the government and provide publicly shareable evidence. The public can generate such evidence upon its own initiative or guided by intelligence tips provided by the government. As the public will either find evidence for a hint or not,

97. See for example John C. Tang, Manuel Cebrian, Nicklaus A. Giacobe, Hyun-Woo Kim, Taemie Kim and Douglas Wickert, 'Reflecting on the DARPA Red Balloon Challenge,' *Communications of the ACM*, Vol. 54, No. 4, April 2011, https://web.media.mit.edu/~cebrian/p78-tang.pdf; Mark Harris, 'How A Lone Hacker Shredded the Myth of Crowdsourcing,' *WIRED*, 9 February 2015, https://www.wired.com/2015/02/how-a-lone-hacker-shredded-the-myth-of-crowdsourcing/.

98. Bryan Lee, 'Crowdsourcing Systems and Potential Applications in Nonproliferation,' *CNS Occasional Paper*, No. 30, August 2017, www.nonproliferation.org/wp-content/uploads/2017/08/op30-crowdsourcing-systems-and-potential-applications-in-nonproliferation.pdf.

99. Conversation with Melissa Hanham, Affiliate, Freeman Spogli Institute for International Studies at Stanford University; Board Member at the British American Security Information Council; former Director of the Datayo Project at the One Earth Future Foundation, 21 April 2021; 'Meet Nuclear Analyst Tianran Xu,' *One Earth Future*, accessed 15 September 2021, https://oneearthfuture.org/es/news/open-source-nuclear-analyst-tianran-xu.

100. Arms Control Wonk, Patreon page, https://www.patreon.com/acwpodcast.

101. 'Investigating PS752 with Open-Source Intelligence,' *Arms Control Wonk*, 22 January 2020, https://podcasts.apple.com/us/podcast/investigating-ps752-with-open-source-intelligence/id872594726?i=1000463375456.

102. Aaron Stein, op. cit.

the credibility of its work should not depend on the quality of the hint itself. Because of its public and open-source nature, societal monitoring also allows states to jointly fund monitoring capabilities without investing in expensive indigenous monitoring tools like satellites. This could open up possibilities for states that have not yet engaged in monitoring for financial or technological reasons.

There is also a methodological aspect to this. Under certain conditions, collaboration can be more effective than individual action or decision-making. As such, more people investigating missile (non-)proliferation cases can lead to better outcomes, especially if you filter out those spreading disturbance and attempting sabotage.

However, as in any other field today, monitoring is prone to the spread of false or manipulative information. While open-source information can be verified, it does not need to be true in the first place. So while some actors may want to use information to generate transparency, others may want to use it to manipulate public debate. And although disinformation can be corrected, once you have been exposed to it, it is difficult to suppress its influence. The 2020 war between Armenia and Azerbaijan over Nagorno-Karabakh exemplified this, with analyses of missiles or missile strikes that were not always reliable, as they tended to relay or lend credence to official propaganda.[103] However, mitigating bad or debunked information in the monitoring context most likely does not differ much from combating disinformation and misinformation in any other field.

Finally, some information made public could become a proliferation factor or create security gaps. However, as many technological developments are based on the laws of physics, the speed of their dissemination is limited by engineering capabilities and materials.

How can HCoC harness greater transparency?

HCoC is built on the premise of transparency and on Subscribing States' initiative to broaden the spectrum of tools and activities aimed at implementing its goals. Technological development and access can aid Subscribing States in taking advantage of the room for manoeuvre offered by this missile control instrument.

How to use HCoC's room for manoeuvre to better harness transparency? Because HCoC is not limited to the existing tools to create transparency, Subscribing States can be flexible in adding new ones. For example, they can consider using the above-mentioned monitoring techniques in a more systematic way to check pre-launch notifications (PLN). In 2018, the German

103. Karine Ghazaryan, 'Pictures Of Armenian Su-30SM Show Missiles That, According To Pashinyan, Armenia Did Not Manage To Buy,' *Media.am*, 29 March 2021, https://media.am/en/verified/2021/03/29/27066/?__cf_chl_jschl_tk__=pmd_a9ce6b9e5ef75b4c0df92ae3a8c9c077a0d2e21a-1626866771-0-gqNtZGzNAjijcnBszQgO.

government shared 'an overview, based on open sources, of the number of starts of ballistic missiles, space launch vehicles and scientific rockets in comparison to the PLN communicated.'[104] This made it possible to measure the PLN implementation rate. It provided an opportunity to voice concerns about a possible 'discrepancy between the recorded launches and those pre-notified', which then opened up an opportunity to clarify definitions (ballistic missile) and terms (PLN threshold).

Think more broadly. The democratisation of technologies creates momentum to supplement governmental monitoring activities and spread their breadth and width. States can join forces in educating, setting up and financing monitoring capabilities. This could serve to strengthen regional cooperation. It would also substantiate governmental claims on military situational awareness and generate more independence from external intelligence. Establishing separate but parallel interpretation teams makes crosscheck findings possible.

Widen the geographical scope of monitoring activities. While search and monitoring based on unclassified data can help build our understanding of specific missile development cases, current efforts are limited in scope and geographical spread. North Korea, Iran and China are the main focal points, but search and monitoring should not only concentrate on a few cases; instead, it should expand throughout the international community.

To harness the full potential of available information, governments and the private sector need to consider engaging, empowering and supporting the non-governmental sector. Engagement happens only if governments accept the value-added of societal monitoring. Empowerment means entrusting non-governmental actors to monitor activities. Support can range from financing data and software procurement, to providing access to area-surveillance data and close-look data from military satellites, establishing and financing educational curricula aimed at training a strong and diverse workforce and building bridges between disciplines. Creating governmental points of contact for scientists could allow better information circulation.

Could increased transparency render HCoC useless? If information is out there and available to anybody, what is the value of sticking or subscribing to a formal mechanism that aims at increasing transparency? Can states be convinced that HCoC remains a crucial way of gaining information if they can get it by other means? Can states be convinced that the information they share is important for stability if everybody has access to it

104. 'Statement at the HCoC States Signatories Annual Meeting (The Hague Code of Conduct against Ballistic Missile Proliferation),' 3-4 June 2019, https://wien-io.diplo.de/iow-en/news/statement-hcoc/2223288 .

anyway?

First of all, we are not yet at the point where we are either able or have the capacity to analyse all available open-source information. There are still many technological and resource-related obstacles to generating full transparency. Satellites do not cover every corner of the world continuously, do not always provide optimal resolution and sometimes get blinded or blurred. Drones have limited access and can be shot down, while algorithms can be limited by a too-small amount of data to learn from. The amount of trained analysts and funding to undertake comprehensive monitoring activities all around the world is still limited. Also, while there is increased access to educational programmes that equip analysts with the know-how required to analyse data, their number and accessibility is still fairly limited, with interdisciplinary approaches requiring popularisation. This buys time for Subscribing States to think about how they would want to approach and possibly harness greater transparency in the future.

While more transparency may mean a change of focus for HCoC, it is unlikely to eliminate its raison d'être. In fact, more transparency can strengthen HCoC. While transparency can force change, it cannot act as a substitute for political will and the need for consensus-building. It can open doors but will not solve disagreements or alleviate concerns. Having the means to generate transparency does not automatically solve non-proliferation problems. For example, if evidence is found that a state conducted more missile launches than it reported, the problem is what to do with this information. What are the means to pursue clarity or demand course correction? There needs to be political will on the part of governments to act upon this evidence. And there must be platforms to discuss the evidence and reach a consensus on its meaning. HCoC offers a closed-door and safe space to create an official narrative, which constitutes a shared basis for discussion between states. It offers a platform for raising and addressing concerns about specific missile-related activities, exchanging official information and discussing non-official information. It allows states to put a collective official stamp on information. In the end, it is all about framing political processes to take advantage of transparency. □

ABOUT THE AUTHORS

Katarzyna Kubiak is a Senior Policy Fellow on nuclear and arms control policy at the European Leadership Network. Previously, she was a Transatlantic Post-Doc Fellow for International Relations and Security at the Norwegian Institute for Defence Studies (IFS), an associate at the German Institute for International and Security Affairs (SWP), a research assistant at the Institute for Peace Research and Security Policy (IFSH), a field researcher for the National Consortium for the Study of Terrorism and Responses to Terrorism (START) and a fellow in the German Bundestag. Following her PhD thesis on NATO nuclear extended deterrence her research areas include nuclear arms control, non-proliferation, disarmament, missile defence and translating what new emerging technologies means for nuclear decision-making.

Previously published

HCoC Research Papers

- Antoine Bondaz, Dan Liu and Emmanuelle Maitre, 'The HCoC and China,' *HCoC Research Paper n°8*, FRS, September 2020.
- Kolja Brockmann, 'Controlling ballistic missile proliferation—Assessing complementarity between the HCoC, MTCR and UNSCR 1540,' *HCoC Research Paper n°7*, FRS, June 2020.
- Stéphane Delory, 'Ballistic missiles and conventional strike weapons: Adapting the HCoC to address the dissemination of conventional ballistic missiles,' *HCoC Research Paper n°6*, FRS, January 2020.
- Stéphane Delory, Emmanuelle Maitre & Jean Masson, 'Opening HCoC to cruise missiles: A proposal to overcome political hurdles,' *HCoC Research Paper n°5*, FRS, February 2019.

HCoC Issue Briefs

- Emmanuelle Maitre & Sabrina Barré, 'The HCoC and Space,' *HCoC Issue Brief n°8*, FRS, September 2021.
- Emmanuelle Maitre & Lauriane Héau, 'The HCoC and the Caribbean,' *HCoC Issue Brief n°7*, FRS, May 2020.
- Emmanuelle Maitre & Lauriane Héau, 'The HCoC and Latin America,' *HCoC Issue Brief n°6*, FRS, April 2021.
- Emmanuelle Maitre & Lauriane Héau, 'The HCoC and South Asia,' *HCoC Issue Brief n° 5*, FRS, March 2021.
- Eloise Watson, 'From Small Arms to WMD Arms Control: Linkages and Shared Benefits,' *HCoC Issue Brief n°5*, FRS, February 2021.
- Emmanuelle Maitre & Lauriane Héau, 'The HCoC and African States,' *HCoC Issue Brief n°4*, FRS, December 2020.
- Emmanuelle Maitre & Lauriane Héau, 'Why Does the HCoC Focus on Ballistic Missiles?' *HCoC Issue Brief n°3*, FRS, November 2020.
- Emmanuelle Maitre & Lauriane Héau, 'The HCoC: A Small Yet Key Tool Against Ballistic Missile Proliferation,' *HCoC Issue Brief n°2*, FRS, October 2020.
- Emmanuelle Maitre & Lauriane Héau, 'Current Trends in Ballistic Missile Proliferation,' *HCoC Issue Brief n°1*, FRS, September 2020.

Papers can be downloaded on the https://www.nonproliferation.eu/hcoc/ website.

THE HAGUE CODE OF CONDUCT

The objective of the HCoC is to prevent and curb the proliferation of ballistic missiles systems capable of delivering weapons of mass destruction and related technologies. Although non-binding, the Code is the only universal instrument addressing this issue today. Multilateral instrument of political nature, it proposes a set of transparency and confidence-building measures. Subscribing States are committed not to proliferate ballistic missiles and to exercise the maximum degree of restraint possible regarding the development, the testing and the deployment of these systems.

The Fondation pour la Recherche Stratégique, with the support of the Council of the European Union, has been implementing activities which aim at promoting the implementation of the Code, contributing to its universal subscription, and offering a platform for conducting discussions on how to further enhance multilateral efforts against missile proliferation.

CONTACTS

Service européen pour l'action extérieure (SEAE)
EEAS Building, Rond-Point Schuman 9A
1040 Bruxelles, Belgique
https://eeas.europa.eu

Fondation pour la Recherche Stratégique
4 bis rue des Pâtures
75016 Paris, France
www.frstrategie.org

USEFUL LINKS

www.hcoc.at

www.nonproliferation.eu/hcoc

This project is financed by the European Union

This project is implemented by the Fondation pour la Recherche Stratégique