Introductions, Licensing Pathway and Technical Summary

NRC Project Number 99902088 supporting pre-application licensing activities

Dr. Rusty Towell

NEXT Lab Director, Abilene Christian University

September 29, 2020

Abilene Christian University

NEXT

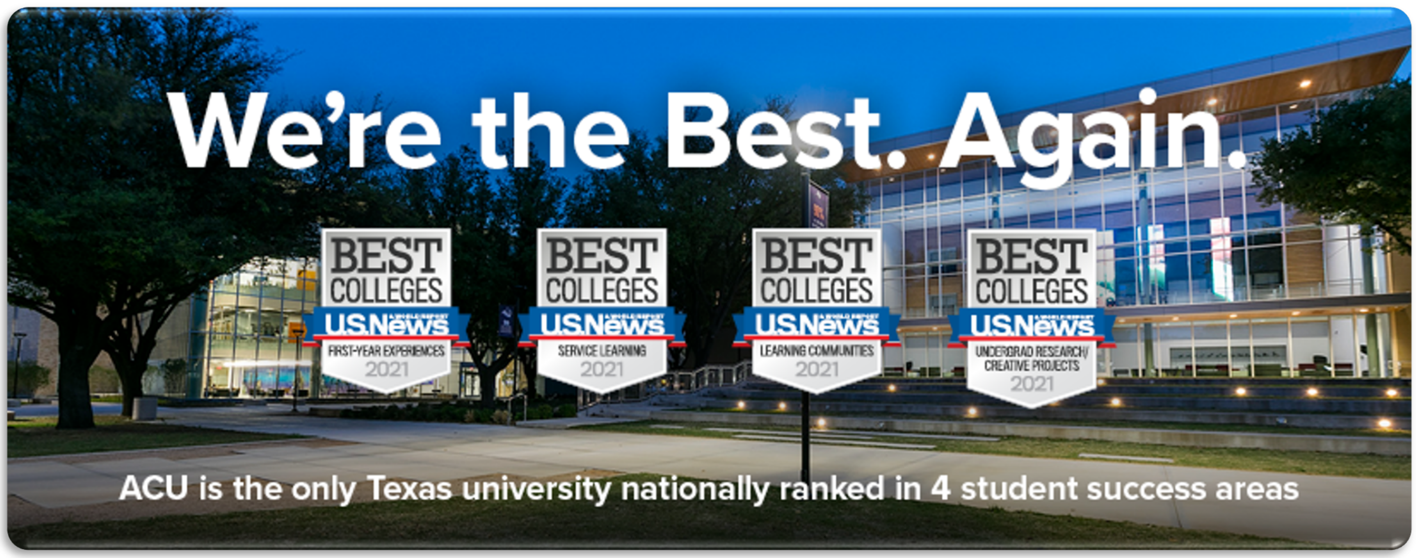
Introductions

ABILENE CHRISTIAN UNIVERSITY

Abilene Christian University

NEXT
Nuclear Energy eXperimental Testing

- Main Campus in Abilene, Texas - population 123,000
- Fall 2020 marks the third consecutive year for a record number of students enrolling at ACU - 5,293 students.
  - Main campus is in Abilene Texas - 3,675 students
  - ACU Dallas - 1,618 students



ACU Commitment to Research

NEXT
Nuclear Energy eXperimental Testing

- Physics program started in 1969 focused on research
- ABET accredited engineering program started in 2012
  - 19 faculty, 174 undergraduate students
- $50M+ invested in science and engineering infrastructure
- Hired Vice President of Research to incentivize research and technology invention, and corporate engagement activities
- Planning a new $15M Science and Engineering Research facility
- Administrative and financial support of NEXT Lab vision

ACU History of Research

NEXT
Nuclear Energy eXperimental Testing

- 60 years of continuously funded research through the Robert A. Welch Foundation, NIH, the Petroleum Research Fund, and others.
- 40 years of continuous DOE funded nuclear research
- ACU research successes
  - Old Model
    Take students to world-class facilities
  - New model
    Bring world-class facilities to ACU
    Bring the world to ACU

U.S. DEPARTMENT OF ENERGY

INL Idaho National Laboratory 70 YEARS OF SCIENCE & INNOVATION

VTR VERSATILE TEST REACTOR

Fermilab

NSF

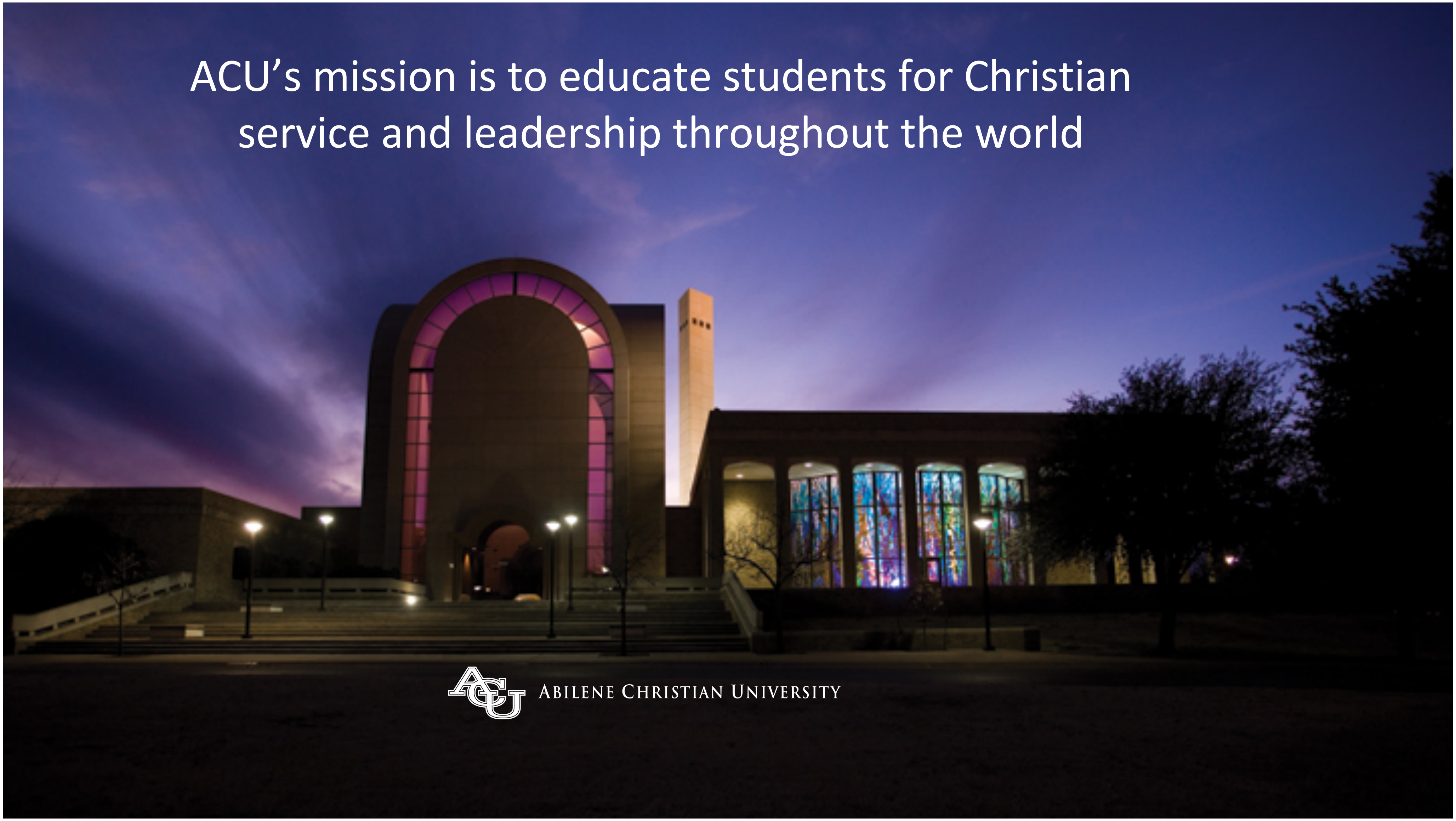
Los Alamos NATIONAL LABORATORY EST. 1943

NIH

BROOKHAVEN NATIONAL LABORATORY

Lawrence Livermore National Laboratory

GAIN Gateway for Accelerated Innovation in Nuclear

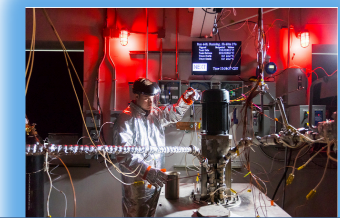

ACU's mission is to educate students for Christian service and leadership throughout the world
ABILENE CHRISTIAN UNIVERSITY

Nuclear Energy eXperimental Testing Lab

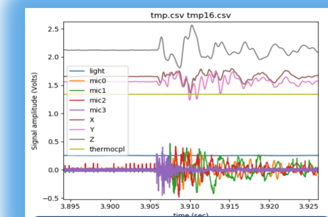
Finding global solutions to the world's critical needs

NEXT Lab Research Projects

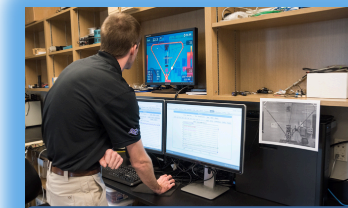
NEXT
Nuclear Energy eXperimental Testing

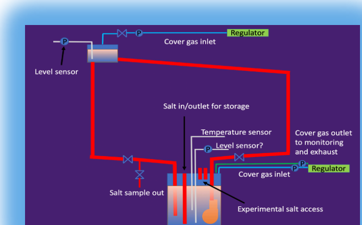

Molten Salt Test Loop


Fission Fragment Removal



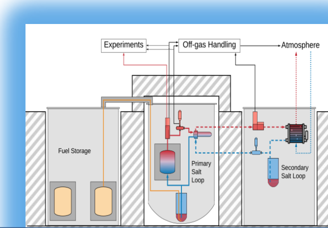
Instrumentation


Data Acquisition



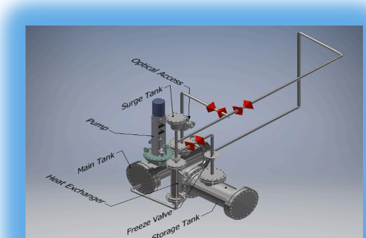
Fluoride Molten Salt Test Loop


Salt Purification System

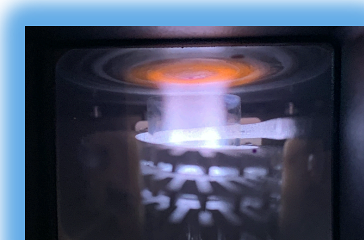


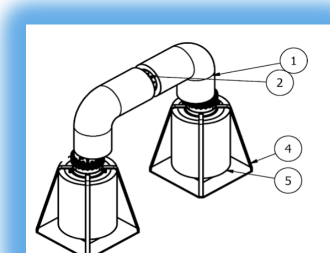
Molten Salt Research Reactor


Component Test System



Molten Salt Test System

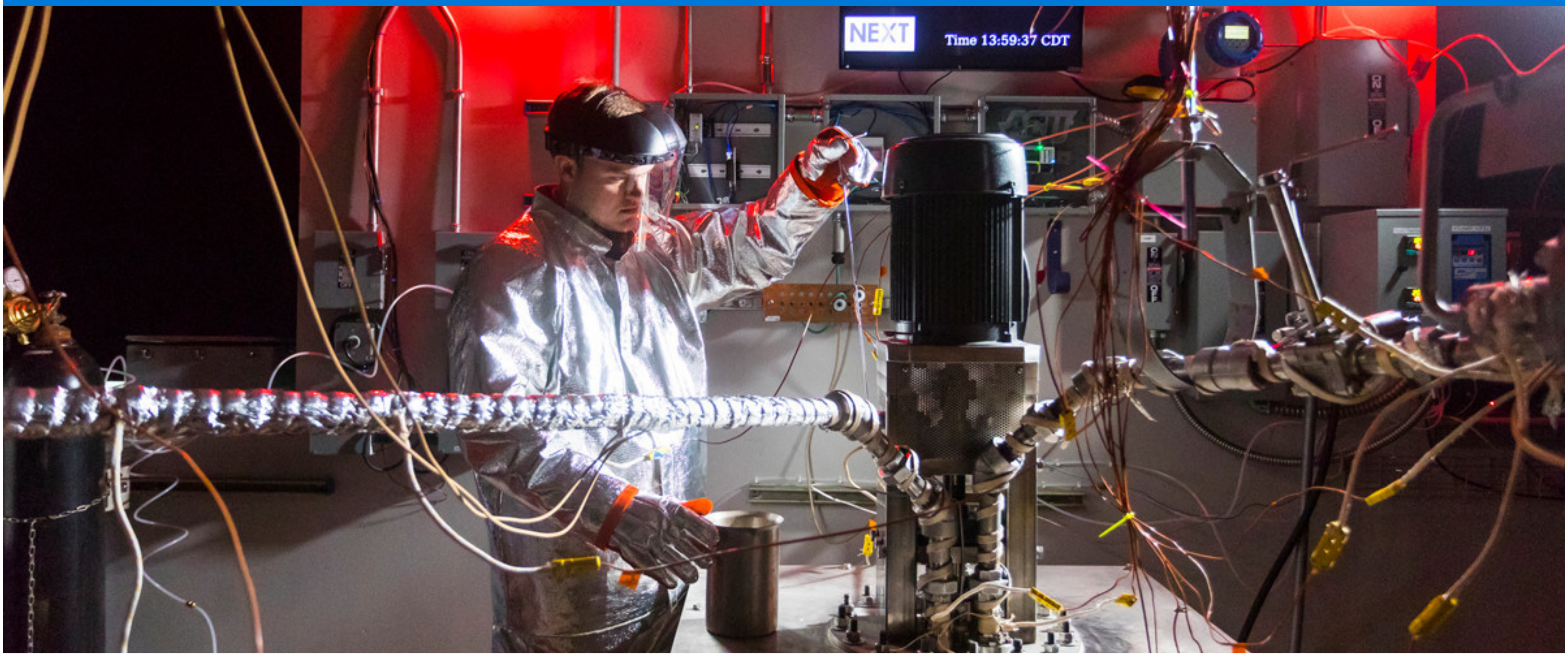

Chemical Analysis System

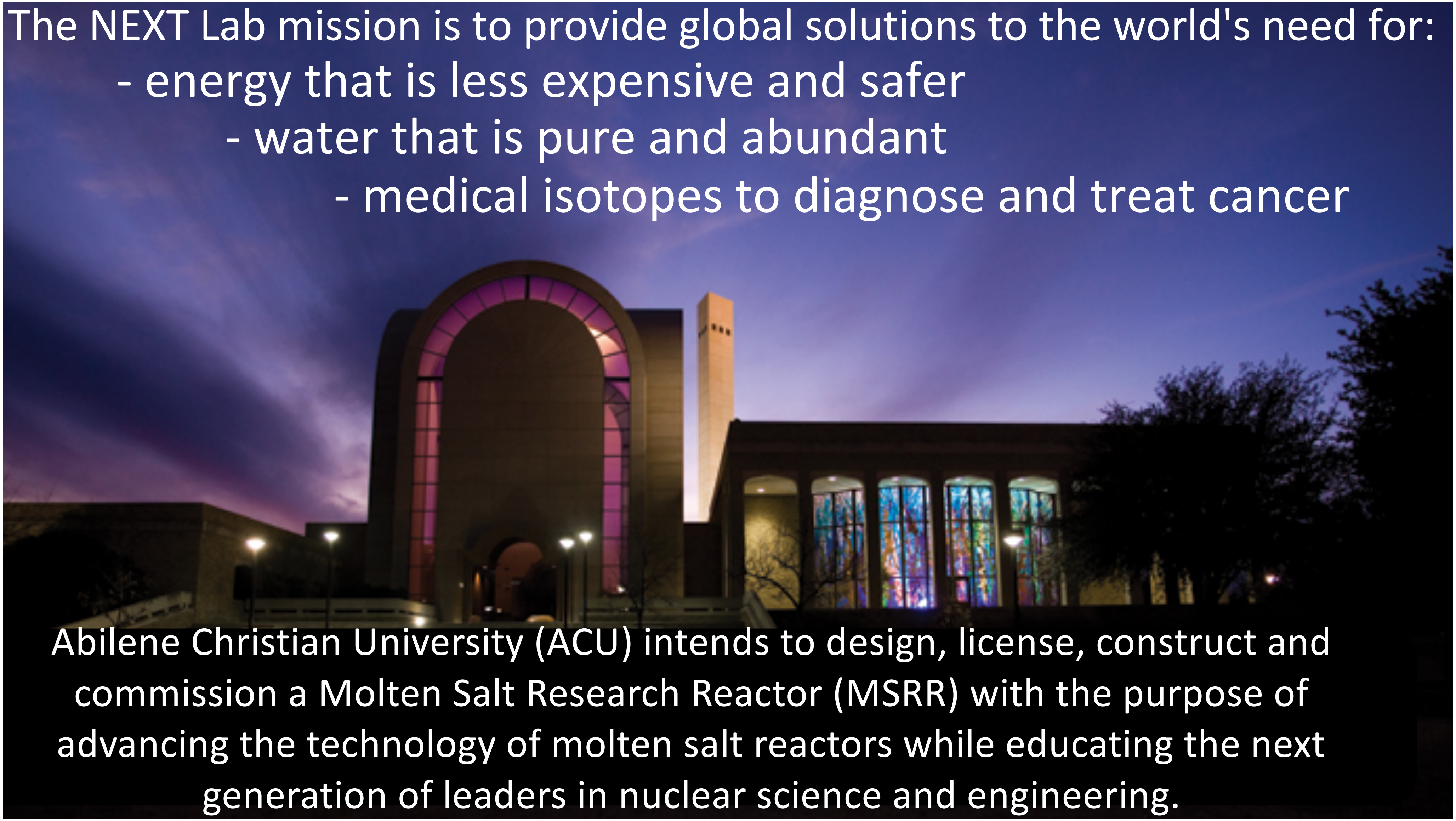


Molten Salt Filters

The NEXT Lab mission is to provide global solutions to the world's need for:

- energy that is less expensive and safer
- water that is pure and abundant
- medical isotopes to diagnose and treat cancer




The NEXT Lab mission is to provide global solutions to the world's need for:
- energy that is less expensive and safer
- water that is pure and abundant
- medical isotopes to diagnose and treat cancer
Abilene Christian University (ACU) intends to design, license, construct and commission a Molten Salt Research Reactor (MSRR) with the purpose of advancing the technology of molten salt reactors while educating the next generation of leaders in nuclear science and engineering.

NEXTRA Introduction

NEXT
Nuclear Energy eXperimental Testing

Georgia Tech

UNIVERSITY OF TEXAS • NATURA RESOURCES • ABILENE CHRISTIAN UNIVERSITY • GEORGIA TECH • TEXAS A&M UNIVERSITY •

NEXTRA

From Doubt to Astonishment
- Galilieo

TEXAS A&M UNIVERSITY

ABILENE CHRISTIAN UNIVERSITY

TEXAS
The University of Texas at Austin

Abilene Christian University

NEXT
Nuclear Energy eXperimental Testing

Dr. Rusty Towell is a Professor of Engineering and Physics at ACU and is the Director of NEXT Lab. He taught at the U.S. Naval Nuclear Power School and worked at several national labs before joining the ACU faculty.

Dr. Tim Head is a Professor and Department Chair of Engineering and Physics and leads the Molten Salt Systems Development and Testing at NEXT Lab.

Dr. Kim Pamplin is a Professor of Chemistry and Biochemistry at ACU and is the NEXT Senior Chemist and leads the Salt Chemistry Team at NEXT Lab.

Steve Vanderslice is a professional staff member at ACU NEXT Lab and has over 45 years of experience in commercial nuclear power and safety systems design, licensing, construction, and startup. Steve is the MSRR Engineering Design & Construction Manager.

Rosario Gibbs is an industrial engineer at NEXT Lab with more than 20 years of experience working in world-class manufacturing companies such as Sony, Canon, Flextronics and Boeing.

Alexander Adams Jr. is a professional staff member at ACU's NEXT Lab and has over 46 years of experience in research reactor facility engineering, operation, management and licensing. He regulated research and test reactors during 33 years at the U.S. Nuclear Regulatory Commission (NRC) including six years as the chief of research and test reactor licensing.

Abilene Christian University

NEXT
Nuclear Energy eXperimental Testing

Dr. Jonathan Scherr is the Engineering Lead for the MSRR Conceptual Design development and evaluation efforts in support of deployment and licensing. He guides efforts of the NEXTRA members coordinating design activities of the team. His experience includes design R&D for fast reactors and MSRs as well as design methods development.

Warren Busch is an engineer who has over 35 years of experience in commercial nuclear power and safety systems design and licensing of instrumentation and control, data acquisition, and electrical power systems, with extensive experience in safety analyses, licensing submittals, protection system setpoint methodologies, implementation of regulatory requirements and industry guidance in nuclear plants.

Brian Haynes is an engineer with over 40 years of experience in commercial nuclear power design, licensing, construction and startup. He has provided design (Engineer of Record) and licensing support for over 120 reactors world-wide including C-E, Westinghouse, B&W, GE, CANDU, VVER and Chinese PWR reactors.

University of Texas, Austin

Dr. Derek Haas, Assistant Professor in the Nuclear and Radiation Engineering (NRE) program of the Mechanical Engineering Department of the University of Texas at Austin and experimental researcher focused on non-proliferation with eight years experience at Pacific Northwest National Laboratory, who is the lead for the MSRR Reactor Research Bay Interface design team.

Dr. William (Bill) Charlton, Director of the UT Nuclear Engineering Teaching Laboratory, which includes the 1 MW TRIGA reactor, is the John J. McKetta Energy Professor in the Nuclear and Radiation Engineering Program and a primary contributor in reactor operations and experimental planning.

Dr. Kevin Clarno, former lead of the Reactor Physics Group at Oak Ridge National Laboratory, which develops the SCALE nuclear analysis code suite, and lead of CASL (Consortium for the Advanced Simulation of LWRs), is an Associate Professor in the Nuclear and Radiation Engineering program of the Mechanical Engineering Department, Chair of the UT Reactor Oversight Committee and a primary contributor in the reactor design.

Texas A&M University

NEXT
Nuclear Energy eXperimental Testing

Dr. Pavel Tsvetkov is an Associate Professor in the Texas A&M University Nuclear Engineering Department and leads the MSRR Fuel Handling Subsystem design team. He joined A&M in 2005 focusing on design and instrumentation and control for novel systems. Dr. Tsvetkov's focus is providing key contributions and evaluations in design decisions that guide and inform licensing and deployment.

Dr. Mark Kimber is an Assistant Professor in the Department of Nuclear Engineering at Texas A&M University and leads the MSRR Thermal Management Subsystem design team.

Dr. Sean M. McDeavitt joined the faculty of Texas A&M University in the Fall of 2006 and has multidisciplinary experience in nuclear, materials, and chemical engineering and is the Director of Nuclear Engineering & Science Center and the Nuclear Power Institute for workforce development. Sean leads the Chemistry group for the NEXTRA.

Georgia Institute of Technology

NEXT
Nuclear Energy eXperimental Testing

Dr. Steven Biegalski is the Chair of Nuclear and Radiological Engineering and Medical Physics Program at Georgia Institute of Technology and was a faculty member at The University of Texas at Austin for 15 years and held the position of Reactor Director for The University of Texas at Austin TRIGA reactor for over a decade.

Dr. Bojan Petrovic is a Professor of Nuclear and Radiological Engineering at Georgia Institute of Technology whose expertise is in the areas of advanced reactors design and numerical simulations of nuclear systems.

Dr. Preet Singh focuses on corrosion and materials engineering within the context of molten salt reactors. His work includes understanding the basic mechanisms involved in material degradation and using that knowledge to develop a mitigation strategy against environment-induced failures.

NEXT

Licensing Pathway

ABILENE CHRISTIAN UNIVERSITY

MSRR to be Licensed as a University Research Reactor

- ACU is seeking a license under AEA Section 104c pursuant to 10 CFR 50.21(c) for a University Research Reactor facility with a maximum licensed power level of 1 MW_{th}.

- The ACU MSRR will be a non-power utilization facility as described in 10 CFR 50.21(c) - “useful in the conduct of research and development activities of the types specified in Section 31 of the Atomic Energy Act (AEA).”

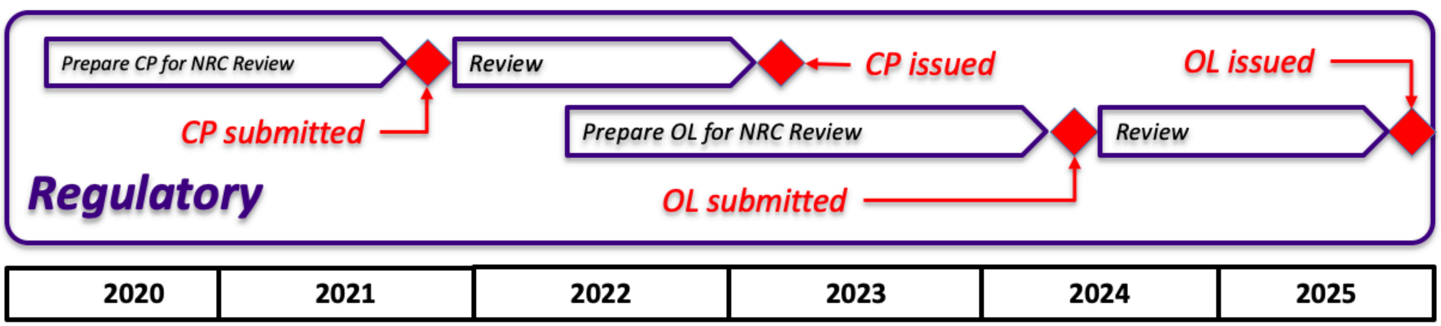
- The MSRR will not be a commercial or industrial facility as specified in paragraph (b) of 10 CFR 50.21 or in 10 CFR 50.22 and MSRR activities will be consistent with licensing under Section 104c of the AEA as amended by NEIMA.

MSRR Two-Step Licensing Process (10 CFR Part 50)

ACU submittals will be separate Construction Permit (CP) and Operating License (OL) applications.

Operational activities are subject to other NRC regulations which will be incorporated into the Part 50 license for the facility:

- 10 CFR Part 70, "Domestic Licensing of Special Nuclear Material," license to receive, possess, and use special nuclear material
  - Receiving LEU from U.S. Department of Energy (DOE) Research Reactor Infrastructure program (have received letter of support from DOE-NE)
- 10 CFR Part 30, "Rules of General Applicability to Domestic Licensing of Byproduct Material," license to receive, possess and use byproduct material produced by operation of the reactor and from other licensees



Existing and Updated Guidance Documents

NEXT
Nuclear Energy eXperimental Testing

- NUREG-1537 "Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors"
- Division 2 Regulatory Guides for Research Reactors
- American Nuclear Society ANS-15 Series Standards for Research Reactors

We are aware of work within the ANS-15 standards committee to develop a structures, systems and components (SSCs) standard and at ORNL to develop interim staff guidance to NUREG-1537 for molten salt reactor technology.

ACU CP Application

NEXT
Nuclear Energy eXperimental Testing

The CP application will be submitted in accordance with:

- 10 CFR 2.101, Filing of Application
- 10 CFR 50.4, Written Communication

The CP application content will be prepared in accordance with:

- 10 CFR 50.33, Contents of applications; general information
- 10 CFR 50.34, Contents of applications; technical information
- 10 CFR 50.34(a), Preliminary safety analysis report

The CP submittal package will include:

- Preliminary Safety Analysis Report
- Preliminary Emergency Plan
- Environmental Report
- Quality Assurance Plan

Site Selection

NEXT
Nuclear Energy eXperimental Testing

Multiple sites are under consideration

- Environmental/radiological aspects of site selection are considered
- Goal is to build on or near the ACU campus in Abilene, TX.

Regulatory Intent of 10 CFR 50.10(a)(2)(x)

This research and education facility includes:

- radiochemistry labs
- molten salt systems labs
- instrumentation lab
- flexible research bay
- office space
- training room.

- Early discussion of this facility will improve our understanding of the innovative use of a new structure.
- The construction plan of the facility does not include designing or placement of MSRR Structures, Systems and Components (SSC), prior to NRC issued CP.

ACU R&D Program to Support MSRR Licensing

NEXT
Nuclear Energy eXperimental Testing

At the time of the CP application, research and development (R&D) will be planned or underway to confirm the adequacy of design of certain MSRR SSCs.

The CP application will contain the information requested in 10 CFR 50.34(a)(8):

- Identification of SSCs that require R&D to confirm adequacy of design
- Description of the R&D program to resolve safety questions associated with the identified SSCs, and
- Schedule of the R&D program showing resolution of safety questions at or before the latest date to complete construction.
    - For example, the proper handling of the off-gas system will be important to MSRR operation and site safety. The technical challenge of assessing the off-gas system performance during reactor operation will be an objective of R&D.

ACU's goal is to provide sufficient information in the CP application to allow the Commission to make the findings required by 50.35(a) to issue a CP with R&D ongoing.

The results of the R&D program showing resolution of safety questions will be submitted as part of the OL application in the FSAR as required by 50.34(b)(5).

NEXT

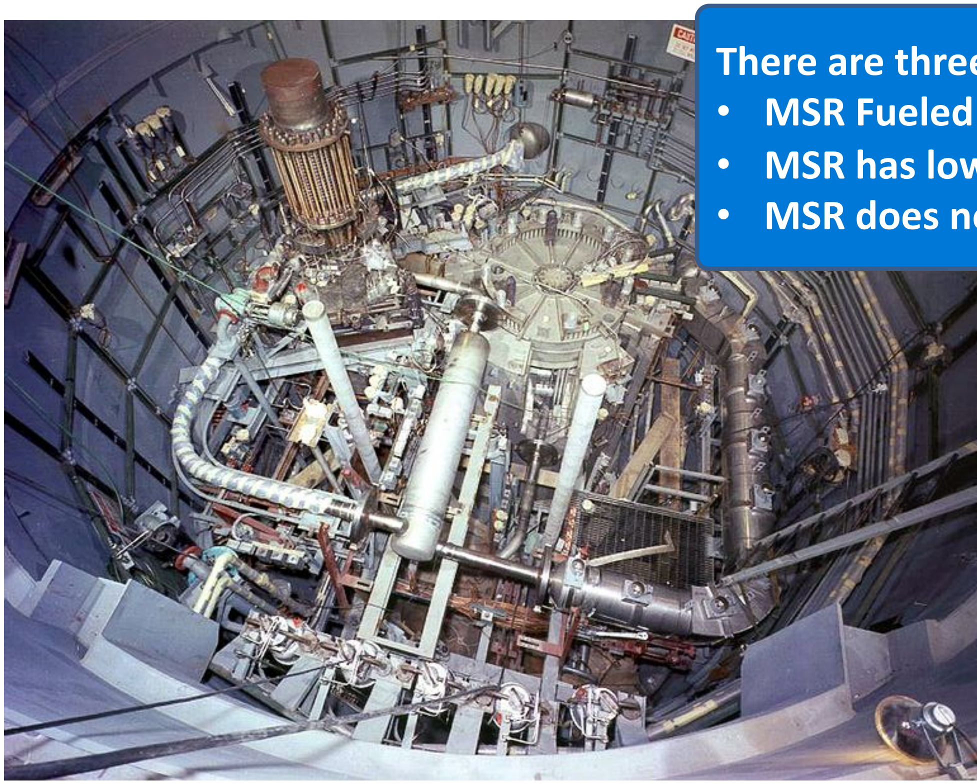
Technical Summary

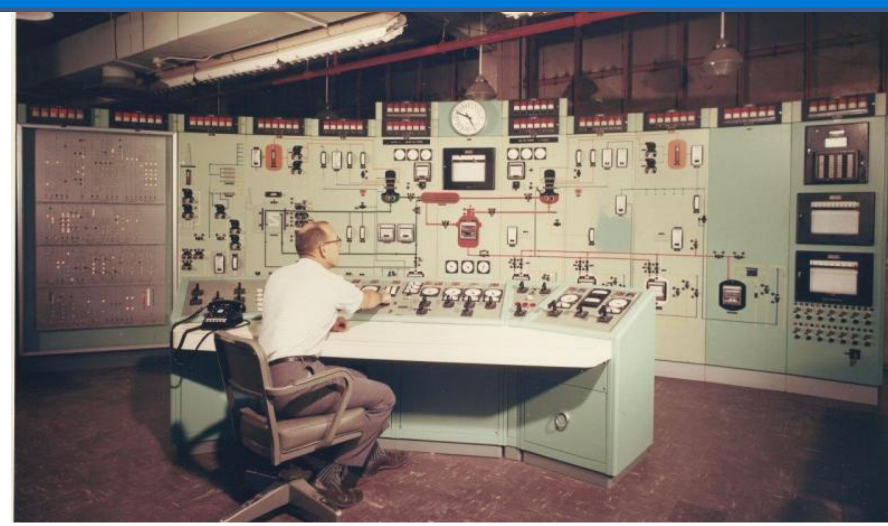
Abilene Christian University

MSRR is Simplified MSRE

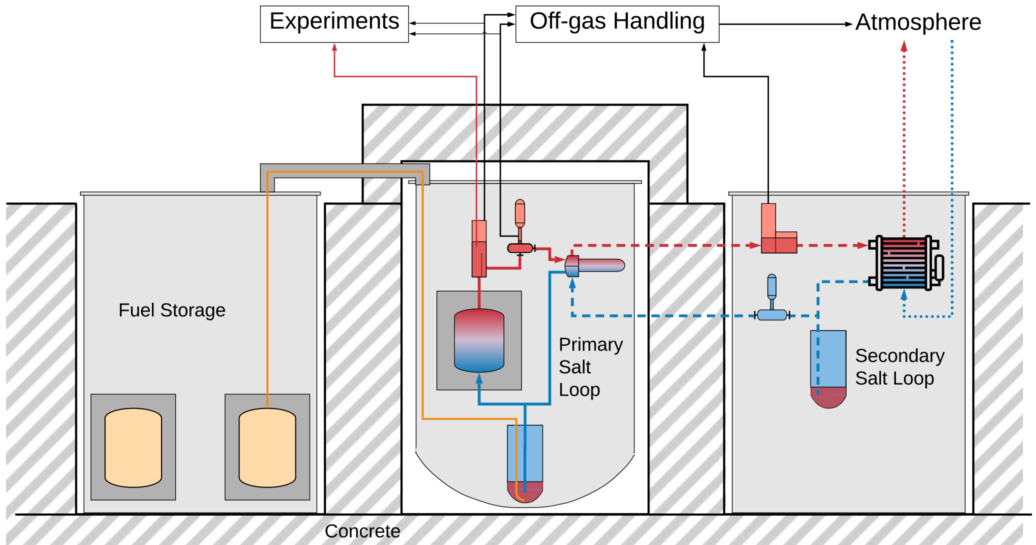
NEXT
Nuclear Energy eXperimental Testing

There are three major differences between the MSRE and the MSRR
- MSR Fueled with HALEU instead of HEU
- MSR has lower power and power density
- MSR does not require external cooling water

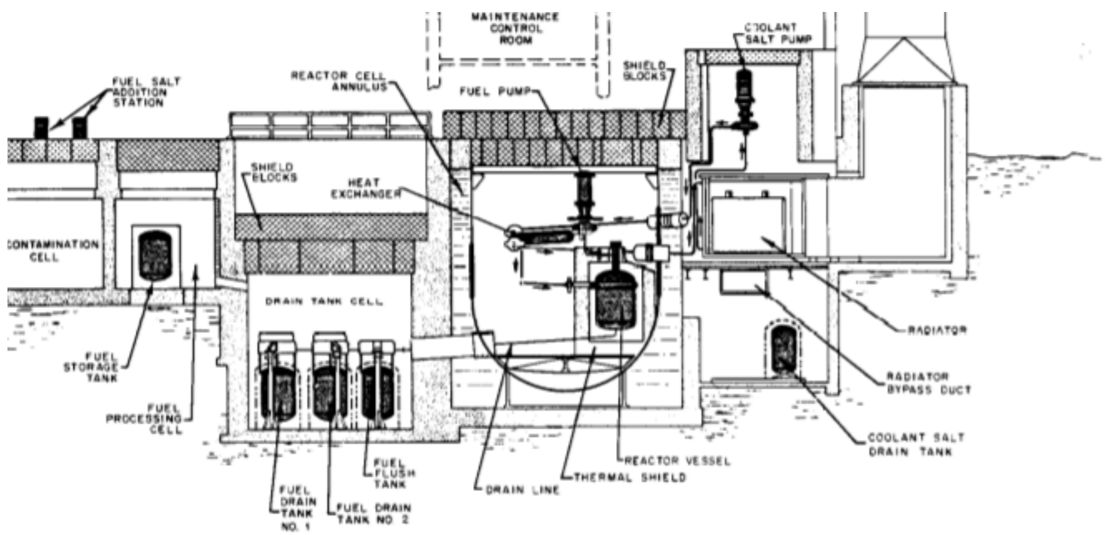




MSRR

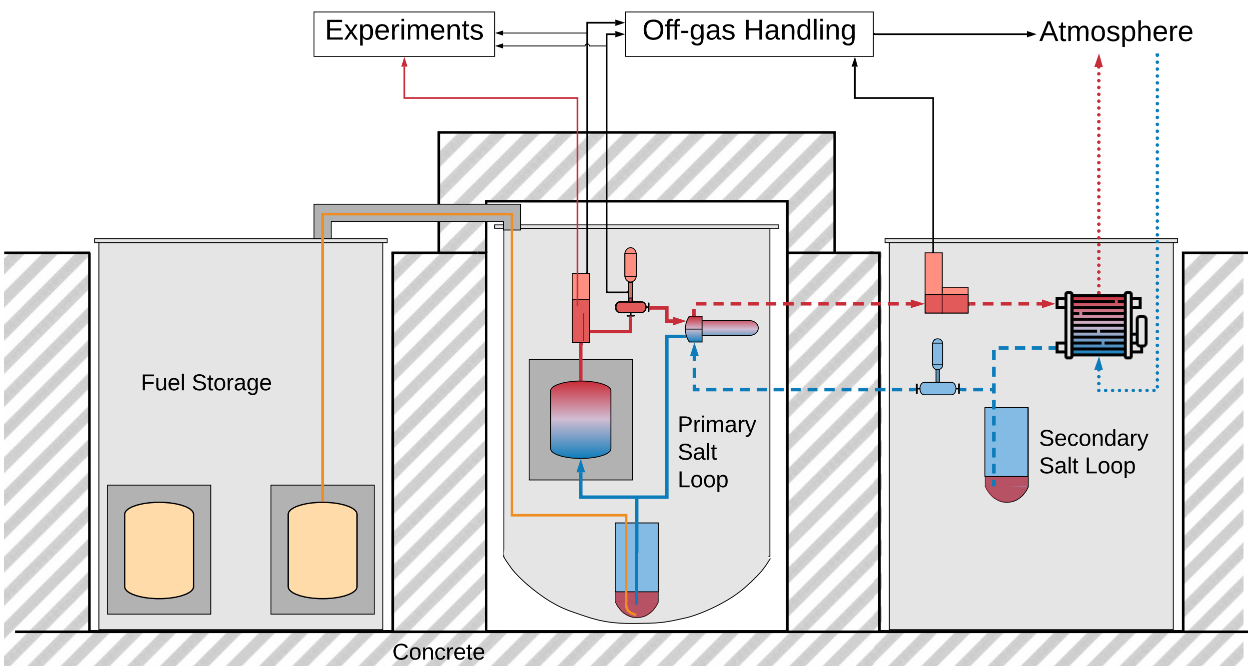

Experiments
Off-gas Handling
Atmosphere
Fuel Storage
Primary
Salt
Loop
Secondary
Salt Loop
Concrete

MSRE


MAINTENANCE CONTROL ROOM
COOLANT SALT PUMP
FUEL SALT ADDITION STATION
REACTOR CELL ANNULUS
FUEL PUMP
SHIELD BLOCKS
SHIELD BLOCKS
HEAT EXCHANGER
CONTAMINATION CELL
DRAIN TANK CELL
RADIATOR
FUEL STORAGE TANK
RADIATOR BYPASS DUCT
FUEL PROCESSING CELL
COOLANT SALT DRAIN TANK
REACTOR VESSEL
FUEL FLUSH TANK
THERMAL SHIELD
DRAIN LINE
FUEL DRAIN TANK NO. 1
FUEL DRAIN TANK NO 2

Overview of Conceptual Design

NEXT
Nuclear Energy eXperimental Testing



Reactor Parameters:

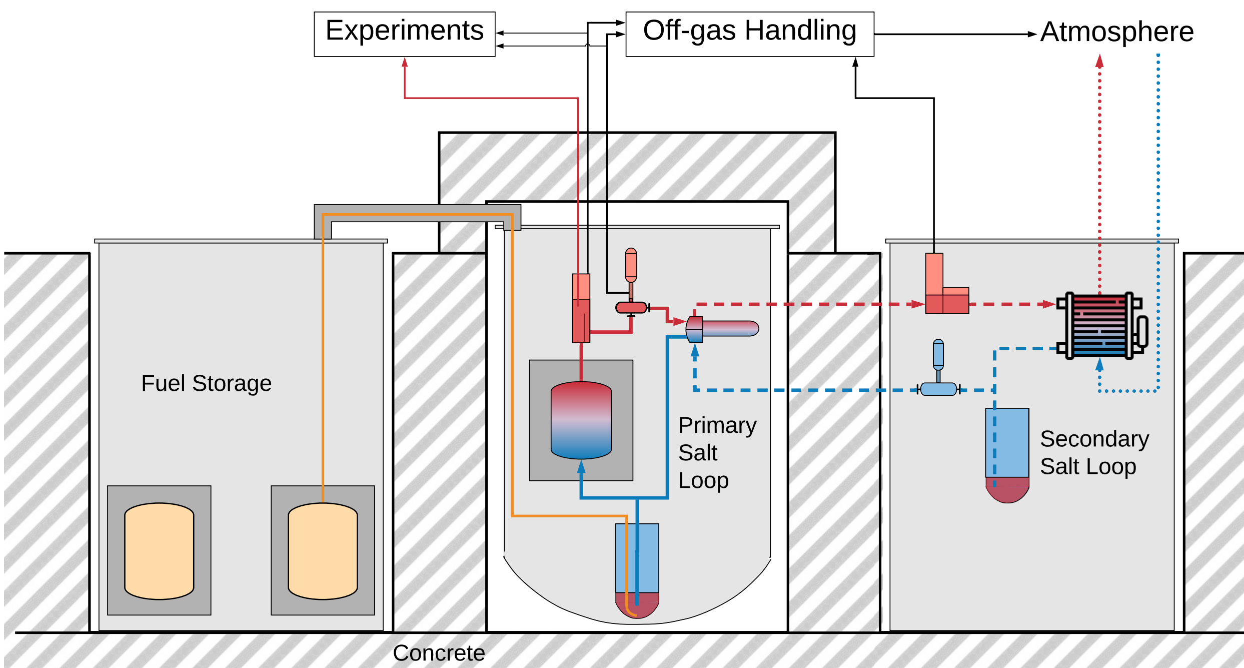
The MSRR design will employ

- Lower power
- Lower power density
- Lower pressure drop

Size:

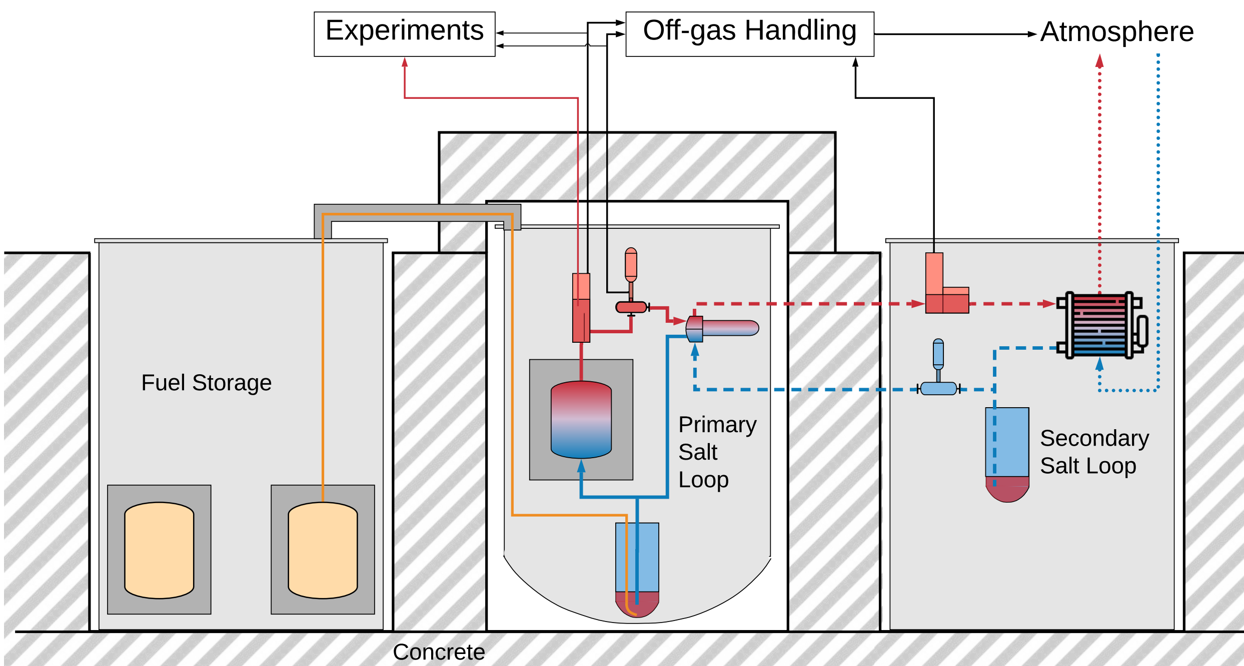
- 1 MW_{th}
- Reactor vessel is 6 feet tall and 4.5 feet in diameter

MSRR is a Loop-type Design



- The MSRR will have forced primary flow for full power operations.
- A secondary loop will be used to remove the reactor thermal power.
- The ultimate heat sink will be air.

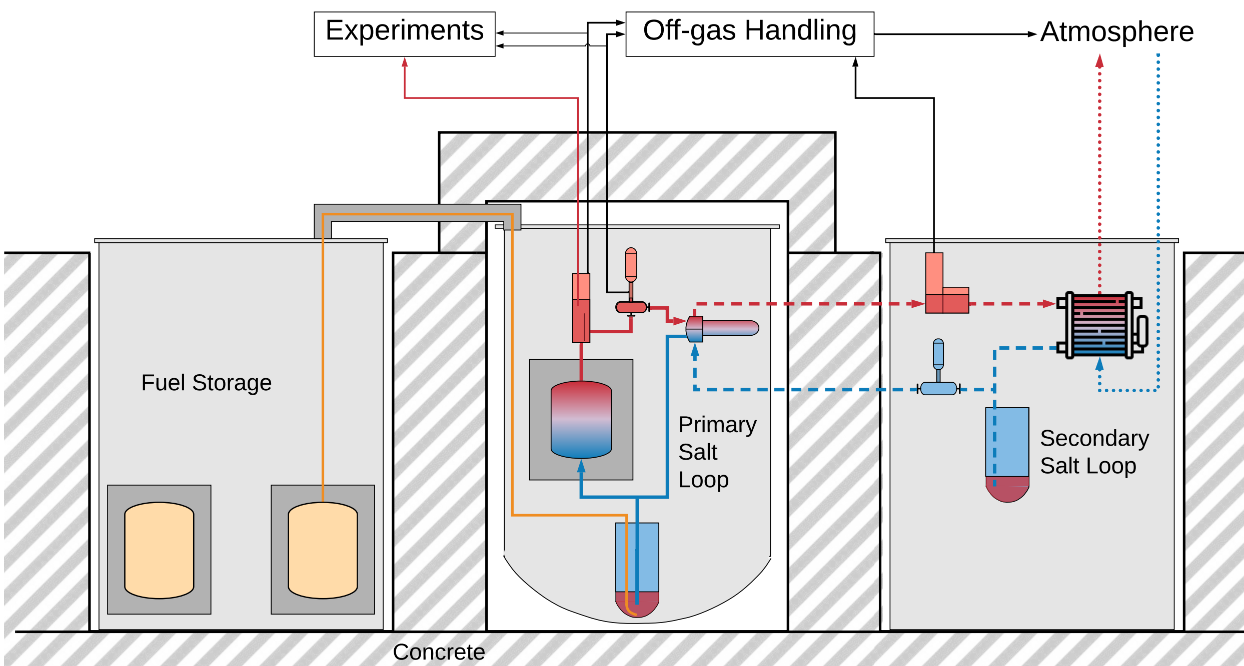
Fuel Characteristics



- $LiF-BeF_2-UF_4$ is the anticipated fuel
- HALEU (~19.5%) will be used.
- Lithium enrichment greater than 99.99%.

Fuel Handling System (FHS)

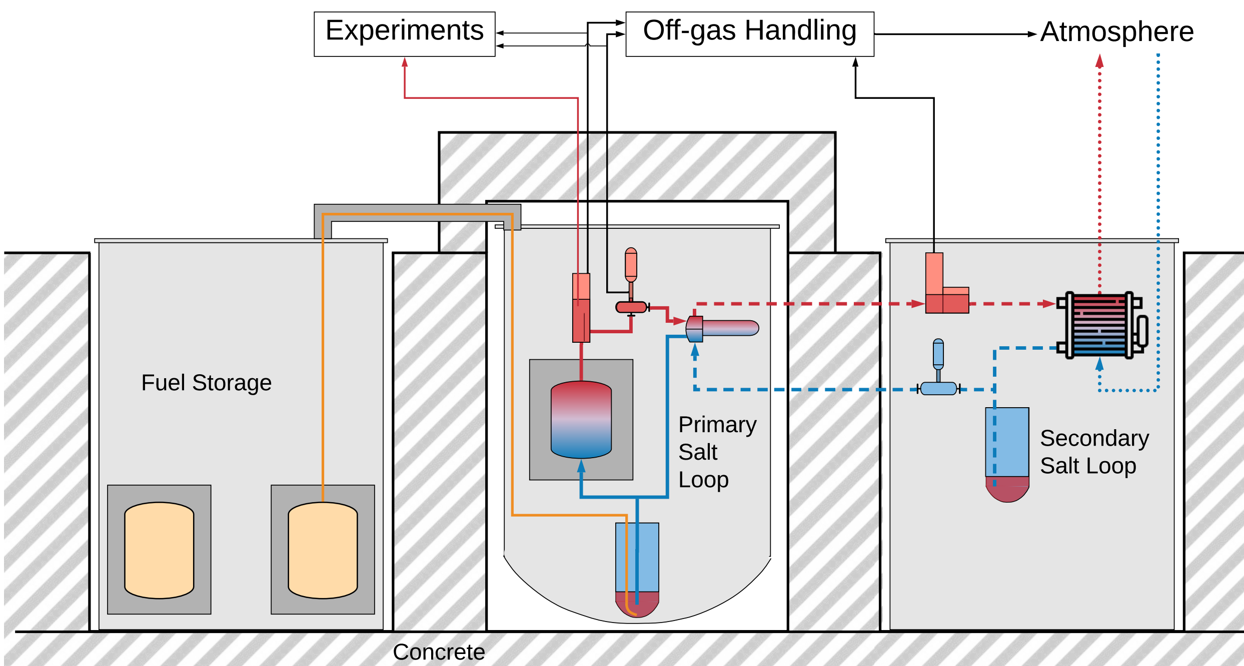
NEXT
Nuclear Energy eXperimental Testing



- The MSRR design employs Defense-In-Depth (DID) approach. The FHS will be designed with multiple physical barriers.
- The fuel handling system is connected to the reactor subsystem through the drain tank.
- Because the FHS is a supporting auxiliary system located external to the MSRR reactor containment vessel, the FHS will need its own suitably designed containment.

Heat Removal

NEXT
Nuclear Energy eXperimental Testing



- Reactor power will be rejected through a heat exchange to a secondary salt loop.
- Outer wall of containment vessel is actively cooled with air.
- Cooling during an accident or power outage will be completely passive.

MSRR Safety Features

Nuclear Energy eXperimental Testing

- ✓ Low power system (1 MW_{th})
- ✓ Low reactor power density
- ✓ Large thermal capacity
- ✓ Fuel salt maximum temperature less than 700° C
- ✓ No strong pressure differentials
- ✓ Leak-tight, low operating pressure, high design-pressure secondary containment vessel
- ✓ No freeze valves separating drain tank and reactor enabling rapid removal of fuel salt from system through loss of drain tank pressure
- ✓ Completely passive decay heat removal under normal and accident conditions

THANK YOU

acunextlab.org

ABILENE CHRISTIAN UNIVERSITY

NEXTRA

From Doubt to Astonishment
- Galilieo

Natura Resources Sustainable Energy

Develop Abilene
Development Corporation of Abilene

Excelsior

U.S. DEPARTMENT OF ENERGY