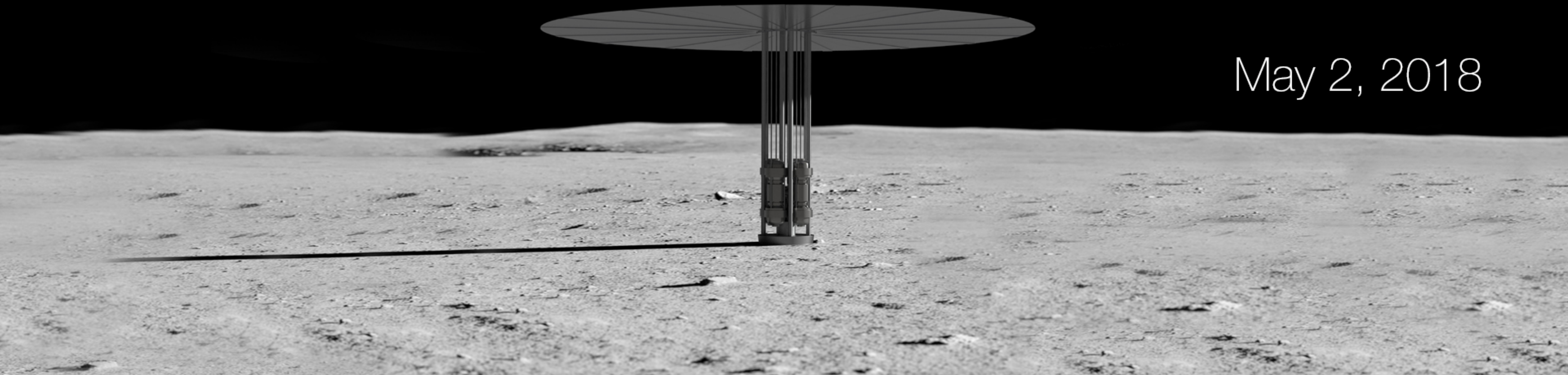
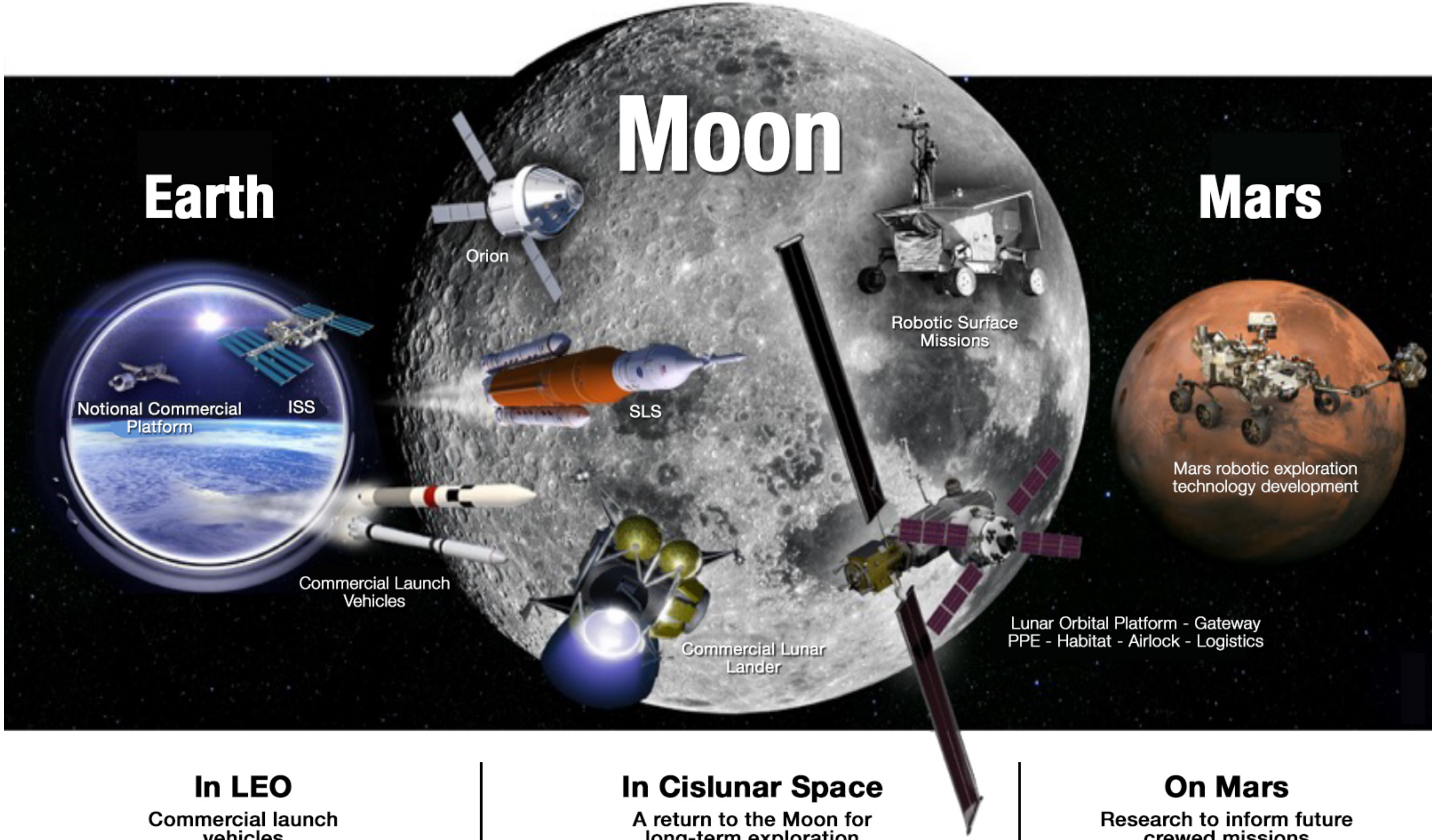
National Aeronautics and Space Administration

Welcome
to the Kilopower Press Conference

May 2, 2018



Future of NASA Space Exploration



In LEO
Commercial launch vehicles

In Cislunar Space
A return to the Moon for long-term exploration

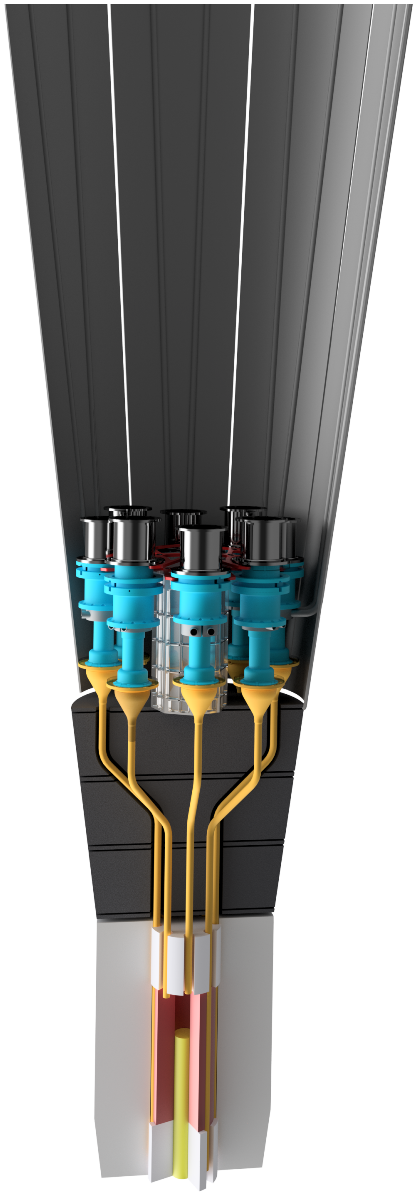
On Mars
Research to inform future crewed missions

Marc Gibson
NASA's Glenn Research Center

Kilopower Reactor
Development and Testing

Kilopower 1-3 kWe Multi-Mission

1000 W: 400 kg



Titanium/Water Heat Pipe Radiator

Stirling Power Conversion System

Haynes 230/Sodium Heat Pipes (Reactor Coolant)

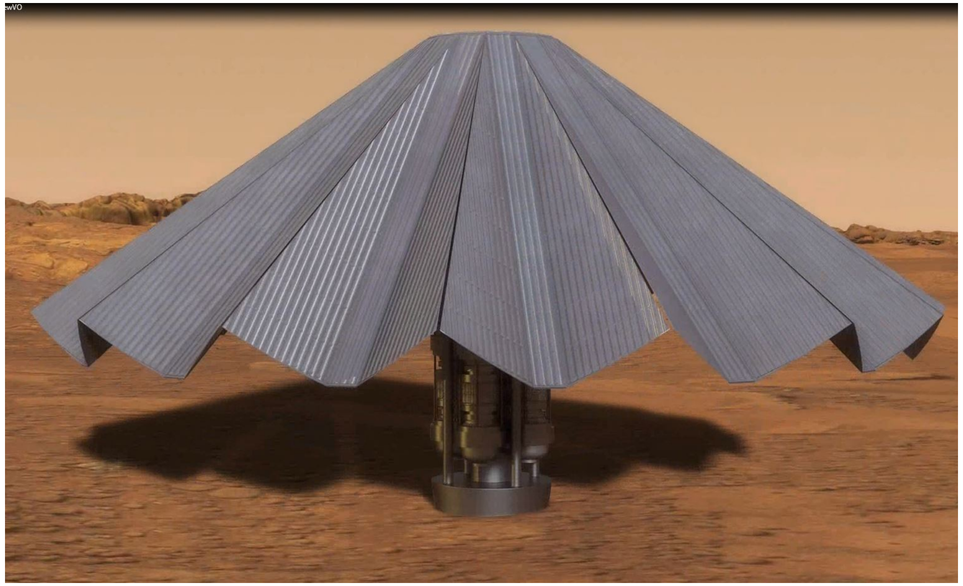
Lithium Hydride/Tungsten Shielding

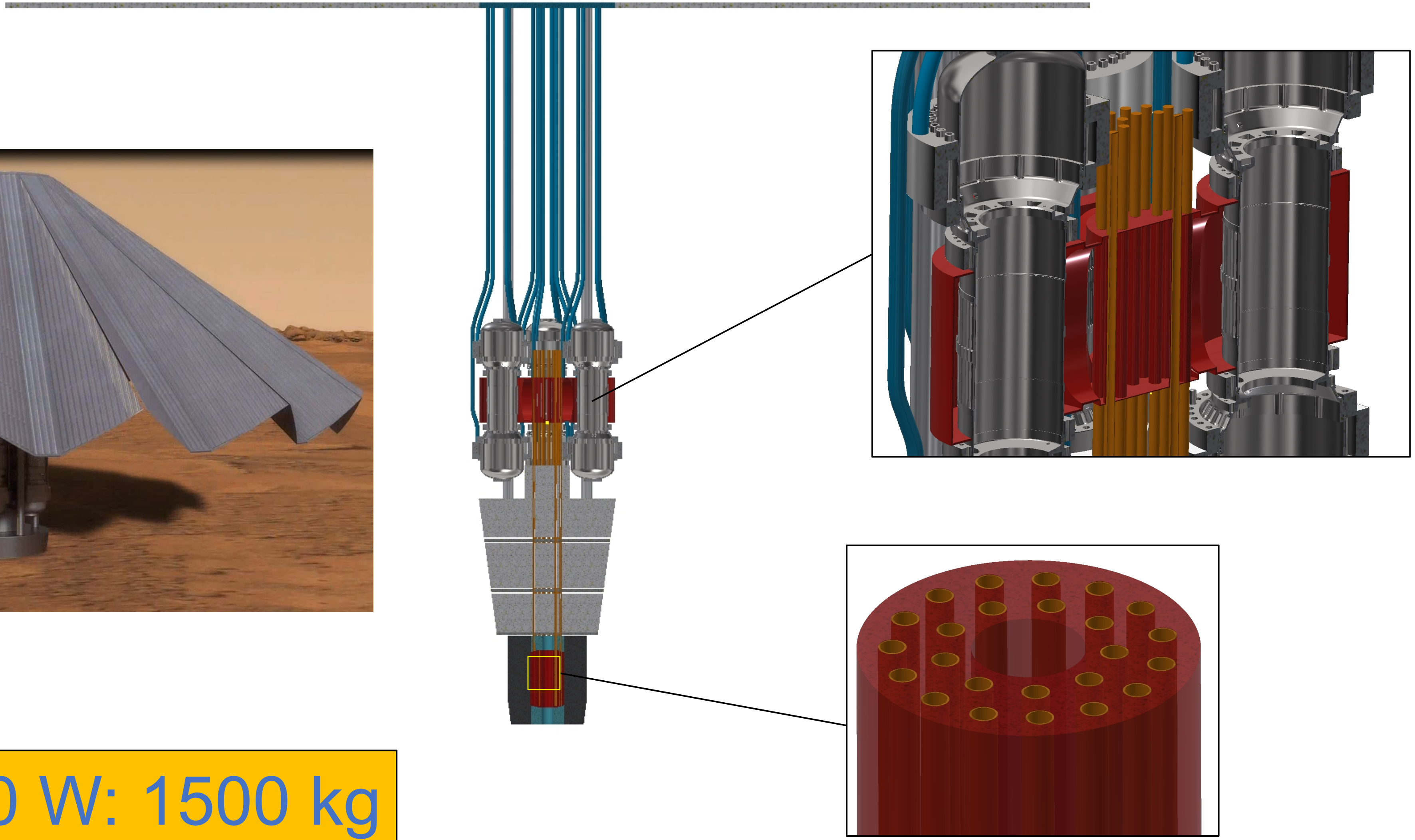
Beryllium Oxide Neutron Reflector

Uranium Molybdenum Cast Metal Fuel

B_4C Neutron Absorber Control Rod

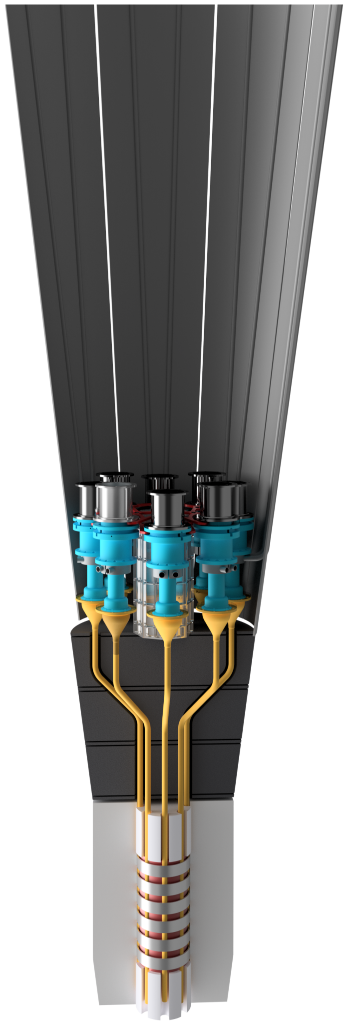
3-10 kWe Surface Concept



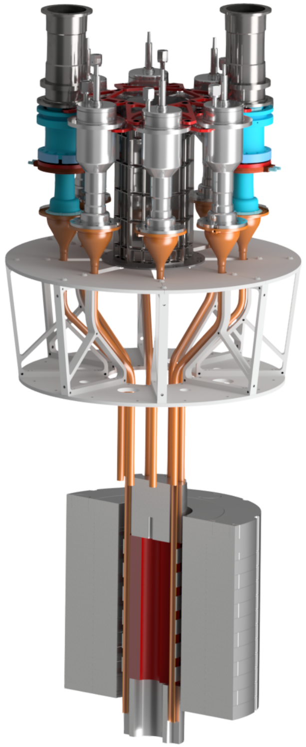


10,000 W: 1500 kg

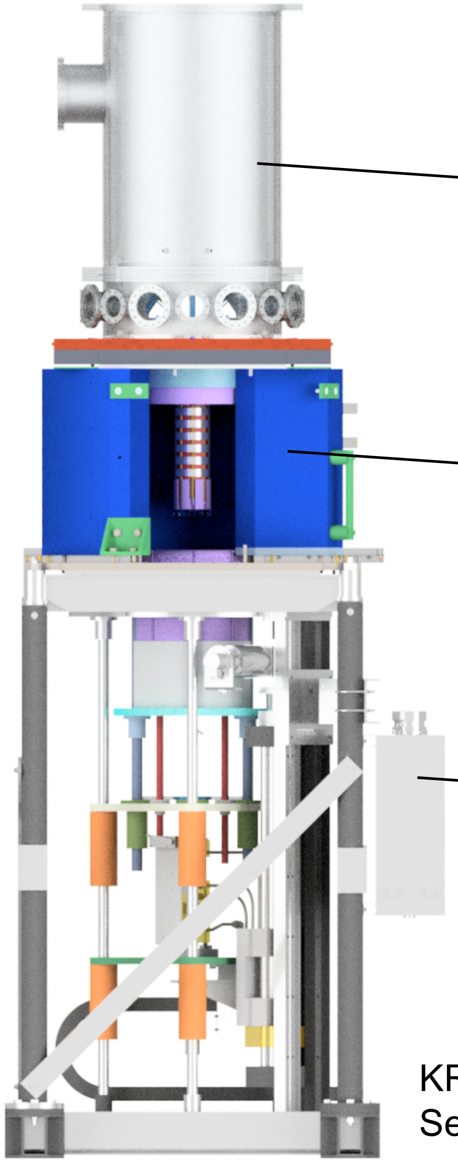
KRUSTY: Kilopower Reactor Using Stirling TechnologY



Flight Concept



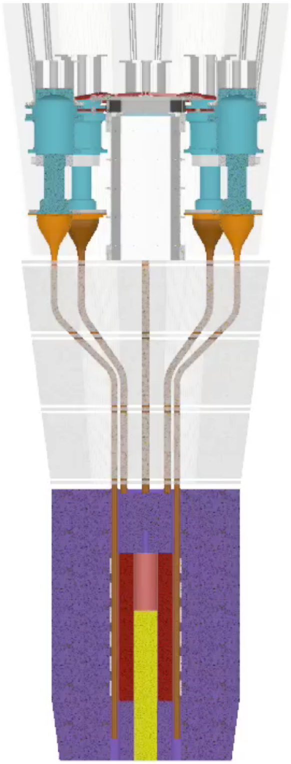
Flight Prototypic Power System

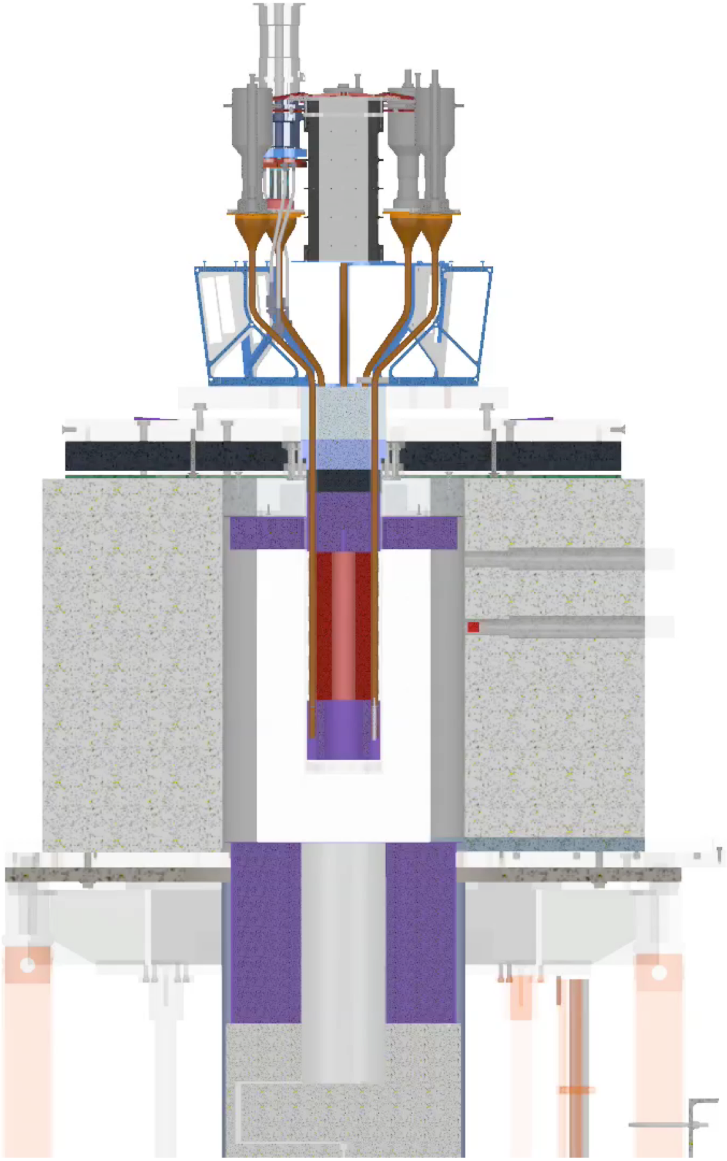


KRUSTY Experimental Setup

Flight vs. KRUSTY

Flight Unit



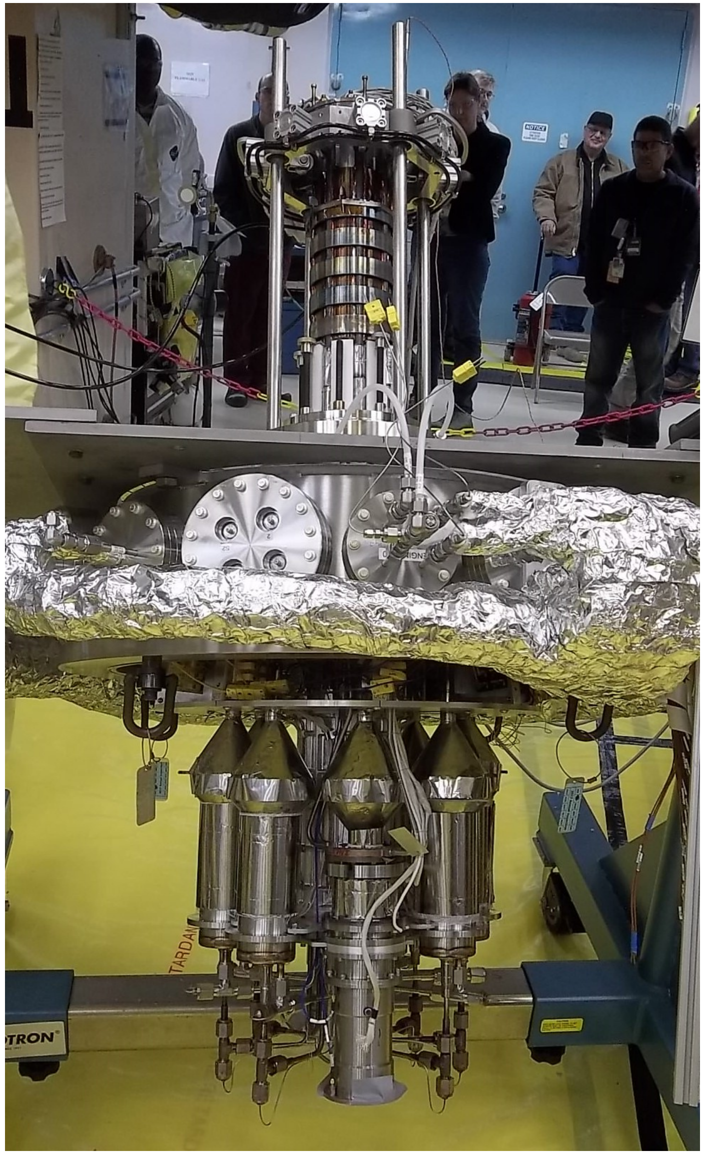


KRUSTY
Experiment

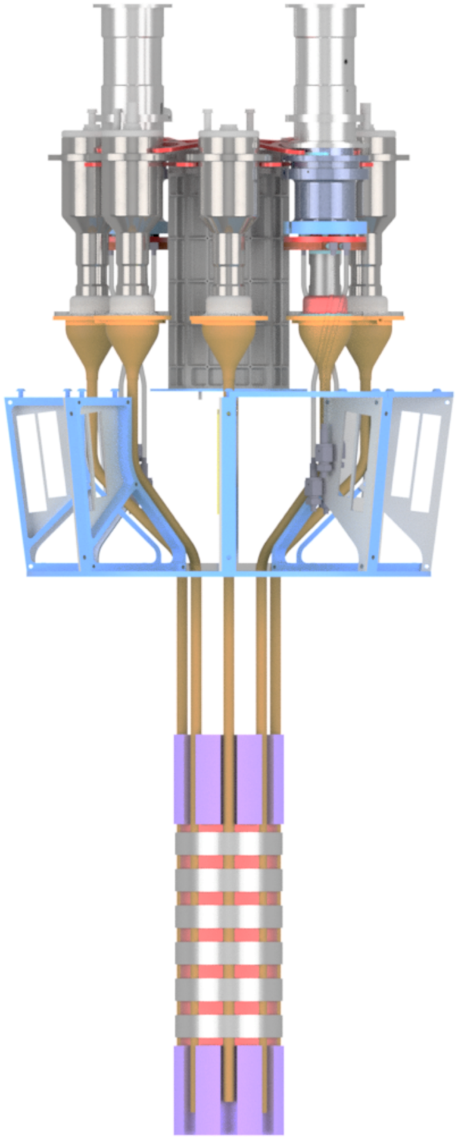
KRUSTY Performance Metrics

Event Scenario	Performance Metric	KRUSTY Experiment	Performance Status
Reactor Startup	3 hours to 800 deg. C	1.5 hours to 800 deg. C	Exceeds
Steady State Performance	4 kWt at 800 deg. C	> 4 kWt at 800 deg. C	Exceeds
Total Loss of Coolant	< 50 deg. C transient	< 15 deg. C transient	Exceeds
Maximum Coolant	< 50 deg. C transient	< 10 deg. C transient	Exceeds
Convertor Efficiency	> 25 %	> 35 %	Exceeds
Convertor Operation	Start, Stop, Hold, Restart	Start, Stop, Hold, Restart	Meets
System Electric Power Turn Down Ratio	> 2:1 (half power)	> 16:1	Exceeds

Reactor Assembly



Experiment Assembly



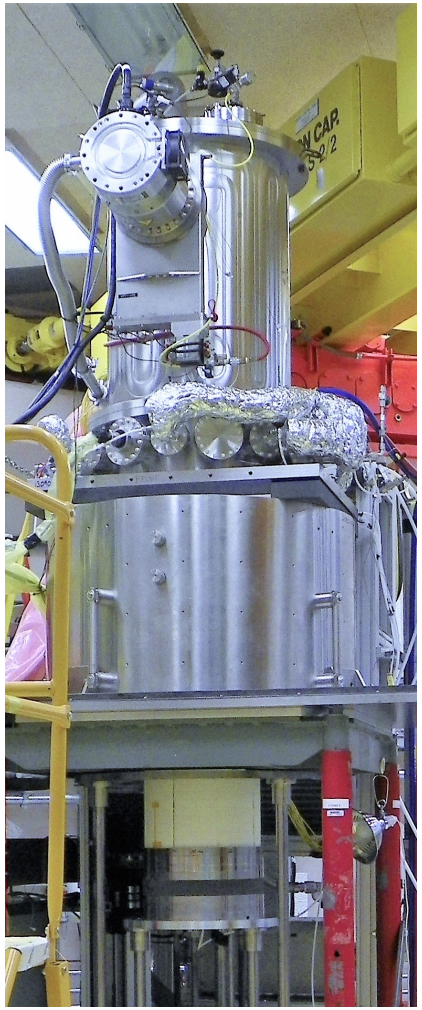
David Poston
Los Alamos National Laboratory

KRUSTY Test Results

KRUSTY: Summary of Nuclear Experiments

KRUSTY was conducted in 4 phases over 5 months from November 2017 to March 2018 at the Nevada National Security Site (NNSS).

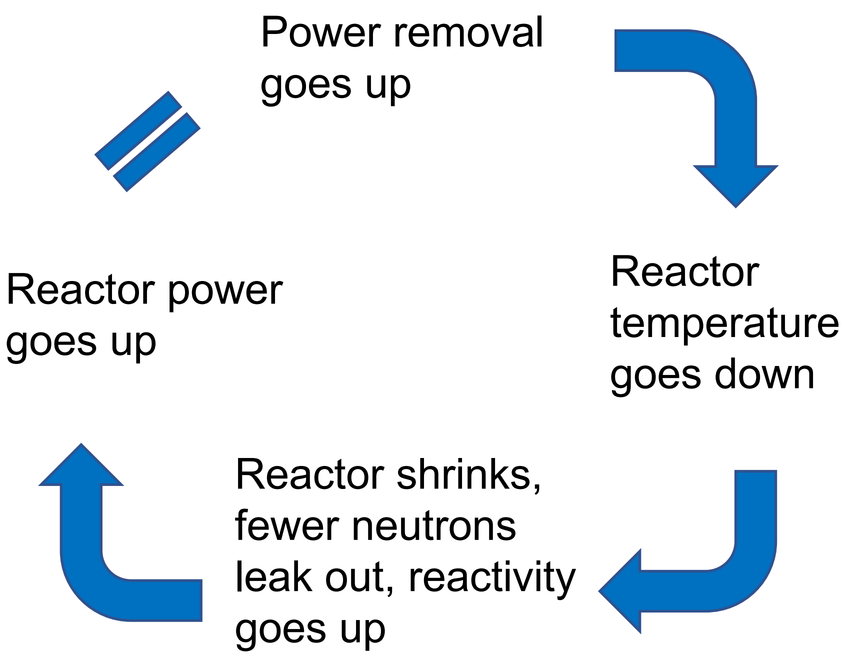
- Component Criticals: Fuel, neutron reflector, shield, and startup rod were placed in dozens of configurations to measure reactivity.
  - Reactivity (neutron multiplication) is measured at “zero-power,” i.e. power is so low that no significant heating occurs.
- Cold Criticals: The KRUSTY heat pipes, clamps, insulation, vacuum-vessel were added, and many more zero-power criticals performed.
  - Data used to help determine how much reactivity was actually added during the heated tests.
- Warm Criticals: Fission power was used to heat the core to incrementally higher temperatures.
  - Results were used as a go/no-go for full-power and temperature testing.
- Full-Power Run: A notional mission profile was simulated including reactor start up, ramp to full power, steady state operation at ~800 degrees C, several operational transients, and shut down.
  - Demonstrated steady-state and transient performance.



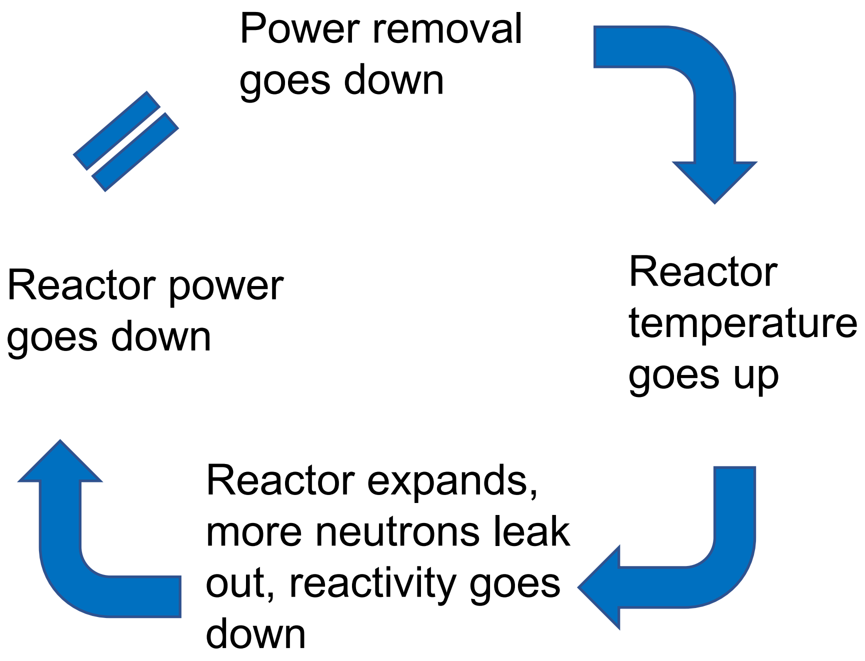
Kilopower Reactors are Self-Regulating

KRUSTY and all Kilopower reactors are designed to passively accommodate all possible states of the power-conversion system, including worst-case failures.

Stirling Engines Draw More Power



Stirling Engines Draw Less Power



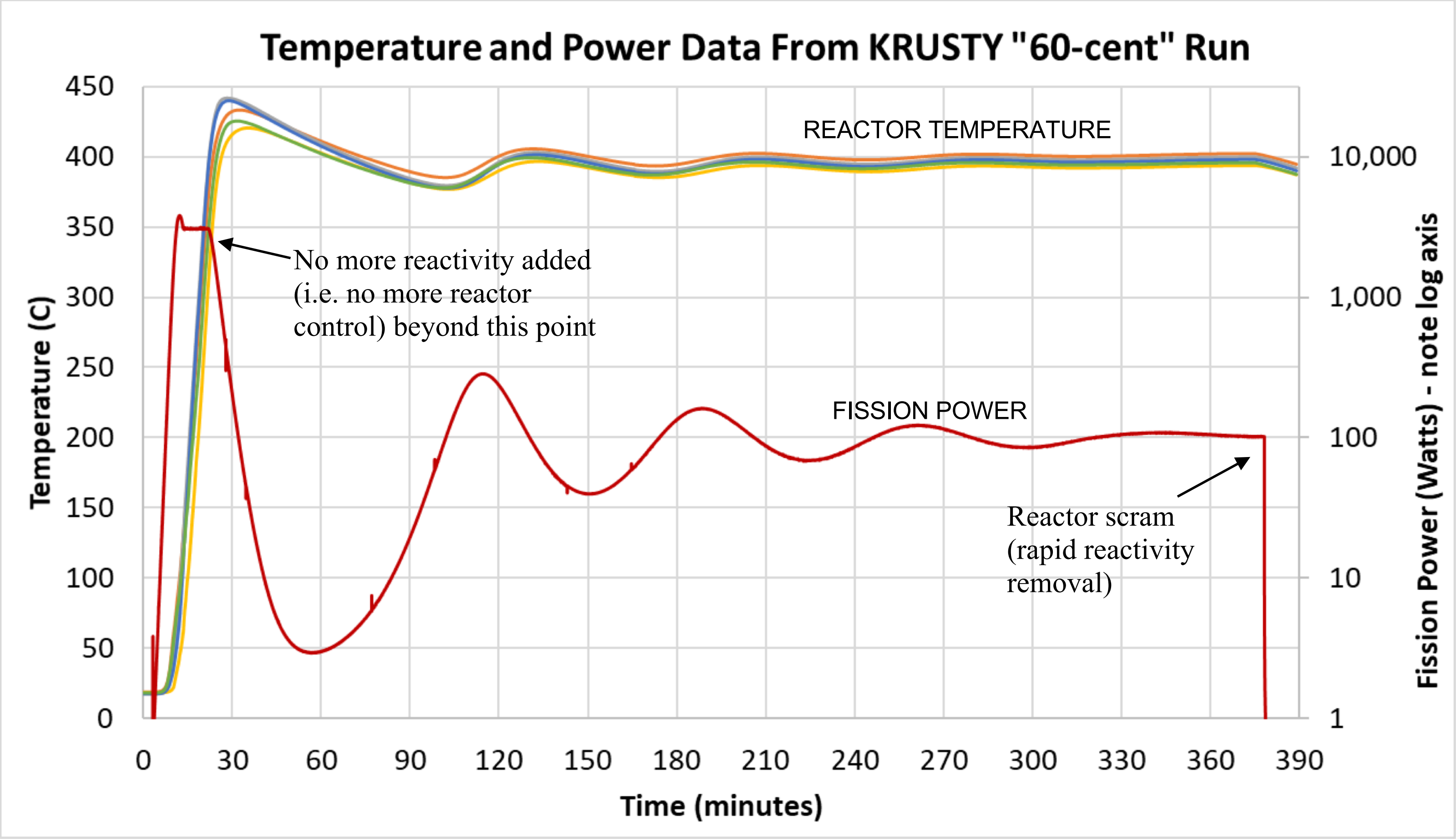
Note: the above occurs via a few dampened oscillations, similar to any classical underdamped stable system.

The bottom line is that the reactor “wants” to stay at a constant temperature, so that if power demand rises, the power will rise to keep the reactor at its “preferred” temperature, or vice-versa.

Warm Criticals Data

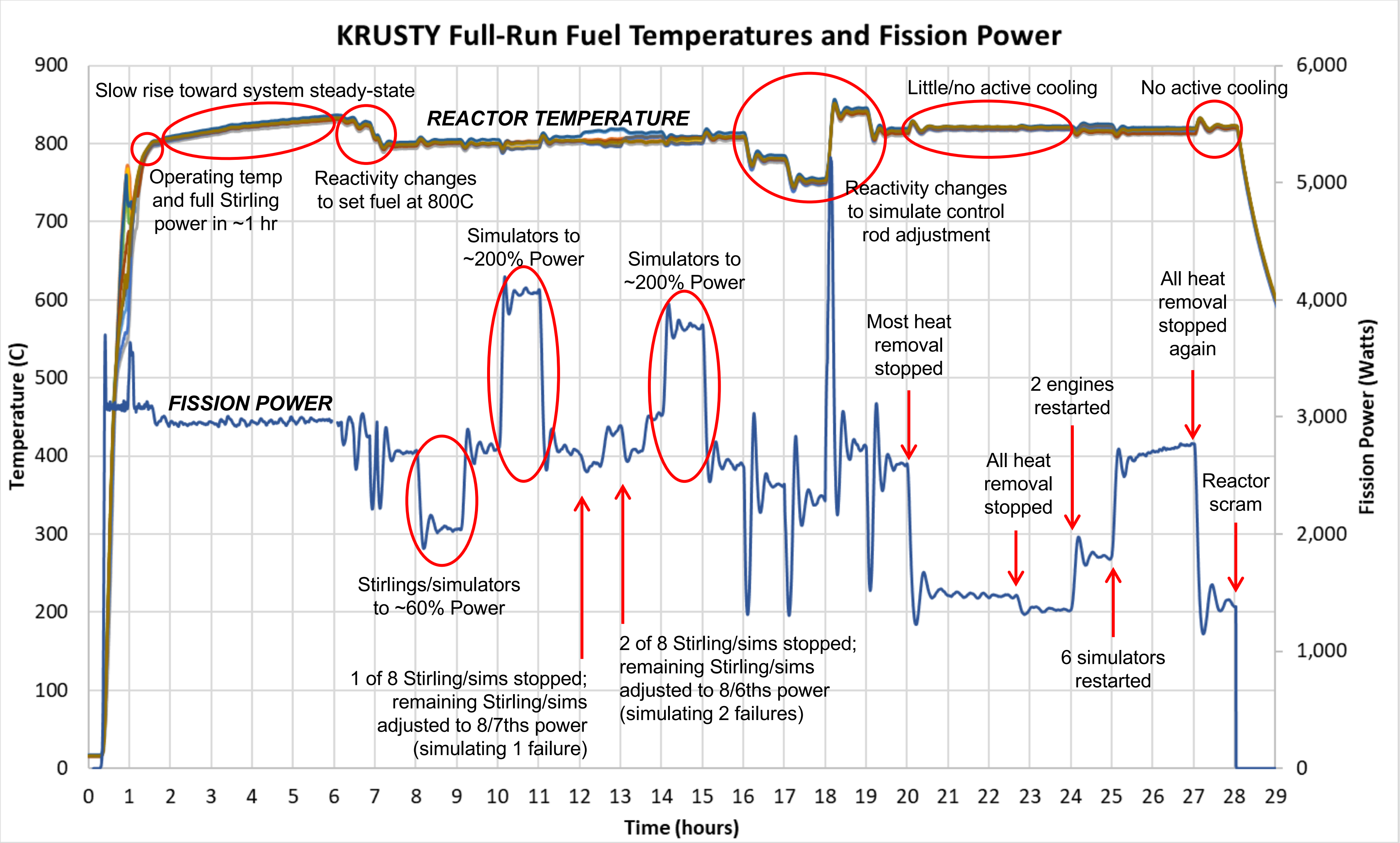
The warm criticals proved the simple, stable, passive behavior of the KRUSTY reactor.

In the case below, the reactivity was set so the fuel wants to maintain a temperature of 400 C.



Note: the period of oscillation is rather long in this example (75 minutes) because the passive power draw is very low (only 100 Watts) – just as lower gravity would make a pendulum take longer to swing back and forth.

KRUSTY Full-Power Run



Actual test data from Kilopower nuclear test performed Mar 20-21, 2018 – reactor temperature is measured by thermocouples on fuel perimeter, fission power is directly scaled from neutron flux.

The Significance of KRUSTY

- KRUSTY was the first nuclear-powered operation of a truly new fission reactor concept in the U.S. in over 40 years.
- KRUSTY provided valuable experience and data.
  - Successfully exercised nuclear infrastructure, expertise, regulatory framework, etc.
  - Data from KRUSTY will help benchmark codes to design and fission systems well beyond Kilopower.
- KRUSTY demonstrated the passive reactor operation of the Kilopower reactor class.
  - The nuclear performance of KRUSTY is highly prototypic to any Kilopower concept between 1 and 10 kWe.
- KRUSTY showed that developing a small reactor is not inherently expensive.
  - A new reactor concept was designed, fabricated and tested for <$20M.
- KRUSTY demonstrated a space reactor concept that can be used for near-term space science and exploration.
- KRUSTY/Kilopower is the first step towards truly astounding space fission capabilities.

Question-and-Answer Session