TOWN AND COUNTRY PLANNING ACT 1990 - SECTION 77 AND TOWN AND COUNTRY PLANNING (INQUIRIES PROCEDURE) (ENGLAND) RULES 2000

APPLICATIONS BY LONDON ASHFORD AIRPORT LTD
SITE AT LONDON ASHFORD AIRPORT LIMITED, LYDD, ROMNEY MARSH, TN29 9QL

REVIEW OF THE RISKS AND HAZARDS PRESENTED TO THE NUCLEAR POWER PLANTS AT DUNGENESS FROM THE PROPOSED DEVELOPMENT OF LYDD AIRPORT (LONDON ASHFORD AIRPORT)

Client: LYDD AIRPORT ACTION GROUP (LAAG)

Statement of JOHN H LARGE

PLANNING INSPECTORATE REFERENCE: APP/L2250/V/10/2131934

LPA REFERENCES: Y06/1647/SH and Y06/1648/SH

INQUIRY DOCUMENT REFERENCE: LAAG/4/A

1ST ISSUE	REVISION N^{O}	APPROVED	CURRENT ISSUE DATE
1 DECEMBER 2010	LAAG-4-A-R12		**16 JANUARY 2011**

This pdf version of LAAG-4-A contains hyperlinks that directly link to other text sections of this document shown thus **PART 1** or specific paragraphs as [¶34] – mouse clicking on the highlighted text will jump to and bring up that text section. Hyperlinks shown thus *The 2007 UK Radioactive Waste Inventory* will display the whole of the paper, report, etc., referred to providing the host computer is internet connected. Where appropriate, the relevant paragraph (¶) and page (p) of text of the linked document are shown enclosed thus R3136 [¶2, p1]. Hyperlinks shown thus **BERKELEY** will bring the relevant Google *StreetView* of the location which is directly controllable by the viewer, and from which a satellite overhead view of the locality may be accessed. The printed hard copy of this document does not contain these links or full citation of the source references - access to the Large & Associates web page displaying the linked documents is direct by entering the Secure Passcode CZ3136 on the Client Zones tab.

RISKS, HAZARDS AND POTENTIAL OUTCOMES PRESENTED TO THE NUCLEAR POWER PLANTS AT DUNGENESS FROM THE PROPOSED DEVELOPMENT OF LONDON ASHFORD INTERNATIONAL AIRPORT

1 QUALIFICATIONS AND EXPERIENCE

2 I am John H Large of the Gatehouse, 1 Repository Road, Ha Ha Road, London SE18 4BQ.

3 I am a Consulting Engineer, Chartered Engineer, Fellow of the Institution of Mechanical Engineers, Member of the Nuclear Institute, Graduate Member of the Institution Civil Engineers, and a Fellow of the Royal Society of Arts.

4 My qualifications and experience in nuclear matters relating to this Planning Inquiry are given in R3136-A1[1] [¶4 to 6].

5 My evidence relates to the potential radiological consequences arising from aircraft impact within either of the sites and/or associated activities of Dungeness A and B nuclear power plants (NPPs).

6 Specifically and recently, I have reported on the risks and hazards of transporting irradiated (spent) fuel by rail, including for transits from Dungeness,[2] for the Mayor of London; I analysed the risks associated with possible new nuclear power plants constructed near to London, including at Dungeness;[3] on the weaknesses of nuclear plants to aircraft crash;[4] and I have published on the vulnerability of nuclear facilities to terrorist attack,[5] including closed down nuclear power plants undergoing decommissioning.[6]

7 I consider myself to be sufficiently qualified, experienced and practised in the topics relating to this Inquiry.

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[1] *Planning Applications Y06/1647/SH and T06/1648/SH Safety of the Existing and Future Nuclear Power Plants at Dungeness*, March 2007

[2] *Risks and Hazards arising from the Transportation of Irradiated Fuel and Nuclear Materials in the United Kingdom*, March 2006

[3] *HM Government Energy Review and its Influence on London*, Greater London Authority, Mayor of London, R3155-2, August 2006

[4] *Brief Review of Edf Document Demarche de Dimensionnement des Ouvrages EPR Vis-À-Vis Du Risque Lie Aux Chutes D'avions Civils (Assessment of the Operational Risks and Hazards of the EPR when subject to Aircraft Crash)*, May 2006

[5] *Additional Analysis and Comments on the Threat of Terrorist Attack to the Proposed 3rd Nuclear Power Plant at Flamanville*, States of Jersey, R3155-3, August 2006 - *The Implications of 11 September for the Nuclear Industry*, United Nations for Disarmament Research, Disarmament Forum, 2003 No 2

[6] *Decommissioning Nuclear Plants - Openings for the Terrorist Threat*, 10th Global Conference & Exhibition on Decommissioning Nuclear Facilities - Taking the Experience Forward, London 20-22 November 2006

8 INSTRUCTIONS:

9 On 1 December 2010, Ms Louise Barton of the Lydd Airport Action Group (LAAG), asked me to provide a Witness Statement in support of LAAG's opposition to the further development of Lydd Airport (London Ashford International Airport – LAIA).

10 My instructions include:

11 a) on the assumption that the Planning Authority is duty bound to identify and take into account all material considerations, including public health and safety, and with regard to the close proximity of the Dungeness NPPs site, whether public safety relating to the nuclear plants should be a material consideration; and in this regard

12 b) to identify any vulnerabilities of the existing NPPs; and

13 c) to provide my assessment of the response of these plants to impact by a commercial airframe, and thereafter outline the potential consequences in account of the likely level of emergency response.

14 I address these instructions in two parts of this submission:

15 **PART I** demonstrates that the radiological hazards associated with the remaining operation and decommissioning of the Dungeness NPPs will remain on the Dungeness sites in part for about 100 or more years into the future.

15 **PART II** examines the vulnerability the Dungeness NPPs to aircraft crash, identifying in outline those parts and aspects of the plants, etc., that could result in a significant off-site radioactive release in the aftermath of an aircraft crash; and

16 In R3136-A1 [¶98 to 131] I have provided a summary of the nuclear safety and other statutory regulations that specifically require reassessment and review of the existing nuclear safety cases, off-site emergency planning and licensing for the Dungeness NPPs as each progresses from commercial operation, defueling, through decommissioning to final site clearance in about 100 or more years time.

17 Since government has determined under the *Habitat Regulations* that a new-build NPP would not be permitted to proceed at Dungeness,[12] there is no need for me to consider how operations at LAIA might have impinged on the safety of a new NPP at Dungeness.

18 That said, I acknowledge that this HM government decision may be subject to appeal and possible reversal in future so it may remain a material consideration for this Inquiry - I have previously dealt with this issue in R3136-A1 [¶26 to 35].

19 PART I HAZARDS ARISING FROM THE NUCLEAR ACTIVITIES AT DUNGENESS

20 Dungeness A and Dungeness B nuclear power plants comprise four graphite moderated, gas-cooled nuclear reactors.

21 The Dungeness A Magnox NPP first commenced commercial operation in 1965, ceased power generation in December 2006 and is presently undergoing final defueling in preparation for decommissioning and eventual complete dismantling.

22 The Dungeness B AGR NPP first commenced commercial operation in 1983 and is scheduled to continue in commercial power operation until 2018, thereafter it will be defueled in preparation for its eventual decommissioning.

23 DUNGENESS A MAGNOX

24 The two Magnox reactors are now entering the decommissioning programme that I have described in R3136-A1 [¶132 to 140]. I have summarised the radiological and chemical hazards present during the various phases of decommissioning and that are to remain on the Dungeness A site until the presently planned final site clearance date in or about year 2111 in R3136-A1 [¶36 to 39].

25 Since the March 2007 compilation date of R3136-A1 there has been some slippage in the early phases of the decommissioning schedule, particularly with the defueling of the two reactors. Although it was originally planned to commence the removal of the 340 or so tonnes of unenriched uranium fuel from each of the reactors in mid-2007 and complete this by March 2011,[7] delays have been encountered with the availability of rail transportation flasks and receipt at the British Nuclear Fuels Sellafield works in Cumbria. These delays have resulted in spent fuel remaining in the shut down reactor cores as an interim storage measure.

26 To date (April 2010),[8] approximately 15,000 of the total ~48,000 fuel elements (about 30%) contained in the two reactor cores have been transferred into the spent fuel ponds awaiting transfer to Sellafield.

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[7] *The Magnox Operating Programme (MOP8)*, NDA, October 2007

[8] *Dungeness Site Stakeholder Group, Minutes of the 9th Meeting*, 15 April 2010

27 A *full* nuclear site licence[9] would be expected to remain in place so long as there remains fuel in the core of either reactor. Once each of the reactors has been completely defueled, the nuclear safety case is dominated by the risks and hazards associated with the spent fuel storage ponds and, to a lesser extent, by the radioactive waste (radwaste) arisings present stored or in-situ on site (activated and/or contaminated parts of buildings, etc).

28 The on-site radwastes comprise a) operational radwaste that has accumulated over the years of operation (filters, ion-exchange resins, etc), and b) the (radio)activated and contaminated items of plant, including all of the two reactors (pressure vessels, graphite cores, etc) and much of the building structures, most of which will remain in situ and untreated during the extended decommissioning period.

29 The in situ radwastes of b) are very much greater in volume than the operational wastes of a).

30 So long as a radiological hazard exists on the Dungeness A site, that is the combined radwastes of a) and b), then the management and use of the site has to comply with the conditions of the prevailing nuclear site licence. Also, in contingency for any reasonably foreseeable radiological incident arising from these radwastes and/or the treatment, packaging, etc., thereof, adequate off-site emergency plans have to be maintained in compliance with the *Radiation (Emergency Preparedness and Public Information) Regulations 2001* (REPPIR). Like the Nuclear Site Licence, the REPPIR emergency planning requirement is likely to be amended as the radiological burden (ie the amount and types of radwaste, involved processes, etc) reduce and/or change during the longer term decommissioning process.

31 Even when all of the spent fuel has been removed from the Dungeness A reactor cores and the on-site storage ponds, there remains a sufficiently large amount of (radio)activated and radioactively contaminated materials for regulatory controls to stay in place for so long as the nuclear island, or its remnants, remain in situ (that is about 100 or more years).

32 The Nuclear Decommissioning Authority (NDA), the government agency responsible for the decommissioning and management of the radwastes arising from the decommissioning of Dungeness A, recently clarified the time frames for completion of the decommissioning and dismantling is stages.[10]

33 These stages: i) *Care and Maintenance Preparations* (C&M Preps); ii) *Care and Maintenance* (C&M); and iii) *Final Site Clearance* (FSC) could be undertaken within a number of alternative time frames such

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[9] *Nuclear Site Licence N^o 88*, Nuclear Installations Act 1965 (NIA65) – *Nuclear Site Licence Conditions*, HSE 2009

[10] *NDA Dungeness A – Future Plans*, 2009

as, somewhat ambitiously, by 2030 but more realistically with FSC successfully undertaken in about 100 years hence, that is releasing the site from its Nuclear Site Licence by year 2111 or thereabouts.[11,12]

34 Although somewhat speculative, the NDA's decommissioning strategy for Dungeness A will result in large volumes of radwaste remaining on-site for the foreseeable future.[13] This is because, following defueling of the reactor cores and fuel ponds, the turbine halls are to be demolished (2011$^+$) to make way for an intermediate level waste (ILW)[14] store for completion in or about 2014 that, together with the remaining reactor island hulks, will remain under C&M until final site clearance and closure (FSC) in or about 2111.

35 The total volumes of radwaste, comprising packaged wastes transferring into the ILW store (about 400m^3) from about 2014 and, separately, remaining in situ in the two reactor hulks comprising ILW (4,200m^3 mostly the graphite moderator cores), and low level waste (LLW – 28,000m^3) comprising concrete building materials (biological shield, etc) and steel primary circuit components (boiler pods) immediately beyond each reactor pressure vessel and concrete biological shield.

36 APPENDIX A identifies the various component parts of a single reactor plant of a typical Magnox NPP. The items, structural components and building facades to be removed during the *C&M Preps* stage are referred to thus and those components remaining until FSC thus.

37 Certain of these stored and remaining in-situ wastes are also hazardous substances in a chemical sense.

38 For example, the 100m^3 or so of ILW ion-exchange (cationic and anionic) resins are highly flammable and prone to self-ignition when exposed to air at ambient temperatures, and in so doing providing an efficient mechanism for radioactive release in aerosol form. I have previously identified the large volume of ILW graphite moderator (about 4,000m^3 or 1,800 tonnes) and associated hazards of energy release in the form of air reactivity (burning), Wigner Energy and the potential for carbonaceous dust explosion-deflagration in R3136-A1 [¶31 to 35].

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[11] *The 2007 UK Radioactive Waste Inventory*, DEFR/RAS/08.002/NDA/RWMD/004, NDA-Defra, March 2008 – Table A4 – List of Waste Streams in the Inventory and their Volumes, page 111.

[12] The reliability of this decommissioning timetable should be regarded with caution, particularly because of the acknowledged sensitive nature of the Dungeness locality as identified by the *Habitats Regulations Assessment: Site Report for Dungeness EN5 Draft National Policy Statement for Nuclear Power Generation*, Department of Energy and Climate Change, November 2009. The original operator of the Dungeness NPPs, the Central Electricity Generating Board (CEGB) proposed the *'SafeStore'* decommissioning programme wherein the reactor hulks would remain in situ on the site for 150 years before progressing to the final dismantling phase.

[13] *Technical Baseline and Research & Development Document Dungeness A, Lifetime Plan 2008/09*, Technical Baseline and Research & Development Document, Magnox South, November 2007.

[14] The legal definition of ILW and LLW radioactive waste categories are given as, for LLW *'radioactive waste having a radioactive content not exceeding four gigabecquerels per tonne (GBq/te) of alpha or 12 GBq/te of beta/gamma activity'* and ILW as waste that exceeds the LLW specific activity but which is not heat emitting sufficient to be defined as high level waste (HLW)– see *Policy for the Long Term Management of Solid Low Level Radioactive Waste in the United Kingdom*, Defra, DTI and the Devolved Administrations, March 2007 – see also *The Environmental Permitting Regulations (England and Wales) 2010*.

39 SUMMARY - DUNGENESS A HAZARDS

40 Large volumes of radwastes will remain on the Dungeness A site until at least year 2111.

41 The present NDA plan is for about 400m^3 of ILW to be packaged and progressively transferred into an intermediate waste store from about 2014 – these transfer operations will continue through the *C&M Preps* period (up to about 20 years or to 2034 or thereabouts). If and when a national radioactive waste repository is established, presently forecast for around 2050, the packaged wastes from the intermediate waste store might be progressively removed from storage at the Dungeness A site.

42 The hulks of the two reactors, containing in total about 4,200m^3 of ILW and 28,000m^3 LLW (depending on the level of *'concentrate and contain'*[15] decontamination works implemented during the *C&M Preps* period) are likely to remain in situ under *C&M* until final site clearance projected for about year 2111, if not longer.[16]

43 During the extended decommissioning period [my para 34], especially when dismantling of the reactor cores for *FSC* is underway, the containment systems (ie the reactor pressure vessel and the concrete biological shield) will themselves have to be dismantled thus exposing the remaining radioactive contents of the reactors (the graphite cores and supporting steelwork structures – about 3,500 tonnes in total for each reactor) to risk of dispersion by an external event such as, as considered here, aircraft crash.

44 Although both reactors of Dungeness A are shut down, the nuclear plant remains subject to a *Nuclear Site Licence*, as required by the *Nuclear Installations Act 1965*. This licensing and nuclear safety requirement will remain in place until the *Nuclear Installations Inspectorate* (NII, a division of the Health & Safety Executive) is satisfied that the radiological risk and hazard are tolerable, a state that is defined by the *Ionising Radiations Regulations 1999*.

45 Even though the two Magnox reactors of Dungeness A have closed down and all of the fuel is likely to have been removed from the reactor cores by the time any effective redevelopment of the LAIA could take place (assumed to be 2014$^+$), there will remain several significant sources of radioactivity on the Dungeness A site - I summarise the radioactive materials, substances and radioactive activities that will be present on the Dungeness A site as follows:

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[15] *Concentrate and Contain* as opposed to *Dilute and Disperse* is Government policy as applied to radioactive waste management.

[16] The Magnox power station at Berkeley, although of smaller capacity than Dungeness A, gives an indication of the practical realisation of the time scales involved in Magnox decommissioning: ceasing generation in 1989, fuel being removed by late 1992, demolition of the turbine hall and fuel ponds in 2001, thereafter continuing *C&M Preps* stages with, for example, the axolite sand filters being removed off-site in March 2008 – it is only now (2010) that test piling for the foundations of the intermediate waste store is underway on the Berkeley site which, when completed (~2014), will mark the end of the *C&M Preps* stage with the site entering the longer term *C&M* stage through to *FSC* in or about year 2100 – the hulk of one of the Berkeley reactors is visible above the tree line of the Google StreetView from a camera location just outside the continuing Berkeley Nuclear Licenced Site.

46 TABLE 1 – RADIOACTIVE HAZARDS ON THE DUNGENESS A SITE[17]

	PRE-2010 SHUTDOWN	2010–15 SPENT FUEL REMOVAL	2015–2040 C&M PREPS	2040–2090 C&M DWELL	2090 - 2110 CLEARING SITE	2110 FSC
	Irradiated fuel remaining in reactor cores	All fuel removed off site	Fuel ponds demolished – Turbine hall demolished – Intermediate waste store commissioned – Primary circuit boilers, etc., dismantled	Reactor hulks, comprising graphite core, steel pressure vessel, etc., and biological shields remain in-situ	Reactor hulks dismantled, waste treated on site – intermediate waste store emptied and dismantled	Returned to *Brown Field Site*
RADWASTE HAZARD	HLW/ILW/LLW	Overall comprising equivalent packaged volumes ILW 5,930m^3 and LLW 33,600m^3				Site clear of radwaste
RADWASTE MOVEMENTS		HLW Spent Fuel ~370[18] M2 flask movements	LLW/ILW movements to intermediate store within Dungeness A site, some LLW off-site	minimal	550 ILW 1,700 LLW package movements	none
PACKAGE ACTIVITY		Typically 35E+15Bq	Varies with particular radwaste stream[19]			none

47 It should not be assumed that the level of risk and the overall hazard of the Dungeness A site will progressively reduce throughout the decommissioning period (from *C&M Preps* to *FSC*). This is because certain dismantling, radwaste processing and packaging procedures may, for periods, heighten the risk and hazard present on the site – the conditions of the prevalent Nuclear Site Licence and the REPPIR off-site emergency planning measures are expected to reflect the risk and hazard levels at all times during the complex decommissioning process.

48 During dismantling operations, particularly when the reactor pressure vessel and graphite core[20] are being removed, the containment buildings and concrete shields themselves will have to be partially dismantled thereby removing the main defence against radioactive release when subject to an energetic external event, such as aircraft crash.

49 Packaging of the radioactive and other wastes arising during decommissioning operations will require handling and processing operations in a number of dedicated facilities located on the Dungeness A site.

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[17] Waste volumes from the *2007 National Radioactive Waste Inventory*, p85.

[18] Estimate on the basis that, including spent fuel presently in the ponds, an equivalent of three reactor cores loads are present in the reactor cores and 2 fuel ponds, that is a total of, say, 75,000 fuel elements – the Magnox M2 transport flask carries up to 200 elements. Also, there is a total of 30 M2 flasks required to service all 26 Magnox reactors, including the Oldbury and Wylfa NPPs still in commercial operation so further delays in defueling Dungeness A might be expected to arise in this respect – see *The Risks and Hazards Arising in the Transportation of Irradiated Fuel and Nuclear Materials in the United Kingdom*, March 2006.

[19] Full details of the projected (radio)activity of the decommissioning wastes streams are given in the *2007 National Radioactive Waste Inventory*. The graphite moderator cores at Dungeness A each contain about 2,250 tonnes of activated graphite of about 1.0E+16 Bq activity which will decay to a relatively stable level (due to the long half life of 5,730 years of the dominant C14 radioisotope) of 1.0E+14 Bq after about 100 years post reactor closure – see *Radioactive Graphite Management at UK Magnox Power Stations*, G Holt, BNFL, undated.

[20] *Review of the Possibility of Graphite Core Degradation during Care and Maintenance and Safestore Deferral Periods and Disposal Options Thereafter*, R3069-A5, Environment Council, December 2008.

These facilities, in themselves, will present a hazard and risk of radioactive release if subject to an energetic external event, such as aircraft crash.

50 During the final phase of decommissioning when packaged radwaste is being moved from the Dungeness A site to a regional or national radioactive waste repository, about 550 ILW packages and 1,700 LLW packages[21] will dispatch from the site – these radwaste transport movements are likely to commence once (and if) a waste repository has been established around 2050 and will continue until final release of the site in about 2110.[22]

51 Although yet to be determined, the most obvious route for dispatch of these wastes from the NPP is via the existing railway line that runs from loading railhead located on the Denge at about 2.6km from LAIA, with the track passing within 200m of the southern end of the LAIA runaway.

52 DUNGENESS B ADVANCED GAS-COOLED REACTORS

53 The Dungeness B station comprises 2 *Advanced Gas-Cooled Reactors* (AGRs) operated by British Energy which is part of Électricité de France (EDF).

54 Each AGR reactor contains approximately 120 tonnes of low enriched uranium fuel.[23]

55 Dungeness B is expected to operate until 2018, thereafter it will proceed along yet to be confirmed decommissioning measures and timescales, although the decommissioning schedule is likely to be similar to that set down by the NDA for the adjacent Dungeness A NPP - that is following through defueling and removal of the fuel from the spent fuel pond, with periods of *C&M Preps*, *C&M* and finally *FSC*.

56 Each graphite reactor core, together with the boiler steamraising plant, is enclosed within a massive, reinforced concrete pressure vessel and, like the Magnox NPP, there is no secondary containment beyond the reactor pressure vessel.

57 Reactor components are irradiated during service operation, although Wigner energy accumulation is not considered significant in the AGR core because of the self-annealing higher core operating temperatures. Accumulation of carbonaceous dust within the reactor core is at a higher rate than that in the Magnox

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[21] Radioactive waste packages are custom designed for the particular wastes stream and volumes will vary from 200 litre drums to 9 to 10 m3 solid waste boxes and some wastes streams have yet to be designated a specific waste package – the final choice of repository, type and location will also determine the final package design and volume.

[22] *Brief Report On The Potential Implications For Nuclear Material Transportation Issues Across London In Account Of HM Government's 2006 Energy Review*, Mayor of London, September 2006

[23] Natural uranium contains 0.7% of the fissile uranium isotope U-235 and this fuel is used in the Magnox reactors. For the AGR reactor the U-235 content is enriched to between 2 to 4% which increases the amount of (thermal) energy that can be extracted from the fuel but which, it follows, increases the amount of fission product retained in the fuel, rendering it more radioactive than its Magnox counterpart and, in the event of a release from an operating reactor, potentially greater radiological consequences.

moderator. The components making up each AGR reactor - graphite core, steelwork structures, secondary baffle domes and the reinforced steel concrete pressure vessels - are also rendered radioactive over the lifetime of the reactor.

58 APPENDIX B identifies the various component parts of one of the twin reactors of Dungeness B NPP. The items, structural components and building facades to be removed during the *C&M Preps* stage are referred to thus and those components remaining until FSC thus.

59 SUMMARY - DUNGENESS B HAZARDS

60 With the Dungeness B reactors remaining in operation, by far the most significant radiological hazard is the irradiated fuel in the reactor core and, quite separately and depending on how many spent fuel modules are in storage, the spent fuel storage ponds.

61 If, as predicted, Dungeness B NPP continues in operation until at least 2018[24] there will be regular nuclear fuel throughput to the spent fuel storage ponds and, following cooling, rail transportation of the spent fuel to Sellafield. The operational Dungeness B plant will also continue to generate operational radwastes.

62 Assuming that Dungeness B follows through much the same phasing as that planned by the NDA for Dungeness A, there will remain significant sources of radioactivity on the Dungeness B site - I summarise the presence of radioactive materials and substances that will be present on the Dungeness B site as follows:

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[24] *Appendix 3: statutory authorities, government and related organisations, utilities*, Shepway District Council, Appendix 3, Report A 09-01, 2005.

63 TABLE 2 – RADIOACTIVE HAZARDS ON THE DUNGENESS B SITE[25]

	PRE-2018 SHUTDOWN	2020 – 25 SPENT FUEL REMOVAL	2025 – 2055 C&M PREPS	2055 – 2105 C&M DWELL	2105 - 2125 CLEARING SITE	2125 FSC
	Irradiated fuel remaining in reactor cores and fuel ponds	All fuel removed off site	Fuel ponds demolished – Turbine hall demolished – Intermediate waste store commissioned	Reactor hulks, comprising graphite core, pressure vessel steel internals, boilers., etc., and biological shields remain in-situ	Reactor hulks dismantled, waste treated on site – intermediate waste store emptied and dismantled	Returned to *Brown Field Site*
RADWASTE HAZARD	HLW/ILW/LLW	Overall comprising equivalent packaged volumes ILW 6,660m^3 and LLW 19,200m^3				Site clear of radwaste
RADWASTE MOVEMENTS		HLW Spent Fuel ~700[26] A2 flask movements	LLW/ILW movements to intermediate store within Dungeness B site, some LLW off-site	minimal	534 ILW 972 LLW package movements	none
PACKAGE ACTIVITY		Typically 63-90E+15Bq	Varies with particular radwaste stream[27]			none

64 Like the Dungeness A Magnox power station, the Dungeness B spent fuel is transferred from the reactor cores and stored in a water filled pond, but for a longer period of 2 to 5 years because of the higher levels of fuel burn-up (fissioning) and radioactivity, before being rail transported to Sellafield for chemical separation (reprocessing).

65 The fuel dispatching operation involves flasks of spent fuel being transferred to the remote railhead loading terminal on the Denge via an armoured articulated road vehicle, where the fuel flask is offloaded onto a waiting freight train. Since the road vehicle is only capable of hauling a single flask, to make up a flask train of typically three or four flasks, the train and loaded flasks remain at the railhead for several hours whilst the road vehicle moves to-and-fro for each successive flask transfer.

66 This off-site spent fuel dispatching operation occurs about once every two weeks throughout the year and will continue so long as Dungeness B remains in operation, with the last of the spent fuel being dispatched about five to six or more years thereafter. As previously noted [¶25], at this present time spent fuel from Dungeness A NPP are also being dispatched to Sellafield to clear a backlog in the defueling operations.

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[25] Waste volumes from the *2007 National Radioactive Waste Inventory*, [p85].

[26] Estimate on the basis of a continuing level of fuel burn-up until closure and that there are sufficient AGR A2 flasks available for servicing continued production at Dungeness A. – see *The Risks and Hazards Arising in the Transportation of Irradiated Fuel and Nuclear Materials in the United Kingdom*, March 2006.

[27] Full details of the projected (radio)activity of the decommissioning wastes streams are given in the *2007 National Radioactive Waste Inventory*. The graphite moderator cores at Dungeness A each contain about 2,250 tonne of activated graphite of about 1.0E+16 Bq activity which will decay to a relatively stable level (due to the long half life (5,730 years) of the dominant C14 radioisotope) of 1.0E+14 Bq after about 100 years post reactor closure – see *Radioactive Graphite Management at UK Magnox Power Stations*, G Holt, BNFL, undated.

67 PART I SUMMARY

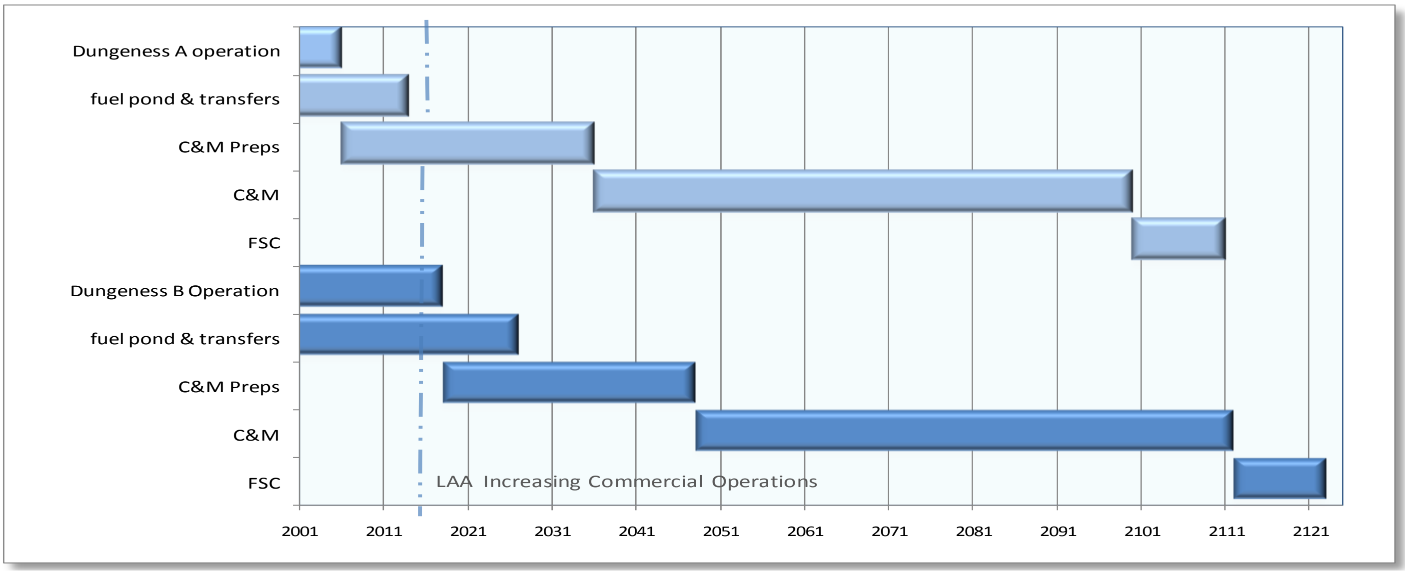
68 Both of the two neighbouring sites of Dungeness A and B will continue to contain hazardous activities and radioactive materials for the foreseeable future.

69 I shall assume that if the LAIA development proceeds and by the time that LAIA is operating as a commercial airport, then by that date all of the spent fuel from past operation of Dungeness A would have been removed from the site.

70 I have also assumed, for the purposes of this analysis, that there will be no future new nuclear build at Dungeness [¶17- 18]. However, if a new nuclear build was to proceed in accord with EdF Energy's anticipated year 2025 start date for such a project to move forward, then there will be active NPP operations continuing on a new Dungeness C[28] site for about 60 to 70 years thereafter, with follow-on decommissioning and radwaste operations.

71 However, without any new nuclear build, the presence of radiologically hazardous materials and activities as follows:

72 CHART 1 PRESENCE OF RADIOACTIVE ACTIVITIES & HAZARDS - DUNGENESS A & B SITES



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[28] The present new build NPPs are so called *Generation III*, such as the AREVA European Pressurised Reactor (EPR) and the Westinghouse Advanced Passive (AP) PWER plants. *Generation III* reactors have an operational design life expectation of 60 to 70 years and there is emerging a trend to store the spent fuel on site for 40 or more years prior to dispatch for reprocessing or permanent disposal off-site – under this spent fuel management regime, upwards of 2,000 tonnes of spent fuel might accumulate at the NPP site, thereby providing a very large radioactive source term available for potential release. Presently, the US Nuclear Regulatory Commission (NRC), which is the trendsetting nuclear safety regulator World-Wide, is assembling a regulatory framework that requires *Generation III* NPPs to be resilient to commercial airline crash – if this is enacted then it is likely to be adopted by the European Community and hence the UK.

73 For compilation of **TABLE 2** and **CHART 1** I have assumed the 2018 shut down date for Dungeness B NPP to be that adopted by Shepway District Council [¶ i) p 84] for its planning considerations – this gives a current operational lifetime of 35 years.

74 However, the similar AGR NPPs at Hunterston and Hinkley Point, both of which commenced commercial operation in 1976, have a current licensed lifetime of 40 years. The operator of these plants is presently seeking further 5 year lifetime extension under the NII's Periodic Safety Review and, no doubt, similar lifetime extensions will be sought for Dungeness B NPP.

75 In other words, operation of Dungeness B NPP most probably will be extended to 2023 and perhaps beyond to 2028. If so the various periods identified in **TABLE 2** and **CHART 1** should be extended appropriately.

76 PART II VULNERABILITY OF DUNGENESS A & B SITES TO AIRCRAFT CRASH

77 **Forecasting the Risk:** Others have provided expert opinion on the air traffic movements[29] and the projected frequency of accidental aircraft crash.[30]

78 So far as I am concerned, the general findings of these two expert opinions are that air traffic management for the proposed LAIA development will

79 i) Spaven [¶6.4]

> *"With the exception of the new RNAV approaches, all of those changes either increase the constraints on Lydd Airport operations and/or* ***reduce the margins of safety*** *in respect of the risk of an* ***aircraft crashing on the Dungeness NPP[s]****"*

80 ii) Pitfield [¶6.3]

> *"Using relatively conservative rates for UK accidents and minimal correction for these two factors gives an estimate of 1.57103E-05 for a 2 million throughput; an* ***unacceptable rate****"*.

my added **emphasis** and **[clarification]**

81 **Potential Targets:** So with respect to *reduced* margins of safety and an *unacceptable rate* of aircraft crash, I shall test the vulnerability of a number of potential *'targets'* for aircraft crash that might exist over a reasonable timescale of commercial operations of LAIA.

82 The obvious targets are a) the nuclear activities and radioactive and other hazardous materials present on the Dungeness A and B sites (at that particular time as shown by CHART 1) ; b) the loading and standing

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[29] Proof of Evidence, Applications by London Ashford Airport Ltd, Site at London Ashford Airport, Lydd, Romney Marsh, TN29 9QL, LAAG/10/A, Spaven M, December 2019.

[30] Proof of Evidence, Applications by London Ashford Airport Ltd, Site at London Ashford Airport, Lydd, Romney Marsh, TN29 9QL, LAAG/5/A, Pitfield D, December 2019.

of spent fuel flasks (and possibly radioactive waste)[31] at the railhead; and c) the rail movement of spent fuel (and possibly radwaste) on the rail tracks running within 200m of the southern end of the LAIA runway.[32]

83 Not so obvious targets are d) the metalled roads providing access to the Dungeness A and B sites and other localities for access by emergency services vehicle and resources; and e) the electricity transmission lines feeding from the West.[33]

84 Not to cut across the expert opinion of Pitfield, I summarise the assessment of accidental aircraft impact onto a nominated target comprise assumptions that there will be i) some form of loss of control of the subject aircraft, ii) its subsequent deviation from the intended flight path, and iii) the chance of it crashing into the target nuclear plant. The nuclear plant is defined as a *crash area* and the parameters relating to this are calculated from the *effective fly-in*, *footprint*, *shadow* and *skid areas* that are determined from established codes and methodologies.[34]

85 Of course, the *'crash area'* relates not just to the nuclear reactors but also to activities and services that are essential for the continuing safe operation of the nuclear plants or related nuclear activities shown in **CHART 1**. These other related activities include, for example, the remote spent fuel railhead, the overhead electricity transmission lines and transformer and switchgear yard that feed essential power for cooling *into* the power station when the reactors are shut down, the location of the intermediate radwaste store, and so on.

86 If these separate targets are collected together, aggregated, then the target area would be significantly larger and more widespread than that assumed by the AREVA [¶18 p4, FIGURE 2 p13] assessment that results in a significant under-prediction of the target susceptibility to aircraft crash.

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[31] Although it is possible to estimate the volumes of the various streams of radwaste for both Dungeness A and B decommissioning programmes, it remains undetermined when and how the radwaste will be eventually dispatched from the sites, although it is most probable that by far greater volume of the decommissioning radwaste (excluding the spent fuel) will remain on the sites for the next 50 to 100 years.

[32] Contrary to the statement of AREVA [¶30 p6] that *"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"* the current UK AIP AD 2-EGMD-1-6 order clearly states that this convention applies only to *'training take-offs involving practice engine failure'* and not to normal air traffic operations. On its part the NII and the Department of Transport (Division of Radioactive Materials Transport), have not challenged these arrangements so it follows there would be no further restriction on full commercial flying operations (save training take-offs) if and when LAA was to be fully developed.

[33] So long as the Dungeness B nuclear reactors remain in operational transmission grid power is required to operate the vital gas circulators in the event of a forced shutdown (SCRAM) of the reactor(s). In the event of loss of grid connection the operating reactors SCRAM and immediate gas circulation and other essential services are provided by standby diesels located on the site. Off-site power is also required for maintaining the spent fuel cooling ponds, although the demand (load) and immediacy of continuing supplies is neither so great or as urgent as that required to maintain a reactor SCRAM.

[34] STD-3014-96, US Department of Energy, 1996.

87 Moreover, the chain of events culminating in the impact to the target are drawn from the supposition that accidents are by their very nature accidental and, moreover, that circumstances steering the course of events is both unintelligent and unintentional. Even so, it is assumed that human endeavour will persevere to mitigate the outcome.[35]

88 Essentially, the crash frequency assessment outcome is determined by the chance of a very small missile, the aircraft, accidentally hitting a relatively small target, the nuclear plant, located in a very large geographical space. Applied to a commercial airliner operating at altitude and passing along a prescribed flight path, or to aircraft traffic at nearby airports, this *a posteriori* probabilistic approach adopts rates drawn from actual crash incidents, yields a very low accidental crash probability.[36,37,38]

89 That said, absolute confidence should not be placed in such projected aircraft crash rates. An apposite analogy is that SS *Titanic* was a small dot in an expansive ocean but it collided with, so it seems purely by chance, a small ice floe and, as a result, the unsinkable ship sank – my point here is that accidents do happen and so predictions of chance, with all of the inbuilt frailties, should be considered with caution.

90 **Opportunity for Terrorist Attack:** Another consideration that defies the predictions of the aircraft crash rates for LAIA, is whether the proximity and operation of LAIA so nearby the Dungeness nuclear power plants would provide opportunity for terrorist attack or other malicious action aimed at the Dungeness sites?

91 I am of the opinion that the increased levels of commercial air traffic movements in the immediate vicinity could mask opportunity for at least two different types of terrorist attack:

92 The first type of attack that I believe to be highly plausible is whereby an anti-aircraft missile[39] is launched from a ground position near to the airport – this attack could be deployed against either aircraft taking off or landing. The crashing of such a *'downed'* aircraft onto any one of the NPP targets identified [¶133 –

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[35] The approach to assessing the impact of aircraft crash in the UK is, generally, drawn from the United States NUREG-0800 that permits the introduction of the mitigation that the pilot will retain sufficient control to avoid striking the nuclear plant – for military pilots this is assumed to be for 95% of the time or that, independent of all other considerations, the *Phit* probability is equal to 0.05.

[36] For example see *Evaluation of Aircraft Crash Hazards for Nuclear Power Plants*, Kot C A, et al, Argonne National Laboratory, 1982 which gives a chance of crash into a nuclear plant 11.5 miles to the south of an air corridor at 33,000 ft to be about 2.36x107 per year and *Evaluation of Air Traffic Hazards at Nuclear Power Plants*, Hornyik K, Nucl Technology 23, 28, 1974.

[37] Aircraft Impact on Sizewell B, Part 1 Safety Involvement of Buildings on Site, PWR/RX774 (pt 1) 1987.

[38] Sizewell B PWR Supplement to the Pre-Construction Safety Report on External Hazards, Aircraft Crash, CEGB Report No GD/PE-N/403, 1982, Aircraft Impact on Sizewell B, Part 2(a), The Effects of Impact of Heavy Aircraft Adjacent to but not directly on Vulnerable Buildings. (b) Light Aircraft on the Vulnerable Buildings, PWR/RX774 (Pt 2), 1987 and Aircraft Impact on Sizewell B Part 3 Fire Following Aircraft Crash, PWR/RX774 Part 3, 1987.

[39] Such as, although not necessarily, an anti-aircraft man-portable, shoulder-launched US General Dynamics *Stinger* that has a target acquisition range of 4.8 to 8km – it is believed that the US (CIA) supplied 500 or more Stingers to the Mujahideen in Afghanistan during the Soviet occupation and that not all of these have been recovered to date.

TABLE 3] would be a matter of chance, about the same as if an aircraft had run into difficulty by, for example, bird strike, when forced to abort a landing and 'go-around'.

93 The second basis for a terrorist attack is if, as for the four aircraft involved in the 9/11 incident, the aircraft was hijacked and intentionally crashed into a preselected NPP target.

94 If so, a terrorist commandeered aircraft could, upon aborting a landing,[40] be mistaken for 'going-around' and there would be little opportunity in the minute of so left before the aircraft reached the intended target, for those operating the nuclear activity to prepare and/or put in place any mitigating measures. Thus, the imposition of notional restraints such as no-fly or air exclusion zones[41] near to nuclear plants are to no effect once an aircraft has been commandeered and the terrorist attack is underway.

95 Of course the probability or chance of the occurrence of a malicious human act, such as the terrorist attack of 11th September 2001 (9-11), can only be determined by classical *a priori* means because the human actions and decisions involved swamp any historic data base. Thus, it is only realistic to apply chance to the success of the attack once it has been initiated.

96 Put another way, applied to the terrorist attack of 9-11, the P_{hit} or success rate was 3 out of 4 airborne aircraft, ($P_{hit} = 0.75$).[42] If the aircraft that crashed in Pennsylvania is discounted, the P_{hit} for those aircraft on their target run was 3 out of 3 or 100%. In other words, the hijackers had obtained sufficient flying skills to ensure that, once that the aircraft has been commandeered, the mission would have a high, almost certain rate of achieving its objective.

97 Moreover, whereas the military or civil pilot would not be expected to have been trained to identify the vulnerable parts of a nuclear plant, even though it is assumed that the pilot will strive to avoid certain parts of the plant [¶85], it would be in the hijacker's interest to identify and aim the aircraft at the most vulnerable parts of the selected target.

98 In other words, not surprisingly an airborne terrorist attack would be an intentional and intelligently driven event that seeks out the vulnerabilities of the nuclear power plant target.[43]

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40 Obviously, an incoming aircraft would provide greater opportunity for a hijacking during the hours of the incoming flight, rather than being commandeered during the short boarding and taxiing time for an outward LAA flight.

41 The Air Exclusion Area that encompasses the existing Dungeness nuclear power station (EG R063) overlaps with the Ministry of Defence Danger Area that contains the Lydd Training Area (EG D044). The site identified for a new nuclear power station is west of the existing facility and as such a new Air Exclusion Zone (or expansion of EG R063) would extend further across EG D044.

42 Although it is acknowledged that this is drawn from a statistically insignificant grouping (just the 11th September data), the assumptions for the reliability of military pilots to avoid the vulnerable parts of the building must also be drawn from a lean set of data.

43 *The Implications of 11 September for the Nuclear Industry*, Large J H, United Nations for Disarmament Research, No 2, 2003.

99 **Vulnerability of Nuclear Plants and Activities to Aircraft Crash:** Based on the premise that an aircraft crash onto a nuclear plant would be *accidental*, the requirement to provide defence in depth against such a remote event was not given that much attention in the licensing process[44] for which, generally, only military aircraft (fixed wing fighter aircraft and helicopters) were considered because this air traffic was not restrained to operating within fixed corridors.

100 The requirement to account for aircraft crash was introduced in the United Kingdom in 1979[45] and its first application was for the Sizewell B PWR then at the design and evaluation stage.[46] Both Dungeness A and B NPPs (first commissioned into generation in 1965 and 1983 respectively)[47] and their respective designs and nuclear safety cases,[48] considerably predate any formal consideration of account of (large) aircraft crash in the UK nuclear regulatory framework.[49,50]

101 In other words, in the 1950s, 60s and 70s when both Dungeness A and B nuclear plants were designed and set down, there existed no requirement to include for the impact of a large commercial aircraft. Even so, designing these plants to be *'fit for purpose'* the inclusion for aircraft crash survivability would not have

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[44] For example: DOE-STD-3014-96, Accident Analysis for Aircraft Crash into Hazardous Facilities, 1996

[45] *Safety Assessment Principles for Nuclear Plants*, NII, Health & Safety Executive, May 2000 first introduced for nuclear reactors in 1979 and for nuclear chemical plants in 1983 – these have since been revised in 2006.

[46] Sizewell B PWR Preconstruction Safety Report, Chapter 3, November 1987.

[47] Dungeness B was originally scheduled for commissioning in 1970 but during construction many problems were encountered, particularly with internal reactor structures that delayed completion of the project for some 13 years.

[48] The Nuclear Site Licence requires demonstration of nuclear safety on the plant and its management under the *Nuclear Installations Act 1965* (NIA65).

[49] Further legislation on nuclear activities in the UK includes the overriding *Health and Safety at Work etc Act 1974*, by which radiation protection is regulated against the *Ionising Radiation Regulations 1999* (IRR). Emergency preparedness and associated radiation protection are regulated against the *Radiation (Emergency Preparedness and Public Information) Regulations 2001* (REPPIR). Other relevant legislation is contained in the *Management of Health and Safety at Work Regulations 1999*, that require, among other things, a suitable and sufficient risk assessment, and in the other regulations made under the HSW Act, eg *Nuclear Reactors (Environmental Impact Assessment for Decommissioning) (Amendment) Regulations 2006* (EIADR); *Provision and Use of Work Equipment Regulations*; *Lifting Operations and Lifting Equipment Regulations*; *Personal Protective Equipment at Work Regulations*; *Pressure Systems Safety Regulations*; *Control of Major Accident Hazards Regulations (as amended)* and *Dangerous Substances and Explosive Atmospheres Regulations*. Nuclear operators must comply with these regulations in the same way as any other employer, and the codes of practice associated with these regulations will often contain relevant good practice that can be used in safety cases when demonstrating what is reasonably practicable. Not all relevant legislation is covered by the HSW Act. Other examples include the *Anti-Terrorism, Crime and Security Act 2001* and its subordinate *Nuclear Industry Security Regulations 2003*, the *Electricity Act 1989*, the *Environmental Protection Act 1990*, the *Radioactive Substances Act 1993*, various planning acts and the *Building Act 1984* and its subordinate *Building Regulations*.

[50] The pre-SAPs requirement for external hazards, including accidental aircraft crash, the assumption was that there is a spectrum of external disturbances which tend to increase in magnitude with decreasing frequency of occurrence. The disturbance then chosen for design purposes is one that has a frequency of occurrence of 10^{-4} events per year. Design then ensures that the probability of failure of the protective systems following this rare event is not higher than 10^{-3} per demand, thus the outright failure criterion for external events is 1 in 7 million per reactor operating year (10^{-7}/yr) – *The Design of the AGR*, CEGB/SSEB, 1982.

been included because the very low *accidental* aircraft crash frequency ($<10^7$ per year) would render such an event incredible and, similarly, terrorist attack from the air would have then been inconceivable.[51]

102 Aircraft, for all of their speed and power, are relatively fragile structures.

103 The 190 or so tonnes of each Boeing 767 that crashed into the South and North towers of the World Trade Center on 9/11 may have provided a colossal kinetic energy but the fuselage and much of the wing structures would have shredded almost immediately, leaving just the compact masses of the engines, the wing root shear boxes and harness frames, and a few solid spars and undercarriage frames in the role of very energetic projectiles to penetrate deep into the building structure. Accompanying this high-energy impact was the release of the 80,000 litres or so of aviation fuel, partially vaporised that erupted into fireballs to ignite flammable materials in the vicinity.[52]

104 Vaporised and unburnt fuel would have been squeezed into World Trade Center and Pentagon building voids by the expanding flame and pressure fronts and the remaining fuel would have gushed into the internals of building, spreading downwards through buckled and holed floors. As the 9/11 tragedy unfurled it was clear within minutes that about ten floors of each of the towers of the World Trade Center were burning furiously, so intensely that the structures buckled and progressive collapse commenced on the South Tower within one hour of the aircraft impact.

105 **Aircraft Crash Impact Loading:** Now that a full analysis of the collapse of both the World Trade Center towers and the Pentagon has been published,[53] it is clear that both impact and fire phases of the crash played active roles in the destruction of the buildings. The initial impact would have destroyed or weakened the structure of the buildings and the immediately following fire was of sufficient temperature to ignite all flammable materials within, which provoked further structural member buckling and damage leading to catastrophic structural failure.

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[51] The approach for assessing accidental aircraft crash for nuclear new-builds, ie the Generation III NPPs such as the EPR and AP1000, is given by the latest edition of the HSE SAPs (2008). Aircraft crash is to be treated as an external hazard and operators are required to determine the total predicted frequency of aircraft crash on or near any facility with structures important to continuing safety of the facility as specified by SAPs EHA.8. If the total frequency is less than 10-4 per year but not more than 10-7 per year then the operator should make efforts to understand and minimise the potential consequences of such impacts (SAPs ¶218 – 219). For high consequence impacts, that is with an off-site dose consequence of >100mSv, SAPs FA.15 and FA.16 (¶543 – 550) apply requiring reasonably practicable measure to be installed to prevent or minimise consequences. For malicious (terrorist) attacks (including aircraft impact attack), these are treated as *'beyond design basis'* events the operator is required to make a case that either the design is safe or propose practicable mitigating measures. The SAPs also apply to existing NPPs, both operational and those undergoing decommissioning, although the NII has discretionary powers on the interpretation and application in these cases.

[52] The fuel load and aircraft mass could be significantly larger. Embarking on a transatlantic flight, from Amsterdam a Boeing 747 would commence its flight with about 175 tonnes of aviation fuel on board.

[53] Now published the official report produced by the American Society of Civil Engineers (ASCE) for the Federal Emergency Management Agency (FEMA), May 2002.

106 As a result of impact of the aircraft, (kinetic) energy[54] is transferred from the aircraft to the building,[55] in two distinct phases:

107 a) **Impact:** In the first of these phases, the impacting airframe acts as a *'soft'* projectile with energy transferred being absorbed over a time period, the length of which is determined by the inertial and stiffness properties of both the airframe and target structures, the striking velocity and, essentially, size of the airframe, as a finite amount of kinetic energy is transferred to and dissipated by the building structure. The building components receive this imparted energy in the form of strain energy whilst each component is deforming elastically and beyond up to the point of permanent yielding.[56]

108 b) **Impulse:** The second loading phase follows and involves those components of the aircraft that are sufficiently tough to form rigid projectiles that will strike and commence to penetrate, again by kinetic energy, components of the building fabric and structure – the components involved in this second phase will include the jet engines and the spars, etc., of the undercarriages – in certain situations these projectiles might be thrown forward onto the target from a crashed airframe that has been arrested short of the target.[57]

109 Essentially, the target structure responds to these loadings in three ways:

110 i) **Global:** This includes excessive structural deformation and/or displacement, structural collapse, overturning, etc., of the main structure, particularly the outer and exposed structures of the target, mostly from the impact phase of the strike.

111 ii) **Localised:** Arising from the hardened component (engines, etc.) strikes, leading to penetration and failure of specific structural elements.

112 iii) **Propagated & Remote:** Dynamic effects transmitted to structures and components that might be situated remote from the direct area of impact within the target enclosure, particularly the fixings and frames of machinery, linings, etc..

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[54] The kinetic energy of a non-rotating object of mass m travelling at a velocity v is $mv^2/2$. If a rigid body is arrested then, under the conservation of energy, all of the kinetic energy of motion has to be transferred into other energy forms such as heat, elastic and plastic deformation, etc..

[55] Just on the basis of kinetic energy alone the three levels of aircraft crash referred to by the STUK regulator increase from Level 1 (light aircraft) to Level 2 (Jet Fighter) to Level 3 (Commercial) airliner in the ratio 1 to 50 to 1500 or that the energy available from a crashing commercial airline (impact alone) is 1500 times that of a light aircraft.

[56] *Preliminary Analysis of an Aircraft Impact, G. Forasassi, R. Lofrano* Agenzia Nazionale per le Nuove Tecnologie, l'Energia e lo Sviluppo Economico Sostenibile 2010 – see also Riera, JD. *On the stress analysis of structures subjected to aircraft impact forces*, Nucl. Eng. Des. 8 (1968) 415–426

[57] For military aircraft crashes, throw forward distances up to 300m if the airframe descent angle is greater than 15° to the horizontal, and for descents shallower than 15° throw forward distances of up to 2km are possible - *The Throw Forward of Missiles Following Low Level Military Combat Aircraft Crashes in the UK,* Byrne J P, AEA RS 5615 January 1994.

113 The outcome of the single aircraft crash into the Pentagon building on 9-11 illustrates the extent of *global* and *localised* damage achieved by a crashing airframe.

114 First, the collapse of the entire section of the Pentagon shows the devastating failure of the various reinforced concrete (rc) frame components mainly as a result of impact loading from the crashing of the airframe. Second, a hardened component of the airframe, here believed to be an undercarriage strut, punched through three buildings forming an exit hole in the outermost wall of the third block.

115 Obviously, the 9/11 building collapses prompted a great deal of interest in the resilience of building structures, some of which has been specifically applied to the design of containment structures of existing nuclear power plants in the United States. These US NPPs, mostly light water reactors (PWR and Boiling Water Reactor – BWR) are characterised by the dome-like structure that forms the protective or secondary containment of the reactor primary circuit.

116 The Magnox and AGR reactors on the Dungeness sites are not contained within any resilient secondary, dome-like enclosure [¶123 & 125] and, should the reactor circuit be breached as result of an aircraft crash, there is no effective secondary barrier to prevent a radioactive release into the environment.

117 **Aircraft Fuel Fires:** Generally, one half of severe airframe crashes involving commercial aircraft will trigger burning of the aviation fuel and, for military aircraft, 80% of fuel fires occurred for crashes during the landing and take-off phases.[58]

118 If the fuel spills into the confines of a building space (ducts, compartments, etc) there is good probability of a *confined* vapour explosion if the air-fuel proportions reaches optimum conditions but the resulting blast overpressure is relatively modest (~10kPa) and unlikely to result in structural damage.

119 There exists the lesser probability of an *unconfined* vapour explosion immediately following the spillage of a large quantity of aviation fuel, with a large volume of aviation fuel could deflagrate and generate a significant blast overpressure. However, an *unconfined* vapour explosion could be seriously damaging across a large area of the NPP site, certainly powerful enough to trigger building collapse by this means alone.[59]

120 In the crash aftermath, burning (not exploding) aviation fuel could spread from the immediate impact site providing a source of combustion for flammable components of the nuclear plants (for example, a graphite

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[58] The Hazard to Nuclear Facilities from Aircraft Fuel Fires and Explosions, AEA RS 5475, March 1993

[59] Deflagration - explosions in which the flame propagates through the fuel-air heterogeneous at a speed less than the speed of sound. In effect, under certain conditions the aviation fuel spill can act as a thermobaric munitions – the damaging effect of a fuel-air deflagration is not necessarily confined just to the peak overpressure of 2,100kPa (compared to 27,000KpA for TNT) but also the much longer duration of the deflagration blast wave, which is an important factor in the response of built structures to a blast.

reactor core exposed during decommissioning operations) and for certain of the radwaste streams under preparation for interim storage (for example, ion exchange resins).

121 **Target Response and Potential Consequences:** A full and detailed analysis of all the potential targets that I have previously identified [¶81 to 83], when considered subject to a variety of airframes (available now and those that might become available in future years), for differing conditions of strike (airframe velocity, strike angle, etc) is beyond the financing resources of LAAG and, moreover, complete details of the structural design of the Dungeness NPPs are not available to me.

122 However, it is possible for me to arrive at a qualified judgment of how the potential targets would likely perform by consideration of the basis of the containment strategy adopted for the Dungeness A and B NPPs:

123 Each Dungeness A (APPENDIX A) reactor pressure vessel (RPV) is located within a rc biological shield which is not pressure- or air-tight since this is arranged discharge a continuous stream of cooling air over the outer surface of the RPV. Running to and from the RPV is a series of large diameter ducts feeding the radially located boiler pods positioned just inside the lightweight cladding of the reactor building. Essentially, the (radio)active reactor primary circuit (RPV + ducts + boiler pods) is not contained within any structurally resilient containment. A clear illustration of this is the earlier Berkeley NPP showing the (radio)active RPV circuit extending to the boiler pods that are located *outside* the building.

124 As I have previously noted [¶69 - **CHART 1**], I expect that all of the fuel presently in temporary storage in the Dungeness A reactors would have been transferred off-site should any development of the LAIA proceed and, if so, the *operational* nuclear safety of the Dungeness A reactors will not be an issue.

125 The RPV of each Dungeness B reactor is fashioned in massive reinforced concrete containing the reactor core, baffle dome and eight boiler stacks dispersed radially around the baffle dome. Clustered around the periphery of the RPV are compartments that house the essential equipment (gas circulator, steam and feedwater penetrations into the RPV) that is replicated in each of four quadrants of the reactor.

126 Since Dungeness B is likely to be in operation to 2018^{+} *operational* nuclear safety of the nuclear plant is an issue.

127 The underlying basis of the AGR *operational* nuclear safety case centres on the redundancy and diversity of equipment and safety systems provided across the four quadrants of each reactor. This approach endeavours to ensure that each reactor can shut down and remain cooled, and safely shut down thereafter, with a number of combinations of the four quadrants in operation. The safety case requires that the reactor systems do so when challenged by a number of distinctive faults, including 1) total loss of external

(Grid) electrical supplies during which the RPV is and remains pressurised; 2) depressurisation of the RPV whilst external electrical supplies are maintained; together with fault groups relating to the provision of feedwater to the RPV boilers, failure of the steam side of the boilers within the RPV, reactivity faults, etc..

128 Both Magnox and AGR NPPs have the capability to refuel whilst on load and fully pressurised. For refuelling operations, a fuel handling machine operates on the charging floor formed by the top of, for Dungeness A, the biological shield and, for Dungeness B, the RPV. To refuel a fuel channel, the charge machine seals itself to the pile cap floor, pressurises up to RPV pressure and removes a floor access plug enabling it to reach down into the reactor core to withdraw the individual Magnox fuel elements (A) or the entire channel fuel stringer (B). During these refuelling operations the RPV (radio)active circuit extends into the charge handling machine.

129 Even though it could be convincingly argued that the rc concrete pressure vessels of the Dungeness B AGR reactors are so massive as to be failsafe, I am of the opinion that there are a number of weakness in the detailed containment design (eg the boiler steam and feedwater penetrations passing through the RPV), and in the fuel handling systems (opening the RPV at the pile cap charge face for refuelling) that would be challenged in the event of a crash involving a large, commercial aircraft.

130 It is the combination of a loss of external electrical supplies and a depressurisation[60] fault extending over one or two quadrants that would, in my opinion, present a very demanding challenge to the Dungeness B safety systems. I also believe that the enormity of a large, commercial aircraft crashing into the Dungeness B NPP, could threaten the main control room of the power station, that is damaging many of the control systems and incapacitating vital control room personnel who would, otherwise, be required to manage and mitigate the aftermath of such a serious incident.

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[60] The depressurisation of an AGR reactor results in a rapid loss of CO_2 coolant gas density which immediately increases the fuel pin temperatures and as the depressurisation transient develops the reactor will fall below the fuel pin internal pressure which increases the susceptibility of the cladding to fail under tensile stress. In an in-quadrant fault, where the escaping gas vents into the rooms providing reactor quadrant, all of the equipment is assumed to fail so reactor safety depends totally on the surviving quadrant(s). Ex-quadrant breaches are where the reactor coolant vents to an area outside the quadrants, such as from a localised failure of the pile cap sealing plug.

Generic maximum breach sizes for an ex-quadrant fault are about $0.03m^2$ and in-quadrant $0.006m^2$ (about the size of a postcard) – the design of the secondary restraints and penetration restrictors aim to constrain the breach areas to the design permitted maximums but these, to my knowledge, have never been determined against a significant external event such as a commercial aircraft crash [¶99 to 101] – should the in- and ex-quadrant breach areas exceed the design permitted maxima, then increasing numbers of fuel pin failures contaminate the escaping coolant gas with fission product resulting in what could be a very significant release of radioactivity to the atmosphere and local environment.

A rapid depressurisation of the reactor would also impart additional differential stress loading of the graphite core and the core restraint into which the core sits – the core is essentially a loose stack of individual graphite bricks which, during a rapid depressurisation event is required to maintain fuel and control rod channel alignment, although recent inspections at other AGRs have revealed cracking of individual bricks which raises doubts [S4, p5] over the adequacy of the graphite cores to fulfil the this role and, hence, raising the issue of potential core disruption, failure to insert the control rods, and whether the final shut and hold down nitrogen purge system would be effective in such circumstances.

131 Much same reasoning applies to the catastrophic failure of the building enclosure of the spent fuel ponds, that is where a crashing aircraft could readily penetrate the external walling of the NPP and either disrupt and/or totally demolish the spent fuel pond structures resulting in a complete loss of cooling water.[61] This scenario would leave the spent fuel exposed to air and without sufficient cooling, subject to self-heating due to continuing radioactive decay of the irradiated fuel, during which the internally pressurised fuel pins would be subject to failure and release of at least the clad-gap radioactive inventory.

132 I summarise a number of severely damaging scenarios for the operational (B) and shutdown (A) reactor plants, spent fuel storage (B) and radwaste facilities at the Dungeness NPPs as follows:

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[61] The amount of spent fuel in storage at the AGR NPPs is no longer published. However, the spent fuel storage capacity is sufficient to accommodate spent fuel being held over for 3 to 5 years for post-core decay and, in addition, there has to be extra capacity for spent fuel being held on-site should hold-ups be experienced with transport to and storage at Sellafield, and there must always be capacity enough for the reactors to be emptied of all fuel should the need arise – in all, several hundred tonnes of spent fuel might be held over at Dungeness B NPP at any time.

133 TABLE 3 LIKELY PERFORMANCE OF THE DUNGENESS A & B TARGETS TO AIRCRAFT IMPACT

	TARGETS	RISK PERIOD	POTENTIAL SCENARIO	POTENTIAL ON-SITE OUTCOME	POTENTIAL OFF-SITE CONSEQUENCES	DESIGN BASIS[51]
1	B Reactors	up to 2018$^+$	a) Impulse loading disrupts reactor internal gas baffle and/or, core restraint tank and/or diagrid graphite core support resulting in core misalignment, loss of water cooling of the skirt and core control channel alignment. b) *Impact* unlikely to breach massive rc pressure vessel but hard missile *impulse* could dislodge/shear boiler steam and feedwater services penetrations through the reactor pressure vessel – failures extend beyond single quadrant unavailability. c) Aircraft penetration into fuel charging hall likely to damage and/or topple charge machine, if in operation exposing fuel charge route and depressurising single reactor undergoing refuelling. Fuel-Air vapour explosion/deflagration annihilates pile cap and control room staff with loss of human intervention possibility. d) As a) above, shock damage to core restraint turnbuckles, known degradation of graphite core[62] includes axial cracking of graphite channel bricks and unquantifiable loss of graphite core integrity, potential loss of fuel and control channel structural integrity and alignment.	a) Potential development into a catastrophic failure leading to loss of primary containment, continuing in-core reactivity and substantial release fraction of fuel fission products, with progressive system failure continuing. b) Rapid depressurisation of reactor, commencement of fuel pin failures and radioactive fission product release and widespread dispersion, potential to cascade into graphite core collapse of c) following. c) Fuel machine more than likely to be in refuelling operation, so at least radioactive inventory of one fuel stringer released, fuel channel charge plug will be disengaged, rapid reactor depressurisation within core with fuel pin failure of a) above - if control room lost then control of other reactor also lost and thus dependent upon automatic safe shutdown being achieved entirely automatically. d) Conventional control rod SCRAM not possible, localised fuel channel overheating and fuel pin melt, nitrogen injection and then boron bead initiated but potential for reactor pressure circuit rapid depressurisation with simultaneous occurrence of service penetration failures of a) above.	Individual off-site dose >100mSv. For b), c) and d) varying times of onset, rate and overall severity of radioactive release, dominated by fuel fission products, fuel oxide particles reduced to aerosol by accompanying aviation fuel fire – high plume loft and widespread dispersion - on site station emergency services largely disabled, off-site emergency services attendance hindered by lack of on-site expertise availability, assuming fuel fire/deflagration disabled those staff on site, particularly when Dungeness A staffing reduced to skeletal levels once spent Magnox fuel removed from reactor cores and decommissioning is underway – major radiological incident, exceeding the REPPIR 5mSv/year dose exposure trigger level.	Scenarios a) and b) are beyond-design-basis failures for which no fault-specific post-incident mitigation is pre-prepared . Scenarios c) and d) could be marginal beyond-design-basis failures if fuel-air vapour explosion generated, else release could be time managed to cut off off-site radiological consequences within hours of incident.

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[62] *Brief Review of the Documents Relating to the Graphite Moderator Cores at Hinkley Point B and OtherAdvanced Gas-Cooled Reactors*. Large & Associates, R3154-Graphite, June 2006

2	B Fuel Pond	up to 2023^{+}	a) Aircraft penetration into fuel pond building, cooling services pipework guillotine failure,[63] rapid drain down of spent fuel pond, aviation fuel fire/deflagration fails all safety control systems and could devastate nearby main station control room and incapacitate occupants.	a) Loss of pond water leads to fuel cladding failure and eventual fuel melt, rate and severity depending on rapidity of water loss, release of fuel-cladding gap inventory for part or all of spent fuel in store.	Aviation fuel fire, together with other flammables in situ, provides high plume loft and widespread aerosol dispersion - major radiological incident, exceeding the REPPIR 5mSv/year dose exposure trigger level.	Scenario a) is a beyond-design-basis failure for which no fault-specific post-incident mitigation is pre-prepared
3	B Essential Services	up to 2023^{+} thereafter reducing dependence	a) Part or all of essential services disabled, possibly including some stand-by diesel generating sets, control/general servicing staff lost or incapacitated by aviation fuel fire/deflagration.	a) Similar to 6 a) but severity could be significant if loss of services whilst reactor operational and/or spent fuel in pond	Similar to 6 a).	
4	B Radwastes	2025 to 2125	a) No details of radwaste processing, packaging and interim on-site storage are available – generally, see 7(a) below	a) Likely to be similar to 8 a) but excluding any significant Wigner energy release (AGR core operating temperature prompts self-annealing in most of core cross section)	Similar to 8 a).	
5	A Reactors	2006	a) Reactor cores presently in use as temporary fuel stores but most probably cleared by the date of any commercial development of LAIA	a) If spent fuel cleared from reactor cores then N/A	No radiological consequence.	
6	A Fuel Ponds	up to 2015	a) Fuel ponds presently in use as temporary fuel stores but most probably cleared by the date of any commercial development of LAIA.	a) If spent fuel cleared from site then N/A	No radiological consequence.	
7	A Essential Services	up to 2015^{+} thereafter reducing	a) Part or all of essential services disabled, possibly including some stand-by diesel generating sets, control/general servicing staff lost or incapacitated in aviation fuel fire/deflagration.	a) If spent fuel cleared from site then loss of essential services would be unlikely to result serious nuclear safety issues arising – some problems may be encountered if radwaste is being processed at the time of the loss	Possibly some but manageable radiological consequences.	

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[63] *Sizewell A – Cooling Pond Recirculation Pipe Failure Incident of 7 January 2007, Assessment of the NII Decision Making Process*, Large & Associates, R3179-A1, March 2009

8	A Radwastes	2015-2110	a) Structural details of the planned intermediate waste store not publicly available.	a) Unless specifically designed and constructed to be aircraft crash resistant, impact and follow-on aviation fuel fire could result in damage to overall store and individual package containment losses – at the later stages towards FSC when the reactor graphic cores are being removed from the in situ reactor hulks, risk of graphite reactivity in air (fire) and exacerbating release of Wigner energy.	Radiological consequences depends on the types and volume of radwaste in storage (and/or under preparation/packaging) – ILW graphite release via loss of containment and air reactivity could result in significant and widespread radiological consequences. Off-Site radiation exposure most probably to significantly exceed REPPIR.	
9	Spent Fuel/Radwaste Railhead	A - 2015 B - 2023 (Radwaste 2125)	a) Airframe impact and aviation fuel engulfment of up to three/four flask spent fuel (or Radwaste) train waiting to dispatch for the Railhead – similar scenario could equally apply to the articulated road vehicle moving a single spent fuel flask from the station (either A or B) to the railhead.	a) Containment of individual flasks likely to survive impact forces but may remain in aircraft wreckage, ensuing aviation fuel fire may burn longer then the prescribed 30 minute thermal endurance[64] requirement and flask containment may fail due to thermal overstressing.	For AGR spent fuel, a total fuel cladding-pellet gap inventory of ~180PBq available for release with intensity of fire making for a high release fraction – containment failure would, depending on the particular circumstances, commence about 80 to 120 minutes into the incident,[65] plume lofting would be high and dispersion widespread. Off-Site radiation exposure most probably to significantly exceed REPPIR.	Scenario a) is a beyond-design-basis failure for which no fault-specific post-incident mitigation is pre-prepared
10	Spent Fuel/Radwaste Runway	A - 2015 B - 2023 (Radwaste 2125)	a) Train hauling spent fuel across southern end of runway is at risk of 'runway excursion' landing accident which is not included in any of the risk analysis undertaken by the NII or AREVA. As	a) As for 9a) above.	As for 9 a) above	Scenario a) is a beyond-design-basis failure for which no fault-specific post-incident mitigation is pre-

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[64] *Regulations for the Safe Transport of Radioactive Materials*, 2005 Edition, Safety Requirements No Ts-R-1 IAEA – these regulation are adopted in the UK for the transportation of spent fuel requiring the Magnox M2 and AGR A2 flask to withstand, amongst other applied conditions, 30 minute engulfment in a hydrocarbon fire of 800^{o}C temperature [¶728 p107]..

[65] If the flask remains upright then with yielding of the bolts the steam formed in the ullage space above the water level within the flask would vent until the pressure reduced for the lid to be pulled shut by the elastically extended lid bolts – this whole process of puff and shut, puff and shut, and so on for a flask immersed in a hydrocarbon fire generating steam at 600kg/h would take about 100 minutes to completely expel all of the flask cooling water. If, however, the flask is upside down, the venting through the lid would be water and not steam so the entire water contents would be expelled in 30 seconds or so. Once uncovered and depending on burn-up and how pond storage time had elapsed, the spent fuel self heat generation would lead to clad failure and gap inventory release in the following 30 or so minutes. Some fuel clad may have been damaged in the impact sequences – see *Risks and Hazards arising the Transportation of Irradiated Fuel and Nuclear Materials in the United Kingdom*, March 2006 [photographs p12]

			noted previously,[32] only *training take-take* offs are halted when spent fuel train is positioned across end of runway and there is no such restriction for normal airport air traffic.			prepared
11	Service Roads	up to 2125	a) Service road availability critical requirement whilst fuel remains on the Dungeness A site and there is continuing nuclear generation and spent fuel storage at Dungeness B.	a) Could delay access times to the Dungeness A/B sites by off-site emergency services if sites were also subject to damage, could be applicable in a multi-target terrorist attack.	Has both on- and off-site consequences, particularly for multi-target terrorist scenario with power plant staff incapacitated because on-site assessment of hazard could be significantly delayed.	
12	Transmission Lines	up to 2025$^+$ thereafter reducing	a) Aircraft impact either with transmission line pylons or with transmission lines, or with switchgear buildings, resulting in loss of connection requiring the operating Dungeness B reactors to immediately shutdown and invoke emergency diesel generator sets to provide power for core and fuel pond cooling.	a) Loss of Grid connection requires operating reactor plants to immediately shut down and to establish on-site emergency electricity supplies – could be applicable in a multi-target terrorist attack.	Much the same as 11 a) above.	

134 In **TABLE 3** I identify a number of scenarios whereby a crashing aircraft is likely to penetrate or sufficiently damage the building structures to trigger an initiating fault and knock-on effect(s) that could develop into a radioactive release with off-site radiological consequences.

135 My point here is that it is not at all necessary to penetrate the reactor *primary* containment because the impact and impulse damage would be sufficient to break through the enclosing building structures that are, for both Dungeness A and B NPPs relatively flimsy. For example, an aircraft crash penetrating into two or more of the equipment/reactor services quadrant areas could disable two or more of the four coolant gas circulators; it might shear the packing glands of the feedwater, reheat, and decay heat penetrations through the RPV walls, and the impulse loading might be sufficient to dislodge critical equipment and structural elements within the RPV, that is without hardened aircraft components actually penetrating the RPV.

136 As a guide, a good approximation of the resilience of a conventional reinforced concrete (rc) framed structure (a typical commercial office building) shows that the impulse force of a crashing commercial aircraft is sufficient to yield the rc structural elements.[66]

137 So although it is clear to me that the building structures surrounding key nuclear safety areas of the Dungeness NPPs would not be expected to reasonably withstand the impact of a commercial aircraft, to my knowledge there has never been, published or otherwise, a substantial analysis of the Dungeness NPP structures when subject to a commercial aircraft impact and, particularly, there has never been published a projection of the on- and off-site radiological consequences arising therefrom.

138 However, an indication of the potential radiological consequences may be taken from a recent study of severely damaging incidents at French nuclear plants for which the pressurised water reactor (PWR) at Fessenheim (Eastern France, near to the German-Swiss-French border) yielded the following probabilistically-based prediction:[67,68]

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[66] The maximum impact before yielding commences is given by

$$ir = [2Lim/En]0.5\ \partial y/Ah$$

which (adopting conventional notation) for a typical rc construction, with a roof slab load per column assumed at 35t, the structure yields at about 1,750 Pa-s. The force arising from an crashing aircraft of, say 200 tonnes all-up weight considered impacting over its projected front end fuselage area (about 30m^2) with event lasting in time over the entire collapse of the fuselage length, gives an impulse force of about 20,000 Pa-s or about x10 the yield strength of the typical rc structure described above.

[67] *Assessments of the Radiological Consequences of Releases from Existing and Proposed French EPR/PWR Nuclear Power Plants*, February 2007 (in French).

[68] The comparison should be considered with caution because the Fessenheim reactor at 880MWe output is larger than the 600MWe Dungeness B reactor and its fuel is burnt-up to a higher degree which means a greater amount of radioactivity being released at the French location. Other factors included different population distributions, emergency planning measures and countermeasures, etc.. The *EXPECTED E* column on the right side of the table is the *Expectation Value*, ie that most probably to result if the accident took place with the probability relating to the atmospheric stability conditions pertaining at the time and following the release.

139 **TABLE 4 RADIOLOGICAL CONSEQUENCES OF PWR NPP ACCIDENTAL RELEASE**

		N^{o} OF HEALTH EFFECTS pth percentile		
NPP SITE	**HEALTH EFFECT/COUNTERMEASURES**	**99th**	**EXPECTED E**	**50th**
Fessenheim EXISTING 880MWe PWR 100% LEU core	EARLY Death	194	26	10
	LATE Fatal Cancer	36,010	10,340	8,913
	Thyroid Cancer DEATHS	2,599	492	479
	LAND Area (ideally) Evacuated km^2	6,188	2,206	1,950
	Area (ideally) Iodine Prophylaxis km^2	1,268	273	200
	NUMBERS Persons (ideally) evacuated	2,960,000	563,300	331,100
	Persons (ideally) I-131 Prophylaxis	502,900	90,180	31,150

140 Similarly, for the now-operational larger PWR plant at Sizewell, the predicted radiological outcomes for a moderately severe degraded core accident are:[69]

141 **TABLE 5 RADIOLOGICAL CONSEQUENCES OF SIZEWELL PWR NPP ACCIDENTAL RELEASE**

		N^{o} OF HEALTH EFFECTS pth percentile		
NPP SITE	**HEALTH EFFECT/COUNTERMEASURES**	**99th**	**EXPECTED E**	**50th**
Sizewell B EXISTING 1,100 MWe PWR 100% LEU core	EARLY Death	1,800	78	0
	LATE Fatal Cancer	33,000	3,600	100
	Thyroid Cancer NON-FATAL	71,000	7,900	190
	LAND Area (ideally) Evacuated km^2	1,500	140	9
	NUMBERS Persons (ideally) evacuated	420,000	31,000	480

142 A number of assessments of accidents involving fuel transport flasks have been published, although these mostly relate to radioactive releases arising from incidents to spent PWR fuel in transit through an urban area.[70]

143 The transportation risks to AGR spent fuel shipments has been undertaken for a train hauling three flasks caught in a tunnel fire. In this somewhat extreme scenario, all three AGR flasks are expected to completely fail and the fuel cladding rupture, releasing the entire clad gap radionuclide inventory[71] and a fraction of fuel aerosol, some of which is retained by the tunnel surfaces. The radiation dose exposure, air and ground contamination levels for mid-range atmospheric stability conditions (E) are summarised as follows:

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[69] *An Assessment of the Radiological Consequences of Releases from Degraded Core Accidents for the Sizewell PWR*, NRPB-R137, 1982 – the table summarises the results for release scenario UK 2A and some caution has to be applied to interpretation of the dose related results because at that time (1982) the assumed causal relationships between exposure and health detriment for fatal cancers and other health detriment were then based on the International Commission on Radiological Protection (ICRP) Recommendation 26, being 0.0125 per Sievert risk factor prior to the ICRP 60 (1990) in which the risk factor was increased to 0.05 per Sievert, that is an increase of x4 (ie the same modelling today would result in higher outcomes). The National Radiological Protection Board (NRPB) is now incorporated into the Health Protection Agency (HPA).

[70] Shaw K, The Radiological Impact of Postulated Accidental Releases during the Transportation of Irradiated PWR Fuel through Greater London, NRPB-R147, 1983

[71] The clad gap inventory is the radioactive fission products and gases that have migrated to the pressurised annular gap between the stack fuel pellets and the thin sheath tubing of stainless steel of the individual fuel pin. There is an additional component that builds up in the plenum space at the end of the fuel pin – these fission products are immediately available for release should the pin sheathing or cladding fail.

144 TABLE 6 DISPERSION & EXPOSURES – 3 AGR FLASK - SPENT FUEL CLAD GAP INVENTORY

DISTANCE km	1 DAY EFFECTIVE DOSE Sv	AIR CONCENTRATION Bq-sec/m^3	GROUND DEPOSITION kBq/m^2	SURFACE SHINE DOSE Sv/hr	ARRIVAL TIME hr:min
0.100	2.9E+02	3.3E+13	1.9E+08	1.6E-01	00:01
0.500	1.3E+01	1.5E+12	4.6E+06	6.5E-03	00:09
1.000	3.7E+00	4.2E+11	1.2E+06	1.8E-03	00:19
10.000	9.9E-02	1.1E+10	3.3E+04	4.8E-05	03:15
20.000	3.5E-02	4.0E+09	1.2E+04	1.7E-05	06:30
40.000	1.0E-02	1.2E+09	3.4E+03	4.9E-06	13:00
60.000	4.1E-03	5.0E+08	1.3E+03	2.0E-06	19:30
80.000	2.1E-03	2.8E+08	6.9E+02	1.0E-06	>24:00

145 The radiological impact of the three flask AGR incident can be compared to other types of nuclear fuel involved in similar circumstances:[72,73]

146 TABLE 7 COMPARISON OF SPENT FUEL FLASK INCIDENT ASSESSMENTS

				N^{o} LATE FATAL HEALTH EFFECTS PROBABILITY[74]		
	SCENARIO	INVENTORY PBq	RELEASE FRACTION Cs^{137}	EXPECTED *E*	p=1	p=99.9
NRPB PWR – URBAN	Explosive 3 min release	74	1.E-3	45	4.4	670
NRPB PWR - URBAN	Explosive 3 min Short-Cooled Fuel	120	1.E-3	99	9.5	1,300
3 MAGNOX - URBAN	Explosion + 6 hour Tunnel Fire	3 x 35	3.E-2	2,815	-	8,491
3 AGR - URBAN	Explosion + 6 hour Tunnel Fire	3 x 90	1.E-3	**1,511**	-	3,022

147 These examples of the radiological consequences of relatively severe incidents,[75] although not directly comparable to the scenarios that I have nominated in **TABLE 3**, suggest that 100 or more fatalities would likely arise in the immediate, interim and longer terms for my scenarios 1a), 1b), 1c) and 1d), all of which relate to damage to vital systems/components *outside* Dungeness B RPV. Scenario 2a) involves breaching a Dungeness B fuel pond, and scenarios 9a) and 10a) are off-site relating to a spent fuel train dispatching from either Dungeness A or B NPPs.

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[72] The incident modelled for all four cases of TABLE 6 is a munitions explosion followed by a fierce fire with the flask(s) stranded in a tunnel – ie a terrorist attack.

[73] *Risks and Hazards arising the Transportation of Irradiated Fuel and Nuclear Materials in the United Kingdom*, R3144-A1, March 2006.

[74] The two sets of NRPB analysis dates from 1983 when the ICRP fatal cancer risk factor was 4x lower than that in use today so, cautiously, the NRPB tabulated results could be increased by x4.

[75] The operating reactor release scenarios are not as severe as the actual incident, radioactive release and radiological consequences of the Chernobyl catastrophe of April 1986 – the release fractions adopted for the reactor incidents are very much lower than the actual 40 to 50% release fractions liberated from the Chernobyl N^{O} 4 reactor core.

148 On this basis, each of my selected scenarios [¶147] qualify for consideration under the societal risk criteria of *Target 9* of the HSE SAPs.[76]

149 **PART II – SUMMARY**

150 I concluded in **PART I** that for at least 100 years into the future radioactive hazards will persist in a variety of forms on the Dungeness NPP sites [¶66 & **CHART 1**].

151 Having identified the radioactive hazards, in this part of my evidence I have assessed how each of these hazards, or targets, would respond when subject to the impact forces imparted from a large commercial aircraft crashing onto the structure.

152 In evaluating the targets and the aircraft crashes I have not differentiated between accidental and terrorist implemented aircraft crashes, although I note here that a '*fly-in*' crash, that is with well-informed hijacker(s) on board aiming at a preselected target, would be more likely to result in more significant radiological consequences.

153 As one would expect, the regulatory approach follows a commonsense rationale.

154 For example, the International Atomic Energy Agency (IAEA) recommends[77] that

> ". . *3.44 The potential for aircraft crashes on the site shall be assessed with account taken, to the extent practicable, of characteristics of future air traffic and aircraft.*
>
> *3.45. If the assessment shows that there is a potential for an aircraft crash on the site that could affect the safety of the installation, then an assessment of the hazards shall be made.*
>
> *3.46. The hazards associated with an aircraft crash to be considered shall include impact, fire and explosions. . .*"

155 In the UK the IAEA 3.44 recommendation is interpreted by latest edition of the HSE SAPs (2006): Accidental aircraft crash is considered to be an external hazard for which the total predicted frequency on or *near* any nuclear facility housing systems important to continuing safety, has to be determined and accounted for in the nuclear safety case and nuclear site licence [SAPs EHA.8].

156 Similarly, IAEA 3.45 is covered by [SAPs ¶218] in that ¶218 requires the *'most recent crash statistics'* to be used in the assessment, although the application of aircraft crash statistics by both the NII [¶157] and

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[76] 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.

[77] *Site Evaluation for Nuclear Installations*, IAEA Safety Standards Series, Safety Requirements N^{o}. NS-R-3, 2003

the operators [¶170] is contrary to the opinion of Pitfield [¶2.1 & 2.2] who found the crash rates adopted for the Byrne methodology to be *'limited and dated'*.

157 Fires and explosions of IAEA 3.46 are covered by [SAPs ¶219] which also specify the crash frequency in terms of the SAPs limits for a *'design basis event'* being less then 10^{-4} per year but not more than 10^{-7} per year and, similarly, for high consequence events (off-site individual dose >100mSv) SAPs FA.15 and FA.16 (¶543 – 550) apply requiring reasonably practicable measure to be installed to prevent or minimise consequences.

158 The NII indirectly refers to the Byrne methodology in its *Freedom of Information Act* (FOIA) response to LAAG of 7 May 2009 referring to *'independent risk studies by an external consultant'*, but for which the NII provide no further details other than to give a tabulated calculated frequency of significant radiological release. Thus NII aircraft crash frequency cannot be directly compared to the AREVA [Table B8 p25] Byrne derived crash frequency of LAIA, nevertheless the following results give a sense of the range (and hence uncertainty) of frequencies predicted:

159 **Table 8 NII *vs* AREVA Aircraft Crash Frequency - 500,000** ppa

		Target	**Background** per year	**Airport** per year	**Total** per year	~ year
1	**NII**	unspecified assumed Dungeness B	$5.4\ 10^{-8}$	$1.6\ 10^{-8}$	$7.0\ 10^{-8}$	1 in 14,300,000
2	**AREVA**	Dungeness B Nuclear Island excludes light aircraft	$4.00\ 10^{-7}$	$1.58\ 10^{-7}$	$5.58\ 10^{-7}$	1 in 1,800,000
3	**AREVA**§	Dungeness B Whole Site excludes light aircraft	$1.00\ 10^{-7}$	$3.97\ 10^{-7}$	$4.97\ 10^{-7}$	1 in 2,012,000
4	**AREVA**	Dungeness B Whole Site includes light aircraft	$7.28\ 10^{-6}$	$9.97\ 10^{-7}$	$8.26\ 10^{-6}$	1 in 120,000

§ Derived from AREVA Table B8

160 It is difficult to fathom out why there is such a difference in the NII and AREVA aircraft crash frequency projections, particularly because each draws on the same data base and each is for the same air traffic density. Effectively, there are only remaining factors that would contribute significantly to the difference, these being:

161 i) differences in the size and height of the target, although this is largely accounted for in the range provided by the AREVA target adjustment [rows 2 & 3 above];

162 ii) that the NII has introduced a mitigating factor (ie that there is, say, 1 in 10 chance of radioactive release following a successful impact onto the target) for the particular (unspecified) target under consideration.

163 One persistent difficulty is the dogged taciturnity of the NII in not providing details of assessments that it claims to have been undertaken, but the details of which it will not publish.

164 For example, in its FOIA response to LAAG of 7 May 2009, the NII refers [¶3 p4] to its review of the *'risk assessment methodology adopted by British Energy'* and the *'appropriate target area'*; separately to *'independent risk studies'*; and to *'consultation with relevant statutory bodies'*, but it has never published any further details of these. Indeed, the NII goes on, quite remarkably, with a totally unsubstantiated *'swings and roundabout'* reasoning:

165 ". . *Whilst there will be an increase in the numbers of larger commercial aircraft, (which have high reliability but more significant accident consequences), there will be a significant decrease in the numbers of light aircraft and helicopters using the airport.*

> *Light aircraft and helicopters have a much lower reliability but also lower accident consequences. The combined effects of these factors mean that the overall risk to the Dungeness licensed site posed by air traffic using the airport will be more or less unchanged and still dominated by the background risk. . . "*

166 In another letter to LAAG of 22 January 2009, the NII [¶2 p1] gives its reasons for refusing to discuss matters relating to LAIA:

167 ". . *Our decision not to discuss the topic of Lydd airport developments at the stakeholder group meeting is a deliberate one. We do not consider it appropriate that this forum be used for the purposes of discussing proposed planning applications beyond the site boundary. . . "*

168 Despite requests for further information under the FOIA the NII has continued with its refusal to provide any further information on its approach to and results of the review of the LAIA crash risk, going so far as failing to provide information requested by Large & Associates under FOIA almost a full year following the initial request.

169 The failure to properly review nuclear safety issues arising from the potential development of LAIA also applies to the other 'targets' that I have previously identified [**CHART 1**].

170 For example, the last published Periodic Safety Review submission[78] for Dungeness A (August 2005) concludes that the then (2005) risk of aircraft crash was *'acceptably low'*. However, this assessment could not have then included for the 500,000ppa and 2mppa crash rate projections for LAIA and, even though

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[78] *Post Operations and Defuelling Safety Case*, NP/SC 4773 Stage Submission D5, BNFL to NII letter 19 August 2005 – redacted.

the submission goes on to acknowledge the proposals to develop Lydd airport (now LAIA), it considers only the increase in the time period required for plant staff to re-establish spent fuel cooling (if lost because of aircraft crash) if and by which time the LAIA entered commercial operation.

171 There are a number of implausible aspects to this line of reasoning, namely

172 a) Pitfield's opinion [¶2.2 p6] that Byrne methodology of determining the aircraft crash rate is deeply flawed;

173 b) there is no account of intentional air crash by terrorist act – either hijacked fly-in or downed by a missile;

174 c) the lightly constructed building enclosure of the fuel ponds are assumed to survive relatively intact without loss of containment and the pond remains capable of holding coolant water levels, whereas the 9-11 Pentagon damage severity demonstrates otherwise;[79] and

175 d) at that time (2005) there seems to have been a complete unawareness of the long defueling delays [¶25] that could and were to arise in the dispatch of spent fuel from Dungeness A.

176 The aircraft crash *rate* analyses undertaken by the several parties (Pitfield, AREVA, NII and myself) generate a range of aircraft crash frequencies applied to a series of nominated targets. Part of this range is within the SAPs limits that defines consideration as a *'design basis event'* [¶157], some of which would be likely to result in an off-site individual dose in excess of 100mSv.

177 This latter group of higher-consequence events requires reasonably practicable measures to be installed to prevent and/or minimise the consequences. Later [¶197] I express my opinion that it is not practicably possibly to crash-proof the existing nuclear installations on the Dungeness NPP sites.

178 PART II SUMMARY

179 **PART I** established that nuclear activities will continue on both Dungeness A and B sites for about 100 years or more following the cessation of nuclear operation of Dungeness B NPP in or

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[79] Damage to one of the Dungeness A spent fuel ponds of similar severity to that of the Pentagon, could result in a calamitous situation in which all of the remote fuel handling and radiation shielding had been destroyed and with no means of covering the exposed Magnox fuel with coolant so the mechanically damaged fuel, possibly exposing hydride formation on the elemental metal uranium could result in fuel ignition and efficacious dispersion – see Large J H, *Corrosion of Magnox Cladding*, Evidence to House of Commons Environment Committee, 6th Report, *Radioactive Waste*, by Order of the Committee, January 1986 and *Sizewell A – Cooling Pond recirculation Pipe Failure Incident of 7 January 2007 – Assessment of the NII Decision Making Process,* R3179-A1, June 2009 [Footnote viii].

about 2018 - **CHART 1** illustrates the time scales over which these nuclear/radioactive activities and the radwastes arising therefrom, will persist as radiological hazards on and about the Dungeness A and B sites.

180 **PART II** identifies a range of accidental air crash scenarios, which generally encompass malevolent attacks, together with the level of damage and potential radiological outcome that might arise - I have outlined these in **TABLE 3**.

181 **TABLE 4**, **TABLE 5**, **TABLE 6** and **TABLE 7** summarise the radiological consequences (health detriment) in the public off-site domain for a number of situations that are not that dissimilar to the scenarios of **TABLE 3** Dungeness A and B activities identified by **CHART 1**.

182 The overall finding of **PART II** is that aircraft crash, either accidental or intentional, of a large commercial airliner onto parts of the Dungeness NPP sites and/or related activities could, and probably would, result in sufficient severity of damage to effect a radioactive release with some off-site radiological consequences.

183 IN CONCLUSION

184 I note that Spaven [¶6.4] concludes that the proposed changes to air traffic operations at LAIA will '***reduce the margins of safety** in respect of the risk of an **aircraft crashing on the Dungeness NPPs'*** ; and that

185 Pitfield notes that the method adopted by both the NII and AREVA yields a crash rate for airport operations that is ***'unacceptable'*** [¶6.3], and that AREVA wrongly assessed runway usage and *'**understated** the overall risk'* [¶2.1], and he finds the '*AREVA estimate to be **unreliable**'* [Summary ¶1.31].

186 I consider this combined expert opinion (Spaven and Pitfield) to cast considerable doubts about the applicability of the Byrne methodology (and accompanying outdated data base) used to predict the aircraft crash rates for both background and LAIA air traffic, as this applies as a risk of aircraft crash onto any one of the targets associated with nuclear and radioactive operations at the Dungeness A and B NPP sites.

187 This is particularly concerning since it relates to the direct and indirect inputs to this Planning Inquiry by the HSE NII who specifically advised Shepway District Council that it was *'satisfied that the risk to the Nuclear Installations at Dungeness in their current plant states [that it] is*

sufficiently remote that we have no grounds for objection to the proposed development on the grounds of Nuclear Safety' [¶1 p2].

188 The NII has expressed similar opinion, showing its dependency upon the Bryne methodology to determine the aircraft crash risk, in its Lydd Airport Briefing Note to HM Office for Nuclear Development who queried whether the LAIA development could compromise the current and future nuclear activities on the Dungeness sites [2nd e-mail p1].

187 I consider that the underlying basis of any judgment on risk, particularly relating to nuclear safety, is that if certain externally driven events, over which the NPP operator has no control (such as severely damaging air crash), are to be discounted on probability alone, then the basis of the judgment must be absolutely indisputable.

188 Expert Spaven has expressed questions regarding the safety of LAIA procedures, particularly those where landing aircraft on *'go arounds'* are channelled towards the NPPs; Pitfield shows the unreliability of the method adopted for predicting aircraft crash frequency onto and/or about the Dungeness NPP sites; and I have introduced my fears that LAIA activities could provide opportunity for an airborne terrorist attack on the NPPs.

189 I am concerned that the NII has not provided LAAG, despite repeated requests, or this Inquiry with further details, substantiation and the results of its assessment of the nuclear safety cases revisions necessary in account of the proposed LAIA development.

190 I am also uncomfortable with the NII's dismissal that LAIA air traffic movements might provide the opportunity for airborne terrorist attack against the Dungeness NPPs. Moreover, the NII offers no substantiation of this other than that it considers such malevolent acts not *'reasonably foreseeable'* and, on this basis alone, it effectively directs that no further consideration by this Inquiry is necessary.

191 Interpreted in terms the SAPs, the NII's stance that terrorist attack is not *'reasonably foreseeable'* means that no *'design basis event'* remedial/mitigation action is deemed necessary. This clearly contradicts other government opinion that *"There is sufficient information in the public domain to identify possible ways terrorists might bring about a release of radioactive material from a nuclear facility"*.[80]

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[80] *Assessing the Risks of Terrorist Attacks on Nuclear Facilities*, Parliamentary Office of Science and Technology, Report 222, July 2004

192 An airborne terrorist attack against the plant would be an intentional, intelligently driven act that sought out the vulnerabilities of the nuclear targets so, in this respect, the likelihood of imparting severe damage to the NPP (etc) and the resulting radiological consequences would be both greater than an accidental crash of the same aircraft type.

193 I would have expected the HSE (NII), as a Statutory Consultee, to have advised the planning authority on this issue but, to my knowledge, it has not done so – there is no other government agency[81] that is sufficiently knowledgeable to provide advice on this important public safety issue.

194 Of the skimpy nuclear safety related reckoning that has been made available to me:

195 i) the summary of Periodic Review undertaken by the Dungeness A operator deploys entirely unsubstantiated if not confused reasoning, considering only the relatively short term risk associated with on-site spent fuel but with no account of the other radioactive activities and materials that will be on the Dungeness A site for 100 or more years ahead.

196 ii) The NII Lydd Airport Briefing Note is introduced by an NII Inspector who unabashedly states that *'There is a long, long history to all of this . . . Happily, I am not really involved in any of this any more'*, with the Note [Table p5] providing little information other than to state the NII's global findings of the risk of radiological release,[82] which when compared to the AREVA (albeit suspect) calculation of risk using the same methodology, is unduly optimistic.

197 I do not believe it possible to proof the existing Dungeness A and B NPPs, or a future Generation III NPP that might be built on the Dungeness site, against aircraft crash, particularly that of a fully fuelled, commercial airliner of any of the types proposed for the LAIA development. This being so, the reasonable possibility of aircraft crash must be ruled out by other means by, first, limiting the gross size (weight and fuel capacity) of the aircraft and, second, by setting a limit to the predicted frequency of crash.

198 The proposed development at LAIA does neither: it raises the size of the aircraft using the airport and it increases the number of air traffic movements.

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[81] Previously, the government's regulator on nuclear security issues was the Office for Civil Nuclear Security (OCNS) but on 1 April 2007, OCNS transferred from the Department fo Trade and Industry (DTI) and merged with the Health and Safety Executive (HSE) Nuclear Safety Directorate (NSD) to become a part of the Nuclear Directorate (ND) of the HSE. OCNS is now Division 5 of the ND.

[82] *Risk of Radiological Release* (per year) in not necessarily the same as the risk of aircraft crash onto the NPPs – see ¶162.

199 Because of the doubts and uncertainties over the air crash frequency, the questionable resilience of the Dungeness A and B building structures, and the potential enormity of the radiological consequences should an aircraft crash occur – either as chance would have it or by malevolent intent - I consider it to be in the public interest that the NII fully disclose its assessment of all relevant nuclear safety case reviews and the like.[83]

200 The potential radiological consequences resulting from an aircraft crash on the Dungeness NPPs will be of great public concern and thus, I suggest, continuing nuclear safety of the Dungeness NPP sites is the paramount material consideration for this Inquiry. So, it follows, all of these aspects of the relationship between the Dungeness nuclear sites, etc., as they each relate to the proposed development of the London Ashford International Airport and public health and safety, are material considerations and should, therefore, be fully disclosed to and considered by this Inquiry.

201 Given the facts and opinion that I and the other experts acting for LAAG have presented, taken together with the commonsense notion that it would be folly indeed for such a development to proceed so near to the highly hazardous NPPs, radwastes and continuing radiological activities of Dungeness, the Inquiry should wholly reject this Planning Application.

202 I state here that I confirm that I have made clear which facts and matters referred to in this Statement that are within my own knowledge and which are not. Those that are within my own knowledge I confirm to be true. The opinions I have expressed represent my true and complete professional opinions on the matters to which they refer.

JOHN H LARGE
LARGE & ASSOCIATES
CONSULTING ENGINEERS, LONDON

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[83] I have similar reservations about the risks and potential radiological consequences relating to aircraft crash on the completely unprotected railhead for loading irradiated fuel flasks and for the rail dispatch of these flasks over a track that passes (within 200m) along the southern end of the LAIA runway. Again, I consider it prudent for the railhead and transportation safety cases be reviewed and included in this review should be consideration of the very large volumes of radioactive wastes that will arise during decommissioning of, first, Dungeness A and then Dungeness B.