Westinghouse UK
AP1000® GENERIC DESIGN ASSESSMENT
Resolution Plan for GI-AP1000-PSA-02
Fire PSA

MAIN ASSESSMENT AREA	RELATED ASSESSMENT AREA(S)	RESOLUTION PLAN REVISION	GDA ISSUE REVISION
PSA	Internal Hazards	2	0

GDA ISSUE:	From the GDA assessment of the **AP1000®** PSA it cannot be concluded that the current prediction of internal fire risk is representative for the **AP1000** design. This leaves ONR with a lack of understanding of the potential gap between the current estimated **AP1000** risk associated with internal fires, and the **AP1000** fire risk based on an up-to-date, realistic and complete evaluation. Since the current prediction of the fire Core Damage Frequency (CDF) is 5E-08/yr (approx 25% of the overall CDF) the uncertainty in the fire risk translates directly into uncertainty in the overall plant risk. Therefore a modern standards Fire PSA should be developed for the **AP1000** design to close this gap.
ACTION: GI-AP1000-PSA-02.A1	Westinghouse should provide the final approved procedure (Guidebook) established to guide the development of Fire PSA for the **AP1000** PSA. With agreement from the Regulator this action may be completed by alternative means.
ACTION: GI-AP1000-PSA-02.A2	Westinghouse should provide detailed information on the Database/s established / selected to be used to support the Fire PSA. The database/s should be populated with up-to-date design information. Example of information expected to be found in the database/s selected or developed to support the Fire PSA include: • List of fire PSA components and failure modes. • Circuit analysis, cable selection and routing process (with identification of uncertainties). • Physical characteristics of the fire compartments and their inventories, barriers and penetrations, ignition sources, transient combustibles, etc. • Equipment & power supplies location. Data on relevant fire events in other NPPs. A database of assumptions should also be developed. This should provide clarity on: • General assumptions of the fire PSA analysis. • The type of assumptions (related to design, operation, fire impact, etc).

	• Specific information on those assumptions that are not yet substantiated in specific design documentation. • Pointers to the area of the Fire PSA where the specific assumptions are used. It is expected that the assumptions database (updated as appropriate) should feature in most of the deliverables for relevant GDA Issue Actions. With agreement from the Regulator this action may be completed by alternative means.
ACTION: GI-AP1000-PSA-02.A3	Westinghouse should provide information (including a programme of work) of the modifications to the internal events PSA model required to support the development of the Fire PSA. This should address the following: • Updates to the internal events PSA model and data to comply with Westinghouse's PSA Guidebooks which are required to support the development of the Fire PSA. • Updates to the internal events PSA model and data to address relevant findings from ONR's review of the **AP1000** PSA during GDA, which are required to support the development of the Fire PSA. This should include completion of the list of Initiating Events and associated models as required. • Specific changes to the internal events PSA required by the Fire PSA itself. With agreement from the Regulator this action may be completed by alternative means.
ACTION: GI-AP1000-PSA-02.A4	Westinghouse should provide detailed documentation of any qualitative screening of fire compartments including the screening criteria used and assumptions made. With agreement from the Regulator this action may be completed by alternative means.
ACTION: GI-AP1000-PSA-02.A5	Westinghouse should undertake and document thoroughly an evaluation of Hot Shorts that could impact the risk associated to internal fires. ONR would expect Westinghouse to convene an expert panel to address single and multiple spurious actuation issues which may impact one or more safety functions (Note this would also be a requirement to support a modern deterministic safe shutdown analysis; albeit extended to address additional systems considered within the fire PSA). With agreement from the Regulator this action may be completed by alternative means.
ACTION: GI-AP1000-PSA-	Westinghouse should provide detailed documentation on

02.A6	the Evaluation of Fire frequencies. With agreement from the Regulator this action may be completed by alternative means.
ACTION: GI-AP1000-PSA-02.A7	Westinghouse should provide detailed documentation of any quantitative screening of fire compartments including the screening criteria used. With agreement from the Regulator this action may be completed by alternative means.
ACTION: GI-AP1000-PSA-02.A8	Westinghouse should provide fire progression event trees (or equivalent) for all compartments screened in accompanied by detailed documentation of fire impact in each compartment and details of all the fire scenarios identified. • Details of any fire modelling undertaken to support this task should also be included. • The identification of the most onerous Initiating Event for each fire scenario should be clearly documented. With agreement from the Regulator this action may be completed by alternative means.
ACTION: GI-AP1000-PSA-02.A9	Westinghouse should provide documented evaluation of the reliability of the fire protection measures claimed (e.g. PSA models for fire protection systems claimed and human reliability analyses as appropriate). With agreement from the Regulator this action may be completed by alternative means.
ACTION: GI-AP1000-PSA-02.A10	Westinghouse should provide documented evaluation of the inter-compartment fire propagation. Fire progression event trees for all relevant multi-compartment fires and details of any fire modelling undertaken to support this task should also be included as per Action 08. With agreement from the Regulator this action may be completed by alternative means.
ACTION: GI-AP1000-PSA-02.A11	Westinghouse should provide documented re-evaluation of the Human Reliability Analysis for all the fire scenarios identified. The effects of the fire, both direct (e.g. the need to evacuate the control room) and indirect (e.g. confusing information resulting from spurious indications, impact of smoke), on operator actions have to be considered. With agreement from the Regulator this action may be completed by alternative means.
ACTION: GI-AP1000-PSA-02.A12	Westinghouse should provide a documented Fire PSA model in CAFTA together with the results of the CDF quantification and evaluation of the results. With agreement from the Regulator this action may be

	completed by alternative means.
ACTION: GI-AP1000-PSA-02.A13	Westinghouse should provide an estimation of the Large Release Frequency associated with internal fires. With agreement from the Regulator this action may be completed by alternative means.
ACTION: GI-AP1000-PSA-02.A14	Westinghouse should provide the complete fire PSA documentation and ALARP assessment. With agreement from the Regulator this action may be completed by alternative means.
ACTION: GI-AP1000-PSA-02.A15	Westinghouse should develop and provide a Living PSA procedure to allow the Fire PSA to be updated as further design information becomes available and when the Internal Events PSA evolves in a way that may impact the Fire PSA. With agreement from the Regulator this action may be completed by alternative means.
RELEVANT REFERENCE DOCUMENTATION RELATED TO GDA ISSUE	
Technical Queries	
Regulatory Observations	
Other Documentation	

Scope of work:

The current **AP1000** plant fire PSA was based on the EPRI FIVE methodology, which was published in 1992. In 2005, EPRI and the NRC published a much more rigorous and comprehensive fire PSA methodology, NUREG/CR-6850. Application of this new methodology at legacy plants has resulted in higher, often significantly higher, calculations of fire-induced CDF and LERF. As a result, the ONR is concerned that the current **AP1000** plant fire PSA may not be an accurate representation of fire risk. This concern is especially acute since fire risk comprises about 25% of overall **AP1000** plant risk, so there is some potential to change the overall risk profile of the plant design when a modern fire PSA is developed.

To resolve this issue, Westinghouse will develop a fire PSA following the NUREG/CR-6850 methodology and the ASME/ANS RA Sa 2009 PSA Standard to the extent achievable by a pre-operational plant with limited spatial data available. The Fire PSA will be based on a staged approach in which the analysis is progressively refined according to the output of the results. Any assumptions or engineering judgement used to supplement available reference material will be documented to support Fire PSA model refinement.

The Fire PSA will be based off the most recent available cable routing information as of a specific date which will be determined at the initiation of the work. The Fire PSA will use an Internal Events model reflective of the **AP1000** plant designed as of an appropriate revision of the DCD. A qualitative analysis will be performed for Class 1 and Class 2 design changes occurring after the internal events PRA was developed to provide a comparison of the Fire PSA to the UK GDA design reference point. This

information will be supplemented with specific assumptions as necessary. All assumptions will be documented and characterised. On a case by case basis, design changes may be requested to be reviewed on a quantitative basis. A systematic approach will be used to define which design changes will be quantitatively assessed.

Description of work:

The fire PSA development will consist of the tasks identified in the Fire PSA Guidebook which follows the NUREG/CR-6850 guidance to the extent achievable by a pre-operational plant with limited spatial data available. A high level description of each task is provided below. A Fire PSA database containing information used to support development of the Fire PSA consistent with the tasks below will be developed.

Plant Boundary Definition and Partitioning – This task will first define the Global Plant Analysis Boundary (GPAB), which encompasses all areas on the site with the potential to contribute visibly to fire risk. The GPAB is then subdivided into fire compartments, which will serve as the basic physical analysis units for the fire PSA.

Component Selection – This task will identify the initiators, sequences, components, and failure modes to be modelled by the fire PSA. Component selection will involve a review of the internal events PSA. It is followed by a series of additional reviews aimed at identifying fire risk-relevant failures that may not have been captured by the internal events model. Single and multiple spurious operations will be addressed in the Fire PSA. The multiple spurious operation review will document the results of an expert panel.

Cable Analysis – This task will identify all cables, and their corresponding routing through the plant, whose fire-induced failure could affect equipment on the fire PSA component list. All cables associated with a particular component may be assumed to fail all basic events associated with that component. Cable layout input for this task will use the latest available cable routing information for the **AP1000** plant. Site specific cable routing changes will be incorporated in future site specific work. Assumptions and engineering judgement related to refinement of the cable analysis for risk significant contributors will be documented.

Ignition Frequency – This task identifies each credible ignition source within the global plant analysis boundary, then fire frequencies for each ignition source and each fire compartment are calculated.

Main Control Room (MCR) Analysis – This task will assess risk associated with fires originating inside the control room, including the risk contribution of both abandonment and non-abandonment scenarios.

Fire Human Reliability Analysis – This task starts with identifying Human Failure Events (HFEs) to include in the fire PSA, which generally includes all HFEs from the internal events model required to mitigate fire-induced initiators and potentially may include a limited set of new HFEs developed specifically for fire. Then, Human Error Probabilities (HEPs) are calculated based on fire impacts to credited cues, fire-generated conditions affecting the travel path to the action location, environmental conditions at the action location, and potentially increased stress due to the fire. This

approach applies increased factors to the Internal Events HFEs. Finally, a recovery rule process is developed to apply each relevant HFE to the fire cutsets.

Fire-Induced CCDP and CLRP Model – This task develops a model and quantification process for determining fire-induced Conditional Core Damage Probabilities (CCDPs) and Conditional Large Release Probabilities (CLRPs). The task starts with modification of the internal events one top fault tree to capture potentially fire risk-relevant failures not included in the internal events analysis. The task then develops a quantification process for calculating scenario CCDPs and CLRPS using the EPRI FRANX software.

Quantification – This task will document the following:

- *Qualitative Screening* – This task screens fire compartments from further consideration based on the following criteria:
    - Fire originating within the compartment will not cause a reactor trip (either automatic, manual, or forced shutdown), and
    - Fire originating within the compartment will not affect fire PSA components or cables.
- Quantitative Screening will not be used to remove fire compartments from the Fire PSA but will provide criteria for understanding when the model is sufficiently realistic and further refinement is no longer required.
- *Quantification Results* –This task quantifies the fire-induced CDF and LRF for each fire scenario developed in previous steps. The fire PSA results, including significant fire risk contributors and fire risk insights, are identified and documented. Assumptions and engineering judgement related to refinement of the results will be documented.
- *Uncertainty and Sensitivity Analysis* – This task performs a fire PSA uncertainty analysis to the extent afforded by current technology. It begins with identification of all potentially significant sources of uncertainty. Then, each source is assessed using for example, propagation of probability distributions using a Monte Carlo sampling technique, performance of a sensitivity study by varying the value of certain parameters and re-quantifying the model, or simply performing a qualitative assessment. Finally, insights are documented and model refinements are made, if necessary, to minimise significant sources of uncertainty.

In addition to these tasks, an ALARP assessment will be performed to identify options for Fire risk reduction based on the risk significant fire compartments as well as the cables/systems/components driving the risk. Additionally, a Configuration Control Procedure will be developed for the long-term configuration control of the fire PSA. This procedure will ensure that future changes to the plant design, operating strategies, and fire PSA methodology are incorporated into the fire PSA. Finally, a qualitative assessment of unincorporated Class 1 and 2 design changes will be provided for their qualitative impact to the Fire PSA. This deliverable will provide a comparison of the Fire PSA to the UK GDA design reference point.

Schedule/ programme milestones:

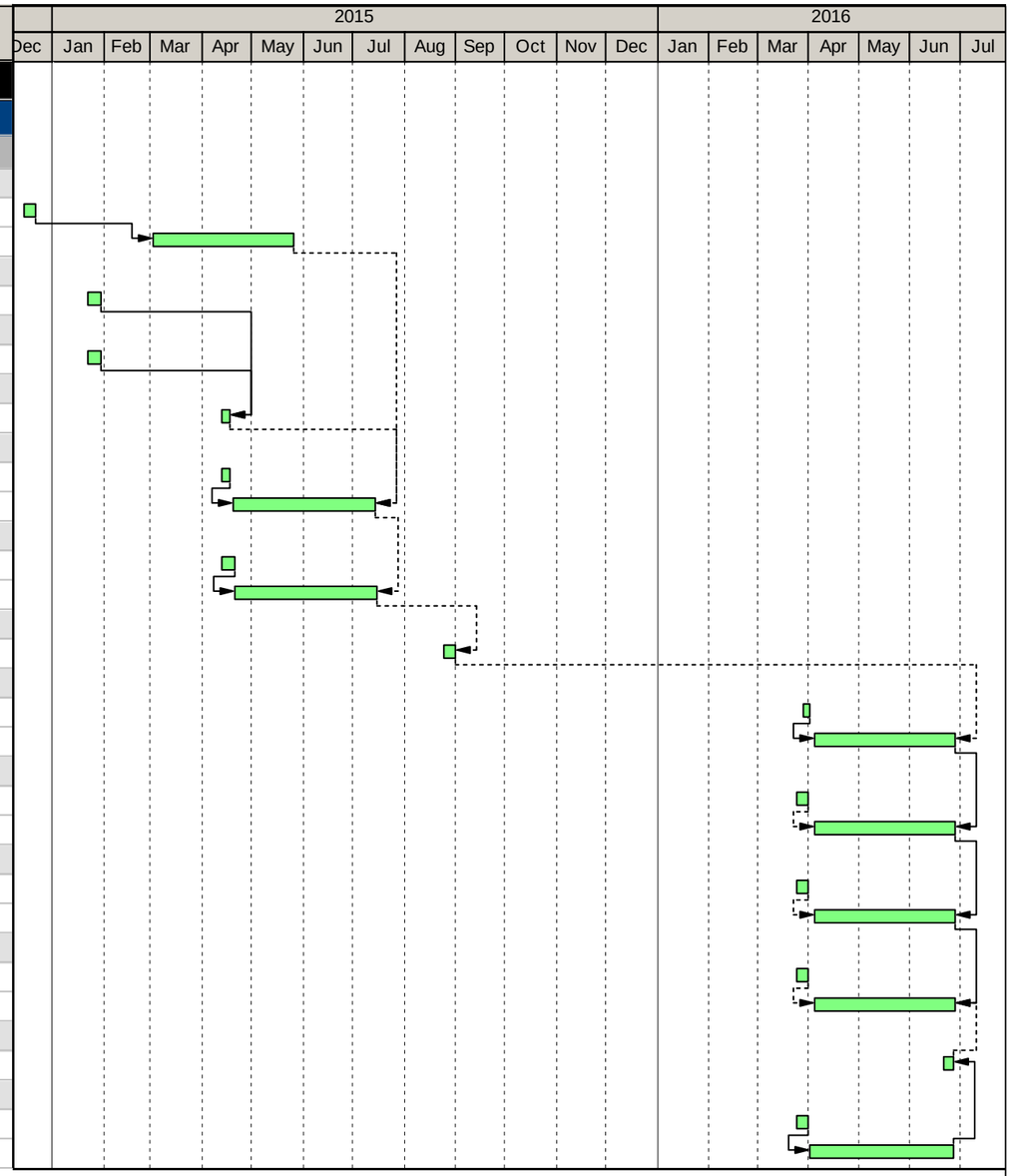
This effort will result in 12 deliverables:

1. **AP1000** Plant Fire PSA Guidebook
2. **AP1000** Plant Fire PSA, Plant Partitioning Notebook
3. **AP1000** Plant Fire PSA, Equipment Selection Notebook
4. **AP1000** Plant Fire PSA, Cable Notebook
5. **AP1000** Plant Fire PSA, Fire Ignition Frequencies Notebook
6. **AP1000** Plant Fire PSA, Fire Human Reliability Analysis Notebook
7. **AP1000** Plant Fire PSA, Main Control Room Analysis Notebook
8. **AP1000** Plant Fire PSA, Fire Risk Model Notebook
9. **AP1000** Plant Fire PSA, Quantification and Results Notebook
10. **AP1000** Plant Living Fire PSA Procedure
11. ALARP Assessment
12. Qualitative Assessment of Class 1 and 2 Design Changes

Note that the Fire PSA Database will be included as an attachment to the Fire Risk Model Notebook listed above. Additional deliverables may be added if required for issue resolution.

Please see the following page for the schedule.

#	Activity Name
1	**UK Generic Design Assessment (GDA) Resolution Plans (51)**
2	**PROBALISTIC SAFETY ANALYSIS (PSA)**
3	**PS.02 Fire PSA-Resolution Plan**
4	**PS.02 Fire PSA Guidebook**
5	Fire PSA Guidebook-Submit to ONR
6	Fire PSA Guidebook-ONR Review of Submittal
7	**PS.02 Plant Partitioning Notebook**
8	Plant Partitioning Notebook-Submit to ONR
9	**PS.02 Fire Ignition Frequency Notebook**
10	Fire Ignition Frequency Notebook-Submit to ONR
11	**PS.02 MSO Expert Panel**
12	MSO Expert Panel Report-Submit to ONR
13	**PS.02 Equipment Selection Notebook**
14	Equipment Selection Notebook-Submit to ONR
15	Equipment Selection Notebook-ONR Review of Submittal
16	**PS.02 Cable Notebook**
17	Cable Notebook-Submit to ONR
18	Cable Notebook-ONR Review of Submittal
19	**PS.02 Qualitative Assessment of Class 1 & 2 Design Changes**
20	Qualitative Assessment of Class 1 & 2 Design Changes-Submit to ONR
21	**PS.02 Fire Induced Risk Model Notebook**
22	Fire Induced Risk Model-Submit to ONR
23	Fire Induced Risk Model-ONR Review of Submittal
24	**PS.02 Fire HRA Notebook**
25	Fire HRA-(Final Notebook)-Submit to ONR
26	Fire HRA-(Final Notebook)-ONR Review of Submittal
27	**PS.02 MCR Analysis Notebook**
28	MCR Analysis Notebook-(Final Notebook)-Submit to ONR
29	MCR Analysis Notebook-(Final Notebook)-ONR Review of Submittal
30	**PS.02 Quantification Notebook**
31	Quantification Notebook-Submit to ONR
32	Quantification Notebook-ONR Review of Submittal
33	**PS.02 Living Procedure**
34	Living Procedure-Submit to ONR
35	**PS.02 ALARP**
36	ALARP-Submit to ONR
37	ALARP-ONR Review of Submittal



Methodology:
The fire PSA will primarily be developed using the methodology documented in NUREG/CR-6850 and its supplemental reports. The project will use the following computer codes: CAFTA, CFAST, FRANX, FTREX, and HRA Calculator. Other codes may be added during the model refinement stages such as FDS or NRC Fire Dynamic Tools.

Justification of adequacy:
The proposed plan of work will result in a fire PSA, following methodology NUREG/CR-6850 and the ASME/ANS RA Sa 2009 PSA Standard to the extent achievable by a pre-operational plant with limited spatial data available.

Impact assessment:
The Pre-Construction Safety Report will be updated as appropriate.