Blueprint for NTR
Ground Test Facilities
SRNL-STI-2011-00425

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Mars Society Convention 2011
14th Annual International Mars Society Convention

OVERALL CLASSIFICATION, if needed
SRNL is located on Savannah River Site in SC

Savannah River Site is a 300 square mile Department of Energy nuclear facility operated by SRNS located between Augusta, GA and Barnwell, SC
SRS has three deactivated reactors and two decommissioned reactors

Reactors R and P are decommissioned and Reactors C, L and K are deactivated from former weapons production function.

1. A Area
   SRNL Fuel Fabrication Laboratories and Shielded Cells
   DOE Office of Environmental Management’s National Laboratory

2. H Area
   H Canyon and Tank Farm Facilities
   SRNS and SRR Operations processing radioactive materials

3. Central Shops
   Medical and Construction Facilities
   SRNS Support Operations

4. B Area
   DOE Operations
   DOE and SRNS Administrative Offices
Savannah River National Laboratory

SRNL puts science to work to create and deploy practical high-value cost-effective technology solutions.

Established in 1951 to provide research and development support for startup and operation of SRS with its mission of producing nuclear materials for national defense. SRNL serves DOE, nation, other federal agencies, across the country and around the world in three areas.

- Environmental Management
  - Cleanup Technology-other DOE facilities and around the world including Japan and Russia
  - Hazardous Materials Disposition
    - Immobilization of radioactive waste in DWPF located in Z area

Several thousand canisters of high level radioactive waste produced to date destined for Yucca Mountain Repository.
Savannah River National Laboratory

National and Homeland Security

- Tritium Technology - Radioactive form of hydrogen
- Nuclear Materials Technology - Supporting safe handling and disposition of plutonium and spent nuclear fuel with MOX facility in F Area and spent fuel processing in H Area.

- Homeland Security
- Nuclear Forensics for the FBI
- Nuclear monitoring and detection for nonproliferation
- Biological and chemical collection technologies for nonproliferation

MOX fuel fabrication facility will startup in 2016 converting weapons plutonium and uranium into commercial nuclear power plant fuel.
Energy Security

- Hydrogen Technology-HYSYS Pilot Electrolizer in EDL
- Fusion Technology-ITER support in France
- Renewable Energy-Wind Energy, Biomass Power Plants in A and TNX areas
- Unconventional Energy-Algae fuel
- Nuclear Energy-Next Generation and Small Modular Reactor Technology
  - GNEP
  - GE PRISM and ARC
  - Hyperion
  - General Atomic
SRNL and Mission to Mars

1/14/04 - President’s vision for Space Exploration

- NASA was challenged to build a Crewed Exploration Vehicle CEV by 2015: LEO - Mars - beyond (Project Constellation)-
  SRNL in CEV proposal rated technically superior by NASA

- President’s Commission - Implementation of US Space Exploration Policy
  - Identified Nuclear Thermal Propulsion (NTP) as near term highest TRL available for CEV application
  - Electric power capability from a bimodal NTP needed from 10 to several hundred kWe
  - Nuclear Test Facilities required to develop systems & demonstrate readiness

SRNL-STI-2011-00425 from srnl.doe.gov
SRNL Westinghouse and NERVA

- 1989 – Westinghouse awarded SRS M&O contract which includes SRNL for SRS from DuPont
  - In 1961, Aerojet and Westinghouse awarded subcontracts by Space Nuclear Propulsion Office for Nuclear Engine for Rocket Vehicle Applications, NERVA
  - NERVA engine tests had progressively higher power densities culminating in the Peewee (1970) and Peewee 2.
    - Tests of the improved Peewee 2 design were canceled in 1970 in favor of the Nuclear Furnace, NF-1.
President John F. Kennedy at NERVA Test facility

From 1959 to 1972, the US tested 20 different sizes and designs during Project ROVER and NERVA program at Nevada Test Site.

Test Designations

- Kiwi
- Phoebus
- NRX/EST
- NRX/XE
- Peewee
- Peewee 2
- Nuclear Furnace
NERVA Program Objectives and Accomplishments

Nuclear Thermal Rocket, NTR working fluid was hydrogen which was heated by a nuclear reactor and then expanded through a rocket nozzle to create thrust.

NERVA Objectives

- Man-rated flight capability
- Minimum chamber temperature of 2360 degrees K and minimum pressure of 450 psia
- Minimum thrust of 75K foot pounds
- Endurance of 600 minutes and 60 cycles
- Capable of 85K foot pounds thrust and 500 psia transients
- Adequate shielding for manned missions
- Storable for 5 years on ground, 6 months on pad, and 3 years in space
- Transportable by land, sea, and air

Accomplishments

- 4500 MWth power
- 5500 degrees F exhaust temperature
- 250K foot pounds of thrust
- 850 seconds of specific impulse
- 90 minutes of burn time
- Thrust to weight ratio of 3 to 4
Status of Nuclear Test Facilities for NTR Ground Testing

The Nuclear Research and Development Area (NRDA) - established at the Nevada Test Site for NERVA Space Nuclear Power System Testing in the 1950’s and 1960’s

- NRDA facilities status - deactivated and facilities reassigned to other functions
- A NASA Subpanel Final Report evaluation - using existing rocket test cells on the NRDA is anticipated to cost as much as new facilities
- The NRDA facility condition - significantly degraded and within view of the Yucca Mountain Nuclear Waste Repository complicating NEPA review of both facilities
Requirements for New Nuclear Test Facilities for NTR Ground Testing

New Nuclear Test Facilities must comply with many current DOE facility requirements. The NASA Subpanel defines test facility scope and evaluates existing facilities under the following working assumptions:

- Evolving technologies cannot compete in the near term with solid core concepts derived from NERVA technology
- All nuclear testing will be performed at DOE facilities.
- No full-scale reactor/engine test to failure is required during ground testing
- Full expansion-ratio NTP engine nozzle tests are not required to be tested during ground testing.
- Reactor assembly & low-power critical tests will be required in LEO after mission vehicle is assembled.
- An unmanned flight demonstration program will be conducted prior to a manned flight.
SRNL/SRS Test Facility Considerations for NTR Ground Testing

SRNL/SRS were previously evaluated by NASA Subpanel:

- NASA Subpanel determined SRNL/SRS an acceptable Test Facility for Space Power System Testing up to the full scale Ground Test Facility.

- SRNL/SRS currently disposing of excess Highly Enriched Uranium, HEU, by down blending for commercial reactor fuel; access to HEU for NASA nuclear fuel reduces logistics concerns and proliferation issues.

- Demonstrated success in fabricating fuel for the US Navy and SRS production reactors for decades

- SRNL/SRS in possession of metal hydride technology for hydrogen purification and storage capacity needs

- SRNL/SRS has completed testing of standby gas treatment enabling technology for service on high level waste tanks

- SRNL/SRS demonstrated success immobilizing high level waste.
NASA Test Facility Considerations for NTR Ground Testing at DOE Facilities

Nuclear Testing Facility requirements for NASA Subpanel:

- A suitable open-cycle effluent treatment system installed and tested at DOE facility for a full-size NTR ground engine test.
- SRNL/SRS has DOE nuclear facilities currently involved in the Nuclear Materials Stabilization Program for non-pit plutonium utilizing safety class sand filters as a suitable open-cycle effluent treatment system to prevent airborne contamination.
- The testing process involves cooling reactor nozzle exhaust with a spray, dehydrating the cooled gases, and then removing noble gases including xenon and krypton from the hydrogen leaving a clean stream of hydrogen gas. Demonstration required before reactor testing utilizing radioactive tracer gases to confirm removal.
- Prior studies used a 60 psia driving pressure from engine to force the effluent through the gas scrubbing system.
SRNL Fuel Fabrication Laboratory support for NTR Ground Testing

SRNL Fuel Fabrication Laboratory in service for decades supporting SRS production reactors and new reactor concepts:

- Staffed by experienced personnel in reactors and nuclear materials
- Laboratory has access to materials and equipment needed to blueprint NTR capability
- Laboratory is in possession of improved fuel fabricating procedures
- Laboratory is capable of pilot plant fabrication of test cores
- Laboratory is capable of fabricating test fuels replicated from NERVA or new concept fuels
- Laboratory is capable of fabricating fuel elements
Additional NASA Test Facility Considerations for NTR Ground Testing

SRNL/SRS additional testing to support NASA Subpanel:

- Hot hydrogen propellant testing on unirradiated nuclear fuel at NP2N pilot concept test facility developed with NASA Stennis for deployment at SRS to meet desired hydrogen flow parameters with the ability to conduct blowdown or closed loop experiments.

- Larger turbo pumps to feed the NTR as well as larger NTR engine nozzles can be tested at existing NASA Hot Hydrogen Flow Test Facilities.

- Irradiation testing to produce a qualified nuclear fuel for the NTR can be conducted at SRS irradiation test facilities and other DOE Complex irradiation test facilities such as at the ATR in INL.

- SRS reactor structures for C, L and K reactors were rated for 2800 MWth power operation until de-activation, but can be modified for use as a prototypic Fuel Element and NTR Ground Test Facility (NERVA Nuclear Furnace)
SRS can Modify Nuclear Facilities to support NTR Testing

SRNL/SRS have applied technology to modify existing Nuclear Facilities to support new missions such as MOX fuel fabrication, FBI laboratory for Nuclear Forensics and Homeland Security.
SRNL Brayton Cycle Test Facility Concept for NASA

SRNL In-Situ Cleanable Ceramic Filter Media for Gas Treatment

Filtration Flow Path

Membrane/Monolith Cross-Section

Clean Exhaust

Particulate Buildup

Microporous Membrane

Particulate Laden Exhaust

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OVERALL CLASSIFICATION, if needed
Lessons learned from prior NTR Ground Testing

Some major SNAP and NERVA Program testing lessons learned:

- Nuclear reactivity of fast reactors affected by neutron reflection from nearby test facility structures.
- Evaluating performance of equipment shield in presence of scattered radiation within shield is difficult.
- Neutron activation and gamma heating of test cell concrete shielding can cause reactor operational problems to account for in test facility design.
- Orientation of test article in hydrogen flow must be considered in test cell design.
- Prevention of metal refractory degradation from exposure to air at high temperature may require a high vacuum environment.
- Sealing the test stand around the NERVA reactor to achieve a partial vacuum was a challenge to design for.
- Provisions for maintenance and repair of highly radioactive test articles requires significant design effort.
- Early SNAP-8 reactor testing methods utilized a simulated radiator integrated with the reactor system to provide an equivalent heat sink without initial vacuum testing.
- Redundancy in critical systems and components by separation of subsystems within test facility permitted flexible operations and extended endurance testing.
SRNL/ SRS Test Facility Conclusions for NTR Ground Testing

SRNL/SRS was previously evaluated by NASA TM-105708 in April 1993 and its capacity to address test factors has improved:

- Ability to process fuel and high level radioactive waste to immobilized form has improved.

- Extensive gas treatment system design tested for waste gas treatment utilizing ceramic filters for in-situ cleanable application.

- Sand filters and infrastructure available to support NTR ground testing due to the reduction in SRS mission requirements for nuclear operations

- SRNL laboratories for fuel fabrication and Hot Cells available to support radioactive test operations and maintenance

- Lessons learned from previous SNAP and NERVA testing can be applied with current DOE requirements to ensure mission success.