LANL Microreactors

History, capabilities, and current directions with Westinghouse/SCO

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Managed by Triad National Security, LLC for the U.S. Department of Energy's NNSA

Los Alamos National Laboratory Participants Background of Interest

Matt Griffin, Applied Energy Program Manager

- Leading Westinghouse endeavors
  - Design, testing
- Led Nuclear Facility Safety activities
- Led radiation protection activities including technical oversite for the largest, most diverse nuclear site
- Participated in and managed
  - Reactor design/testing
  - Nonproliferation/safeguards

Pat McClure, over 30 years of engineering leadership experience

- Led, created, and taught risk/safety analysis/licensing implementation and regulations
- Heat Pipe Reactor inventor/designer/leader
- Kilopower/KRUSTY Lead
  - Designed, built, tested a heat pipe reactor

History of LANL special purpose reactors

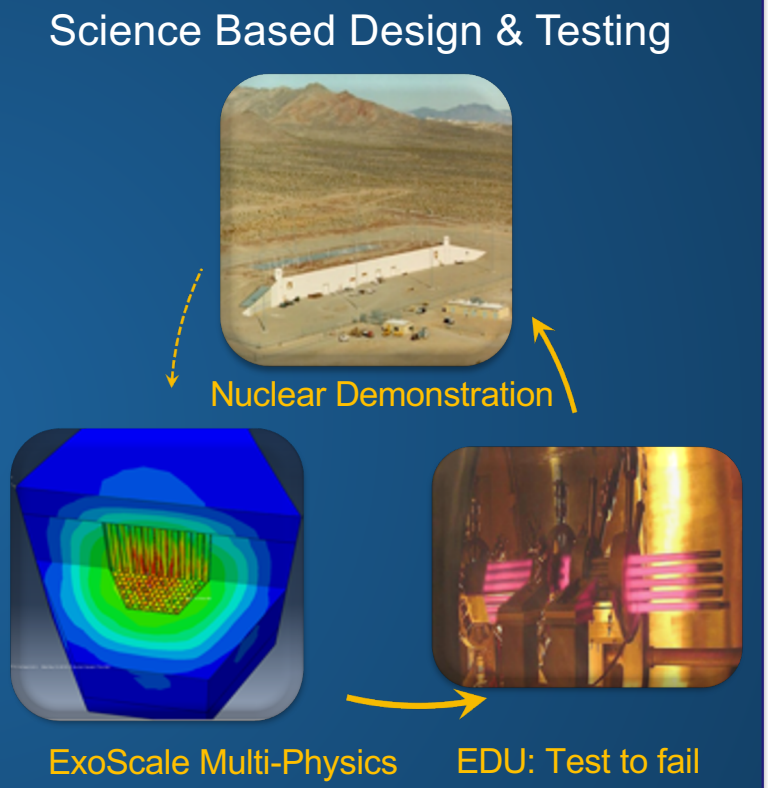
- 70 years of applicable work
- Designed, built, and tested more than 50 variants of nuclear reactors
- At one time over ¼ of the laboratories budget was directed towards special purpose reactors
- Many design options
  - Gas cooled, Molten salt, etc.
  - Recent focus on heat pipe micro reactor designs
    - Heat pipes were invented at Los Alamos in 1963
    - Micro reactors have a niche market where they can compete

Los Alamos has always occupied a central role at the interface of nuclear energy, criticality safety, and national security

- Nuclear physics and associated theory and codes
- Nuclear experiments
- Nuclear and specialty materials
- Criticality safety
- Nuclear reactor design and demonstration
- Materials modeling and simulation
- Design and operation of nuclear facilities and handling processes
- Nuclear instrumentation
- Radiochemistry
- Nuclear Safeguards

LANL has unique capabilities to DESIGN, BUILD, and TEST special purpose reactors

- Coupling decades of experience with the best computational and scientific tools
- Leveraging existing NNSA resources to provide relatively inexpensive design, computing evaluations, and testing
- With a long history of innovation in nuclear, space, and energy technologies; ***Los Alamos has the expertise to foster the transformation of novel design into operational reality***



We have successfully tested - KRUSTY

The 2017 KRUSTY Test was the first American nuclear demo on space reactors in recent history

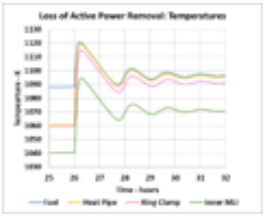
Tested at the Nevada Test Site:

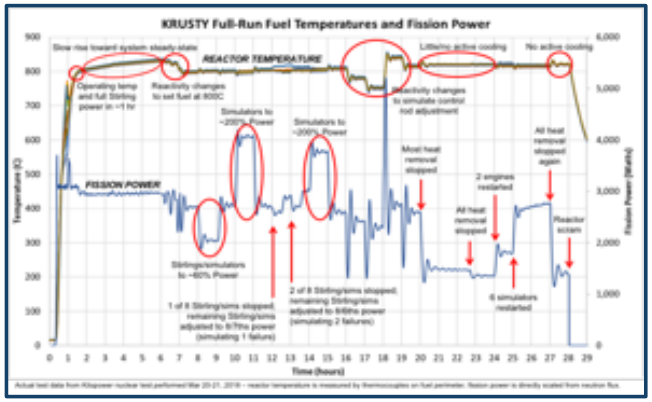
- Component Criticals
- Cold Criticals
- Warm Criticals
- Full Nuclear Power Run

Demonstration Accomplishments:

- Start-up, stability, and steady-state performance.
- Self-regulation
- Fault tolerance
- Remain operational after acute failure of all active heat removal
- Confirmed predictive modeling capabilities

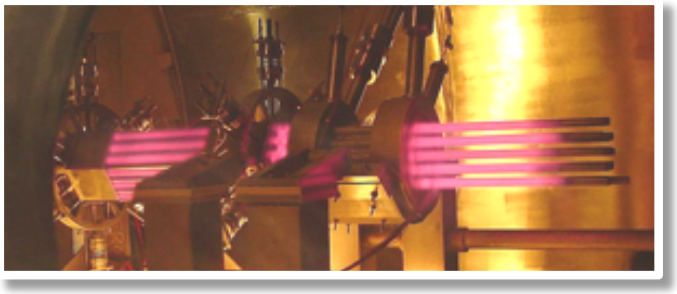
We achieved all of this in a 3 year cycle





Why the heat pipe reactor design?

- **For small special purpose designs the heat pipe is an ideal match**
- **Heat pipe reactors are simple, reliable, and robust**
  - Eliminates components associated with pumped loops; simplifies integration
  - Fault tolerant power and heat transport system
  - Options to preclude single point failure
  - Options to create self regulating systems
  - Ease of operations in remote locations
  - Passive cooling, walk away safe



- **Fuel and power conversion agnostic**
- **Low cost testing and demonstration**
  - Non-nuclear system demonstration requires very little infrastructure and power.
  - Nuclear demonstrations can be accommodated in existing facilities, the thermal power and physical size can fit within current activities at the Nevada National Security Site.

Focusing on established technologies and following the physics

Designs prioritize simplicity and ease of building/testing by combining existing technologies and following well-known nuclear physics, eliminating the need for complicated control systems

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eVinci – Following the physics to next level

LANL has partnered with Westinghouse

Westinghouse is advancing design components and aggressively pursuing commercialization of Microreactors

Applications include disaster relief, remote research, economic development, defense

LANL/Westinghouse Heat Pipe Reactor Activities

- TCF CRADA: Reactor Designs, Component Technologies
- ARPA-E: Reactor technology advancements
- FOA-1817: Nuclear Demonstration
- DoD SCO: Mobile heat pipe reactor
  - TRISO based 1-10MWe Mobile Nuclear Reactor
    - 11 Month Award for Preliminary Design
    - Specified fuel (TRISO), 7 day safe transport, ISO CONEX box, Semiautonomous
  - LANL supporting- Core design/materials/components, licensing, safety, attack resistance, non-proliferation/safeguards
- Future:
  - Commercial continuation
  - Follow on for SCO
  - Other military applications….

SCO- Mobile Reactor

- Preliminary design within 11 Months
  - Three current vendor teams
- Key design attributes required by SCO
  - < 40 tons in ISO containers (C-17)
  - HALEU TRISO AGR Fuel
  - 1-10 MWe
  - Minimal battle damage response
  - Minimized proliferation
  - Ultimate heat sink
  - Inherently safe

Resilient reliable power

Uninterrupted clean power for key needs
Consistent regardless of external factors
Options that don't require specialized operators
Ability to run for years without supplies
Alternatives for applications of all types

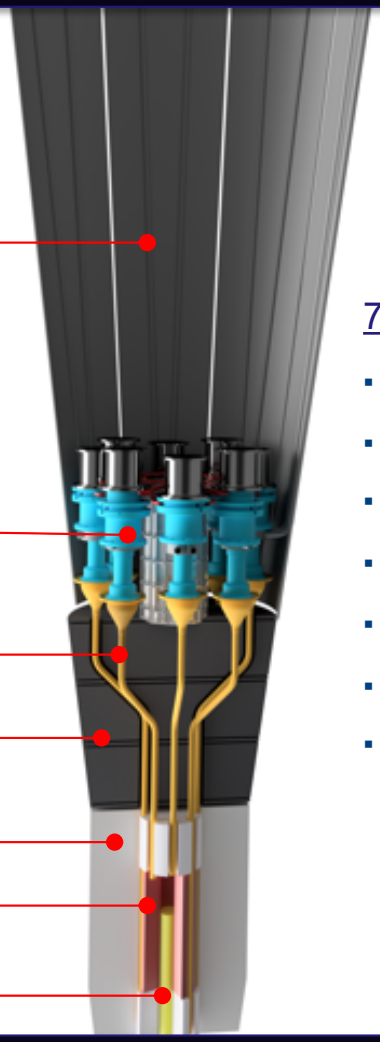
"Fuel convoys are easy targets… Nearly half of all American deaths in Iraq and almost 40 % of deaths in Afghanistan" (Forbes, 2009)

Safety and Security Considerations
Military Microreactor

- Potential risks currently managed throughout the world
  - 220 research reactors in 53 countries
  - 440 power reactors around the world
- U.S. Military has applicable experience
  - Air Force- Transporting/protecting nuclear material
  - Nuclear navy
  - Army- 8 reactors, White Sands
- Standard Safety Analysis & Threat Assessments
  - Drive appropriate controls
  - Ensure safety/security programs

BACK UP SLIDES

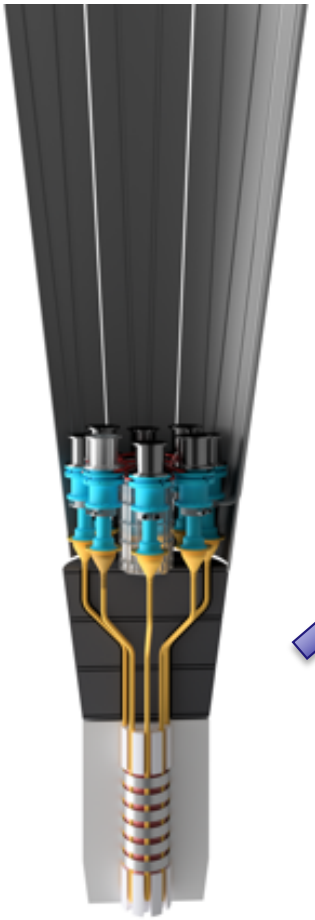
Kilopower – Reactor Concept for Deep Space



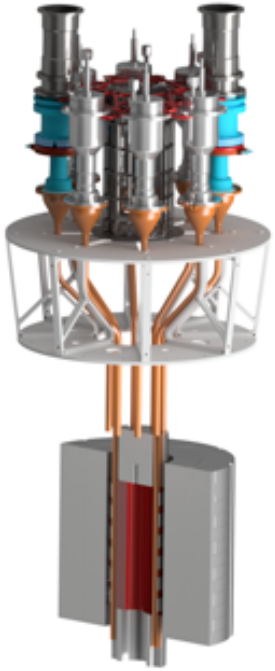
7 COMPENENTS

- Core
- Neutron reflector
- Heat pipes
- Radiation shielding
- Start-stop rod
- Stirling engine convertors
- Radiator to remove excess heat

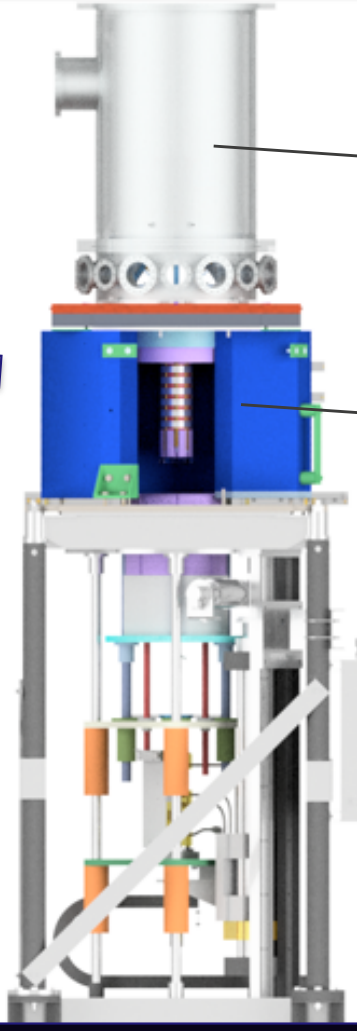
KRUSTY: Kilopower Reactor Using Stirling TechnologY



Flight Concept



Flight
Prototypic
Power System



Vacuum Chamber
for Simulated Space
Environment

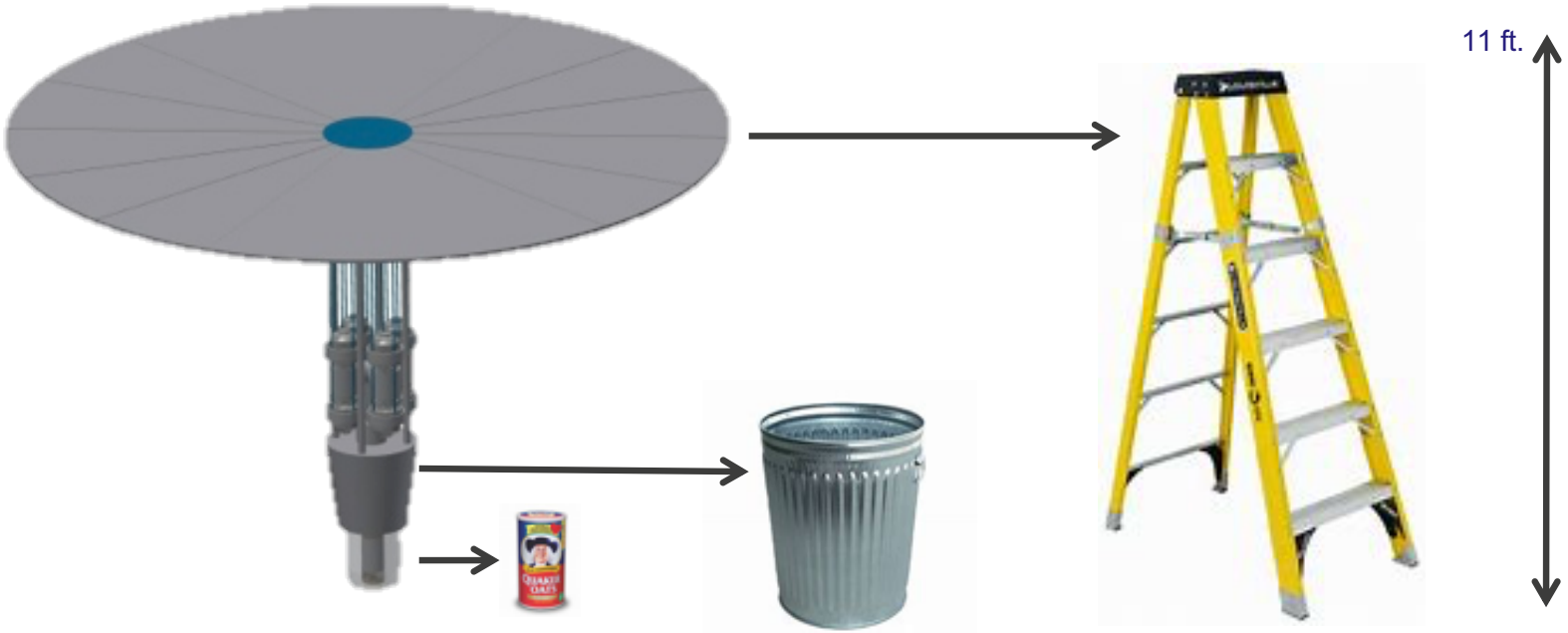
Facility Shielding

COMET
Machine used to
start and stop
reactor by lifting
reflectors
around core

KRUSTY
Experimental Setup

How big is Kilopower?

10 kilowatt electric Kilopower reactor



Oatmeal Box = Core

Trash Can = Reactor

Very Tall Step Ladder = System Height

Innovative and Elegantly Simple Design

We followed the physics - letting the reactor run itself

By combining Heat pipe technology and solid fuel – our reactor designs are;

- *Simple*
- *Compact*
- *Lightweight*
- *Reliable*
- *Efficient*
- *And <u>self-regulating through fundamental physical changes</u>*

LANL's reactor design was taken critical during LANL/NASA experiments at the Device Assembly Facility (DAF) in Nevada:
<u>The design and the underlying physics have been validated.</u>