The Safety Case and Acceptance Review Process at AWE

M Jones MBE, PhD., F.Inst. P., CPhys, CEng, CSci; AWE, Aldermaston, UK

Keywords: Safety cases, Acceptance review, Hazards, Risk assessments.

Abstract

The Atomic Weapons Establishment (AWE) in the UK operates a formal, safety case and acceptance review process for all of its operations. In fact for the Licence Site areas within AWE the process is mandatory through licence condition 13 from the Nuclear Installations Inspectorate (NII), the civil nuclear regulator, to whose standards AWE is expected to comply through contract. The NII standards relate principally to radiological hazards as a result of normal operations or through accident conditions. One major area where the process is applied is in relation to Nuclear Explosive Safety Cases (NESC) whereby the processes of warhead assembly and disassembly take place and will be the particular example covered in this paper. The Director ultimately responsible for the process sponsors the safety case in question. The Acceptance Review Team (ART), led by an Acceptance Review Team Leader (ARTL), is responsible to AWE's Assurance Director and will be explicitly independent of the Directorate sponsoring the case. Cases may relate to a new process, a significant process modification, periodic reviews, and authority to continue to operate. The ART in staged fashion reviews each proposed case. A major new process might include all of the following stages; Scope Review, Standards to be Applied, Preliminary Safety Report (PSR), Pre-constructional Safety Report (PCSR), Pre-commissioning Safety Report (PCmSR), Commissioning Safety Report (CSR), Pre-operational Safety Report (POSR). At each stage the ART will respond by, either accepting the case and explaining the basis for acceptance, or not accepting and giving the reasons for non acceptance. The case and the acceptance review will go forward to AWE's Nuclear Safety Committee (NSC) for endorsement and if successful the case (and the review where appropriate) will then go forward to the civil regulator. A case failed by the ART is unlikely to gain NSC endorsement.

This paper describes the overall process in more detail.

Introduction

Modern significant corporate concerns have now almost universally adopted the safety case approach to assessing and certifying the safety of their processes and in particular where such processes engender significant potential hazards. Such assessments and certifications are made against a set of standards, which are either based on best practice or set by regulators and through contract. Operations at the UK's Atomic Weapons Establishment (AWE) are no exception. The current process has evolved over time in terms of complying with standards set down by the UK Ministry of Defence (MoD) and more recently with civil regulators. Examples of the latter are the Nuclear Installations Inspectorate (NII) part of the UK's Health and Safety Executive (HSE) and the Environmental Agency (EA). Civil regulation has played a full part in AWE's operations ever since the laboratory became contractor operated in 1992. In fact part of the AWE site now comes under full NII licensing with a requirement to meet some 38 clauses in order to operate. Although full licensing conditions are not mandatory for the non-licence site areas at AWE, nevertheless the general safety case, review and acceptance procedure is common across the whole site.

Although the licensing conditions set down the requirements, AWE has developed its own methodology in relation to how safety case, review and acceptance is carried out. For the particular case of Nuclear Explosive Safety Cases (NESC) and Nuclear Explosive Like Assemblies (NELA), the standards are a composite of both those set by the NII and those of the MoD with the latter regulated by the Nuclear Weapons Regulator (NWR). In general the latter are more demanding and include aspects in addition to those of the NII. Hence, AWE finds itself in the position of needing to meet NII standards so that the site satisfies civil licensing requirements and the MoD in order to meet MoD contractual requirements. One further point to note is that civil regulators have no jurisdiction over the design of Nuclear Explosives (NE) or NELA. Design of such items falls under the jurisdiction of the MoD.

The whole process is described in AWE's Company Safety Instructions (CSI) documentation system. This covers responsibilities and accountabilities, process requirements and methodologies, licensing requirements, appropriate standards and training requirements. These cover the formal process requirements but of course as with all such systems success is equally dependent on the people. That is on the level of experience, knowledge, commitment, and ability to spot concerns and the culture inherent in the individuals concerned.

The Top Level Process

The top-level executive committee responsible for overseeing the safety of operations within AWE is the Nuclear Safety Committee (NSC). The NSC considers safety reports for Hazard Category 4 and 5 facilities (Table 1), and in addition all category A and B modifications (Table 2). All submissions to the NSC should clearly request either NSC 'endorsement, 'consideration and advice', or 'noting'. For example 'For Endorsement' will include:

Safety Cases (SC) and Periodic Safety Review Reports (PSRR)

Cases for Continued Operations (CfCO) for authority to operate (ATO) renewal

Stage Safety Reports (SSR) for Category A or B modifications for facilities, major organisational changes and changes to hazard categories.

Operating rules and arrangements approved by the NII

Stage Safety Reports for Hazard Category 4 and 5 facilities.
Documentation requested by or forwarded to NII for agreement or consent
Amendments for documents approved by the NII.

Table 1 - General Basis for Facility/Operations Hazard Category

Category	General Basis
5	These are facilities or operations, which are capable of yielding a **significant hazard off –site** at a level which countermeasures (such as sheltering or evacuation) would be required by the public. **Any facility designated as Hazard Category 5 on the basis of its potential importance to Company Stakeholders.**
4	These are facilities or operations which are capable of having an off-site effect but for which no public response is required. Facilities or operations with potential to cause a **significant hazard on – site** outside of the facility would be categorised as 4. **Any facility designated as Hazard Category 4 on the basis of its potential importance to Company Stakeholders.**
3	These are facilities capable of creating a **significant in-facility hazard** as well as no-significant **on-site** hazards
2	These are facilities, which may have **significant localised in-facility hazards** but no out of facility hazards. Serious injuries local to hazard source.
1	These are facilities or operations, which have **no significant hazards** other than those associated with everyday typical office environments.

Company documentation gives further details for individual radiological, explosives, Health & Safety (H&S) and environmental categories.

Table 2 - General Basis for Change Categorisation

Category	General Basis
A	Modifications and any associated commissioning/test activities which if inadequately conceived or implemented have the potential to create **a significant off-site hazard** requiring a public response. **Any modification designated as a Category A on the basis of its potential importance to Company Stakeholders (e.g. novel or contentious issues).**
B	Modifications and any associated commissioning/test activities which if inadequately conceived or implemented have the potential to create **a significant on-site hazard.** **Any modification designated as a Category B on the basis of its potential importance to Company Stakeholders (e.g. novel or contentious issues).**
C	Modifications and any associated commissioning/test activities which if inadequately conceived or implemented have the potential to create **a significant in-facility hazard.**
D	Modifications and any associated commissioning/test activities which if inadequately conceived or implemented pose **no significant hazards.**

Company documentation gives further details for individual radiological, explosives, H&S and environmental categories.

Safety documentation for Hazard Category 3 facilities (unless a category A or B modification) is subject to Directorate rather than NSC review, unless specifically requested by NSC or NII. Nevertheless the same Acceptance Review (AR) process is undertaken.

The broad approach will take the form of a submission sponsored by the AWE Director concerned, through for example a facility or process manager, which in turn is interactively reviewed and accepted or otherwise by an Acceptance Review Team (ART) led by an Acceptance Review Team Leader (ARTL). This team is independent of the sponsoring organisation and is responsible to the AWE Director of Assurance (DA), managed through the Head of Assessment and Review (HAR).

Proposals which the NSC endorses (and which have been accepted by the ART) are made available to the NII for inspection who will, in turn, comment if it has reservations. The NII will formally review the safety cases but will not normally inspect the Acceptance Review Reports (ARR). However, the NII may request to see ARR and related documentation in the event of a subsequent safety deficiency incident.

As noted previously, the regulation of nuclear explosive safety at AWE does not rest solely with the civil regulator. There is also a requirement to undertake an assessment against MoD standards which are generally more demanding than those of the civil regulator who does not cover nuclear yield. The MoD retains formal visibility of the review process for these NESC and NELA cases. In fact the Warhead Safety Committee, WSC, (whose chair is a member of the NSC) will separately review the ARR but not the safety cases themselves. This is an MoD requirement based on the fact that the WSC provides the technical expertise for assessing nuclear explosive product design safety. As such the chair of the WSC appropriately advises the NSC. The formality of MoD's Nuclear Weapon Regulator's (NWR) involvement in this process is still to be finalised. However, this process will include a set of MoD licensing conditions, which is similar in form to that of the NII. In addition the current MoD standards are set within Joint Service Publication (**JSP) 538**, which includes in an annex, the Nuclear Weapons Safety Principles and Safety Criteria (NWSPSC). In fact **JSP 538**, and NWR's responsibilities, cover the cradle to grave lifetime of the Nuclear Weapon product, in addition to the AWE's assembly and disassembly processes.

Nature of the Safety Case Process.

Safety Case production: In general the facility manager or process manager is responsible for the proposal for the safe operations within a facility or for a project. . However, for the case of NE and NELA operations, the facility manager supported by the warhead Design Authority (DA), is responsible for producing a case to show that the facility and process characteristics and the safety attributes of the warhead/nuclear explosive together meet the appropriate standards. The case takes the form of case documentation, covering the process and equipment descriptions together with its safety analysis and commissioning, the potential hazards to the warhead/nuclear explosive, and the mitigating features together with the overall risk assessment set against the required criteria. The documentation is supplemented by evidence from appropriate trials, process and equipment demonstrations, explosive response analysis, criticality analysis and nuclear analysis where appropriate. The case moves forward in a number of stages, with each stage requiring acceptance before moving onto the next. The case culminates with demonstration of the full process in the appropriate venue, with the final process instructions, with the final version of the process equipment and as near as possible the actual warhead hardware. Finally the facility manager, together with the warhead DA takes responsibility for ensuring that the process declared in a successful case is adhered to, and of course for identifying any subsequent issues that may arise and could undermine the assessments within the case. Any modifications as a result of this would themselves go through the same safety case and acceptance process.

Safety Case Review and Acceptance**:** This process is undertaken by an Acceptance Review Team (ART) whose responsibility is to review each stage of the safety case in an interactive manner with the purpose of recommending or otherwise that the case stage should go forward for endorsement by the senior AWE Nuclear Safety Committee (NSC). The ARTL is responsible for assembling a core team with sufficient breadth and depth of experience and knowledge to undertake the review. The ARTL is appointed through the Assurance Directorate and the ARTL together with his team needs to demonstrate the appropriate level of independence. The ARTL is responsible when audited by the NSC to clearly show the basis on which the ART has accepted the staged case and highlight any major issues that arose during the review process and how they were successfully closed out. The NSC in turn scrutinises the case and review prior to a decision to endorse or not.

The Acceptance Review Process

NII Licence Condition (LC) 14 requires that a licensed site has adequate arrangements for the production and assessment of safety cases. In addition LC 15 requires that the site also has a independent review and assessment process. AWE accomplishes the latter through its Acceptance Review (AR) Process. This process provides advice to the NSC (and the WSC where appropriate), to facility and project managers and to directorate assurance committees, on the acceptability of SC, SSR, Cf CO, Category A and B modifications and related documentation in compliance with various NII licensing conditions. The general process is also applied to other activities and to areas, which do not constitute the licence site.

The AR process is owned by AWE's Assurance Director (AD), managed by the Head of Assessment and Review (HAR) through individual directorate Heads of Assurance (HoAS).

Scope of AR: AR independently assesses the suitability, adequacy and practical application of accepted safety, health, and environmental standards, thereby ensuring that NSC submissions meet AWE and other requirements. AR will identify deficiencies together with the required follow-up with recommendations for acceptable resolution and close out. The AR is interactive, includes review of documentation, physical inspection of facilities, equipment and processes and whatever other aspects deemed necessary by the ARTL. The ART will review the procedure undertaken for option choice and down selection, that the proposal follows the company procedures, meets the appropriate standards and follows the As Low As Reasonably Practicably (ALARP) principle. In addition the AR will make judgement on the experience and knowledge of the personnel associated with the production of the safety case.

Responsibilities**:** The **HAR** is responsible for overseeing the AR process, determining policy, advising on ARTL appointments, process training and carrying out periodic reviews of the overall AR process.

Facility and Project Mangers (FM, PM) who are responsible for the production of the safety case, should request an AR through their HoAS, request and even advise on the suitability of an ARTL. In turn they should agree on the scope and standards to be applied and provide sufficient time for the AR process to be completed and should formerly authorise documents issued to the ART for review.

The **HoAS** of the directorate sponsoring the submission is responsible for appointing a suitable, independent ARTL. The HoAS provides a focal point for Directorate AR advice, keeps a record of directorate staff who are suitable as ARTL and ART members and aids the ARTL in the selection of ART members.

Line Managers are responsible for ensuring that ART members are allowed time to integrate their AR responsibilities into their day to day responsibilities and should play no part in influencing the outcome of a review.

The **ARTL** is responsible for the conduct and adequacy of the review, for forming a suitable ART which meets the scope and depth of capabilities needed, for engaging the Site Response Group (SRG) and the internal facility regulator where appropriate, and with the concurrence of the HoAS, appoint a deputy ARTL. The ARTL is also responsible for ensuring that full records are kept of the review process, that appropriate Acceptance Review Reports (ARR) are produced on time and present findings to the appropriate Assurance committees. A senior ARTL may oversee a number of AR and has responsibilities in the mentoring process of ARTL. In addition there is a restricted category of Nuclear Warhead ARTL, which is responsible for major NE and NELA safety cases and where, depths of knowledge and experience of nuclear warhead design is essential. It is also best practice in this case for the ARTL to ensure attendance at major stages of device Design Reviews. In special cases the ARTL may be appointed from an external source if no appropriate internal source is available.

The **ART member** is responsible for carrying out appropriate inspections, assessments and document review as specified by the ARTL and to assist the ARTL with the close out of recommendations. If appropriate the ARTL may contract in an external member if no suitable experience resides within AWE.

Competencies and Resources: AWE has identified the competencies and behavioural aspects required for each of the responsibilities identified above. These are formally listed in CSI documents. AWE is also responsible for ensuring that it has the appropriate resources to fill the roles identified above and that processes are in place to train and mentor appropriate people. The CSI also gives advice on the type and size of ART membership in respect to different categories of reviews.

Independence: There is always the difficulty of true independence when relevant knowledge and experience is essential for carrying out an effective review and where resources will be limited. For this reason AWE CSI have set down a number of requirements to ensure that the requirement of independence is protected. For example ART members must be independent of the line management of the facility or project management teams and will not have been involved in direct engineering aspects involved in the proposals. In addition, the CSI lists a number of prohibitions with regard to links between Line Management and Acceptance Reviewers.

Acceptance Review Report: The production of the ARR is the responsibility of the ARTL. In fact a typical review will be in staged form with ARR produced for each stage. The ARR must demonstrate both the independence and competence of the ART members and the ARTL. It must clearly identify the agreed scope, the agreed standards, and the range of review activities exercised. It must demonstrate compliance with the company AR process. It must clearly identify the significant issues covered during the review together with their resolution. Issues outstanding should be clearly identified with the level of impact on safety, health and the environmental, together with recommendations on how they should be closed out. The ARR should give clear reasons for formally endorsing a given stage of the safety case or for not endorsing the case. Concerns are raised in the form of recommendations, which are categorised as shown in Table 3.

Table 3 - Category of Recommendations.

Category	Definition	Description	Action required
1	Essential to Safety, Health or Environment	A problem has been identified which is so serious that the facility/project would be unsafe or in breach of legislation, if action was not taken. Alternatively, there is a flaw in the justification of safe operations or environmental compliance, which is likely to result in the rejection of the safety case/report/project, or the facility/project is operating outside of Company Procedures.	Should be closed down or down

			categorised on the basis of progress prior to submission to the NSC. Exceptionally this can be an action plan and specified hold point, agreed with the ARTL, which can be closed out after NSC consideration, or the ARTL may recommend that a NSC action be placed. The ARTL will however need to provide NSC with an update of progress against the action and inform the NSC secretariat when the action is closed before the facility/project can proceed past the hold point.
2	Safety, Health or Environmental Concern	A lesser deficiency in the safety of operations has been identified which should be addressed. Alternatively, there is a deficiency in the safety, health or environment justification, which would result in a process or element failing to demonstrate safe operation, but this would not threaten acceptability of the whole safety case/report/project	Should be closed, where reasonably practicable, prior to submission to the NSC. Otherwise they may be placed on a forward action plan (FAP).
3	Observation	An issue not directly affecting health, safety or environment, such as documentation error and quality concerns of a minor nature, which does not affect the progress of the safety case/report/project	Documentation issues should be closed out prior to submission to the NSC. In other cases they may be placed on the FAP.

The ARR, including its recommendation, will form a major part of the evidence for NSC in relation to NSC decisions.

The Hazards

A nuclear warhead represents a somewhat unique situation where high explosive (HE) and radioactive materials are allowed in close proximity with one another and as such, unique hazards pertain. In fact there is a wide range of potential hazards associated with the processing of a nuclear warhead/ nuclear explosive and in general the order of consequence is:

Nuclear yield/ Radioactive material dispersal/ HE event/ Criticality/ Radiological effects/ Toxicity/ General workplace hazards.

Of course the effort will be biased towards the hazards of greatest consequence. However, all risks to the worker, the public and the environment will need to be assessed and shown to comply with the appropriate safety and environmental criteria. Most of the items in the list relate to hazards derived from abnormal stimuli to the warhead (e.g. to its HE) but of course some materials are hazardous in their own right and require appropriate handling precautions. The hazards may be realised as a result of fault sequences arising from a range of initiator sources. The major concerns associated with these fault sequence initiators relate to their ‘impact’ on and the subsequent response of explosive items, but there are also other concerns, which can be equally important.

A Typical NESC

General: In order to illustrate the process the example is taken of a major NESC, which includes the full process of building a nuclear warhead. These cases are complex and involve a number of facilities, processes, tooling sets, testers and process teams. Typically a NE assembly case will cover all phases, starting when the item first has the potential (although remote) for creating inadvertent yield and finishes when the completed product leaves the AWE site. The disassembly process covers the reverse procedure.

The typical classes of fault initiators are shown in Table 4.

Table – 4 Fault Sequence Initiator Classes with Potential Implication for Warhead.

Fault initiator
class
Typical fault initiator type
Potential effects
Natural events
Seismic. Excessive
wind/storm. Flooding.
Excessive snow loading.
Lightning.
Building collapse. Transmitted shock. Equipment
failure/topple. EM environment.
External events
Aircraft impact. Vehicle
impact. Violent even from
neighbouring facility.
Building collapse. Facility penetration. Transmitted
shocks. Thermal (fire). EM environment, chemicals.
Facility failures
Structural failure/breakage. Mechanical (loss of
control). Electrical (mains/RF/ESD)
Thermal (fire).
Equipment failures
Structural failure/breakage. Mechanical (loss of
control/impacts/abrasions/over-stressing). Electrical
(loss of control/faulty testers, ESD, RF).
Facility process
events
Human
reliability/management
Thermal (ignition sources/combustible material).
Wrong/incomplete instructions. Poor supervision.
Wrong interpretation. Poor control. Poor training.
Drops/trips/falls. Wrong
equipment/chemicals/materials. Poor working
conditions. Interaction/interference between
operators.

This case does not include any aspect associated with technical deficiencies in the design or components making up the warhead itself. An independent product safety process covers this.

Table -5. Typical NESC and ART Areas of Expertise.

Area
Expertise
Warhead design
Nuclear physicists. HE experts. Warhead mechanical and
electrical engineers
Materials
Warhead metallurgists. Warhead chemists. Criticality

experts. Contamination experts.
Facility/processing
Facility personnel. Process personnel. Equipment engineers.
Test equipment engineers.
Assessment
Health physicists. Environmental experts. Human reliability
experts. Risk assessors.
Including independent external expertise as required.

In order to both generate the SC and the AR, experts in a range of technical disciplines are required. Table 5 illustrates the range of requirements for a NESC.

The Safety Assessment Strategy: This is briefly described in Figure 1 and includes both independent Lines of Defence (LoD) deterministic analysis and a parallel Probabilistic Risk Assessment (PRA). The overall risk from the operations should be small in relation to the other risks borne in life. The design principles should enable one to

determine an appropriate set of LoD, (or strength in depth arguments) to defend against the risk posed and where the defence is equally weighted across the LoD. The LoD strengths are set such that if the LoD requirements are met then so will the resulting PRA meet the numerical safety requirements. The Basic Safety Limit (BSL) represents the limit of tolerability of risk and the Basic Safety Assessment (BSO) is the standard one aims to meet or exceed in NESC.

A Single Warhead Process**:** The process will include a number of comprehensive HAZOP, which involves both the case and AR teams. This will result in an agreed comprehensive set of fault initiators covering the broad categories listed in Table 4. A typical major NESC can generate fault sequence lists of order 2000 or so.

Table 6 – Illustration of the use of LoD Auditing against Top Level Event

Potential initiating fault of sequence	Unwanted top event	LoD Claimed for sequence*	Compliance
………………	……………………	…………………….	……………
…….			
Source n-2	Nuclear yield	LoD1	No
Source n-1	Nuclear yield	LoD2, LoD4, partial LoD	No£
Source n	Nuclear yield	LoD1, LoD2, LoD7	Yes
Source n+1	Nuclear yield	LoD4, LoD5	No
Source n+2	Nuclear yield	LoD1, LoD3, LoD7, LoD8	Yes
…………….	…………………	……………………………..	……………
……….			
Source m-2	Dispersal	LoD6, LoD9, LoD2	Yes
Source m-1	Dispersal		

LoD 5
No
Source
Dispersal
LoD 8, partial LoD
No£
………………
……………………
……………………..
……………
………..
* LoD are briefly described here but with reference to evidence to support LoD claim for strength and independence.
£ Further action required or ALARP measures and corresponding arguments for risk minimisation.
Top level requirements
Overall risk small compared with other risks but still within scope of reasonable supporting case
Avoid undue dependence on numerical arguments alone (LoD approach)
Overall numerical case (against BSL/BSO)
Risk assessment
Design principles
Figure 1- The Overall Safety Logic Flow.

The fault sequence list is then subject to dual LoD and numerical PRA processes. The former is based on a LoD deterministic audit. Basically, each unwanted top level event must be protected from the occurrence of a complete fault sequence leading to it (from the initiating event) by the correct number of independent LoD. Table 6 illustrates the process for the top events of inadvertent nuclear yield and radioactive material dispersal. In the former case **at least 3 LoD** of sufficient strength and independence are required and in the latter case **at least 2 LoD** of sufficient strength and independence are required.
The fault sequence tables will have a referencing system to direct reviewers to where the evidence can be found which supports the claim of the strength and independence of the LoD. All LoD are declared for each fault sequence in the table rather than stopping at the minimum required. This is essential in the sense that any situation can be rapidly reviewed should future developments throw some doubt on the validity of an LoD. This process looks for a safety argument based on strength in depth and where the argument is roughly weighted equally across the LoD. This avoids putting too much faith in any one argument.
The second process involves a full PRA covering all of the fault sequences identified in a ‘real world Table 6’. The process usually goes through a pre-screening activity, which screens out all those sequences, which will clearly have a minor influence on the overall PRA.
Application to the Site Safety Envelope: The PRA output from a single warhead processed is then multiplied by the number of warheads of that type processed per year. This is repeated for each warhead type and the results summed and added for all other operations within the site, which add further contributions to the PRA. The overall PRA is then assessed against the acceptable operating envelope for the whole site, which is covered in terms of the BSL, BSO and the As Low As Reasonably Practicable (ALARP) requirements. The latter relates to outcomes where the BSO is not met and where arguments are requirement to show why the effort and cost far outweighs any further risk reduction gains.
Contributing Elements to the Overall Assessment Study: All of the elements which contribute to the identification of risk, together with the arguments which mitigate the risk and the resulting assessment for a given NESC are described by an element breakdown and process path as depicted in Figure 2.
The HE Assessment: One of the most difficult and sometimes controversial aspects of the risk assessment lies in the field of the assessment of HE response to classes of insult both in the bare and protected configuration.
Deterministic
screening
Process tooling

& equipment
management
Process tooling
& tester
description
Warhead
potential
hazards
Warhead
intrinsic safety
attributes
Critical item
stress analysis
Tooling/tester
failures
Abnormal
environment
s
External
hazards
Management
failures
Facility failures
Human
failures
Fault
initiators
Tooling &
tester safety
analysis
Process & tooling
assessment
Fault schedule &
normal process stresses
Warhead hazards &
intrinsic protection
PRA
Safety case

Figure 2 – Contributing Elements in a Typical Nuclear Explosive Process Safety Case.

Table 7 – HE Detonation Probability Allocation Scheme.

Severity rank (bare)	Tied rank (protected)	Event prob. range
Insult list 1	Equivalence list 1	P1 – P2
Insult list 2	Equivalence list 2	P2 – P3
……………………	…..	…………………………….
…………………	……….	……………………
…..	…………………………….	…………………
……….		
Insult list n	Equivalence list n	Pn-1 – Pn+1

The process has honed down into placing insults into group categories (or severity ranks) where items in a single category will attract a similar probabilistic HE response as exemplified in Table 7. Given a level of protection then the insult is then placed in the equivalent bare severity rank based on relevant evidence and expert elicitation in respect to the properties of the protection. The events in the table are themselves spit into two categories. (a) A detonation which, has the potential for off-facility and offsite consequences. (b) A violent reaction which, does not have the potential for off-facility or offsite consequences, but has the potential for causing worker death or injury.

Electrical Hazards: Explosives and electro-explosive circuitry are potentially vulnerable to electrical threats and one of the most potent is the natural threat posed by lightning. As such facilities, processes and associated tooling have been specially designed and configured to remove this threat. This process not only meets regulation standards for protection but also includes special elements of protection, which require customer developed testing methodologies and theoretical analysis. Figure 3 depicts the potential threat paths and categories posed by lightning strike and where the assessment steps are required for the associated safety analysis.

Hazardous
event
Current through
sensitive item
Fragment impact
on sensitive item
Abnormal thermal
environment at
sensitive material
Abnormal environment
at sensitive material
EM coupling
to associated
conductors
Direct current
path to sensitive
material
Fragment
generation
Fire
Abnormal
equipment
event
EM environment at
sensitive item
Penetration of
LPS
Lightning strike in
vicinity

Figure 3 – Schematic Lightning Threat Routes.

LPS – Lightning
protection system

Biography

Malcolm Jones
Room 101, Building D2.1, Atomic Weapons Establishment, Aldermaston, Berkshire, RG7 4PR, UK.
Phone +44(0)11898 24747, Fax +44(0)11898 27589
E-mail Malcolm.Jones@awe.co.uk

Malcolm leads the Distinguished Scientists group at AWE and holds the post of Design Authority Scientific Adviser. His career at AWE has taken him through a wide range of scientific and engineering topics, but he has maintained a continuous association with the safety of nuclear weapon design, associated processes and safety standards. His interests extend to corporate safety cultures and the reasons for failures. He is a fellow of the System Safety Society and is an adviser to a number of senior UK Ministry of Defence and AWE safety bodies. He has been awarded an MBE in the Queens Birthday Honours list for contributions to the UK defence industry and is a recipient of the John Challens Medal, which is AWE’s highest award for lifetime contributions to Science, Engineering and Technology. He has also been honoured by VNIIA in the RF for his work in fostering nuclear weapon safety collaboration between the UK and the RF.