Assessment of Naval Reactor Infrastructure for Domestic Cobalt-60 Production

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INTRODUCTION

Activated materials generated through nuclear reactions have historically been viewed primarily as a waste management challenge for the nuclear industry. However, a subset of radioisotopes produced through neutron activation possesses substantial commercial, industrial, and national security value. Among these, cobalt-60 remains one of the most widely utilized isotopes, with applications spanning medical sterilization, food irradiation, and radiation-hardness qualification of military and commercial microelectronics. Following the dissolution of the Soviet Union and the subsequent reorientation of federal nuclear priorities in the 1990s, U.S. isotope production capabilities were largely divested, and the global supply chain transitioned toward foreign government reactors, primarily in Canada and Russia. For several decades, this arrangement remained viable due to the long half-life of Co-60 (5.27 years), which allowed previously manufactured sources to remain in service for periods approaching 25–30 years.

Today, however, many of these legacy gamma irradiation facilities are reaching end-of-life, and the international reactor fleet responsible for isotope production is aging, capacity-constrained, and geopolitically fragile. This has created renewed urgency to reestablish domestic isotope production capabilities to support both commercial demand and military readiness. While new civilian isotope production reactors represent a long-term solution, they require substantial capital investment and extended licensing timelines. An alternative near- and medium-term pathway is the utilization of existing government nuclear infrastructure, including retired and surplus naval reactor platforms, for neutron activation of cobalt and other strategic isotopes. Naval reactors were designed for sustained high-power operation, exceptional reliability, and stringent military quality assurance standards, making them well-suited for high-specific-activity isotope production.

Recent federal initiatives focused on expanding domestic nuclear energy capacity and repurposing retired naval reactor assets for civilian power applications further highlight the opportunity to evaluate these platforms for dual-use isotope production missions. This paper examines the technical feasibility, operational considerations, and strategic value of employing naval reactor infrastructure for domestic radioisotope production to enhance U.S. supply chain resilience and national security.

BACKGROUND

One of the challenges that has stricken the decommissioning of nuclear aircraft carriers and submarines for decades is the high activity of Co-60 and Ni-63 found in the reactor corrosion products coequally known as *Chalk River Unidentified Deposits* (CRUD). A Russian paper states that immediately following transfer from active service, a submarine may have up to 1.1×10^5 Ci of long-lived isotopes, excluding the fuel. [1] While absolute inventories depend on materials selection, reactor power history, and coolant chemistry, nuclear-powered vessels of comparable class and operating lifetime can be expected to exhibit similar orders of magnitude of long-lived activation products.

CRUD is not an isolated occurrence related to decommissioning; it remains an ongoing issue throughout the service life of a vessel. Where specific evolutions may induce mechanical agitation and subsequent release of CRUD into the primary coolant system. Though historically treated as a radiological liability, the persistent formation of Co-60-bearing CRUD demonstrates that naval reactors inherently generate and manage high-activity gamma-emitting isotopes under routine operating conditions. [2] While intentionally produced isotopes would be contained to maintain their utility for industrial applications, these reactor designs were engineered to handle the specific gamma energies and mitigate the risk for Co-60 and other activation products.

One significant advantage of naval reactor designs is their high-power density, a necessity driven by the geometric constraints of submarine propulsion plants. For a given fuel composition and neutron spectrum, high power density correlates directly with elevated neutron flux, which is desirable for efficient neutron activation. However, operational power variability driven by propulsion and electrical demand introduces temporal fluctuations in neutron flux, complicating the predictable production of isotopes with half-lives exceeding several hours. Additionally, active vessels lack the logistical accessibility required for routine target insertion and retrieval. These factors render deployed naval reactors unsuitable for sustained isotope production, despite their favorable neutronic characteristics. Many of these challenges can be translated to most power-producing reactors, except for the CANDU design. Which offers the ability to load isotopes at atmospheric pressure. [3]

Despite the aforementioned challenges, the *Genesis Mission* announced by the Trump administration in *Executive Order 14363* states its purpose as “A national initiative led by the Department of Energy and its 17 National Laboratories to build the world's most powerful scientific platform to accelerate discovery, strengthen national security, and drive energy innovation." [4] One proposal to stem from this executive action is a proposal from a Texas-based startup called HGP Intelligent Energy. This company proposes in its letter of intent to the *U.S. House Committee on Energy and Commerce Subcommittee on Energy,* that it offers the only near-term solution for scaling land-based nuclear power this decade. Their solution, titled *CoreHeld,* seeks the repurposing of retired naval nuclear propulsion plants as baseload power for AI datacenters. The first deployment is planned for Oak Ridge National Laboratory in Tennessee, with the use of modified 4th-generation Westinghouse aircraft carrier reactors (A4W). The letter to Congress specifies a cost of \$1-4-million per Megawatt and a capital cost of \$2-billion, making it a fraction of the cost of current modular and research designs. [5]

With few modifications beyond those planned by HPG Intelligent Energy, we propose that retired naval reactor infrastructure can provide a technically feasible, near-term pathway for domestic Co-60 production using existing shielding, activation physics, and operational experience.

TECHNICAL FEASIBILITY

The production of cobalt-60 from elemental cobalt follows the reaction shown in equation (1), where it then beta decays with a half-life of 5.27 years into Ni-60, shown in equation (2). The gammas produced from Co-60 are 1.17 and 1.33 MeV.

$$^{59}_{27}Co + ^{1}_{0}n \rightarrow ^{60}_{27}Co^{*} \tag{1}$$

$$^{60}_{27}Co^{*} \rightarrow \beta^{-} + \gamma + ^{60}_{26}Ni + \bar{\nu} \tag{2}$$

The challenge with producing industrial amounts of Co-60 lies in the time-integrated neutron flux. Given that the proposed use of the retired reactor is a data center, it can be assumed that the power is consistent and near 100% of the operating capacity of the reactor. The neutron flux can be approximated through the function of reactor volume (V), operating power (P), fission cross-section (Σ_f), and energy per fission (E_f) shown in equation (3). Assuming a 550 MW_e output, a highly enriched fuel, and a 3 m^3 core, the neutron flux may reside between 1×10^{12} - 1×10^{14} $cm^{-2}\times s^{-1}$.

$$\phi = \frac{P}{VE_f\Sigma_f} \tag{3}$$

Naval reactors are designed to be thermal; thus, it can be assumed that the vast majority of the neutron flux exists at thermal energies. Subsequently, the ENDF value cross-section for absorption for Co-59 is 37.2 barns for a neutron energy of 2200 m/s. Furthermore, an industrially relevant Co-60 activity is typically 1 MCi. [6] The relationship in equation (4) provides the Bateman time-dependent expression for solving for the time required to achieve the target activity, and equation (5) displays the time-dependent activity solution.

$$\frac{dN_p}{dt} = \sigma\phi N_t - \lambda N_p \tag{4}$$

$$A(t) = \sigma\phi N_t(1 - e^{-\lambda t}) \tag{5}$$

Where (σ) is the capture cross-section, (ϕ) is the neutron flux, (N_p) is the produced nuclei, (N_t) is the target nuclei, (λ) is the decay-constant, and (t) is time. Where the production capacity is limited by the ability to shut down power to the data center. With the proposed dual reactors, a frequent production schedule can be maintained without interrupting power service to the end-user. The time to achieve the target activity is both a function of initial Co-59 mass and neutron flux. On the high end, 100 kg of target material can reach 1 MCi in a month of continuous operation at full power. Table I provides a reference for how long it would take various initial masses of Co-59 to activate at the estimated neutron flux.

Table I. Time to Activate 1 MCi of Cobalt-60.

	Neutron Flux ($n\times cm^{-2}\times s^{-1}$)		
Initial Co-59 mass (kg)	1×10^{12}	1×10^{13}	1×10^{14}
1	Impossible[1]	Impossible[1]	29.2 y
10	Impossible[1]	29.2 y	0.78 y
100	29.2 y	0.78 y	0.07 y

[1] The saturation activity is less than the 1MCi target for the initial mass or flux.

OPERATIONAL CONSIDERATION

The success of a retired naval reactor participating in an isotope production program is fundamentally dependent on the reactor's continuous operation. As described above, nuclear power offers reliable baseload energy, making it particularly appealing for applications such as data centers, which benefit from consistent and uninterrupted power. For isotope production, this operational consistency is critical: as shown in equation (4), the target isotope is continuously consumed, so the production source must match or exceed this sink to maintain activity.

While advanced Gen 3+ or Gen 4 reactors have the technical potential to produce isotopes, their variable operational schedules, driven by shifting power demands, may complicate sustained isotope production. Industrial heat applications, such as electrical arc furnaces, similarly require near-constant operation. The X-Energy Xe-100, a leading pebble bed reactor design, offers a thermal neutron flux on the order of 1×10^{13} $n\cdot cm^{-2}\cdot s^{-1}$, but its fuel loading configuration has not been extensively evaluated for isotope production. [7] Moreover, there are no Gen 3+/4 reactors in the U.S. that currently have projected dates of criticality beyond their pilot designs as of July 4, 2026. [8] In contrast, leveraging retired naval reactors presents a near-term pathway for domestic isotope production. These reactors are already designed for continuous, high-power operation and can provide a reliable neutron source, offering a technically feasible solution by the end of the decade.

More of a logistical consideration is the workforce development for operating the reactor. The Congressional letter drafted by HPG Intelligent Energy specifies their intent to source a majority of their operators from the Naval Nuclear Propulsion Program following their tenure in the U.S. Navy. Many of whom have already been qualified to operate the A4W plant. Those who were qualified on the S8G/S1B/A1B would have a minor learning curve and requalification timeline, but fundamentally, all naval reactors have similar operations. Unlike other commercial reactors, including dedicated isotope production reactors, have and may continue have problems recruiting qualified operators. [9] Once again, indicating a more immediate timeline for the naval reactor option.

STRATEGIC NECESSITY

The role of radioisotopes in medicine, food, microelectronics, and other industries cannot be overstated. Co-60 in particular is used to sterilize medical devices, acts as a cancer treatment, assures microelectronic radiation hardness, and prevents agricultural blight from affecting the food supply. Without a steady domestic supply, key industries would come to a halt or would be at the whim of geopolitical tension. Some of these uses could and have been replaced by X-ray technologies to mitigate proliferation. However, due to the energy of the Cobalt gammas, some applications have no substitute.

The United States currently has three dedicated reactors for full-time isotope production. High Flux Isotope Reactor (HFIR), Advanced Test Reactor, and The University of Missouri Research Reactor (MURR). All of which are at production capacity and nearing facility age limit. The NRC is looking to extend some licenses, and the MURR has renovations planned. However, without extensive capital, both human and fiscal, the United States cannot scale production in a large-scale conflict. [10]

Given the lead time required to construct new reactors and the criticality of maintaining uninterrupted isotope availability, near-term solutions are essential. One promising pathway is the repurposing of retired naval reactors, which offer continuous high-flux operation, existing shielding, and robust infrastructure. Utilizing these reactors for short-term isotope production could alleviate bottlenecks, ensure strategic resilience, and bridge the gap until domestic commercial reactors or advanced reactor designs can come online.

FACILITY REQUIREMENTS

Permitting aside, the largest challenges associated with designing a facility to produce radioactive isotopes are the design of dummy fuel cells to contain the activated material in the core, a hot cell for collection and processing, physical security, and a shipping capacity.

Perhaps the most obvious is the physical security of a site handling Nuclear Regulatory Commission Categories 1 and 2 Co-60 sources. However, by the nature of the request to repurpose the A4W core, the Department of Energy maintains control of the highly enriched uranium and requires such physical security for this site. Therefore, the security exists by default, and there will be minimal expense increase.

Developing a dummy fuel cell for the A4W reactor to house the isotopes during irradiation is not terribly difficult, as there are already approved designs for instruments. However, the reactor containment facility must be constructed in such a manner that the pressure vessel can regularly be opened for isotope collection. Unlike current pool-type isotope reactors, the pressurized design makes removal more expensive. Certainly, the inclusion of a cell will affect the neutronics of the core, but the process of transporting the core to the new land-based location will affect this as well. During the current simulation and core requalification process, the inclusion of isotope production can be conducted simultaneously.

Finally, it is unclear if HPG Intelligent Energy plans to recoup the A4W's steam plant. However, given that it is highly tailored to naval propulsion and nearly 30 years old, it is unlikely that this would be the case. Therefore, a new auxiliary plant must be constructed to support electrical production. In this new plant, a hot cell and transportation hub can easily be integrated into the design.

While the isotope production will add to the projected costs of the *CoreHeld* project, many of the challenges that would exist for developing a new isotope facility from the ground up can be addressed for minimal cost increases by the very nature of the request to reuse the naval reactors. Thus, much of the cost can easily be justified in the project. Without a full financial analysis, it is difficult to determine if there would be an economic advantage to a corporation seeking to implement this strategy. However, the strategic advantage at a discount may be worth any construction or permitting inconvenience in the short-term.

CONCLUSION

The proposal to reuse naval reactors to meet the energy crisis that faces data center infrastructure is nothing short of bold. However, it certainly offers a better alternative to a useful reactor core sitting idly at the Hanford site in Washington state. If Congress and the Department of Energy are willing to entertain this proposal as one of many solutions to the recent executive orders for large-scale AI and nuclear development, there is utility in solving more than one problem at once. In this paper, we propose that the use of naval reactors as a means to power data centers offers a unique opportunity to scale the United States' domestic capacity for isotope production by the end of the decade.

The constant power requirement for the data centers and the high-power density of the reactor core make the A4W an ideal candidate for isotope production when it is no longer serving in an active navy vessel. The strategic importance and the U.S. divestment in isotopes establish an absolute urgency to explore all options for expanding capabilities. While there is no full substitute to a reactor designed solely to produce isotopes, the retired naval reactor provides one of the most promising solutions until capital is allocated and a new facility goes critical.

While proposed efforts are not cheap to any extent, combining them with the engineering challenges and site requirements of situating the sea-faring reactor at a stationary land-based location offers the ability to reduce costs when compared to two independent projects. Moreover, the proposed timeline for the data center rollout correlates strongly with the point in time when isotope supply and demand will invert strongly in opposition to the United States favor.

Ultimately, the reuse of retired naval reactor cores represents a pragmatic, near-term pathway to mitigate both emerging energy infrastructure constraints and long-standing vulnerabilities in the domestic radioisotope supply chain. While this approach does not replace the need for purpose-built isotope production reactors, it offers a technically feasible, operationally mature, and time-relevant bridge until new facilities are licensed and constructed. Given the long lead times associated with nuclear infrastructure and the inability to stockpile radioisotopes, early evaluation of this concept is warranted. If pursued in parallel with broader investments in advanced reactors and isotope programs, repurposed aval reactors could provide a critical margin of resilience during a period of accelerating demand and strategic uncertainty.

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DISCLAIMER

The views expressed in this article are those of the author and do not reflect the official policy or position of the United States Air Force, Department of Defense, or the U.S. Government.

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