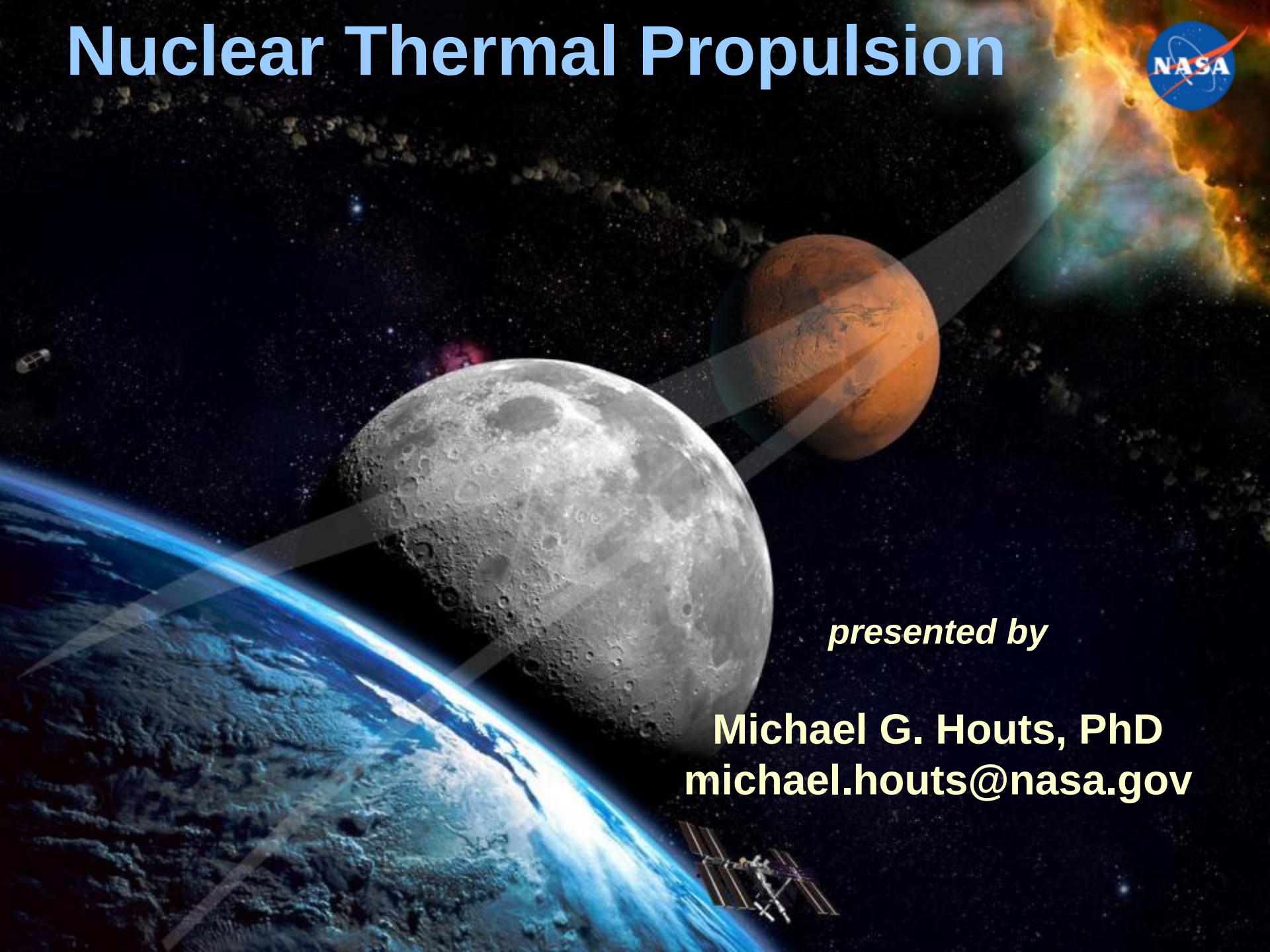
# Nuclear Thermal Propulsion



*presented by*

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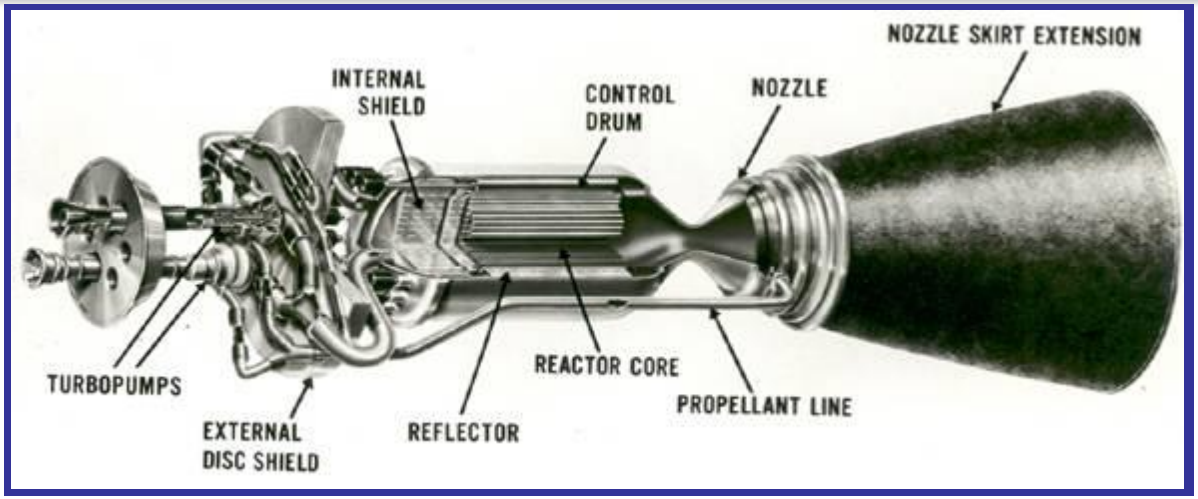
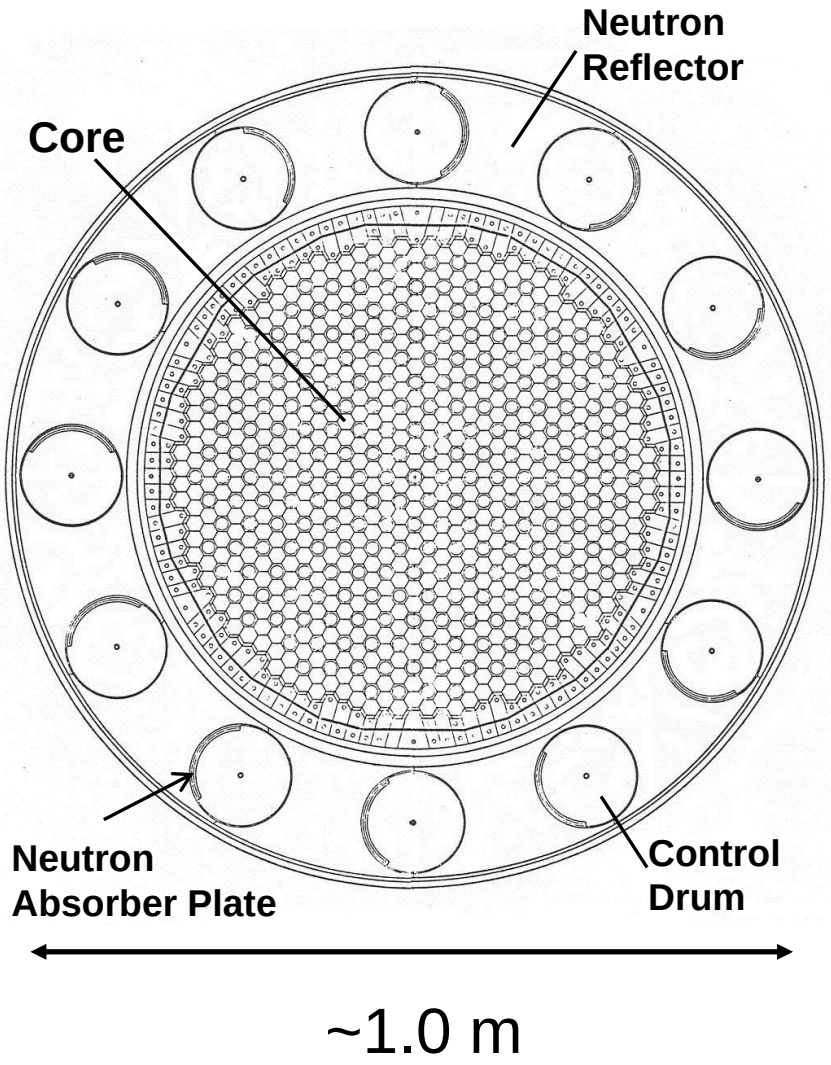
# NASA HEOMD is Currently Funding an "Advanced Exploration Systems" Project Investigating Nuclear Thermal Propulsion (NTP)




- Nuclear thermal propulsion (NTP) is a fundamentally new capability
  - Energy comes from fission, not chemical reactions
  - Virtually unlimited energy density
- Initial systems will have specific impulses roughly twice that of the best chemical systems
  - Reduced propellant (launch) requirements, reduced trip time
  - Beneficial to near-term/far-term missions currently under consideration
- Advanced nuclear propulsion systems could have extremely high performance and unique capabilities
- A first generation NTP system could serve as the "DC-3" of space nuclear power and propulsion

# Typical Space Fission System Operation




- System power controlled by neutron balance
- Average 2.5 neutrons produced per fission
  - Including delayed
- Constant power if 1.0 of those neutrons goes on to cause another fission
- Decreasing power if < 1.0 neutron causes another fission, increasing if > 1.0
- System controlled by passively and actively controlling fraction of neutrons that escape or are captured
- Natural feedback enables straightforward control, constant temperature operation
- 200 kWt system burns 1 kg uranium every 13 yrs
- 45 grams per 1000 MW-hr

## Project Objectives

- Develop an affordable and fast NTP technology demonstration to show that the technology is ready for flight
  - ✓ Affordable - no more than $300M for a technology demonstration
  - ✓ Fast – in about 10 years
  - ✓ Feasibility must be determined through the evaluation of mission requirements, availability of manufacturing and testing capabilities, and the capability of accomplishing the task within cost and schedule
- The near-term NTP focus is to ***Complete initial NTREES testing of ~16" coated graphite composite fuel element with prototypic depleted uranium loading***

# *The potential of NTP has been recognized for over half a century …*

President John F. Kennedy …

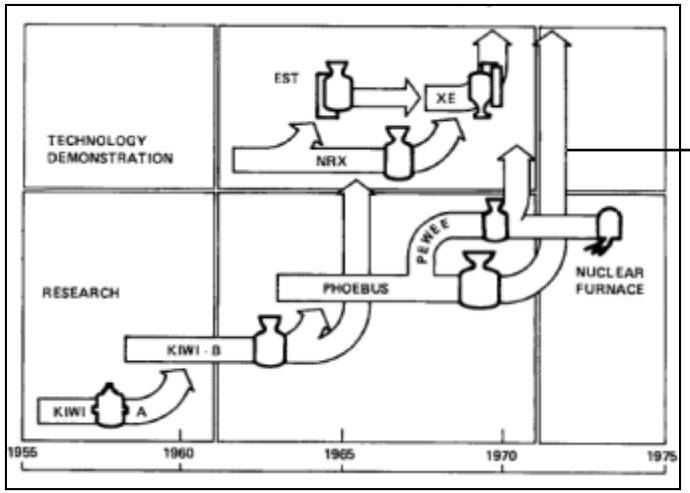
- First, I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the Moon and returning him safely to the Earth….
- Secondly, an additional 23 million dollars, together with 7 million dollars already available, will accelerate development of the Rover nuclear rocket. This gives promise of some day providing a means for even more exciting and ambitious exploration of space, perhaps beyond the Moon, perhaps to the very end of the solar system itself.

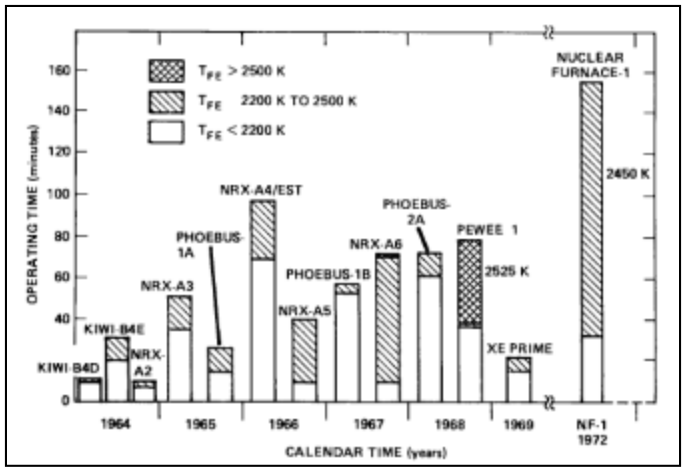
Excerpt from the 'Special Message to the Congress on Urgent National Needs'

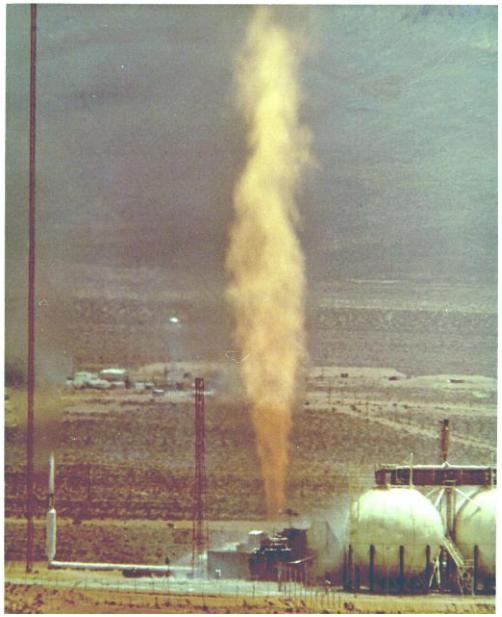
**President John F. Kennedy**

**Delivered in person before a joint session of Congress May 25, 1961**

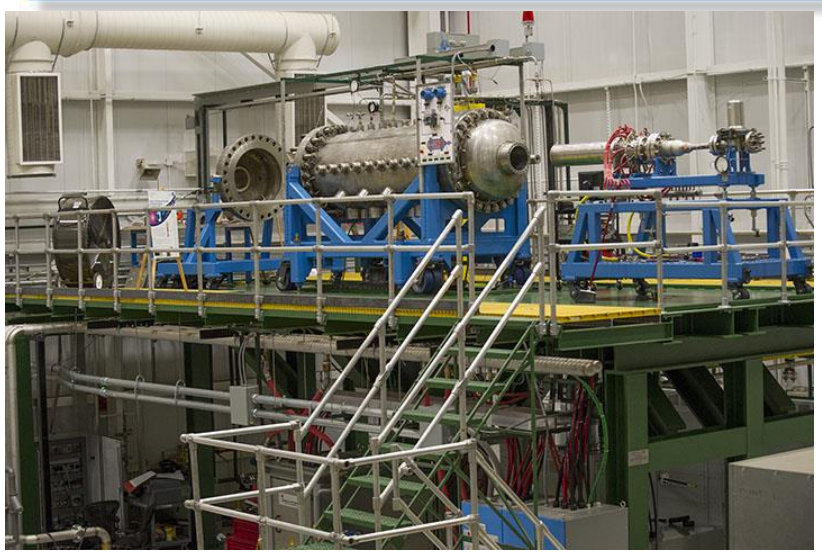
# A 21st Century NTP development effort could build on the highly successful Rover/NERVA program (1955-1973) and more recent programs



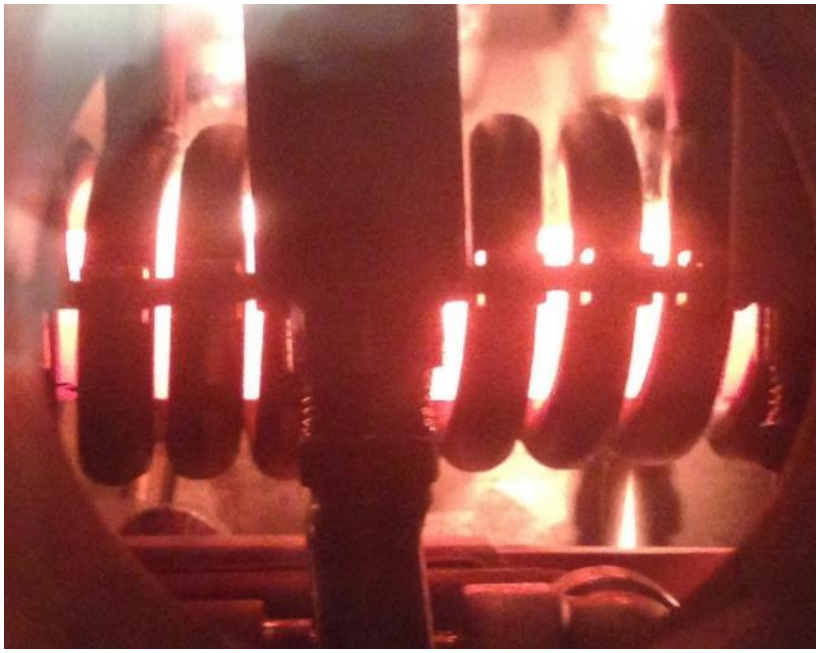



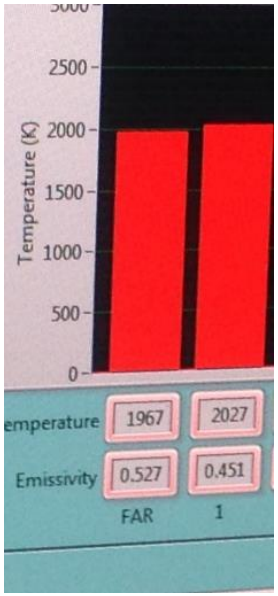
# Nuclear Thermal Rocket Element Environmental Simulator (NTREES)



- Achieved 2000K in $N_2$ with dummy graphite test piece - held temp for 1 hour before ramping down
- No water flow issues, leaks, arcing or melting of materials
- NTREES test of coated graphite composite fuel element with prototypic depleted uranium loading planned for FY15



View from front of chamber;
In view is cart and mixer face




Max temp: 2000K

# NTP Must be Safe and Affordable in order to be Developed and Utilized

***Consider using Low-Enriched Uranium (LEU) instead of Highly Enriched Uranium (HEU).***

- *May have minimal performance penalty in thrust range of interest*
- *Eliminate political opposition based on "safeguards"*
- *Significantly reduce security-related impacts on cost and schedule*
- *Significantly increase programmatic flexibility*

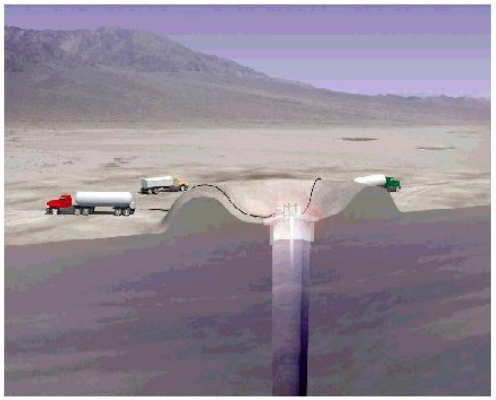
***Use state-of-the-art modeling and analysis techniques***

- *Fuel design, development, and qualification*
- *Reactor*
- *Engine*
- *Stage*

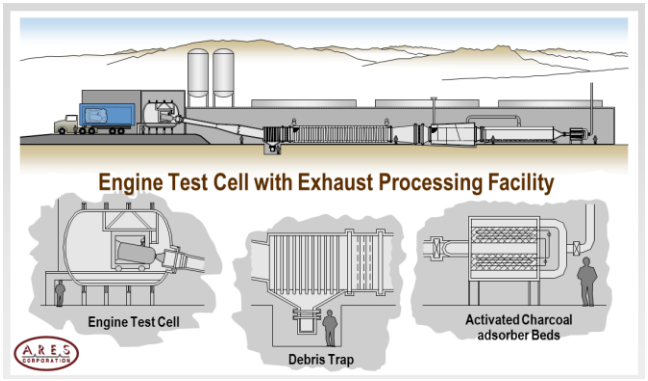
***Dual-use (when possible)***

***Safe, affordable, acceptable ground testing.***

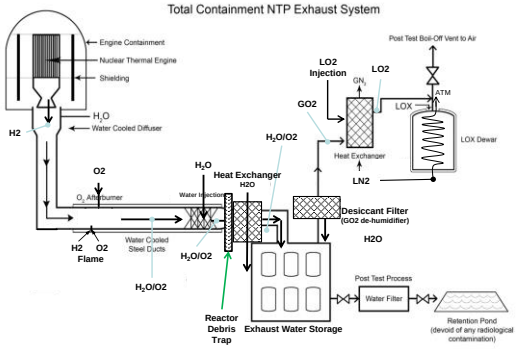
# NTP Ground Test Options



**Bore hole**




**Above ground scrubber with filters**




**Total containment with combustion and condensation**

- Bore Hole
  - Relies on permeability of desert alluvium soil to filter engine exhaust
    - Unresolved issues on water saturation effects on soil permeability, hole pressure during engine operation, and soil effectiveness in exhaust filtering
- Above Ground Scrubber
  - Engine exhaust is filtered of radioactive aerosols and noble gases and directly flared to atmosphere
    - Nuclear Furnace (NF-1) ground test scrubber successfully tested at the end of Rover/NERVA project
- Total Containment
  - Engine hydrogen exhaust is burned at high temperatures with oxygen and produces steam to be cooled, condensed, and collected for controlled processing and disposal
    - All analyses to date indicate system will reliability and economically accomplish task

# Summary

- Nuclear power and propulsion systems can enable exciting space exploration missions. These include bases on the moon and Mars; and the exploration, development, and utilization of the solar system.

- In the near-term, fission surface power systems could provide abundant, constant, cost-effective power anywhere on the surface of the Moon or Mars, independent of available sunlight. Affordable access to Mars, the asteroid belt, or other destinations could be provided by nuclear thermal rockets.

- In the further term, high performance fission power supplies could enable both extremely high power levels on planetary surfaces and fission electric propulsion vehicles for rapid, efficient cargo and crew transfer. Advanced fission propulsion systems could eventually allow routine access to the entire solar system. Fission systems could also enable the utilization of resources within the solar system.