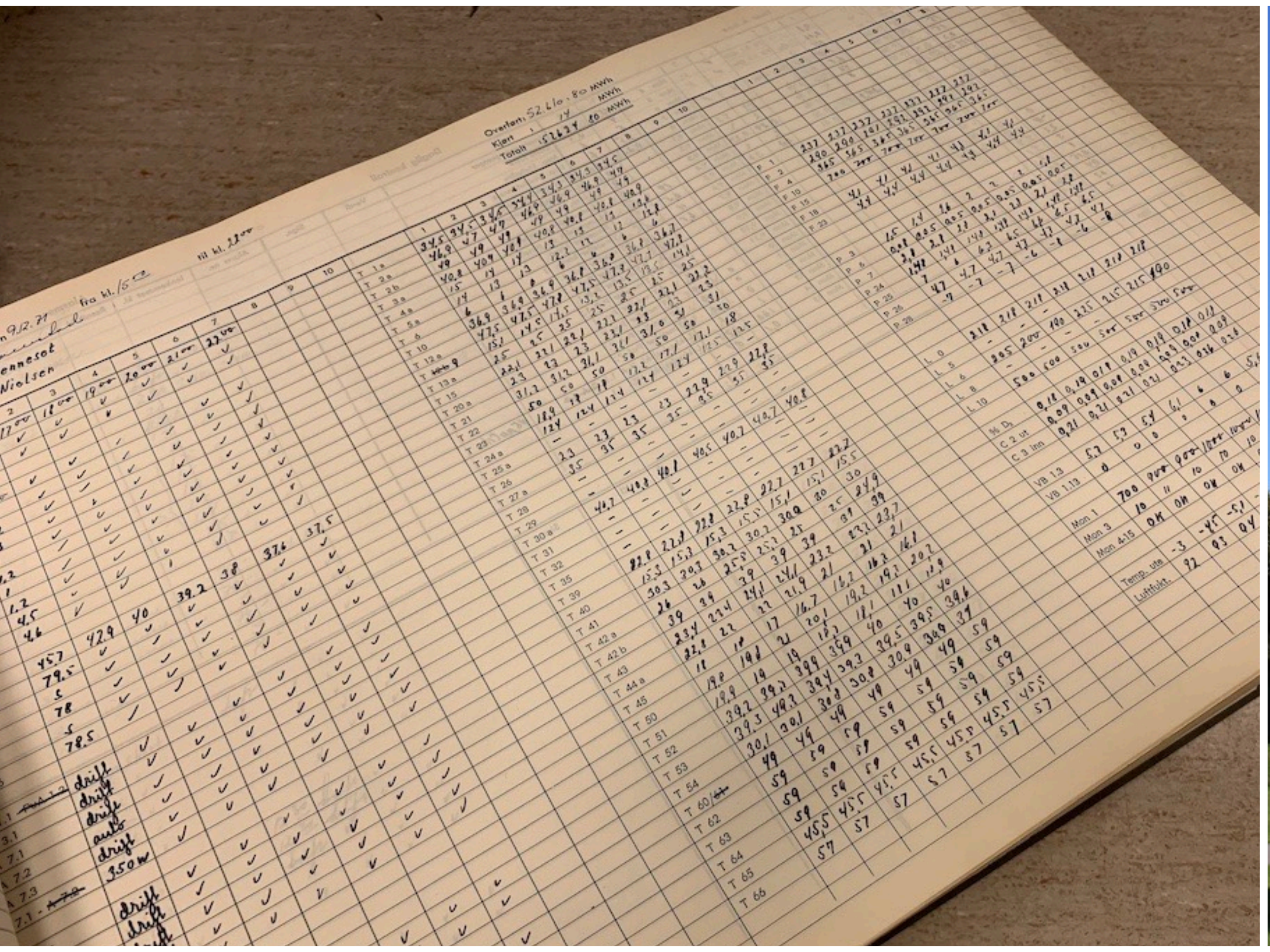



NUKLEARE ARCHÄOLOGIE

ODER: WIE FORSCHUNGSREAKTOREN ZUR NUKLEAREN ABRÜSTUNG BEITRAGEN KÖNNEN

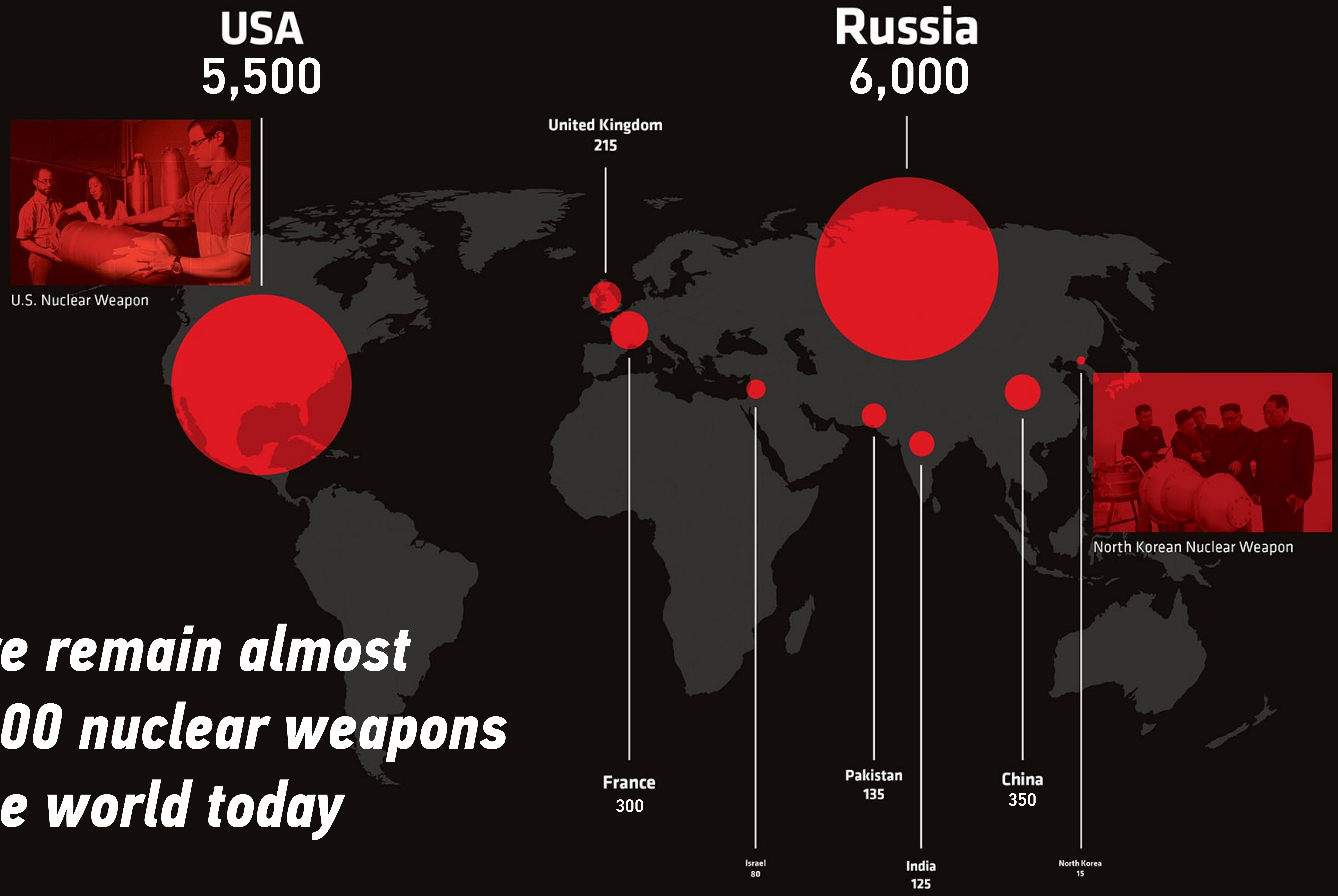
Alex Glaser

Program on Science and Global Security, Princeton University
Einstein Center Digital Future, Berlin

Helmholtz Zentrum Berlin, 17. November 2022

Revision 0

BACKGROUND

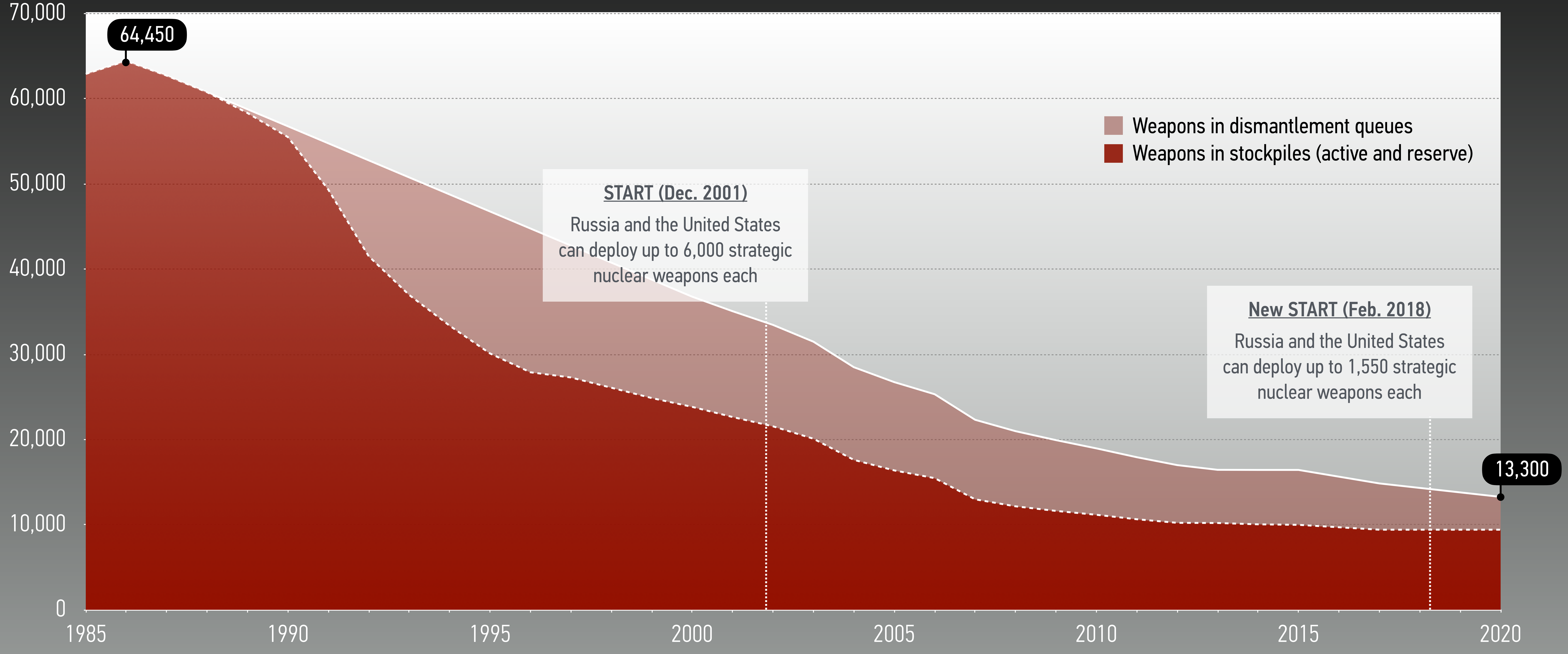


There remain almost 13,000 nuclear weapons in the world today

Hans Kristensen, Matt Korda, and Robert Norris, Nuclear Notebook, Federation of American Scientists and thebulletin.org/nuclear-risk/nuclear-weapons/nuclear-notebook/

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

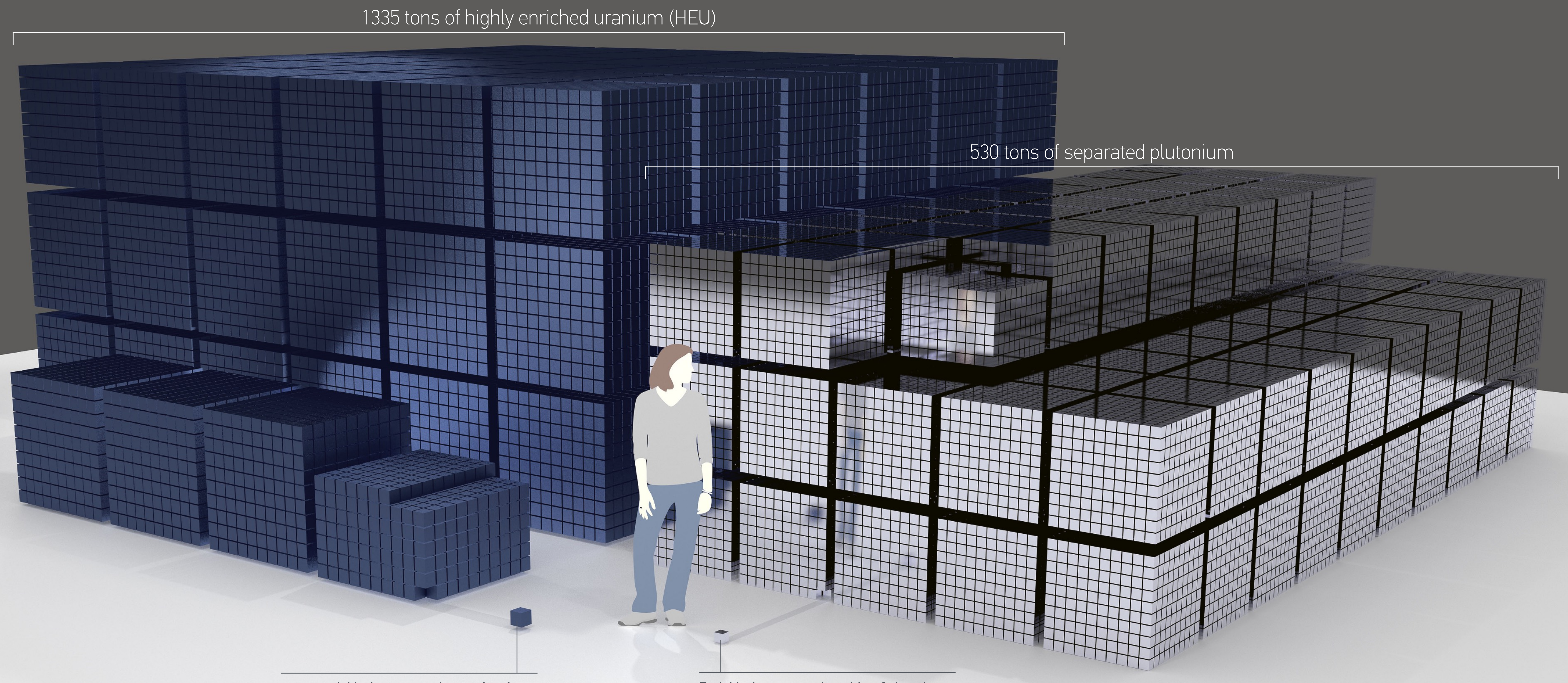
Non-nuclear-weapon states accept comprehensive IAEA safeguards to ensure peaceful use

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

Graphic/concept by Alex Wellerstein and Tamara Patton
Status as of the beginning of 2019

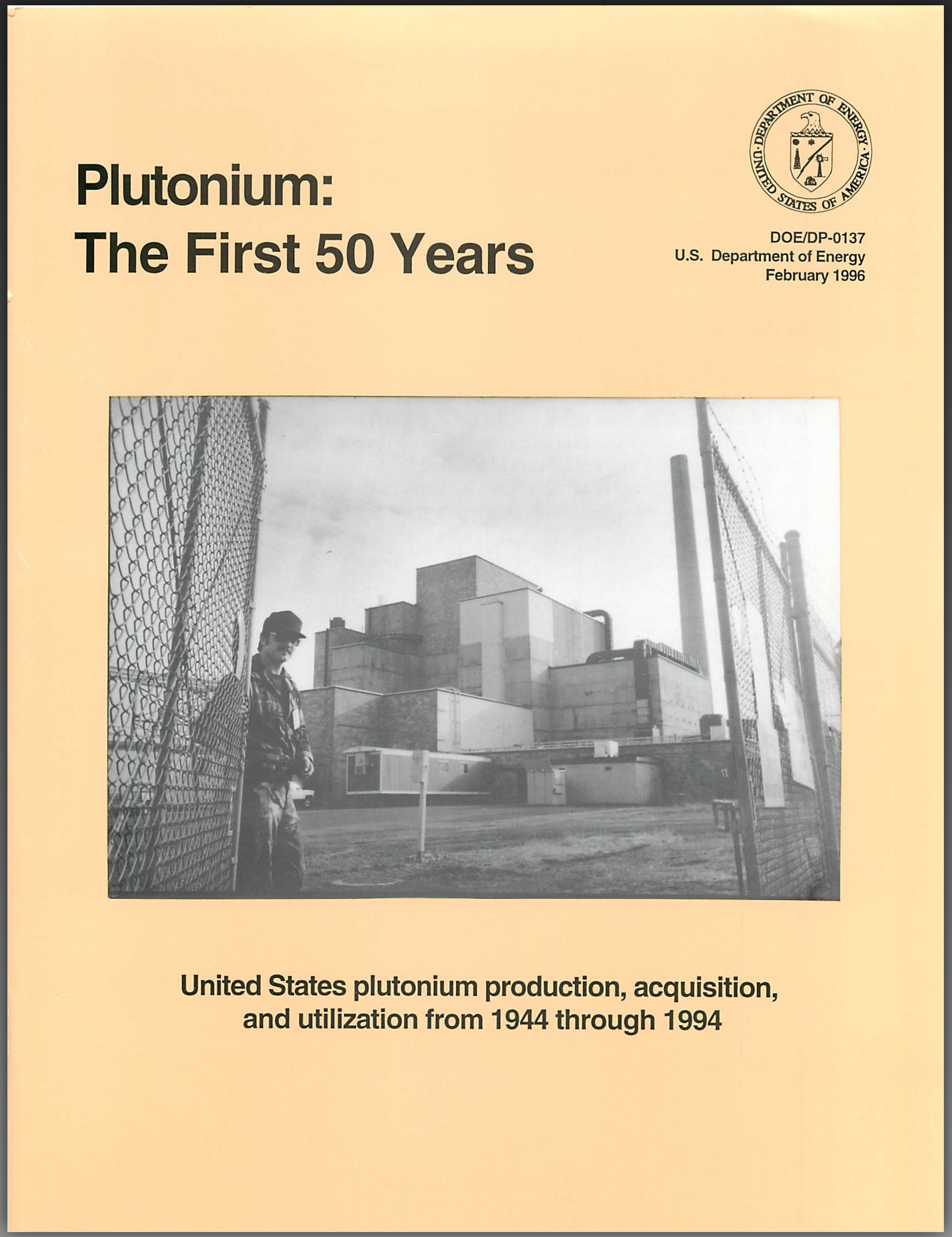


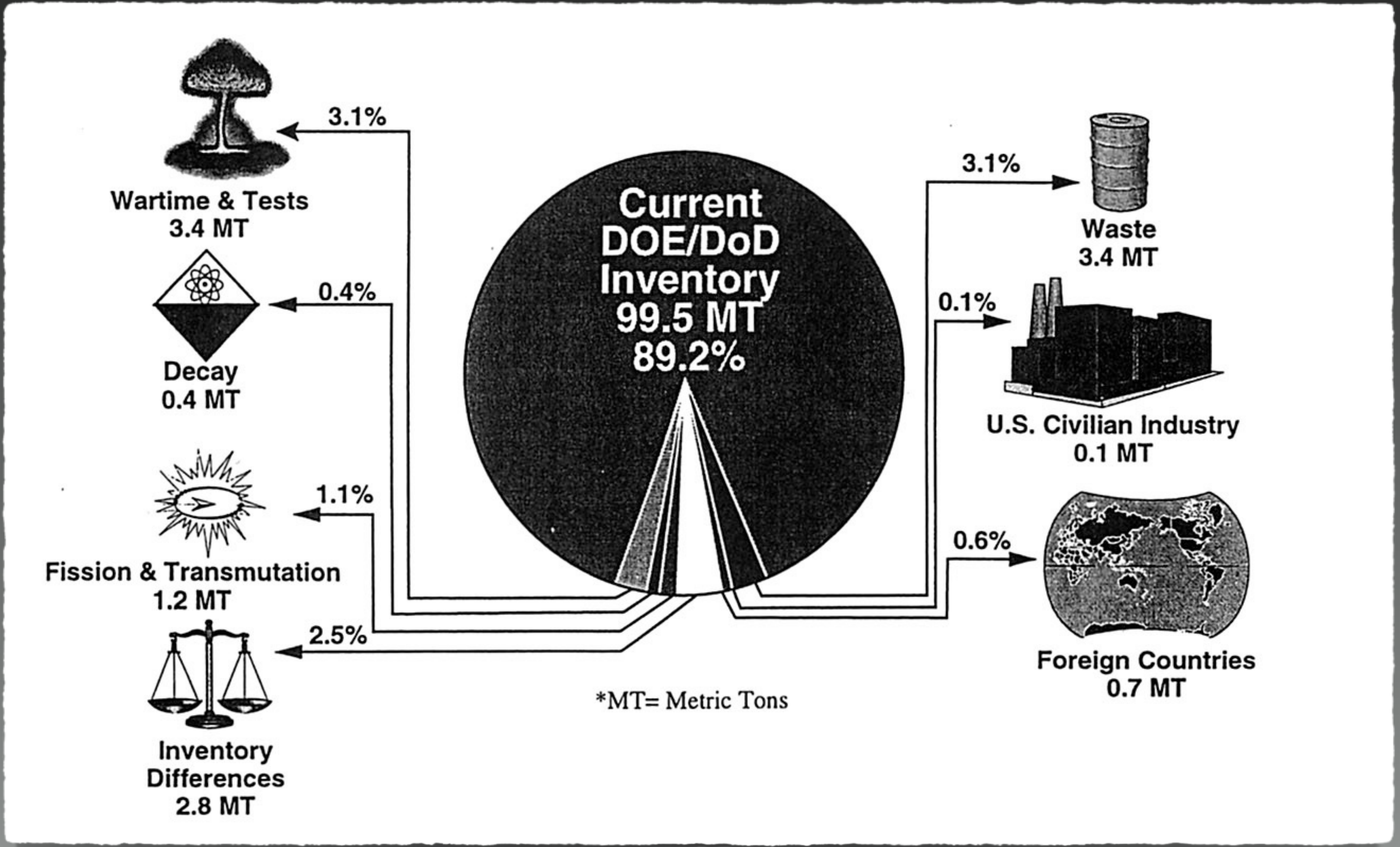
Each block corresponds to 12 kg of HEU, the amount necessary to make a fission bomb; about 111,670 bombs-worth total

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)



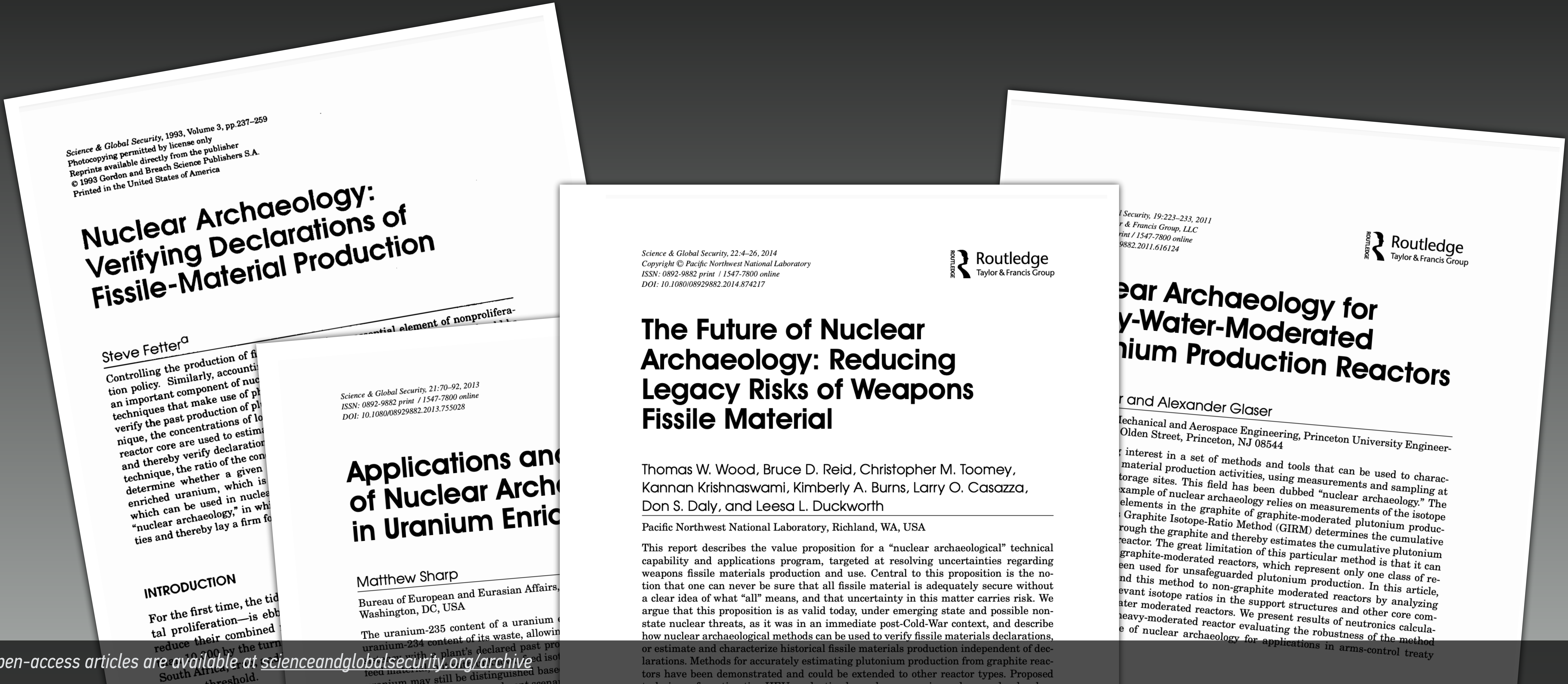


Plutonium: The First 50 Years, DOE/DP-0137, U.S. Department of Energy, Washington, DC, February 1996, www.ipfmlibrary.org/doe96.pdf

K Reactor, Savannah River Site, i.imgur.com/CPrBoCK.jpg

NUCLEAR ARCHAEOLOGY

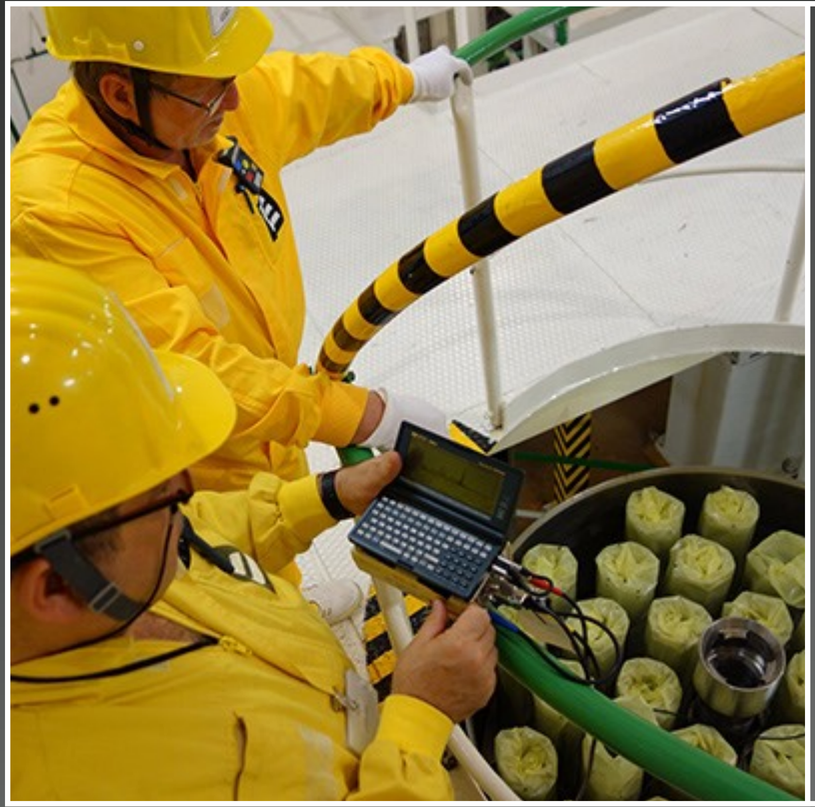
UNDERSTANDING THE OPERATIONAL HISTORY OF NUCLEAR FACILITIES



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

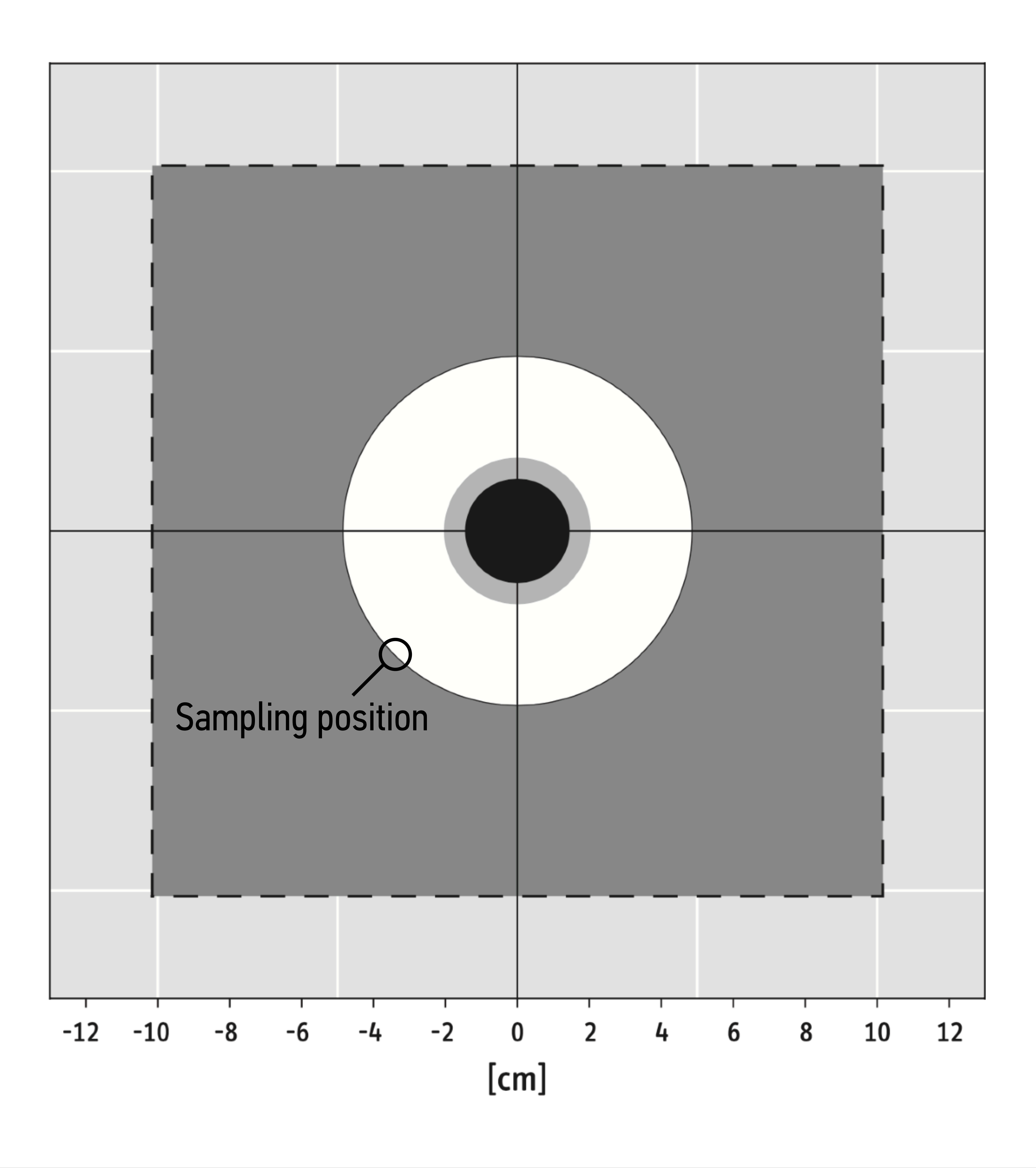
Source: www.flickr.com/photos/gruban/336920038

SAMPLE-BASED NUCLEAR ARCHAEOLOGY

(A possible use case)

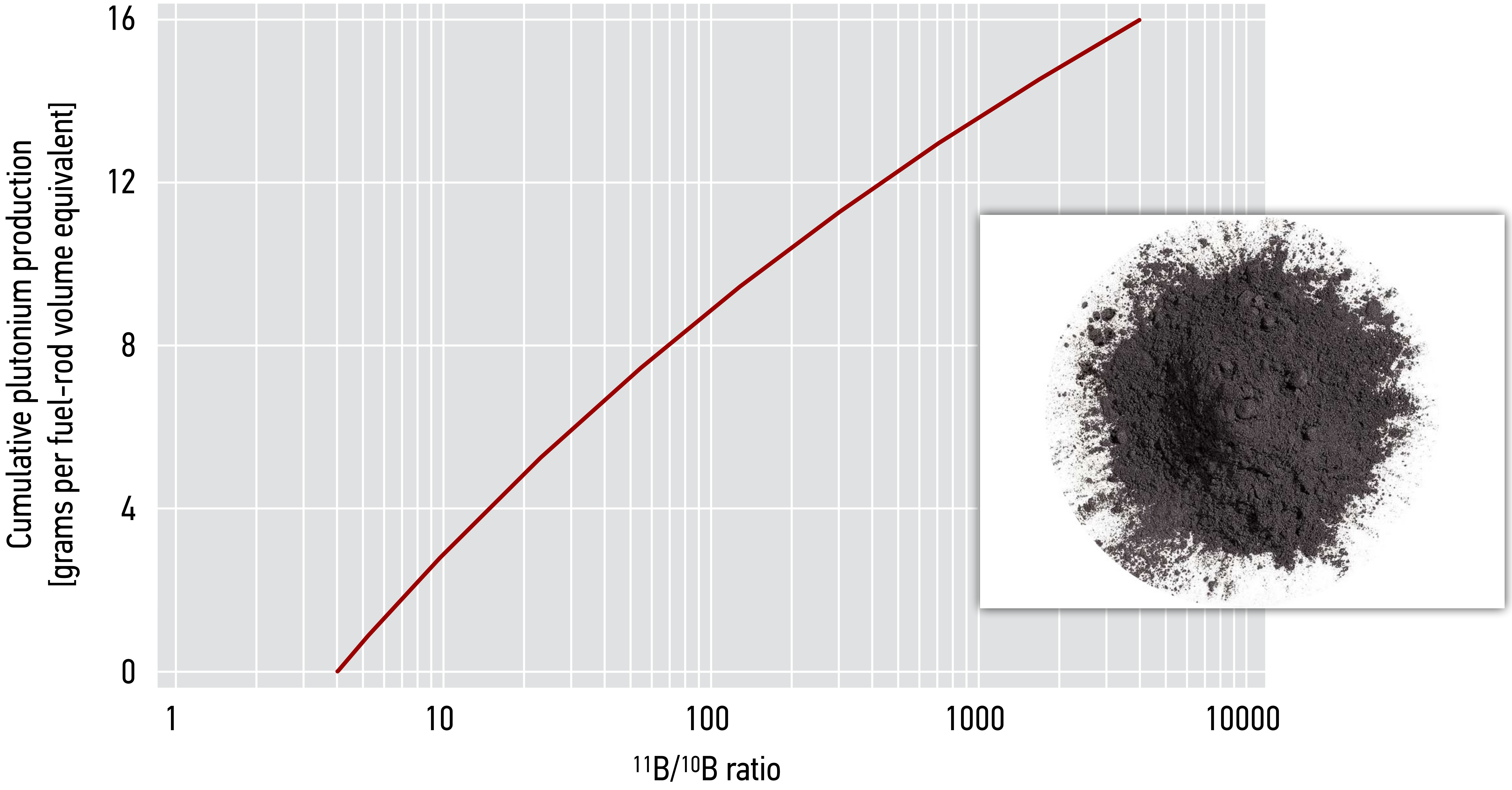
NUCLEAR ARCHAEOLOGY COULD BE USED TO VERIFY A NORTH KOREAN PLUTONIUM DECLARATION

Credit: CNN/Brian Rokus, 2008



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

DOCUMENT-BASED NUCLEAR ARCHAEOLOGY

(A first case study)

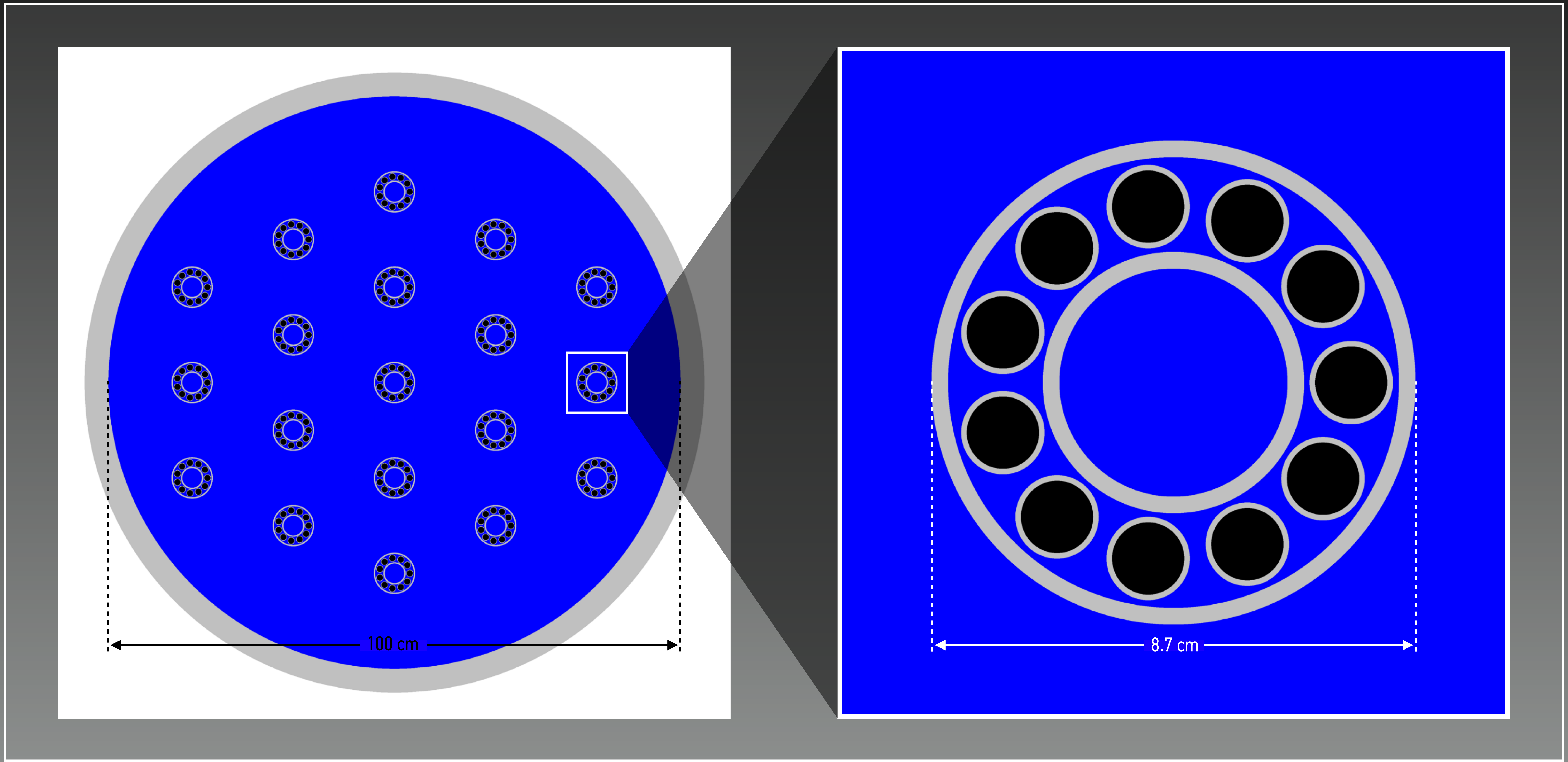
Indiana Jones: Raiders of the Lost Ark
Paramount Pictures, 1981

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

OPENMC/ONIX MODEL OF JEEP II

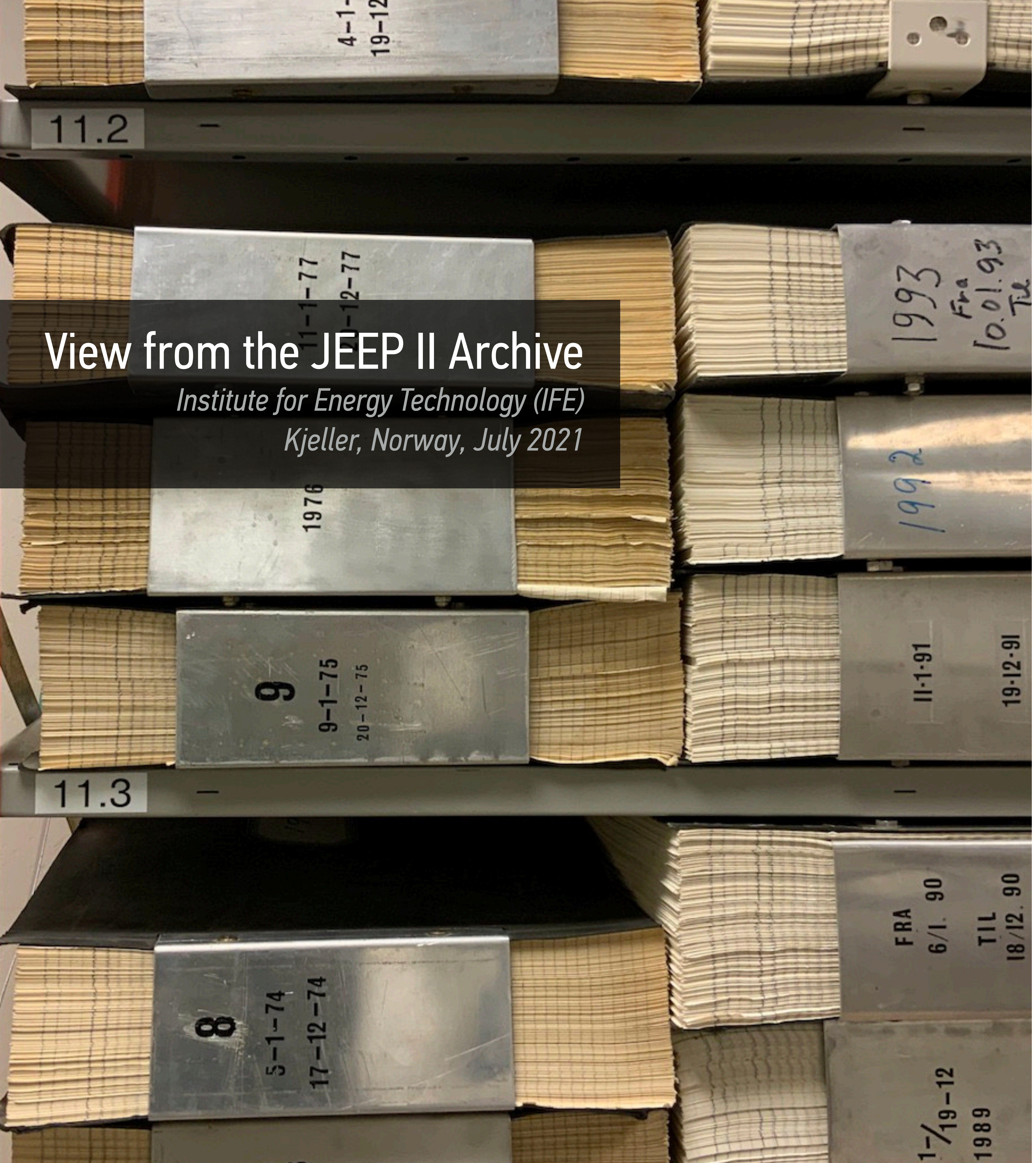


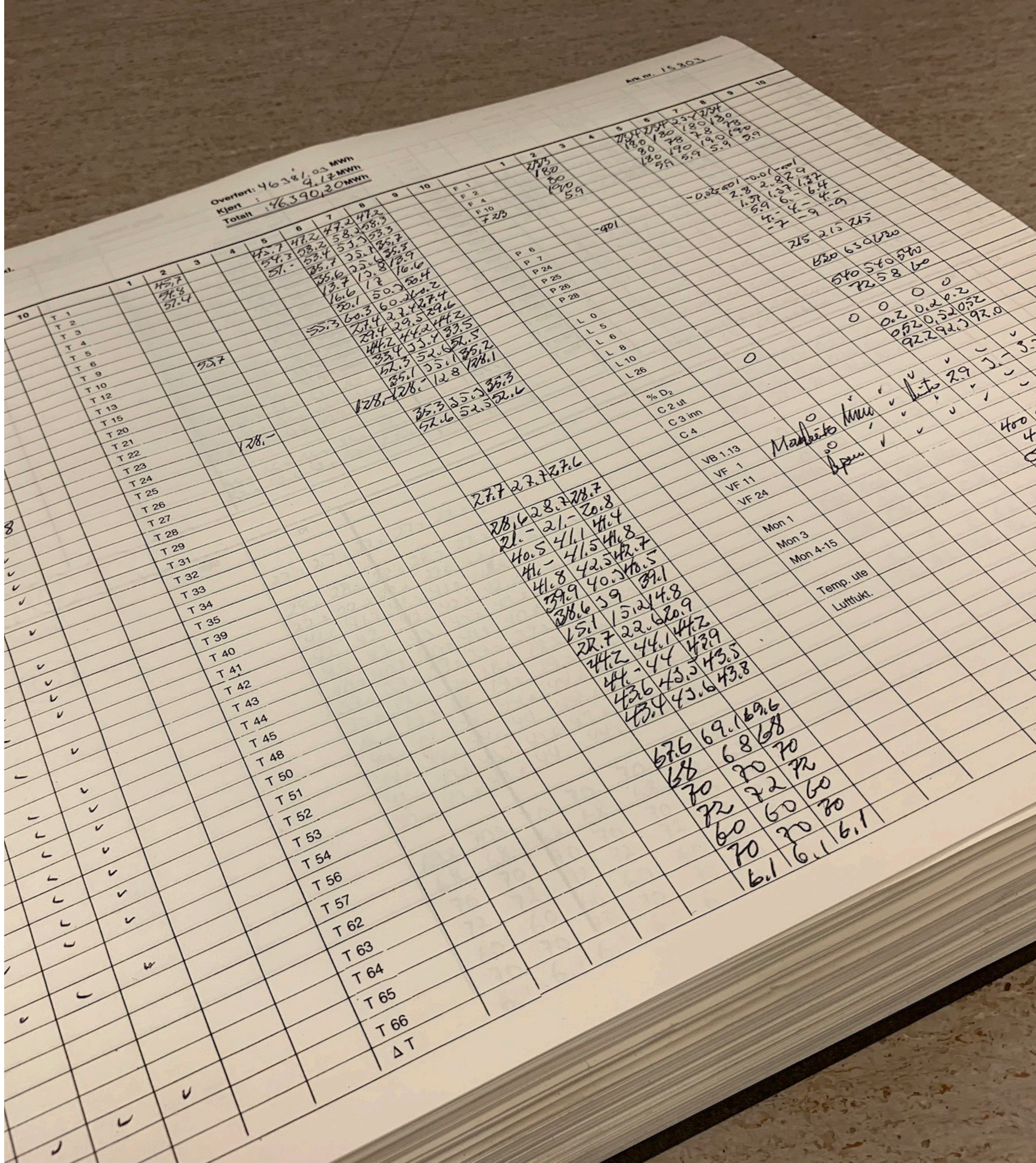
Paul K. Romano et al., “OpenMC: A State-of-the-Art Monte Carlo Code for Research and Development,” *Annals of Nuclear Energy,* 82, 2015
Julien de Troullioud de Lanversin, Moritz Kütt, and Alexander Glaser, “ONIX: An Open-source Depletion Code,” *Annals of Nuclear Energy,* 151, 2021

View from the JEEP II Archive

Institute for Energy Technology (IFE)

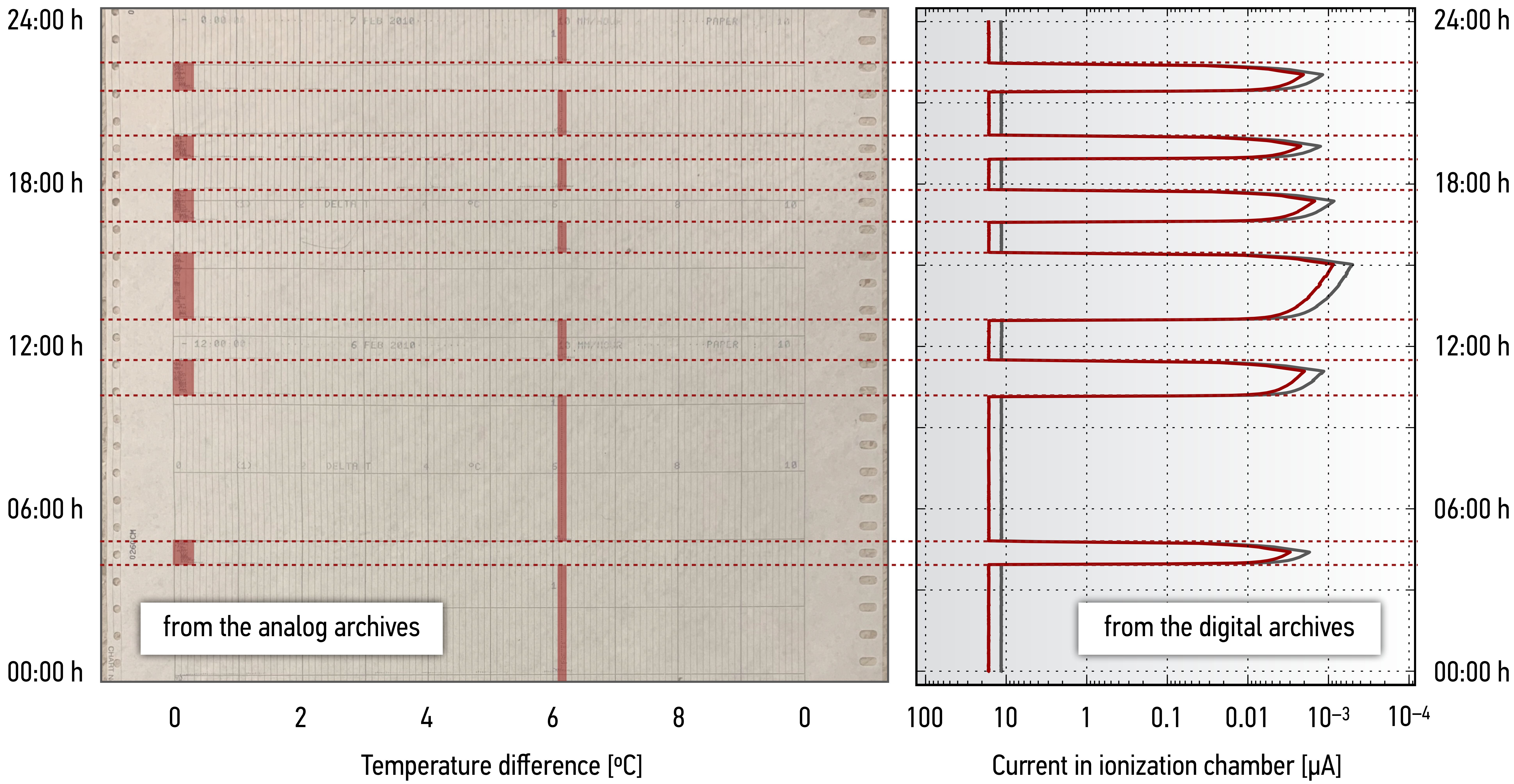
Kjeller, Norway, July 2021





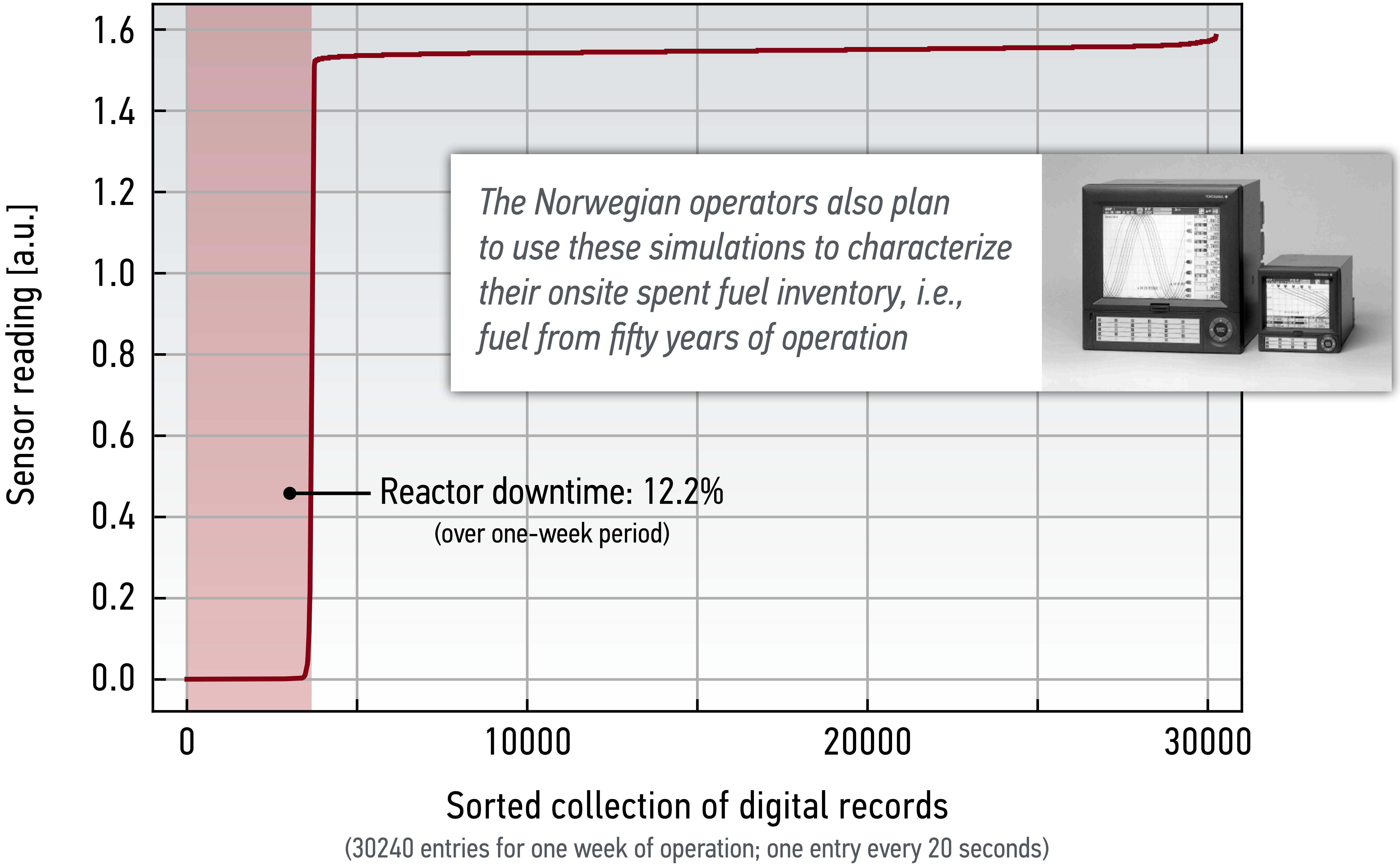
RECONCILING ANALOG AND DIGITAL RECORDS

SATURDAY, FEBRUARY 6, 2010



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

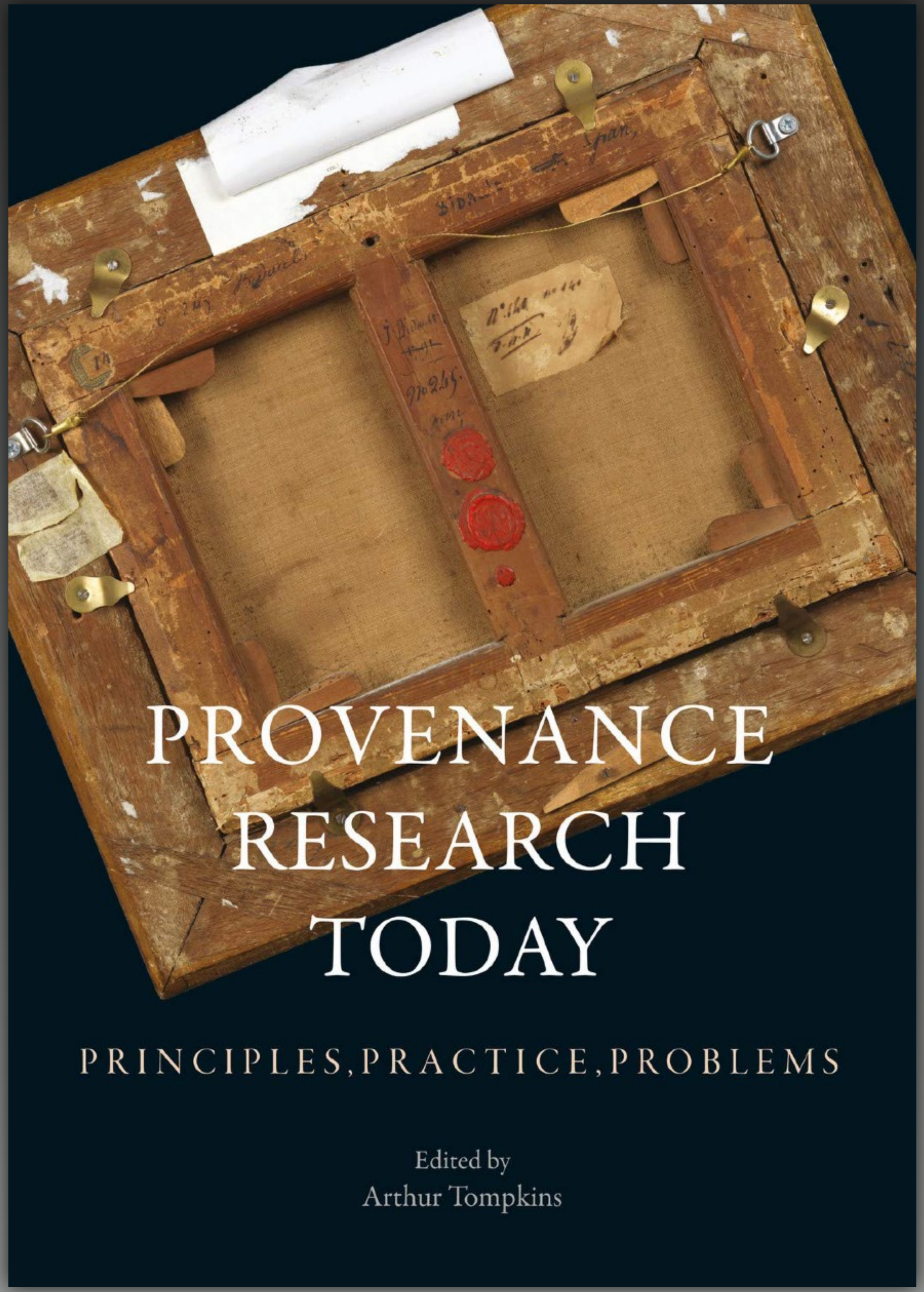
Ågesta Reactor, Sweden

NRX, Canada

G2/G3, France

A MULTIDISCIPLINARY EFFORT

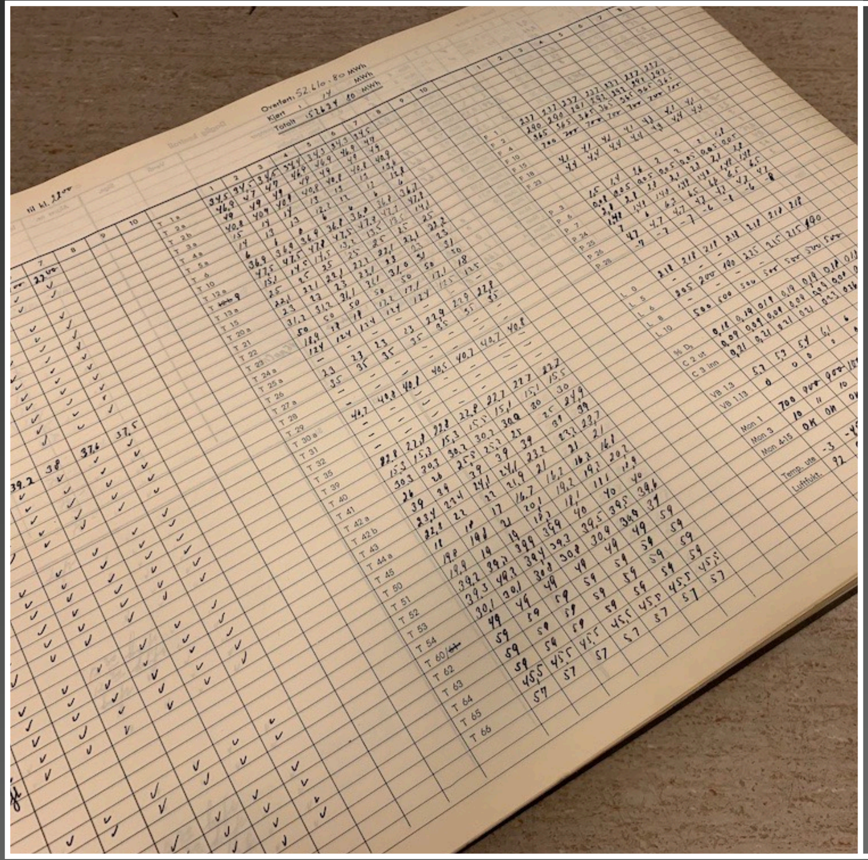
HOW TO CURATE AND PRESERVE ANALOG & DIGITAL DATA
HOW TO CONFIRM INTEGRITY, AUTHENTICITY, AND PROVENANCE OF RECORDS



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

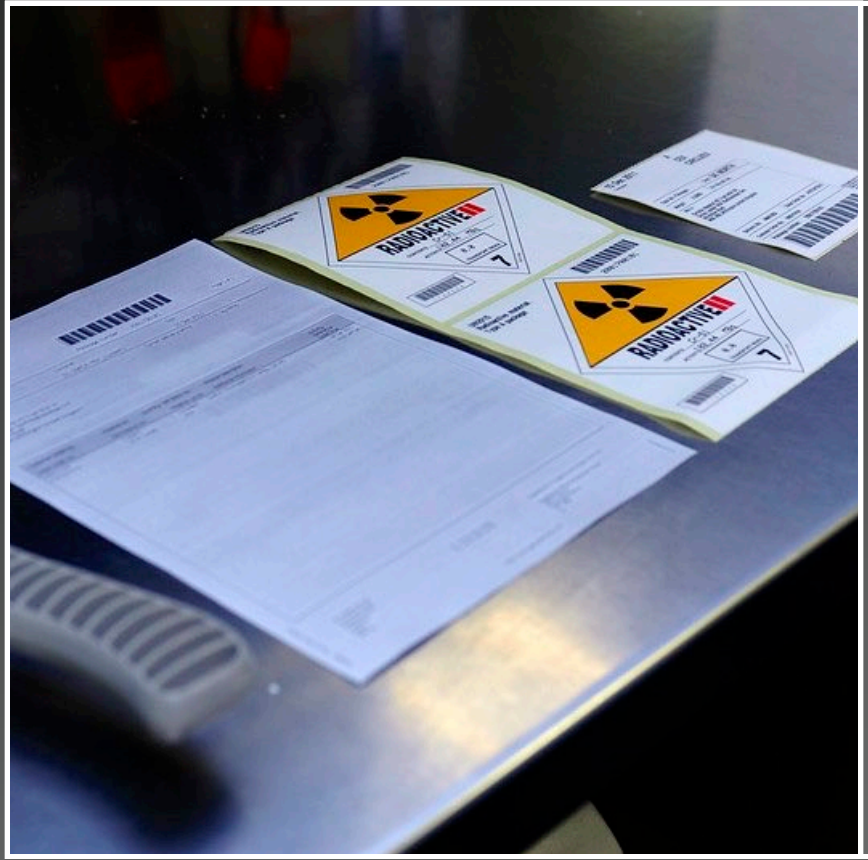
Digital records are more difficult to maintain than their analog counterparts

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

Ole Reistad, Rebecca D. Frank, Alex Glaser, and Sindre H. Kaald, Document-based Nuclear Archaeology, *Science & Global Security,* 30 (2), 2022

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)

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