INEST

Institute for Nuclear Energy Science and Technology

Space Nuclear Power

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CORE MISSION

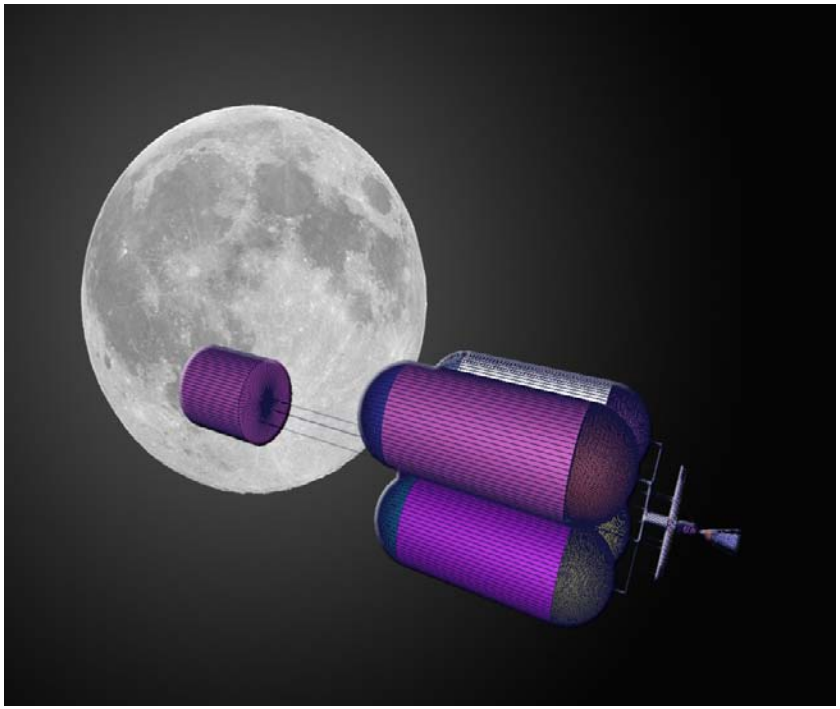
The **mission** of the Space Nuclear Power CORE of the INL INEST is to develop the technology and people needed to implement space nuclear power and propulsion applications and to position INL and CSNR to be win major research programs in space power and propulsion from NASA, DOE, DOD and ESA as the programs become available.

Current projects and sponsors

1) Mars Hopper prototype – INL LDRD
2) NTR fuel fabrication - Aerojet Corp

CORE VISION

The **vision** for the Space Nuclear Power CORE of the Idaho National Laboratory (INL) Institute for Nuclear Energy Science and Technology (INEST) is to become a hub of technology research and development that provides interface between NASA, the INL, industry and universities for nuclear reactor and radioisotope power and propulsion in space.



CURRENT STATE

- Two NRC committees and the most recent NASA Mars Architecture Team (MAT) have recommended that the nuclear thermal rocket be pursued to support human exploration of Mars. The same MAT stated that nuclear power was ENABLING for human exploration of Mars meaning that the mission could not be accomplished by any other means.
- The current administration has terminated the Moon/Mars Mission started by the Bush administration without replacing it with a similarly demanding mission
- Potentially, the lack of a major mission could lead to more investment in technology development
- Space Science will continue
- Industry is showing signs of strategic planning in technology

Current State – Challenges

- What are the near-term and long-term challenges being faced by the nation and/or DOE?)
  - NO funding in DOE for technology development for space
  - The NASA/DOE interface is unproductive for new technology development
  - Lack of Pu-238 production
  - Ability to launch other payloads containing nuclear material, e.g. NTR

OPPORTUNITIES

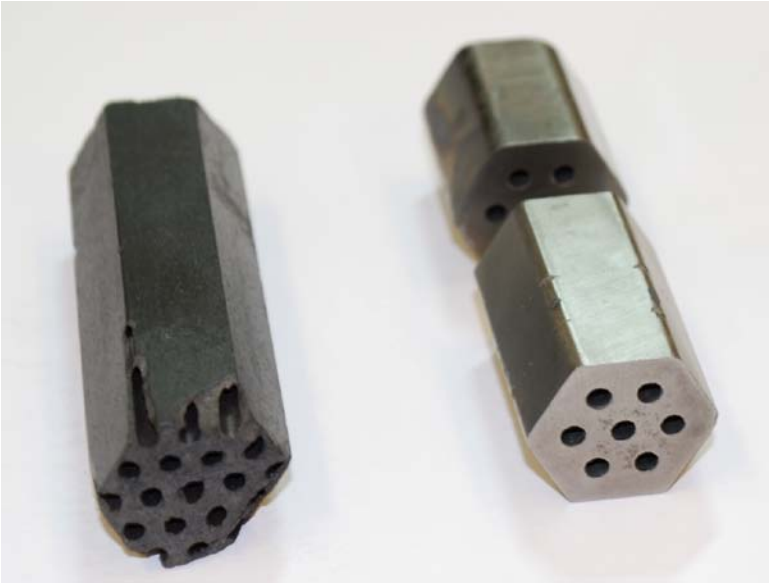
(Including funding opportunities)

Near-Term

- Office of the Chief Technologist has initiated three new technology programs-
  - NIAC,
  - Game Changing, and
  - Technology Demonstration
- Industrial
  - Joint purchase of the SPS/Glove Box with the Aerojet Corp.
- DARPA forward deployed reactor
- NEUP

Long-Term

- NASA SMD of the Hopper
- Mars Sample Return mission
- NTR support
- RTPV development
- RPS for DOD



CAPABILITIES

- INL
  - SPS fabrication
  - Handling of radioisotopes
  - Handling of DU and HEU
  - Computational modeling
  - Testing to TRL-6
- University (include all universities—NUC and others)
  - Early phase testing and system trades
  - Students
  - Research reactors
  - Computational modeling

COMPETITORS

Main competitors in power sources are NASA centers

approach is to collaborate on proposals and establish joint working efforts

Main competitors for nuclear materials are National Laboratories

approach is to lead by rapid development

No other Laboratory or NASA center has a CSNR equivalent that combines the nuclear capability and the power/propulsion technology

FY 2011 GOALS AND OBJECTIVES

Progress on the Mars Hopper LDRD:

- construction of the test rig
- computational modeling of the heat transfer for irregular flow channels
- demonstration of CO2 liquefaction
- design of the power conversion system

- Significant CSNR presence at the Nuclear and Emerging Technologies Symposium (NETS 2011)

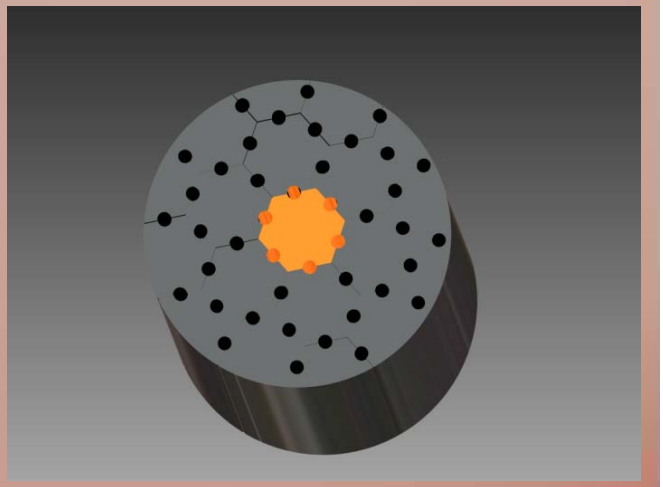
- Execute a successful Summer Fellows program

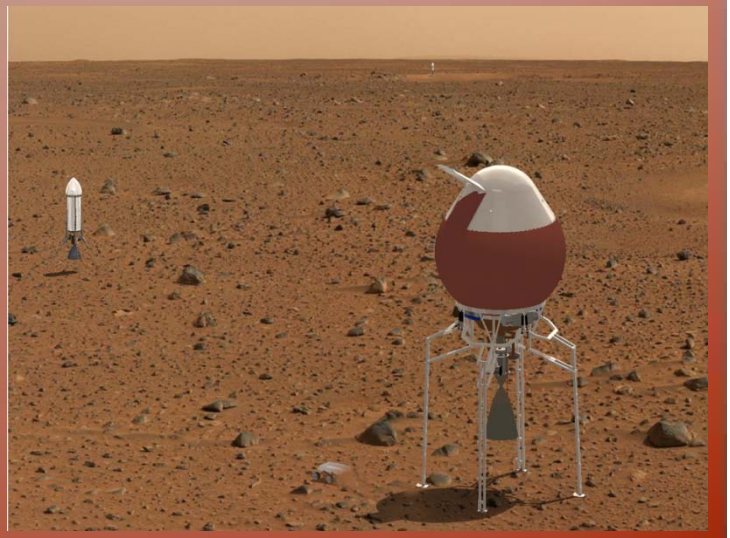
- Acquire visibility at DOE and NASA for the Hopper and NTR

- Publish technical papers

FY 2011 ACCOMPLISHMENTS

- Hopper
  - Test rig designed - all but one part acquired
  - Heat transfer of flow channel geometries modeled in STAR-CCM+ by CSNR and Oregon State
  - Utah State successfully demonstrates CO2 liquefaction
  - Univ. of Idaho team builds Brayton test rig – open vs closed
- NETS – 12 of 90 papers were from CSNR staff or Summer Fellows, with additional papers by Hopper team members
- 2012 Summer Fellows – 16 Fellows accepted from 11 states and 14 universities; 5 topics explored
- Visibility – presentations made to Pete Lyons (DOE), Jim Green (NASA SMD) about Hopper and NTR based MSR
- Publish – 12 NETS papers; one paper in Acta Astronautica, 3 papers in Jour. Of Aerospace Engineering
- Awarded a NIAC grant- 1 of 30 out of 1000 applications
- Industrial supported contract with Aerojet Corp





Accomplishments – Hopper flow channel modeling and optimization

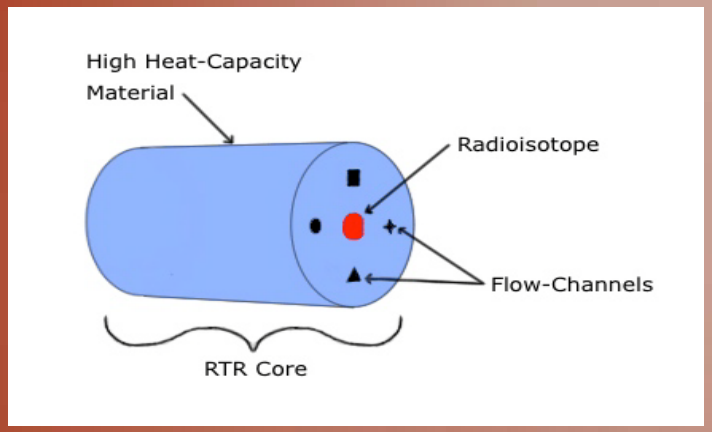


Figure . The RTR core with flow-channels and radioisotope.

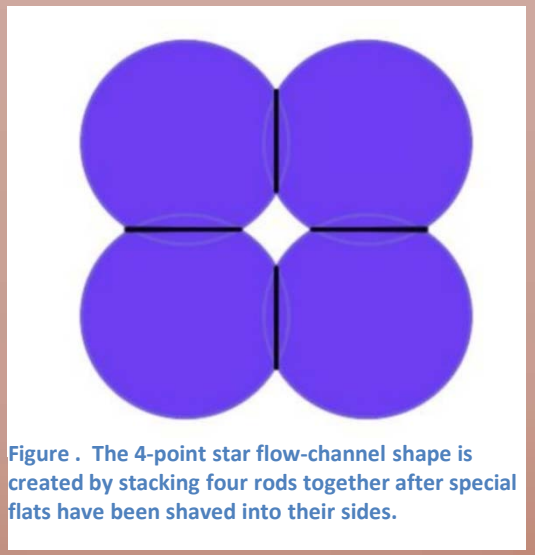


Figure . The 4-point star flow-channel shape is created by stacking four rods together after special flats have been shaved into their sides.

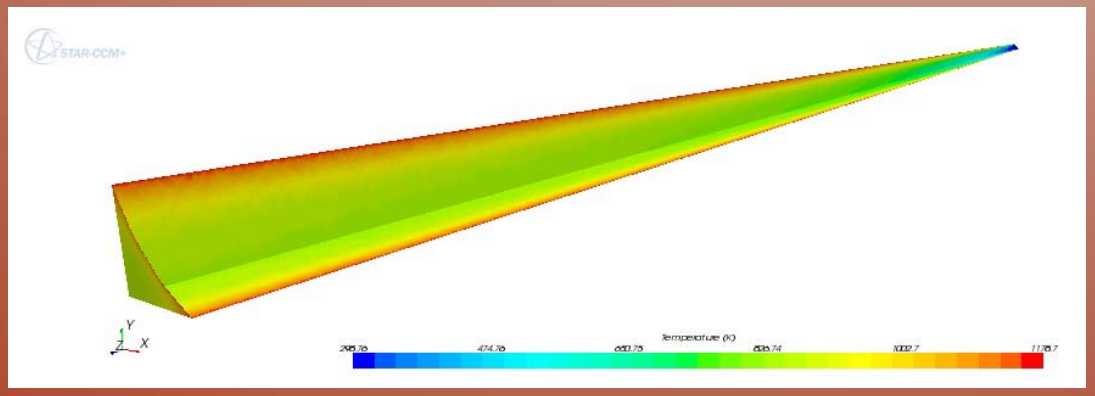
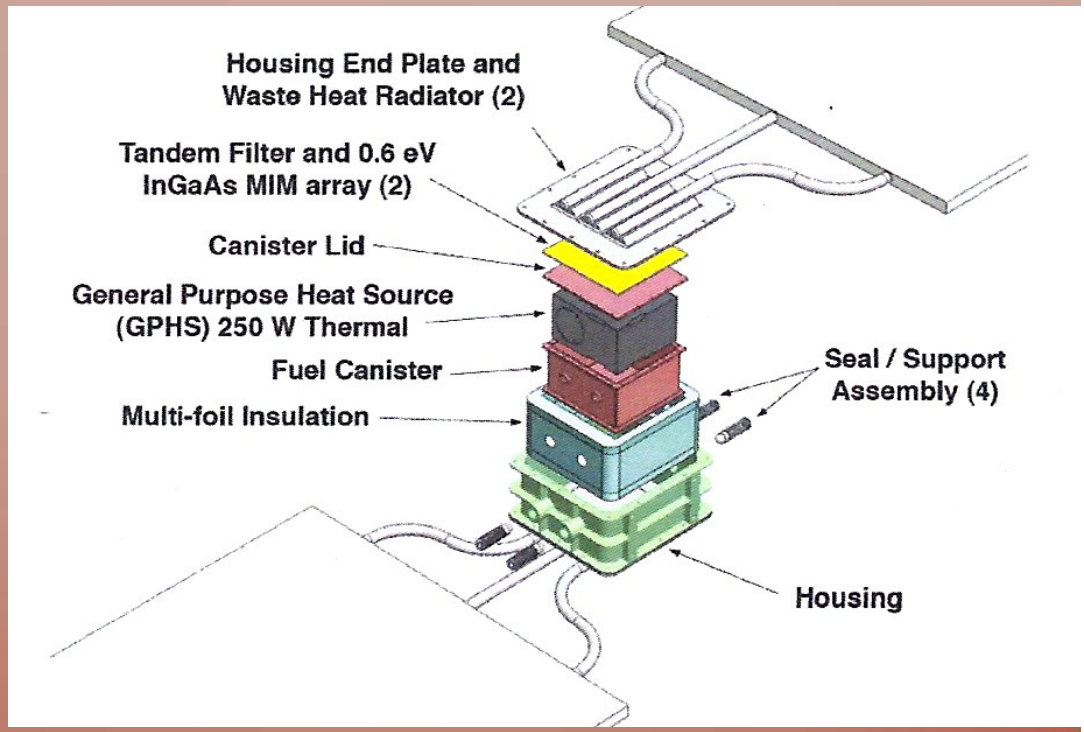


Figure . An example temperature profile for a 4-point star flow-channel. The outlet is on the left.

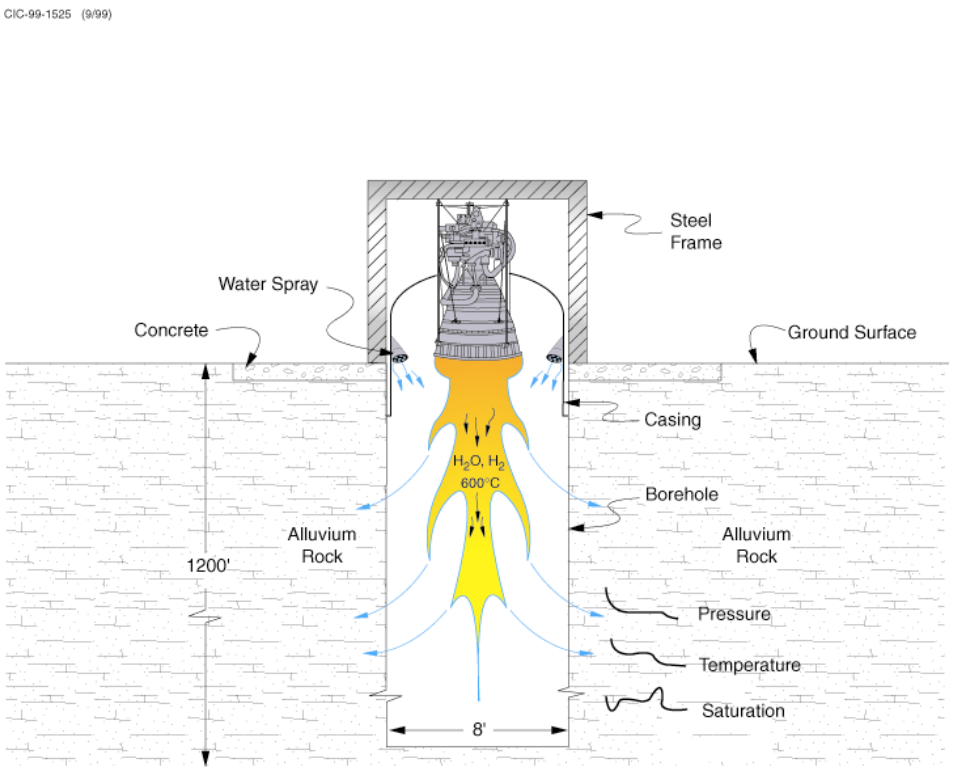
Assessment of the RTPV

- Radioisotope Thermo-Photo-Voltaic (RTPV) conversion offers the possibility of a very low specific mass power source
- NASA GRC has designed a RTPV system based on a GPHS brick – 15 % efficient, 167 kg/kw
- Tungsten encapsulation offers 5 times the power density and variable shape
- CSNR Summer Fellows' study implies the possibility of a 2-3 reduction in mass to around 50-70 kg/kw



Cost of Development– Sub-surface Active Filtering of Exhaust (SAFE) may enable much cheaper ground tests

- Nuclear furnace proved ability to scrub exhaust
- Scaling to full power engines implies a costly facility
- SAFE offers one cheaper option if proven feasible
- If fuel doesn't leak fission products, then test facility is only for off-nominal conditions



FY 2011 CORE FUNDING

	Allocation	How Used
CORE Management	30 K	1 workshop, 1 steering committee meeting
LDRD	322 K	Mars Hopper prototype; 2011 Summer Fellows
Program Development	50 K	Numerous conferences and briefings (see following)
University Contract	20 K	Hopper sub-tasks
Joint Appointment – A. Klein, Oregon State	72 K	CORE Steering Committee Chair, manage and perform Hopper research, promote hopper concept to NASA and others, attend and present Hopper paper at NETS 2011, attend and lead SNP CORE workshop, INEST Advisory Board participation

INEST SNP Workshop

- Held 9/15/2011
- “Future of Space Nuclear Power and Propulsion”
- Representatives from all NUC schools except UNM plus U of Idaho and Boise State.
- NASA GRC and MSFC provided their vision
- Roughly 35 attendees
- Substantial feedback provided by attendees
- Possible collaboration in tungsten fuels for SMRs and naval reactors (MIT)
- SNP announced need for RTPV collaboration

Program Development Activities

- NETS – 12 of 90 papers were CSNR and Fellows; booth
- Briefings to Lyons (DOE), Green (NASA), and Braun (NASA) on CSNR
- Briefings to NASA GRC on RTPV
- organizational meetings with NSTec; tours of NTS for Aerojet
- fact finding meeting at General Atomics on Pu production
- Int'l Astronautics Congress – Prague – presented 2 papers on Hopper and NTR
- 50th anniversary celebration of space nuclear power at Smithsonian
- ANS winter and summer meetings, ANSTD committee; Fellows papers and attendance
- Rocky Mt Space Grant Consortium annual meeting and technical committee

UNIVERSITY CONTRIBUTIONS

- Pursued technical issues in support of the Mars Hopper prototype definition.
- Universities involved included University of Idaho, Oregon State, and Utah State.
- Predominantly senior capstone projects and MS thesis research.
- Oregon State University research includes simulation of the Mars Hopper thermal capacitor to understand the propulsive operational dynamics using the STAR CCM+ software. Models being developed include single and multi-channel configurations to to understand flow dynamics through the channel under various inlet and outlet conditions. Additionally, the models can be used to simulate varying wall roughness and partially blocked channels. One MS student is involved in this research and will this work will form the core of his MS thesis.

FY 2012 GOALS AND OBJECTIVES

- Progress on the Mars Hopper LDRD:
  - Commissioning and testing of the test rig
  - Computational modeling of the heat transfer for irregular flow channels
  - Demonstration of higher throughput CO2 liquefaction
  - Experimental comparison of power conversion systems

- Significant CSNR presence at the Nuclear and Emerging Technologies Symposium (NETS 2012)

- Execute a successful Summer Fellows program

- Acquire NASA support of Hopper design

- Complete NIAC Phase I and acquire Phase II

- Install, commission and utilize new SOPS/glove box combination

- Fulfill fabrication objectives for Aerospace Corp.

FY 2013/2014 GOALS AND OBJECTIVES

Progress on the Mars Hopper:

- complete tests demonstrating viability of the test rig
- Succeed in getting beryllium elements to CAES
- Fly test rig up cable
- acquire NASA support

- Execute a successful Summer Fellows programs

- Acquire NASA support for RTPV demonstration

- fabricate full length NTR fuel elements

- Expand Aerospace Corp. collaboration, acquire other industrial support

- Become recognized as a hub for space nuclear technology development

NEEDS

- INL needs to –
  - continue support of the LDRD projects
  - Support the SNP Core as the INL focus for advanced concept research
- Short term research needed- RTPV; finish Hopper
- Long term research needed – advanced power reactor fuels; alternative isotopes
- Collaborations - more university and industrial
- Educational -- Continue support of the CSNR Summer Fellows program

RISKS AND RISK MANAGEMENT

- Risk – Congress and OMB interaction and stalemate on Pu-238 production
  - Mitigation – investigate private production
- Risk – lack of support by NASA for advanced technology
  - Mitigation – demonstration top TRL 4-5 through LDRD
- Risk – lack of young researchers in space nuclear
  - Mitigation – space nuclear power and propulsion courses; Summer Fellows

MEASURES OF SUCCESS

1) Returning Fellows
2) Funding for technology development
3) Requests for collaboration
4) Technology demonstrations
5) Industrial funding
6) Collaborations with NASA centers on technology or flight experiments
7) Growth of staff and projects

SUMMARY

- The CSNR is developing new encapsulation technology that is applicable to several nuclear systems

- The Mars Hopper concept can revolutionize planetary exploration and provide dramatically greater science per launch dollar

- The Hopper requires several capabilities that directly overlap the ability to design and test a NTR

- The SNP Core/CSNR has performed several mission studies that show the benefit of the NTR and the tungsten-cermet fuel