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WSP Group / Lydd Airport

London Ashford Airport (Lydd) Development: Aircraft Crash Risks to Dungeness Nuclear Power Stations

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NON-TECHNICAL SUMMARY

Introduction

1. London Ashford Airport Limited (LAA), the owner of London Ashford Airport (Lydd), is seeking planning permission from Shepway District Council to expand the terminal facilities to enable a throughput of up to 500,000 passengers per annum (Planning Application Y06/1647/SH), and to extend the runway northward by 294 metres and provide a further 150 metre starter extension (Planning Application Y06/1648/SH).

2. These developments would enable larger aircraft to take off or land with greater payloads, and hence are expected to encourage the development of a slightly modified fleet mix, with some larger aircraft.

3. This report presents an assessment of the effects of these developments on the risk of aircraft crash onto the nuclear power stations at Dungeness.

The Airport and the Power Stations

4. London Ashford Airport (Lydd) lies about 5 km north of the nuclear power stations at Dungeness. The older of the two stations, Dungeness A, ceased operation in 2006 and is now being decommissioned. Dungeness B is still operational. The operator, British Energy, currently plans to keep it in operation until 2018, after which it will be decommissioned.

Previous Studies

5. The aircraft crash risk following expansion of the airport has already been assessed as part of the station operators' safety case documentation. Having reviewed these assessments and carried out its own studies, the nuclear safety regulator, the Nuclear Installations Inspectorate (NII) within the Health and Safety Executive (HSE), has confirmed to Shepway District Council that it has no objection to the two planning applications.

6. An assessment of the aircraft crash risk has been carried out by Large & Associates on behalf of Lydd Airport Action Group (LAAG). However this assessment cannot be relied upon, as it contains several significant errors in assumptions, calculations and data, and misinterprets the regulatory guidance on nuclear safety, presenting an excessively pessimistic picture of the risks. The present report was therefore commissioned by LAA as an independent assessment.

Objectives

7. The objectives of this assessment are:

- To estimate the risk (frequency and consequences) of an aircraft crash in the 'with-development' case i.e. the runway extension and starter strip and the terminal building both having been constructed and the airport handling 500,000 passengers per annum, with the likely aircraft traffic and fleet mix as provided by LAA; and hence
- To assess the tolerability of the risk against the criteria defined by the NII, and hence its significance as a factor in determining the planning application.

Scope

8. This assessment focuses on potential crashes onto the operational station (Dungeness B), and onto the railhead and rail line used to remove wastes from the site.

9. Crashes onto the closed station (Dungeness A) are likely to present a much lower risk, for a number of reasons, principally because the nuclear fuel, which contains the greatest radioactive inventory, is already being removed. The current programme is that all fuel will have been removed from the site by March 2011, and once this is complete, the hazard will be greatly reduced. Accordingly, there is unlikely to be any significant period of overlap between increased activity at the airport and the presence of fuel at Dungeness A. The risk associated with Dungeness A is therefore not considered to contribute a significant additional risk to that for Dungeness B, and so has not been analysed further.

Assessment Method and Data

10. Crash frequencies have been predicted using an 'industry-standard' model for nuclear safety assessment.

11. Because details of the station nuclear safety cases are confidential to BE and the NII, conservative, bounding assumptions have been made. For example, the 'target' area has been defined to include the whole of the main site, not just the buildings that contain radioactive material or are critical to the safe operation of the reactors, and the NII criteria for 'design basis' accidents have been interpreted conservatively.

12. Where there are other limitations or unquantifiable elements in the data or models, conservative assumptions have been made. For example, no credit has been taken for the effectiveness of the current restricted flying zone around the power station.

Results

13. A conservative assessment of the frequencies and consequences of crashes indicates that the risk with the likely aircraft traffic remains below the NII ‘design basis’ level: the level at which a plant should be designed to withstand an aircraft crash. Rather, it lies within what the HSE defines as the ‘tolerable’ region: the range of risk levels that society is prepared to tolerate, in order to secure benefits, provided that the risk is kept as low as reasonably practicable (ALARP) and properly monitored, assessed and controlled. Hence the airport and the power station can co-exist.

14. The risk is largely attributed to background air traffic, i.e. overflying aircraft unconnected with the airport (en-route between the main London airports and continental Europe, for example).

15. This below design basis risk will further reduce in future when Dungeness B is shut down and decommissioned.

16. The assessment indicates that the aircraft crash frequency would be above the NII screening criterion of 1 in 10 million per year, but below the NII ‘design basis’ level as set out above. This does not mean (as claimed in the Large & Associates report) that the risk is unacceptable. A frequency above the NII screening criterion only means that aircraft crash risk cannot be excluded from consideration purely on the grounds of low frequency alone, and that further assessment of risk (frequencies and consequences) is required. This further assessment has been undertaken. The risk has been found to be below the NII 'design basis' level and is therefore classed as 'tolerable'.

Conclusions

17. For the likely aircraft traffic levels assumed for the scenario of 500,000 passengers per annum, the assessment, even with the various conservative assumptions, predicts that risk will remain below the 'design basis’ level. The risk is therefore within the ‘tolerable’ region, indicating that, with the proposed developments and assumed aircraft traffic, the airport can operate in a way that would not invalidate existing arguments about the tolerability of the power station risk.

18. The risk does not increase to an unacceptable level, but remains in a region where the ALARP principle can continue to be applied and satisfied by the operators of the power station and the airport. In addition, the overall crash risk remains dominated by that from background (non-LAA (Lydd)) aircraft traffic, rather than LAA (Lydd) airport-related traffic.

19. We therefore support the NII’s conclusion that they should have no reason to object to the proposed developments.

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2. These developments would enable larger aircraft to take off or land with greater payloads, and is expected to encourage the development of a slightly modified fleet mix, with a greater number of larger aircraft.

3. This report presents an assessment of the effects of these developments on the risk of aircraft crash onto the nuclear power stations at Dungeness.

1.1 The airport and the power stations

4. London Ashford Airport (Lydd) lies about 5 km north of the two nuclear power stations at Dungeness (Figure 1). Although there is a restricted flying zone around the power stations to minimise the possibility of aircraft crash, the risk still needs to be assessed.

5. The older of the two stations, Dungeness A, is a Magnox design. It ceased operation in 2006 and is now being decommissioned. Dungeness B is an Advanced Gas-cooled Reactor (AGR) design, and is still operational. The operator (British Energy – BE) currently plans to keep it in operation until 2018, after which it will be decommissioned. Each station contains two reactors.

1.2 Previous studies

6. The aircraft crash risk following expansion of the airport has already been assessed as part of the station operators' Safety Cases and Periodic Safety Reviews. On the basis of a review of these assessments and its own studies, and after clarification of some details of flight paths, the nuclear safety regulator – the Nuclear Installations Inspectorate (NII) within the Health and Safety Executive (HSE) - has confirmed to Shepway District Council that it has no objection to the two planning applications. This provides confidence that the airport, developed as proposed in the two current planning applications, and the Dungeness power stations can continue to operate side by side.

7. An assessment of the aircraft crash risk [Ref 1] has been carried out by Large & Associates on behalf of Lydd Airport Action Group (LAAG), a local group of objectors. However this assessment – which we have reviewed in Appendix A – cannot be relied upon. The main reasons for this are as follows:

   - There are significant errors in the assumptions, data and calculations for the quantitative assessment of crash frequency;
   - The conclusion that a crash frequency above the NII screening level of 1 in 10 million per year (1E-07 per year) makes the risk 'unacceptable' is incorrect. 1E-07 per year is a screening level, below which the potential for aircraft crash does not need to be considered further. Where crash frequency is above this level,

further consideration of risk (frequencies and consequences of crashes) is required to establish whether or not the risk is tolerable, but it does not in itself indicate unacceptable risk;

- The frequencies presented are for crashes anywhere on the Dungeness A or B sites, whilst the consequence assessment focuses on worst-case scenarios that could only result from crashes causing serious damage to an operational reactor. By not properly acknowledging that most crashes onto the site would have far lower consequences, this gives an excessively pessimistic picture;
- The report claims that aircraft crash frequency is a 'design basis event' – i.e. one that the Dungeness power stations should have been designed to withstand (but have not). This is incorrect; the crash frequency (whether from Large & Associates' predictions or those in the present report) is not sufficiently high to require this;
- Results are presented for aircraft movements corresponding to 2 million passengers per annum, but these are not applicable to the determination of the present planning applications, which are only for facilities that would enable a throughput of 500,000 passengers per annum.

8. As the Large & Associates report does not give a comprehensive and reliable picture of the risk, LAA commissioned the present report to provide an independent assessment.

1.3 Objectives

9. This assessment is intended to inform the planning process by assessing the risk of an aircraft crash onto the power stations. The specific objectives are:

- To estimate the risk (frequency and consequences) of an aircraft crash in the 'with-development' case (the runway extension and starter strip and the terminal building both having been constructed and the airport handling 500,000 passengers per annum), for the likely aircraft traffic and fleet mix as provided by LAA; and hence
- To assess the tolerability of the risk against the criteria defined by the NII, and its significance as a factor in determining the planning application.

1.4 Scope

10. As already noted, there are two power stations at Dungeness. This report focuses on crashes onto the operational station (Dungeness B), since this provides a bounding case. Crashes onto the railhead and rail line used to remove decommissioning wastes are also considered.

11. Crashes onto the closed station (Dungeness A) are likely to present a much lower risk, for the following reasons:

- The risk from Dungeness A will reduce over the years as decommissioning progresses. The reactors are currently being defuelled. The fuel contains the greatest radioactive inventory on the site, so once this is removed the potential for harm in the event of a crash will be greatly reduced. The current programme is that all fuel will have been removed from the site by March 2011 [Ref 2]. Accordingly, there is unlikely to be any significant period of overlap between increased activity at the airport and the presence of nuclear fuel at Dungeness A.

- Although decommissioning necessarily involves removing and handling radioactive materials, the reactor is unlikely to be in any more vulnerable state during decommissioning than during operation. Fuel rods, for example, would in any case have been regularly removed from the core as part of normal operations. The pressure vessel and concrete biological shield that protect the reactor core would not be dismantled until well after fuel had been removed from the site.
- Now that the reactor has been shut down, the fission products that can be released if fuel is damaged are decaying and thus their inventory is continually reducing. Fission products are the principal radiotoxic material to be considered in major accident analyses. Thus the potential consequences of any damage to the fuel are reducing.
- Once the fuel has been removed, the remainder of the radioactive inventory will comprise activated reactor components such as steelwork and core graphite. The inventories are much lower than for fuel fission products and are less likely to be released to the environment, being bound in solid form within the steel or graphite.
- The fuel at Dungeness A was of lower radiotoxicity than at Dungeness B.

12. For all the above reasons, the additional risk associated with Dungeness A is not considered to contribute a significant additional risk to that predicted for Dungeness B. It has therefore not been analysed further.

13. The study has not assessed any implications of aircraft crash risk for the possibility of any new nuclear power station being built at Dungeness. Aircraft crash risk will be one of many considerations in decisions about new reactors, but at the time of writing (March 2009) no planning application has been submitted for any such reactor at Dungeness, neither is there as yet any National Policy Statement on favoured locations for new nuclear power stations. Industry information, and the general tightening of regulatory expectations, suggests that the new generation of reactors will have to meet more rigorous safety criteria than Dungeness B. In addition, no new reactors are expected to be in operation before 2018, when Dungeness B is planned to be shut down, so it is unlikely that there would be more than one power station in operation at any one time.

2. ASSESSMENT METHOD

14. This section provides an overview of the methods used to produce quantitative estimates of risk. Further details of the assumptions made, the application of the methods, and the selection of appropriate data are given in Appendix B.

2.1 Overall approach to crash frequency and consequence analysis

15. Risk involves both the frequency (or probability, or likelihood) of a given potential event, and the severity of its consequences.

16. There are many different buildings and facilities within the Dungeness B power station site. The buildings vary in size, which determines the 'target' area that they present to a crashing aircraft, and hence their probability of being struck in a given period of time. Crash frequencies therefore vary from building to building.

17. The buildings and facilities also vary widely in structural and system vulnerability to aircraft crash, and in the nature and quantity of any radioactive materials that they contain. The consequences of a crash therefore also vary from building to building.

18. Because of these variations in crash frequency and consequence between buildings, it is appropriate to look at a range of different buildings, considering the crash frequencies and potential consequences for each. Details of the power station Safety Case, which are confidential to BE and the NII, would be needed to assess crash frequencies or consequences for each building individually. We have therefore bounded the range of risk levels by calculating frequencies and consequences for two different target areas, defined to span the range of possibilities. These two areas, as shown in Figure 2, are:

    - The '**nuclear island'**, comprising the reactors themselves, the spent fuel ponds and the main control room. Severe crash damage to these elements of the station could lead directly to the largest releases; and
    - The **whole Dungeness B site**, including all buildings and facilities that, if damaged, could lead, directly or indirectly, to a radioactive release. Conservatively, this area is drawn around the entire main site boundary to include all the nuclear plant, its supporting systems and the waste and effluent facilities (but excluding the visitor areas etc to the north). It therefore includes some open areas and ancillary buildings where an aircraft crash would have no significant impact on plant safety.

2.2 Aircraft traffic assumptions

19. Crash frequencies and consequences depend on the number and type of aircraft in the vicinity of the power station. It is informative to break this traffic down into an 'airport-related' component, from aircraft landing at or taking off from London Ashford Airport, and a 'background' component, from overflying traffic unconnected with the airport – for example en-route between Heathrow and continental Europe.

20. For airport-related traffic, a forecast of likely movements and fleet mix was provided by LAA, and are consistent with those used in the 2009 noise assessments.

21. For background traffic, generic UK data were used. These data are implicit in the crash frequency calculation method (Section 2.3).

2.3 Crash frequency prediction

22 The frequency of aircraft crash was predicted using a method developed for the HSE by Byrne [Ref 3]. This is a standard method used in nuclear industry safety cases.

23. The traffic data are treated differently for the nuclear island and for the whole site. Within the nuclear island, plant elements are generally protected within, or shielded by, massive reinforced concrete structures. It is therefore assumed that they would not be damaged by the crash of any aircraft in the 'light aircraft' or helicopter category, and movements of such aircraft are excluded from the data set. Other buildings within the whole site area are generally less well protected, so it is assumed that damage could occur as a result of a crash by aircraft in any of the categories, and the full data set is used.

24. Adopting a conservative approach, no credit has been taken for the restricted zone around the power station, the design of standard arrival and departure routes to take aircraft well away from the power station, or the fact that the Air Traffic Control service at London Ashford Airport provides positive control of aircraft in the vicinity and some ability to monitor and correct any that stray towards the restricted zone.

25. Also, no credit (beyond that implicit in the effective target areas calculations) has been taken for the likelihood that the pilot of a troubled aircraft would, assuming that some degree of situation awareness and control is retained, make every effort to avoid crashing into such a conspicuous and well-known site, especially when there are large areas of flat land in the vicinity available for a forced landing.

2.4 Crash consequence prediction

26. A full quantitative assessment of the consequences of an aircraft crash would require detailed information on many factors, such as the structural response of the various buildings, their radioactive inventories, and the operation of safety systems. In the absence of such details, which are confidential to the NII and BE, we have taken a broad approach, defining qualitative levels of consequence for each of the two target areas.

27. For the nuclear island, a crash could lead to events such as direct physical damage to the reactor cores, a loss of coolant, or damage to spent fuel. Any of these events could be accompanied by an aircraft fuel fire. Such events could lead to a major uncontrolled release of radioactivity, with significant off-site radiological doses. As it is not possible to evaluate all these possibilities without detail from the station safety cases, the potential consequences have been grouped under a single qualitative description 'potential for a severe release of radioactivity'.

28. The buildings and facilities in the 'whole site' area include some, such as waste stores and effluent treatment plant, that contain radioactive material. However, the radioactive inventory in such areas is typically much lower than that in the nuclear island. There is also plant on the 'secondary' (non-radioactive) side of the reactor system which, whilst not in itself containing radioactive materials, could lead to a release if the effects of damage propagate to the primary side without adequate mitigation by the various protective systems and procedures. Taking account of such factors, the potential consequences of a crash on this area are grouped under the description 'potential for minor release of radioactivity'.

3. RESULTS

29. The results of the frequency and consequence analyses are summarised in Table 1 following.

Table 1: Predicted Crash frequencies and potential consequences

	Nuclear Island	Whole Site area
	Potential for severe release of radioactivity	Potential for minor release of radioactivity
Contribution	Crash frequencies (per year)	
Airport-related	1.6E-07	9.8E-07
Background	4.0E-07	7.3E-06
Total	**5.6E-07**	**8.3E-06**

4. RISK TO RADIOACTIVE WASTE TRANSPORT

30. Operational and decommissioning wastes from the Dungeness sites are removed using the railway line that passes south-west of the airport. These transport operations themselves require a nuclear Transport Safety Case to provide assurance of their safety. The airport has indicated that it will continue the present Air Traffic Control procedure, whereby no aircraft are allowed to land on runway 03, or take off from runway 21, while a loaded waste train is passing.

5. DISCUSSION

31. Sections 5.1 to 5.2 of this report discuss the tolerability of the estimated risk levels, as against the criteria used by NII inspectors when assessing the adequacy of safety cases for nuclear power stations. The relevant criteria are principally set out in the NII Safety Assessment Principles (SAPs) [Ref 4] and the 'Explanatory Note' on targets and legal limits [Ref 5]. Section 5.5 of this report reviews the effects of uncertainty in the assessment, and Section 5.6 discusses the implications of all these findings for the planning process.

5.1 Comparison against NII 'screening' criterion

32. In nuclear safety cases, aircraft crash is usually considered as one generic type of external hazard (i.e. a potential event, originating outside the site, that may lead to harm). The commentary on NII SAP EHA.1 regarding external and internal hazards states that: *"any generic type of hazard with a total frequency that is demonstrably below one in ten million years may be excluded".*

33. The total crash frequencies (adding background and airport-related traffic) for the nuclear island alone, and for the whole site, exceed this screening level. However, this does not mean that the risk is unacceptable, but only that it cannot be ruled out purely on the grounds of low frequency. The consequences also need to be taken into account.

5.2 Comparison against NII 'design basis' criterion

34. The NII SAPs also define 'design basis' criteria. A design basis event is one whose frequency is considered sufficiently high that the plant should be designed to withstand it – in general no credit can be taken for how unlikely it is to occur. It is unlikely that Dungeness B was specifically designed to withstand aircraft crash, so the risk level relative to the design basis is a useful indictor of tolerability.

35. For aircraft crash the design basis event is defined in the SAPs as one that occurs at a frequency of 1 in 100,000 per year (1E-05 per year) or greater. This criterion is to be applied to *"the total predicted frequency of aircraft crash, including helicopters and other airborne vehicles on or near any facility housing structures, systems and components important to safety should be determined".* Conservatively, we have taken this to apply to the whole site area, even though only a proportion of the whole site area could be considered as 'housing structures, systems and components important to safety'.

36. There is further conservatism in applying the 1 in 100,000 per year criterion to the whole site. The Explanatory Note [Ref 5] states that this criterion can be relaxed, to 1 in 10,000 per year or even more, for events that could not lead to off-site doses over a threshold of 100 milliSieverts. Based on our experience of other nuclear safety cases, we consider that it is only crashes on the nuclear island that could lead to doses above this threshold.

37. For the estimated traffic (background plus airport-related) the crash frequency onto the whole site area is predicted to be about 8.3E-06 per year, which is below the design basis, even with the conservative assumptions. For the nuclear island only the predicted frequency is even lower, at about 5.6E-7 per year: well below the design basis criterion.

38. Thus the crash frequency lies between the NII's screening criterion and the design basis criterion, falling within the 'look further' region. The commentary on NII SAP EHA.8 states that, in such cases: *"….efforts should be made to understand and minimise the potential impact consequences on structures, systems and components important to safety".*

39. In other words, the risk falls within what the HSE [Ref 6] define as the 'tolerable' region: the range of risk levels that society is prepared to tolerate, in order to secure benefits, provided that the risk is kept as low as reasonably practicable (ALARP) and properly monitored, assessed and controlled. It does not increase to an unacceptable level, but remains within the range where the ALARP principle is to be applied.

40. Power station operators and airport operators, like most employers, already have a duty to keep risks ALARP, under the Health and Safety at Work etc Act 1974. Changes in traffic resulting from the proposed development of the airport (or indeed traffic increases that could occur anyway) should be monitored by the station operator., as would be normal. Continuous review and adaptation to change is an ongoing process for all nuclear plant and does not, in itself, preclude changes being made. Similarly, airport operators have a duty to monitor risks and manage the safety of the airport in accordance with the ALARP principle, and the requirements of the CAA and other regulators, in a manner proportionate to the level and nature of the aircraft traffic.

41. Hence the airport and the power station can co-exist; with the proposed developments to the airport the risk remains in a region where the ALARP principle is to be applied.

5.3 Comparison against NII societal risk criteria

42. Some further indication of the significance of the risk can be gained by looking at societal risk – the frequency of a large accident affecting many people.

43. The relevant societal risk criteria are given in Target 9 of the NII SAPS. For accidents causing one hundred or more fatalities, the Basic Safety Level (BSL) – the intolerable level - is set at 1.0E-05 per year. The Basic Safety Objective (BSO) – the 'broadly acceptable level' below which detailed regulatory scrutiny is not normally required - is set at 1.0E-07 per year

44. The Target 9 criteria are intended to be applied to the entire nuclear plant, including risks from all external hazards as well as internal hazards and failures. Hence it is not possible to apply these criteria directly to any one particular type of hazard such as aircraft crash. However, it is nevertheless informative to check whether aircraft crash risk alone might exceed the BSL.

45. In the case of Dungeness, only a crash onto the nuclear island has the potential for consequences of sufficient severity to fall within the 'large accident' category that the societal risk criteria are designed to control. The predicted frequency of aircraft crash onto the nuclear island in the with-development case is 5.6E-07 per year – which is well below the BSL. The frequency of crashes that would actually constitute a 'large accident' as defined in Target 9 would be even lower.

46. Hence the frequency of aircraft crash alone does not exceed the societal risk BSL for the plant as a whole.

5.4 Risk contributions from background and airport-related traffic

47. For both the nuclear island and the whole site, the background crash frequency contributes over 70% of the total. This illustrates that the development proposals have a relatively small effect on the overall risk.

5.5 Review of assumptions

48. A conservative approach has been taken throughout the assessment. All the major assumptions that were required in order to allow for uncertainties in models and data, as summarised below, have been pessimistic:

    - no credit has been taken for the restricted flying zone around the power station or the arrival and departure routes that are designed to keep aircraft well away from it;
    - no credit has been taken for the ability of the pilot(s) of a troubled aircraft to avoid the power station, even though it is such a conspicuous and well-known building, and there are large areas of flat land in the vicinity available for a forced landing;
    - the crash frequency over the whole site has been predicted on the basis of the full area within the main site boundary, even though only a proportion of this area contains radioactive materials or structures, systems and components important to nuclear safety; and
    - the crash frequency across the whole site area has been compared against the most stringent design basis criterion of 1 in 100,000 per year, even though a criterion of 1 in 10,000 per year or more is likely to be appropriate, given that a crash onto this area is unlikely to lead to high off-site doses.

49. There is thus a high degree of confidence that the results presented give a pessimistic view of the risk for the assumed with-development scenario.

5.6 Implications for the planning process

50. Even with the various conservative assumptions in the assessment, it is predicted that, for the likely aircraft traffic, risk will remain below the 'design basis' level in the with-development case. We therefore support the NII's conclusion that they have no reason to object to the proposed developments on the grounds of nuclear safety.

51. With the proposed developments and likely aircraft traffic risk remains in a region where the ALARP principle can continue to be applied and satisfied by the operators of the power station and the airport.

52. In addition, the overall crash risk remains dominated by that from background aircraft traffic, rather than airport-related traffic.

6. CONCLUSIONS

53. The risk assessment by Large & Associates cannot be relied upon, as it contains several significant errors in assumptions, calculations and data, and also misinterprets the regulatory guidance on nuclear safety, presenting an excessively pessimistic picture of the risks.

54. The NII has reviewed the station operator's safety case documentation and carried out its own risk assessments. It has concluded that any increase in risk resulting from the proposed developments would be too small to give them reason to object on nuclear safety grounds.

55. This report has assessed the risk for the with-development case, using forecasts of likely aircraft traffic provided by LAA. It has been based on industry-standard models and data where available. A conservative approach has been taken, making pessimistic assumptions where there are uncertainties.

56. The assessment indicates that the aircraft crash frequency would be above the NII screening criterion of 1E-07 per year (as is the case with current conditions). However, this does not mean (as claimed in the Large & Associates report) that the risk is unacceptable, but only that it cannot be ruled out purely on the grounds of low frequency and that further consideration of risk (frequencies and consequences) is required.

57. Such further consideration of the frequencies and consequences of crashes indicates that, even with the various conservative assumptions, the risk for the likely aircraft traffic will remain below the 'design basis' level in the with-development case, and hence be within the 'tolerable' region as defined by the HSE. Risk remains in a region where the ALARP principle can continue to be applied, and satisfied, by the operators of the power station and the airport.

58. In addition, the overall crash risk remains dominated by that from background aircraft traffic, rather than airport-related traffic.

59. We therefore support the NII's conclusion that they have no reason to object to the proposed developments on the grounds of nuclear safety.

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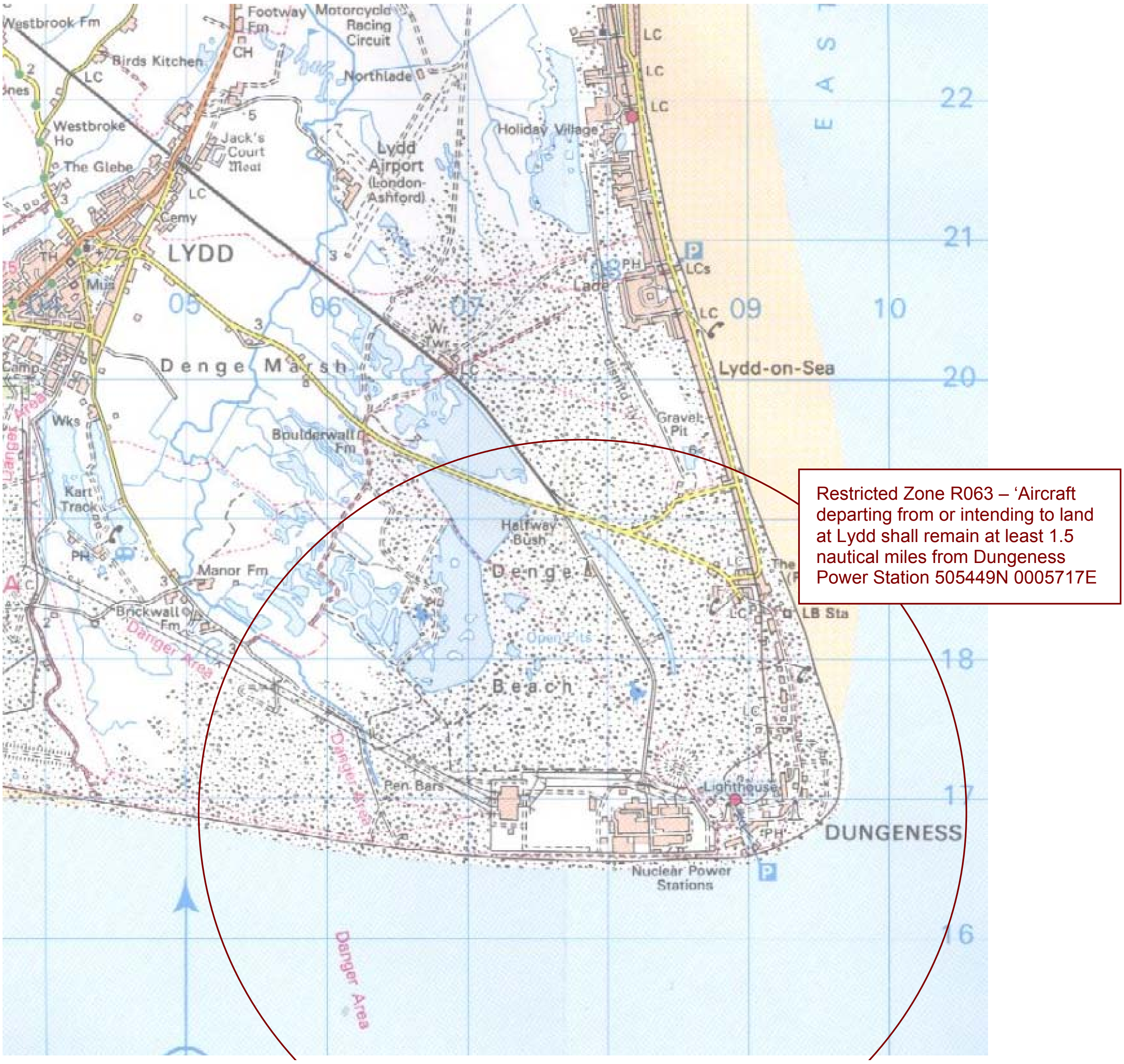

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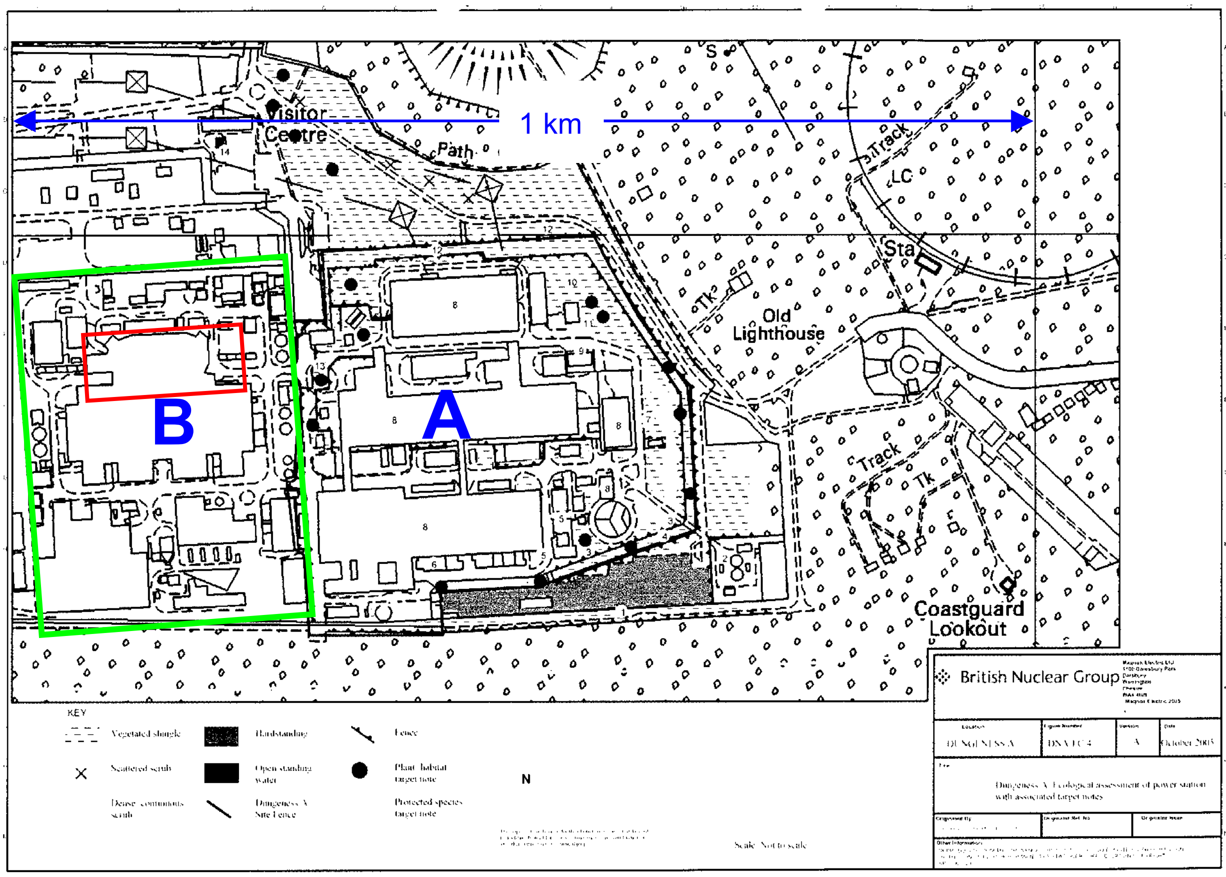
Note: For clarity, Danger Area D0444 (Lydd Ranges) is not shown

Figure 1: Map of the Airport and Power Stations



'Nuclear island'

'Whole site'

Note: *The area of the nuclear island area has not subtracted from that of the whole site, to reflect the fact that a crash on the nuclear island may lead to a minor release of radioactivity as a well as a larger release*

Figure 2: Dungeness B Power Station Target Areas

APPENDIX A: REVIEW OF LARGE & ASSOCIATES REPORT

The following is a brief technical review of the Large & Associates report [Ref 1] prepared in March 2007 on behalf of LAAG.

Overview

A1. The Large & Associates report is incorrect in stating that a crash frequency above the NII screening level of1E-07 makes the risk 'unacceptable'. 1E-07 per year is simply a screening level, below which aircraft crash does not need to be considered further. Where crash frequency is predicted to be above the NII screening level, further consideration of risk (frequencies and consequences of crashes) is required to establish whether or not the risk is acceptable. A frequency above the screening level does not in itself mean that risk is unacceptable.

A2. The Large & Associates report is also incorrect in claiming that aircraft crash is a 'design basis event' – one that the reactor should be designed to withstand. The frequency (whether using Large & Associates' predictions or our own) is not sufficiently high to require this.

A3. Results are presented for aircraft movements corresponding to 2 million passengers per annum, but these are irrelevant to the determination of the present planning applications. The terminal building planning application is specifically for facilities to enable a throughput of 500,000 passengers per annum.

A4. There is no systematic or robust consideration of risk in the Large & Associates report. The quantitative crash frequency analysis contains significant errors in assumptions, data and calculations. The consequence assessment gives an excessively pessimistic picture, by describing worst-case scenarios without properly acknowledging that, in most cases, a crash onto the plant would have far lower consequences.

A5. In summary, the Large & Associates report incorrectly interprets the regulatory guidance on nuclear safety and there are significant errors in the analyses. Its conclusions should therefore not be relied upon.

Detailed comments

The following detailed comments are referenced to the section headings or paragraph numbers of the Large & Associates report.

Summary, para (i). Here, and at several other points in the report, it is stated that an aircraft crash frequency of greater than 1E-07 is unacceptable because it is greater than the screening level given in the NII SAPs. This is not the case. The commentary on NII SAP EHA.1 *("External and internal hazards that could affect the safety of the facility should be identified and treated as events that can give rise to possible initiating events")* states that: *"any generic type of hazard with a total frequency that is demonstrably below one in ten million years may be excluded".* A crash frequency greater than 1E-07 per year only means that the hazard must be considered further, the frequencies and consequences of crashes being assessed in more detail. It does not mean that the risk is unacceptable.

Summary, para (i). The report compares the crash frequency for only one type of aircraft, commercial airliners, against the NII screening level. However, it is the *total* crash frequency that should be compared with the screening level (see commentary on SAP EHA.8: *"The total predicted frequency of aircraft crash, including helicopters and other airborne vehicles …should be determined"*). Because the frequency for commercial airliners alone is predicted to exceed the screening level, the frequency for all aircraft would also do so. This is a further instance of misunderstanding of the regulatory guidance. (In fact, as described in the previous comment, the Large & Associates report goes on to misinterpret the significance of exceeding the screening level.)

Summary, para (i). Results for 2 million passengers per annum are not pertinent to the determination of the present planning applications. The terminal building planning application is for facilities to enable a throughput of 500,000 passengers per annum.

Summary, para (iii). We agree that safety cases for transport of waste from the site need to be reviewed to take account of changes in aircraft traffic. Monitoring and taking account of changes in external hazards should be an ongoing process for any nuclear safety case. However, it should be noted that the airport is willing to continue the existing procedure whereby aircraft are not allowed to land or take off across the rail line while an outbound waste train (not just those carrying fuel flasks, as the Large & Associates report states) is passing (see also comment on Para 39).

Para 24. It is not planned, neither is it current practice, for spent fuel to remain for 'three or more years' in the storage pond before dispatch to Sellafield. As noted in the comment on Para 85, the significance of this error is that the actual radioactive inventory in the pond, and hence the risks, are lower than the Large & Associates report implies.

Para 33. Whilst there may, as stated, be a large release of Wigner energy in the event of a crash or fire affecting the graphite core of Dungeness A, the consequences after defuelling (which is due to be completed in 2011) will be much lower than for an operating reactor. With no fuel to overheat, releases will only be of the activation products in the graphite.

Paras 36 - 37. While it is correct that there would be significant radioactivity remaining on site after defuelling until decommissioning is fully completed, a balanced summary of the hazards should note that the radiological consequences of an aircraft crash would be significantly lower (probably by orders of magnitude) than for an operating reactor.

Para 38. The consequences of a crash involving waste transport are also likely to be many times lower than for the operational reactor.

Para 39. The Large & Associates report states that the existing procedure, whereby aircraft are not allowed to land or take off across the rail line while a waste transport train is passing, 'may not be practicable' with the increased traffic. However, we understand that the airport is willing to continue applying this procedure with the foreseen levels of traffic after development. The delay to aircraft while a train passes is only a matter of minutes, and trains are infrequent.

Para 40. As in the comment on Para 24, spent fuel is not generally stored in the ponds for as long as the stated 2 to 5 years (see also comments on Paras 24 and 85).

Para 46. The Large & Associates report only presents predicted consequences for a 'severely damaging incident' (i.e. core damage or core melt, presumably) at a French reactor (Fessenheim). It rightly acknowledges that these results need to be treated with great caution, as the Fessenheim reactor is of a different design (Pressurised Water Reactor), the fuel burn-up is higher and population distributions and emergency planning measures are different. While these results may serve to illustrate the consequences of serious core damage / core melt in very broad terms, it should be made clear that an aircraft crash does not necessarily constitute such an incident. Except in the case of an impact severely damaging the operating reactors at Dungeness B, the radiological consequences of a crash would be significantly lower than the figures presented for Fessenheim. As noted in the comment on Para 65/ Table 1, and in our own analysis, the probability of such a crash is much lower than that for the site as a whole.

Para 46/ footnote 16. It should be clarified that the 'MEAN' column gives the consequences 'most probably to result' from a severely damaging incident at Fessenheim. It does not (as might be inferred) give the most probable consequence of an aircraft crash at Dungeness.

Para 58/ footnote 25. The value of the x co-ordinate in these equations for crash frequency at a given location should be 2.4 km (measured to the centre of the nuclear island within Dungeness B site) rather than the 2.91 km stated by Large & Associates. It appears that Large & Associates have measured the distance from the centre of the runway rather than, as required in the Byrne model [Ref 3], from the end nearest the target site. In this limited respect, the Large & Associates assessment underestimates crash frequencies on the plant by a few percent. This is, however, insignificant by comparison with the effect of other errors in the Large & Associates analysis.

Para 58/ footnote 25. There are errors in the transcription of the impact probability formulae from the source reference [Ref 3]. In the first equation (for landing) the number 1.8 should be part of the exponent. In the second (take-off) equation the first number inside the square brackets should be 46.25 not 56.25. In both equations 'S2π' is presumably intended to represent the square root of 2π - i.e. $\sqrt{2\pi}$. Because the steps in the calculations are not fully explained (see comments on Para 65) it is unclear, without a full reworking of the Large & Associates calculations, whether any or all of these errors have affected the actual calculation, or whether they are only typographic errors in the report.

Para 58/ footnote 25. In the Byrne crash model, it is not necessary to assume that the 'incident resulting in the crash' occurs at any particular altitude, except in the case of military combat aircraft (MCA). This footnote, stating that an altitude of around 1000 ft was assumed is, therefore, superfluous, as there are no MCA in the assumed traffic mix. However, see the following comment on Table 1, in which it appears that the effective target area for MCA has, incorrectly, been used in some cases.

Para 65 (Table 1). The meanings of the columns in this table are not entirely clear, and the calculations are not set out in full, so it has not been possible to check the working in detail. However some spot checks have revealed several significant errors, as follows:

- In the 500,000 passengers per annum case, it is unclear why the 'crash rate' (presumably expressed in units of per km^2 per year) for C3 (Small Transport) aircraft is nearly 100 times greater than that for C4 (Large Transport) aircraft. Using the data in the table itself, C3 aircraft have a crash probability per movement (shown in the 'reliability' column) about three times greater than C4 aircraft, but half as many C3 movements as C4 are forecast. It would therefore be expected that the 'crash rate' for C3 aircraft would be only a factor of about 3/2 greater.
- The assumed target dimensions **(footnote 28)** - a cuboid 750 m by 600 m in plan and 80 m high - are too large. In plan, this is greater than the entire area of both the A and B station sites. The height is also too large; only one point on the site - the stack on Dungeness B - is 80 m tall, and most buildings are considerably lower.
- The effective target area used for most scenarios and aircraft types (0.839 km^2) appears to have been calculated using Equation 14 from Byrne, which is only for MCA accidents initiated below 2000 ft. As there are no MCA in the assumed traffic mix, it would have been more appropriate to use Byrne's Equation 13, which would give an effective area of 0.536 km^2.
- An exception is the effective target area for C4 (Large Transport) aircraft in the 500,000 passengers per annum case, for which an effective target area of 0.517 km^2 appears to have been used. This is the area that would result using Byrne's Equation 15, which is for helicopters. This is presumably a slip in calculation rather than for any deliberate reason.
- From spot checks in cases where other errors did not make it impossible to trace the calculation process, the Large & Associates report seems to have assumed that *all* movements are to or from the south of the airport (landings on runway 03 and take offs on runway 21). This will overestimate the crash frequency at the Dungeness site, since in reality the movements in the opposite directions (landings on runway 21 and take offs on runway 03) are much less likely to crash on the power station and so do not contribute significantly to the overall crash frequency at the site.

Para 65 (Table 1). Results for 2 million passengers per annum are not pertinent to the determination of the present planning applications. The terminal building application is specifically for 500,000 passengers per annum.

Para 72. This is one example of several places where there is confusion of frequency and risk. The numbers quoted here are frequencies of a crash, not the resulting risk. Another general remark is that quoting numbers to five decimal places implies a much higher level of accuracy than could ever be achieved with the available models and data.

Para 81. The statement about "the hardened projectile striking most of the concrete structures of a nuclear power plant would achieve full penetration" needs qualifying. It may not be true for the massive structure of the Dungeness B pressure vessel, which has 3.8 m thick walls and 6.1 m thick top and bottom caps [Ref 7]. This wall thickness is provided for radiological shielding rather than structural strength alone, so the pressure vessel should have considerable 'spare capacity' against impact loads. Note also that the pressure vessel is designed for up to 2.5 times the normal working pressure [Ref 8].

Para 85. The amount of fuel in a storage pond would never equal "several times, or more, the reactor core load". The AGR fuel route strategy does not allow for this, moreover the ponds are much too small to accommodate anything like this amount of spent fuel.

Para 86. There is unlikely to be any fuel remaining at Dungeness A, as the Large & Associates report itself acknowledges at Para 36. The programme is for all fuel to be off-site by March 2011 [Ref 2].

Para 89. The statement that a crash onto waste storage buildings could lead to a 'significant' release of radioactivity should be set in context by stating that the radiological consequences would be much less than those that could arise from impact on a reactor.

Para 97. The conclusion does not follow from the arguments. The safety cases do consider aircraft crash and it must, therefore, be assumed that the NII believe that a suitable and sufficient safety case is currently made. Our assessment shows that the crash frequency remains below the design basis region (see Section 4.3 in the main text of this report), and hence we believe it is incorrect to imply that the station would require physical adaptations (strengthening, shielding etc) aimed at withstanding an aircraft crash if the developments proceed.

Para 104. This paragraph is not relevant. It is referring to normal operation, not accidents.

Para 106. The meaning of this paragraph is very unclear – in part because (as in the comment on Para 72) it is another case in which the report confuses "risk" and "frequency".

Para 111. It is not correct to state that aircraft crash must be considered a design basis event and the plant designed to withstand it – see comment on Paras 97 and 116.

Para 113. Not all BSLs are legal limits. Those that are legal limits relate to normal operation and are identified as such in the SAPs.

Para 116. An aircraft crash frequency below 1E-07 per year need not be considered further (SAP EHA.1) and is therefore most definitely not a design basis event. Even if the frequency is greater than 1E-07 per year the crash is not a design basis event. It would have to be of the order of 1E-05 per year (1 in 100,000 years) to be a design basis event. (See also comments on Paras 97 and 111.)

Paras 127/ 128. It is unlikely that the *justification* for decommissioning – i.e. the rationale for decommissioning the reactor as soon as possible - will need to be reviewed. A change in aircraft crash risk would not to alter the efficacy of the decommissioning process itself or its consequences'.

Para 137. Discussion of the possibility of new reactors at the site is not material to the present planning application. At the time of writing (March 2009), no planning application regarding Dungeness had been submitted, neither had the government published any National Policy Statement on reactor siting.

Para 138. As in previous comments on the misinterpretation of the NII screening frequency, there is no "one in ten million years requirement".

Para 140. It is incorrect to state that the development would place a 'prohibition' on any future development of the Dungeness nuclear site. Aircraft crash may be a consideration in site selection and the planning process, but it is premature to judge the outcome in this way.

Para 143. As already noted, this conclusion is erroneous. The "NII screening limit" referred to here is (presumably) merely the screening level on frequency (1E-07 per year) used to decide whether or not aircraft crash requires further consideration. A crash frequency above this level does not invalidate the safety case or make the risk "unacceptable".

APPENDIX B: CRASH FREQUENCY ANALYSIS

B1. The frequency of aircraft crash was predicted using a method developed for the HSE by Byrne [Ref 3]. This is a standard method used in nuclear industry safety cases. Where there was uncertainty in the data required by the model, conservative assumptions were made.

B2. Because different aircraft types have different crash rates and impact consequences, the model calculates risks separately for the following categories of aircraft:

Light aircraft: Less than 2.3 tonnes maximum take-off weight authorised (te MTWA)

Helicopters

Small transport aircraft 2.3 to 20.0 tonnes MTWA

Large transport aircraft: more than 20.0 tonnes MTWA

Military combat/ training aircraft (MCA)

B3. There are three main stages in the calculation, as follows:

- Evaluate the crash rate (per km^2 per year) at the target site. This is evaluated as the sum of the rates for airport-related traffic, and for background traffic. It takes account of the crash probability per movement for each aircraft category, the number of movements by each category, and the location of the target site in relation to the airport.
- Evaluate the effective target area for the site, taking account of its plan area and height
- Multiply the crash rate per km^2 per year by the effective target area to obtain a crash frequency per year onto the target site

B4. Further details of each calculation stage for the with-development case are given in the following sections.

Assumed Aircraft Traffic

Table B1 following presents the assumed aircraft traffic data for the with-development case, taken from LAA's forecasts of the likely traffic for 500,000 passengers per annum. These data are compatible with those used in the 2009 Noise reports.

Table B1: Assumed airport-related aircraft traffic

Movements per year, by aircraft category			
Light aircraft	Small Transport and Executive Jet	Large Transport	Military Combat/ Training
29200	12045	3650	0

B5. The number of military combat/ training aircraft (MCA) movements is shown as zero in the above table, as they are included in the 'background' military traffic. Military aircraft overfly the airport for practice airfield attacks, but only a few times per year, and such aircraft fly a path different from the runway alignment and do not take off or land at the airport. In addition, the runway extension and the terminal building are not connected to, and will have no impact on, military aircraft movements.

B6. Movements and aerial displays related to Air Shows are also excluded. If any Air Show is planned at the airport in future it will require a separate risk assessment.

Crash Rate per km^2

B7. The overall crash rate at the site is evaluated as the sum of that for airport-related traffic (aircraft taking off from or intending to land at London Ashford Airport) and for background traffic (overflying aircraft in the vicinity, unrelated to the presence of the airport). Airways traffic is not considered to make any significant contribution to crash rate – see Section 5.5 of Ref [3]. The nearest airways pass north of the airport, further away from the power station site.

B8. For airport-related traffic, the first step is to calculate a weighted average crash rate per movement for the airport, based on the crash probabilities per movement for aircraft in each category and the numbers of movements by each.

B9. Helicopter movements are excluded from the airport-related crash rate. Byrne [Ref 3] found that all the recorded helicopter crashes during landing or take off phases of flight occurred within 200 m of the take-off or landing site, and recommends that beyond this distance the background rate applies. Other models for airport-related crash frequency/ location, as used for Public Safety Zone determination [Refs 9, 10, 11], also exclude helicopters.

B10. As described in Section 2.1 of the main report, airport-related traffic data are treated differently for the nuclear island and for the whole site. Within the nuclear island, plant elements are generally protected within, or shielded by, massive reinforced concrete structures. It is therefore assumed that they would not be damaged by the crash of any aircraft in the 'light aircraft' category, and movements of such aircraft are excluded from the data set. Other buildings within the whole site area are generally less well protected, so it is assumed that damage could occur as a result of a crash by aircraft in any category.

Table B2: Crash rates per movement

	Light aircraft	Small Transport and Executive Jet	Large Transport	Average crash rate per million movements	
Crashes per million movements from Ref [3]	1.2	1.8	0.59	Excluding light aircraft	Including light aircraft
Movements per year	29200	12045	3650	**1.52**	**1.31**

B11. For the Dungeness site, we are principally concerned with crashes by aircraft whose flight paths are south of the airport (landings on runway 03 and take offs on runway 21). Movements in the opposite directions (landings on runway 21 and take offs on runway 03) are much less likely to crash on the power station and it is reasonable to discount their contribution, within the context of the other generally conservative assumptions in the analysis.

B12. No credit has been taken for the restricted zone around the power station, the design of arrival and departure routes to take aircraft well away from the power station, or the fact that the Air Traffic Control service at the Airport provides positive control of aircraft in the vicinity and some ability to monitor and correct any that stray towards the restricted zone.

B13. Assuming that the runway utilisation split remains at approximately 70% of movements on runway 21, and 30% on runway 03, the relevant numbers of movements for crash frequency calculation are as shown in Table B3 following:

Table B3: Airport-related movements relevant to crash frequency at power station

	Excluding light aircraft	Including light aircraft
Landings on 03	2354	6734
Take offs on 21	5493	15713

B14. The next step is to evaluate the crash rate per km^2 per year at the target location. The probability of a crash at a particular unit area of ground, given that an accident occurs, is given by the following functions for landing and take-off respectively (Equations 7 and 8 from Ref [3]).

$$F_L(x,y) = \frac{(x+3.275)}{3.24} e^{\frac{-(x+3.275)}{1.8}} \left[\frac{56.25}{\sqrt{2\pi}} e^{-0.5(125y)^2} + 0.625 e^{-\frac{|y|}{0.4}} + 0.005 e^{-\frac{|y|}{5}} \right] \qquad (7)$$

and

$$F_T(x,y) = \frac{(x+0.6)}{1.44} e^{\frac{-(x+0.65)}{1.2}} \left[\frac{46.25}{\sqrt{2\pi}} e^{-0.5(125y)^2} + 0.9635 e^{-4.1|y|} + 0.08 e^{-|y|} \right] \qquad (8)$$

where:

x is the distance in km to the target from the nearer runway threshold, in the direction of the extended runway centreline; and

y is the distance in km to the target perpendicular to the extended runway centreline.

B15. Multiplying together the average crash rates per movement from Table B1, the numbers of movements from Table B2 and the location functions F above, we evaluate the crash rates per km^2 per year at the target site, as shown in Table B4 following:

Table B4: Airport-related crash rates per km^2 per year at the target site

		Excluding light aircraft			Including light aircraft		
	Location factors F(x,y)	Mvts/ year	Average crashes/mvt	Crashes per km^2 per year	Mvts/ year	Average crashes/mvt	Crashes per km^2 per year
Landing on 03	0.000178524	2354	1.52E-06	6.38E-07	6734	1.31E-06	1.58E-06
Take off on 21	0.000293588	5493	1.52E-06	2.45E-06	15713	1.31E-06	6.05E-06
			Total	**3.09E-06**		**Total**	**7.63E-06**

B16. Background crash rates were taken directly from Byrne's generic values, which are based on historic numbers of crashes and the land area of the UK. Although aircraft traffic has increased considerably since Byrne's analysis, this has been offset by a reduction in accident rates per movement, and the number of accidents per year shows no clear trend (see, for example, [Ref 12]. We have therefore not updated Byrne's data.

B17. As for the airport-related contribution, light aircraft are excluded from the calculation of background crash rate for the nuclear island, it being assumed that they could not significantly damage the massive structures. For the same reason, rate for helicopters is excluded from the calculation of background crash rate for the nuclear island. However helicopters are *included* in the background crash rate calculation for the whole site area. The resulting background crash rates are shown in Table B5.

Table B5: Background crash rates per km^2 per year

	Background crash rates (per km^2 per year)	
	Excluding light aircraft	Including light aircraft
Light aircraft	-	3.73E-05
Helicopters	-	1.16E-05
Small transport aircraft	1.20E-06	1.20E-06
Large transport aircraft	2.00E-06	2.00E-06
Military combat/ training aircraft (MCA)	4.60E-06	4.60E-06
Total	**7.80E-06**	**5.67E-05**

Effective Target Area

B18. The effective target area of a structure is greater than its plan area, since crashing aircraft generally descend at a fairly shallow angle, rather than falling vertically. A 'shadow area' is therefore calculated in addition to the plan area of the structure. The formulae for effective target areas for the different categories of aircraft, from Byrne [Ref 3], are given in Table B6 following:

Table B6: Effective Target Area formulae for each aircraft type

Aircraft Category	Effective Target Area, A (m^2)
Light aircraft, small & large transport aircraft (whether or not initiated above or below 2000 ft) and MCA accidents initiated over 2000 feet	$A_1 = lw + 0.8h(w+l)$
MCA accidents initiated below 2000 feet	$A_2 = lw + 3.6h(w+l)$
Helicopters	$A_3 = lw + 0.62h(w+l)$

where h, w and l are the height, width and length of the building respectively, in metres.

B19. As there are so few MCA in the area, only the first formula was used. This is slightly non-conservative, but not significant within the overall calculation. For simplicity, and conservatively, the first formula was also used for helicopters.

B20. The physical site length and width were increased by twice the wingspan or length of aircraft to allow for the fact that any part of the aircraft may strike the structure. For the nuclear island we have assumed a 30m span or length, typical of the commercial aircraft that may use the airport in future such as a Fokker-50. For the whole site area, for which the more numerous light aircraft are also taken into account, the assumed width/ span was reduced to 10 m.

B21. The site dimensions (see Figure 2) for the nuclear island and the whole site, and the resulting effective target areas are shown in Table B7 following.

Table B7: Site dimensions and effective target areas

	Nuclear island			Whole site area		
Dimensions (m)	Actual dimension	Wingspan allowance	Total	Actual dimension	Wingspan allowance	Total
h	78	-	78		-	40
l	150	60	210	350	20	370
w	80	60	140	270	20	290
Effective Target Area = lw + 0.8h(w+l) (km^2)	0.0512			0.1284		

Crash Frequency

B22. Multiplying the crash rates per km^2 per year from Tables B4 (airport-related) and B5 (background) by the effective target areas from Table B8 gives the following crash frequencies per year onto the target sites.

Table B8: Crash frequencies per year onto the target sites

	Nuclear island		Whole site area	
	Airport-related	Background	Airport-related	Background
Crash rate per km2	3.09E-06	7.80E-06	7.63E-06	5.67E-05
Effective target area (km2)	0.0512		0.1284	
Crash frequency onto target, per year	1.58E-07	4.00E-07	9.79E-07	7.28E-06
Total Crash frequency onto target, per year	**5.58E-07**		**8.26E-06**	