

Preliminary Operational Requirements for ROK Military Microreactors: Lessons from U.S. Defense Microreactor Programs

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1. Introduction

Modern military operations are becoming dependent on reliable electrical power. The deployment of high power weapon systems and the proliferation of autonomous and AI driven platforms is substantially driving up both continuous and peak electricity demands. Electricity is no longer a utility, and it is becoming an enabler of combat readiness and mission assurance.

However, this heavy dependence on electric power represents a double-edged sword given that military bases rely heavily on commercial grids vulnerable to targeted interdiction during conflict [1]. Consequently, 10 U.S.C. §2920 mandates mission assurance through the Mission Critical Load (MCL) [2], establishing a strict requirement for bases to generate and sustain this essential power autonomously on-site during prolonged grid disruptions.

A previous study by the authors examined this problem for the ROK Army, estimating that a reference forward-deployed infantry division will require approximately 3.11 MWe of average MCL and 5.59 MWe of peak MCL by 2050 [3]. The limited renewables support energy resilience but could not reliably serve as long duration primary power sources. Also, conventional diesel generators remain vulnerable to supply chain disruptions. Consequently, in the previous study, microreactors were identified as the most promising source of firm, long duration power.

The United States has advanced military microreactors from concept studies into fueled demonstrations and site level acquisition through initiatives such as Project Pele for transportable power, alongside the Eielson Air Force Base (AFB) pilot, Advanced Nuclear Power for Installations (ANPI), and Army Janus programs for permanent base resilience. Internationally, Canada launched a defense funded feasibility program in 2026 to evaluate microreactors for remote and northern military facilities [4].

This study reviews recent U.S. military microreactor initiatives and investigates the essential technical characteristics required for microreactors operating within ROK military, utilizing the quantitative MCL baseline from [3]. This analysis is necessary because commercial civilian reactors cannot be directly adopted for defense applications without significant technical adaptation. The military microreactors must operate under unique constraints including mission continuity, physical and cyber threats, limited logistics,

transportability, and operation after external infrastructure failures, which are not part of a civilian design basis.

2. Review of U.S. Military Microreactor Programs

U.S. military microreactor initiatives differ in mission and deployment concepts. Project Pele emphasizes transportable nuclear power, whereas the Eielson AFB pilot and ANPI focus on resilient generation at fixed military installations. Janus establishes a broader Army framework for deploying commercial microreactors according to mission and site requirements. Table I summarizes the purpose and status of these programs.

Table I. Major U.S. military microreactor programs and recent status [5–8].

Program	Primary objective	Recent status
Project Pele	Transportable nuclear power	BWXT prototype under assembly
Eielson AFB pilot	Fixed remote installation resilience	Oklo selected; target around 2030
ANPI	On-site nuclear power for critical DAF missions	Three site vendor pairs selected
Janus	Grid-independent Army installation power	Nine candidate installations

2.1 Project Pele

Project Pele is the most mature U.S. demonstration of a transportable military microreactor. The current BWXT prototype produces 1.5 MWe and uses a gas cooled reactor with HALEU TRISO fuel. As illustrated in Fig. 1, The reactor and supporting systems are divided among four standard 20 ft shipping containers. It is intended to provide electricity for up to three years without refueling. Rolls Royce is developing the power conversion module, while Northrop Grumman provides the control module [5].

The Project Pele Final Environmental Impact Statement further shows how the military mission affects reactor design. Its design basis employs an HTGR with an open Brayton gas cycle and atmospheric heat rejection, while semi-autonomous operation and limited routine manning are included among the technical objectives [9]. Project Pele consequently treats power generation, fuel endurance, transportability, safety, and operating burden as a single integrated design problem rather than

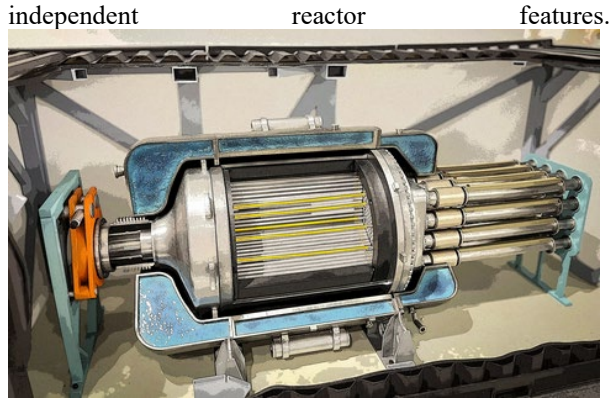


Fig. 1. A graphical rendering of the Project Pele reactor [5].

2.2 Eielson AFB microreactor pilot

The Eielson AFB pilot represents a different military application. Rather than emphasizing relocation, the project aims to provide up to 5 MWe of resilient power directly to critical infrastructure at a permanent but geographically remote installation. Under the proposed 30 year power purchase agreement, a commercial provider would construct, own, operate, maintain, and decommission the NRC licensed reactor [6].

Oklo was selected as the intended provider and has proposed its Aurora powerhouse platform [10]. The platform is based on liquid metal cooled, metal fueled fast reactor technology. A representative Aurora concept is shown in Fig. 2. Oklo has selected a conventional condensing steam turbine and generator for its first Aurora plant at INL, although the final Eielson specific power conversion configuration remains subject to project design and NRC licensing [11, 12]. The Eielson case therefore demonstrates that a fixed military installation can prioritize long term reliability and regulatory integration over rapid relocation.



Fig. 2. Oklo Aurora powerhouse concept proposed for the Eielson AFB Microreactor Pilot [10]

2.3 Advanced Nuclear Power for Installations

ANPI extends the fixed installation approach while deliberately retaining technology diversity. In April 2026, the U.S. Department of Air Force (DAF) paired Buckley Space Force Base (SFB) with Radiant Industries, Malmstrom AFB with Westinghouse Government

Services, and Joint Base San Antonio (JBSA) with Antares Nuclear [7]. The three developers employ substantially different reactors and power conversion technologies.

Radiant proposes its Kaleidos microreactor for Buckley SFB [13]. Kaleidos is a helium cooled HTGR using TRISO fuel and is designed to provide 1 MWe together with up to 1.9 MW of useful thermal energy. The unit is returned to the factory for refueling after approximately five or more years of operation [14]. Radiant has also publicly described a closed supercritical CO₂ Brayton cycle for power conversion [15]. The Kaleidos concept is shown in Fig. 3. In August 2026, a full scale Kaleidos unit was transported by road to the INL test facility, demonstrating its intended transportability [16]. The planned test campaign will progress from zero-power criticality to full heat and power operation, followed by 150 continuous hours of operation without operator intervention.



Fig. 3. A rendering of the Radiant Kaleidos reactor [17].

Westinghouse proposes the eVinci microreactor for Malmstrom AFB [18]. Unlike Kaleidos, eVinci transfers heat from the core through passive heat pipes rather than a forced circulation primary coolant system. The design produces 5 MWe from a 15 MWth core, uses 19.75% enriched TRISO fuel, and is designed for at least eight full power years before refueling [19]. As shown in Fig. 4, the heat pipe architecture substantially simplifies the primary heat transport system. The terrestrial design employs an open air Brayton power conversion cycle and requires no cooling water [19, 20].



Fig. 4. Westinghouse eVinci microreactor showing the compact heat pipe based reactor configuration [18].

Antares Nuclear has been paired with JBSA, although the final reactor configuration for the installation has not yet been publicly specified [7]. The company's publicly disclosed R1 platform therefore provides a technology reference rather than a confirmed

Program / Design	Reactor and heat transport	Fuel	Power conversion system	Power / endurance	Military relevant characteristics
Project Pele / BWXT	Gas-cooled HTGR	HALEU TRISO	Open Brayton gas cycle ¹	1.5 MWe / up to ~3 yr	Four 20 ft transport modules; air heat rejection; semi-autonomous operation; reduced manning objective ¹
Eielson AFB pilot / Oklo Aurora	Sodium-cooled fast reactor platform ²	Metal fuel	Steam turbine	Up to 5 MWe	Fixed remote base resilience; commercial ownership; NRC licensing
ANPI (Buckley SFB) / Radiant Kaleidos	Helium-cooled HTGR	TRISO	Closed sCO ₂ Brayton ³	1 MWe; 1.9 MW useful heat / ≥ 5 yr before factory refueling	Full scale road transport demonstrated; factory refueling; 150 h unattended test planned
ANPI (Malmstrom AFB) / Westinghouse eVinci	Passive heat pipe reactor	19.75% enriched TRISO	Open air Brayton cycle	5 MWe; 15 MWth / ≥ 8 FPY	No cooling water; passive heat transport and decay heat removal; factory assembly; rapid load response
ANPI (JBSA) / Antares R1 platform ⁴	Prismatic graphite core with sodium heat pipes	TRISO	Recuperated N ₂ closed Brayton, <300 psi	0.1–1 MWe / >6 yr	Passive heat transport; integrated shielding and transport cradle; direct microgrid interface

1. The PCS description is based on the Project Pele Final EIS design basis (working fluid not publicly specified) [9].

2. The reactor and PCS characteristics shown represent Oklo's publicly disclosed Aurora technology. The final Eielson configuration remains subject to project design and NRC licensing [10–12].

3. Radiant has publicly described a closed sCO₂ Brayton power conversion approach for Kaleidos [15].

4. Antares is the selected ANPI vendor for JBSA, but the final JBSA reactor configuration has not yet been publicly disclosed. The table therefore presents the published R1 technology platform, not a confirmed JBSA plant design [21].

JBSA design. As illustrated in Fig. 5, R1 integrates TRISO fuel in a prismatic graphite core with passive sodium heat pipes, a fin and tube primary heat exchanger, and a recuperated nitrogen closed Brayton cycle operating below 300 psi. The platform covers approximately 100 kWe to 1 MWe and targets more than six years of operation. Integrated shielding, a transport cradle, and a local microgrid interface are included in the same system architecture [21].

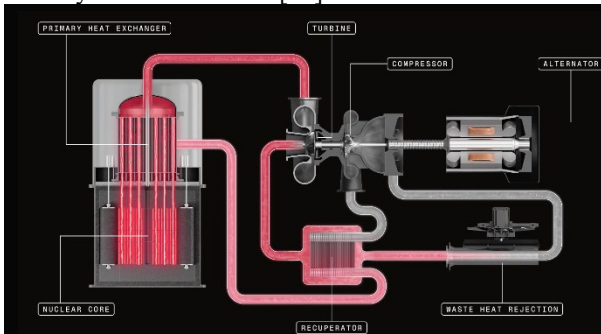


Fig. 5. A schematic diagram of Antares reactor [21].

A recent milestone further demonstrates the technical maturity of the Antares development pathway. On June 4, 2026, the Mark-0 reactor achieved zero-power fueled criticality at INL under the DOE Reactor Pilot Program [22]. Mark-0 is a high temperature heat pipe reactor configured specifically for zero-power testing and does not include heat removal or power conversion systems [23]. The experiment therefore validates reactor physics, reactivity control, and regulatory processes rather than electricity generation. The U.S. Army participated in the

associated safety and regulatory activities, and experience from the Reactor Pilot Program is intended to support subsequent Janus deployment [22].

As Table II shows, military microreactor development is not converging on a single reactor or power conversion technology. The concepts range from gas cooled thermal reactors to fast and heat pipe reactors, while their power conversion systems include open and closed Brayton cycles and conventional steam turbine systems. The commonality lies instead in the intended performance. Long fuel endurance, reliable operation, compact deployment, passive or inherent safety, and reduced dependence on external logistics repeatedly appear across different concepts.

2.4 U.S. Army Janus Program

The Janus Program extends military microreactor deployment specifically to U.S. Army installations. In November 2025, nine installations were selected for initial consideration, and the Army began a process to pair commercial reactor designs with individual sites according to their mission, energy, infrastructure, and resilience requirements [8]. Unlike Project Pele, Janus is not centered on a single government demonstration reactor but on the deployment of multiple commercial technologies across Army installations.

A more distinctive feature of Janus is its regulatory pathway. ANPI was established to use civil Nuclear Regulatory Commission licensing for commercial microreactor deployment [7], whereas Executive Order 14299 directs the operation of a reactor regulated by the

U.S. Army at a domestic military installation no later than September 30, 2028 [24]. The parallel development of civilian and military regulatory pathways indicates that reactor technology alone does not determine military deployability. The appropriate licensing and regulatory framework must also be established according to the intended defense application.

Overall, the reviewed U.S. programs do not converge on a single reactor or power conversion technology. Instead, common design priorities emerge across different concepts, including long fuel endurance, grid independent operation, compact deployment, passive safety, and reduced dependence on external support. These priorities are combined with the ROK Army MCL basis from the previous study [3] in the following section to derive preliminary requirements for an ROK military microreactor.

3. Preliminary Operational Requirements of ROK Military Microreactor

Preliminary requirements for an ROK military microreactor are derived by combining two inputs: the recurring operational priorities identified from the U.S. programs reviewed and the quantitative ROK Army MCL basis established in the previous study [3]. The previous study estimated that a reference forward-deployed infantry division would require an average MCL of 3.11 MWe and a peak MCL of 5.59 MWe by 2050. Requirements directly supported by these values are stated quantitatively, whereas those dependent on undefined ROK military mission profiles are stated functionally rather than adopting numerical targets from foreign programs.

3.1 Power Availability, Modularity and Low Manning

The continuous average MCL should remain available following the loss of a single generating module. For identical modules,

$$(N - 1) P_{\text{unit}} \geq 3.11 \text{ MWe} \quad (1)$$

where N is the number of installed modules and P_{unit} is the electrical output of each module.

Table III. Effect of module size on N+1 adequacy at 3.11 MWe average MCL.

Single module output	Required modules	Capacity after one module loss	Single module exposure
1 MWe	5	4 MWe	20.0%
2 MWe	3	4 MWe	33.3%
5 MWe	2	5 MWe	50.0%

Table III illustrates the basic trade off associated with module size. Smaller modules make the loss of a single unit less critical and allow generating capacity to be increased in smaller steps. For example, the loss of one 1 MWe module removes only 20% of the installed capacity, whereas the loss of one 5 MWe module removes 50%.

However, increasing the number of modules also increases the number of balance of plant (BOP) interfaces, control systems, maintenance activities, and safeguards requirements that must be managed. Therefore, low MWe modularization is advantageous only when multiple modules can be operated and maintained efficiently.

This requirement is closely related to low manning operation. Full unmanned operation is not necessary, but automated monitoring, diagnostics, and routine control should enable a limited operating crew to supervise multiple modules. At the same time, centralized supervision should not create common-cause vulnerabilities. Essential electrical, heat-rejection, and protection systems should retain sufficient functional independence and physical separation so that a single failure or attack does not disable several modules simultaneously. In addition, the reactor modules should be compatible with the local military power grid, enabling stable islanded operation and coordinated power sharing among multiple units.

3.2 Fuel Endurance and Fuel Cycle Constraints

Multi year fuel endurance should be regarded as a fundamental requirement for a military microreactor. However, the achievable core life should not be specified simply by adopting the three to eight year operating periods of existing U.S. programs. It depends on the available uranium enrichment, fuel form and allowable burnup, core power density, reactivity management, and material performance.

Fuel availability is particularly important for the ROK application. Higher enrichment including HALEU can support a more compact core and longer operating cycle, but such fuel may not be available through an assured supply pathway and may also require additional safeguards and physical protection considerations. Therefore, the practically available enrichment and fuel supply conditions should be treated as boundary conditions for the core design rather than assumed in advance. Accordingly, the specific core lifetime should be determined from the achievable enrichment, fuel availability, neutronic design, and safeguards constraints rather than prescribed in advance.

3.3 Deployability, Heat Rejection, and Compactness

Deployability should be defined according to the intended military application. Transportable systems such as Project Pele and Kaleidos require compact packaging and minimum dependence on site specific infrastructure, whereas fixed installations such as Eielson can place greater emphasis on long term reliability and maintainability. This distinction also affects the ultimate heat sink. A relocatable reactor should preferably minimize dependence on an assured external water source, making ambient air heat rejection attractive, while a fixed installation may use either air or

water based heat rejection depending on site conditions and resilience requirements. Therefore, compactness should be evaluated for the complete power system, including shielding, PCS, heat rejection, and auxiliary equipment, rather than for the reactor core alone.

3.4 Safety, Security, and Regulatory Framework

Military deployment does not change fundamental nuclear safety principles, but it may require the reactor to remain safe while external power, supporting infrastructure, communications, or operator availability are degraded. Strong inherent feedback, reliable shutdown, and decay heat removal with minimal dependence on external support are therefore desirable. A low potential source term is also important because a radiological event that restricts access to nearby command or communication facilities may directly affect mission continuity.

Security and safeguards should be considered together with safety from the conceptual design stage. Robust fuel forms can provide benefits for both safety and nonproliferation. For a deployed military reactor, TRISO fuel is attractive not only because of its strong fission product retention but also because its coated particle structure and graphite matrix introduce additional barriers to unauthorized material access and subsequent fuel processing [25, 26]. However, the benefit should be evaluated together with enrichment, transport security, and safeguards requirements.

The regulatory framework is another prerequisite for deployment. The U.S. programs reviewed demonstrate two different approaches: the Eielson pilot follows a commercial NRC licensing and ownership model, whereas Executive Order 14299 directs the operation of a reactor regulated by the U.S. Army [6, 24]. A future ROK program would therefore need to establish an appropriate regulatory and operating framework for military microreactors, including the roles of the military operator, reactor vendor, and civilian nuclear regulator, before detailed deployment.

4. Summary and conclusions

This study reviewed current U.S. military microreactor programs and identified common design priorities relevant to future ROK military applications. Despite differences in reactor and power conversion technologies, the reviewed systems consistently emphasize long fuel endurance, modularity, grid-independent operation, compact deployment, passive safety, and reduced operating burden.

Based on the ROK Army MCL from the previous study [3], a reference forward-deployed infantry division requires 3.11 MWe of average MCL by 2050. This supports a modular reactor architecture capable of maintaining the required power following the loss of one generating module. Core lifetime, deployability, fuel supply, and safety requirements should be determined

under realistic ROK operating and fuel-cycle constraints rather than directly adopting foreign design targets.

These results provide preliminary engineering requirements for future ROK military microreactor development. Detailed military mission conditions should be defined first, after which suitable reactor technologies can be selected and evaluated.

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