THE APPLICATION OF SIMULATION MODELLING IN NUCLEAR DECOMMISSIONING. (10405)

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ABSTRACT

Within several key decommissioning projects currently being carried out on the Sellafield site, simulation modelling is being successfully deployed to achieve a number of varied, but equally significant goals. Amongst these projects, the remediation of the "First Generation Magnox Storage Pond" (FGMSP) has presented the greatest challenge, with a huge variety of complex issues related to long term logistical planning, through to managing radiological uptake amongst a resource pool.

After identifying that a requirement existed for a mechanism to pull the many strands of a multi discipline strategy together, the Sellafield Operational Research Group began the development cycle of a Discrete Event Simulation Model, to provide a unique insight into the overall timeline for project completion. The delivered model represents a major step forward in the functionality provided by simulation modelling, over that which has previously been deployed in decommissioning environments, and enables an holistic view of the project with regard to multi facetted operations, skill & resource availability and radiological uptake to plant operators. This paper discusses the build & development philosophy behind the model, the challenges met by the solution, and the wider benefits to nuclear decommissioning projects across the site.

INTRODUCTION

From its main site in Cumbria, (UK), Sellafield Ltd is the company responsible for safely managing nuclear reprocessing, fuel storage, waste management & decommissioning of the UK's atomic legacy with the Sellafield Sites, whilst paving the way for future energy policy decisions. Sellafield Operational Research Group (SORG) is the modelling capability group for the whole of the Sellafield site, providing both simulation and analytical services to projects ranging from simple laboratory studies, through to highly detailed representations of plant operations.

One of the flagship projects upon the site is the long term "Retrievals & Remediation" required to move the legacy FGMSP, to an end state termed "dark & dry". The scope of the project involves multiple operations, complex interactions and sequences. The sheer mass of data and information regarding project specifics quickly became unwieldy, preventing a clear view on the overall timeline required to effect the retrievals. At an early stage in planning, it became clear that there was a significant requirement for some means to visualise and communicate the data pertaining to each aspect of the project, thus enabling stakeholders to understand its very nature. A second key requirement would be the ability to demonstrate to a wide ranging audience, the cost and efficiency of various strategic options, in both a financial and a durational context.

THE CHALLENGE

The FGMSP is one of several legacy ponds within the Sellafield portfolio, and has been the subject of ongoing remediation planning for some years. Ahead of decommissioning, a project was established to clear the ponds and wet bay areas of any fuel and residual sludge & debris. The inventory is huge, comprising various types of skips within the ponds, and large amounts of miscellaneous waste forms within the bays. Legacy fuel from the plants operational period further increases the local hazards within the Ponds and Bays, as well as significantly increasing the sludge activity through corrosion, and the background activity throughout the building.

Previous models, which had been built in support of other decommissioning projects, had shown how it was possible to gain a high level view of the processes and interactions, but now the challenge was to provide a much more detailed substantiation of the timeline, and use a simulation tool in areas that had not been modelled before;

- Applying a resource pool to the project tasks
- Develop methodologies to reflect the nature and structure of inventory
- Radiological uptake by the resource pool
- Simulate the dynamic nature of the retrievals environment
- Illustrate the effects of strategic options

PLANT INFRASTRUCTURE & SCOPE OF MODEL

Geographically, the structure comprises fuel ponds, wet bay areas (plant operations are carried out) and the Inlet building, providing access for flasks and equipment.

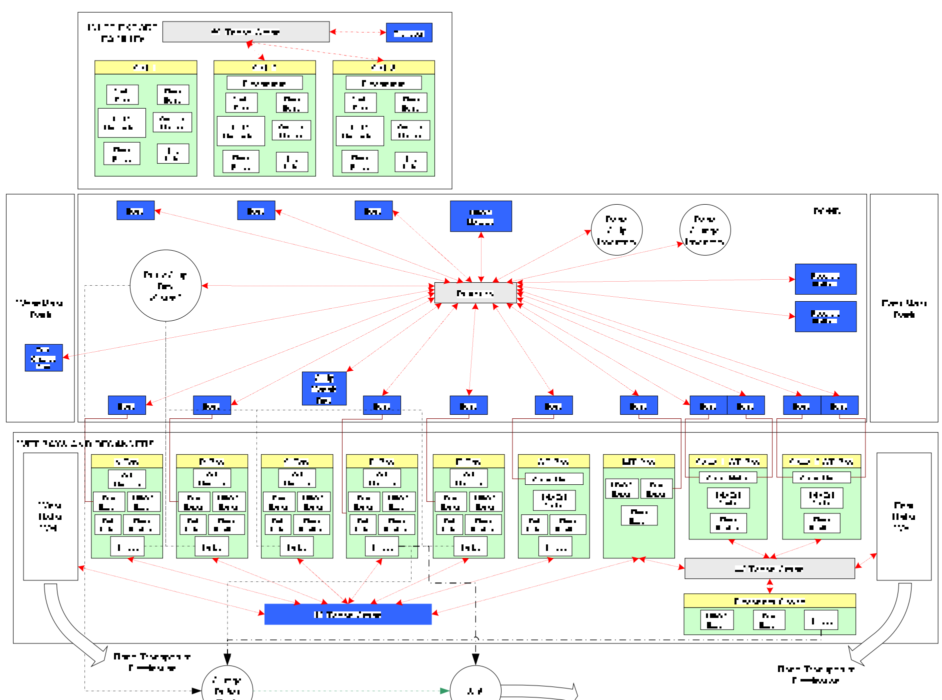

Fig 1. FGMSP Physical Infrastructure

Separate areas of the building are equipped with their own cranes, sized in accordance with the respective roles in the project, and ranging from a 60 tonne capability in the inlet building, through to a 12 tonne unit in the wet bays area. Each of the cranes plays a pivotal role in the retrievals process, with tasks related to the set up & construction phase of the project, through to flask and package movements involved in waste clearance activities.

Central to the clearance of the pond sludge and inventory is the Skip Handling Machine or "Butterley". This is an intrinsic asset of the "pond tactical plan", the scheme proposed to achieve the remediation goals, and is central to the structure of the model. As the infrastructure detail diagram shows, in terms of pond operations, very little can be achieved without the Butterley, as it is the only device available for the movement and extraction of skips, along with deployment of the tooling required for desludging and retrievals.

The model would provide a visual representation of the activities assigned to this machine, and allow deep analysis of its utilisation and operation, to ensure that both the tactical plan and operational philosophy for pond based activities were as efficient as possible in reducing the timeline for safe retrievals.

MODELLING TECHNIQUES

After ascertaining that there were no commercially available packages capable of accommodating the project requirements, SORG chose to develop a bespoke model on the Flexsim software platform. This provides an immersive environment capable of visually portraying the project in a 3D setting, coupled with a bespoke materials handling tool. Flexsim models have been used within the nuclear industry for several years, although some of the challenges presented by this project, particularly with regard to operational dose, had not been met before [1]. Furthermore, Flexsim lends itself more easily to presenting a spatially correct solution. The 3D aspects of Flexsim also provide additional confidence in the Validation & Verification of simulation models, with the analyst having the benefit of visually confirming the operating logic of the model, after all, "seeing is believing".

All of the model input data is held in an Excel spreadsheet, providing a familiar tool and framework for collation purposes, along with a readily accessible means to further analyse each of the results from each scenario. This then presented an initial challenge to the modelling team, in determining suitable methods for representation of the waste streams. The key would be to provide an interface giving the plant teams a readily understandable grasp of the waste inventory, whilst at the same, structuring the data in a way that could be graphically detailed within the model.

The waste profile modelled covers three main categories; namely Sludge, Skips & Wet Bay materials, which were generally shared amongst most areas within the building. Within the main ponds, the bulk of the inventory was the sludge on the floor, with the skips located in and around the sludge bed itself.

Each material type within the pond would also require specific tooling and equipment to retrieve it, based upon item type, physical orientation and operational priority.

Modelling of the pond was structured as a grid, which would then allow the each cell of the grid to be populated with a series of "contents" to indicate pond status over time. The cells within each grid could then represent the "top down" order in which each of the items/tasks would be approached.

The layers within each grid could be assigned with a range of contents, which would specify either an inventory type or the tooling required in order to effect a recovery in that cell at that level. This built into a multi dimensional representation of the pond content, alongside the task specific tooling required. Understanding the required tooling for any given task was a vital part of the model structure, as a future requirement from the simulation would be assurance that the strategy was being deployed in the most efficient fashion, with tool changes on the Skip Handler being managed in order to keep them as low as possible.

Within the Wet Bays, a similar approach was taken with the waste being built up into layers within each bay. Layers could be assigned with one of a number of categories (ILW, LLW, Fuel, Set Up, Sludge, or Delay) and a corresponding measure in m3 or time where appropriate. The actual physical structure of waste within the bays is hugely random with variables relating to size, mass, material, & activity, which is problematic from a simulation perspective. The solution provided the means to apply differing recovery times and operational periods to different types of waste. Furthermore, the model used a series of mathematical distributions to apply variability to the results, and further evolving the timeline beyond a simple "add up the variables" routine.

RADIOLOGICAL DOSE MODELLING

Previous work done to couple a discrete event simulation tool with a dose capability, had established some of the basic principles [2], but centred on the Time/Distance/Shielding philosophy and calculated the dose instantaneously. The approach required in this instance involved applying a measured background within the plant, and then influencing this throughout the retrievals cycle, thus taking the static background to a dynamic level.

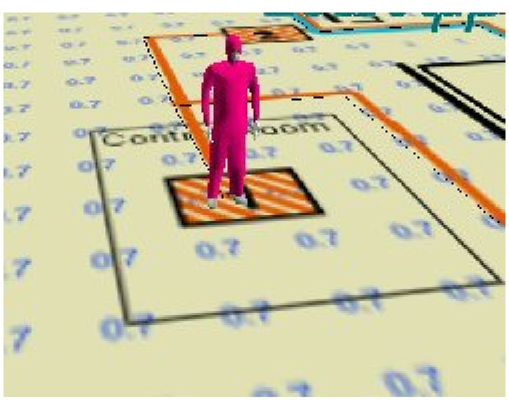

Figure 2. Operator on "dose map"

Periodic dose survey figures were added to an Excel spreadsheet, which in turn was overlaid with a scaled CAD drawing of the building. All of the key work areas were then identified on the plan, along with the transit routes within the building to get to and from various locations.

Separate tasks were identified throughout the process and analysed to determine the number of operators required to perform each one, along with any associated confluence of skills.

The model assigns operators to tasks as required at the beginning of each shift, and then monitors each worker as they move around the plant, calculating the dose accrued throughout the day. A running total is kept of the annual dose on each operator, and should the annual limit be reached, they are taken out of the resource pool and not assigned anymore jobs until their dose total is reset on the 1st January of the next year. The dose aspects of this model have required the creation of bespoke "Dose Library" items within Flexsim, and these can now be re-used within future models, providing uniform dose functionality at no extra cost.

Plant operators were set up as three groups; standard operators responsible for retrievals and asset care, craft personnel performing maintenance & responding to breakdowns, and HP&S teams responsible for plant & export monitoring. Each of the resource groups has the capability to assign skill levels to each task, thus reflecting real staff abilities.

Incorporation of the plant operators was further complicated by the need to accurately reflect their travel routes around the building, and observe the relative barrier procedures in place, which in some cases tie up other resources and constrain other activities from taking place.

MODEL INTEGRATION

Another major step forward achieved through this project was the integration of previously developed & validated models, to become a part of a larger, highly detailed plant view. A separate project looking to determine the throughput of the Inlet building had also chosen to develop a Flexsim model of their preferred design. This standalone "Export" model was subsequently integrated into the overall FGMSP model, providing continuity of approach and also the ability to better assess the constraints of one project area upon another. The linkage of these models was performed using a "harness" philosophy, to ensure a seamless handshake between the two. This approach has since been used to bring in a third model, of the Sludge Buffer Plant (SPP1), providing greater granularity in the data & results. This much simplified integration, through the Flexsim platform, enables both modellers and plant analysts to gauge the interactions between work-streams on a significantly more detailed level than has been possible.

THE DELIVERED SOLUTION

Development of the model has fulfilled a number of requirements;

- Establish & underpinned the overall timeline to perform retrievals
- Communicate the project philosophy to a wider audience
- Forecast & optimised the required resource pool size
- Forecast the radiological uptake to the resource with dynamic properties
- Determine the utilisation of key infrastructure
- Centralise and collate project specific data
- Provide a means to evaluate strategic options and their impact

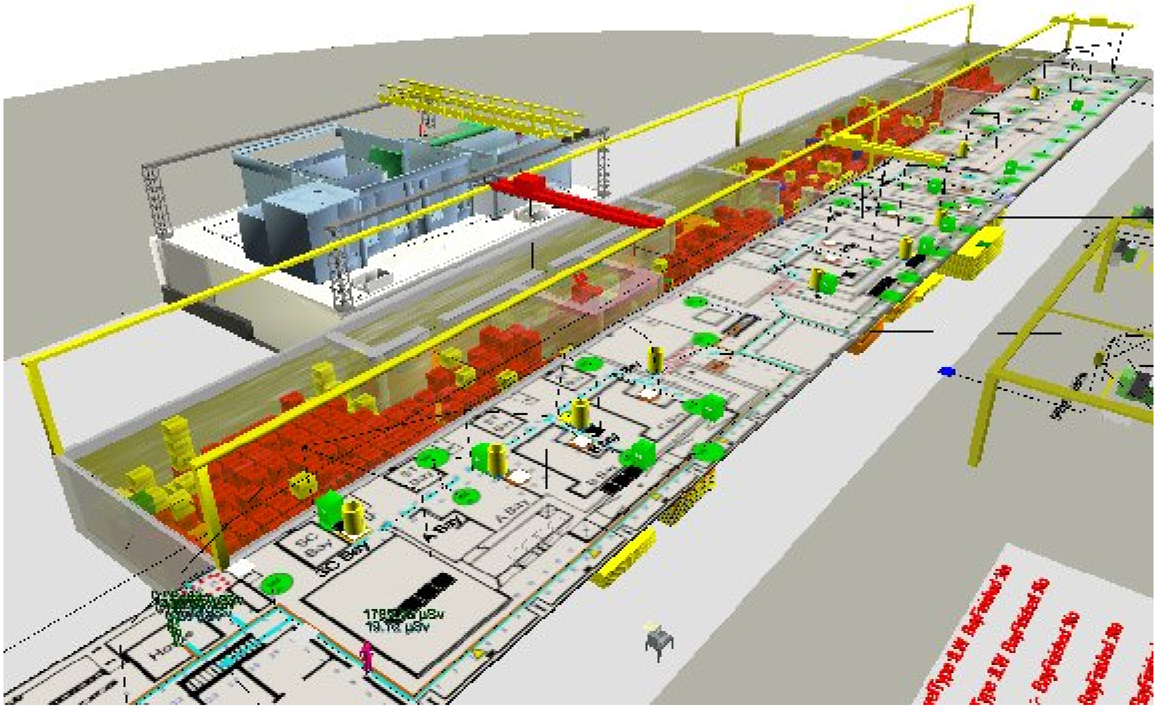

Figure 3. The delivered model in operation

Through a continuing development cycle, the model has taken around 3 years to reach its current level of sophistication & detail.

THE BENEFITS

With previously unheralded insight into the duration required to complete the project, the model has enabled project stakeholders to understand how individual aspects of the project relate to each other, and what this means to an end date.

In addition, the ability to perform “what if?” scenarios has highlighted potential savings in excess of £30,000,000 through various waste routing options. The plant teams now have an underpinned viewpoint of the future radiological impact upon the resource, and the required manning levels for each resource type have been identified.

Clearly, a significant infrastructure with multiple interfaces of the key resources quickly becomes a logistical nightmare. The major concern from a long term perspective was the lack of insight as to the overall timeline to perform the retrievals. This issue has taken on an even greater significance in recent times with the transfer of the site to Nuclear Management Partners Ltd. Future revenues for NMP will derived from the relative success of the company in delivering against targets identified within the sites “Life Time Plan”. The model therefore would be critical in underpinning both the overall strategy for the project, as well as helping to provide a holistic overview of the timeline to feed into the plan.

The ability to model within the Flexsim library structure also means that the dose functionality can now be reused on future modelling projects across the company at a significantly reduced cost.

REFERENCES

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