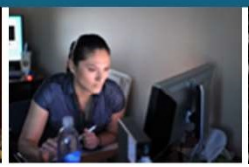
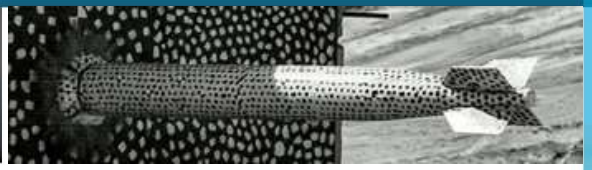
Sandia Capabilities in Support of Advanced Nuclear Reactors





Richard Griffith, Program Manager,

Nuclear Energy Safety and Security

SAND2020-5588 O

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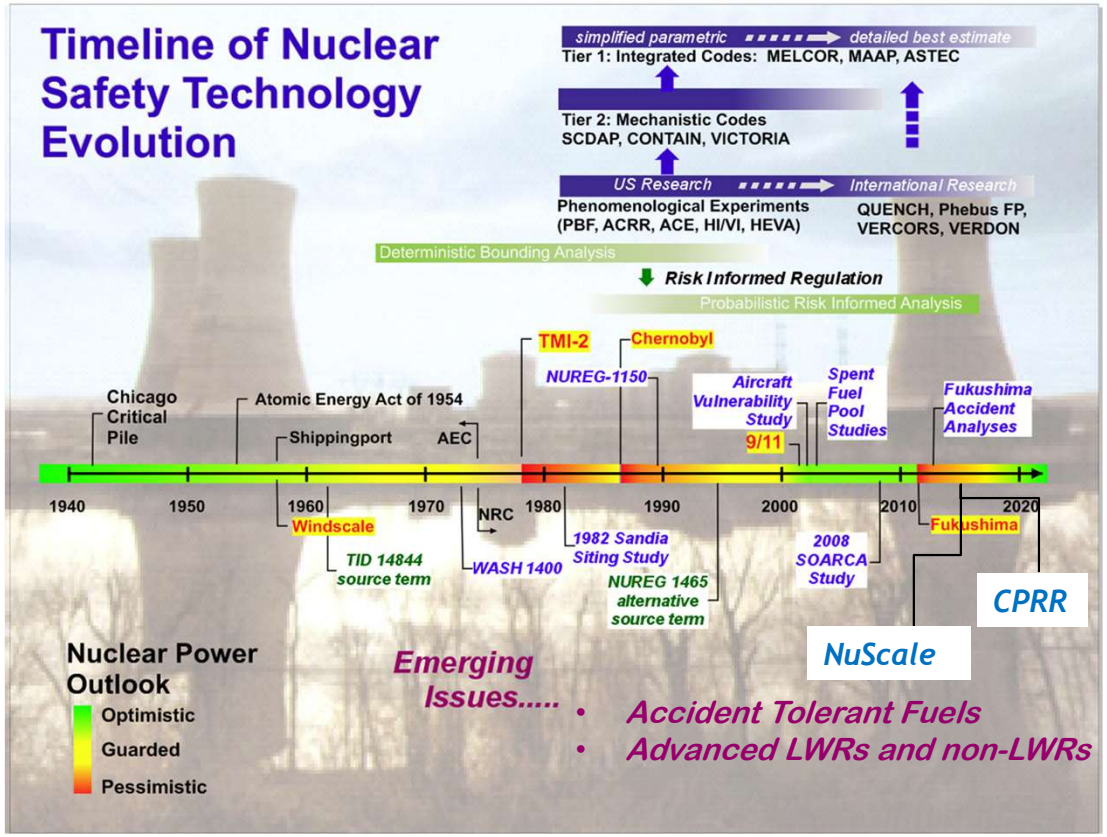
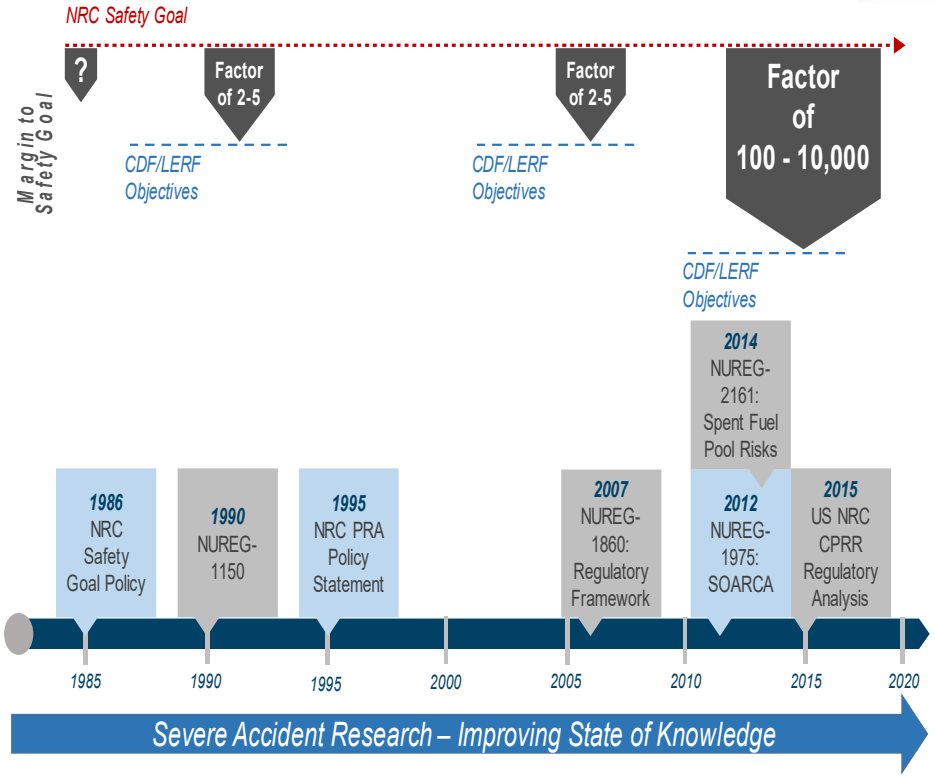
Sandia's Array of Capabilities

Sandia has a range of **unique mod/sim and experimental capabilities** that can support DOE NE and industry partner's needs. We **create computational tools and validate them** through our experimental facilities.

Many of our unique capabilities have been developed to **support the NRC** in its regulatory mission, which gives Sandia deep insight into the **regulatory process**.

When working with Sandia, our partners can access an **extraordinary array of capabilities** that have been created and sustained by **multiple national security sponsors**, not just the NRC and DOE-NE.





From NEI

Sandia nuclear safety research

Modeling and Simulation Capabilities

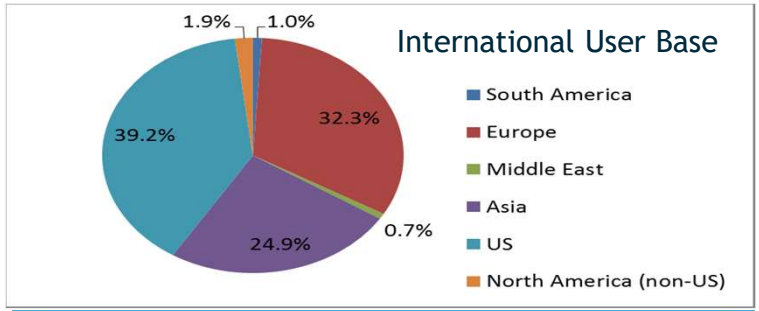
MELCOR/MACCS – ADVANCED REACTORS

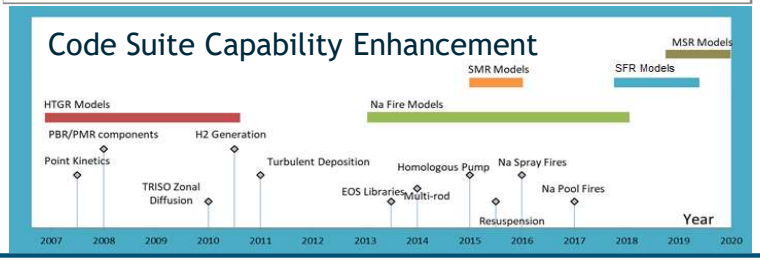
MELCOR — Integrated Accident and Source Term Modeling

- Hydrodynamics for range of working fluids
- Accident response of plant structures, systems and components
- Generalized fission product transport modeling inside facilities

MACCS — Consequence Assessment

- Near- and far-field atmospheric transport and deposition
- Assessment of health and economic impacts of radiological accidents





Nuclear Reactor System Applications

Safety/Risk Assessment

- Technology-neutral
  - Experimental
  - Naval
  - Advanced LWRs
  - Advanced Non-LWRs
- Accident forensics (Fukushima, TMI)
- Probabilistic risk assessment

Regulatory

- License amendments
- Risk-informed regulation
- Design certification (e.g., NuScale)
- Vulnerability studies
- Emergency preparedness
- Emergency Planning Zone determination

Design/Operational Support

- Design analysis scoping calculations
- Training simulators

Non-Reactor Applications

Fusion

- Neutron beam injectors
- Li loop LOFA transient analysis
- ITER cryostat modeling
- He-cooled pebble test blanket (H^3)

Spent Fuel

- Risk studies
- Multi-unit accidents
- Dry storage

Facility Safety

- Leak path factor calculations
- DOE safety toolbox codes
- DOE nuclear facilities (Pantex, Hanford, Los Alamos, Savannah River Site)

Security and Risk Analysis Efforts

Cyber and Physical Security Threat Analysis for Nuclear Reactors

Sandia integrates an array of modeling and simulation capabilities to manage this risk and secure digital systems:

- Threat modeling, Adversary-based vulnerability assessment, Network and control system emulation, simulation and analysis, Physical system modeling and simulation , Critical infrastructure modeling

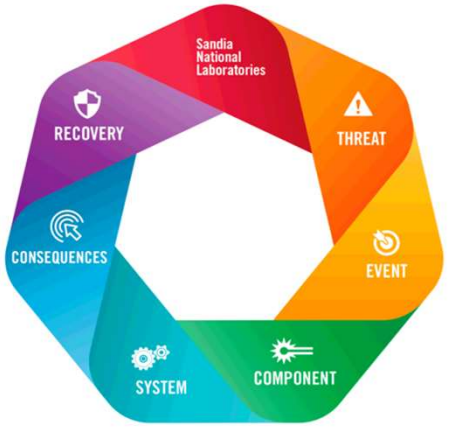
HAZCADS Approach to System Hazards

- Combination of aspects of traditional PRA and Systems Theoretical Process Analysis (STPA) for understanding security risks at nuclear facilities

Risk Analysis Efforts

- ADAPT – Dynamic PRA analysis software
- Advanced Reactor Source Term Development
- Fire PRA methods and experiments (Arc Fault Experiments)
- L3 PRA of Current LWRs
- Development of PRA standards for advanced reactors

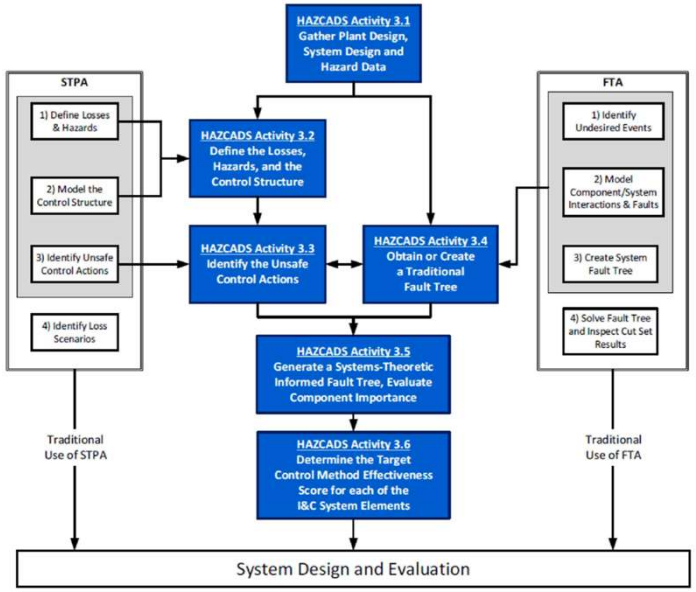
High Energy Arc Fault Testing



Integrated Cyber Physical Impact Analysis (ICPIA)™

Full Spectrum Modeling Framework

HAZCADS Methodology

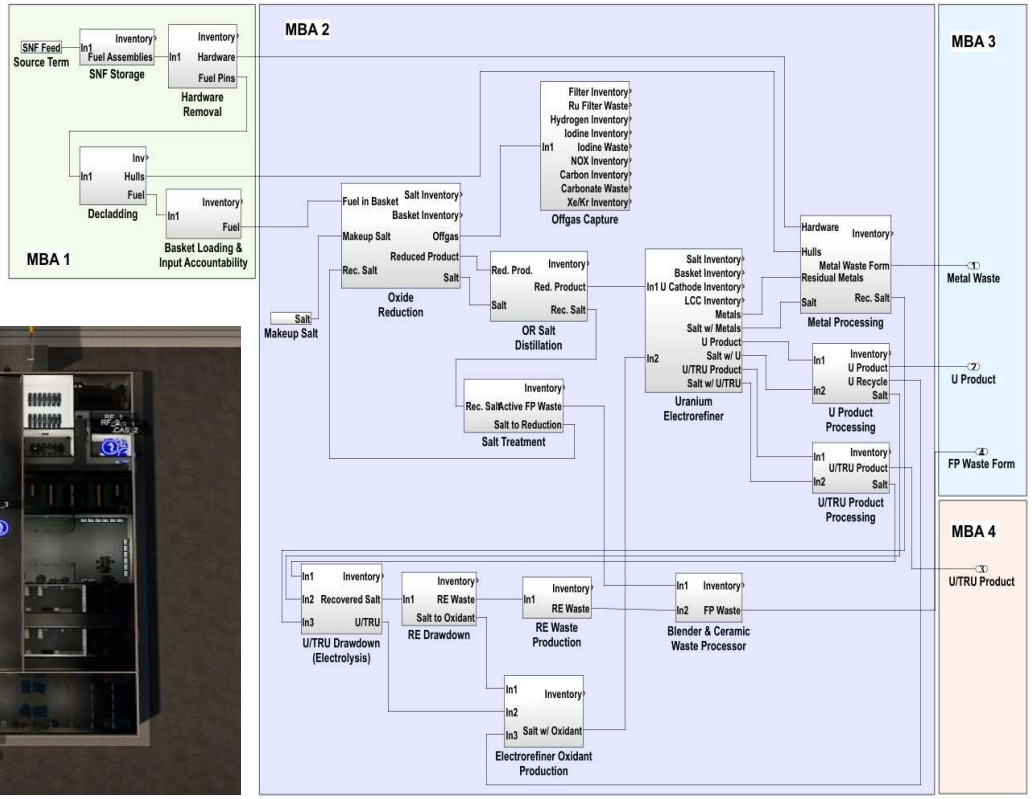


Safeguards and Security for Existing and Advanced Fuel Cycles

Sandia has recognized capabilities in **safeguards and security for reactors and fuel cycle facilities** to enhance national energy security

- Safeguards system design and analysis through the Separation and **Safeguards Performance Model** (SSPM)
- Alternative safeguards strategies including the use of process monitoring and machine learning algorithms
- Security analyses through the use of single analyst tools including **Scribe3D©** and **PathTrace©**

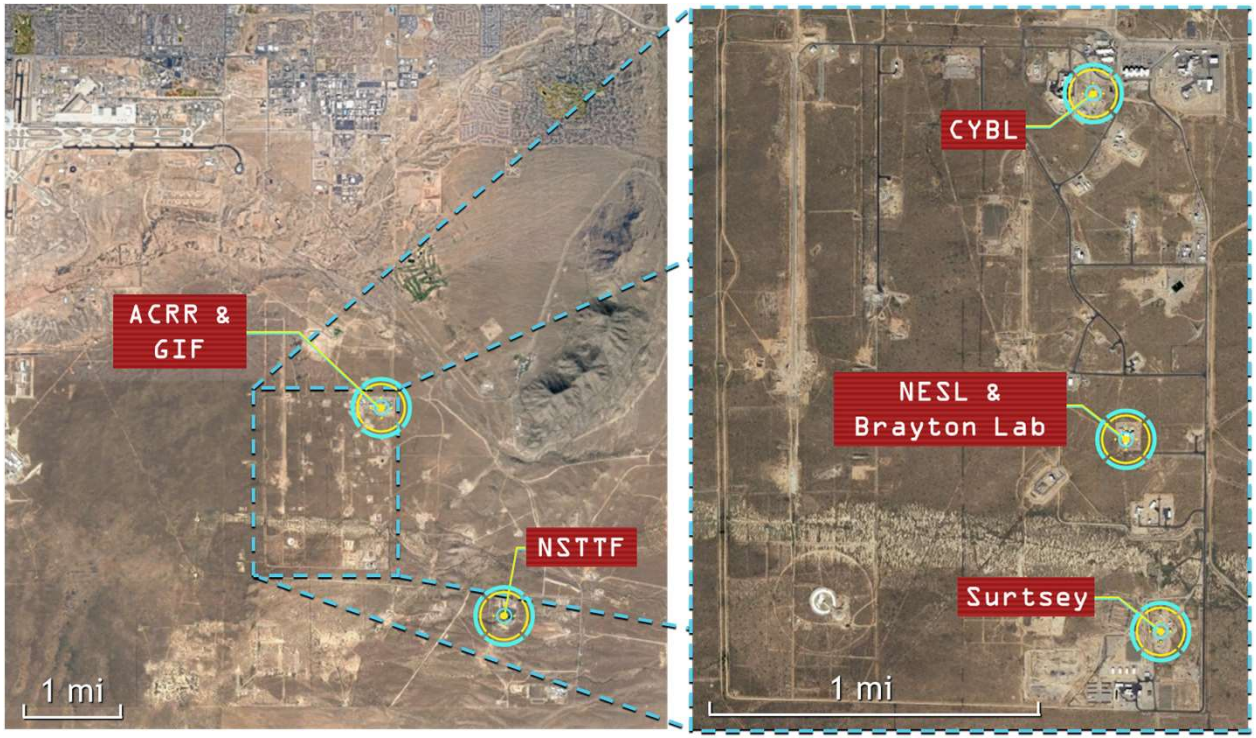
Security Modeling



Safeguards Modeling

Large-Scale Test Facilities

Sandia Nuclear Energy Unique Experimental/Test Facilities



Annular Core Research Reactor (ACRR) and **Gamma Irradiation Facility** (GIF)

- Core melt experiments
- Accelerated irradiation aging of materials

National Solar Thermal Test Facility (NSTFF)

- Molten Salt Test Loop
- Heat pipe research

Cylindrical Boiling Facility (CYBL)

- Spent fuel pool fires
- Dry cask simulators

Nuclear Energy Systems Laboratory (NESL) & **Brayton Laboratory**

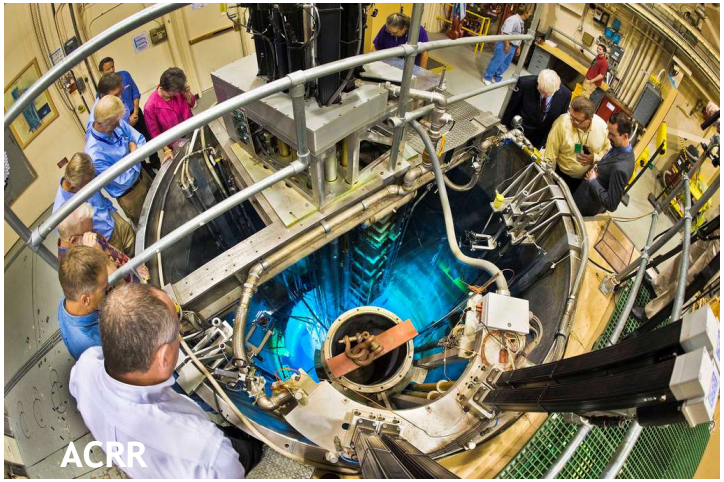
- Advanced power conversion cycle research

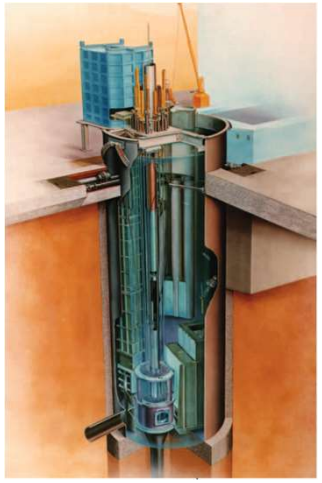
Surtsey

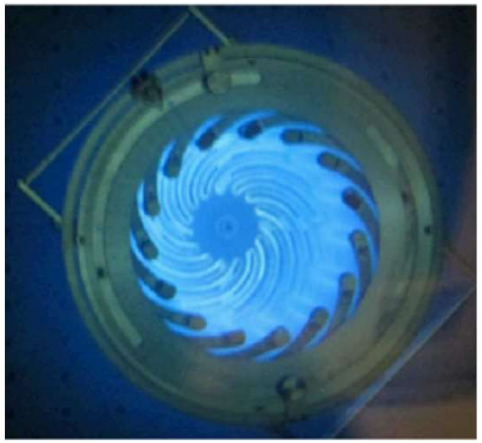
- High-energy reactor and containment accidents
- Sodium coolant fires

Annular Core Research Reactor and Gamma Irradiation Facility

SNL maintains several unique capabilities







Annular Core Research Reactor (ACRR)

- Primary mission to test electronics and reactor safety research
- Steady state, pulsed, and tailored transient operations
- Core melt experiments have been performed inside the annulus

Gamma Irradiation Facility (GIF)

- Variety of Co-60 sources
- Dry in-cell and submerged in-pool operations possible
- Accelerated irradiation testing of all types of components

National Solar Thermal Test Facility

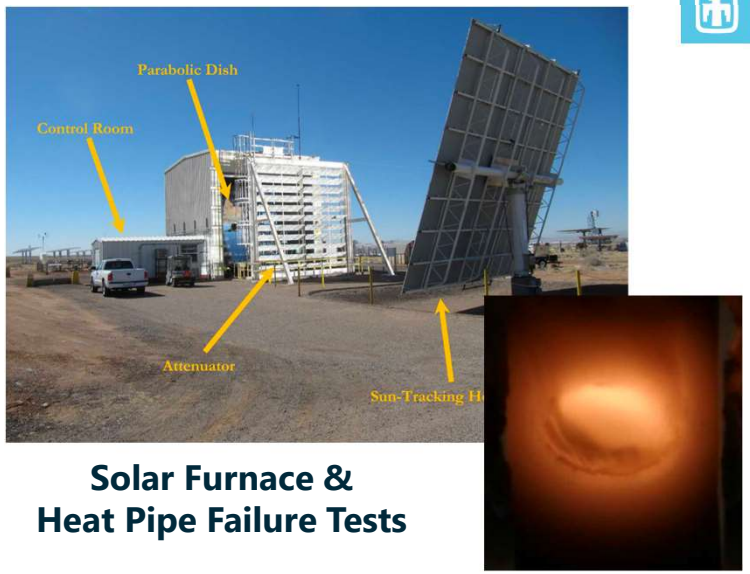
Molten Salt Testing Capabilities

National Solar Thermal Test Facility

- DOE-EERE lead on evaluating solar thermal technologies
- Expertise in high temperature heat transfer fluids: molten salt, sodium, heat pipes
- Chloride salt experimental capabilities for next gen designs

Molten Salt Test Loop (MSTL)

- Evaluate the performance of salts for storage of solar energy
- Nitrate salt loop



Solar Furnace &
Heat Pipe Failure Tests

MSTL
Facility

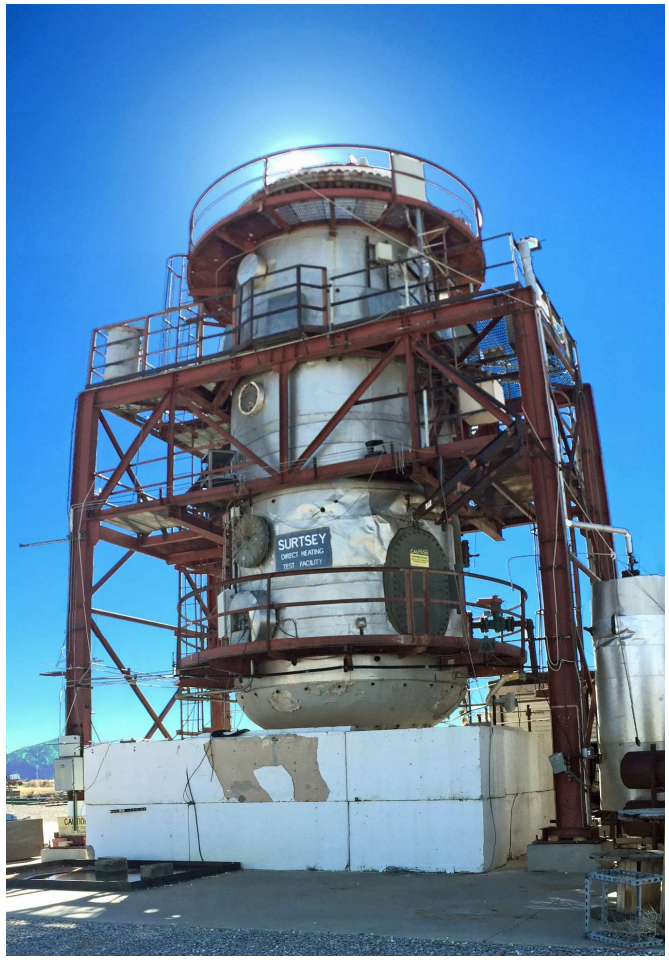
Solar Furnace Facility

Concentrates solar energy with a parabolic dish to reach extremely high heat fluxes (much higher than an operating reactor)

Testing of Heat Pipes within the GAIN Program with OKLO

- Heat pipe failure tests
- High thermal flux failure tests of multiple heat pipe designs

Surtsey Facility



Surtsey vessel → 100 m^3 ASME pressure vessel → 1 MPa MAWP

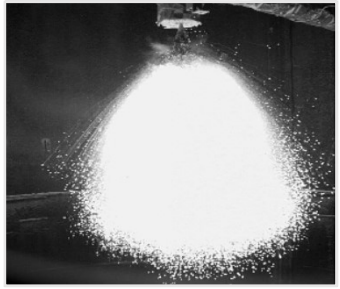
LWR Safety Research

- Reactor pressure vessel rupture
- Direct containment heating
- Molten Core interactions with concrete
- Hydrogen recombiners

Offsite mitigation

- "Knockdown" of releases from containment
- Standard firefighting equipment

Sodium coolant fires

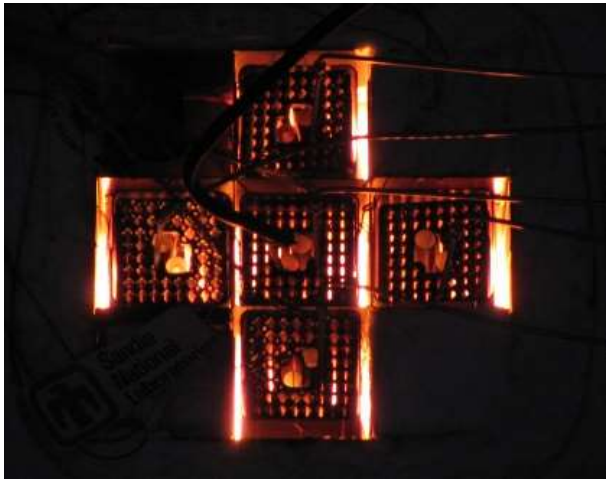


- Line breaks and pool ignitions in SFRs

CYBL Facility

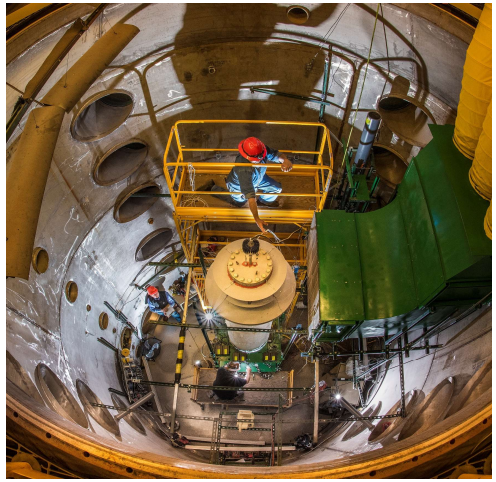
Cylindrical Boiling vessel

- Tank-within-a-tank design (Inner tank currently removed)
- Originally built to test flooded cavity concept



Spent nuclear fuel pool fires

- Full-length simulated fuel assemblies
- Zircaloy cladding ignition conditions demonstrated for BWR and PWR



Dry cask simulators

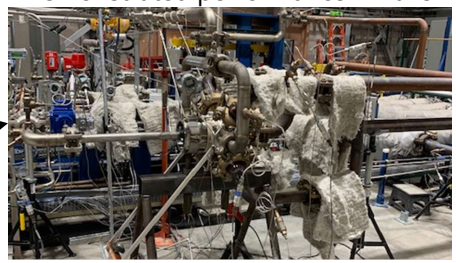
- Full-length thermal-hydraulics
- All current designs represented

Nuclear Energy Systems Laboratory and Brayton Laboratory

Artist rendering ~ late 2017

1 MWe Turbocompressor

Demonstrated performance ~ 2019

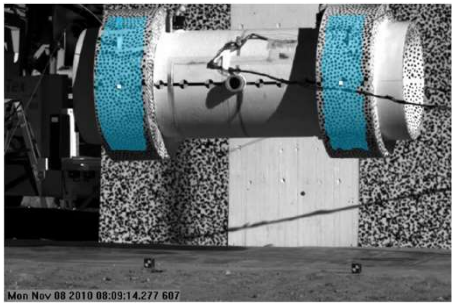


Turbomachinery development platform at SNL

Recompression Closed Brayton Cycle (RCBC)

- Designed to couple with advanced reactors through high process temperatures (550 °C)
- Higher efficiency than traditional Rankine cycle
- Uses supercritical carbon dioxide (s-CO_2)
- Development platform used to demonstrate first-of-a-kind power conversion technologies

Fire, Risk, and Transportation Systems



Testing of transport packages

- Drop tests and engulfing fires
- Rocket sled tracks (2,000 and 10,000 ft.)
- Normal conditions of transport (NCT)
- Hypothetical accident conditions (HAC)

Mobile Instrumentation and Data Acquisition System (MIDAS)

- NQA-1 compliant
- Fast collection at 10,000,000 samples/second
  - 168 channels of piezo-resistive type gages
  - 100 channels of thermocouple data