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 detailed design assessment of the Electricité de France SA and AREVA NP SAS UK EPR™ nuclear reactor (Step 4 of the Generic Design Assessment process)

14 December 2011

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

First published December 2011

ONR Report ONR-GDA-SR-11-001 Revision 0

Foreword

I am pleased to present this report which summarises the findings of the Office for Nuclear Regulation (ONR) from Step 4 of its Generic Design Assessment (GDA) of the UK EPR™ reactor. This is our third summary report since we started the Generic Design Assessment (GDA) process in 2007. We are publishing these documents as part of our commitment to be open and transparent about our work. This report, together with a series of more detailed supporting technical reports, provides the main conclusions of our planned GDA assessment. It does not directly address the lessons from the accident at Fukushima as that occurred after the Step 4 submissions were provided to us and the scope of the Step 4 technical assessment reports therefore did not include Fukushima. However, we have ensured that we will address the lessons from Fukushima by including this as a specific GDA Issue (see below).

GDA enables 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 while the designs are still “on paper”. The conclusions of this report demonstrate that we have achieved this objective. A number of safety improvements have been identified as a result of our assessment and these are being incorporated into the design long before any construction work starts at a UK site.

We have completed a significant amount of work in our assessment of the UK EPR™ reactor, and EDF and AREVA have worked hard to close out many of the technical questions we have raised. We have concluded that we are largely satisfied with the design and safety cases presented to us by EDF and AREVA for the UK EPR™ reactor, although some issues remain and require further work.

At a late stage in our Step 4 assessment the accident at Fukushima occurred. The key impact on GDA was that we did not believe it was appropriate to draw conclusions from our assessment work in June 2011 as originally planned, nor publish our GDA technical assessment reports, until the lessons learnt from Fukushima emerged. In effect, our assessment was extended to await the HM Chief Inspector of Nuclear Installations’ report on the implications of Fukushima. We also introduced an additional GDA Issue to take account of the Fukushima lessons learnt work. The Chief Inspector’s report has now been issued and EDF and AREVA have provided a resolution plan for the Fukushima GDA Issue, including a description of how they will address the Chief Inspector’s report’s recommendations.

Our original GDA guidance indicated that some issues might remain at the end of Step 4, and this has indeed proven to be the case. Even though we are largely satisfied with the design and safety cases presented to us by EDF and AREVA for the UK EPR™ reactor, we have 31 GDA Issues remaining which must be addressed before we will say that GDA is “complete”. We published these issues together with the industry’s resolution plans in July 2011, apart from the plan for responding to the Fukushima GDA Issue, which is now being published alongside this report. These GDA Issues should not be interpreted as a negative regulatory view of the UK EPR™ reactor design. Rather, they should be seen as evidence of the operation of an independent and robust regulatory process and a demonstration of our mission of securing 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.

As we are largely satisfied, we have decided to issue an interim Design Acceptance Confirmation (DAC) for the UK EPR™ reactor. The interim DAC does not in itself permit any additional action in terms of nuclear power station construction, but it does signify that a major milestone has been achieved in that we have reached the end of our planned assessment. It also means that our further assessment work will be targeted on the remaining GDA Issues and will be progressed in accordance with the resolution plans that EDF and AREVA have provided to us, and that we have accepted as credible. When the GDA Issues have been addressed to our satisfaction we should then be in a position to consider issue of a final DAC. Until that time, no nuclear island safety-related construction of a power station based on the UK EPR™ reactor will be permitted.

A feature of GDA has been the programme and administration arrangements that we put in place to ensure efficiency and joint working between ONR and the Environment Agency. All correspondence and contacts have been managed through a single Joint Programme Office and this has proven to be particularly effective. We have also made extensive use of programme working; we have published plans and performance metrics, and we have placed around 150 support contracts to further bolster the specialist analytical resources available to us

From the outset we have been committed to conducting GDA in an open and transparent manner and we believe we have achieved this. We have published much information on our website, including regular technical and progress reports, and the Requesting Party safety cases have been published on their websites. We have invited public comment on these and we have also attended and spoken at many events throughout GDA to publicise our work.

Along with the assessment of the AP1000® design, this is the first application of GDA. As such, there have been some “teething” problems and completion of Steps 1 to 4 has taken over four years, which is longer than originally envisaged. The reasons for this are diverse and include a lack of ONR resource in the early stages, the spreading of this resource to assess four reactor designs in parallel until Step 3, and difficulties in getting the Requesting Parties to understand the UK regulatory approach and safety case requirements. Despite these factors, GDA is accepted by industry and government to have been a success. Nevertheless, we will review the lessons learnt to help us make improvements for any future GDA projects and to inform the developing improvements in ONR.

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

Kevin Allars
Director for Nuclear New Build
Office for Nuclear Regulation
An agency of the Health and Safety Executive
December 2011

Executive summary

This is our third GDA summary report on the UK EPR™ reactor and it provides our findings at the end of GDA Step 4. This report is supported by a series of detailed technical reports, and together these provide the main conclusions of our planned GDA assessment. It does not directly address the lessons from the accident at Fukushima as that occurred after the Step 4 submissions were provided to us and the scope of the Step 4 technical assessment reports therefore did not include Fukushima. However, we have ensured that we will address the lessons from Fukushima by including this as a specific GDA Issue (see below).

We have also published reports on the outcome of GDA Step 2, the fundamental safety review, in March 2008 and on the outcome of GDA Step 3, the overall design safety and security review, in November 2009. This Step 4 report is on the detailed design assessment – although it also provides an overview of the overall GDA project through Steps 1, 2 and 3.

In addition, since May 2009, we have published a series of quarterly reports. These have described progress, identified key issues, and provided our views on the anticipated position at the end of Step 4.

The aim of GDA Step 4 was to provide a detailed design assessment of the UK EPR™ reactor and, specifically, to:

- move from the system level assessment of Step 3 to a fully detailed examination of the evidence, on a sampling basis, given by the safety analyses;
- confirm that the higher level claims such as system functionality are properly justified;
- assess the conceptual security arrangements for the reactor; and
- complete sufficient detailed assessment to allow us to come to a judgement on whether a DAC can be issued.

To achieve these aims, ONR has undertaken an in-depth assessment of the generic design safety case and conceptual security arrangements. Plans were developed for each technical area to set out a strategy for our assessment based on a systematic sample of the information provided by EDF and AREVA. We have completed a substantial amount of work in our assessment of the UK EPR™ reactor, expending around £23.5m of effort, which has included around £7.5m worth of technical contract support. EDF and AREVA have provided us with over 3500 documents; we have posed over 1600 formal technical questions, and held 500 technical meetings. EDF and AREVA have worked hard to close out many of the technical questions we raised. We are thus confident that we have completed a meaningful assessment of the UK EPR™ reactor. This work has been completed well before the start of any UK EPR™ reactor power station construction project.

The conclusions in this report represent the end of our planned GDA assessment, and the end of GDA Step 4. We have concluded that we are largely satisfied with the safety and security aspects of the UK EPR™ reactor generic design that have been presented to us by EDF and AREVA and we believe that the UK EPR™ reactor could be suitable for construction on licensed sites in the UK. We have also concluded that there are a number of GDA Issues remaining that must be addressed before we can declare that GDA is “complete”.

EDF and AREVA have produced a resolution plan for each of the GDA Issues and we have reviewed these and judge them to be credible. In recognition of this, and in accordance with our published guidance (Reference 1), we have decided to issue an interim Design Acceptance

Confirmation (DAC) that references these GDA Issues. When the GDA Issues are addressed to our satisfaction, and the safety case is updated and assessed, then we should be in a position to consider issue of a final DAC. Until that time, no nuclear island safety-related construction of a nuclear power station based on the UK EPR™ reactor will be permitted.

The interim DAC does not in itself permit any additional action in terms of nuclear power station construction, but it does signify that a major milestone has been achieved in that we have reached the end of our planned assessment. It also means that our further assessment work will be targeted on the GDA Issues and will be progressed in accordance with the resolution plans that EDF and AREVA have provided to us, and that we have accepted as credible. Some of these GDA Issues may be resolved with additional safety case changes while others may require design changes. We will summarise our progress on these in our quarterly reports, which we will continue to place on our website, and we will also publish a final report to summarise this work should we decide that it is appropriate to issue a DAC at some point in the future.

Office for Nuclear Regulation

In 2008, the Government commissioned a major review into the UK's nuclear regulatory regime. This review was conducted by Dr Tim Stone, senior adviser on nuclear new build to the Secretary of State for Energy and Climate Change and to the Chief Secretary of the Treasury.

Dr Stone made a number of recommendations, which included the need to restructure what was the nuclear regulatory body, the Nuclear Directorate (ND). He proposed the creation of a new, sector-specific regulator for the nuclear industry – the Office for Nuclear Regulation.

ONR was established by HSE on 1 April 2011, signalling the commitment to securing an appropriately resourced and responsive regulator for the future challenges of the nuclear sector. ONR has been set up as an agency of HSE, pending planned legislation to establish it as a statutory body. It has now brought together the relevant nuclear regulatory functions of HSE (through its Nuclear Directorate) and the Department for Transport (DfT).

The functions, structure and future plan for ONR are set out in our Corporate Plan, which can be found on our website at www.hse.gov.uk/nuclear/corporate-plan-2011-2015.pdf. The plan identifies the outcomes we must deliver, our core activities, and the breadth of activities that we will undertake to achieve those outcomes.

In this report we therefore generally use the term “ONR” for our organisation, except where we refer back to documents or actions that originated when we were still HSE’s Nuclear Directorate.

Contents

Background

The safety of nuclear installations is achieved by good design and operation, but it is assured by a system of regulatory control at the heart of which is the nuclear site licensing process. This 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 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. This led to the production of guidance on the Generic Design Assessment (GDA) process, which was originally published in January 2007: *Nuclear power station generic design assessment – guidance to requesting* parties (Reference 2) and *Guidance document for generic design assessment activities* (Reference 3).

The updated arrangements are based on a two-phase regulatory assessment process which separates the GDA from the site-specific ONR licensing assessment and Environment Agency permitting process. Phase 1, 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.

GDA consists of four steps.

- GDA Step 1 is the preparatory part of the design assessment process. It involves discussions between the Requesting Party and ONR to ensure a full understanding of the requirements and processes that would be applied, and to arrive at formal agreements to allow ONR to recover its costs from the Requesting Party. Step 1 commenced in July 2007 and completed in August 2007.
- GDA Step 2 is an overview of the fundamental acceptability of the proposed reactor design concept within the UK regulatory regime. The aim is to identify any fundamental design aspects or safety shortfalls that could prevent the proposed design from being acceptable for construction in the UK. Step 2 commenced in August 2007 and completed in March 2008, when we published a series of reports on our work. These are listed in Annex 2.
- GDA Step 3 is a system design safety and security review of the proposed reactor. The general intention is to move from considering the fundamental safety claims of the previous step to an analysis of the design, primarily by examination at the system level and analysing the supporting arguments made by the Requesting Party. From a security perspective, the foundations for developing the conceptual security arrangements are laid through dialogue with the Requesting Party. Step 3 commenced in June 2008 and completed in November 2009 with the publication of a series of reports on our work. These are listed in Annex 2.

- GDA Step 4 is a detailed design review and is intended to move from the system-level assessment of GDA Step 3 to a detailed examination of the evidence provided within the safety analyses, on a sampling basis. It also examines the proposed conceptual security arrangements. If the generic design is considered acceptable, a DAC could be issued at the end of GDA Step 4. Step 4 commenced in November 2009 and has been completed with the publication of this report.

Initially, four reactor designs were accepted for GDA, and work on Step 1 on each began in July 2007. The designs were:

- ACR-1000 reactor (Atomic Energy of Canada Limited)
- AP1000 reactor (Westinghouse)
- ESBWR reactor (GE-Hitachi)
- UK EPR™ reactor (EDF and AREVA)

In April 2008, following Step 2, Atomic Energy of Canada Limited withdrew the ACR-1000 reactor from GDA and in June 2008 we began GDA Step 3 on the remaining three designs. In September 2008, GE-Hitachi requested that assessment work on the ESBWR reactor be suspended and we therefore continued to progress GDA Step 3 on the UK EPR™ and AP1000 reactor designs only.

The step-wise assessment approach to GDA allowed us to look in increasing detail at the safety and security issues as we progressed through the various steps. It enabled us to start with a fairly small assessment team and to grow this as we moved through the project. In parallel with our work on safety and security aspects, the Environment Agency examined the potential environmental impact.

Phase 2 of the new build regulatory assessment process, will involve an applicant seeking Permits from the Environment Agency and a nuclear site licence from ONR. Therefore, in Phase 2, ONR will first carry out a site licence assessment, in which we will 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 will grant a Nuclear Site Licence. Subsequently, before construction of a reactor can commence, permission to start the construction must be obtained from ONR under the conditions attached to the site licence.

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

The Energy Act 2011 contains an enabling power for the Government to make regulations on the security of civil nuclear sites including power stations while they are being constructed, and before a site licence is granted. DECC intends to make regulations in 2012 on security at civil nuclear construction sites using these new powers and existing ones in the Anti-terrorism, Crime and Security Act 2001. ONR (CNS) will use these powers to regulate security aspects of new build activities from the start of significant civil works.

The expectation is that any DAC provided to EDF and AREVA would be carried forward from GDA by the future licensee to support the Phase 2 site-specific work and, in particular, ONR's assessment of whether to permit nuclear island safety-related construction. 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 the future operator (Reference 1).

It should be noted that Phase 1 GDA and Phase 2 site-specific work can overlap. In these cases, it is our current intention that a DAC will be required, before permission to begin nuclear island safety-related construction will be given, but not necessarily before a site licence is granted. Ultimately, a DAC can be used to underpin the permissions required from ONR to construct a fleet of identical reactors, except for site or operator-specific changes.

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.

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 via our website: www.hse.gov.uk/newreactors. Furthermore, the public has been encouraged to comment on the reactor designs and we have considered these comments, along with the responses from the designers, within our assessment.

On 11 March 2011 the accident at Fukushima occurred. On 14 March 2011 the Secretary of State for Energy and Climate Change requested HM Chief Inspector of Nuclear Installations to examine the circumstances of the Fukushima accident to see what lessons could be learnt to enhance the safety of the UK nuclear industry. The key impact on GDA was that we did not believe it was appropriate to draw conclusions from our assessment work in June 2011 as originally planned, nor publish our technical findings, until the lessons learnt from Fukushima had emerged and been considered by ONR and the Requesting Parties. In effect, our assessment was extended by several months to await the Chief Inspector's report on the implications of Fukushima.

The scope of the Step 4 technical assessment reports did not include Fukushima as the accident occurred after the Step 4 submissions were provided to us. However, we have ensured that we will address the lessons from Fukushima by including this as a specific GDA Issue.

The Chief Inspector's report was published on 11 October 2011 and EDF and AREVA have provided a resolution plan for the Fukushima GDA Issue, including a description of how it will address the Chief Inspector's report's recommendations. ONR will continue to assess their progress on this matter and closure of the GDA Issue will be required, alongside closure of all the other GDA Issues, before GDA could be considered complete.

A timetable of key events in GDA is included in Annex 1 of this report.

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 two reactor* designs. We are examining these particular designs as they have been identified by DECC as those most likely to be built in the UK and those which could, therefore, present a potential hazard to the public.

We launched GDA in July 2007. GDA Step 1 was devoted to preparatory work and was completed in August 2007. GDA Step 2, the fundamental safety overview, was completed in March 2008 and GDA Step 3, the overall design safety and security review, was completed in November 2009. We published a series of reports summarising our work and, in each of these steps, concluded that we had found no shortfalls that would rule out eventual construction of these reactors on licensed sites in the UK. These reports are listed in Annex 2.

This report is on GDA Step 4 of our assessment of the EDF and AREVA UK EPR™ reactor, the detailed design assessment, and it covers the period from November 2009 to the summer of 2011. The aim of GDA Step 4 was to provide an overall detailed assessment of each design submitted – in this case the UK EPR™ reactor – and, specifically, to:

- move from the system level assessment of Step 3 to a fully detailed examination of the evidence, on a sampling basis, given by the safety analyses;
- confirm that the higher level claims such as system functionality are properly justified;
- assess the conceptual security arrangements for the reactor; and
- complete sufficient, detailed, assessment to allow us to come to a judgement whether a DAC can be issued.

To achieve these aims, ONR has undertaken an in-depth assessment of the safety case and the generic site envelope. From a security perspective, we have examined the conceptual security arrangements.

In this report we describe the work we have completed, and the issues that have emerged, and we summarise the conclusions of our assessment. To help manage our work, we have split it into 15 technical topic areas, plus the security topic, and our progress in each of these is summarised below. There are some additional introductory sections to help put our work into context and there are some additional summary sections (that do not fit easily into the technical topic areas) which describe activities such as our work with overseas regulators and on public involvement.

This report is intended to inform the public of our work on GDA and we believe it provides a comprehensive overview of our assessment to date. Further details can be found in the detailed supporting technical reports which have also been published via our website at www.hse.gov.uk/newreactors.

* In this report, the word "reactor" can be taken to cover all nuclear safety- and security-related areas of the proposed nuclear power station design including radioactive waste and spent fuel storage facilities.

ONR expectations for modern reactors

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. This means we will assure ourselves that the potential risk from the operation of such a reactor in the UK has been reduced to "as low as is reasonably practicable" (ALARP).

Potential accidents in a reactor could arise from failures of equipment, for example pipe leaks or pump breakdowns, or from hazards such as fires, floods, extreme winds, earthquakes, or aircraft crash, or from human errors. ONR expects the reactor to be designed to remain safe under all these scenarios. We expect to see a robust demonstration of three key features: the ability to shut down the reactor and stop the nuclear chain reaction; the ability to cool the shutdown reactor; and the ability to contain radioactivity.

The adequacy of protection provided needs to be demonstrated by a comprehensive safety analysis that examines all the faults and hazards that could threaten the reactor. This should show that the reactor design is sufficiently robust to tolerate these faults and hazards, and that it operates with large margins of safety. ONR expects an approach of defence-in-depth to be adopted. This means that if one part of the plant fails then another part is available to fulfil the same safety duty. To maximise protection, different back-up systems and other safety features can be provided. This multi-barrier protection concept has to be applied repeatedly until the risk of an accident is acceptably low.

In modern reactor design, these concepts are well understood and ONR therefore expects to see a comprehensive demonstration that an acceptably low level of risk has been achieved. The principles used by ONR in assessing whether the safety demonstration is adequate are set out in the document *Safety assessment principles for nuclear facilities* (SAP) (Reference 5). To help ensure ONR applies good international practice in its assessment, the SAPs were revised and updated in 2006 and this included benchmarking against the International Atomic Energy Agency (IAEA) Safety Standards.

ONR expectations from the GDA process

Details of ONR's expectations for the GDA process as a whole, and specifically for GDA Step 4 of the GDA process, can be found in the GDA guidance (Reference 2). For the completeness of this report a key section of that document, which describes what ONR expects from a Requesting Party for GDA, is summarised in Annex 3.

Details of the expectations of the Office for Civil Nuclear Security (OCNS), now part of ONR – ONR(CNS) – for GDA Step 4 can be found in the ONR(CNS) guidance (Reference 3). In summary, the expectation is that a Requesting Party would provide sufficient information to enable ONR(CNS) to become familiar with the technology, and to form a view of the measures required to deliver appropriate security.

A key aim of this report is to provide a summary of the GDA Step 4 assessment ONR has undertaken of the information gathered from EDF and AREVA to address the points listed in Annex 3.

The safety standards and criteria used

The main document used for the GDA Step 4 assessment was the 2006 edition of our SAPs (Reference 5). For radiological protection we also considered the requirements of the *Ionising Radiations Regulations 1999* (IRR99) and the *Radiation (Emergency Preparedness and Public Information) Regulations 2001* (REPPIR2001).

Management of GDA outcomes

Our original GDA guidance (Reference 2) indicated that some technical issues might remain at the end of Step 4 but it didn't provide much information about how these issues would be managed. We therefore published, in June 2010, additional guidance on the management of GDA outcomes (Reference 1) to provide clarity on how any remaining issues would be handled during the ongoing design, procurement, construction and commissioning phases of a power station based on the assessed generic design.

This guidance identified that there could be three potential outcomes at the end of Step 4:

1) If we were fully content with the generic safety and security aspects then we would provide the Requesting Party with a DAC which would mark the end of GDA for that generic design.

2) If we were largely content with the generic safety and security aspects then we would provide the Requesting Party with an interim DAC and identify the unresolved GDA Issues. These issues would need to be cleared before a final DAC could be provided or before we could consider granting permission for the start of nuclear island safety-related construction for a power station based on that design.

3) If we were not content with the generic safety and security aspects then no DAC would be issued.

In this report we review our GDA assessment results for the UK EPR™ reactor and conclude that outcome 2, above, is appropriate, and that an interim DAC can be issued.

GDA Issues and resolution plans

GDA Issues were defined in Reference 1 as follows:

> *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.*

In this report, we identify the GDA Issues for the UK EPR™ reactor at Annex 4.

For each GDA Issue, Reference 1 requires that the Requesting Party would need to provide a resolution plan to demonstrate that the issue is resolvable. We would have to accept that the resolution plan is credible before coming to a decision to issue an interim DAC. In this report we list at Annex 4 the resolution plans that EDF and AREVA have provided.

The GDA Issues and resolution plans have also been published on our website at www.hse.gov.uk/newreactors.

Interim Design Acceptance Confirmation

Provision of the interim DAC for the UK EPR™ reactor means that we are confident that the design is capable of being built and operated in the UK, on a site bounded by the generic site envelope, in a way that is safe and secure. However, it also means that there are some GDA Issues remaining that need to be addressed to our satisfaction before nuclear-island safety-related construction of that reactor could commence.

Design Acceptance Confirmation

Once all the resolution plans are completed and GDA Issues addressed satisfactorily, and the safety case updated, we will consider whether a final DAC could be issued.

Assessment Findings

GDA was designed to assess the generic safety case for future reactor designs, it was not intended to provide a complete assessment of the final reactor design, as there will be other factors, operator specific or site specific, that we would expect to be considered during the site specific stages. Also, in some instances, final 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. This validation process is normal regulatory business and will be subject to appropriate regulatory controls.

The generic safety case that forms the basis of the GDA submission will also inform any site-specific safety case and it therefore follows that our GDA assessment will inform our site-specific assessment. Part of the link from GDA to site-specific assessment is assured by identification of GDA Assessment Findings, which are defined in Reference 1 as follows:

> *Findings identified during the regulators' GDA assessment that are important to safety, but not considered critical to the decision to start nuclear island safety-related construction of such a reactor.*

The Assessment Findings arising from our GDA assessment for the UK EPR™ reactor are identified in the detailed Step 4 assessment reports for each technical topic area. We expect these to be addressed either by the designer or by a future operator / licensee, as appropriate, during the detailed design, procurement, construction or commissioning phase of the new build project.

Management of the GDA process

GDA is a new process which was devised during 2006 and commenced in 2007. We have implemented a number of new ways of managing our work, some of which are described below.

Guidance documents

We developed and published a number of guidance documents to assist Requesting Parties to understand our expectations for the GDA process and the UK regulatory regime. The main guidance documents produced are:

- GDA guidance – HSE and ONR(CNS), References 2 and 3
- Top-level guide for regulator joint working, Reference 6
- Management of GDA outcomes, Reference 1
- Assessment in an international context, Reference 7
- Strategy for international input into GDA, Reference 8
- Radioactive waste guide for GDA, Reference 9

These supplement and build on guidance already in the public domain, available via the ONR website, principally our Safety Assessment Principles and their supporting Technical Assessment Guides (TAG).

Joint working with the Environment Agency using the Joint Programme Office

GDA was designed to allow the Nuclear Regulators (ONR and the Environment Agency) to work closely together. In support of this we set up a Joint Programme Office (JPO), which administers the GDA process on behalf of both Regulators, providing a "one-stop shop" for the assessment of potential new nuclear power stations. Both ONR and the Environment Agency used a common process for receiving GDA submissions, for correspondence, and for raising and tackling technical matters. We believe this has improved efficiency, both for the nuclear regulators and the Requesting Parties.

Technical Queries, Regulatory Observations and Regulatory Issues

To help us to track the progress of our assessments and our technical interactions with Requesting Parties in an auditable way, we introduced a tiered system to reflect the importance of information and technical issues which emerged during the GDA process. In increasing order of importance these are:

Technical Queries: These were the means by which we routinely sought clarification or further technical information from the Requesting Party. Typically this might be a request for supporting documentation or other clarification of claims or arguments made by a Requesting Party in their safety case. A Technical Query may have resulted in a Regulatory Observation or Regulatory Issue being raised where the query was not satisfactorily resolved.

Regulatory Observations: We used Regulatory Observations to bring significant assessment matters to the attention of a Requesting Party, to highlight that further justification was required. Regulatory Observations were supplemented by one or more actions which set out our expectations for the work required. The Requesting Party response was then the subject of further assessment by the regulators.

Regulatory Issues: We used Regulatory Issues to identify matters that we considered were of sufficient importance that they may, if not resolved, have prevented the successful completion of GDA. Regulatory Issues were supplemented by one or more actions which set out our expectations for the work required for a satisfactory resolution. Their response was then the subject of further assessment by the Regulators.

Technical Support Contractors

We placed work packages with contractors to help us carry out our detailed technical assessment. We established a framework agreement, including 31 Technical Support Contractors (TSC), across a range of 15 technical areas using the Official Journal of the European Union (OJEU) process.

It is common practice for us to engage specialist contractors in this manner to give technical and scientific support and advice to our regulatory assessment. However, all regulatory decisions are made by the nuclear regulators – not by contractors.

The scale and timeframe of GDA meant that we utilised significant additional technical support to assist our work. We placed over 150 separate contracts under this framework in support of GDA, at a cost of around £15m, of which around half have been in support of our work on the UK EPR™ reactor.

Resourcing

In 2007, we set up a specific GDA programme assessment team separate from other assessment demands in ONR. This helped their focus on GDA. Due to recruitment difficulties, we were unable to fully resource the team at the outset and this led to the need for some back-end loading, where we used additional staff to help minimise overall timescales, while ensuring we completed a robust and timely assessment.

Programme and project management

We introduced dedicated, professional project managers to help co-ordinate and progress GDA. This improved the degree of planning and monitoring of the project and had a positive effect on helping ensure programme objectives were achieved. We are now introducing a programme management approach for much of our work in ONR.

Openness and transparency

We conducted GDA in a spirit of openness. We have published reports of our work at key stages, as well as regular reports of progress that have included performance metrics. EDF and AREVA have published their safety submissions on their websites and have engaged in the public comment process that we set up for GDA. Further details are given in the relevant section of this report.

Addressing the accident at Fukushima

On 11 March 2011 Japan suffered its worst recorded earthquake. Reactor Units 1, 2 and 3 on the Fukushima Dai-ichi (Fukushima-1) site were operating at power before the event and on detection of the earthquake shut down safely. Within an hour a massive tsunami from the earthquake inundated the site. This resulted in the loss of all but one diesel generator, some Direct Current (DC) supplies and essential instrumentation, and created massive damage around the site. Despite the efforts of the operators, eventually back-up cooling was lost. With the loss of cooling systems, Reactor Units 1 to 3 overheated. This resulted in several explosions and what is predicted to be melting of the fuel in the reactors leading to major releases of radioactivity, initially to air, but later by leakage of contaminated water to sea.

On 14 March 2011 the Secretary of State for Energy and Climate Change requested that HM Chief Inspector of Nuclear Installations examine the circumstances of the Fukushima accident to see what lessons could be learnt to enhance the safety of the UK nuclear industry. The Secretary of State requested HM Chief Inspector to provide an interim report by the middle of May 2011, with a final report six months later. The interim report (Reference 10) was published on 18 May 2011 and the final report on 11 October 2011 (Reference 11).

The key impact on GDA is that, as we were waiting for any lessons learnt from Fukushima to emerge in the final report, we did not believe it was appropriate to draw conclusions from our GDA assessment work in June 2011 as originally planned, nor publish our GDA technical assessment reports on that date. In effect, our assessment was extended to await the recommendations of HM Chief Inspector's reports.

The interim and final reports identify the implications for the UK nuclear Industry and set out a number of recommendations for the UK Government, the UK Nuclear Regulator and the UK nuclear industry to address. In total, there are 38 recommendations, one of which has been completed, four of which are relevant to the Regulator, 23 of which are relevant to the nuclear industry and nine of which are generally relevant to the UK Government, the Regulator and the nuclear industry. The final recommendation requires reports of progress responding to the recommendations to be made to ONR by June 2012.

In an international context there are a number of ongoing initiatives:

- The European Nuclear Safety Regulatory Group (ENSREG) has defined a set of "Stress Tests" to be carried out in European member states for nuclear power plants in operation or being constructed. Each member state will report the outcome of the "Stress Tests" by the end of December 2011, and these reports will be peer reviewed in early 2012 by an expert panel drawn from European member states.
- IAEA has initiated a number of activities to draw lessons from the accident, assist the Japanese authorities and report to IAEA member states. These include:
  - A preliminary mission to find facts and identify initial lessons to be learnt, undertaken by a team of experts from across the world, conducted from 24 May to 2 June 2011.
  - An IAEA *Action plan on nuclear safety*, which is aimed at making nuclear safety post-Fukushima more robust and effective.
  - An extraordinary meeting of the Convention on Nuclear Safety to share lessons learnt and actions taken in response to events at Fukushima, to be held in August 2012.

The scope of the Step 4 technical assessment reports did not include Fukushima as the accident occurred after the Step 4 submissions were provided to us. So, to ensure that the lessons learnt from the Fukushima accident are considered within GDA, we raised a further GDA Issue on EDF and AREVA to address any lessons to be learnt for the generic UK EPR™ reactor design. This GDA Issue requests EDF and AREVA to demonstrate how they will take account of the lessons learnt from the events at Fukushima, both those arising out of EDF and AREVA's own internal reviews as well as those lessons and recommendations identified in HM Chief Inspector's interim and final reports. These should also take account of the wider international initiatives.

EDF and AREVA have provided a resolution plan for this Fukushima GDA Issue, including a description of how they will address the Chief Inspector's report's recommendations and we judge that this is credible. We will continue to assess their progress on this matter and closure of the GDA Issue will be required, alongside closure of all the other GDA Issues, before GDA could be considered complete.

Main features of the UK EPR™ reactor design and safety systems

The UK EPR™ reactor as proposed to us by EDF and AREVA is described in the EDF and AREVA December 2011 *UK EPR™ Pre-construction Safety Report* (PCSR), Reference 12.

EDF and AREVA describe the UK EPR™ reactor as an evolutionary four-loop Pressurised Water Reactor (PWR), with a net electrical output of between 1600 and 1660MWe being an evolution of the French N4 and German Konvoi designs. The N4 series is the latest family of four PWRs commissioned in France at the end of the 1990s, and the Konvoi is a series of German PWRs commissioned in the early 1990s. EDF and AREVA claim that the UK EPR™ reactor meets the 2000 version of the Franco-German technical guidelines developed between 1993 and 2000 and has a good level of compliance with the European Utility Requirements. The design therefore draws maximum benefit from the operating experience of the French and German fleets.

The UK EPR™ reactor core can accommodate different fuel assembly designs. There are 241 fuel assemblies, each containing 265 fuel rods. It is designed for enrichments up to 5wt% U^{235}, and for fuel rod burn-up of up to 62GWd/t.

The core is contained in a Reactor Pressure Vessel (RPV), and the reactor coolant system is a conventional design. The primary heat transfer mechanism is pressurised light water in four loops circulating through the core, transporting the heat to the four steam generators. The steam from the steam generators is transported to the single turbine by the secondary circuit pipework.

EDF and AREVA claim that the general layout of primary and secondary circuits closely resembles the N4s, with a few significant differences:

- Larger primary and secondary water volumes to increase the thermal inertia of the system and slow down changes of temperature in transients.
- The provision of a larger RPV. There is a heavy neutron reflector (baffle) between the core and the RPV to reduce the neutron fluence on the vessel, which is claimed to reduce the effect of irradiation embrittlement of the RPV.
- There are no RPV bottom penetrations. Removal of the bottom mounted in-core penetrations has the advantage of removing the risk of having to repair leaking penetrations in very adverse conditions, as well as that of facilitating implementation of a core-catcher in the reactor pit.

EDF and AREVA claim that the main safety systems, safety injection, steam generator emergency water feed and supporting electrical systems are designed along a four-train architecture (which gives four separate lines of protection for design basis accident sequences). Each safety train is set up in a separate building. Furthermore, two of these four buildings (and the fuel building) are “bunkerised” to strengthen their resistance to external hazards.

EDF and AREVA claim that the UK EPR™ reactor safety systems are designed to mitigate the consequences of plant failures, ensure reactor shutdown, removal of decay heat and prevention of radioactive releases. Key systems identified by EDF and AREVA are described below.

Reactor shutdown

- Reactivity is controlled by adjusting the boron concentration in the primary circuit and by adjusting the position of the Rod Control Cluster Assemblies (RCCA). The RCCAs are a fast shutdown system consisting of 89 rod control assemblies containing neutron-absorbing materials. EDF and AREVA claim that the boration system is designed to satisfy long-term sub-criticality requirements and ensure automatic reactor shutdown, for example in case of rods failing to insert in the core.

Emergency cooling

- The emergency feedwater system supplies water to the steam generators to maintain water level and remove decay heat following a loss of normal feedwater supplies.
- In the unlikely event of a loss of cooling accident, there is a safety injection / residual heat removal system consisting of four independent trains, each providing injection capability by an accumulator pressurised with nitrogen gas, a Medium Head Safety Injection system (MHSI) and a Low Head Safety Injection System (LHSI). The high head injection system, conventional in other PWRs, has been replaced by the MHSI system. This has been made possible by the large volume of reactor water and EDF and AREVA claim this can have benefits in some accident scenarios. Each of the four safety injection trains is provided with a separate suction connection to the In-containment Refuelling Water Storage Tank (IRWST).
- The IRWST is the source of borated water for safety injection and containment cooling in the event of a severe accident. In addition, the IRWST collects water discharged from the reactor coolant system, allowing it to be re-circulated by the Safety Injection System (SIS).

Containment

- The UK EPR™ reactor has a double concrete containment. The inner containment is made of pre-stressed concrete with a steel liner. The outer containment is made of reinforced concrete and is primarily intended to withstand severe external hazards (aircraft crash, explosion etc.). There is a containment heat removal system to control the containment pressure in the event of a severe accident.

Core meltdown

- EDF and AREVA claim that the concept of the UK EPR™ reactor decreases the potential core meltdown frequency by a factor of ten compared to plants presently in operation. In addition, in the unlikely event that core melt should happen, EDF and AREVA claim that the following UK EPR™ reactor systems would limit the consequences:
  - a primary depressurisation system to prevent core meltdown at high pressure;
  - a “core-catcher” to contain and cool the molten corium (i.e. the mix of fuel and reactor internals resulting from the meltdown of the core) if it were to escape from the RPV;
  - A system of passive autocatalytic recombiners inside the containment, to significantly reduce the likelihood of hydrogen concentration exceeding acceptable limits in accident conditions; and

- a spray system dedicated to pressure control and cooling inside the containment after reactor meltdown.

Summary of UK EPR™ reactor GDA safety and security submissions

A key aim of this report is to provide a summary of the assessment of the information ONR has gathered from EDF and AREVA during GDA Step 4 to address the points listed in Annex 3, which describes what ONR expects from a Requesting Party for GDA Step 4.

The information provided by EDF and AREVA for GDA is presented in a number of documents, including the GDA Design Reference and the GDA Safety, Security and Environment Submissions. The key documents for ONR's assessment include the generic Pre-construction Safety Report (PCSR), the Design Reference (DR) and the Submission Master List (SML). These are described below.

Generic Pre-construction Safety Report

EDF and AREVA's initial safety case for GDA Step 4 was described in their November 2009 PCSR (Reference 13). This was updated during Step 4 to take account of matters raised during our assessment: to improve the presentation of the safety arguments, and to include agreed design changes. The updates were incorporated into a consolidated version of the PCSR which was submitted in March 2011 (Reference 12).

Submission Master List

As we progressed through Step 4, to allow more detailed information to be examined, we requested submission of a selection of references identified in the PCSR. In addition, developments in the safety case, design modifications, and responses to regulator assessment questions arose during Step 4. The totality of the GDA submission is listed in the SML list which includes the documentation sampled by the regulators during GDA.

EDF and AREVA have provided and updated a SML since November 2009. The final SML was provided November 2011 (Reference 14), which incorporated all the submissions included in our Step 4 assessment.

Design Reference

EDF and AREVA were required to submit a Design Reference 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 design reference point date was set at end of 2008. The final version of the design reference was submitted in May 2011 (Reference 16).

The DR includes a small number of design changes that we have accepted into GDA. The design change details have been incorporated into all impacted DR documents, and the SML documentation including the PCSR.

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.

The scope of GDA includes the containment structure, the nuclear reactor buildings and supporting equipment within the nuclear island (i.e. within the main body of the reactor and auxiliary support buildings, such as diesel houses and fuel storage facilities). It also includes examination of the performance of these structures and components in the face of generic hazards such as earthquakes or airplane crash. It does not, however, include site-specific matters such as the cooling water pumphouse or the sea wall as these will be different at every site and can only be addressed at the site-specific stage.

Also, in some instances, final validation of the safety case cannot be completed until the final detailed design is developed for a specific site by a future licensee; until certain equipment designs are confirmed by their manufacturers / suppliers; or until the facility is being constructed and is in the process of being tested. In these technical areas the system and equipment safety functions and requirements are set out within GDA and the later validation and provision of additional evidence should underwrite the specifications that were provided in GDA and confirm that they have been achieved. This validation process is normal regulatory business and will be subject to appropriate regulatory controls.

Finally, there are some matters that are out-of-scope, such as the use of MOX fuel, because there is no current UK plan in relation to them.

A breakdown of the items that are out-of-scope is provided within Reference 17. 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. The impact that the out-of-scope items have had on our assessment varies between topic areas, and key out-of-scope items are identified in each topic area report. Examples of out-of-scope items are as follows:

- The quality assurance arrangements for reactor equipment manufacture, procurement and supply.
- Civil engineering detail design of some of the auxiliary buildings.
- Detailed Technical Specifications and emergency operating procedures.
- The detailed design of some mechanical and electrical equipment.
- Details of the plant maintenance schedule.
- Verification of electrical transient analysis.
- Radiation protection details for some maintenance practices.
- Load-following (variation of reactor power to respond to national grid demands).
- The use of reprocessed or mixed-oxide (MOX) fuels.
- Mid-loop operations for maintenance activities (operation with the main coolant loops partially drained).

However, it should be noted that the outcomes of GDA may have an impact on some plant areas that have been out-of-scope for GDA. For example, the nuclear safety-related buildings not included in GDA, such as the plant-specific cooling water pumphouses, will still need to take account of the civil engineering construction codes that we have examined in GDA. Future licensees will need to demonstrate that they have considered this as their design and construction plans progress.

Assessment strategy

The aim of GDA Step 4 was to provide an overall detailed design assessment of each design, and this report covers our assessment conclusions for the UK EPR™ reactor. We have focused on an examination of the safety claims, arguments and evidence for the UK EPR™ reactor. We have, on a sampling basis, looked at available detailed design level information and analysed the available evidence. Our objective was to ensure that sufficient evidence exists to support EDF and AREVA's safety arguments and safety claims that we examined in Step 3, and to ensure that it is adequate in the light of our current understanding of reactor technology.

In our GDA Step 4 assessment, we have assessed the safety claims, arguments and evidence as presented in EDF and AREVA's December 2009 *UK EPR Pre-construction Safety Report* (Reference 12), and supporting documents. We have compared these against the relevant parts of our SAPs (Reference 5). To help us in this task we developed a strategy to define both the technical areas to be sampled and those SAPs most relevant for Step 4, and we planned and conducted our assessment accordingly. In doing this, we took account of our expectations for modern reactors, as described above. So our sample included the defence-in-depth provided by the systems for shutting down and cooling the reactor, and for containment of radioactivity.

Specific assessment plans were developed for each technical area. As Step 4 has built upon our work in Steps 2 and 3, we targeted our sampling based on our increasing knowledge of the EDF and AREVA UK EPR™ reactor generic design and safety case. The Step 4 assessment plans also took into account the findings of our Step 3 assessment reports, including those technical issues that we had noted, in November 2009, as unresolved.

Some further information on the scope of the Step 4 assessment is given within this report in the summaries for each technical area.

Summary of ONR GDA findings

A significant amount of assessment was completed in GDA Steps 2 and 3. During Step 2 this was fairly limited in scope and depth, concentrating on EDF and AREVA's high-level safety claims. In Step 3 our assessment was wide ranging, focusing on the safety arguments, and was quite detailed in some topic areas. For some of these topic areas, the assessment of certain aspects was completed. This work is reported in detail in our Step 2 and Step 3 assessment reports, which are listed in Annex 2 and copies of which are available on our website: www.hse.gov.uk/newreactors.

The GDA Step 4 assessment of the UK EPR™ reactor has been a period of intense activity where both ONR and EDF and AREVA have expended significant effort.

ONR has used over 23,000 person-days of effort employing around £7.5m worth of technical contract support in the process. EDF and AREVA have provided us with over 3500 documents; we have posed over 1600 formal technical questions and, during Step 4 alone, we have held over 500 technical meetings. In some areas we identified significant issues, primarily due to a combination of late delivery of information from EDF and AREVA and a lack of clarity in the safety arguments and documentation.

EDF and AREVA have worked hard to close out these issues, and the technical questions we raised, and significant progress was made during Step 4.

The result was 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 well before any UK EPR™ nuclear power station construction project has commenced in the UK.

The sections below summarise the key findings of the GDA detailed design and safety case review for each of the technical topic areas. These primarily summarise the work that has been undertaken in Step 4, but for completeness, some topic areas also include findings from Step 3, where these were particularly significant. Full details are given in the individual topic area assessment reports that are listed in Annex 2 and are available on our website: www.hse.gov.uk/newreactors.

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 generic site boundary. 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.

For GDA, our assessment included the following:

- Dropped loads and impact, high energy line break, internal missile, fire, steam release, internal flooding, and internal explosion.
- Deep slice sampling of the evidence for a number of areas, including common cause failure and hydrogen generation.

- Examination of the principal claims and arguments presented by EDF and AREVA for redundancy and segregation of plant and equipment important to nuclear safety.
- Progressing those matters we raised during Step 3.

From our assessment, we have concluded:

- EDF and AREVA have been proactive in addressing observations made within Steps 3 and 4 of the GDA and this has resulted in positive improvements in the design of the UK EPR™ reactor, specifically, door control measures for doors performing nuclear safety functions, and improvements in fire modelling. These are examples that provide confidence in the strength and robustness of the safety case for Internal Hazards.
- Redundancy is 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, electrical supplies etc.) Additional protection comes from the physical segregation of each of the trains.
- There are areas where full segregation has not been achieved: in these situations claims and arguments have been presented relating to the application of additional passive protection and the use of geographical distance to separate the trains.
- The design of the UK EPR™ reactor is broadly in line with our expectations in relation to current national and international standards, guidance and relevant good practice. Furthermore, a great deal of work has been undertaken by EDF and AREVA relating to detailed analysis of potential internal hazards which has arisen from a thorough understanding of both the safety case and the design.
- There are a number of areas where further internal hazards substantiation is required in order to ensure that the safety case for these specific hazards areas is robust and we have identified these as GDA Issues.

There are four GDA Issues in this topic area, related to:

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

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. This includes building foundations and the building superstructures. 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.

The design codes and methodologies proposed by EDF and AREVA have been examined in detail during GDA; however the application into site-specific structures can only be undertaken during the site-specific detail design phase. A further complication for this assessment topic area is the site-dependent nature of both the magnitude of the external hazards and the local conditions that may dictate design choices. As a consequence there are a number of areas where the detailed design cannot be confirmed until the site-licensing and construction phase, for example confirmation that the site specific seismic hazard is bounded by the generic site envelope used in GDA.

For GDA, our assessment included the following:

- Load schedule.
- Safety classification of structures.
- Use of finite element codes.
- Use of the design code ETC-C (Reference 18).
- Containment design.
- Nuclear island design.
- Aircraft shell design.
- Equipment qualification against hazards.
- Seismic margins assessment.
- Decommissioning.

A number of items have been agreed with EDF and AREVA as being outside the scope of the GDA process and hence have not been included in our assessment, for instance, detailed design of some of the auxiliary buildings. These primarily relate to those aspects of the design which cannot be undertaken until a site has been chosen.

From our assessment, we have concluded:

- The treatment of loads arising from hazards, methodologies for equipment qualification against hazards, seismic margins assessment, the safety classification of structures, and plans for decommissioning are broadly acceptable, although further work will be required at the site-specific phase.
- The process of designing the UK EPR™ reactor nuclear island structures has used a wide range of finite element codes and other analysis tools. These appear suitable for the purposes they have been used for, with the exception of the code used for the analysis of soil structure interaction, which is not yet sufficiently justified for softer sites that may be experienced in the UK. This will be progressed, as appropriate, in the site-specific phase.
- The use of the ETC-C (Reference 18) as a design code has been examined in some detail and it has been modified by EDF and AREVA during GDA to address some of our concerns. However,

there remain areas where there is not yet sufficient justification. We have identified three GDA Issues related to the use of ETC-C and the reliability it assures.

- The design of the containment structure has been subjected to considerable scrutiny and has generally been found to be satisfactory. This includes the use of grouted-in-place pre-stressing tendons, which is novel in the UK for nuclear applications. EDF and AREVA have also introduced some improvements, for example to the means of fixing the metallic containment liner to the concrete base mat. We do, however, have remaining questions relating to the justification of the beyond design basis capability and a GDA Issue has been identified for this topic.
- The design of the nuclear island structures, including the fuel pond, has been found broadly acceptable, although for some parts we have only seen information from the Flamanville 3 EPR construction project in France and these will undergo substantial re-analysis for application in the UK in order to reflect site and operator-specific requirements. There remains an issue on the overall design specifications (which are referred to as “hypothesis notes”) which we have identified as a GDA Issue. The hypothesis notes presented in GDA were Flamanville 3 specific examples and will require amendment for use in the UK.
- We are satisfied that the aircraft protection shell is sufficiently robust to withstand military and commercial aircraft impact.

There are six GDA Issues in this topic area relating to:

- Specification, methodology and hypothesis notes for the nuclear island structures.
- Use of the design code ETC-C in the UK.
- The reliability assured by design code ETC-C.
- Detailed methodologies for the treatment of soil structure interaction and seismic analysis.
- Beyond design basis behaviour of the inner containment.
- The analysis of the inner containment.
- Detailed methodologies for the treatment of soil structure interaction and seismic analysis.

Probabilistic Safety Analysis

Probabilistic Safety Analysis (PSA) is an integrated, structured, logical safety analysis that combines engineering and operational features in a consistent overall framework. It is a quantitative analysis that provides measures of the overall risk to the public that might result from a range of faults (for example, failure of equipment to operate, human errors, or hazards such as fires). PSA enables complex interactions, for example between different systems across the reactor, to be identified and examined and it provides a logical basis for identifying any relative weak points in the proposed reactor system design.

For GDA, our assessment included the following:

- Details of the PSA models and data, and the underlying supporting analyses.
- The methods, techniques and scope of the PSA.

- Conduct of an independent Risk Gap Analysis (RGA).
- Progressing issues identified during GDA Step 3.
- In addition, we asked EDF and AREVA to undertake sensitivity studies using the PSA model to demonstrate the impact of different levels of reliability and independence on the performance of the Control and Instrumentation (C&I) systems. This work underlined the importance of resolving the Regulatory Issue raised in the C&I topic area, concerning the system architecture and claimed reliabilities (see C&I section).

From our assessment, we have concluded:

- EDF and AREVA have provided large, full-scope, modern standards PSA as part of their overall GDA submission.
- The scope of the PSA includes internal faults, internal and external hazards, all operating states and reasonable allowances for maintenance and test. It also includes all significant sources of radioactivity.
- In PSA, initiating events or faults are those disturbances (for example the failure of a system to operate, or the start of a fire in an electrical system) that demand / require operation of safeguard systems to prevent radioactive releases. The initiating event identification process for the UK EPR™ reactor design conforms with current PSA standards and is satisfactory.
- The PSA is an adequate representation of the design described in the GDA submissions and there is good evidence that the PSA has been used to inform the development of the design.
- There are necessarily some areas where the analysis is incomplete or at an early stage, since detailed design information is not yet available, but these are identified within the PSA. These will be addressed at the site-specific stage.
- The results of the PSA show that the risk to the public is low and estimated risks are generally better than the Basic Safety Objectives (BSO) given in our SAPs (Reference 5).
- The PSA and its results meet our expectations.

There are no GDA Issues. However, some inputs can only be addressed in the site-specific phase so that the PSA will provide an appropriate tool to support operation of a UK EPR™ in the UK. Also there may be a need to review the PSA submission, should it be impacted by work undertaken to address other identified GDA Issues.

Fault Studies, Transient Analysis and Severe Accidents

Fault Studies

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 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.

For GDA, our assessment included the following:

- The design basis analyses performed in support of the UK EPR™ reactor, sub-divided into:
  - faults where the integrity of the primary circuit is maintained (such as loss of feed faults, loss of flow faults, and reactivity faults);
  - faults where a break occurs somewhere on the primary circuit (Loss of Coolant Accidents (LOCA));
  - faults occurring during shutdown conditions; or
  - faults occurring away from the reactor in the spent fuel pool.
- The validation of the computer codes which are used to model design basis faults, including independent confirmatory analysis undertaken by our technical support contractors using alternative computer codes and analysis.

It was agreed with EDF and AREVA that it is more appropriate to assess operational matters such as load-following, the proposed Technical Specifications, the emergency operating procedures and the site-specific radiological consequence assessments during the site-specific phase. Hence these items are considered as being outside the scope of the GDA, although certain generic aspects, such as the limits and conditions for safe operation, or operator actions required to respond to faults, are covered within GDA.

From our assessment, we have concluded:

- EDF and AREVA have provided a safety analysis that is generally satisfactory but there are some areas where further work is required. These are identified below as GDA Issues.
- EDF and AREVA have undertaken a large amount of analysis work within the fault studies assessment area during GDA Step 4 and have made very significant progress against the issues identified in our GDA Step 3 assessment report.
- EDF and AREVA have improved the design basis safety case for the UK EPR™ reactor through the additional analysis performed in response to our regulatory challenges.
- EDF and AREVA have performed a large number of additional sensitivity studies and have demonstrated that the design is particularly well protected against passive single failures. They have also been able to extend the design basis to cover complex situations in which a combination of events may occur, although there is still some further work to be done by EDF and AREVA in this area and we have identified a GDA Issue.
- EDF and AREVA have proposed a number of important design changes to the reactor protection system on the UK EPR™ reactor that will significantly improve the safety of the design. The design changes include:
  - an increase in the automatic partial cool-down rate following a loss of coolant accident which has considerably increased the margin of safety for these faults;
  - an improvement to the activity detectors for Steam Generator Tube Rupture (SGTR) faults.

- the addition, on one of the diverse reactor protection systems, of a high neutron flux trip signal, a high axial offset trip signal, a hot leg high pressure trip signal, a low reactor coolant pump speed trip signal; and
- the addition, on the diverse reactor protection system, of an automatic actuation signal for the emergency feedwater system using a low steam generator pressure.
- Automatic activation of the emergency boronation system in the event of a steam line break.

There are five GDA Issues in this topic area related to:

- Heterogeneous boron dilution events.
- Implementation of modifications to the reactor protection system and provision of further analysis to ensure adequate diversity for frequent faults.
- The spent fuel pool and faults associated with the cask loading pit.
- Steam generator single tube rupture faults and design changes to the protection for these faults.
- Design basis analysis of failures of essential support systems.

We believe that it is highly unlikely that there will be a need for any significant changes to plant layout or safety systems from addressing these Fault Studies-related GDA Issues.

Containment and Severe Accidents

Included within the Fault Studies area is the topic of severe accident mitigation. Here ONR is looking at safety arguments for challenges to the containment from high pressure or temperature in accident conditions and design features that are provided to cope with such challenges as a molten core. For the UK EPR™ reactor one of the key features of the safety case is the claimed ability to retain and cool the molten core within a core-catcher, built into the containment structure underneath the reactor pressure vessel. The main lines of our investigation have been the examination of the key uncertainties within the modelling of these complex phenomena and how they are validated, and, the capability of the combustible gas control system to maintain the containment hydrogen concentration within acceptable limits.

For GDA, our assessment included the following:

- Thermal-hydraulics challenges to the containment during design basis accident conditions.
- Strategy for severe accident progression management.
- Key features of the design to mitigate against the consequence of a severe accident.
- Challenges to the containment hydrogen control and management system and the ability to maintain the containment hydrogen concentration within acceptable limits.
- Aspects of validation of the computer codes employed to support the claims within the safety submissions.

From our assessment, we have concluded:

- During the Step 4 assessment, EDF and AREVA have provided additional information and supporting analysis to improve their safety case in response to our regulatory challenges.
- Considering the large uncertainties associated with conditions likely to exist during severe accidents, an acceptable safety case has been made for the main design features of the UK EPR™ reactor, including the core-catcher.
- An adequate safety case has been provided to show that the containment design can withstand the various thermal hydraulics challenges in design basis accident conditions.
- There are complex phenomena associated with the thermal hydraulics and chemistry associated with core melt progression, configuration, transfer and final stabilisation during accident transients. Large uncertainties are associated with predicting this behaviour using the current computer codes but the safety submissions provide a reasonable understanding of the complex melt processes.
- The hydrogen management and control system designed to mitigate against the hazards of combustible gases released during severe accidents has received a reasonable coverage within the safety submission and is the subject of a GDA Issue, reported under the reactor chemistry topic area.
- International research is continuing to further improve the understanding of the phenomena of core melt progression and molten core concrete interaction. We note that EDF and AREVA have been active in support of these areas and intend to maintain their involvement.

There are no GDA Issues in this topic area.

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 (C&I) but in other countries the order is reversed and I&C is used, but we will refer to the former throughout this report.

For GDA our assessment covered topics of particular relevance to C&I system-level design, including review of C&I system architecture and the diversity of systems implementing reactor protection functionality. This included:

- Arguments and evidence presented in the safety case.
- Principal design and implementation standards for all C&I safety and safety-related systems (i.e. the Systems Important to Safety (SIS)).
- Key C&I platforms (e.g. covering the Safety Class 1 Protection System (PS), Class 2 Safety Automation System (SAS) and Class 3 Process Automation System (PAS)).
- C&I architecture including provision for defence-in-depth, independence and diversity (including review of EDF and AREVA’s responses to the Regulatory Issue).

- Diversity of those systems contributing to implementation of the highest category safety functions (e.g. PS and SAS / PAS).

At an early stage we identified significant concerns in relation to the adequacy of the UK EPR™ reactor C&I architecture, namely:

- It was complex and had a high degree of interconnectivity, which resulted in a lack of independence between control and protection systems.
- The reliability claims for the computer-based SIS went beyond what is accepted as normal practice and we believed that, with the current state of methods for justifying such systems, the figures used were impossible to substantiate.
- There was shortfall in the provision of safety classified displays and manual controls in the control room.

These issues were sufficiently important for us to raise a Regulatory Issue in April 2009. EDF and AREVA's response to the Regulatory Issue included provision of a non-computer-based back-up system, safety classified displays and manual controls in the control room, reduction of reliability claims for the computer-based SIS and other measures such as one-way network communication from high to lower classified safety systems. By November 2010, we were satisfied that, while there was still outstanding work to complete, the majority of the key actions associated with the Regulatory Issue had been addressed and we wrote to EDF and AREVA to close the Regulatory Issue. The remaining work was to be pursued as part of the ongoing GDA Step 4 assessment.

From our assessment, we have concluded:

- The PCSR and supporting documentation cover the main C&I SIS expected in a modern nuclear reactor.
- The principal design and implementation standards used by EDF and AREVA for all C&I SIS are broadly in accordance with those expected in the nuclear sector.
- EDF and AREVA's safety case for the sampled key C&I SIS and platforms used to implement the SIS is broadly in line with our expectations.
- The significant C&I architecture concerns raised in the Regulatory Issue have been addressed by the introduction of a safety Class 2 Non-computerised Safety System (NCSS), the introduction of one-way network communication from the PS to lower classified systems, Class 1 displays and manual controls, and reduction of reliability claims for the computer-based SIS.
- We do not believe that the classification scheme for C&I is fully satisfactory. This will be pursued as part of the Cross-cutting GDA Issue on the classification of Structures, Systems and Components (SSC).
- A significant amount of further work is required in some areas and these have been identified as GDA Issues.

There are six GDA Issues in this topic area that relate to:

- Revision of the safety case to address the introduction of the NCSS, including the demonstration of its diversity from the computer-based safety systems.

- Finalisation of the scope of the 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 SIS.
- 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).
- An appropriate justification for equipment that incorporates SMART devices (i.e. all the equipment that makes use of built-in computer chips and software).
- Revision of the SAS / PAS safety case to address obsolescence of the SPPA-T2000 (Siemens S5 based) platform.
- Justification of the adequacy of the C&I architecture (ongoing actions related to closure of the Regulatory Issue).

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.

A number of items have been agreed with EDF and AREVA as being out of scope of the GDA, primarily because they relate to aspects of the design which cannot be undertaken until the site-specific stage of the work. It is only then that the detailed design, specification and procurement will be undertaken, including verification of electrical transient analysis, high and low voltage protection, grid connections and co-ordination with grid protection systems. For example, for some electrical equipment, the safety functions and the specification of technical requirements were examined in GDA, but the evidence of fulfilment of those functions and requirements can only be demonstrated when the detail design of the equipment is completed and it has been tested, during the site-specific phase.

For GDA, our assessment included the following:

- Review of power system protection in the generic UK EPR™ reactor design.
- Review of the principles and methodologies that show the resilience of the electrical distribution network to the effects of fast transient disturbances.
- Review of design and construction rules to be followed for the UK EPR™ reactor electrical systems.
- Study of three-phase and single-phase short circuits on the system.
- Study of the effects of transient disturbances on the electrical system during motor starting and power system fault conditions.
- Review of earth fault monitoring on the 10kV system.
- Review of the Direct Current (DC) and uninterruptible Alternating Current (AC) systems.
- Review of power quality on the distribution system.

- Review of maintenance philosophy and condition monitoring.
- Review of earthing and lightning protection.
- Review of the electrical system design against ONR SAPs.
- Impact of grid disturbances.

From our assessment, we have concluded:

- Independent assessment of the EDF and AREVA design, including modelling extremes of transient operating conditions, has confirmed the resilience of the design of the electrical network to system disturbances due to such events as short circuits or overvoltage transients.
- The structure of the electrical system provides sufficient capacity to meet load requirements in all operating modes of grid supply, diesel supply and battery supply. Capability is provided in the system to facilitate maintenance of electrical systems while maximising supply continuity. Continuity of supply can be maintained in the event of unavailability of equipment due to faults.
- The protection principles provide a good basis for protecting the electrical system to minimise the effects of electrical faults.
- The Class 1 battery-powered systems are designed in a well-structured manner according to defined and documented processes. Adequate margins are applied and battery rating is based on worst condition of operating temperature and ageing.
- The basic structure presented for equipment specifications is comprehensive and provides a sound basis for specifying requirements during detailed design in the site-specific phase.
- Although we have no significant concerns regarding the system integrity, EDF and AREVA have yet to provide the evidence to support their claims. A GDA Issue has been identified for the supply of this evidence.
- Although we have assessed the principles on which the UK EPR™ reactor design is based, including performance specifications, the detailed design will be carried out at the site-specific stage and this has limited the extent of our assessment. As a result we will need to assess the detailed design when it is available. This will be progressed during the site-specific phase.

During the course of the assessment, discussions have taken place with EDF and AREVA on subjects arising from the assessment. This has resulted in a number of changes to either the design or the requirement for additional design verification studies. The most significant changes agreed have been as follows:

- Removal of the time delay on the high voltage circuit breaker operation. This gives faster fault clearance times which improve electrical system integrity.
- Modification of the safety classification of electrical systems to bring them into line with other equipment. This provides a standardised approach to safety classification across all disciplines. However, we do not yet believe that the classification scheme for SSCs in this technical topic area is fully satisfactory. This will be pursued as part of the Cross-cutting GDA Issue we have identified on classification of SSCs.

- Incorporation of studies of fast transients, Automatic Voltage Regulator (AVR) failure, and harmonics in the design process to address potential threats to system integrity.

There is one GDA Issue in this topic area related to:

- Provision, using a structure of claims, arguments and evidence, of substantiation that the design of the electrical distribution system fully meets its safety role.

Fuel Design

Within this topic we typically look at the performance of the reactor fuel under a wide range of in-reactor and storage conditions.

For GDA, our assessment included the following:

- Aspects of the fuel and core design that could conceivably lead to impairment of fuel cooling.
- Design criteria which during Step 3 appeared not to meet UK safety objectives or modern standards.
- Areas of the design that introduce novel features.
- Validation of key computer models.

The use of mixed oxide fuel, or reprocessed fuel is out of scope for GDA.

From our assessment, we have concluded:

- Fuel distortion and contamination of the cladding with CRUD,[†] will not significantly erode safety margins.
- Previously identified shortfalls in safety criteria to prevent fuel clad cracking in power transients have been rectified.
- The reactor control system will be able to mitigate the consequences of more frequent faults and avoid over-stressing the fuel cladding, independently of the reactor protection system.
- The fuel proposed for loading is a variant of the fuel operating successfully at Sizewell B and benefits from experience in existing reactors.
- Relevant experience indicates that there should not be any significant safety issues as the fuel reaches its limiting irradiation.
- Computer models used for the analysis are generally well documented and substantiated by experimental evidence. Our independent calculations give reasonable agreement with EDF and AREVA's predictions.
- An acceptable generic case has been made for loading AREVA fuel into the UK EPR™ reactor. However, ONR will need to assess the additional information that becomes available on a

[†] Crystalline material (usually oxides) deposited on a heat transfer surface, increasing its roughness and, in some cases, introducing a resistance to heat transfer.

site-by-site basis, including information from research programmes, details of specific core load proposals, and the monitoring of irradiated fuel during core reloads.

There are no GDA Issues in this topic area.

Reactor Chemistry

The safety assessment of the chemistry of new nuclear reactors 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.

For GDA, our assessment included the following:

- The justification, implications and control of primary coolant chemistry during all modes of operation. This included consideration of nuclear reactivity control using boron, the effects of coolant chemistry on the integrity of pressure boundaries, protection of fuel and core components and production, transport and deposition of radioactivity, including its influence on radiological doses to workers and ultimately to wastes.
- Features of the design, material choices or chemistry controls which reduce radioactivity to ALARP.
- The main secondary circuit systems which control or are influenced by chemistry.
- Engineered systems that allow the operator to control, monitor or change the plant chemistry.
- Storage of nuclear fuel within pools, including the effects of pool chemistry.
- Systems that mitigate the release of radioactivity to the environment in either liquid or gaseous form.
- Design basis and beyond design basis accidents, including the production, release and control of hydrogen and fission product nuclides.
- Arrangements for moving the safety case to an operating regime, including the derivation of suitable limits and conditions and the arrangements for specifying plant chemistry.

From our assessment, we have concluded:

- The UK EPR™ reactor has a number of sophisticated systems that allow the operator to control, monitor and change the primary chemistry, including those that are used during accidents. These are derived from, and often improve on, successful systems which are in operation in PWRs today.
- UK EPR™ reactor uses Passive Autocatalytic Recombiners (PAR) to control and remove combustible gases released into the containment during an accident. Although many of our questions have been responded to, there remain several aspects on which we are seeking additional information and we have identified this as a GDA Issue.
- EDF and AREVA propose to use enriched boric acid in the UK EPR™ reactor for efficiency and this requires more active management than natural boric acid. General arrangements for the

management of boron are satisfactory but we do still have questions regarding boron dilution, which are being taken forward in the fault studies topic area.

- The cobalt content of alloys in a UK EPR™ reactor has been reduced significantly in comparison with earlier generation reactors. Also, addition of zinc to primary coolant is proposed to help control radiation fields and this appears to be justified. Nevertheless, the increased power of the UK EPR™ reactor may mean that more radioactive material such as CRUD is produced and we have identified a GDA Issue seeking demonstration that radiation levels have been reduced to ALARP.
- EDF and AREVA have demonstrated that tritium can be managed safely, but the predicted levels of tritium will to some extent depend on the coolant management strategy adopted by a future operator. The safety case for this will therefore continue to develop during the site-specific construction and commissioning stages.
- The core-catcher is a complex system comprising a melting pit, a fusible plug, a transfer tunnel and a water-cooled spreading area. We assessed the chemical aspects including the extensive testing and calculation by AREVA, by European research institutions and elsewhere. There are uncertainties in some of the predictions but we are satisfied that the overall core stabilisation goal is assured.
- The UK EPR™ reactor incorporates dedicated systems for the storage, processing and treatment of radioactive gaseous and liquid effluents. We are satisfied with the chemistry aspects of these systems.
- As a result of the GDA assessments, the generic PCSR for the UK-EPR™ reactor has been updated to include a chapter dedicated to Reactor Chemistry. This is a valuable addition to the safety case.
- As a result of the GDA assessment discussions, EDF and AREVA introduced some changes to the UK EPR™ reactor start-up procedure to improve plant conditions.

There are two GDA Issues in this topic area related to:

- Evidence supporting operation of the combustible gas mitigation system.
- Demonstration that radiation levels have been reduced to ALARP.

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.

For GDA, our assessment included the following:

- Engineered features that would restrict exposures of workers to ionising radiation “so far as is reasonably practicable” (SFAIRP) during normal operation.
- The approach taken to optimise exposures of workers to ionising radiation when carrying out high-dose work activities.

- Engineered features would restrict exposures of workers to ionising radiation to SFAIRP during accident conditions.
- Radiation sources.
- Designated areas (radiological classification of areas / radiological zoning).
- Shielding.
- Contaminated areas.
- Ventilation.
- Radiological instrumentation.
- Decontamination.
- Optimisation for work activities (including fuel route).
- Waste handling and decommissioning.
- Public exposure from "direct shine" (direct radiation originating from within the site boundary).
- Persons on-site during accident conditions.
- Intervention of personnel during accidents.
- Criticality safety for fuel stored outside the reactor core (e.g. in spent fuel pools).

A number of items have been agreed with EDF and AREVA as being outside the scope of the GDA process as they are heavily reliant on operational factors, and hence these have not been included in our assessment. These include mid-loop operations, and some details of radiological protection aspects of operation and maintenance practices which will be assessed, as required, at the site-specific phase.

From our assessment, we have concluded:

- The plant and its operations have been designed to ensure that engineered features would restrict ionising radiation exposures to workers to SFAIRP during normal operation.
- The plant and its operations have been designed to ensure that engineered features would restrict ionising radiation exposures to workers to SFAIRP during accident conditions.
- The approach to optimising radiation exposures of workers when carrying out high-dose work activities is adequate.
- Predicted doses to members of the public are very low.
- The criticality safety case for stored new and used fuel is satisfactory.
- Radiological zoning for restriction of radiation exposure to workers is fundamental to the design of the nuclear island, as bulk shielding is provided by concrete and is thus linked with civil engineering aspects. The radiological zoning classification scheme underpinned by design shielding calculations is not referenced in the PCSR for the UK EPR™ reactor design. We have therefore identified a GDA Issue to address this matter.

There is one GDA Issue in this topic area related to:

- Radiological zoning and bulk shielding.

Mechanical Engineering

This typically includes the safety assessment of mechanical items important to safety such as pumps, valves, lifting equipment including cranes, fuel handling equipment, ventilation systems etc. It also includes the layout and routeing of the mechanical equipment and systems to ensure that appropriate maintenance regimes can be developed, and that equipment is protected from hazards and degradation.

Much of EDF and AREVA's GDA submission has been restricted to high-level specifications, since the detailed equipment designs will be defined as part of procurement, and this has limited the extent of our assessment. Nevertheless, for GDA our assessment included:

- Assessment against the safety functions of reactivity control, heat transfer and removal, and containment of radioactive substances associated with mechanical equipment and systems.
- Review of a wide range of mechanical items and systems important to safety, including cranes used for nuclear lifting, nuclear ventilation systems, pumps and valves, heat exchangers and associated heat transport systems, Control Rod Drive Mechanisms (CRDM), and mechanical handling systems.
- Assessment of the scope and extent of claims, arguments and evidence presented.
- A review of the level of design completeness.
- Assessment of safety categorisation and classification, design and reliability claims and equipment qualification.
- Consideration of the layout, access, ingress and egress provisions to facilitate operation, inspection, testing, maintenance and equipment replacement.
- The mechanical engineering design process described by EDF and AREVA and examples of detailed design information from other projects such as the Flamanville 3 EPR construction project in France.

From our assessment, we have concluded:

- In general the UK EPR™ reactor has evolved from a good nuclear engineering pedigree, and the mechanical engineering systems and equipment are well supported by operational experience feedback.
- Information from factory acceptance tests and site acceptance tests, which in general form an important suite of evidential information, are not generally available within GDA since in many cases suppliers have not yet been selected.
- In response to our assessment, EDF and AREVA have made improvements to the safety justification for lifts of nuclear safety significance by identifying preferred load paths, in particular for the RPV head lift, and the lift of the spent fuel pool stop-gate. We consider these represent a significant improvement in safety analyses.

- EDF and AREVA have made improvements to the safety classification of mechanical equipment in response to our assessment and this will be further applied to the developing design through the Cross-cutting GDA Issues identified on classification of SSCs. This will help ensure an appropriate graded approach to safety during design, procurement, operation, and maintenance.
- The Spent Fuel Cask Transfer Facility, used to transfer fuel out of the spent fuel pool uses a bottom-loading design to avoid the lifting hazard associated with a large cask of spent fuel. This introduces the requirement for a complex interface between the spent fuel cask and the underside of the fuel loading pit which is connected to the spent fuel pool. We have assessed this and are satisfied with the mechanical engineering design aspects of this feature.

There are no GDA Issues in this topic area.

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 assessment (including neutron irradiation embrittlement).

For GDA, our assessment included the following:

- Categorisation and classification of SSCs.
- 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).
- Lifetime ageing of materials (including neutron irradiation embrittlement).
- In-service inspection to the extent of ensuring that there is adequate access, but noting that detailed in-service inspection proposals have been agreed as being outside the scope of GDA.
- A particular focus on components where it is necessary to show that the likelihood of gross failure is so low that it can be discounted. EDF and AREVA have designated these as High Integrity Components (HIC).

From our assessment, we have concluded:

- EDF and AREVA have designed the UK EPR™ pressure vessels and piping against the French nuclear design code, RCC-M (Reference 19). The design requirements set by the RCC-M code have been reviewed and are judged to be generally acceptable.
- The basis of RPV construction with a circumferential weld at core mid height has been appropriately justified.
- The principle of using of cast stainless steel for the reactor coolant pump bowl construction has been justified.

- EDF and AREVA have proposed the use of Alloy 690 in the “thermally treated” condition, and we consider this is a sound choice of material for steam generator tubing.
- There are a small number of critical components for which it is necessary to show that the likelihood of gross failure is so low that it can be discounted. We do not accept that the normal code requirements are sufficient to provide this level of confidence and EDF and AREVA have accepted the need to make a higher level of demonstration of structural integrity, integrating supplementary fracture mechanics analyses, material toughness and qualification of manufacturing inspections.
- EDF and AREVA’s approach to fracture mechanics was found to give some different results to the UK approach. Following our review, EDF and AREVA have developed an alternative approach that we are satisfied with, but further detailed assessment of some of the fracture mechanics calculations is still required. This has been identified as part of a GDA Issue.
- We found that EDF and AREVA’s original inspection proposals did not meet our expectations. A satisfactory position has now been reached for the ferritic welds in the main vessels, but the proposals are not yet sufficiently developed for the austenitic and dissimilar metal welds in the reactor coolant loop pipework. This has been identified as part of a GDA Issue.
- Due to the extensive discussions in this topic area, a number of the important reports on avoidance of fracture for the HICs arrived later than had been originally planned. An initial review gives confidence in the approach used, but a more detailed assessment is required. A GDA Issue has been identified to support this ongoing assessment work and to provide additional evidence to justify claims for Non-destructive Testing (NDT) capability.
- The RPV material surveillance samples are placed between the reactor core and the reactor pressure vessel, where the energy spectrum of the neutrons will differ from that seen by the vessel. We have identified a GDA Issue requiring justification of the proposed surveillance scheme.
- We do not believe that the classification scheme for pressurised mechanical components is fully satisfactory. This will be pursued as part of the Cross-cutting GDA Issue on classification of SSCs.
- We do not believe that the consequences of failure of vessels, tanks, pumps and valves have been adequately addressed. This will be pursued in the Internal Hazard topic area under the GDA Issue identified on consequence analysis for failure of pressure boundary components.

There are 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 HIC.
- Justification of the RPV surveillance scheme.

Human Factors

Human Factors 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, Human Factors 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.

For GDA, our assessment included the following:

- Substantiation of human-based safety actions - ensuring that the risks from human actions have been reduced to ALARP. This included providing judgement on the completeness of the human based safety claims, and the adequacy of the justification or process to ensure that claims are reasonable and will be achieved by the design.
- Generic Human Reliability Assessment (HRA); particularly relating to HRA methods and application.
- Engineering systems' maintenance reliability from a human factors perspective.
- Human Factors Integration (HFI) into the design and safety case of the UK EPR™ reactor.
- Plant-wide generic Human Factors assessment to provide a judgement on the adequacy of the overall plant design from a human factors perspective.

The following items have been agreed with EDF and AREVA as being outside the scope of GDA:

- Team organisation.
- Staffing levels.
- Operating and maintenance procedures.
- Use of state-oriented approach.
- Display breakdown.
- Training.

From our assessment, we have concluded:

- Overall, we consider that EDF and AREVA have not presented an adequate safety case for HF. EDF and AREVA have provided some additional evidence relating to their design process, but much of this was received late in our assessment. They have only been able to provide a very small part of the required substantiation for their key Human Factors claims. This results in a substantial gap in their safety submission for GDA remaining at the end of GDA Step 4 and this is being progressed as a GDA Issue.
- We accept that there is a significant difference in the regulatory approach to Human Factors between the UK and France and we consider that this has contributed to the position.
- The material that we have assessed to form our judgements has largely been extracted from the considerable amount of documentation provided from the Flammanville 3 design. EDF and AREVA have not provided a consolidated Human Factors safety case based on appropriate Human Factors analyses aligned with UK expectations. Furthermore, the timing of documentation supplied predominantly in response to regulatory questions and observations, was very late in the GDA Step 4 process and we have not yet been able to assess it in its entirety.

- We recognise that the UK EPR™ design is an evolution of a standard PWR and consequently benefits from significant operating experience (particularly relating to N4 and Konvoi plants). We also note that the PSA model shows that the safety of the UK EPR™ is not overly sensitive to human errors and we believe that, should subsequent Human Factors assessment reveal further deficiencies in the design or safety analysis, Human Factors solutions can be developed and implemented without undue effect on the design of civil structures.

There is 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.

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.

For GDA, our assessment included the following:

- The management system, including audit and assessment, non-conformance and records management.
- Training and competency of personnel.
- QA arrangements for control of design development.
- QA arrangements for software control supporting design development.
- QA arrangements for control of design changes.
- QA arrangements supporting the procurement of GDA services.
- Configuration control of GDA submission documentation, i.e. the Safety Case, DR and the GDA SML.
- The Project Quality Assurance Plan and the quality assurance-related sections of the PCSR.

The quality assurance arrangements for all manufacturing activities have been agreed as being outside the scope of GDA and will be addressed during the site-specific phase.

From our assessment, we have concluded:

- EDF and AREVA have developed and applied suitable quality management system (QMS) arrangements to the UK EPR™ reactor project and these have included adequate project controls and suitable execution of audit and assessment activities.
- In response to our assessment, EDF and AREVA are taking steps to improve the management of GDA supplier selection, and non-conformances arising from supplier audits.

- EDF and AREVA have well-established arrangements for the development and maintenance of technical competency and have demonstrated adequate competency of project personnel involved in the UK EPR™ reactor project.
- The UK EPR™ reactor design was frozen in December 2008 based on Flamanville 3 reference design configuration. Design changes arising from Flamanville 3, and other changes proposed by EDF and AREVA for inclusion in the UK EPR™ reactor, together with design changes arising from the UK regulatory assessment agreed for inclusion into GDA, have been adequately controlled, impact assessed and the details successfully incorporated into the relevant GDA documentation.
- Supporting documentation, including the PCSR and the PCER, impacted by agreed design changes and any other changes arising from GDA resolution plans will not be updated until the end of GDA. A joint GDA Issue has been identified by ONR and the Environment Agency to progress this within the Cross-cutting topic area, including application of arrangements for handing over any incomplete design changes and for later changes to other supporting documents, and permissioning activities and environmental permitting.
- EDF and AREVA have established arrangements for design engineering within their respective organisations. However, evidence for the overall controls for design detail has been limited and will be assessed further, where appropriate through the GDA Issue identified on design change implementation.
- Configuration control of the GDA submission document by EDF and AREVA has been good. The tools used to control the submission, the SML and the PCSR route map, have been independently reviewed and the completeness and accuracy assured.

There is 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.

Radioactive Waste and Spent Fuel Management

Under this topic, we have examined the proposals for the safe minimisation, handling, storage and disposal of radioactive waste arising from all parts of the power station, and we have reviewed the proposals for decommissioning. Where possible, ONR and the Environment Agency have worked together in our dealings with EDF and AREVA in this topic area.

The radioactive waste facilities not on the nuclear island will not be developed until the site-specific phase. So, for GDA, we asked to see sufficient information to give us confidence that these facilities can be developed and the spent fuel and waste can be safely stored and then retrieved, transported and, finally, disposed of.

For GDA, our assessment included the following:

- Whether the wastes that a UK EPR™ reactor will produce have been identified in sufficient detail.
- The suitability of the plans put forward for short-term storage and conditioning of the wastes for long-term storage and eventual disposal.

- The suitability of the plans for long-term storage of Intermediate Level Waste (ILW) and spent fuel to show that this is safe and that the waste will be in a condition that would allow it to be transported for disposal.
- Whether the wastes that a UK EPR™ reactor will produce are suitable for disposal.
- The outline plans for the decommissioning a UK EPR™ reactor.
- The suitability of proposals for knowledge management over the lifetime of the facilities.
- The ability of EDF and AREVA to produce the radioactive waste management safety case for the UK EPR™ reactor, showing the through-life safety proposals.
- The EDF and AREVA plan for the development of waste management facilities to show that these can be developed in a timely manner.

From our assessment, we have concluded:

- EDF and AREVA have identified the typical wastes that a UK EPR™ reactor will produce.
- EDF and AREVA have developed a robust set of credible waste management processes that could be used by a licensee to deal with the wastes produced.
- EDF and AREVA have worked together with the Nuclear Decommissioning Authority's Radioactive Waste Management Directorate to show that these wastes could be disposed of in a geological disposal facility.
- There is sufficient flexibility within the layout of the Effluent Treatment Building (ETB) to provide safe and environmentally acceptable short-term storage options for the wastes.
- The wastes are compatible with a range of conditioning processes and there is no reason to believe that the resulting products are not suitable for long-term storage and eventual disposal.
- The plans for long-term storage of ILW are similar to those used elsewhere in the UK nuclear industry.
- There is sufficient flexibility in the design of the spent fuel storage facilities to allow a licensee to address the needs of the long-term storage requirements so that spent fuel remains in a condition that would allow it to be transported for disposal.
- The plans for decommissioning a UK EPR™ reactor are to a suitable level to show that this can be achieved in a safe and environmentally acceptable way and that the wastes produced are suitable for disposal.

In undertaking our GDA Step 4 assessment, we have worked with the Environment Agency to ensure that all significant waste arisings and discharge routes have been identified by EDF and AREVA, and that those wastes can be effectively managed. We have not identified any significant issues, or significant design or safety case changes that could impact on radioactive waste arisings or have a significant negative environmental impact.

There are no GDA Issues in this topic area.

Cross-cutting Topics

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. These are discussed in this section.

Most of these "cross-cutting" aspects have been addressed within the topic area where the bulk of the work lies – i.e. the "lead" topic area. Examples are:

- Severe accidents.
- Boron dilution.
- SMART instruments (computer-based devices).
- Dropped loads.
- Radioactive source terms.

The assessment of these aspects is reported in the summary sections above, and within the detailed assessment reports.

However, for some Cross-cutting aspects, there is no obvious lead topic area and so these are reported within this section. These topics are:

- Management of design changes.
- Safety function (SF) categorisation and SSC safety classification.
- Operating limits and conditions and Examination, Maintenance, Inspection and Testing (EMIT).

There were, however, limitations on what aspects of these cross-cutting topics could be included within the scope of GDA:

- Only design changes which have significant impact on the safety submission have been agreed for inclusion in GDA, such as changes to address the regulatory concerns raised in our assessment (for example C&I architecture), and changes arising from EDF and AREVA's own proposals to improve the UK EPR™ reactor design. Other design changes will have to be incorporated at a later stage.
- Full application of the SF categorisation and safety classification of SSCs to the UK EPR™ reactor design requires a level of design detail and supplier information that was not available for GDA.
- Similarly, the QA arrangements for the control of design detail development post-GDA, and equipment manufacture has not been examined in GDA.
- It has also been agreed that full development of operational technical specifications and EMIT will be the responsibility of future plant operators.

From our assessment, we have concluded:

- EDF and AREVA have developed robust arrangements for managing agreed design changes within GDA.

- Generally, EDF and AREVA have submitted sufficient supporting documentation to underpin design changes that we have already agreed for inclusion in GDA. However, this is not the case for those design changes that remain at an early stage of development and further work will be required to progress some of these. This requirement has been identified within the GDA Issue for control and update of the GDA submission.
- EDF and AREVA have 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.
- Additional work is required within GDA to further apply these methodologies and criteria for the categorisation of SF and classification of SSCs throughout the UK EPR™ reactor design. This requirement has been identified as a GDA Issue.
- EDF and AREVA have provided a GDA safety case for design limits, conditions and EMIT requirements for the UK EPR™ reactor. The key design limits and conditions and EMIT principles provide a sound starting point for a site-specific safety case from which future operators can develop and derive operational technical specifications, operating constraints and EMIT programmes for a UK EPR™ reactor.

We have also asked EDF and AREVA to demonstrate how they will be taking account of the lessons learnt from the events at Fukushima, including from EDF and AREVA's internal reviews and from those lessons and recommendations that are identified in the HM Chief Inspector of Nuclear Installations' interim and final reports (References 10 and 11).

There are three GDA Issues in this topic area related to:

- The requirement for EDF and AREVA to further demonstrate that, in some areas, the methodology developed and applied for categorising SF and classifying SSCs is in line with UK and international standards and Relevant Good Practice (RGP).
- Implementation of design changes, and maintenance and control of the GDA submission documentation to include changes arising from resolution plans associated with GDA Issues, (including Fukushima) and to deliver updated versions of the key references to any DAC we may issue at the end of GDA. (This has been identified as a joint GDA Issue with the Environment Agency, since the same requirements apply to any Statement of Design Acceptability (SoDA) it may issue.)
- To respond to the lessons learnt from the Fukushima accident, both from EDF and AREVA internal reviews and in response to HM Chief Inspector of Nuclear Installations' interim and final reports (References 10 and 11). (This has been identified as a joint GDA Issue with the Environment Agency.)

Demonstration of "as low as reasonably practicable"

Our assessment in Step 3 concluded that EDF and AREVA's approach to ALARP was satisfactory and was in line with our expectations for the GDA process (Annex 3 of Reference 20). At the time of our Step 3 public report, we anticipated that the focus of ALARP discussions for Step 4 would be within each of the individual topic areas and would be primarily concerned with assessing EDF and AREVA's evidence justifying relevant good practices, or indicating that those relevant good practices had been adequately implemented or followed. This has proven to be the case. In some topic areas, additional design changes have been made as a result of our assessment and these are discussed elsewhere in this report. In some topic areas, there are matters that remain under discussion: these we have identified as GDA Issues and their resolution could lead to some further design changes. In addition, the PSA assessment topic area looked across the whole design to see that risk was balanced, with an absence of "weak" areas, and an overall level of public risk that was consistent with the Basic Safety Objectives (BSO) given in our SAPs.

Our GDA guidance (Annex 3 of Reference 20) notes four key elements to the ALARP justification and a summary of the current position on these is given here:

- EDF and AREVA conclude that there are no further reasonably practicable measures that can be implemented. Overall, we accept their conclusion subject to satisfactory resolution of GDA Issues and Assessment Findings. Future developments may identify new or enhanced standards that are judged reasonably practicable. Clearly, timescales and the status of the project when these new or enhanced standards arise will have an impact on reasonable practicability.
- The relevant good practices have been identified and summarised. Where our assessment does not fully concur we have identified GDA Issues for the more significant matters that need to be addressed before a final DAC can be issued, or GDA Assessment Findings where we are content that the matter can be satisfactorily dealt with on a site-specific basis. We will require all GDA Issues and Assessment Findings to be adequately addressed within GDA or as part of future site-specific activities, as appropriate.
- It is clear that 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 N4 and Konvoi. Further options for improvement have been considered and were deemed not reasonably practicable by EDF and AREVA. The conclusions were generally accepted, except in a small number of areas where our regulatory challenges in GDA have led to additional design changes. One example is the case of the C&I modifications we asked for, where EDF and AREVA's response included provision of an additional safety system. In this particular instance it was not the ALARP process that was the issue; rather we disagreed with the assumptions regarding the reliability claims and level of independence between existing systems, such that when acceptable engineering assumptions were used the analysis clearly pointed to the need for additional protection.
- We noted that good use had been made of PSA during the design process and as part of the GDA interactions.

Our overall conclusion from our detailed assessment in Step 4 is that, subject to satisfactory resolution of the GDA Issues, within GDA, and the Assessment Findings, as part of future site-specific activities, the current UK EPR™ reactor design has reduced risks to workers and the public to ALARP.

Security

Under this topic we consider whether the security protection provided on the nuclear power station is adequate to protect against the theft or sabotage of nuclear materials or associated facilities.

During GDA Step 4, OCNS, now ONR(CNS), has improved its understanding of the security philosophy applied to the UK EPR™ reactor design.

For GDA, our assessment included the following:

- Vital area identification and the related security measures (physical and electronic).
- Computer Based Systems Important to Nuclear Safety and the physical security of the associated equipment.
- Conceptual security arrangements (CSA) proposed by EDF and AREVA.

From our assessment, we have concluded:

- We are satisfied that the claims, arguments and evidence laid down within the conceptual security arrangements present an adequate security case for the generic UK EPR™ reactor design. From a security perspective the UK EPR™ reactor is therefore suitable for construction in the UK, although further development will be required by future site licensees during the site-specific phase.

There are no GDA Issues in this topic area.

Safeguards

Nuclear safeguards are measures to verify that states comply with their international obligations not to use nuclear materials (e.g. plutonium and uranium) for nuclear explosives purposes. Global recognition of the need for such verification is reflected in the requirements of an International Treaty on the Non-proliferation of Nuclear Weapons (NPT). The safeguards measures that apply in the UK follow from the NPT and also the requirements of the Euratom Treaty. They include the provision of nuclear material accountancy information combined with independent inspections by the European Commission (Euratom) and, in some instances, also IAEA, to verify the facility design, the nuclear material inventory and associated records.

Safeguards are not a formal part of the GDA process, but as any new power reactors built in the UK will be subject to safeguards obligations, we have adopted an approach of early engagement with the reactor design companies. The basic approach to applying safeguards at modern PWRs is quite mature and implementation does not involve fundamental design challenges, but is instead a matter of ensuring arrangements for the necessary equipment installation (e.g. a limited number of safeguards cameras and seals, with associated cabling) are included in planning for reactor construction and commissioning. We followed our early engagement in GDA Step 3 with a briefing event in September 2010 that included EDF and AREVA and prospective reactor operators, where we and the Euratom safeguards inspectorate covered the safeguards reporting and verification arrangements necessary for reactors of the UK EPR™ type. Follow-up discussions are underway with prospective reactor operators and the Euratom safeguards inspectorate to confirm that these detailed safeguards requirements are included in plans going forward, and this will be progressed as part of site-specific activities.

Conventional safety, construction and general fire precautions

As well as ONR's role for regulating nuclear safety, HSE is responsible for regulating conventional safety, by which we mean normal industrial matters such as safety during construction, and fire safety and protection provisions. Conventional safety is not within the scope of GDA, nevertheless ONR, together with colleagues from HSE, have taken the opportunity to ensure that EDF and AREVA are fully aware of their responsibilities in these matters.

As well as the general requirements of the Health and Safety at Work etc. Act 1974 (HSWA74), particular attention has been given to early engagement with respect to both the application of the Construction (Design and Management) Regulations 2007 (CDM2007) and the Regulatory Reform (Fire Safety) Order 2005 relating to general fire precautions (GFP). This has included a combination of workshops and formal meetings. The potential impact CDM2007 and GFP could have on the overall project, should both aspects not be adequately addressed prior to the construction of any proposed facility, has been stressed.

While we are aware that EDF and AREVA are making progress, some further work is required in the treatment of GFP aspects. ONR has suggested that there may be benefit in dealing with this issue at the design stage by encompassing the control measures necessary during the construction phase, and ongoing maintenance, as well as during day-to-day operations. EDF and AREVA are currently reviewing their design codes to ensure they better reflect UK expectations and the approach to GFP, including the application of existing relevant good practice.

We will engage with the various dutyholders (licensees, designers, contractors etc.) throughout the design and construction of the facility. The aim will be to satisfy ourselves that the project can be built safely, and can be used and maintained safely within the conventional non-nuclear meaning. We will do this by examination of policies and procedures, meetings with the dutyholders, and testing arrangements by inspection. Themes will include leadership for health and safety, competence of workers involved in the construction, and worker involvement in the management of health and safety on-site.

Western European Nuclear Regulators' Association

In 2008, the Western European Nuclear Regulators' Association (WENRA) published a set of reactor reference safety levels (Reference 21). Although these were intended primarily for operating nuclear reactors, we have considered these, where appropriate, in our assessment of the UK EPR™ reactor, as they are already covered within our SAPs and technical assessment guides, and form part of our guidance on the legal requirement to reduce risks "*so far as is reasonably practicable*" (SFAIRP).

Since then, WENRA has published two further documents:

- In 2009, a set of safety objectives for new power reactors (Reference 22), updated in November 2010. ONR was active in the development of these objectives and we consider them to be in line with our own SAPs, and therefore are included within GDA. As a result, we conclude that, once the GDA Issues have been dealt with, and the GDA Assessment Findings adequately addressed, the UK EPR™ will meet the WENRA safety objectives for new reactors.
- In 2011, a set of safety reference levels for waste and fuel pools (Reference 23). Again, we have reviewed the requirements of this document and have concluded that it would not have changed our Step 4 conclusions. This is because the reference levels for waste and spent fuel pools, in common with the reactor reference levels above, are already covered by our SAPs and technical assessment guides, and form part of our guidance on the legal requirement to reduce risks by SFAIRP.

Issues raised through the public involvement process / stakeholder engagement

We recognise the importance of building public confidence in our ability to secure the protection of people and society from the hazards of new nuclear power stations, and that working in a way that is open and transparent is a good way of helping build that confidence.

The GDA process was designed to be open and transparent, and decisions were taken early on to encourage the Requesting Parties to publish their safety, security and environmental submissions and to invite comments from the public on those. Summaries of the comments received are published in reports on the "public involvement process" at the end of each step of the GDA process. These reports are available on the GDA website: www.hse.gov.uk/newreactors.

During GDA Steps 2, 3 and 4, a total of 130 comments were received, of which 64 were directed at the Requesting Parties and 66 at ONR. Of these, 65 related to the designs being assessed, 29 related to the GDA process more generally, and 36 fell outside the scope of GDA.

The GDA website has continued to attract around 5000 visitors per month. We use the website extensively to publish information on the GDA process. We also continue to publish joint "new-build eBulletins" with the Environment Agency to notify subscribers of any new developments.

As well as publishing general information, our GDA guidance and technical assessment reports, we have published a range of other useful documents, including joint quarterly reports. These summarise where we are, highlight the key future challenges we face going forward, and describe the technical issues we have raised against each of the designs we are assessing.

We also continue to speak at regional, national and international events, and have proactively organised seminars for key stakeholders.

For more information on the public involvement process for GDA Step 4 see *Update on the Public Involvement Process for GDA Step 4 of the Generic Design Assessment Process,* (Reference 24).

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 with overseas regulators, particularly those in France, Finland and the USA, where the EPR reactor is also under active regulatory assessment. We have used these exchanges both to help our assessment (and theirs) during GDA Step 4 and to confirm that we are applying the best international standards.

This work has taken several forms in different topic areas:

- Taking information from overseas regulator websites.
- Sharing technical reports.
- Conducting joint inspections.
- Having 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, civil engineering, fault analysis, and radioactive waste management.

In addition, we have participated in working group meetings of the Multinational Design Evaluation Programme (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 ten countries where new nuclear power station programmes are commencing: USA, Canada, China, France, Japan, the Russian Federation, UK, Republic of Korea, South Africa and Finland, plus IAEA. ONR represents the UK and takes a full part in the information sharing activities. In specific meetings related to the UK EPR™ reactor, discussion has included the following topics: civil engineering; fault studies, control and instrumentation; control rod drive mechanisms; human factors; structural integrity; PSA; radiological protection and oversight of manufacturing and fabrication of long lead items.

A measure of our commitment to working with overseas regulators can be gauged by the fact that, overall, we had around 70 such information exchange meetings during Step 4. In one instance, we issued a joint statement with French and Finnish regulators about the need for improvements and design changes on the C&I system.

We have found these exchanges of information most valuable and we have taken account of them in the individual topic areas as appropriate.

Summary of main design changes that result from our assessment

In response to our assessment challenges, EDF and AREVA have made significant changes to the safety case for the UK EPR™ reactor and a number of design changes.

The UK EPR™ GDA design is based on a Design Reference Point (DRP) of December 2008. Changes to the GDA Design Reference (DR) since this date were subject to a change control procedure which requires agreement from the Regulators to include any design changes in GDA.

During Step 4, 16 design changes were agreed for inclusion in GDA. These design changes arose from proposals from 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 challenges. The ten design changes that originated from the regulator’s interventions included the following aspects:

- The significant C&I architecture concerns raised in our Regulatory Issue have been addressed by the introduction of changes to the control and instrumentation, including:
  - the addition of a non-computerised C&I safety back-up system;
  - the introduction of one-way network communication from the protection system to lower classified systems; and
  - the introduction of Class 1 displays and manual controls and indications in the main control room and remote shutdown station.
- Improved controls for the opening of fire doors which form part of a nuclear safety fire barrier.
- Improvements to the means of fixing the metallic containment liner to the concrete base mat.
- The addition, on one of the diverse reactor protection systems, of a high neutron flux trip signal, a high axial offset trip signal, a hot leg high-pressure trip signal, and a low reactor coolant pump speed trip signal.

- Modification of the system for detecting small SGTRs.
- Changes to the classification of SSCs to reflect the difference in requirements between UK and French nuclear regulatory authorities.
- Automatic activation of the emergency boration system in the event of a steam line break.
- Change to the UK EPR™ reactor start-up procedure to improve plant conditions.

There may, of course, be a requirement for further design changes prior to issue of any final DAC depending on the responses to address the GDA Issues we have identified.

Summary of GDA Issues

We identified technical issues as early as possible in our assessment, and we discussed and progressed these with EDF and AREVA and attempted to resolve them within Step 4. EDF and AREVA have worked hard to successfully close out many of the technical questions we raised. However, previous ONR and international experience has shown that, in projects such as GDA, it is not unusual for industry to take significant time to completely resolve some of the technical issues raised by regulators, in view of the need for new analysis, re-design, tests or research etc. to be carried out. Therefore, we always envisaged that there would be issues remaining at the end of Step 4.

In total there are 31 GDA Issues we have identified for the UK EPR™ reactor. These are described in the above technical sections and are listed in Annex 4. The full descriptions of the Issues and their associated "issue actions" were published on 14 July 2011 on our website: www.hse.gov.uk/newreactors. Further details on the background to the development of the GDA Issues is given in topic area summaries, above, and in the detailed technical assessment reports listed in Annex 2.

When the GDA Issues have been addressed to our satisfaction, we will be in a position to 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 will be permitted.

Requesting Party resolution plans

In response to the GDA Issues, EDF and AREVA have provided detailed resolution plans that identify the details of how they intend to respond to the issues. We have reviewed these resolution plans and discussed them with EDF and AREVA and we agree that they are credible. A credible resolution plan is one that provides persuasive arguments that the work proposed will be sufficient to satisfactorily 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. A timely manner here refers to the duration of resolution plan itself, not to the predicted start or end dates.

It should be noted, however, that these resolution plans represent only one way of tackling each GDA Issue and EDF and AREVA may, in the end, choose another equally effective way of responding. Also, the resolution plans in no way represent a contract from ONR to complete assessment of GDA Issues within a particular programme, or to reach agreement on the matter.

The resolution plan references are listed in Annex 4 and are provided in full on our website: www.hse.gov.uk/newreactors.

Assessment Findings

The Assessment Findings arising from our GDA assessment for the UK EPR™ reactor are identified in the detailed Step 4 assessment reports for each technical topic area. In total there are 484 Assessment Findings for the UK EPR™ reactor.

The Assessment Findings provide the link from GDA to site-specific assessment for important safety items. They are primarily about ensuring the provision of additional safety case evidence to confirm certain safety aspects as the project progresses through the detailed design, construction and commissioning stages. For example, for some mechanical equipment, the safety functions and the specification of technical requirements were examined in GDA, but the evidence of fulfilment of those functions and requirements can only be demonstrated when the detail design of the equipment is completed and it has been tested, during the site-specific phase.

Assessment Findings are also mostly matters that we would anyway have raised during our site-specific assessments. By identifying them now, 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, and it will be the responsibility of the future operator / licensee to ensure they are addressed appropriately.

Conclusions

This is the third public summary report on our GDA work for the UK EPR™ reactor and it summarises our findings at the end of GDA Step 4.

The aim of GDA Step 4 was to provide an overall detailed design assessment of each design submitted – in this case the UK EPR™ reactor – and, specifically, to:

- move from the system level assessment of Step 3 to a fully detailed examination of the evidence, on a sampling basis, given by the safety analyses;
- confirm that the higher level claims such as system functionality are properly justified; and
- complete sufficient, detailed, assessment to allow us to come to a judgement whether a DAC can be issued.

To achieve these aims, ONR has undertaken an in-depth assessment of the generic safety case. From a security perspective, we have examined the conceptual security arrangements.

For those assessment areas for which we only commenced work late during GDA Step 3, or for which insufficient information on the claims and arguments was available during that step, we have also completed work equivalent to the Step 3 overall design safety review.

EDF and AREVA's initial safety case for GDA Step 4 was described in their November 2009 PCSR (Reference 13). This was updated during Step 4 to take account of matters raised during our assessment: to improve the presentation of the safety arguments, and to include agreed design changes. The updates were incorporated into a consolidated version of the PCSR which was submitted in March 2011 (Reference 12).

We have undertaken a large volume of work and we have completed our planned assessment of the UK EPR™ reactor. EDF and AREVA have worked hard to close out many of the technical questions we raised, and we have judged many aspects to be acceptable and our assessment work in these areas is complete. We are thus confident that we have completed a meaningful assessment of the UK EPR™ reactor.

Nevertheless, we have identified 31 GDA Issues for the UK EPR™ reactor, which we require to be addressed before we would consider issue of a DAC, or allow any safety-related nuclear island construction to begin for power station based on the UK EPR™ reactor design. Some of these issues may be resolved with additional safety case changes while others may require design changes. We will summarise our progress on these in our quarterly progress reports, which we will continue to place on our website. We will also update the GDA Issues pages on our website as each GDA Issue is closed.

The scope of the Step 4 technical assessment reports did not include Fukushima as the accident occurred after the Step 4 submissions were provided to us. However, we have ensured that we will address the lessons from Fukushima by including this as a specific GDA Issue.

EDF and AREVA have produced a resolution plan for each of the GDA Issues, including the issue to address the lessons learnt from Fukushima. We have reviewed these and judged them to be credible.

EDF and AREVA have also updated their PCSR to reflect the outcomes of our assessment. We have reviewed this and are content that it is an adequate basis for reference in the interim DAC, noting that, in some technical areas, work will continue within the GDA Issues.

We have therefore concluded that we are largely satisfied with the design and safety case that has been presented to us by EDF and AREVA for the UK EPR™ reactor.

In recognition of this we have decided to issue an interim DAC.

The interim DAC does not in itself permit any additional action in terms of nuclear power station construction, but it does signify that a major milestone has been achieved in that we have reached the end of our planned assessment. It also means that our further assessment work will be targeted on the remaining GDA Issues that will be progressed in accordance with the resolution plans that EDF and AREVA have provided to us.

Once the work identified in the GDA Issues has been addressed satisfactorily, then we should be in a position to consider issue of a final DAC, which will be supported by a report of our assessment.

By completing a comprehensive, robust and independent assessment, and by identifying the GDA Issues and the Assessment Findings well ahead of any UK EPR™ reactor construction, we believe that we have met the key objectives of the GDA process.

Annex 1: Key GDA milestones

January 2007

HSE and EA publish guidance on the GDA process.

July 2007

Four companies make valid applications for GDA:

- EDF and AREVA – UK EPR™ reactor
- Westinghouse Electric Company LLC – AP1000 reactor
- GE-Hitachi Nuclear Energy – ESBWR reactor
- Atomic Energy of Canada Limited – ACR-1000 reactor

July 2007

GDA process launched (Step 1).

September 2007

Initial assessment of the designs begins (Step 2).

March 2008

HSE and the Environment Agency announce that their initial assessment of four new nuclear power station designs found no shortfalls at this stage.

April 2008

Atomic Energy of Canada Ltd announces that it is withdrawing its ACR-1000 design from the assessment process.

June 2008

HSE and the Environment Agency announce that they are starting the next, more detailed stage of the assessment process for the remaining three designs (Step 3).

September 2008

GE-Hitachi requests a temporary suspension from GDA. As a result, both Regulators suspend assessment work on the ESBWR reactor.

May 2009

HSE and the Environment Agency publish their first quarterly report for 2009 (January–March), which provides an update on their assessment work. This is the first of a series of regular updates to be produced.

July 2009

HSE and the Environment Agency publish their second quarterly report for 2009 (April–June). This provides an update on their work to assess new nuclear power station designs.

October 2009

HSE and the Environment Agency publish their third quarterly report for 2009 (July–September). This provides an update on their work to assess new nuclear power station designs.

November 2009

HSE publishes Step 3 reports. The detailed Step 4 assessment begins.

February 2010

HSE and the Environment Agency publish their fourth quarterly report for 2009 (October–December). This provides an update on their work to assess new nuclear power station designs.

April 2010

HSE and the Environment Agency publish their first quarterly report for 2010 (January–March). This provides an update on their work to assess new nuclear power station designs.

May 2010

Environment Agency begins a public consultation, running until September 2010, to help inform its decision on the designs.

June 2010

HSE and the Environment Agency publish guidance on “Management of GDA outcomes”. This guidance sets out the outcomes that can be expected in June 2011, when we were expecting to complete our assessment of the safety cases of both the designs. It also simplifies and makes clear what these outcomes mean and how any outstanding GDA Issues will be managed subsequently within the GDA process.

July 2010

HSE and the Environment Agency publish their second quarterly report for 2010 (April–June). This provides an update on their work to assess new nuclear power station designs.

October 2010

HSE and the Environment Agency publish their third quarterly report for 2010 (July–September). This provides an update on their work to assess new nuclear power station designs.

January 2011

HSE and the Environment Agency publish their fourth quarterly report for 2010 (October–December). This provides an update on their work to assess new nuclear power station designs.

March 2011

On 11 March 2011 an earthquake and tsunami inundate the Fukushima-1 site in Japan, resulting in massive damage around the site and loss of cooling systems for Reactor Units 1 to 3. There are several explosions and what is predicted to be melting of the fuel in the reactors leading to major releases of radioactivity, initially to air but later by leakage of contaminated water to sea.

On 14 March 2011 the Secretary of State for Energy and Climate Change requested HM Chief Inspector of Nuclear Installations to examine the circumstances of the Fukushima accident to see what lessons could be learnt to enhance the safety of the UK nuclear industry. He requested an interim report to be provided by the middle of May 2011 and a final report within six months.

It is decided to delay drawing conclusions from GDA until the lessons learnt from Fukushima emerge.

April 2011

HSE and the Environment Agency publish their first quarterly report for 2011 (January–March). This provides an update on their work to assess new nuclear power station designs and looks at the likely implications for GDA following the events at Fukushima.

May 2011

HM Chief Inspector of Nuclear Installations publishes his interim report on the lessons learnt from the Fukushima accident in Japan.

July 2011

HSE and the Environment Agency publish their second quarterly report for 2011 (April–June), identifying and listing the GDA Issues, which are also published on the GDA website. The Requesting Parties resolutions plans, with the exception of the resolution plan for identifying and applying the lessons learnt from the Fukushima accident, are also published.

October 2011

HSE and the Environment Agency publish their third quarterly report for 2011 (July–September). HM Chief Inspector of Nuclear Installations publishes his final report on the lessons learnt from the Fukushima accident in Japan.

October–November 2011

Requesting Parties submit resolution plans for the Fukushima lessons learnt GDA Issue.

December 2011

ONR publishes Step 4 summary, assessment and other reports which set out its findings and conclusions of the assessment. ONR also issues an interim DAC for the EDF and AREVA UK EPR™ reactor.

Annex 2: Generic Design Assessment published reports

GDA Step 2 reports

Public summary report

Public Report on the Generic Design Assessment of New Reactor Designs. Conclusions of the fundamental safety overview of the UK EPR Nuclear Reactor (Step 2 of the Generic Design Assessment process) HSE GDA-002 March 2008
www.hse.gov.uk/newreactors/reports/eprreport.pdf

Assessment reports

EDF and AREVA EPR Step 2 ALARP Assessment Health and Safety Executive Nuclear Directorate Division 6 Assessment Report AR 08/016 March 2008

EDF and AREVA EPR Step 2 C&I Assessment Health and Safety Executive Nuclear Directorate Division 6 Assessment Report AR 07/005 March 2008

Step 2 EDF and AREVA EPR Civil Engineering and External Hazard Assessment Health and Safety Executive Nuclear Directorate Division 6 Assessment Report AR 08/002 March 2008

Step 2 Fault Analysis Assessment of the EDF and AREVA Submission for the EPR Health and Safety Executive Nuclear Directorate Division 6 Assessment Report AR 07/017 March 2008

Step 2 EDF and AREVA – EPR Internal Hazard Assessment Health and Safety Executive Nuclear Directorate Division 6 Assessment Report AR 07/013 March 2008

EDF and AREVA EPR Step 2 PSA Assessment Health and Safety Executive Nuclear Directorate Division 6 Assessment Report AR 08/011 March 2008

Step 2 – Preliminary Review Assessment of Structural Integrity Aspects of EDF and AREVA EPR Health and Safety Executive Nuclear Directorate Division 6 Assessment Report AR 08/006 March 2008

The above reports are available on the GDA website at: www.hse.gov.uk/newreactors.

Other reports

IAEA Generic Review for UK HSE of New Reactor Designs against IAEA Safety Standards IAEA Nuclear Installation Safety Division Review Summary Report HSE March 2008
www.hse.gov.uk/newreactors/reports/iaeasummary.pdf

New Reactor Build. GDA Step 2 Summary of Overseas Regulatory Assessments HSE Nuclear Directorate Assessment Report March 2008
www.hse.gov.uk/newreactors/reports/overseas.pdf

Report on the Joint Regulators' Team Inspection of EDF / AREVA's Arrangements as part of the Generic Design Assessment (Quality Management Arrangements) HSE Joint Programme

Office July 2009 www.hse.gov.uk/newreactors/reports/edf-areva-inspection-report-2009.pdf

Description and outcome of the public involvement process carried out on behalf of the Health and Safety Executive and the Environment Agency during the initial assessment of the: AREVA NP SAS and Electricité de France SA UK EPR Nuclear Reactor; Atomic Energy of Canada Limited ACR-1000 Nuclear Reactor; GE-Hitachi Nuclear Energy International LLC ESBWR Nuclear Reactor; Westinghouse Electric Company LLC AP1000 Nuclear Reactor HSE March 2008 www.hse.gov.uk/newreactors/reports/publicinvolvment.pdf

GDA Step 3 reports

Summary report

Public Report on the Generic Design Assessment of New Reactor Designs. AREVA NP SAS and EDF SA UK EPR Reactor. Report of the System Design and Security Review of the UK EPR Nuclear Reactor June 2008 – October 2009 (Step 3 of the Generic Design Assessment Process) HSE-GDA/006 November 2009 www.hse.gov.uk/newreactors/reports/step3-edf-areva-public-report-gda.pdf

Assessment reports

Step 3 Internal Hazards Assessment of the EDF and AREVA UK EPR HSE-ND Assessment Report AR 09/026 November 2009

Step 3 Civil Engineering and External Hazards Assessment of the EDF and AREVA UK EPR HSE-ND Assessment Report AR 09/039 November 2009

Step 3 Probabilistic Safety Analysis Assessment of the EDF and AREVA UK EPR HSE-ND Assessment Report AR 09/027 November 2009

Step 3 Fault Studies Assessment of the EDF and AREVA UK EPR HSE-ND Assessment Report AR 09/028 November 2009

Step 3 Control and Instrumentation Assessment of the EDF and AREVA UK EPR HSE-ND Assessment Report AR 09/038 November 2009

Step 3 Electrical Systems Assessment of the EDF and AREVA UK EPR HSE-ND Assessment Report AR 09/029 November 2009

Step 3 Fuel Design Assessment of the EDF and AREVA UK EPR HSE-ND Assessment Report AR 09/041 November 2009

Step 3 Reactor Chemistry Assessment of the EDF and AREVA UK EPR HSE-ND Assessment Report AR 09/036 December 2009

Step 3 Radiological and Level 3 PSA Assessment of the EDF and AREVA UK EPR HSE-ND Assessment Report AR 09/030 November 2009

Step 3 Mechanical Engineering Assessment of the EDF and AREVA UK EPR HSE-ND Assessment Report AR 09/014 November 2009

Step 3 Structural Integrity Assessment of the EDF and AREVA UK EPR HSE-ND Assessment Report AR 09/012 November 2009

Step 3 Human Factors Assessment of the EDF and AREVA UK EPR HSE-ND Assessment Report AR 09/031 November 2009

Step 3 Management of Safety and Quality Assurance Assessment of the EDF and AREVA UK EPR HSE-ND Assessment Report AR 09/032 November 2009

Step 3 Radioactive Waste and Decommissioning Assessment of the EDF and AREVA UK EPR HSE-ND Assessment Report AR 09/033 November 2009

Step 3 Security Assessment of the EDF and AREVA UK EPR HSE-ND Assessment Report AR 09/043 October 2009

The above reports are available on the GDA website at: www.hse.gov.uk/newreactors.

Other reports

Public Report on the Generic Design Assessment of New Nuclear Reactor Designs Update on the Public Involvement Process for Step 3 of the Generic Design Assessment Process November 2009 www.hse.gov.uk/newreactors/reports/step3-public-report-gda-new-nuclear-reactor-designs.pdf

GDA Step 4 reports

Summary report

New nuclear reactors: Generic Design Assessment. Electricité de France SA and AREVA NP SAS UK EPR™ nuclear reactor. Summary of the detailed design assessment of the UK EPR™ nuclear reactor (Step 4 of the Generic Design Assessment Process) ONR Summary Report ONR-GDA-SR-11-001 Revision 0 Office for Nuclear Regulation December 2011 Available via www.hse.gov.uk/newreactors

Assessment reports

Step 4 Cross-cutting Topics Assessment of the EDF and AREVA UK EPR™ Reactor ONR Assessment Report ONR-GDA-AR-11-032 Revision 0

Step 4 Internal Hazards Assessment of the EDF and AREVA UK EPR™ Reactor ONR Assessment Report ONR-GDA-AR-11-017 Revision 0

Step 4 Civil Engineering and External Hazards Assessment of the EDF and AREVA UK EPR™ Reactor ONR Assessment Report ONR-GDA-AR-11-018 Revision 0

Step 4 Probabilistic Safety Analysis Assessment of the EDF and AREVA UK EPR™ Reactor ONR Assessment Report ONR-GDA-AR-11-019 Revision 0

Step 4 Fault Studies – Design Basis Faults Assessment of the EDF and AREVA UK EPR™ Reactor ONR Assessment Report ONR-GDA-AR-11-020a Revision 0

Step 4 Fault Studies – Containment and Severe Accident Assessment of the EDF and AREVA UK EPR™ Reactor ONR Assessment Report ONR-GDA-AR-11-020b Revision 0

Step 4 Control and Instrumentation Assessment of the EDF and AREVA UK EPR™ Reactor ONR Assessment Report ONR-GDA-AR-11-022 Revision 0

Step 4 Electrical Systems Assessment of the EDF and AREVA UK EPR™ Reactor ONR Assessment Report ONR-GDA-AR-11-023 Revision 0

Step 4 Fuel and Core Design Assessment of the EDF and AREVA UK EPR™ Reactor ONR Assessment Report ONR-GDA-AR-11-021 Revision 0

Step 4 Reactor Chemistry Assessment of the EDF and AREVA UK EPR™ Reactor ONR Assessment Report ONR-GDA-AR-11-024 Revision 0

Step 4 Radiological Protection Assessment of the EDF and AREVA UK EPR™ Reactor ONR Assessment Report ONR-GDA-AR-11-025 Revision 0

Step 4 Mechanical Engineering Assessment of the EDF and AREVA UK EPR™ Reactor ONR Assessment Report ONR-GDA-AR-11-026 Revision 0

Step 4 Structural Integrity Assessment of the EDF and AREVA UK EPR™ Reactor ONR Assessment Report ONR-GDA-AR-11-027 Revision 0

Step 4 Human Factors Assessment of the EDF and AREVA UK EPR™ Reactor ONR Assessment Report ONR-GDA-AR-11-028 Revision 0

Step 4 Management of Safety and Quality Assurance Assessment of the EDF and AREVA UK EPR™ Reactor ONR Assessment Report ONR-GDA-AR-11-029 Revision 0

Step 4 Radioactive Waste and Decommissioning Assessment of the EDF and AREVA UK EPR™ Reactor ONR Assessment Report ONR-GDA-AR-11-030 Revision 0

Step 4 Security Assessment of the EDF and AREVA UK EPR™ Reactor ONR Assessment Report ONR-GDA-AR-11-031 Revision 0

The above reports are available on the GDA website at: www.hse.gov.uk/newreactors.

Other reports

New nuclear reactors: Generic Design Assessment. Update on the Public Involvement Process for GDA Step 4 of the Generic Design Assessment Process ONR-GDA-SR-11-003 Revision 0 December 2011. Available via website www.hse.gov.uk/newreactors

Annex 3: Summary of HSE expectations for the GDA process

HSE expectations for Step 2 of the GDA process

Details of HSE's expectations for Step 2 of the GDA process can be found in the GDA guidance (Reference 2). From that document, the key expectations of Requesting Parties for Step 2 are:

Provide a Preliminary Safety Report that includes sufficient information for the Step 2 Fundamental Safety Overview, in particular:

1. *A statement of the design philosophy and a description of the resultant conceptual design sufficient to allow identification of the main nuclear safety hazards, control measures and protection systems.*
2. *A description of the process being adopted by the applicant to demonstrate compliance with the UK legal duty to reduce risks to workers and the public so far as is reasonably practicable (SFAIRP).*
3. *Details of the safety principles and criteria that have been applied by the Requesting Party in its own assessment processes, including risks to workers and the public.*
4. *A broad demonstration that the principles and criteria are likely to be achieved.*
5. *An overview statement of the approach, scope, criteria and output of the deterministic safety analyses.*
6. *An overview statement of the approach, scope, criteria and output of the probabilistic safety analyses.*
7. *Specification of the site characteristics to be used as the basis for the safety analysis (the "generic siting envelope").*
8. *Explicit references to standards and design codes used, justification of their applicability and a broad demonstration that they have been met (or exceptions justified).*
9. *Information on the quality management arrangements for the design, including design controls; control of standards; verification and validation; and interface between design and safety.*
10. *A statement giving details of the safety case development process, including peer review arrangements, and how this gives assurance that nuclear risks are identified and managed.*
11. *Information on the quality management system for the safety case production.*
12. *Identification and explanation of any novel features, including their importance to safety.*
13. *Identification and explanation of any deviations from modern international good practices.*

14. *Sufficient detail for HSE to satisfy itself that HSE's Safety Assessment Principles (SAPs) and that the Western European Nuclear Regulators' Association (WENRA) Reference Levels are likely to be satisfied.*

15. *Where appropriate, information about all the assessments completed by overseas regulators.*

16. *Identification of outstanding information that remains to be developed and its significance.*

17. *Information about any long lead items that may be manufactured in parallel with the Design Acceptance process.*

18. *Information on radioactive waste management and decommissioning. The Requesting Party will also be required to respond to questions and points of clarification raised by HSE during its assessment, and to issues arising from public comments.*

HSE expectations for Step 3 of the GDA process

Details of HSE expectations for Step 3 of the GDA process can be found in the GDA guidance (Reference 2). From that document, the key expectations of Requesting Parties for GDA Step 3 are:

Provide a detailed Pre-construction Safety Report that includes sufficient information for the GDA Step 3 Safety and Security Review, in particular:

1. *Definition of the documentary scope and extent of the safety case.*

2. *Explanation of how the decisions regarding the achievement of safety functions ensure that the overall risk to workers and public will be ALARP.*

3. *Responses to any issues outstanding from GDA Step 2.*

4. *Sufficient information to substantiate the claims made in GDA Step 2 (in the Preliminary Safety Report).*

5. *Sufficient information to enable HSE Nuclear Directorate to assess the design against all relevant SAPs.*

6. *A demonstration that the detailed design proposal will meet the safety objectives before construction or installation commences, and that sufficient analysis and engineering substantiation has been performed to prove that the plant will be safe.*

7. *Detailed descriptions of system architectures, their safety functions and reliability and availability requirements.*

8. *Confirmation and justification of the design codes and standards that have been used and where they have been applied, non-compliances and their justification.*

9. *Fault analyses including Design Basis Analysis, Severe Accident Analysis and PSA.*

10. *Justification of the safety of the design throughout the plant's life cycle, from construction through operation to decommissioning, and including on-site spent fuel and radioactive waste management issues.*
11. *Identification of potentially significant safety issues raised during previous assessments of the design by overseas nuclear safety regulators, and explanations of how their resolution has been or is to be achieved.*
12. *Identification of the safe operating envelope and the operating regime that maintains the integrity of the envelope.*
13. *Confirmation of:*
    - *(a) which aspects of the design and its supporting documentation are complete and are to be covered by the Design Acceptance Confirmation;*
    - *(b) which aspects are still under development and identification of outstanding confirmatory work that will be addressed during GDA Step 4.*

HSE expectations for Step 4 of the GDA process

Details of HSE expectations for Step 4 of the GDA process can be found in the GDA guidance (Reference 2). From that document, the key expectations of Requesting Parties for GDA Step 4 are:

Provide any outstanding information, safety case material and research results that support the [Step 3] submission and, in addition, submit:

1. *A demonstration that construction and installation activities will result in a plant of appropriate quality.*
2. *A demonstration that the constructed plant will be capable of being operated within safe limits.*
3. *Arrangements for moving the safety case to an operating regime, i.e. the arrangements to ensure that the requirements of, and assumptions in, the safety case will be captured in:*
    - *(a) technical specifications;*
    - *(b) maintenance schedule;*
    - *(c) procedures (normal operation, emergency, accident management);*
    - *(d) training programmes;*
    - *(e) emergency preparedness;*
    - *(f) operating limits;*
    - *(g) radiation protection arrangements for operators;*
    - *(h) lifetime records; and*
    - *(i) commissioning requirements etc.*
4. *Arrangements for design and safety case definition and freeze.*
5. *Arrangements for putting in place a design authority.*

6. *Arrangements that demonstrate that any site-specific changes against the generic design will be managed within an agreed control process.*
7. *Responses to any issues outstanding from Step 3.*

Annex 4: EDF and AREVA UK EPR™ reactor GDA Issues and resolution plans

GDA Issue	GDA Issue Reference	Resolution Plan Reference
Internal Hazards		
Dropped Loads and Impact	GI-UKEPR-IH-01 GDA Issue Revision 2	GI-UKEPR-IH-01Resolution Plan Revision 0
Verification and Validation Studies	GI-UKEPR-IH-02 GDA Issue Revision 2	GI-UKEPR-IH-02 Resolution Plan Revision 0
Internal Flooding and Operator Actions	GI-UKEPR-IH-03 GDA Issue Revision 2	GI-UKEPR-IH-03 Resolution Plan Revision 1
Substantiation of Break Preclusion Claims for RCC-M Components	GI-UKEPR-IH-04 GDA Issue Revision 2	GI-UKEPR-IH-04 Resolution Plan Revision 0
Civil Engineering		
Hypothesis and Methodology Notes for Class 1 Structures	GI-UKEPR-CE-01 GDA Issue Revision 1	GI-UKEPR-CE-01 Resolution Plan Revision 1
Use of ETC-C for the Design and Construction of the UK EPR™	GI-UKEPR-CE-02 GDA Issue Revision 1	GI-UKEPR-CE-02 Resolution Plan Revision 0
Beyond Design Basis Behaviour of the Containment	GI-UKEPR-CE-03 GDA Issue Revision 1	GI-UKEPR-CE-03 Resolution Plan Revision 1
Containment Analysis	GI-UKEPR-CE-04 GDA Issue Revision 1	GI-UKEPR-CE-04 Resolution Plan Revision 0
Reliability of the ETC-C	GI-UKEPR-CE-05 GDA Issue Revision 1	GI-UKEPR-CE-05 Resolution Plan Revision 0
Seismic Analysis Methodology	GI-UKEPR-CE-06 GDA Issue Revision 1	GI-UKEPR-CE-06 Resolution Plan Revision 0
Fault Studies		
Heterogeneous Boron Dilution Faults	GI-UKEPR-FS-01 GDA Issue Revision 0	GI-UKEPR-FS-01 Resolution Plan Revision 0
Diversity for Frequent Faults	GI-UKEPR-FS-02 GDA Issue Revision 0	GI-UKEPR-FS-02 Resolution Plan Revision 0
Spent Fuel Pool Safety Case	GI-UKEPR-FS-03 GDA Issue Revision 2	GI-UKEPR-FS-03 Resolution Plan Revision 0
Steam Generator Tube Rupture Safety Case	GI-UKEPR-FS-04 GDA Issue Revision 1	GI-UKEPR-FS-04 Resolution Plan Revision 0

GDA Issue	GDA Issue Reference	Resolution Plan Reference
Design Basis Analysis of Essential Support Systems	GI-UKEPR-FS-05 GDA Issue Revision 0	GI-UKEPR-FS-05 Resolution Plan Revision 0
Control & Instrumentation		
Design Information for Non-computerised Safety System Required	GI-UKEPR-CI-01 GDA Issue Revision 2	GI-UKEPR-CI-01 Resolution Plan Revision 0
Protection System Independent Confidence Building Measures	GI-UKEPR-CI-02 GDA Issue Revision 2	GI-UKEPR-CI-02 Resolution Plan Revision 0
Claims, Arguments, Evidence Trail	GI-UKEPR-CI-03 GDA Issue Revision 2	GI-UKEPR-CI-03 Resolution Plan Revision 0
SMART Devices	GI-UKEPR-CI-04 GDA Issue Revision 1	GI-UKEPR-CI-04 Resolution Plan Revision 0
Obsolescence of SPPA T2000 Platform	GI-UKEPR-CI-05 GDA Issue Revision 2	GI-UKEPR-CI-05 Resolution Plan Revision 0
Absence of Adequate C&I Architecture	GI-UKEPR-CI-06 GDA Issue Revision 3	GI-UKEPR-CI-06 Resolution Plan Revision 0
Essential Electrical Systems		
PCSR Presentation of Claims Arguments and Evidence	GI-UKEPR-EE-01 GDA Issue Revision 1	GI-UKEPR-EE-01 Resolution Plan Revision 0
Reactor Chemistry		
Combustible Gas Mitigation	GI-UKEPR-RC-01 GDA Issue Revision 1	GI-UKEPR-RC-01 Resolution Plan Revision 0
Control and Minimisation of Ex-core Radiation	GI-UKEPR-RC-02 GDA Issue Revision 0	GI-UKEPR-RC-02 Resolution Plan Revision 1
Structural Integrity		
Avoidance of Fracture	GI-UKEPR-SI-01 GDA Issue Revision 2	GI-UKEPR-SI-01 Resolution Plan Revision 0
Structural Integrity – RPV Surveillance Scheme	GI-UKEPR-SI-02 GDA Issue Revision 1	GI-UKEPR-SI-02 Resolution Plan Revision 1
Radiation Protection		
Radiological Zoning and Bulk Shielding	GI-UKEPR-RP-01 GDA Issue Revision 0	GI-UKEPR-RP-01 Resolution Plan Revision 0

GDA Issue	GDA Issue Reference	Resolution Plan Reference
Human Factors		
Inadequate Substantiation of Human-based Safety Claims	GI-UKEPR-HF-01 GDA Issue Revision 0	GI-UKEPR-HF-01 Resolution Plan Revision 1
Cross-cutting Topics		
Categorisation and Classification of Systems Structures and Components	GI-UKEPR-CC-01 GDA Issue Revision 1	GI-UKEPR-CC-01 Resolution Plan Revision 0
Consolidated Final GDA Submission	GI-UKEPR-CC-02 GDA Issue Revision 3	GI-UKEPR-CC-02 Resolution Plan Revision 1
Consider and Action Plans to Address the Lessons Learnt from the Fukushima Event	GI-UKEPR-CC-03 GDA Issue Revision 3	GI-UKEPR-CC-03 Resolution Plan Revision 0

The GDA Issues and EDF and AREVA's resolution plans are available on the GDA website at: www.hse.gov.uk/newreactors.

References

1 *New nuclear power stations. Generic Design Assessment. Guidance on the management of GDA outcomes* Version 1 June 2010 HSE www.hse.gov.uk/newreactors/reports/management-gda-outcomes.pdf

2 *Nuclear* power *station generic design assessment – guidance to requesting parties* (Version 3) HSE August 2008 www.hse.gov.uk/newreactors/ngn03.pdf

3 *Guidance document for generic design assessment activities* (Version 2) Office for Civil Nuclear Security 201206 January 2007 www.hse.gov.uk/nuclear/ocns/ocnsdesign.pdf

4 *The licensing of nuclear installations* HSE www.hse.gov.uk/nuclear/notesforapplicants.pdf

5 *Safety assessment principles for nuclear facilities* (2006 Edition Version 1) HSE December 2006 www.hse.gov.uk/nuclear/saps/saps2006.pdf [2.8MB]

6 *New nuclear power stations. Generic Design Assessment. Guide to the regulatory processes* Version 2 August 2008 HSE and Environment Agency www.hse.gov.uk/newreactors/ngn01.pdf

7 *New nuclear power stations Generic Design Assessment Safety assessment in an international* Version 3 March 2009 HSE www.hse.gov.uk/newreactors/ngn05.pdf

8 *New nuclear power stations generic design assessment -strategy for working with overseas regulators* HSE NGN04 March 2009 www.hse.gov.uk/newreactors/ngn04.pdf

9 *Paper on the required level of design waste plants for new build reactors in the Generic Design Assessment* HSE Nuclear Directorate 19 May 2009 www.hse.gov.uk/newreactors/wasteplants.pdf

10 *Japanese earthquake and tsunami: Implications for the UK Nuclear Industry. Interim Report* HM Chief Inspector of Nuclear Installations ONR-FR-REP-001 Revision 3 18 May 2011 www.hse.gov.uk/nuclear/fukushima/interim-report.pdf [1.6MB]

11 *Japanese earthquake and tsunami: Implications for the UK Nuclear Industry. Final Report* HM Chief Inspector of Nuclear Installations ONR-FR-REP-002 Revision 3 September 2011 www.hse.gov.uk/nuclear/fukushima/final-report.pdf [6.3MB]

12 *UK EPR GDA Step 4 Consolidated Pre-construction Safety Report – March 2011* EDF and AREVA Detailed in EDF and AREVA letter UN REG EPR00997N 18 November 2011

13 *UK EPR Pre-construction Safety Report – November 2009* EDF and AREVA Detailed in UK EPR™ Submission Master List of November 2009

14 *UK EPR GDA Submission Master List* UKEPR-0018-001 Issue 01 EDF and AREVA 18 November 2011

15 *Reference Design Configuration*. UKEPR-I-002 Revision 2 EDF and AREVA November 2008

16 *Reference Design Configuration* UKEPR-I-002 Revision 10 EDF and AREVA May 2011

17 *Agreed list of out of scope items for the UK EPR™ for GDA* Letter UN ND(NII) EPR00836 EDF and AREVA 15 April 2011

18 *ETC-C (EPR Technical Code for Civil Works) Part 1* ENGSGC050076 Revision B EDF April 2006

19 *Design and Construction Rules for Mechanical Components of PWR Nuclear Islands* RCC-M 2007 Edition, including Addendum 1 (December 2008), Addendum 2 (December 2009) and Addendum 3 (December 2009) AFCEN Available via www.afcen.org

20 *Guidance on the demonstration of ALARP (as low as reasonably practicable)* T/AST/005 Issue 4 – Rev 1 Office for Nuclear Regulation January 2009 www.hse.gov.uk/nuclear/operational/tech_asst_guides/tast005.htm

21 *WENRA Reactor Safety Reference Levels* Reactor Harmonization Working Group. Western European Nuclear Regulators' Association January 2007 Available via www.wenra.org

22 *WENRA statement on safety objectives for new nuclear power plants* Western European Nuclear Regulators' Association November 2010 Available via www.wenra.org

23 *Waste and Spent Fuel Pool Safety Reference Levels* WENRA harmonized storage reference levels report. WENRA Working Group on waste and decommissioning (WGWD) Western European Nuclear Regulators' Association Version 2.1 February 2011 Available via www.wenra.org

24 *New nuclear reactors: Generic Design Assessment. Update on the Public Involvement Process for GDA Step 4 of the Generic Design Assessment Process* ONR-GDA-SR-11-003 Revision 0 December 2011. Available via website www.hse.gov.uk/newreactors

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 the 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

Contacts

Director for Nuclear New Build
Office for Nuclear Regulation
Redgrave Court
Merton Road
Bootle
Merseyside
L20 7HS
www.hse.gov.uk/nuclear
email: new.reactor.build@hse.gsi.gov.uk

For information about health and safety visit www.hse.gov.uk. You can view HSE guidance online and order priced publications from the website. HSE priced publications are also available from bookshops.

This document is issued by the Office for Nuclear Regulation (ONR), an agency of HSE. For further information about ONR, or to report inconsistencies or inaccuracies in this publication please visit www.hse.gov.uk/nuclear.

ONR-GDA-SR-11-001 Revision 0
2010 / 573486