Applied Nuclear Physics in the Alva Myrdal Centre for Nuclear Disarmament: Non-Proliferation and Safeguards Activities

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Outline

- Background to the establishment of Alva Myrdal Centre for Nuclear Disarmament
- Overview of the Alva Myrdal Centre for Nuclear Disarmament
- Education and Training within AMC
- Outreach within Alva Myrdal Centre (AMC)
- Technical research within Alva Myrdal Centre (AMC)
- Conclusion
- Notes & References

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Background

- In 2018, nuclear disarmament had been on the international agenda for decades, but little progress had followed from it
  - US announced withdrawal from Intermediate-Range Nuclear Forces (INF) Treaty
  - New Strategic Arms Reduction Treaty (New START) in effect but for how long?

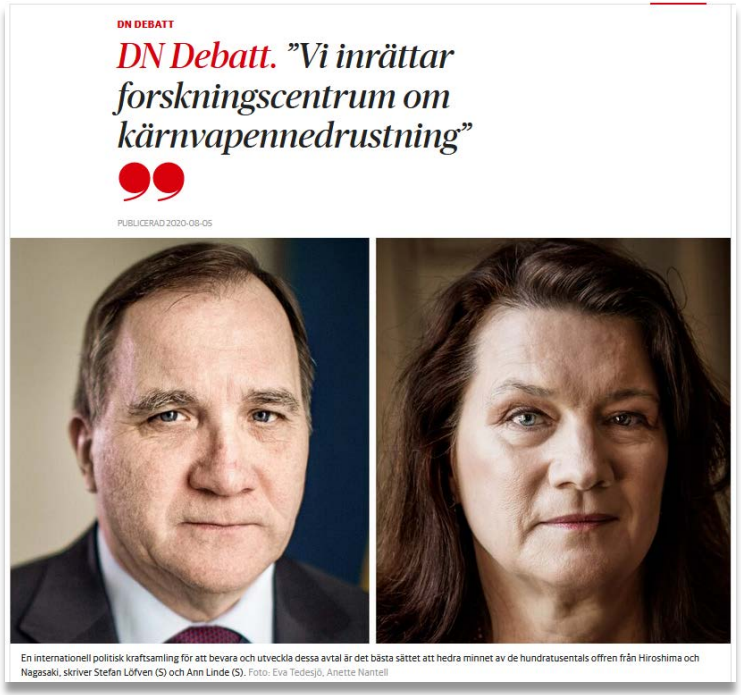
- Proposal for a Treaty on the Prohibition of Nuclear Weapons (TPNW); in force since January 2021

- Sweden decided not to sign TPNW in 2019, but remained dedicated to prevent the proliferation of nuclear weapons and support efforts on nuclear disarmament (legacy from Alva Myrdal, Hans Blix, Rolf Ekeus etc)

- Important to show committment to nuclear disarmament both nationally and internationally, but how?

Background

- Announcement by the government to establish a national disarmament center
- Swedish reserach council opened call for interest to host the center
- 4 applications submitted, one of them from UU
- Decision by the government to establish the center at UU in December 2020



DN DEBATT

DN Debatt. ”Vi inrättar forskningscentrum om kärnvapennedrustning”

PUBLICERAD 2020-08-05

En internationell politisk kraftsamling för att bevara och utveckla dessa avtal är det bästa sättet att hedra minnet av de hundratusentals offren från Hiroshima och Nagasaki, skriver Stefan Löfven (S) och Ann Linde (S). Foto: Eva Tedesjö, Anette Nantell

Nationellt kunskapscentrum för kärnvapennedrustning etableras vid Uppsala universitet

Publicerad 22 december 2020

Regeringen har idag fattat beslut att avsätta 10 miljoner kronor till Uppsala universitet för att inrätta ett kunskapscentrum för kärnvapennedrustning.

Kunskapscentrumet ska bidra till ökad kunskap om kärnvapennedrustning genom att bedriva utbildning och forskning inom relevanta områden, att säkra framtida expertkompetens och utgöra ett tvärvetenskapligt stöd till policyarbetet inom området. En tvärvetenskaplig ansats är nödvändig för att föra nedrustningsarbetet framåt.

Ett kunskapscentrum kommer att bidra till att öka allmänhetens medvetenhet om kärnvapennedrustning och därmed bidra till en offentlig debatt om nedrustningsarbetets utmaningar.

Bakgrunden är de senaste årens säkerhetspolitiska utveckling och de ökade riskerna för kärnvapenanvändning. Detta ställer det internationella nedrustningsarbetet inför nya utmaningar. För att långsiktigt kunna möta dessa behöver Sverige säkra en stark nationell kunskapsbas.

Overview: Alva Myrdal Centre (AMC) for nuclear disarmament

- AMC is established to provide **teaching, research, and policy support** on nuclear disarmament

- AMC aims to study “the whole **process** in which nuclear disarmament occurs; i.e., preconditions and hurdles, negotiations and decision-making, and implementation and verification.”

- AMC is a **cross-disciplinary center** that combines insights from different disciplines such as peace and conflict research, applied nuclear physics, and international law.

- AMC **disseminates knowledge** of nuclear disarmament by holding and hosting conferences and workshops. AMC **raises public awareness** about nuclear disarmament and contributes to the public debate on the challenges of disarmament work.

Overview: Alva Myrdal Centre (AMC) for nuclear disarmament

- A director:
  Professor Erik Melander at the Department of Peace and Conflict research (PCR)

- A board:
  Chaired by Cecilia Wikström. 2 members from social sciences, 2 members from science and technology, 3 members from external partners, 1 student representative

- Six working groups:
  Arranged around specific themes, lead by different researchers.

- An overview of AMC can be found on https://www.uu.se/alvamyrdalcentre/ and in an IAEA conference proceeding from 2022[1].

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Overview: Alva Myrdal Centre (AMC) for nuclear disarmament

WG	WG name	WG leader
1	Negotiating Nuclear Disarmament	Dr Isak Svensson, Professor at the Department of Peace and Conflict Research, UU
2	International Measures for Compliance to Nuclear Disarmament Regimes	Dr Peter Wallensteen, Senior Professor of Peace and Conflict Research at UU and Richard G. Starmann Sr. Research Professor Emeritus of Peace Studies at the Kroc Institute, University of Notre Dame, USA
3	Data on Nuclear Rivalries, Negotiations, and Agreements	Dr Magnus Öberg, Director of the Uppsala Conflict Data Program (UCDP), and Dr Margareta Sollenberg deputy Director of the Uppsala Conflict Data Program (UCDP) at the Department of Peace and Conflict Research, UU
4	Technical Nuclear Non-Proliferation and Safeguards	Dr Sophie Grape, Associate professor at the Division of Applied Nuclear Physics, UU
5	Nuclear Disarmament in Policy and International Law	Dr Sibylle Bauer, Director of Studies, Armament and Disarmament at the Stockholm International Peace Research Institute (SIPRI)
6	Nuclear Disarmament and Non-Proliferation	Dr Målfrid Braut-Hegghammer is Professor of Political Science at the University of Oslo, and Director of Oslo Nuclear Project

Overview: Alva Myrdal Centre (AMC) for nuclear disarmament

- **WG1 – Negotiating Nuclear Disarmament (Dr Isak Svensson):**
  Studies of multilateral negotiations aimed at disarmament, non-proliferation, and NW management. How can processes of nuclear negotiations become more effective in containing, controlling, and reducing nuclear weapon programs? Identification of key procedural conditions that impact negotiation effectiveness.
- **WG2 - International Measures for Compliance to Nuclear Disarmament Regimes (Dr Peter Wallensteen):**
  Investigations on the role of sanctions in making countries join and adhere to the Non-Proliferation Treaty (NPT) or other non-proliferation arrangements. Research includes studies of historical cases and current situations. The goal is to establish an empirical basis for the role of sanctions in non-proliferation and disarmament initiatives.
- **WG3 - Data on Nuclear Rivalries, Negotiations, and Agreements (Dr Magnus Öberg & Dr Margareta Sollenberg):**
  Identification of data gaps and development of new data on issues related to nuclear weapons. Systematic mapping of available data, identification of key areas where important contributions can be made. Intentions are that the new data will facilitate research on nuclear rivalry, proliferation, crises/escalation processes and treaty negotiations.




Overview: Alva Myrdal Centre (AMC) for nuclear disarmament

- **WG4 - Technical Nuclear Non-Proliferation and Safeguards (Dr Sophie Grape):** Development of technical measures that support the non-proliferation and disarmament community. Covers research on approaches, methodologies and measurement techniques. Research topics include fuel cycle studies, simulations and analysis of nuclear material, development of detection techniques and data analysis, and verification under existing and future non-proliferation and disarmament treaties.
- **WG5 - Nuclear Disarmament in Policy and International Law (Dr Sibylle Bauer)** Issues related to nuclear disarmament in the context of policy and international law. Studies of ongoing developments in a strategic context and exploration of pathways to help multilateral arms control and disarmament efforts. Increase awareness of nuclear issues, training of next generation disarmament experts. Coordinating the EU Non-proliferation and Disarmament Consortium (EUNPDC).
- **WG6 - Nuclear Disarmament and Non-Proliferation (Dr Målfrid Braut-Hegghammer)** Studies of NW focusing on questions relating to security using a holistic approach covering empirical work, past experiences and new tools, as well as emerging challenges. The work aims to benefit nuclear disarmament and nuclear non-proliferation by facilitating a rigorous discussion and relevant outputs.

Education and Training within AMC

- **Nuclear weapons and disarmament**
  7.5 credit undergraduate course open for students enrolled in Bachelor's programmes in Physics, Law and Peace and Development studies at Uppsala University. The course mixes interdisciplinary lectures with interactive seminars with simulation games.
- **Verification of nuclear test explosions**[2]
  A 7.5 credit PhD course (5 weeks) organized by AMC and FOI (Swedish Defence Reserach Agency). Arranged in 2022 as a hybrid course featuring 14 lectures (≈14x90 min) and a laboratory exercise. The course spans over treaties, identification and analysis of seismic and radionuclide signatures as well as a scenario analysis.
- **Armament and Disarmament Summer School**
  A 1-week summer school organized by AMC together with Sipri and Odessa Center for Nonproliferation. A great opportunity for the next generation of academics, researchers, opinion leaders and policymakers in the field of disarmament, non-proliferation and arms control. (2022: 240 applicants for 40 positions)

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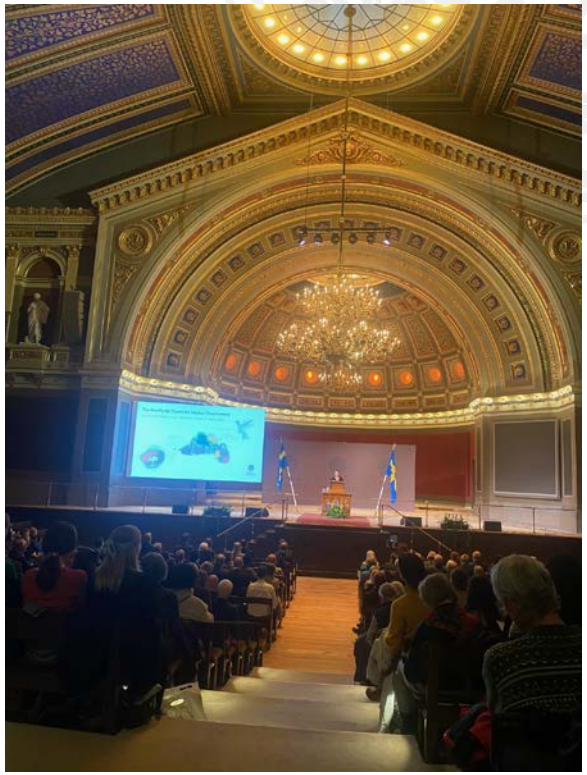
Outreach within Alva Myrdal Centre (AMC)

- International, cross-disciplinary conference on nuclear disarmament!
- First Annual Conference in Uppsala, Sweden, on October 19-21, 2022 together with the official inauguration
- Second Annual Conference will take place in Uppsala on June 14-16, 2023
- Call for proposals closed in February, but (free) registration of attendance to the conference is possible. More information on: https://www.uu.se/alvamyrdalcentre/cross-disciplinary-conference-2023



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Outreach within Alva Myrdal Centre (AMC)

- ”Researching Peace” podcast in collaboration between AMC and the Department of Peace and Conflict Research at Uppsala University
- First twelve episodes produced in English, newer episodes are in Swedish

Episodes in English	Episodes in Swedish
#22 From nuclear weapons development to disarmament	#23 From submarines to statistics
#12 Peace Research in the Global South	#21 From peace activist to Professor
#11 Doing Field Research	#20 An eye on the world
#10 Predicting Armed Conflicts	#19 A nuclear detective
#12 Peace Research in the Global South	#18 The global struggle
#11 Doing Field Research	#17 A roadmap for the future
#10 Predicting Armed Conflicts	#16 In the eye of the storm
#9 Diplomacy & Peace Research	#15 In case of the worst
#8 Researching Conflicts Ethically	#14 The year the world should remember
#7 Collecting Conflict Data	#13 The most powerful weapon

- Episodes are available on: https://www.uu.se/alvamyrdalcentre/Podcast+-+Researching+Peace or on Spotify

Technical research within Alva Myrdal Centre (AMC)

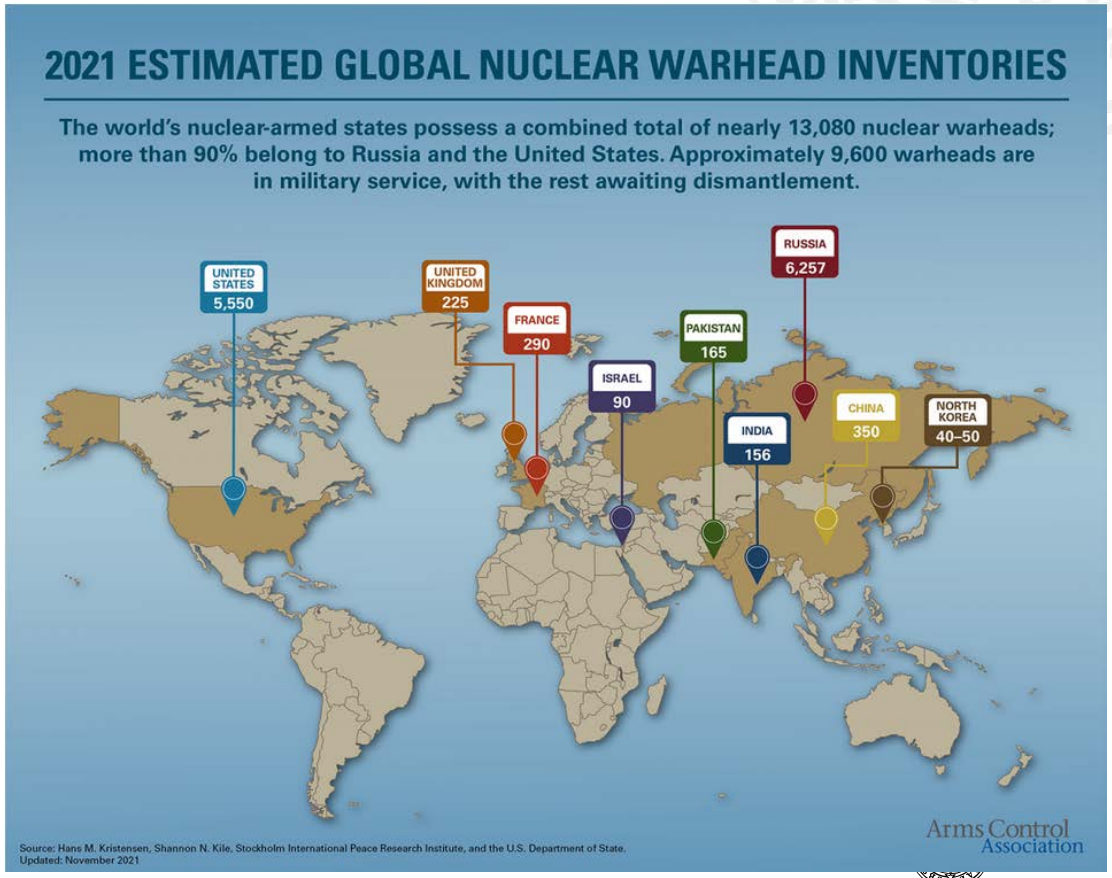
- Nuclear weapons pose a particularly destructive threat to the world, a threat that has recently been renewed.
- How can the six WGs jointly, and AMC as a whole, contribute with research on nuclear disarmament?
  - In this presentation: How can research in the only technical working group, entitled “Technical nuclear non-proliferation and safeguards” contribute to global disarmament efforts?
- In order to be relevant, we must know:
  - What are the relevant questions and challenges?
  - How can we best exploit our expertise to promote nuclear disarmament efforts?

Disarmament and the proliferation of nuclear weapons

The world is divided between states that posess nuclear weapons and those that do not. For complete nuclear disarmament to occur, it is necessary to control, limit and abolish nuclear proliferation:

- **Fight horizontal proliferation**
  where the number of states acquiring nuclear weapons or developing the capability and materials for producing them increase.

- **Fight vertical proliferation**
  where states possessing NWs increase stockpiles of these weapons, improve the technical sophistication or reliability of their weapons, or developing new weapons.



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WG4 targets needs and challenges associated with **technical non-proliferation and safeguards**

- where ”non-proliferation” is mainly concerned with the **prevention of horizontal nuclear weapon proliferation**, and
- ”safeguards” is concerned with measures put in place to deter from the **misuse of civil technologies and facilities** for the manufacture of nuclear weapons.

WG4 aims to contribute with technical expertise that can both **promote successful negotiations and decision-making, and help ensure that existing and future treaties on non-proliferation and disarmament can be verified**.

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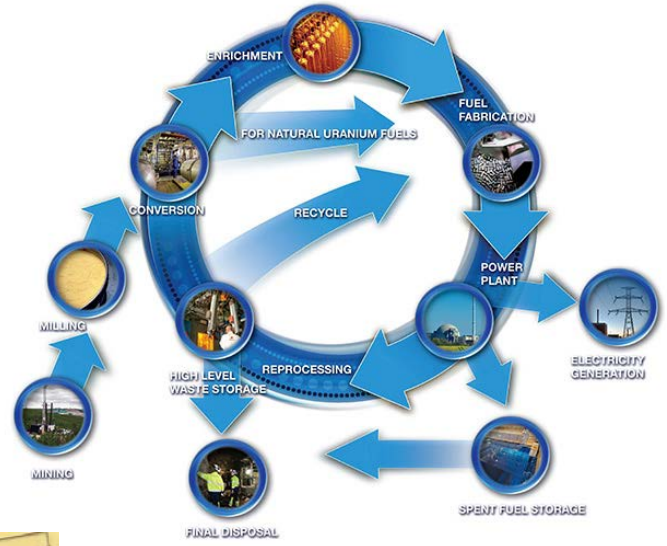

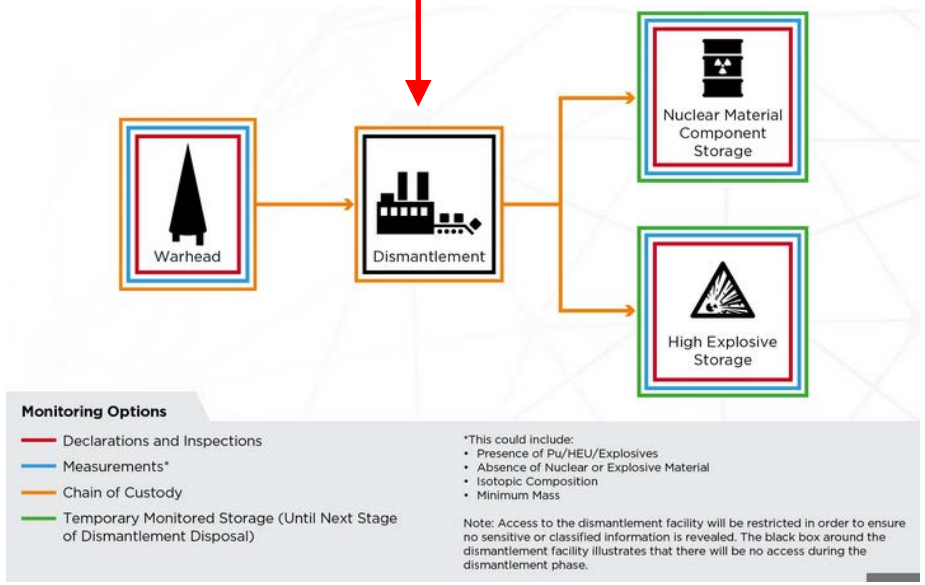

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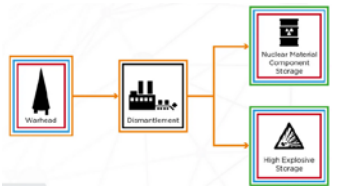
Relevant challenges in a nuclear disarmament context[3]

1. Where are the **known sensitive materials** available in existing and future **nuclear fuel cycles**?
   - What are the properties of the available uranium and plutonium?
   - What can we say about the availability?
   - How attractive is the material for a possible nuclear proliferator?
   - How can we ensure non-diversion from existing and future fuel cycles?

2. Are there **other nuclear materials** than uranium and plutonium that can be used in NWs?
   - How attractive are they for a possible nuclear proliferator?
   - Should additional nuclear materials be controlled and verified?
   - Should additional non-nuclear materials be monitored to indicate NW ambitions and programmes?

3. How to **detect and verify activities** and associated with **nuclear weapons (programmes)**?
   - How can a NW programme be detected?
   - What approached and methods can we apply to learn more about it?
   - How can we learn more about past activitites?
   - What is needed to ensure nuclear disarmament verification?

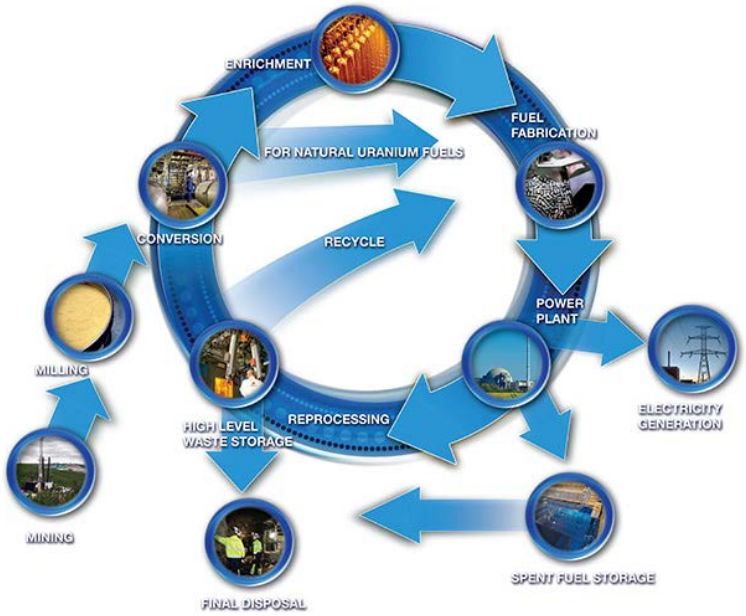


4. How can efficient **verification of new treaties and agreements** be ensured?
   - What can be learn from existing verification bodies and frameworks?
   - How do we ensure that the verification of the treaties cover all technical possibilities?

1. Where are the **known sensitive materials** available in existing and future **nuclear fuel cycles**?

Assessments of uranium and plutonium in the nuclear fuel cycle

- How can we use knowledge from the civil nuclear fuel cycle and its safeguards verification to learn more about U and Pu availability and properties in the military fuel cycle?
  - Some power reactors have been (are) used to produce plutonium for NWs. What can be deduced about material production from studying these reactors? [4,5]
  - Enrichment and reprocessing are considered the most sensitive parts of the fuel cycle. What can be said about their operation? How can they be used to feed NW programmes? [6]
  - Nuclear material can legally be removed from nuclear safeguards for nuclear propulsion purposes. What may be the non-proliferation implications of this? [7,8]
  - New nuclear reactors (Gen IV) are proposed to both breed fissile material, and to burn it. How does this impact nuclear non-proliferation and disarmament? (ongoing work)
  - Can detection techniques and instruments from safeguards be used to verify Chain of Custody (CoC) in nuclear disarmament, or the presence or absence of nuclear material in nuclear warheads?



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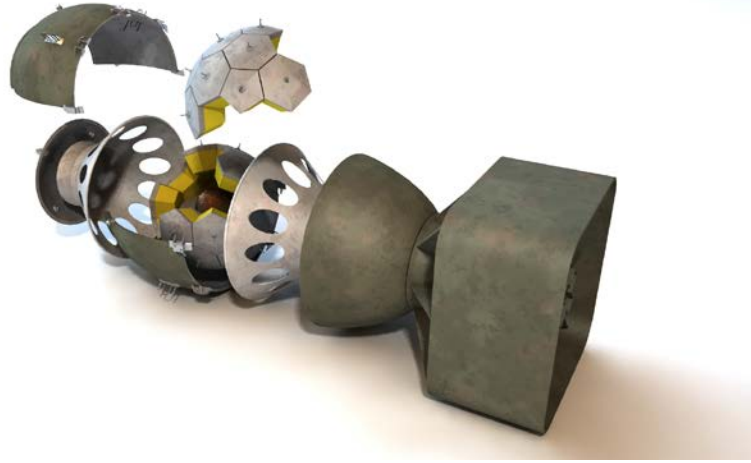
2. Are there **other nuclear materials** than uranium and plutonium that can be used in NWs?

What (nuclear) material needs to be controlled and verified?

- Typically, nuclear weapons contain HEU enriched to >90%, or Pu with a Pu239 content > 90%. These materials are under IAEA safeguards.[9]
- Other materials are able to sustain a chain reaction, and could in principle be used to manufacture nuclear weapons.[10]
- How can we develop methods to identify and evaluate what other nuclear materials that can be used in NWs? (ongoing work)
  - What are the determining factors for not doing so (yet)?
  - Should these materials be safeguarded (ie monitored and verified) by the IAEA as well?
- Evaluating attractiveness of nuclear materials in various fuel cycles can help identify systems, facilities and materials where the risk of diversion may be great. (ongoing work)
- To what extent can the use of non-nuclear materials be monitored to support evaluations that concern the status and development of nuclear weapons (programmes)? (ongoing work)
  - How do we ensure that new treaties consider all possible nuclear materials, and that tools to ensure their verification are developed?



3D model of Fat Man. Image from: https://www.turbosquid.com/3d-models/fat-man-atomic-bomb-with-interior-3d-model-1722195

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3. How to **detect and verify activities** and objects associated with **nuclear weapons (programmes)**?

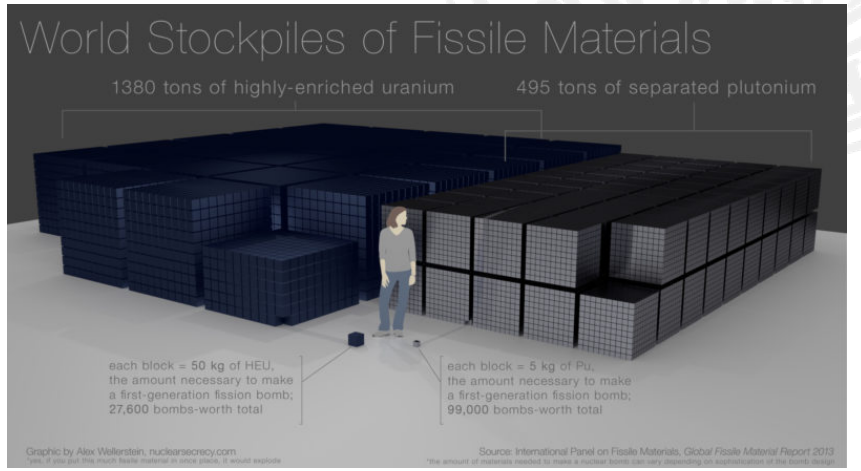
Nuclear weapons programmes and test explosions

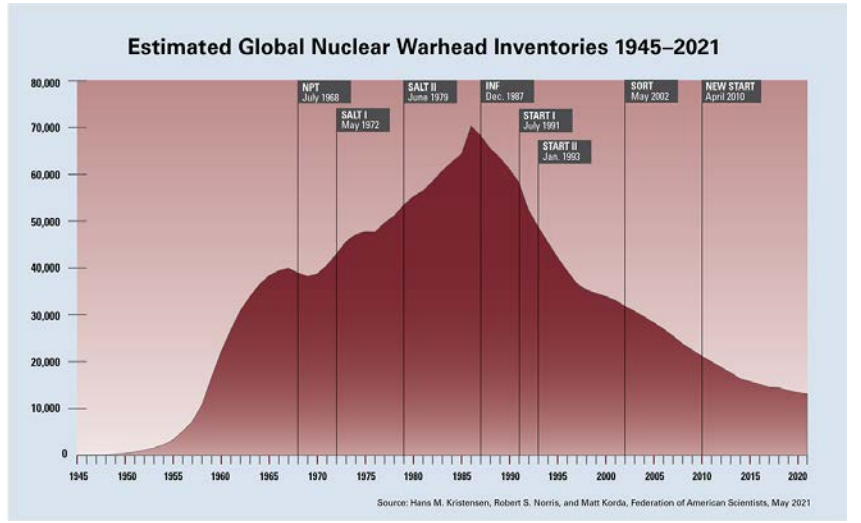
- NWs are developed within NW programmes. Major projects with huge amounts of human and financial capital, that exploit domestic expertise in relevant competences.
- Test explosions have historically been part of a nuclear weapon programme to evaluate the performance of the weapon and its design.
- The International Monitoring System (IMS) of the (Comprehensive Nuclear-Test-Ban Treaty Organization) CTBTO is designed to detect nuclear test explosions by seismic, infrasound, hydro-acoustic and radionuclide monitoring.
- Underground explosions can be detected though analysis of seismic signals and noble gases leaking out from the underground test site.
- Development of instrumentation and improvements related to measurement and analysis techniques could potentially improve detection capability[11], and be used to verify undeclared reprocessing facilities part of a weapons programme.

3. How to **detect and verify activities** and objects associated with **nuclear weapons (programmes)**?

Estimating fissile material (and weapon) production

- Assessments of produced nuclear material in facilities or in states as a whole are essential in evaluations where a state's nuclear capabilities are analysed.[5]
- Such evaluations may become useful (crucial) for verification under non-proliferation and disarmament treaties such as the TPNW or the Fissile Material Cut-off Treaty (FMCT).[12]
- Such evaluations can also be used to estimate production of nuclear warheads in states, and support conclusions drawn in states under existing non-proliferation and disarmament treaties. (ongoing work)
- Evaluations can be linked to nuclear archaeology, where the researcher (like a historian) tries to reconstruct information and data on past fissile material production through simulations, calculations and analysis of samples from the facilities. (ongoing work)
    - Evaluations in states with past NW programmes should also consider dismantlement of the infrastructure surrounding the fissile material production.
- Verification of nuclear disarmament verification requires verification of absence as well as presence. What can we learn from verifying unknown objects, and what do we need to know? (ongoing work)





4. How can efficient **verification of new treaties and agreements** be ensured?

- The Treaty on the Prohibition of Nuclear Weapons (TPNW) signed and ratified by over 60 state parties (is currently in effect)
- For the TPNW, or any other treaty or agreement (such as e.g. FMCT) to have an impact on nuclear disarmament, one must define an organizational structure and a competent authority leading its mission (to discover, verify and eliminate nuclear weapons)
- R. Kelley et al[12] has studied the OPCW, and the CTBTO as a template for a future TPNW secretariat to carry out its mission
- The verification of any disarmament treaty will, in essence, have to define decisions criteria that will guide the technical solutions to be applied to the treaty verification. V. Fedchenko has elaborated on this in the WG4 State of the Art Report[3].

Conclusions

- Non-proliferation of NW and nuclear disarmament are cross-disciplinary issues
- WG4 is contributing with technical expertise that can be used to support negotiations and decision-making, and help ensure that existing and future treaties on non-proliferation and disarmament can be verified. This is central to the success of any treaty.
- To combat proliferation of NWs and promote nuclear disarmament, we need to identify production and management of nuclear material in civil and military fuel cycles and develop technical tools needed to verify non-proliferation and disarmament activities.
- The success of any developed tool will dependent on how well it is adapted to the unique context, and on the willingness of states to use it. A holistic view is important!
- WG4 has surveyed challenges in the field, and identified ways forward. Ongoing efforts are targeting:
  - the availability of sensitive materials in nuclear fuel cycles,
  - methodology development for identification of sensitive materials to control or safeguard,
  - detection and verification of activities and objects associated with nuclear weapons (programmes), and
  - efficient verification under new treaties and agreements.
- This presentation has been focused on technical reserach within one specific working group. However, there are five other working groups actively contriobuting to nuclear disarmament, and also joint efforts targeting education, training and outreach!

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Thank you for your kind attention!

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