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Risks of Life-time Extensions of Ageing Nuclear Power Plants: UK and France

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Reactor Ageing in the UK

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UK Hunterston B 965 MW AGR Nuclear Power Plant

- Hunterston B is now 42 years old.
- Built pre 9/11, pre-Fukushima, pre-Chernobyl.
- Key external risks: Reactor and spent fuel pond vulnerability, i.e. plane crash risk from military and loaded large civil.

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Hunterston B: Technical Problems

- Insulation Degradation, Graphite Oxidation, Boiler Spine Cracking, Boiler Superheating Cracking, and Graphite Cracking.
- The most significant risk is cracking of the graphite core moderator.
- The graphite core cannot be repaired or replaced.

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- The role of the graphite core moderator is to slow down fast neutrons to allow chain reaction to continue.
- Channels run through the graphite bricks which allow control rod entry to shut-down the reactor in an emergency.

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Safety System Fail

- But irradiation damage changes the structure of graphite.
- Symptoms include graphite weight loss and brick cracking.
- As the number of cracked bricks increases and core distortion increases, essential safety systems fail.

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Graphite Keyway Route Cracking

- Keyway route cracking (KWRC) is a very specific form of cracking which splits the graphic bricks (or barrels) in two. Keyway cracks risks the core could become misaligned, and the fuel modules stick in the core. If this happens, the fuel temperature rises and can melt. If radioactivity gets into the gas stream and the reactor is venting because it's over-pressurized, then significant radioactive release to the atmosphere follows.

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Seven Graphite Keyways at Hunterston B are Cracked

- The cause of this damage is not fully understood as there are limited means of detecting hidden, but developing, sub-surface cracks.
- So it is entirely possible that this age-related damage is much more extensive.

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Hunterston B 4 Recent Safety Incidents

- Loss of reactor cooling.
- Shut-down pump failure.
- Smoke from a control room panel.
- Power failure prevented cooling gas from being circulated around a reactor.

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Recent Safety Incidents

- No radiological consequences – only because reactors were not in operation.
- Loss of cooling is an important safety incident – if the reactors were in full operation, could have been extremely serious.

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Implications for the UK AGR Reactor Fleet

- As UK nuclear regulators ONR state *'Hunterston B is … generally representative of the other stations'* (ONR, 2017b, p. 103).
- The graphite cores of Hunterston B and, hence, all 14 UK AGR reactors, have developed and continue to develop significant structural damage to graphite bricks including keyway route cracks in the fuelled section of the reactor.

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Ageing French Reactors

Centrale Nucléaire du Tricastin France, 4 x CP1 Class 915 MW PWRs, 3,660 MW Total Out-put

- 2019: French nuclear safety regulator Autorité de Sûreté Nucléaire (ASN) will began a PLEX review of Tricastin-1.
- Key PLEX issues for Tricastin: No reinforced spent fuel pools, and no 'core catchers'.

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No Core-Catchers

- Particularly worrying is the lack of a core-catcher which, in the event of a failure of the emergency reactor core cooling system, would catch the core if it breached the reactor pressure vessel.
- Core catchers are normaly expected in new-build reactors in the EU

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- Spent fuel pond vulnerability is a common weakness for Tricastin and France's 58 nuclear plant.
- French National Assembly's *Commission of Inquiry into the Safety and Security of Nuclear Installations*: ASN should take security (terrorism) into account when making recommendations on safety features of nuclear facilities, especially security of spent fuel pools.

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Post 9/11

- Tricastin, like all France's 58 operating nuclear plants, was built before the accidental or deliberate crash of a large commercial or military aircraft was considered a real threat.
- If hit, it follows that primary containment will fail via localised through-rupture, and sustain deep structural fracturing.

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L'Institute de Radioprotection et de Sûreté Nucléaire (IRSN)

- 'Hardened safety cores should be installed'.
- Since French nuclear plant need hardened safety cores, it follows they are currently at heightened risk of catastrophic failure should they be subject to an extreme external event.

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Centre National de la Recherche Scientifique

- CNRS concludes, perhaps unsurprisingly, that ageing has a significant effect on safety.
- For the older 900 MW fleet, 1 year of ageing corresponds to a 15% increase in reactor safety-related shut-downs.
- Since the majority of the French fleet is 900 MW reactors (34 reactors total), this finding is significant.

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Recent Safety Flaws

- Last week EDF announced at least five nuclear reactors have safety problems with welds on their steam generators - a fault which has raised fears of closures, according to ASN French nuclear regulators.
- EDF's shares plunged 7%, wiping nearly €3bn off its market value, and European power prices surged as investors worry about potential reactor shutdowns.

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Calculating Nuclear Risk

- But EDF announced on Wednesday there was no need to close any of its nuclear reactors 'for now' following the discovery of problems.
- EDF shares recovered 2.3%.
- ASN, French nuclear regulators, have yet comment.

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So ?

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UK Findings

- Given ageing has a significant effect on reactor safety, and weight-loss in graphite blocks and subsequent graphite cracking occurs in all UK AGRs, the Hunterston B example has significant implications across the entire UK AGR fleet.

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FR Findings

- Given that ageing has a significant effect on reactor safety, and lack of core-catcher and spent fuel pond vulnerability comprises a common weakness in all French nuclear plant - the Tricastin example has significant implications across the entire French 900 MW fleet.

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New Nuclear Costs

- The economics of new nuclear is ramping and impossible to fund without huge public subsidy.
- Vast cost and time over-runs for all nuclear projects world-wide – as wind and solar renewable energy costs are plummeting.
- If new nuclear is too expensive, how can the industry buy time to keep the show on the road and balance their books?

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Nuclear Plant Life-span Extension (PLEX)

- The answer is to extend the life-time of the current nuclear fleet by a further 20 years in Europe.
- But it's not easy. There are significant complications
- How many 'trips' any reactor has gone through, and resulting load cycle exhaustion.
- And the basic physical ageing of systems, structures and components.

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PLEX Power Up-rating

- For economic reasons, reactor lifetime extension often involves power uprating - increasing electricity output by increasing the reactor power.
- This super-charging of the reactor decreases safety margins and increases risk of catastrophic failures.

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Nuclear Climate Crisis

- All the first and second wave of EU nuclear plants were constructed well before the threat of attack, and the effects of global warming - sea-level rise, storm surge, tidal ingress and flooding for coastal nuclear, and loss and heating of river-flow for inland - were considered in 'Design Base'.

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Ageing Reactors

- The design life-span of current pan-EU reactors is between 30-40 years.
- Average age of those reactors is 38 years.
- As these reactors age, the reactor pressure vessel and internal components undergo stress. processes, including embrittlement and vessel head penetration cracking.

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Increased Risk

- Older nuclear have less protection against external hazards and the risks of a long-term loss of cooling due to poor redundancy and low-quality standards in spent fuel pool cooling systems.
- The older the reactor, the more spent fuel accumulates on-site.

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WENRA (Western European Nuclear Regulators Association) 'Stress Tests'

- WENRA Stress Test Post-Fukushima reassessment of NPP safety margins.
- But the European Nuclear Safety Regulators Group (ENSREG) decided that security issues were outside WENRA's remit
- So Stress Tests of EU's 143 nuclear power reactors did not include risk of accident and incident from a large aeroplane strike or terrorist attack.