Princeton School on Science and Global Security

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Book of Abstracts

SCIENCE &
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TYPESETTING IN LATEX WITH TUFTE DOCUMENT CLASS

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The Princeton School on Science and Global Security

The Princeton School on Science and Global Security, launched in 2020, trains next-generation scientists and engineers from around the world in technical perspectives on understanding, reducing, and ending the threat from nuclear weapons. The goal is to provide skills and insights that participants can use in their own research, encourage and inspire them to investigate new ideas to advance global security and a safer and more peaceful world and to foster an international community of such researchers. The School is organized by Princeton University's Program on Science and Global Security (SGS), part of the School of Public and International Affairs.

The meeting includes presentations by invited graduate students, post-doctoral researchers and established researchers on topics such as fissile materials, verification, emerging technologies, and missile defense. It also includes interactive learning experiences and tutorials on nuclear policy.

History

The Princeton School on Science and Global Security traces its origins to the international School on Science and World Affairs organized by the forerunner of the Program on Science and Global Security and the Moscow Institute of Physics and Technology held over eight days in September 1989 outside Moscow. Princeton hosted the second International Summer School on Science and World Affairs in August 1990. The schools focused on nuclear disarmament and global environmental issues. The two schools grew out of discussions between the U.S. physicist Frank von Hippel and the Soviet physicist Roald Sagdeev about the lack of a younger generation of Russian scientists knowledgeable about arms control issues. These discussions also led to the publication of a new international journal, *Science & Global Security,* with an initial editorial board of U.S. and Soviet scientists.

The third Summer School was hosted in Moscow by the newly established Center for Arms Control, Energy, and Environmental Studies at Moscow Institute of Physics and Technology in 1991. The

1992 Summer School was held in Shanghai, hosted by the Center for American Studies (CAS) at Fudan University. It was organized together with the Union of Concerned Scientists (UCS) which took lead responsibility for future meetings. These meetings became known as the International Summer Symposium on Science and World Affairs. Since the first meeting in 1989, these gatherings have hosted over 500 scientists and researchers from over 40 countries.

Program on Science and Global Security

Princeton University's Program on Science and Global Security (SGS), based in the School of Public and International Affairs, conducts scientific, technical and policy research, analysis and outreach to advance national and international policies for a safer and more peaceful world. The Program was founded in 1974 by Harold Feiveson and Frank von Hippel.

Throughout its history, SGS has worked on nuclear arms control, nonproliferation, and disarmament to reduce the dangers from nuclear weapons and nuclear power. The control and elimination of fissile materials (the key ingredients for nuclear weapons) is a major part of the SGS agenda. SGS works to understand and reduce the risks from nuclear weapons and the strategies, postures, forces and policies of the nine nuclear armed states. SGS also helps develop confidence-building measures to reduce the risks of crisis, arms racing and nuclear weapons use in the U.S.-NATO-Russian region, South Asia, the Middle East, East Asia, and the Pacific.

SGS does research to support the 2017 United Nations Treaty on the Prohibition of Nuclear Weapons and the goal of the verified and irreversible elimination of all nuclear weapons and weapon programs. SGS is home to *Science & Global Security*, the leading academic peer-reviewed journal for technical arms-control analysis. The journal covers nuclear, biological, chemical, space, and cyber technologies and programs and related security issues. Its goals are to help develop the technical basis for new policy initiatives to reduce the risks from these technologies to international peace and security and to provide a resource for further scholarship and policy analysis.

SGS provides training opportunities for post-doctoral and senior scientists interested in science and security policy. It has helped train technical nuclear arms control and nonproliferation researchers from around the world.

Participants and Abstracts

Almuntaser Albalawi (he/him/his)
United Nations Institute for Disarmament Research

The Nuclear Weapons-Free Zone in the Middle East: Scope, Verification, and Possible Limits on National Nuclear Capabilities

Abstract. A half century has passed since the UN endorsed the goal of establishing a Middle East Nuclear Weapon Free as a way to limit regional arms race and reduce tensions while advancing global nuclear disarmament and nonproliferation. This goal has become more urgent since then, but there has been limited progress. Along with political obstacles, there are technical dimensions that now need to be resolved concerning the scope of the prohibition and verification to detect violations, including concerns about the utility of IAEA Safeguards and the Additional Protocol to monitor tritium and uranium production and processing, and the manufacturing and imports of uranium enrichment components, and dual-use items with possible weapon applications.

This presentation will examine ways to address some of these technical issues, including the limits of existing verification regimes and the feasibility of proposed measures such as technical constraints on reactor designs, reprocessing and plutonium separation, and the scale of uranium enrichment operations.

Biography. Almuntaser Albalawi is a researcher in the Middle East Weapons of Mass Destruction Free Zone (ME WMDFZ) project at the United Nations Institute for Disarmament Research (UNIDIR). Prior to UNIDIR, Almuntaser was a doctoral researcher in the International Security Department at the Peace Research Institute Frankfurt (PRIF), the largest peace research institute in Germany. Before PRIF, Almuntaser worked at the Royal Scientific Society in Jordan, where he led the CBRN Threat Office and served as a senior staff scientist at the Biosafety and Biosecurity Center. Almuntaser has a Bachelor of science degree in nuclear engineering and a Master's degree in international relations and conflict resolution. He is currently a PhD candidate in political science with a focus on Weapons of Mass Destruction (WMD) studies.

Lucas Arthur
Massachusetts Institute of Technology

Is Trident Survivable? SLBM Guidance Under the Microscope

Abstract. I examine whether anti-satellite capabilities render a key component of the U.S. nuclear triad vulnerable due to reliance on GPS for calibration of shipboard inertial guidance systems. A key feature of submarine-launched ballistic missiles (SLBMs) is thought to be their survivability against attack by a nuclear adversary, thus ensuring a retaliatory capability. The U.S. Trident II D5 SLBM, carried by the Ohio class ballistic missile submarine, is one such system. However, the stellar-inertial guidance used by Trident relies on precise knowledge of the position, velocity, and orientation of the submarine at the time of launch. Because the uncertainty in the shipboard inertial guidance system increases with time, the submarine must periodically perform GPS calibrations at the sea surface. I propagate the uncertainties in initial conditions over ballistic trajectories and report significantly degraded accuracy at the aimpoint, potentially rendering the Trident system ineffective against localized targets, in the absence of GPS, raising concerns about vulnerability to anti-satellite weapons.

Biography. Lucas Arthur is a Technical Associate in the MIT Laboratory for Nuclear Security and Policy (LNSP). He grew up outside of Palmer, Alaska, before heading to MIT to study physics with a minor in political science. His research interests include the development of novel methods for modeling systems with uncertain parameters, and using physics to inform policy and mitigate emerging and existential risks. Much of his current work focuses on the security implications of emerging technologies, including advanced sensing, computing, and guidance systems. When not working, he can often be found trail running, hiking, or climbing.

Nathaniel Barbour
University of Maryland

Radar Blackout: Discussing the Vulnerability of Early-Warning Radar Systems to High-Altitude Nuclear Detonations

Abstract. Decades after the end of the Cold War, expanding ballistic missile defense systems remains a common national security objective for Russia and NATO member states. Ground-based early warning radar systems remain integral to modern ballistic missile detection strategies. However, these radar systems are fundamentally vulnerable to high-altitude nuclear detonations. Two separate physical phenomena associated with high-altitude nuclear detonations can degrade the performance of ground-based radar systems: emission of an electromagnetic pulse and radar attenuation by the formation of atmospheric regions of increased ionization. Because missile defense systems rely on both early-warning radar systems and nuclear detonations that destroy incoming missiles, the radar blackout following an interception would provide a window that would allow subsequent missiles to penetrate the defense. Though NATO has expanded its missile detection systems to incorporate radar satellites, Russia primarily relies on its ground-based systems. This asymmetry increases the risk of miscalculation amid increased tensions between Russia and NATO over Russia's armed conflict with Ukraine and NATO's subsequent expansion to Finland.

Biography. Nathaniel Barbour is a Physics PhD candidate at the University of Maryland, studying plasma physics for nuclear fusion energy. His research explores the potential for machine learning algorithms to accelerate gyrokinetic turbulence simulations. As an undergraduate at Yale University, he studied cosmology and began his path into fusion energy with two internships at the Princeton Plasma Physics Laboratory. His experiences at the national laboratory and in science and environmental policy courses have inspired him to seek solutions to critical global challenges at the intersection of science and policy.

Yacopo Damizia (he/him/his)
University of Liverpool and UK Atomic Energy Authority

Fusion Energy, Nuclear Disarmament, and Nonproliferation

Abstract. Nuclear weaponry and its potential proliferation pose major threats to global security. This presentation will examine nuclear fusion's role as a sustainable alternative to fission-based power, with an emphasis on its impact on disarmament and nonproliferation. We will delve into current advancements in fusion research, emphasizing the diminished weaponization potential associated with fusion technology.

In our critical assessment, we will address key security issues linked to fusion technology. We will discuss strategies to mitigate the potential of breeding fissile materials, such as employing fuel cycles that minimize weapon-grade plutonium production and incorporating safeguards to monitor and regulate the production, transportation, and disposal of fissile materials. Tritium management, a crucial aspect of fusion safety and security, will also be analysed. We will explore challenges around the extraction, storage, and containment of tritium, examining current best practices and potential areas for improvement. The burgeoning field of fusion startups, such as *Commonwealth Fusion Systems* and *Tokamak Energy*, will be briefly discussed, emphasizing their innovative approaches and potential impact on the fusion research landscape. Finally, we'll propose a possible strategic plan integrating fusion energy into global disarmament and nonproliferation initiatives, including policy recommendations and collaboration frameworks. In conclusion, this presentation intends to comprehensively examine fusion energy's technical, security, and policy aspects, and its potential role in promoting a safer global landscape. We aim to underscore the opportunities and challenges of adopting fusion power for nuclear disarmament and nonproliferation.

Biography. I am a passionate physicist specializing in particle and astroparticle physics. With a Bachelor's and Master's degree from the prestigious Sapienza University of Rome, I became captivated by the realm of nuclear fusion. My enthusiasm led me to pursue a Master's thesis at the fusion department of ENEA in Frascati, Italy, where I contributed to the Frascati Tokamak Upgrade and Protosphera experiments. Currently, I am pursuing a PhD in Plasma Physics and Fusion Science in collaboration with the UK Atomic Energy Authority (UKAEA). My research focuses on ion temperature measurements within the novel Super X divertor of the MAST-U tokamak.

Chanese Forté (her/hers/she/they/theirs/them)
Union of Concerned Scientists

Introduction to Nuclear Toxicology and Applications

Abstract. Nuclear weapons harm human health. From collecting the raw materials to detonating nuclear weapons with communities downwind, humans pay the cost again and again in the name of 'national security.' Areas in the United States are contaminated by more than 1,054 nuclear weapons tests, 219 of which were above ground. People in the United States are living with more than 3 billion metric tons of uranium mining and milling wastes, more than 1 million cubic meters of transuranic radioactive wastes; which have resulted in more than 100,000 sick nuclear weapons workers who have received more than $10 billion in compensation for this harm (a mere fraction of the workers harmed). This alongside recently declassified documents showing that U.S. military officials not only ignored radiation risks of nuclear weapons, but actively spread misinformation and mislead community members and workers.

For decades, nuclear weapon policy decision-making has included prioritizing national security or engineering efficiency and poisoning nuclear frontline communities and workers along the way. There is a lack of public health professionals and human health data that is publicly available to researchers and communities. Without a foundation in cancer epidemiology and nuclear toxicology decision makers cannot create nuclear weapons policy that protects people, especially the most disenfranchised communities.

This session aims to train the audience on the basics of human health research as it pertains to the nuclear weapons complex and the regulatory science—for example, the International Commission on Radiological Protection and the Agency for Toxic Substances and Disease Registry—evidence base, and the statistical errors created by not considering cumulative burdens, biological susceptibility (such as sex and age), community vulnerability, or the nuances of exposure pathways and individual metabolism.

Biography. Dr. Chanese Forté is a Scientist at the Union of Concerned Scientists (UCS) who focuses her research on nuclear weapons exposure and human health risks in the United States. She employs environmental epidemiology and toxicology to understand how communities are affected by the nuclear weapons complex. Dr. Forté has spearheaded research focused on understanding the unique burden of nuclear weapons on women and girl's health that nuclear weapons pose. She was also a 2023 Harvard Black Health Conference panelist. She collaborates directly with community and scientists to best approach applying pressure to decision makers as it pertains to nuclear weapons.

Valerie Hsieh (she/they)
Columbia University

The Moral and Ethical Education of Early-Career Physicists

Abstract: The Manhattan Project stands as one of the most influential scientific endeavors of the 20th century, ultimately leading to the development of atomic weapons and reshaping the course of global history. Since the inception of the Manhattan Project in the basement of Columbia University's Pupin Hall, several scientists who participated in the project publicly issued statements condemning further development of nuclear weapons—yet institutions such as Columbia have yet to acknowledge the ethical considerations of many of its own scientists, choosing only to address and highlight the technical advancements made during this period of weapons development and usage.

This presentation will discuss the current state of institutional recognition of nuclear weapons policy and development—with a particular focus on Columbia University's acknowledgement of its historical role in the Manhattan Project—as well as a proposed graduate student questionnaire that surveys graduate students' awareness of and attitudes towards nuclear weapons policy, as well as the role of faculty members, career prospects, and institutional history in shaping those attitudes. By combining these surveys, discussions with physics graduate students, as well as an analysis of the historical documents and contemporary media that current graduate students may be exposed to, this project proposes to provide an in-depth understanding of the factors that shape early-career scientists' understanding of the current state of nuclear weapons policy. This presentation aims to facilitate a discussion on methodologies and techniques to best equip the next generation of physicists to navigate the complex ethical considerations that arise and have arisen historically in nuclear weapons research, with the ultimate goal of providing department- and institution-wide recommendations for best practices in integrating discussions of nuclear weapons policy into the formal training of early-career scientists.

Biography: Valerie Hsieh is a PhD candidate in physics at Columbia University. Her graduate research focuses on the electronic and optical properties of 2D heterostructures. She is passionate about science policy and science communication, particularly concerning topics of difficult knowledge in STEM disciplines. Most recently as a Senior Lead Teaching Fellow through Columbia University's Center for Teaching and Learning, she organized and facilitated a university-wide seminar for graduate instructors about difficult knowledge and inclusive teaching practices. Outside of academia, she is an avid language learner and plays competitive ultimate frisbee. She holds a BA in physics and German from UC Berkeley.

Emma Houston (she/her/hers)
University of Tennessee

Using Antineutrino Monitoring to Maintain a Continuity of Knowledge

Abstract. The ability to monitor naval reactors while in port without core access can be addressed using antineutrino detectors. Antineutrino detectors have a unique capability to monitor nuclear reactors from significant distances and have demonstrated the ability to detect reactor power from several kilometers away. Antineutrinos are produced as a product of beta decay from fission fragments in nuclear reactors. Burnup measurements can be determined based on the antineutrino energy spectra depending on the isotopes of interest, which are most commonly uranium-235 and plutonium-239. Antineutrinos have extremely small cross-sections and thus are difficult to detect and impossible to shield. The safeguards application of these detectors often provides information on core composition or operational history.

AUKUS is a multilateral treaty between Australia, the United Kingdom, and the United States to transfer nuclear-powered submarines to Australia. The reactor core may not be accessed for several years to refuel. This technology transfer presents a unique challenge to the existing safeguards regime and to the implementation of material control and accountability (MC&A) measures that typically occur during the refueling of the reactor. Antineutrinos may provide a unique capability to monitor the composition of these cores in ports without the need to open the core. Various configurations of antineutrino detectors will change the detector sensitivity to the antineutrino signal, and therefore the ability to monitor naval reactors. In this presentation, the application of antineutrino detectors to monitor Highly Enriched Uranium (HEU) cores within naval reactors will be studied using the simulation tool RATPAC.

Biography. Emma Houston is a graduate student at the University of Tennessee pursuing a PhD in nuclear engineering. She received her Bachelors from the University of Tennessee's Nuclear Engineering Department in 2022. In the fall of 2023, she will be a Nuclear Nonproliferation and International Safeguards (NNIS) fellow. Over the last year, she has worked with Lawrence Livermore National Laboratory on applications of antineutrino detectors to address SMR safeguards challenges. She was raised in Northern Virginia and loves cooking, spending time with friends and family, and getting outdoors.

Hugh Irving (he/him)
University College Dublin

Policy Implications of Advances in Modelling and Simulation

Abstract. Computational modelling has been integral to the development of nuclear weapons since their inception and its significance has only grown, with nuclear weapons laboratories now possessing many of the world's fastest supercomputers. Computationally intensive numerical models are used widely for the design, analysis and sustainment of nuclear weapons and their delivery systems, due to their cost effectiveness and restrictions on nuclear testing. High energy material and inertial confinement fusion models are used in nuclear warhead development, while fluid and structural mechanics models enable the design of delivery methods such as missile systems. Control of these capabilities may become a priority for nuclear disarmament goals, with the Treaty on the Prohibition of Nuclear Weapons calling for "elimination or irreversible conversion of all nuclear-weapons-related facilities." This talk will investigate how computational modelling is being applied to nuclear weapons development and what strategies might be used to control these activities. Past efforts in the control of computing technology have faced significant challenges, including smuggling and the use of adapted consumer hardware. There are also significant opportunities for control, such as hardware enabled restrictions, component tracking, trade controls and remote inspection of known facilities. This analysis considers recent international attention on the control of advances in artificial intelligence and potential conflict surrounding global semiconductor supply chains.

Biography. Hugh Irving is an engineering researcher, pursuing a PhD at University College Dublin, Ireland. His areas of interest include experimental fluid dynamics, computational modelling and material science. Hugh has published and presented research on topics such as wind energy, aerospace and biomedical engineering. Hugh also carries out research for High Impact Engineers, a charity affiliated with the Centre for Effective Altruism, on how engineers can tackle the world's most pressing problems. Hugh holds a BSc in mechanical engineering and an ME in material science and engineering.

J. Thokozile Kabini (she/her)
Princeton University

Strengthening Security Through Nuclear Forensics

Abstract. Nuclear forensics is a set of techniques for the analysis of nuclear materials to help identify their origin, history, and intended use. Today, one of the major objectives of nuclear forensics is to detect theft and illicit trafficking of nuclear and radioactive materials. This presentation will present some initiatives and capabilities of the South African Nuclear Energy Corporation's nuclear forensics complex, located in Pelindaba, for conducting analyses of radioactive materials found outside regulatory bounds to meet the goal of strengthening regional nuclear security. It will look in particular at non-destructive techniques such as gamma spectrometry, scanning electron microscopy, and X-ray diffraction for the analysis of nuclear materials which involve uranium ore concentrates (UOCs) and radioactive sources

Biography. Thokozile Kabini is a pre-doctoral fellow at Princeton University's Program on Science and Global Security. She holds a Master's degree in Nuclear Physics from the University of Pretoria in South Africa, where she specialized in nuclear and radiation science. She holds undergraduate degrees in Physical Sciences and in International Relations. In 2012 she joined the South African Nuclear Energy Corporation and in 2014 became a nuclear forensics analyst, with a focus on the analysis of nuclear materials using non-destructive techniques. Additionally, Thokozile worked as an analyst at the Comprehensive Nuclear-Test-Ban Treaty Organisation (CTBTO) laboratory as part of a team responsible for analyzing radionuclide samples from international monitoring stations.

Paige Kunkle (she/her)
Johns Hopkins University

Complementary Safeguards Potential in Neutrino Detection Technology

Abstract: Proliferation concerns related to civilian nuclear power facilities, plutonium production, and reprocessing have persisted since the first use nuclear weapons in 1945. Developing comprehensive safeguards to monitor these facilities is an important part of addressing these concerns. As nuclear materials undergo fission in a reactor core, electrically neutral and nearly massless particles called neutrinos are produced in the beta decay of fission fragments. These weakly interacting reactor neutrinos are not easily spoofed or shielded and therefore offer a means of monitoring reactors remotely via neutrino detectors, reducing reliance on the host country's transparency and cooperation and providing additional assurance that fissionable material is not misused or diverted. Different types of detectors deployed at various standoff distances require different amounts of host cooperation, access to reactor site, and detector maintenance, and recover information of varying degrees of specificity. Incorporating neutrino detectors into monitoring frameworks as further assurance beyond current safeguards like surveillance cameras, cask seals, and environmental sampling could significantly improve the detection capabilities and overall effectiveness of the current monitoring regime. This presentation seeks to explore a comprehensive assessment of whether the collaborative potential of neutrino detectors can provide a more robust solution to the persistent challenges of proliferation risks associated with civilian reactor facilities in the context of the NPT and the complexities of global politics, technical challenges of neutrino detection technology, and bureaucratic obstacles associated with the establishment of international protocols governing the use of neutrino data.

Biography: Paige Kunkle is a PhD candidate in the particle physics program at Boston University; she specializes in neutrino physics with applications in reactor monitoring and nonproliferation. She earned her AB in physics from Princeton University, where she developed neutron detector technology for zero-knowledge warhead verification, and during graduate school has worked on WATCHMAN and PROSPECT, neutrino experiments capable of monitoring nuclear reactors. She is interested in utilizing fundamental physics to develop and fortify safeguards technology. She has received a BU Dean's Fellowship, NSF graduate research fellowship, and MTV doctoral fellowship in applied antineutrino physics to pursue her studies.

Nick McGreivy (he/him)
Princeton University

Strategic Conventional Deterrence and Its Implications for Nuclear Proliferation and Disarmament

Abstract. In this talk I propose an alternative deterrence construct that, in a world without nuclear weapons, could fill the role that nuclear deterrence currently plays in disincentivizing aggression and providing stability to the international system. I begin by comparing the physical effects of conventional and nuclear explosions, and calculating the relative destructiveness between them. I then revisit deterrence theory, focusing on why nuclear deterrence is considered so much more effective than pre-1945 (non-strategic) conventional deterrence.

Deterrence theorists generally agree that what makes nuclear deterrence so effective isn't the higher level of destruction in a nuclear war, but that this destruction would seem inevitable under any strategy. A deterrence strategy that threatens intolerable levels of destruction can be made to seem inevitable using large numbers of high-precision missiles armed with conventional warheads. Next, I consider the economics of this strategy, called strategic conventional deterrence. I find that, for a given magnitude of destructive capability, nuclear deterrence is more cost-effective than strategic conventional deterrence. I consider how these increased costs constrain the options available to states that rely on strategic conventional deterrence. Finally, I consider the implications of strategic conventional deterrence for nuclear nonproliferation and disarmament.

I emphasize two implications. First, that strategic conventional deterrence may be a feasible alternative to nuclear proliferation for non-nuclear states looking to enhance their strategic deterrence capabilities. Second, while strategic conventional deterrence cannot feasibly replace a large nuclear arsenal, it is reasonable to imagine replacing a small nuclear arsenal with thousands (or tens of thousands) of conventional warheads on long- and medium-range delivery systems.

Biography. Nick McGreivy is a 7th-year PhD student at Princeton University in the Program in Plasma Physics. He grew up in Bethesda, Maryland, and received a BA in physics from the University of Pennsylvania. He has broad research interests besides nuclear weapons policy and is currently working on a dissertation about applications of machine learning to computational plasma physics.

Ryan Nesselrodt (he/him)
Georgetown University

Applications of Quantum Sensing to Nuclear Safeguarding and Nonproliferation

Abstract. Quantum sensing, where atoms are used as "sensors" to measure tiny environmental fluctuations, the most mature category of quantum technologies, may prove useful for a number of IAEA nuclear safeguarding and nonproliferation missions, from on-line monitoring of material diversion to imaging in unsafe environments. We are presently living through the "second quantum revolution," where control over individual atoms becomes possible, and new technologies seek to exploit the unique properties of the atom-scale world.

In this talk I will discuss the theory of quantum mechanics, introduce "the quantum mystery," and unique quantum properties like entanglement and quantum indeterminacy. Then, I will discuss types of quantum sensors, a typical sensing protocol, and advantages over classical sensor measurements. Finally, I will discuss proposed applications of quantum techniques to improve nuclear safeguarding. In particular, I will discuss how "squeezed" light could be used to improve the sensitivity of the IAEA's 3-D laser range-finder, used in design and information verification activities as well as improve detection of material diversion from reprocessing, as well as other proposed safeguarding applications of new quantum technologies.

Biography. Ryan Nesselrodt earned his PhD from Georgetown University for work exploring the properties of correlated quantum materials. He is currently doing postdoctoral physics research as well as learning and writing about science policy issues like advanced computing research and semiconductor export controls.

Patrick Park (he/him/his)
Princeton University

Improved Archival and Neutronics Analysis of the Heisenberg B-VIII Reactor

Abstract. The B-VIII, as built in 1945 in Haigerloch, Germany, was an assembly of 664 natural uranium cubes and 1.5 tons of heavy water; it was the last but most successful pile built by the wartime German nuclear program. Despite a reported k-infinite of 1.11, it was ultimately subcritical, with Heisenberg later determining 50% more material was necessary for criticality. Since then, many of the technical conclusions of the B-VIII stem from a 2009 Italian analysis, but their model and methods leave opportunity for improvement.

In 2019, Dr. Miriam Hiebert and Prof. Tim Koeth from the University of Maryland identified additional uranium and heavy water used by the Germans and located various extant samples brought into the United States. Together, we re-analyze the B-VIII to the best detail possible with the new data.

In this talk, I will present the first German-to-English translation of Heisenberg's B-VIII criticality calculations; an improved core materials specifications through meticulous forensic analysis of museum archives and national laboratory samples; calculations of two-group diffusion parameters and six-factors; a full MCNP neutronics analysis of the B-VIII re-modelled with the new data; and a design optimization of the core geometry.

Biography. I am a first-year graduate student in Mechanical Engineering. Prior to Princeton, my research experience has been in neutronics analyses of research reactors. I was a licensed senior operator of a 250 kW TRIGA reactor in Portland, OR and interned for 2.5 years at the Reactor Engineering Group at the NIST Center for Neutron Research. Through a dual program, I received my BA in physics from Reed College and a BS in applied physics and history from Columbia University in 2023.

Eli Sanchez (he/him)
Massachusetts Institute of Technology

The Vulnerability of ICBM Silos to Precision-guided, Conventional Hypersonic Weapons

Abstract. U.S. programs to develop precision-guided, conventionally-armed hypersonic boost-glide weapons have engendered anxieties among Russian and Chinese policymakers and security experts over the long-term survivability of their nuclear forces. They have expressed concerns that their nation's nuclear assets may be vulnerable to these weapons. Such weapons would not be subject to numerical limits under nuclear arms control treaties, potentially providing an avenue for an unconstrained expansion of counter-nuclear first-strike capabilities. While this may also be true of existing conventional, precision guided weapons, the far greater speeds and ranges achievable by hypersonic weapons are better suited for long range, preemptive strikes. There are strong indications that these anxieties have, in part, motivated Russia's and China's nuclear modernization programs and heightened their skepticism of nuclear arms control.

I assess the vulnerability of silo-based ICBMs to conventional hypersonic weapons. I first consider a number of conventional attack modalities and determine that hypersonic weapons would be most effective against ICBM silos if employed as kinetic energy weapons. I find that, for such weapons to achieve silo kill probabilities comparable to nuclear-armed ballistic missiles, CEPs similar to silo radii (i.e., 3–6 meters) would be required. This is less stringent than stated accuracy goals for U.S. hypersonic weapons. These programs are therefore likely to appear threatening to Russia and China until meaningful limits are imposed on this technology. I recommend conventional hypersonic weapons—as well as all future prompt, long range conventional weapons—be treated as strategic weapons if their ranges and accuracies exceed threshold values informed by this analysis. This should assuage Russian and Chinese concerns without requiring the United States to forego the capabilities it hopes to gain from these weapons.

Biography. Eli Sanchez grew up in Smithville, Texas, a small town roughly midway between Houston and Austin. He received a Bachelor's degree in chemistry and a minor in physics from the University of Texas at Dallas. He then worked for a year at Oak Ridge National Laboratory where he used computational models to estimate the impacts of various forms of radiation on the human body. He is currently studying the strategic implications of hypersonic weapons for a doctoral research project in the Nuclear Engineering department at MIT.

Clayton Strawn
University of California, Santa Cruz

Capabilities of Infrared Early Warning Satellites and Their Connection With Ballistic Missile Defense

Abstract. We present a brief history and analysis of the United States ballistic missile early-warning satellite system, specifically focusing on the Defense Support Program (DSP) of the 1970s–2010s, the Space-Based InfraRed System (SBIRS) program of the 2010s–2020s, and proposed next-generation systems, extracted from estimates of known telescope technology and some declassified documents. The costs and improvements of each successive iteration are tracked, as well as the metamorphosis of the initial mission away from early warning of Inter-Continental Ballistic Missile (ICBM) launches, which was broadly successful, towards other purposes, both civilian and military. Continuation of funding for these systems after cost overruns and delays is increasingly justified by the significance of the satellite systems for the much more difficult problem of Anti-Ballistic Missile (ABM) defense, or destroying incoming missiles in transit. However, there is little evidence that improved satellite systems will make ABM any more feasible. We analyze the role played by the IR satellite system in multiple ABM constellations, including the midcourse defense system currently claimed to be "operational" as well as other proposed systems such as boost-phase defense, and discuss what other technological problems will need to be solved before ABM is possible at all, both inherently with simple ICBM technology and in light of the kinds of countermeasures which would be available to a persistent adversary. Finally, we discuss from a global security perspective the overall effectiveness of the current ABM posture from the United States and its allies.

Biography. Clayton Strawn is a finishing graduate student at the University of California, Santa Cruz. His thesis focuses on galaxy formation and evolution, specifically focusing on the region in the outskirts of galaxy simulations. He is also very interested in nuclear weapons and policies surrounding them, and is a 2023 Next-Generation Fellow for the Physicist's Coalition for Nuclear Threat Reduction. With this team and under the mentorship of leading nuclear arms control experts, he focuses studying the satellite constellations used by the United States for ballistic missile defense.

Sarah Thiele (she/her)
Princeton University

The Damaging Effects of Kinetic Anti-Satellite Tests and the Need for a Multilateral Test Ban Treaty

Abstract: In November 2021, Russia conducted a direct-ascent anti-satellite (DA-ASAT) test, in which an anti-ballistic missile interceptor was used to destroy a defunct 1750 kg satellite. This test generated almost 1800 pieces of trackable debris fragments, of which 300 remain in orbit almost two years later, and endangered existing space infrastructure, including the International Space Station. Kinetic ASAT tests like this one—which have also been conducted by the U.S., China, and India—have been globally criticized for the long-term risks they pose to low Earth orbit (LEO) spacecraft. There is growing agreement among nations that limiting the creation of long-term debris in orbit is crucial to ensure the sustainability of LEO, and that kinetic ASAT tests are irresponsible, debris-generating events. A December 2022 resolution by the UN General Assembly advocated for unilateral moratoriums on destructive ASAT testing, and 13 countries have declared such bans in the past year. The risks of ASAT tests are exacerbated with the rise of satellite constellations, which will increase the number of spacecraft in LEO by multiple orders of magnitude. In this presentation I will discuss current national regulatory frameworks surrounding space weapons, broader policy to prevent an arms race in outer space, and barriers like national opposition to reaching a multilateral ban on DA-ASAT testing. I will also present models of the debris clouds generated by kinetic ASATs and an investigation of the probabilities for debris-satellite collisions that arise in my forecasted LEO environment for 2035. The results show that the debris generated by a single kinetic ASAT test would almost certainly collide with the future satellite population in LEO, underscoring the urgency for a ban on kinetic ASAT tests in an age where LEO is becoming increasingly commercialized.

Biography: Sarah is a PhD student in Princeton's Department of Astrophysical Sciences and a junior fellow of the Outer Space Institute (OSI). She models orbital debris created by destructive anti-satellite testing and advocates for multilateral moratoriums on such activities. She also studies the risks posed by satellite constellations in Low Earth Orbit. As a member of a working group within the International Astronomical Union's Centre for the Protection of the Dark and Quiet Sky, she is studying national policy to mitigate light pollution from satellites and other space-based sources.

Fabian Unruh (he/him)
RWTH Aachen University

Reconstructing Nuclear Reactor Parameters of Spent Nuclear Fuel Using Neural Networks

Abstract. Nuclear reactors are used for civilian purposes, such as energy production, as well as for dedicated military programs to support nuclear weapons programs. With knowledge of the operational history of a nuclear reactor, it is possible to verify the declared operational history of the reactor, estimate the amount of produced weaponizable isotopes or check for clandestine military programs disguised as civilian operations. Nuclear archaeology is a field of research that includes methods for reconstructing the operational reactor history such as its cumulative plutonium production or properties of spent nuclear fuel such as the irradiation time. Some methods use ratios of measured isotope concentrations in structural material, spent fuel or the moderator of the reactor.

In this study, the application of neural networks for reconstructing reactor parameters of spent nuclear fuel is investigated. A dataset of isotopic ratios is obtained by repeated simulations of the reactor operation using the neutron simulation codes OpenMC and Onix with different parameters of the fuel and the reactor operation. The parameter dependent isotopic ratios are used for training the neural networks. The presentation will show the training, testing and application of neural networks using an example scenario. The considered scenario consists of simulating the heavy-water moderated L Reactor at the Savannah River Site. In the investigated scenario, the neural network is used to reconstruct burnup, initial enrichment and cooling time of the spent fuel, given a set of isotopic ratios of the spent fuel. The effects of the network's architecture, the preprocessing of the data and the individual isotopic ratios on the results of the reactor parameter reconstruction are evaluated.

Biography. Fabian Unruh is a physicist currently pursuing a Master's degree at RWTH Aachen University. For his Bachelor's thesis in physics, he analyzed data from the CMS experiment. Throughout his Master's degree, Fabian focused on statistical data analysis, machine learning, experimental particle physics, and nuclear disarmament. Presently, he is on the verge of completing his Master's thesis at the Nuclear Verification and Disarmament Group at RWTH University. His research involves exploring the application of neural networks for nuclear archaeology, a field that combines his expertise in physics and interests in peace research.

Raven Witherspoon (she/her)
Princeton University

Modeling Radiological Risks Associated with Fires at Plutonium Pit Production Plants

Abstract. As part of the modernization of its nuclear weapon arsenal, the United States has decided to restart the large-scale production of plutonium pits, the hollow-shells of several kg of plutonium that are the fission "triggers" for thermonuclear warheads. New Mexico's Los Alamos National Laboratory (LANL) and South Carolina's Savannah River Site (SRS) have been selected as the sites for pit production, with LANL expected to produce its first "war reserve" pit in 2024 with plans to increase capacity by 2030 to 30 pits per year at LANL and 50 pits per year at SRS. These plans have faced criticism from experts and civil society groups who question the feasibility, scale, cost, risk, and necessity of increasing plutonium pit production at this time. A key concern has been the poor safety record associated with plutonium handling at LANL in the past decade as well as previous episodes of environmental contamination at the former U.S. pit production plant in Rocky Flats, Colorado, prior to its closure in 1989 for repeated failures to comply with environmental and safety standards.

This presentation will discuss the risks associated with large releases of plutonium from major fires at pit production facilities, and their implications for public health and safety. It will provide results from a reconstruction of the radiological consequences of the 1957 Rocky Flats fire using modern atmospheric particle transport software and archived weather data, and show how favorable wind conditions helped reduce the potential impacts of this accident. The same techniques will be applied to estimate possible consequences from a plutonium fire taking place at LANL using publicly available source-term data.

Biography. Raven Witherspoon is a pre-doctoral research fellow at Princeton University's Program on Science and Global Security. She received her Master's degree in global affairs from Tsinghua University as a Schwarzman Scholar, where she studied nuclear risk reduction and confidence-building measures between the United States and China. Raven received her Bachelor's degree in physics from Virginia Commonwealth University with minors in political science, international social justice studies, and mathematics. She is a former Legislative Aide for the Virginia General Assembly.

School Lecturers & Organizers

Sara Al-Sayed
Princeton University

Sara Al-Sayed is a Postdoctoral Research Associate in the Program on Science and Global Security (SGS) at Princeton University. She received her BSc degree from the German University in Cairo, Egypt, M.Sc. degree from Universität Ulm, Germany, and PhD degree from Technische Universität Darmstadt, Germany—all in communications engineering, with the focus of her PhD dissertation being on statistical data processing. After an appointment as a postdoctoral research and teaching associate at Technische Universität Darmstadt, she picked up an Master's program in philosophy of technology at the same university.

Hamza El-Asaad
Princeton University

Nuclear Power Plant Disasters and Evacuation

Hamza El-Asaad is a postdoctoral fellow at SGS. He attended the University of Calgary, where he earned a BSc with concentrations in Physics and Computer Science. Following the Fukushima nuclear accident, his focus shifted towards investigating the impacts caused by the incident. He pursued graduate studies at the Tokyo Institute of Technology, achieving an MEng in Environmental Engineering and a PhD in Nuclear Engineering. His present research interests revolve around nuclear security and policy, with a specific focus on the environmental behavior of radioactive materials resulting from significant nuclear incidents. He also examines the implications of these incidents on public policies.

Alex Glaser (he/him)
Princeton University

Nuclear Arms Control and Verification

Alexander Glaser is associate professor in the School of Public and International Affairs and in the Department of Mechanical and Aerospace Engineering. Alex has been co-directing the Program on Science and Global Security since 2016. For Princeton's work on nuclear warhead verification, Foreign Policy Magazine selected him as one of the 100 Leading Global Thinkers of 2014. In September 2020, Alex was elected a Fellow of the American Physical Society. Alex holds a PhD in physics from Darmstadt University, Germany.

Robert J. Goldston (he/him)
Princeton University

How to Avert the Coming Arms Race and End Russia's War on Ukraine

Rob Goldston is a Professor of Astrophysical Sciences at Princeton University. He was director of the Princeton Plasma Physics Laboratory from 1997 to 2009. He does research on fusion energy and verification technologies for arms control and nonproliferation, serves on the Board of the Council for a Livable World, and writes policy pieces for the Bulletin of the Atomic Scientists.

Jihye Jeon
Princeton University

Jihye Jeon is a PhD student in the department of Mechanical and Aerospace Engineering at Princeton University. Prior to coming to Princeton, Jihye worked at the Korea Institute of Nuclear Nonproliferation and Control (KINAC), analyzing international nuclear safeguards and security policy. Jihye graduated from Seoul National University with a BS in nuclear engineering and a BA in English language and literature, and from Sejong University with an MS in nuclear engineering focused on radiation measurement and applications. Her research interests are in developing verification technologies to support nuclear disarmament and nonproliferation.

Geralyn McDermott
Princeton University

Geralyn McDermott joined the Program on Science and Global Security as Administrative Assistant in 2012. She provides administrative and research support to the Program's faculty, staff, and graduate students. In addition, Geralyn coordinates logistics for domestic and international conferences, arranges travel, and is responsible for expense reporting, and purchasing.

Zia Mian
Princeton University

The Treaty on the Prohibition of Nuclear Weapons

Zia Mian is a physicist and co-director of Princeton University's Program on Science and Global Security. His research interests include issues of nuclear arms control, nonproliferation, and disarmament and international peace and security. Mian is the co-author of Unmaking the Bomb (MIT Press, 2014) and a co-editor of *Science & Global Security*, the international peer-reviewed technical journal of arms control, nonproliferation, and disarmament. He is a co-founder of the Physicists Coalition for Nuclear Threat Reduction. Mian serves on the Boards of the Arms Control Association and of the Union of Concerned Scientists. In 2022, he was appointed to the UN Secretary-General's Advisory Board on Disarmament Matters.

Igor Moric
Princeton University

Igor Moric is a Postdoctoral Research Associate in the Program on Science and Global Security. Previously, he worked as a postdoctoral researcher on the MIMAC and PandaX dark matter detectors at Tsinghua University in Beijing and SJTU in Shanghai, respectively. During his PhD at CNES and Paris Sorbonne he worked on the space atomic clock PHARAO. He has an advanced Master's degree in "Space Systems Engineering" from ISAE-SUPAERO in Toulouse.

Sébastien Philippe (he/him)
Princeton University

Modeling the Radiological Impact of Nuclear Explosions

Sébastien Philippe is a Research Scholar with Princeton University's Program on Science and Global Security. His research interests include nuclear arms control, disarmament, and justice issues. His work on the reconstruction of fallout from past nuclear weapon tests, including French tests in the Pacific and the Trinity test in the United States, has been covered in major media around the world. Philippe's book Toxique was a 2021 finalist for the Albert Londres Prize and won a 2022 Sigma Award for best data journalism in the world. He received his PhD in Mechanical and Aerospace Engineering from Princeton, was a Stanton Postdoctoral fellow at Harvard, and was a nuclear weapon safety engineer in France. He currently serves on the Scientific Advisory Group of the United Nations Treaty on the Prohibition of Nuclear Weapons.

Stewart Prager
Princeton University

Stewart Prager is a professor of astrophysical sciences at Princeton University, and an affiliated faculty member with the Program on Science and Global Security. From 2009–2016, he was director of the Princeton Plasma Physics Laboratory. Previously, he was professor of physics at the University of Wisconsin-Madison, where he was director of the Madison Symmetric Torus experimental program and director of the Center for Magnetic Self-Organization in Laboratory and Astrophysical Plasmas, a multi-institutional NSF Physics Frontier Center. From 2012–2019, he co-directed the Max-Planck/Princeton Center for Plasma Physics. Prager received the Dawson Award for Excellence in Plasma Physics from the American Physical Society (APS) and the Leadership and Distinguished Career awards from Fusion Power Associates. His service has included chair of the Department of Energy Fusion Energy Sciences Advisory Committee, President of the University Fusion Association, Chair of the APS Division of Plasma Physics. He is currently vice-chair of the APS Forum on Physics and Society and a co-founder of the Physicist Coalition for Nuclear Threat Reduction. He holds a PhD in plasma physics from Columbia University.

Leonor Tomero
JA Green & Company

Report of the Congressional Commission on Strategic Posture

Leonor Tomero is a leading expert on nuclear deterrence, national security space and missile defense, including applying innovative technologies and concepts for strategic deterrence. She is Vice-President for Government Relations at JA Green & Company where she supports innovative companies offering national security capabilities. She founded and owns LeoSpace LLC consulting company, supporting transformational government and commercial capabilities that enable rapid acquisition and resilience for defense. She also currently serves as a Commissioner on the congressional 2023 Commission on Strategic Posture of the United States and is a visiting lecturer at Princeton University where she is teaching a course on Avoiding Nuclear War with Russia and China with Prof. Frank von Hippel. In 2021, she served as Deputy Assistant Secretary of Defense for Nuclear and Missile Defense Policy where she was responsible for the United States' nuclear deterrence policy, and chaired the Missile Defense Review and Nuclear Posture Review. Prior to this role, she served for over a decade as Counsel and Strategic Forces Subcommittee Staff Lead on the House Armed Services Committee covering strategic forces issues, including national security space and establishment of the U.S. Space Force, nuclear weapons, nuclear nonproliferation, nuclear clean-up, missile defense, hypersonics and strategic stability issues. She holds a BA from Cornell University, an MA in Security Studies from Georgetown University and a JD, cum laude, from American University.

Frank von Hippel
Princeton University

A Physicist Wanders into Public Policy, and It Proves Very Interesting

Frank von Hippel is a senior research physicist and professor of public and international affairs emeritus with Princeton's Program on Science & Global Security which he co-founded. He received a D.Phil. in theoretical physics in 1962 from the University of Oxford, where he was a Rhodes Scholar and held research positions at the University of Chicago, Cornell University, and Argonne National Laboratory, and served on the physics faculty at Stanford University. From 1983 to 1991, he was chairman of the Federation of American Scientists (FAS) and partnered with the Committee of Soviet Scientists for Peace and Against the Nuclear Threat to help provide technical support for initiatives to achieve a Comprehensive Test Ban, the Intermediate-range Nuclear Forces and Strategic Arms Reductions Treaties. He was assistant director for national security in the White House Office of Science and Technology Policy (1993 to 1994) and played a major role in developing what is now called the International Nuclear Materials Protection and Cooperation Program. Von Hippel's awards include the American Physical Society's (APS) 2010 Leo Szilard Lectureship Award; the American Association for the Advancement of Science's 1994 Hilliard Roderick Prize; and a MacArthur Foundation Prize Fellowship. His books include Advice and Dissent, Scientists in the Political Arena (1974); "Citizen Scientist" (1991) published in the American Institute of Physics "Masters of Modern Physics" series; "Unmaking the Bomb" (2014); and, Plutonium: How Nuclear Power's Dream Fuel Became a Nightmare (2019).

Sharon Weiner (she/her)
American University

Ethics and Deterrence

Sharon K. Weiner is a visiting researcher from American University where she is an Associate Professor of International Relations in the School of International Service. She was a 2018 Carnegie Fellow and a Council on Foreign Relations International Affairs Fellow in Nuclear Security (2014–2015). Her book Our Own Worst Enemy? Institutional Interests and the Proliferation of Nuclear Weapons Expertise (MIT Press 2011) was the winner of the 2012 Louis Brownlow award from the National Academy of Public Administration. She is also the author of Managing the Military: The Joint Chiefs of Staff and Civil-Military Relations (Columbia University Press, 2022). Sharon has worked in both houses of Congress, the Pentagon's Joint Staff, and the White House Office of Management and Budget. She holds a PhD in Political Science from MIT.

David Wright (he/him)
Massachusetts Institute of Technology (MIT)

Hypersonic Weapons and Missile Defense

David Wright received his PhD in theoretical condensed matter physics from Cornell University in 1983 and worked as a research physicist until 1988. Since then he has worked on arms control and international security issues, researching technical aspects of nuclear weapons policy, missile defense systems, missile proliferation, hypersonic weapons, and space weapons. From 1992 to 2020 he was a researcher with the Global Security Program at the Union of Concerned Scientists, serving as co-director of the program from 2002 to 2020. He also held research positions in the Defense and Arms Control/Security Studies Program at MIT, the Center for Science and International Affairs at Harvard's Kennedy School of Government, and the Federation of American Scientists. From 1990 to 2019, he was a primary organizer of the International Summer Symposiums on Science and World Affairs, which fostered cooperation among scientists around the world working on arms control and security issues. In 2001, he was a co-recipient of the American Physical Society's Joseph A. Burton Forum Award for his arms control research and his work with international scientists. He is a Fellow of the American Physical Society.

Lili Xia
Rutgers University

Impacts of Nuclear War on Climate and Food Security

Lili Xia is an Assistant Research Professor in the Department of Environmental Sciences at Rutgers University and serves as the Co-Director of Rutgers Impact Studies of Climate Intervention (RISCI). She earned her PhD in the Atmospheric Sciences Graduate Program at Rutgers University. Since 2017, she has been a research collaborator in the Developing Country Impact Modelling Analysis for Solar Radiation Management (DECIMALS) project, assisting teams from the Philippines, Jamaica, West Africa, and South Africa. She was also a steering committee member of the Geoengineering Modeling Research Consortium from 2019 to 2022. Additionally, she is slated to be the chair of Gordon Research Conference – Climate Engineering in 2026. Dr. Xia has been actively working on the impact of climate change on agriculture, ecosystem, and air pollutants. Her research primarily focuses on two climate scenarios: stratospheric aerosol climate intervention and nuclear war. In recognition of her significant contributions, she was honored with the Global Peach and Health Award in 2022 by the International Physicians for Prevention of Nuclear War and the Boston Chapter of Physicians for Social Responsibility.

Tong Zhao
Princeton University

Chinese Nuclear Policy and Development

Tong Zhao is a Visiting Research Scholar at SGS. He is also a Senior Fellow at the Carnegie Endowment for International Peace. He was a Stanton Nuclear Security Fellow at Harvard's Kennedy School of Government. He is on the Board of the Asia Pacific Leadership Network for Nuclear Non-Proliferation & Disarmament. Tong Zhao holds a PhD in science, technology, and international affairs from Georgia Institute of Technology, as well as an MA in international relations and a BS in physics from Tsinghua University.