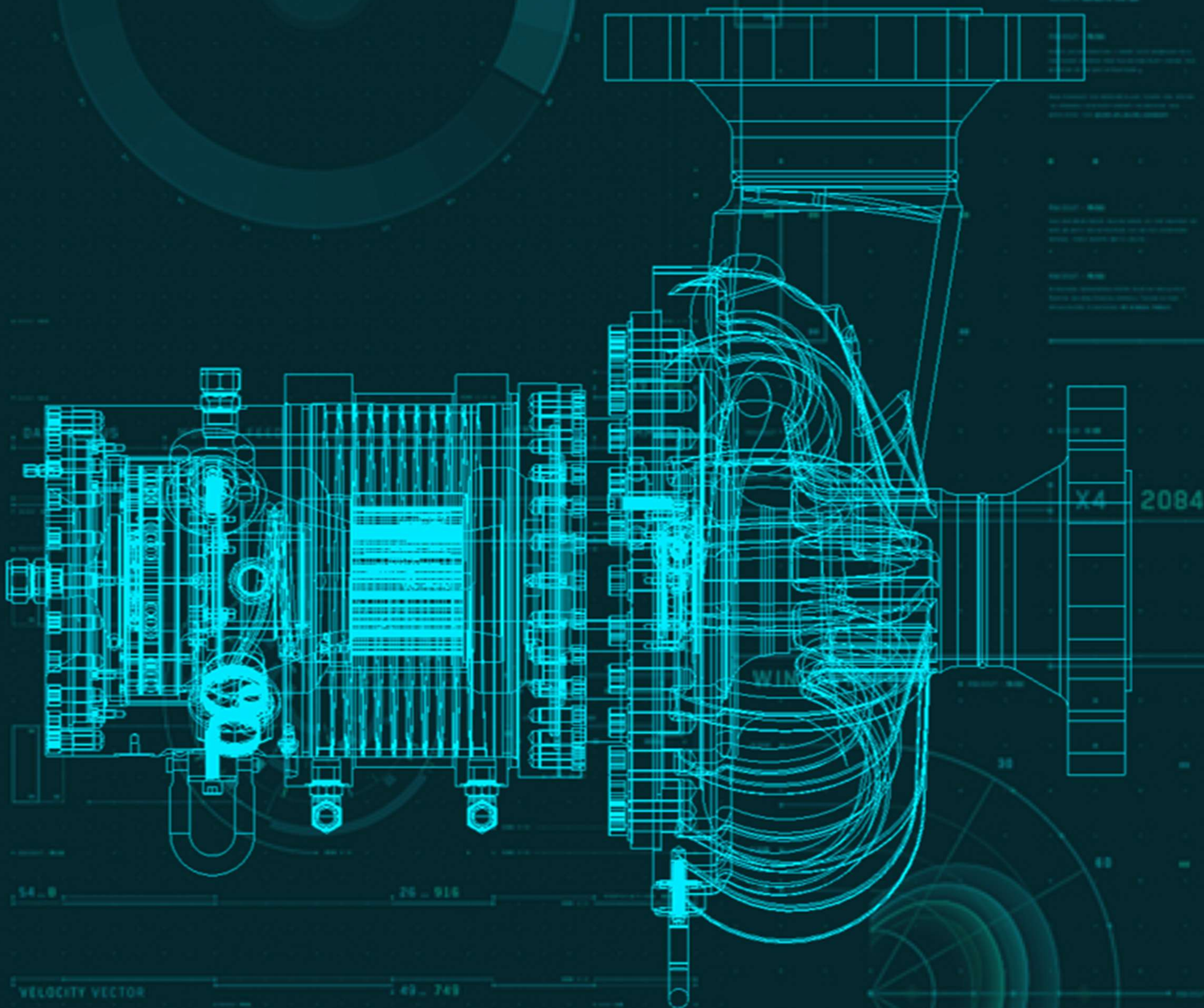
RADIANT

Kaleidos Factory Fueling Operations



Radiant Industries, LLC

1 INTRODUCTION

Radiant's fuel and test operations represent a hazard scenario that is significantly diminished compared to the existing fleet and is therefore less suited to the practices used to review and regulate those existing reactors. Kaleidos's combination of functional containment—in the form of TRISO particle fuel—and fuel loading two orders of magnitude smaller than a typical LWR result in a dramatically lower risk profile for the proposed production site. In light of these conditions, Radiant proposes a safety and environmental review process in line with non-power reactors; this approach is consistent with the Commission's direction for functional testing of a factory-fabricated reactor as outlined in SRM-SECY-24-0008. This paper provides a general description and model for the production site operations; the intent of this primer is to inform the staff of Radiant's operations and highlight areas for further clarification and discussion as part of the pre-application process.

2 RADIOLOGICAL HAZARDS

Nuclear microreactors will be manufactured, fueled, refueled, defueled, and decommissioned at Radiant's production site (see Figure 1). This flow is built around a production rate that requires no more than 15 cores worth of fuel onsite at any time; this rate is set to limit the total amount of U-235 material onsite at any point in operation. In addition to the overall control of material quantity, this report briefly summarizes the potential radiological hazards and accidents associated with these processes, mitigations in place to prevent accidents, and potential impacts on site workers and the public. Physical, chemical, and natural phenomena hazards are only mentioned herein as initiators to potential accidents with radiological dose consequence. While not an exhaustive list, safety-class structures, systems and components (SSCs) which are credited for safety functions include TRISO fuel for fission product retention, Kaleidos components for reactivity control and radionuclide retention, and site structures for withstanding safe shutdown earthquakes.

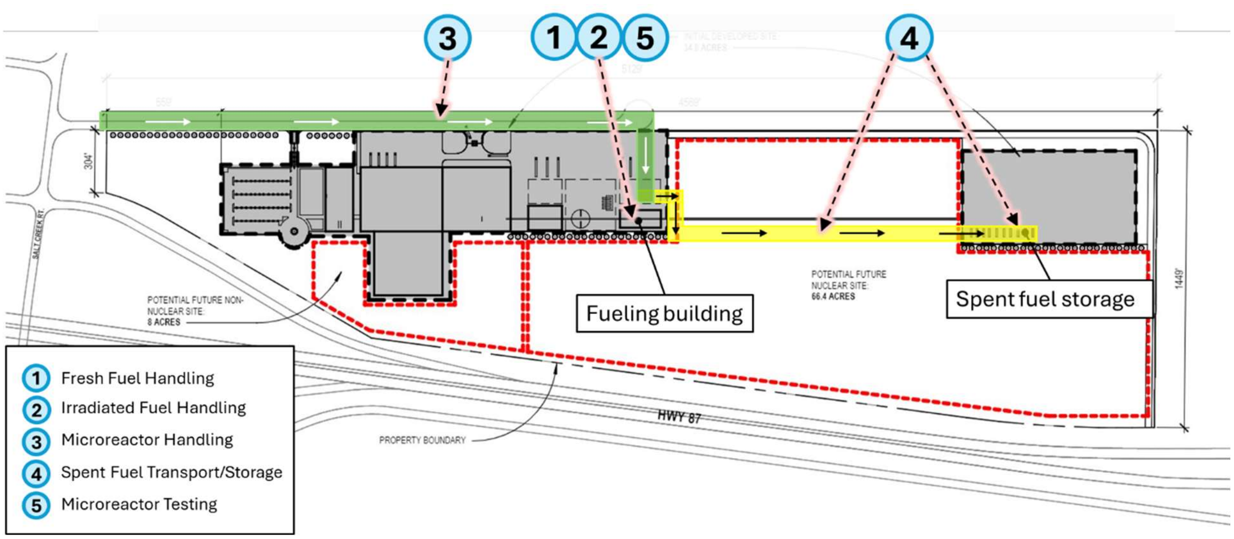


Figure 1: Conceptual diagram of Radiant's production site with relevant parameters and nuclear operation areas.

3 PRODUCTION SITE OPERATIONS

Most nuclear operations occur within Radiant's fueling building, including (1) fresh fuel receipt, handling, assembly, and storage; (2) irradiated fuel handling; and (3) microreactor handling. Nuclear operations that occur outside of Radiant's fueling building include (4) spent fuel transportation and storage and (5) microreactor transportation, storage, and testing within the boundary of the production site (see Table 1). Dozens of initiating events set forth potential accident progressions that could lead to worker and/or public dose; these events are either (A) associated with an inadvertent criticality or (B) lead to a radionuclide release.

Table 1. Summary of nuclear operations and associated hazards with select mitigations

	Operation	*Location*	*Hazard categories*	*Mitigations*
1	Fresh fuel receipt, handling, assembly, and storage	• Fueling building	• Inadvertent criticality	• Physically limiting material in working areas • Material accounting
2	Irradiated fuel handling	• Fueling building	• Radiological release • Inadvertent criticality	• Irradiated fuel handling system design • Defueling procedures
3	Microreactor handling	• Roads • Fueling building • Test site	• Radiological release • Inadvertent criticality	• Kaleidos structural design • Transportation controls
4	Spent fuel transportation	• Roads • Fueling building • Spent fuel storage	• Radiological release	• Transfer canister design features • Transportation controls
4	Dry cask storage	• Spent fuel storage	• Radiological release	• Dry cask design features • Monitoring procedures
5	Microreactor testing	• Test site	• Radiological release • Inadvertent criticality	• Reactor safety features • Reactor test procedures

4 BOUNDING PUBLIC HAZARD

The maximum nuclear hazard to the public immediately surrounding Radiant's production site is scenario where a radiological release during refueling operations that is initiated by mishandling of a microreactor and a breach in the reactor pressure retention boundary to the environment. For this event, the bounding radiological inventory is that from a Kaleidos unit operated to full burnup and returned to the production site after 90 days of cooling. The decay heat remaining in the core is less than 5 kW, resulting in material temperatures of less than 90 °C. As with any facility, inadvertent fires are also assessed as a potential hazard requiring assessment and mitigation. Fires are prevented during handling and defueling operations per the site's fire protection plan, though dose consequence analyses consider elevated temperatures to induce further radionuclide mobility. Using a mechanistic source term for the release, a standard plume dispersion model, and assuming some physical energy is imparted during depressurization, the dose consequence from this bounding event is well under the 1–25 rem public evaluation guideline for the public (see Figure 2). At maximum, dry casks are loaded with two spent Kaleidos cores and present a much lower failure probability than defueling operations.

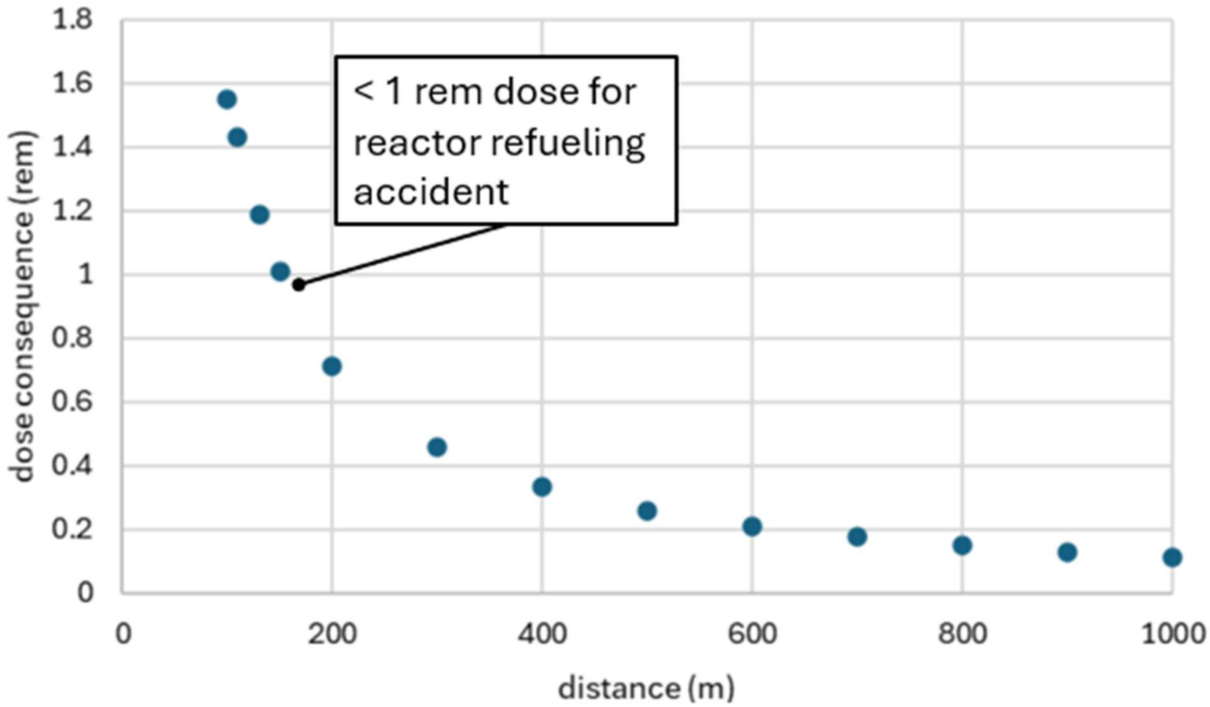


Figure 2. Bounding dose at the public boundary during a hypothetical core drop at the refueling building (190 m). (NOTE: Preliminary results take credit for retention in TRISO fuel and core graphite materials.)

5 BOUNDING WORKER HAZARD

The maximum nuclear hazard to a production site worker is an inadvertent criticality associated with a mishandling of fresh fuel in assembly or core reloading operations within the fueling building. To prevent this, the fuel assembly area is designed around the Versa Pac 55-gallon package (VP-55) to physically and administratively limit the amount of fuel available to less than that required for criticality in a fully flooded upset event (see Figure 3). Areas indicated in orange may be permanent, temporary, or configurable barriers that allow for control of material flow. In the subsequent fuel handling areas, the controls are adjusted to maintain subcritical configurations in upset conditions through safety-class SSCs, including a monolith (fueled reactor unit cell assembly) transfer cart and monolith storage areas.

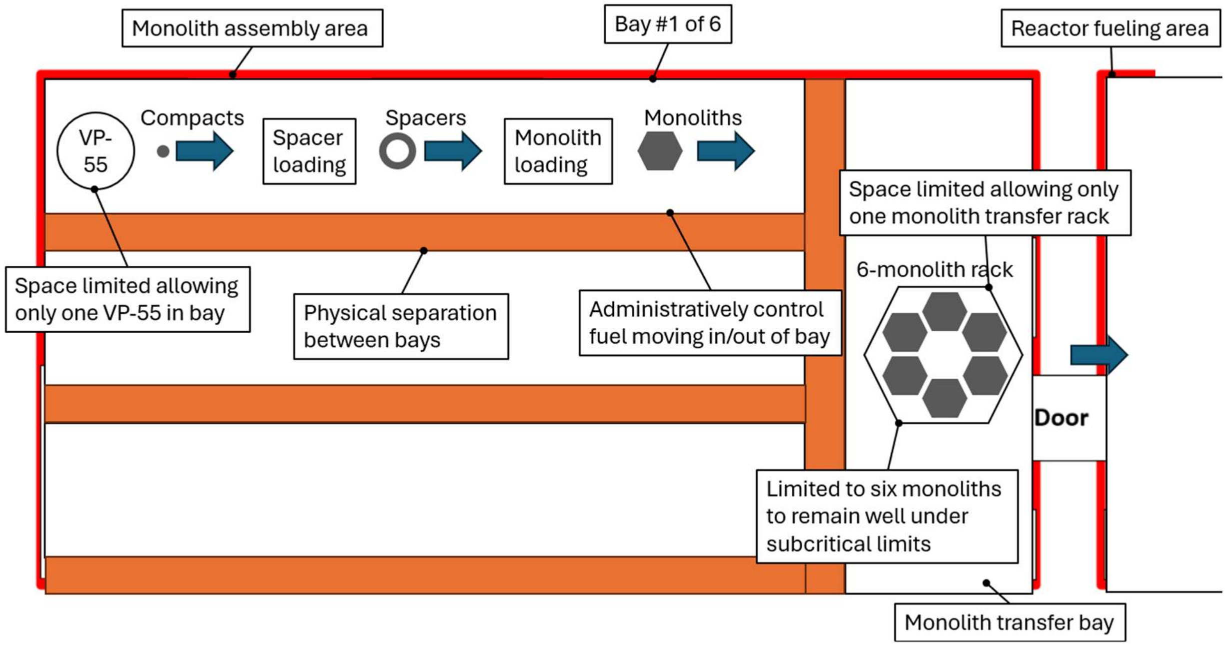


Figure 3. Conceptual layout of the monolith assembly area noting controls to prevent inadvertent criticality.

6 SUMMARY

Traditional light water reactors can contain upwards of 7100 kg of U-235 while the entire Radiant production site will represent less than 10% of that quantity. This gap between potential hazard scenarios is further widened by the fact that functional containment is provided throughout the entire process by way of the fuel's TRISO form. These differences in combination with process mitigations for site operations and the bounding hazards assessment support the categorization of factory testing operations as similar to a non-power reactor. This proposed treatment follows the NRC staff's rationale provided in Option 3b in the paper "Micro-Reactor Licensing and Deployment Considerations: Fuel Loading and Operational Testing at a Factory", dated January 24, 2024 (SECY-24-0008, ML23207A250). Further detail and substantiation for each of the topics covered in the paper will be delivered in an upcoming license application.