PRESERVING THE RECORD

A DOCUMENT-BASED APPROACH TO NUCLEAR ARCHAEOLOGY

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BACKGROUND
There remain about 13,000 nuclear weapons in the world today.
PROGRESS TOWARD NUCLEAR DISARMAMENT HAS BEEN REAL
(BUT IT HAS SLOWED DOWN SIGNIFICANTLY OVER THE PAST DECADE)

Based on the Nuclear Notebook, maintained by Hans M. Kristensen and Matt Korda, thebulletin.org/nuclear-notebook/
There is enough nuclear explosive material worldwide to make over 200,000 nuclear weapons

1335 tons of highly enriched uranium (HEU)

530 tons of separated plutonium

Each block corresponds to 12 kg of HEU, the amount necessary to make a fission bomb; about 111,670 bombs-worth total

Each block corresponds to 4 kg of plutonium, the amount necessary to make a fission bomb; about 130,000 bombs-worth total
ESTIMATING INVENTORIES CAN BE HARD

(AN EXAMPLE FROM THE 1996 U.S. PLUTONIUM DECLARATION)
NUCLEAR ARCHAEOLOGY
UNDERSTANDING THE OPERATIONAL HISTORY OF NUCLEAR FACILITIES

The Future of Nuclear Archaeology: Reducing Legacy Risks of Weapons Fissile Material

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This report describes the value proposition for a "nuclear archaeological" technical capability and applications program, targeted at resolving uncertainties regarding weapons fissile materials production and use. Central to this proposition is the notion that one can never be sure that all fissile material is adequately secure without a clear idea of what "all means, and that uncertainty in this matter carries risk. We argue that this proposition is as valid today, under emerging state and possible non-nuclear threats, as it was in an immediate post-Cold-War context, and describe how nuclear archaeological methods can be used to verify fissile materials dedications, or estimate and characterize historical fissile materials production independent of declarations. Methods for accurately estimating plutonium production from graphite reactors have been demonstrated and could be extended to other reactor types. Proposed open-container storage of spent nuclear fuel in shallow-ground, cement-lined underground canisters may also require understanding the operational history of nuclear facilities.

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NUCLEAR ARCHAEOLOGY

DOCUMENTING THE PAST TO ENABLE A NUCLEAR-WEAPON-FREE FUTURE

THE CHALLENGE

Future progress toward verified nuclear disarmament will require a much better understanding of the stockpile of fissile materials that have been produced in unsafeguarded facilities; “nuclear archaeology” seeks to provide the tools to do so.

THE IDEA

Develop of a framework that can provide a basis for preserving the history of relevant nuclear facilities; examine, in particular, the potential role of operating records to do so.

Such a framework would complement other nuclear archaeology techniques, which rely on physical samples taken from structural components or waste materials for forensic analysis to draw conclusions about past activities.

Source: IAEA (top), asian-defence-news.blogspot.com (bottom)
DEVELOPING THE TOOLS FOR POSSIBLE NUCLEAR ARCHAEOLOGY IN NORTH KOREA

Uranium mine at Pyongsan
Credit: Google Earth

Inside North Korea’s Yongbyon Reactor
Credit: CNN/Brian Rokus, 2008

Operating records shared in 2008
Credit: Chung Sung-Jun
WHY GERMANY?
ONGOING VERIFICATION INITIATIVES

(AS OF 2021, ALL WITH GERMAN PARTICIPATION)

INTERNATIONAL PARTNERSHIP FOR DISARMAMENT VERIFICATION

Established in 2015; currently 29 participating countries

IPNDV seeks to identify challenges associated with nuclear disarmament verification and to develop potential procedures and technologies to address those challenges

Phase III will begin in Spring/Summer 2021

Germany is co-chairing two (out of three) working groups

www.ipndv.org

Source: ipndv.org

GROUP OF GOVERNMENTAL EXPERTS ON DISARMAMENT VERIFICATION

Group of Governmental Experts (GGE) considers “the role of verification in advancing nuclear disarmament”

Established by the UN Secretary General following a resolution of the UN General Assembly (A/RES/71/67, Dec. 2016), the first GGE delivered its final report in May 2019 (A/71/67)

The second GGE will be convening in Geneva in 2021 and 2022

25 members, including Germany

Source: www.flickr.com/photos/gruban/336920038
SAMPLE-BASED
NUCLEAR ARCHAEOLOGY
(A case study)
NUCLEAR ARCHAEOLOGY COULD BE USED TO VERIFY A NORTH KOREAN PLUTONIUM DECLARATION

Credit: CNN/Brian Rokus, 2008

Unit cell of the North Korea’s Yongbyon reactor
GRAPHITE ISOTOPE RATIO METHOD (GIRM)

Based on data from Jungmin Kang, “Using the GIRM to Verify the DPRK’s Plutonium-Production Declaration,” Science & Global Security, 19 (2), 2011
Below is a list of measures that would be applied to undertake verification activities. These measures will form the basis for development of a verification implementation plan that assigns specific responsibilities and requirements. These measures provide a means to address all elements of a nuclear program, to include plutonium production, uranium enrichment, weapons, weapons production and testing, and proliferation activities.

The verification regime consists of experts of the six parties and is responsible to the Working Group on Denuclearization of the Korean Peninsula.

- Six Party Experts will be authorized to coordinate their actions in the course of exercising their responsibilities, to include measurement devices, radiation detection equipment, and GPS receivers.

- As relates to a graphite-moderated reactor, collect, and remove from the Party physical samples of the graphite moderator after the core has been de-fueled.
DOCUMENT-BASED NUCLEAR ARCHAEOLOGY

(A case study)
Indiana Jones: Raiders of the Lost Ark
Paramount Pictures, 1981
JEEP II Reactor
Institute for Energy Technology (IFE)
Kjeller, Norway, 12/1966–12/2018

2 MW
Heavy-water moderated and cooled
3.5%-enriched uranium fuel
FIRST LOOK AT DIGITAL RECORDS OF JEEP II

DDS file generated with Yokogawa DAQSTATION DX100/200 Series of Paperless Recorders

Sensor readings are from RC6 ionization chamber and can be used to estimate the current power level of the reactor.
DETERMINING A CAPACITY FACTOR
FROM DIGITAL DATA AVAILABLE IN THE ARCHIVE

The Norwegian operators also plan to use these simulations to characterize their onsite spent fuel inventory, i.e., fuel from fifty years of operation.
WHAT'S NEXT?
WHAT AN ACTUAL PROJECT COULD LOOK LIKE

(“THE PROOF OF THE PUDDING IS IN THE EATING”)

REVIEW TYPES OF RECORDS AND DATA AVAILABLE

Determine which types of information are most relevant for nuclear archaeology purposes

Determine what equipment and “tacit knowledge” are needed to read and correctly interpret the data; determine ways to best preserve the records and ensure their integrity

Note: The data itself is never made public

PERHAPS ALSO: CHOOSE A (SMALL) BENCHMARK PROBLEM TO DEMONSTRATE THE CONCEPT/IDEA

Focus on a well-defined episode/era of a plant’s history

If/when needed, one could use computational tools to simulate a selected time period and develop a better understanding of the potential and the limits of the technique

Note: Possibly of interest for RERTR 2021 or INMM 2021/2022

Source: www.flickr.com/photos/iaea_imagebank (bottom)
A MULTIDISCIPLINARY EFFORT

HOW TO CURATE AND PRESERVE ANALOG & DIGITAL DATA
HOW TO CONFIRM INTEGRITY, AUTHENTICITY, AND PROVENANCE OF RECORDS
WHY IT MATTERS

DEVELOP BEST PRACTICES FOR DOCUMENTING AND ARCHIVAL
No systematic efforts currently exist to archive and preserve the historical records of nuclear facilities at a level required for potential nuclear archaeology applications.
Make recommendations for data collection and storage at operational and future plants.
This is a time critical effort (as facilities are being demolished, records destroyed, and staff retires).

SUPPORT ONGOING & FUTURE DECOMMISSIONING EFFORTS (FOR CIVILIAN FACILITIES)
Lead by example with regard to openness and transparency.
Example of the Norwegian case: Document-based archaeology could help inform calculations to characterize spent fuel inventory using modern computer codes and cross-section data.

Source: www.flickr.com/photos/iaeaimagebank (top) and www.jen-juelich.de (bottom)