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Airliner Crash on Nuclear Facilities
The Sellafield Case

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Paris, 29 October 2001

1. Sellafield Particularly Exposed to Plane Crash Risk

Among the nuclear facilities located on the British territory, the scenario of a targeted plane crash on BNFL's Sellafield facilities would be the most extreme in terms of impact on the environment and public health: the spent fuel reprocessing facilities in Cumbria represent an inventory of radioactive substances several orders of magnitude larger than that of a nuclear power station. The site is used to store hundreds of cubic meters of liquid high level waste, thousands of tons of irradiated fuel, tens of tons of separated plutonium.

Sellafield vulnerability regarding an aircraft crash stems in particular from the 1,550 m^3 of liquid high level waste in storage, which represent a non conditioned and therefore very volatile inventory of liquid fission products. In addition, over 75 t of separated plutonium in powder form were in storage on the site as of 31 December 2000[1].

With its French equivalent in La Hague, the Sellafield site concentrates the largest inventory of radioactivity in Europe. With nominal reprocessing capacities of 1,580 t per year of Magnox fuel for the B205 plant and around 1,200 t of oxide fuels for the B570 THORP[2] plant, Sellafield differs however from the La Hague site[3] by the way reprocessing have been operated during the last decade.

Frequent operational problems have led to low load factors of the reprocessing lines during the last 11 years, as well as the waste conditioning facilities. During these years, waste has been accumulating year after year of which hundreds of cubic meters of liquid high level waste.

The unavailability of the vitrification facility, which has achieved a production of only 34% of its nominal capacity over the last decade, made the temporary stock of liquid fission products grow to more than 1,550 m^3 as of September 2001. That situation has been considered unacceptable by the Nuclear Installations Inspectorate in late September 2001. The subsequent closure of the two reprocessing plants on 22 September 2001 can be interpreted as BNFL's response to the NII warning. Opening of two of the three vitrification lines in October 2001 (according to BNFL) will not rule out the particular risks that will continue to remain for years.

In January 2001, the NII issued BNFL with a Specification (a legal order), which limits the volume of liquid high level waste to 1,575 m^3, lowers this limit by 35 m^3 per year until 2012, and requires a subsequent reduction to 200 m^3 in 2015; thereafter, BNFL would be permitted to store 200 m^3 of liquid high level waste as a buffer stock. This Specification is designed to accommodate BNFL's business plan, and to minimise the cost and inconvenience to BNFL of reducing the stock of liquid high level waste.

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*Research Associate, **Deputy Director, ***Executive Director

[1] DTI, PQ N° 2001/474, 17 July 2001.

[2] Thermal Oxide Reprocessing Plant.

[3] See WISE-Paris briefing, *"La Hague Particularly exposed to Plane Crash Risk"*, 26 September 2001.

2. The potential impact of a typical accident

Although there are three main areas of concern regarding the risk of an accidental or voluntary plane crash on reprocessing facilities – i.e. respectively the spent fuel, separated plutonium and highly active waste stocks –, the specific, and probably major risk in Sellafield (see the site map in ***Annex 1***) is due to the liquid form of large amounts of highly active waste in storage.

WISE-Paris has carried out some calculations on the hypothesis of an aircraft crash on the high level waste tanks building with loss of safety equipment i.e. cooling systems. In this scenario, the temperature inside one or more tanks could increase significantly, up to the boiling and evaporation temperature of the solution. Once evaporated, the solid residue obtained would release volatile radioactive materials contained and especially the caesium-137. Uncertainty remains on the fraction of materials released in such a scenario, but a significant share of the inventory could be assumed as *"BNFL accept that if there were to be complete failure of cooling in all the HASTs (Highly Active Storage Tanks), the system including electrostatic precipitators, and scrubbers, could be overwhelmed".*[4]

In order to simplify the approach, we limit our consideration in the present paper to the question of caesium-137. The choice is justified by the experience of the Chernobyl accident. Many radionuclides in various quantities were released in the course of this accident, but the release and dispersion of caesium-137 accounts for about three quarters of the long term and collective offsite exposure following the reactor accident.

The B215 building, which is housing all of the 21 tanks of liquid high level waste is partitioned in cells separating the different storage tanks. However, the 1-8 tanks of 70 m^3 capacity are grouped by two for one cell and each of the 9-21 tanks of 160 m^3 capacity are placed in single separate cells.

The average composition of the high level liquid waste stored at Sellafield arrives at a total of around 1.63 kg of caesium-137 per cubic meter of fission products solution (5.26 TBq or 1.63 g per liter). It can therefore be assumed that the total inventory of caesium-137 in the 21 tanks is currently around 2.53 t of which 173 kg in the 1-8 tanks and 2,353 kg in the 9-21 storage tank[5]. Calculations have shown that in a "loss of cooling" scenario, the boiling temperature could be reached within 10-14 hours and that significant evaporation could start after 12.5 hours. However these calculations do not take into account the high thermal input of the jet fuel fire following a plane crash which could probably significantly shorten these figures.

Moreover, the B215 building and the cells in which the storage tanks are housed have not been designed to resist a commercial or military plane crash. In such an event, the two scenarios of release, either loss of cooling leading to boiling, or immediate aerial release due to tank rupture following the direct crash on one cell, would lead to significant doses. In 1994, the COSYMA computer model was used to assess the consequences of an atmospheric release from the Sellafield high level waste tanks, to range up to tens of millions of person-Sievert.[6] According to the internationally used risk factor of 5% fatal cancer risk per person-Sievert[7], this release could lead over the long term to hundreds of thousands of deaths.

However, the scenarios of caesium-137 releases should not be limited to the rupture of a single storage tank alone, but should also take into account the possible "domino" effect that could lead to the release of the radioactivity contained in several storage tanks. The UK Nuclear Installations Inspectorate (NII) has described the safety level in B215 "*where active systems, requiring operator control, are needed to keep the HAL [liquid high level waste] in a safe state.*" In fact, the cooling circuits of the different

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[4] FJ Turvey and C Hone, RPII, "*Storage of Liquid High-Level Radioactive Waste at Sellafield*", December 2000.

[5] Idem.

[6] Taylor P. (1994), *Consequence Analysis of a Catastrophic Failure of Highly Active Liquid Waste Tanks Serving the THORP and Magnox Nuclear Fuel Reprocessing Plants at Sellafield*, Nuclear Policy and Information Unit, Manchester Town Hall, Manchester, February 1994.

ICRP *1990 Recommendations of the International Commission on Radiological Protection*, ICRP, Publication 60, Pergamon Press storage tanks are not absolutely independent, and a single storage tank accident would likely lead to the disability of other cooling circuits (because of fire and/or explosion) which itself would finally engender boiling and release from some other storage tanks. We can therefore assume that because of the possible "domino" effect in loss of cooling systems, a scenario of the release of all the caesium-137 contained in the 21 storage tanks cannot be ruled out.

Moreover, considering the dimensions of a commercial airplane such as a Boeing-767, it seems highly optimistic to look at the consequences of a single storage tank release. A direct hit on the B215 would certainly concern more than one storage tank. The projection of the potential zone of damage in the event of a large plane crash shows that large parts or even the entire building could be affected (see ***Annex 2***).

On the hypothesis of a release of 50% of the B215 caesium-137 inventory, such an accident would lead to up to 48 times the quantities of caesium-137 released during the Chernobyl accident (or 26,4 kg).

Conclusion

Although the release mechanism would be very different from that of a core melt accident and the forecasting of the precise release fraction is impossible, a severe accident or terrorist attack on the high level waste tanks in building B215 could lead, considering the same conditions of dispersion[8], to an impact **several dozen times the global and long term impact of the Chernobyl accident**.

With the radioactive caesium-137 inventory of the high level waste tanks reaching about 100 times the quantity released at Chernobyl, even a limited release of 1% of the total ceasium-137 inventory, the dimension of the impact under such a scenario would be still comparable to the Chernobyl accident.

3. UK legal framework and BNFL's aircraft risk assessment

• *Risk analysis*

Under the Nuclear Installations Act (1965), the safety of a nuclear plant is the responsibility of the operator, or licencee. The latter is required to submit to the Nuclear Installations Inspectorate (NII) *"a written demonstration of safety, the safety case, which is periodically updated to reflect changing conditions"*. The Safety Case is then assessed by the NII to determine whether it is *"adequate"*, within the framework of a set of principles called "Safety assessment principles for nuclear plants"[9].

The role of risk analysis is important in a safety case in that it examines how different scenarios of accidents may develop and how the consequences may be mitigated.

One of the aspects that are necessarily dealt with, is the occurrence of natural and man-made hazards that may affect normal operation on site. *"Earthquakes, flooding, drought, high winds and extremes of ambient temperature are examples of natural hazards which need to be considered. Man-made hazards include the possibility of an aircraft crash on the site and the storage, processing or transport of hazardous materials in the vicinity."*[10]

• *Risk analysis of aircraft crash in Sellafield*

Safety cases are regularly reviewed to take account of changes to plant and procedures. As far as the risks of aircraft crash are concerned, *"the predicted frequency of aircraft and helicopter crash on or near safety-related plant at the nuclear site"* as well as *"the risk associated with the impacts, including the possibility of aircraft fuel ignition,"* have to be determined[11].

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[8] The dispersion of radionuclides after their release in the atmosphere depends on various parameters, including the height reached by the emissions, the wind and/or rain conditions, and can only be described through complex modelling.

[9] Health & Safety Executive, *Safety assessment principles for Nuclear plants* www.hse.gov.uk/.

[10] Idem.

[11] Idem.

The safety case of B215 in Sellafield in particular was *"revised and reissued at the end of 1994 and assessed by the NII"*.[12]

In its February 2000 report on *the storage of liquid high level waste at BNFL, Sellafield*, the NII explained that *"BNFL reviewed the previously generated aircraft crash assessment data and methodology, applicable specifically to the Sellafield site"*. It concluded that *"no significant differences to the previously identified data and methodology were identified"*, without specifying however the criteria used by BNFL to assess this risk and whether *"the most recent crash statistics, flight paths and flight movements for all types of aircraft"* were taken into account.

Commenting on BNFL's study, NII declared itself *"satisfied"* with *"the current aircraft crash hazard assessment"*.[13] According to the NII, BNFL's aircraft crash assessment carried out in 1994 *"concludes that in absolute terms the likelihood of an aircraft impact onto any individual plant is very remote"*, the total impact being below 1×10^{-6}/year.

Nevertheless, the NII recognised in the beginning of the paragraph dealing with the aircraft crash risk that ***"there has been no specific design provision to protect against crashing aircraft*"**.

A spokesman for BNFL declared that both reactors and reprocessing plants were *"extremely robust"* and were designed to withstand a plane crash[14]. This statement is in total contradiction with the NII's position and has not been backed up by any published document. BNFL has suggested before that the facilities could withstand a plane crash, for example in commenting on the crash of a light plane in January 1993, only 3 miles from the Sellafield site[15]. The Sellafield spokesman at the time, Alan Irving, explained that the buildings were constructed *"to withstand the most severe impact. They are designed and built to be earthquake-proof"*.

If *"there are two stages in an assessment of the probability of an uncontrolled release caused by an aircraft crash"*:

- first, the assessment of the probability of an aircraft impact; and
- secondly, the conditional probability of the impact leading to an uncontrolled release,

there is no doubt today that, following the 11 September 2001 events, the terrorist threat constitutes a parameter that renders *"previously identified data and methodology"* obsolete. "*Hence the probability of a civil airliner crash threatening nuclear safety*" can no longer be *"concerned low enough to be discounted"*.[16]

As far as regulations are concerned, little has been done to protect nuclear sites efficiently against voluntary aircraft crashes. The UK's civil aviation regulation does include r*estrictions of flying*[17], forbidding flying in the vicinity of certain nuclear installations. For Sellafield in particular, the no-flying zone comprises a 2-mile radius area and a 2,200-feet height. According to aviation sources, Sellafield is located near an air traffic corridor used by airliners linking the UK to the US West Coast[18].

In July 1996 on the other hand, BNFL complained to the Civil Aviation Authority about an air race that took place between Blackpool and the Isle of Man, and which involved *"some 40 piston-engine light aircraft"*. Although they were briefed about the necessity to avoid the no-flying zone near Sellafield, a number of aircraft nevertheless flew in the vicinity of the nuclear site[19].

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[12] Nuclear Installations Inspectorate, *The storage of liquid high level waste at BNFL, Sellafield*, February 2000

[13] Idem

[14] Guardian, *Sellafield nuclear plant could be prime target for terrorists*, 18 September 2001.

[15] Barrow evening Mail, *Lost in the Mist*, 14 January 1993.

[16] Barnes M, *Hinkley Point Public Inquiries*, Vol 6, Ch 47, 1990.

[17] Statutory Instrument 2001 No. 1607: the Air Navigation (Restriction of Flying) (Nuclear Installations), which came into force on 11th May 2001.

[18] New Scientist, *the Nightmare Scenario*, 13 October 2001.

[19] WN, *A-plant anger over air race*, 19 July 1996.

On 25 October 2001, the French government greatly increased the no-fly zone from 100 m to 10 km around the La Hague reprocessing plant and to 5000 feet (1500 m) height[20]. On 26 October 2001, the installation of an unspecified number of CROTALE anti-aircraft missiles started on the La Hague site.

It is extremely surprising that no precise similar measures have been taken yet in order to drastically increase security and protection at Sellafield, by far the most sensitive site in Great Britain.

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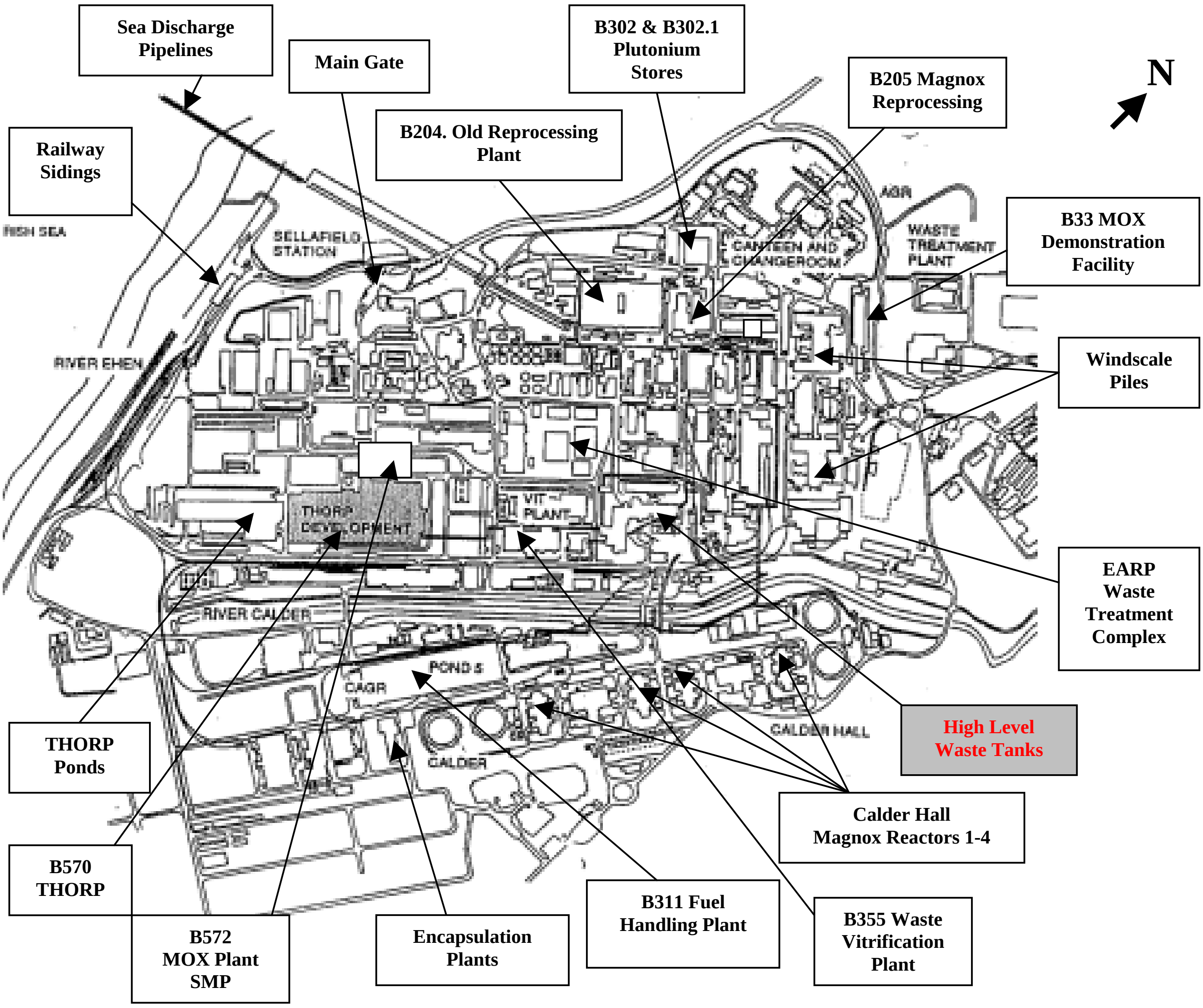
[20] *Arrêté du 23 octobre 2001 portant création d'une zone interdite temporaire dans la région de La Hague (Manche):*
http://www.legifrance.gouv.fr/citoyen/jorf_nor.ow?numjo=DEFV0102227A

Annex 1:

Presentation of the Sellafield reprocessing facilities



Source: WISE-Paris, based on map transmitted by CORE[21]

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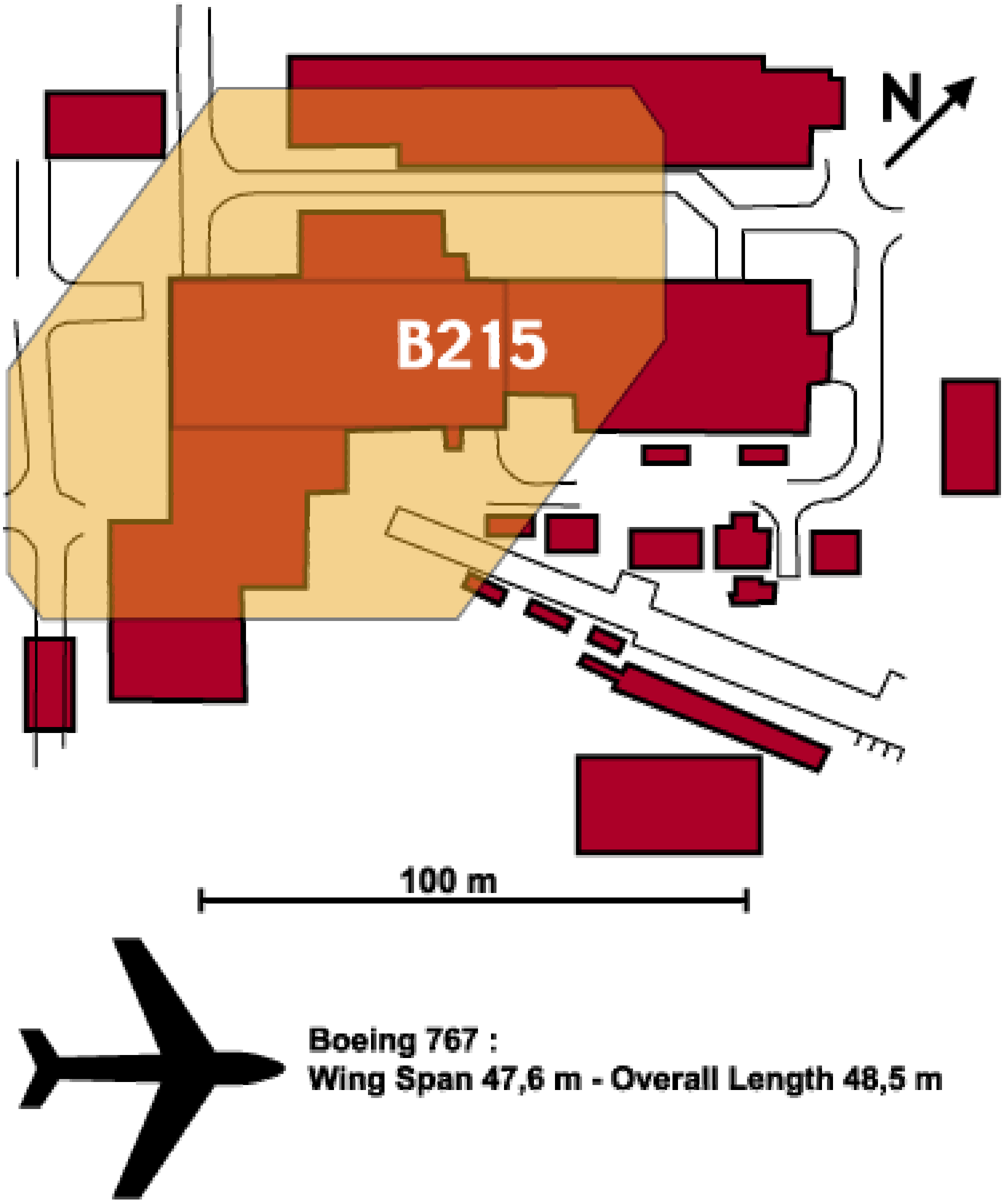
[21] *Cumbrians Opposed to Radioactive Environment*

Annex 2:

Area of potential damage in the case of an impact on Sellafield B215 liquid high level waste storage



Source: WISE-Paris according to NRC 2000[22]*, based on a map transmitted by CORE*

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[22] US NRC, « *Study of Spent Fuel Pool Accident Risk at Decommissioning Nuclear Power Plants* », October 2000.