Modeling and Simulation Development Pathways to Accelerating KP-FHR Licensing

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Program: Advanced Reactor Development

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ABSTRACT:

Project Objectives. As stated in this DOE Funding Opportunity Announcement (FOA), new U.S. advanced reactors must be deployed in the mid-to-late 2020's and be globally competitive to augment U.S. commercial nuclear capability. This two-year project collaboration between Kairos Power LLC (Kairos) and DOE national laboratories will help accelerate time to licensing for a KP-FHR design (KP-FHR) and leverage prior DOE investment in FHR technology and modeling and simulation tools. The KP-FHR Program will ultimately address all of 11 FOA objectives. As shown in the table on the right, this specific proposed Project meets four key FOA objectives.

FOA Objectives from I.B	Project	Program
Advanced nuclear reactor design	✓	✓
Addresses design, certification, and licensing issues	✓	✓
Advanced manufacturing fabrication and construction		✓
Sensors, instrumentation, and control systems		✓
Plant auxiliary and support systems		✓
Operational inspection and monitoring capabilities		✓
Modeling and simulation	✓	✓
Can impact operational efficiencies		✓
Hybrid applications		✓
Economic improvements		✓
Address regulatory and licensing issues	✓	✓

Major Deliverables. Key deliverables include the updated System Analysis Module (SAM) program with improved capability and features to support mechanistic source term modeling. Kairos validation of SAM for selected Separate Effect Tests (SET) and Integral Effect Tests (IET) performed at Kairos test facilities. Improved Bison program for modeling of TRISO in the KP-FHR including fission product transport in support of mechanistic source term and application of newly developed failure probability predictions. Kairos validation of Bison against IAEA CRP benchmark and AGR PIE data. Improved version of Grizzly with SS 316H specific constitutive models for application to the KP-FHR SSCs. Kairos support of Grizzly development including design and environmental conditions and development of an analysis workflow for design and safety evaluations.

Technical Description. The KP-FHR is a new, U.S.-developed advanced reactor technology that has progressed rapidly in the last decade, following over $20M of DOE-sponsored R&D at universities and national laboratories. The fundamental concept uses the combination of tristructural isotropic (TRISO)

particle fuel coupled with molten fluoride salt coolant. This combination results in a high-temperature, low-pressure reactor with robust, fully-passive safety systems. Kairos has concluded that collaborating with the key DOE Laboratories and Scientists can accelerate the development and licensing of the KP-FHR. This project is focusing on leveraging the capability and investment by DOE in advanced modeling and simulation tools to reduce the time to readiness for licensing the tools with the USNRC. This is done by focusing on the key areas of needed development specific to the KP-FHR design. Using resources at Kairos to guide this work and perform validation and analysis with the tools will provide needed feedback and application for these advanced tools. This has two benefits, 1) the use of the tools in real analysis with ongoing testing programs provides key information into the features that are needed and models that need calibration, 2) the more a tool is exercised in a specific area of application the more mature it becomes.

Major Tasks. The project has three areas of scope, all supporting the goal of accelerating U.S. deployment of the prototype KP-FHR from the late 2020's to the mid 2020's: (1) The overarching goal of this Project is to accelerate critical path to licensing for modeling and simulation tools in support of the safety case for the KP-FHR, (2) Develop a framework and capability to support mechanistic source term analysis for the KP-FHR. And (3) Extend the capability of Nuclear Energy Advanced Modeling and Simulation (NEAMS) tools into new areas of application reducing the burden of legacy tool use.

Methods to Be Employed. Kairos has concluded that testing, along with modeling and simulation, are essential to enable accelerated advanced reactor development. Testing in Kairos' R-Lab and S-Lab will enable and support design and manufacturing of major KP-FHR structures, systems, and components (SSCs). Validation testing needs for SAM, Bison, and Grizzly will be driven by KP-FHR licensing activities and will focus on SSCs that require sufficient design maturity to support early interactions with the NRC.

Project Impact. This Project directly and indirectly influences a significant number of strategic programs currently funded by Department of Energy, Office of Nuclear Energy (DOE-NE). Direct benefits are the collaborations between Kairos Power, LLC and the national laboratories in developing the modeling and simulation tools, knowledge, and talent for these strategic programs. The effort from this Project will influence programmatic direction for the NEAMS and molten salt reactor and fluoride high-temperature reactor development programs.

Major Participants. This proposal assembles a strong U.S. industry and national laboratory team to complete our scope of work. Kairos, headquartered in Alameda, CA, is the leader of this effort and has built an internal team of highly competent engineers and managers with extensive combined experience in nuclear power, conventional power, product development, and licensing. Idaho National Laboratory (INL), Argonne National Laboratory (ANL), and Los Alamos National Laboratory (LANL) bring unique capabilities in advanced reactor research, development, and licensing.

Summary. KP-FHR brings attributes of robust simplified safety, affordable costs, and flexible operation to accommodate the expansion of variable renewables, providing a strong potential to improve the overall economic outlook for nuclear power in the U.S. The scope of work that Kairos and its partners will perform will have high impact on the KP-FHR critical path. This Project will produce significant value to DOE and the nation as it will enhance the economic viability and accelerate the time to market of advanced nuclear technology in the U.S., leverage past and current DOE investments in advanced reactor modeling and simulation.