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

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

RELATING TO

1) **DECOMMISSIONED STRUCTURES AND RADIOACTIVE WASTES REMAINING IN-SITU**
2) **FUTURE OPERATION OF ANY NUCLEAR NEW BUILD GENERATION III NUCLEAR POWER STATION AT DUNGENESS C**

Client: LYDD AIRPORT ACTION GROUP (LAAG)

Opinion of **JOHN H LARGE**

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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 – relevant sections of text referred to are show thus [¶2 p2]. 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

Summary

In his recent evaluation of the Bryne methodology for projecting the background and local air crash rates, Roberto Trotta concludes that this approach *'cannot be considered to be robust nor accurate'* and that its output '*is insufficient as a basis for sound and informed decision making'*. Yet the Office for Nuclear Regulation (ONR) almost entirely relies upon Bryne for calculating the aggregate national background and local Lydd Airport crash rate, from which it concludes that the risk of a commercial-size aircraft crash onto Dungeness is so low as to be considered an incredible event.

On the basis that if, as Trotta advocates, the aircraft crash risk cannot be so readily discounted, and the ONR's rationale for not opposing the planned airport development narrows to the claim that the existing plants at Dungeness do not present a radiological hazard, LAAG has asked for my opinion of the levels of radiological hazard persisting at the Dungeness A and B nuclear sites following the complete shut down and defueling of the reactors and spent fuel ponds. Similarly, I have been asked for an opinion on the risks of a significant radiological release from a new-build nuclear plant at Dungeness C, should it go ahead, on the premise that its advanced design would safeguard it against any extreme external event, including commercial-sized aircraft crash.

Dungeness A and B NPPs: It is a matter of fact that the built structures and containments of the Dungeness A and B nuclear power plants (NPPs) never took into account the crashing of a commercial-size aircraft – there was no requirement in the UK nuclear regulatory system at the times of their respective design and construction phases, nor in the interim has it been practicable to render any substantial structural modification to the built plants to improve resilience. In my opinion, should either of these plants be subject of aircraft crash then severe damage to the various containment structures would most likely result.

Even when all four of the existing Dungeness reactors and spent fuel ponds have been defueled and the fuel moved off site (Dungeness A has recently completed this and Dungeness B would be expected to shut down in 2018-22 and defuel three to four years following), I show there to remain sufficient quantities of radioactive waste and (radio)activated materials on the sites to present the potential for significant radiological consequences in the public domain should an aircraft crash provoked radioactive release occur.

I demonstrate that the risk of significant radiological consequences will remain with the Dungeness A and B sites for about 100 years or so into the future, that is throughout the period presently allocated by government for deferred decommissioning and the eventual removal of the bulk of the radioactive wastes and structures from the sites.

Dungeness C Generation III EPR: If Dungeness C is built and commissioned, it will be in a fully fuelled and operational state for 60 to 70 years, thereafter it might be mothballed for 20 to 30 years before dismantling.

Over the past four years the ONR has been conducting a detailed *Generic Design Assessment* (GDA) of the European Pressurised Reactor (EPR). Other re-evaluations of the EPR design have been undertaken in response to concerns raised about nuclear safety by the Fukushima Daiichi accident of March 2011 – these re-assessments have been in the form of *Stress Tests* to determine the resilience of the EPR (and other designs of NPPs) against extreme external events, including aircraft crash.

I show that seven of the 30 or so outstanding *GDA Issues* identified by the ONR for the EPR design relate to the continuing vulnerability to commercial-size aircraft crash. Similarly, I have examined the Stress Tests evaluations of the EPR independently undertaken by French and Finnish nuclear safety regulators for the two EPR NPPs presently in advanced stages of construction and, again, I identify that about one-half of the 18 modifications required to improve the resilience of the EPR apply to the vulnerability of this NPP design to commercial-size aircraft crash.

I consider that the EPR (and other Generation III) NPPs remain vulnerable and, moreover, that little effective modification to improve the resilience of this design can be practicably achieved because the design was settled in the 1980-1990s, that is at a time when aircraft crash was not considered to be a realistic external threat to NPPs.

In conclusion: The ONR must be cognisant of these facts on the vulnerability, hazards and risks associated with the existing and future Dungeness NPPs so, it follows, the rationale underpinning the ONR's almost steadfast stance not to object to the commercial development of Lydd Airport can only be its belief that the probability of an accidental aircraft crash is so low as to be incredible.

In determining this probability the ONR seems to exclusively depend upon the Bryne methodology - it is the reliability of the Bryne methodology that Trotta has robustly challenged and demonstrated to be flawed.

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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, 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 opinion are given in R3136-A1[1] [¶4 to 6].

5 This opinion relates to the potential radiological consequences arising from accidental or intentional aircraft impact on either of the Dungeness A and B nuclear power station sites and, should a new Generation III nuclear power station be developed at Dungeness, on the Dungeness C site.

6 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;[4,5] and I have published on the vulnerability of nuclear facilities to terrorist attack,[6] including closed down nuclear power plants undergoing decommissioning.[7]

7 Specifically relating to the subject Planning Inquiry, I have previously prepared evidence for

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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 *Vulnerability of French Nuclear Power Plants to Aircraft Crash*, R3205-A1, Large J H, April 2012

6 *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

7 *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

cross-examination – a list and copies my evidence are accessible on the Large & Associates website.

8 I am presently undertaking a review of the outstanding design issues relating to the acceptance of the Generation III *European Pressurised Reactor* (EPR) which would, should development of Dungeness C proceed, most likely be the type of nuclear power plant (NPP) at Dungeness C (and possibly D if two Generation III NPPs were to be developed).

9 I consider myself to be sufficiently qualified, experienced and practised in the topics relating to this consultation to provide this opinion.

10 **INSTRUCTIONS:**

11 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).

12 I understand that LAAG has submitted a further Expert opinion[28] on the so called Bryne methodology of assessing aircraft crash risk by the *Office for Nuclear Regulation* (ONR) which, in effect, claims that the

13 "*. . . resulting estimate for the crash probability into the Dungeness nuclear power plants cannot be considered robust nor accurate". Furthermore, since the Byrne model lacks a statistically principled definition and application of risk, I conclude that its output is insufficient as a basis for sound and informed decision making regarding the increased level of risk of a major radiological release in connection with the planned expansion of Lydd airport . . .*"

14 Previous studies on the accidental aircraft crash risk at the Dungeness nuclear power complex undertaken on behalf of the ONR have concluded, on the basis of probability, that the risk of aircraft crash was so low that it could be ignored.

15 Since this new expert opinion challenges the basis on which the ONR chose not to oppose the commercial development of Lydd Airport, LAAG has asked me to express further opinion on the line of thought that might now be put forward by the ONR, hypothetically

16 a) *that since the reactors and fuel ponds at Dungeness A have now been completely defueled, the radiological consequences if a severely damaging aircraft crash did occur would be tolerable; similarly*

17 b) *setting aside the remaining period of operation of the Dungeness B NPPs, when these NPPs are finally shut down and defueled, the radiological consequences resulting from aircraft crash would be tolerable; and*

18 c) *the potential for a significant radiological release and radiological consequences arising from a new-build Dungeness C would be acceptably low because of its higher design standard with regard to extreme external event, such as aircraft crash,*

19 If the above arguments were to be proffered by the ONR then I would strongly disagree with each.

20 In this respect, I refer to my previous evidence LAAG/4/A and LAAG/4/I so here I shall highlight the salient points

21 **A) CLOSED DOWN DUNGENESS NPPS**

22 Considering the two permanently shut down Magnox reactors and, skipping ahead to about 2018/22 when the Dungeness B NPPs are expected to permanently shut down, it is a matter of fact that the conjoined sites of Dungeness A and B will be subject to a *Nuclear Site Licence* as required by the *Nuclear Installations Act 1965* (NIA65).

23 Even in account of all of the irradiated (spent) fuel being removed from the Dungeness A site, and similarly post-2018/22 from the Dungeness B site, there will be sufficient radioactive materials and substances remaining on these sites to represent a continuing radiological hazard. Since present government policy is for delayed final dismantling, decommissioning operations and site clearance for about one-hundred years or more, NIA65 Nuclear Site Licences will be required until at least 2120 or thereabouts.

24 Even if there was a change of government policy and the decommissioning/dismantling timescales were condensed for both Dungeness A and B, it would not be possible to provide a regional or national radioactive waste repository until 2040 or later.[8] In these unlikely circumstances, the radioactive wastes from the dismantled Dungeness A and B nuclear islands (reactors, activated and operational wastes, etc.) would have to remain in some form of protected and secure storage on the Dungeness sites until a national or regional radioactive waste repository was developed and operational at some site remote from Dungeness.

25 Put simply, there is no opportunity to transfer any of the operational radioactive wastes presently stored at the Dungeness sites and if dismantling and decommissioning of the NPPs proceeded apace the radioactive waste arisings would also have to remain on the Dungeness sites.

8 It is generally agreed that a National Radioactive Waste Repository could not be practicably available until at least 2040 – the design options and siting have yet to be determined. The National Repository would be expected to receive Low- and Intermediate-level wastes and some 'queuing' for disposal may be required and decommissioning of certain NPPs may be delayed.

26 In LAAG/4/A I outlined the categories and quantities of radioactive wastes remaining on the Dungeness A and B sites:

27 **TABLE 1 – RADIOACTIVE HAZARDS ON THE DUNGENESS A SITE**[9]

	PRE-2010 SHUT DOWN	2010–15 SPENT FUEL REMOVAL	2015–2040 C&M PREPS	2040–2090 C&M DWELL	2090-2110 CLEARING SITE	2110 FSC
	All fuel now discharged from 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			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			Varies with particular radwaste stream[10]			none

28 **TABLE 2 – RADIOACTIVE HAZARDS ON THE DUNGENESS B SITE**[9]

	PRE-2018 SHUT DOWN	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[11] 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[10]			none

29 I also noted that I considered that the vulnerability of the hulks of these decommissioning NPPs would be expected to change at the various stages of dismantling.

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9 Waste volumes from the *2007 National Radioactive Waste Inventory*, p85.

10 The graphite moderator cores at Dungeness A each contain ~2,250 tonnes of activated graphite of about 1.0E+16 Bq activity which will decay to a relatively stable level after about 100 years, thereafter further decay is dominated by the long-lived radioisotopes of carbon-14 (C14 - half-life 5,730 years) and chlorine-36 (36Cl – half-life ~300,000 years) . In other words, there is virtually no benefit to be gained in delaying dismantling after 100 years by virtue of the decay of radioactivity. See *Radioactive Graphite Management at UK Magnox Power Stations*, G Holt, BNFL, undated.

11 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 B – see *The Risks and Hazards Arising in the Transportation of Irradiated Fuel and Nuclear Materials in the United Kingdom*, March 2006 – although note this Opinion skips ahead of the remaining operational life of the Dungeness B AGR NPP and relates to the period following the shut down of Dungeness B and when all spent fuel has been removed off-site.

30 At certain times in the dismantling programmes, the nuclear islands would be expected to become more vulnerable to aircraft crash, particularly when the reinforced concrete shielding (the biological shield of the Magnox reactors and reactor pressure vessel of the AGR reactors) was partially opened to access the inner reactor core components, comprising steelwork supporting and bracing structures and graphite moderator pile.

31 That said, because the ONR does not require detailed decommissioning plans and schedules of each phase of the decommissioning timetable at the time of the shut down of the plant,[12] for the deferred decommissioning approach adopted in the UK, it is difficult to identify how and when the risks will occur. Added to this uncertainty, is the unpredictability of the difficulties and challenges[13] that are likely to be encountered as dismantling proceeds along the decommissioning path.

32 Indeed, I cautioned against the assumption that the level of risk and the overall hazard of the Dungeness NPPs 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[14] off-site emergency planning measures are expected to reflect the risk and hazard levels at all times during the complex decommissioning process**.**

33 The moderator cores of graphite are likely to present particularly demanding challenges to future dismantlers.

34 For the Magnox reactors, prior to closure the graphite moderator cores were never annealed to release and dissipate the accumulated Wigner Energy that has built-up in the core structure over its operational service life – this annealing could have only been achieved with nuclear fuel present in the core with all of the attendant cooling and safety systems in place and operational. I provide further explanation Wigner energy and it challenges with respect to the future dismantling and storage of the graphite moderator cores of the Magnox A NPPs[15] in APPENDIX I.

35 Another risk relates to the graphite and carbonaceous dusts formed over the years of operation by the i) radiolysis of the graphite and, separately, by ii) irradiation of traces of carbon monoxide present in the

12 In fact, usually the licensing information is required about two years in advance of the particular decommissioning phase commencement.

13 For example, account of structural steelwork corrosion of the steel reactor pressure vessel and the core restraint bracing; changes in the tolerable dose limitation regimes for the workforce; degradation of materials and structures; and all manner of things that might change and/or occur over the one hundred or more years over which the reactor hulks will remain in-situ.

14 REPPIR – Radiation *(Emergency Preparedness and Public Information) Regulations 2001* – relates to the provision of off-site emergency plans.

15 Wigner energy accumulation does not present the same level of hazard in the AGR graphite cores because the higher AGR core operating temperatures results in self-annealing and progressive Wigner energy release whilst the reactor is operating.

carbon dioxide cooling gas - in fine particle sizes (~5 µm), both forms of dust are *'weakly explosible'*.[16,17]

36 During dismantling operations, particularly when the reactor pressure vessel and graphite core[18] 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.

37 Thermal and explosive conditions resulting from aircraft crash, particularly from the burning, deflagration and possible explosion of the 80,000 or so kilograms of fuel carried by a modern commercial-size airliner can be intense, sufficient to breach the containment of radiological enclosures and set ablaze flammables within. The in-situ graphite cores of the four Dungeness A and B NPPs, and a number of the radioactive wastes streams (deriving from both past operation and dismantling arisings) would be highly reactive under such conditions.[19]

38 Such an external heat source (even if by chance moderate) could initiate a release of Wigner energy from the graphite, either in situ or at a stage when package in storage on the Dungeness site, leading to self-heating and radiological release.

39 In conclusion, I can summarise the presence of radiologically hazardous materials and activities on the Dungeness A and B sites will extend many years into the future:

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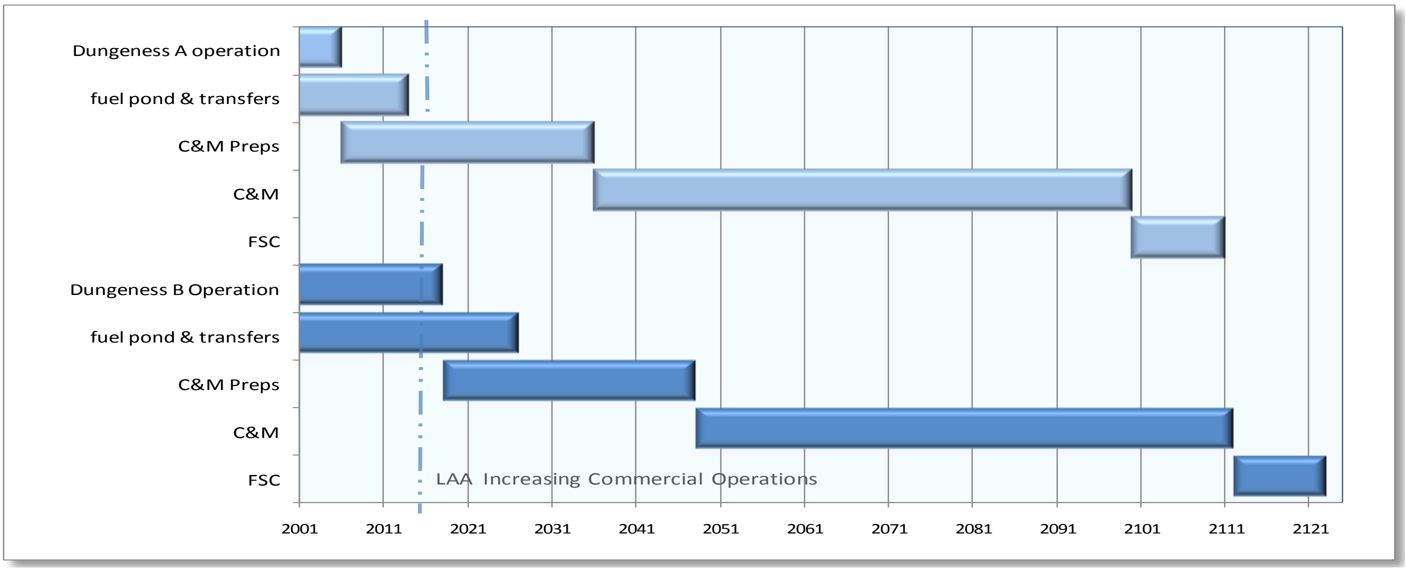
16 Graphite Dust Deflagration: A Review of International Data with Particular Reference to the Decommissioning of Graphite Moderated Reactors. EPRI, Palo Alto, CA:2007.

17 *Graphite dust explosibility in decommissioning: A demonstration of minimal risk*, Wickham A J, Rahmani L IAEA TecDoc 1647

18 *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.

19 For a discussion on the potential outcome of aircraft crash onto a NPP, using previous air crashes of Lockerbie (1988), World Trade Centre and the Pentagon (2001) see *Vulnerability of French Nuclear Power Plants to Aircraft Crash*, R3205-A1, Large J H, April 2012

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



37 Throughout the time periods expressed in CHART 1, that is for the next one hundred and twenty years or so, the decommissioned and dismantling nuclear plants at Dungeness will remain vulnerable to aircraft crash – an extreme external event that could result in a significant radiological release.

41 Put simply, so long as radioactive materials and wastes remain on the Dungeness sites, it will be hazardous and, in my opinion, vulnerable to aircraft crash. Moreover, some of the operations necessary to commence the involved process of dismantling the long defunct NPPs will strip away the *defence-in-defence* structures and enclosures that contain the radioactivity. It follows that as the dismantling/decommissioning programme proceeds; at some points in its progress the risk of radioactive release will be heightened.

42 This being so, I would strongly disagree with any suggestion put by the ONR that when the reactor islands at Dungeness have been defueled, the consequences of a radioactive release as a result of a commercial-size aircraft crash would be tolerable.

43 **B) FUTURE OPERATIONAL GENERATION III REACTOR**

44 Notwithstanding that further development of the Dungeness C site was ruled out by the assessments undertaken via the *Habitats Directive*,[20] it is possible that this could be overcome in future years and that the Dungeness C site could be developed with a Generation III NPP (or with two separate NPPs).

45 At this time the ONR is conducting the final stages of its *Generic Design Assessment* (GDA).

20 The Habitats and Conservation of Species Regulations 2001.

46 The GDA, also referred to as *pre-licensing*, aims to assess the generic safety, security and environmental aspects of new designs (to the UK) of nuclear power plant. The GDA is undertaken separately and in advance of applications being made for the nuclear licences and permits required for the operation at each of the proposed new-build sites.

47 The NPP design under GDA consideration is the European Pressurised Reactor (EPR). If a decision was made to proceed with development at Dungeness C (and quite possibly D), then the most likely plant to be adopted would be the EPR.

48 The relevance of the GDA here is that it provides insight into the resilience of the EPR NPP design to extreme external events, including commercial-size aircraft crash.

49 Although the ONR has awarded an *Interim Design Compliance Acceptance* (I-DAC), there remains thirty outstanding *GDA Issues* that have to be resolved before the *Final* DAC (F-DAC) is granted and the NPP permitted to proceed to the NIA65 site licensing stage - I have listed these GDA Issues in TABLE 3.

50 Quite separate from the GDA process underway in the United Kingdom, on a pan-European front the European Commission required each national regulator to assess the adequacy of existing and proposed NPPs in responding to extreme external events. This re-evaluation, referred to as *Stress Tests*, was specified in conjunction with the *European Nuclear Safety Regulators Group* (ENSREG) following the Fukushima Daiichi incident of March 2011 during which three operational NPPs were destroyed and a fourth defueled NPP was severely damaged.

51 I provide a background note on the European Commission's reasoning and process to be adopted for the Stress Tests in APPENDIX II.

52 In the UK, the ONR (which is a party to ENSREG) was required to evaluate and report to ENSREG for peer review, producing its Country or *National Final Report* in December 2011.[21]

53 ONR's National Report is a compilation of the stress tests evaluations prepared by the individual operators,[22] although these NPP-specific evaluations have not been made publicly available.

21 Published 4 January 2012.

54 Whereas the European Commission required new NPPs under construction (but yet to be commissioned into generation service) to be subject to the Stress Tests, the ONR argued in its *National Progress Report* of September 2011 that *'As none of the three potential licensees are currently constructing a new NPP they are excluded from the UK national report on the stress tests'*.[23]

55 However, in response to the Stress Tests, the French nuclear safety regulator, *Autorité de Sûreté Nucléaire* (Nuclear Safety Authority - ASN), required the sole French nuclear power plant operator EdF to specifically address all issues arising from the ENSREG Stress Tests requirement as theses applied to the EPR NPP under construction at Flamanville and the virtually identical NPP presently planned for Penly. This complementary assessment (CSA), reported in *évaluations de la sécurité complémentaires des centrales nucléaires françaises - stress tests européens* of December 2011, addresses and identifies a number of topics and areas relating to the performance and resilience of the EPR design when subject to extreme external events.

56 The topics and areas requiring further analysis and/or design amendment identified by the French nuclear safety regulator ASN via the CSAs are listed in the 5th column of TABLE 3. Those entries not corresponding to a neighbouring GDA Issue are identified in the 1st column by the prefix **ASN** – the 11 ASN requirements, subject to the limited detail available in the CSA and GDA Issues documentation, are additional to the 30 outstanding GDA Issues.

57 A similar review has been undertaken of the Finnish nuclear safety regulator's (*Säteilyturvakeskus* - Radiation and Nuclear Safety Authority – STUK) stress test evaluation of the lead EPR nearing construction completion at Olkiluoto – the 8 STUK requirements are also included in the 5th column and prefixed STU in the 1st column of TABLE 3.

58 The ASN and STUK requirements following their application of the European Commission Stress Tests to the EPR NPP design also provide further insight into the resilience of this NPP to commercial-size aircraft crash.

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22 For proposed UK NPPs EdF and the Nuclear Decommissioning Authority (NDA) are the relevant operators,

23 Instead, the ONR raised a *General Issue* under the GDA process which, for the EPR design, refers the requesting parties to the ONR Chief Inspector's Interim and Final Fukushima Reports of May and September 2011 respectively – this requirement, in the form of a *Resolution Plan*, is presently being considered by the GDA requesting party AREVA-EdF. In other words, the UK has yet to submit its adaptation of the EPR to the European Commission's *Stress Tests*, thereby missing the December 2011 deadline set for the submission of the National Reports.

59 In my paragraph 18 c) I reiterated the line of argument that LAAG suggested might be adopted by the ONR (and the developer of Lydd Airport), in that the Generation III EPR NPP design would be considerably advanced, so much so that it would have guaranteed resilience against aircraft crash.

60 In TABLE 3 I have highlighted (■) areas and design shortcomings, etc those ONR Issues, together with the ASN and STUK Stress Tests requirements that I consider to relate to the uncertainty of the EPR's resilience against a commercial-size aircraft crash.

61 The highlighted sections of TABLE 3 demonstrate that there remain design areas that require substantial effort if the resilience of the EPR design against commercial-size aircraft crash is to be improved.

62 That said, I am of the opinion that it will not be practicable to entirely proof the EPR design against aircraft crash, both accidental or malevolent. This is because the EPR design was settled in the 1980-90s, that is at a time when commercial-size aircraft crash was not considered to be a realistic external threat to NPPs.

63 I am of the opinion that should a new-build EPR be developed on the Dungeness C site it will remain, like the presently shut down Dungeness A and the operating Dungeness B NPPs, at risk of commercial-size aircraft crash, arising from which the radiological consequences could be very severe indeed.

64 Finally, it might be useful to compare the potential radiological impact of a significant radioactive release from an operational EPR to the risk posed by one of the shut down but fuelled Magnox reactors at Dungeness. Until the recent transfer of the spent fuel from the already shut down Dungeness A NPPs, the ONR considered that the radiological hazard of accident at the Dungeness site was dominated by the Magnox plants, each of these presenting a greater risk and potential consequences than the operational Dungeness B AGR reactors.

65 The main reason why the Magnox outranks the AGR NPP is because of the i) instability of the Magnox fuel system, with the magnesium alloy cladding (ie Magnox) and the elemental metal uranium fuel rod both being susceptible to self-ignition when exposed to air; and ii) that the reactor pressure vessel is not enclosed within any primary containment shell.

66 The EPR reactor core contains about x150 the radioactive fission product *'source term'* of a

shut down but fuelled single Dungeness A Magnox NPP[24] so, it follows, the radiological consequences of a proportionate release from an EPR could be very significant indeed.[25] Of course, if the EPR was in operation at the time of a severely damaging accident then the radioactive release from the fuel in the nuclear reactor core would also include short-lived radioactive fission products, so the potential radiological consequences would be even larger.[26,27]

67 **IN CONCLUSION:** The recent work of Trotta[28] endorses the previous finding of Pitfield,[29] essentially being that the Bryne methodology for reckoning the aircraft crash rate deriving from background and local air traffic movements is unreliable in a number of important respects.

68 My informed opinion is that the crashing of a commercial-size aircraft on to any one of the nuclear islands – Dungeness A, B and hypothetically C - could (is likely to) result in significant radiological consequences for NPPs that are operational and/or shut down and defueled and mothballed, and/or in the process of dismantling.

69 I note that this radiological risk will persist so long as the NPP hulks remain on the Dungeness sites which, for the present Dungeness A and B NPPs will persevere for about one hundred or so years into the future. If Dungeness C is built and commissioned, it will be in a fully fuelled

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24 Each of the Dungeness A NPPs was rated at around 220MW_e capacity, the fuel core mass was approximately 250 tons, and the average spent fuel irradiation or burn-up was probably no greater than 3,000MWday per ton – the product of the capacity (MW_e), fuel tonnage and burn-up (MWday/t) yields a very rough and ready gauge of the interim and longer term radioactive fission product content or radioactive *'source term'* of the spent fuel. In comparison with a single Dungeness A reactor, the EPR is x4 the generating capacity at 1,600MWe, the reactor fuel core is about 100 tonnes, and the burn-up around 65MWday/t so the EPR reactor core contains about x150 the source term of a shut down single Dungeness A Magnox NPP.

25 In fact, in order that any radioactive release from a EPR remains radiologically tolerable in the public domain, the EPR design claims that the maximum release in any *credible* incident (including terrorist act) will not exceed 0.03% per day of the reactor core fission product inventory, and that the release pathway will be confined to a small bypass of the primary containment. Thus the EPR nuclear safety case is entirely dependent upon the primary containment remaining virtually 100% wholesome in any external event, including aircraft crash if, that is, aircraft crash is considered a *credible* event.

26 Much the same line of reasoning applies to an accident involving the spent fuel storage ponds, particularly if large quantities of spent EPR fuel are amassed on-site awaiting reprocessing and/or movement to an off-site repository for storage – it is generally accepted that the fuel storage pond enclosure of the EPR is not absolutely resilient against aircraft crash and aviation fuel fire and explosion blast.

27 Because the EPR presents such a large source term available for release, the containment structures have to be designed to limit the amount of radioactivity released in any *design-basis* accident for the public domain consequences to be tolerable. The surety of containment claim for the EPR is that in the worse case *design-basis* incident, including for terrorist attack, the containment systems would remain sound permitting a maximum rate of release no greater than 0.03% per day of the reactor fuel core inventory, and that this release would be via a bypassing and not structural failure of the primary containment. It is doubtful that this very demanding level of surety could be maintained in an extreme event such as a commercial-size aircraft crash.

28 *Review of the Bryne Model for Aircraft Crash probability in relation with the Planned Expansion of London Ashford Airport at Lydd*, Trotta R, LAAG, March 2012.

29 *Aircraft Accident Modelling for Lydd Airport, Kent*, Pitfield D, December 2010

and operational state for 60 to 70 years, thereafter it might be mothballed fro 20 to 30 years before dismantling.

70 The ONR must be cognisant of these facts on the vulnerability, hazards and risks associated with the Dungeness NPPs so, it follows, the rationale underpinning the ONR's almost steadfast stance not to oppose the commercial development of Lydd Airport is that the probability of an accidental aircraft crash is so low as to be incredible.

71 In determining this probability the ONR seems to exclusively depend upon the Bryne methodology.

72 It is the reliability of the Bryne methodology that the Experts Trotta and Pitfield have robustly challenged.

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TABLE 3 OUTSTANDING GDA ISSUES FOR EPR & ASN CSA & STUK REQUIREMENTS – ADAPTED FROM REF 30

ITEM	GDA ISSUE	ONR REF	DESCRIPTION	ASN CSA SUBJECT – FLAMANVILLE/PENLY EPR
INTERNAL HAZARDS				
GDA 1	Dropped Loads and Impact	GI-UKEPR-IH-01 GDA Issue Revision 2	Drop load impact on reactor plant and fuel pond, etc., requires further analysis and substantiation	
GDA 2	Verification & Validation Studies	GI-UKEPR-IH-02 GDA Issue Revision 2	Internal hazards associated with and deriving from flooding of the site generally and nuclear island specifically.	ASN requires EdF reinforce the robustness of the equipment contributing to the management of a whole-site flooding (H1) situation.
GDA 3	Internal Flooding and Operator Actions	GI-UKEPR-IH-03 GDA Issue Revision 2	Internal flooding arising from failure, etc of internal tanks and reservoirs and external barriers and drainage	ASN requires revision of PSA 1 and 2 in account of internal flooding. STUK requires evaluation of modifications necessary to counter threat against loss of EDGs in the event of flooding.
GDA 4	Substantiation Break Preclusion Claims for RCC-M Components	GI-UKEPR-IH-04 GDA Issue Revision 2	Internally generated missile (debris) penetration and damage	
ASN 1				EdF is required to re-evaluate the maintenance and management strategy for the systems shared between the spent fuel pool and the reactor (such as the fire-fighting water system) in order to minimise their temporary unavailability.
CIVIL ENGINEERING				
GDA 5	Hypothesis and Methodology Notes for Class 1 Structures	GI-UKEPR-CE-01 GDA Issue Revision 1	Nuclear Island built structures requiring further justification on global stability, lack of UK-applicability, no UK ground data, long term consolidation of foundation structures omitted, non-compliance of opening reinforcement	
GDA 6	Use of ETC-C for the Design and Construction of the UK EPR™	GI-UKEPR-CE-02 GDA Issue Revision 1	Inadequate cross-referencing to UK structural Codes and Buildings Regulations.	
GDA 7	Beyond Design Basis Behaviour of the Containment	GI-UKEPR-CE-03 GDA Issue Revision 1	Beyond-design-basis event response and performance of the primary containment structure insufficiently justified	

30 *1st Interim Review of the Generic Design Assessment Outstanding Issues*, Large & Associates, May 2012

GDA 8	Containment Analysis	GI-UKEPR-CE-04 GDA Issue Revision 1	Modelling and analysis of the primary containment structure(s) nor adequately demonstrated, seismic methodology and stress models comparisons not possible, foundation system inadequately modelled, mostly related to the inner containment reinforced concrete shell.	
GDA 9	Reliability of the ETC-C	GI-UKEPR-CE-05 GDA Issue Revision 1	Reliability of the seismic design code unsubstantiated.	
GDA 10	Seismic Analysis Methodology	GI-UKEPR-CE-06 GDA Issue Revision 1	Justification of the seismic performance of the raft foundation design inadequate.	
STUK 1				STUK requires fire fighting system within nuclear island and other nuclear safety related areas to be verified.
FAULT STUDIES				
GDA 11	Heterogeneous Boron Dilution Faults	GI-UKEPR-FS-01 GDA Issue Revision 0	Safety case for boron (neutron absorbent) dilution fault events required.	
GDA 12	Diversity for Frequent Faults	GI-UKEPR-FS-02 GDA Issue Revision 0	High hot-leg (primary circuit) pressure trip diversity not included requiring a fresh design.	
GDA 13	Spent Fuel Pool Safety Case	GI-UKEPR-FS-03 GDA Issue Revision 2	Fault analysis should include events relating to flask loading area	
STUK 2				STUK requires evaluation of jury-rigged heat removal systems from the spent fuel pond water, including possible use of the fire water system.
GDA 12	Steam Generator Tube Rupture Safety Case	GI-UKEPR-FS-04 GDA Issue Revision 1	Leak-before-break steam generator rupture, safety case submission does not include recent design changes	
STUK 3				STUK requires consideration of proving independent feedwater means, route and source to steam generators secondary side at normal operating pressure.
GDA 14	Design Basis Analysis of Essential Support Systems	GI-UKEPR-FS-05 GDA Issue Revision 0	Missing elements relating to loss of cooling chain faults, electrical system faults and HVAC (heating and air conditioning) and other essential support systems have not been identified	
ASN 2				ASN require EdF to evaluate the robustness of the

				Flamanville 3 EPR reactor with respect to complete loss of the primary and alternate heat sinks, and the combination of this with a general electrical power loss situation.
ASN 3				ASN requires EdF, EDF to assess the consequences of the successive loss of, first, the primary heat sink, and then the alternate heat sink on the safety of the reactor. This configuration has only been assessed for the spent fuel pools and has to be combined with a total loss of the electrical power supplies. EDF is required to conduct complementary studies to assess the consequences of a complete loss of the primary heat sink (ESWS) and alternate heat sink (SRU) on the damage to the reactor core. Regarding the assessment of the consequences of heat sink loss on the spent fuel pools, the time lapses before the core becomes exposed are purported to be longer than the time specified in the baseline safety standard: a few days with maximum residual power in the spent fuel pool building, and about one week in the states other than APR - RCD. These times seem compatible with an external intervention and with the means that EDF envisages implementing to make an additional water make-up. EDF is required to conduct complementary studies to assess the consequences of a complete loss of the primary heat sink (ESWS) and alternate heat sink (SRU) of the Flamanville 3 EPR on the damage to the reactor core.
ASN 4				ASN requires that the ultimate make-up means must have substantial autonomy and function in a situation of total electrical power supply loss – this relates to the other safety objectives of this ultimate make-up requirement i) to be functional at the natural hazard levels considered in the CSAs, ii) to be able to be implemented under the particular conditions that may be present on the site, iii) especially skyshine irradiation from the fuel stored in the BK building spent fuel pit (low

				water inventory), iv) to be able to be implemented within a time scale compatible with the envelope scenario considered, and v) to allow boration of the water injected into the primary system.
CONTROL & INSTRUMENTATION				
GDA 15	Design Information for Non-Computerised Safety System Required	GI-UKEPR-CI-01 GDA Issue Revision 2	Hardware back-up system design not submitted to GDA and extent of diversity unknown, no basic safety case submitted	
GDA 16	Protection System Independent Confidence Building Measures	GI-UKEPR-CI-02 GDA Issue Revision 2	The method of testing the central control and instrumentation system and its statistical interpretation (validation), number test proposed at 5000 but required (ONR) 50,000, too many elements have yet to be defined.	
GDA 17	Claims, Arguments, Evidence Trail	GI-UKEPR-CI-03 GDA Issue Revision 2	CAE trial requires revision and improvement.	
GDA 18	SMART Devices	GI-UKEPR-CI-04 GDA Issue Revision 1	Method and standard of qualification of SMART devices yet to be defined – a significant programme of work may be required.	
GDA 19	Obsolescence of SPPA T2000 Platform	GI-UKEPR-CI-05 GDA Issue Revision 2	Siemens S5 systems obsolete and not available for UK EPR so replacement systems has to be defined and proven and this may render presently developed code unusable	
GDA 20	Absence of Adequate C&I Architecture	GI-UKEPR-CI-06 GDA Issue Revision 3	Comprehensive justification of diversity and independence of the control and instrumentation systems required, parts of which have yet to be designed	
ASN 5				ASN requires further demonstration of NPPs to manage a degraded situation (H1 or H3) on several plant units simultaneously on the same site – ie Sizewell B and C and/or D.
ESSENTIAL ELECTRICAL SYSTEMS				
GDA 21	PCSR Presentation of Claims Arguments and Evidence	GI-UKEPR-EE-01 GDA Issue Revision 1	Pre Construction Safety Case (PCSR) issues with electrical distribution systems, further substantiation required.	

ASN 6				Further diversification of the '2 hour' standby batteries for continuing instrumentation and control functions to avoid Cliff Edge effects
ASN 7				SBO on-site generator sets to be *'hard-cored'* in accord with ISRN specification for earthquake and flooding tolerance
STUK 4				SBO generator set required to be fitted with auto-start and possibly increasing the quantity of fuel oil stored on site.
Reactor Chemistry				
GDA 22	Combustible Gas Mitigation	GI-UKEPR-RC-01 GDA Issue Revision 1	Failsafe operation of Passive Autocatalytic Recombiners (hydrogen sparkers) (primary containment + 6 plant rooms) requires further substantiation	
GDA 23	Control and Minimisation of Ex-Core Radiation	GI-UKEPR-RC-02 GDA Issue Revision 0	Mechanisms of fuel clad CRUD and other radioactive (activated) materials transfer in the primary system and fuel storage ponds requires further demonstration	
Structural Integrity				
GDA 24	Avoidance of Fracture	GI-UKEPR-SI-01 GDA Issue Revision 2	Crack and fracture detection, including tolerable crack lengths, etc., in High Integrity Components (reactor pressure vessel and primary circuit pipework, etc) – submission from AREVA-EdF late and ONR unable to complete its own review.	
GDA 25	RPV Surveillance System	GI-UKEPR-SI-02 GDA Issue Revision 1	Interpretation of sacrificial samples within reactor pressure vessel requires further justification,	
STUK 5			STUK requires evaluation of the severe management systems effectiveness of managing primary containment integrity.	
Radiation Protection				
GDA 26	Radiological Zoning and Bulk Shielding	GI-UKEPR-RP-01 GDA Issue Revision 0	Further information required on effectiveness of radiological zoning and worker dose for the nuclear island required.	
STUK 6				STUK requires re-evaluation of minimum 1m fuel pond water cover to act as sufficient shielding to

				enable essential mitigation measures and actions to be implemented in the fuel pond building.
HUMAN FACTORS				
GDA 27	Inadequate Substantiation of Human Based Safety Claims	GI-UKEPR-HF-01 GDA Issue Revision 0	Further information and substantiation required on human error events, particularly the so-called Type A and B events, Type C events require further substantiation, and violation potential evidence insubstantial.	
STUK 7				STUK is still evaluating organisational issues which include adverse involvement of all three NPPs on the Olkiluoto site.
ASN 8				To prevent reactor fuel core being damaged (melt down) in a loss of off-site electrical power (Station Blackout – SBO) EdF is required to put in place: i) to extend the electrical supply for the functions supplied by the "12-hour" batteries by implementing supplementary fixed or mobile electrical power sources; ii) to put in place a means of restarting the severe accidents I&C in the event of it is has been cut-off; iii) to put in place devices and mobile electrical power supply means necessary to ensure the habitability of the control room, iv) for the spent fuel pool, supply one cooling channel of the PTR system or a water make-up from the tank of the JAC system; v) to integrate the essential information concerning the development of the situation in the fuel building (fuel pool temperature, water level measurement, etc.) on the severe accidents I&C and vi) the severe accidents console (PAG) which are supplied by the "12-hour" batteries, vii) extending the autonomy: mobile means of pumping fuel from the main generator set tanks to replenish the SBO generator sets, viii) extension of the duration of electrical supply for essential functions by deploying

				supplementary fixed or mobile electrical power sources, and ix) means of restarting the severe accidents I&C.
CROSS-CUTTING TOPICS				
GDA 28	Categorisation of Systems Structures & Components	GI-UKEPR-CC-01 GDA Issue Revision 1	Review of all PCC-2 to PCC-4 events required together with identification of all Safety Related Systems (SRSs) required.	
ASN 9				Level 1 and 2 Probabilistic Safety Assessments (PSAs) to be revised to take account of i) internal reactor events, ii) events associated with fuel pond building, iii) earthquake; iv) internal fire and explosion, and v) internal flooding
GDA 29	Consolidated Final GDA Submission	GI-UKEPR-CC-02 GDA Issue Revision 3	Management trail of GDA invoked changes etc., requires reliable method of management and updating.	
ASN 10				Lightening strike in excess of 200kA for equipment located beyond mesh cage required.
GDA 30	Consider and Action Plans to Address the Lessons Learnt from the Fukushima Event	GI-UKEPR-CC-03 GDA Issue Revision 3	Requirement to address lessons learnt from Fukushima Daiichi incident of March 2011 and submission of any design changes relating thereto – the AREVA-EdF Resolution Plan for this specific GDA Issue comprises 21 pages outlining the range of the tasks to be undertaken all to within a somewhat optimistic completion timescale of November 2012.	
ASN 10				EPR NPP site now required to be autonomous for two weeks, notably after earthquake or flooding leading to isolation of the site, particularly for fuel and oil reserves for on-site generators
ASN 11				Further analysis and justification required by ASN from EdF on missing assessment on fuel pond cooling following total loss of off- and on-site electrical power supplies and to include for i) fuel oil transfers between on-site generators, ii) resupply of ASG water tanks form freshwater ponds/reservoirs, iii) means of controlling explosion risk in the

				event of loss of ventilation in the spent fuel building, iv) provide a passive means of opening fuel pit area vent to inhibit pressure build-up, v) provide for gravity make up of fuel pond water, and vi) improve robustness of fuel pond area instrumentation.
STUK 8				STUK's requirements after the Fukushima accident, are for the licensee (TVO) to report on the following issues regarding exceptional extreme external conditions: i) the adequacy and availability of water supply for the cooling of reactor and spent ii) fuel storage; iii) the reliability of heat removal to ultimate heat sink; iv) the impact of extreme high seawater level on the cooling systems of the spent fuel v) storage; vi) the impact of beyond design basis high and low outside temperatures on the safety vii) functions; and viii) the applicability of procedures, and the adequacy of personnel, equipment and facilities.

APPENDIX I

WIGNER ENERGY AND DECOMMISSIONING OF GRAPHITE MODERATOR CORES

The graphite core of the UK gas cooled reactors serves to moderate or slow down the neutron activity within the thereby increasing the efficacy of the fission reaction. During this neutron irradiation process energy, Wigner or *'stored'* energy, accumulates because atoms are displaced from their normal lattice positions into configurations of higher potential energy.

The quantity of stored energy is a function of fast neutron flux, irradiation time, and temperature at which the irradiation takes place. The higher the irradiation temperature, the lower is the amount of *'stored'* energy accumulated in the graphite. Wigner energy build-up will, over long periods of irradiation, reach a saturation level of the total amount of energy stored. In irradiated samples the total Wigner energy level store has been measured at 2,700J/g (which compares with, for example, natural gas at 55,000J/g. The release of ~2,700J/g could, theoretically under adiabatic conditions (ie no heat loss during the conversion process) result in a temperature rise with the graphite of about 1,500^{o}C. The Wigner energy accumulated in a reactor core can be released if the graphite is heated above the temperature at which the irradiation took place – a temperature increment of +50^{o}C will trigger a significant energy release rate, although a temperature in excess of 2000°C is required before all the stored energy can be released.

It was a deliberate attempt to *'anneal'* out some of the Wigner energy accumulated in the ~2,000t graphite moderated Windscale Pile N^{o} 1 which initiated the fire and radioactive release of 1957 – to anneal or release the stored energy from the Windscale pile, the temperature of the graphite was progressively raised by starving the pile of cooling air but, because of faulty instrumentation, the temperature within sections of the pile run out of control, reaching temperatures at which the graphite reacted with air. It is believed that Wigner energy release also contributed to the high and sustained post-accident core temperatures in the Chernobyl accident of 1986.

Consequently, Wigner energy features strongly in the safety arguments being prepared for the dismantling of Magnox reactor moderator cores. The potential risk of triggering an inadvertent release of Wigner energy in these reactors while handling and processing individual graphite blocks during decommissioning, along with the potential for releasing energy during any storage period, packaging, conditioning, and even in the final waste repository, requires assessing. Also, the graphite in some of these early reactors was subject to various incidents which may have resulted in the graphite being potentially more chemically reactive to air as a result of introduced catalysts in the carbon dioxide (CO_2) gas coolant stream. It is believed, although there is little published research, that long term exposure of the piles to salt laden air (the cores will be naturally ventilated during the *Care & Maintenance Periods* lasting several decades each) that the air reactivity temperature decreases markedly heightening the risk of fire during dismantling With a large and heavily irradiated graphite moderator core, such as the Dungeness A Magnox reactors each containing about 2,250 tonnes of graphite, the Wigner energy available for release during a temperature excursion could be very significant indeed.

Unlike the Windscale pile where the irradiation of graphite was at a relatively low temperature of about 130^{o}C, so that the potential for Wigner energy storage throughout the core was high, the Magnox graphite cores at Dungeness operated at generally higher temperatures which preclude or limit the amount of Wigner energy that can be stored. However, there are areas of the Dungeness A Magnox graphite cores that have persistently operated at lower temperatures within the Wigner energy storage threshold – the bottom layers or course of graphite blocks and the periphery blanket areas around the central fuel core – and the irradiation period has been over ~40 years (compared to the Windscale pile of <5 years). In some of the earlier UK Magnox reactors the total Wigner energy in graphite can be higher than in parts of the Windscale piles, the temperature at which this energy starts to be released is over 200^{o}C.

Wigner energy and its potential for uncontrolled release during dismantling and decommissioning operations of the Dungeness Magnox reactors represents a hazard and a challenge – the Dungeness A reactors were not annealed prior to final shut down in 2006 and now that the nuclear fuel has been removed and the core cooling system disabled there is no post-shutdown opportunity the dissipate the accumulated Wigner energy in a managed way

The Wigner stored energy challenge is significantly lower in the AGR reactors where the risk of creating a self-sustaining oxidation in bulk graphite during decommissioning is much lower because of the higher operating temperatures of the AGR graphite cores restrains the accumulation of Wigner energy.

APPENDIX II

EVENTS FUKUSHIMA DAIICHI AND THE EUROPEAN COMMISSION STRESS TESTS

Since my original evidence LAAG/4/A of 15 January 2011, events at the Japanese nuclear power complex of Fukushima Daiichi of March 2011 have prompted a review of nuclear safety Worldwide.[31]

The catastrophe of Fukushima Daiichi compelled the European Commission to request Member States to conduct a series of *Stress Tests* on all nuclear facilities in the European Union. These Stress Tests set out the conditions and parameters for re-evaluation of the NPP resilience to and management of the aftermath of an extreme external event. The requirements of the stress tests were set out by individual State regulators (ie ONR, ASN, etc) usually in the form of a directive for the operator (ie EdF, Electrabel, RWE etc) to undertake and report upon the performance of existing and planned for NPPs when subject to extreme *beyond-design-basis* events, such as severe earthquake, flooding and, quite specifically aircraft crash.

Essentially, one purpose of the *Stress Tests* was to identify any extreme external events that could trigger a Fukushima-like loss of control and fuel meltdown at a NPP, either of the active reactor fuel core, or the spent fuel in the pond, or both. The European Commission also required the Stress Tests to be applied to other types of nuclear facilities, such as nuclear fuel works, radioactive waste stores and nuclear sites, including nuclear power plants, where decommissioning of shut down plants was underway or planned for some time in the future.

Of interest here is that the ONR when specifying to the nuclear plant operators, EdF *(Electricité de France)* and the *Nuclear Decommissioning Agency* (NDA),[32] its requirements for the Stress Tests it excluded any aspect relating to aircraft crash, which is directly contradicting the scope of initiating events specified in the EC-ENSREG *Stress Tests* declaration, viz:

> *". . . the assessment of consequences of loss of safety functions is relevant also if the situation is provoked by indirect initiating events, for instance large disturbance from the electrical power grid . . ., forest fire,* ***airplane crash*** *. . ."*
>
> *my truncation . . and* ***emphasis***

particularly in that ONR confines the type of initiating events to *'other extreme* ***natural*** *events'* thereby, or so it seems, disqualifying man-made incidents such as aircraft crash.

In reporting its findings of the stress tests to the European Commission in December 2011, the only mention of a crashing aircraft being a possible external hazard in the 205 page ONR report[33] is that:

> *". . . Other local hazards, such as passing hazardous shipping, local factories and aircraft, are also considered in the safety case and appropriate hazard protection provided. . ."*

I find this statement to be very misleading and factually incorrect because, first, the Magnox NPP designs (including Dungeness A) gave no account whatsoever to aircraft crash; much the same applied at the time (1960s) of the design of the later advanced gas-cooled reactor (AGR) like Dungeness B; and it was not until the introduction of the ONR's *Safety Assessment Principles* (SAPs)[34] in 1979 that a requirement to assess the risk and damage severity of accidental aircraft crash was introduced into the nuclear safety regulatory framework. Even at that time, commercial-size aircraft and their larger fuel loads were excluded on the basis of the improbability of a crash, so much so that the impact analysis and demands placed upon the reactor plant and primary containment was limited to crash of aircraft of less than 2.7 tonnes all up weight.

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31 In the incident, a severe earthquake followed by a tsunami, four light water moderated NPPs were severely damaged, resulted in the evacuation of upwards of 120,000 members of public, a total exclusion zone of 20km surrounding the nuclear plant which remains enforced today a year later, and the radiological contamination of about 8% of the entire Japanese landmass, of which about 1.5% requires some degree of institutional control and prohibition on use.

32 EdF operates the 7 AGR and 1 PWR NPPs (15 reactors in total), including the 2 AGRs Dungeness B, and the NDA is responsible for the operation of those Magnox plants remaining in service (now just 1 reactor at Wylfa) and the 10 Magnox NPPs that have permanently ceased generation and are awaiting eventual dismantling, including the 2 shut down Magnox reactors at Dungeness A.

33 *European Council "Stress Tests" for UK nuclear power plants*, National Final Report, ONR, December 2011

34 *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

In fact, the first UK NPP to take account of the possibility of aircraft crash was the pressurised water reactor (PWR) at Sizewell B commissioned in the 1990s,[35,36] that is well after the completion of Dungeness and at a point in time when it would not be practicable to make any modification to render Dungeness B more resilient to crash of a commercial-sized aircraft.

Moreover, ONR dismisses the involvement of commercial airliners in an *accidental* crash on probability of occurrence alone. Malevolent acts involving aircraft commandeered by terrorists, such as the 9/11 events in the United States, are considered by the ONR *'not to be reasonably foreseeable'*.

In this way, ONR absolves itself and the operators EDF and NDA of the requirement to plan for aircraft crash at Dungeness because it deems accidental aircraft crash to be a remote and incredible event (ie not a *Titanic* like incident) and, on the basis of an entirely different rationale, that malevolent aircraft crash to be beyond the *design-basis*.

That said, ONR is currently contributing, via its membership of ENSREG, to the European Commission *Ad-hoc Group on Nuclear Security* (AHGNS) that is specifically analysing security threats arising from terrorist acts, currently running as the *Security Track*[37,38] in parallel to the *Stress Tests*. I understand that this separate assessment definitely includes for aircraft crash.

However, international acceptance of this approach to risk from accidental (and *Acts of God*), that is dismissing projected infrequent events as incredible, has changed now that the lessons of Fukushima Daiichi (March 2011) are being absorbed. In Germany, where 8 NPP plants were summarily shut down (May 2011) mainly because of their inability to withstand aircraft crash,[39] Chancellor Angela Merkel opined that *"Fukushima has forever changed the way we define risk in Germany"*,[40] a conclusion echoed by Norbert Röttgen, Germany's Environment Minister that the event at Fukushima:

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35 *Sizewell B PWR Preconstruction Safety Report*, Chapter 3, November 1987.

36 For Sizewell B the nuclear safety case (of 1987) identified aircraft crash onto the power station site as an external hazard that had the potential to initiate events that could lead to an accidental release of radioactivity. The expected frequency of impact of all classes of aircraft onto identified vulnerable areas of the power station site was reckoned to be extremely low, at around 7x10-7 per year and, of these, impact of aircraft and helicopters less than 2.3 tonnes was not expected to penetrate the containment structures. Thus the design criteria for Sizewell B translated into a construction that provided defence against only the first and lightest level of aircraft impact, that from a small aircraft such as a Piper Cherokee nuclear safety case of 1987 designs were only required to account for aircraft of a total all-up mass of less that 2.3 tonnes.

37 The Commission and ENSREG agreed to work on two parallel tracks: i) a *Safety Track* to assess how nuclear installations can withstand the consequences of various unexpected (naturally and/or accidental occurring) events; and ii) a *Security Track* to analyse security threats and the prevention of, and response to, incidents due to malevolent or terrorist acts. While nuclear operators and the national regulators, in close collaboration with the Commission, were in charge of aspects relating to nuclear safety, it was decided that Member States themselves, assisted by the Commission, would be in charge of assessing nuclear security aspects for which the Council set up the Ad-hoc Group on Nuclear Security (AHGNS). Progress made on this security strand is reported in an unpublished annex – for further details see European Commission, *Communication from the Commission to the Council and the European Parliament on the interim report on the comprehensive risk and safety assessments ("stress tests") of nuclear power plants in the European Union*, SEC(2011) 1395 final, Brussels 24 November 2011.

38 ONR provides an insight into the secrecy mutually agreed and adopted by members of AHGNS in its e-mail response of 24 February 2012 when giving it reasons from withholding a request for information on the *Security Track* studies undertaken by AHGSN to be *"Disclosing would adversely affect our relationship as the AHGNS members have agreed that the information should not be disclosed at this stage in their deliberations"* – there is no reason to believe that ASN will also abide by this mutually imposed restriction.

39 In contrast to ASN, the German nuclear safety organisation required its operators to take account of aircraft crash when undertaking the recent round of *European Commission-ENSREG Stress Tests*, *IRRS follow-up mission Germany 2011 Supplement on the Advance Reference Material (ARM), Regulatory implications of the Fukushima Dai-ichi NPP accident*, Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (RSK), specifically noting that:

"... *Aircraft Crash*

- *Consequential mechanical effects due to an aircraft crash that lead to a limited loss of coolant.*
- *Protection of the fuel pool of decommissioned plants. . .* "

40 Guardian Environmental Network, *How Angela Merkel became Germany's unlikely green energy champion*, Christian Schwägerl , 9 May 2011

> “. . . *has swapped a mathematical definition of nuclear energy’s residual risk with a terrible real-life experience . . .we can no longer put forward the argument of a tiny risk of ten to the power of minus seven, as we have seen that it can get real in a high-tech society like Japan . . .”*[40]

Similarly, the German governmental advisor on the Environment concurred:

> “. . . *The widespread view that the extent of the damage due even to major incidents can be adequately determined and limited in order to be weighed up . . is becoming considerably less persuasive . . The fact that the accident was triggered by a process which the nuclear reactor was not designed to withstand . . casts a light on the limitations of technological risk assessment . . based on assumptions, and that reality can prove these assumptions wrong . . .”*[41,42]
>
> *my . . . truncation*

The point to be made here is that although it is acknowledged the Magnox and AGR NPPs at Dungeness were not designed to withstand the process of a commercial-size aircraft crash.

41 Hohmeyer O, Holm-Müller K., Niekisch M., Schreurs M. (2011b): *Pathways towards a 100 % Renewable Electricity System Chapter 10: Executive Summary and Recommendations*, Provisional Translation, Jan 2011, SRU, Berlin

42 For further discussion on this perception of risk see Dorfman, P., & Fucuc, A. (2012): Nuclear Energy Risk Post Fukushima, In: *Late lessons from Early Warnings, European Environment Agency Report*, forthcoming.