PROCESS FLOW DIAGRAMS AND NODE DESCRIPTIONS FOR THE SNF WMS*

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To support spent nuclear fuel (SNF) Waste Management System (WMS) architecture studies for the US Department of Energy (DOE), process flow diagrams and node descriptions (PFDNDs) have been developed to describe the various WMS material flow operations. PFDNDs assist analysts in (1) developing functions and requirements for the waste management system, (2) planning and evaluating scenarios for transportation and storage of spent nuclear fuel, and (3) researching dose and duration data for individual processes. PFDNDs are capable of representing scenarios investigated during recent studies of various potential configurations of the WMS completed for DOE's Nuclear Fuels Storage and Transportation (NFST) Planning Project. The PFDNDs reflect potential operations that may occur as part of an integrated SNF management system, including repackaging, bare fuel and canistered fuel handling and transportation, storage operational considerations, and processes that may be necessary for repackaging to accommodate future repository system interfaces. The PFDNDs are contained within a Microsoft® Visio file, which is the platform for this NFST project. The Visio file also contains links to node descriptions describing the processes contained within the PFDNDs, along with equipment lists of items that might be needed for each operation. PFDNDs use information gleaned from public sources and various DOE studies.

I. INTRODUCTION

NFST, under the US DOE Office of Nuclear Energy's, Office of Fuel Cycle Technologies, is performing integrated SNF management system analysis and applying systems engineering and decision analysis principles to inform future decisions regarding an integrated SNF management system. The WMS system architecture studies provide the DOE and others with information regarding the various alternatives for managing SNF generated by the current fleet of light water reactors operating in the U.S as well as any potential new reactor designs. To support SNF WMS architecture studies for DOE, PFDNDs have been developed to describe the various WMS material flow operations and have been described in previous work.[1] This paper is an update to that work. PFDNDs assist analysts with developing WMS functions and requirements, planning and evaluating scenarios for transportation and storage of SNF, and researching dose and duration data for individual processes. This ongoing work is a collaboration among Oak Ridge National Laboratory (ORNL), Argonne National Laboratory (ANL), and Savannah River National Laboratory (SRNL) for DOE.

PFDNDs represent process flows for various SNF management system strategies and scenarios. The level PFDND slide can be seen in a conceptual view in Fig. 1. The PFDNDs are useful for flowcharting and visualizing the evolving requirements for various aspects of the NFST. Due to the highly detailed nature of the PFDNDs, the representative figures in this paper reflect conceptual top-level views of the PFDNDs with the intent merely of showing the structure of the PFDNDs as well as the various types of pathways that a user can explore.

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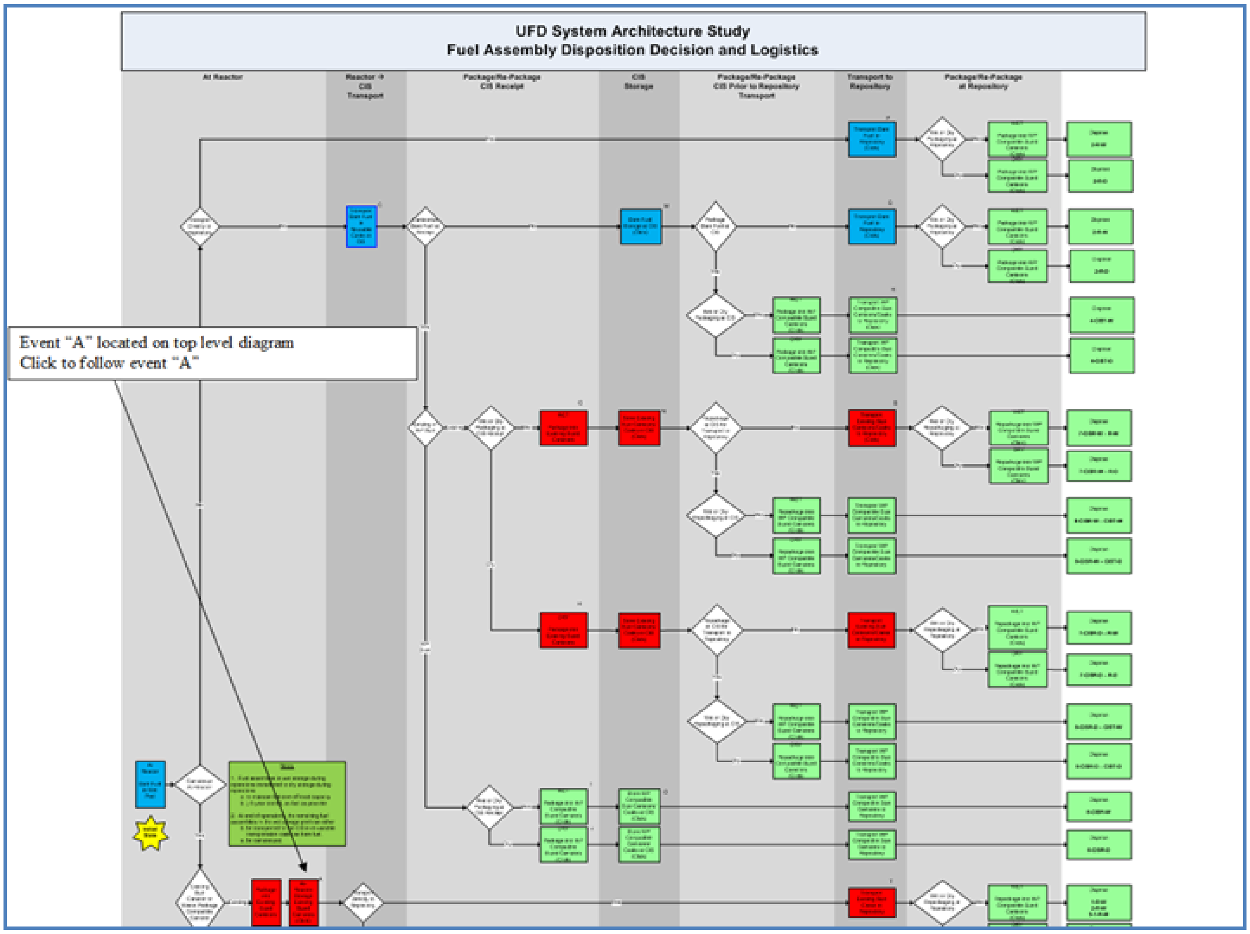

Fig. 1. Top tier PFDND scenario (conceptual view).

PFDNDs represent process flows for various SNF management system strategies and scenarios. PFDNDs have a multilayered organization, with one main level on top, followed by multiple successive layers underneath. These tiers not only allow the analyst to see the broad route from the reactor to the repository from a top level, but they also focus on the basic steps involved in performing any singular operation. The basic assumptions and possible options for the current implementation of the PFDNDs are listed below.

(1) Options are provided for both dry and wet repackaging.
(2) Storage options for existing size canisters include vertical storage on a pad and horizontal storage in a horizontal storage module at an independent spent fuel storage installation (ISFSI).
(3) Fuel is currently assumed to be transported as either bare fuel or canistered fuel[1]. Bare fuel is generally loaded into a basket within the cask. Existing size canisters and waste package size canisters are transported in transportation overpacks instead of casks. Future work will involve adding detailed processes that differentiate between different casks, overpacks, and vendors.
(4) Assumed transportation options include rail, heavy haul truck, and barge. It is assumed that if there is an interim storage facility (ISF), it will have rail access and a direct connection to a repository. Currently it is assumed that once a shipment uses a rail line, it will continue to use a rail line and will not be transferred to a barge or heavy haul truck.
(5) The sites listed are a reactor, an ISF, and a repository. The reactor and repository are used in

[1] Pursuant to the Standard Contract, the U.S. Government will only accept bare used nuclear fuel (10 CFR 961.11, Article VI.A.1.(a)). A modification of the Standard Contract would have to be agreed to in order for the U.S. Government to accept used nuclear fuel in dual-purpose canisters. The potential impacts of this provision of the Standard Contract were not factored into this report.

every scenario as beginning and ending sites for the SNF.

PFDND work is focused on two main areas. First, the PFDND framework is under continual development to add features and capabilities anticipated for use in the architectural studies. Second, the tool is being used as it evolves to perform architectural studies, and its content is being updated to capture additional material process flows and details. Section II describes the additional features and capabilities of the PFDND capture and analysis tools. Section III describes the development and application of PFDNDs relative to two ongoing architectural studies. This includes work on the Fleet Maintenance Facility and the Cask Maintenance Facility.

II. PFDND Capture and Analysis Tools

II.A. Centralized Used Fuel Resource for Information Exchange (CURIE) Document Resource

Making use of Visio's hyperlink capability[2], various objects represented in the PFDNDs can be linked to supporting or referenced documents from a central system that is accessible to all registered users. A central electronic document storage and retrieval system that allows multi-tiered access control to these various documents is a necessary part of the development of this architecture. To this end, an SNF document and data access resource has been created: the Centralized Used Fuel Resource for Information Exchange (CURIE - http://curie.ornl.gov/) is being used in the further development and use of the PFDNDs.

CURIE eliminates the problem of linking documents to local drives and collaboration sites that restrict access through firewall constraints.

II.B. Integration with Microsoft Products

Microsoft products allow for the ability to integrate the results of the Visio flowcharts with several additional tools that are useful in architecture studies. Integration with three commonly used Microsoft tools (Word, Excel, and Access) is discussed below.

II.B.1. Integration with Word

The PFDNDs provide a tool where investigators can explore WMS scenarios. The results of these investigations are typically expected to be included in documented reports. Microsoft products allow for linking the output from one product to another. This is particularly useful, as multiple scenarios can be run with Visio, and the output of these scenarios automatically linked or embedded in standardized reports in Word. This simplifies the process when reports must be generated multiple times for multiple scenario iterations. Macros within Visio and/or Word can be used to automate report generation based upon desired scenario inputs.

II.B.2. Integration with Excel

Visio and Word allow for the visualization and representation of conceptual ideas. An important quantitative extension of the PFDNDs can be developed through the integration of Visio and Excel. This is possible as each of the objects displayed in Visio can be assigned qualitative or quantitative properties (Fig. 2). These properties can be established to allow quantification of certain aspects of the system architecture scenarios. To accomplish this, the properties in Visio are linked to an Excel spreadsheet. Cell formulas and macros in Excel can be used to evaluate these processes, with the resulting values displayed in Visio. A conceptual example of this capability can be seen in Fig. 2, where the cost, duration, and radiation dose values for the process have been established as parameters in Visio. A corresponding conceptual Excel spreadsheet has been developed that provides the means to calculate these values for various scenarios (Fig. 3).

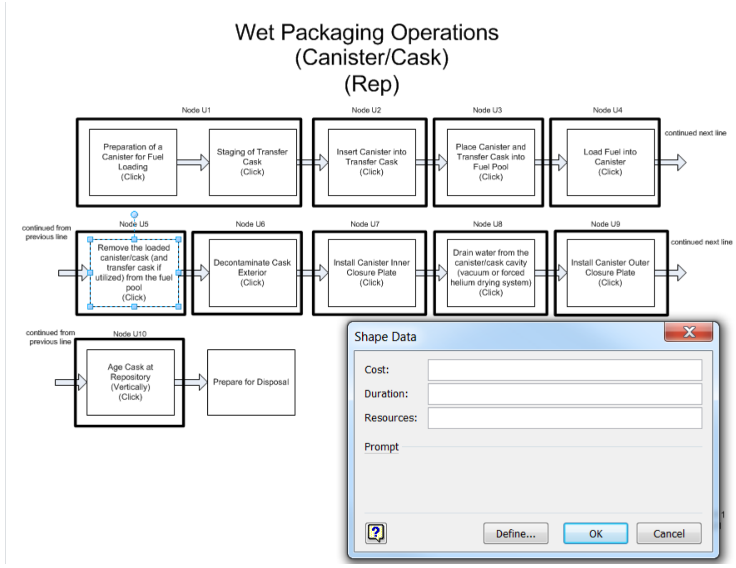

Fig. 2. Example node Visio property values with links to cell values in Excel (conceptual view)

R20C3 — Operations for Transportation from Reactor To Repository

Node	TASK	Activity	SCENARIO	STEP	Cost	Duration	Resources	Dose	Heavy Lifts	Operations
F1	Transport to Repository	Operations for Transportation from Reactor To Repository	9-1	Set Site Specific Campaign Plan						
F2a	Transport to Repository	Operations for Transportation from Reactor To Repository	9-1	Transport Storage Cask to Cask Receiving Bay						
F2b	Transport to Repository	Operations for Transportation from Reactor To Repository	9-1	Prepare Transfer Cask, Storage Cask, and Canister						
F2c	Transport to Repository	Operations for Transportation from Reactor To Repository	9-1	Dock Transfer Cask with Storage Cask and Retrieve Canister						
F2d	Transport to Repository	Operations for Transportation from Reactor To Repository	9-1	Move Canister and Transfer Cask to Cask Decontamination Area						
F3	Transport to Repository	Operations for Transportation from Reactor To Repository	9-1	Transfer Loaded Transportation Cask to Destination Operations Area						
F4	Transport to Repository	Operations for Transportation from Reactor To Repository	9-1	Mode of transportation from the origin site and route information						
F5	Transport to Repository	Operations for Transportation from Reactor To Repository	9-1	General Receipt Operations for Receiving of Cask						
F6	Transport to Repository	Operations for Transportation from Reactor To Repository	9-1	Unloading Cask at Repository						
F7	Transport to Repository	Operations for Transportation from Reactor To Repository	9-1	Unloaded Cask at Repository						
F8	Transport to Repository	Operations for Transportation from Reactor To Repository	9-1	Transfer Canister from transfer cask to storage cask and move to ISFSI (Vertically)						

Fig. 3. Spreadsheet linked to Visio property values (conceptual view)

II.B.3. Integration with Access

Whereas Word provides a convenient means of automatically integrating the output of PFDNDs into reports, and Excel allows for integration of flowcharting visualization with quantitative analysis, Microsoft Access provides a means of sorting and filtering quantified scenarios that have been developed. This is accomplished by taking advantage of the database query tools available in Microsoft's Access program. Access also offers powerful report generation capabilities. A sample conceptual database example can be seen in Fig. 4 where the Visio properties are fields in the database. Currently no comprehensive database has been developed for the PFDNDs; only the architecture necessary to implement this has been completed. Further work to develop this in conjunction with the PFDND is ongoing.

Node	Activity	PROCESS	STEP	Duration	Cost	Resources	Issues	References	NOTES	Click to Add
C1	Reactor a CIS Ti	Transport Bare	Set Site Specific Campaign Plan					BNFL 3	TBD FY14	
C2	Reactor a CIS Ti	Transport Bare	Receive the Bare Fuel Cask (BFC)					BNFL 3	TBD FY15	
C3	Reactor a CIS Ti	Transport Bare	Put the BFC into the Pool					BNFL 4	TBD FY15	
C4	Reactor a CIS Ti	Transport Bare	Load the fuel into BFC					BNFL4,5,6	TBD FY15	
C5	Reactor a CIS Ti	Transport Bare	Remove the cask from the pool					BNFL 1,7	TBD FY15	
C6	Reactor a CIS Ti	Transport Bare	Bolt BFC closure lid and drain water fro					BNFL 1.1	TBD FY16	
C7	Reactor a CIS Ti	Transport Bare	Vacuum dry BFC fuel cavity and backfill					BNFL 1.1	TBD FY15	
C8	Reactor a CIS Ti	Transport Bare	Move Loaded Transportation Cask to De					BNFL 1.1	TBD FY15	
C9	Reactor a CIS Ti	Transport Bare	Mode of transportation from the origin					BNFL 1.1	TBD FY15	
C10	Reactor a CIS Ti	Transport Bare	General Receipt Operations for Receivi					BNFL 2	TBD FY15	

Fig. 4. Spreadsheet linked to conceptual Access database.

II.B.4. PFDND Tool Navigation and Use

The PFDNDs allow for an easy way to see all the potential scenarios that SNF can take in the once-through fuel cycle ending with waste package size containers disposed of in a geologic repository. The analyst controls each scenario by using hyperlinks to move from the reactor worksheets to the repository worksheets. The analyst can also reverse the steps through the model when needed.

III. ARCHITECTURE STUDIES

Because the options for SNF disposition include multiple packaging, storage, and transportation options, system architecture studies must consider potential process permutations to ensure proper integration into an overall disposition strategy. These architectural studies have the following objectives[3]:

- Provide quantitative information on a broad range of SNF management alternatives and considerations.
- Develop a flexible, integrated approach to evaluate storage, transportation, and disposal options.
- Evaluate the impacts of storage choices on SNF storage, handling, and disposal options.
- Identify alternative strategies and evaluate them with respect to cost and flexibility.
- Consider a broad range of factors, including repository emplacement capability, thermal constraints, repackaging needs, storage and transportation alternatives, and their impacts on utility operations.

The PFDND scenarios were based on recent system architecture studies completed by NFST (Reference 3). These scenarios are illustrated in flowcharts, and they represent various potential flow paths for the SNF life cycle.

Recent development has included two areas for consideration: (1) fleet maintenance, which represents the logistics of managing a transportation fleet associated with SNF movement, and (2) cask maintenance, which focuses on SNF storage and transportation cask activities. The use of the PFDNDs for these architectural studies is discussed in the sections below.

III.A. Fleet Maintenance PFDNDs

Fleet maintenance PFDNDs have recently been developed to support ongoing trade studies and scenario development. Fleet maintenance entails providing the necessary services for the transportation fleet to ensure the movement of SNF and its associated equipment. Trade studies and scenario development for maintenance facilities is ongoing. Functions and requirements must be established to facilitate this task. The PFDNDs provide an integrating tool to establish the functions and requirements for NFST activities.

The PFDNDs are useful for flowcharting and visualizing the evolving requirements for various aspects of the NFST. As a starting point, preliminary, high-level transportation fleet functions and requirements have been developed for use in NFST studies (Fig. 5). These functions and requirements are visually organized in a flowchart, providing a mechanism to correlate them with other system requirements. Other functions and requirements are being included for various facilities and processes. These will be linked together through Excel and/or Access.

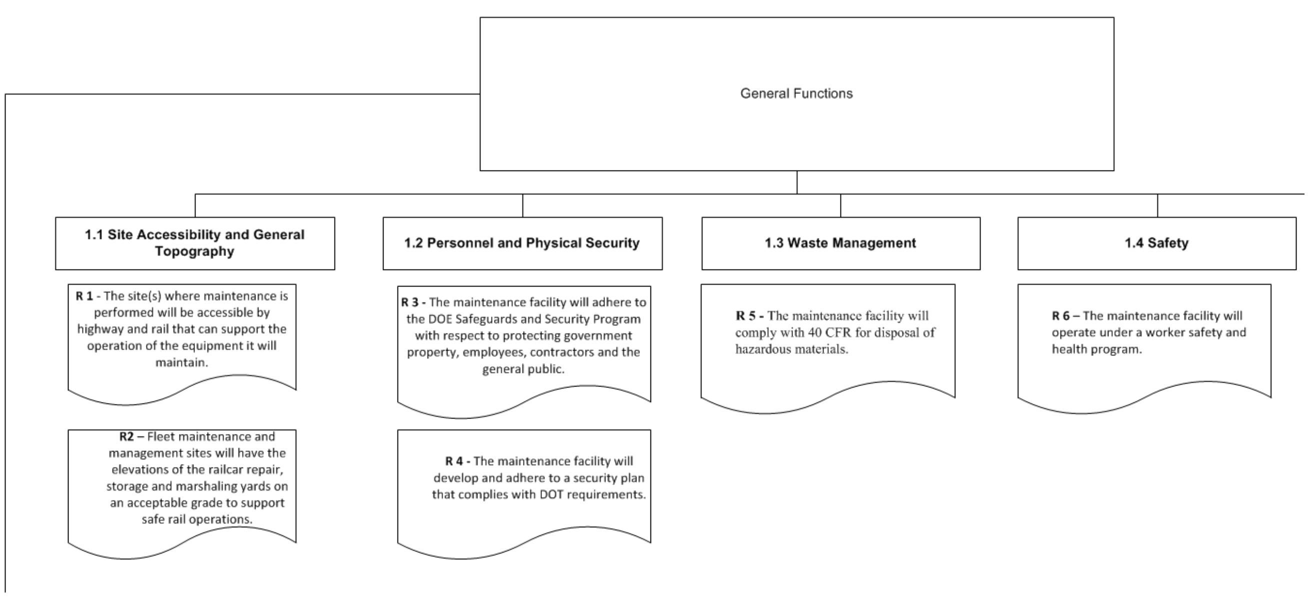

Fig. 5. Transportation Fleet Requirements Flowchart (conceptual view).

III.B. Cask Maintenance PFDNDs

PFDNDs help visualize various cask maintenance activities including (1) cask inspection, (2) cask testing, (3) cask port maintenance, (4) cask trunnion maintenance, and (5) cask basket maintenance. A conceptual flowchart for the overall process flow for cask maintenance is seen in Fig. 6. In this figure, the basic activities are shown in relation to one another and in relation to the facility areas required to perform these functions. Each activity has its own flowchart depicting its established processes, which are linked together through the Microsoft tools discussed above. A brief description of these activity areas is included below.

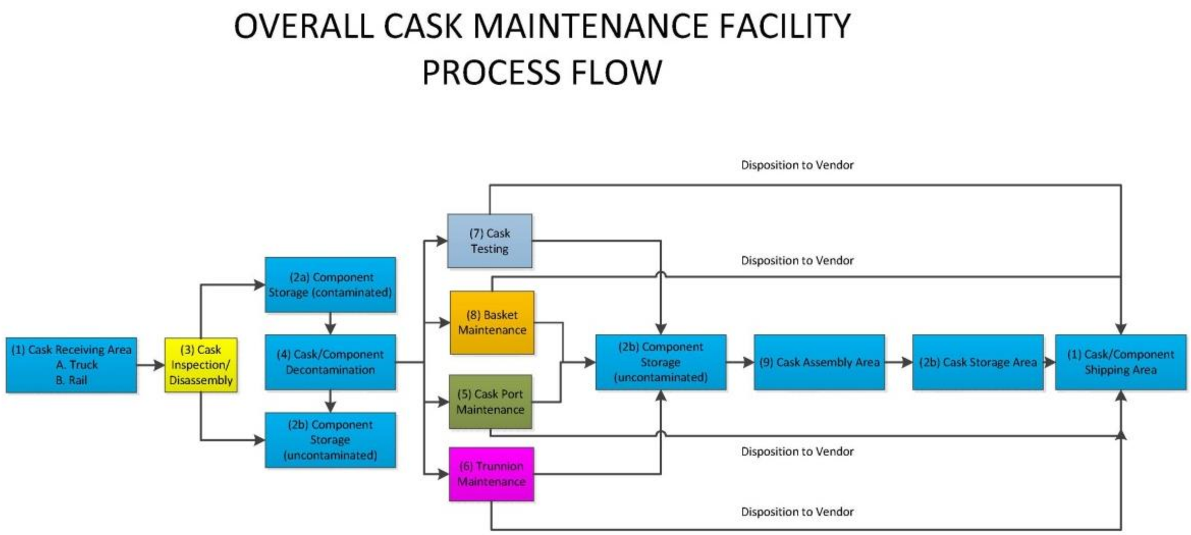

Fig. 6. Cask Maintenance Process Flow Flowchart (conceptual view)

III.B.1. Cask Inspection

Once the cask is received, it undergoes inspection. Major cask inspection activities include (1) exterior cask inspection, (2) cask lid removal and replacement, and (3) inspection and replacement of the O-ring and lid bolts.

III.B.2. Cask Testing

The cask is tested to ensure its integrity under design basis conditions. Major cask testing activities include (1) thermal tests, (2) shield tests, and (3) leak tests. In addition to these activities, the cask is also decontaminated, and the O-rings are inspected and replaced.

III.B.3. Cask Port Maintenance

Cask port maintenance is necessary to ensure the leak-tight integrity of the cask under design basis conditions. Major cask port maintenance activities include (1) inspection of bolts and O-rings, (2) boundary leak/seal tests, and (3) replacement of the port cover.

III.B.4. Cask Trunnion Maintenance

Cask trunnions must be maintained to ensure the integrity of the lifting points used for cask movement under design basis conditions. The major testing activities include (1) nondestructive examination (NDE) of welds associated with trunnion lifting points, (2) inspection /replacement of trunnion bolts and threads, and (3) load testing.

III.B.5. Cask Basket Maintenance

Cask baskets which hold the SNF undergo maintenance to ensure their integrity under design basis conditions. For casks with removable baskets, the major testing activities include (1) basket removal, (2) inspection of the basket and gasket, (3) change out/decontamination of the basket, and (4) basket storage for future use.

IV. CONCLUSIONS

The logistics of SNF transportation and storage are complex. Architectural studies are necessary to determine optimum logistical processes. To facilitate this, Process Flow Diagrams and Node Descriptions (PFDNDs) have been created to provide visualization, as well as quantification of the processes through integration with other Microsoft applications. This tool set allows for rapid scenario development and evaluation and is being developed further as part of the NFST program. Fleet and cask maintenance have recently been added to the PFDNDs, and the PFDNDs are being expanded to include system-dependent steps and processes as additional data become available. The PFDNDs are currently being used to quantify the number of heavy load operations and will continue to be tailored to aid various aspects of NFST systems analysis.

REFERENCES

1. R. A. JOSEPH III et. al., *Process Flow Diagrams and Node Descriptions for the UNF Waste Management System*, Institute of Nuclear Materials Annual Meeting (July 2014).
2. Microsoft Visio 2010, Microsoft Corporation.
3. M. NUTT et al., *Used Fuel Management System Architecture Evaluation, Fiscal Year 2012* (October 31, 2012).