Applying State-of-the-Art Tools for Safety-Optimized D&D-17410

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ABSTRACT

Decommissioning, Demolition and Disposal of "hot" facilities (D^3) is a relatively new science to the extent it has been part our public consciousness for ~50-years. Due to the high hazard of uncontrolled exposure and the possibility of environmental release, the technologies applied to D^3 have not embraced many of the recently developed engineering tools, especially those that leverage the digital and optical advances of the past 10-years. This summary paper provides an overview of how we are layering readily available technologies with sophisticated techniques to D^3, ranging from agile program management to advanced modular construction to augmented reality. Using this approach, we are significantly improving safety and ALARA aspects while saving costs, optimizing schedules, maintaining quality and engaging the customer and the regulator in the D^3 environment.

INTRODUCTION

Stoller Newport News Nuclear (SN3) combines complex nuclear facility management and operations expertise with full service environmental remediation. Our methodologies include radiological characterization, deactivation and demolition, waste management and site closure expertise for federal government and private-sector clients. SN3 is a division of Huntington Ingalls Industry (HII), who is also the parent company for Newport News Shipbuilding (NNS). NNS has its roots in the design, development, construction, testing and commissioning of nuclear-powered aircraft carriers (CVN's) and submarines, as well as the reactor complex overhaul, refueling and decommissioning of the carriers. That is, NNS has the distinct position of designing, building, operating, servicing, refueling, deactivating and decommissioning the nuclear carrier over its 50-year life. This unique business has provided a singular environment for developing and implementing a vast array of safe and innovative technologies on an unprecedented scale.

The safety requirements associated with D^3 are well defined and highly constrained. Demolition and disposal of even the simplest of radioactively contaminated components requires special processes, procedures and pathways that demand robust and detailed characterization within a highly controlled setting. Complexity further arises from the unique nature of virtually every physical environment that has been used for this purpose: even originally identical articles, by the end of life, have differences that must be accommodated in the D^3 process. This presentation addresses an integrated toolkit of advanced technologies for the Decommissioning, Demolition and Disposal process to maximize safety, quality and efficiency while minimizing costs and risks.

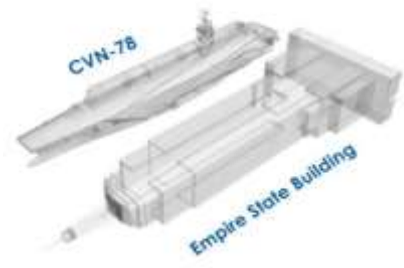


Figure 1

An aircraft carrier is approximately the same size as the Empire State Building (Figure 1). A 2011 comparison between a NIMITZ-Class CVN, a pressurized water reactor (AP1000) power plant and the Hanford Waste Treatment Plant (WTP) complex at Hanford illustrates this point (Table 1):

Table 1

Component	AP1000	CVN	WTP
Structural Steel (ton)	23,000	50,000	40,000
Cable/wire (linear ft.)	16.8 M	10 M	5 M
Piping (linear ft.)	0.5 M	1 M	1 M
Duration (years)	8	8	20
Cost (10^9 – Billions)	$14	$8	$12

HII has developed many tools applicable to working in the nuclear energy environment and we are bringing these to the government-agency and commercial Decommissioning, Demolition and Disposal marketplace.

This paper discusses how we use multi-source data capture and manipulation capabilities to manage the D^3 environment including:

- Modeling and Simulation (M&S)
- Geographic Information System (GIS) modeling
- Reality Capture - Point Cloud technology
- Metrology - Dimensional Control
- Building Information Modeling (BIM)
- Computer Aided Design (CAD) modeling
- Extraction, Transformation and Loading (ETL) modeling

DESCRIPTION

1. **Adaptive Project Management (APM) Tool** - Agile Stochastic Scheduling

D^3 is an extremely complex undertaking including hundreds of tasks, components, facilities and contamination levels, each of these having unique and varied interdependencies. Moreover, operations often occur in tight physical spaces leading to close proximity and associated interferences and constraints. One of the most important first decisions to optimize a D^3 program is to implement an adaptive planning toolkit versus a predictive tool.

By its very nature, D^3 is a complex adaptive system. Thousands of individual inter-related activities must be performed in coordination. Many of these activities are done in parallel, over a distributed, decentralized space. Variability and uncertainty are associated with all levels of the D^3 activities. There is a constant need to synchronize assets and operations. How can we plan it up front and then synchronize the workflow as the project progresses? The challenge is effectively managing complexity. We accomplish this goal using a virtual, adaptive planning approach based on modeling and simulating (M&S) the virtual D^3 process. Adaptive planning takes into account the stochastic nature of all activities and then applies near-real-time data collection for execution feedback. The Adaptive Project

Management (APM) Tool enables situational awareness and results in the ability to continuously forecast alternative futures that can be optimized.

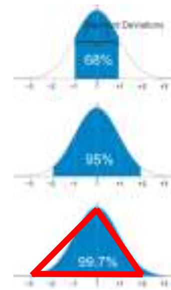


Figure 2

A stochastic process is one in which measured quantity varies and, at any given time, follows a distribution of values, as opposed to a single value. For example, we refer to the "chance" or probability of rainfall at a given time and location that incorporates the variation inherent in weather prediction. So whether you encounter rain depends, e.g., on wind direction, relative humidity, temperature, pressure, specific location, etc. For physics-based systems, the value variations are often modelled using a Gaussian distribution where the average value lies at the peak of a bell-shaped curve and ± 1, ± 2 and ± 3 standard deviations from that average value captures 68%, 95% and 99% of the measured values, respectively. In our adaptive planning computer models we often presume a triangular distribution to take this into account. The triangle is a representation for a distribution curve, where the average value is the most likely outcome, but the range is chosen to incorporate ~99% of all values. For example: if flushing a 2-HP pump normally takes 6-hours, but flushing could be as fast as 3-hours or as long as 8-hours, then the "triangle" representing this variability, denoted 3-6-8, represents a range of 5-hours with the peak or most likely outcome at 6-hours (red triangle in Figure 2).

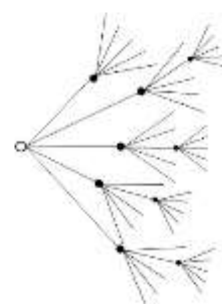


Figure 3

Building the APM model follows a stepwise process in which the project plan is developed hierarchically. Starting with a high-level schedule of key dates and principle events, the contract specific milestones are captured. The intermediate schedule is then fleshed out by identifying time-dependent "buckets" of work for each of the principal events. Finally, each of these buckets are detailed into activities that address work packages of material and assets, e.g. men and equipment, for progress increments or deliverables. Using this process on a complex project, potentially several hundred contract milestones are deconstructed into potentially tens-of-thousands of buckets, which are then broken into hundreds of work packages each. Figure 3 illustrates this concept where one key date is reflected as the hollow dot, and that is further decremented into buckets, etc. The work packages are finally assigned parameters such as task category, manpower/trade required, equivalent-men, shift, etc., with information drawn from experiential and/or experimental databases. Each of these parameters are modeled with a value distribution so that, as the data rolls up, there are ranges associated with each work package, bucket and milestone with range endpoints reflecting the best-case and the worst-case scenario. In this manner, the elephant is eaten, one bite at a time. Depending on the level of fidelity required, the degree of detail varies to accommodate the scope of the output, i.e. whether the analysis is the initial bid rough-order-of-magnitude, or a more detailed approximation.

The result of this approach is to generate a time-versus-% complete so-called Fairway or Hurricane chart that illustrates a band with an upper limit representing the best-case scenario and a lower line representing the worst-case scenario. Note this type of analysis affords management the ability to run what-if scenarios. If the schedule does not support milestones, data can be manipulated in the model to change manpower, trades, or any of the variables or resources included in the model. So, for example, if weather can cause delays, adding a cover may provide a remedy and a cost-versus-benefit analysis can be addressed. Or any number of other what-if scenarios can be analyzed and evaluated.

If the only use for this tool were in the scoping portion of a D^3 project, the investment to build this tool could be a concern. The huge, additional value added, however, comes from utilizing it once the project starts. Figure 4 illustrates this application and compares it to results using another popular scheduling tool, Primavera©. The yellow and black line indicate the static Primavera© best and worst case scenarios based on the activity start. The blue line indicates the actual schedule to date, which is at ~2½-months using real-time progressing. At the tip of the blue line, the APM tool generates the green and red Fairway, which provides an updated best and worst-case schedule, respectively.

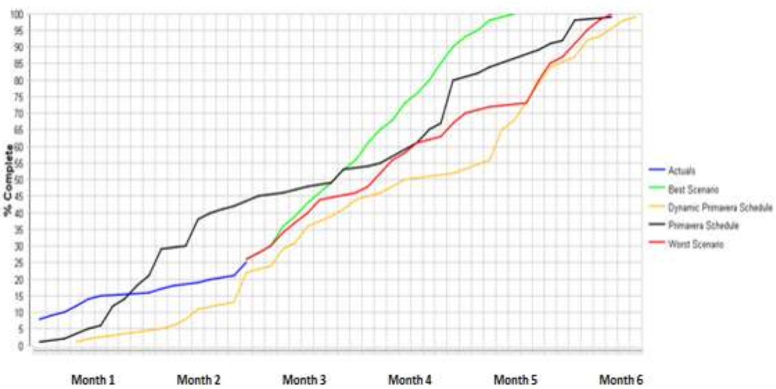


Figure 4

Another particularly valuable aspect of this tool can be observed by noting how, at ~16% complete, the real-time progress stopped ramping up and leveled off. At that point, management is able to dig into the source of the delay and provide relief by addressing the variable(s) not meeting expectations, with the ability to bring progress back on-track.

2. **<u>Modular D^3 Laboratory</u>** - <u>Plug-&-Play Flexible Infrastructure</u>

The design and build-out of the optimal, modular, transportable, scalable radiological characterization and test laboratory is not a new concept, but is definitely not a commercially available commodity, especially in the D^3 marketplace. Part of the implementation challenge is finding the piece parts capable of optimizing the space envelope infrastructure, i.e. the floors, walls, ventilation, lighting, etc.

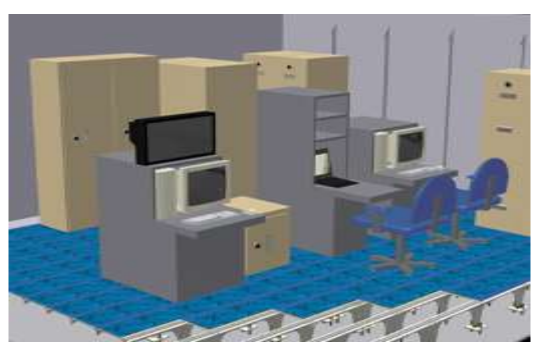


Figure 5

Today, modular homes, offices, schoolrooms and even medical laboratories, are not an oddity. Figure 5, for example, illustrates a modular build-out. The difference for application to a lab for contaminated material analysis, however, is significant, especially if the goal is to make it readily relocate-able and reconfigurable. The challenges associated with maintaining containment, cascading ventilation, sensitive equipment operability, cyber security, etc., call for a unique solution. In addition, customers are seeking an open architecture (OA) solution. OA means the item is transparent to the end user; the user is able to make modifications, upgrades and other changes without relying on input from the vendor.

Our Flexible Infrastructure (FI) product was originally developed for use on seafaring vessels subject to very challenging transient effects. These include racking, vibration and shock, as well as high security and environmental control requirements. This D^3 FI Lab provides Open Architecture so there is footprint flexibility and modularity to facilitate re-configurability, support rapid system upgrades and provide total and complete product integration.

Flexible Infrastructure is a system of systems that provides the capability for rapid compartment re-fit without the use of "hot work." FI is the technology of choice for outfitting spaces that must accommodate incredibly rigorous physical stability and yet maintain the flexibility to be reconfigured and ready for operation in minimum time. The suite of FI systems as illustrated in Figure 6 include:

- Flexible Deck Track System - maximizes the options for initial arrangements of equipment and all subsequent rearrangements for technology refresh and/or insertion.
- Flexible HVAC System – eliminates costly vent system modifications when rearranging equipment and heat loads.
- Flexible Overhead Track System - eliminates hot work for overhead mounted equipment.
- Flexible Sidewall Track System - equipment is bolted easing relocation challenges.

Figure 6

- Portable Partitions and Walls – can be constructed and relocated without hot work; meets requirements for cyber-security and containment.
- Flexible Power Distribution - plug and play efficient power installation and flexibility for future equipment modifications.
- Flexible Lighting System - allows locating or relocating lights, both general and detail configurations, with minimal time and effort.

Using these systems starting at the initial design, the FI product covers delivery requirements for ventilation, information technology (IT), security, wall, floor and ceiling load-bearing capacity and mounting re-configurability. A simple mobile laboratory application could comprise, for example, gamma spectroscopy analyses capabilities for both liquid and solid materials such as water, soils and concrete samples. The FI laboratory is ready to: support and adapt to emerging needs and future systems; perform simultaneous multi-mission tasking; provide an architecture that will adapt to changing operations and technologies; accommodate quickly and cost effectively technology evolution.

3. D[3] 3-D Space Representation (Geospatial) Toolkit for Facility Deconstruction

We employ a handful of tools for capturing 3-dimensional (3-D) structural attributes that have not been developed using a "product model" such as CATIA©. The Geospatial Toolkit includes the geographical footprint, external and internal physical structure and build-outs as well as contamination levels. This toolkit removes the necessity to rely on drawings or other legacy information that invariably do not represent the existing facility conditions, or even CATIA© models that do not capture the as-built details and variations.

Geographic Information Systems (GIS) Modelling

Leveraging commercially available tools for Point Cloud capture, in combination with very-high-accuracy laser positioning Dimensional Control capabilities, the precise location of facilities can be identified and placed with GIS detail. This tool, in combination with computer aided design (CAD) tools, is used not only to identify the footprint of facilities but also to locate utilities, roads and egress paths as well as lay-down-areas for detailed planning and configuration management (Figure 7). Once the physical location of landmark attributes are captured the next set of data, internal facility attributes and details must be attained.

Figure 7

Laser Scanning & Extraction, Transformation, and Loading (ETL)

To understand how to leverage commercial tools, as well as their limitations, it is useful to appreciate how SN3's sister company, Newport News Shipbuilding, has addressed this challenge.

NNS has been in operation since the late 1800's and today includes several of the original facilities, with others spanning the decades since that time. The ability to modify, maintain and use facilities that are 40, 50, 60+ years old, from machine shops to foundries to office buildings, relies on the ability to provide maintenance and system upgrades safely, effectively and efficiently. Moreover, nuclear-powered carriers have been operating for more than 50-years. Over that period, changes made to those ships may be captured on paper drawings, or not, but the ship must be maintained, upgraded and operated. Laser scanning has been implemented in both of these environments (Figure 8) to capture the existing configuration – often significantly altered from historical documents and even from existing modern electronic 3-D design models; the more complex the facility the more it can depart from the original arrangement.

Figure 8

Several toolkits are available that capture surface features based on line-of-site tools. Moreover, sophisticated off-the-shelf software is able to take numerous laser raster-like scans and combine them into models that display 3-dimensionality. The challenge is then to take those representations and to decompose them into components. The D^3 planning benefits tremendously from identifying a pipe, a valve, a component foundation, which can be cataloged and manipulated to essentially reverse engineer a building information model (BIM). Originally, this technology required extensive design and engineering personnel touch time for attribute identification, to allow structural recreation with the necessary fidelity for D^3 reverse engineering. This need has been substantially addressed by using internally developed Extraction, Transformation, and Loading (ETL) codes.

ETL combines CAD, GIS, BIM software customization and post-processing into an extensively enhanced toolkit resulting in a near-CAD-level representation, which can then be used to animate and simulate assorted processes captured in the Adaptive Project Management tool.

The ability to recreate the necessary details to populate a BIM from an existing facility is a dramatic step forward toward optimizing D^3 analysis and strategic planning (Figure 9).

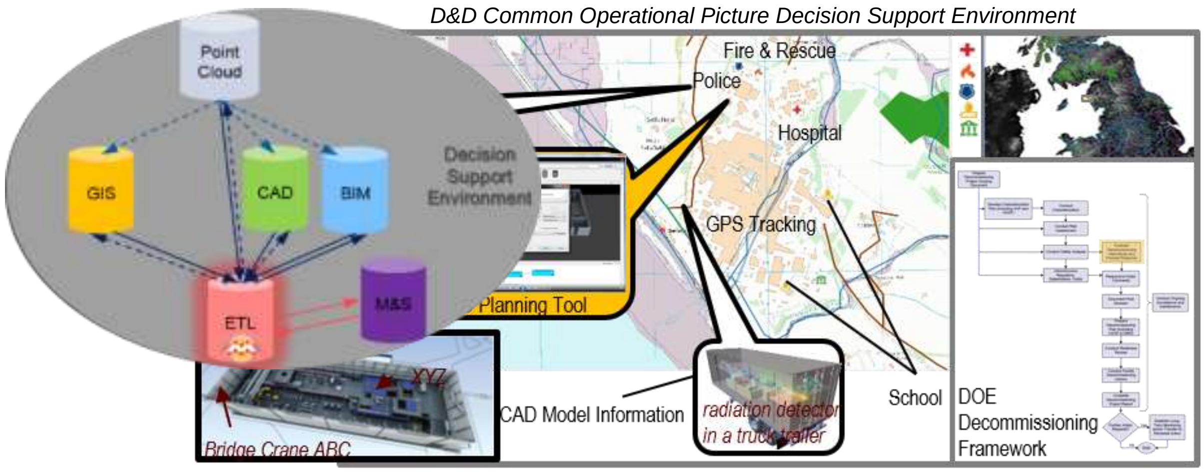


Figure 9

4. **ALARA Initiatives** – ManREM Prediction & Emergency Response Training

Two D[3] initiatives specifically focus on ALARA and radiation worker safety. The first comprises radiation field mapping for both remote and contact operations based on ManREM tracking. This capability uses modelling to calculate transient exposure using standard radiation decay operations. This tool provides the ability to track by individual, or summarized by trade or activity, based on 3-D spatial visualization of the physical layout including waste removal, packaging, storage and movement (Figure 10).

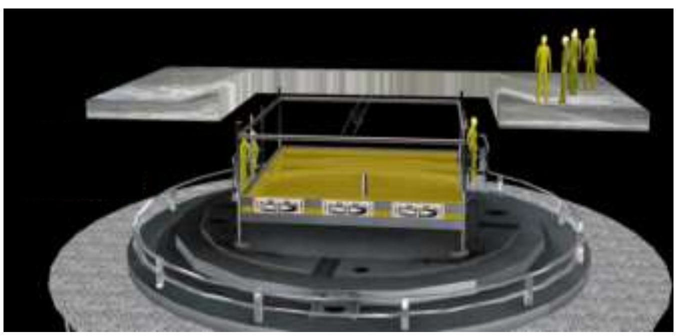


Figure 10

Numerous scenarios can be examined for informing the site-specific decision-making process.

The second initiative addresses radiological emergency response (RES) drills. RES training is costly from the outset, so incorporating changes resulting from evolving conditions or complicated by multiple locations, can cause the expense to become prohibitive. RES drills can discourage what otherwise could result in significant D[3] process improvements that would require re-customized virtual emergency response.

It is neither practicable nor potentially even feasible to start fires or simulate injuries for the sake of a good, live drill. The RES Training Simulator (RESTS) enables emergency response management to develop scenarios to simulate live events without operational halts or physical world constraints (Figure 11).

Figure 11

RESTS provides an interactive team-based virtual training and drill environment with an intuitive scenario configuration tool; immersive and collaborative training for radiological survey teams; a risk-free environment; RES experimentation and repeatability; reduced costs associated with trade resources, props and production stoppages.

5. Virtual Reality Immersive Environment

Virtual Reality (VR) is typically associated with creating fantastical environments for assorted gaming milieus. For SN3, however, VR is applied to the simulated real-world environment for numerous applications. The virtual environment can be used completely outside of the real world to enable, e.g., virtual facility walk-throughs and facility demolition sequencing.

Using commercial tools to map existing facility radiological contamination and activity location and intensity, this information can be overlaid into a 3-D product model built from rapid laser scanning and component parameterization (Figure 12). This allows for detailed step-wise deactivation, demolition, removal, and disposal planning. The VR environment can include component segmentation, complementary fixtures placement and rigging and identify optimum access and removal pathways. Incorporating reserved spaces for lifting and handling and, using the SN3 ManREM tracking tool, enables minimizing ManREM exposure to eliminate burnout, enhance cross training and improve safety.

Figure 12

Visualizing an entire structure, system or component before and while it is being decommissioned and demolished to minimize and optimize final disposal and waste disposition can drastically reduce rework and planning deficiencies, saving costs and improving safety.

We further uses this toolset to communicate simultaneously with our customer, the workforce and the regulator, responding to emergent discrepancies and minimizing delays and downtimes, capturing schedule efficiencies and slowdowns to minimize adverse impacts and provide an agile response.

Implementing Augmented Reality (AR) for large D^3 complements VR by using the same background data for program management, operations optimization and near real time progressing, but enables the field worker to access the information on-site. Secure communications take advantage of the available, open market secure wireless communication protocols that conform to the US Government's requirements for transmission of data up to and including Department of Defense (DOD) Secret classification. Augmented Reality complements and enhances the "traditional field tablet digital information" work environment by introducing a 3-dimensional (3D) model with applications that far surpass simply taking the desktop to the field.

Tablet based project software applications are used throughout the Architectural-Engineering-Construction (AEC) sector, and have even been launched for complex DOE programs. Since 2011, NNS has been investing in this field device capability as well as augmented reality to free the worker from the desk and enable them to have the information they need, when they need it and in the context that it is needed. NNS established that simply using a field tablet saved an average 35%, or more than 2.5 hours, per 8-hour day. This time savings was realized by delivering information to the field, completely eliminating the need for paper drawings and associated activities such as locating, printing and transporting hardcopies as well as revision tracking, storage, vaulting and configuration management.
What does AR bring that so surpasses the benefit of in the field engineering information? In addition to drawings or other project related data, Augmented Reality allows the worker to digitally overlay a 3D model onto the real world image, providing the user the ability to visualize entire pieces of equipment, systems and structure while the item D^3 operation is in progress. For example, one can view how the existing piping and framing structures appears over the course of the proposed deconstruction process. The AR mobile device can range from tablets to 3D glasses to smart phones. Visualizing an entire system or structure can drastically reduce rework and deficiencies in the final product as errors in the process can be spotted before a decontamination or removal process begins. This same toolset allows the user to communicate data back to the configuration-managed document regarding any field information that needs to be updated or reconfigured (Figure 13).

Figure 13

Another benefit of implementing AR is its ability to be transferred to a training toolset by providing information on the systems and equipment in the work environment. As AR digitally overlays to-scale information and maintains perspective of the overlay in relation to the actual system or equipment you can, for example, provide information on how to remove a piece of equipment by imbedding animations in the overlay to communicate the specific stepwise procedures. Being able to animate instructions reduces the amount of ambiguity that can often accompany a written procedure or instruction. In addition to animations, imbedded videos or other digital media can accompany the audio enabled work instruction to provide the trainee many different ways to learn. For example, if there is a large system that is costly and difficult to replicate for use in an offsite setting, an AR application can be created that allows digital overlays of information atop the system to communicate any relevant details, constraints and safety challenges. There is really no limit to what can be displayed in the AR environment.

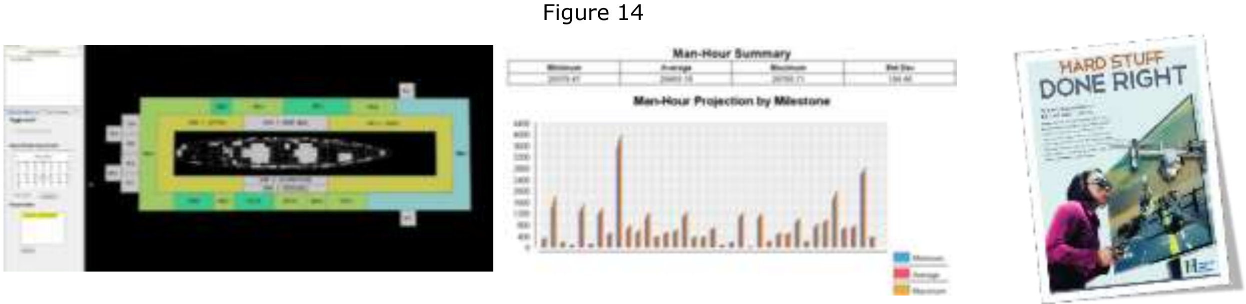
In addition to training, AR complements the engineering field applications with real time Expert-Field-Worker communications by incorporating Remote Telepresence. The field worker's onsite view can be shared real time with the offsite subject matter expert (SME) for immediate assistance. For example, if a worker is having difficulty locating a specific part in a complex system, the mobile field device screen can be shared so that the SME can literally draw on the screen to precisely locate the part in question. Once the AR toolkit is added to the tablet-based environment, the field applications rapidly multiply.

CONCLUSIONS

Today, Stoller Newport News Nuclear is applying state-of-the-art tools to the commercial and government agency nuclear facility decommissioning, demolition and disposal environment to:

- address the complex, highly critical, and precisely procedural-driven D^3 evolutions to reduce cost, schedule and risk;
- provide flexibility to evaluate current process as well as experiment with areas of improvement including rapid development of equipment layouts and manning levels;
- assess alternate equipment quantities and arrangements based on program requirements and to identify the optimal sequence of operations;
- monitor spatial arrangement, material routing and optimal disposal based on real-time material flow and site operations feedback;
- bring situational awareness and identification of areas for improvement;
- allow analysis of future concepts of operation;
- create a rich, 3-dimensional virtual environment based on building information and engineering drawings for planning and movement in all 3 dimensions;
- plan around roadblocks and delays and enhance training objectives;
- make available operations-based ManREM tracking capability including exposure using standard radiation decay operations;
- create logistics for coordinating various activities given rules and constraints to optimize resource usage in confined access areas.

Figure 14



Together these tools (Figure 14) - Adaptive Project Management using Agile Stochastic Scheduling, a Modular D^3 Flexible Infrastructure Laboratory, Facility Deconstruction using a Geospatial Toolkit, ManREM Prediction & Emergency Response Training, and Virtual Reality Immersive Environment, create a shared vision for how to bring adaptive and digital technologies together in the D^3 environment.

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