Project Pele Overview

Mobile Nuclear Power For Future DoD Needs

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Project Pele

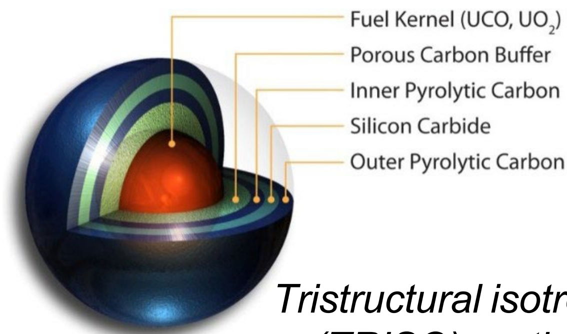
- **A 2016 Defense Science Board (DSB) study[1] found the Department of Defense (DoD) has a need for a mobile, reliable, sustainable, and resilient power source which does not require a long logistics tail**
  - Nuclear power is uniquely suited to meet DoD needs (2M x energy density of diesel)
  - Advances 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**
  - Robust particle coatings are extremely resistant to meltdown or kinetic destruction
  - SCO/DOE/NASA have re-established a national TRISO production capability
- **Two-year reactor design competition kicked off in March 2020**
  - BWXT selected as winning design in Spring 2022
- **Pele hardware purchases have begun**
  - Fuel fabrication began in December 2022
  - Long lead item hardware purchases began in early-2023
- **Pele fabrication will begin once final design received initial DOE approval**
  - Submission of engineering design to DOE targeted for early 2024
  - Targeting delivery of reactor module to Idaho National Laboratory in mid-2025

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

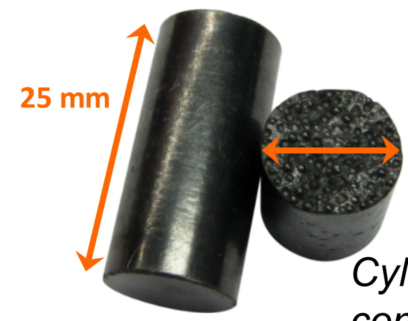
TRISO Fuel: A Paradigm Shift For Nuclear Power

- **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 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



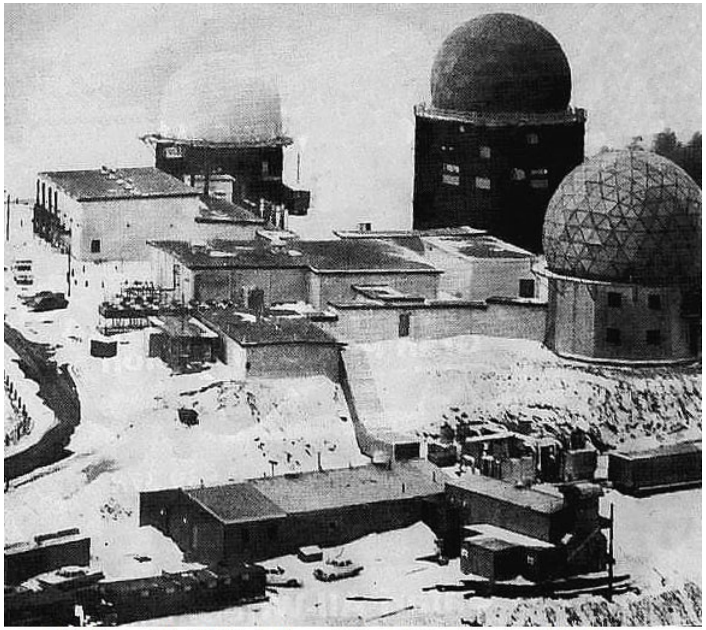
Tristructural isotropic (TRISO) particle



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**

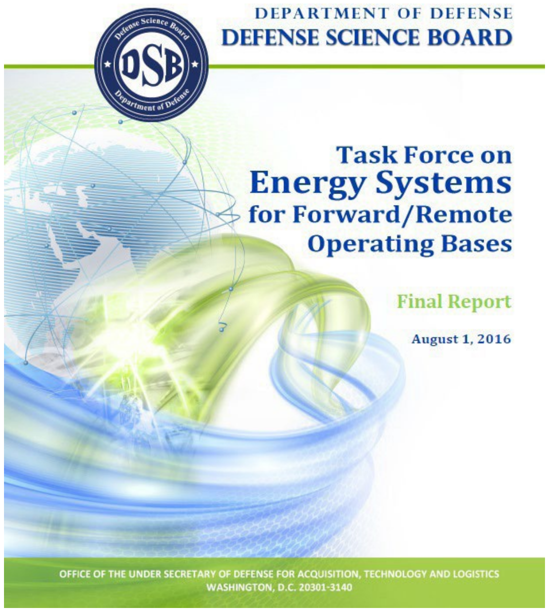


PM-1 Nuclear Plant (PWR), Sundance Air Force Station, Wyoming, 1962-1968

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.
  - Passively safe reactors have been built and tested, allowing autonomous operation and minimizing 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 is participating in a licensing modernization approach for review and approval of 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

US Army Corps of Engineers®

National Nuclear Security Administration

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 using an aircraft carrier reactor design
    - 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*:

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

Vogtle-3 in 2023 became the first new U.S. commercial nuclear reactor to connect to the grid whose construction broke ground after 1978.**

*As of May 2023, per https://pris.iaea.org/PRIS/WorldStatistics/UnderConstructionReactorsByCountry.aspx
**Shearon Harris Nuclear Power Plant

Design → Power

Engineering Design + Safety Approach

- Make final design decisions
- Purchase long lead hardware[1]
- Fabricate Pele fuel
- Review all significant design decisions with INL and DOE safety officials
- Submit PSAR (Preliminary Safety Analysis Report)
- Finalize engineering design

As of Oct 2023, we are here

DOE approves preliminary safety analysis

Fabricate Pele prototype

- Change Control Board reviews any design changes
- Non-nuclear integration testing/quality assurance
- Transport TRISO fuel compacts to INL
- Submit FSAR (Final Safety Analysis Report)

DOE approves final safety analysis

Deliver Completed Reactor

- Transport prototype to INL
- Readiness review for fueling
- **Fuel reactor** in TREAT (Transient Reactor Test Facility)
- Deliver prototype to CITRC (Critical Infrastructure Test Range Complex)

DOE approves Operational Readiness Review

Initial Operational Testing

- **Turn reactor on**
- Validate reactor modeling
- Demonstrate safety
- Initiate TEMP (Test and Evaluation Master Plan)

[1] All long lead item purchases are approved by SCO, DOE-ID, and INL

Path Toward Successful Transition

- **Enforce quality of entire supply chain**
  - Rigorous process to approve all technical specifications before ordering components
  - Audits to ensure quality from both sub-contractors and other suppliers
- **Develop training program**
  - U.S. Army Office of the Chief of Engineers is collaborating with INL and USMA West Point on development of a training program, simulator work, and an operational manual
  - National Guard Bureau personnel will participate in reactor transport/assembly
- **DOTmLPF-P analysis**
  - Doctrine, Organization, Training, materiel, Leadership, Personnel, Facilities, Policy
    - Work has begun to update Service regulations to support a potential transition decision
- **Transition must be cost-efficient**
  - Microreactors must be ordered in sufficient quantities and at sufficient speed for assembly efficiencies of scale to drive costs down to current prices in remote/austere locations
  - The DoD must tie nuclear decision to larger policy question of carbon-free energy and energy resiliency, and how much it is willing to spend to achieve those goals

Whole-of-government decision on future of nuclear power must consider both military and commercial uses of microreactors and SMRs