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# Safety and Licensing Considerations for Micro-Reactors

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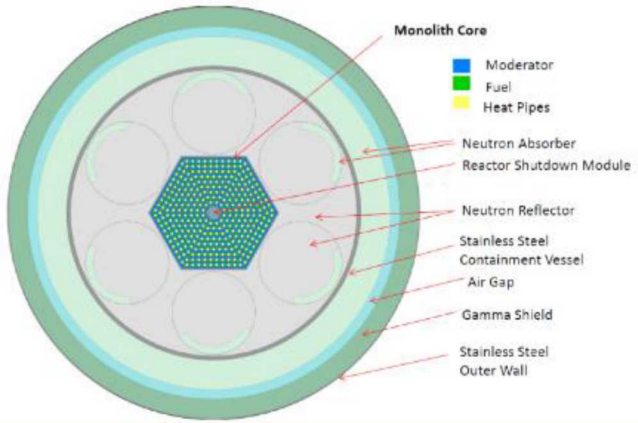
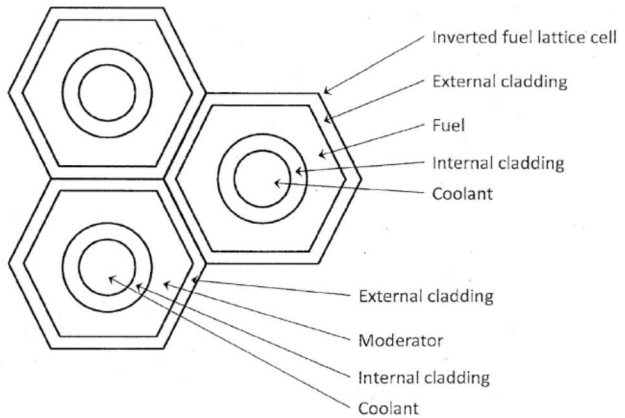
# Micro-Reactors




## Monolith Concept

- Epithermal to thermal neutron spectrum
- 2k fuel elements, 1k heat pipes

## Assembly Concept

- Fast neutron spectrum
- 700 heat pipe/fuel element assemblies

**All concepts focus on achieving high levels of safety using passive SSCs**

A. Levinsky et. al., “Westinghouse eVinci Reactor for Off-Grid Markets”, ANS, 2018.
J. DeWitte and J. Richard, “Passive Inherent Reactivity Coefficient Control in Nuclear Reactors”, USPTO, US20170249999A1, 2017.

# What could go wrong?
## Managing Micro-Reactor Risk

- Transient overpower
  - One or multiple control drum banks
- Multiple heat pipe failure
  - Core side
  - Secondary side
- Air cooling blockage
  - Failure to establish natural circulation

**Internal events that can lead to fission product release to environment**

**How do external events challenge safety functions?**

**Risk profile for micro-reactors likely dominated by external events**
**How does risk management evolve?**

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# Safety-in-Design

## Safety Functions

- Reactivity control
  - eVinci has “Emergency Shutdown Subsystem”
    - Passive with no mechanical moving parts but includes moving working fluids
    - Not the control drums
- Heat removal via conduction to canister and natural convection through air ducts
- Containment via canister
  - Containment (confinement) may be necessary to meet LMP frequency-consequence target for some accident scenarios

## Defense-in-Depth

- How much of the plant capability to withstand events depends on heat pipes?
  - Versus conduction through other materials (e.g., reflector and shield)
- How much do operators matter for event prevention/mitigation?
  - eVinci PRA includes one action: control drum trip
- What common cause failures may be relevant?
  - Manufacturing defects for ~1k heat pipes, ~1k fuel elements
    - Importance of ITAAC
  - Secondary side missile affecting multiple heat pipes
  - Extreme weather impacting regular and decay heat rejection
  - Seismic event upsetting monolith structure and heat transfer pathways

Westinghouse eVinci Micro-Reactor LMP Demonstration, ML19227A322, 2019

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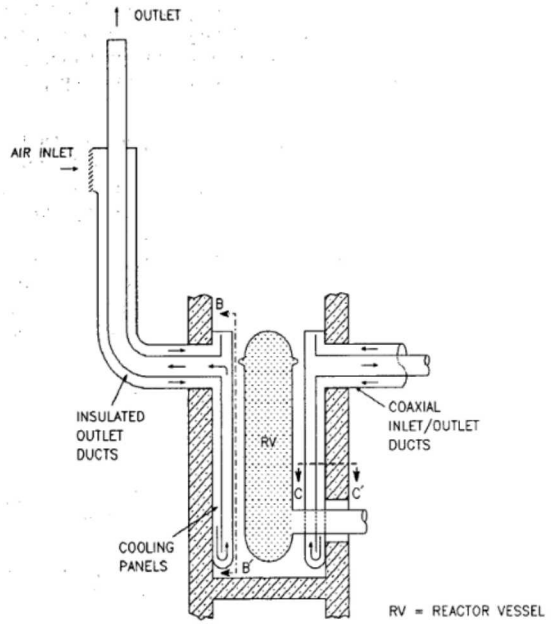
# Micro-Reactors Looking-Forward

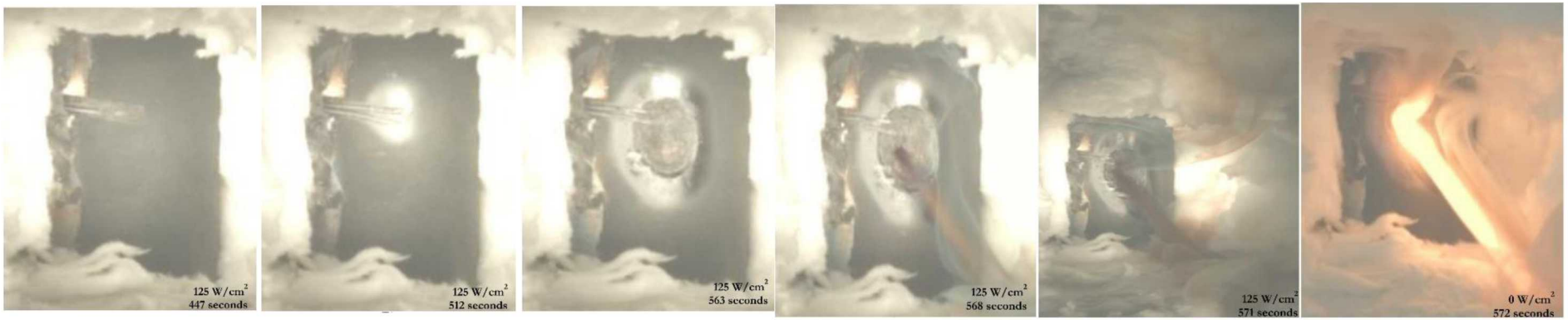
## Challenges

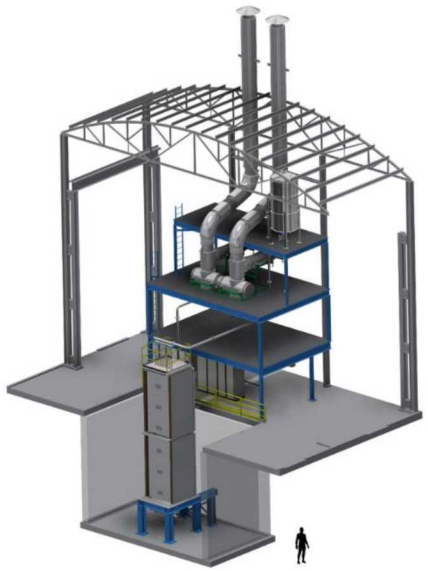
- Relatively small body of evidence
  - Heat pipe behavior in high temperature + radiation environment
    - Many separate effects known
    - Potential for cascading failure?
  - Natural circulation vessel cooling systems
    - Variable environmental and configuration effects
    - Validation of CFD models

## Benefits

- Small and simple designs
  - Few components to qualify and inspect
  - Smaller inventory, smaller exclusion area?
  - Smaller capital/financing decision
    - Cost-competitive with diesel?
- Current political support
  - DOE willingness to provide fuel, siting for demonstrations
  - Bipartisan support for advanced nuclear
- Body of evidence for important concepts is growing
  - Natural circulation vessel cooling testing
  - Heat pipe testing to thermal failure



J. Conklin, "Modeling and Performance of the MHTGR Reactor Cavity Cooling System", NUREG/CR-5514, 1990
D. Lisowski, "Natural Convection Shutdown Heat Removal Test Facility (NSTF) Overview", ML18213A151, 2018
A. Clark, "Failures and Implications of Heat Pipe Systems", SAND2019-11808, 2019

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# Thanks

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