Safeguards and Security by Design
Support for the NGNP Project

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Outline

• Motivation for Safeguards (domestic and international) and Security by Design
• Elements of a Successful Design Project
• Next Generation Nuclear Plant Project Overview
• NGNP Fuel and Plant Concepts
• Regulations and Guidance – Why International Safeguards?
• Project Support for Safeguards-by-Design
• SBD Guidance, Safeguards Relevant Design Considerations
• Summary and Path Forward
Objective: Integrated, balanced design that optimally fulfills its mission while meeting all requirements.
A Modern Nuclear Facility Design Project

A Single, Integrated, Balanced Project

- **Safety**
- **Physical Protection**
- **MC&A**
- **International Safeguards**
- **Proliferation Barriers**
- **Balance of Project**

### ‘Safety-by-Design’
- **State Requirements**
  - State Requirements
  - State Requirements
  - International Requirements
  - No requirements to date

### All Other Req’s
- (I&C, Process, Facility Layout …)
Strong motivation to do it right from the beginning.

Correcting, or retrofitting, systems can be very costly

Committed Life Cycle Cost against Time
Design Toolkit includes:
- Methodologies for design
- Methodologies for assessing performance vs. requirements
- Best practices
- Design guidance
Recent Example of Safeguards and Security by Design

Open Pool Australian Light-water reactor (OPAL)
U. S. Next Generation Nuclear Plant Project
NGNP Project

- Generation IV plant to produce process heat and electricity
- Cost-shared project: U.S. DOE and private industry
- Three participating industry consortia, led by Westinghouse, General Atomics, Areva
NGNP Project Status

• Pre-conceptual design phase completed.
• Conceptual design phase (Phase 1) completed December 2010.
  - Included alternative assessments and some R&D
  - Only General Atomics *formally* participated in Phase 1
• Preliminary design (Phase 2) to start after:
  - Recommendation to proceed by U.S. Secretary of Energy
  - Formation of public/private partnership
• Final design and construction by industry
• Target operating date - 2021
Step 1: Early identification of requirements

- MC&A, security and International safeguards relevant requirements were incorporated into the NGNP “System Requirements Manual” (during the pre-conceptual design phase)
  - 10 CFR 73 – Physical Protection of Plants and Materials
  - 10 CFR 74 – Material Control and Accounting of Special Nuclear Material
  - 10 CFR 75 – Safeguards on Nuclear Material – Implementation of US/IAEA Agreement
  - U. S. NRC “Policy Statement on Regulation of Advanced Reactors” (2008)

- The “System Requirements Manual” is the overarching design requirements document used by industry design teams
U. S. NRC “Policy Statement on Regulation of Advanced Reactors” (2008)

“This final policy statement ... includes new items to be considered during the design of advanced reactors, including security ... threat of theft, and international safeguards.”

- “Designs that include considerations for safety and security requirements together in the design process ... facility design and engineered security features ... mitigation measures with reduced reliance on human actions.”
- “Designs with features to eliminate or reduce the potential theft of nuclear materials.”
- “Designs that emphasize passive barriers to potential theft of nuclear materials.”
Why Consider International Safeguards in the U.S. NGNP Project?

- NRC “Policy Statement on Regulation of Advanced Reactors”
- Follow-on plants may be exported to Non-Nuclear-Weapons-States
- NGNP may become selected by IAEA for application of international safeguards under the Voluntary Offer Safeguards Agreement between the United States and IAEA
• ~8 grams UO2 per pebble, ~8% enrichment (equilibrium cycle)
• ~452,000 pebbles in core (PBMR)
• ~107,000 pebbles for 1 Significant Quantity (75 kg U-235 as LEU)
Pebble Bed Modular Reactor Concept

- Pebble bed reactor core
- Graphite reflector
- Small absorber spheres shut-down system
- Control rods
- Reactor pressure vessel
- Fuel discharge system
- Hot gas duct
- Live-steam line
- Blower
- Steam generator pressure vessel
- Steam generator tube bundle
- Feedwater line
Prismatic Fuel Element

- 6252 fuel compacts per element
- Cemented graphite plugs seal the compacts into the fuel elements
- Fuel elements are uniquely identified
- ~125 prismatic blocks for 1 SQ of U-235
Core of Prismatic Fueled HTGR

Material Graphite
102 Fuel Columns
Hexagonal Fuel Block Dimensions:
   - Width Across Flats 0.36 m
   - Height 0.8 m
Number of Fuel Blocks:
   - Standard 720
   - Control 120
   - Reserve Shutdown 180
Number of Fuel Compacts 2919600
Mass 870 Tons
Safeguards-by-Design Guidance Reports

• Purpose – To provide design stakeholders with ...
  - Insights regarding IAEA safeguards objectives, approaches and best practices
  - Design features of potential safeguards importance
  - Starting basis for early discussions with IAEA
• MC&A guidance report was also produced (U.S. DOE NE ...)
• Meeting with Phase 1 industry participants

Sponsored by NNSA Next Generation Safeguards Initiative (NGSI)
The safeguards guidance reports cover:

- Safeguards Objectives for a High Temperature Gas Reactor (HTGR)
- Fundamental Safeguards Measures
- Providing Design Information to the IAEA
- Defining Nuclear Material Balance Areas (MBAs) and Key Measurement Points (KMPs)
- Preparing Subsidiary Arrangements (Facility Attachments)
- Verification of Nuclear Material and Inventory
- Nuclear Material Verification Practices
- Material Balance Evaluation
- Design Information Examination and Verification (DIE/DIV)
- Confirming the Absence of Facility Misuse and Undeclared Fissile Material Production
- Nuclear Material Accounting and Operating Records
- State Reports for the IAEA
- Verification Under the Additional Protocol
- Advanced Concepts
Guidance example: MBA’s and KMP’s for a PBMR
Accountancy Considerations

Prismatic Fueled HTGR:
- 1 element is a uniquely identifiable item
- Accountancy: Expect accountancy approach for LWR’s to apply (item counting)

Pebble Fueled HTGR:
- Pebbles are small, not uniquely identifiable
- Accountancy: Propose mixed approach
  - Item where possible (e.g. sealed canisters)
  - Bulk elsewhere
Westinghouse PBMR Fuel Handling System

- Item accounting
- Pebble movements counted, recorded
- Bulk accounting
Example Safeguards and Design Challenges for the Prismatic Fueled HTGR

- Verification of spent fuel
  - Cerenkov technique not applicable
  - Multiple stacking of fuel elements (8 to 10 high)
    - In-core and spent fuel interim storage
    - Long term dry storage?
    - Inaccessible dry storage?

- Re-examination and verification of design information (DIE/DIV)
  - Spent fuel storage area
  - Misuse, undeclared spent fuel
Example Safeguards and Design Challenges for the Pebble-Fueled HTGR

- Fuel flow monitoring
  - Distinguish moderator, fresh, damaged and used pebbles
- Model the reactor physics to indirectly verify nuclear material in the core? (Modeling has been proposed to detect facility misuse for illicit production)
- Re-verification of inventory in bulk locations if IAEA dual containment/surveillance measures fail.
  - Pre-installed ‘guide tubes’ for IAEA ‘level’ probes?
- DIE/DIV of fuel locations and handling system (core, damaged fuel, used fuel, moderator pebbles…) which may become highly radioactive and inaccessible.
Summary and path forward

- The U.S. Next Generation Nuclear Plant project will be a Generation IV HTGR plant for production of process heat and electricity.

- NGNP project has progressed through pre-conceptual and conceptual design stages. Preliminary design phase has not yet begun.

- NGSI sponsored support has been provided to facilitate early design consideration of international safeguards – early introduction of requirements, preparation of safeguards and SBD guidance reports, consultation with Phase 1 (conceptual) design team.

- Support is also being provided for MC&A and security (in progress)

- Future possibilities, to be discussed and mutually agreed:
  - Stakeholder workshops on international safeguards, MC&A, physical protection and ICS-cyber security.
  - Stakeholders: Reactor designers, architect-engineers, operators, U.S. NRC, IAEA