Kilopower

A small fission reactor for planetary surface and deep space power

Human to Mars Summit

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The Future?

Reactors on Mars – NASA Concept

Picture – NASA Glenn Research

Los Alamos National Laboratory
1 to 10 kWe Kilopower Surface Reactors

- Use multiple 10 kWe units for human missions
- Utilizes a deployable radiator
- Buried configuration at Lunar and Mars surface
- Full shield for lander configurations

10 kW: 1500 kg
How big is Kilopower?

10 kilowatt electric Kilopower reactor

Oatmeal Box = Core
Trash Can = Reactor
Very Tall Step Ladder = System Height

11 ft.
What is needed for Humans to go to Mars

- **Electricity would be used to make:**
  - Propellant to get back to Mars orbit
    - Liquid Oxygen
    - Methane

- **Electricity is needed for:**
  - Oxygen for astronauts
  - Purify water
  - Power of habitat and rover
Why this reactor design?

- **Very simple, reliable design**
  - Self-regulating design using simple reactor physics
  - The power is so low there should be no measurable nuclear effects
  - Low power allows small temperature gradients and stresses, and high tolerance to any potential transient

- **Available fuel with existing Infrastructure**

- **Heat pipe reactors are simple, reliable, and robust**
  - Eliminates components associated with pumped loops; simplifies integration
  - Fault tolerant power and heat transport system
  - The only reactor startup action is to withdraw reactivity control

- **Systems use existing thermoelectric or Stirling engine technology and design**

- **Low cost testing and demonstration**
  - Non-nuclear system demonstration requires very little infrastructure and power.
  - Nuclear demonstration accommodated in existing facility, the thermal power and physical size fits within current activities at the Nevada National Security Site.
Self Regulating Reactor

**Increasing Electric Power Draw**
- More Power demand
- Power from reactor goes up
- Reactor gets smaller, less neutrons leak out, reactivity goes up
- temperature goes down

**Decreasing Electric Power Draw**
- Less Power demand
- Power from reactor goes down
- Reactor gets larger, more neutrons leak out, reactivity goes down
- temperature goes up
• A reactor that has not undergone fission, (been turned on), has very very low safety concerns. It will have from 1 to 10’s of curies of naturally occurring radioactivity

• This is 1,000s to 10,000s times lower radioactivity than in current radioisotope systems already flown in space

• Launch accidents will have consequences 100’s of times less than background radiation or radiation from a commercial plane flight

• After the reactor has fissioned, it will become radioactive
  – Reactors would only be used in deep space, very high Earth orbit (long term decay) and on other planets.
Kilopower Reactor Using Stirling Technology = KRUSTY – Nuclear Demonstration Experiment

- Designed with space flight-like components
  - Uranium core, neutron reflector, heat pipes, Stirling engines
- Tested at flight-like conditions
  - In a vacuum
  - Design thermal power
  - Design temperature
  - Design system dynamics
- Performs tasks needed for space flight
  - Computer modeling
  - Nuclear test operations
  - Ground safety
  - Transport and assembly
## KRUSTY Performance Metrics

<table>
<thead>
<tr>
<th>Event Scenario</th>
<th>Performance Metric</th>
<th>KRUSTY Experiment</th>
<th>Performance Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reactor Startup</td>
<td>&lt; 3 hours to 800 deg. C</td>
<td>1.5 hours to 800 deg. C</td>
<td>Exceeds</td>
</tr>
<tr>
<td>Steady State Performance</td>
<td>4 kWt at 800 deg. C</td>
<td>&gt; 4 kWt at 800 deg. C</td>
<td>Exceeds</td>
</tr>
<tr>
<td>Total Loss of Coolant</td>
<td>&lt; 50 deg. C transient</td>
<td>&lt; 15 deg. C transient</td>
<td>Exceeds</td>
</tr>
<tr>
<td>Maximum Coolant</td>
<td>&lt; 50 deg. C transient</td>
<td>&lt; 10 deg. C transient</td>
<td>Exceeds</td>
</tr>
<tr>
<td>Convertor Efficiency</td>
<td>&gt; 25 %</td>
<td>&gt; 30 %</td>
<td>Exceeds</td>
</tr>
<tr>
<td>Convertor Operation</td>
<td>Start, Stop, Hold, Restart</td>
<td>Start, Stop, Hold, Restart</td>
<td>Meets</td>
</tr>
<tr>
<td>System Electric Power Turn Down Ratio</td>
<td>&gt; 2:1 (half power)</td>
<td>&gt; 16:1</td>
<td>Exceeds</td>
</tr>
</tbody>
</table>
Current Work

- Project needs a **technology demonstration mission**
- NASA is looking at a reactor on the moon to power an ISRU unit (make propellant)
- Development work on Kilopower system and components is continuing
Conclusions

• KRUSTY test complete!!
  – First real space reactor test in over 50 years
  – Less than 20 million dollars invested
  – Completed in just over 3 years
  – All objectives were met or exceeded

• What does this mean for NASA?
  – The ability to move forward towards a flight mission
  – A proven design capable of providing multiple kilowatts of electrical power for several years or decades