Safeguards by design:

Preparing for small modular reactors

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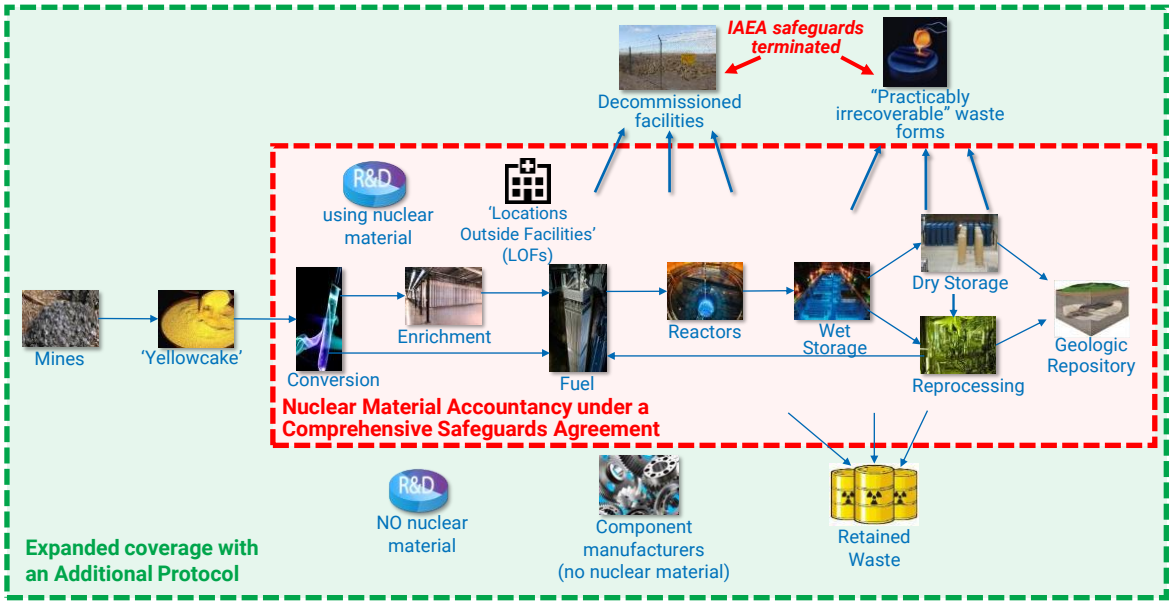
State obligation

Under the Nuclear Non-proliferation Treaty (NPT),
all nuclear material and activities in a non-nuclear weapons State
require IAEA verification of peaceful use

- No diversion of nuclear material
- No misuse of nuclear facilities
- No undeclared nuclear material or activities anywhere in the State

Safeguarding the nuclear fuel cycle (CSA)



The challenge:

Any new nuclear facility in a non-nuclear-weapon State (NNWS) will need to be safeguarded by the IAEA **when deployed**

☞ *regardless of size, complexity, accessibility, owner/operator or supplier*

Many vendors are unaware of the significance of this **end-user requirement**

☞ *lack of awareness of IAEA safeguards, or perception of not impacting design*

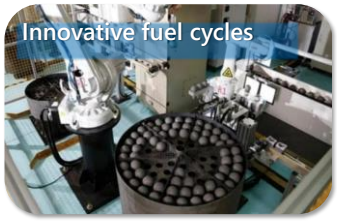
Advanced reactors **may require advanced safeguards** (requires R&D…+ ***time***)

☞ *new core/fuel designs, plant layouts, fuel management, fuel cycle facilities*

Enhanced security and 'inherent' proliferation resistance **do not necessarily mean simpler safeguards**

☞ *'safeguardability': often overlooked external component of PR*

We must be ready to safeguard these



New safeguards approaches and arrangements will be needed to support timely deployment of advanced reactors

How can design impact safeguards efficiency?

- Verification of Nuclear Material Accountancy
  - To verify State's **declaration of nuclear material** inventory and flow
- Containment and Surveillance
  - To maintain **continuity-of-knowledge** between inspections
- Design Information Verification
  - To verify State's **declared facility design** (from construction to decommissioning)
- Environmental Sampling, and Complementary Access
  - To assure **"completeness" of declaration** (absence of undeclared nuclear material or activities)

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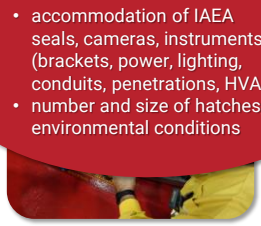
- physical access around facility
- fuel storage configuration
- complexity of fuel movement
- health & safety issues
- potential use of unattended equipment (or shared operator data),
- accommodation of IAEA monitoring (lighting, HVAC, power, security, etc.)

- physical access around facility,
- complexity of layout
- health & safety



- accommodation of IAEA seals, cameras, instruments (brackets, power, lighting, conduits, penetrations, HVAC)
- number and size of hatches, environmental conditions

Safeguards awareness: a new priority

SMRs, advanced reactors:

- **Novel technology and deployment models:** need for new safeguards approaches, measures and equipment

Back-end management:

- **Novel processes, large volumes:** preparation needed for safeguards measures and termination on waste

Safeguards challenges for SMRs

Advanced fuels and fuel cycles	• HALEU, pyroprocessing, Th/Pu MOX, …
Advanced reactor designs	• molten salt, fast reactors, pebble bed, …
Longer operation cycles	• continuity of knowledge between refuelling, high excess reactivity of core (target accommodation)
New supply arrangements	• factory sealed cores, transportable reactors, transnational DIV arrangements
New spent fuel management	• storage configurations, waste forms

(cont'd)

'Safeguards by design' (SBD)

- **Voluntary early engagement** of nuclear technology developers to enable more efficient and effective safeguards implementation
- Allows **integration of safeguards into the design process**
- **Applicable to all aspects of the nuclear fuel cycle**, from initial planning and design through construction, operation, waste management and decommissioning

Safeguards by Design: simply good engineering design practice

Safeguards challenges for SMRs (cont'd)

Small footprint	• access, design verification
Diverse operational roles	• district heating, desalination, hydrogen + electricity
Remote, distributed locations	• access issues, cost-benefit issues
Multiple-module plants	• continuity of knowledge, resource issues
Sheer number of designs!	• >80 in IAEA 2022 guide →
Lack of safeguards awareness	• In design community

Both IAEA and State safeguards capabilities must be ready

'Safeguards by design': not a new concept

Rokkasho Reprocessing Facility, Japan:

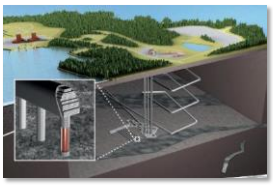
- Unattended process monitoring and sampling systems
- Joint-use equipment

CANDU PHWR reactors:

- Unattended fuel-transfer monitoring systems
- Dry storage sealing and reverification

Onkalo encapsulation plant and DGR, Finland:

- Unattended fuel-transfer monitoring systems and protocols
- Joint-use equipment



…Therefore: safeguards considerations for SMRs:

- **Unattended monitoring systems** and **remote data transmission**
- **Digital connectivity** for remote coverage (reliable, high bandwidth, secure)
- **Safeguards seals** on factory-sealed, transportable cores
- **Design verification**, particularly under transnational supply arrangements
- **New safeguards approaches**, including possibility for customized Agency or joint-use instrumentation (e.g., thermal power monitor for microreactors, process monitoring for MSRs)
- **State-level issues:** e.g., managing effective/efficient safeguards for a fleet of small, remote facilities
- **Training** for safeguards authorities in emerging nuclear energy States

New safeguards approaches need time to develop:
Safeguards by Design (SBD) will be critical

SBD: IAEA/vendor engagement

- 'SBD for SMRs' project under Member State Support Programme (MSSP)
- MSSP tasks: Russia, RoK, US, Canada, Finland, France, China, UK, Belgium, Sweden
- Technologies include FNPP, TNPP, integral PWR, MSR, PB-HTR, LFR
- Goal is to work with Member States to:
  - evaluate design aspects that impact safeguards
  - investigate safeguards implementation strategies
  - develop internal IAEA document to inform future safeguards development

Safeguards by Design: ***collaborative risk management***

SBD: IAEA guidance

www.iaea.org/topics/assistance-for-states/safeguards-by-design

Thank you!

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Dr. Jeremy Whitlock is a Senior Technical Advisor in the Department of Safeguards at the IAEA, with three decades' experience as a scientist and manager in the Canadian and international nuclear community. Prior to moving to the IAEA in 2017 he spent 22 years at Canadian Nuclear Laboratories as a reactor physicist and manager of non-proliferation R&D.

Dr. Whitlock received a B.Sc. in Physics from the University of Waterloo (1988), and an M.Eng. and PhD in Engineering Physics (reactor physics) from McMaster University (1995).

Dr. Whitlock is a Past President, Fellow, and former Communications Director of the Canadian Nuclear Society. Since 1997 he has maintained *The Canadian Nuclear FAQ* (www.nuclearfaq.ca), a personal website of frequently-asked questions (FAQs) on Canadian nuclear technology.

Dr. Whitlock lives in Vienna, Austria, and feels that canoes are the closest humans have come to inventing a perfect machine.

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