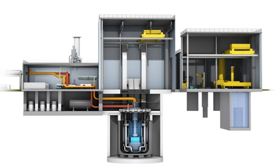
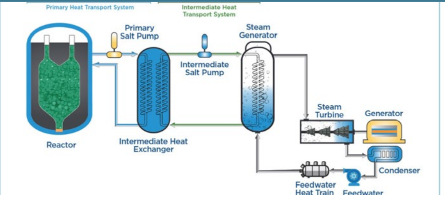
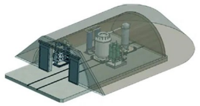
Unique Sabotage Targets for Advanced Reactors







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ADVANCED REACTOR SAFEGUARDS

Stakeholder Workshop, April 2021

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Motivation

As part of a complete physical protection analysis, it is important to understand unique sabotage targets for advanced reactors.

Advanced reactors may contain unique coolants, moderators, fuels, and decay heat cooling systems which are not applicable to the current LWR fleet.

We are working with related security and risk projects to analyze and prioritize targets.

New simulation tools will be built for advanced reactor sabotage consequence analysis.

Outsider Attacks

Given infinite time, tools, and resources, one can hypothesize many potential sabotage targets that are dangerous.

Security analysis constrains the time and what the saboteur can carry.

- Targets that take too long to attack are low priority.
- Targets that require the saboteur to carry heavy weights are low priority.

Insider Attacks

Even for an insider, the PPS can eliminate many targets.

Active monitoring of the reactor by the PPS can detect someone being in the wrong location or spending too much time in an acceptable location.

Monitoring gates and doors will detect an insider trying to carry tools or materials needed for sabotage.

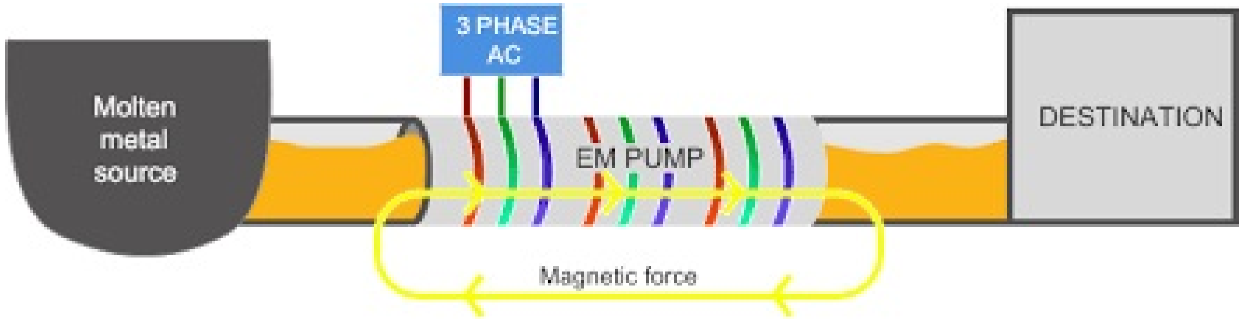
- This lowers priority on targets that require tools or supplies not needed to operate the reactor.

Passive Safety

Passive safety systems greatly improve the reliability and safety of nuclear reactors.

The lack of moving parts and human intervention provides for very low failure rate; however, passive safety systems can be exploited (for example by reversing the magnetic field on an MHD pump) by an insider with knowledge of the reactor operation.

Even when passive safety systems cannot be reversed, they can be slowed down or stopped resulting in damage to the reactor.



J.R. Davis, G.E. Deegan, J.D. Leman, and W.H. Perry, "Operating Experience with Sodium Pumps at EBR-II," Technical Report ANL/EBR-027, Argonne National Laboratory, October 1970.

Integration with Risk

If the reactor shuts down and the decay heat is removed before significant damage is done to the reactor, then the consequences are minimal.

Preventing the reactor from shutting down requires either a large unexpected reactivity insertion or preventing the security grade safety systems from performing.

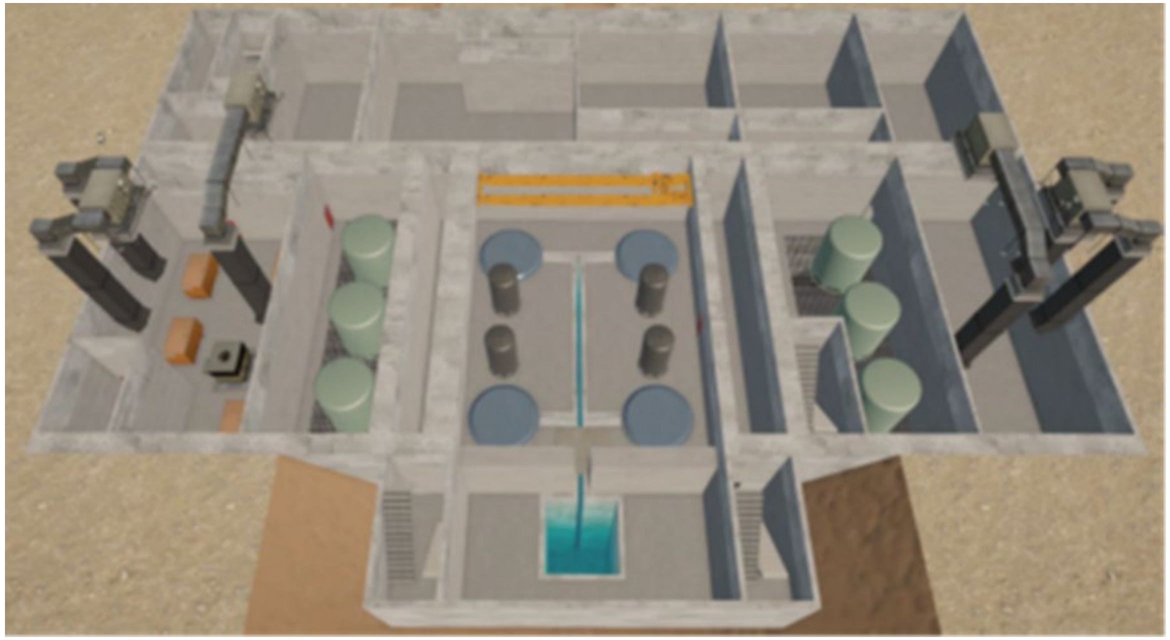
Since all advanced reactors are designed to safely remove the decay heat, the saboteur needs to either disable or slow down the decay heat removal system to damage the reactor.

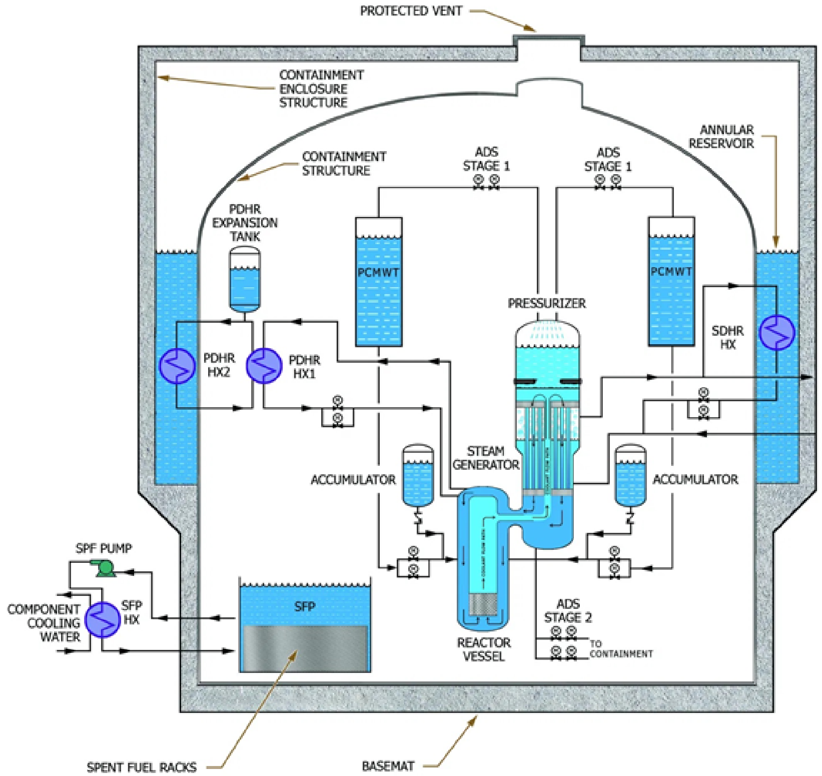
It is this race between the passive system and the saboteur’s damage that is the key to consequence analysis.

There are new physics that impact transients in advanced reactors that do not have any counterpart in LWRs. Modeling and simulation will be required for viable targets.

Combining Security and Safety and Risk

Different ways of looking at a nuclear reactor





Security

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Safety and Risk

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"RELAP5/Mod3.3 Code Manual Volume V: User's Guidelines,"
Technical Report, Information Systems Laboratories, Inc.
Rockville, Maryland, 2001

Attacks on heat removal systems

Oxygen ingress in a HTGR con initiate a graphite fire.

Heat flow can be reversed in a heat pipe.

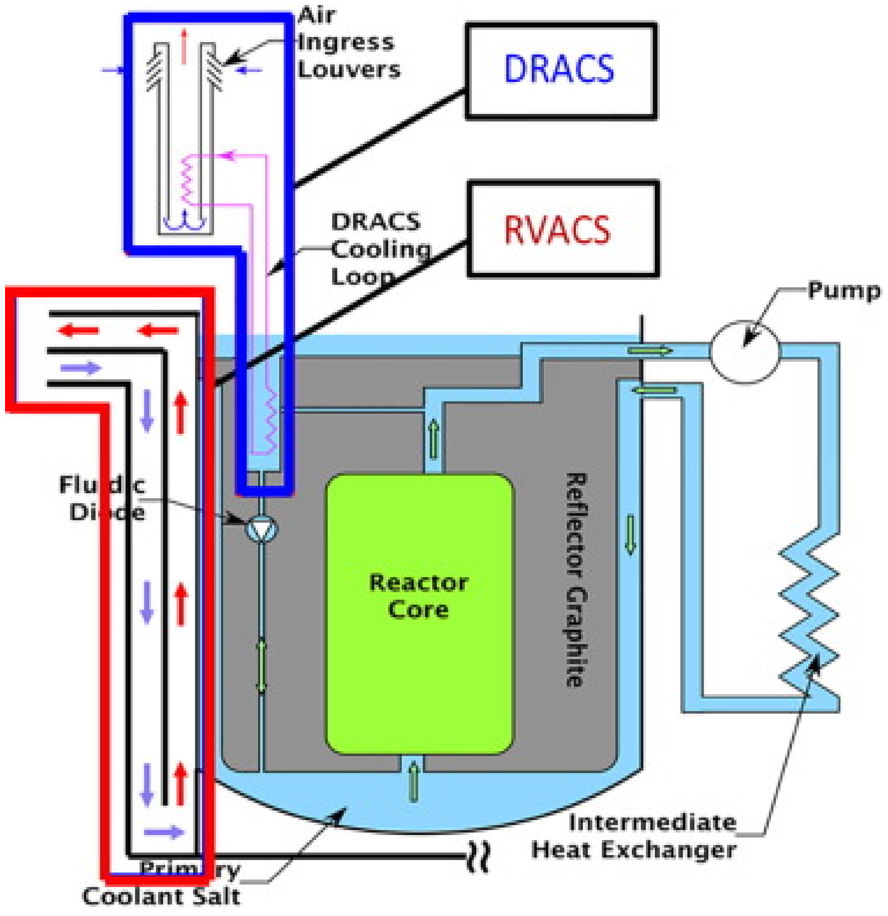
Magnetohydrodynamic pumps can be reversed.

Natural circulation can short circuit (exclude the heat sink).

Direct Reactor Auxiliary Cooling System (DRACS) can freeze.

Molten salt drain plugs can be made bigger (slowing down shutdown).

Thermal radiation systems can be slowed down with dust, steam, or smoke.



Zohuri, Bahman. (2019).
Direct Reactor Auxiliary Cooling System.
DOI 10.1007/978-3-030-05882-1_7.

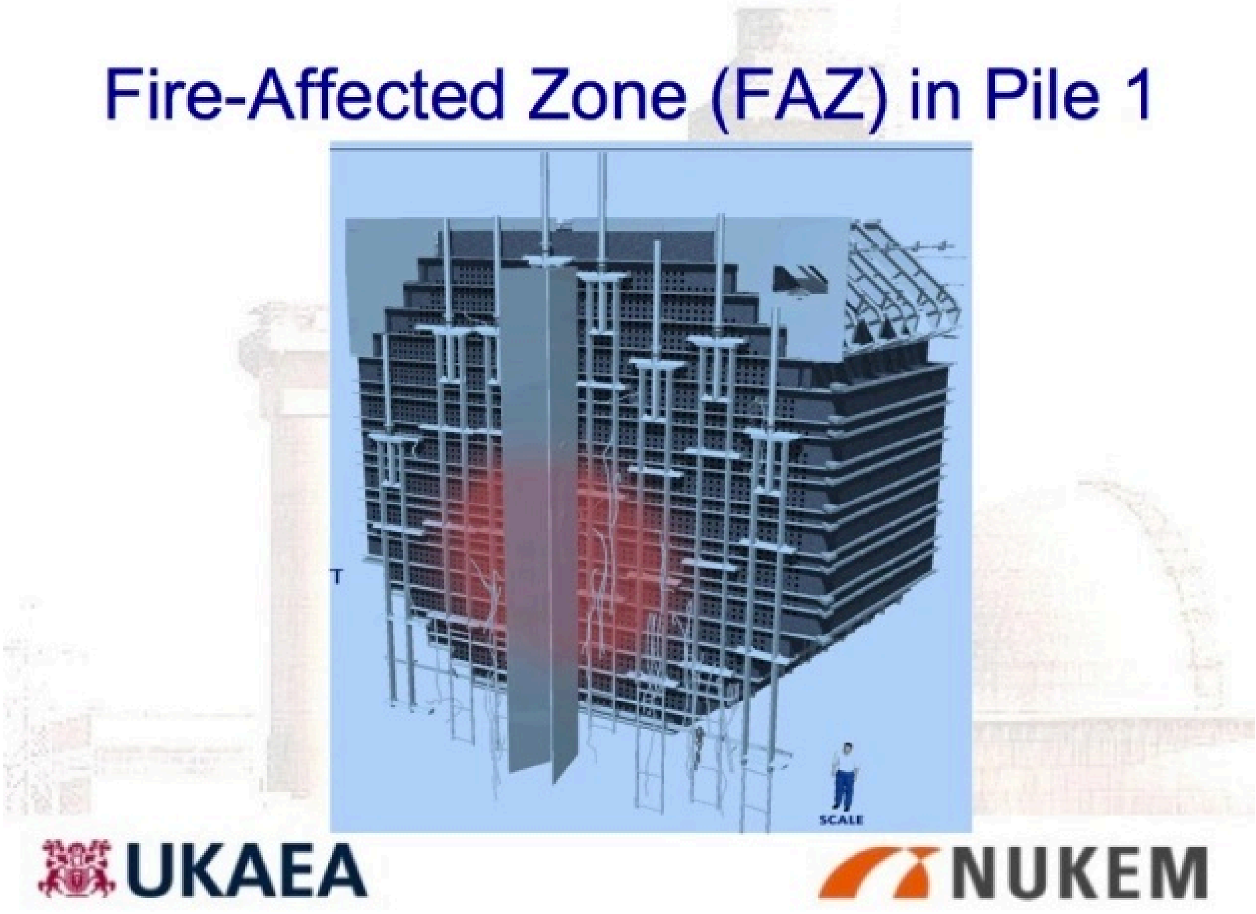
Attacks on coolants and moderators

Graphite burns and graphite dust explodes

Sodium burns, boils (positive void coefficient), and freezes

Low heat capacity of helium creates very long transient times (no way to respond quickly)

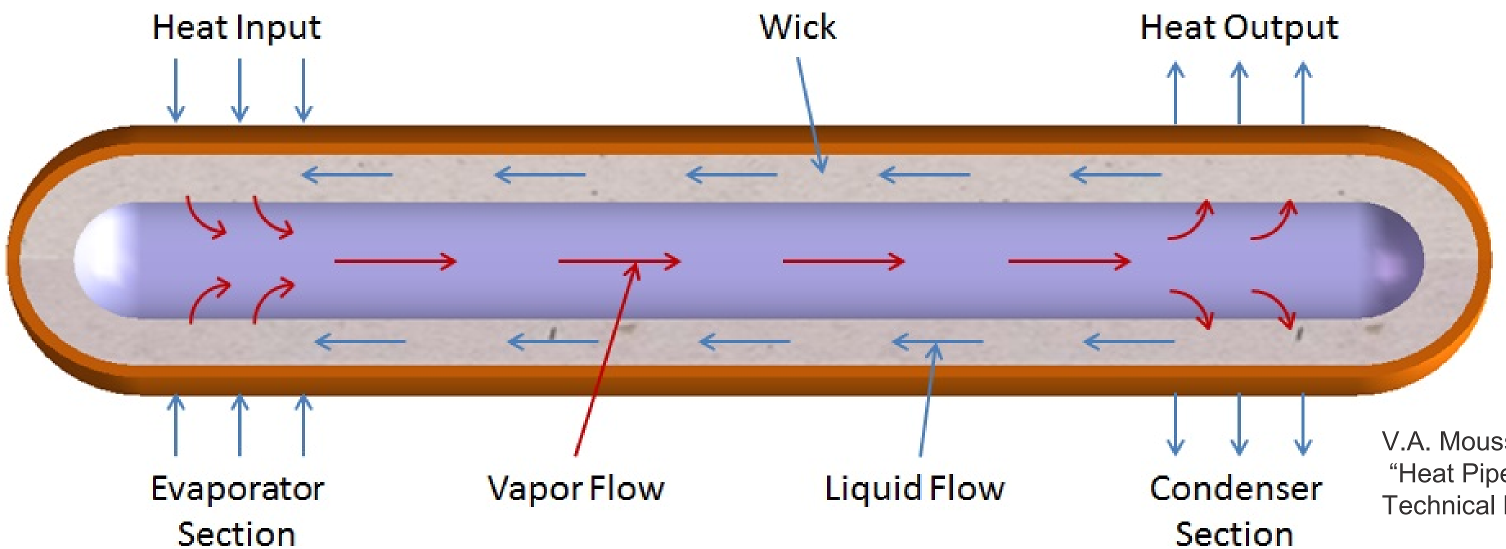
Molten salt freezes, liquid fueled molten salt has decay heat and fission products throughout the primary system



W. Penney, B.F.J. Schonland, J.M. Kay, J. Diamond, and D.E.H. Peirson, "Report on the accident at Windscale No 1 Pile on 10 October 1957," Journal of Radiological Protection, Vol. 38, pages 780-796, 2017.

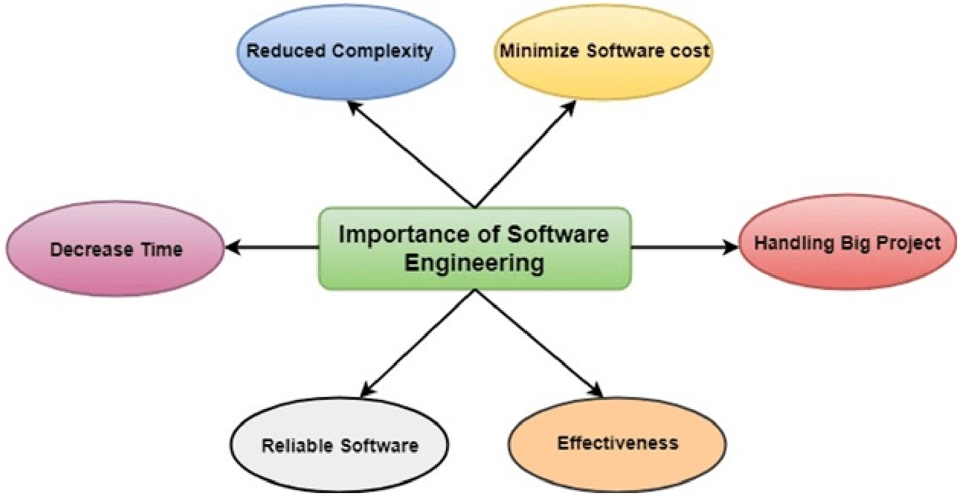
Current Work

- Initial work has outlined unique sabotage scenarios that are being considered for a variety of advanced reactor classes.
- Current work is down-selecting these scenarios based on feasibility with some preference given to more near-term designs.
- Currently developing transient heat pipe model and simulation software.



V.A. Mousseau, G.A. Mortenson, and V.H. Ransom, "Heat Pipe Model for ATHENA," Technical Report EGG-CATT 7864, INL, 1987.

Sabotage Consequence Simulation Software



Modern Software Engineering

The solution method is physics agnostic

Models are very general equations

Equations are defined through specified interfaces using a declarative framework.

Build Simulation by "stacking" model equations into a matrix

Quickly get new software that is well documented and ready for testing

Future Work

Work with related ARS security projects to eliminate targets that cannot be addressed before responders arrive.

Work with related ARS risk projects to eliminate targets with minimal consequences.

Work with related ARS projects to define software requirements for consequence modeling.

Write new consequence software for use by risk analysis.

Conclusions

The goal of this work is to identify and analyze sabotage targets for the different advanced reactor classes.

The targets will be prioritized based on feasibility and consequence.

Ultimately this work will feed into force-on-force modeling to help ensure that PPS designs are robust to varying threats.