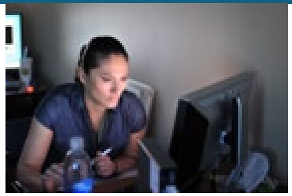
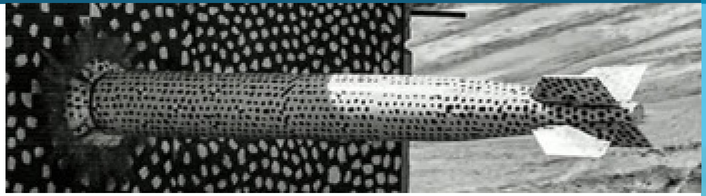
DOE ARS – SMR Security by Design and Analysis





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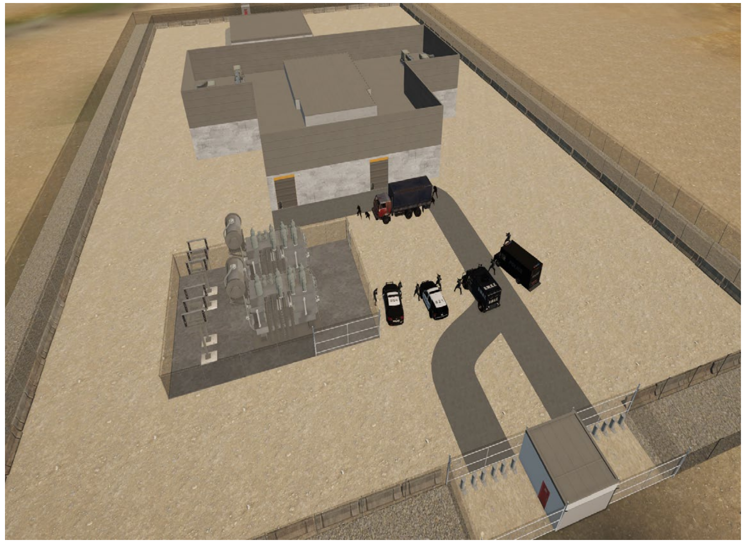
Motivation

- Reduction of cost for Small Modular Reactor (SMR) deployment and operations
- Increase security measures inherent to SMR facility designs
- Security systems designs based on limited or no onsite response
- Understand the regulatory changes for SMR facilities
- Develop security strategies for various SMR types (iPWR, PBR, Microreactor)



Introduction

- Hypothetical integral Pressurized Water Reactor (iPWR) facility was designed
- Design incorporated safety, security, and operations
- Design focused on developing a security system and facility design that created adequate detection and delay to allow for an offsite response force
  - Incorporated understanding of site safety and operations
- The hypothetical facility was designed with a denial strategy in place
- Offsite response force teams were considered
  - 30-Minute Response Time
  - 60-Minute Response Time
  - 2 Manned Hardened Fighting Positions

Security Regulation Changes for SMRs

- "Alternative Physical Security Requirements for Advanced Reactors," A Proposed Rule by the Nuclear Regulatory Commission, Docket No. NRC-2017-0227
- Keep the requirements of 73.55 to protect against sabotage but set out additional guidance in 73.55(s) for advanced reactors which can establish a performance-based approach
  - Relieved of 73.55(k)(5)(ii) **minimum number of armed responders**
  - Relieved of 73.55(e)(9)(v) and 73.55(i)(4)(iii) requiring that the **secondary alarm station, including if offsite, be designated and protected as a vital area**
  - Sites must still have two onsite alarm stations per 73.55(i)(2), but a designated secondary alarm station may be offsite. It is not required to be a vital area, nor is its associated secondary power supply required to be.
- One of the most significant NRC comments is the allowance for the use of local law enforcement rather than licensee security personnel to interdict and neutralize the DBT
- Nuclear Energy Institute developing guidance to demonstrate an applicant meets eligibility criteria : NEI 20-05, "Methodological Approach and Considerations for a Technical Analysis to Demonstrate Compliance with the Performance Criteria of 10 CFR 73.55(a)(7)"

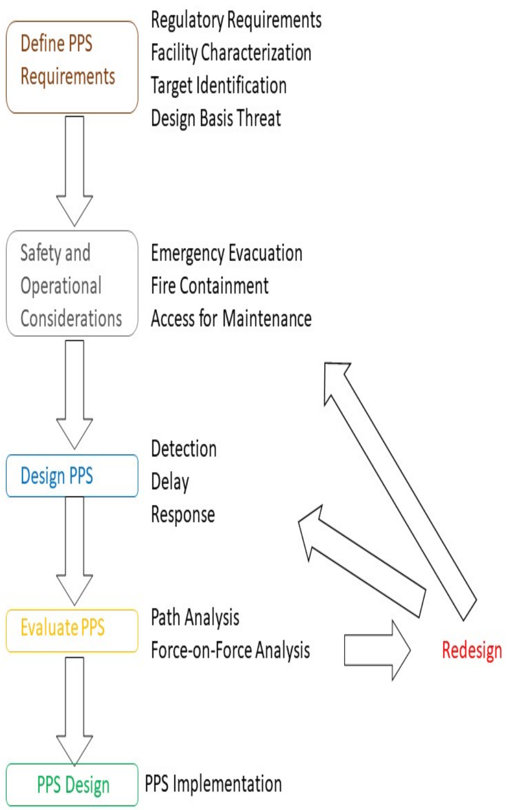
Security Regulation Changes for SMRs (Cont.)

- The NRC is proposing to amend security requirements based on three **eligibility criteria** specified in a new 73.55(a)(7). If any individual criterion is met the revised requirements the licensee would be **eligible** to able to follow the performance-based alternative approach in 73.55(s): (The following are paraphrased. Please see NRC-2017-0227-0023 for entire language)

  - Dose limits in 10 CFR 50.34 and 52.79 are not met after a radiological event involving loss of engineered safety features and physical structures.
    - i.e., there are no target sets which would result in exceeding dose limits
  - The DBT cannot compromise plant features necessary to mitigate an event, which prevents the release from reaching values in the CFR sections.
    - i.e., the DBT is not capable of compromising a target set which would result in exceeding limits
  - The reactor and facility includes inherent safety features which would maintain the dose below consequences above if a target set is successfully sabotaged.
    - i.e., mitigation measures prevent the sabotage of the target set from exceeding dose limits

SMR Security-by-Design

- Security-by-Design utilizes many factors to increase design performance and cost-effectiveness of facility designs and physical protection systems
- SBD utilizes the following methods:
  - Implementing security into the design phase of the SMR facility
  - Facility designs that increase the effectiveness of the physical protection system
    - Minimize entry points (where allowable)
    - Minimize access points to target locations
    - Utilize building materials to increase delay time
    - Identify locations where active delay features can be used to multiply adversary task time
  - SBD allows the facility to:
    - Decrease long-term facility costs
    - Increase resiliency to adversary attacks



Development of a Domestic SMR

- Review of U.S.-based SMR designs in advanced design and licensing stages
- Collection of characteristics
- Integral PWR design
- Internals include two once-through steam generators and 10 coolant pumps
- 4.9%-enriched LEU
- Below-grade containment and spent fuel pool
- Four units per plant
- Passive Residual Decay Heat Removal System (PRDHRS)
- 72 hours of cooling after power loss

Sabotage Targets

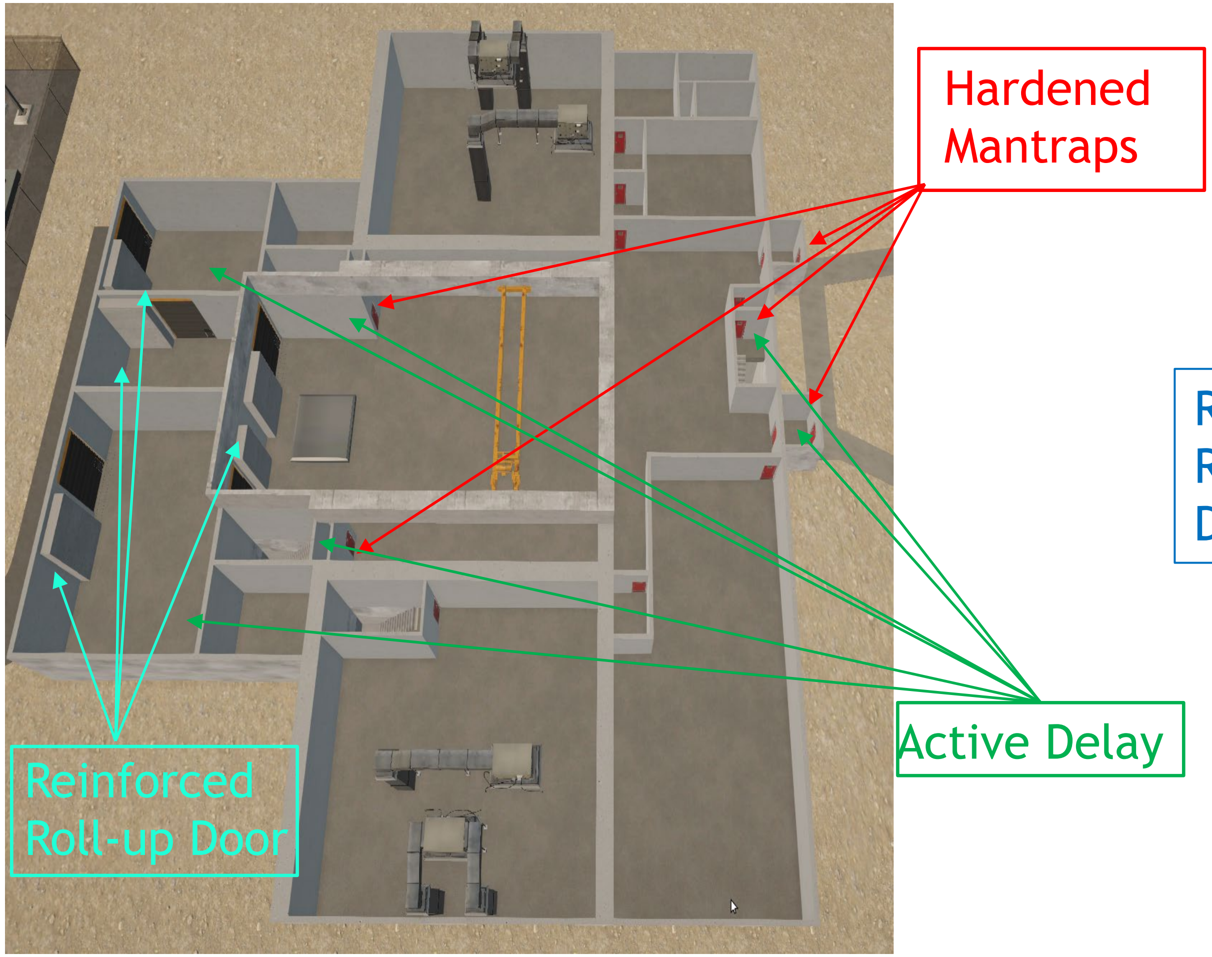
Location	Form of Material	Amount of Material On-site (wt% enrichment)	Total Isotope Amounts	Level of Radiation
Reactor Core	UO_2 pellets in rods	13,478 kg U (4.9% U-235)	660 kg U-235	High
Spent Fuel Pool	UO_2 pellets in rods	53,192 kg U (4.9% U-235)	2,606 kg U-235	High

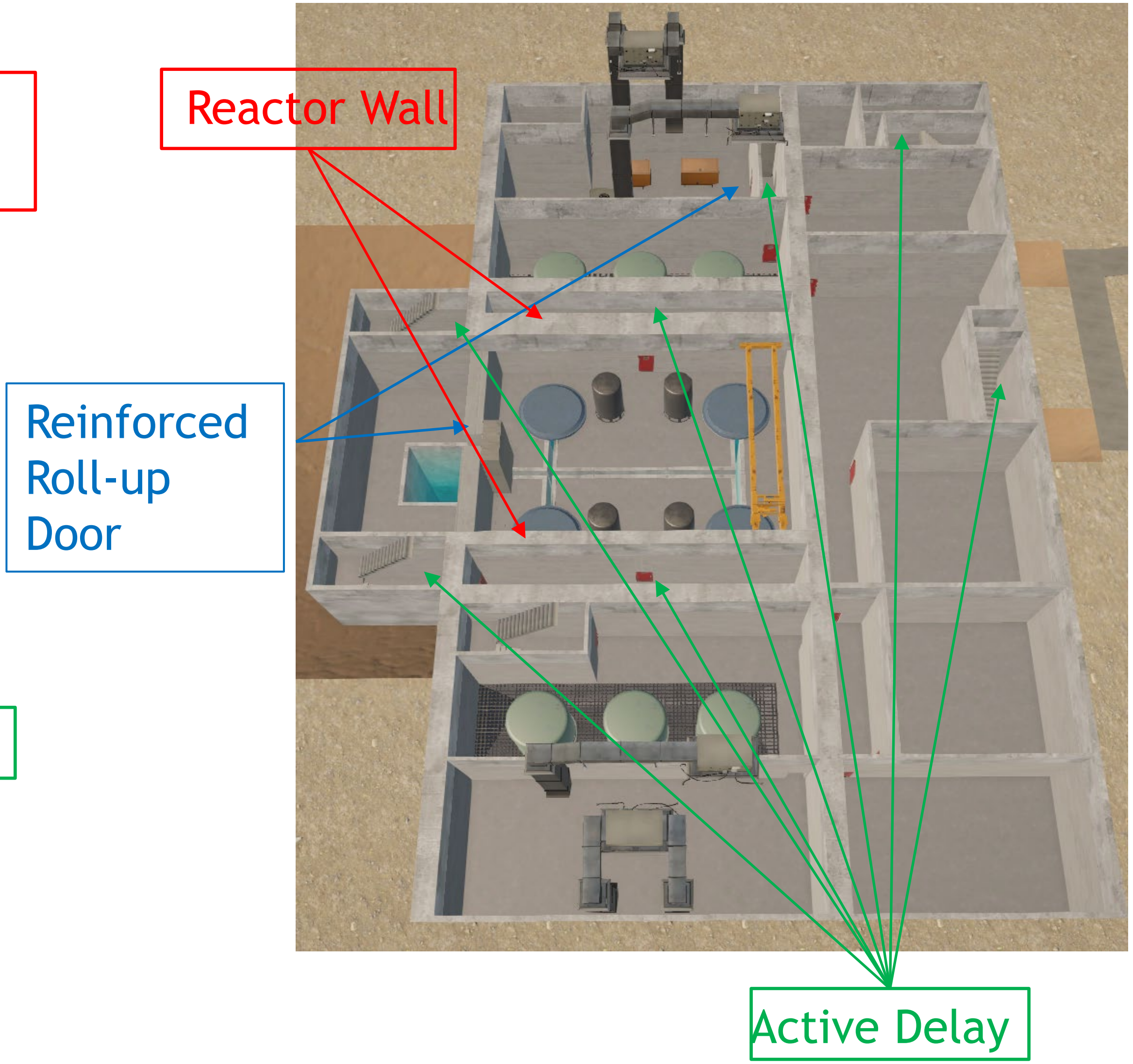
Direct Sabotage Targets

Location	Safety Purpose
Battery Bank/Diesel Generator Rooms	Provide backup power to the site
Passive Safety Injection Tank	Provide cooling water to the reactor core

Indirect Sabotage Targets

Small Modular Reactor Facility Design





Scenario Video

PPS Path Analysis Results

Target	Task Time (s)	Probability of Detection (%)	Probability of Interruption (%)	Response Time (s)
Reactor	5513	99	99	1800
Spent Fuel Pool	5032	99	99	1800
Battery Bank	2567	99	100	1800
Control Room	3043	99	99	1800
Reactor PSIT	4307	99	99	1800
CAS	3037	99	99	1800

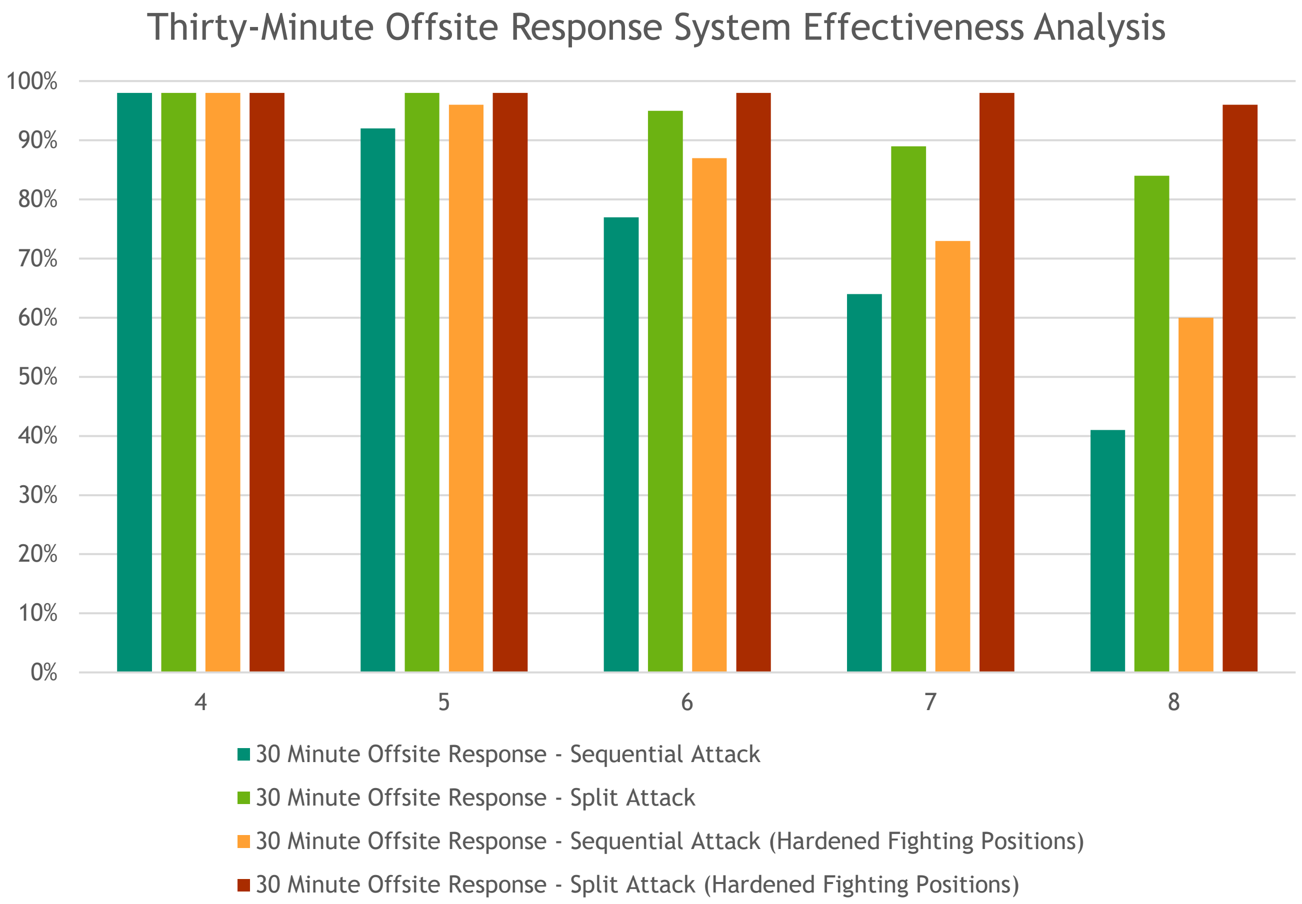
Response Force Integration

- An offsite response force was considered at this site
  - Consisted of 8 members
  - SWAT-like response team
  - Response time of 30 minutes
  - Response time of 60 minutes
- An offsite response force with an augmented onsite response force
  - 6 offsite members, 2 onsite members
  - SWAT-like response team
  - 2 onsite members in hardened fighting positions
  - Response time of 30 minutes
  - Response time of 60 minutes

Sabotage Scenarios

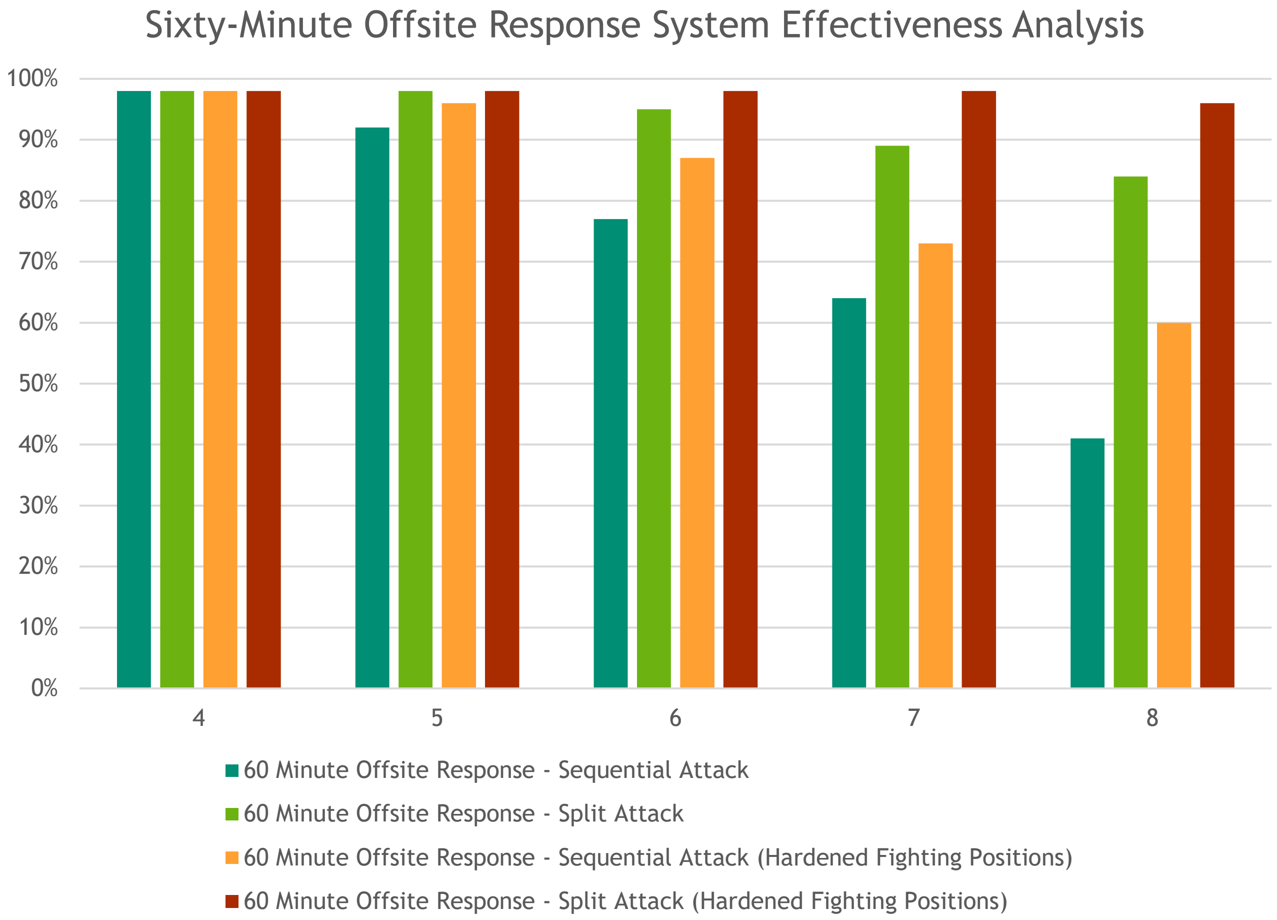
- The force-on-force simulations and probability of neutralization analysis were based on two different scenarios
- Split Attack
  - Adversary team splits into two teams to conduct and complete sabotage at the facility
  - Adversary team must successfully sabotage the switchyard, passive safety injection tanks, battery bank and diesel generators, and reactor containment
- Sequential Attack
  - Adversary team attacks the facility in one group to conduct and complete sabotage at the facility
  - Adversary team must successfully sabotage the switchyard, passive safety injection tanks, battery bank and diesel generators, and reactor containment

30-Minute Response Force Results



- Use of augmented onsite response force increases system effectiveness
- System effectiveness is greater for split attack scenarios than sequential attack scenarios

60-Minute Response Force Results



- Results show higher system effectiveness for 60-minute response force
  - Increased number of engagements
  - Higher response force-to-adversary ratios in engagements
- Increased system effectiveness against split attack as compared to sequential attack
- Augmented onsite response force in hardened fighting positions increases system effectiveness

Conclusions

- Facility Design Conclusions
  - Decrease access points into the facility
  - Design facility with multiple material types to increase delay
  - Decrease amount of door entrances and access control points
  - Consider facility siting and construction to allow for extended detection
  - Increased safety system redundancy

- Physical Protection System Conclusions
  - Increase extended and early detection
  - Active delay systems
    - Vehicle barriers
    - Obscurants
  - Understanding of potential adversary attack scenarios
    - Split vs Sequential
  - Offsite Response Force
    - Ability to recover the site
    - Design of hardened fighting positions

Future Work

Additional Small Modular Reactor and Advanced Reactor Studies

- Pebble Bed Reactor
  - Advanced physical protection system design
  - Varying response force strategies
  - Remote backup alarm station and control room
- Microreactor
  - Remote deployment
  - Increased response force time
  - Remote central alarm station and control room

Integration and Interface with Safety

- Link sabotage timelines with system accident timelines
- Can an SMR plant be recovered after sabotage occurs?

Full report and analysis on iPWR is available upon request.