The General Case Integrated Waste Algorithm, a Universal Model for Decommissioning – 9195

Dr Paul E. Mort
Sellafield Ltd,
Sellafield, Seascale, Cumbria, CA20 1PG, UK.

Prof. Bernard Kelly
University of Manchester, School of Mechanical, Aerospace and Civil Engineering, Pariser Building, PO Box 88, M60 1QD, UK[1]

Dr Andrew J. Lowe
University of Manchester, School of Mechanical, Aerospace and Civil Engineering, Pariser Building, PO Box 88, M60 1QD, UK

ABSTRACT

The General Case Integrated Waste Algorithm (GIA), a universal model for decommissioning nuclear plants, power plants, waste arisings and knowledge capture is presented in this paper. The algorithm has four concurrent processes that define nuclear decommissioning. These are processes for decommissioning plants and buildings and for the gaseous, solid and liquid waste streams. Each process is broken down into key individual stages. Furthermore, these stages are linked to complete the integrated approach to decommissioning. A simple algorithm leads to seven key strategic decision stages where stakeholders and a multitude of constraints will influence decisions. A pilot study showing the potential of GIA was conducted and focus on the restrictions imposed by the limitations of computational resources. The importance and challenges associated with decision analysis are also highlighted. This information will be required to build a powerful predictive simulation, planning and decision making tool for future generations.

INTRODUCTION

A detailed introduction to decommissioning is given in Bayliss and Langley's Nuclear Decommissioning, Waste Management and Environmental Site Remediation [1]. Nuclear decommissioning in the UK has been estimated to cost £70 billion although this figure could be an underestimate given the lack of engineering solutions for decommissioning [2,3]. This reflects the equivalent uncertainties in non-nuclear decommissioning e.g. oil/gas marine platforms in the North Sea. There is a significant amount of experience with decommissioning reactor systems [1]. However, many of the chemical processing and fuel cycle plants present a greater challenge due to issues such as:

- waste inventories within buildings are unknown and historic records are poor,
- alpha and beta-gamma species are present,
- wastes are varied in form – solids, liquids, gases and sludge,
- the structural integrity of some buildings is uncertain,
- deterioration of ponds has caused leaks on site into land.

Stakeholders (regulators, local community, government, unions, etc.), have differing interests and needs from decommissioning activities. So GIA will be an evolving tool for use by industry, researchers and stakeholders. GIA must deliver ever more precise information quickly as a national planning tool. As a

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[1] Corresponding Author.

basis for expert and intelligent systems, the ability to test *what ifs* and through excellent “knowledge capture” ensure future generations learn from past decommissioning experience. It will drive research and development, aligning research with gaps in technology. GIA will do this via the identification of established *norms* (e.g. concrete removal rate for mechanical scabbling). GIA will simultaneously build an auditable database of *norms* and make decommissioning more efficient.

The numerical simulation of GIA [4] is essential to the continuation and future efficiency of the UK's nuclear decommissioning activities. It is at the core of the University of Manchester's research into nuclear engineering decommissioning. Knowledge Capture, decision analysis and future forecasting are vital in making decommissioning efficient. The computational needs of such an approach are vast, a general introduction is given in *Decision Behavior Analysis and Support* [5]. The GIA project is unique; this is the first time fundamental research into GIA has been undertaken. As an interdisciplinary project it will draw extensively on well established academic fields; Decision Analysis [5], Computational Physics[6] Numerical Analysis [7], Supercomputing [8], and Operational Research [9].

GIA is based on decommissioning experience. It compresses the entire decommissioning program into 31 stages. It is useful to describe the levels of sophistication expected as GIA develops:

• Level 1 – Captures current decommissioning practices. This assists in training current engineers and informing future generations. To a large extent, Level 1 work is completed. It has assisted Sellafield Ltd in their discussions with IMechE concerning the accreditation of their training courses in order to design a new national qualification for *Professional Decommissioning Engineers.*

• Level 2 – Converts GIA into a mathematical model. It will be capable of predicting rapidly the impacts of high level decisions on, for example, the volumes of waste generated, costs and program durations. This work will be initiated in collaboration with Sellafield Ltd. Its national and international potential can be appreciated.

• Level 3 – Is an expert system based on GIA. It will be capable of detecting patterns in decommissioning experiences and suggesting solutions to future decommissioning teams. This will make it impossible for future teams to proceed in ignorance of lessons learned. This will be based on advanced decommissioning modeling work; for example, Artificial Intelligence, Expert Systems, Multi-Attribute Decision Analysis and Complex Problem Solving.

The paper will first describe and present the GIA. Four processes, the key stage of Characterization, key decision stages and the scope of the GIA (defined by the start and end points for decommissioning) will be identified. The GIA description will be completed by showing schematically how GIA assimilates large amounts of data in a form appropriate for the user. A pilot study will be described that tests the fundamental elements for the numerical simulation of GIA and shows the data can easily be simplified into graphical representations. Multi-core software development needs are also presented.

THE GENERAL CASE INTEGRATED WASTE ALGORITHM - GIA

The GIA is shown in Figure 1. It uses a systems approach to capture the practical experience gained from decommissioning of Sellafield. Sellafield is one of the most complex nuclear sites in the UK. GIA is an algorithm applicable to all waste species generated during decommissioning. Stakeholder decisions will significantly influence our processing of waste. A large number of waste species are expected and each must be tracked carefully through the algorithm. Waste species need not pass through every stage of GIA (e.g. a building could be entombed and then demolished).

GIA's key processes, decision stages and start and end points are identified and briefly described below. The stage considered most important is "Characterization". The algorithm is divided into:

- decommissioning processes – this is made up of the building decommissioning process (5 stages) and the plant decommissioning process (16 stages),
- waste processes – this is made up of solid waste process (6 stages) and liquid waste process (2 stages),
- decision stages – here regulators and stakeholders will make decisions (e.g. NDA, local community, public sector, etc.) that govern the route waste species take through GIA.

From each start point the waste species are tracked through GIA's stages. Finally, they arrive at an end point of disposal. Waste species exit GIA via:

- disposal to storage (solids) - after immobilization in an encapsulating matrix such as concrete, wastes are ready to be stored in an above surface interim storage area prior to ultimate disposal in a deep geological repository,
- disposal to sea (liquids) or to atmosphere (aerial) - after appropriate treatment, very low active effluents can be discharged as a last resort and subject to detailed local legislation.

In all cases this abatement and discharge is a last resort. The Waste Management Hierarchy demands first considering avoidance of the creation of a waste or minimizing and recycling it.

Entry to the algorithm can occur at one of three stages;

- Post Operations Clean Out (POCO),
- Building Characterization,
- Solid Waste Characterization.

Characterization (i.e. knowing in advance what has to be faced) allows the clean up to be planned effectively. Characterization is complex and can take many forms. The contents of some vessels may not have been emptied completely during POCO. The residual materials are known as '*heels*'. *Heels* are usually heterogeneous in composition (e.g. sludges). So representative sampling is frequently difficult to guarantee. Any sampling usually has to be taken in a high background dose. This further complicates the characterization stage. It should be noted at this stage that 100% characterization is normally unachievable. However, this is no excuse for commencing decommissioning in complete ignorance of what will be encountered.

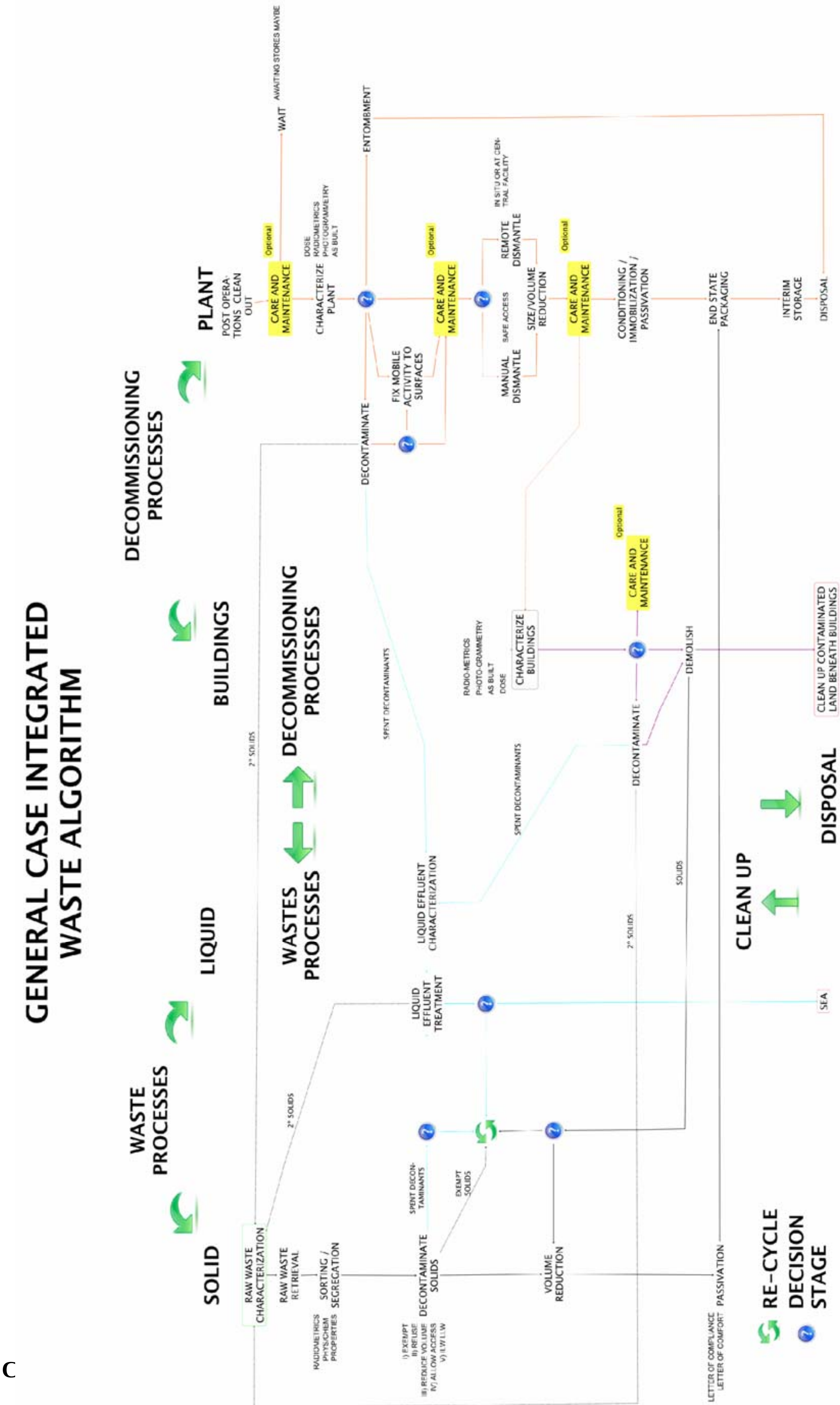

Fig. 1. The General C

Gamma cameras such as the Radscan can be deployed to assess the extent and depth of contamination (e.g. inside cell walls). Laser photogrammetry is routinely deployed. This offers the decommissioning engineer detailed 3D computer models of the cell and building contents. In the future, it will become increasingly important to integrate these devices into a single characterization tool.

Generally, characterization investigates buildings, ponds, cells, cell contents, etc. Cells typically contain large volumes of stainless steel pipe work and vessels. It is assumed that the vast majority of the radioactive inventory is removed during POCO. Ideally, this occurs immediately after the cessation of beneficial production or power generation. Characterization is an essential precursor to effective planning for decommissioning. Of course, characterization includes detailed study of historic records. Unfortunately, older facilities were operated according to the political imperatives of past eras. Back then, the *Cold War* and the production of nuclear weapons were the drivers. The environmental considerations of today were not considered a priority. Detailed records are lost or were simply not produced. Cell walls may have been accidentally contaminated during abnormal operations. The witnesses are usually long deceased or retired. Vent ducts may contain large volumes of long since settled radioactive dust which is typically dislodged during the disruption endemic to decommissioning. At every turn the decommissioning engineer faces uncertainty and attempts to clean up risk triggering unauthorized releases to the environment if inadequately planned. Even in modern day engineering *'as built'* models frequently differ from drawings.

Figure 2 shows schematically the path of waste species through GIA. At all times, the decommissioning strategy will move the waste towards a disposal point. GIA will provide detailed information about the waste routes to disposal. The Pilot Study gives an example of this.

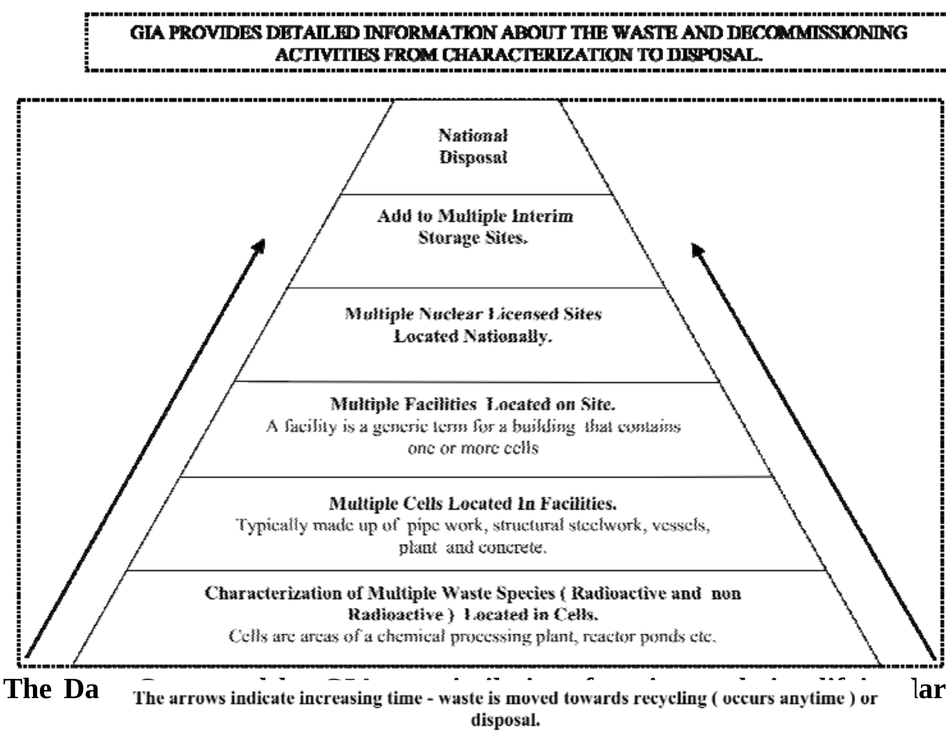

Fig. 2. The Da **large quantities of data.**

PILOT STUDY

A pilot study was conducted to investigate the feasibility of using the GIA. The pilot study investigated three fundamental approaches used in GIA's numerical simulations;

- characterization of wastes into a range of inventories
- representation (using established *norms*) of decommissioning as a simple mathematical function that calculates volumes/activities of primary and secondary wastes, timings, cost etc.
- calculation of ensemble averaged results from multiple simulations

This focused and simplified approach allows us to use an *off the shelf* spreadsheet. The ensemble-averaged results are built from five hundred initial waste conditions. Each condition considers the waste in a site with three facilities, each containing six cells. Essentially, a different scenario is set out, each facility and cell will contain a different inventory for each of the five hundred simulations. GIA tracks the characterized waste from the cells, through decommissioning (e.g. decontamination, scabbling, manual dismantling etc.) and then to the point of disposal. The results from each of the five hundred initial conditions are then used to calculate ensemble statistics, means, minima and maxima.

For the pilot study, the waste in the cells is characterized. Each cell is given a range within which the mass tracked will fall (i.e., a random mass of Low Level Waste, Intermediate Level Waste, PCM etc.). The general engineering dimensions for each of the cells is defined. The waste ranges are based on an assumed statistical distribution where the maximum, minimum and mean for the range are specified. Each individual cell is attributed to a facility.

The spreadsheet then randomly assigns a mass of waste to each cell. It is assumed that each of the six cells in the facility is decommissioned one after the other. It is also assumed that all facilities are decommissioned at the same time, i.e. concurrently. The simple functions representing the decommissioning process calculate quantities such as the masses of primary and secondary waste, the time taken, costs etc. These functions require *norms* to be established, such as the cost per kg of PCM (Plutonium Contaminated Waste) removed from a cell. As the only the feasibility of GIA was being investigated in this study dummy data was used.

The pilot study identified limitations with existing *off the self* software. It is woefully slow and inadequate. Simulations took minutes to undertake. These simple and relatively basic simulations quickly consumed resources. It is clear that for 200+ facilities and literally 1000's of cells the computational task is formidable. Therefore, it is vital to write multi-core optimized parallel software to harness more advanced hardware architectures.

Figure 2 shows the GIA could assimilate information at cell, facility, site and national levels. Figure 3 shows a selection of results from the pilot study. In particular, it shows how the integrated approach can deliver results appropriate to the needs of the user. Graphs of facility data and site data are also included. This data is detailed and covers costs, waste inventory and safety data also. GIA, therefore, allows all users, in particular stakeholders, to understand their decisions more fully.

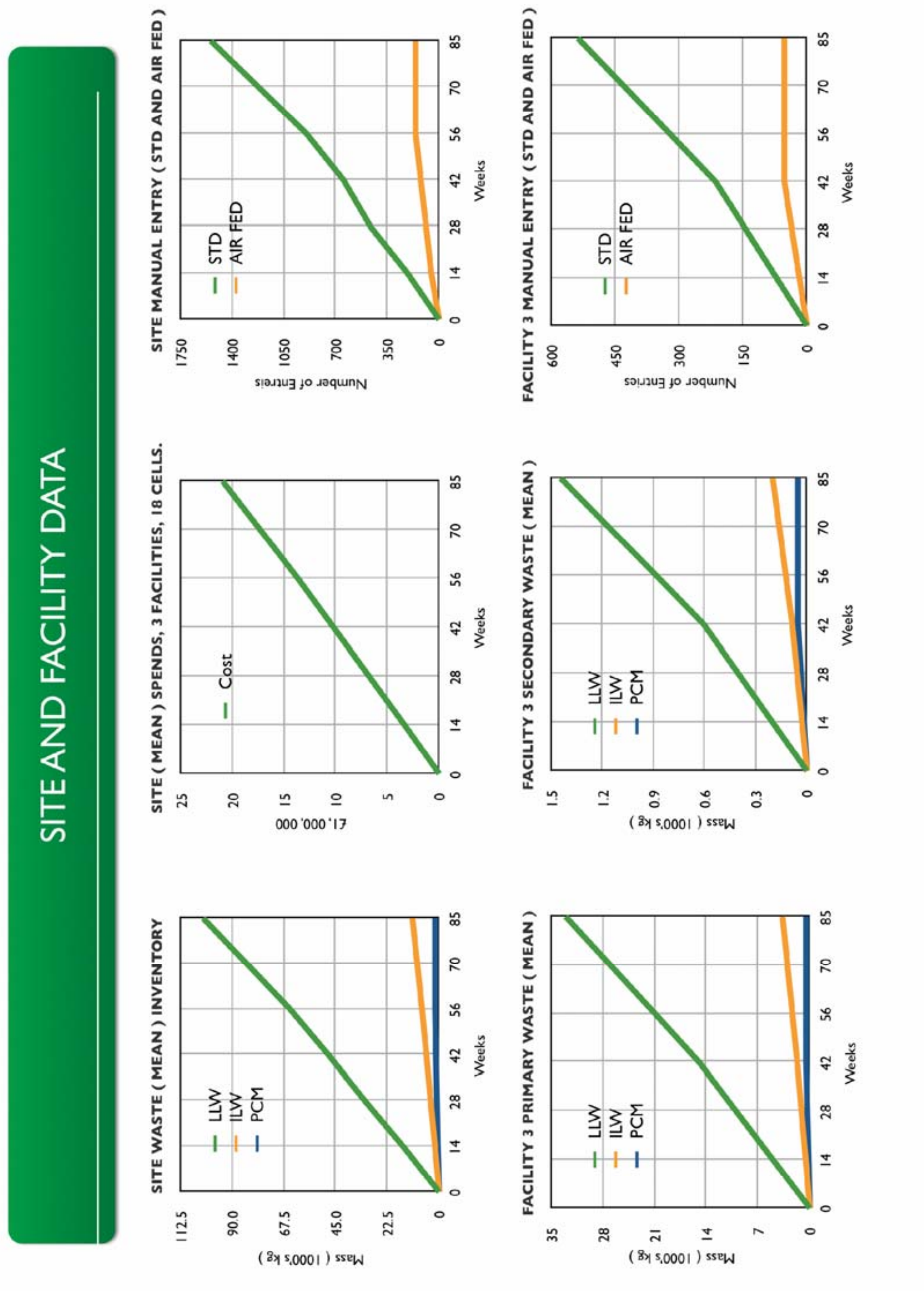

Figure 3 Examples o

CONCLUSION

In this paper the GIA was described. Seven key decision stages were identified that influence the route waste takes through GIA. Furthermore, a top down strategy (influenced by stakeholders) will affect every stage of GIA. The pilot study demonstrated the feasibility of capturing the decommissioning process in an algorithm that can be simulated numerically. Furthermore, these simulations will be able to track real waste from characterization to disposal. In doing so, a large data set is assimilated and can be display by graphical means. Thus the GIA is a powerful, predictive tool capable of answering *what if* cases very rapidly.

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