

UNITED STATES OF AMERICA  
NUCLEAR REGULATORY COMMISSION

COMMISSIONERS:

Christopher T. Hanson, Chair  
David A. Wright  
Annie Caputo  
Bradley R. Crowell

In the Matter of

KAIROS POWER LLC

(Hermes Test Reactor)

Docket No. 50-7513-CP

**CLI-23-05**

**MEMORANDUM AND ORDER**

On October 19, 2023, we held a hearing on the application of Kairos Power LLC (Kairos) for a construction permit for the Hermes non-power test reactor.<sup>1</sup> In this uncontested proceeding, we consider the sufficiency of the NRC Staff's review of Kairos's application. As discussed below, we find that the Staff's review was sufficient to support the regulatory findings. We authorize issuance of the construction permit.

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<sup>1</sup> See Kairos Power LLC; Construction Permit Application; Notice of Hearing, 88 Fed. Reg. 60,724 (Sept. 5, 2023) (Hearing Notice); Tr. at 1-165 (attached to Order of the Secretary (Setting Deadline for Proposed Transcript Corrections) (Oct. 24, 2023) (unpublished) (as amended by Order of the Secretary (Adopting Transcript Corrections and Admitting Revised Exhibit) (Nov. 13, 2023) (unpublished))).

## I. BACKGROUND

### A. Proposed Action

The construction permit would allow construction of a 35-megawatt thermal test reactor on an approximately 185-acre brownfield site in Oak Ridge, Tennessee.<sup>2</sup> The Hermes test reactor will use a combination of tri-structural isotropic (TRISO) fuel particles and a molten fluoride salt coolant known as Flibe. The non-power reactor will serve as a scaled demonstration plant to test and demonstrate key technical elements, design features, safety functions, and equipment performance for Kairos's salt-cooled, fluoride high temperature reactor technology.<sup>3</sup> Kairos expects to complete construction by the end of 2026 and then to operate for four years.<sup>4</sup>

Before submitting its construction permit application in 2021,<sup>5</sup> Kairos engaged in extensive preapplication activities with the Staff, including the development of topical reports and participation in public meetings and audits.<sup>6</sup> Topical reports cover safety-related topics that apply to multiple nuclear reactors and increase the efficiency of the licensing process by minimizing the time and resources that both applicants and the Staff spend on multiple reviews of the same topic. Kairos submitted eleven topical reports for the Staff's review and approval,

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<sup>2</sup> Ex. KRS-001, *Applicant's Pre-Filed Testimony of Peter Hastings; Kairos Power LLC; Evidentiary Hearing* (Sept. 28, 2023), at 3, 8 (Kairos Testimony).

<sup>3</sup> *Id.* at 3.

<sup>4</sup> *Id.* at 4, 25; Ex. NRC-007, "Safety Evaluation Related to the Kairos Power LLC Construction Permit Application for the Hermes Test Reactor" (June 13, 2023), at 1-8, 1-11 (Safety Evaluation).

<sup>5</sup> The public version of the application can be found in Exhibits NRC-005A through NRC-005E in this proceeding.

<sup>6</sup> Ex. NRC-001, "Staff's Statement in Support of the Uncontested Hearing for Issuance of a Construction Permit for the Kairos Hermes Test Reactor," Commission Paper SECY-23-0074 (Aug. 23, 2023), at 2 (Staff Information Paper). The topics covered by the topical reports, preapplication meetings, and preapplication audits are listed in the Staff Information Paper. *Id.* at 2-3.

eight of which were referenced in its application.<sup>7</sup> Kairos supplemented its application and provided clarifications through timely responses to several hundred Staff questions during audit meetings and in docketed correspondence.<sup>8</sup> The Staff also issued three requests for additional information and one request for confirmation of information.<sup>9</sup> Kairos and the Staff used regulatory guidance in NUREG-1537 in the preparation and review of the construction permit application.<sup>10</sup> Kairos did not request, and the Staff did not grant, any exemptions from NRC regulations.<sup>11</sup>

The Staff conducted a safety review of the application to determine whether it complies with the Atomic Energy Act of 1954, as amended (AEA), and the NRC's regulations.<sup>12</sup> The Advisory Committee on Reactor Safeguards (ACRS), a committee of technical experts charged with reviewing and reporting on safety studies and applications for construction permits and facility operating licenses, provided an independent assessment of the safety aspects of the

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<sup>7</sup> *Id.* The Staff prepared a safety evaluation for each of the topical reports, and any condition or limitation on the use of a topical report is provided in the approved version of the report. *Id.* at 3. The Staff's review of the construction permit application confirmed that the conditions or limitations for the topical reports referenced in the application were satisfied or could reasonably be left for the operating license application. *Id.*

<sup>8</sup> Ex. KRS-001, Kairos Testimony, at 20.

<sup>9</sup> *Id.*

<sup>10</sup> See *id.* at 6 (citing "Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors: Format and Content," NUREG-1537, pt. 1 (Feb. 1996) (ADAMS accession no. ML042430055); "Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors: Standard Review Plan and Acceptance Criteria," NUREG-1537, pt. 2 (Feb. 1996) (ML042430048)); Ex. NRC-001, Staff Information Paper, at 6-8.

<sup>11</sup> Ex. NRC-001, Staff Information Paper, at 8.

<sup>12</sup> See Ex. NRC-007, Safety Evaluation.

application.<sup>13</sup> The ACRS recommended that the construction permit be issued.<sup>14</sup> The Staff also performed an environmental review, in accordance with the National Environmental Policy Act of 1969 (NEPA),<sup>15</sup> that evaluated the environmental impacts of constructing, operating, and decommissioning the Hermes test reactor.<sup>16</sup> Based on its safety and environmental reviews, the Staff recommended that the Commission issue the construction permit to Kairos once the National Historic Preservation Act of 1966 (NHPA) section 106 consultation process is complete.<sup>17</sup>

## **B. Review Standards**

Section 189a. of the AEA requires that we hold a hearing on an application to construct a testing facility.<sup>18</sup> The Staff published a notice of hearing in the *Federal Register* and provided an opportunity for interested members of the public to petition for leave to intervene.<sup>19</sup> No petitions to intervene were filed. Therefore, there was no separate contested hearing.

We issued a second notice that set the time and place for the uncontested hearing and outlined the standards for our review.<sup>20</sup> These standards track the two major areas of focus for

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<sup>13</sup> See Letter from Joy L. Rempe, ACRS, Chairman, to Christopher T. Hanson, Chair, NRC, “Kairos Non-Power Reactor Hermes Construction Permit Application” (May 16, 2023) (ML23130A183) (ACRS Letter).

<sup>14</sup> *Id.* at 2.

<sup>15</sup> 42 U.S.C. § 4321 et seq.

<sup>16</sup> See Ex. NRC-008, “Environmental Impact Statement for the Construction Permit for the Kairos Hermes Test Reactor” (Final Report), NUREG-2263 (Aug. 2023) (FEIS).

<sup>17</sup> Ex. NRC-001, Staff Information Paper, at 22; Tr. at 61 (Mr. Regan). At the time of the hearing, the Staff had not yet completed the section 106 consultation process.

<sup>18</sup> AEA § 189a., 42 U.S.C. § 2239(a) (“The Commission shall hold a hearing . . . on any application under section 104c. for a construction permit for a testing facility.”).

<sup>19</sup> Kairos Power, LLC; Construction Permit Application; Opportunity to Request a Hearing and Petition for Leave to Intervene; Order Imposing Procedures, 87 Fed. Reg. 7503 (Feb. 9, 2022).

<sup>20</sup> Hearing Notice, 88 Fed. Reg. at 60,724-25.

the review of a construction permit application: the Staff's safety and environmental reviews. For the safety review, we must determine whether:

1. the applicant has described the proposed design of the facility, including, but not limited to, the principal architectural and engineering criteria for the design, and has identified the major features or components incorporated therein for the protection of the health and safety of the public;
2. such further technical or design information as may be required to complete the safety analysis, and which can reasonably be left for later consideration, will be supplied in the final safety analysis report;
3. safety features or components, if any, which require research and development have been described by the applicant and the applicant has identified, and there will be conducted, a research and development program reasonably designed to resolve any safety questions associated with such features or components; and
4. on the basis of the foregoing, there is reasonable assurance that (i) such safety questions will be satisfactorily resolved at or before the latest date stated in the application for completion of construction of the proposed facility, and (ii) taking into consideration the site criteria contained in 10 C.F.R. Part 100, the proposed facility can be constructed and operated at the proposed location without undue risk to the health and safety of the public.<sup>21</sup>

In making these findings, we are guided by the additional considerations in 10 C.F.R.

§ 50.40. We consider whether:

1. the processes to be performed, the operating procedures, the facility and equipment, the use of the facility, and other technical specifications, or the proposals, in regard to any of the foregoing collectively provide reasonable assurance that the applicant will comply with NRC regulations, including the regulations in 10 C.F.R. Part 20,<sup>22</sup> and that the health and safety of the public will not be endangered;

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<sup>21</sup> 10 C.F.R. § 50.35(a); Hearing Notice, 88 Fed. Reg. at 60,724-25.

<sup>22</sup> The regulations in Part 20 "apply to persons licensed by the Commission to receive, possess, use, transfer, or dispose of byproduct, source, or special nuclear material or to operate a production or utilization facility." 10 C.F.R. § 20.1002. Kairos has neither requested approval of design information nor has applied for a license to receive, possess, use, transfer, or dispose of byproduct, source, or special nuclear material at the facility. Ex. NRC-007, Safety Evaluation, at 11-2. "Therefore, the [S]taff did not evaluate whether requirements in 10 CFR Part 20 would be met for the construction of the Hermes reactor. Instead, the [S]taff assessed whether Kairos had identified the relevant requirements for an operating facility and provided descriptions of the preliminary facility design and provisions for protecting the health and safety of the public, workers, and the environment in sufficient detail to determine whether the [preliminary safety analysis report] provides an acceptable basis for the development of the radiation protection programs and radioactive waste management, and whether there is reasonable assurance that

2. the applicant is technically and financially qualified to engage in the proposed activities;
3. the issuance of the construction permit will not be inimical to the common defense and security or to the health and safety of the public; and
4. any applicable requirements of Subpart A of 10 C.F.R. Part 51 have been satisfied.<sup>23</sup>

Overlapping this last consideration are the environmental findings that we must make to support issuance of the construction permit.<sup>24</sup> The findings reflect our agency's obligations under NEPA, a statute that requires us to consider the impacts of NRC actions on environmental values.<sup>25</sup> To ensure that these obligations are fulfilled for this construction permit proceeding, we must:

1. determine whether the requirements of NEPA Sections 102(2)(A), (C), and (E),<sup>26</sup> and the applicable regulations in 10 C.F.R. Part 51, have been met;
2. independently consider the final balance among conflicting factors contained in the record of the proceeding with a view to determining the appropriate action to be taken;
3. determine, after weighing the environmental, economic, technical, and other benefits against environmental and other costs, and considering reasonable alternatives, whether the construction permit should be issued, denied, or appropriately conditioned to protect environmental values; and

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Kairos will comply with the regulations in 10 CFR Part 20 during operation of the Hermes facility." *Id.* We agree that the Staff's approach meets 10 C.F.R. § 50.40(a).

<sup>23</sup> 10 C.F.R. § 50.40(a)-(d).

<sup>24</sup> *See, e.g., id.* § 51.105(a).

<sup>25</sup> NEPA § 102(2), 42 U.S.C. § 4332(2); *see* 10 C.F.R. § 51.10.

<sup>26</sup> On June 3, 2023, President Biden signed into law the Fiscal Responsibility Act of 2023. Pub. L. No. 118-5, 137 Stat. 10. In addition to increasing the debt ceiling and addressing other matters related to federal spending, the Act, in section 321, included amendments to NEPA. The amendments added new sections (D), (E), and (F) to section 102(2); as a result, the section 102(2)(E) referred to in 10 C.F.R. § 51.105(a)(1) is now section 102(2)(H), but the substance of the provision remains the same.

4. determine whether the NEPA review conducted by the NRC Staff has been adequate.<sup>27</sup>

If we determine that the application meets the standards and requirements of the AEA and the NRC's regulations and that any notifications to other agencies or bodies have been duly made, we will issue a construction permit "in such form and containing such conditions and limitations" that we deem "appropriate and necessary."<sup>28</sup>

We do not review Kairos's application de novo; rather, we consider the sufficiency of the Staff's review of the application on both safety and environmental matters.<sup>29</sup> In other words, we consider whether the safety and environmental record is adequate to support issuance of the construction permit and whether the Staff's findings are reasonably supported in logic and fact.<sup>30</sup> Under our regulations, we must reach our own independent determination on certain environmental findings—i.e., whether the relevant NEPA requirements have been met, what is the appropriate "final balance among conflicting factors," and whether the construction permit "should be issued, denied[,] or appropriately conditioned."<sup>31</sup> But we will not "second-guess [the Staff's] underlying technical or factual findings" unless we find the Staff's review incomplete or inadequate or its findings insufficiently explained in the record.<sup>32</sup>

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<sup>27</sup> 10 C.F.R. § 51.105(a)(1)-(4); Hearing Notice, 88 Fed. Reg. at 60,725. Because this is an uncontested proceeding, 10 C.F.R. § 51.105(a)(5), which concerns only contested proceedings, does not apply.

<sup>28</sup> 10 C.F.R. § 50.50.

<sup>29</sup> See *Exelon Generation Co.* (Early Site Permit for Clinton ESP Site), CLI-05-17, 62 NRC 5, 34, 38-39 (2005).

<sup>30</sup> See *id.* at 39.

<sup>31</sup> *Id.* at 45 (quoting 10 C.F.R. § 51.105(a)(1)-(3)).

<sup>32</sup> *Id.*

## **C. The Hearing Process**

The Staff completed its safety review of the Hermes application in June 2023, with the publication of the Safety Evaluation, and its environmental review in August 2023, with the issuance of the Final Environmental Impact Statement (FEIS).<sup>33</sup> Shortly after publication of the FEIS we received the Staff's information paper, which serves as the Staff's pre-filed testimony for the uncontested hearing.<sup>34</sup>

### **1. Pre-Hearing Activities**

The notice of hearing set a schedule for pre-hearing filings.<sup>35</sup> We issued twenty-eight questions on environmental and safety-related topics for the Staff and Kairos to answer in writing in advance of the hearing. The questions addressed a variety of topics including functional containment, temperature monitoring of the safety-related decay heat removal system, how to address the new NEPA requirements enacted in June 2023, and whether the cumulative impacts of the proposed Hermes 2 facility are analyzed in the FEIS.<sup>36</sup>

We also invited interested states, local government bodies, and federally recognized Indian tribes to provide statements for us to consider as part of the uncontested proceeding.<sup>37</sup> In response, we received a statement from the City of Oak Ridge, Tennessee.<sup>38</sup> The letter from the

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<sup>33</sup> See Ex. NRC-007, Safety Evaluation; Ex. NRC-008, FEIS.

<sup>34</sup> See Ex. NRC-001, Staff Information Paper.

<sup>35</sup> Hearing Notice, 88 Fed. Reg. at 60,725.

<sup>36</sup> See Order of the Secretary (Transmitting Pre-Hearing Questions) (Sept. 15, 2023) (unpublished), at 2-16 (Pre-Hearing Questions Order).

<sup>37</sup> See Hearing Notice, 88 Fed. Reg. at 60,725.

<sup>38</sup> See Letter from Jack Suggs, Interim City Manager, City of Oak Ridge, Tennessee, to NRC Document Control Desk (Sept. 22, 2023) (ML23268A361).

City of Oak Ridge expressed its continued support for the Kairos project and described the positive interaction with Kairos during the City's zoning approval process.<sup>39</sup>

## **2. The Hearing**

We set the topics for and the order of presentations at the hearing.<sup>40</sup> In the first panel, witnesses for Kairos provided an overview of the Hermes test reactor project and the Hermes construction permit application.<sup>41</sup> In the second panel, witnesses for the Staff provided an overview of the construction permit review process and a summary of the Staff's review and regulatory findings.<sup>42</sup> The third panel focused on safety-related issues, and the fourth panel focused on environmental issues.<sup>43</sup> The Staff made available thirty-two witnesses at the hearing.<sup>44</sup> Thirteen of these witnesses were scheduled panelists; the remainder stood by to answer questions on topics related to their areas of expertise.<sup>45</sup> A total of twenty-one Kairos

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<sup>39</sup> *Id.* at 2-3.

<sup>40</sup> See Memorandum from Brooke P. Clark, Secretary of the Commission, to Counsel for Applicant and Staff (Oct. 5, 2023), Encl. (ML23278A210) (Scheduling Note).

<sup>41</sup> Ex. KRS-002, Hermes Mandatory Hearing—Overview Panel (Oct. 12, 2023) (Kairos Overview Panel Presentation).

<sup>42</sup> Ex. NRC-009-R, Kairos Hermes Mandatory Hearing Construction Permit Application Review: Overview of Review Methodology and Summary of Key Regulatory Findings (Oct. 24, 2023) (Staff Overview Panel Presentation).

<sup>43</sup> See Ex. KRS-003, Hermes Mandatory Hearing—Safety Panel (Oct. 12, 2023) (Kairos Safety Panel Presentation); Ex. NRC-010, Kairos Hermes Mandatory Hearing Construction Permit Application Review: Safety Panel (Oct. 12, 2023) (Staff Safety Panel Presentation); Ex. KRS-004, Hermes Mandatory Hearing—Environmental Panel (Oct. 12, 2023) (Kairos Environmental Panel Presentation); Ex. NRC-011, Kairos Hermes Mandatory Hearing Construction Permit Application Review (Oct. 12, 2023) (Staff Environmental Panel Presentation).

<sup>44</sup> See Tr. at 10-11 (Ms. Wright); see also *NRC Staff Witness List* (Sep. 28, 2023), Attach. (ML23271A251).

<sup>45</sup> See Ex. NRC-009-R, Staff Overview Panel Presentation, at 3; Ex. NRC-010, Staff Safety Panel Presentation, at 3 (ML23285A164) (Staff Safety Panel Presentation); Ex. NRC-011, Staff Environmental Panel Presentation, at 3.

witnesses attended the hearing, four of whom offered testimony on behalf of Kairos on panels at the hearing and in pre-filed written testimony.<sup>46</sup>

a. *Summary of the Overview Panels*

Mike Laufer, Chief Executive Officer; Ed Blandford, Chief Technology Officer; Per Peterson, Chief Nuclear Officer; and Peter Hastings, Vice President, Regulatory Affairs and Quality of Kairos Power LLC, provided testimony for the Kairos overview panel.<sup>47</sup> Dr. Laufer provided information on the background and mission of Kairos.<sup>48</sup> Dr. Peterson provided testimony on technical aspects and the objectives for the Hermes reactor project.<sup>49</sup> Dr. Laufer, Dr. Peterson, and Mr. Hastings also answered questions regarding the effectiveness of Kairos's interactions with the Staff during its review, the interactions with the community around Oak Ridge, Tennessee, and the public more generally, and the purpose of the mandatory hearing process.<sup>50</sup>

Robert Taylor, Deputy Director of the Office of Nuclear Reactor Regulation (NRR); Mohamed Shams, Director, Division of Advanced Reactors and Non-Power Production and Utilization Facilities (DANU), NRR; Jeremy Bowen, Deputy Director, DANU, NRR; and Christopher Regan, Director, Division of Rulemaking, Environmental, and Financial Support (REFS), Office of Nuclear Material Safety and Safeguards (NMSS), presented the Staff's overview panel and provided testimony on the Staff's review of the Kairos construction permit

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<sup>46</sup> See *List of Anticipated Witnesses for Kairos Power, LLC for the Hearing on Uncontested Issues* (Sep. 28, 2023), at 1-3; Tr. at 7-8 (Mr. Lighty); Ex. KRS-001, Kairos Testimony; Ex. KRS-002, Kairos Overview Panel Presentation, at 1; Ex. KRS-003, Kairos Safety Panel Presentation, at 1; Ex. KRS-004, Kairos Environmental Panel Presentation, at 1.

<sup>47</sup> Tr. at 13-26 (Dr. Laufer, Dr. Peterson); Scheduling Note, Encl. at 1.

<sup>48</sup> Tr. at 13-22 (Dr. Laufer).

<sup>49</sup> *Id.* at 22-26 (Dr. Peterson).

<sup>50</sup> *Id.* at 26-42 (Dr. Laufer, Dr. Peterson, Mr. Hastings).

application.<sup>51</sup> Mr. Taylor provided an overview of the Kairos construction permit application.<sup>52</sup> Mr. Shams described the pre-application engagement with Kairos, regulatory standards governing the construction permit application review, and public engagement during the review.<sup>53</sup> Mr. Bowen provided insights into the Staff's safety review.<sup>54</sup> Mr. Regan provided an overview of the Staff's environmental review and findings in support of issuance of the construction permit.<sup>55</sup> Mr. Shams, Mr. Taylor, and Mr. Bowen answered questions relating to the applicant's construction permit application, research activities, pre-application engagement, the use of topical reports in the construction permit application review, knowledge management for future advanced reactor applications, and lessons learned from the Staff's review of this construction permit application that can be applied to the Hermes 2 construction permit application.<sup>56</sup>

*b. Summary of the Safety Panel*

The safety panel discussed the Kairos construction permit application and Staff conclusions from the Safety Evaluation, focusing on unique features of the facility and novel issues, including TRISO fuel, molten salt coolant, high-temperature materials, functional containment, and passive accident response.<sup>57</sup> Ed Blandford, Chief Technology Officer, Kairos

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<sup>51</sup> *Id.* at 42-63 (Mr. Taylor, Mr. Shams, Mr. Bowen, Mr. Regan); Scheduling Note, Encl. at 2.

<sup>52</sup> *Id.* at 43-47 (Mr. Taylor).

<sup>53</sup> *Id.* at 47-51 (Mr. Shams).

<sup>54</sup> *Id.* at 51-55 (Mr. Bowen).

<sup>55</sup> *Id.* at 55-62 (Mr. Regan).

<sup>56</sup> *Id.* at 63-82 (Mr. Shams, Mr. Taylor, Mr. Bowen).

<sup>57</sup> *Id.* at 82-107 (Mr. Blandford, Mr. Jessup, Mr. Helvenston, Mr. Van Wert, Mr. Chereskin, Ms. Hart, Ms. Siwy); Ex. KRS-003, Kairos Safety Panel Presentation, at 3-6; Ex. NRC-010, Staff Safety Panel Presentation, at 4-26.

Power LLC, served as the witness for Kairos.<sup>58</sup> William Jessup, Chief, Advanced Reactor Licensing Branch 1, DANU, NRR; Edward Helvenston, Project Manager, DANU, NRR; Chris Van Wert, Senior Technical Advisor for Reactor Fuel, Division of Safety Systems, NRR; Alexander Chereskin, Materials Engineer, DANU, NRR; Michelle Hart, Senior Reactor Engineer, DANU, NRR; and Alexandra Siwy, Senior Nuclear Engineer, DANU, NRR, testified for the Staff.<sup>59</sup>

Kairos's testimony focused on the inherent safety features of the Hermes test reactor, including how the TRISO fuel and the Fluoride salt coolant allow for the use of functional containment in making Kairos's safety case.<sup>60</sup> The Staff's testimony addressed the regulatory requirements for issuing a construction permit and covered novel technical issues presented by the Hermes test reactor, including the TRISO fuel, molten salt coolant, high temperature materials, functional containment, and passive accident response.<sup>61</sup> Following the safety panel presentations, we posed questions to witnesses for both Kairos and the Staff.

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<sup>58</sup> Tr. at 83-87 (Mr. Blandford); Scheduling Note, Encl. at 2.

<sup>59</sup> *Id.* at 87-107 (Mr. Jessup, Mr. Helvenston, Mr. Van Wert, Mr. Chereskin, Ms. Hart, Ms. Siwy); Scheduling Note, Encl. at 2.

<sup>60</sup> Tr. at 83-87 (Mr. Blandford).

<sup>61</sup> *Id.* at 87-107 (Mr. Jessup, Mr. Helvenston, Mr. Van Wert, Mr. Chereskin, Ms. Hart, Ms. Siwy).

*c. Summary of the Environmental Panel*

The environmental panel focused on the FEIS, including the proposed federal action, purpose and need for the project, the environmental review process and public outreach, NEPA findings, and alternatives to the proposed action.<sup>62</sup> Peter Hastings, Vice President, Regulatory Affairs and Quality, represented Kairos.<sup>63</sup> Kenneth Erwin, Branch Chief, New Reactor Environmental Review Branch, REFS, NMSS; Tamsen Dozier, Project Manager, REFS, NMSS; and Peyton Doub, Environmental Scientist, REFS, NMSS, testified on behalf of the Staff.<sup>64</sup> Mr. Hastings discussed the environmental report, the site-selection process, and characteristics of the Hermes test reactor site.<sup>65</sup> The Staff described the proposed federal action, its environmental review process, evaluation of alternatives to the proposed action, consultation with other agencies and tribes, public outreach, and consideration of and conclusions on environmental impacts.<sup>66</sup> Following the environmental panel presentations, we posed questions to witnesses for both Kairos and the Staff.

**3. Post-Hearing Activities**

After the hearing, we adopted corrections to the hearing transcript and admitted a revised Staff exhibit.<sup>67</sup> We held the record open because the Staff had not yet completed its

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<sup>62</sup> *Id.* at 123-35 (Mr. Hastings, Mr. Erwin, Ms. Dozier, Mr. Doub); Scheduling Note, Encl. at 3; Ex. KRS-004, Kairos Environmental Panel Presentation, at 3-7; Ex. NRC-011, Staff Environmental Panel Presentation, at 4-17.

<sup>63</sup> Tr. at 123-27 (Mr. Hastings); Scheduling Note, Encl. at 3.

<sup>64</sup> *Id.* at 127-35 (Mr. Erwin, Ms. Dozier, Mr. Doub); Scheduling Note, Encl. at 3.

<sup>65</sup> Tr. at 124-27 (Mr. Hastings).

<sup>66</sup> *Id.* at 127-35 (Mr. Erwin, Ms. Dozier, Mr. Doub).

<sup>67</sup> Order of the Secretary (Adopting Transcript Corrections and Admitting Revised Exhibit) (Nov. 13, 2023) (unpublished).

consultation activities under the NHPA.<sup>68</sup> On December 1, the Staff filed revisions to two exhibits: NRC-002, the draft construction permit, and NRC-003, the draft record of decision.<sup>69</sup> In the revised draft construction permit, the Staff made several non-substantive edits and replaced placeholder language relating to NHPA section 106 with a requirement that Kairos implement its Archaeological Resource Monitoring and Unanticipated Discovery Plan.<sup>70</sup> In the revised draft record of decision, the Staff documented completion of the NHPA section 106 process for this licensing action.<sup>71</sup> Kairos does not object to the admission of these exhibits.<sup>72</sup> Accordingly, we strike exhibits NRC-002 and NRC-003, admit exhibits NRC-002-R and NRC-003-R, and close the evidentiary record.

## II. DISCUSSION

As discussed in Section II.E, we find that Kairos's application meets our regulatory requirements for issuance of a construction permit. Although we authorize issuance of a construction permit, our decision does not constitute approval of the design.<sup>73</sup> Kairos has represented that it will apply for an operating license and submit with that application a final

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<sup>68</sup> *Id.* at 1.

<sup>69</sup> *NRC Staff Exhibit List* (Dec. 1, 2023) (Staff Revised Exhibit List), at 1; see Ex. NRC-002-R, Kairos Power LLC, Docket No. 50-7513, Hermes Test Reactor Construction Permit (Oct. 6, 2023) (Draft Construction Permit); Ex. NRC-003-R, Draft Summary Record of Decision, U.S. Nuclear Regulatory Commission, Docket No. 50-7513, Construction Permit Application for the Kairos Hermes Test Reactor (Nov. 30, 2023) (Draft Record of Decision).

<sup>70</sup> See Staff Revised Exhibit List at 1-2; Ex. NRC-002-R, Draft Construction Permit, app. A, at A-3.

<sup>71</sup> Staff Revised Exhibit List at 2; Ex. NRC-003-R, Draft Record of Decision, at 7, 8.

<sup>72</sup> Staff Revised Exhibit List at 2.

<sup>73</sup> See 10 C.F.R. § 50.35(b) ("A construction permit will constitute authorization to the applicant to proceed with construction but will not constitute Commission approval of the safety of any design feature or specification unless the applicant specifically requests such approval and such approval is incorporated into the permit."). Kairos did not request such approval.

safety analysis report, which will contain the final detailed design.<sup>74</sup> The discussion that follows provides a survey of the key facts that support our findings and certain novel issues in the Staff's safety review. We do not discuss every aspect of Kairos's construction permit application, the Staff's review, or our sufficiency review. Our decision to authorize issuance of the construction permit, however, is based on the record in its entirety.

**A. The Proposed Design**

Kairos's Hermes reactor will be configured as a pebble bed with a chemically stable, low-pressure molten fluoride salt coolant known as Flibe.<sup>75</sup> The pairing of high-temperature-tolerant TRISO fuel and low-pressure, single-phase, chemically stable reactor coolant reduces the number of potential fuel-damage scenarios, thus simplifying the reactor design and reducing the number of required safety systems.<sup>76</sup> For example, low-leakage, pressure retaining containment structures are not necessary due to the low pressure of the reactor and associated piping in combination with the fission product retention provided by the TRISO fuel.<sup>77</sup> The Hermes design further relies on passive decay heat removal and does not require an emergency core cooling system for decay heat removal or replacement of coolant inventory.<sup>78</sup>

The Hermes reactor has three major plant systems: the reactor system, the primary heat transport system, and the decay heat removal system.<sup>79</sup> The facility includes engineered safety

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<sup>74</sup> See, e.g., Ex. KRS-001, Kairos Testimony, at 44.

<sup>75</sup> Ex. NRC-007, Safety Evaluation, at 4-1.

<sup>76</sup> Ex. KRS-001, Kairos Testimony, at 3.

<sup>77</sup> *Id.*; Tr. at 23 (Dr. Peterson).

<sup>78</sup> Ex. KRS-001, Kairos Testimony, at 3.

<sup>79</sup> *Id.*

features that provide functional containment and decay heat removal—these features are credited for mitigation of the consequences of postulated events.<sup>80</sup>

Kairos uses a definition of “safety-related structures, systems, and components” that differs from the definition found in 10 C.F.R. § 50.2 to establish those structures, systems, and components that are classified as safety related for the Hermes reactor. Specifically, in lieu of using “the integrity of the reactor coolant pressure boundary” terminology in 10 C.F.R. § 50.2, Kairos's definition reads: “the integrity of the *portions* of the reactor coolant boundary *relied upon to maintain coolant level above the active core*.”<sup>81</sup> Kairos uses this definition because the Hermes reactor does not rely on the functional capability of the primary heat transport system to remove decay heat from the reactor core, and the Staff found this definition acceptable for the proposed facility.<sup>82</sup>

#### **1. TRISO Fuel**

Hermes will use TRISO fuel particles embedded in a carbon matrix pebble.<sup>83</sup> The pebbles are roughly the size of golf balls, and the TRISO particles are roughly the size of poppy seeds.<sup>84</sup> The fuel particle is composed of a uranium oxycarbide fuel kernel encased in coating layers to limit fission product releases.<sup>85</sup> The fuel particles will contain high assay low enriched

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<sup>80</sup> See Ex. KRS-001, Kairos Testimony, at 10.

<sup>81</sup> Ex. NRC-007, Safety Evaluation, at 3-20 (emphasis added). The Staff found that the 10 C.F.R. § 50.2 definition of “safety-related structures, systems, and components” is not applicable to the Hermes facility. *Id.*; Ex. NRC-004, *NRC Staff Responses to Commission Pre-Hearing Questions* (Sept. 28, 2023), at 11 (Staff Pre-Hearing Responses).

<sup>82</sup> Ex. NRC-007, Safety Evaluation, at 3-20, 3-4 to 3-5.

<sup>83</sup> Ex. NRC-010, Staff Safety Panel Presentation, at 11.

<sup>84</sup> Tr. at 94 (Mr. Van Wert).

<sup>85</sup> Ex. NRC-001, Staff Information Paper, at 9.

uranium.<sup>86</sup> The coating layers are composed of pyrolytic carbon and silicon carbide.<sup>87</sup> In addition, there is a carbon buffer layer between the kernel and the inner pyrolytic carbon layer that serves to accommodate fission gases and limit pressure buildup.<sup>88</sup> The TRISO particles are arranged in a fuel annulus near the outer surface of the pebble surrounding a low-density graphite core.<sup>89</sup> In addition to fuel pebbles, the reactor also contains moderator pebbles, which have the same diameter as the fuel pebbles but contain no uranium and are made of graphite material.<sup>90</sup> Both the fuel and moderator pebbles are designed to maintain positive buoyancy under normal operation and postulated events.<sup>91</sup> Pebbles are buoyant in Flibe and travel upward through the core.<sup>92</sup>

The TRISO particle specification is based on the U.S. Department of Energy (DOE) Advanced Gas Reactor program.<sup>93</sup> The TRISO fuel is similar to that developed for high temperature gas-cooled reactors, and the coatings on the particle fuel have demonstrated retention of fission products to temperatures above 1,600°C.<sup>94</sup> In comparison, the Hermes test reactor normal operating temperature is up to 650°C.<sup>95</sup>

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<sup>86</sup> Ex. NRC-007, Safety Evaluation, at ii.

<sup>87</sup> Ex. NRC-001, Staff Information Paper, at 9.

<sup>88</sup> *Id.*

<sup>89</sup> Ex. NRC-001, Staff Information Paper, at 10; Tr. at 94 (Mr. Van Wert); Ex. NRC-010, Staff Safety Panel Presentation, at 11.

<sup>90</sup> Ex. NRC-007, Safety Evaluation, at 4-2.

<sup>91</sup> *Id.*

<sup>92</sup> *Id.* at 4-35.

<sup>93</sup> Ex. NRC-001, Staff Information Paper, at 9.

<sup>94</sup> *Id.* at 10; Ex. NRC-007, Safety Evaluation, at 1-12 to 1-14; Tr. at 23-24 (Dr. Peterson).

<sup>95</sup> Ex. NRC-001, Staff Information Paper, at 14; Ex. KRS-001, Kairos Testimony, at 11.

The Staff evaluated the Kairos fuel qualification program as described in the topical report and concluded that it meets the applicable regulatory requirements.<sup>96</sup> Tribology testing will be conducted on fuel pebbles in two separate environments: (1) Flibe with an argon cover gas, and (2) an argon only environment.<sup>97</sup> The coefficient of friction and wear rates will be determined during tribology tests in both of these environments.<sup>98</sup> In its preliminary safety analysis report, Kairos provided the relevant principal design criteria, a design description of the TRISO particle and corresponding fuel elements (pebbles), and a preliminary analysis and evaluation of the fuel element demonstrating the margins of safety during normal operations and transient conditions anticipated during the life of the facility.<sup>99</sup> The Staff concluded that the information was sufficient to conform to the applicable guidance and meet the regulatory requirements of 10 C.F.R. §§ 50.35 and 50.40.<sup>100</sup>

Both fuel and moderator pebbles will be inspected by the pebble handling and storage system as they are removed from the core.<sup>101</sup> Therefore, neither the fuel nor moderator pebbles are expected to produce debris or dust in the reactor coolant that could inhibit the removal of heat from the core.<sup>102</sup>

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<sup>96</sup> *Id.*; see “Final Safety Evaluation for Topical Report KP-TR-011, Revision 2, ‘Fuel Qualification Methodology for the Kairos Power Fluoride Salt-Cooled High Temperature Reactor (KP-FHR),’” (Mar. 2, 2023) (ML23089A398).

<sup>97</sup> Ex. KRS-006, *Kairos Power LLC’s Responses to Commission’s Pre-hearing Questions* (Oct. 12, 2023), at 14 (Kairos Pre-Hearing Responses).

<sup>98</sup> *Id.*

<sup>99</sup> Ex. NRC-001, Staff Information Paper, at 11.

<sup>100</sup> *Id.*

<sup>101</sup> Ex. NRC-007, Safety Evaluation, at 4-7; Ex. KRS-006, Kairos Pre-Hearing Responses, at 10.

<sup>102</sup> Ex. KRS-006, Kairos Pre-Hearing Responses, at 10; Ex. NRC-007, Safety Evaluation, at 4-6 to 4-7; see *also* Ex. NRC-004, Staff Pre-Hearing Responses, at 13.

## 2. **Molten Salt Coolant**

Flibe is a lithium fluoride-beryllium fluoride mixture (2LiF-BeF<sub>2</sub>).<sup>103</sup> In the Hermes design, the Flibe coolant is credited with supporting reactivity control and serving as a fission product barrier.<sup>104</sup> Flibe is able to retain radionuclides and prevent radionuclide release to the environment during normal operations and postulated events.<sup>105</sup> The Staff reviewed the capabilities of Flibe to retain fission products in its review of Kairos's topical report on mechanistic source term.<sup>106</sup>

Flibe has advantageous heat transfer properties and is thermally and radiolytically stable at high temperatures.<sup>107</sup> But Flibe contains beryllium, which requires controls to mitigate potential worker exposure, and the transmutation of lithium will generate tritium, which will also need to be managed.<sup>108</sup> The Staff will evaluate the potential beryllium hazard and its ability to impact operations or accident response and the methods and systems to control tritium during the operating license review.<sup>109</sup> During reactor operations, the Flibe coolant is expected to accumulate impurities, which may affect the corrosion of primary system components, create some circulating activity in the primary system, affect reactivity characteristics, and potentially affect thermophysical properties.<sup>110</sup> To ensure that the Flibe coolant maintains the properties needed for natural circulation heat transfer, Kairos must monitor, and potentially correct, the salt

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<sup>103</sup> Ex. KRS-003, Kairos Safety Panel Presentation, at 3.

<sup>104</sup> Ex. NRC-001, Staff Information Paper, at 9.

<sup>105</sup> Ex. KRS-001, Kairos Testimony, at 11.

<sup>106</sup> Tr. at 97 (Mr. Chereskin).

<sup>107</sup> Ex. NRC-001, Staff Information Paper, at 9.

<sup>108</sup> Tr. at 97 (Mr. Chereskin).

<sup>109</sup> *Id.*

<sup>110</sup> Ex. NRC-001, Staff Information Paper, at 9.

composition.<sup>111</sup> Kairos expects to include a limiting condition of operation to maintain the reactor coolant composition within allowable limits as part of the technical specifications in its operating license application.<sup>112</sup>

### **3. High-Temperature Materials**

The Hermes test reactor design operates at higher temperatures than light-water reactors.<sup>113</sup> Therefore, the primary system components must be qualified for these high temperatures as well as for the Flibe coolant environment.<sup>114</sup> This construction permit application is the first to reference American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code Section III, Division 5, "High Temperature Materials," which was endorsed in NRC Regulatory Guide 1.87, Revision 2.<sup>115</sup> Kairos will use 316H stainless steel and ER-16-8-2 weld filler material for safety-related metallic components and ET-10 for graphite reflector components.<sup>116</sup>

ASME Boiler and Pressure Vessel Code Section III, Division 5 provides an approach to ensure the mechanical and structural integrity of components that operate in high-temperature environments. It specifies material properties, such as allowable stresses based on creep damage for the metallic materials at the times and temperatures the Hermes reactor

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<sup>111</sup> *Id.*

<sup>112</sup> See Ex. NRC-007, Safety Evaluation, at 5-4.

<sup>113</sup> Ex. NRC-001, Staff Information Paper, at 14.

<sup>114</sup> *Id.*

<sup>115</sup> Ex. NRC-010, Staff Safety Panel Presentation, at 17; Ex. NRC-001, Staff Information Paper, at 14; Tr. at 99 (Mr. Chereskin).

<sup>116</sup> Tr. at 98-99 (Mr. Chereskin); Ex. NRC-010, Staff Safety Panel Presentation, at 17-18; Ex. NRC-001, Staff Information Paper, at 14.

components will experience.<sup>117</sup> The use of Section III, Division 5 also provides rules for aspects related to structural and mechanical integrity for the use of 316H stainless steel.<sup>118</sup>

ASME Boiler and Pressure Vessel Code Section III, Division 5 does not address the interactions between the Flibe environment and metallic structural materials.<sup>119</sup> Therefore, Kairos submitted a topical report describing its qualification plan for metallic structural materials used in Flibe-wetted areas for safety-related high-temperature components of its reactor designs, including the Hermes test reactor.<sup>120</sup> The qualification plan includes extensive testing to quantify degradation mechanisms in normal and postulated accident conditions, and the Staff's evaluation of the topical report concluded that the Kairos qualification program for metallic materials satisfies the regulatory requirements related to the qualification of 316H stainless steel in the Flibe environment.<sup>121</sup>

The Hermes test reactor uses graphite reflector blocks to moderate and reflect neutrons back into the reactor core and protect the reactor vessel from the effects of neutron fluence.<sup>122</sup> The reflector blocks provide a heat sink for the core and form coolant flow channels, the pebble defueling chute, and channels for the insertion and withdrawal of reactivity control and shutdown elements.<sup>123</sup> For graphite components, Kairos cited an approved topical report for the

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<sup>117</sup> Tr. at 99 (Mr. Chereskin).

<sup>118</sup> *Id.*

<sup>119</sup> Tr. at 100 (Mr. Chereskin).

<sup>120</sup> See "Metallic Material Qualification for the Kairos Power Fluoride Salt-Cooled High Temperature Reactor," KP-TR-013-NP-A, Revision 4 (Sept. 2022) (ML23102A179).

<sup>121</sup> Ex. NRC-001, Staff Information Paper, at 14.

<sup>122</sup> *Id.*

<sup>123</sup> *Id.*; Ex. NRC-007, Safety Evaluation, at 4-16.

qualification of the material.<sup>124</sup> In its evaluation of the topical report on graphite qualification, the Staff concluded that the methodology is acceptable because it is generally consistent with applicable portions of ASME Boiler and Pressure Vessel Code, Section III, Division 5, with departures related to graphite material qualification.<sup>125</sup> The behavior of graphite as a function of fluence and temperature is an important design consideration to ensure graphite components maintain their integrity and perform their design functions.<sup>126</sup>

#### **4. Functional Containment**

The safety case for the Hermes reactor is based on the concept of functional containment, which is a barrier, or a set of barriers taken together, that effectively limits the physical transport of radioactive materials to the environment.<sup>127</sup> For the Hermes test reactor, functional containment consists of physical barriers, operating conditions, coolant design, and fuel form.<sup>128</sup> We previously approved the concept of functional containment in SRM-SECY-18-0096.<sup>129</sup> Instead of using the event categorization scheme described in SECY-18-0096, Kairos identified anticipated operational occurrences, design-basis events, and beyond-design-basis-events, consistent with a maximum hypothetical accident (MHA)

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<sup>124</sup> See “Graphite Material Qualification for the Kairos Power Fluoride Salt-Cooled High-Temperature Reactor,” KP-TR-014-NP-A, Revision 4 (Sept. 2022) (ML23108A317).

<sup>125</sup> Ex. NRC-001, Staff Information Paper, at 14.

<sup>126</sup> *Id.*; see Tr. at 99-100 (Mr. Chereskin).

<sup>127</sup> See Ex. KRS-003, Kairos Safety Panel Presentation, at 4; Ex. NRC-010, Staff Safety Panel Presentation, at 20 (citing SECY-18-0096, “Functional Containment Performance Criteria for Non-Light-Water-Reactors,” (ML18114A546)).

<sup>128</sup> Ex. NRC-007, Safety Evaluation, at 6-2.

<sup>129</sup> Staff Requirements—SECY-18-0096—Functional Containment Performance Criteria for Non-Light-Water-Reactors (Dec. 4, 2018) (ML18338A502).

approach.<sup>130</sup> The MHA is intended to bound all postulated events in terms of dose consequences, consistent with the guidance for non-power reactors in NUREG-1537.<sup>131</sup>

To establish the MHA, Kairos considered a broad range of event categories, including insertion of reactivity, salt spills, loss of forced circulation, malfunction of the pebble handling and storage system, radioactive releases from a subsystem or component, general challenges to normal operation, internal hazards (fire and flood), and external hazards (seismic, wind, and flood).<sup>132</sup> The Staff concluded that Kairos's MHA analysis demonstrates that the dose consequences of the MHA are within the accident dose criteria of 10 C.F.R. § 100.11(a).<sup>133</sup> Even with conservative estimates for releases from TRISO fuel, tritium in graphite structures, and argon-41 from activation of the cover gas, the MHA results in radiological doses at the site boundary that are well below the siting criteria of 25 rem and also below the U.S. Environmental Protection Agency Protective Action Guides.<sup>134</sup>

The safety case for the Hermes reactor does not rely on traditional containment barriers like reactor coolant piping or the reactor building due to the effectiveness of the TRISO fuel particle and the Flibe coolant at retaining radionuclides.<sup>135</sup> The fuel particle forms four of the five fission product barriers credited for functional containment: the fuel kernel, an inner pyrolytic carbon layer, a silicon carbide layer, and an outer pyrolytic carbon layer.<sup>136</sup> Additionally, the fuel

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<sup>130</sup> Ex. NRC-001, Staff Information Paper, at 12.

<sup>131</sup> See Ex. KRS-006, Kairos Pre-Hearing Responses, at 1.

<sup>132</sup> ACRS Letter at 6.

<sup>133</sup> Ex. NRC-001, Staff Information Paper, at 12.

<sup>134</sup> ACRS Letter at 6. The dose consequences of the MHA are less than 1 rem at the site boundary. Ex. KRS-003, Kairos Safety Panel Presentation, at 6.

<sup>135</sup> See Ex. KRS-003, Kairos Safety Panel Presentation, at 4.

<sup>136</sup> Ex. NRC-001, Staff Information Paper, at 12.

particles are embedded in an annular shell arrangement inside a spherical pebble, which provides physical protection against mechanical damage.<sup>137</sup> The majority of radioactive material at risk for release is held within the TRISO fuel, and the Flibe coolant serves as an additional barrier for release of radionuclides for submerged fuel pebbles.<sup>138</sup> Because the TRISO fuel and Flibe coolant effectively contain fission products such as cesium and iodine, the MHA's dose driving elements are mobile activation products, such as argon-41 and tritium, rather than fission products.<sup>139</sup>

Kairos described the components and operating conditions that define the Hermes test reactor functional containment in its preliminary safety analysis report.<sup>140</sup> Kairos also identified key performance criteria on specific structures, systems, and components to ensure that the MHA remains bounding: (1) specified acceptable system radionuclide release design limits for the fuel and (2) circulating activity limits for the Flibe coolant.<sup>141</sup>

## **5. *Passive Accident Response***

The reactor vessel system contains the reactor core and provides for circulation of reactor coolant and pebbles as well as insertion of the reactivity control and shutdown system elements in the reactor core.<sup>142</sup> The Hermes test reactor is designed with three safety-related shutdown elements, only two of which are needed to shut down the reactor and maintain it in a

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<sup>137</sup> Ex. NRC-007, Safety Evaluation, at 6-2.

<sup>138</sup> See Ex. KRS-003, Kairos Safety Panel Presentation, at 4.

<sup>139</sup> Ex. KRS-006, Kairos Pre-Hearing Responses, at 15; ACRS Letter at 6.

<sup>140</sup> Ex. NRC-001, Staff Information Paper, at 13.

<sup>141</sup> *Id.*

<sup>142</sup> Ex. NRC-007, Safety Evaluation, at 4-14.

safe condition.<sup>143</sup> These elements have two positions—fully withdrawn or fully inserted.<sup>144</sup> The shutdown elements accomplish a safe shutdown (reactor trip) through gravity insertion on a reactor trip signal or on a loss of normal electrical power, after a short delay to mitigate spurious trips.<sup>145</sup> The reactor trip signal removes power from an electromagnetic clutch, which causes the shutdown elements to fall into the core by gravity and shut down the reactor.<sup>146</sup>

The reactor relies on passive decay heat removal and does not need an active emergency core cooling system for decay heat removal or replacement of coolant inventory.<sup>147</sup> The decay heat removal system removes residual decay heat from the reactor core through the reactor vessel wall during both normal and off-normal conditions.<sup>148</sup> In postulated events where the normal heat rejection system is unavailable, the decay heat removal system, along with natural circulation flow within the core, provides heat removal from fuel in the reactor core via thermal radiation and convection without the need for external sources of electrical power or operator intervention.<sup>149</sup> Natural circulation and the passive decay heat removal system reject residual heat from the reactor core to the atmosphere.<sup>150</sup> The decay heat removal system and

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<sup>143</sup> See Ex. NRC-004, Staff Pre-Hearing Responses, at 9.

<sup>144</sup> Ex. NRC-001, Staff Information Paper, at 13.

<sup>145</sup> *Id.*; Ex. NRC-007, Safety Evaluation, at 4-11.

<sup>146</sup> Ex. NRC-010, Staff Safety Panel Presentation, at 24.

<sup>147</sup> Ex. NRC-001, Staff Information Paper, at 13; Ex. KRS-002, Kairos Overview Panel Presentation, at 9. Active emergency replacement of coolant inventory is not required based on the results of the maximum Fluoride salt spill event. See Ex. NRC-007, Safety Evaluation, 13-14 to 13-17. The evaluation determined that, without active emergency makeup, sufficient inventory was maintained to support adequate in-vessel natural circulation, to ensure the fuel remains covered, and to limit the heat up and radionuclide release. Additionally, the Staff determined that a Fluoride salt spill beyond that assumed in the analysis is not expected to occur. *Id.* at 13-34.

<sup>148</sup> Ex. NRC-001, Staff Information Paper, at 13.

<sup>149</sup> Ex. KRS-001, Kairos Testimony, at 11.

<sup>150</sup> See Ex. KRS-003, Kairos Safety Panel Presentation, at 5.

natural circulation together provide adequate heat removal to ensure that the vessel temperature remains below design limits and that the fuel integrity is not challenged.<sup>151</sup>

The decay heat removal system is made up of four independent trains to provide redundancy in the event of a single failure.<sup>152</sup> The decay heat removal system has sufficient inventory in the thermosyphons to operate for up to seven days to mitigate a postulated event where normal cooling systems are unavailable.<sup>153</sup> The fluidic diodes, which are part of the reactor internals and enable natural circulation when forced circulation is lost, will be subject to planned qualification testing and inspection.<sup>154</sup> The Staff concluded that there is reasonable assurance that the reactor vessel system will perform its safety functions of maintaining structural integrity, geometry, and coolant inventory to ensure sufficient heat removal.<sup>155</sup>

## **B. The Proposed Site**

The site is located in an industrial area of Oak Ridge, Tennessee. The property is at the site of former Buildings K-31 and K-33 of the DOE gaseous diffusion plant, where uranium enrichment occurred between the mid-1950s and mid-1980s.<sup>156</sup> The site boundary encompasses 185 acres, of which about 30 acres would be permanently disturbed for operations of the facility.<sup>157</sup> The site is adjacent to Poplar Creek and 0.4 mile (0.6 kilometer) from the Clinch River arm of the Watts Bar Reservoir.<sup>158</sup>

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<sup>151</sup> Ex. KRS-001, Kairos Testimony, at 11.

<sup>152</sup> *Id.*

<sup>153</sup> Ex. NRC-001, Staff Information Paper, at 13.

<sup>154</sup> *Id.*; Ex. NRC-007, Safety Evaluation, at 4-23.

<sup>155</sup> Ex. NRC-001, Staff Information Paper, at 13-14.

<sup>156</sup> *Id.* at 4; Ex. KRS-001, Kairos Testimony, at 4.

<sup>157</sup> Ex. KRS-002, Kairos Overview Panel Presentation, at 10.

<sup>158</sup> Ex. KRS-001, Kairos Testimony, at 8.

The Staff considered the relevant siting criteria in Part 100 and guidance in NUREG-1537 and concluded that the Hermes facility can be constructed and operated at the proposed location without undue risk to the health and safety of the public.<sup>159</sup> The Staff considered site characteristics such as geography and demography; nearby industrial, transportation, and military facilities; meteorology; hydrology; and geology, seismology, and geotechnical engineering.<sup>160</sup> In addition, the Staff evaluated structures, systems, and components and equipment designed to ensure safe operation, performance, and shutdown when subjected to extreme weather, floods, seismic events, missiles (including aircraft impacts), chemical and radiological releases, and loss of offsite power.<sup>161</sup> As stated earlier, Kairos plans to operate the reactor for four years. When the Staff assessed flooding hazards from potential dam failures, it relied on this limited operating lifetime to approve the acceptability of the site.<sup>162</sup> Therefore, an operating license, if issued, would include “a license term that would be limited to ensure the validity of assumptions and conclusions in the safety analysis for the final design of the Hermes facility.”<sup>163</sup>

The Staff verified that the Hermes emergency planning zone size is appropriate and consistent with guidance based on the preliminary MHA calculations, which indicate that accident doses at the emergency planning zone boundary would not exceed the doses recommended by the U.S. Environmental Protection Agency protective action guidelines of 1 rem total effective dose equivalent or 5 rem projected child thyroid dose.<sup>164</sup> The Staff will

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<sup>159</sup> See 10 C.F.R. § 50.35(a)(4)(ii).

<sup>160</sup> Ex. NRC-007, Safety Evaluation, at 1-3 to 1-4.

<sup>161</sup> *Id.*

<sup>162</sup> Ex. NRC-004, Staff Pre-Hearing Responses, at 6-7.

<sup>163</sup> *Id.* at 7.

<sup>164</sup> Ex. NRC-007, Safety Evaluation, at 2-3; Ex. NRC-004, Staff Pre-Hearing Responses, at 2-4.

review the final justification for the emergency planning zone size based on more detailed plant design information during review of the operating license application.<sup>165</sup>

In pre-hearing questions, we inquired into potential hazards associated with the proposed Oak Ridge Airport. Kairos used DOE guidelines and methodologies in its evaluation of crash frequencies related to the proposed airport in its preliminary safety analysis report.<sup>166</sup> Kairos will design the safety-related portion of the reactor building to withstand the impact of general aviation aircraft associated with operations at the proposed airport.<sup>167</sup> Based on information in the environmental assessment prepared by DOE for the proposed Oak Ridge Airport, the Staff expects that the Beechcraft King Air 350i likely bounds the other types of general aviation aircraft that would use the airport.<sup>168</sup> Additionally, Kairos stated that any proposed configuration of the airport runways is not anticipated to change the need to design for aircraft impact.<sup>169</sup>

### **C. Technical and Design Information for Later Consideration**

Kairos has described the principal design features and the technology that it plans to use, but Kairos will supply further technical and design information in the final safety analysis report filed as part of the operating license application in accordance with 10 C.F.R. § 50.35(a)(2). The construction permit will not constitute approval of the safety of any design feature or specification.<sup>170</sup> Because Kairos did not request approval of any design features or

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<sup>165</sup> Ex. NRC-004, Staff Pre-Hearing Responses, at 4.

<sup>166</sup> Ex. KRS-006, Kairos Pre-Hearing Responses, at 4.

<sup>167</sup> *Id.* at 4-5; see Ex. NRC-004, Staff Pre-Hearing Responses, at 6.

<sup>168</sup> Ex. NRC-004, Staff Pre-Hearing Responses, at 5.

<sup>169</sup> Ex. KRS-006, Kairos Pre-Hearing Responses, at 4.

<sup>170</sup> Ex. NRC-001, Staff Information Paper, at 8; Ex. NRC-010, Staff Safety Panel Presentation, at 7.

specifications to be included in the construction permit, the Staff did not make any findings regarding the safety of any Part 50 design feature or specification.<sup>171</sup>

The Staff identified two conditions to include in the construction permit—one relating to site characteristics and one relating to quality assurance. The first condition directs Kairos to confirm the condition of bedrock supporting the facility and provides for examination of excavations by the Staff, if necessary.<sup>172</sup> The second requires Kairos to implement its quality assurance program for design, procurement, and construction of the Hermes reactor.<sup>173</sup> By including this condition, the construction permit will have an explicit requirement comparable to 10 C.F.R. § 50.55(f)(1). This condition will allow Kairos to make changes to the program without prior NRC approval that do not reduce commitments in the program description previously approved by the NRC, consistent with 10 C.F.R. § 50.55(f)(3).<sup>174</sup> Without this license condition, the Staff would need to approve a license amendment request from Kairos to make any changes to the quality assurance plan regardless of whether the change would reduce a commitment.<sup>175</sup>

As it finalizes the design of its facility, Kairos will need to complete the following research and development activities: (1) perform a laboratory testing program to confirm fuel pebble behavior; (2) develop a high-temperature material surveillance sampling program for the reactor vessel and internals; (3) perform testing of high-temperature material to qualify Alloy 316H and ER-16-8-2; (4) perform an analysis related to potential oxidation in certain postulated events for

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<sup>171</sup> Ex. NRC-001, Staff Information Paper, at 8; Ex. NRC-004, Staff Pre-Hearing Responses, at 1.

<sup>172</sup> Ex. NRC-010, Staff Safety Panel Presentation, at 7; Ex. NRC-001, Staff Information Paper, at 18; Ex. KRS-001, Kairos Testimony, at 31.

<sup>173</sup> Ex. NRC-010, Staff Safety Panel Presentation, at 7; Ex. NRC-001, Staff Information Paper, at 18; Ex. KRS-001, Kairos Testimony, at 31.

<sup>174</sup> Ex. KRS-006, Kairos Pre-Hearing Responses, at 14.

<sup>175</sup> *Id.*

the qualification of the graphite used in the reflector structure; (5) develop and validate computer codes for core design and analysis methodology; (6) develop a fluidic diode device to ensure proper circulation during normal operation and passive cooling by natural circulation; (7) justify thermodynamic data and associated vapor pressure correlations of representative species; (8) develop process sensor technology for key reactor process variables; and (9) develop the reactor coolant chemical monitoring instrumentation.<sup>176</sup> The Staff listed these activities in Appendix A, Section A.3 of the Safety Evaluation and will verify that they are completed prior to the completion of construction, which Kairos projects to be December 2026.<sup>177</sup>

The Staff will also track several other items listed in Appendix A, Section A.2 of the Safety Evaluation that Kairos must address in its operating license application.<sup>178</sup> This list contains elements of design, analysis, and administration that are not necessary for issuance of a construction permit but need additional development or resolution before issuance of an operating license.

After reviewing the construction permit application, the ACRS recommended that Kairos address three topics in the operating license application: (1) combustible gas generation, (2) tritium release levels, and (3) management of airborne tritium and beryllium in the facility.<sup>179</sup> In response to the ACRS review, the Staff stated that it will consider the identified topics in its review of the operating license application.<sup>180</sup> In response to our pre-hearing questions, Kairos stated that the specific instrumentation of the tritium management system and its capabilities to

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<sup>176</sup> Ex. NRC-001, Staff Information Paper, at 17-18; Ex. KRS-001, Kairos Testimony, at 24.

<sup>177</sup> Ex. NRC-001, Staff Information Paper, at 18; Ex. KRS-001, Kairos Testimony, at 24-25; see also Ex. NRC-002-R, Draft Construction Permit, at 2.

<sup>178</sup> See Ex. KRS-001, Kairos Testimony, at 23.

<sup>179</sup> Ex. NRC-010, Staff Safety Panel Presentation, at 8, 15; Tr. at 97 (Mr. Chereskin).

<sup>180</sup> See Letter from Robert Taylor on behalf of Andrea D. Veil, NRR, to Joy L. Rempe, ACRS (June 20, 2023) (ML23160A255).

measure tritium, for comparison with limits derived from the MHA, will be discussed in further detail in the final safety analysis report.<sup>181</sup>

#### **D. The Staff's Environmental Review**

As required by our regulations, the Staff prepared an environmental impact statement (EIS) for the Hermes construction permit application.<sup>182</sup> Although the Staff's safety review was limited to the findings necessary for issuance of the construction permit, the Staff's environmental review was broader in scope. In addition to evaluating the environmental impacts of facility construction, the Staff evaluated the impacts of facility operation and decommissioning to the extent that information was available for these activities.<sup>183</sup> In its review of the Hermes project, the Staff made effective use of existing resources, such as the recently completed EIS for the Tennessee Valley Authority's early site permit application for the Clinch River small modular reactor project, which would be situated approximately two miles south of where the Hermes reactor would be constructed.<sup>184</sup>

The Staff issued the draft EIS (DEIS) in September 2022 and the FEIS in August 2023.<sup>185</sup> After publishing a notice of its intent to prepare an EIS, the Staff conducted a virtual joint public outreach and scoping meeting in March 2022.<sup>186</sup> The Staff received public comments

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<sup>181</sup> Ex. KRS-006, Kairos Pre-Hearing Responses, at 12-13; Ex. NRC-004, Staff Pre-Hearing Responses, at 15-16.

<sup>182</sup> See 10 C.F.R. § 51.20(b)(1) (requiring EIS for issuance of a permit to construct a nuclear testing facility); Ex. NRC-008, FEIS, at xiii, 1-1.

<sup>183</sup> Ex. NRC-008, FEIS, at 1-2, 3-1. The Staff would perform separate environmental reviews for any subsequent licensing actions, such as an operating license application, operating license renewal, and decommissioning.

<sup>184</sup> See *id.* at 1-1.

<sup>185</sup> "Environmental Impact Statement for the Construction Permit for the Kairos Hermes Test Reactor" (Draft Report for Comment), NUREG-2263 (ML22259A126); Ex. NRC-008, FEIS.

<sup>186</sup> Ex. NRC-008, FEIS, at 1-4. The Staff's decision to conduct a virtual meeting was based on high Covid-19 transmission rates in the Oak Ridge area at that time. *Id.* at G-28.

during a sixty-day scoping process in early 2022. The Staff also conducted a virtual environmental audit in March 2022 to verify information in the Kairos environmental report and discuss information needs with Kairos staff and their contractors.<sup>187</sup> The DEIS was issued for public comment, and the comments received were addressed by the Staff in the FEIS.<sup>188</sup>

As discussed above, the proposed site for the Hermes project is a 185-acre site in the Heritage Center Industrial Park of the East Tennessee Technology Park, located within the corporate limits of the City of Oak Ridge, Tennessee.<sup>189</sup> The industrial park was established on land formerly owned by DOE, and the site proposed for the Hermes project was previously the site of two buildings that formed part of the Oak Ridge Gaseous Diffusion Plant. These buildings were razed after the gaseous diffusion plant ceased operations in the 1980s, and the site was environmentally remediated and released for industrial reuse, subject to certain restrictions.<sup>190</sup> Most of the 185-acre site consists of developed land and herbaceous grassland, with bands of forested land in perimeter areas between previously developed land and adjacent waterways.<sup>191</sup> The site is bounded on the south and east by Poplar Creek, and the Clinch River arm of the Watts Bar Reservoir lies near the western border of the site boundary.<sup>192</sup> The Hermes project would make use of existing industrial infrastructure, with the exception of additional roads and

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<sup>187</sup> *Id.* at 1-4.

<sup>188</sup> *Id.*, app. G.

<sup>189</sup> *Id.* at 1-1.

<sup>190</sup> *Id.* at 1-1, G-20 to G-22. These restrictions pertain to the use of and occupational exposure to contaminated groundwater and at the site. *See id.* at G-17 to G-22.

<sup>191</sup> *Id.* at 3-27.

<sup>192</sup> *Id.* at 1-2 fig. 1-1, 3-23. The only wetland on or adjacent to the Hermes site occurs in the forested perimeter lands adjoining Poplar Creek. *Id.* at 3-27 to 3-28.

parking lots that would be constructed to service the 30-acre portion of the site on which the reactor and its auxiliary buildings would be situated.<sup>193</sup>

The Staff evaluated the environmental impacts of constructing, operating, and decommissioning the Hermes reactor across a variety of resource areas: land use and visual resources; air quality and noise; hydrogeology and water resources; ecological resources; historic and cultural resources; socioeconomics and environmental justice; human health; nonradiological waste management; uranium fuel cycle and radiological waste management; transportation; accidents; and climate change.<sup>194</sup> The Staff also analyzed the cumulative environmental impacts of other projects proposed in the Oak Ridge region in conjunction with the Hermes project for each resource area considered.<sup>195</sup> The Staff found that the direct and indirect impacts of the proposed action in each of these areas would be small.<sup>196</sup> Impacts are considered “small” if they are “not detectable or are so minor that they will neither destabilize nor noticeably alter any important attribute of the resource.”<sup>197</sup>

In July 2023, Kairos submitted a construction permit application for the Hermes 2 project, a two-unit fluoride salt-cooled, high temperature test reactor that would be situated adjacent to the Hermes test reactor. We asked the Staff whether the analysis in the FEIS accounted for the cumulative impacts of the applicant’s new proposed project. The Staff

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<sup>193</sup> See *id.* at 2-2.

<sup>194</sup> *Id.* at 5-1 tbl. 5-1.

<sup>195</sup> *Id.* at 1-1. These included continuing DOE operations at Oak Ridge National Laboratory and the Y-12 site; industrial development in the East Tennessee Technology Park; the Ultra Safe Nuclear Corporation Pilot Fuel Manufacturing Facility; the Sequoyah and Watts Bar nuclear plants; and future projects such as the construction and operation of small modular reactors at the Clinch River Nuclear site; the applicant’s plan to construct and operate the Kairos Atlas Fuel Fabrication Facility at the Hermes site; the planned TRISO-X fuel fabrication facility; and development of a general aviation airport to the south of the Hermes site. *Id.* at 3-2.

<sup>196</sup> *Id.* at 5-1 tbl. 5-1.

<sup>197</sup> *Id.* at 1-3.

explained that the FEIS was published too soon after submission of the Hermes 2 application to account for these impacts in the Hermes FEIS, but that an evaluation was performed to determine the significance of the Hermes 2 project on the FEIS's cumulative impacts analysis.<sup>198</sup> The Staff concluded in this evaluation that the proposed Hermes 2 project "would not alter the conclusion in the FEIS that the cumulative impacts from the Hermes reactor and other past, present, and reasonably foreseeable actions would be SMALL for all environmental resources."<sup>199</sup> Accordingly, the Staff determined that information in the Hermes 2 application did not require preparation of a supplement to the Hermes FEIS.<sup>200</sup>

To fulfill its obligations under section 7 of the Endangered Species Act of 1973, the Staff compiled a table of federally listed endangered species using databases maintained by the U.S. Fish and Wildlife Service (FWS) and the Tennessee Department of Environment and Conservation, and the information in Kairos's environmental report.<sup>201</sup> The Staff defined the action area for the purposes of this review as the 185-acre Hermes site, which consists of lands previously disturbed by DOE's operations but also includes, for conservatism, "slivers of riparian forested land on the site bordering Poplar Creek that might be affected by project-related

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<sup>198</sup> Ex. NRC-004, Staff Pre-Hearing Responses, at 20-21.

<sup>199</sup> Memorandum from Christopher M. Regan, Director, Division of Rulemaking, Environmental, and Financial Support, NMSS, to John W. Lubinski, Director, NMSS, "Consideration of New Information Regarding Potential Cumulative Impacts from the Proposed Kairos Hermes 2 Test Reactor on the Kairos Hermes Construction Permit Review" (Sept. 7, 2023), Encl. at 7 (ML23220A164 (package)).

<sup>200</sup> *Id.*

<sup>201</sup> Ex. NRC-008, FEIS, at 1-3, 3-28. Section 7 of the Endangered Species Act requires an agency, in consultation with the Secretary of the Interior or the Secretary of Commerce (as appropriate), to ensure that "any action authorized, funded, or carried out by such an agency . . . is not likely to jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of [critical] habitat of such species." Endangered Species Act § 7(a)(2), 16 U.S.C. § 1536(a)(2). The Fish and Wildlife Service (under the Department of the Interior) and the National Marine Fisheries Service (under the Department of Commerce) jointly administer the Act.

noise.”<sup>202</sup> The Staff identified the potential for four federally listed engendered species, four federally listed threatened species, and one federal candidate species to occur at the site.<sup>203</sup> At the request of the FWS, the Staff included in the FEIS a biological evaluation addressing the potential impacts from the Hermes project on these species.<sup>204</sup> Because of historical disturbances to the affected site and the lack of disturbance to forest and other natural vegetation, wetlands, or aquatic habitat from construction activities, the Staff found that effects on terrestrial wildlife habitats would be minimal, and the potential ecological impacts of the proposed action would be small.<sup>205</sup> The Staff determined that the Hermes project may affect, but is not likely to adversely affect (or would not affect), any of these endangered species.<sup>206</sup> On January 27, 2023, the FWS concurred with the Staff’s conclusions in its biological evaluation, which completed the NRC’s responsibilities under section 7 of the Endangered Species Act.<sup>207</sup>

The Staff originally proposed to include a condition in the Environmental Protection Plan (EPP), which is incorporated into the construction permit, that Kairos must request a license amendment to incorporate the requirements of any Terms and Conditions set forth in the Incidental Take Statement of Biological Opinions issued subsequent to the effective date of this EPP.<sup>208</sup> However, the Staff did not engage in formal consultation with FWS and, as a result, did

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<sup>202</sup> Ex. NRC-008, FEIS, at 3-28.

<sup>203</sup> *Id.* at 3-28. The endangered species are the gray bat, the Indiana bat, and two freshwater clam species—the finereyed pigtoe and shiny pigtoe. The threatened species are the northern long-eared bat, the spotfin chub, and two plant species—the Virginia spiraea and white fringeless orchid. The federal candidate species is the monarch butterfly. The Staff did not identify the presence of critical habitat within the action area. *Id.* at 3-28 to 3-29.

<sup>204</sup> *Id.* at 3-29; *see id.* at 3-29 to 3-34 & tbl. 3-5.

<sup>205</sup> *Id.* at 3-29.

<sup>206</sup> *Id.* at 3-36.

<sup>207</sup> *Id.* at 3-34.

<sup>208</sup> *See* Ex. NRC-002-R, Draft Construction Permit, app. A, Environmental Protection Plan.

not receive from FWS a biological opinion containing an Incidental Take Statement with Terms and Conditions.<sup>209</sup> In response to our pre-hearing question asking about the necessity of this condition, the Staff elected to remove this condition from the construction permit and noted that it will consider whether the condition should be added at the operating license stage.<sup>210</sup>

Section 106 of the NHPA requires federal agencies to consider the effects of their undertakings on historic properties listed or eligible for listing on the National Register of Historic Places.<sup>211</sup> The section 106 process must be completed “prior to the issuance of any license.”<sup>212</sup> The Staff considered the direct effects of the construction and operation of the Hermes facility on the 185-acre Hermes site, as well as the indirect effects of these activities on a 0.5-mile area around the site.<sup>213</sup> Relying on an environmental assessment prepared in 2011 by DOE for the East Tennessee Technology Park, the Staff initially concluded that there are likely no intact archaeological sites or prehistorical archaeological resources to be found within the APE due to extensive prior cut and fill excavation activities associated with construction of the former DOE facilities and their subsequent decontamination, demolition, and decommissioning.<sup>214</sup> However, in response to a comment on the DEIS from a consulting tribe, the Staff gathered additional

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<sup>209</sup> See Ex. NRC-004, Staff Pre-Hearing Responses, at 19.

<sup>210</sup> *Id.*

<sup>211</sup> Section 106 of the NHPA requires federal agencies to consider the effects of their undertakings on historic properties listed or eligible for listing on the National Register of Historic Places. NHPA § 106, 54 U.S.C. § 306108. The NRC’s undertaking is the issuance of a construction permit to Kairos that allows for the construction of the proposed Kairos Hermes project. Ex. NRC-008, FEIS, at 3-37.

<sup>212</sup> 36 C.F.R. § 800.1(c).

<sup>213</sup> Ex. NRC-008, FEIS, at 3-38. Together, these areas constitute the area of potential effects (APE) for the NRC’s section 106 review. See *generally id.* at 3-37 to 3-47.

<sup>214</sup> See DEIS at 3-39, 3-41. The Staff also reviewed information held by the Tennessee Historical Commission and determined that there are no extant architectural resources within the direct-effects APE. *Id.*

information from DOE related to the geology and geomorphology of the site, as well as the total area and depth of prior disturbance at the former DOE facility locations.<sup>215</sup> Based on this new information and a discussion with DOE, the Staff determined that there is a potential for deeply buried archaeological deposits to occur within the APE.<sup>216</sup>

To satisfy its consultation responsibilities under the NHPA, the Staff contacted the Tennessee Historical Commission, the Advisory Council on Historic Preservation, the National Park Service, and eighteen federally recognized Indian tribes.<sup>217</sup> The Tennessee Historical Commission advised that the Kairos project would not adversely affect the Manhattan Project National Historic Park, the only property located within the APE that is eligible for listing on the National Register of Historic Places.<sup>218</sup> In December 2022, after publication of the DEIS, one Tribe initiated government-to-government consultation, requested consulting party status, and requested that a cultural resources survey be conducted for the proposed project.<sup>219</sup> The Staff met with Kairos several times between February and April 2023 to discuss information needs to support the Staff's consultations with the Tribe. In April 2023, the Staff forwarded additional information Kairos provided to the consulting Tribe for review and comment. Between June and the publication of the FEIS in August 2023, the Staff met with the Tribe and Kairos to discuss the Tribe's request for an additional reconnaissance field investigation, updates to the

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<sup>215</sup> Ex. NRC-008, FEIS, at 3-41, *see id.* at G-18 to G-19.

<sup>216</sup> *Id.* at 3-41.

<sup>217</sup> *Id.* at 3-42.

<sup>218</sup> *Id.* at 3-41, 3-42. The Manhattan Project National Historical Park, which is jointly administered by DOE and the National Park Service, includes the K-25 History Center, which opened in 2020 and focuses on the men and women who built and operated the K-25 Gaseous Diffusion Plant during the Manhattan Project and Cold War. *Id.* at 3-41; *see National Park Service, K-25 History Center*, <https://www.nps.gov/places/k-25-history-center.htm> (last visited Nov. 15, 2023).

<sup>219</sup> Ex. NRC-008, FEIS, at 3-44, G-18 to G-19.

archaeological resource monitoring and unanticipated discovery plan, and a path forward to support NHPA section 106 consultation closure.<sup>220</sup>

The Staff's section 106 consultation efforts were still in progress when we held the hearing on Kairos's construction permit application. Prior to the hearing, we asked the Staff to clarify the purpose of the additional reconnaissance field investigation and the basis for the Staff's conclusions regarding impacts to historic and cultural resources from the Hermes project.<sup>221</sup> At the hearing, the Staff informed us that Kairos had completed the requested field investigation, had used the resulting information to update its monitoring plan, and had incorporated the Staff's and Tribe's input into the plan.<sup>222</sup>

After the hearing, the Staff provided notice of consultation closure in a revised draft record of decision.<sup>223</sup> The draft record of decision explained that after Kairos submitted the updated monitoring plan and Geoarchaeological Reconnaissance Survey Report, the Staff sent the monitoring plan and Kairos's report to the Tennessee Historical Commission and the consulting Tribe.<sup>224</sup> The Tennessee Historical Commission responded that it had no objections to the project proceeding as proposed. Likewise, the consulting Tribe stated that it had no objections to the project proceeding, "provided the NRC agrees to notify the consulting Tribe of changes to project activities on the site and to any unanticipated discoveries."<sup>225</sup> The Staff noted that these stipulations were previously discussed and agreed upon between the consulting

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<sup>220</sup> *Id.* at 3-44 to 3-45; Ex. NRC-001, Staff Information Paper, at 6, 20; Ex. NRC-004, Staff Pre-Hearing Responses, at 21.

<sup>221</sup> See Pre-Hearing Questions Order at 14-15.

<sup>222</sup> See Tr. at 59 (Mr. Regan); see *also* Ex. NRC-003-R, Draft Record of Decision, at 7 (stating that the reconnaissance field investigation was completed in August 2023).

<sup>223</sup> See Staff Revised Exhibit List at 1; Ex. NRC-003-R, Draft Record of Decision, at 7.

<sup>224</sup> Ex. NRC-003-R, Draft Record of Decision, at 7.

<sup>225</sup> *Id.*

parties and that the NRC's process for implementing these stipulations had been documented in a memorandum to the NRC's Federal Preservation Officer.<sup>226</sup>

Because there are no known historic properties on the proposed Hermes site and mitigation measures will be in place to protect any undiscovered resources, the Staff determined under the NHPA that there would be no adverse effects to historic properties from the proposed undertaking.<sup>227</sup> For the same reason, the Staff concluded for the purposes of NEPA that the potential environmental impacts on cultural and historic resources from constructing, operating, and decommissioning the Hermes project would be small.<sup>228</sup>

In its environmental review of the Hermes project, the Staff also analyzed alternatives to the proposed action.<sup>229</sup> This review included consideration of the no-action alternative and one alternative site.<sup>230</sup> For the no-action alternative, i.e., if the construction permit were to be denied, the Staff found that the environmental effects described in the FEIS would not occur, but because these effects were found to be small, any environmental benefit from selecting the no-action alternative would be minimal.<sup>231</sup> Moreover, the proposed site would remain available for other government or private industrial development projects, which might lead to similar

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<sup>226</sup> *Id.* (citing Memorandum from Tamsen Dozier, NRC, to Christopher M. Regan, NRC, "Implementation of Provisions from Consultations Under Section 106 of the National Historic Preservation Act on the Kairos Hermes Test Reactor Construction Permit Review" (Nov. 30, 2023) (ML23318A516)).

<sup>227</sup> *See id.* at 7, 8; Ex. NRC-004, Staff Pre-Hearing Responses, at 21-22; Ex. NRC-008, FEIS, at 3-45 to 3-47.

<sup>228</sup> *See* Ex. NRC-003-R, Draft Record of Decision, at 4, 6, 8; Ex. NRC-004, Staff Pre-Hearing Responses, at 21-22; Ex. NRC-008, FEIS, at 3-45 to 3-47.

<sup>229</sup> Ex. NRC-008, FEIS, ch. 4.

<sup>230</sup> *Id.* at 4-2.

<sup>231</sup> *Id.*

environmental effects as the proposed project.<sup>232</sup> In addition, this alternative would not meet the purpose of the proposed action—to demonstrate key elements of the Kairos Power Fluoride Salt-Cooled, High Temperature Reactor technology for possible future commercial deployment.<sup>233</sup>

After reviewing the applicant's systematic site-selection process and finding it to have been reasonable, the Staff examined an alternative site on federal land approximately twenty miles west of Idaho Falls, Idaho, termed the Eagle Rock site.<sup>234</sup> The Staff compared the environmental costs and benefits of the proposed action at the Eagle Rock site with the costs and benefits of the proposed action at the Oak Ridge site. The Staff found that the impacts at the Eagle Rock site would be small for all resource areas except for visual, ecological, and cultural resources, which would experience moderate impacts from construction, reflecting the Staff's determination that building the Hermes facilities at the Eagle Rock site could be visually intrusive in that rural setting and "would require disturbance of soils supporting natural vegetation and potentially containing subsurface archaeological resources."<sup>235</sup> With the Oak Ridge site presenting only small environmental impacts, as contrasted with the Eagle Rock site, the Staff concluded that the Oak Ridge site was the environmentally preferable alternative.<sup>236</sup>

On the basis of its environmental review, the Staff recommended issuing the construction permit to Kairos.<sup>237</sup> At the operating license stage, the Staff will prepare a

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<sup>232</sup> *Id.*

<sup>233</sup> *Id.* at 4-11; *see id.* at 1-3. For the same reason, Kairos and the Staff did not consider alternative technologies for the Hermes reactor. *Id.* at 4-1.

<sup>234</sup> *Id.* at 4-2.

<sup>235</sup> *Id.* at 4-7 to 4-8, 4-10 & tbl. 4-1.

<sup>236</sup> *Id.* at 4-10 to 4-11.

<sup>237</sup> *Id.* at 5-11. The Staff conditioned its recommendation on completion of the NHPA section 106 process, which was not yet complete at the time the FEIS was issued. *Id.*

supplement to the FEIS to address any new and significant information that was not available during its review of the construction permit application.<sup>238</sup>

## **E. Findings**

We have conducted an independent review of the sufficiency of the Staff's safety findings, with particular attention to the topics discussed above. Our findings, however, are based on the record as a whole.

### **1. Safety Findings**

Based on the evidence presented in the uncontested hearing, including the Staff's review documents and the testimony provided, we find that Kairos has described the proposed design of the facility, including, but not limited to, the principal architectural and engineering criteria for the design, and it has identified major features or components incorporated therein for the protection of the health and safety of the public.<sup>239</sup> Further technical or design information as may be required to complete the safety analysis has reasonably been left for later consideration and will be supplied in the final safety analysis report. Kairos has described the safety features or components that require research and development and has identified and will establish a research and development program reasonably designed to resolve any safety questions associated with these features or components. On the basis of the foregoing, we find that there is reasonable assurance that open safety questions will be resolved satisfactorily at or before the latest date stated in the application for completion of construction of the proposed facility. Taking into consideration the site criteria in 10 C.F.R. Part 100, the proposed facility can be constructed and operated at the proposed location without undue risk to the health and safety of the public.

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<sup>238</sup> See 10 C.F.R. § 51.95(b); Ex. NRC-008, FEIS, at 1-3; Tr. at 132 (Mr. Doub) (stating that the Staff "would supplement the EIS and update the analysis for later life cycle stages should the applicant apply for future licenses for Hermes").

<sup>239</sup> See Ex. KRS-006, Kairos Pre-Hearing Responses, at 1-2.

In making these findings, we also conclude that: (1) there is reasonable assurance that construction of the facility will not endanger the health and safety of the public, and the authorized activities can be conducted in compliance with the NRC's regulations, including the requirements in 10 C.F.R. Part 20; (2) Kairos is technically and financially qualified to engage in the activities authorized;<sup>240</sup> (3) issuance of the construction permit will not be inimical to the common defense and security or to the health and safety of the public; and (4) Kairos's application meets the standards and requirements of the AEA and the NRC's regulations. Required notifications to other agencies have been duly made.<sup>241</sup> Additionally, we find that the Staff's proposed permit conditions are appropriately drawn and sufficient to provide reasonable assurance of adequate protection of public health and safety.<sup>242</sup>

## **2. Environmental Findings**

We also conducted an independent review of the Staff's environmental analysis in the FEIS, taking into account the particular requirements of NEPA. NEPA section 102(2)(A) requires agencies to use "a systematic, interdisciplinary approach which will ensure the integrated use of the natural and social sciences and the environmental design arts" in decision making that may impact the environment.<sup>243</sup> We find that the environmental review team used the systematic, interdisciplinary approach that NEPA requires.<sup>244</sup> The environmental review team consisted of

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<sup>240</sup> Ex. NRC-007, Safety Evaluation, chs. 12, 15; Ex. NRC-001, Staff Information Paper, at 22; Ex. KRS-001, Kairos Testimony, at 28-29.

<sup>241</sup> See, e.g., 10 C.F.R. § 2.104(a); Ex. NRC-004, Staff Pre-Hearing Responses, at 2; Ex. NRC-008, FEIS, app. B.

<sup>242</sup> See 10 C.F.R. §§ 50.35(b), 50.50; Ex. NRC-002-R, Draft Construction Permit, at 2-3.

<sup>243</sup> NEPA § 102(2)(A), 42 U.S.C. § 4332(2)(A), as amended.

<sup>244</sup> See, e.g., Tr. at 127-35 (Mr. Erwin, Ms. Dozier, Mr. Doub) (providing an overview of the Staff's environmental review methodology and findings); Ex. NRC-011, Staff Environmental Panel Presentation, at 4-16.

over two dozen individuals with expertise in disciplines including ecology, geology, hydrology, human health, socioeconomics, and cultural resources.<sup>245</sup>

In addition to the general requirement that an EIS address the reasonably foreseeable environmental effects of a proposed action, NEPA section 102(2)(C) requires federal agencies to describe (1) any reasonably foreseeable adverse environmental effects which cannot be avoided should the proposal be implemented; (2) a reasonable range of alternatives to the proposed agency action, “including an analysis of any negative environmental impacts of not implementing the proposed agency action in the case of a no action alternative, that are technically and economically feasible, and meet the purpose and need of the proposal”; (3) the relationship between local short-term uses and long-term productivity of the environment; and (4) any irreversible and irretrievable commitments of federal resources associated with the proposed agency action.<sup>246</sup> The Staff’s evaluation of alternatives is in chapter 4 of the FEIS and summarized in chapter 5; the other enumerated items are discussed under the heading of “resource commitments” in chapter 5.

Because the Staff issued the FEIS shortly after Congress amended section 102(2)(C), we asked the Staff to provide additional information explaining how its environmental review satisfied these standards, as amended by the Fiscal Responsibility Act.<sup>247</sup> The Staff stated that

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<sup>245</sup> See Ex. NRC-008, FEIS, app. A tbl. A-1 (listing contributors from the NRC and Pacific Northwest National Laboratory).

<sup>246</sup> NEPA § 102(2)(C)(i)-(v), 42 U.S.C. § 4332(2)(C)(i)-(v), as amended.

<sup>247</sup> See Pre-Hearing Questions Order at 13, 15-16; Tr. at 150-51 (Commissioner Wright). As noted above, pursuant to 10 C.F.R. § 51.105(a), we must “determine whether the requirements of NEPA Sections 102(2)(A), (C), and (E) have been met,” and determine as a general matter “whether the NEPA review conducted by the NRC Staff has been adequate.” The amendments to NEPA which became effective upon enactment of the Fiscal Responsibility Act substantively affect the requirements in NEPA section 102(2)(C). For example, section 102(2)(C)(iii) has been amended to specify that the alternatives analysis must include a discussion of the negative impacts of not implementing the proposed action, and section 102(2)(C)(v) now requires an analysis of any irreversible and irretrievable commitment of federal resources, as opposed to the broader analysis of resources typically performed by the Staff to satisfy this requirement.

prior to issuing the FEIS, the Staff reviewed the Fiscal Responsibility Act and the amendments to NEPA, and found that the FEIS was consistent with the Staff's current understanding of these new requirements and that it had made all the findings necessary in the FEIS to support issuance of the construction permit.<sup>248</sup> In response to our question, the Staff revised the record of decision to reflect this determination.<sup>249</sup> In further questions to the Staff before and during the hearing, we asked the Staff to clarify whether the FEIS considered the irreversible and irretrievable commitment of exclusively federal resources involved in issuing a construction permit to Kairos, commensurate with the more specific analysis required by amended NEPA section 102(2)(C)(v).<sup>250</sup> The Staff explained that its comprehensive analysis of irreversible and irretrievable resources in the FEIS accounted for federal resources as well.<sup>251</sup>

*a. Resource Commitments*

Chapter 5 of the FEIS includes a table of the unavoidable adverse environmental impacts anticipated from construction, operation, and decommissioning, along with actions to mitigate those impacts.<sup>252</sup> As noted above, the Staff concluded that the impacts of the proposed action in all resource areas would be small, despite the potential unavoidable adverse impacts presented in this table. To address these unavoidable impacts, the Staff identified mitigation and control measures that Kairos could implement to lessen some of these potential adverse effects.<sup>253</sup> Examples of such mitigation measures include instituting best management practices to control dust and manage stormwater runoff, developing an Archaeological Resources

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<sup>248</sup> Ex. NRC-004, Staff Pre-Hearing Responses, at 19-20; Tr. at 62 (Mr. Regan).

<sup>249</sup> Ex. NRC-004, Staff Pre-Hearing Responses, at 19-20.

<sup>250</sup> See Pre-Hearing Questions Order at 15-16; Tr. at 150-51 (Commissioner Wright).

<sup>251</sup> See Ex. NRC-004, Staff Pre-Hearing Responses, at 24; Tr. at 151 (Mr. Doub).

<sup>252</sup> Ex. NRC-008, FEIS, at 5-6 to 5-8 tbl. 5-2.

<sup>253</sup> *Id.* at 5-5.

Monitoring and Unanticipated Discovery Plan to address unexpected discoveries of human remains and archaeological materials, and restoring temporarily disturbed lands with native plants or landscaping when no longer needed for construction or decommissioning activities.<sup>254</sup>

Concerning irreversible and irretrievable commitments of federal resources, the Staff found that construction of the Hermes facility would irretrievably commit capital, energy, labor, and material resources, some of which are expended by the NRC during its review of the Hermes application and would thus constitute federal resources.<sup>255</sup> Although the Staff did not separately analyze federal resources in the FEIS, the Staff clarified that the FEIS analysis considered the totality of resources, including but not limited to federal resources, and therefore adequately addressed the requirements of the Fiscal Responsibility Act.<sup>256</sup> With respect to other resources, the Staff concluded that construction of the Hermes facility would irretrievably consume energy, water, chemicals, fossil fuels, as well as construction materials, unless Kairos recycles them during decommissioning.<sup>257</sup> Historic and cultural resources buried beneath the 1949 surface or in deeply buried paleosoils are nonrenewable and may be disturbed by construction, but impacts to any such resources would be mitigated by implementation of Kairos's Archaeological Resources Monitoring and Unanticipated Discovery Plan.<sup>258</sup> During operations, uranium used in TRISO fuel pebbles would be irreversibly and irretrievably committed, and nonradiological irreversible impacts on occupational human health could occur but are expected to be comparable to potential hazards at any industrial construction site.<sup>259</sup>

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<sup>254</sup> *Id.* at 5-6 to 5-8 tbl. 5-2.

<sup>255</sup> *Id.* at 5-10; Ex. NRC-004, Staff Pre-Hearing Responses, at 24; *see also* Tr. at 60 (Mr. Regan).

<sup>256</sup> Tr. at 151 (Mr. Erwin, Mr. Doub).

<sup>257</sup> Ex. NRC-008, FEIS, at 5-10.

<sup>258</sup> *Id.*

<sup>259</sup> *Id.* at 5-10 to 5-11.

Finally, with respect to the relationship between local short-term uses and long-term productivity of the environment, the Staff found that the short-term uses of the environment—construction, operation, and decommissioning of the Hermes facility—would commit 30 acres of previously used industrial land over the life of the project and up to 108 acres of land during construction and decommissioning. Use of the entire 185-acre Hermes site would also be limited during operation due to its designation as the exclusion area.<sup>260</sup> Further short-term uses of the environment would include consumption of small quantities of water supplied by municipal or commercial sources, small increases in demand for housing and services in the local community, an increase in the volume of traffic on local roads, and energy consumption.<sup>261</sup> The Staff noted that management and disposal of waste—radioactive, hazardous, and nonhazardous—would consume space at treatment, storage, or disposal facilities, and the use of land to meet waste disposal needs would reduce the long-term productivity of the land, but Hermes would contribute only a minimal amount to these reductions.<sup>262</sup> In addition, in the short term, the project would bring increased employment, expenditures, and tax revenues that would directly benefit local, regional, and State economies.<sup>263</sup> As compared to the minimal impacts of the project over the short term, the Staff found substantial potential long-term benefits from the Hermes project, including demonstrating the commercial viability of its fluoride salt-cooled, high temperature reactor technology, generating data helpful in future commercial deployment of the technology, and helping the nation meet its climate change objectives with less reliance on more land-intensive energy generation processes.<sup>264</sup>

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<sup>260</sup> *Id.* at 5-8.

<sup>261</sup> *Id.* at 5-9.

<sup>262</sup> *Id.*

<sup>263</sup> *Id.*

<sup>264</sup> *Id.*

Having considered the unavoidable adverse environmental impacts and resource commitments—the environmental “costs” of the project—as well as the project’s benefits as summarized above, we agree with the Staff’s conclusion that the benefits of the project outweigh the costs.<sup>265</sup>

*b. Alternatives*

The alternatives analysis is the “heart of the environmental impact statement.”<sup>266</sup> NEPA section 102(2)(H), formerly section 102(2)(E), calls for agencies to study, develop, and describe appropriate alternatives to recommended courses of action in any proposal which involves unresolved conflicts involving alternative uses of available resources.<sup>267</sup> Further, section 102(2)(C) requires consideration of a reasonable range of alternatives to the proposed agency action that are technically and economically feasible, and meet the purpose and need of the proposed action. Where the alternatives considered include taking no action on the proposal, the analysis must consider any negative environmental impacts of not implementing the proposed agency action.<sup>268</sup> Based on the Staff’s testimony at the hearing, as well as the discussion in the FEIS, we find that the environmental review identified an appropriate range of alternatives with respect to the no-action alternative and the alternative Eagle Rock site, and adequately described the environmental impacts of both alternatives. The Staff’s decision not to consider alternative technologies was reasonable in light of the purpose and need of the proposed project, which is to demonstrate and test its reactor technologies.<sup>269</sup>

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<sup>265</sup> Cf. 10 C.F.R. § 51.105(a); see Ex. NRC-008, FEIS, at 4-10.

<sup>266</sup> 10 C.F.R. pt. 51, subpt. A, app. A, § 5.

<sup>267</sup> NEPA § 102(2)(H), 42 U.S.C. § 4332(2)(H). In its review of the potential impacts associated with the proposed action, the Staff did not identify any unresolved conflicts concerning alternative uses of available resources. Ex. NRC-008, FEIS, at 5-11.

<sup>268</sup> NEPA § 102(2)(C)(iii), 42 U.S.C. § 4332(2)(C)(iii), as amended.

<sup>269</sup> See Ex. NRC-008, FEIS, at 4-1, 5-4.

We also find that the Staff adequately considered the negative impacts of not implementing the proposed action. For example, the Staff found that under the no-action alternative, Kairos could not build the proposed Hermes reactor, and therefore would not have an opportunity to test its technologies, design features, and safety functions at a reduced scale relative to a potential commercial power reactor. The Staff noted that forgoing the opportunity provided by Hermes may not necessarily preclude future development of reactors using the salt-cooled, fluoride high temperature reactor technologies but anticipated that it could slow or impede safe and efficient development of the technologies.<sup>270</sup> The Staff also identified that any environmental benefits from implementing the proposed action would not be realized if the action is not approved, and additionally, the proposed site would remain available for other development projects, potentially giving rise to environmental impacts from land disturbance and construction from those projects in the future.<sup>271</sup>

In sum, we find reasonable the Staff's conclusion that, because there are no "environmentally preferable alternatives that meet the purpose and need of the proposed action, . . . there are no obviously superior alternatives to the proposed action from an environmental perspective."<sup>272</sup>

*c. Commission Determination*

For each of the topics discussed at the hearing and in today's decision, we find that the Staff's review was reasonably supported in logic and fact and sufficient to support the Staff's conclusions. Based on our review of the FEIS, we also find that the remainder of the FEIS was reasonably supported and sufficient to support the Staff's conclusions. Therefore, as a result of our review of the FEIS, and in accordance with the notice of hearing for this uncontested

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<sup>270</sup> *Id.* at 4-2.

<sup>271</sup> *Id.*; *see also id.* at G-11.

<sup>272</sup> *Id.* at 4-11; *see also id.* at 5-5.

proceeding, we find that the relevant requirements of NEPA section 102(2), and the applicable regulations in 10 C.F.R. Part 51, have been satisfied with respect to the construction permit application.<sup>273</sup> We independently considered the final balance among conflicting factors contained in the record of this proceeding. We find, after weighing the environmental, economic, technical, and other benefits against environmental and other costs, and considering reasonable alternatives, that the construction permit should be issued.

### III. CONCLUSION

We find that, with respect to the safety and environmental issues before us, the Staff's review of Kairos's construction permit application was sufficient to support issuance of the construction permit. We *authorize* the Director of the Office of Nuclear Reactor Regulation to issue the permit for the construction of the Hermes Test Reactor. Additionally, we *authorize* the Staff to issue the record of decision.

IT IS SO ORDERED.



For the Commission

A handwritten signature in blue ink that reads "Tomas E. Herrera". The signature is written in a cursive style and is positioned above a horizontal line.

Tomas E. Herrera  
Acting Secretary of the Commission

Dated at Rockville, Maryland,  
this 12th day of December 2023.

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<sup>273</sup> See *supra* note 26.

