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Overview of ONR Activities for Regulating Advanced Modular Reactors

A Structural Integrity Perspective

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Objectives

- Scope of UK regulatory interest in Gen IV reactors and materials development
- Areas for further consideration
- Potential knowledge gaps for Gen IV reactor designs against ONR expectations

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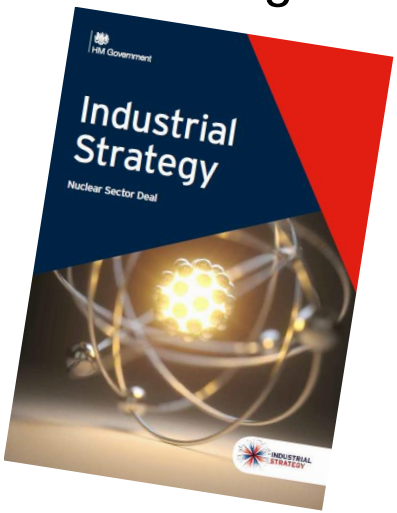
Scope of UK Regulatory Interest in Gen IV Designs

- In 2017, the UK Government launched a clean growth strategy setting out the intention to invest in new nuclear technology
- One of the objectives included investment of up to £12 million (~$15 million) to ensure that the regulators (ONR and Environment Agency) develop the capability and capacity to regulate Advanced Nuclear Technologies (ANTs), including SMRs (light water and non-light water types [AMRs])
- Regarding AMRs the focus is on four of the six GIF technologies:
  - ✓ Sodium Fast Reactors (SFR)
  - ✓ Lead Fast Reactors (LFR)
  - ✓ Molten Salt Reactors (MSR)
  - ✓ High Temperature Gas Reactors (HTGR)
  - x Gas Fast Reactors (GFR)
  - x Super Critical Water Reactors (SCWR)



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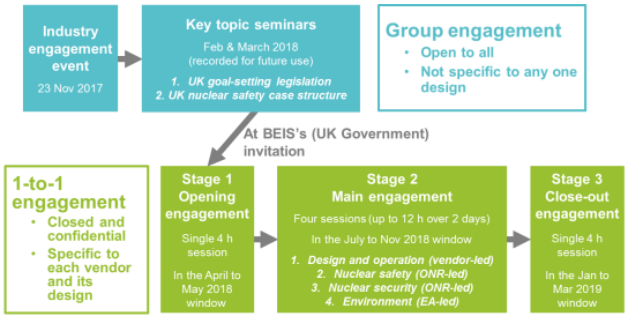
Objectives of our work on ANTs



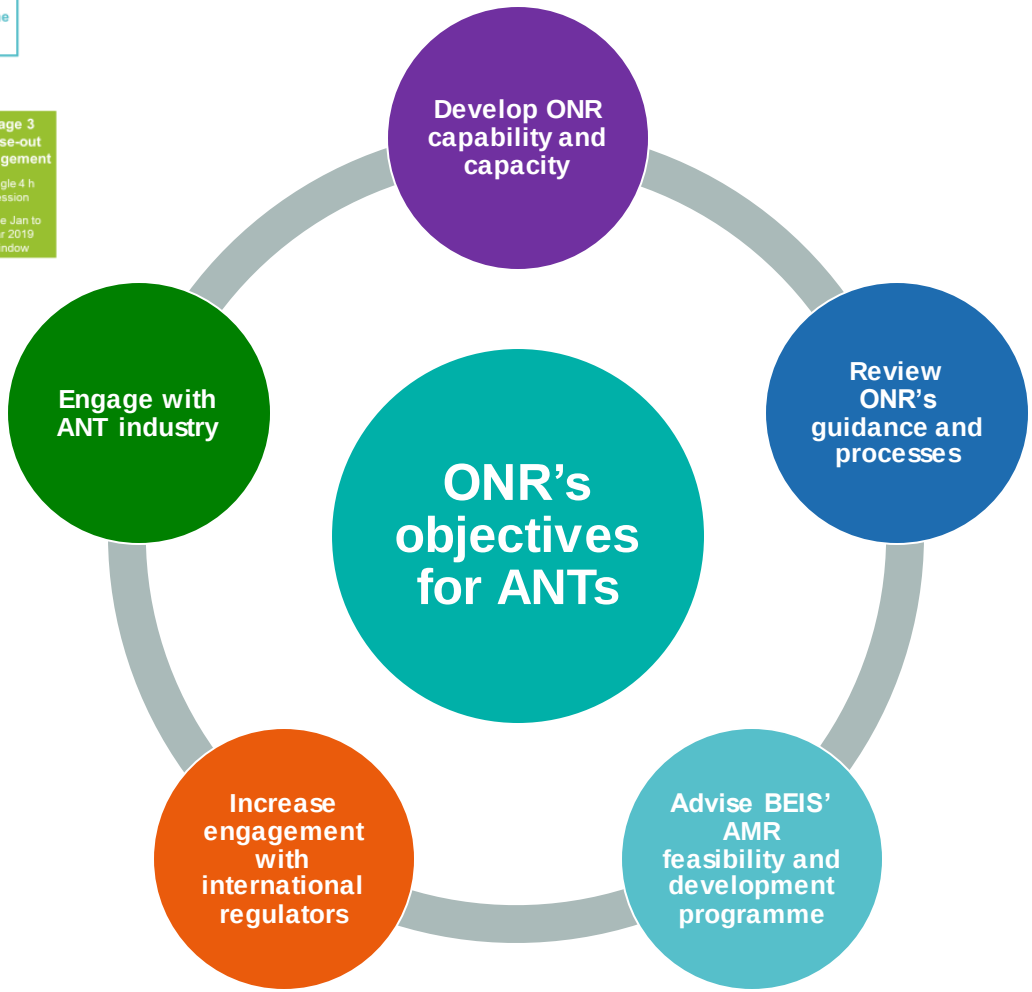
IAEA

SMR REGULATORS' FORUM

NEA NUCLEAR ENERGY AGENCY

CNSC CCSN

U.S.NRC United States Nuclear Regulatory Commission *Protecting People and the Environment*



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Regulatory Activities to Build Capability and Capacity

- Knowledge capture and transfer through:
  - Attendance at international forums, workshops, conferences and working groups
  - Targeted technology-specific training courses
- Review suitability of existing regulatory assessment guidance and arrangements for regulating ANTs

In addition, ONR undertook the following:

- Modernisation of UK ONR Generic Design Assessment (GDA) process
- Provided advice to the UK Government Department for Business, Energy and Industrial Strategy (BEIS) in the Advanced Modular Reactor Feasibility and Development Project

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AMR Feasibility and Development Project

- In 2017, UK government department for Business, Energy and Industrial Strategy (BEIS) launched a £44 million (~$55 million) Feasibility and Development Project
- With over 20 initial applicants for phase 1, BEIS selected 8 designs do for consideration in phase 1 - **7 fission designs (plus 1 fusion)**
- **1 SFRs, 2 LFRs, 3 HTGRs, 1 MSR:**
  - Advanced Reactor Concepts LLC
  - Westinghouse Electric Company UK Limited
  - LeadCold
  - U-Battery Developments Ltd
  - Ultra Safe Nuclear Corporation
  - DBD Ltd
  - Moltex
  - Tokamak Energy Ltd*

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ONR Activities on Materials Challenges for Advanced Modular Reactors

- Production of safety consideration reports **(complete)**
- Production of targeted materials' knowledge capture reports **(in process)**
- Identification of structural integrity challenges for the four targeted Gen IV technologies focused around:
  - OPEX
  - materials development/selection
  - understanding of ageing and degradation mechanisms
  - development of codes and standards, and
  - international approach to regulation
- Ongoing scope of ONR involvement is dependant on UK government strategy for engagement with AMR industry

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Challenges for Advanced Modular Reactors: Structural Integrity

- Using ONR SAPs and TAGs, identification of structural integrity challenges for ANTs based on information gathered from knowledge capture activities, key findings are presented under three topics:
    - Design of SSCs important for safety
    - Materials selection and development
    - Accessibility for Inspection and Maintenance
- Note that regulatory expectations are highly dependent on reactor design and safety claim placed on components and structures
- Current stage of design maturity means that safety claims may not be fully developed yet for Gen IV structures and component
- Proposed use of advanced manufacturing and inspection techniques – how to provide confidence for defect prediction and detection?

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Sodium Fast Reactors

Materials

- Determination of any cliff edge effects that may undermine extrapolation of existing OPEX
- Understanding materials performance to resist localised thermal fatigue/striping in above core components – development of high cycle fatigue modelling/assessment methodologies.
- Understand the level of reliance on chemical control of primary coolant (oxygen, Na impurities) for materials performance

Design

- Application of leak-before break methodology for low pressure, ductile components
- Importance of robust material selection, design and fabrication to avoid/minimise likelihood of IHX/steam generator failures
- Ability to detect and isolate leaks particularly for inter-cooling loop barriers

Inspection

- Capability and reliability of under-sodium viewing technology

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Lead Fast Reactors

Materials

- Performance and application of advanced coating technologies and importance for demonstrating component integrity through life
- Use of coatings to reduce reliance on active primary circuit chemistry control
- Availability of research and test facilities (especially for irradiation)
- Understanding of ageing and degradation mechanisms as a result of aggregated operating conditions (chemical, flow, thermal, mechanical, irradiation)

Inspection & Design

- Challenges faced by inspection of core and primary circuit internal structures and components

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High Temperature Gas Reactors

Materials

- Understanding effects of high temperature, chemical environment and radiation on graphite and chemical effects on primary/secondary interfaces (S/GS, (i)H/Xs)
- Availability and applicability of relevant codes and standards for graphite design, manufacture and in-service inspection
- Tribological effects of mechanical interaction of graphite/metallic structures and components in He primary circuits
- Effect of graphite/carbon dust generation

Inspection

- Inspection of concealed in-core components such as:
  - graphite moderator, reflector, thermal shields and
  - metallic core support structure, gas baffles etc)

Design

- Reliance on plant control and instrumentation to ensure materials operate within the design safe operating envelope (temperatures, high cycle fatigue)

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Molten Salt Reactors

Materials

- Active monitoring and managing primary circuit chemistry to minimise degradation of primary circuit components
- Control of corrosion by avoidance of contaminants – safety classification of chemical/volume control systems?
- Shielding of structural materials to limit effects of thermal/irradiation degradation mechanisms
- Materials performance in varying/mixed chloride/fluoride salt environments
- Potential for crack initiation and growth requiring validated fatigue assessment procedures

Design

- Design of fuel dump tanks to be tolerant of thermal shock

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Summary of Identified Knowledge Gaps

Design

- Use of advanced manufacturing techniques
- Performance of engineered barriers and design features to control ageing and degradation
- High temperature assessment methodologies/codes
- Use of novel heat exchanger/steam generator technology (e.g. printed circuit, microchannel, plate-type)

Materials

- Performance of materials in excess of current OPEX - regulatory expectations for extrapolation
- Use of codes and standards to demonstrate appropriateness of material selection
- Development of a standardised approach to materials testing
- Materials selection in areas where OPEX is limited
- Multidiscipline approach to materials selection

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Summary of Identified Knowledge Gaps

Inspection

- Accessibility of key structural components and capability to inspect
- Reliance on performance/condition monitoring to supplement limitations of inspectability
- Application of risk informed inspection methodology
- Expectations and demonstration of claims on in-service inspection capability to demonstrate through life reliability
- Strength of condition monitoring to support claims of through life integrity
- Basis for maintenance strategy and accessibility in design

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Currently Ongoing

- Review of ONR guidance to evaluate applicability to new Gen IV reactor technologies.
- Review of advanced manufacturing techniques and associated application within the UK nuclear industry.
- Gather OPEX/LFE of non-light water reactor designs.
- Build knowledge of developments in codes and standards for use of high temperature materials.
- Continued engagement with safety regulatory forums e.g. in NEA WGSAR, IAEA and bilateral meetings with other nuclear regulators to develop expectations and share experience/learning.
- Continued attendance at workshops/conferences/seminars to support knowledge transfer and build technical capability/capacity of ANT designs.

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Next Steps

- Dependent on BEIS' decisions for future phases of ANT project
- Possible engagement with Feasibility and Development project participants
- Consider outcome of ONR guidance review and develop a strategy to implement findings.
- Build understanding of how advanced manufacturing is expected to be used within the UK nuclear industry and engage with supply chain to communicate regulatory expectations.
- Continue to support BEIS as necessary.

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Thank you for Listening

Any Questions?

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