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Editors' Note

In the nuclear age, past, present and future co-exist in complex and often troubling ways. This issue of the journal has three articles and a book review that each in their own way aim to highlight the need to understand the past and act responsibly in the present to forestall the past becoming an even greater problem in the future.

In "The Long-Term Global Health Burden from Nuclear Weapon Test Explosions in the Atmosphere: Revisiting Andrei Sakharov's 1958 Estimates" Frank von Hippel goes back to the effort by a handful of Soviet and US scientists to warn of the long-term impacts on public health around the world of the large and frequent thermonuclear weapon tests by the United States and USSR. A prominent example was the article by Andrei Sakharov in June 1958 in the Soviet journal, *Atomic Energy*. [This article was reproduced in the first volume of *Science & Global Security* – Andrei D. Sakharov, "Radioactive Carbon from Nuclear Explosions and Nonthreshold Biological Effects," *Science & Global Security* 1, no. 3–4 (1990).]

Soviet scientist O.I. Leipunskii had noted that radioactive carbon-14 would be produced by nuclear explosions in the atmosphere, leading Sakharov to try to assess the scale of serious health effects that would follow from this carbon-14 as it entered the biosphere. Linus Pauling in the United States produced his own assessment. Leipunskii emphasized the need to understand and be sensitive to the "impact not only on the present generation but for illness of the twentieth generation" due to nuclear testing. The health impacts of atmospheric nuclear testing from 1945 to 1980 (amounting to about 440 megatons) will last for thousands of years into the future because of the 5700-year half-life of radioactive carbon-14.

Von Hippel traces Sakharov's assumptions of the population radiation dose and the dose-effect coefficients that permit estimates of health effects and compares these to more recent values adopted by the U.N. Scientific Committee on the Effects of Atomic Radiation in 2000 and in a report by the U.S. National Academies in 2006. Von Hippel finds that Sakharov's estimate of 3 million (after scaling for global population) falls in the range of a modern estimate of "1.3–5.2 million serious health effects from atmospheric testing." Von Hippel concludes "millions of people over thousands of years … will suffer from health effects from atmospheric nuclear tests [they] will not know the cause but their suffering will be no less."

In "Radiation Exposures and Compensation of Victims of French Atmospheric Nuclear Tests in Polynesia," Sébastien Philippe, Sonya Schoenberger, and Nabil Ahmed focus on deepening the understanding of the past, present and future humanitarian impacts of six of the 41 nuclear weapon tests in the Pacific between 1966 and 1974 by France. These tests led to radioactive fallout that impacted local communities and ecosystems and French veterans. The article uses declassified French government documents, historical meteorological data and state-of-the-art atmospheric transport modeling using the US NOAA Hybrid Single-Particle Integrated Trajectory (HYSPLIT) code to reassess the upper bound of radiation doses received by local populations at the time of the testing. It also illuminates the various reasons these doses may have been underestimated in French government studies now used to establish a basis for

eligibility for compensation for veterans and Pacific islanders claiming to be affected. It considers also possible exposure to populations in Polynesia beyond the three islands and atolls considered in official studies.

France's Loi Morin compensation program entitles individuals with one or more of 23 listed possibly radiation-induced cancers to the presumption that nuclear testing had caused their illness if at the time of testing they were in French Polynesia. In 2018, this was qualified to require claimants had been exposed to a radiation dose of 1 mSv or above in any given year during the period of testing, based on French government fallout and exposure studies. The article (along with a detailed appendix on the modeling and a supplementary video showing a simulation of one of the tests, Centaure) finds significant shortcoming in the official studies. The upper bound estimates of effective doses due to groundshine, cloudshine and inhalation received by local Polynesian communities due to French atmospheric testing may be too low by factors of about 2–10, even without including all measurement and model uncertainties which could further increase the margin. This assessment would make eligible for compensation about 110,000 people (90% of the total Polynesian population in 1974) who received effective doses greater than 1 mSv/yr, about ten times more people than considered eligible based on French government studies and so denied recognition until now. The many other French nuclear tests carried out in the Pacific may add to this total.

Similar studies are needed for communities affected by nuclear testing around the world. Such studies may be given new priority because of the UN Treaty on the Prohibition of Nuclear Weapons. The treaty requires states to provide people affected by testing "assistance, without discrimination, including medical care, rehabilitation and psychological support, as well as provide for their social and economic inclusion." It requires states also take "necessary and appropriate measures towards the environmental remediation of areas" contaminated by nuclear testing.

In the third article in this issue, *Document-Based Nuclear Archaeology*, Ole Reistad, Alex Glaser, Rebecca Frank, and Sindre Kaald open a new line of research that aims to develop a shared basis for understanding the value of and methods for archiving, preserving, and assessing the authenticity of the historical records of nuclear facilities to enable future nuclear archaeology applications for verifying nuclear disarmament and for other purposes. These records would allow reconstructing the history of a nuclear program in ways that complement traditional material sampling nuclear archaeology techniques. The use of records was part of the plan for verifying plutonium production in North Korea, which led North Korea to hand over to the United States 18,000 pages of paper records. There is no public information about what the US government has inferred from these records.

Since military nuclear facility records are largely unavailable to independent experts, the article uses a research reactor operated for peaceful purposes as a test bed for thinking through concepts and technologies that could in principle be applied to future nuclear archaeology at nuclear weapons plutonium production and possibly other fissile material production sites. The test bed in this case is the 2 MW JEEP II reactor at Norway's Institute for Energy Technology, which operated for more than 50 years (1966–2018) before being shut-down. By analyzing the reactor's operating records, some of which were analog and others digital, and using OpenMC/ONIX neutronics codes to model reactor operations, the article shows it is possible to simulate the entire operational history of the reactor, including refueling, discharge and repositioning of fuel assemblies, and new fuel assemblies being loaded.

This work also proposes specific guidelines for best practices for long-term preservation and curation of nuclear facility operating records based on the standards and practices in archival science and digital preservation. This is important since verification significant information can indeed be extracted from such records but timeliness is critical, since as facilities shut-down, staff retire and records may be lost. The proposed guidelines include "nondestructive digitization for the logbooks and other physical records" and for the original physical items to be "housed and stored in a secure, climate controlled archival environment." The authors call for "a dedicated and broadly supported initiative to establish a better understanding of the recordkeeping landscape and the relevance of inevitable gaps."

The final article in this issue is by Ian Crawford and is a review of *Dark Skies: Space Expansionism, Planetary Geopolitics, and the Ends of Humanity* by Daniel Deudney (Oxford University Press, 2020). Crawford describes it as an "important and thought-provoking book" that "provides a panoramic survey of diverse schools of thought relating to the future of human activities in space, and provides a systematic attempt to assess their relative merits. The discussion is framed in the wider context of global problems faced by our contemporary planetary civilization, and the risks and benefits of technological choices." It challenges "overly optimistic visions of a human future in space" which are based on a perspective of "space expansionism" that sees an expansion of human activities into space as both desirable and inevitable. Crawford concludes *Dark Skies* "performs a hugely valuable service by raising important, and often neglected, geopolitical considerations related to the future of human activities in space. It deserves to be read by anyone with an interest in the future of space exploration."