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NRC Regulatory Research Perspectives Related to NGNP V/HTGR Licensing

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March 16, 2009

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2005 Energy Policy Act: Congress Required an NGNP Licensing Strategy

- The ways in which current NRC LWR licensing requirements will need to be adapted for the types of reactors considered for the project
- The analytical tools that the NRC will need to independently verify the NGNP design and its safety performance
- Other research or development activities that the NRC will need to review an NGNP license application

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NGNP Safety R&D Needs Development

- NGNP Licensing Strategy Report to Congress - NRC/DOE
- NRC Advanced Reactor Research Plan - NRC
- NGNP Phenomena Identification & Ranking Tables - NRC/DOE
- HTGR Fuels Phenomena Identification & Ranking Tables - NRC
- HF Phenomena Identification & Ranking Tables - NRC
- NGNP Gap Analysis Report - ORNL

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NGNP Licensing Strategy Report to Congress

- Risk-informed, performance-based approach to establish NGNP design-specific technical licensing requirements
- Analytical tools, models and associated data needed to address VHTR safety-relevant phenomena and perform confirmatory analysis - utilize R&D from DOE, NGNP applicant and cooperative activities to the extent possible
- Regulatory infrastructure development to include: regulatory guides, SRPs, codes and standards, reactor oversight process development and inspection programs

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NGNP VHTR Design and Safety Concept

- Higher operating temperatures and accident temperatures
- Graphite used for moderator, core structures and support structures
- Helium coolant is single phase and chemically inert
- High performance TRISO fuel particles in graphite matrix retain fission products
- Metallic pressure vessels thermally insulated by graphite and composites
- Inherent reactor characteristics, passive SSCs mitigate design basis accidents
- Greater emphasis on accident prevention vs. accident mitigation
- Event-specific, mechanistic source term for accident consequence analysis
- Vented low pressure confinement vs. leak-tight containment
- PRA insights used for design, safety and licensing basis decisions
- Highly automated plant controls and advanced digital I&C
- Modular fabrication and construction methods; longer operating cycles
- Deeply embedded, below grade reactor-plant structures
- Reactor protection for multiple BOP functions: electric power, process heat, H2

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NRC Advanced Reactor Research Plan Technical Arenas

- Fuel Performance Analysis**
- Nuclear Analysis**
- Thermal-Fluids Analysis**
- Accident Analysis**
- Consequence Analysis*
- Graphite Component Analysis**
- Metallic Component Analysis*
- Structural/Seismic Analysis*
- Risk-Informed Licensing**
- PRA**
- Human Factors**
- Advanced I&C*
- Fuel Cycle/Materials Safety*
- Material Protection
- H_2 Production Facility

*** Arena contributes to HTGR Accident Analysis Evaluation Model** *** Generic Arena**

*** Arena depends directly or indirectly on some aspect of graphite R&D**

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NGNP R&D Infrastructure Needs Assessment

Identified:

- Key NGNP technical, safety, safety research, policy issues
- Gaps in NRC's technical information and analysis capabilities need to support the NGNP licensing review
- Experimental data, models, codes, technical knowledge and technical guidance needed for NGNP regulatory decisions

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Perspectives on Research and Development Needed for NGNP Licensing

NGNP vs. LWR Differences →	Involving Differences In →	Resulting in R&D Gaps →	Involving →	Technical Infrastructure Development Goals
Reactor Plant Layout Materials Structures Systems Components Fuel forms Operating modes and states Reactor operating conditions BOP functions/systems Containment design PRA use in licensing basis Source term calculation Expanded Adv digital I & C Concept of operations Manufacturing methods Outage lengths Etc.	Licensing Basis Events (LBE) LBE conditions Safety important phenomena Safety functions Safety-related SSCs Safety figures of merit SSC failure mechanisms Success criteria Maintenance and testing DID approach Risk metrics Role of the operator Man-machine interface Approach to ISI and IST Etc.	PIRTs Experimental/test facilities Experimental data Phenomena modeling Design analysis methods Qualification methods Analytical tools Accident evaluation models Operational data Commission policies Standards (e.g., materials) Aging management Inspection capabilities Technical training Etc.	Analytical tool development Code to data benchmarks Code to code benchmarks Sensitivity studies Uncertainty analyses Analyses and evaluations Policy option development NRC-sponsored research Cooperative research Collaborative research DOE laboratory research NGNP designer research Public involvement Etc.	NGNP technical requirements SSC design criteria Analytical tools Accident evaluation models Fabrication Control Docs Codes and Standards Licensing policy decisions Regulatory requirements Regulatory guidance Inspection procedures Reactor oversight process Technical data bases Technical reference docs Knowledge and Know-How Etc.

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Illustrative NGNP PIRT Results: Number of Graphite Phenomena Effecting FOMs

Safety Figure of Merit (FOM)	Number of Phenomena
Maintain passive accident heat transfer	22
Maintain reactivity control	25
Thermal protection of metallic components	22
Radiation shielding of metallic components	11
Maintain helium core cooling flow	23
Prevent elevated mechanical loads on fuel	14
Limit fuel fission product release to He coolant	19

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NGNP Licensing Strategy Report to Congress: Graphite Safety R&D Issues Identified

- Analytical tools and design methods for graphite performance
- Models for graphite reactions in accident analysis tools
- Models for fission product transport through, retention in, graphite
- Effects of neutron fast fluence on graphite properties
- ASME code design requirements and tools for graphite structures
- Corrosion behavior of graphite structures during air ingress
- Construction inspection techniques/procedures for graphite

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Role of NRC NGNP Regulatory Research

- Develop NRC staff knowledge, expertise, capabilities and review guidance
- Independently confirm technical basis for requirements and criteria
- Develop NRC independent analytical capabilities
- Confirm or interpret technical information involving significant uncertainty
- Validate/scope-out technical issues to justify request for follow-up resolution by the applicant

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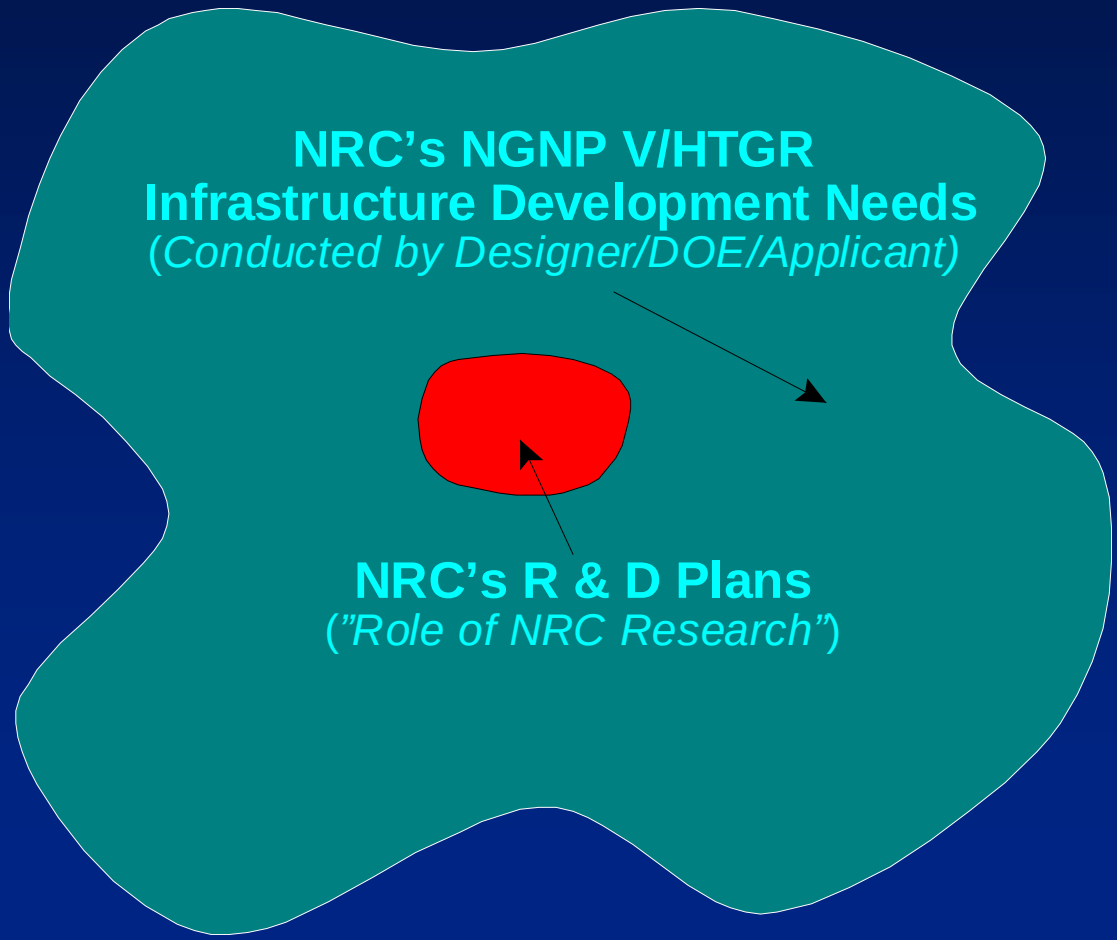
NGNP V/HTGR Infrastructure Development Needs vs. NRC Research and Development Plans



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NRC NGNP V/HTGR Graphite R&D Plans

- Support codes and standards development
- Conduct graphite workshop
- Participate in international irradiations
- Develop independent evaluation capability
- Develop capability to predict failure probability
- Conduct selective R&D to support regulatory decisions
- Support NRC HTGR accident evaluation model development

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NGNP Licensing Policy Issues

- Containment functional performance requirements
- Allowable dose consequences for licensing basis event categories
- Use of the PRA (e.g., select LBEs, establish special treatment requirements)
- Acceptable basis for event-specific mechanistic source term calculation, including siting source term
- Necessary DID measures

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NRC NGNP V/HTGR R& D Summary

- Focus on NGNP V/HTGR COL technical review needs
- Consistent with completed PIRTs: NGNP, TRISO Fuels and HFs
- Consistent with the “Role of NRC Research”
- Recognize/utilize DOE NGNP VHTR R&D plans/results
- Include prismatic block & pebble bed reactor designs….for now
- Focus on the NGNP-specific reactor design….after DOE selection
- Utilize cooperative research agreements where possible
- Support the NGNP COL application review schedule