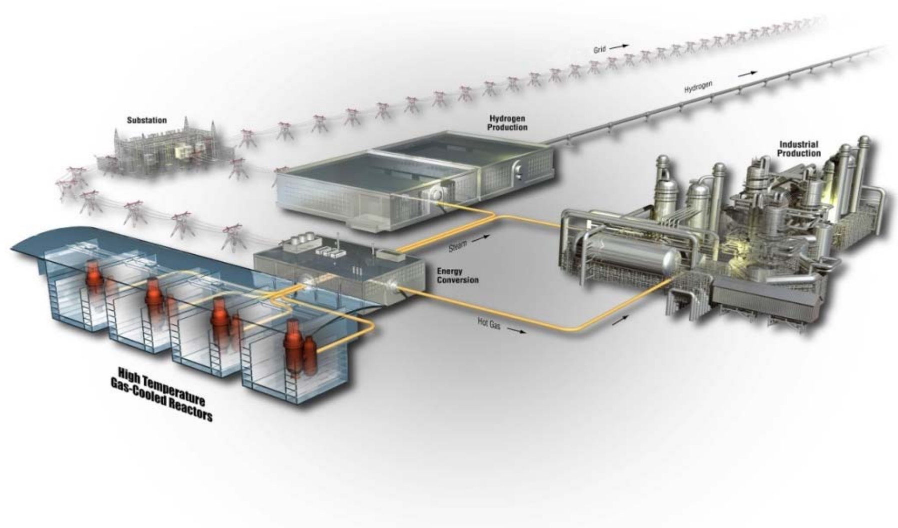
Next Generation Nuclear Plant Risk-Informed Licensing Approach

Presentation to NRC/NEI SMR Workshop by Next Generation Nuclear Plant Project

April 20, 2011



www.inl.gov

Idaho National Laboratory

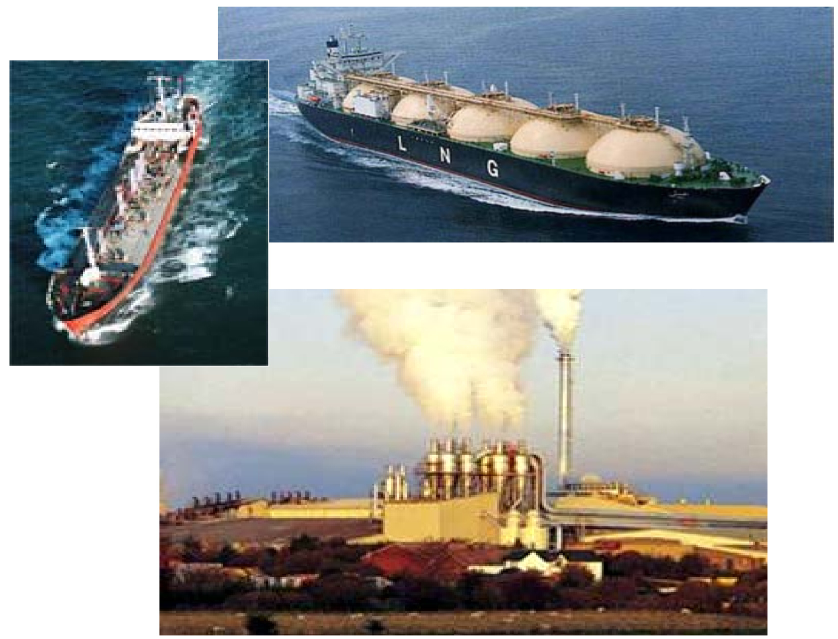
Presentation Outline

- **What is NGNP?**
- **NGNP Licensing Path**
- **NGNP Safety Basis**
- **Use of Probabilistic Risk Assessment**
- **HTGR Risk Metrics**
- **Licensing Basis Event (LBE) Selection**
- **SSC Safety Classification**
- **Summary**

What is NGNP?

The Next Generation Nuclear Plant (NGNP) Project is focused on the deployment of High Temperature Gas Cooled Reactors

- Supports a transformative application of nuclear energy to address the President's goals for reducing greenhouse gas emissions and enhancing energy security
  - Process heat applications (petrochemical, oil sands, etc.)
  - Generation of electricity
  - Generation of hydrogen

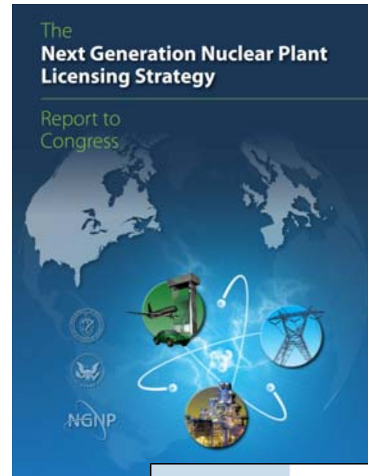


60% of oil and 16% of natural gas used in U.S. is imported

NGNP Licensing Path to HTGR Deployment

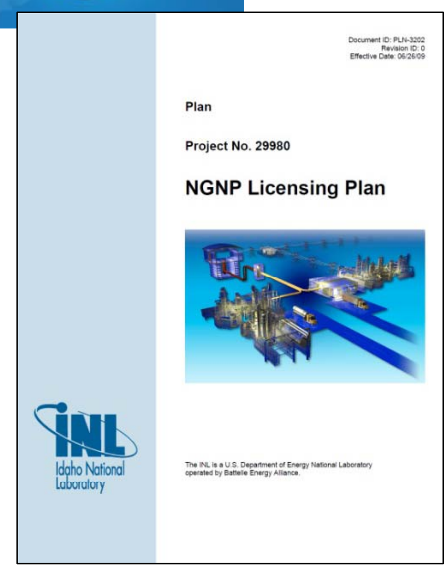
Overall strategy established in DOE-NRC Report to Congress (August, 2008)

- Recommended the Part 52 Combined License (COL) process be utilized
  - Lowers licensing risk - builds on recent industry experience
  - Increases project certainty for stakeholders
- Identified initial set of priority licensing issues requiring resolution to license /operate NGNP
  - Described process for adaptation of existing LWR rules
  - Identified likely need for new or revised regulatory approaches in certain areas



NGNP Licensing Plan defines the path for documenting Part 52 COL application content for HTGRs

- Utilizes Reg. Guide 1.206 concept (COLA Content Guide for LWRs)
- Key inputs are results of white paper disposition and regulatory gap analysis



White Papers Submitted to NRC

Eight white papers submitted to NRC for review to date

- Defense in Depth (December 2009)
- Licensing Basis Event Selection (September 2010)
- Structures, Systems, and Components Safety Classification (September 2010)
- Mechanistic Source Terms Description (July 2010)
- Probabilistic Risk Assessment (under development – expected by late April 2011)
- License Structure for Multi-Module Facilities (August 2010)
- High Temperature Materials Qualification (June 2010)
- Fuel Qualification Process (July 2010)
- Emergency Planning Zone Size and Emergency Planning Attributes (October 2010)

NGNP Safety Basis - Overview

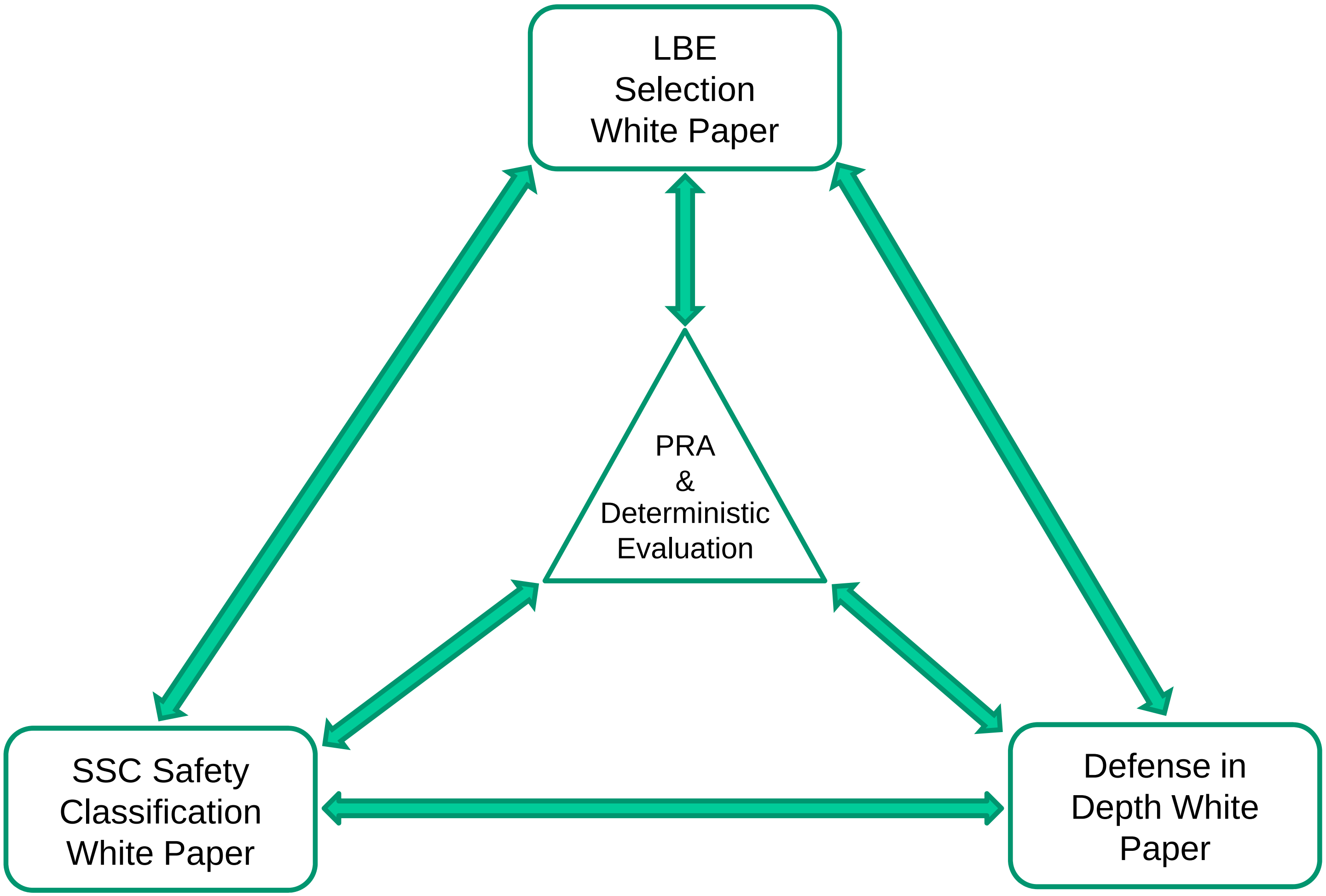
- The objectives of the NGNP safety basis include:
  - Limit dose from releases so that regulatory requirements for protection of the health and safety of the public and protection of the environment are met at an Exclusion Area Boundary (EAB) that is no more than a few hundred meters (e.g., 400m) from the reactor

- NGNP design objective is to meet the EPA Protective Action Guides at the EAB

NGNP Safety Basis - Overview

- To achieve these objectives, the NGNP Risk Informed approach relies on fundamental HTGR safety features and design approaches:
  - Coated fuel particles retain radionuclides
  - Helium primary coolant
  - Decay Heat Removal via passive systems
  - Core design with low power density and negative temperature coefficients for fuel and moderator
  - Large heat capacity of graphite (slow heat-up) and margins between maximum operating temperature and fuel particle failure limits
  - Multiple barriers to the release of radionuclides
  - Use of PRA to inform the design for Licensing Basis Event identification, SSC classification, and assurance of adequate Defense in Depth

NGNP Safety Basis – Risk Informed Approach



Licensing Basis Events

- Events derived from the HTGR technology and plant design that are considered by the licensing process and are used in development of the license application
  - LBEs include:
    - Anticipated Operational Occurrences (AOOs)
    - Design Basis Events (DBEs)
    - Beyond Design Basis Events (BDBEs)
    - Design Basis Accidents (DBAs)
- LBEs are evaluated collectively to show compliance with Quantitative Health Objectives (QHOs) of Safety Goals.
- LBEs define the circumstances under which the applicable regulatory requirements and associated guidance must be met

Types of LBEs

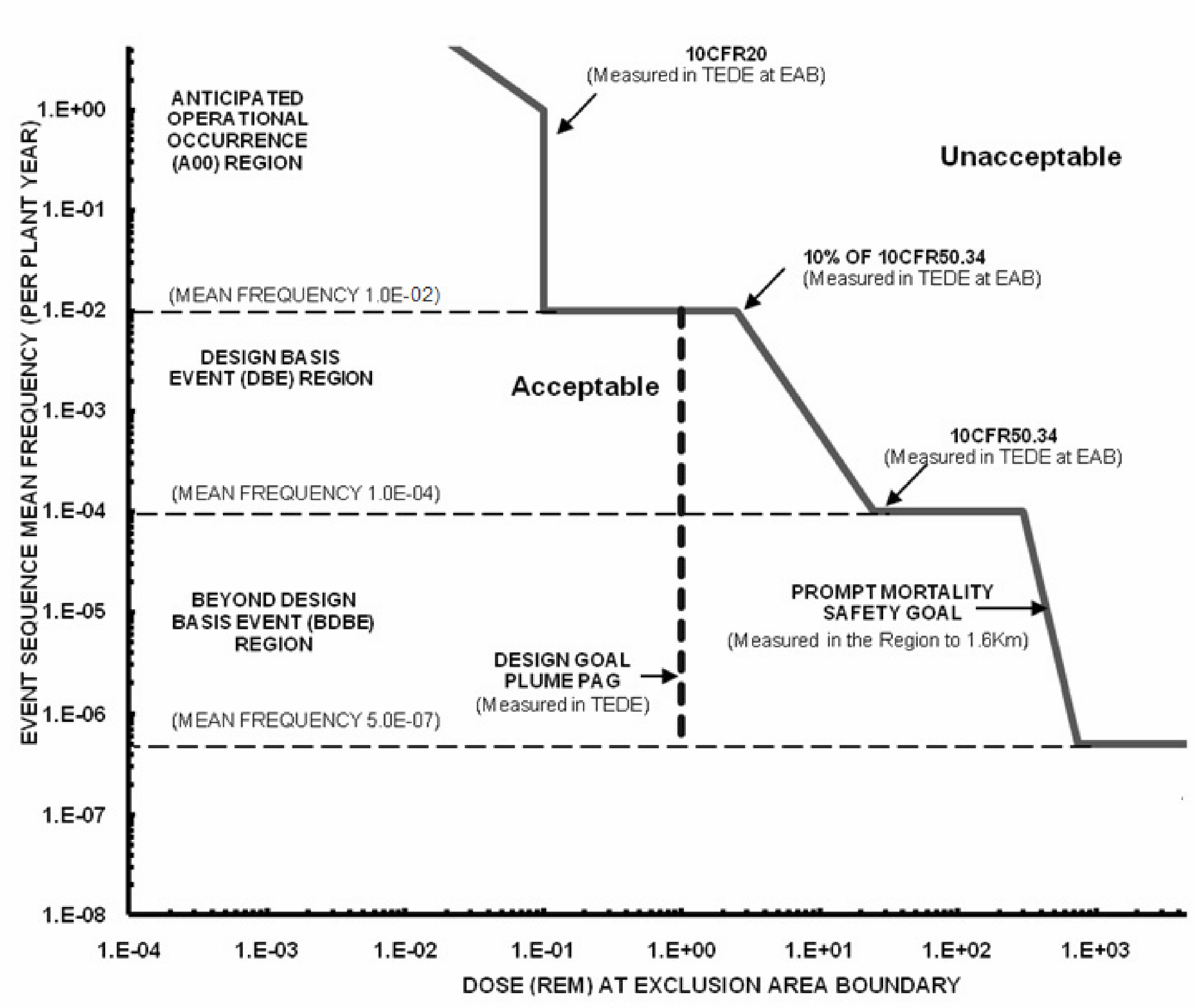
Although the selection process has not been applied to a plant design with enough detail to complete the process, an initial list of LBEs based on prior HTGR experience would be expected to include:

- Loss of forced cooling events
- Depressurized loss of forced cooling events
- External events (e.g., earthquakes)
- Moisture ingress events
- Inadvertent control rod withdrawal events
- Station blackout

LBE Selection Process

- Design development uses a systematic, top-down approach to regulatory and end-user requirements
- Conventional design and analysis techniques are used to satisfy requirements
- Existing HTGR experience will be used by design process
- Combination of deterministic and probabilistic risk analysis are used to identify & classify events
- Iterative design process leads to refinement of identified LBEs

Frequency-Consequence Chart with Regulatory Criteria



Anticipated Operational Occurrences

- Events expected once or more in the plant lifetime
  - lower frequency of 0.01/plant year
- Identified as families of events that could exceed public consequence criteria in 10 CFR 20 if certain equipment or design features had not been selected
- Consequences realistically analyzed for compliance with 10 CFR 20 100 mrem TEDE at the EAB
- Used as basis for operational limits

Design Basis Events

- DBEs are events of lower frequency than AOOs, not expected to occur in the lifetime of the plant
  - lower boundary frequency of 10^{-4}/plant year
  - events at 10^{-4}/plant year have less than 1% chance of occurring in plant lifetime
- Identified as families of event sequences with similar initiating events and safety function responses that could exceed 10 CFR 50.34 dose criteria if certain equipment or design features had not been selected
- Used as basis for design, SSC classification, and for assuring EPA PAGs will be met

Beyond Design Basis Events

- Events that are not expected to occur during the lifetime of a fleet of plants
  - lower frequency of 5×10^{-7}/plant yr
  - Used to confirm prompt fatality safety goal QHO
- Consequences realistically evaluated with other LBEs for compliance with the NRC Safety Goal QHOs
- Used as basis for rare event analysis for assuring EPA PAGs will be met

Design Basis Accidents

- DBAs provide deterministic confirmation that the safety-related SSCs can alone mitigate the consequences of the selected DBEs
- DBAs are used to develop the limiting parameter values i.e., temperatures, stresses, heat loads, etc., that safety-related SSCs must be able to meet in order to fulfill their mission for each DBE
- DBAs are used to establish conservative operating conditions

NGNP SSC Safety Classification

- Safety classification is made in the context of specific, required safety functions performed by the SSC.
- SSCs classified as Safety-Related are those relied on to prevent or mitigate the consequences of accidents which could result in potential significant offsite exposures.
- SSCs classified as non-safety-related with special treatment are those relied on to perform safety functions to mitigate the consequences of AOOs or prevent the frequency of DBEs from increasing into the AOO region
- Special treatments are applied to SR and NSRST SSCs to ensure they have the capability and reliability to perform their safety functions

Use of PRA

- Provides a logical and structured safety evaluation
- Incorporates and builds on a deterministic evaluation of the plant capability to prevent and mitigate accidents
- Captures dependencies and interactions within a comprehensive plant perspective
- Allows for identifying and addressing uncertainties while anchoring assessments on realistic assumptions
- Confirm that the plant's design meets the NGNP safety objectives
- Supports evaluation of Defense in Depth

NGNP PRA

- Will consist of a full scope PRA, similar to a Level 3 PRA developed for LWRs developed in accordance with Draft ASME/ANS non-LWR PRA Standard
- Systematic enumeration of representative event sequences and families
  - Addresses Full Power and Low Power/Shutdown States
  - Includes fires, internal, external, and common-cause events
  - Includes non-core sources of material at risk
- Use of PRA is commensurate with design level

Consideration of LWR Risk Metrics

- No Core Damage Frequency (CDF) or Large Early Release Frequency (LERF) risk metrics
  - Core damage as defined for light-water reactors is precluded by HTGR safety design approach
    - Ceramic core including fuel particle coating
    - Core geometry
    - Helium (inert) coolant
    - Passive heat removal
  - No release large enough (or early enough) to meet the LERF definition
    - Heat capacity of graphite provides long accident response time constants

HTGR Risk Metrics

- Primary Risk Metrics – Quantitative Health Objectives
  - Cumulative estimates of risk to the public

- LBEs provide expected dose from event sequences at EAB

- Relies on PRA to develop HTGR-specific plant state frequencies and to confirm LBEs that are analyzed for source term calculations
  - Event sequence frequencies are calculated on a per-plant-year basis, where a plant may consist of a number of reactor modules
  - The consequences of event sequences may involve source terms from one, multiple, or all reactor modules that comprise the plant

Summary

- NGNP risk-informed performance-based licensing approach is HTGR technology-neutral
- HTGR risk metrics
- Use of PRA in the evaluations of LBEs is a key element of the approach upon which other elements build, e.g., SSC safety classification, DID
  - Systematic search for initiating events and event sequences
  - Includes internal, external, and common cause events and events involving more than one reactor module
  - Addresses Full Power and Low Power/Shutdown States