Nuclear submarines in Tromsø
An overview of available information on risks and preparedness

Version 31 August 2020

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1. Background

From early 2021 onwards, the Norwegian port of Tønsnes (Grøtsund industry and offshore base), owned by the Tromsø municipality, is set to receive nuclear-powered submarines from the country's NATO allies (in practice from the US, but later possibly from the UK and France as well) for visits lasting several days, four to five times per year, mainly for crew changes and non-nuclear maintenance purposes.

The port of Tønsnes is located about 8 km (as the crow flies) north of the main campus of the Arctic University of Norway (UiT) and the University Hospital of Northern Norway (UNN), and about 12 km north of the centre of Tromsø.

This discussion paper is a holistic, non-sensitive and reader-friendly overview of this case, prepared in August 2020. Besides the publicly available information, the editor has consulted some of the main stakeholders involved in the process of this planned activity, such as representatives of the Norwegian Radiation and Nuclear Safety Authority (DSA, *Direktoratet for strålevern og atomsikkerhet*),[1] the County Governor (*Fylkesmannen*) of Troms and Finnmark,[2] the Municipality of Tromsø,[3] and UNN.[4]

This introductory section provides some background information on the case. In the subsequent sections, the paper draws a concise picture of the risk assessment information in particular, as well as preparedness plans regarding the current case, particularly from the perspective of a nuclear or radiological event[5] or any other unwanted event that could have a bearing on such a situation. The paper concludes with some remarks summarising the identified challenges that might warrant further attention.

What is a nuclear-powered submarine?

The first nuclear-powered submarine, USS Nautilus, was launched in 1955. The innovative use of a nuclear reactor as a power supply revolutionised the operational capacity of submarines. Nuclear power allowed submarines to run for about twenty years without needing to refuel, unlike the diesel-engine-powered submarines that had to dock for fuel. Nuclear propulsion increased the mission time, range and speed of submarines considerably. It also increased the time that the vessels could remain submerged because, unlike diesel-engine-powered craft, air intake is not required.[6]

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[1] Consultation with the DSA 10.8.2020 (Seksjon nordområdene, Tromsø).
[2] Consultation with the County Governor of Troms and Finnmark 21.8.2020.
[3] Consultation with the Municipality of Tromsø 25.8.2020.
[4] Consultation with UNN 24.8.2020.
[5] Even in the International Atomic Energy Agency (IAEA) documents, as the agency acknowledges, the terminology is not consistent, varying in terms of purpose and context. However, following the *IAEA Safety Glossary*, we use the word 'event' here to refer to "any occurrence unintended by the operator, including operating error, equipment failure or other mishap, and deliberate action on the part of others, the consequences or potential consequences of which are not negligible from the point of view of protection and safety". An event comprises both 'incidents' and more severe 'accidents', discussed in this overview in more detail below in terms of the so-called INES Scale. While the terms 'nuclear' and 'radiation/radiological' are often used interchangeably and with a variety of meanings related to the context, they have certain impact scope-related, physical and definitional differences. Not delving into these differences more than needed, we use the term 'nuclear *or* radiological event' here, and sometimes 'nuclear *and* radiological event' to refer to what are classified as such on the INES Scale. We use the term 'radioactive' to refer to such material that emits radiation. Apart from direct citations, we sometimes have to adhere to the vocabulary of the documents referred to in this paper, however. IAEA (n.d.). *IAEA Safety Glossary*. International Atomic Energy Glossary. [Online]: Available at: https://kos.iaea.org/iaea-safety-glossary.html.
[6] Ragheb, M. (2010). *Nuclear Naval Propulsion*. [Online] Available at: https://www.intechopen.com/books/nuclear-power-deployment-operation-and-sustainability/nuclear-naval-propulsion.

It is estimated that there are currently around 150 nuclear-powered submarines in use, of which the US has 70, Russia 40, China 19, the UK 10, France 9, and India 3. As some may have two reactors, there might be around 200 nuclear reactors in submarines at sea, while the total accumulated number of reactors from the 1950s would be around 700.[7]

Nuclear reactors

According to the classification currently adopted by the International Atomic Energy Agency (IAEA), the electric power of small reactors is less than 300 MW, while medium-sized reactors have electric power in the 300 to 700 MW range, and typical nuclear power plants (NPP) are within the 600 to 1250 MW range.[8]

In all likelihood, the most typical submarine that would visit Tønsnes, the US Navy *Los Angeles*-class nuclear-powered submarine, has a 165 MW GE S6G reactor driving two 26 MW steam turbines. The *Virginia*-class submarine, which might also visit the port, has an S9G reactor of about 150 MW driving a 30 MW pump-jet propulsion system. Both have a refuelling interval of about 30 years, which in practice covers their whole service life.[9] In our case, we are therefore talking about small-size reactors.

Most nuclear submarine reactors and all US reactors use pressurised water reactors, understood as a reactor type with an established safety history and well-understood operational behaviour and risks. The basic design of this type of submarine reactor is relatively simple. When the uranium atoms are split in the vessel's sealed nuclear reactor(s), the fission process produces radiation but also results in heat that is led to the primary circuit, which contains water that is maintained under high pressure so that it does not boil. This heated water in the primary circuit is routed through a steam generator that is part of a separate secondary circuit. The water in the secondary circuit is converted into steam, which is then led to the turbine(s) that is (are) connected to a generator(s). These turbine-powered generators supply the vessel with electricity and power its propellers. The steam leaving the turbine(s) is converted back into water, the water is directed back through the system, and the process starts again. The two water circuits are duly kept separate the whole time.[10] Some submarines may also have diesel engines and batteries for added power redundancy.

Unlike commercial NPPs, most or all of the nuclear-powered submarines currently in use, particularly from the US and the UK, are fuelled by highly enriched uranium (HEU).[11] There are, however, plans to switch from this weapons-grade uranium fuel to low-enriched uranium (LEU) by 2040. France and China are already using LEU fuel in their submarines, while Russia and India use medium-enriched uranium. Changing from HEU to LEU in the US-manufactured submarines would, however, lead to shorter periods of refuelling and/or require some redesigning of the submarines. For this reason, the largest remaining non-weapons use of HEU is as fuel for naval propulsion reactors.

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[7] E.g. the World Nuclear Association (n.d.). *Nuclear-Powered Ships* (Updated May 2020). [Online] Available at: https://www.world-nuclear.org/information-library/non-power-nuclear-applications/transport/nuclear-powered-ships.aspx.

[8] IAEA (2007). *Status of Small Reactor Designs Without On-Site Refuelling*. IAEA-TECDOC-1536. Vienna: International Atomic Energy Agency. [Online] Available at: https://www-pub.iaea.org/MTCD/Publications/PDF/te_1536_web.pdf.

[9] E.g. the World Nuclear Association (n.d.), op. cit.

[10] For more information, sometimes with illustrative pictures of the nuclear reactor design of the type in question, see e.g. FAS (n.d.). *Military analysis network.* [Online] Available at: https://fas.org/man/dod-101/sys/ship/eng/reactor.html; Energy education (n.d.). *Pressurized water reactor.* [Online] Available at: https://energyeducation.ca/encyclopedia/Pressurized_water_reactor; EPA (n.d.). *Nuclear Submarines and Aircraft Carriers.* United States Environmental Protection Agency. [Online] Available at: https://www.epa.gov/radtown/nuclear-submarines-and-aircraft-carriers.

[11] E.g. the World Nuclear Association (n.d.), op. cit.

The concern about HEU in submarines is not public safety hazard-related, however. The issue is that non-nuclear-weapon states interested in acquiring or developing nuclear-powered submarines could use the US example to justify producing and stockpiling weapon-usable HEU. This, in turn, would destabilise the non-proliferation regime (Treaty on the Non-Proliferation of Nuclear Weapons, NPT), creating a so-called ‘submarine loophole’ in the NPT.[12]

Nuclear weapons

Most nuclear-powered submarines do not carry, and are not even designed to carry nuclear missiles. In the Tromsø municipality background information on receiving such vessels, dated March 2019, it is stated that: “Reactor-powered vessels shall not carry nuclear weapons on board, as stipulated in the Bratteli Doctrine of October 1975”.[13] This refers to the then prime minister, Trygve Bratteli, who formulated the issue as follows: “Our assumption, as to foreign ships visit, has been and is that nuclear weapons are not carried on board. Norwegian authorities anticipate that allied, as well as other nuclear powers, respect this assumption”. This doctrine was sometimes subsequently repeated but mostly omitted in terms of any formal controls or demands as it evoked strong reactions from the allied nuclear powers.[14]

Some kind of balance was established in the so-called ‘neither confirming, nor denying’ (NCND) principle that has been applied by the US in particular.[15] In essence, this practice is still followed. In connection to the 2018 NATO Trident Juncture exercise, with the participation of a US aircraft carrier basically capable of carrying nuclear weapons, the US representative did not issue a clear-cut denial of the absence of nuclear weapons. However, the representative of the Norwegian Ministry of Defence confirmed that they expect Norway’s allied countries to follow the non-nuclear-weapon principle.[16]

As for the submarines, the presence of nuclear weapons is rather easy to monitor as only certain types of submarines are designed for that purpose. The treaty data and other data collected in 2018 and 2019 show[17] that the US Navy has around 240 submarine-launched ballistic missiles (so-called SLBM), corresponding to 10 ballistic missile submarines fully loaded, and two others in various stages of missile loading or offloading. For these missiles, the US has a total of fourteen *Ohio*-class submarines that are able to carry SLBMs. Six are operating in the Atlantic (with the other eight in the Pacific). Since 2011, the US Navy has not had any nuclear submarine-launched cruise missiles (so-called TLAM/N).

[12] E.g. Von Hippel, F. (2019a). Mitigating the Threat of Nuclear-Weapon Proliferation via Nuclear-Submarine Programs. *Journal for Peace and Nuclear Disarmament*, 2:1, pp. 133-150; Von Hippel, F.N. (2019b). *U.S. shift away from HEU-fueled naval nuclear reactors could begin in the 2040s. International Panel on Fissile Materials.* [Online] Available at: http://fissilematerials.org/blog/2019/06/us_shift_away_from_heu-fu.html; Moore, G.M., Banuelos, C.A. and Gray, T.T. (2016). *Replacing Highly Enriched Uranium in Naval Reactors.* NTI Paper, March. The Nuclear Threat Initiative. [Online] Available at: https://media.nti.org/pdfs/Replacing_HEU_in_Naval_Reactors_Report_FINAL.pdf.

[13] Tromsø kommune (2019). *Orientering om mulig bruk av Tøsnes havn till mottak av reaktordrevne fartøy*. Ref. 19/2210/16204/19X20. 13.03.2020.

[14] Børresen, J. (2011). Alliance Naval Strategies and Norway in the Final Years of the Cold War. *Naval War College Review*, Volume 64, Number 2, Spring, Article 7, pp. 98-115, here p. 103. [Online] Available at: https://digital-commons.usnwc.edu/nwc-review/vol64/iss2/7.

[15] E.g. Kristensen, H.M. (2006). *The Neither Confirm Nor Deny Policy: Nuclear Diplomacy At Work*. A Working Paper. [Online] Available at: http://www.nukestrat.com/pubs/NCND.pdf.

[16] Not confirmed if the US aircraft carrier carries nukes. *Norway Today*, 26.11.2018. [Online] Available at: https://norwaytoday.info/news/not-confirmed-us-aircraft-carrier-free-nuclear-weapons/.

[17] Kristensen, H.M. and Korda, M. (2019). United States nuclear forces, 2019. *Journal Bulletin of the Atomic Scientists*, Volume 75, Issue 3, pp. 122-134; Kristensen H.M and Norris, R.S. (2018). United States nuclear forces, 2018. *Journal Bulletin of the Atomic Scientists*, Volume 74, Issue 2, pp. 120-131.

According to the Norwegian DSA,[18] they have been informed about the exact US nuclear-powered submarine class and types that are expected to visit Tromsø. None of these are of the *Ohio*-class, with the ability to carry nuclear missiles. Instead, those submarines set to visit Tromsø are so-called attack submarines. In times of warfare, these types of submarines would be used to hunt down and destroy enemy submarines or other vessels.[19]

Decision points and reactions

The only port in Norway currently designated to receive nuclear-powered submarines is Haakonsvern near Bergen, which is however a full-fledged military naval base with its own safety and security arrangements. Since early 2014, the geopolitical tension between NATO and Russia has also been reflected in the Arctic military activity. This geopolitical change has duly resulted in the need to have a port for allied nuclear-powered submarines in the north of Norway as well.

A national-level decision?

The Armed Forces used to have a naval military base in Olavsvern in Ramfjørd, approximately twenty km from the town of Tromsø. It was closed in 2009 and sold to a private entrepreneur in 2013. Probably due to the increased geopolitical tension in general, but also in view of the information that a Russian research vessel had been using the port in Olavsvern for purposes that were visibly questioned by the international media, a company close to the Armed Forces reinstated the base in 2015 with the latter's majority ownership.[20]

Although Olavsvern was previously used by visiting allied nuclear-powered submarines, the base was apparently no longer considered adequate or suitable for navigation by the alliance's submarines, or for other needs. Hence, the Armed Forces Joint Headquarters (FOH) looked into other options and opted for the Tønsnes port instead.

It is not easy, however, to find a specific national government-level decision on why the submarines should be received by a civilian port in Tromsø. In an official Tromsø municipality background document from 19 March 2019, provided 'for orientation' for the municipal bodies concerned, the formal origin of the issue is reported as follows:

> "The decision to study Tønsnes as a port for receiving reactor-powered vessels originates from the national level, in light of Norway's membership of NATO and an obligation to provide support for Allied Forces. The assignment has been given by the Defence Staff to the Armed Forces' Operational Headquarters so that Norway will be able to provide host country support for such vessels. The regulations behind the current decision were laid down by the Royal Decree of 2 May 1997 on access to and residence in Norwegian territory under peace conditions for foreign military and civilian state vessels. The Armed Forces have considered the port of Tønsnes to be the most appropriate port for receiving reactor-powered vessels in the north, and have carried out a risk and vulnerability analysis for this purpose."[21]

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[18] Consultation with the DSA, 10.8.2020 (*Seksjon nordområdene*, Tromsø).

[19] For illustrative pictures of submarines with and without nuclear weapons, see for instance: https://whatisnuclear.com/propulsion.html.

[20] Solgte ubåtbase til privatperson - nå gjenvinner rederi tilknyttet Forsvaret kontrollen. *Aftenposten*, 3.9.2019. [Online] Available at: https://www.aftenposten.no/norge/i/Joqdn7/solgte-ubaatbase-til-privatperson-naa-gjenvinner-rederi-tilknyttet-for.

[21] Tromsø kommune (2019), op. cit.; Tromsø kommunstyret (2019). *Saksprotokoll – Orientering om mulig bruk av Tøsnes havn till mottak av reaktordrevne fartøy.* Arkivsak 19/2210. Sak 39/19. 27.03.2019.

If we look at the 1997 Royal Decree referred to above,[22] there are some general regulations about how "foreign military and civilian state vessels" will be allowed to enter Norwegian territorial waters, using the proper diplomatic channels and following the Norwegian regulations when in those waters. However, one cannot find any detailed legal basis for why and how an allied nuclear-powered submarine should be given the right to regularly use a civilian municipal port on the basis of this particular piece of legislation. The closest reference to our case can be found in §16, where it is stated that: "Foreign military and civilian state vessels shall use the anchor, mooring or landing sites instructed by the Norwegian authorities". In that particular legislative document, the term 'Norwegian authorities' (*norske myndigheter*) refers to the Ministry of Defence or the authority approved by the Ministry.

In more specific terms, the main civilian stakeholders consulted for the current overview were not aware of any national-level decision concerning by whom, when and why Tønsnes would have been chosen for the current purpose. Nor were they informed about any related feasibility or similar studies comparing different alternatives.

The port legislation

In order to justify the civilian port of Tønsnes being visited by allied nuclear-powered submarines, some official statements issued in the newspapers,[23] as well as justifications provided in communication with most stakeholders of the current case, refer to Norway's general responsibilities as a NATO member as well as the legal obligations following the national legislation on the ports. This concerns §27 in particular, dealing with the so-called 'duty to receive'. The part in the paragraph in question reads as follows:

> "Owners and operators of ports and port terminals have a duty to receive vessels. The obligation applies as far as the capacity in the port so dictates, and as long as the vessel is not unreasonably displaced for the owner's own use of the port or others who are guaranteed the right to use the port. The obligation does not apply if receiving the vessel may involve a risk to the environment or to safety."[24]

Referring mainly to the last sentence in the quoted paragraph, it appears that any obligation by the municipality or the port concerned to receive allied nuclear-powered vessels is ambiguous, at least on the basis of this particular law.

While it appears that the Tromsø municipality in its internal legal analysis has come to this conclusion, the Norwegian Minister of Defence thinks differently. According to him, the legislation related to the ports obliges "every owner and operator of ports that operate port services in general to receive vessels that wish to visit the port to the extent that there is spare capacity".[25]

Tromsø municipality's position

The issue has been dealt with in the Tromsø municipal bodies and particularly in the Municipal Council from early 2019 onwards at least. On 27 March 2019, the Municipal Council voted in support

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[22] Kungliga resolusjonen 2.5.1997. *Forskrift om adgang til og opphold på norsk territorium under fredsforhold for fremmede militære og sivile statsfartøyer*. FOR-1997-05-02-396. Forsvarsdepartementet [Online] Available at: https://lovdata.no/dokument/SF/forskrift/1997-05-02-396.

[23] E.g. Tromsø kommune tvunget til å ta imot atomubåter fra Nato. *Försvarets Forum*, 7.5.2020 [Online] Available at: https://www.highnorthnews.com/nb/tromso-klargjor-atomubat-havn-professor-advarer-mot-en-overhengende-krigsfare.

[24] *Lov om havner og farvann (havne- og farvannsloven)* §27. Lovdata. [Online] Available at: https://lovdata.no/dokument/NL/lov/2019-06-21-70/KAPITTEL_3#§27.

[25] Bakke-Jensen, F. (2020a). Det er Tromsø kommunes ansvar å lage beredskapsplaner. Hva har Olsen bidratt med? *Nordlys/Nordnorsk Debatt* 16.7.2020. [Online] Available at: https://nordnorskdebatt.no/article/tilsvar.

of the position that the nuclear-powered vessels were not welcome to dock in the municipality-owned Tøsnes port, by a majority of 25 to 17. Following the protocol, the municipality was concerned about the obstacles that this activity would pose for other possible uses and the value production of the area in question. The Council was also of the opinion that should the state nonetheless impose its will and allow the port to be used in part by the military, the state should reimburse any costs and compensate any future loss of (alternative) income. Most notably, safety and security issues were not mentioned in the position protocol of the Municipal Council. [26]

While the above decision is the current baseline as regards the municipality's elected decision-makers' opinion, the issue is still open for discussion at this level of decision-making. Probably, a new vote will be taken in autumn 2020. This vote will be based on updated information, most notably the then completed risk assessments and preparedness plans.

With regard to the local decision-makers' positions, one should also take into account that three smaller municipalities are involved insomuch as they are vulnerable to the potential risks (either during transit or while at berth) of a visiting allied nuclear-powered submarine, namely the Karlsøy, Lyngen and Skjervøy municipalities.

The port's decision

The municipal port company that owns Tønsnes port, namely Tromsø Havn KF, is cited in the Tromsø municipality's background paper from March 2019. In that statement, the company mainly draws a positive picture of the port's multiple opportunities in general. When it comes to receiving nuclear reactor-powered submarines, the statement includes only one condition, namely that there should be a preparedness plan approved by the competent Radiation and Nuclear Safety Authority (DSA) before the first submarine visits the port.[27]

According to a local newspaper in June 2020, however, the port company had already by that time signed the contract with the US Navy.[28] More detailed information about this contract does not seem to be publicly available, and it is difficult to locate someone who has seen the agreement. It appears that the agreement and its contents, should such an agreement exist, remain classified as far as most stakeholders involved in the current case are concerned.

Impact assessments

From the public sources, it is not clear whether the planned new type of use of the previously purely civilian Tønsnes port would or should warrant any economic, environmental and/or social impact assessments. After all, it is not a question of a permanent building or storage construction. Nevertheless, should one consider the respective impact assessment regulation, this new use could be understood as an initiative to change the existing land-use plan by adding risks. In this case the municipality is the competent authority for re-assessing the municipal plans.

Following the impact assessment regulation, normally the basic legal criterion for such an assessment is whether a plan or initiative may have a significant impact on the environment or society in terms of "risk of serious accidents and/or disasters" and "consequences for the health of the population, for example, due to water or air pollution".[29] While the visiting nuclear-powered submarines have not

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[26] Tromsø kommune (2019), op. cit.; Tromsø kommunstyret (2019), op. cit.

[27] Tromsø kommune (2019), op. cit., p. 3.

[28] Atomubåter til Tønsnes. *Nordlys/Nordnorsk debatt* 16.7.2020. [Online] Available at: https://nordnorskdebatt.no/article/atomubater-tonsnes.

[29] Ministry of Local Government and Modernisation/Ministry of Climate and Environment (2017). *Regulations on impact assessments*. Chapter 3, Section 10. [Online] Available at: https://www.regjeringen.no/en/dokumenter/regulations-on-impact-assessments/id2573435/; Ministry of

been considered in the respective legislation as a reference case, the legislation nonetheless "always" demands an impact assessment for "nuclear power plants and other core reactors".[30] Should this be applied to using the area for regular 'visiting nuclear reactors' is a matter of legal interpretation. If so, the impact assessment regulation and the respective legal structure and process should be followed.

Public reaction and consultation

According to newspapers in February 2020, the Armed Forces FOH reported that the port could be prepared to receive the first submarines even before mid-2020, as physical restructuring and preparedness plans were ready, including exercises and public consultations.[31] This seemed somewhat overoptimistic. The reason most often cited for any setback is the Covid-19 crisis,[32] rather than the delay in preparing the related risk assessments and preparedness plans and measures.

In July 2020, during a visit to Tromsø, Norway's Minister of Defence stated that certain preconditions would have to be in place, namely an approved contingency plan that had been practised, and the stipulation that the various actors knew their roles and responsibilities. "Until this is in place, the arrival of reactor-powered vessels will not take place."[33] Should this be the case in practice, it seems that any allied nuclear-powered submarine visits to Tønsnes would not begin until early 2021 at the earliest.

The issue has attracted some heated local publicity, predominantly critical and generated by local politicians mostly in local newspapers and opinion columns.[34] The general public have not participated in the discussion, nor been invited to do so in a visible way. Should the question concern a normal environmental or social impact assessment, the regulation would demand the local and regional environmental authorities, NGOs and other relevant organisations, as well as the general public to participate in the process as early as the preparatory phases. Furthermore, once the assessment report is drawn up, there would be a need for further consultation and a public meeting with those who may be affected by the respective project or initiative.

Environment (n.d.). *Environmental Impact Assessment*. [Online] Available at: https://www.regjeringen.no/globalassets/upload/kilde/md/bro/2003/0001/ddd/pdfv/182783-t-1428_e.pdf.

[30] *ANNEX I. Plans under the Planning and Building Act and initiatives under other legislation that shall always have a planning programme or notification and an impact assessment, 2b.* [Online] Available at: https://www.regjeringen.no/contentassets/0b68c8007fd640ca8af67df07ec5b03d/annex-i.pdf.

[31] Forsvaret bekrefter: Første mottak av reaktor-ubåt til Tromsø før sommeren. *High North News*, 28.2.2020. [Online] Available at: https://www.highnorthnews.com/nb/forsvaret-bekrefter-forste-mottak-av-reaktor-ubat-til-tromso-sommeren.

[32] E.g. Tvunget til å ta imot atomubåter ved kommunal havn i Tromsø. *NRK*, 27.6.2020. [Online] Available at: https://www.nrk.no/tromsogfinnmark/atomubater-i-kommunal-havn-i-troms-1.15030928.

[33] Bakke-Jensen, F. (2020b). Før godkjent beredskap er på plass, vil ikke anløp av reaktordrevne fartøyer finne sted. *Nordlys/Nordnorsk Debatt* 15.7.2020. [Online] Available at: https://nordnorskdebatt.no/article/godkjent-beredskap-pa-plass-vil.

[34] Olsen, J.I. (2019). Er det best at folk ikke får vite noe om risiko og beredskap ved anløp av atomubåter i Tromsø? Åpent brev til fylkesmannen i Troms og Finnmark. *Nordlys/Nordnorsk Debatt* 28.11.2019. [Online] Available at: https://nordnorskdebatt.no/article/atom; Olsen, J.I. (2020). Forsvarsministeren serverer bortforklaringer. *Nordlys/Nordnorsk Debatt* 15.7.2020. [Online] Available at: https://nordnorskdebatt.no/article/forsvarsministeren-serverer; Atomubåter til Tønsnes. *Nordlys/Nordnorsk debatt* 16.7.2020. [Online] Available at: https://nordnorskdebatt.no/article/atomubater-tonsnes. For an opinion defending the visits of the allied submarines, see: Echroll, L. (2020). Atomfartøyer i Tromsø er ikke noe nytt. *ITromso*, 16.8.2020. [Online] Available at: https://www.itromso.no/meninger/2020/08/16/Atomfart%C3%B8yer-i-Troms%C3%B8-er-ikke-noe-nytt-22489117.ece. For the ongoing debate on the issue's geopolitical consequences for Tromsø, see: Trellevik, A. (2020). Slik blir Tromsø rammet av det elendige forholdet mellom USA og Russland. *Nordlys*, 26.8.2020. [Online] Available at: https://www.nordlys.no/slik-blir-tromso-rammet-av-det-elendige-forholdet-mellom-usa-og-russland/f/5-34-1343244?access=granted&fbclid=IwAR2U2nJLcoWokUyt0hSc3HrmkrHN_VF5ERNKVChq6PBTPFamWZC-y_d98tQ.

In our case, when it comes to the relevant authorities, specialised agencies and expert stakeholders, one can conclude that there have been events where the issue has been discussed, for instance from the perspective of risk scenarios.[35] As regards any broader communication with the public, no proper consultation has been organised during the process as of August 2020. In its background paper from March 2019, Tromsø municipality provided information about the planned public consultation on the issue.

> “A joint communication meeting is planned together with the actors involved, as well as an information session for the population in the affected area around the Port of Tønsnes. The County Governor of Troms and Finnmark will coordinate the joint communication meeting, and assist Tromsø municipality in conducting the information session for the population.”[36]

Such a public consultation has not been organised but is now planned to take place in autumn 2020. The reason why it could not take place earlier concerns the fact that the respective authorities wanted to be able to present the issue based on well-prepared and solid risk assessments and preparedness plans, which have not yet been completed.[37]

2. Overview of relevant risk information and assessments

Risk assessment is a highly developed field, with its own standardised vocabulary and a wide set of quantitative, semi-quantitative and qualitative methodologies.[38] It consists of defining the scope and context, identifying the risks, choosing the most relevant risks for detailed analysis,[39] and evaluating the results in order to see which of the risks need further treatment.[40] This treatment entails implementing strategies to prevent the risk from materialising, typically minimising its likelihood and mitigating its consequences. Should all of this be done properly, with due communication and consultation with relevant stakeholders, and planned as an iterative process taking into account the changing risks and conditions, it would be called risk management.

Most risk-related information concerning regular visits by allied nuclear-powered submarines to Tromsø is either classified or not yet available from open sources. Furthermore, to date, most authorities and stakeholders concerned have not yet prepared their risk assessments. As a result, there is no shared, jointly discussed and agreed-upon picture about the risks related to this planned activity. Let us however take a look at the kind of risk information we may find concerning, or relevant to our case.

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[35] E.g. in June 2019, the DSA and the County Governor organised such a workshop in Tromsø, with participants from the respective municipalities, the police, UNN, the Norwegian Food Safety Authority, the Directorate of Fisheries, and UiT. *Utfordringer, håndtering og oppfølging av en atomhendelse. Seminar for lokale myndigheter, kommuner, interesseorganisasjoner og andre berørte parter.* Framsenteret, Tromsø 13.6. 2019.

[36] Tromsø kommune (2019), op. cit.

[37] Consultation with the County Governor 21.8.2020 and with the Municipality of Tromsø on 25.8.2020.

[38] ISO (2018). *Risk management – Guidelines*. ISO 31000:2018; ISO/IEC (2019). *Risk management — Risk assessment techniques*. Edition 2.0. IEC 31010.

[39] In basic risk analysis, one typically assumes that ‘risk’ is the combined linear effect of the likelihood/probability and the impact/consequences of an unwanted event. Risk is sometimes expressed as the combined nonlinear effect of vulnerability and exposure instead, when one emphasises that the hazard consequence is dependent on the probability, or the probability is dependent on the consequence. As risk analyses are always uncertain, it is sometimes useful to openly express the degree of uncertainty in quantitative or qualitative terms.

[40] While high risks should always be treated and low risks are usually not worth treating, a body of analysed risks usually turns out to be such where one has to use different cost-benefit or other approaches and calculations to determine whether a risk should be tolerated, or whether further efforts and investments for its treatment are needed and justified.

Generic classification of nuclear and radiological events and facilities

The IAEA defines nuclear and radiological events on the so-called INES Scale according to seven (or actually eight) levels.[41] Below the scale is 0, which refers to events known as 'deviations', which have no safety significance. Levels 1 to 3 are called 'incidents' and include 'anomaly', 'incident' and 'serious incident' respectively. Levels 4 to 7 are called 'accidents' and include 'accident with local consequences', 'accident with wider consequences', 'serious accident' and 'major accident' respectively. The scale is designed so that the severity of an event is about ten times greater for each increase in level on the scale.

Looking at the available history of nuclear and radiation events related to nuclear-powered submarines, one can find in public sources at least one level 5 accident – the explosion of a Soviet nuclear submarine reactor in the early Cold War era, creating an 'accident with local consequences'. This can be considered a worst-case scenario, very unlikely today, especially in the context of the current case. A lower event would remain a level 4 'accident', which is defined as a minor release of radioactive material. While it would include at least one on-site death from radiation, for the environment and the population in general it would not demand countermeasures other than local food controls. Level 3 would constitute a 'serious incident', defined as exposure in excess of ten times the statutory annual limit for workers on site, with non-lethal deterministic health effects from radiation for the contaminated workers, but with a low probability of significant public exposure outside the facility. A less severe level 2 'incident' would mean exposure of a worker in excess of the statutory annual limits, and significant contamination within the facility. Level 1 would be considered an 'anomaly', defined as a minor problem with safety components.

Should we follow the IAEA classification of facilities in terms of the necessary emergency preparedness instead, nuclear-powered submarines should be regarded as Category II facilities. In these types of facilities, it is postulated that on-site events "could give rise to doses to people off the site that would warrant urgent protective actions or early protective actions and other response actions to achieve the goals of emergency response in accordance with international standards". However, it is noteworthy that, unlike in more risky Category I facilities in terms of *consequences* (e.g. nuclear power plants, NPPs), such Category II on-site events would *not* give rise to so-called severe 'deterministic effects' off-site. According to this categorisation, nuclear-driven submarines could *not* result in fatal or life-threatening consequences *outside the facility* (submarine), or in permanent injury that reduces quality of life.[42]

The US Navy on a 'highly unlikely event'

Historically, according to available lists of serious incidents in nuclear-powered vessels, the Soviet/Russian nuclear-powered submarines appear to predominate overwhelmingly, while NATO vessels have experienced very few unwanted safety events.[43] Indeed, the World Nuclear Association claims that (including both nuclear-powered aircraft carrier ships and submarines) the US Navy "has accumulated over 6200 reactor-years of accident-free experience involving 526 nuclear reactor cores over the course of 240 million kilometres, without a single radiological incident".[44]

The US Navy itself explains this good reactor-safety record as follows:

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[41] IAEA/OECD (n.d.). *INES. The international nuclear and radiological event scale.* International Atomic Energy Agency (IAEA) and Nuclear Energy Agency (NEA), Organisation for Economic Co-operation and Development (OECD). [Online] Available at: https://www.iaea.org/sites/default/files/ines.pdf.

[42] IAEA (2015). *Preparedness and Response for a Nuclear or Radiological Emergency. General Safety Requirements. No. GSR Part 7*. Vienna: International Atomic Energy Agency, here pp. 13, 80. [Online] Available at: https://www-pub.iaea.org/MTCD/Publications/PDF/P_1708_web.pdf.

[43] Oelgaard, P.L. (1996). *Accidents in Nuclear Ships.* Rise National Laboratory. Roskilde: Technical University of Denmark. [Online] Available at: https://inis.iaea.org/search/search.aspx?orig_q=RN:28026137.

[44] E.g. the World Nuclear Association (n.d.), op. cit.

> "The robust and redundant design, relatively low power operation history particularly in port (typically shut down), and very strict control of radioactive waste all contribute to the fact that there has never been a reactor accident nor any release of radioactivity that has had an adverse effect on human health, marine life, or the quality of the environment throughout the entire history of the U.S. Naval Nuclear Propulsion Program."[45]

Even in the academic engineering literature, when compared to the more innovative but less safety-focused traditional Soviet approach to reactor design, the more conservative approach adopted by the US has been appreciated.[46] It was argued that the US nuclear-powered submarine development, based on a stable design that could be developed when needed without redesigning the basic functions, proved to be the winning solution in terms of reliability.

The US Navy does not publish risk assessments about its nuclear-powered submarine safety and security. Even less material has been issued by the US Navy in relation to the current case of its submarines arriving at the port of Tønsnes. This secrecy concerns not only the general public but also cooperation partners. All of the Norwegian stakeholders, including the Armed Forces FOH, acknowledge that any details concerning potential 'incident factors' in the allied nuclear-powered submarines are considered sensitive military secrets by the flag states, and are therefore not shared with the host country or port.

However, one can find some generic but applicable descriptions by the US Navy about the 'highly unlikely event' of a radiological leakage from a US nuclear-powered vessel when in a foreign port. According to the US Navy factsheet on nuclear-powered warship safety,[47] it is argued that their reactors are better designed and equipped in terms of safety than commercial civilian reactors. This is because the former are designed to survive wartime attack, especially focusing on damage control capacities and the ability to continue to fight while protecting their crews against hazards. Furthermore, the submarine reactors are based on conservative safety thinking, including several layers of safeguards and barriers to keep radioactivity inside the ship. The unlikelihood of any nuclear or radiological event is particularly due to the reactor's 'four barriers':

> "To get into the environment, fission products would have to pass through each of the four barriers: the fuel [which is in solid metal form designed for shocks being ten times the shock used for designing commercial NPPs], the all-welded reactor primary system, the reactor compartment, and the ship's hull. Also, it would require that all reactor safety systems and their back-ups malfunction. Further, it would require that the fully trained and very capable crew could not react to and control the situation. If all of these abnormalities took place simultaneously in a highly unlikely accident scenario, then a U.S. NPW [nuclear-powered warship] could potentially release fission products to the environment. In other words, such an accident would be possible only in a very unrealistic situation of multifold and simultaneous errors and malfunctions."[48]

While the above is undoubtedly so, from a balanced point of view one should note that all major nuclear reactor accidents have been traced back to similar, unrealistic conjunctures of unrelated events. Therefore, the historical probability of nuclear reactor accidents seems to be significantly higher if

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[45] The document in question is related to nuclear-powered US vessels visiting Japan. *Fact Sheet on U.S. Nuclear Powered Warship (NPW) Safety* (n.d.). [Online] Available at: https://www.mofa.go.jp/region/n-america/us/security/fact0604.pdf, p. 5.

[46] Bierly III, P.E., Gallagher, S. and Spender, J.C. (2008). Innovation and Learning in High-Reliability Organizations: A Case Study of United States and Russian Nuclear Attack Submarines, 1970–2000. *IEEE Transactions on Engineering Management*, Vol. 55, No. 3, August, pp. 393-408.

[47] *Fact Sheet on U.S. Nuclear Powered Warship (NPW) Safety* (n.d.) op. cit.

[48] *Fact Sheet on U.S. Nuclear Powered Warship (NPW) Safety* (n.d), op. cit., p. 8.

based on materialised INES-Scale cases compared to relying on theoretical reactor malfunction-risk calculations, where the probability is always estimated as minimal.[49]

However, it can be confirmed that based on historical data, the likelihood or probability of any severe nuclear or radiological event in the US submarines remains low. Following the above-discussed IAEA-related information, one can also conclude that the other side of risk, the consequences, would remain relatively limited (compared to the popular perception of a nuclear disaster). In the US Navy's description, in the unlikely event of an accident occurring, its consequences would be assessed in no uncertain terms as follows:

> "Even in these highly unlikely events, the maximum possible effect of the predicted amount of radioactivity released would be localized and not severe: the effect would be so small that the area where protective actions, such as sheltering, would be considered at all would be very limited, and only in the immediate vicinity of the ship […] Even in a very unrealistic situation where radioactivity passed through all four barriers, the amount of radioactivity for potential release would be significantly reduced after passing through each successive barrier. This means that the amount of radioactivity eventually released from the ship during an accident would be only an extremely small portion of what could have been released into the primary coolant. Second, the process through which radioactivity would be potentially released from the ship would not be a short-time event like an explosion. It would take a long time for radioactivity to pass through the four barriers. The high-strength reactor compartment and ship's hull would restrict the movement of radioactivity such that the radioactivity could not be released in a short time period through an explosive-like force. Third, since it would take a long time for radioactivity to pass through the four barriers, there would be sufficient time for the crew to respond to the problem and mitigate potential consequences before any radioactivity reached the outside of the ship. Also, a large fraction of the fission products that are produced during the operation of the reactor, and are of concern for human health, decay away shortly after the reactor is shut down and before they could pass through the four barriers."[50]

While the good nuclear and radiation safety record of NATO and particularly US nuclear-powered submarines is arguably true, one should nonetheless add that even US nuclear-powered submarines have experienced non-nuclear unwanted events, such as fires and collisions.[51] These include, for instance, the *Los Angeles*-class nuclear-powered (but not capable of carrying nuclear weapons) submarine USS Jacksonville,[52] which reportedly experienced a small fire while "undergoing an Engineered Refueling Overhaul (ERO)" at the Portsmouth Naval Shipyard in Kittery, Maine, in 2004: "The fire was immediately extinguished and the reactor was never in danger, though a shipyard firefighter and a sailor were treated at the scene for smoke inhalation". Furthermore, in 2013, the same vessel collided with a small fishing vessel in the Arabian Gulf, again without any reactor damage. Similarly, the same *Los Angeles*-class nuclear-powered USS Montpelier[53] collided with a US cruiser off the east coast of the US in 2012, also without causing any reactor damage. One could add that the nuclear-powered USS Miami, again of the same class, suffered a fire in 2012, also at the Portsmouth Naval Shipyard, and was so badly damaged, albeit without nuclear or radiological danger, that a

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[49] Ha-Duong, M. and V. Journé, V. (2014). Calculating nuclear accident probabilities from empirical frequencies. *Environment Systems and Decisions*, 34 (2), pp. 249-258.
[50] *Fact Sheet on U.S. Nuclear Powered Warship (NPW) Safety* (n.d.), op. cit., p. 9.
[51] Tingle, C. (2009). Submarine Accidents. A 60-year statistical assessment. *Professional Safety*, September, pp. 31-39. [Online] Available at: https://www.onepetro.org/download/journal-paper/ASSE-09-09-31?id=journal-paper%2FASSE-09-09-31.
[52] See e.g. the event history of USS Jacksonville SSN 699. [Online] Available at: http://www.uscarriers.net/ssn699history.htm.
[53] See the declassified report of the US Navy: [Online] Available at: https://www.public.navy.mil/usff/foia/Documents/readingroom/MON_SJAC_invrept.pdf.

decision was made to decommission rather than repair it.[54] In the Arctic, the UK *Trafalgar*-class nuclear-powered submarine HMS Talent was reported to be damaged after hitting ice when monitoring a Russian submarine in 2015.[55]

The Norwegian Armed Forces ROS

While some information provided for the municipal decision-makers in Tromsø in March 2019 before they voted stated that the Armed Forces had "carried out a risk and vulnerability analysis" in the process of determining Tønsnes to be "the most appropriate port for receiving reactor-powered vessels in the north",[56] it appears that the Norwegian Armed Forces FOH did not prepare its first Risk and Vulnerability Analysis (the so-called ROS in Norwegian) of the current case until August 2020. This document has yet to be published, or made available to the public. However, a concise description of what we know about it appears below.

The ROS includes a risk assessment part, which is a list of all kinds of unwanted events that a nuclear-powered submarine can encounter. While not perhaps structured in the most optimal way, one could re-structure this information into three parts. It includes, first, a kind of qualitative list or short descriptions of the most obvious technological factors or scenarios that might lead to a nuclear or radiological event. This information is restricted to some paragraphs, based on publicly available data about nuclear reactor accidents. Second, there is a simulation-based discussion about the plumes that could follow a serious radioactive release. Third, the document includes a descriptive list of types of non-nuclear events, such as collisions or terrorism, which may or may not lead to a nuclear or radiological event. The risks arising from this presentation are then combined and a simple risk map is presented at the end of the document. Let us consider the issues outlined above in further detail below.

Basic technological causes of a nuclear or radiological event in a submarine

The causes of a nuclear or radiological event during a submarine's transit to the port or during the time the vessel is at berth, discussed in the Armed Forces' ROS, are all more or less related to the overheating of the reactor, and are interrelated in terms of the severity of a potential accident. The information provided is a compilation of the basic failure modes that a submarine reactor can face, available in the generic literature. First, there is a risk of a loss of cooling of the reactor. This means that the coolant circuits in the system do not transfer the heat resulting from the fission process in the reactor, which then leads to the overheating of the reactor core. Such a malfunction can result for example from problems with the water pumps or blocked pipes and leaks in the primary or secondary coolant circuits. It is expected, according to the ROS, that the water surrounding the submarine would largely compensate for a malfunctioning cooling system. Second, and following from the previous or a similar malfunction, overheating could lead to breaks in the containment of the reactor fuel, and cause radioactive substances in the fuel to be released in larger amounts into the primary circuit (the pressured water circuit). Third, a fire in a nuclear reactor can occur as a result of overheating and cooling failure, which would cause a greater spread of radioactive material in the water or air outside the submarine. A fire can also destroy critical systems related to the reactor and lead to more serious accidents. Finally, there is always a theoretical possibility of a so-called 'criticality accident', which is an uncontrolled nuclear fission chain reaction, leading to a rapid overheating, explosion or even melting of the reactor. This in turn can break the protective shields or containments, resulting in radioactive material being freely released into the environment.

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[54] E.g. McDermott, J. (2014). *Fire-stricken submarine USS Miami is decommissioned. Stars and Stripes*. Stripes.com, March 29. [Online] Available at: https://www.stripes.com/news/us/fire-stricken-submarine-uss-miami-is-decommissioned-1.275179#.UziilcKRVZI.

[55] Nicol, M. (2015). Bang goes the no claims! Royal Navy nuclear submarine suffers £500,000 damage after 'hitting floating ice' while tracking Russian vessels. *Daily Mail*, 4 April. [Online] Available at: https://www.dailymail.co.uk/news/article-3025839/Royal-Navy-nuclear-submarine-suffers-500-000-damage-hitting-floating-ice-tracking-Russian-vessels.html.

[56] Tromsø kommune (2019), op. cit.

The ROS also includes a short discussion on the difference between emission into water and emission into air, drawing the conclusion that the latter potentially affects larger population groups. A simulation tool, originally devised for Haakonsvern, is applied to illustrate the possibly affected area. It is, however, not (yet) calibrated to the new conditions, and the population variable, for instance, is therefore dismissed. In any case, the simulation tool considers two roughly defined accident variations, moderate and serious. Both are then simulated in south-west and north-east 5 m/s wind conditions, calculating the accumulated dose over four days after the accident (other weather conditions such as rain are not covered).

The resulting data are illustrated in map-based figures consisting of four wedge-shaped radioactive plumes. The different colours in the plume extension denote the areas for the different types of actions/consequences that will ensue, such as life-saving, evacuation, sheltering and monitoring, with the more serious consequences arising closer to the source. In the serious accident scenario with the wind blowing from the north-east, the plume reaches Tromsø centre (island). The colour in the plume simulation reflects that this area should in the more serious case be a subject of extraordinary radiation monitoring to detect the contaminated areas/elements.

Non-nuclear threat pictures

The Armed Forces FOH ROS goes on to describe non-radiological risks or threat pictures. First, it discusses what are termed TESSOC threats, standing for terrorism, espionage, subversion, sabotage and organised crime. These threats are described very briefly and are not particularly contextualised in the current case. Second, partially the same threats, especially terrorism but also accident scenarios such as engine failure, grounding, collision and fire/explosion are briefly mentioned in two contexts, namely during transit to the port and when at berth. The analysis is not elaborated any further to consider cascading or multi-risks between the different types of risks.

Summary conclusions and risk treatment plans

The Armed Forces FOH ROS concludes with a risk map, based on the simple linear Risk = Likelihood x Consequences. The analysis results for likelihood and consequences are semi-quantified (probably between 0 and 5 but this is not explicitly expressed). The above-mentioned radiological and non-radiological risks are included for the most part, categorised into ‘during transit’ and ‘at berth’ risks. While the likelihood of any of these unwanted events is considered low (1 or 2), the consequences are considered high (4 or 5) in the two separate cases, namely that of a radioactive leakage and that of terrorism/sabotage.

The risk map also includes a revised version, envisaged after the proposed risk treatment. Treatment here refers to generic notions such as escorting the submarine during transit from open seas to the port by a tug and pilot, having proper warning routines and measurement equipment in place, following operational security routines for protecting sensitive information, and ensuring proper security arrangements at the port. When implemented, these are supposed to affect both the likelihood and consequences of unwanted events and to diminish the risks in all scenarios. For instance, the consequence factor of a radiological leakage is reduced from 5 to 4 by adding automatic warning systems and routines, and other similar measures.

The exact methodology for calculating or quantifying these figures, the kind of expert opinions that have been used and how they have been semi-quantified, the uncertainty of the analysis, and so forth, are not discussed.

DSA-related risk information

As of August 2020, no risk assessment had been prepared by the DSA concerning the projected submarine port in Tromsø. While such an assessment will probably be made in autumn 2020, and will be at least partially published, in the meantime we can look in some detail at risk information from the DSA that is related and relevant to our case.

Allied reactor-powered vessels in Norway's waters

In 2018, the DSA published a report about the new nuclear and radiation event threat pictures.[57] This is a 22-page report that includes a short, one-page chapter entitled 'Military activity in the north and the arrival of allied reactor-powered vessels in Norway'. The issue is 'new' due to the increasing tension between NATO and Russia after the latter's annexation of Crimea and continuing military activity in Ukraine, which has been reflected in the Arctic military activities.

The report concludes that increased activity by vessels with nuclear material points to an increased probability that Norway will be affected by a nuclear or radiological event. It states that Norway may be hit by a serious emission as a result of an event on board a nuclear-powered vessel in its vicinity, or be faced with a situation where a military vessel with nuclear material on board needs to seek refuge or make an emergency landing on Norwegian soil.

Besides the long-term concern that Russian nuclear-powered submarines and other vessels may create safety problems, the increasing activity of allied military reactor-powered vessels in Norwegian waters is a cause for concern, according to the DSA report. In the space of a few years, visits to Norwegian waters have increased from 10 to 15 annually to between 30 and 40 per year. The visits are accounted for by French, UK and US nuclear-powered submarines, and have mainly taken place in the past at Haakonsvern military naval base outside Bergen, but the country is increasingly receiving visits in the waters of northern Norway. "In the last year, there have been significantly more passages to waters outside Tromsø than to Haakonsvern. The Armed Forces are working to establish a new port for the arrival of reactor-powered vessels in the north." The DSA goes on to conclude that the increase in visits of this type to Norway will increase risks:

> "[…] Norway runs an increased risk that it may be affected by a major or minor incident in a reactor-powered vessel. Grounding, collision, leakage, fire or serious reactor failure will require handling by the Norwegian authorities."

While the aforementioned five accident risks (grounding, collision, leakage, fire, or serious reactor failure) can be seen as the basic hazard types, in a seminar[58] organised in Tromsø in June 2019 by the DSA together with the County Governor, a somewhat broader set of scenarios was discussed. First, an ordinary visit by a nuclear-powered submarine to a port in Tromsø municipality, without any hazards, accidents or malfunctions was considered. Second, the seminar discussed some events involving the vessel, which would have no bearing on the reactor safety, such as a public demonstration against the submarine visit. Finally, a scenario was considered that involved the vessel, which would have consequences for reactor safety, and in which radioactive substances would or might be released into the air and water, such as a fire and reactor malfunction on board.

ARPANSA principles as a model?

While there is no DSA risk assessment to date for our particular case, the DSA has stated[59] that it will follow the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) standard or guidelines on *Nuclear powered warships visit planning* to a certain extent in its forthcoming risk

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[57] Selnæs, Ø.G, Eikelmann, I.M. and Amundsen I. (2018). *Endringer i trusselbildet, Trusselvurdering for Kriseutvalget for atomberedskap, 2018*. Strålevern Rapport 2018:10. Østerås: Norwegian Radiation Protection Authority, here p. 9. [Online]: Available at: https://www.dsa.no/publikasjon/straalevernrapport-2018-10-endringer-i-trusselbildet.pdf.
[58] *Utfordringer, håndtering og oppfølging av en atomhendelse. Seminar for lokale myndigheter, kommuner, interesseorganisasjoner og andre berørte parter*. Framsenteret, Tromsø 13.6.2019.
[59] Consultation with the DSA 10.8.2020 (*Seksjon nordområdene*, Tromsø).

assessment and preparedness planning in this instance.[60] The reason, according to the DSA, is that the Australian standards are stricter than the respective US, UK or French standards and guidelines as they are specifically tailored to *foreign* allied vessels.

The ARPANSA risk assessment guidance and related results in the Australian context have been published,[61] unlike the respective US, French and UK documents. Should the same basic principles be followed in Norway's risk management work on receiving nuclear-powered submarines, they are as follows:[62]

> (a) Visits will be for purposes such as crew rest and recreation, and not for fuel handling or repairs to reactor plant (necessitating breach of reactor containment).
> (b) Visits will be subject to satisfactory arrangements concerning liability and indemnity, and to provision of assurances relating to the operation and safety of the warships while they are in […] waters.
> (c) Movement of vessels must take place during daylight hours under conditions where visibility is no less than three-quarters of a nautical mile [1.852 km].
> (d) Navigational controls on other shipping will be applied during the time that nuclear-powered ships are entering or leaving port.
> (e) There must be a capability to remove the vessel, either under its own power or under tow, to a designated safe anchorage or a designated distance to sea, as soon as possible within the time frame specified for the particular berth or anchorage, and in any case within 24 hours, if an incident should occur.
> (f) An operating safety organisation, competent to conduct a suitable radiation monitoring program and able to initiate actions and provide services necessary to safeguard the public in the event of a release of radioactivity following an accident, must exist in the port being visited.

The risk scenario on which ARPANSA's planning is based is the so-called *2000 Reference Accident Used to Assess the Suitability of Australian Ports for Visits by Nuclear Powered Warships.*[63] In this scenario, the so-called loss-of-coolant accident is assumed to result in a full reactor core meltdown. The reactor primary and secondary containments are assumed to remain intact, limiting the fraction of fission products released into the atmosphere. The results are supposed to represent an upper bound risk to the surrounding population. The radiological consequences of the hypothetical event scenario are then calculated and compared with radiological acceptance criteria.

In the general scenario-based risk assessment, the affected area is divided into three zones focusing on the immediate consequences of an event. Should the DSA follow or apply ARPANSA's reference accident zones (as it has stated), the most seriously affected zone is a circle with a 600m radius centred on the submarine. This zone is one within which the surrounding population may be exposed to direct gamma shine from the vessel, as well as airborne radioactive material following an accident in the reactor. This calls for evacuation from the area. We know that the responsibility of the Armed Forces is supposed to cover an area 500m from the vessel, so this area would then be evacuated for the most part by the military, if needed.

The second and third zones are dependent on the direction of the wind, which carries the plume. In the ARPANSA scenario, the second zone covers any 30-degree downwind sector within a radius of 1.4

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[60] ARPANSA (n.d.). *Nuclear powered warships visit planning*. Australian Radiation Protection and Nuclear Safety Agency. [Online] Available at: https://www.arpansa.gov.au/research/radiation-emergency-preparedness-and-response/visits-by-nuclear-powered-warships.

[61] ARPANSA (2001). *The 2000 Reference Accident Used to Assess the Suitability of Australian Ports for Visits by Nuclear Powered Warships*. RB - NPW - 66/00, December 2000/January 2001. Australian Radiation Protection and Nuclear Safety Agency. [Online] Available at: https://www.arpansa.gov.au/sites/default/files/ref_acc.pdf.

[62] ARPANSA (2001), op. cit., p. ix.

[63] ARPANSA (2001), op. cit.

km. It represents an area within which the projected doses do not justify evacuation, but where, subject to actual field measurements of radioactivity, the maximum avertable doses that are estimated may justify sheltering as a countermeasure.

The third and least affected zone is subject to contamination measurements but does not require any immediate action to protect the population. The situation is, however, expected to lead to potential long-term consequences due to ground-deposited radioactive material and ingestion of contaminated water, foodstuffs, milk and agricultural produce. Decisions to implement protective actions, such as relocation and food restrictions, would be made based on the results of extensive radiation and contamination monitoring.

The zones are supposed to be applicable to any port. In addition, in the ARPANSA risk assessment scenario, so-called collective dose measurement is also considered, which depends on each particular port's idiosyncrasies should a worst-case event take place. The term 'collective dose' refers to the total number of health effects, which may appear over the ensuing lifetime of the surrounding population. The collective dose is calculated on a port-specific basis for 12 different wind directions, with the direction producing the highest collective dose being used to assess port acceptability.

While the ARPANSA risk management standard or guidelines define the basic methodology before determining a port's suitability for receiving nuclear-powered submarines, they are also used iteratively on an annual basis in terms of creating and monitoring historical data. This means that the Australian Government/Department of Defence publishes a radiation monitoring report every year on each and every nuclear-powered vessel visit to Australian ports.[64]

Russian nuclear submarine accident impact analysis: a comparable risk?

In 2018, the DSA published a 141-page report entitled *Radiological impact assessment for hypothetical accident scenarios involving the Russian nuclear submarine K-159*.[65] While the issue is not directly comparable, it highlights that even accidents outside of Norway's territory or territorial waters may pose a serious risk. The highly detailed and technically sophisticated report with modelling and simulations is based on a real case, namely the decommissioned Russian nuclear submarine K-159, which foundered and sank in heavy seas whilst under tow, with four floatation pontoons, northwest of Kildin Island in the Barents Sea. It lies at a depth of 246 metres. K-159 had been out of service since 1989 and its two 70 MW nuclear reactors had been shut down since 1988, but still contained around 800 kg of spent nuclear fuel. The 'hypothetical accident scenarios' refer to situations where significant radiation would occur, more precisely either in situ (released into the sea due to erosion etc.) or during potential lifting (accident occurring while releasing radiation into the sea), or during a potential docking in the port (accidental release into the atmosphere).

The report concludes that with regard to "potential impacts on Norway (both economically and environmentally), the sunken Russian nuclear submarine K-159 is of great concern". The docking scenario was considered to be the worst case in terms of potential consequences for Norway. The pathways to humans would be in the form of radionuclide releases into the sea and thus via contaminated fish to the population, and in the form of releases into the atmosphere and via contaminated terrestrial foodstuffs. Restrictions on using the contaminated food would therefore be needed, at least in the shorter term.

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[64] E.g. Australian Government (2018). *Visits by Nuclear Powered Warships to Australian Ports. Report on Radiation Monitoring during 2017*. Canberra, Australia: Department of Defence. 2018 [Online] Available at: https://www.arpansa.gov.au/sites/default/files/d1844096_report_on_radiation_monitoring_during_2017.pdf.

[65] Hosseini, A., Amundsen, I., Brown, J., Dowdall, M., Dyve, J.E. and Klein, H. (2017). *Radiological impact assessment for hypothetical accident scenarios involving the Russian nuclear submarine K-159.* Strålevern Rapport 2017:12. Østerås: Statens strålevern.

Halden and Kjeller research reactors: a comparable risk?

While Norway does not have any NPPs, it has two research reactors. The Halden reactor went into operation in 1958 and the Kjeller reactor in 1967, and both were shut down in 2018 and 2019 respectively. Yet the decommissioning may take some 25 years. On its website, the DSA has a description of the research reactors and brief risk information. While this information is partially outdated, it gives an approximate indication of the type of worst-case accident caused by a smaller reactor:

> "The reactors have an energy production of less than 1% of a typical nuclear power plant. Accident and impact assessments have been carried out on both reactors. Even very serious accidents at these reactors will not cause radiation injury to people in the surroundings. In the event of serious accidents, it may nevertheless be relevant to evacuate people in the immediate vicinity (500–1000m) for a short period. In the event of a serious accident at the Halden reactor, radioactive gases could be forced out through cracks in the rock that surrounds the reactor. If the valves in the ventilation system through the doors to the reactor hall fail, there will be a direct blow-out into air. The consequences will be local. An accident at the Kjeller reactor could result in direct radiation at the plant and radioactive emissions into the air that could lead to local consequences."[66]

It has to be taken into account that these research reactors are about one-tenth of those in the nuclear-powered submarines, the former being in the range of 18–20 MW.[67]

DSB national risk assessment of a nuclear accident

In Norway, the Norwegian Directorate for Civil Protection (DSB, *Direktoratet for samfunnssikkerhet og beredskap*), which reports to the Ministry of Justice and Public Security, coordinates, prepares and publishes a national risk analysis. This is a part of the wider triennial practice, carried out for about a decade, of collecting national risk assessments from European countries connected to the Union Civil Protection Mechanism (UCPM) and coordinated by the European Commission. In practice, the DSB prepares its scenario-based risk assessment 'case studies' as an ongoing process, adds them to the existing case scenarios, updates the older ones, and then publishes its compiled national risk assessment, which currently goes under the name of 'Analyses of crisis scenarios' (AKS).

The last edition was published in 2019,[68] supplemented with a detailed methodological explanation document.[69] Each scenario follows the same methodology that has become increasingly sophisticated over the years. While the AKS does not consider nuclear submarine events, it mentions that particular issue in passing:

> "The traffic of reactor-driven vessels in Norwegian Sea areas and adjacent areas is clearly increasing. Accidents involving such reactors near the coast can cause large emissions into the air and sea and serious consequences in Norway."[70]

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[66] Available on the DSB website: https://www.dsa.no/temaartikler/90276/norske-atomanlegg. The translation from Norwegian into English is by the editor of the current overview.
[67] E.g. Institutt for energiteknikk (n.d.). *Dette är Halden-raktor*. [Online] Available at: https://web.archive.org/web/20160205164943/http://www.ife.no/no/ife/detaljer/hrp/detteerhrp.
[68] DSB (2019a). *Analyser av krisescenarioer 2019. Alvorlige hendelser som kan ramme Norge*. Direktoratet for samfunnssikkerhet og beredskap (DSB). [Online] Available at: https://www.dsb.no/globalassets/dokumenter/rapporter/p1808779_aks_2018.cleaned.pdf.
[69] DSB (2019b). *Risikoanalyse på samfunnsnivå - Metode og prosess ved utarbeidinga av "Analysar av krisescenario (AKS)" (nynorsk)*. Direktoratet for samfunnssikkerhet og beredskap. [Online] Available at: https://www.dsb.no/globalassets/dokumenter/rapporter/risikoanalyse_pa_samfunnsniva_nn.pdf.
[70] DSB (2019a), op. cit., p. 133.

However, the AKS discusses a much more serious accident scenario in some detail, which has general relevance to our case. The 227-page AKS 2019 includes a scenario case nr. 11 entitled 'Nuclear accidents' (*Atomulykker*), which is a seven-page treatment of the theme, including three pages of general background information on nuclear accidents, an overview of the existence of NPPs in the vicinity of Norway, a generic description of nuclear and radiological risks, and a description of the nuclear and radiological event prevention and preparedness status in Norway. This is followed by a four-page scenario-based risk analysis.

The latter is an updated analysis of an original 2010 scenario, duly published in earlier versions in previous editions of the national risk assessment. It is based on a scenario of an accident in Sellafield, UK, a formerly operational NPP, which is currently involved in nuclear fuel reprocessing and nuclear waste storage, and is subject to nuclear decommissioning. No nuclear power generation has taken place at the plant since 2003.

The scenario is that a technical failure at the used nuclear fuel reprocessing plant leads to the loss of cooling and a subsequent explosion in one of the waste tanks. The emissions of highly radioactive waste reach Norway on air currents, and the precipitation over the country, especially in Vestlandet, is higher than after the Chernobyl accident. The accident occurs in mid-October, and the plume hits Norwegian territory after nine hours. The emissions are registered throughout the country after 48 hours.

The likelihood of this specific scenario is considered to be 0.02% annually, which corresponds to a 2% probability over 100 years. In the DSB's metrics, this is considered to fall into the category of 'very low probability'. The risk analysis, however, remarks that there are many other facilities and other sources of radiation fallout with a larger emission that could potentially affect Norway. Thus, the accumulated annual probability of an accident of a type similar to the Sellafield scenario is considered to be 1%, which corresponds to a 65% probability within 100 years. This would then fall under the category of 'medium high probability'.

Unlike the likelihood, the societal consequences of the given scenario are considered 'very considerable'. As for life and health, no direct deaths are expected, but several hundred may die in the decades after the event, primarily as a result of an increase in the number of cancer cases. Several thousand may have mental illness problems. When it comes to the environment and food production, they will be hit hard, leading to the slaughter of animals and destruction of dairy products/milk. The long-term consequences of radioactive fallout are greater for outfield-based food production (reindeer husbandry, sheep farming, mushroom picking, game meat and freshwater fish) than agriculture. All in all, the direct and indirect financial costs are estimated to be around NOK 5 billion. Lastly, a nuclear accident will also create great social unrest in the population, and provoke reactions such as fear and powerlessness.

As historical data for such events is limited and typically based on expert opinions, risk assessments should provide some kind of uncertainty assessment as well, justified with proper methodology. The uncertainty associated with the combined likelihood and consequence analysis of this DSB scenario is considered 'moderate'. As for consequences related to life and health, the uncertainty is 'considerable'.

The AKS scenarios are frequently used as the basis for exercises. In 2021, exercise Arctic Rhein will highlight a scenario whereby a ship with nuclear waste comes adrift close to the Norwegian coast.

County Governor ROS

The DSB provides guidance[71] for the County Governor's ROS analyses, or so-called FylkesROS, albeit not dealing with nuclear or radiological event risks in particular. The FylkesROS currently in force (2019–2020) in Troms and Finnmark county[72] is a revisited amalgam of Troms 2016–2019 and Finnmark 2014–2017 FylkesROS, prepared after the merger of the counties. A new edition will be produced by the end of 2020, and will include something about our case in particular.

The existing ROS is an 82-page document, which includes 18 risk scenarios divided into 'natural events', 'major accidents' and 'malicious events'. One of the three major accident scenarios is a 'nuclear accident', which is a concise five-page treatment of this type of hazard. The document refers to six possible generic scenarios (following the DSA/government risk identification) and chooses to focus on two of them, namely 'airborne radiation release from foreign countries' (NPPs) and 'local events'. The latter is more to the point in our context.

No detailed scenario is presented but the ROS mentions some examples at a generic level:

> "[…] the transport of radioactive material along the coast, the use of radioactive material for terrorist purposes, radiation sources going astray or satellites with radioactive material crashing. Reactor-powered surface vessels and submarines, and submarines with nuclear-powered weapon systems along our coast or in Norwegian waters are also a possible risk."

The ROS explains that the reactors on nuclear-powered vessels have an effect equivalent to approximately 10% of the reactors in a typical commercial NPP, which implies that the possible hazard would also be limited compared to an NPP accident. The assumption of the ROS appears to be that any accident of this type will take place not in the immediate vicinity of a population centre but rather on the open sea:

> "With wind directions towards Norwegian territory, a serious reactor accident in a vessel near the Norwegian coast can have significant consequences for the coastal areas closest to the casualty. If the emission into the air leaks out of the casualty, it will be carried by the wind and can enter the coastal areas in a short time."

The likelihood of this type of accident without a local physical connection is evaluated as medium (3 on a 5-stage scale), corresponding to once every 50 to 100 years, based on the respective activities along the coast. The exact data source and respective methodology are not elaborated.

The overall consequences of such an event are considered major (D on an A–E scale). The short-term consequences of this scenario would primarily be in respect of life and health, and secondarily in respect of the environment. It is also mentioned that radiation emissions can affect the stability of society.

No specific risk treatment strategies are outlined in this document.

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[71] DSB (2020). *Veileder for Fylkesmannens arbeid med risiko- og sårbarhetsanalyser (fylkesROS). Versjon 4 – mars 2020.* Skien: Direktoratet for samfunnssikkerhet og beredskap. [Online] Available at: https://www.dsb.no/globalassets/dokumenter/veiledere-handboker-og-informasjonsmateriell/veiledere/veileder_for_fylkesros_v.3.pdf.

[72] FylkesROS Troms og Finnmark (2019). *Risiko- og sårbarhetsanalyse for Troms og Finnmark 2019-2020*. Fylkesmannen i Troms og Finnmark, here pp. 58-62. [Online] Available at: https://www.fylkesmannen.no/globalassets/fm-troms-og-finnmark/samfunnssikkerhet-og-beredskap/fylkesros_troms_og_finnmark.pdf.

The municipality of Tromsø ROS

DSB guides also apply to the Norwegian municipalities in their ROS work with the publication *Guidance to holistic risk and vulnerability assessment in the municipality*.[73] While it does not focus on nuclear or radiological events as such and only mentions them in passing, it provides a good conceptual and methodological basis and step-by-step guidance that can be applied to a case such as the one discussed here, both in terms of a single-risk event and a cascading or multi-risk event.

There is no municipal ROS for the purpose of identifying, analysing and evaluating the risks, and possibly the risk treatment strategies, related to our case. The current Tromsø municipality ROS is outdated and therefore not publicly available, and the part related to nuclear or radiological events is short and not particularly relevant to the current case. An updated municipal ROS is in progress. Prior to that, in autumn 2020, a section related to the current case will probably be prepared.

3. Overview of relevant preparedness information and plans

While risk management is designed to prevent or at least minimize the most obvious risks, in preparedness work the occurrence of an unwanted event is assumed. This preparedness should be based on the risk treatment results. The efforts should be directed towards those risks that were selected as risk treatment-worthy, but that could not be completely eliminated or mitigated sufficiently so that the risk would be tolerably low.

Preparedness starts with good planning and is followed by its implementation, testing with exercises, and continuous auditing. A proper preparedness plan should in cases such as ours include at least the following elements: a clear picture about the multi-agency organisation and respective responsibilities; a monitoring and early warning system; a response plan, including at least the immediate safety and security arrangements; an associated training and exercise system; and liability pre-arrangements.

In its 2018 guidelines on organisational responsibilities and roles in case of nuclear and radiation events (*Ansvarsforhold: Atomberedskap og redningsaksjoner*),[74] the DSA distinguishes between preparedness work in general, on the one hand, and the response to an unwanted event when it happens, on the other. As both are nevertheless about planning in advance, they can be both understood as, and discussed under, the title of preparedness.

Organisation and responsibilities

The need for preparedness planning is rooted in the very nature of a crisis or an emergency, where time is an important currency; one usually has too little of it, due to an approaching deadline or the growing costs of inactivity. The point of planning is to make as many necessary decisions and preparations as possible before a crisis occurs.

The basics of preparedness planning entail defining the decision-making system or, in more concrete terms, the crisis organisation and respective roles and responsibilities. In a case such as ours, this is even more important due to the complicated multi-level (national, regional, local, foreign, etc.) and multi-agency character of the issue.

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[73] DSB (2020/2014). *Guidance to holistic risk and vulnerability assessment in the municipality*. Tønsberg: Norwegian Directorate for Civil Protection. [Online] Available at: https://www.dsb.no/globalassets/dokumenter/brann-og-redning-bre/skogbrannhelikopter/2019/guidance_to_holistic_risk_and_vulnerability_assessment_in_the_municipality.pdf
[74] DSA (2018b). *Ansvarsforhold: Atomberedskap og redningsaksjoner. Samhandling mellom Kriseutvalget for atomberedskap og den norske redningstjenesten*. Strålevern Hefte 32. Østerås: Statens strålevern.

On the other hand, the current crisis management literature is rather unanimous in warning about the 'delusion of preparedness'. It is simply too difficult to produce a single plan that covers all of the potential challenges emerging from crisis situations. Some even emphasise that preparedness planning should actually be about planning how to improvise. In any case, it would not be out of place to bear in mind that planning should not be too rigid, and should not pose an obstacle to improvisation if the situation so demands.

Arrival of a nuclear-powered submarine in Tromsø

Visits by allied nuclear-powered submarines to the port of Tønsnes are supposed to take place relatively seldom, which obviously limits both the risks and the related preparedness activities. In a background paper from the Tromsø municipality, it is mentioned that the "estimated number of visits at Tønsnes port is set at approx. 4–5 visits a year, with a duration of a few days per visit".[75]

When an allied reactor-powered submarine wants to enter Norwegian territorial waters and potentially dock, this activity is governed by the Royal Decree from 1997.[76] In the first instance, an application is required from the flag country, which is sent via the flag state's embassy to Norway's Armed Forces FOH at least two weeks prior to the desired arrival date. The FOH in turn forwards the application to the Ministry of Defence and to the DSA to obtain the latter's recommendation. It is the Ministry of Defence that ultimately grants a licence and diplomatic clearance for the visit on behalf of the Ministry of Foreign Affairs.

When a nuclear-powered submarine then plans to visit Tønsnes, the FOH will notify the County Governor at least three days in advance. Information is provided about the duration of the visit, the vessel's nationality and type, but not its name as this information is classified. Details about the vessel's arrival are also classified, with only a few people being privy to this information, including at least the County Governor, the Police, the Civil Defence, and the Tromsø Fire Brigade.

It is also worth noting that according to the above-mentioned Royal Decree (§7), foreign military submarines must always sail on the surface in Norwegian territorial waters and display their flag, except when a part of approved exercises and training.

The DSA and the inter-agency Crisis Committee for Nuclear Preparedness

When related to a situation with nuclear and radiological event risks, the preparedness work in Norway is organised differently from other types of preparedness work. Following the Royal Decree on Nuclear and Radiation Preparedness from 2013[77] and its later specifications,[78] the responsible inter-agency Crisis Committee for Nuclear Preparedness (*Kriseutvalget for atomberedskap*) coordinates and leads the work. In the acute phase of a nuclear or radiological event, the Crisis Committee has the authority to make decisions and issue orders for specified measures. The Crisis Committee is chaired by the Norwegian Radiation Protection Authority, and its institutional membership consists of the National Police Directorate, the Norwegian Coastal Administration, the Norwegian Food Safety Authority, the Norwegian Directorate of Health, the Norwegian Directorate for Civil Protection (DSB), the Defence Staff, and the Ministry of Foreign Affairs. While all activities should be coordinated with the respective departments if the situation allows, measures affecting military conditions and operations must always be cleared with the Ministry of Defence.

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[75] Tromsø kommune (2019), op. cit., p. 1.
[76] Kungliga resolusjonen 2.5.1997. *Forskrift om adgang til og opphold på norsk territorium under fredsforhold for fremmede militære og sivile statsfartøyer*. FOR-1997-05-02-396. Forsvarsdepartementet [Online] Available at: https://lovdata.no/dokument/SF/forskrift/1997-05-02-396.
[77] DSA (2013/2017). *Atomberedskap – Sentral og regional organisering.* Kgl. res av 23. august 2013. Unofficial translation. Revised as of January 2017. Strålevern Hefte 31. Østerås: Statens strålevern. [Online] Available at: https://www.dsa.no/filer/a54820bf5c.pdf.
[78] DSA (2018b), op. cit.

Associated to the Crisis Committee are its secretariat, which is the DSA, the committee's advisory body, which includes fourteen central agencies and institutions with tasks within nuclear preparedness, and the County Governor. The Crisis Committee can invite advisers as needed from other agencies or institutions when the situation demands it. In accordance with the sector principle, the ministries are responsible for ensuring that the emergency preparedness within their own sectors is satisfactory and coordinated with other sectors. The County Governor is responsible for the coordination of preparedness at the regional levels.

The County Council as the regional preparedness coordinator

Following the Royal Decree from 2013,[79] the County Governor is responsible for establishing the "necessary regional forum" for coordination in nuclear preparedness, including regional and local agencies. These agencies should prepare "satisfactory plans for nuclear or radiological incidents as part of a coordinated set of plans". The County Governor will report on this to the secretariat for the Crisis Committee, namely the DSA.

During a materialised nuclear or radiological event, the Crisis Committee usually tasks the County Governor with ensuring the coordination and assisting in the implementation of measures regionally and locally, adapting to the regional factors. The County Governor reports back to the Crisis Committee about this implementation.

Concerning the current case, these responsibilities belong to the County Governor of the recently merged Troms and Finnmark, who has offices in both Tromsø (Troms) and Vadsø (Finnmark). According to the respective County Governor,[80] they see the Crisis Committee as a national-level decision-maker, whereas the County Governor has the regional lead heading the Nuclear Preparedness Council (*Atomberedskapsutvalg*), including all of the regional and local stakeholders concerned, as well as the Tromsø-based DSA filial.

The municipality's role in preparedness

Following the DSA's 2017 guidelines for municipal nuclear preparedness (*Kommunal atomberedskap plangrunnlag*),[81] the municipality's role and task in the case of a nuclear or radiological event will be to maintain its own service production. Its role is defined as "assisting other authorities with responsibility for the implementation of measures, general safeguarding of the population's safety and dissemination of locally adapted information, including population notification". In terms of municipal preparedness planning, the DSA guidelines state that the municipalities will use their ROS analysis to prepare a nuclear preparedness plan. This plan will be an extension of the municipality's general preparedness plan. In practice, this means preparing the so-called action cards that summarise the municipality's role in a nuclear or radiological event and that refer to other parts of the preparedness plan. The cards are organised according to the tasks. A task can entail informing other authorities or warning the general public, for instance. The cards mention the responsible person or position and describe the action in more detail.

Concerning the current case, Tromsø municipality has an existing preparedness plan that was revised in 2019. It consists of a public administrative part,[82] whereas the operational part is classified. The

[79] DSA (2013/2017), op. cit., p. 14.
[80] Consultation with the County Governor of Troms and Finnmark 21.8.2020.
[81] DSA (2017). *Kommunal atomberedskap plangrunnlag*. Østerås: Statens strålevern/Norwegian Radiation Protection Authority, particularly pp.12-14. [Online] Available at: https://www.dsa.no/publikasjon/kommunal-atomberedskap-plangrunnlag.pdf.
[82] Tromsø kommune (2019). *Overordnet beredskapsplan for Tromsø kommune. Overordnet beredskapsplan for Tromsø kommune – administrativ del*. Revidert 2019. [Online] Available at:

former document functions at a rather generic level, explaining how the preparedness in Tromsø municipality is organised, coordinated and documented, and outlining the principles, priorities and methods. The classified operational part in turn functions as a crisis management tool in the response phase of a crisis, with detailed instructions, checklists, action cards for selected crisis scenarios, and necessary contact information.

The administrative part of the municipality's preparedness plan relies on the generic 'four principles' of Norwegian crisis management, including the stipulation that events must be handled at the lowest possible level based on the responsibility areas during normal times. The municipal preparedness plan includes an organisation plan for crisis events, working under the municipal director and including several pre-defined responsibility areas and the respective nominated persons, such as representatives of different sectors (e.g. health, transport), and persons responsible for public communication and liaison with other relevant actors (e.g. the DSB, the County Governor). Besides the overall division of labour, the positions/persons are guided by special checklists and action cards.

The 18-page administrative part lists the crisis scenarios under three main categories, namely 'natural hazards', 'large accidents', and 'malicious threats', where 'nuclear accidents' are classified under large accidents. In the published part of the plan, no other remarks on how to act in case of a nuclear or radiological event, and nothing that would be directly relevant to the current theme can be found.

However, the current situation has led Tromsø municipality to start updating its preparedness plan to accommodate this new risk factor. Following information received from the municipality,[83] this work is in progress.

The rescue service's role

Rescue service refers to the publicly organised activity that is carried out in connection with immediate efforts to save people from death and injury as a result of acute accident or danger situations. According to the DSA guidelines,[84] the rescue service's operational management in nuclear and radiological events is exercised by the Joint Rescue Coordination Centre (HRS in Norwegian), which in northern Norway is in Bodø (HRS-NN), led by the Police Chief of the town. In addition to the Police Chief, the rescue management consist of representatives from the Armed Forces Operational Headquarters (FOH), the Directorate for Civil Protection and Emergency Planning (DSB), the Civil Aviation Authority, the Norwegian Coastal Administration, the Norwegian Maritime Directorate, the Norwegian Directorate of Health, Avinor, Kystradio (maritime radio), and Redningsselskap (FORF, a voluntary rescue organisation). The HRS in turn has overall responsibility for the local rescue centres (LRS) within its regions. The local rescue centres have been established in the country's police districts. Each LRS has a rescue management with representatives from relevant public and private companies, a representative from the volunteers, and the Police Chief as leader. The centres are staffed with police officers and other persons it may nominate to be included in the individual rescue operation.

Following the DSA,[85] the rescue service's responsibility in nuclear and radiological events is limited to rescuing people in acute need, including informing the media. Protection of the environment, material values and production are not part of the remit of the publicly organised rescue service. Nor are general preventive activities the responsibility of the rescue authorities, but it will often be necessary to make decisions in the rescue service in advance of a possible development.

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https://img8.custompublish.com/getfile.php/4448039.1308.77i7ww7jibkmzl/Overordnet+beredskapsplan+for+Tromsø+kommune_administrativ+del_2019.pdf?return=www.tromso.kommune.no

[83] Consultation with the Municipality of Tromsø 25.8.2020.

[84] DSA (2018b), op. cit., pp. 9-12.

[85] DSA (2018b), op. cit., p. 9.

Response coordination

In addition to the above, the DSA has produced plans and schemes on how all of this should be coordinated in response actions. On paper, there is a rather detailed division of responsibilities. A scheme[86] shows how these are categorised into agencies and authorities that bear either the *main responsibility,* or are in a *supervisory, assisting* or *coordinating* position. As these are further divided into different sectoral responsibilities, including the justice sector, health sector, food, agriculture, fisheries and environment, foreign service sector, defence sector, and others, with each covering *eleven groups of identified response actions altogether*, the resulting multidimensional picture is not self-explanatory. This generic plan in any case conveys the impression of an emergency management system that may face coordination challenges in practice.

Capacity building

A commitment to emergency preparedness necessitates the respective resources, including monetary resources, equipment, and staff time. In the IAEA standard concerning nuclear and radiological event management, it is particularly emphasised that the "government shall ensure that response organizations, operating organizations and the regulatory body have the necessary human, financial and other resources, in view of their expected roles and responsibilities and the assessed hazards, to prepare for and to deal with both radiological and non-radiological consequences of a nuclear or radiological emergency […]".[87]

In our case, some individual stakeholders already seem to have started to enhance their material capacity. It appears that the authorities and other stakeholders concerned regard the additional nuclear and radiological event preparedness caused by the submarine case as belonging within their normal scope of affairs, and consequently handled within their normal budget planning systems. No specific audit system, confirming that the above-mentioned IAEA standard as to capacity building is being taken into account, seems to have been prepared or to be publicly available.

These kinds of issues usually come up in the IAEA's regular review mission reports to the member states. In its 2019 report on the review mission to Norway, the IAEA noted that while the DSA is responsible for controlling and regulating the access of nuclear-powered vessels, mainly submarines, to Norway, there was no assigned DSA financing for the task.[88] According to the DSA in August 2020,[89] at least some additional capacity building has now been determined (see below under 'Monitoring').

Monitoring

There are several objectives for monitoring[90] radioactivity, of which providing a warning in case of a nuclear or radiological event as well as taking the proper protective and counter-measures are the most relevant ones in our case. Monitoring is supposed to shorten the reaction time from the nuclear or radiological event to warning, and from warning to response. As in many other emergencies, even a short spell of additional time might provide leeway for at least some preparatory or mitigating measures, such as sheltering, evacuation or preparing the necessary equipment for an early response.

[86] DSA (2012). *Statens strålevern. Roller, ansvar, krisehåndtering og utfordringer i norsk atomberedskap*. StrålevernRapport 2012:5. Østerås: Statens strålevern, Table 7.3, pp. 48-50. [Online] Available at: https://www.dsa.no/publikasjon/straalevernrapport-2012-5-roller-ansvar-krisehaandtering-og-utfordringer-i-norsk-atomberedskap.pdf.
[87] IAEA (2015), op. cit., p. 9.
[88] IAEA (2019). *Integrated Regulatory Review Service (IRRS) Mission to Kingdom of Norway*. Oslo, Norway, 17 to 28 June 2019. Department of Nuclear Safety and Security. IAEA-NS-IRRS-2019/04, pp. 12, 24.
[89] Consultation with the DSA 10.8.2020 (Seksjon nordområdene, Tromsø).
[90] CBSS (2011). *Report on environmental radiation monitoring programmes among the members and observers of the Council of the Baltic Sea States*. Expert Group on Nuclear and Radiation Safety. [Online] Available at: https://inis.iaea.org/collection/NCLCollectionStore/_Public/36/050/36050080.pdf.

Some monitoring equipment is more suited to *early* warning than others. For early warning purposes, automatic measurement stations for the external ambient gamma dose rates from all external sources[91] are relevant due to the fact that they are usually based on continuous 24/7 monitoring and reporting. They are thus useful both as a warning system and as a tool to predict doses to the affected population, enabling precautionary additional surveys or outright countermeasures.

Countries are markedly different in terms of how many stationary automatic gamma monitoring stations they have, ranging from one or two to many hundreds. Norway does not have any NPPs of its own and its gamma-monitoring network is not very dense, comprising 28 such monitoring stations. One of these is located in Tromsø, under the auspices of the Norwegian Meteorological Institute in Tromsø, administrated by the DSA. It is located about a kilometre uphill west of the centre of Tromsø. According to the DSA,[92] two more DSA stations will be added to the region due to the current case as well as one more station in Tønsnes/Grøtsund port itself, the latter being administrated by the Armed Forces but connected to the DSA network. The latter station in particular may have an early warning effect.

Another stationary monitoring system is aimed at the identification of airborne radionuclides and information about their dispersion. In such devices, air is pumped through filters and then regularly, or when needed, removed and analysed. While this adds to the monitoring and analysis in normal and emergency situations, it is not automatic/continuous in the same early-warning sense as the gamma monitoring stations. According to the DSA,[93] while there are only seven filters currently in use in Norway, and none in the vicinity of Tromsø, one will be installed due to the visiting reactor-powered submarines.

In the post-release phase, when the issue is to identify the contaminated locations, environments and materials, mobile environmental (air, soil, water, fish, sediments, grass, milk etc.) monitoring and sample survey techniques and equipment are more suitable than the stationary solutions.[94] In such a case, Tromsø has the advantage of having a DSA section (*Seksjon nordområdene*) with its own laboratory, which may carry out many types of environmental tests.[95]

Following the 2013 Royal Decree,[96] the DSA has a 24-hour watch and is a national and international contact point for notification and information in case of nuclear and radiological events. The DSA is responsible for coordinating national monitoring programmes for radioactivity in the environment, as well as national networks for measuring radiation, and is affiliated to corresponding international networks. As a player in the emergency preparedness organisation, the DSA is said to have the competence and resources for measuring radiation and radioactivity.

The efficacy of the local monitoring system will probably be discussed in the forthcoming DSA risk assessment and preparedness reports. In principle, there are many related monitoring and measurement technologies available that are particularly useful in emergency situations when the time and speed of procuring evidence to support decision-making are important factors.

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[91] Lauritzen, B., Hedemann Jensen, P. and Nielsen, F. (2005). *Requirements to a Norwegian National Automatic Gamma Monitoring System*. Roskilde, DK: Risø National Laboratory.
[92] Consultation with DSA 10.8.2020 (*Seksjon nordområdene*, Tromsø).
[93] Consultation with DSA 10.8.2020 (*Seksjon nordområdene*, Tromsø).
[94] CBSS (2011), op. cit.
[95] Further information on the DSA laboratory *Seksjon nordområdene*, Tromsø is available at: https://www.dsa.no/temaartikler/91920/laboratoriene-paa-nordomraadeseksjonen.
[96] DSA (2013). *Atomberedskap – Sentral og regional organisering.* Kgl.res av 23. august 2013. Strålevern Hefte 31. Østerås: Statens strålevern.

Response

Response typically refers to the provision of emergency services and public assistance during or immediately after an event in order to save lives, reduce health impacts, ensure public safety and meet the basic subsistence needs of the people affected. Disaster response is generally focused on immediate and short-term needs, rather than longer-term recovery efforts.

Preparedness levels and decision-making

Preparedness will turn to response when an unwanted event defined in the preparedness plan, or sometimes an unimaginable crisis event, takes place. This is, however, a matter of degree and evaluation. To start with, three so-called preparedness levels, determined by the chair of the Crisis Committee in consultation with the secretariat (DSA), have been defined which will be activated according to the specific nuclear or radiological event. Level 0 is the probability and the extent of consequences of an event that is minimal or equal to zero. At level 1, there is already an increased probability of consequences of greater severity and/or extent. The situation is unpredictable. At level 2, the probability is high that an event may result in consequences of a greater extent or a greater degree of severity. In this case, it may already be understood from available information that the event has consequences for life, the environment, health or other important societal interests.

In local settings, the HRS/LRS has a special responsibility for notifying the DSA in accident and rescue operations where radioactivity may be involved, and the DSA is responsible for notifying the rescue service in the event of a possible rescue task. The DSA also immediately notifies the head of the Crisis Committee and the whole nuclear emergency preparedness organisation in accordance with established routines.

In an acute nuclear or radiation event, the Crisis Committee is responsible for imposing restrictive and protection measures. In practice, however, many of these decisions, measures and actions in an acute phase are handled locally in accordance with current emergency preparedness principles due to a lack of time and availability. The authorities that normally perform an action during an event still do so with the same authority as otherwise.

Warning the public and further communication

The DSA acknowledges that due to the many actors involved, the communication of nuclear and radiological events to the public is complicated and must be carefully coordinated. In its publications, the DSA explains that it is a (receiving) warning point for national and international events. If they receive a warning, they in turn will contact the County Governor, who is responsible for disseminating this warning further, including the municipalities. The municipalities will have established systems for warning the general public. In addition, it is stated that the Crisis Committee (consisting of several authorities as described above) will make use of its websites and the media to convey information and messages to the public.[97] Yet, in another context it is pointed out that the HRS/LRS handles media inquiries about the rescue operation and what happens during the rescue work, but when asked about the nuclear or radiological event, reference must be made to the Crisis Committee or the County Governor.[98]

Hence, it is not quite clear from the documents how these different levels and channels of information are coordinated in practice to avoid potential contradictory or unclear information being issued to the public. It is therefore exceptionally important to cultivate this system so that all authorities have a shared situation picture and a shared understanding of their tasks in terms of communication to the

[97] DSA (2017), op. cit., p. 13.
[98] DSA (2018b), op. cit., p. 15.

public. Too often in emergency management, a communication crisis is created in addition to the actual event.

Immediate actions

In the case of a nuclear or radiological event, the Crisis Committee can order or give advice on how to decontaminate persons, advise the public to remain indoors, advise on the use of iodine tablets, and provide dietary advice, for example on refraining from consuming certain contaminated foodstuffs.[99]

The most immediate actions may involve such issues as securing and isolating the scene of the accident, or sheltering or evacuating members of the public in immediate danger.[100] Securing and isolation would most probably be limited to the immediate vicinity of the port, with the inner 500m handled by the Norwegian Armed Forces military police, and the area beyond that by the civilian police. Should there be a danger of leakage of radioactive material as modelled in the draft simulations of the Armed Forces FOH ROS, a potential action by the authorities might be so-called 'sheltering in place', namely asking the population to stay at home, close windows and take shelter rather than attempting to evacuate. Besides, the need for a larger evacuation seems unlikely in our case due to the limited scope of a potential nuclear or radiological event.

Larger-scale evacuation and other wider measures, according to the County Governor,[101] are subject to a decision by the Crisis Committee at the national level, not by regional or local authorities. Should a wider evacuation be necessitated, the time needed for this local-, regional-, and national-level communication and coordination might become a challenge in cases where time is scarce.

Municipal responsibility in an acute case

According to the 2008 DSA guidelines for municipalities,[102] the role of the latter is basically expressed in terms of implementing the Crisis Committee's decisions. The decisions of the Crisis Committee reach the municipality via the County Governor, and the municipality again reports back to the County Governor. In the above document, nine special tasks and roles are highlighted, which should be implemented by a municipality in cooperation with the respective sectoral authorities and according to the respective legal regulation:

> 1) Impose security in areas that are heavily polluted, such as restricting access and traffic or securing and removing radioactive fragments.
> 2) Impose acute evacuation of local communities in cases where the source of emissions, such as a local reactor, a wrecked vessel with a reactor or fragments from a satellite, constitutes a direct threat to life and health locally.
> 3) Impose short-term measures/restrictions on the production of food, for example by keeping livestock indoors or postponing harvesting.
> 4) Order/advise on the decontamination of persons.
> 5) Give the public advice on staying indoors.
> 6) Give advice on staying in shelters (as in the case of evacuation).
> 7) Give advice on the use of iodine tablets.
> 8) Give dietary advice, such as advice on refraining from consuming certain contaminated foods.
> 9) Give advice on other dose-reducing measures.

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[99] DSB (2019a), op. cit.
[100] DSA (2017), op. cit., p. 13.
[101] Consultation with the County Governor of Troms and Finnmark 21.8.2020.
[102] DSA (2008). *Plangrunnlag for kommunal atomberedskap.* Revidert oktober 2008. Utarbeidet i samarbeid mellom Fylkesmennene og Statens Strålevern. [Online] Available at: https://www.dsa.no/publikasjon/plangrunnlag-for-kommunal-atomberedskap.pdf.

Medical readiness

During a nuclear or radiological event, the exposure of people can be measured with simple mobile Geiger counters or more developed devices. However, so-called acute radiation syndrome, rapidly leading to serious illnesses or death, is generally very rare and related to large-scale nuclear disasters and exposure to large amounts of ionizing radiation over a short period of time. This is hardly possible from scenarios related to the current case if one is not in the immediate vicinity of the radiating source. Yet a longer-term impact in terms of increasing the potential for causing cancer, for instance, may ensue.

In our case, the nearest hospital able to deal with acute emergency cases of radioactive exposure is the University Hospital of Northern Norway (UNN). Following information received from UNN,[103] the hospital's preparedness administration has been involved in the inter-agency discussions since 2019. UNN already has good capacity and capability with regard to nuclear and radiological events, and a related medical preparedness and emergency response system. The current case has led to the need to calibrate the preparedness in this field. As such, the UNN organisation in emergencies remains the same, based on the existing 'crisis leadership' organisation. This organisation will be updated and exercises conducted in light of the challenges posed by the current case and respective scenarios. Should the capacity of UNN be overstretched, critically ill patients would be flown to Oslo University Hospital.

Some challenges remain related to medical readiness, however. The most direct challenge concerns the need to prepare the ambulance service to respond to a possible nuclear or radiological event on the submarine, in terms of protective clothing, equipment and routines. However, the 2020 corona crisis has already led to many such changes and practices that can also be applied to our case.

A second challenge, in a worst-case scenario for UNN, is related to the possibility that the plume carries airborne radioactive particles to the area where the hospital (and UiT) is located, as simulated in the Armed Forces FOH ROS scenario. Following the information received from UNN,[104] while this would not paralyse the hospital's work, it would not be possible to switch off the ventilation, which would then create a potential contamination hazard inside UNN. To date, there is no specific preparedness for this case.

Finally, any information, correct or not, about a nuclear or radiological event might lead people to perceive or experience unrelated health issues, which could easily result in overloading the emergency number (113) and increase visits to the hospital's emergency reception. This in turn might have an impact on the normal service capacity of the hospital.

Restrictions on foods and other contaminated material

After the immediate rescue operation, there might be a need to impose measures and restrictions on the production of foods and other material subject to contamination. The Norwegian Food Safety Authority (*Mattilsynet*) is the main responsible authority in terms of radioactivity control of food production and sales. Being a full member of the Crisis Committee, it collects and processes information and measurement data and implements the measures to prevent radioactive contamination of feed, food, animals and fish, as well as providing measurements of radioactivity in foodstuffs, and advice on slaughter times, feeding, animal welfare aspects of measures and so on. The Norwegian Food Safety Authority also gives dietary advice to the public, is an advisor for municipal or state health authorities with regard to drinking water, and is the supervisory authority vis-à-vis waterworks owners with regard to imposed measures.

[103] Consultation with UNN 24.8.2020.
[104] Consultation with UNN 24.8.2020.

Training and exercises

Exercises are typically organised as simulations of an unwanted event. They are mostly needed to validate the preparedness plan and to test how well established the structures, procedures, capacities and capabilities for crisis management are. They are also used as training tools to develop staff competencies and to provide practice in carrying out the roles that staff are assigned in the contingency or preparedness plan.

There are many different types of exercises. Discussion-based exercises are the most economical to run and the easiest to prepare, and are used to develop awareness about the contingency plan through discussion. Tabletop exercises are also relatively cheap and based on simulation, involving a realistic scenario with an accelerated timeline. A full-scale exercise is a live rehearsal for implementing a preparedness plan. Full (field) exercises are often the only means of really testing logistics, communications and physical resources. A fourth type of exercise would then combine certain elements of those above.

According to the County Governor,[105] an exercise related to the current case is to be organised among the main actors and stakeholders before the first visit by an allied nuclear-powered submarine. Based on the current knowledge,[106] this probably refers to a tabletop exercise organised by mid-November 2020 with the participation of at least the County Governor and the four municipalities of Tromsø, Karlsøy, Lyngen and Skjervøy. UNN has stated[107] that it will organise its internal tabletop exercise within its existing crisis leadership organisation in autumn 2020 to familiarise participants with a related event scenario.

Liability and indemnities

The liability issue with particular regard to US nuclear-powered vessels visiting foreign ports has a history. It became an issue in the 1960s, especially after some non-radiological accidents affecting US nuclear-powered submarines, leading many allied countries to deny nuclear-powered submarines access to their ports. While the US Department of Defense was originally reluctant to apply any liability agreements to their warships, in the early 1970s the US passed legislation that promised to meet claims resulting from reactor accidents. Although it is difficult to find much confirmatory information in public sources, the countries that have been mentioned as having obtained explicit American assurances about liability for nuclear and radiological events seem to include New Zealand, Australia, Japan and NATO member Canada.[108]

Hence, as far as Japan is concerned, there would appear to be liability clauses in the US port-use agreement whereby the US is obliged to provide financial compensation that may be paid in the event of a US nuclear-powered warship reactor event, with no statutory limit.[109] Similarly, the above-mentioned Australian ARPANSA principles for visiting nuclear-powered submarines include the requirement that such visits will be "subject to satisfactory arrangements concerning liability and indemnity".[110]

Whether these kinds of liability rules will be applied in the case of Norway for allied NATO nuclear-powered visits to civilian ports, what they would cover, what the process would entail and so forth, is not available in public sources or in consultation with major authorities. Nor can one find any specific

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[105] Consultation with the County Governor of Troms and Finnmark 21.8.2020.
[106] Consultation with the Municipality of Tromsø 25.8.2020.
[107] Consultation with UNN 24.8.2020.
[108] Pugh, M. (1989). Nuclear Warship Visiting: Storms in Ports. *The World Today*, Vol. 45, No. 10, pp. 180-183.
[109] This is related to nuclear-powered US vessels visiting Japan. *Fact Sheet on U.S. Nuclear Powered Warship (NPW) Safety* (n.d), op. cit., p. 9.
[110] ARPANSA (2001), op. cit., p. ix.

information about the division of liabilities between Norwegian authorities or administrative levels after a potential nuclear or radiological event, or any insurance arrangements to the same effect.

4. Conclusions

The current report rests on the prerequisite that from early 2021 onwards, the Norwegian port of Tønsnes (Grøtsund industry and offshore base), owned by Tromsø municipality, will be receiving nuclear-powered submarines from Norway's NATO allies (in practice from the US, but subsequently from the UK and France as well) for visits lasting several days four to five times per year, mainly for the purposes of crew changes and non-nuclear maintenance. The report has presented a non-sensitive overview of the case, based on publicly available information and short consultations with some major public stakeholders involved in the issue. While many issues discussed above call for more careful and multidimensional scrutiny, the following issues can be highlighted as the main conclusions of the current overview, as of the end of August 2020.

General overview. The planned regular, albeit rather infrequent, short visits by allied nuclear-powered submarines to the port of Tønsnes in the Tromsø municipality create the need for enhanced risk management and preparedness work for several related actors. The likelihood of a nuclear or radiological event during transit or while at berth is slight, and its consequences would remain local. Even in the worst case, the immediate life-threatening consequences would be confined to the immediate vicinity of the leakage, although a limited area would be contaminated through the air and/or to a lesser extent via water, depending on the weather conditions. On the basis of current regulations, should they be carefully applied to the above risk picture, well implemented in practical work, and tested in exercises, the Norwegian civil protection and nuclear and radiological emergency management system is highly capable of dealing with the envisaged worst-case scenarios.

Decision. The issue is understood to be a national-level decision, especially as the Minister of Defence has actively appeared as its spokesperson publicly, presenting it as a matter that has already been decided. There is, however, no publicly available, clear-cut documentation concerning the authority or institution, or the who, when, why and on which exact legal basis the formal decision to receive allied nuclear-powered vessels in a civilian port owned by the Tromsø municipality was made. Nor have any proper publicly available economic, environmental and social impact assessments been prepared or even discussed, even if the case could be interpreted as a change of existing land-use plans, particularly when it comes to supplementing them with environmental and public safety risks involving nuclear reactors. One would expect better clarity from the perspective of democratic accountability and transparency, particularly in an issue related to public safety, which furthermore seems to be a decision implemented against the expressed majority will of the elected local decision-makers.

Public consultation. It is not clear, nor documented anywhere in a satisfactory way, why there has not been a proper process of public consultation during the decision-making phase of the current case. The first public consultation will be organised only after the factual decisions and preparations have been made, and this consultation therefore remains a mere formality. This is not in line with the good risk governance practices of a democratic society, and may be reflected in exaggerated risk perceptions and the respective unwanted behaviour among the general public, even in cases where no safety concerns are at stake.

Risk assessments. As of August 2020, only the Armed Forces FOH has produced a document or rather a draft of a risk and vulnerability analysis. The basis for its data and methodologies is not clear. Moreover, it is closed to public scrutiny. The DSA, the County Governor and Tromsø municipality are in the process of preparing their respective risk assessments, and hence could not be considered in the current paper. One concern, however, is that these various stakeholder risk assessments will not be combined into a more generic risk assessment. There is a danger of creating a system that includes potentially contradictory or even rival risk assessment results and their respective risk perceptions, instead of a holistic, coordinated risk picture. It also seems that unintended but partially self-made non-radiological and non-public safety or environmental risks, such as possible social-political, communication and reputation risks, have not been considered to a satisfactory degree by the stakeholders.

Preparedness. The Norwegian system of preparedness in case of nuclear and radiological events is well regulated, although not with the current case in mind. Regional and local adaptation needs duly call for calibration and training. This is especially true with regard to the practical coordination of inter-agency and multi-level cooperation and decision-making, (early) warning for the general public, and further communication to the public and the media during a potential unwanted event.

Liability. A worst-case scenario, if it materialised, would probably result in some health and environmental consequences, but also in many negative material consequences and losses, for example due to suspending important activities as a result of the danger of contamination. There is no information available on any liability agreements or principles in case of an unwanted event of a nuclear, radiological or non-radiological nature related to these submarine visits. If this is indeed the case, it is neither clear, nor publicly documented anywhere in a satisfactory way, as to why there is no liability agreement with the US Navy, following the example of many other countries facing the same task of receiving allied nuclear-powered vessels in their civilian ports. In any case, clarity in liability issues, including insurance policies, is part of the core of good risk management and governance. Indeed, so-called risk sharing is usually understood as one of the risk-treatment strategies, namely dealing with and mitigating the unwanted consequences for the actors involved.

UiT. The UiT Tromsø campus is the biggest employer in the area to be potentially affected in case of a nuclear or radiological event during the submarine visits. In one of the scenarios envisaged by the Armed Forces FOH ROS, the radioactive plume would reach UiT (together with UNN). UiT’s emergency preparedness, while well-functioning, trained and tested in practice, is not designed for the current risk picture. Due to the risk perceptions related to nuclear and radiological events and the fact that many adults have minors in day-care or schools outside the campus, it is probable that coordination of the behaviour of staff and students might be particularly challenging. Such routine issues as in-advance risk information, exercises, early warning and communication to staff, students and guests, evacuation/staying indoors rules, ventilation systems, the availability of iodine tablets, and so forth, demand clear internal planning as well as guidelines from the municipality.