International Safeguards, Security, and Regulatory Aspects of U.S. Light Water Small Modular Reactors

National Nuclear Security Administration

Office of Nonproliferation and International Security (NIS)

- **Safeguard and Secure** nuclear material to prevent its diversion, theft and sabotage.
- **Control** the spread of WMD-related material, equipment, technology and expertise.
- Negotiate, monitor and **verify** compliance with international nonproliferation and arms control treaties and agreements.
- Develop and implement DOE/NNSA nonproliferation and arms control **policy** to reduce the risk of weapons of mass destruction.

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May 2014

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President Obama and Small Modular Reactors

"And with rising oil prices and a warming climate, nuclear energy will only become more important. That's why, in the United States we've restarted our nuclear industry as part of a comprehensive strategy to develop every energy source. We supported the first new nuclear power plant in three decades. **We're investing in innovative technologies so we can build the next generation of safe, clean nuclear power plants**."

Hankuk Univ., March 26, 2012

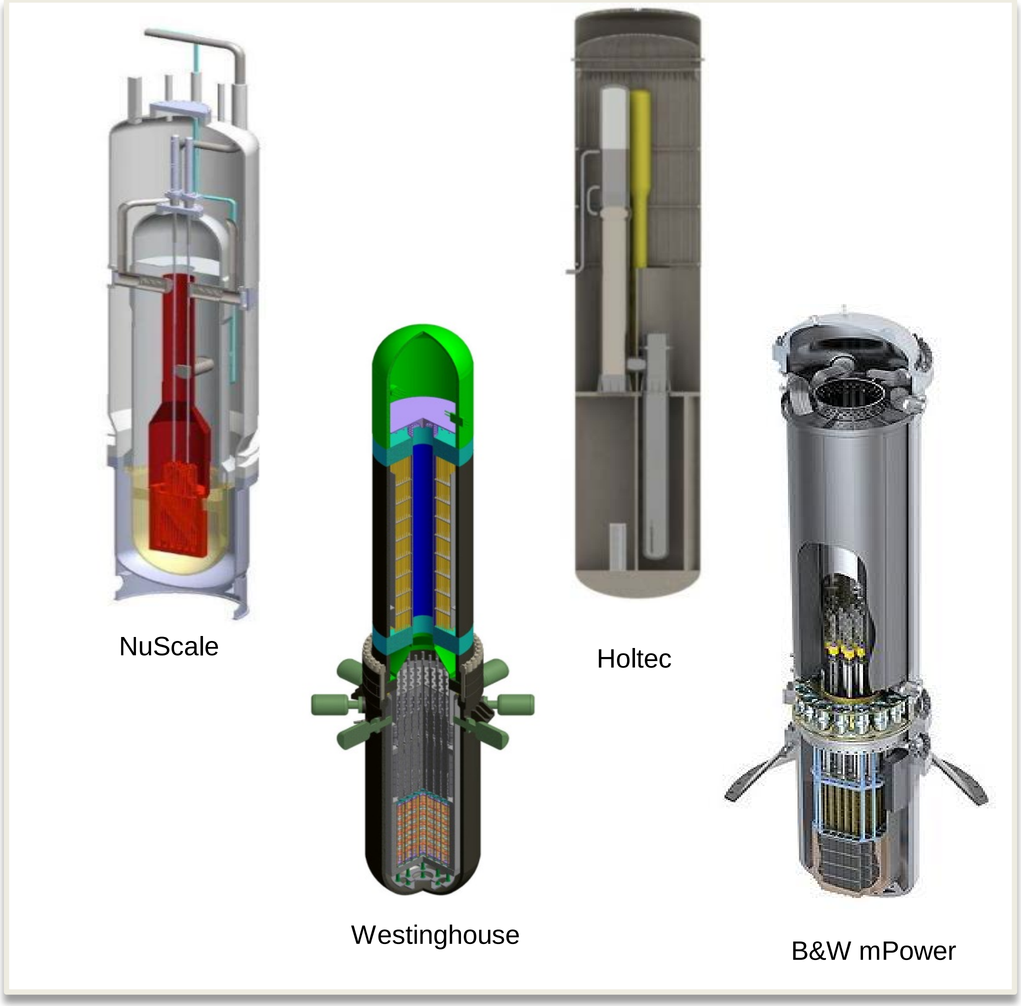
"We can build the next-generation nuclear reactors that are **smaller** and safer, cleaner and cheaper."

Ohio State Univ., March 22, 2012

U.S. Light Water-Based SMR Designs

- Well-Understood Technology
  - Uranium oxide fuels
  - Applicable regulatory and operating experience
  - Safety features that build on GEN III+ reactors
  - Licensing horizon 5-10 years

- NuScale and mPower selected by DOE for support



DOE/NNSA Study of US LW SMRs

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- A look at the security (physical protection), international safeguards, and regulatory aspects of the US LW SMRs
- Challenges: the 4 designs are at various stages of development and still evolving; proprietary and security information involved
- Identified 10 technical features that can be found in US designs
  - below-grade siting, redundant safety equipment separation, factory fabrication, multi-modularity, small source term, ultimate heat sink, passive safety, fuel type, fuel cycle management, integrated primary components
- In addition, looked at 4 characteristics of SMR deployment
  - host state infrastructure, host state international commitments, reactor mission, reactor location

Not all identified technical features or deployment characteristics are assessed to have implications for both physical protection and international safeguards

Technical Features (1)

1. **Below-grade siting** refers to the below ground level placement of most or all elements of the nuclear steam supply system (i.e., reactor core, steam generators, pressurizers, etc.), the spent fuel pool (SFP), and other safety systems.
   - Physical Protection: Generally makes the reactor more secure against intruders, but may impede security response in a barricading scenario; easier to protect against plane impacts and stand-off weapons; would provide an extra barrier to the dispersion of radioactive material in the event of a successful attack
   - IAEA Safeguards: No clear advantages or disadvantages

Technical Features (2)

2. **Redundant safety equipment separation** refers to the physical isolation of secondary mechanical elements related to reactor safety.
   - Physical Protection: May offer security advantages by complicating attack planning, requiring multiple synchronized or sequential actions using coordinated attack teams, and likely lowering the chance an attack succeeds
   - IAEA Safeguards: No clear advantages or disadvantages
3. **Factory fabrication** refers to the possibility that reactor modules or systems may be constructed in a manufacturer’s facility and then delivered to the operation site as a complete unit
   - Physical Protection: No clear advantages or disadvantages
   - IAEA Safeguards: May create a need for partial DIV at factory

Technical Features (3)

4. **Multi-modularity** refers to the integration of multiple reactor "modules" into larger power production systems.
   - Physical Protection: Has the potential to complicate planning and increase physical protection requirements and cost
   - IAEA Safeguards: Tracking nuclear material at multi-modular sites could be more complicated; potentially more frequent inspector visits and greater costs
5. **Small source term** refers to the amount of potentially vulnerable fissile or radioactive material.
   - Physical Protection: May reduce the consequences of a successful sabotage attack
   - IAEA Safeguards: No clear advantages or disadvantages

Technical Features (4)

6. **Ultimate heat sink** (UHS) refers to the system of structures and components and associated assured water supply and atmospheric condition(s) credited for functioning as a heat sink to absorb reactor decay heat and essential station heat loads after a normal reactor shutdown or a shutdown following a design-basis accident or transient.
   - Physical Protection: Lower power capacity and compact size of SMRs can permit smaller UHS requirements and novel approaches that reduce the potential for loss of the UHS
   - IAEA Safeguards: No clear advantages or disadvantages

Technical Features (5)

7. **Passive safety** refers to safety features that rely on natural phenomena (e.g., gravity, natural circulation, and direct heat transfer from the containment vessel to the environment) that function without intervention from an operator or reliance on external power.
   - Physical Protection: Greater use of passive safety features, including natural circulation, offers advantages in specific sabotage scenarios and eliminates some potential security targets
   - IAEA Safeguards: No clear advantages or disadvantages

Technical Features (6)

8. **Fuel type** refers to the chemical form, enrichment level, and geometry of the reactor fuel.
   - Physical Protection: No clear advantages or disadvantages
   - IAEA Safeguards: Standard fuel designs allow use of standard verification approaches; double-stacking of spent fuel could pose challenges
9. **Fuel cycle management** refers to the loading of fresh fuel, refueling frequency, the portion of the core replaced during refueling (up to the entire core), capacity for fuel shuffling, nominal outage duration, and movement of used fuel to the SFP.
   - Physical Protection: No clear advantages or disadvantages
   - IAEA Safeguards: Longer refueling cycles could reduce verification activities but increase dependence on containment and surveillance for core verification

Technical Features (7)

10. **Integrated primary components** refers to the integration of the elements of the nuclear steam supply system (reactor core, steam generator, pressurizer, etc.) within a single pressure vessel.
    - Physical Protection: Elimination of most large coolant pipes and reduction in the number of vessel penetrations makes the reactor easier to protect
    - IAEA Safeguards: Confined spaces and difficulty with sealing the vessel may complicate verification activities

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Takeaways

- Reviewed the IAEA's "Milestones in the Development of a National Infrastructure for Nuclear Power" document
  - No identified differences in how a country would need to develop its national infrastructure for LW SMR deployment versus a large reactor (i.e., no steps that could be skipped)
- IAEA should be able to effectively safeguard LW SMRs, they may just be more resource intensive on a per MW basis (or even a per site basis)
- Several technical features provide advantages against subnational threats
- Overall, features indicate only small safeguards and physical protection differences relative to deployment of conventional LWRs
- There are uncertainties to this assessment, as LW SMR designs are still evolving