NUKLEARE ARCHÄOLOGIE

ODER: WIE FORSCHUNGSREAKTORENTEN
ZUR NUKLEAREN ABRÜSTUNG BEITRAGEN KÖNNEN

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Revision 0
BACKGROUND
There remain almost 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/.
"THE GRAND BARGAIN"

NUCLEAR NONPROLIFERATION, DISARMAMENT & PEACEFUL USE

**NUCLEAR NON-PROLIFERATION TREATY (1970)**

Existing nuclear weapon states agree not to transfer nuclear weapons to any other states

All other states agree to never acquire nuclear weapons

Nuclear weapon states (along with all others) undertake to pursue "good-faith negotiations" on effective measures relating to nuclear disarmament

*Source: Zia Mian (August 2022)*

**PEACEFUL USE OF NUCLEAR ENERGY & IAEA SAFEGUARDS**

The NPT acknowledges the right of all parties to develop nuclear energy for peaceful purposes

Non-nuclear-weapon states accept comprehensive IAEA safeguards to ensure peaceful use

As of November 2022, the NPT has 191 states parties
(5 weapon states, 186 non-weapon states)

*Source: IAEA*
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

Nuclear Archaeology: Verifying Declarations of Fissile-Material Production
Steve Fortier

The Future of Nuclear Archaeology: Reducing Legacy Risks of Weapons Fissile Material
Thomas W. Wood, Bruce D. Reid, Christopher M. Toomey, Kannan Krishnaswami, Kimberly A. Burns, Larry O. Casazza, Don S. Daly, and Leesa L. Duckworth
Pacific Northwest National Laboratory, Richland, WA, USA

Applications and Opportunities of Nuclear Archaeology in Uranium Enrichment
Matthew Sharp

Open-access articles are available at scienceandglobalsecurity.org/archive
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)
WHY GERMANY?
(and/or other non-nuclear-weapon states)
ONGOING VERIFICATION INITIATIVES

(AS OF 2022, 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 began 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 has been convening in Geneva since 2021

25 members, including Germany

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

Credit: CNN/Brian Rokus, 2008

Sampling position

Unit cell of the North Korea’s Yongbyon reactor
The Graphite Isotope Ratio Method (GIRM) is a technique used to verify nuclear production declarations. The graph illustrates the relationship between the cumulative plutonium production (in grams per fuel-rod volume equivalent) and the $^{11}$B/$^{10}$B ratio. The analysis is based on data from Jungmin Kang, "Using the GIRM to Verify the DPRK’s Plutonium-Production Declaration," *Science & Global Security*, 19 (2), 2011.
DOCUMENT-BASED
NUCLEAR ARCHAEOLOGY

(A first 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
RECONCILING ANALOG AND DIGITAL RECORDS
SATURDAY, FEBRUARY 6, 2010

Temperature difference [°C]

Current in ionization chamber [µA]

from the analog archives

from the digital archives
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?
TEST BEDS FOR NUCLEAR ARCHAEOLOGY

Ågesta Reactor, Sweden
NRX, Canada
G2/G3, France
A MULTIDISCIPLINARY EFFORT

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

Source: asian-defence-news.blogspot.com
DEVELOPING A FIRST SET OF GUIDELINES
FOR DOCUMENT-BASED ARCHAEOLOGY

**ANALOG RECORDS**

Analog records can survive for decades, but require significant amounts of storage space

- Assess each type of a record’s suitability for digitization
- Determine what properties of the physical records should be preserved in the digital surrogates
- Seek non-destructive digitization of logbooks and other physical records

**DIGITAL OBJECTS**

Digital records are more difficult to maintain than their analog counterparts

Requires decisions about file formats, metadata standards, and data management systems

Storage in repository that follows the Open Archival Information System (OAIS, www.oais.info) reference model and meets the criteria of established repository certification systems

CONCLUSION & WAY FORWARD

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.

Develop 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).

A TIME FOR ACTION

Lead by example with regard to openness and transparency.

Document-based archaeology can help support ongoing or planned decommissioning efforts.

JEEP II case study has provided first insights … but other participants are urgently needed.

Source: www.flickr.com/photos/iaea_imagebank (top) and IFE (bottom)