Project Pele Overview

Mobile Nuclear Power For Future DoD Needs

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May 2022

Project Pele

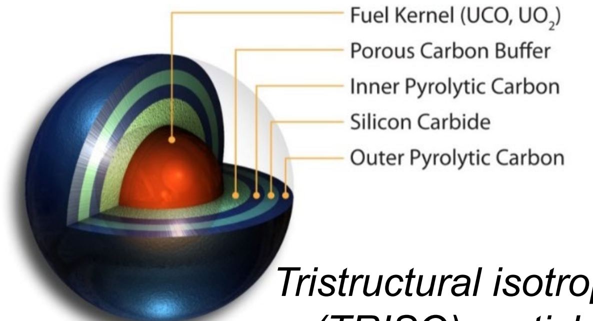
- **A 2016 Defense Science Board (DSB) study[1] found the Department of Defense (DoD) has a need for a mobile, reliable, sustainable, and resilient power source which does not require a long logistics tail**
  - Nuclear power is uniquely suited to meet DoD needs (2M x energy density of diesel)
  - Advances in technology have made feasible highly autonomous, inherently safe, reactors.
  - Funded as a Climate program (can offset >1 million gallons of diesel/year)
- **Incorporates Advanced Tristructural Isotropic (TRISO) encapsulated nuclear fuel for safe operations**
  - Each encapsulated particle is <1 mm in diameter
  - Robust particle coatings are extremely resistant to meltdown or kinetic destruction
  - Paradigm changer for containment, nuclear safety, and transportation
  - SCO/DOE/NASA have re-established a national TRISO production capability
- **Two-year reactor design competition kicked off in March 2020**
  - Final down-select design decision will be made in Spring 2022
- **Pele reactor fabrication will begin in the latter half of 2022**
  - Targeting delivery of a prototype reactor to Idaho National Laboratory in mid-2024
  - After Operational Readiness Review, targeting first power production in late-2024

[1] Defense Science Board, Final Report, Task Force on Energy Systems for Forward/Remote Operating Bases (August 1, 2016)

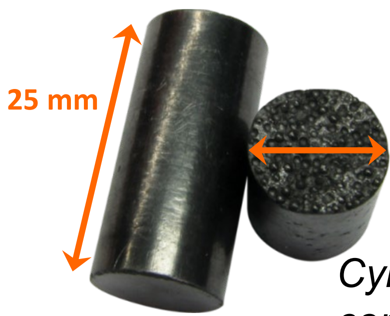
TRISO Fuel: A Paradigm Shift For Nuclear Power

- **The Advanced Gas Reactor (AGR) Fuel Development Program was initiated in 2002**
  - TRISO fuel has already been subjected to rigorous testing by DoE, eliminating the need for DOD/SCO to develop or qualify a new fuel
- **Silicon carbide keeps fission products sealed inside, meaning that a containment vessel failure is no longer catastrophic**
  - Design reduces diversion and proliferation risks due to low (< 20% U235) enrichment and individually coated particles
  - Rugged, robust fuel structure deters use as an improvised weapon such as a dirty bomb
- **Innovative design as first line of containment is a paradigm shift in safety for nuclear power**
  - TRISO fuel and compacts could significantly lower manufacturing/safety/O&M/regulatory costs
  - Pellets minimize consequences to the environment and population from events affecting integrity of reactor or threatening release of contamination

Kinetic impact testing of TRISO simulants is an element of Project Pele



Tristructural isotropic (TRISO) particle



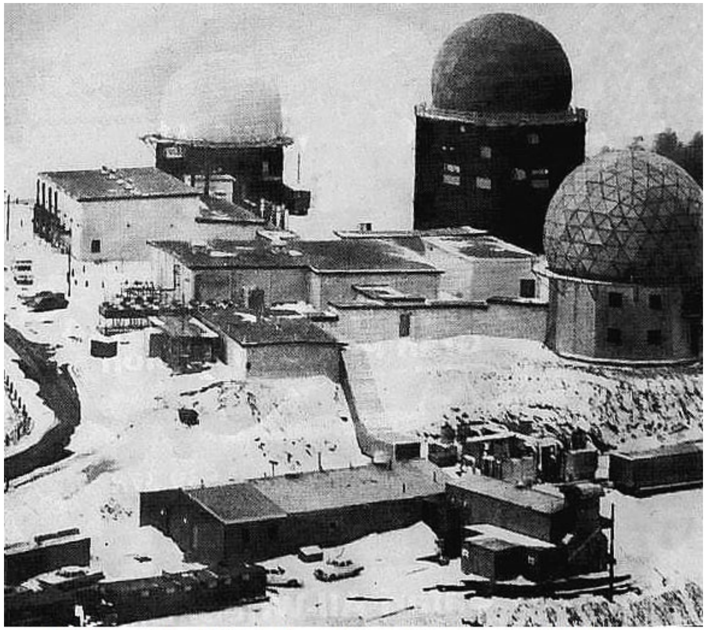
Cylindrical fuel compacts

Portable Nuclear Power: An Old Idea

- **The U.S. Army Nuclear Power Program ran from 1954 through 1977**
  - Eight reactors were constructed (five were portable), each between 1-10 MWe, of various designs and for various purposes

- **The first U.S. nuclear reactor to be connected to an electrical grid, in 1957, was an Army reactor (SM-1)**

- **As some of the earliest nuclear reactors ever built, they were technologically difficult to operate, unreliable, and too expensive relative to abundant fossil fuel alternatives**

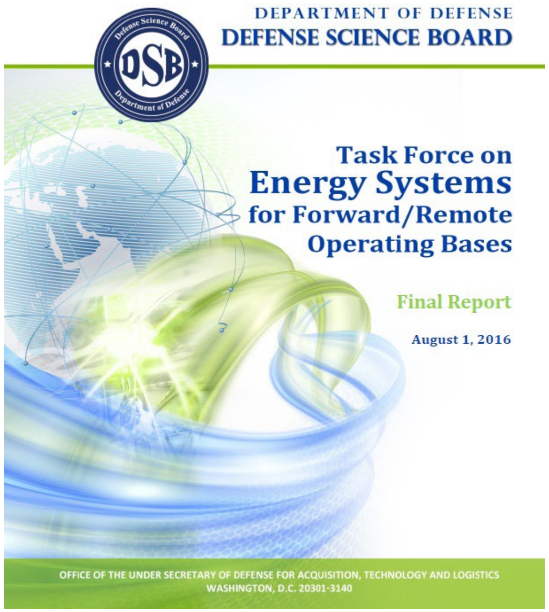


PM-1 Nuclear Plant (PWR), Sundance Air Force Station, Wyoming, 1962-1968

ML-1 US Army reactor, 1958, Arco, Idaho

Portable Nuclear Power: Why Now?

- **Defense Science Board (DSB) in 2016 identified critical growing energy challenges**
  - Energy usage on the battlefield is likely to increase significantly over the next few decades making energy delivery and management a continuing challenge.
  - Exponential growth in energy demand is forcing a serious re-evaluation of DoD energy logistics
  - The study found that longer term energy solutions should support sustainment of technical superiority.
  - New modern warfighting systems (e.g. directed-energy lasers, railguns, and UAVs) have ever-increasing demands for reliable, high-density energy.
- **Significant technological advances in nuclear power since the 1960s**
  - Generation III reactors have been operating safely since 1996, and significant development and risk-reduction on Generation IV reactors is already complete.
  - Fully inherently safe reactors have been built and tested, allowing autonomous operation and eliminating meltdown risks.
- **Climate Change is now a strategic threat**
  - Nuclear power must be part of the clean energy solution to replace fossil fuels.



DSB Conclusion: "There is opportunity to invert the paradigm of military energy. The U.S. military could become the beneficiaries of reliable, abundant, and continuous energy through the deployment of nuclear energy power systems."

Whole of Government Approach

- **Interagency collaboration is crucial to the success achieved by SCO's Project Pele. This includes:**
  - Department of Energy (DOE) and Nuclear Regulatory Commission (NRC) are providing technical support, design/safety advice, and guidance on reducing current and future licensing risk
  - DOE is providing reactor safety oversight and authorization, and through an interagency agreement is providing an extension of Price-Anderson nuclear indemnification
  - NRC will approve the Pele reactor module transportation package for over-the-road transport
  - Army Corps of Engineers and DOE supported NEPA Environmental Impact Statement
  - NNSA is providing Pele with enriched uranium from its stockpile
  - NASA and DOE have developed, jointly with SCO, a commercial-scale TRISO facility

Pathfinder To Commercial Advanced Reactors

- **Regulatory Test Case**
  - NRC has been instructed by Congress to develop a new regulatory approach for advanced reactors[1]
  - In 2020, the NRC approved the risk-informed regulatory approach of the Licensing Modernization Project, but there has yet to be a commercial reactor design licensed through this process
  - The NRC is participating in Project Pele as an observer, giving them hands-on experience and data for the initial safety basis demonstration testing of an advanced non-light water reactor
  - NRC is also working closely with SCO to advise on qualification of materials/components, which will significantly advance the regulatory readiness of a commercial spin-off of Pele

- **TRISO was designed to be a commercial reactor game-changer**
  - AGR particles have already been extensively tested and qualified by DOE
  - High melting temperatures allow for a passively safe reactor which can significantly reduce capital investment and O&M costs

- **DoD requirements and application can drive commercial future**
  - Shippingport reactor (1957) was built by the Navy out of a surplus aircraft carrier reactor
    - To this day, most commercial nuclear reactors around the world are light water PWRs[2] because that's what Admiral Rickover chose for the USS Nautilus
  - Pele is designed to be maximally resilient to external hazards and nuclear proliferation
    - Potential to drive high standards for nuclear safety and non-proliferation if a U.S. DoD reactor becomes the pathfinder for Generation IV reactors, rather than Chinese or Russian designs

[1] Nuclear Energy Innovation and Modernization Act (NEIMA) and Nuclear Energy Innovation Capabilities Act (NEICA)
[2] Pressurized Water Reactors

Nuclear Power Is Hard

"An academic reactor or reactor plant almost always has the following characteristics: (1) It is simple. (2) It is small. (3) It is cheap. (4) It is light. (5) It can be built very quickly. (6) It is very flexible in purpose ("omnibus reactor"). (7) Very little development is required. It will use mostly "off-the-shelf" components. (8) The reactor is in the study phase. It is not being built now.

On the other hand, a practical reactor plant can be distinguished by the following characteristics: (1) It is being built now. (2) It is behind schedule. (3) It is requiring an immense amount of development on apparently trivial items. Corrosion, in particular, is a problem. (4) It is very expensive. (5) It takes a long time to build because of the engineering development problems. (6) It is large. (7) It is heavy. (8) It is complicated."

--Hyman Rickover, 1953
"The Father of the Nuclear Navy"

Number of non-Naval power reactors currently under construction, by nation*:

16: China
6: India
4: Russia, South Korea
3: Turkey
2: Bangladesh, Japan, Slovakia, Ukraine, UAE, United Kingdom, **USA**
1: Argentina, Belarus, Brazil, Iran, France

The last successfully completed non-Naval nuclear power reactor in the United States broke ground on construction in 1978.**

*As of April 2022, per https://pris.iaea.org/PRIS/WorldStatistics/UnderConstructionReactorsByCountry.aspx
**Shearon Harris Nuclear Power Plant

Pele Path Forward

- **Complete detailed design and associated testing**
  - Rigorous process to approve all technical specifications before ordering components.
  - Significant re-designs can be crippling to budget/schedule.
- **Enforce Quality Assurance through entire supply chain**
  - Finding suppliers who can meet all nuclear quality standards has been a challenge for other nuclear programs.
  - It cannot be assumed that subcontractors will deliver what they say they can deliver.
- **Complete Department of Energy authorization process**
  - Preliminary and Final Safety Analysis Report (P/FSAR) for reactor, as well as acceptance review for reactor fueling in TREAT.
  - Operational Readiness Review will be final step before turning on reactor.
- **Train operators**
  - Experienced reactor operators will be hired for initial operations.
  - Army Corps of Engineers and National Guard personnel will be trained to assemble, move, and operate the Pele reactor.

DoD SCO and NRC Engagement on Reactor Transportation

- **NRC is part of a trilateral MOU with SCO and DOE in support of Project Pele. NRC provides technical expertise and knowledge in support of DoD's Project Pele, and is provided with opportunities to enhance its understanding of advanced technology and inform its approach to licensing advanced reactors. In this model, NRC is being leveraged to:**
  - Review, advise, and provide the transportation package certification of the Project Pele reactor and supporting modules for over-the-road transport as a first step to future multimodal transport (rail, highway, barge/ship, air)
  - DOT also engaged as NRC counterpart
    - Two topics preliminarily discussed for current continental U.S. application – DOT special permit and transportation routing
  - Provide review to supplement DOE reactor safety oversight and authorization but not to regulate operation

- **SCO has requested that the NRC review products as they are developed that feed into and form the overarching safety basis for the Pele reactor module to be considered as a transportation package suitable for certification under 10CFR71**

Establishing/defining a reactor as an over-the-road transportation package per 10 Code of Federal Regulations Part 71 (10CFR71) is a novel objective

Pathway to Transportation Package Licensing

- **SCO and NRC have collectively discussed and established a list of products/deliverables and associated reviews identified as most meaningful to aid in the safety basis development and pathway to transportation package licensing. These include:**
  - Probabilistic Risk Assessment Plan for Populating a Safety Basis Framework
    - Recently provided and currently under agency review
  - Risk Informed Pele Transportation Package Approval Document for Domestic Highway Shipment
  - Pele Transportation Package Physical Testing and Demonstration Plan
  - Pele Transportation Package Modeling and Simulation Plan
  - Pele Preliminary Transportation Benchmarking and V&V[1] Incorporating Select Package Modeling and Simulation Results, Physical Testing and Demonstration Results, and Supporting Safety Basis Documentation
  - Project Pele Safety Analysis Report for Packaging and Packaging License Application

- **SCO, the Prototype Design Team, and NRC plan to conduct interactive reviews and face-to-face discussions to support finalization of each of the products/deliverables**

[1] Verification and Validation

Strategic Game Changer

- **Nuclear power has the opportunity to offer resilient, reliable energy for key mission success for the DoD in both remote and strategically important locations within the United States**
  - Transportable nuclear power will allow a transformation in capabilities for the future warfighter

- **Pele would be a pathfinder to advanced nuclear reactors in the commercial sector**
  - Commercial nuclear reactors, which provide the majority of zero-carbon energy in the United States, are all direct descendants of U.S. Navy reactors

- **Nuclear power has significant technical and regulatory challenges which must be addressed**
  - Pele will address all key areas of nuclear energy uncertainty: Regulatory regime, safety/environmental procedures, industrial supply chain, levelized cost of electricity, CONEMPs, technical requirements, and training

It is necessary to demonstrate a full prototype nuclear reactor in order to determine the feasibility of future technology transition.