The Platypus Philosophy and Long Term Hazard Management

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The Platypus philosophy has been introduced as a framework, or potential lead indicator, for identifying, collating and analysing weak signals of potential hazardous events so that they can be managed and avoid potential incidents.

The nuclear industry, internationally, has, in many areas, entered a phase of shutdown, decommissioning and storage. There is consideration of repurposing of facilities and readying existing locations for the build of new facilities. These are not just nuclear reactors but the facilities associated with the management of the whole fuel cycle.

The predominant factor in these activities is long term duration. Due to the challenges of radiation, contamination and access, the timescales can be decades long and often inter-generational. Within the UK, long term storage of nuclear waste has already been such a challenge, currently 60 plus years, and, with the further delays in the delivery of a Geological Disposal Facility, management will be even longer.

The acceleration of decommissioning of nuclear sites and the necessary management of spent nuclear fuel, radioactive waste and other byproducts of nuclear processing for future decades, will cause the source of the challenge of long term management to grow.

Although it can be slowed the process of entropy can never be halted. The effects of entropy on managed material must be understood and that understanding must also be carried forward alongside that management. For instance, corrosion cannot be reversed but its forward progression can be slowed if you know its mechanisms.

This paper proposes to demonstrate that the platypus framework can and should be applied, through appropriate adaption, to activities associated with the very long term processing and management operations of the nuclear industry. Intergenerational timescales require intergenerational knowledge retention, reinforcing the need to identify, look for and record the right kinds of weak signals and the why behind them and manage that knowledge as the people and systems change through decades.

The paper further encourages readers to consider that the use of the framework can enable both operators and regulators to raise the hazard horizon viewpoint from the near term, 5 to 10 years, to decades or probably century level impacts of weak signal failures.

The application of weak signal recognition and the need to extrapolate effects into the multi-decade timeframe will be of interest to not only those in the nuclear industry but to those involved in the management of long term dormant facilities that still contain or processed lingering hazardous materials e.g. asbestos or PCB ground contamination.

Setting the Scene

The civil nuclear fuel cycle is international. Simplistically, it involves:

- mining and processing uranium ore
- converting source material to reactor fuel feedstock including the enrichment of the fissile isotope U^{235}
- fuel fabrication
- fuel usage (in reactor),
- spent fuel management for potential disposal or for recovery of plutonium and uranium with associated waste management.

Nuclear power usage also has, and continues to have, with it the necessity of managing challenges that cross social generational boundaries, where a generation is considered 20-30 years. Each of those steps highlighted above generate materials that need cross-generational management either for retention as a future fuel source or as an interim measure before full waste disposal can be achieved.

Many nuclear energy countries are already managing material that has been in existence for up to 80 years. It is recognised that there may be a need to manage such material safely for potentially a further 100 plus years. For instance, with regards to those UK nuclear legacy wastes requiring long term management, the recent UK NDA strategy shows that government level planning is working towards delivering an operational deep geological repository (GDF) for waste disposal by around 2050-2060[1]. Operationally it will continue to exist to ensure most waste emplacement by 2150[2]. Most will be emplaced by then, but in planning there is also the consideration for some wastes to be managed to 2324.

Thus, within the UK there is a need to manage existing wastes, and future generated wastes, above ground, safely, for periods of up to 100 years and possibly longer. In social terms this highlights that the management must cross through 5 generations

[1] Geological Disposal - a programme like no other - GOV.UK (www.gov.uk)
[2] SG/2024/32, Nuclear Decommissioning Authority Business Plan, 1 April 2024 to 31 March 2027, April 2024, NDA Draft Business Plan 2020 to 2023 (publishing.service.gov.uk)

and our great, great, great grandchildren will be the people who will consign today's challenges to the GDF. The UK is not alone with this challenge. There are no operating civil disposal facilities yet within the world[3].

A challenge associated with very long term processes is entropy. In long term material management this can be considered as an increasing lack of predictability and / or a gradual decline into disorder (perhaps decay). Although it can be slowed the process of entropy can never be halted. The effects of entropy when managing material should be understood and that understanding should also be carried forward alongside that management. For instance, corrosion cannot be reversed but its forward progression can be slowed if the mechanisms generating corrosion are understood.

With understanding, the potential for these mechanisms can be managed but importantly where the responsibility for that management moves from owner to owner (operator/organisation/manager) that understanding must be retained and maintained live. In a simple example of this , a recent event in Liverpool[4] in which two individuals died from a falling platform it was found that an additional maintenance/inspection instruction for the platform brake, that failed, was never transferred from the manufacturer to the user who was a subcontractor of a subcontractor. Analogous to three generations.

Such events highlight that management systems that learn from experience and adapt to changing circumstances must be in place to ensure that our descendants are best equipped to remove those wastes from the need to be managed or considered as disposed of. There have been several examples where 'entropic related' events have occurred that have generated significant investigations to determine the root cause.

The outcome of one such investigation discovered that the reason for an apparently minor process requirement, originally derived from the understanding of a materials behaviour, had not been maintained with a high profile and been 'forgotten'. It was not a requirement that would result in an immediate hazard it was one that generated hazards in the intergenerational context. Operators had then, many years later, repeatedly deviated from the requirement to meet production rates resulting in a product that now has a significant risk associated with its onward management.

Such events demonstrate the importance of incremental change and the need for the identification of weak signals and the potential application of the Platypus Philosophy[5],[6].

Realisation of a Long Term Hazard

Material that generates ionising radiation is hazardous. The risk associated with ionising radiation depends on the amount of exposure. Being exposed to high levels of ionising radiation or being exposed to ionising radiation for long periods of time or on a regular basis increases the dose received which, in turn, increases the risk of harm. Ionising radiation from radioactive materials often continues to exist for generations.

A fundamental aim should be to ensure that radioactive materials are managed in a way that protects the public, workforce and environment and safeguards the interest of existing and future generations and the wider environment in a manner that commands public confidence.

The UK government has put this principle within a risk informed framework for solid radioactive waste stated thus: " A risk-informed approach should be used as a decision-making framework for the management of all solid radioactive waste by those responsible for creating and managing solid radioactive waste. A risk-informed approach means considering the properties of the waste (radiological, chemical, physical), the hazard these properties pose to people and the environment and the risk of harm to people and the environment occurring from managing the waste. This means that radioactive waste management plans for current and future arisings of all solid radioactive waste should take into account the radiological and non-radiological properties (physical and chemical) and should be used together with the radioactive waste classification. This approach should be adopted throughout the waste management lifecycle. Consideration of the radiological, chemical and physical properties should be used to demonstrate that the waste is managed safely, securely and will have the best overall outcome for people and the environment."[7].

The hazard associated with ionising radiation is both via direct exposure to the source material and via contamination by the source material. Thus management involves both control of the material and its containment. Failure of either results in realisation of the hazard. This is the same for other non-radiation related long term hazardous materials, e.g. asbestos, PCB ground contamination, lead, tin.

[3] The Onkalu Spent Fuel Repository in Finland is still in construction in 2024.
[4] BBC Article, 18 September 2024, 'Brakes failure led to pair's building fall – inquest', https://www.bbc.co.uk/news/articles/cx2lnjngdd4o
[5] The Platypus Philosophy, Trish Kerin, 2023, Amazon, ISBN: 9798377495789
[6] https://www.liverpoolecho.co.uk/news/liverpool-news/dad-son-died-after-platform-29944257
[7] https://assets.publishing.service.gov.uk/media/63fddc308fa8f527fd7e23cb/part_II_draft_policy_managing_radioactive_substances_and_nuclear_decommissioning.pdf

The long term, cross generational, management of hazards of the nature of these types of long term hazardous materials introduces several additional key factors/risks that need to be considered as a possibility in decision making associated with the prevention of hazard realisation:

- Corrosion to failure
- Erosion of hazard awareness with time
- Potential evolution of the environment
- Changes in society
- Waste evolution
- Secondary waste generation

The need for such considerations points to a need for identifying how they might be defined and looked out for to prevent them being realised and releasing the hazard. The possibility also of expanding the hazard by secondary waste generation should form a consideration.

Applying the Platypus Philosophy

Trish Kerin, with the platypus philosophy, has introduced a framework, or potential lead indicator, for identifying, collating and analysing weak signals of potential hazardous events so that they can be managed and avoid potential incidents.

Simplifying for this paper, the PLATYPUS consists of:

- **P**artial sightings – identify and report the weak signals, including near misses?
- **L**ink the data – align the weak signals into appropriate data trends,
- **A**ssess the data – look at the weak signal conditions, challenge complacency
- **T**asks and timing – what else was happening , when did it occur
- **Y**esterday and yonder – history of weak signals before and elsewhere
- **P**erceive the scenarios – what could have happened? serious outcomes?
- **U**nderstand the controls – identify controls to avoid the non-benign outcomes
- **S**ecure the Platypus – inform and involve – knowledge and people management

These have been applied to the prevention of significant ‘near term’ hazards. This thinking can however be applied to long term hazard management, where the hazard and its controls are present for decades but realisation could be 50 to 60 years hence if unchecked. This necessitates raising the horizon of a safety assessment and safety management from the near term, perhaps 5 to 10 years, to half a century or more, considering failures that might be discounted conventionally, and identifying weak signals to flag deviations from expectations.

As recognised by Kerin cognitive biases generate a strong effect in the considerations of weak signals. Especially, for very long term effects and slow ‘reaction rate’ or developing behaviour. Typical statements that might display such bias when considering the very long term are as follows with sample challenges for the assessor:

Bias	Statement	Challenge
Ostriches	We would never see that because we have controls and the staff are experienced	Controls fail. People can make mistakes and long term monitoring with little change can cause complacency
Confirmation bias	I would see that before it happens	Would a future you see this?
Anchoring	Those other management systems are for different material	What are the differences? Do they matter?
Framing	We have had a pigeon fly in here and we chased it out. We can always chase out wildlife	What if you didn’t see it and it died or left deposits? Other wildlife e.g.rats?
Illusory Truth	You get a bit of corrosion but its on the surface and the material is thick	Is there a potential for a pitting mechanism? Are there seals that could be damaged by corrosion?

Bias	Statement	Challenge
Curse of knowledge	We are well aware of how to manage this store and the manipulations to keep the environment constant	Are they set down in independent accessible means or do they need one-to one explanations?
Pareidolia – we see a pattern and draw a meaning where none exists – need verification	We've seen a bit of corrosion but that's just because we lost the dehumidifier for a few weeks	Can you confirm no corrosion before the dehumidifier failure, has the degree of corrosion stayed the same since you observed it?
Anecdotal	We never saw it in the other facilities	Were you looking for it? What might be different in this facility
Neglect of probability	Loss of ventilation for more than 30 days is unlikely?	Have you checked events in other facilities? What is the fan failure rate and repair/ replacement history there? Obsolesence?
Information bias	I have never seen wildlife in other facilities	Did they have a different entry and exit system? Are breaks in containment to additional containment or the environment?
Illusion of control	I ensure the containers in this facility are managed properly	Do you also manage the facility to ensure the waste in the container behaves as expected

Existing Guidance and Techniques

Joint guidance concerning the long term management of higher activity radioactive waste on nuclear licensed sites from the UK nuclear and environmental regulators exists[8]. It sets out good practice for defining a system for managing the long term hazard posed by these wastes. It sets out a number of qualities that require monitoring and maintaining. It recommends establishing:

- An oversight body in the form of a Product Quality Review Committee, PQRC, that controls the data surrounding that management, including trending
- Criteria against which the preparation and conditioning of the waste can be assessed
- A waste package baseline condition
- Monitoring and inspection programmes of typical performance criteria.

Typical performance criteria include:

- Container corrosion (external, internal);
- Wasteform expansion (indicator of internal corrosion stress, pressure);
- Lifting feature degradation; (because waste needs to be retrieved as well as received)
- Loss of mechanical strength;

However, it does not specify the weak signals that might indicate a drive towards a fault or failure condition. It focusses on feedback (a problem has happened, why?) rather than feed forward (If this changes then this may be the outcome). It is these feed forward weak signals that need to be identified, defined and looked for. In the case of the above qualities such weak signals could include:

Performance Criteria	Potential Weak signals
Corrosion	• Temperature trends • Humidity trends • Periodic loss of facility climate control • Ingress of natural activity – wildlife/flora
Waste form expansion	• Adherence to conditions for acceptance • Trends as those for corrosion
Lifting feature degradation	• Precursors of damage mechanisms including dissimilar metals and action by aggressive lifting techniques
Loss of mechanical strength	• All of the weak signals described above

[8] The long term management of higher activity radioactive waste on nuclear licensed sites, July 2021, https://www.onr.org.uk/media/by2nkmad/waste-management-joint-guidance.pdf

Examples of existing feed forward weak signals

Introduction of a contaminant with a waste stream

A new radioactive waste storage facility is in design. The store is to receive waste in packages from multiple donor sources via an existing store receipt route. The design assumed that all waste packages will be made and received in a controlled environment. The ventilation system and store monitoring regime of the new store is designed assuming this.

However, a design change occurred late in the existing, connecting, stores operation that requires one donor source to be unpacked in an uncontrolled environment exposed to unconditioned sea air. That source's containment package is susceptible to chloride related corrosion. The fact of receiving waste in an uncontrolled environment exposed to salt is an indicator that a weak signal should be defined. However, as this was not shared, due to a focus on short term safety concerns by another project, the definition of a monitorable weak signal could not be made.

Instead the store design assumes conditioned clean packages and no need for chloride monitoring, 'as this is done at source and cannot change,. As a consequence this capability is not provided and the monitoring regime, similarly, is light on trending this. The example demonstrates that not sharing / understanding this weak signal of discontinuity in the reception process has created a risk of missing a mechanism that causes long term failure of waste packages.

Wildlife and Weather

A recently commissioned facility that provides protection for shielded waste packages is designed to receive, and export, those packages through a roller door in the side of the building shell. The packages are prepared and filled in a distant facility before being transported to the building. Transport is provided by a flat bed, weather protected tractor trailer. When inside they will be emplaced in an open topped shielded vault.

The facility is provided with a ventilation system that manages the air around that vault but not within it. I.e. the flow is insufficient to purge the vault cavity. The design of the ventilation system considers that the door, breaching the wall's integrity, will be open only for 10 minutes during package import/export. The potential for the release of activity from the waste is managed through high efficiency stainless steel filters installed within the package. These are susceptible to corrosion in the right conditions. A Condition, Monitoring and Inspection (CM&I) regime has been devised to look for corrosion, throughout the facility.

Given the location of the facility and the doorway breach, it's operation is particularly exposed to the potential ingress of wildlife, especially birds, rain via the receipt of a wet trailer and disturbance of the ventilation by opening the door. Although modelling suggests the effects from the latter will be minor but not unlikely. Thus mechanisms exist that may impact on the integrity or capability of the stainless steel filters over the anticipated storage times of at least 50 years.

Weak signals in this situation would include logging of incidents of bird intrusion, wet day waste receipts, logging door opening times, humidity and temperature levels. Upward trends or repeated incidents may provide warnings that there may be deviations from the predicted behaviour of the store environment resulting in previously ignored filter deterioration mechanisms damaging filters and requiring a change in CM&I or even early filter replacement.

Long Term Slow Increases in Temperature

A facility is managing a waste over a very long term that has a small heat generation rate from both radioactive decay and chemical reaction. It is known that there can be a significant exotherm if the temperature of the waste exceeds a specific point. Limits have therefore been set on its allowable temperature. The heat generation rate was such that the waste temperature remained stable but cyclic seasonally for a number of years using only a ventilation system flow and some natural convection as the heat sink.

Modifications were made to the ventilation system which changed the heat sink capacity. The changes were assessed mathematically and the analysis predicted a rise in temperature to a new steady state plateau. The predicted plateau would still be below the temperature limit. The operators were briefed on this and it was anticipated that the temperature rise would be monitored.

The time period of the resulting temperature rise extended to approximately 1^{o}C per year with regular monitoring. This rate rise was such that the defined weekly monitoring showed little incremental change in numbers. Each operator could note this as little change on the previous week with no risk to the temperature limit. Particularly given the accuracy of the temperature instrument is +/- 0.1^{o}C at best and the system retained a cyclical seasonal effect. Rising and falling 2 degrees between summer and winter. However over 5 years the temperature had risen such that the limit of safety would be exceeded if the system continued to follow the cyclical temperature rise. At this point it was also realised that the rate of rise had also begun to increase, possibly causing the identification, and the operator then reacted.

The only solution was to increase the heat sink rate and it was established that the time period for cooling using the evaporative effect of ventilation and natural convection was extremely long and would not stop the temperature rise but slow it. Thus, there was a need to re-establish an existing, but old, forced cooling system. A system that had in some areas been removed and in others been allowed to deteriorate due to:

- Never being needed in over 10 years
- Its existence interfering with other operations that had been initiated in the interim
- Modifications to the source cooling elsewhere to serve a different facility
- Unverified assumptions that:
    - the system could be brought into operation relatively rapidly
    - The waste would in turn react rapidly to additional forced cooling

The weak signals in this case would be effective trended temperature monitoring coupled with effective oversight and an appreciation of the heat capacity of the bulk waste. In addition the oversight and challenge to complacency entering into decision making around the provision and maintenance of of emergency/standby cooling.

Applying PLATYPUS to Long Term Hazard Management (LTHM)

Applying the PLATYPUS can add significant value to the development of a long term hazard management framework by prompting the users to raise their risk horizon when seeking the realisation of potential intergenerational hazards and looking for the symptoms of slow build ups to failure.

Original	LTHM Application
Partial sightings	Identify slow impact safety eroders, their potential source terms and domino effects Examples: Water Ingress / Condensation Organic Matter presence Slow Temperature rise Fire Sources: Failure of building integrity – engineered / age Transport mechanisms for biological intrusion – moss build up on filters?
Link the data	Set up focussed event logging that includes factors around human behaviour against expectations. Examine deviations from Operational Assumptions, weather behaviour against the expectations / historical trends
Assess the data – look at the background	Add questions to the overseers remit including: What if this unexpected event continues? Does this observed data affect the operational assumptions
Tasks and timing	what else was happening? , when did it happen? Is likely to repeat in a year or even a decade?
Yesterday and yonder - history	Has it happened before? Have other similar facilities seen this? Are other unusual but potentially similar events seen elsewhere. E.g. flooding from not rain but unseen water table rises
Perceive the scenarios – was the outcome benign / would it have been	Is the potential outcome benign / can it be been a significant barrier eroder?
Understand the controls – establish performance criteria to get the non-benign	What needs controlling to reduce or eliminate barrier erosion? If barriers are eroding can the erosion be reversed?
Secure the Platypus – educate and involve – knowledge and people management	Are we ensuring that the knowledge and guidance is clear and can withstand the test of time? Particularly, intergenerational timescales. Including no reliance on single points of knowledge or verbal transfers. Are we encouraging operators and maintainers to raise the time horizon of events they experience or perceive?

Conclusion : Raising the Horizon

This paper has explored the PLATYPUS philosophy and presented a case for its application to addressing long term hazards that have barriers which may slowly erode and fail in extended intergenerational timescales. Examples have been given of some weak signals that could be considered when addressing long term management of hazardous materials.

A key to the application is raising the time horizon of the risk assessment (safety case in nuclear terms) to encompass long duration mechanisms that erode the safety barriers or prevent the hazard being removed at the end of a long durations.

Operators of such facilities need to be encouraged to both recognise existing weak signals as well as record, raise and investigate deviations from the norm to confirm if the deviation is benign or a new weak signal of a future challenge.

Intergenerational timescales must also be a consideration when setting down the guidance / activities associated with the long term management and be embedded within the information gathering during operation and maintenance. It can be perceived that the scope of this philosophy is such that when applied to long term hazard management the dataset becomes too large to manage. In such situations it might be envisaged that AI data management could be brought to bear on the task and used to identify and monitor a multitude of weak signals in parallel or identify key signals that can be managed by a physical operator. The next step in developing this technique is to perform a more comprehensive analysis of a specific situation / facility for which we may seek a volunteer.