Working Group on Physics and Disarmament
Arbeitsgruppe Physik und Abrüstung (AGA)

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Zur Abrüstung, der Verhinderung der Verbreitung von Massenvernichtungsmitteln und der Beurteilung neuer Waffentechnologien sind naturwissenschaftliche Untersuchungen unverzichtbar. Auch bei der Verifikation von Rüstungskontrollabkommen werden neue Techniken und Verfahren benötigt und eingesetzt. Schwerpunkte in diesem Jahr bilden Themen wie die nukleare Abrüstung, Verifikation bzw. die Detektion von Nuklearanlagen und Materialien, Raketenabwehr und Zerstörung von Nuklearsprengköpfen, neue militärrelevante Technologien wie Drohnen. Die Fachsitzung wird von der DPG gemeinsam mit dem Forschungsverbund Naturwissenschaft, Abrüstung und internationale Sicherheit FONAS durchgeführt. Die 1998 gegründete Arbeitsgruppe Physik und Abrüstung ist für die Organisation verantwortlich. Die Sitzung soll international vorrangige Themen behandeln, Hintergrundwissen vermitteln und Ergebnisse neuerer Forschung darstellen.

Overview of Invited Talks and Sessions

(Lecture hall PTB HS HvHB)

Max-von-Laue Lecture

PSV IV	Tue	19:00–20:00	A 151	**Max-von-Laue Lecture: Global Famine after Nuclear War** — •Alan Robock

Invited Talks

AGA 1.1	Wed	15:00–16:00	PTB HS HvHB	**Not A Bluff! - North Korea's "combat proven" missile program** — •Markus Schiller
AGA 3.1	Thu	9:30–10:30	PTB HS HvHB	**The Three-Body Problem in Nuclear Deterrence** — •Steve Fetter
AGA 5.1	Thu	15:00–16:00	PTB HS HvHB	**Gender- and age-specific characteristics in radiosensitivity and their consequences for radiation protection - Overview of the current knowledge** — •Lisa Deloch, Lena Winterling, Laura Ruspeckhofer, Tom Unterleiter, Michael Rückert, Thomas Weissmann, Antonia Völlings, Eva Titova, Rainer Fietkau, Udo S. Gaipl, Margaux Piltz
AGA 6.1	Thu	16:00–17:00	PTB HS HvHB	**Proliferation Issues of Future Nuclear Fuel Cycles** — •Friederike Friess
AGA 8.1	Fri	9:30–10:30	PTB HS HvHB	**Irreversible Elimination of Large Strategic Nuclear Weapons** — •Robert Kelley

Sessions

AGA 1.1–1.3	Wed	15:00–17:00	PTB HS HvHB	**Arms Control, Missiles and Outer Space**
AGA 2.1–2.2	Wed	17:00–18:00	PTB HS HvHB	**Nuclear Safeguards**
AGA 3.1–3.3	Thu	9:30–11:30	PTB HS HvHB	**Nuclear Deterrence and Nuclear Disarmament**
AGA 4.1–4.2	Thu	11:45–12:45	PTB HS HvHB	**Nuclear Archeology**
AGA 5.1–5.1	Thu	15:00–16:00	PTB HS HvHB	**Effects of Radiation**
AGA 6.1–6.3	Thu	16:00–18:00	PTB HS HvHB	**Nuclear Fuel Cycle and Proliferation**
AGA 7	Thu	18:30–19:30	PTB HS HvHB	**Members' Assembly**
AGA 8.1–8.3	Fri	9:30–11:30	PTB HS HvHB	**Nuclear Weapons**

Annual General Meeting of the Working Group on Physics and Disarmament

Donnerstag 18:30–19:30 PTB HS HvHB

- Bericht
- Wahl
- Verschiedenes

AGA 1: Arms Control, Missiles and Outer Space

Time: Wednesday 15:00–17:00 Location: PTB HS HvHB

Invited Talk AGA 1.1 Wed 15:00 PTB HS HvHB

Not A Bluff! - North Korea's "combat proven" missile program — •Markus Schiller — ST Analytics, München

Just around New Year's, North Korean ballistic missiles were used for the first time in combat, namely in the Russian invasion of Ukraine. With this, North Korean missiles are now "combat proven", clearly showing that they are more than just a bluff. The presentation will look at this development, as well as at other developments in the North Korean program over the past year, trying to figure out what else to expect in the near future.

AGA 1.2 Wed 16:00 PTB HS HvHB

Uncrewed Armed Vehicles and Missiles in the Russian War Against Ukraine — •Jürgen Altmann — Experimentelle Physik III, TU Dortmund

In the Russian war against Ukraine uncrewed armed vehicles (mainly in the air, UAVs) and missiles (tactical, ballistic and cruise) are being employed at unprecedented levels by both sides. Commercial UAVs are being armed, and new armed UAV types are being developed. Imports from other countries play a significant role. Autonomous targeting seems to have begun. Russia has also used hypersonic missiles. In parallel, efforts for UAV and missile defence have increased. Many armed forces are studying the war and draw conclusions for their own armaments. The talk will give an overview of various systems and their properties, including imported types, and will discuss effects on international security.

AGA 1.3 Wed 16:30 PTB HS HvHB

Critical infrastructure and conflict in outer space: vulnerability, risk reduction and arms control — •Jürgen Scheffran — Institute of Geography, University of Hamburg, Germany

Outer space is considered as part of the critical infrastructures in the civilian and security sector. Satellites conduct numerous tasks, often dual-use, for reconnaissance, early warning, monitoring, weather observation, communication, navigation, environmental protection and research. They support infrastructures on earth, e.g. for the economy and society, energy and resources, political stability and security, health and climate. While space-related activities and investments are increasing, security risks and conflicts are multiplying. The space infrastructure is becoming more vulnerable to multiple risks: interruption of communication by accidents, jamming or ground attacks; collision with other space objects and space debris; physical attack by explosive devices, cyber, nuclear, kinetic or directed energy weapons; sensor blinding; hacking, deception or hijacking. The survivability of space objects can be improved by protection and risk reduction measures, including hardening and shielding, manoeuvring capability, dummies, or active countermeasures. A code of conduct for responsible space behaviour can contribute to confidence-building, rules of the road, risk reduction and stabilization. With the proliferation of space launchers and missiles, missile defense and anti-satellite weapons, threats to space infrastructure would increase, jeopardizing international stability. A space arms race can be avoided through preventive arms control and disarmament, reducing risks to space infrastructure.

AGA 2: Nuclear Safeguards

Time: Wednesday 17:00–18:00 Location: PTB HS HvHB

AGA 2.1 Wed 17:00 PTB HS HvHB

Antineutrino-based Safeguards for the Monitoring of Spent Nuclear Fuel — •Yan-Jie Schnellbach[1], Thomas Radermacher[1], Irmgard Niemeyer[2], Stefan Roth[1], and Malte Göttsche[1] — [1]Physics Institute III B, RWTH Aachen University, Aachen, Germany — [2]Forschungszentrum Jülich, Jülich, Germany

Spent nuclear fuel (SNF) is an inevitable by-product of nuclear power generation and must be safeguarded. These safeguards are also required during the operation of storage facilities, which is expected to continue for decades to centuries. Antineutrino emissions from the ongoing beta decay of fission fragments can provide a monitoring channel complementary to current safeguards techniques as antineutrinos pass unhindered through any surrounding shielding. This study investigates antineutrino detector concepts for monitoring SNF storage facilities, using Geant4-based detector simulations combined with the modelling of different storage sites configurations. The expected signal rate, sensitivity and directional capabilities of the concept detectors are investigated for different deployment scenarios and use cases, including general monitoring, reducing the burden on operators and inspectors or re-verification of specific casks. Several technological approaches, including liquid organic (LOr) time projection chambers (TPCs), will be compared to establish requirements for background levels, directionality, scalability and positioning. This ongoing work will determine the feasibility of antineutrino detectors as complementary safeguards for SNF facilities and highlight the strengths of the different technologies compared.

AGA 2.2 Wed 17:30 PTB HS HvHB

Digital Tools in Support of Safeguards and Verification Inspections — •Manuel Kreutle[1], Irmgard Niemeyer[1], and Alexander Glaser[2] — [1]Forschungszentrum Jülich, Germany — [2]Princeton University, USA

Safeguards inspections and potential nuclear disarmament verification inspections need thorough planning, long preparation periods and, given that possible errors might cause an interruption of the continuity of knowledge, happen under the risk of vast political consequences. Digital tools in the form of virtual reality (VR) applications or digital twins can support decision making and risk assessment before and during inspections through live data analysis and thus can help to mitigate the source of errors. They might further allow for remote access to inspected sites which otherwise would not be physically accessible due to conditions like danger, timeliness or political tension. In the context of nuclear disarmament, they could contribute to trust building between parties by disclosing (just the) agreed information to the inspecting party while protecting interests of the inspected party.

In this talk we will present a proof-of-concept VR tool for remote nuclear disarmament verification inspection developed at the Program on Science and Global Security at Princeton University as well as the ongoing work on a digital twin of an interim or final nuclear waste disposal sites for safeguard inspections executed at Forschungszentrum Jülich. Both projects will serve as a basis to discuss the benefits and limits of digital inspection tools.

AGA 3: Nuclear Deterrence and Nuclear Disarmament

Time: Thursday 9:30–11:30 Location: PTB HS HvHB

Invited Talk AGA 3.1 Thu 9:30 PTB HS HvHB

The Three-Body Problem in Nuclear Deterrence — •Steve Fetter — Professor, School of Public Policy, University of Maryland

U.S. intelligence agencies are projecting that China*s nuclear arsenal will expand to 1500 warheads by 2035. For the first time, the United States will confront two nuclear peers. These potential adversaries have entered into a *no limits* partnership that may include coordination of military forces and opportunistic aggression. In response, a recent U.S. commission declared that "modifications to both strategic nuclear forces and theater nuclear forces are urgently necessary*; others have called for a doubling of U.S. nuclear forces. But expansion of U.S. nuclear forces is neither necessary nor wise. Current and planned U.S. forces are more than adequate to deter both Russia and China if it abandons counterforce targeting, which generates increased force requirements and increases the risk of nuclear escalation. Although it is often claimed that alternatives to counterforce violate the laws of war, there is little difference in terms of civilian deaths.

AGA 3.2 Thu 10:30 PTB HS HvHB

Next-Generation Warhead Authentication — •Christopher Fichtlscherer[1,2] and Moritz Kütt[2,3] — [1]RWTH Aachen, Germany — [2]Institute for Peace Research and Security Policy, Hamburg, Germany — [3]Program on Science and Global Security, Princeton University, USA

The verification of international treaties represents a critical task, particularly in the realm of nuclear disarmament. Gamma spectroscopy is acclaimed for its effectiveness, cost-efficiency, and non-destructive approach in the authentication of nuclear warheads and their components. A pivotal challenge in this process is the delicate balance between acquiring sufficient data for reliable authentication and preserving the confidentiality of sensitive information. Traditional methods have attempted to address this by employing a limited number of broad energy bins. However, these systems are prone to deception and often falter in distinguishing between similar objects. Here, a new, innovative methodology for ascertaining an object's gamma signature that is both tamper-proof and non-disclosing in terms of weapon specifics is proposed.

AGA 3.3 Thu 11:00 PTB HS HvHB

How to Verify the Comprehensive Test Ban Treaty at Very Low Yields? — •Christopher Fichtlscherer[1,2], Moritz Kütt[2,3], and Julien de Troullioud de Lanversin[4] — [1]RWTH Aachen, Germany — [2]Institute for Peace Research and Security Policy, Hamburg, Germany — [3]Program on Science and Global Security, Princeton University, USA — [4]Hong Kong University of Science and Technology, Hong Kong

The Comprehensive Test Ban Treaty (CTBT), though not in force, effectively acts as a moratorium on nuclear testing. The US conducted its last test in 1992, Russia in 1990, and China in 1996. Despite the end of tests, these states continue experiments (that include fission reactions in weapon-grade material) to maintain and develop their nuclear arsenals. The United States has accused Russia and China of conducting very low yield nuclear tests, potentially violating the CTBT. Satellite imagery showing increased activity at nuclear test sites might be part of these concerns. These alleged tests, suspected to be in the kilogram-range, could involve supercritical chain reactions, challenging to distinguish from permitted subcritical tests without direct evidence. At the 2023 CTBT Conference, Jill Hruby, Administrator of the U.S. National Nuclear Security Administration, called for a joint verification regime to enhance transparency. We propose a gamma-spectroscopy-based method for this verification.

AGA 4: Nuclear Archeology

Time: Thursday 11:45–12:45 Location: PTB HS HvHB

AGA 4.1 Thu 11:45 PTB HS HvHB

Applying Nuclear Archaeology to Reprocessing Waste in DPRK — •Johannes Bosse and Malte Göttsche — RWTH, Aachen, Deutschland

At some point, endeavors aimed at denuclearizing the Democratic People's Republic of Korea (DPRK) must confront the challenge posed by its stockpiles of fissile material. The available information on the historical and current operation of North Korea's fuel cycle is incomplete, making it challenging to establish a reliable and quantitative assessment without additional information. This knowledge gap could prove to be a significant hurdle in future verification efforts during disarmament initiatives.

To address this issue, inspectors could employ techniques derived from nuclear archaeology to gain valuable insights into DPRK*s historical fissile material production. My work demonstrates how the Bayesian approach to nuclear archaeology we develop in Aachen can leverage measurements of isotopic ratios of high-level reprocessing waste to extract meaningful information.

In this work, I simulate potential measurements and utilize them as evidence in a Bayesian nuclear archaeology model. A notable challenge arises from the fact that reprocessing waste from different batches of spent fuel is combined, making it non-trivial to deduce the operational history of the reactor. This study showcases how such an approach could enhance disarmament verification efforts in the DPRK and potentially in other regions.

AGA 4.2 Thu 12:15 PTB HS HvHB

Nuclear Archaeology with Reprocessing Waste: Discriminating Reactor Types — •Benjamin Jung and Malte Göttsche — Nukleare Verifikation und Abrüstung, RWTH Aachen

Sustainable nuclear disarmament requires a concept for accounting for the fissile material that would emerge from the dismantled warheads and the existing stockpiles of fissile material that are not currently under safeguards. Nuclear archaeology provides a toolkit with the potential to answer some of the questions that arise during related verification activities.

Previously, we have shown that a Bayesian inference framework can reconstruct reactor parameters such as fuel burnup and time since irradiation. Here, we present an extension of this framework to infer the source reactor type as well as several parameters of interest. This inference model discriminates between three reactor types (Magnox, PHWR, and PWR) and simultaneously reconstructs the fuel burnup, time since irradiation, initial enrichment, and average power density. We apply this model to a set of simulated test data and evaluate the performance by comparing the highest posterior density region with the ground truth. The model performs well on the test data, demonstrating that Bayesian inference can potentially extract information from samples of reprocessing waste even when the reactor of origin is unknown.

AGA 5: Effects of Radiation

Time: Thursday 15:00–16:00 Location: PTB HS HvHB

Invited Talk AGA 5.1 Thu 15:00 PTB HS HvHB

Gender- and age-specific characteristics in radiosensitivity and their consequences for radiation protection - Overview of the current knowledge — •Lisa Deloch[1,2], Lena Winterling[1,2], Laura Ruspeckhofer[1,2], Tom Unterleiter[1,2], Michael Rückert[1,2], Thomas Weissmann[1], Antonia Völlings[1,2], Eva Titova[1,2], Rainer Fietkau[1], Udo S. Gaipl[1,2], and Margaux Piltz[1,2] — [1]Department of Radiation Oncology, Uniklinikum Erlangen, Friedrich-Alexander- Universität Erlangen-Nürnberg, Germany — [2]Translational Radiobiology, Department of Radiation Oncology, Uniklinikum Erlangen, Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany

The main aim of radiation protection is to keep the population from damage caused by ionizing and non-ionizing radiation, whereby deterministic damage should be prevented and stochastic risks should be reduced to a minimum. Biological research relevant to radiation protection has so far mostly focused on DNA as the most radiation-sensitive component of the cell. Nevertheless, a paradigm shift has become noticeable in recent years, which not only places direct, DNA-mediated effects at the center of research, but also focuses on systemic, immune-mediated effects that also occur after exposure to radiation. Additionally, age and gender have also an impact on the immune system, a rather basic but crucial factor that has been widely neglected in research. Some of these gender-specific influences are also known for radiation exposure, where women have shown to exploit a two-fold increased risk for solid tumors than men after exposition to radiation. Similar, preclinical studies revealed gender-specific differences in DNA-mediated radiation response. A more detailed understanding of the molecular mechanisms is thus required to define more specific threshold values in radiation protection issues but also in therapeutic approaches, disarmament and dismantling processes. As these important questions have not yet been systematically investigated, our NukSiFutur workgroup is focusing on answering the influence of age and gender on radiation responses in an osteo-immunological setting.

AGA 6: Nuclear Fuel Cycle and Proliferation

Time: Thursday 16:00–18:00 Location: PTB HS HvHB

Invited Talk AGA 6.1 Thu 16:00 PTB HS HvHB

Proliferation Issues of Future Nuclear Fuel Cycles — •Friederike Friess — Institute of Safety and Risk Sciences, BOKU, Vienna

The current reactor fleet consists almost exclusively of light water reactors. There are some countries that are actively researching other reactor concepts, in particular fast, sodium-cooled reactors. In addition to better fuel utilization, their use should also simplify the disposal of radioactive waste. In order to achieve this, reprocessing of spent fuel rods must be carried out on an industrial scale. This involves the separation of weapons-grade fissile material.

The presentation provides an overview of the activities of various countries on so-called closed fuel cycles and related reactor technology. It focuses on the proliferation risk posed by those technologies and explains why they would thus increase the risk of unauthorized diversion of nuclear material, technology and knowledge.

AGA 6.2 Thu 17:00 PTB HS HvHB

Unusual fissile materials in nuclear weapons — •Matthias Englert[1] and Friederike Friess[2] — [1]Institute for Applied Ecology, Rheinstr. 95, 64283 Darmstadt — [2]Institute of Safety and Risk Sciences, BOKU Vienna

Today's nuclear arsenals typically utilize fissile materials such as uranium - enriched to over 90% in uranium-235 - and plutonium with an isotopic composition exceeding 93% plutonium-239. It has been long established that lower enrichments of uranium or different isotopic variations of plutonium, like reactor-grade plutonium, can still be employed in nuclear weapons. However, their use comes with drawbacks that render them suboptimal for military purposes. All plutonium containing Pu-239 as well as uranium-235 are categorized as 'special fissile material' under the International Atomic Energy Agency (IAEA) safeguards system. Additionally, uranium-233 is considered a special fissile material, produced through neutron capture in a thorium-uranium fuel cycle and subsequently fissioned in a thorium-fueled reactor to generate energy. IAEA defines U-233, uranium enriched beyond 20% U-235, and plutonium with less than 80% Pu-238 as 'direct use' materials, encompassing their compounds such as irradiated reactor fuel (spent fuel) and mixtures like mixed oxide (MOX) fuel. Not as widely recognized are alternative nuclear materials, specifically higher actinoids formed in nuclear reactors through neutron reactions. Neptunium-237, a fissile material reportedly used in a nuclear test explosion, along with isotopes of americium, fall into this category. While these materials are not currently extensively utilized or separated in the nuclear fuel cycle, future plans for alternative reactor designs addressing nuclear waste transmutation could increase the accessibility of these materials and technologies for their separation.

AGA 6.3 Thu 17:30 PTB HS HvHB

Building a Fuel Cycle Simulation Toolkit for Nuclear Verification — •Max Schalz and Malte Göttsche — Nuclear Verification and Disarmament Group, RWTH Aachen University, Aachen, Germany

Nuclear fuel cycle (NFC) codes are regularly used in civilian nuclear programmes, for example to model energy transition scenarios. In contrast to this, NFC simulators have not yet been established in verification or disarmament contexts, despite their many benefits. We present Bicyclus, an open-source Python3 framework aimed at analysing NFCs in such contexts. Bicyclus couples Cyclus, an existing NFC simulator, to a Monte Carlo and a Bayesian inference software. These couplings open up various new applications: The Monte Carlo approach can be used to propagate uncertainties and improve fissile material estimates, while the Bayesian approach is relevant in verification scenarios to reconstruct past NFC operations. We demonstrate both applications in a case study based on a complex, military NFC with HEU and plutonium production, as well as capacities to re-enrich reprocessed, irradiated uranium.

AGA 7: Members' Assembly

Time: Thursday 18:30–19:30 Location: PTB HS HvHB

All members of the Working Group Physics and Disarmament are invited to participate.

AGA 8: Nuclear Weapons

Time: Friday 9:30–11:30 Location: PTB HS HvHB

Invited Talk AGA 8.1 Fri 9:30 PTB HS HvHB

Irreversible Elimination of Large Strategic Nuclear Weapons — •Robert Kelley — Distinguished Associate Fellow, SIPRI

Very large strategic nuclear weapons that threaten mankind depend on tritium boosting of their fission stages to produce the higher yield. If tritium is denied, the weapons will cease to work because natural radioactive tritium decay occurs. If no new production of civil tritium is allowed under a tritium production halt treaty, stockpiles will quickly begin to cease to function. About half of large weapons will be rendered useless every 12 years while tritium must be redistributed to the remaining devices. This reduces numbers of weapons, but it also makes existing nuclear war planning obsolete. Note that Ukraine gave up old Soviet weapons due to lack of tritium. Weapons without tritium are irreversibly deleted from the inventory if there is no new tritium. New weapons without tritium can be designed, of course, but the status quo will be destroyed until then.

AGA 8.2 Fri 10:30 PTB HS HvHB

Back to the Origins: Who knows what in the Manhattan project and the Uranium Club? — •Götz Neuneck — IFSH, U Hamburg

The development of building the first atomic bomb during WWII was a race of scientists in allied states and Nazi-Germany based on fundamental discoveries, theoretical considerations and experiments in the new field of nuclear physics. Although it is very clear that the German Uranium Project did not construct a nuclear bomb, until today there are ongoing controversies about the motivations, resources and knowledge of the key scientists on both sides. It is important to understand the chronology of events and achievements in both projects. The Manhattan Engineering District Project achieved the goal and three nuclear devices exploded in New Mexico, Hiroshima and Nagasaki. Beyond the technical skills the question is what did the scientists know about the purpose of the nuclear gadgets they created. 85 years after the events a lot of documents, analysis and comments are available to assess the development of the programmes and to answer the three questions: 1. What did the main actors know how to build a bomb? 2. What was there motivation and justification? 3. When did they realize the implication of their work and how did they react? Until today this story of great and dedicated science and politics, moral, conspiracy and secrecy is an important lesson about the ambivalence of science and the responsibility how to handle the nuclear threat.

AGA 8.3 Fri 11:00 PTB HS HvHB

What you never wanted to know about the atomic bomb — •Olaf Schumann — Fraunhofer INT, Euskirchen

Unfortunately, nuclear weapons still play a great role in our time: Russian officials openly discuss their use in the Ukrainian war, the Joint Comprehensive Plan of Action (JCPOA), that was to prevent an Iranian bomb, has basically failed, Russia has withdrawn from the Comprehensive Nuclear-Test-Ban Treaty (CTBT) and in the war between Israel and the Hamas a large-scale escalation with Israel's neighbors might force Israel to use its nuclear weapons as a matter of last resort, just to name some recent examples.

Research on this subject has many facets, like nuclear disarmament, mitigation of nuclear weapons effects, studies on strategic deterrence, prevention of nuclear proliferation, detection of special nuclear material, or the ban of fissile material or complete weapons. In all these areas, varying knowledge about design and functioning of a nuclear weapon itself is needed. This talk will give several examples of open sources, where such information can be found and that may be valuable for other researchers. It will discuss some aspects of nuclear weapons that everybody in the field should be aware of, and it will present some more obscure findings that show how much is known about (mostly US) weapons.