Office for Nuclear Regulation
An agency of HSE

New nuclear reactors: Generic Design Assessment

Electricité de France SA and AREVA NP SAS UK EPR™ nuclear reactor

Summary of the GDA Issue close-out assessment of the Electricité de France SA and AREVA NP SAS UK EPR™ nuclear reactor

13 December 2012

Report by the Office for Nuclear Regulation on the Generic Design Assessment of new nuclear reactor designs

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Foreword

This is our fourth and final summary report for the Generic Design Assessment (GDA) of the UK EPR™ reactor. It provides the main conclusions of our assessment of EDF and AREVA's responses to the 31 GDA Issues that we published in 2011. We are publishing this document as part of our commitment to be open and transparent about our work.

EDF and AREVA have addressed each of the 31 GDA Issues with a suite of revised safety case documents, ONR has assessed these, and a significant number of design changes have been incorporated into the generic design as a result. We have concluded that all the GDA Issues have been addressed.

In view of the safety case and design change improvements that have resulted from this work, we are now content that the current UK EPR™ generic reactor design and safety case have demonstrated that the risks to workers and the public are as low as reasonably practicable (ALARP), for this stage in the design process.

I am therefore pleased to report that I have today signed a Design Acceptance Confirmation (DAC) for the UK EPR™ reactor. Provision of this DAC means that we believe that the UK EPR™ reactor is suitable for construction on licensed sites in the UK, subject to site specific assessment and licensing.

This is a particularly significant milestone as it is the first such DAC to be granted by ONR. It also represents a commitment by ONR not to revisit, at the site specific stage, matters that are covered by the GDA scope.

GDA has been a new process that we set up in 2007 with the objective of enabling the nuclear regulators to get involved at an early stage in the development of proposals for new nuclear power stations. It allows the technical assessments to be conducted before commitments are made to construct the reactors, meaning that regulatory questions and challenges can be addressed, and any necessary modifications made, while the designs are still "on paper". The conclusions of this report demonstrate that we have achieved this objective.

Our assessment has been professionally undertaken, wide ranging and challenging and a number of safety improvements have been identified as a result. This should be seen as evidence of the operation of an independent and robust regulatory process and a demonstration of our mission to secure the protection of people and society from the hazards of the nuclear industry. By carrying out such a robust and transparent assessment we aim to ensure that any new nuclear power station based on the UK EPR™ design will be safe, secure and – through our colleagues in the Environment Agency – environmentally acceptable.

If you have any comments on this report I will be pleased to hear from you.

Colin Patchett
Acting Chief Inspector of Nuclear Installations
Office for Nuclear Regulation
An agency of the Health and Safety Executive
December 2012

Executive summary

In December 2011, ONR provided an interim Design Assessment Confirmation (iDAC) for the UK EPR™ reactor. This meant that ONR was largely satisfied with the design and safety case presented to us by EDF and AREVA for the UK EPR™ reactor, but there were a number of GDA Issues remaining which would have to be addressed before we could say that GDA is "complete".

For each of the GDA Issues we asked EDF and AREVA to provide a resolution plan to show how they would be addressed. The GDA Issues and the resolution plans were published in 2011.

This report summarises the work undertaken to assess EDF and AREVA's responses to the 31 GDA Issues and it documents why we are content to provide a Design Acceptance Confirmation (DAC).

Since 2011, EDF and AREVA have followed their resolution plans, updating them where necessary. They have addressed each of the 31 GDA Issues through development of improved safety cases and, in a number of areas, through identification of additional design improvements.

During GDA a total of 82 design change proposals have been identified and included in the UK EPR™ Reference Design. ONR's view is that these design improvements significantly strengthen the safety case for this reactor.

ONR has assessed each of the GDA Issue responses and the related safety case updates and design changes. When we reached the position of being satisfied with the response made, we have closed that GDA Issue, and then published a letter to confirm this. GDA Issue closure has continued throughout 2012. We are now at the point where we have concluded that all the GDA Issues have been addressed.

In view of the safety case and design change improvements that have resulted from this work, we are now content, for this stage in the design process, that the UK EPR™ generic reactor design and safety case have demonstrated that the risks to workers and the public are ALARP.

In recognition of the fact that all the GDA Issues are closed, and in accordance with our published guidance (References 1 and 2), we have therefore decided to issue a DAC for the UK EPR™ reactor. This has been issued alongside this report and indicates that we believe that the UK EPR™ reactor is suitable for construction on licensed sites in the UK, subject to site specific assessment and licensing.

While this is a significant milestone for the UK EPR™, the DAC does not in itself permit any additional action in terms of nuclear power station construction, as that requires a specific regulatory permission be given by ONR under a Nuclear Site Licence condition. This will be progressed separately by ONR.

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Background

The safety of nuclear installations is achieved by good design and operation, but is assured by a system of regulatory control at the heart of which is the nuclear site licensing process. The construction of a new nuclear power plant requires a licence to be granted and arrangements to be made to control the activities on the site in accordance with the conditions that are attached to the licence. Permission must be given under these licence conditions before any significant construction work can start (defined as: the placement of the first structural concrete for buildings with nuclear safety significance). The licence is granted by ONR, after assessment of the application, to a corporate body (e.g. an operator) to use a site for specified activities. In doing this we also look at the siting and organisational factors. The site licence, together with the attached licence conditions, apply throughout the lifetime of an installation from manufacture, through construction, commissioning, operation, modification and on to eventual decommissioning.

In response to growing interest in nuclear power and in anticipation of possible applications for new build in the UK, the nuclear regulators (the Office for Nuclear Regulation – ONR – and the Environment Agency) developed a revised assessment process for new nuclear power stations. The updated arrangements are based on a two-phase regulatory assessment process which separates the GDA (Phase 1) from the site specific ONR licensing assessment and Environment Agency permitting process (Phase 2). GDA is a rigorous and structured examination of the generic safety and security features of the reactor design and is undertaken independently of any site specific assessment, although the two could overlap.

Guidance on the GDA process (References 1, 2 and 3) was originally published in January 2007 and was updated in 2008 and 2010.

GDA consists of four steps during which we examine the safety and security aspects of the reactor design in increasing detail. In parallel with our work on safety and security aspects, the Environment Agency examines the potential environmental impact.

Progress through GDA does not guarantee that any of the designs will eventually be constructed in the UK. What it does do is allow us to examine the safety and security aspects at an early stage where we can have significant influence, and to make public reports about our opinions so that:

- The public can be informed about our independent review of the designs; and
- Industry can have clarity on our opinions and thus take due account of them in developing new construction projects.

For the UK EPR™, GDA Step 1 started in July 2007 and Step 4 was largely completed in 2011, when we published the 31 remaining GDA Issues. At the same time we provided an iDAC. Our work since 2011 has been focused on assessing EDF and AREVA's responses to these 31 GDA Issues.

This report describes the work we have undertaken during this GDA close-out period. It is best read in conjunction with the Step 4 reports that describe the detailed background of each GDA Issue. These are available on our website: www.hse.gov.uk/newreactors.

Our guidance requires that all GDA Issues must be addressed to our satisfaction, before we would consider issue of a final DAC. Until that time, no nuclear island safety-related construction of a power station based on a UK EPR™ reactor would be permitted.

GDA is being conducted in an open and transparent way. We have made information about our process and the reactor designs available to the public and we have published a series of reports to describe our progress and conclusions at key milestones. This information is on our website.

Phase 2 of the new build regulatory assessment process, which can be in parallel with Phase 1, involves an applicant seeking Permits from the Environment Agency and a nuclear site licence from ONR. Therefore, in Phase 2, ONR first carries out a site licence assessment, in which we examine the proposed site, the management organisation of the operating company, and the proposed type of facility to be installed on the site. If the application is judged to be acceptable we grant a Nuclear Site Licence.

In the specific case of UK EPR™, such an assessment has been completed in response to NNB GenCo Ltd's application to build two reactors at the Hinkley Point C site in Somerset. A Nuclear Site Licence was granted on 26 November 2012.

The Nuclear Site Licence gives ONR regulatory control of the site, but it does not in itself permit any nuclear power station construction. That requires a specific regulatory permission to be given by ONR under a licence condition. This will be progressed separately by ONR.

The expectation is that the generic safety case developed for GDA will be carried forward by future licensees to support the Phase 2 site specific work for any UK EPR™ that will be built in the UK. It is our intention that we will not reassess aspects covered by the DAC except, of course, to address any significant changes to the safety case, any new developments, site specific elements, or design changes proposed by a future licensee (Reference 1).

A DAC remains valid for ten years and, ultimately, could be used to underpin the permissions required from ONR to construct a fleet of identical reactors, except for site or licensee-specific changes.

More information on the licensing process can be found in the publication, *The licensing of nuclear installations* (Reference 4).

During the GDA Issue closure phase, EDF and AREVA worked closely with NNB GenCo, in their role as the licensee of Hinkley Point C and the company planning to build the first UK EPR™, at Hinkley Point C. NNB GenCo were primarily seeking confirmation that the methodologies and strategies for addressing the GDA Issues will result in positive and early outcomes that support the Hinkley Point C design engineering sequence and the contracting process. However, NNB GenCo also contributed to ensuring that the GDA Issue responses were complete and addressed the regulators' concerns.

We believe that this additional effort, at an early stage in the overall programme, is helping reinforce the benefits of GDA in resolving key safety issues by achieving technical convergence ahead of any nuclear island construction. This enhances regulatory effectiveness and should in turn lead to more predictable and achievable schedules for the construction phase.

Within GDA, ONR has also conducted a security assessment alongside the safety assessment. The overall aim was for EDF and AREVA to develop an acceptable conceptual security arrangements document. This document will influence and be referenced in the nuclear site security plan, approval of which is required before construction commences. A report on the generic security assessment was provided at the end of Step 4, and there were no GDA Issues arising. Security is therefore not discussed within this GDA Issue close-out report, but it is included within the scope of the DAC.

Introduction

The role of ONR is to secure the protection of people and society from the hazards of the nuclear industry. To achieve this aim in the light of proposals for construction of new nuclear power stations we have been assessing the nuclear safety and security aspects of new reactor designs, including UK EPR™.

For the UK EPR™, GDA Step 1 started in July 2007 and Step 4 was completed in 2011. By the end of Step 4, ONR had completed an in-depth assessment of the generic design safety case and conceptual security arrangements of the UK EPR™. We concluded that we were largely satisfied with the design and safety cases presented to us by EDF and AREVA for the UK EPR™ reactor, although some issues remained and required further work. As we were largely satisfied, we judged it appropriate to issue an iDAC for the UK EPR™ reactor that referenced the 31 remaining GDA Issues.

The detailed background to these Issues, and the history of our GDA work, is given in our detailed technical assessment reports for Step 4 that are published on our website.

EDF and AREVA developed resolution plans that identified how they intended to respond to the UK EPR™ GDA Issues. ONR discussed these with EDF and AREVA, who revised and developed them until ONR was satisfied that they represented credible plans to achieve complete responses to the GDA Issues. In arriving at this conclusion, ONR was satisfied that if EDF and AREVA delivered the scheduled documents and scope of work identified in the plans, then this should be sufficient to satisfactorily address, and allow closure of, the GDA Issues.

Since 2011, EDF and AREVA have been working to deliver the documents identified in these resolution plans and to address each of the 31 GDA Issues. In doing so they have developed improved safety cases and, in a number of areas, they have identified additional design improvements.

ONR has undertaken an in-depth assessment of each of the GDA Issue responses and the related safety case updates and design changes. When we reached the position of being satisfied with the response made, we have closed that GDA Issue, and then published a letter to confirm this. GDA Issue closure has continued throughout 2012 and we are now at the point where we have concluded that all the GDA Issues have been addressed.

In recognition of the fact that all the GDA Issues are closed, and in accordance with our published guidance (References 1 and 2), we have therefore decided to issue a DAC for the UK EPR™ reactor. This indicates that we believe that the UK EPR™ reactor is suitable for construction on licensed sites in the UK, subject to site specific assessment and licensing.

This report summarises the assessment work and it documents why we are content to provide a DAC.

This report is best read in conjunction with the Step 4 reports that describe the detailed background of each GDA Issue. We have not included background or assessment information within this report if it is already documented in the Step 4 reports.

This report is intended to inform the public of our work on GDA and we believe it provides a comprehensive overview of our assessment.

Management of GDA outcomes

ONR's work during the GDA Issue close-out phase for the UK EPR™ has been undertaken in accordance with the published guidance on the management of GDA outcomes (Reference 1). This document, which was published in June 2010, describes how issues remaining at the end of GDA Step 4 would be managed and what would be required for a DAC to be issued. This guidance defines the terms DAC, iDAC, GDA Issue, resolution plan, and Assessment Finding.

In December 2011, we completed Step 4 by concluding that we were largely content with the generic safety and security aspects of the UK EPR™ reactor and we issued an iDAC in which we identified 31 GDA Issues.

GDA Issues were defined in Reference 1 as:

> *Unresolved issues considered by regulators to be significant, but resolvable, and which require resolution before nuclear island safety-related construction of such a reactor could be considered.*

For each GDA Issue, Reference 1 requires that the Requesting Party (which is EDF and AREVA for the UK EPR™) provides a resolution plan to identify how they intended to respond to it. ONR's GDA Issues for the UK EPR™ and the resolution plans that EDF and AREVA have provided in response to them have been published on our website at www.hse.gov.uk/newreactors.

Some of the schedules were updated during the close-out phase to revise the delivery dates and these revised schedules are also published on our website alongside the original resolution plans.

It should be noted that the regulators took an active role in reviewing EDF and AREVA's resolution plans during their development, and we asked for amendments or additional information as necessary, before we were able to conclude that the plans were credible. A credible resolution plan is one that provides persuasive arguments that the work proposed will be sufficient to address the GDA Issue, in a timely manner, when considering the proposed scope of work, the deliverable descriptions, the timetable and milestone programme, the methodologies to be employed, and the impact on the overall GDA submission documentation. We were therefore satisfied that if EDF and AREVA delivered the scheduled documents and scope of work identified in the plans, then this should be sufficient to address the GDA Issue.

Since 2011, EDF and AREVA have been working to deliver the documents identified in the resolution plans and the regulators have been assessing them.

Reference 1 states that we could consider whether a DAC could be issued once all the resolution plans are completed and GDA Issues are addressed satisfactorily, and the safety case updated

For GDA of the UK EPR™ reactor, we have now reached the stage where EDF and AREVA have submitted the agreed Resolution Plan deliverables, we have assessed them and judged them to be satisfactory. We have therefore closed all the GDA Issues and we have decided to provide a DAC.

GDA was designed to assess the generic safety case for future reactor designs. It is followed by more detailed design work at the site specific phase. ONR's assessment will therefore continue at the site specific phase, where full validation of the safety case can inevitably only be completed when the final detailed design of equipment is developed by a manufacturer / supplier, or when the facility is being constructed and is in the process of being tested.

Findings that were identified during the regulators' GDA assessment are important to safety, but not considered critical to the decision to start nuclear island safety-related construction, are known as Assessment Findings. These are matters that we identified during GDA that can best be further developed at the site specific phase. These are identified in our Step 4 and GDA Issue close-out assessment reports. After GDA, the Assessment Findings will be subject to appropriate control as part of normal regulatory oversight, and it will be the responsibility of the future licensee to ensure they are addressed during the detailed design, procurement, construction, or commissioning phase of the new build project.

The Assessment Findings arising from our GDA assessment for the UK EPR™ reactor were identified in the detailed Step 4 assessment reports for each technical topic area. Where new Assessment Findings are identified as a result of GDA Issue close-out, then these are included in the detailed ONR close-out assessment reports.

This summary report describes the extensive work we have undertaken during the GDA Issue close-out phase and, together with the work we completed in Steps 1, 2, 3 and 4, it underlines that we have completed a meaningful assessment of the UK EPR™ reactor. We are therefore confident that the decision to provide a DAC is soundly based and, although there are Assessment Findings included in the GDA Issue close-out assessment reports, there will be nothing arising that will affect this DAC decision.

Assessment Findings are mostly matters that we would anyway have raised during our site specific assessments. By identifying them during the GDA process we are maximising the time available for future licensees and operators of the UK EPR™ reactor to address them. Early identification of Assessment Findings in this way thus represents one of the key benefits of the GDA process.

After GDA, the Assessment Findings will be subject to appropriate control as part of normal regulatory oversight of new nuclear power station projects, under the nuclear site licence. It will be the responsibility of the future licensee to ensure they are addressed appropriately during the detailed design, procurement, construction, or commissioning phase of the new build project. It will be ONR's responsibility to satisfy itself that this has been done.

Management of GDA Issue close-out assessment

Programme of work undertaken

The GDA close-out phase used the same ways of working and programme management arrangements as for the previous GDA Steps 1 to 4.

The GDA Issue close-out phase for the UK EPR™ reactor has been a period of intense activity where both ONR and EDF and AREVA have expended significant effort.

EDF and AREVA have worked hard to provide the additional information identified in the resolution plans and to respond to the technical questions we raised.

ONR has undertaken an in-depth assessment of the GDA Issue responses. Plans were developed for each technical area to set out a strategy for our assessment based on a wide-ranging comprehensive systematic sample of the information provided by EDF and AREVA. This assessment includes review of documentation, technical meetings with EDF and AREVA, consideration of responses to questions, and the use of advice from Technical Support Contractors.

During the close-out phase ONR has expended around £7.5m worth of effort, which has included around £1.1m on technical contract support. EDF and AREVA provided around 450 documents and ONR asked 165 formal technical questions.

This brings the total effort we expended on our GDA for the UK EPR™ reactor to around £32m which has been fully funded by EDF and AREVA. This has covered our examination of over 4000 documents; we have posed over 1630 formal technical questions, and held around 600 technical meetings. The result is that we have been able to complete a wide-ranging, comprehensive, detailed, robust and meaningful assessment of the UK EPR™ reactor, and this work has been completed before any UK EPR™ nuclear power station construction project has commenced in the UK.

The assessment standards and demonstration of "as low as reasonably practicable" (ALARP)

The main document we used for our assessment was our *Safety assessment principles for nuclear facilities* (SAPs) (Reference 5). In doing our assessment we check if the proposed design and safety case complies with these SAPs. Compliance is not mandatory and we will consider alternative arguments, but if the design conforms with the SAPs then it tends to make our acceptance more straightforward.

ONR will require any nuclear reactor that is built in the UK to be of a robust design that provides adequate protection against potential accidents to a degree that meets modern international good practice. In order to confirm that the expectations of good practice have been met for the UK EPR™, the assessments undertaken were all based on established nuclear safety standards and relevant operational experience gleaned from events, both in the UK and internationally. The key references cited have been the SAPs, International Atomic Energy Agency (IAEA) standards, and other standards and guidance such as those of the International Electrotechnical Commission (IEC), the American Society of Mechanical Engineers (ASME), United States Nuclear Regulatory Commission Regulatory standards and guidance (NUREG) etc and from national and internationally available operating experience. It would not be appropriate to include in this summary report details of exactly which specific standards and guidance were used for assessment of each GDA Issue. However, this information can be found within the specific technical assessment reports that will be produced for each GDA Issue.

Our judgements on international good practice were also informed by our discussions in international forums such as the Multinational Design Evaluation Programme (MDEP), where experience and information is shared with other national regulators in relation to design safety issues for new reactors. We used this information on international good practice to inform our assessment of the potential risk from the operation of the UK EPR™ in the UK and to inform our judgements on whether the risk has been reduced ALARP.

The development of the UK EPR™ reactor has considered a number of potential design options, seeking to build on, and improve, past designs such as the N4 and Konvoi reactors that were developed in the 1980s and 1990s in France and Germany. Further options for improvement were considered by EDF and AREVA and were deemed not reasonably practicable. ONR's Step 4 assessment generally accepted these conclusions, except that the 31 GDA Issues were in effect matters on which we were not yet satisfied with the safety and ALARP arguments.

This GDA close-out summary report identifies all the work EDF and AREVA have undertaken to address the 31 GDA Issues. They have developed improved safety cases in response to the Issues and in a number of areas they have identified additional design improvements. ONR has assessed these GDA Issue responses, and the related design improvements, and we have judged that they are sufficient to allow closure of the GDA Issues.

We are therefore now content, at this stage in the design process, that the generic safety case for the UK EPR™, including the identified design improvements, will demonstrate that risks to workers and the public are ALARP.

During the site specific detailed design and construction phase we will regulate the further detailed development of the identified design changes, and there will be the opportunity for checking that risks have been reduced ALARP as the detailed design progresses, and as the Assessment Findings are addressed.

Assessment strategy

ONR's assessment strategy was based on completing a wide-ranging and comprehensive systematic sample of the information provided by EDF and AREVA in response to each of the GDA Issues. Specific assessment plans were developed for each technical area that identified the topic areas to be sampled and those SAPs that were most relevant. Our sample included the defence-in-depth provided by the systems for shutting down and cooling the reactor, and for containment of radioactivity.

As a result of this strategy we have examined the safety claims, arguments and evidence provided for each GDA Issue, on a sampling basis. Our objective was to ensure that sufficient evidence existed to allow us to judge that the GDA Issues had been adequately addressed.

Governance of GDA Issue close-out

As the GDA close-out progressed it became clear that, after completion of the assessment of the responses to a GDA Issue, it would take some time for the associated assessment reports to go through our completion, review and publication process. The result was a delay of a few months before they could be published on our website. We therefore decided to adopt a quicker, but robust close-out process. In addition, in view of the importance of these GDA Issues, we took the opportunity to introduce an additional level of internal challenge to moderate and decide on GDA

Issue closure. This was over and above ONR's normal issue resolution and assessment reporting process.

The robust close-out process required written confirmation that for an individual GDA Issue:

- EDF and AREVA have submitted all the information agreed to be provided;
- This information had been reviewed;
- All responses to Technical Queries had been received;
- All relevant modifications had been identified; and
- The information provided was judged to provide an adequate response to the GDA Issue.

When this written confirmation was completed, it then had to be presented to the Assessment Review Group (ARG), which is a peer review, challenge and moderation panel, who were the final arbiters on GDA Issue closure. Only when the ARG agreed that the GDA Issue could be closedwould confirmation letters be sent to EDF and AREVA and then posted on our website.

All 31 GDA Issues have been cleared through this process. The first Issue was closed on 28 March 2012 and the last was closed on 7 December 2012.

Production of assessment reports for each GDA Issue closure will follow our normal completion, review and publication process, following which they will be published on our website.

Joint working with the Environment Agency using the Joint Programme Office

During the GDA issue close-out phase ONR continued to work jointly with the Environment Agency. Both ONR and the Environment Agency used a common process for receiving GDA submissions, for correspondence, and for raising and tackling technical matters, administered by the Joint Programme Office (JPO).

Two of the GDA Issues (GI-UKEPR-CC-02 and GI-UKEPR-CC-03) were joint Issues for ONR and the Environment Agency. These are discussed later in this report.

The Environment Agency will report separately on its conclusions on whether to provide a Statement of Design Acceptability.

Technical Support Contractors

We continued to use specialist contractors to help us carry out our detailed technical assessment during the close-out phase. However, all regulatory decisions were made by the nuclear regulators – not by the contractors.

During the close-out phase for the UK EPR™ reactor, ONR placed 16 contracts at a cost of around £1.1m.

Openness and transparency

A key objective of GDA was to work in a spirit of openness. We published the GDA Issues and resolution plans and, as soon as GDA Issues were closed out, we published the closure letters and, as soon as they are available, the associated assessment reports.

The remaining assessment reports have to go through our completion, review and publication process, which takes a few months, but after this they will be published on our website. Our current target date for publication of all remaining reports is the end of March 2013.

EDF and AREVA have updated their website to incorporate revisions to the safety case for the UK EPR™ that have arisen from the GDA Issue responses.

In addition, throughout the close-out, we continued to publish regular reports to summarise progress. These included performance metrics to help highlight good performance and problem areas and focus management effort appropriately.

Working with overseas regulators

Our strategy for working with overseas regulators during GDA is given on our website (see Reference 8). In accordance with this we have, throughout GDA, worked in particular with those regulators in France, Finland and the USA, where the EPR™ reactor is also under active assessment. We have used these exchanges both to help our assessment (and theirs) and to confirm that we are applying the international standards and relevant good practice.

These technical exchanges with overseas regulators have continued throughout the GDA Issue close-out phase, usually through bilateral or multilateral face-to-face meetings.

Of particular benefit have been the information exchange meetings with our overseas counterparts. Topics discussed have included control and instrumentation, probabilistic safety analysis, fault analysis, structural integrity, and oversight of manufacturing and fabrication of long lead items.

We have continued to participate in working group meetings of MDEP (see www.nea.fr). The aim of MDEP is to promote international sharing of information between regulators on their new nuclear power station safety assessments and to promote consistent nuclear safety assessment standards among different countries. The participants are 12 countries where new nuclear power station programmes are commencing: USA, Canada, China, France, Japan, the Russian Federation, UK, Republic of Korea, South Africa, Finland, India, the United Arab Emirates, plus IAEA. ONR takes a full part in the information sharing activities, in particular on the UK EPR™ reactor. Discussions during the GDA Issue close-out phase have included: fault studies, control and instrumentation, Probabilistic Safety Assessment, and Technical Specifications There was also information exchange on the lessons learnt from Fukushima and how these could affect the UK EPR™.

We have found these exchanges of information to be most valuable and we have taken account of them as appropriate in our assessment of GDA Issue responses.

Summary of UK EPR™ reactor GDA safety and security submissions

The aim of this report is to provide a summary of the assessment of the information ONR has gathered from EDF and AREVA during the GDA Issue close-out phase.

The information provided by EDF and AREVA for GDA was presented in a number of documents, including the generic Pre-Construction Safety Report (PCSR), the Design Reference (DR) and the Submission Master List (SML). These are described below. As these documents form key references to the DAC, it was important that they were updated and managed appropriately. ONR monitored this via a specific GDA Issue, GI-UKEPR-CC-02, which is described later in this report.

Generic Pre-Construction Safety Report

EDF and AREVA's safety case for GDA Step 4 was described in their March 2011 PCSR (Reference 12). This was updated during the GDA Issue close-out phase to take account of new information, to improve the clarity of the safety arguments, and to include agreed design changes. The updates were incorporated into a final version of the PCSR which was submitted in November 2012 (Reference 25).

Submission Master List

The SML was updated during the GDA Issue close-out phase to capture, developments in the safety case, design modifications, and responses to regulator assessment questions. The totality of the GDA submission is listed in the SML and this includes all the documentation sampled by the regulators during GDA.

EDF and AREVA have provided and updated a SML since November 2009. The Step 4 SML was provided in November 2011 (Reference 14), and this was updated in December 2012 to become the final GDA SML (Reference 26).

Design Reference

EDF and AREVA were required to submit a DR to list all the documents that describe the design of the UK EPR™ reactor and associated plant that the GDA submissions refer to. We required this to be "frozen" at a specific date, known as the Design Reference Point (DRP).

EDF and AREVA submitted their first DR in 2008 (Reference 15) and the DRP date was set at end of 2008. For GDA Step 4, the design reference was submitted in May 2011 (Reference 16).

The DR has been updated to include 82 design change proposals that we have accepted into GDA. For the GDA close-out phase the DR was updated and re-submitted in December 2012 (Reference 27).

Out-of-scope items

GDA was designed to assess the generic safety case for future reactor designs, within a generic site envelope, and not the adequacy of a complete design that will be built on a specific site, as there will be operator and site specific factors that can only be considered during the site specific stages.

A description of the items that are out-of-scope was provided in ONR's summary report for Step 4 (Reference 28). There have been minor modifications to this during the GDA close-out phase and these are reflected in minor changes to the DR.

Anything that is out-of-scope will need to be addressed, as appropriate, by a future licensee and will be examined by ONR as part of our normal regulatory business during the site specific stage.

Summary of design changes that result from our assessment

In response to our assessment challenges, both during Step 4 and during the GDA Issue close-out phase, EDF and AREVA have made significant additions and updates to the safety case for the UK EPR™ reactor, together with a number of design changes.

The UK EPR™ design is based on a DRP of December 2008. Changes to the GDA DR since this date were subject to a change control procedure, which requires agreement from the regulators to include any design changes.

During GDA a total of 82 design change proposals have been identified and included in the GDA DR and they will therefore be referenced in the DAC.

Sixteen design change proposals were agreed for inclusion in GDA during Step 4, in addition to 12 others previously identified in the DR by EDF and AREVA. These design changes were proposed by EDF and AREVA to improve the UK EPR™ reactor design, either as a result of experience gained on other EPR™ projects, or as a result of regulatory questions and challenges.

During the GDA close-out phase a further 54 design improvements have been proposed by EDF and AREVA within their responses to the GDA Issues. In some topic areas, for example control and instrumentation, the design change proposals that were offered in Step 4 have been further developed, detailed and assessed during the close-out phase.

These design and safety improvements have now been accepted within GDA by ONR. Further development of the details of these modifications will be progressed after GDA, during the site specific phase.

ONR’s view is that these design improvements significantly strengthen the safety case for the UK EPR™.

Examples of the design changes are given below.

- Changes to the architecture of the control and instrumentation (C&I) systems, including the:
  - Addition of a non-computerised C&I safety back-up system;
  - Introduction of one-way network communication from the protection system to lower classified systems; and
  - Introduction of Class 1 displays and manual controls and indications in the main control room and remote shutdown station.

- The addition of additional reactor protection system trip signals, such as:
  - A high neutron flux trip;
  - A high axial offset trip;
  - A hot leg high-pressure trip; and
  - A reactor coolant pump low speed trip.

- Automation of certain actions such as:

- Activation of the emergency boration system in the event of a steam line break;
- Isolation of pipework in the event of leaks to prevent flooding; and
- Actuation of the emergency feedwater system on detection of low steam generator pressure.

- Improvements to the spent fuel cooling pond, including:
  - Removal of several penetrations and openings in the spent fuel pool to increase the robustness of the structure;
  - Installation of protection (such as penetration covers, secondary containments etc) to prevent leaks from spent fuel pond penetrations;
  - Improvements to the cooling water supply systems to the spent fuel cooling pond; and
  - Changes to SFP fuel handling procedures.

- Upgrade of the safety classification of numerous structures, systems and components (SSCs) that are important to safety including:
  - Parts of the C&I systems;
  - The primary circuit safety injection accumulators;
  - The Ultimate Diesel Generators (UDG);
  - The electrical earth system;
  - The actuation signals for:
    - Starting the UDGs;
    - Starting the Primary Depressurisation System (PDS);
    - Closing the diverse full load Main Feedwater Isolation Valves;
    - Actuation of the Emergency Boration System (EBS).

- Other modifications that provide additional diversity, defence-in-depth, or other safety improvements such as
  - Provision of additional diversification in the electrical power supplies to key components to reduce the probability of common cause failure;
  - Modification of the primary circuit pipework to facilitate through life inspection;
  - Strengthening part of the civil structure to improve protection against potential dropped loads near the reactor primary circuit;
  - Upgrading the heating and ventilation support systems which play an important role in cooling essential safety systems such as C&I;
  - Providing a diverse heating and ventilation system;
  - Upgrading the control systems for the main and diverse heating and ventilation systems;
  - Improvements to the system for detecting small steam generator tube leaks; and

- Reassessment of the irradiation embrittlement surveillance scheme to take account of the effects of the heavy reflector inside the UK EPR™ reactor pressure vessel.

■ Although the above changes were identified independently of the Fukushima lessons learnt reviews many of them do help provide additional protection in extremely challenging hazard or plant failure scenarios. In addition, directly as a result of the Fukushima lessons learnt review, EDF and AREVA identified five design change proposals, covering 16 resilience enhancements, that include the following:

- Improved flood protection for emergency electrical supplies (both AC and DC);
- Extension of the capability and autonomy of emergency electrical supplies (both AC and DC);
- Identified connection points for proposed mobile diesel generators;
- Addition of SFP instrumentation into the severe accident management C&I systems;
- Identification of a reserve ultimate water supply: and
- Delivery of water via mobile pumps for SFP make-up and containment pressure control.

In view of these additional safety improvements that have been secured through assessment of the responses to the GDA Issues, we are now content that the current UK EPR™ generic reactor design has demonstrated that the risks to workers and the public are ALARP.

Summary of ONR GDA Issue close-out assessment

The full background to each GDA Issue was detailed in the Step 4 assessment reports for each technical area that we published in December 2011. These can all be viewed at:

http://www.hse.gov.uk/newreactors/regulators-issue-interim-dac-soda-gda-key-milestone.htm

The sections below summarise the outcome of ONR's GDA Issue close-out assessment. The summary is presented by technical topic area and information is given for each GDA Issue about why we believe it has been addressed satisfactorily.

In addition, full details of our assessment of the GDA Issue responses will be given in the individual topic area assessment reports. These are being put on our website, as soon as they have been completed, and can be found at:

http://www.hse.gov.uk/newreactors/gda-issue-close-out-uk-epr.htm#close-out-reports

Assessment reports that are not yet finished will be published once they have been through our normal review and publication process. It is our intention that all reports will be complete and published online before end March 2013. These reports should be read in conjunction with our Step 4 reports, which describe the conclusions of our Step 4 assessment, and which provide the background to each GDA Issue.

Internal Hazards

ONR's safety assessment within this topic includes hazards such as fire, explosion, flood, dropped loads, pressure part failure, and steam release etc. arising within the boundary of the UK EPR™ plant. We have considered the adequacy of: the identification of hazards; prevention of hazards; and the protective barriers, segregation, separation, and active protection systems that are included within the design to provide mitigation in the unlikely event that such internal hazards should occur.

From our Step 4 assessment, we identified four GDA Issues in this topic area, related to:

- Substantiation and analysis of the consequences of dropped loads and impact from lifting equipment (GI-UKEPR-IH-01).
- Completeness of evidence associated with safety claims on internal missiles, cable routing, and internal flooding (GI-UKEPR-IH-02).
- The basis of the safety case for internal flooding (GI-UKEPR-IH-03).
- Substantiation of the claims made associated with the consequences of missile generation arising from failure of pressure boundary components (GI-UKEPR-IH-04).

Closure of GI-UKEPR-IH-01

The aim of this Issue was to seek additional assurance that the nuclear safety consequences of dropped loads and impact from lifting equipment were acceptable.

ONR assessment during GDA Steps 3 and 4 identified that sufficient arguments and evidence had not been presented in support of the claims made associated with dropped loads and impact. As a result, GDA Issue GI-UKEPR-IH-01 was raised, which required EDF and AREVA to provide further substantiation of the claims made within the safety case.

In response to this Issue, EDF and AREVA provided additional documentation, including detailed consequence analyses for a number of potential lifting operations with a view to demonstrating that the risk to nuclear safety from a dropped load or impact was ALARP. Responses were also provided to technical questions we asked during our assessment.

ONR's work has judged that:

- The approach to the analysis of dropped loads and impacts is in line with the HSE SAPs and relevant good practice.
- The design of the lifting equipment is to a high standard and consistent with international standards.
- The consequential effects on civil structures are acceptable.
- The analyses provided are comprehensive and the consequences of a dropped load or impact from lifting equipment proposed for the UK EPR™ are acceptable to nuclear safety.

In addition, EDF and AREVA have proposed design changes as a result of their analyses which will improve the protection against a dropped load or impact, and as a result the risk to nuclear safety from a dropped load or impact will be ALARP.

On the basis of this assessment ONR has concluded that the safety case for dropped loads and impact for the UK EPR™ is now adequate. ONR is therefore satisfied that GDA Issue GI-UKEPR-IH-01 has been addressed.

Closure of GI-UKEPR-IH-02

The aim of this Issue was to seek additional evidence, in the form of verification and validation, for internal flooding, cable routing, high energy line break and missiles, to substantiate the claims made within the safety case.

On a nuclear power plant, ensuring redundancy and segregation of safety-related systems and equipment is important for nuclear safety. Redundancy on the UK EPR™ is generally achieved through four "trains" of protection, with each train able to provide 100% of the safety duty required to enable safe shutdown and post-trip cooling. A "train" of protection includes all the elements necessary to perform the safety function, for example water source, pumps, pipes, and electrical supplies. Additional protection comes from the physical segregation of each of the trains. It is important that these safety trains are adequately protected in the unlikely event that internal hazards should occur.

During ONR's Step 4 assessment, evidence was sought relating to the verification and validation of the safety case claims for the protection of safety trains from a range of internal hazards. In a number of cases, this information was not available, and EDF and AREVA stated this would not be completed until the site specific detailed design phase. To get more confidence in the generic EPR™ design, ONR asked to have sight of similar studies performed for Flamanville 3 (FA3), however, EDF and AREVA advised that, at the time of Step 4, the work was not yet complete. As a result, GDA Issue GI-UKEPR-IH-02 was raised.

The approach taken by EDF and AREVA in response to this Issue was to provide the verification and validation studies that were undertaken for Flamanville 3 in the areas of internal flooding, protected cable routes, high energy line break, and internal missile.

ONR has assessed this additional information.

- We judge that the approach to the analyses provided has been comprehensive and robust for each of the areas in which verification and validation was sought.
- For internal flooding EDF and AREVA calculated potential flood volumes and justified that watertight seals, doors, barriers and cable penetrations are adequately rated to withstand the effects of water, and that drainage into retention sumps is adequate. There is safety classified level monitoring to ensure that any flooding event is detected and the information relayed to the main control room. This is also related to GDA Issue GI-UKEPR-IH-03. Our assessment has confirmed that the requirements of the Issue have been met.
- For the verification and validation of cable routing our assessment has considered a submission looking at the whole of the nuclear island. This has allowed us to confirm that the routing, segregation and protection of the cables and cable trays are adequate.
- For high energy line breaks our assessment has looked at the consequences of breaks in both the Fuel building and the Safeguards buildings. It has also looked at how the loads from such breaks affect the structural steelwork, and the protection that is provided by the presence of barriers. We are satisfied that the requirements of the Issue have been met.

- For internal missiles the submission dealt with the analysis of the most onerous potential missiles, the mechanisms which could generate them and the quantitative consequences of the missiles and the protection provided by barriers. This submission has been assessed as part of GDA Issue GI-UKEPR-IH-04 and has been judged to meet our expectations.
- The analyses have demonstrated that the potential for loss of more than one redundant train of safety systems is low, and where the potential exists there are robust operational arguments presented to demonstrate that this would be tolerable, and nuclear safety would not be compromised. In some cases, diverse means by which nuclear safety can be assured have been presented as part of the analysis, thus demonstrating that at least one safety system would be available.
- The evidence provided in response to the GDA Issue aligns with ONR expectations in relation to standards, guidance, and relevant good practice.

On the basis of this assessment, ONR has concluded that sufficient evidence has been provided to demonstrate that the approach taken to the verification and validation for the internal hazards in the areas of internal flooding, cable routing, high energy line break, and internal missile is of a good standard. ONR is therefore satisfied that GDA Issue GI-UKEPR-IH-02 has been addressed.

Closure of GI-UKEPR-IH-03

The aim of this Issue was to seek additional assurance on the basis of the safety case for internal flooding. ONR assessment during GDA Step 4 identified that there were inconsistencies between claims stated within the safety case for internal flooding and the potential sources of water that could cause internal flooding. As a result, GDA Issue GI-UKEPR-IH-03 was raised, which required EDF and AREVA to provide further substantiation of the claims in the internal flooding safety case.

In response to the GDA Issue, EDF and AREVA provided an improved safety case based on a multi-legged deterministic analysis that initially assumes unmitigated sources of flood. EDF and AREVA split their analysis into two separate tasks.

- Task 1 was an analysis of the main potential flooding initiators in each safety classified building of the nuclear island, with the assumption that the flood was not mitigated by a manual action. Each bounding leak volume was compared to the water volume for which the particular safety classified building had been sized. If the flooding event demonstrated that there was insufficient water retention within the affected building, the consequences were considered to be unacceptable as the event could threaten another safety division.
- Task 2 then considered these specific scenarios and provided further detailed mitigation that considered the following additional risk reduction measures:
    - Enhancement of the hazard barriers.
    - Further engineered solutions, e.g. automatic means by which to isolate potential sources of internal flooding.
    - Operator actions, including the viability of the potential action to be undertaken.

ONR assessed this additional information and did not agree with the assumption of leak rather than full break for moderate energy pipework systems with a nominal diameter greater than 50mm. In response, EDF and AREVA provided multi-legged arguments and a consequence analysis based on the revised assumptions of internal flooding arising from full break of such moderate energy pipework systems. As a result of this additional analysis, EDF and AREVA identified several systems where gross failure could lead to an internal flooding event with the potential to affect more than one redundant safety significant system. To address this new finding, EDF and AREVA identified three design modifications to improve protection.

The first relates to improved isolation of the nuclear island fire fighting system within the annulus (the space between the two containment structures in the Reactor building). This is achieved by automatic isolation of the system in order to terminate a leak in the annulus and to ensure that flood levels do not result in loss of safety-related equipment. The modification involves changing seven manual valves to motorised ones, the addition of a further four motorised valves, and new provision for initiating automatic isolation.

The second modification relates to additional flood level detection and preventative isolation of the Essential Service Water System (ESWS) in the Safeguard Auxiliary Building. This modification will ensure that, if failure of the ESWS occurs, then there is sufficient time for operators to take action in advance of water reaching the safety significant levels.

The final modification relates to improved isolation of the Demineralised Water System (SED) within the annulus. This is achieved by a change from a manual valve to one that is motorised. There are also changes to the operational procedures associated with preventative isolation in the event of detection of flooding within the annulus.

ONR assessment has concluded that:

- The totality of the deliverables submitted in response to the GDA Issue provides a comprehensive analysis of potential sources of internal flooding and the drainage and discharge routes that are available within the UK EPR™.
- The submissions address the range of potential failure mechanisms, consider the barriers and doors in place to prevent flood propagation affecting more than one redundant safety train, and include both engineered and administrative measures to mitigate potential flooding events. As a result the analysis has identified reasonably practicable modifications which result in improvements in the robustness of the internal flooding safety case.

The new information provided, together with the proposed design modifications, will result in a far more robust safety case, particularly in the event of gross failure of systems contained within the Safeguard Auxiliary Buildings and annulus. We are therefore satisfied that GDA Issue GI-UKEPR-IH-03 has been addressed.

Closure of GI-UKEPR-IH-04

The aim of this Issue was to seek additional assurance that the nuclear safety consequences of missile generation arising from failure of pressure boundary components were acceptable.

In nuclear power station design it is normal practice to take account of the potential effects of energetic failure of pressurised components, both due to the loss of that component and also due to the damage that can be caused to neighbouring equipment by missiles (flying debris). During GDA Step 4 ONR assessment identified that sufficient arguments and evidence had not been presented in support of the claims associated with missile generation arising from failure of pressure boundary components that were designed to nuclear codes but were not designated as High Integrity Components (HIC). As a result GDA Issue GI-UKEPR-IH-04 was raised which required EDF and AREVA to provide further substantiation of the claims made within the safety case and to provide additional assurance that the consequences of missile generation arising from failure of pressure boundary components were acceptable.

In response to this Issue, EDF and AREVA provided additional documentation including a detailed consequence analyses for a number of potential missiles, which aimed to demonstrate that the nuclear safety risk was ALARP.

ONR’s assessment has judged that:

- EDF and AREVA’s approach to the analysis of the consequences of the most bounding missile scenarios is in line with the HSE SAPs and international guidance.
- The analysis undertaken has considered the most onerous potential missile events and the calculations performed for these events have been comprehensive.
- The failure mechanisms postulated by EDF and AREVA that result in the generation of missiles are considered to be reasonable and bounding.
- Passive structural barriers are provided within the design to protect against the effects of internal missiles.

On the basis of this assessment ONR has judged that the safety case for missile generation arising from failure of pressure boundary components for the UK EPR™ is now adequate. We are therefore satisfied that GDA Issue GI-UKEPR-IH-04 has been addressed.

Civil Engineering and External Hazards

ONR's assessment of the UK EPR™ reactor civil structures includes consideration of the design of the safety-critical civil structures such as the buildings comprising the nuclear island, including the inner containment structure. This includes building foundations and the building superstructures of the nuclear island. Reinforced concrete, pre-stressed concrete and structural steelwork elements are all included.

Our assessment of external hazards includes those natural or man-made hazards that originate externally to the site and over which the operator has little control. External hazards include earthquake, aircraft impact, extreme weather, flooding, and the effects of climate change.

From our Step 4 assessment, we identified that there were six GDA Issues in this topic area relating to:

- Specification, methodology and hypothesis notes for the nuclear island structures (GI-UKEPR-CE-01).
- Use of the design code ETC-C in the UK (GI-UKEPR-CE-02).
- Beyond design basis behaviour of the inner containment structure (GI-UKEPR-CE-03).
- The analysis of the inner containment structure (GI-UKEPR-CE-04).
- The reliability assured by the design code ETC-C (GI-UKEPR-CE-05).
- Detailed methodologies for the treatment of soil structure interaction and seismic analysis (GI-UKEPR-CE-06).

Closure of GI-UKEPR-CE-01

The aim of this Issue was to ask EDF and AREVA to produce satisfactory hypothesis notes for the nuclear island structures for the UK EPR™.

The civil structures in the UK EPR™ reference design, Flamanville 3, were designed using a French design code called the EPR™ Technical Code for Civil Structures (ETC-C). Our Step 4 assessment of the design process found that the ETC-C does not provide the full information a designer needs, but has to be read with additional information, called hypothesis notes, for the particular building under examination. Our assessment found that the basis of design for the most important civil structures on the nuclear island was contained within a large number of "hypothesis notes", which we judged to be heavily biased towards the Flamanville 3 project, which was the reference design for GDA. To meet the principles of good practice ONR considered that a number of changes and additions would be required to ensure that the hypothesis notes will be suitable for use in the UK, for instance removal of references to French standards. Furthermore, these hypothesis notes referred to design criteria, specifications and methodologies that were spread across a suite of documents and ONR concluded these did not provide sufficient clarity and did not adequately describe the design of the generic aspects of the UK EPR™. It was because of these Step 4 conclusions that we raised the GDA Issue.

In response to this Issue, EDF and AREVA have produced an overarching document, *the EPR™ Nuclear Island Civil Engineering Design Process Note*. This forms a high level basis of design document for the nuclear safety classified buildings; and forms a platform that the individual building hypothesis notes can use at the detailed design and construction phase. The Design Process Note includes summary descriptions of the structural philosophy for each building, design principles, and it marshals the design codes and standards and design methodologies that will be used.

ONR assessment judged that the new overarching document is a significant improvement in providing clarity of the overall design specification and methodologies to be used for the UK EPR™. ONR is satisfied that this document has addressed the concerns we identified in Step 4 in that it will signpost the designers to the information necessary to achieve an acceptable civil structure detailed design.

We have therefore judged EDF and AREVA's response to GI-UKEPR-CE-01 to be satisfactory.

Closure of GI-UKEPR-CE-02

The summary of ONR's Civil Engineering close-out assessment of GDA Issue GI-UKEPR-CE-02 is given below. The civil structures in the UK EPR™ reference design, Flamanville 3, were designed using the 2006 version of the code ETC-C. The aim of this Issue was to ensure provision of appropriate supporting documentation, and a suitable justification, to enable safe use of this design code in the UK.

In response to challenges made during ONR's Step 4 assessment, EDF and AREVA proposed to use an updated version of this code, developed in 2010, and they also developed an accompanying UK Companion Document (UK CD) which was written to specify supplementary information to the ETC-C to ensure successful application of the code within the UK.

Despite these developments, the Step 4 ONR assessment of both the ETC-C and the UK CD judged that there was not sufficient guidance given to designers and some of the technical clauses within them had not been fully justified. Furthermore the UK CD did not adapt the ETC-C sufficiently for use in the UK, for instance many French standards were quoted rather than using UK or international standards that are regarded as current good practice.

ONR's outstanding queries about these documents could not be resolved during GDA Step 4 and therefore GDA Issue GI-UKEPR-CE-02 was raised. The aim was to ensure provision of appropriate supporting documentation, and a suitable justification, to enable the safe use of the 2010 version of ETC-C, and its accompanying UK CD, in the UK.

In response to this Issue EDF and AREVA provided an updated UK CD in which the technical clauses of the ETC-C are adequately modified to comply with UK standards and good practice. A suite of technical documents and methodologies was also submitted and these provided the justification behind the technical clauses.

ONR assessment of the information provided concluded that the latest revision of the UK CD provides adequate guidance to designers and that the technical clauses are in accordance with good international standards. ONR considers that the ETC-C, as modified by the UK CD, is now suitable for use as the design code for the nuclear safety-related structures of the UK EPR™. It also provides additional criteria for the construction of these structures, for instance special requirements for the pre-stressed containment building, which have benefited from operational knowledge at existing EPR™ sites. ONR judges that the methodologies submitted for structural detailing, SFP liner design and assessment of impact from dropped loads and missiles are now adequate.

ONR judges that the 2010 version of the ETC-C is acceptable for use in the UK. We note that it is not a full construction specification for civil works, as these can only be produced during the site specific detailed design phase. These will be monitored by ONR as part of our normal regulatory business.

On the basis of this assessment, we have confidence that any site specific design in the UK will be completed to appropriate standards. We have therefore judged EDF and AREVA's response to GI-UKEPR-CE-02 to be satisfactory.

Closure of GI-UKEPR-CE-03

The aim of this Issue was to seek additional justification that the beyond design basis behaviour of the UK EPR™ inner containment structure was acceptable.

The containment structure is an important part of the UK EPR™ design that prevents release of radioactivity in accident conditions. It comprises a pre-stressed concrete cylindrical structure with a domed roof, and is lined with stainless steel. The concrete structure provides the strength and the liner provides the pressure boundary. It is important that its structural performance is demonstrated for a range of conditions to which it might be exposed (for example internal pressure, seismic events), including extreme loadings that go beyond the design basis.

In response to this Issue, EDF and AREVA submitted revised and additional documents, in particular explaining the behaviour of the inner containment structure under beyond design basis conditions. The two most onerous load cases are internal pressure and seismic. EDF and AREVA's response to the GDA Issue aimed at demonstrating that there is no disproportionate increase in risk as a result of changes in the design basis parameters, and to demonstrate the structure's behaviour remains safe as the loads increase beyond the design basis. This work has confirmed there is sufficient margin beyond the design basis for the most dominant load case of containment pressure.

ONR's has concluded that this additional information provides a much greater level of detail and justification for the approach used. In particular, the overpressure case is much more clearly presented and the summary of the beyond design basis assessment of the inner containment structure is satisfactory. This clarifies how the containment structure would behave in the event of the loads becoming higher than the design basis values, and demonstrates that there will be no cliff-edge effects.

ONR concludes that there is sufficient margin in the analyses for containment loads and that there is no disproportionate increase in risk when considering beyond design basis scenarios. This has provided the confidence in the robustness of the justification of the containment structure that we had felt was missing at the end of Step 4.

On the basis of this assessment, we have judged EDF and AREVA's response to GI-UKEPR-CE-03 to be satisfactory.

Closure of GI-UKEPR-CE-04

The aim of this Issue was to seek additional assurance that the design analysis of the inner containment structure captures its behaviour in a sufficiently accurate manner. (This Issue is closely related to GI-UKEPR-CE-03 above.)

The containment structure has a key safety role, it is important that the overall design is demonstrated to a high level of reliability. From our Step 4 assessment, ONR was not satisfied that the computer analysis model was sufficiently accurate or sensitive to adequately model the structure and the load actions applied to it. The model was also not always constructed in line with internationally recognised methods and so needed further justification.

In response to this issue, EDF and AREVA submitted revised and additional documents. These documents described the process for constructing the model and how it will be tested for sensitivity to any variation in the input data. Methods were given explaining how the accuracy of the model will be checked and this included comparison against physical data measured on containments that are already operating.

We have concluded that these documents adequately justify the computer analyses carried out for the design of the Inner Containment structure for the reference design of the Flamanville 3 plant. EDF and AREVA recognise that the reference design is specific to a site with very hard ground and based on modelling techniques that were developed over the last decade. The methodology documents have also confirmed how future UK site specific analysis models will benefit from up to date software and current good practice. It has also identified which factors are generic and which are site specific. During the site specific detailed design stage, models will be constructed in line with these methodologies, and will also include modelling of the actual soil conditions for that site (and the techniques for doing this have been assessed under GI-UKEPR-CE-06). ONR will monitor this as part of our normal regulatory business.

ONR is satisfied that the proposed methodologies for constructing the analysis models will result in sufficient accuracy in modelling the behaviour of the inner containment structure. In addition, generic aspects such as how the model will be checked at the detailed design stage to confirm its accuracy and reliability have been demonstrated. ONR therefore judges that the response to the GDA Issue is acceptable.

ONR is therefore satisfied that GDA Issue GI-UKEPR-CE-04 has been addressed.

Closure of GI-UKEPR-CE-05

The aim of this Issue was to seek additional assurance that that the French design code ETC-C provides an appropriate level of reliability for the design of the civil structures.

Each of the civil structures in the UK EPR™ reference design has been designed using ETC-C, which is an EDF and AREVA code, developed specifically for the EPR™ project. The ETC-C describes the various codes and standards to be applied for the EPR™ project and it is essentially a signposting document which directs the designer to Eurocodes, European Standards (EN), French standards and other guidance.

ONR's Step 4 assessment concluded that the reliability of the ETC-C had not been justified sufficiently, i.e. we were not sufficiently confident that the civil structures designed in accordance with it would meet the safety demands placed upon them. The ETC-C refers to codes and standards and other guidance that are not written specifically for the design of special construction works such as nuclear installations. ONR expected that ETC-C should have a higher safety consideration than standard industrial or commercial buildings reflecting the higher demands placed on nuclear structures. The two most critical areas were identified as the design of the inner containment structure against seismic loading and against overpressure and ONR assessment judged that the detailed calculations of the achieved reliabilities submitted during GDA Step 4 were not satisfactory.

In response to this GDA Issue, EDF and AREVA provided documents that summarised the containment design, carried out in accordance with the ETC-C, for the seismic and overpressure loadings. They also clarified how the reliability of that design was calculated, including the use of data from other EPR™ projects and from operating experience feedback.

ONR assessment of this further evidence judged that the methods used were in line with international good practice, the responses provided adequate justification of the reliability calculations for the containment for the two dominant loadings, and demonstrated that the ETC-C does ensure that the necessary reliability can be achieved through its appropriate use. We have therefore judged EDF and AREVA's response to GI-UKEPR-CE-05 to be satisfactory.

Closure of GI-UKEPR-CE-06

The aim of this Issue was to seek additional assurance that the methodology for the seismic analysis of the raft foundation and nuclear island superstructures was appropriately justified.

ONR Step 4 civil engineering and external hazard assessment judged that the methodologies proposed for the seismic analysis of the UK EPR™ and the raft foundation had not been sufficiently justified. In response to the questions we raised on this matter, EDF and AREVA submitted revised and additional documents towards the end of Step 4 of GDA. However, there was insufficient time to review them and therefore GDA Issue GI-UKEPR-CE-06 was raised.

EDF and AREVA provided adequate responses to our assessment of these methodology documents. This resulted in a revised set of methodology documents which clarify the boundary between the generic and the site specific seismic analyses of the UK EPR™. For GDA, EDF and AREVA have considered a range of site ground types and demonstrated that the generic design is adequate for this envelope. The analysis of the raft foundation, and its interaction with the ground and with adjacent structures, is dependent on the specific site soil conditions. Therefore the submission documents have also detailed where generic assumptions need to be expanded or adjusted to suit the specific site.

ONR has concluded that the applied seismic methodologies EDF and AREVA propose to use for the UK EPR™ will ensure that the analysis is adequate. We have therefore judged EDF and AREVA's response to GI-UKEPR-CE-06 to be satisfactory.

Once the site characteristics are known, they will be compared with the generic cases presented in GDA to confirm that they are bounded by them. If there are any differences, these will be justified and ONR will monitor this during the site specific detailed design phase as part of our normal regulatory business.

Fault Studies, and Transient Analysis

The transient analysis and fault studies are the safety analyses of nuclear reactors on matters such as reactor core physics, thermal hydraulics, heat transfer and a wide range of other physical phenomena under steady state, transient and fault conditions. Fault analysis involves a detailed study of the reactor system, its characteristics and mode of operation, with the aim of identifying possible faults that might occur and potentially lead to the release of radioactive material. This is followed by a thorough examination of the conditions brought about by those faults. In particular, for those conditions that might affect the integrity of the nuclear fuel, the aim is to demonstrate the adequacy of the engineered protection systems in preventing a release of radioactive material.

From our Step 4 assessment, we identified five GDA Issues in this topic area related to:

- Heterogeneous boron dilution events (GI-UKEPR-FS-01).
- Demonstration of diversity for frequent faults (GI-UKEPR-FS-02).
- The spent fuel pool and faults associated with the cask loading pit (GI-UKEPR-FS-03).
- Steam generator single tube rupture faults and design changes to the protection for these faults (GI-UKEPR-FS-04).
- Design basis analysis of failures of essential support systems (GI-UKEPR-FS-05).

Closure of GI-UKEPR-FS-01

The aim of this Issue was to seek additional assurance that there was an appropriate safety justification for heterogeneous boron dilution faults in the UK EPR™.

Boron is a neutron poison that is added to the primary coolant water in PWRs as an additional means of reactivity control. The concentration of boron can be varied during operation to compensate for such things as fuel burn-up. If for some reason a fault occurs where the concentration of boron in the water in the reactor core is suddenly reduced, this could result in an increase in reactivity which would then need to be appropriately controlled. Such faults are referred to as homogeneous dilution faults (a general reduction in boron content of all the primary coolant) or heterogeneous dilution faults (where a ’slug’ of diluted coolant circulates in the primary circuit and enters the reactor causing a rapid rise in reactivity). This Issue relates to the justification for heterogeneous dilution faults, with most of the potential scenarios only being possible on a reactor that is shut-down for maintenance.

During ONR’s Step 4 assessment it became apparent that EDF and AREVA had not provided a sufficiently comprehensive safety case for heterogeneous boron dilution faults. In response to this GDA Issue EDF and AREVA have provided additional supporting documentation to improve the safety justification and they have proposed significant changes to the design of the UK EPR™ protection system, and changes in the plant operating procedures

ONR assessment of this new information focused on the design basis safety case for both external and inherent heterogeneous boron dilution faults for the UK EPR™, including the underpinning technical arguments. This included examination of the potential faults identified, technical arguments used, the robustness of the proposed interlock protection systems, and on the quality of the ALARP justification.

ONR also assessed the thermal hydraulic test rigs that were used to support the validation of the computer models used in the boron dilution safety cases. Furthermore, in addition to assessing the validation evidence provided by EDF and AREVA, independent confirmatory analysis was commissioned from a technical support contractor using alternative computer codes and analysts.

From this assessment ONR has concluded that EDF and AREVA have undertaken a large amount of additional analysis, have provided additional safety case information, and have considerably strengthened the design basis safety case for heterogeneous boron dilution faults.

This has resulted in a clearer safety case which in turn has helped to focus the comprehensive review of potential risk reduction improvements, and has resulted in a number of important design changes to the C&I systems on the UK EPR™. This has also led to some design changes in proposed operating procedures. These changes have been proactively identified by EDF and AREVA. They include new protection system interlocks or new procedural instructions to prevent the starting of pumps, or to shut valves, in some scenarios where boron dilution could potentially occur.

ONR has therefore concluded that EDF and AREVA have considerably strengthened the design basis safety case for heterogeneous boron dilution faults and that the C&I and procedural modifications identified will improve the safety of the design. We have therefore judged EDF and AREVA's response to GI-UKEPR-FS-01 to be satisfactory.

Closure of GI-UKEPR-FS-02

The aim of this Issue was to demonstrate that adequate functional diversity is provided for each safety function for all frequent faults.

To ensure defence-in-depth for nuclear power plants, it is important that there is more than one means of achieving key safety functions, such as cooling the reactor. This ensures that the safety function can be achieved with a high degree of reliability. To ensure that there is more than one means of achieving the safety function, even during hazard or fault conditions, the designers provide back-up systems (so called redundancy), that are physically separated and segregated (to prevent several systems being rendered unusable because of a single event such as a fire), and that have diversity between the systems. Having diversity means that systems providing the same safety function use different technologies (e.g. different types of pumps), thus reducing the likelihood that the back-up system would suffer from systematic faults similar to the main system. These features of safety system redundancy, segregation and diversity are fundamental to the design of modern nuclear power plants.

During ONR's Step 4 assessment, EDF and AREVA were requested to demonstrate that adequate functional diversity is provided for each safety function for all frequent design basis faults. While EDF and AREVA were able to provide the required demonstration for many faults, nine areas were identified where additional information or plant modifications were required. GDA Issue GI-UKEPR-FS-02 was raised to require EDF and AREVA to provide such demonstrations and to incorporate them within the safety case.

In response, EDF and AREVA produced new safety submissions for each of the nine areas to complete the demonstration of functional diversity for frequent faults. In some cases this has resulted in design changes to the UK EPR™ protection system being proactively identified by EDF and AREVA. The changes identified are:

- Addition of a hot leg high pressure trip signal on the Safety Actuation System (SAS) to improve the protection against loss of normal feedwater faults occurring together with a failure of the main reactor protection system.
- Addition of a Reactor Coolant Pump (RCP) low speed trip signal on the SAS to improve the protection against reduction in flow faults occurring together with a failure of the main reactor protection system.
- Addition of a high neutron flux trip signal and a high axial offset trip signal on the SAS to improve the protection against reactivity faults occurring together with a failure of the main reactor protection system.
- Implementation of a diverse protection function to mitigate homogeneous boron dilution faults in shutdown conditions occurring together with a failure of the main reactor protection system.
- Upgrade to Class 2 of the actuation signal used for manually starting the Ultimate Diesel Generators (UDG).
- Upgrade to Class 2 of the actuation signal used for manually opening the PDS.
- Upgrade to Class 2 of the actuation signal used for automatically closing the diverse full load Main Feedwater Isolation Valves.
- Upgrade to Class 2 of the Anticipated Trip without Scram (ATWS) signal used for the automatic actuation of the EBS.
- Upgrade to Class 2 of the automatic Chemical and Volume Control System (CVCS) charging pump switchover.
- Upgrade to Class 2 of the automatic diverse CVCS anti-dilution isolation.
- Upgrade to Class 2 of the manual start-up of the diverse 3rd FPCS train.
- Upgrade to Class 2 of the Spent Fuel Pool Cooling System (FPCS) purification pump trip.

ONR's assessment considered the adequacy of the analytical demonstration of functional diversity for frequent faults, together with the adequacy of the improved reactor protection that results from the proposed design changes (which are closely related to the assessment of the functional diversity of sensors and actuators associated with the reactor protection systems under GI-UKEPR-CI-06).

ONR has concluded that EDF and AREVA have undertaken a large amount of analysis within the Fault Studies assessment area during the close-out phase of GDA and improved the demonstration of functional diversity for frequent faults. The design changes to C&I systems that have been identified in response to this Issue are significant and will improve the safety of the UK EPR™. On this basis, ONR is satisfied that GDA Issue GI-UKEPR-FS-02 has been addressed.

Closure of GI-UKEPR-FS-03

The aim of this Issue was to seek additional assurance that there was an adequate safety case in support of the Spent Fuel Pool (SFP) and associated fuel handling areas and compartments.

Fuel that is taken out of the reactor core during refuelling is moved through an underwater fuel transfer tube into the SFP. Used fuel is stored for several years in the SFP before it is moved through other transfer compartments and loaded into a fuel transfer cask for transport out of the main nuclear island buildings to a separate storage facility.

The used fuel is highly radioactive and produces heat, and during the SFP transfer operations and storage period it needs to be covered with water to ensure both cooling and shielding to reduce radiation outside the SFP to low levels. Cooling systems are therefore provided and these need to be shown to be of appropriate reliability. Where there are penetrations in the SFP structure or associated compartments (for cooling pipe connections, purification lines, transfer tube connections, or personnel access doors etc.) these could act as potential leak paths in fault scenarios.

Also within the SFP is the cask loading pit, which is used to transfer the used fuel to a cask for transport out of the nuclear island buildings. This pit has a large penetration at its base to allow loading of fuel into the cask and the failure of this could also lead to loss of water from the SFP.

Safety cases supporting the operation of the cask loading pit, associated penetrations and other penetrations in SFP and fuel transfer route are required. These need to address the potential for failure of these penetrations, as a loss of cooling water could result in overheating of irradiated fuel, and loss of radiation shielding. ONR’s Step 4 assessment concluded that EDF and AREVA had not provided an adequate safety case for all the fuel handling transfer areas and compartments associated with the SFP and hence GI-UKEPR-FS-03 was raised. This safety case would also need to consider the failure of SFP structural penetrations and the consequences that could result.

This concern was identified before the accident at Fukushima occurred; nevertheless, this event only served to underline the importance of demonstrating, via a safety case, that there is appropriate protection in place for the fuel in storage in the SFP.

To address this GDA Issue, EDF and AREVA provided additional information and presented an analysis of credible failures of the SFP cooling systems, or penetrations in the walls or floors of the SFP structure, that could potentially result in loss of water and lead to uncovering of fuel assemblies and fuel overheating. The safety submissions also consider the potential for internal flooding within the nuclear island buildings as an additional consequence of penetration failure and significant leakage from the SFP, as well as the potential radiological consequences for operators involved in plant recovery and repair. In addition, the safety case identifies additional procedures that may be required to move a ‘stranded’ fuel assembly into a safe location prior to taking recovery action in the event of loss of SFP water.

As a result of the additional safety analysis that EDF and AREVA provided, they have proposed a number of significant design modifications to the SFP cooling systems, the SFP structure, and to associated compartments.

The proposed design modifications include:

- Upgrading of the safety classification for the two train SFP Cooling System to Class 1.
- Upgrading of the safety classification of the third train of SFP Cooling System to Class 2.
- Upgrading elements of the SFP water make-up system to Class 1 safety classification.
- Design-out of some SFP structural penetrations, including removal of personnel access doors in several of the fuel handling transfer compartments.
- Improvements to reduce the likelihood or consequences of failure for those penetrations that remain, through for example the provision of covers for drain line penetrations.

- Improvements to the performance of different nuclear island compartments to reduce consequences in the event of flooding, such as the provision of a secondary containment to envelope the Fuel Transfer Tube to prevent significant leakages in the event of its gross failure.
- Provision of a penetration cover and modification of the operating procedures for the transfer of fuel assemblies from the SFP to the Fuel Transfer Cask to ensure that the gate between the SFP and the Cask Loading Pit is closed whenever the Cask Loading penetration cover is open.

ONR assessment concluded that EDF and AREVA have, through the combination of the proposed design changes and the new analysis, significantly strengthened the safety case for the SFP and adjacent compartments. In addition to responding satisfactorily to the GDA Issue, we consider that the proposed modifications take into consideration the recommendation of the HM Chief Inspector's Report on Fukushima associated with the need to minimise penetrations in the design of SFPs on new reactors.

We have therefore judged EDF and AREVA's response to GI-UKEPR-FS-03 to be satisfactory.

Closure of GI-UKEPR-FS-04

The aim of this Issue was to review and represent the safety case for Steam Generator Tube Rupture (SGTR) faults.

During the GDA Step 4 EDF and AREVA identified that the make-up capacity of the CVCS is sufficient to compensate for a leakage of up to more than a guillotine break of a single SG tube such that there would not be an automatic reactor trip on low pressuriser level. The problem this creates is that the leak might not be obvious to the operator. EDF and AREVA proactively proposed to incorporate a design change to improve the reliability of the system that detects radioactivity leakage from SG tubes, and then requires operator intervention to manage and control the leak. In light of the design change, GDA Issue GI-UKEPR-FS-04 was raised to require the safety analyses for the detection and management of the SGTR faults to be revisited, and to provide a revised SGTR fault safety case that incorporates the proposed design changes and a human factors analysis to justify claimed operator actions.

In response to this GDA Issue EDF and AREVA provided additional information and supporting analysis on the modification, SGTR sensitivity studies, SGTR mitigation strategy, monitoring for coolant leaks, human factors analysis to support operator action claims, and an examination of international experience feedback.

The human factors analysis and review of operational experience have supported the claims made for operator actions to limit the consequences of SG tube leaks. However, several changes to the detailed procedures have been identified to make the operator responses more robust and to reduce the likely time taken to manually trip the reactor.

To minimise the potential for release of radioactive material from the affected SG to the environment during SGTR events, EDF and AREVA have also updated the relevant section of the safety submissions to provide additional analyses demonstrating that there is margin to overfill of the affected SG. This is important because overfill of the SG with water could lead to malfunction of the relief valves and increased leakage to the environment, as they are only designed for steam release.

ONR has concluded that EDF and AREVA have satisfactorily reviewed and considerably strengthened their safety case for SGTR faults and made significant improvements on the case for the detection and management of such faults. We have therefore judged EDF and AREVA's response to GI-UKEPR-FS-04 to be satisfactory.

This is a good example of a topic where our Assessment Findings will require further work which can only be done at the site specific detailed design and construction phase, such as detailing the position of the steam line activity sensor in order to maximise their sensitivity for detecting the activity released from SGTR faults and thus to minimise potential for a radioactive discharge to atmosphere. ONR will monitor these as part of our normal regulatory activities.

Closure of GI-UKEPR-FS-05

ONR's Step 4 assessment identified that EDF and AREVA had not provided a design basis safety case for loss of essential support systems. This is important because without these systems the main safety systems will not function correctly. The aim of this Issue was therefore to require EDF and AREVA to provide such a case which should either demonstrate the adequacy of the existing design or provide a basis for its modification.

In response to this GDA Issue, EDF and AREVA reviewed the safety cases for all the essential support systems on the UK EPR™, including the essential electrical systems, the Heating, Ventilation and Air Conditioning (HVAC) systems, the instrument air systems, the nitrogen supply systems, and the cooling chain systems comprising the Component Cooling Water System (CCWS) and the ESWS. For each system, EDF and AREVA have considered the implications of both their partial or complete failure. This work has resulted in the identification by EDF and AREVA of a significant number of design changes to the essential support systems.

The main design changes identified include:

- Improving diversity by upgrade of safety classification of the maintenance trains of the safeguard building ventilation system.
- Upgrade of a significant number of equipments to Safety Class 1, including the safeguard building chilled water system and the safeguard building ventilation system.
- Creation of an extra single storey to be added to safeguard buildings 1 and 4 to accommodate some of the above.
- Addition of a common header on the CCWS lines cooling the RCP thermal barriers.
- Creation of a new main control room air conditioning system consisting of several local recirculation units.
- Additional measures against the loss of the pumping station HVAC system.
- Implementation of a back-up electrical supply to the EBS trains and associated C&I and support systems.
- A reallocation of the electrical supplies of the CCWS common isolation valves on trains 1 and 4 to the 220V DC essential electrical system.
- A reallocation of the electrical supplies of the ESWS heat exchanger regulation valves on trains 1 and 4 to the 220V DC essential electrical system.

- A reallocation of the electrical supplies for one of the common isolation valves on each train of the steam generator blowdown system to the 220V DC essential electrical system.
- A reallocation of the electrical supplies of one of the two pumps on each train of theFPCS to the 400V AC essential electrical system.
- A reallocation of the electrical supplies of the safeguard building chilled water system on trains 1 and 4 to the 400V AC essential electrical system.

ONR assessment considered the analysis performed in support of the design basis safety case for loss of essential support system faults and whether this demonstrated that sufficient systems remain available to reach the safe shutdown state following either the partial or complete loss of each essential support system. In particular, we considered whether adequate functional diversity is provided within the design of the essential support systems so as to minimise the consequences of single failures and the likelihood of common mode failure on these important safety systems.

ONR has concluded that EDF and AREVA have undertaken a large amount of additional analysis that, together with the agreed design changes, have considerably strengthened the design basis safety case against loss of essential support system faults for the UK EPR™. We have therefore judged EDF and AREVA’s response to GI-UKEPR-FS-05 to be satisfactory.

The proposed modifications will require significant further development which in our judgement can best be done during the site specific detailed design and construction phase. ONR will monitor these as part of our normal regulatory activities.

Control and Instrumentation

Control systems are typically those that are used to operate the plant under normal conditions and reactor protection systems are those safety systems that are used to maintain control of the plant if it goes outside normal conditions. ONR's assessment in this topic area includes reviews of both hardware and software aspects of these systems.

In the UK this topic is commonly referred to as Control and Instrumentation or C&I; in other countries the order is reversed and I&C is used, but we will refer to the former throughout this report.

From our Step 4 assessment, we identified six GDA Issues in this topic area that relate to:

- Revision of the safety case to address the introduction of the Non-Computerised Safety System (NCSS), including the demonstration of its diversity from the computer-based safety systems (GI-UKEPR-CI-01).
- Finalisation of the scope of the Protection System (PS) independent confidence building activities (covering statistical testing, static analysis and compiler validation), and definition of production excellence and independent confidence building measures for other Systems Important to Safety (GI-UKEPR-CI-02).
- Enhancements to the safety case, in particular, to the presentation of the claims-arguments-evidence trail (i.e. covering key safety case claims and SAP conformance) (GI-UKEPR-CI-03).
- An appropriate justification for equipment that incorporates SMART devices (i.e. all the equipment that makes use of built-in computer chips and software) (GI-UKEPR-CI-04).
- Revision of the SAS / PAS safety case to address obsolescence of the SPPA-T2000 (Siemens S5 based) platform (GI-UKEPR-CI-05).
- Justification of the adequacy of the C&I architecture (ongoing actions related to closure of the Regulatory Issue) (GI-UKEPR-CI-06).

Closure of GI-UKEPR-CI-01

The aim of GI-UKEPR-CI-01 was to seek additional assurance on the NCSS through the production of a Basis of Safety Case (BSC).

ONR's Step 3 assessment identified that the C&I architecture was overly complex with reliance on two computer-based systems (originally developed by the same company) and a high degree of connectivity between systems. There were a number of concerns with this, one being that the reliability claims for the complex computer-based C&I systems that provide reactor protection were so high that they would prove very difficult to substantiate. As a result, ONR raised a Regulatory Issue on the concerns with the C&I architecture. In response EDF and AREVA provided further substantiation of the UK EPR™ C&I design and provided a number of key commitments, including identification of modifications to the UK EPR™ C&I architecture.

One of these modifications was to introduce the NCSS, which is an independent non-computerised system that provides a high integrity back-up in the event of total failure of the computer-based systems. Introduction of this system is important because it significantly improves the reliability that can be claimed for the overall reactor protection systems. The NCSS is based on robust and relatively simple electronics and the back-up functions it implements have been kept as simple as possible to avoid the use of complex functions. GDA Issue GI-UKEPR-CI-01 was therefore raised to seek additional assurance on the safety case for the NCSS.

EDF and AREVA submitted 24 documents in response to this GDA Issue, covering:

- Justification note for NCSS platform selection;
- NCSS BSC and schedule of supporting documentation;
- NCSS system specification, functional requirements and diversity criteria;
- Quality plans, module specifications and qualification programme; and
- Justification of typical response times and reliability allocation.

The most important document listed above is the BSC. A BSC is powerful specification for the final safety case that will be produced for the NCCS, which cannot be completed until the first system has been tested in the factory, when all the evidence that can be assembled demonstrates the system meets its requirements. The production of the operational safety case will be the responsibility of a future licensee and will be completed during the site specific phase before the delivery of the NCSS to the site.

As a result of the comments raised during our assessment, EDF and AREVA made further improvements to their documents.

ONR assessment of the BSC and supporting documents judged that:

- They describe the NCSS, outline the functional and performance requirements, list the standards to which the NCSS is to be designed, and describe how quality is managed.
- They provide design substantiation, including an arguments and evidence-based safety demonstration.
- They adequately describe arrangements for quality control of the NCSS system.
- They adequately describe the NCSS functional requirements, for each automatic and manual NCSS function, the task, potential fault sequences, initiating parameters for automatic functions, initiation criteria, and the action carried out.
- The information on NCSS function response times and reliability requirements provided was preliminary but is sufficient to demonstrate that the approach to determining reliability and response times is suitable.

We concluded that the BSC provided complete coverage of all relevant safety functions; it was capable of operating successfully following a major failure of computer systems, and could meet the key reliability targets. To support our conclusion we noted that the underlying technology for the NCSS already exists and is used by AREVA in other applications.

On the basis of this assessment we concluded that EDF and AREVA’s response to GDA Issue GI-UKEPR-CI-01 was acceptable.

Closure of GI-UKEPR-CI-02

The aim of GI-UKEPR-CI-O2 was to seek additional assurance on the adequacy of the Independent Confidence Building Measures (ICBMs) to support the safety case for the Class 1 Reactor protection system based on the Teleperm TXS technology.

In the UK it is good practice that all Class 1 complex C&I systems should be based on two major safety case legs as a basis for substantiation of safety case claims; these are:

- Production Excellence (PE); and
- Independent Confidence Building Measures.

This GDA Issue is about the latter, ICBM. ONR's Step 4 assessment judged that EDF and AREVA did not have a plan for ICBMs, and their safety case was largely based on production excellence alone. Therefore this GDA Issue was raised to require the programme of ICBMs to support the safety case for the main protection system, the Teleperm TXS PS, to be fully defined and agreed.

EDF and AREVA challenged the maturity of ICBM methods and therefore the focus of the GDA Issue was to perform pilot studies to prove their viability and to provide EDF and AREVA sound information on which to develop appropriate programmes to complete this work during the site specific detail design, construction and commissioning phase.

In response to this GDA Issue, EDF and AREVA submitted six documents covering the scope of the overall ICBMs, including statistical testing, static analysis, and computer validation.

One of the challenges of a reactor protection system is that it has to operate with very high reliability, and it is difficult to prove whether this has been achieved by the design. Statistical system testing helps resolve this problem by providing a rigorous basis for testing whether the reliability figure has been achieved. EDF and AREVA developed a pilot study to review both the efficacy and cost of undertaking a programme of statistical testing on the UK EPR. As a result they have agreed a programme that will involve around 50,000 tests in total, including statistical tests on one PS configuration, compiler validation, and static analysis.

Formal static analysis is based on converting the original requirements specification of the TXS computer code into a mathematical specification so that an analysis of the software can be undertaken. This helps overcome some of the limitations on testing complex systems where it is impossible to undertake an exhaustive test.

EDF and AREVA undertook a pilot study using some of the more complex and challenging areas of the original specification and this demonstrated the viability of the formal static analysis process. As a result, EDF and AREVA have agreed to implement a full programme of formal static analysis of the PS software.

Another area where errors can be introduced is in the compilation, linking and loading process, which is where the high level programming language for the PS is converted into the actual binary code that will be run on the PS. In response to this issue EDF and AREVA have validated the feasibility of developing a reverse engineering process known as the source to code comparator. This process takes the binary code on the PS and then translates that back into the original high level language using algorithms diverse to that of the forward compilation, linking and loading process. This diversity means that if there are any differences these will be reported as a potential threat to the validity of the object code.

EDF and AREVA have reviewed the feasibility and extent of undertaking validation of the various component elements of the PS and they have confirmed the extent to which it will be applied. ONR is content with their proposals as now the combination of production excellence and independent confidence building provides a very sound basis for justifying the safety of the UK EPR™ PS.

Statistical testing and other ICBM tests are areas of ongoing research and will need to be kept under review for developments that could enhance the efficacy of testing in the future. There will also be a need to review the extent of formal static analysis as the final detailed site specific designs are developed.

ONR assessment of the new information provided by EDF and AREVA concluded that the programme of ICBMs to support the safety case for the PS has now been adequately defined. We are content that the statistical testing will challenge the functionality of the PS in representative operational conditions and that the package of tests overall will support the claimed reliabilities of the components of the PS. Our judgement is that these additional ICBMs will not only significantly improve confidence in the safety case but they will also have through-life benefits for maintenance and for analysing the safety impact of future modifications and other major system enhancements.

The ICBMs described above, together with the production excellence leg, will ensure that the likelihood of an error remaining in any future TXS-based reactor protection system is very low and that the continued through-life support of these techniques will ensure that the likelihood of an error being introduced is similarly extremely low.

We have therefore judged EDF and AREVA's response to GI-UKEPR-CI-02 to be satisfactory.

Closure of GI-UKEPR-CI-03

The aim of GI-UKEPR-CI-03 was to seek a safety case which presented claims-arguments-evidence (CAE), including the significant design changes that have been agreed in GDA.

This GDA Issue is about developing a rigorous basis for showing how the claims made on complex C&I systems such as the reactor protection system are developed through a series of arguments and easy to follow links to where the evidence can be found of how those claims and arguments are achieved in the design. This is important because for complex systems there needs to be a formal process for managing the wide range of claims on the system, and then having a rigorous but easy to follow summary of the arguments, with easy to follow links to where the detailed evidence to support the claims and arguments can be found.

The CAE trail is a route map to help a future licensee understand the complex set of documents needed for such systems. In addition it is a compact summary of the key design and operational features of the facility's safety systems. A lack of completeness could result in undiscovered flaws in the installed system. The CAE trail is a powerful method in helping to ensure completeness and coverage of a safety system's role within the facility. It is also extremely helpful through the life of the facility in making judgements on the impact of any future design changes.

In response to this GDA Issue EDF and AREVA provided two documents covering the key CAE trail, and the SAPs' conformance demonstration for this trail. EDF and AREVA make six high level safety claims (e.g. "The C&I conforms to standards appropriate to its category and class.") that are broken down into 40 key claims (e.g. "All C&I systems important to safety are designed, manufactured and installed to standards appropriate to their class."). There is a table that contains entries for the 'High level claim', 'Key claim', 'Argument', 'Evidence' and 'Related claims'.

ONR examined the main CAE trail, and our assessment against the SAPs concentrated on a sample of areas that were identified in GDA Step 4 as not having demonstrated an acceptable level of SAP conformance. As a result of comments raised during ONR assessment, EDF and AREVA made further improvements to their documents.

Our assessment concluded that the revised documents demonstrate that the high level and key claims have been met. The arguments presented provide a narrative link between the claims and evidence indicating how the evidence supports the claim. For SAP conformance, our assessment concluded that the previous shortfalls in arguments and evidence have now been addressed.

Undertaking the work has helped to support development of early design changes and has fostered a greater understanding of the considerable strengths of the final UK EPR™ C&I systems. We therefore concluded that the response to GDA Issue GI-UKEPR-CI-03 is satisfactory.

Closure of GI-UKEPR-CI-04

The aim of this Issue was to seek additional assurance on a methodology for providing a justification for equipment that incorporates SMART devices. A SMART device is a component, often embedded in much larger electro-mechanical systems, that employs a high degree of complexity (large software modules and / or complex programmable devices). This is important because SMART devices are used in a wide range of safety and safety support systems. Therefore any failure in these devices could have a serious impact on the safety of the facility. Hence, establishing the correctness of design, manufacturing and testing processes is a critical activity.

ONR has been working with the UK's nuclear industry over the past 15 years to develop a process based on the twin concepts of production excellence and independent confidence building (see GI-UKEPR-CI-02). This has included research and development work on SMART devices. This research has helped the UK licensees develop an effective process for providing such safety justifications and a number have been formally agreed by ONR on currently operating reactors.

The process is graded and proportionate to the safety class of the SMART device. SMART devices with an important safety role can be found in a wide range of UK EPR™ systems such as electrical power systems, HVAC, and many mechanical engineering-based cooling systems, many of which are outside of what are considered the traditional C&I safety systems. The devices include plant sensors (pressure, temperature, flow etc.), actuators (complex valves) and embedded control devices.

Reactor vendors generally do not design, develop or manufacture SMART devices but they rely on industrial suppliers to provide them. When these devices were simple it was relatively straightforward for the reactor vendors to develop safety justifications for them. However, the trend over the past two decades has been to make such devices much more complex with their functionality often dependent on complex software, programmable hardware or often a combination of both. The reactor vendor's difficulty in producing a safety justification can be compounded by a reluctance of the producers of SMART devices to disclose design details for commercial reasons.

EDF and AREVA initially viewed that the safety justification of SMART devices was too detailed for GDA and wanted the subject to be out of scope. Whilst ONR agreed that many of the details of SMART devices were appropriate for the site specific detailed design phase, we considered it important to assess the methodology and its validation during GDA as our experience with justifying SMART devices shows that it is a long and complex process and leaving our agreement until the site specific phase would increase the risk of late and expensive delays. We therefore raised GI-UKEPR-CI-04.

EDF and AREVA submitted 24 documents in response to this GDA Issue, covering:

- Lifecycle approach to the use of SMART devices;
- Evaluation of the suitability of the analysis tool to qualify SMART devices;
- Description of the approach to justify SMART devices for nuclear safety applications;
- Identification of trial application scope, strategy and programme for SMART devices during GDA;
- Trial qualification reports for a Class 2 SMART device including emphasis assessment report; and
- Progress reports for the trial qualification of a Class 1 SMART device.

ONR assessment found that EDF and AREVA have developed a methodology based on the combination of production excellence and independent confidence building. The methodology comprehensively covers a wide range of design (hardware and software) and operational environment (electromagnetic, seismic etc.) issues. EDF and AREVA have justified this by applying it to an example of two typical devices: a Class 1 temperature transmitter used on the Reactor Protection System; and a Class 2 intelligent paperless chart recorder used in the Safety Information and Control System (SICS).

EDF and AREVA validated many aspects of its methodology but some aspects of independent confidence building such as statistical testing can only be completed at the site specific detailed design and construction phase. We will follow these up through our normal regulatory activities.

As a result of the work done in response to this GDA Issue, EDF and AREVA now have a good understanding of the work that needs to be done to justify SMART devices for the UK EPR™ and can develop, together with a site licensee, a comprehensive plan to produce the necessary safety justifications during the site specific detailed design and construction phase. ONR concluded that that the qualification of SMART devices at all safety classes has been adequately defined and we therefore consider that GDA Issue GI-UKEPR-CI-04 has been addressed.

Closure of GI-UKEPR-CI-05

The aim of GI-UKEPR-CI-05 was to seek additional information on the revision of the design and safety case to address obsolescence of the SPPA-T2000 (Siemens S5-based) platform. The SPPA T2000 is a very important platform and is used in the SAS and Process Automation System (PAS) which are responsible for the majority of controls on the UK EPR™.

This issue arose from ONR’s Step 4 assessment where we identified that the GDA submissions were based on an obsolete version (S5) of the SPPA T2000 C&I platform, whereas any future UK EPR™ built in the UK would utilise an updated (S7) version of the platform. We therefore asked EDF and AREVA to examine and consider the safety implications of making this change and provide an appropriate basis of safety case.

EDF and AREVA submitted 14 documents in response to this GDA Issue covering:

- Definition and impact assessment of the design change;
- The BSC; and
- Supporting documents to the BSC.

ONR examined the substantiation of the S5 to S7 version change. As a result of comments raised EDF and AREVA made further improvements to their documents to better:

- Define the safety principles and standards (i.e. company, national and international) that are to be adopted for incorporating in the replacement platform;
- Justify how these safety principles and standards will be complied with at each step of the development and deployment of the replacement systems;
- Justify how functional and performance requirements will be satisfied;
- Demonstrate conformance with relevant SAPs;
- Provide a full analysis of the impact of the replacement platform on the overall C&I design; and
- Provide precise details of the change and demonstrate that the systems (covering all new components, tools and methods etc.) are fit for purpose.

ONR assessment found that the BSC adequately reported the changes made from the S5 to S7 version of the platform and identified the evidence against each of the six points above. A sample of the supporting documents provided was reviewed to check that they adequately supported the claims made in the BSC in the following areas: software development, hardware reliability and time performance.

ONR has accepted the claims in EDF and AREVA's BSC that the software development processes are essentially unchanged and that the change from the S5 to S7 version does not impact on safety.

EDF and AREVA provided documents on the hardware reliability and dependability studies for both the S5 and S7 versions of the platform. ONR review confirmed the method used was the same for both versions and that it complies with current practice for hardware reliability substantiation. Sufficient evidence is available to give confidence the S7 platform version will meet the identified reliability targets.

The response time performance impact of the change from the S5 to S7 versions is shown to be acceptable by EDF and AREVA and we agree with this conclusion.

On the basis of this assessment, we therefore concluded that GDA Issue GI-UKEPR-CI-05 has been addressed and the use of the S7 platform has been justified.

Closure of GI-UKEPR-CI-06

The aim of GI-UKEPR-CI-06 was to seek additional assurance on the justification of the adequacy of the C&I architecture (this relates to commitments given by EDF and AREVA at the closure of Regulatory Issue RI-UKEPR-002).

ONR's Step 3 assessment identified that the C&I architecture was overly complex with reliance on two computer-based systems (originally developed by the same company) and a high degree of connectivity between systems. There were a number of concerns with this, one being that the reliability claims for C&I systems that provide reactor protection were so high that they would prove very difficult to substantiate. As a result, ONR raised a Regulatory Issue on the concerns with the C&I architecture. In response EDF and AREVA provided further substantiation of the UK EPR™ C&I design and provided a number of key commitments, including identification of a number of modifications to the C&I architecture. GDA Issue GI-UKEPR-CI-06 was therefore raised to ensure further developments of the modifications and related matters such as demonstration of diversity between the protection systems, development of a programme of Production Excellence and Independent Confidence Building Measures, and provision of Class 1 control and display facilities etc.

In response to this GDA Issue EDF and AREVA undertook a significant amount of new work and submitted a large number of documents to ONR. These covered the following areas involving the NCSS, SAS and PS:

- Justification of diversity between the NCSS / PS, PS / SAS and SAS / NCSS;
- Justification of the reliability figures used for each of the protection systems individually and in combination;
- Production excellence and independent confidence building measures for computer-based systems important to safety;
- Justification that the hardwired links to the PS, including from systems of a lower safety classification, cannot affect its operation;
- Independence between key C&I systems;
- The BSC for the Class 1 control and display system in the main control room and remote shutdown station and justification in terms of the functional coverage of the system;
- A justification of the transfer of control from the Process Information and Control System (PICS) to the backup SICS;
- Evidence that response times are adequate for those functions important to safety which use elements of Class 3 systems;
- Detailed substantiation for the probabilistic claims for any C&I components used by more than one line of protection (e.g. sensors, SMART devices etc.), and demonstration of absence of potential Common Cause Failure of diverse systems.

ONR examined these documents and, as a result of comments raised during our assessment, EDF and AREVA made further improvements to their documents.

ONR assessment judged that:

- The methodology to justify diversity between the safety important systems (NCSS, SAS and PS) are based on criteria covering design, equipment, human factors, signal, software and separation all linked to international standards.
- Sufficient progress has been made with the platform and system diversity analyses as it not only describes the methodology but has included some detailed examples consistent with the level of detail needed for the site specific safety case.
- The information provided is sufficient to demonstrate that the approach to determining reliability is suitable.
- Information submitted on the claims on independence between key safety systems is adequate and is based on the application of internationally recognised methodologies using examples of data from the reference design that are at a similar level of detail to that which will be produced in the site specific design.

- The justification demonstrated that the hardwired links to the PS, including from systems of a lower safety classification, cannot affect the operation of the PS. The justification was based on the fact that a number of the hardwired links will be removed and in two examples where this is not possible (i.e. Class 2 test equipment for the periodic testing of the PS) other compensating measures will be introduced to ensure that the Class 2 links cannot adversely impact the safe operation of the PS.
- The provisions for the Class 1 control and display facilities, including functional coverage, have been adequately defined and include both the SICS and Protection System Operating Terminals (PSOT) in the main control room and two PSOT terminals in the remote shutdown station.
- The design analysis of the Class 3 response times demonstrates that these are adequate.
- The detailed substantiation for the probabilistic claims for any C&I components used by more than one line of protection is adequate.

On the basis of this assessment, we conclude that EDF and AREVA's response to GDA Issue GI-UKEPR-CI-06 is satisfactory. This work establishes with a high degree of confidence that there will be no significant design changes required to the C&I architecture during the site specific phase.

Electrical Engineering

Many of the important systems on a nuclear power station require electrical power for their operation (pumps, valves etc.). The safety assessment in this topic area typically, therefore, covers the engineering of the essential electrical power supply systems, examines these under a wide range of transient and fault conditions, and considers their likely reliability, and the performance of protection devices.

From our Step 4 assessment, we identified one GDA Issue in this topic area related to using a structure of claims, arguments and evidence to provide substantiation that the design of the electrical distribution system fully meets its safety role (GI-UKEPR-EE-01).

Closure of GI-UKEPR-EE-01

The summary of ONR's Electrical Engineering close-out assessment of GDA Issue GI-UKEPR-EE-01 is given below. ONR's Step 4 assessment concluded that we had no significant concerns regarding the electrical system integrity or basic architecture, but we were not satisfied that sufficient evidence had been provided to support EDF and AREVA's claims in the safety case. The aim of GDA Issue GI-UKEPR-EE-01 was therefore to seek additional assurance to support EDF and AREVA's claims for the performance and integrity of the electrical systems by provision of a structured safety case that clearly identifies and substantiates the claims, arguments and evidence.

In response to this Issue EDF and AREVA provided a Claims, Arguments and Evidence document which presents a hierarchical structure as follows:

- Top Level Claim: The electrical system supports the safety functions of the UK EPR™;
- High Level Claims: Claims articulated in a way that provides a structure below the Top Level Claim;
- Key Claims: Claims that directly support the High Level Claims. These claims are topic based and relate directly relate to the UK EPR™ safety case;
- Sub-Claims: Claims needed to support the Key Claims or to support the arguments behind the Key Claims or other Sub Claims. References are made to relevant SAPs and the underpinning evidence is given.

In addition, relevant sections of the top-level safety case, the UK EPR™ pre-construction safety report (PCSR), were modified for consistency with the Claims, Arguments and Evidence document.

ONR assessment of this new information focused on:

- The adequacy of the presentation of the safety case;
- Conformance with the SAPs;
- The relationship between the safety case claims for the electrical system and the overall safety case claims in other topic areas of the UK EPR™ plant.

The safety case work covered by this Issue (also linked to GI-UKEPR-CC-01 on classification) revealed that the classification of the earth system needed to be increased to Class 1 and the Ultimate Diesel Generators (sometimes also referred to as the Station Blackout (SBO) diesel generators) were increased from Class 3 to Class 2. Additionally, in conjunction with an issue raised by the Finnish Nuclear Safety Authority (STUK), EDF and AREVA have agreed to the principle that the power rating of the Emergency Diesel Generators (EDGs) will be sufficient to withstand extreme events including the loss of off-site power followed by control system failure. In this event at least two of the four EDGs would remain operational even with the sudden demand of all loads being simultaneously connected. A preliminary but in-depth load analysis of this severe fault sequence (LOOP plus a very major failure of all control systems) has shown that the EDG rating will need to increase from the reference design level. This analysis will have to be repeated once more detailed load information is known for the UK EPR™ specific loads during the site specific design phase and we will monitor as part of our normal regulatory activity.

ONR has concluded that the evidence presented now supports the safety claims and arguments and substantiates the generic design and safety case for the electrical distribution system. We have therefore concluded that the response to GDA Issue GI-UKEPR-EE-01 is satisfactory.

Reactor Chemistry

The safety assessment of the chemistry includes the effects of coolant chemistry on pressure boundary integrity, fuel and core component integrity, fuel storage in cooling pools, radioactive waste (accumulation, treatment and storage), and radiological doses to workers.

From our Step 4 assessment, we identified two GDA Issues in this topic area related to:

- Evidence supporting operation of the combustible gas control system (GI-UKEPR-RC-01).
- Demonstration that radiation levels have been reduced ALARP (GI-UKEPR-RC-02).

Closure of GI-UKEPR-RC-01

The aim of this Issue was to seek additional assurance on the performance of the Passive Auto-catalytic Recombiners (PARs), which are an integral part of the UK EPR™ Combustible Gas Control Systems (CGCS).

Although this GDA Issue was identified before the events that took place at Fukushima on 11 March 2011, the explosions that occurred there demonstrate and underline the importance of combustible gas control in severe accident situations. The combustible gases, chiefly hydrogen, are generated as a result of reactions between very hot or molten fuel and the reactor cooling water.

ONR's Step 4 Reactor Chemistry assessment concluded that the UK EPR™ safety case related to combustible gas control required further work in three discrete areas related to the performance of the CGCS:

- Operation of the CGCS with reduced PAR performance.
- Analysis under bounding accident conditions.
- The production of volatile iodine in the containment as a result of operation of the PARs during a severe accident.

To address this GDA Issue EDF and AREVA provided additional information in a series of analysis reports, responses to technical queries and through technical meetings. The main deliverables provided in response to this GDA Issue included:

- A sensitivity study which determines the effects of a reduced PAR performance on the hydrogen distribution within the containment.
- A suite of reports which provide the computational validation procedure of the EPR™ combustible gas control concept, including under bounding accident conditions. These reports consider topics such as the distribution of combustible gases in the containment, its removal by PARs, the potential for ignition and rapid burning of hydrogen, and its consequences with regard to the dynamic pressure on internal walls and the inner containment shell. In order to demonstrate the performance of the CGCS under bounding conditions, EDF and AREVA provided their analysis for the Flamanville 3 reference plant. EDF and AREVA took this approach as they wish to provide site specific, rather than generic analysis for any EPR™ to be built in the UK. The Flamanville 3 analysis presented has been used to build confidence in the generic approach and to demonstrate that the claims, arguments and evidence presented in the generic UK EPR™ safety case are sound. EDF and

AREVA logically consider the main risks and conclude they are successfully avoided or are within the capabilities of the design.

- A sensitivity study which examines the potential increase in the environmental releases caused by the interaction of the recombiners with iodine, creating additional volatile iodine which could escape into the environment, in the very unlikely event of an accident which involves core melting.

ONR's assessment of the information provided by EDF and AREVA concluded that:

- The analyses carried out have provided highly useful additional understanding of the behaviour of the CGCS.
- The results of the sensitivity study for reduced PAR performance indicate that they are able to undergo a significant reduction in their overall effectiveness and still maintain the design intentions of the system and this situation does not lead to conditions which could threaten the containment integrity. The results show that the system as a whole provides significant margin in operational capability with respect to the most demanding accident scenarios, which helps cater for uncertainties in the modelling.
- The analysis of the performance of the CGCS under bounding conditions is thorough and provides confidence that the results are robust, the methodology adopted is appropriate and the resulting data has been used appropriately. The results show the importance of the PAR system in decreasing the combustible gas concentration in the medium and long term, and that while the PAR system is dimensioned to account for the "representative" cases, it remains adequate to respond to more penalising cases.
- EDF and AREVA have demonstrated that the CGCS has the capability to meet the demands that are likely to be placed upon it. As EDF and AREVA have presented information from the Flamanville 3 reference design, the safety case will have to be revisited and further developed for UK EPR™ at the site specific phase.
- The effect of the recombiners on volatile iodine production in UK EPR™ were analysed by EDF and AREVA. This used a specific analysis code which incorporates a detailed treatment of the iodine chemistry, unlike the PCSR which uses assumptions claimed to be bounding. While the detailed chemistry considered in the new calculations changes the predicted form of the iodine in the containment compared to the original safety case assumptions, it does demonstrate that the total amounts predicted to be released to the environment are lower, even assuming a pessimistic conversion rate for the iodine. While there are some inherent uncertainties in this approach, ONR is satisfied that sufficient margin has been demonstrated and the analysis in the safety case has been demonstrated to be bounding for the effect of recombiners. The claims made in the generic PCSR therefore remain valid.

On the basis of this assessment ONR has concluded that the safety case for supporting operation of the combustible gas mitigation system for the UK EPR™ is adequate and in particular provides assurance on the performance of the PARs. ONR is therefore satisfied that GDA Issue GI-UKEPR-RC-01 has been addressed.

Closure of GI-UKEPR-RC-02

The aim of this Issue was to seek additional assurance on the control and minimisation of radioactivity in the reactor systems of the UK EPR™.

ONR's Step 4 Reactor Chemistry assessment concluded that the UK EPR™ safety case related to control and minimisation of radioactivity in the reactor systems required further work to support the claim that radioactivity could be appropriately controlled. This was mainly related to the fact that EDF and AREVA rely on their experience with current plants, whereas the design of UK EPR™ has changed and evolved from these plants, which meant that more comprehensive consideration of the impact of these changes on the control and minimisation of radioactivity was needed. This is important to controlling doses to workers and discharges to the environment.

To address this Issue EDF and AREVA provided additional information, through a series of reports and through technical meetings. This information included:

- A report which provides evidence about how the predicted radioactive content (called the source term) has been derived for the reactor coolant system (RCS), based on both existing plant operating experience and calculations. This also then justifies the selection of radioactive monitoring and measurement equipment for the UK EPR™.
- A report which analyses the principles and main criteria for the management of radioactivity in the auxiliary systems during normal power operation and transients. The role that the different auxiliary systems play in radioactivity management is described, along with the associated operating conditions, with the aim of confirming that the plant limits and conditions are consistent with the appropriate management of radioactivity.
- A summary report which contains the claims-argument-evidence trail for control and minimisation of radioactivity and highlights the key supporting information and conclusions.

ONR's work concluded that:

- EDF and AREVA have incorporated improvements in material selection, manufacturing techniques, and operating chemistry control of the primary circuit. The impact of these measures is to reduce the sources of radioactivity in UK EPR™, minimising both the source term in the primary coolant and its transfer around the plant.
- In addition, there are improvements, compared to current PWRs, to the coolant treatment, storage and monitoring systems of UK EPR™. EDF and AREVA have demonstrated that the UK EPR™ has appropriate design provisions for controlling and minimising radioactivity levels. As a result, UK EPR™ should be capable of controlling radioactivity at least as well as, if not better than, other comparable plants.
- From the information presented, it appears that the activity levels in the primary systems of UK EPR™ are likely to be similar to the newest French PWRs (the N4 plants). At the moment this is a theoretical result only, as EDF and AREVA have used bounding estimates for their radioactive source estimations. While these activity levels would still be acceptable, ONR expects that more detailed calculations should reduce the predicted activity levels and clarify whether any additional controls are necessary to further minimise radioactivity. This is a topic on which we will seek further development during the site specific phase when feedback from the first operational EPR™ becomes available.

ONR has concluded that EDF and AREVA have provided sufficient evidence to demonstrate that radioactivity has been minimised and will be appropriately controlled in the UK EPR™. ONR is therefore satisfied that GDA Issue GI-UKEPR-RC-02 has been addressed.

Radiological Protection

This topic includes the assessment of measures intended to restrict exposure of workers and the public to radiation so far as is reasonably practicable, including the adequacy of engineering control measures (such as radiation shielding) to control radioactive contamination, and criticality safety.

From our Step 4 assessment, we identified one GDA Issue, GI-UKEPR-RP-01, in this topic area related to radiological zoning and bulk shielding.

Closure of GI-UKEPR-RP-01

This GDA Issue arose because ONR considers that suitable and sufficient work should be completed within GDA to demonstrate that the bulk shielding provided by nuclear island construction concrete is adequate. The radiological zoning for the restriction of exposure to ionising radiations of workers is fundamental to the basic design of the UK EPR™. In addition, bulk shielding is inextricably linked with civil engineering aspects of the UK EPR™, and bulk shielding assessments need to be completed before nuclear island construction commences.

The radiological zoning classification scheme was not referenced in the GDA submission for Step 4 of the UK EPR™ design. The objective of the GDA Issue was therefore for EDF and AREVA to provide a radiological zoning classification scheme to demonstrate that there was adequate shielding for all areas of the facility.

In response to the GDA Issue, EDF and AREVA provided an overview document which summarised the predicted dose rates and radiological classifications within all rooms and for all modes of plant operation (for example, power operation, outages, refuelling). This summarised the results of shielding calculations to show that the predicted dose rates within each area met the radiological classification. The document was referenced in the updated consolidated PCSR.

ONR's close-out assessment concluded that the shielding for the radiological zoning of the facility has been designed to ensure that exposures to workers and members of the public to ionising radiation have been restricted so far as is reasonably practicable during all modes of plant operation. From the evidence provided, EDF and AREVA have designed the plant to ensure that the general bulk shielding and other shielding provisions for the dose rate profile throughout the UK EPR™ are acceptable and consistent with UK design guidance and practices. The radiological classification of rooms in the nuclear island of the UK EPR™ is consistent with relevant good practice and comparable to the best operating NPPs abroad.

ONR is satisfied that the additional information submitted to close-out the GDA Issue supports the claims, arguments and evidence already laid down within the PCSR and supporting documentation during Step 4 of the GDA process and presents an adequate safety case for the generic UK EPR™.

ONR is therefore satisfied that GDA Issue GI-UKEPR-RP-01 has been addressed.

Structural Integrity

This topic includes the safety assessment of nuclear safety-related metal pressure vessels, piping, other components and their supports, including materials selection, design, fabrication, in-manufacture examination and testing, the analysis of structural integrity under normal load and faulted conditions (including fracture mechanics-based analyses), and lifetime ageing of materials (including neutron irradiation embrittlement).

From our Step 4 assessment, we identified two GDA Issues in this topic area related to:

- The safety case for avoidance of fracture through demonstration of defect tolerance and the absence of significant defects in HICs (GI-UKEPR-SI-01).
- Justification of the RPV surveillance scheme (GI-UKEPR-SI-02).

Closure of GI-UKEPR-SI-01

The aim of this GDA Issue was to seek assurance on the safety case for avoidance of fracture through demonstration of defect tolerance and the absence of significant defects in HICs.

In the UK there is a recognition that there are a few critical components, for example the reactor pressure vessel, for which it is necessary to argue that gross failure can be discounted throughout the life of the reactor. To provide a successful argument, it is necessary to show that the likelihood of gross failure is extremely low. In these special cases the normal pressure vessel design code requirements are not considered to provide a sufficient level of confidence. EDF and AREVA have accepted the need to make this rigorous safety demonstration in line with UK practice and they have designated these components as HICs.

The evidence needed to show that the likelihood of failure is sufficiently low includes a demonstration that component fracture will be avoided. This demonstration brings together analyses (called fracture mechanics analyses), consideration of the material toughness and a resultant demonstration that defects which could be significant can successfully be detected by the manufacturing inspections.

During Step 4:

- We concluded that the fracture mechanics methodology proposed by EDF and AREVA was satisfactory but as it is different from that normally used in the UK nuclear industry so it was necessary to give this further consideration.
- It was not possible to complete the full assessment of all the fracture mechanics calculations as some arrived later than originally planned.
- ONR also considered that the evidence supporting some of the proposed inspections was insufficient to show that inspection qualification was likely to be achievable.

GDA Issue GI-UKEPR-SI-01 was therefore raised to define the additional evidence, relating to fracture analysis and non-destructive testing. In response, EDF and AREVA provided additional information.

ONR has completed the assessment of the fracture mechanics calculations provided by EDF and AREVA and further reviewed the fracture assessment methodology. This confirmed the position reached in Step 4 that the fracture assessment methodology is acceptable for the purposes of GDA but it will need further justification if it is to be used in the site specific phase. The limiting defect sizes from the fracture mechanics calculations are also acceptable for GDA but will also have to be revisited with the site specific input data.

ONR also assessed additional evidence provided by EDF and AREVA in support of their capability to inspect the HICs both during manufacture and through life. Where necessary, EDF and AREVA have reinforced the proposed inspection techniques to provide greater confidence that all defects of concern can reliably be detected. In the particular case of the primary circuit main coolant line welds, ONR believed that inspection could be further improved and as a result EDF and AREVA have introduced significant design changes that will improve the ability to achieve a high quality ultrasonic inspection.

In addition, late in the close-out process, it became evident that the Main Steam Isolation Valves (MSIV) would also need a HIC claim. EDF and AREVA provided arguments that such a claim could be made, and although the detailed supporting evidence was not available, ONR was satisfied that it would be possible to make a HIC claim for the MSIV pressure boundary, and that the detailed evidence could be left to be developed during the site specific detailed design phase.

On the basis of the additional evidence provided by EDF and AREVA, including the important design changes to the primary circuit main coolant line pipework, ONR are now satisfied that GDA Issue GI-UKEPR-SI-01 has been addressed.

Closure of GI-UKEPR-SI-02

The aim of this Issue was to seek additional assurance on the surveillance of the material properties of the reactor pressure vessel as it is subjected to through-life irradiation.

The UK EPR™ reactor pressure vessel (RPV) will be subjected to neutron irradiation in-service which has the potential to degrade the toughness of the material in the most highly irradiated regions. This degradation is monitored using samples of the material, which are placed inside the reactor vessel in a region of enhanced irradiation, and are withdrawn and tested at intervals during the operating life.

The UK EPR™ design includes a heavy steel neutron reflector which surrounds the core and reduces the neutron dose on the RPV wall. Another effect of the heavy reflector is to change the neutron energy spectrum so that, at the location of the surveillance samples, the spectrum is not the same as at the RPV wall. So unlike a standard pressurised water reactor (PWR) the proportion of damaging lower energy neutrons is substantially increased in the EPR™, which will affect the way that damage builds up in the surveillance specimens.

Because of the difference in neutron spectra experienced by the RPV and the surveillance samples, ONR was not convinced that the surveillance programme was satisfactory. Evidence provided by EDF and AREVA seemed overly reliant on an experimental programme involving only a very small number of test results.

GDA Issue GI-UKEPR-SI-02 therefore required a demonstration that the principles of the surveillance scheme adequately take account of the differences in neutron spectra experienced by the RPV and the surveillance scheme samples.

In response to the GDA Issue, EDF and AREVA undertook a new analysis and proposed a revised approach which comprises:

- Dose-damage estimates that take account of the differences in neutron spectrum between the UK EPR™ surveillance specimen location and the RPV wall;
- Analyses of the advantages and disadvantages of alternative analysis techniques; and
- An example of a flexible specimen withdrawal scheme using alternative dose parameter criteria.

Having assessed this revised approach, ONR judged that EDF and AREVA have now developed an adequate definition of the surveillance programme and withdrawal scheme which will provide an accurate prediction of the irradiation damage to the RPV. ONR has concluded that the safety case for the surveillance of the material properties of the reactor pressure vessel for the UK EPR™ is now adequate.

ONR is therefore now satisfied that GDA Issue GI-UKEPR-SI-02 has been addressed.

Human Factors

Human Factors (HF) is the study of human physical and psychological capabilities and limitations, and the application of that knowledge to the design of work systems. Within the nuclear context, HF is concerned with the human contribution to nuclear safety during facility design, construction, commissioning, operation, maintenance, and decommissioning. ONR requires that a systematic analytical approach be applied to understanding the factors that affect human performance and reliability.

From our Step 4 assessment, we identified one GDA Issue in this topic area related to:

- Addressing both the incompleteness of the identification of human-based safety claims and provision of proportionate supporting evidence to support those claims (GI-UKEPR-HF-01).

Closure of GI-UKEPR-HF-01

The aim of this Issue was to seek a consolidated HF safety case for the UK EPR™ that includes adequate substantiation of Human Based Safety Claims (HBSCs). In particular, ONR required EDF and AREVA to complete the identification and substantiation of human failure events, describe arguments to justify key elements of the UK EPR™ design relevant to HF claims, and provide evidence on how the design of the UK EPR™ prevents and mitigates the potential for operator violations.

In response to this Issue EDF and AREVA have undertaken a considerable amount of work to complete the identification and substantiation of risk significant human failure events. They have provided additional qualitative arguments to support the case and supported this with evidence. These have been consolidated into a revised HF safety case.

ONR has concluded that the identification and substantiation of risk significant human failure events has been completed for the generic design. ONR considers that the substantiations provided by EDF and AREVA are based on reasonable assumptions about the detailed design, maintenance and operations, including the supporting procedures, although further work will be required to confirm this during the site specific phase.

Substantiation of all risk significant post-fault human failure events has been provided. However ONR considers that only a few of these have been fully substantiated to the level of detail consistent with the site specific phase; the majority have been partially substantiated at a level consistent with the generic design. These partial substantiations will be addressed during the site specific phase.

EDF and AREVA also provided additional arguments and evidence on the prevention of misdiagnosis and design-related violations.

ONR considers that the submissions provided along with the material presented for GDA Step 4 now comprise a complete HF safety case for the generic design that provides a clear presentation of all the significant claims, arguments and evidence. This integration of HF into the generic design has improved the safety case. ONR has therefore concluded that EDF and AREVA have addressed GDA Issue GI-UKEPR-HF-01.

Management of Safety and Quality Assurance

The topic of Management of Safety and Quality Assurance (MSQA) addresses the EDF and AREVA Quality Assurance (QA) and Management of Safety (MOS) organisational and procedural arrangements to deliver the UK EPR™ reactor GDA submissions. Where possible, ONR and the Environment Agency have worked together in our dealings with EDF and AREVA in this topic area.

From our Step 4 assessment, we identified one GDA Issue in this topic area associated with updating the GDA submission to include documentation impacted by design changes agreed for inclusion in GDA, including those design changes arising from other GDA Issues. This is reported under the cross-cutting topic area.

Cross-cutting Topics

During the planned GDA assessment, certain safety and environmental aspects cut across a number of different technical topic areas and so these have been managed in a cross-topic manner. Topics that were treated in this manner included:

- Management of design changes.
- Management of the consolidated GDA safety, security and environment submissions.
- Safety Function (SF) categorisation and Systems, Structures and Components (SSC) safety classification.
- Operating limits and conditions and Examination, Maintenance, Inspection and Testing (EMIT).
- Lessons learnt from Fukushima.

From our Step 4 assessment, we identified three GDA Issues in this topic area related to:

- The methodology developed and applied for categorising SF and classifying SSCs (GI-UKEPR-CC-01).
- Consolidation, control and maintenance of GDA submission documentation to reflect the additional work completed during the close-out phase (GI-UKEPR-CC-02). This was a joint GDA Issue with the Environment Agency, since the same requirements apply to the environmental documentation.
- The lessons learnt from the Fukushima accident (GI-UKEPR-CC-03). This was a joint GDA Issue with the Environment Agency as there was a potential for environmental aspects to be impacted.

Closure of GI-UKEPR-CC-01

The aim of this Issue was to seek additional assurance that the methodology developed and applied for categorising SFs and classifying SSCs is in line with UK and international standards and Relevant Good Practice (RGP).

It is normal practice on nuclear power plant to identify for each SF an appropriate SSC. Categorisation of SFs and safety classification of SSCs is based on their safety significance. This is important to ensure that the SSCs are designed, manufactured, installed and then subsequently commissioned, operated and maintained to a level of quality commensurate with their classification.

During ONR’s Step 4 assessment we concluded that EDF and AREVA had made significant progress in developing their methodologies and criteria for SF categorisation and the classification of SSCs for the UK EPR™ reactor to meet UK and international standards and relevant good practice. However, additional work was required within GDA to further develop and apply these methodologies and criteria throughout the UK EPR™ reactor design. This requirement was captured as GDA Issue GI-UKEPR-CC-01.

In response to the GDA Issue, EDF and AREVA provided documents to show how they have further developed their methodologies for SF categorisation and SSC classification. They have also provided examples of the application of these methodologies to different safety-related systems within the UK EPR™ design. In addition, EDF and AREVA proposed a number of design changes to increase the safety classification of key SSCs above the level originally proposed.

EDF and AREVA chose to adopt two different approaches for the application of classification depending on the type of EPR™ system. For civil structures, electrical, C&I and discrete parts of the HVAC system a system-wide approach is applied while for the remaining UK EPR™ mechanical systems EDF and AREVA chose to classify at the Safety Feature Group (SFG) level, which is at sub system rather than a system level. EDF and AREVA provided evidence of the application of the SFG approach, but this was limited to two examples within UK EPR™ design. A future licensee will apply these methodologies throughout all systems during the site specific phase.

ONR judged that the information provided by EDF and AREVA established the following:

- The methodology for categorising plant SF is now clear and well documented within the GDA submission and this approach aligns with UK and international standards and relevant good practice.
- The methodologies for categorising SFs and classifying SSCs associated with civil structures, electrical and C&I systems have been developed in GDA and now align with UK and international standards and relevant good practice.
- The rules used to assign the mechanical design requirements applied to pressure retaining components differ from previous approaches used for PWR reactors. The rules were implemented on the two examples provided for GDA and showed a logical progression and consistency with previous approaches. In some instances, the rules can lead to lower mechanical design requirements compared with previous reactor designs. While the examples given in GDA are acceptable we will require a future licensee to confirm that a consistent and logical progression, from previous approaches, extends to all mechanical systems when the design requirements are defined during the site specific phase.
- The use of nuclear and non-nuclear pressure vessel design codes associated with these mechanical design requirements has been clarified in the SSC classification methodology to meet our expectations.
- Multiple design changes have been agreed in GDA to increase the classification of key SSCs above the level originally proposed for the UK EPR™ and implementation of these changes will significantly improve the robustness of the UK EPR™ design in areas such as Spent Fuel Pond cooling, the make-up water plant and the ultimate diesel generators.
- The supporting technical documentation, including the specification for update of System Design Manuals (SDM), provides sufficient guidance to allow a future licensee to apply these methodologies during the site specific phase.

ONR has concluded that the development of methodologies for categorising SF and classifying SSCs, and the application of these methodologies within the UK EPR™ design, is sufficient at this stage of the design process, and that these are in line with UK and international standards and relevant good practice. SF categorisation and SCC classification fundamentally underpins safe reactor design and therefore the resolution of this issue is seen as a major step forward.

ONR are therefore satisfied that GDA Issue GI-UKEPR-CC-01 has been addressed.

Closure of GI-UKEPR-CC-02

The aim of this Issue was to seek additional assurance that the UK EPR™ final consolidated GDA documentation has been appropriately controlled, maintained and updated to reflect the additional work completed during the close-out phase.

This was a joint Issue because a consistent set of consolidated documents are required as key references to ONR's DAC and the Environment Agency's Statement of Design Acceptability.

The main GDA documentation comprises three documents: the generic Pre-Construction Safety, Security and Environmental Report (SSER); the DR; and the SML (these are described earlier in this report). As these documents form key references to the DAC, it was important that they were updated and managed throughout the close-out process. Because these documents have been impacted by GDA Issue responses and design changes we need to be sure that the developments that arose during the GDA Issue close-out period have been captured.

In response to this GDA Issue EDF and AREVA provided a range of documents including:

- Design change proposals;
- Handover packages for future UK EPR™ licensees;
- A specification for the update of the UK EPR™ design reference;
- The final SML; and
- The final SSER.

Our joint assessment focused on these documents, and on the inspection of EDF and AREVA's GDA project arrangements for control of GDA documentation. These arrangements cover the control of GDA documentation impacted by GDA Issues, and design changes that the regulators have agreed for inclusion in the GDA design reference.

Our assessment concluded that:

- The EDF and AREVA processes for control of updates to the SSER, SML and DR were robust and this provides confidence in the provenance of these key GDA deliverables.
- EDF and AREVA have completed consistency checks across SSER chapters, reviewed the SML and the final revision of the DR to ensure consolidation and concurrence across the GDA deliverables.
- During GDA a total of 82 design change proposals have been identified and included in the GDA Reference Design. These design improvements significantly strengthen the safety case for the UK EPR™.
- The specification for the update of SDMs post-GDA is considered to provide sufficient information to enable a future UK EPR™ licensee to develop site specific SDMs that are consistent with decisions made and agreements reached in GDA.
- The handover documentation provided by EDF and AREVA for agreed design changes is sufficient to enable a future licensee to incorporate these changes into a site specific UK EPR™ design.
- That the final GDA key deliverables including the SSER, SML and DR are acceptable.

From our assessment, we are satisfied that the EDF and AREVA arrangements for the control of updates to the final GDA submission documentation including the SSER, SML and DR for the UK EPR™ are adequate.

ONR are therefore satisfied that GDA Issue GI-UKEPR-CC-02 has been addressed and that these documents can be used as the key references for the DAC.

Closure of GI-UKEPR-CC-03

This GDA Issue requested EDF and AREVA to demonstrate how they will take account of lessons learnt from the events at Fukushima, including those lessons arising out of EDF and AREVA's own internal reviews and the lessons and recommendations identified in HM Chief Inspector's (CI) final report (Reference 11).

The approach taken by EDF and AREVA was to review the robustness of the UK EPR™ design against severe external events and, where appropriate, to identify and develop potential design enhancements recognising developments in other EPR™ projects and wider international initiatives. EDF and AREVA provided reports covering:

- Review of EPR™ robustness against seismic and external flooding events.
- Review of EPR™ ability to withstand loss of power and cooling.
- Review of EPR™ severe accident management arrangements to mitigate the consequences of such events.
- Summarising how the recommendations from CI's report have been addressed for the UK EPR™.
- A description of the enhancements identified from EDF and AREVA's post-Fukushima reviews.
- Work undertaken to address other GDA Issues that identified design changes which improve the robustness of EPR against extreme events.
- A new PCSR sub chapter dealing with post-Fukushima reviews.

From their reviews EDF and AREVA identified 16 resilience enhancements that they grouped into five design change proposals for GDA and these provide the following:

- Improved flood protection for emergency electrical supplies (both AC and DC).
- Extension of the capability and autonomy of emergency electrical supplies (both AC and DC).
- Identified connection points for proposed mobile diesel generators.
- Addition of SFP instrumentation into the severe accident management C&I systems.
- Provision of connections to enable delivery of water via mobile pumps for SFP make-up and containment pressure control.

ONR concluded that the additional information provided established that:

- EDF and AREVA have provided sufficient design reviews and supporting analysis to demonstrate the robustness of the UK EPR™ design. These reviews include normal operation and shutdown during extreme events such as earthquake and flooding (recognising that for flooding the reactor platform height is the critical determining parameter and this is a site specific matter).

- EDF and AREVA have provided appropriate evidence to demonstrate the ability of the plant to maintain a safe state following extreme events which result in loss of electrical power and or cooling.
- The proposed resilience enhancements will improve the robustness of the UK EPR™ against extreme events.
- The development of EPR™ severe accident management arrangements will mitigate the consequences of severe accidents.
- EDF and AREVA responses to the CI's recommendations are considered to be suitable and sufficient.

From our assessment of other GDA Issues, in particular GI-UKEPR-FS-03 relating to the SFP and GI-UKEPR-FS-05 for reactor support systems we have identified plant and system enhancements agreed for inclusion in GDA which we judge will provide further improvements to the robustness of the UK EPR™ design against severe accidents.

- We note that NNB GenCo, in their role as the licensee of Hinkley Point C and the company planning to build the first UK EPR™ at Hinkley Point C, have proposed their own list of site specific considerations and potential design improvements in response to the CI's report. These complement those now incorporated in the generic design.
- Furthermore, from discussions with international regulators in the MDEP additional options to those above are being considered in other EPRTM projects which have the potential to improve the robustness of a UK EPR™. As these options are at an early stage of development we request future UK EPR™ licensees to consider their suitability for implementation into a UK site specific design.
- ONR judges that these design changes offer improved resilience in the safety and robustness of the UK EPR™.

On the basis of our assessment of the information provided by EDF and AREVA we are therefore satisfied that the lessons learnt from Fukushima and the requirements of GDA Issue GI-UKEPR-CC-03 have been addressed.

Conclusions

This is our fourth and final summary report for the Generic Design Assessment of the UK EPR™ reactor. It describes ONR's assessment undertaken during the GDA Issue close-out phase.

The aim of the GDA close-out phase was for EDF and AREVA to provide responses to each of the 31 GDA Issues, and for ONR to assess them and, specifically, to:

- Complete sufficient, detailed, assessment to allow us to form a judgement whether the additional information provided by EDF and AREVA was sufficient to close each Issue;
- Decide whether any additional safety improvements were required; and
- Form a judgement on whether a DAC can be issued.

EDF and AREVA have addressed each of the 31 GDA Issues through development of improved safety cases and through identification of 82 design improvements that have now been incorporated into the GDA design reference.

EDF and AREVA's safety case for GDA Step 4 was described in their March 2011 PCSR (Reference 12). This was updated during the GDA close-out phase in order to:

- Take account of matters raised during our assessment;
- Improve the presentation of the safety arguments; and
- Include agreed design changes.

The updates were incorporated into a consolidated version of the PCSR which was submitted in November 2012 (Reference 25).

This summary report describes how ONR has assessed each of these GDA Issue responses, the updated generic PCSR, and the related design improvements, and it describes why we have accepted that they are sufficient to allow closure of the GDA Issues. Our assessment has been professionally undertaken, wide ranging and challenging and, as a result, a number of safety improvements are being incorporated into the generic design long before any construction work starts at a UK site. ONR's view is that these design improvements significantly strengthen the safety case for the UK EPR™.

We have concluded that all the GDA Issues have been addressed to ONR's satisfaction.

We are confident that we have completed a meaningful assessment of the UK EPR™ reactor. In view of the safety case and design change improvements that EDF and AREVA have provided, we are now content, for this stage in the design process, that the current UK EPR™ generic reactor design and safety case has demonstrated that the risks to workers and the public are ALARP.

In recognition of the fact that all the GDA Issues are closed, and in accordance with our published guidance (Reference 1), we have therefore decided to issue a Design Acceptance Confirmation for the UK EPR™ reactor. This has been issued alongside this report and indicates that we believe that the UK EPR™ reactor is suitable for construction on licensed sites in the UK, subject to site specific assessment and licensing.

The DAC does not in itself permit any additional action in terms of nuclear power station construction as that requires a specific regulatory permission be given by ONR under a Nuclear Site Licence Condition. This will be progressed separately by ONR.

In GDA, ONR conducted a security assessment alongside the safety assessment. So, in addition to addressing nuclear safety matters, the DAC also confirms that security aspects are acceptable. This is based on our assessment of EDF and AREVA's conceptual security arrangements document and our report on the generic security assessment was provided at the end of Step 4. There were no GDA Issues arising.

During the site specific phase we will regulate the further detailed development of the identified generic design changes and we will ensure, as part of our normal regulatory business, that the Assessment Findings that we have identified in GDA are appropriately addressed.

GDA has been a new process that we set up in 2007 with the objective of enabling the nuclear regulators to become involved at an early stage in the development of proposals for new nuclear power stations. It allows the technical assessments to be conducted before commitments are made to construct the reactors, meaning that regulatory questions and challenges can be addressed, and any necessary modifications made, while the designs are still "on paper". The conclusions of this report demonstrate that we have completed a comprehensive, robust and independent assessment ahead of any UK EPR™ reactor construction. We therefore believe that we have met the key objectives of the GDA process.

GDA has been successful in reducing the risk that significant design changes will be required during the construction phase. This will be a significant contribution to ensuring that new build construction work will be 'right first time'.

International co-operation and information exchanges with overseas regulators, particularly through the MDEP, was of significant aid to our assessment. As well as improving regulatory effectiveness, this co-operation helps promote harmonised outcomes that make it easier for reactor vendors to adopt standardised designs in different countries.

Use of the SAPs for assessment of the UK EPR™, and the other designs that were previously in GDA, has underlined that they are a powerful tool for safety assessment, largely due to their goal setting non-prescriptive and technology neutral content. This bodes well for further GDAs on reactors of a variety of technologies.

Completion of our GDA for the UK EPR™ should be seen as evidence of the operation of an independent and robust regulatory process and a demonstration of our mission to secure the protection of people and society from the hazards of the nuclear industry. By carrying out such a robust and transparent assessment we have ensured that any new nuclear power station based on the UK EPR™ generic design will be safe, secure and – through the work of our colleagues in the Environment Agency – environmentally acceptable.

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While every effort has been made to ensure the accuracy of the references listed in this report, their future availability cannot be guaranteed.

Glossary and Abbreviations

AC	Alternating Current
AECL	Atomic Energy of Canada Limited
ALARP	As low as reasonably practicable
AREVA	AREVA NP SAS
ASN	Autorité de Sûreté Nucléaire (French nuclear safety authority)
AVR	Automatic Voltage Regulator
BSO	Basic Safety Objective (in ONR SAPs)
C&I	Control and Instrumentation
CBSIS	Computer Based Systems Important to Nuclear Safety
CDM2007	Construction (Design and Management) Regulations 2007
CNS	Convention on Nuclear Safety
CNS(ONR)	Civil Nuclear Security (Office for Nuclear Regulation)
CRDM	Control Rod Drive Mechanisms
CRUD	Crystalline material (usually oxides) deposited on a heat transfer surface, increasing its roughness and, in some cases, introducing a resistance to heat transfer
CSA	Conceptual Security Arrangements
DAC	Design Acceptance Confirmation (Office for Nuclear Regulation)
DC	Direct Current
DECC	Department of Energy and Climate Change
DfT	Department for Transport
DR	Design Reference
DRP	Design Reference Point
DTI	Department of Trade and Industry (now DECC)
EDF and AREVA	Electricité de France SA and AREVA NP SAS
EMIT	Examination, Maintenance, Inspection and Testing
ENSREG	European Nuclear Safety Regulators' Group
EPR10	Environmental Permitting Regulations 2010
EPRI	Electric Power Research Institute (United States of America)
ETB	Effluent Treatment Building
GDA	Generic Design Assessment
GFP	General Fire Precautions
HEPA	High Efficiency Particulate Air
HFI	Human Factors Integration
HIC	High Integrity Components

HRA	Human Reliability Assessment
HSE	Health and Safety Executive
HSWA74	Health and Safety at Work etc. Act 1974
IAEA	International Atomic Energy Agency
IEC	International Electrotechnical Commission
ILW	Intermediate Level Waste
IRR99	Ionising Radiations Regulations 1999
IRSN	Institut de Radioprotection et de Sûreté Nucléaire (French Radioprotection and Nuclear Safety Institute)
IRWST	In Containment Refuelling Water Storage Tank
JPO	Joint Programme Office
LLW	Low Level Waste
LOLER1998	Lifting Operations and Lifting Equipment Regulations 1998
IRWST	Containment Refuelling Water Storage Tank
JPO	Joint Programme Office
LHSI	Low Head Safety Injection
LOCA	Loss of Coolant Accident
MDEP	Multinational Design Evaluation Programme
MHSI	Medium Head Safety Injection
MOS	Management of Safety
MOX	Mixed-oxide Fuel
MSQA	Management of Safety and Quality Assurance
NCSS	Non-computerised Safety System
ND	Nuclear Directorate (of the Health and Safety Executive, now the Office for Nuclear Regulation, an agency of HSE)
NDT	Non-destructive Testing
NPT	(Nuclear) Non-Proliferation Treaty
OCNS	Office for Civil Nuclear Security (now Civil Nuclear Security, part of the Office for Nuclear Regulation)
OJEU	Official Journal of the European Union
ONR	Office for Nuclear Regulation (formerly the Nuclear Directorate of the Health and Safety Executive)
ONR(CNS)	Civil Nuclear Security (part of the Office for Nuclear Regulation)
PAR	Passive Autocatalytic Recombiners
PAS	Process Automation System
PCI	Pellet Clad Interaction
PCSR	Pre-construction Safety Report

PS	Protection System
PRA	Probabilistic Risk Analysis
PSA	Probabilistic Safety Analysis
PSR	Preliminary Safety Report
PUWER1998	Provision and Use of Work Equipment Regulations 1998
QA	Quality Assurance
QMS	Quality Management System
RCCA	Rod Control Cluster Assemblies
REPPIR2001	Radiation (Emergency Preparedness and Public Information) Regulations 2001
RGA	Risk Gap Analysis
RGP	Relevant Good Practice
RPV	Reactor Pressure Vessel
SAP	Safety Assessment Principles (ONR)
SAS	Safety Automation System
SF	Safety Function
SFAIRP	So far as is reasonably practicable
SGTR	Steam Generator Tube Rupture
SIS	Safety Injection System
SML	Submission Master List
SoDA	Statement of Design Acceptability (Environment Agency)
SSC	Structures, Systems and Components
STUK	Säteilyturvakeskus (the Finnish Nuclear Safety Authority)
SSC	Structures, Systems and Components
TAG	Technical Assessment Guide (ONR)
TSC	Technical Support Contractor
US NRC	United States Nuclear Regulatory Commission
WENRA	Western European Nuclear Regulators' Association
WGWD	WENRA Working Group on Waste and Decommissioning

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