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Defense Nuclear Material Stewardship Integrated Inventory Information Management System (IIIMS)

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Abstract

Sandia National Laboratories was tasked with developing the Defense Nuclear Material Stewardship Integrated Inventory Information Management System (IIIMS) with the sponsorship of NA-125.3 and the concurrence of DOE/NNSA field and area offices. The purpose of IIIMS was to modernize nuclear materials management information systems at the enterprise level. Projects over the course of several years attempted to spearhead this modernization. The scope of IIIMS was broken into broad enterprise-oriented materials management and materials forecasting. The IIIMS prototype was developed to allow multiple participating user groups to explore nuclear material requirements and needs in detail. The purpose of material forecasting was to determine nuclear material availability over a 10 to 15 year period in light of the dynamic nature of nuclear materials management. Formal DOE Directives (requirements) were needed to direct IIIMS efforts but were never issued and the project has been halted. When restarted, duplicating or re-engineering the activities from 1999 to 2003 is unnecessary, and in fact future initiatives can build on previous work. IIIMS requirements should be structured to provide high confidence that discrepancies are detected, and classified information is not divulged. Enterprise-wide materials management systems maintained by the military can be used as overall models to base IIIMS implementation concepts upon.

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Executive Summary

Each DOE/NNSA site has a unique mission within the nuclear weapons complex, and individual sites have historically developed individual internal information systems to support local nuclear material accountancy. Comparable analysis and system development have not occurred at the level of the entire DOE/NNSA complex (the so-called “enterprise level”) aside from certain systems such as the Nuclear Materials Management and Safeguards System. The initial purpose of the Defense Nuclear Material Stewardship Integrated Inventory Information Management System (IIIMS), therefore, was to modernize nuclear materials management information systems at the enterprise level.

Sandia National Laboratories (SNL) was tasked with developing IIIMS with the sponsorship of NA-125.3 and the concurrence of DOE/NNSA field and area offices. Several projects over the course of several years attempted to spearhead the nuclear materials management modernization efforts. Much of the modernization work was fractured because different facilities were tasked with independent efforts. Readiness in Technical Base and Facilities (RTBF) funding for IIIMS work (for FY04 and beyond) was recently redirected in order to free moneys for more urgent priorities, and the IIIMS project did not conclude its mission. This report is, therefore, designed to capture the knowledge from IIIMS project in a single place, and provide a jump start in the event that some similar effort is revived in the future.

Material management modernization to-date has been restricted to a personal computer platform upgrade of Nuclear Materials Management & Safeguards System, the development and deployment of the Local Area Network Material Accounting System at selected sites, stand-alone software material control and accountability applications, and tools including spreadsheets and relational databases at almost all sites.

The scope of IIIMS was broken into two distinct parts: 1) broad Enterprise-oriented materials management; and 2) materials forecasting. Specific requirements, while not derived directly from DOE Orders were advanced from different funding sources, over several years during the life of the project. A major requirement was for a permanent, complex-wide unique identifier which provides the capability to track an item’s movement through the complex, and the capability to track an item’s history as the item changes or is grouped with or removed from other items. The IIIMS prototype was developed to allow the multiple participating user groups to explore nuclear material requirements and needs in detail. The IIIMS Prototype was developed with SQL Server having an Inxight VizServer user interface. VizServer is a scalable enterprise solution for visualizing and exploring large data collections. VizServer creates graphical data visualizations and is deployed from a web browser.

The purpose of material forecasting was to determine nuclear material availability over a 10 to 15 year period in light of the dynamic nature of nuclear materials management. Existing internal site systems plan current detailed operations schedules and drove the material forecasting work since Enterprise-level requirements had not been defined. The forecasting tool utilized linked EXCEL spreadsheets that manipulate material availability at Oak Ridge Y-12 National Security Complex, and reduced Y-12 process flow and plant knowledge to material balance supply and demand equations.

Formal Enterprise level requirements (i.e., DOE Orders) were never issued to direct IIIMS efforts. As such, one lesson learned is that without direct and relevant development of an IIIMS or unified information systems regulation in the form of one or more DOE Directives, any attempt at developing an Enterprise-wide IIIMS will fail. The second lesson learned is that without structured requirements, the constant change of responsible personnel in authority positions at DOE/NNSA HQ, despite anyone’s best efforts and intent, will thwart the long-term efforts of even the best-organized operation.

A top-down approach to IIIMS requirements would first necessitate inclusion of the reporting functions provided by NMMSS, to provide the very same output reports which facilities and U.S. government offices use to manage and safeguard nuclear materials. The migration of NMMSS to the eXtensible Markup Language (XML) for increased capability and integration, as well as Sun Microsystems or PC servers and PC-based desktop computing, may also be important requirements. In most cases, a new NMMSS supporting the Enterprise would have elements of the old NMMSS. For example, production of COEI reports for each facility would be necessary, as would NRC licensee and DOE contractor reports detailing semiannual material balance data. Transaction data for transfers, foreign retransfers, operating losses, inventory differences, burnup, contract reclassifications, origin swaps, project number changes, shipper/receiver data comparisons, and other changes affecting inventory data must be included.

Duplicating or re-engineering the activities from 1999 to the present is unnecessary, and in fact future initiatives can build on previous IIIMS work. Optimum (minimal) cost is not necessarily an appropriate goal. The U.S. Government is willing to pay a premium for safeguards and security systems. IIIMS requirements should be structured to provide high confidence levels that discrepancies are detected, and classified information is not divulged. Some examples of government successes in the area of integrated, Enterprise-wide materials management systems already exist, are maintained by the military, and can be used as overall models to base IIIMS implementation concepts upon. Logically, any one of the sites in the nuclear weapons complex could develop the computerized database IIIMS system(s) in conjunction and/or collaboration with the Defense Programs Nuclear Materials Working Group, made up of representatives from five NNSA sites.

Glossary

AEC	Atomic Energy Commission
B&R	financial codes
BPR	Business Process Reengineering
CIO	Chief Information Office
CMTS	Compliance Monitoring and Tracking System
COEI	Composition of Ending Inventory report
DIAMONDS	Defense Integration and Management of Nuclear Data Services
DNMS	Defense Nuclear Material Stewardship
DoD	Department of Defense
DOE/NNSA	Department of Energy/National Nuclear Security Agency
DOT	Department of Transportation
DTRA	Defense Threat Reduction Agency
DU	depleted uranium
DYMCAS	Y-12 Dynamic Special Nuclear Material Control and Accountability System
EM	Office of Environmental Management
ENI	Enterprise Network Infrastructure
EPA	Environmental Protection Agency
FMC	Field Management Council
FY	fiscal year (FY03 – fiscal year 2003)
HEU	highly enriched uranium
HQ	DOE/NNSA Headquarters
IAEA	International Atomic Energy Agency
IIIMS	Integrated Inventory Information Management System
INMM	Institute of Nuclear Material Management
ITP	In the Pan
LANL	Los Alamos National Laboratory
LANMAS	Local Area Network Material Accounting System
LEP	Lifetime Extension Program
Li	lithium (nominally lithium-6)
LLNL	Lawrence Livermore National Laboratory
LRIS	Location Reporting Identification Symbol

MC&A	material control and accountability
MOA	Memorandum of Agreement
MOX	mixed oxide
MRC	Material Readiness Campaign
NA-115	Office of Stockpile Assessments and Certification
NA-117	Office of Facilities Management and ES&H Support
NM Data Tool	National Nuclear Security Administration (NNSA) Data Analysis Tool [Haselwood Enterprises, Inc.]
NMIA	Nuclear Materials Inventory Assessment
NMIS	Nuclear Materials Information System (pre-NMMSS accounting data kept in manual form)
NMMSS	Nuclear Materials Management and Safeguards System
NMSI SIM	Nuclear Material Stewardship Initiative – Strategic Information Management
NMWG	Nuclear Materials Working Group
NNSA/AL	Albuquerque Operations
NNSA/OAK	Oakland Operations
NPT	Treaty on the Non-Proliferation of Nuclear Weapons
NRRC	Nuclear Risk Reduction Center
NUMIS	Nuclear Management Information System
NWC	nuclear weapons complex
NWCOM	Nuclear Weapons Contingency Operations Module
NWIS	Nuclear Weapons Inventory System
ORNL/Y-12	BWXT Y-12 National Security Complex
OTD	Out the Door
Pantex	BWXT Pantex Plant
PC	personal computer
PDD	Presidential Decision Directive
PO-4	Office of Policy
PRIS	Program Reporting Identification Symbol
Pu	plutonium
PX	BWXT Pantex Plant
RIS	Reporting Identification Symbol
RTBF	Readiness in Technical Base and Facilities
SE&A	Strategic Engagements and Awareness Program
SIPRNET	Secret Internet Protocol Router Network
SLEP	Stockpile Lifetime Extension Program
SNL	Sandia National Laboratories
SNM	Special Nuclear Material
SQL	Structured Query Language
START	Strategic Arms Reduction Talks
STT	Standardization Task Team
SWIM	Special Weapons Information Management System
USAF/XONP	U.S. Air Force Treaties and Agreements Branch
WMS	Weapon Material Stewardship
WMTP	Warhead Monitoring Technology Project
Y-12	BWXT Y-12 National Security Complex
YAO	NNSA Y-12 Area Office

1. Introduction

The Defense Nuclear Material Stewardship (DNMS) Integrated Inventory Information Management System (IIIMS) project was intended to provide a path toward modernizing nuclear materials management information systems, to create true electronic connectivity directly with each of the DOE/NNSA sites, and to provide appropriate reporting to headquarters. This was conceived as an enterprise-level" approach and would necessarily require a large degree of coordination. Specific requirements, while not derived directly from DOE Orders were advanced from different funding sources, over several years during the life of the project. The IIIMS project was most recently funded by the Office of Facilities Management and ES&H Support, NA-117, and managed by the Office of Stockpile Assessments and Certification, NA-115. Funding from NNSA was directed through Sandia National Laboratories (SNL) Readiness in Technical Base and Facilities (RTBF) Program. The RTBF Program includes the following thrust areas: operations of facilities, program readiness, special projects, weapon incident response, and construction (FY 2002 Institutional Plan, SAND2001-3141). The RTBF program provides funding for research and development to support nuclear weapon campaigns, lifetime extension programs, and stockpile lifetime extension programs.

The IIIMS project did not conclude its mission. In March 2003, RTBF funding for fiscal year 2004 (FY04), and beyond, was redirected by the SNL Director of Program and Complex Integration in order to free funding for more urgent priorities, and the IIIMS project was instructed to terminate gracefully (Detry 2003). The overall nuclear weapons program was under stress attempting to meet expectations in FY04 and beyond within the expected levels of funding, and four circumstances contributed to the decision to terminate DNMS activities. First, the source of funding for DNMS, called RTBF Program Readiness, was taking a substantial cut in FY04. Second, NNSA sponsorship was weaker for DNMS than for many other parts of the weapons program, including other activities funded under RTBF Program Readiness. Third, the recently completed review of the twenty-two strategic capabilities by the SNL program directors generated concern for the long-term viability of robotics projects in areas important to the United States, and robotics projects were to receive an infusion of funding. Finally, the weapons program was facing some severe funding problems for FY04 and beyond, driven by increasing urgent requirements compared to essentially flat (less than inflation) budget growth.

With this termination, every effort was made to complete work planned for FY03, with work appropriately documented so the knowledge gained over the past years would not be lost (Detry 2003). This report provides closeout documentation of tasks accomplished prior to intended modernization of IIIMS. This report provides a framework for future nuclear materials management information system modernization efforts which could be applied in the DOE/NNSA enterprise without substantial reinvention of modernizations already accomplished.

This report is, therefore, designed to capture the knowledge from IIIMS project in a single place, and provide a jump start in the event that some similar effort is revived in the future. This report and consists of several sections. First, this report defines the purpose of the IIIMS project and its emphasis or thrust areas. It then provides some of the historical background and context for the project, since the project emphasis changed several times over the life of the project. Next, it describes key deliverables and tools developed to support nuclear materials management including:

1) enterprise-level perspective on the project and the IIIMS prototype developed to this point;
2) Material forecasting model development for highly enriched uranium (HEU), depleted uranium (DU), and lithium (Li); and
3) Nuclear Materials Inventory Assessment (NMIA) consolidation and reporting as defined and addressed by the NNSA Data Analysis Tool (Haselwood Data Tool).

The final section of this report presents IIIMS systems requirements, some conclusions, lessons learned, and next possible steps.

2. Purpose

The initial purpose of the IIIMS project was initiate an association or collaboration with the DOE/NNSA nuclear weapon sites (predominantly Lawrence Livermore National Laboratory, Los Alamos National Laboratory, Y-12 National Security Complex at Oak Ridge, Pantex Plant, and Sandia National Laboratories,) along with DOE/NNSA headquarters (HQ) to modernize nuclear materials management information systems. Each DOE/NNSA site (administrative units, laboratories, and plant operations) has it's own mission and role within the nuclear weapons complex, and each has developed (some independently) nuclear material management information systems to support local operations. In the last few years, little comparable analysis and system development has occurred between sites and headquarters at what would be considered an enterprise level. Some work has been done for specific functions resulting in the Nuclear Materials Management and Safeguards System (NMMSS) database.

In addition, the definition of the enterprise was not always consistent. In some cases the enterprise was considered to be all of DOE (including NNSA EM and Waste Management), and as such exhibited some centralized coordination between Headquarters DOE/NNSA and the sites. In other cases the enterprise was considered to be only NNSA (excluding DOE), and was specifically focused on active weapons work to the point when disposition activities were initiated (at which time the scope of the enterprise was again broadened to all of DOE). Subsequently a third relationship emerged which addressed the cross-site relationships (lab-to-lab, or lab-to-operations) independent of, or in addition to, the corporate-to-site relationship.

In 2000-2001, when enterprise-level requirements were not emerging or being identified, NNSA/NA-125.3, and later the DOE/NNSA Chief Information Officer (CIO), shifted the responsibility of modernizing materials management information systems to the sites themselves, as much by inaction as by verbal direction. In this case, IIIMS was expected to provide tools for individual sites, but within a context of later supporting the enterprise. It was at this time that material forecasting work specifically for Y-12 National Security Complex was initiated.

Finally, there was an expectation that the new Albuquerque Service Center of DOE/NNSA (with a probable default scenario that SNL would actually maintain and operate the IIIMS system and the computer server network(s) required for implementation) develop the computerized database IIIMS server system(s) in conjunction and/or collaboration with the Defense Programs Nuclear Materials Working Group. This group was made up of representatives from five NNSA sites. No further work of this kind has proceeded past some basic conceptualizations. Coordination between and among sites was to be a desired effect and enhance the modernization effort.

Since the time the requirements for nuclear materials management were promulgated, significant independent changes had occurred in use of computational tools and systems. Over almost three decades from the late 1970s, best business practices dictated a shift from a conventional paper-based office to widespread use of desktop personal computers, networked computer systems, modern relational databases, and secure file sharing and file management tools.

E-Government is being designed to use digital technologies to transform the way that government works in order to improve services to citizens, businesses, other government agencies, and its internal components (DOE 2002). However, progress has been slow in coming, e.g., material management modernization to-date has been restricted to a personal computer platform upgrade of Nuclear Materials Management & Safeguards System (NMMSS), the development and deployment of the Local Area Network Material Accounting System (LANMAS) at selected sites, and stand-alone software material control and accountability applications (the Y-12 Dynamic Special Nuclear Material Control and Accountability System) and tools including spreadsheets and relational databases at almost all sites (NMIA Data Analysis Tool). NMMSS and LANMAS are significant materials management models but have generally been outside of the IIIMS development effort. The NMIA Data Analysis Tool was an attempt to ease some of these problems inherent in using disparate systems.

2.1 Nuclear Materials Management and Safeguards System

The Nuclear Materials Management and Safeguards System (NMMSS 2004) is the U.S. government's information system containing current and historic data on the possession, usage, and shipment of nuclear materials (Table 2-1). NMMSS is also used for international reporting purposes. DOE and NRC jointly sponsor the NMMSS program. The centralized NMMSS databases contain information which is separately and manually collected from government and commercial nuclear facilities and provide output reports to those facilities and other interested parties, primarily U.S. government offices charged with managing and safeguarding nuclear materials. During the mid-1990s, the NMMSS system was upgraded by its transfer from a mainframe computer to a PC platform (NMMSS 2003), and more recently NMMSS may be migrating toward adopting the eXtensible Markup Language (XML) for increased capability and integration, such as providing enhanced item-level nuclear material reporting, as well as providing foreign obligations tracking reporting requirements.

Table 2-1. Nuclear Materials Tracked by NMMSS

Source Nuclear Material	Special Nuclear Material	Other Nuclear Material*
Normal Uranium	Enriched Uranium	^{241}Americium
Depleted Uranium	Plutonium	^{243}Americium
Thorium	^{238}Plutonium	Berkelium
	^{242}Plutonium*	^{252}Californium
	^{233}Uranium	Curium
	Uranium in Cascades	Deuterium
		^{6}Lithium
		^{237}Neptunium
		Tritium

* Reported to NMMSS only by DOE facilities and Licensee facilities possessing DOE/NNSA owned material.

2.1.1 NMMSS Inventory Activities

Prior to 1964 and the development of the precursor to NMMSS, the Nuclear Materials Information System (NMIS), operations offices and headquarters offices prepared inventory reports for users by hand, based on feeder reports forwarded by Atomic Energy Commission (AEC) contractors and by Oak Ridge Operations Office for licensees (NMMSS 2003). Selected data was summarized or consolidated to be more useful to program managers. The advent of NMMSS to some extent provided some automation of hand accounting functions and produced so-called Composition of Ending Inventory (COEI) reports for each facility. NMMSS generated COEI reports that were used both by the AEC organizations and the facilities themselves. Over time, composition codes were expanded and project numbers were extended to more nuclear programs.

2.1.2 NMMSS Material Balance

Nuclear Regulatory Commission licensees and DOE contractors also report semiannual material balance data (NMMSS 2003). Contractors reconcile NMMSS-generated reports with in-house accounting systems. The use of reported inventory data and transaction data enables the NMMSS system to generate all other data comprising the material balance report which is submitted to HQ management on a yearly basis. As an example, comparisons of the reported facility inventory and the NMMSS generated inventory result in any inventory difference shown on the report. Forms are prepared by facilities and sent directly to NMMSS.

2.1.3 NMMSS Transaction Data

NMIS began collecting diverse transaction data in 1967. Transaction data is required for transfers, foreign retransfers, operating losses, inventory differences, burn-up, contract reclassifications, origin swaps, project number changes, and other changes affecting inventory data. The specifications of transaction and material balance data are listed in Table 2-2. One of the safeguards features of NMMSS is the comparison of shipper and receiver data on domestic shipments of nuclear material. The comparison serves as an impartial third party in highlighting differences and providing DOE and NRC the initial data necessary to investigate events and trends.

Table 2-2. Reporting Characteristics for Transaction and Material Balance Data in NMMSS

Name of Material	MT Code	Reporting Wt. Unit	Element Wt.	Weight % Isotope	Isotope
Depleted Uranium	10	Whole Kg	Total Uranium	^{235}U	^{235}U
Enriched Uranium	20	Whole Gram	Total Uranium	^{235}U	^{235}U
^{242}Plutonium[1]	40	Whole Gram	Total Pu	^{242}Pu	^{242}Pu
^{241}Americium[2]	44	Whole Gram	Total Am	--	^{241}Am
^{243}Americium[2]	45	Whole Gram	Total Am	--	^{243}Am
Curium	46	Whole Gram	Total Cu	--	^{246}Cm
Berkelium	47	Whole Microgram	--	--	^{249}Bk
Californium	48	Whole Microgram	--	--	^{252}Cf
Plutonium	50	Whole Gram	Total Pu	^{240}Pu	$^{239+241}Pu$
Enriched Lithium	60	Whole Kg	Total Li	^{6}Li	^{6}Li
^{233}Uranium	70	Whole Gram	Total U	^{232}U (ppm)	^{233}U
Normal Uranium	81	Whole Kg	Total U	--	--
^{237}Neptunium	82	Whole Gram	Total Np	--	--
^{238}Plutonium[3]	83	Gram to Tenth	Total Pu	^{238}Pu	^{238}Pu
Deuterium[4]	86	Kg to Tenth	D_2O	--	^{2}D
Tritium[5]	87	Gm to Hundredth	Total ^{3}H	--	--
Thorium	88	Whole Kg	Total Th	--	--
U in Cascades[6]	89	Whole Gram	Total U	^{235}U	^{235}U

[1] As ^{242}Plutonium (^{242}Pu) if the contained ^{242}Pu is 20 percent or greater of total plutonium by weight; otherwise, report as $^{239-241}Pu$.
[2] Americium contained in plutonium as part of the natural in-growth process is not accounted for as another reportable material until it is separated from the plutonium (*except when the material with Americium ingrowth is shipped to a burial site).*
[3] As ^{238}Pu if the contained ^{238}Pu is 10 percent or greater of total plutonium by weight; otherwise as plutonium $^{239-241}Pu$.
[4] For deuterium in the form of heavy water, both the element and isotope weight fields used; otherwise, isotope weight only.
[5] Tritium contained in water (H_2O or D_2O) used as a moderator in a nuclear reactor is not an accountable material.
[6] Uranium in cascades is treated as enriched uranium and reported as material type 89.

2.1.4 International Data Backfit

NMMSS data comparison capabilities also support nuclear nonproliferation initiatives. Historical data pertaining to US international transactions from shipment files, exports, imports, and retransfers of nuclear materials data have been loaded into NMMSS. NMMSS generates reports for IAEA and foreign countries on the inventories, material balances and transactions that the U.S. has agreed to provide. Additionally, the NMMSS provides an analysis function in the review of correspondence and reports provided to the U.S. by foreign entities. This serves as a reasonably reliable source of nuclear material information for reconciliation with foreign governments.

2.2 Local Area Network Material Accounting System

Local Area Network Material Accounting System software provides Material Control and Accountability (MC&A) functionality as a core nuclear material accounting software product designed to replace legacy accounting systems throughout the DOE complex. LANMAS was originally developed by Los Alamos National Laboratory (LANL), and further refined and deployed by the Savannah River Site Development Team in the early 1990s as part of a DOE-HQ initiative to reengineer the collection, accounting, and dissemination of nuclear material information using a standard approach (Raeder 2003). LANMAS provided much-needed standardization for preparing, verifying, and maintaining records of receipts, shipments, and inventories of materials in compliance with DOE Order 474 for many sites. LANMAS is used internally by individual sites, and is a single site system.

LANMAS has been modified site-specifically and installed at Argonne National Laboratory East and West, Bettis Idaho/Pittsburgh, Hanford, Idaho National Environmental Engineering Laboratory, Knolls Atomic Power Laboratory, Mound, Nevada Test Site, New Brunswick Laboratory, Oak Ridge National Laboratory, Rocky Flats Environmental Technology Site, Savannah River Site, and Pantex Plant sites (Raeder 2003). As such, the assertion that LANMAS is becoming the standard software product used by DOE for the accountability of nuclear materials has some merit. LANMAS has not been incorporated into the IIIMS enterprise model since it is an MC&A system and not a nuclear materials management system on the scale of the DOE/NNSA enterprise.

2.3 NMIA Data Analysis Tool

The NMIA Data Analysis Tool was developed as a result of multi-site discussions on methodologies to provide a more effective way to consolidate and report the NMIA data. Several sites, including SNL in 2003, funded Haselwood Enterprises, Inc. to develop the prototype tool based on previous work in this area with Y-12.

Several sites submitted their FY02 NMIA data using the tool. The original intention, although it was not met for the FY02 reports, was to consolidate the data from multiple sites (e.g. SNL, LANL, Y-12, and Pantex) into a single submission. The tool was built upon a Microsoft Access database platform using data from the four subject sites and a set of pre-defined queries, producing both the NMIA report and other data views. Copies of the graphical user interface and database (the tool) would be distributed on compact disks to NNSA HQ as the NMIA submission and to the participating sites. Availability of all site data would be limited to NNSA/HQ and the organization assembling the complete data. Individual sites would only have access to their own data, unless they were specifically authorized by a site to access a limited set of their data for a specific reason for a specific period of time. A paper-based protocol was developed for requesting, granting, and revoking such access authorizations.

The data was therefore a snapshot in time as specified by the NMIA guidance, and not continuous direct access to a site’s operational data. However, the data sharing was through an electronic database which could be queried but not updated (not simply a hardcopy or electronic report). A set of pre-defined queries was included in the tool for quality control. The intention was not to allow authorized users *ad hoc* query capability, primarily for data quality control reasons. Each site wanted to ensure a query generated the appropriate response. The query was sometimes not obvious given the structure of the data and the assumptions underlying the data structure and values. However, with appropriate quality controls, sites seemed willing to allow greater access to the data than with previously submitted NMIA reports. In fact, some sites familiarized with the tool were willing to use it for querying data internally because it provided easier or better access than their own internal query systems.

3. IIIMS Historical Background and Context

The DNMS activities and the IIIMS project were developed out of a litany of progressive efforts to make some fundamental and needed changes in the day-to-day management of valuable nuclear materials. IIIMS work progressed from basic concepts, through high-level needs assessment, to specific tools and prototypes designed to help manage data, provide accountancy, make queries, and mine data. The early perspectives of nuclear materials management are provided in a temporal progression in the following subsections (in some cases anecdotally), and in timeline form in Figure 3-1.

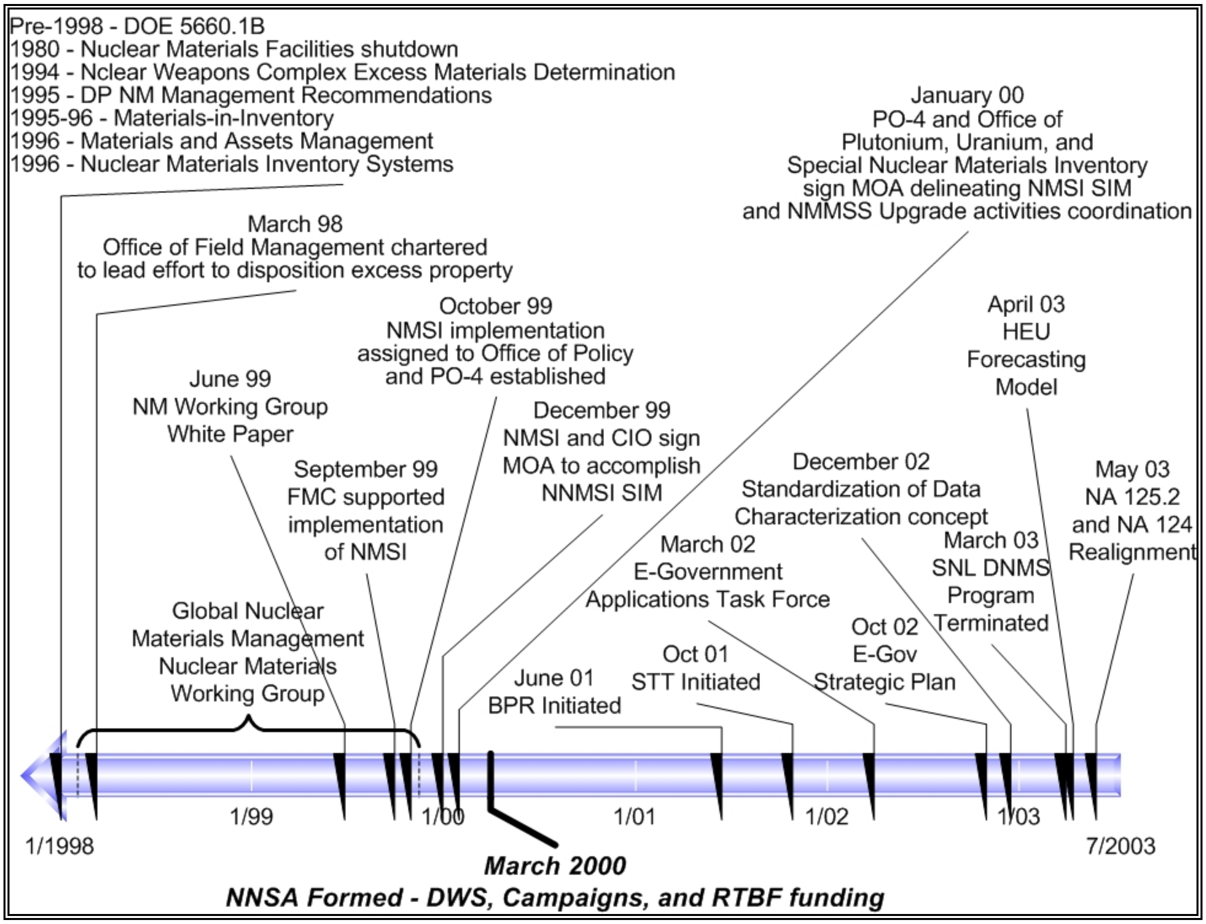


Figure 3-1. Defense Nuclear Materials IIIMS Modernization Activities Timeline

3.1 Pre-1998

A significant trend in consolidation and downsizing of the U.S. nuclear weapons complex (NWC) began after 1979. Facilities at K-25 at Oak Ridge, Hanford, Savannah River, Fernald, and Rocky Flats ceased production between 1987 and 1989. In 1991, the Union of Soviet Socialist Republics was formally dissolved; the cold war, and its associated nuclear proliferation, was over. By 1994, the U.S. NWC closed 13 major nuclear facilities, 5 non-nuclear facilities, and 5 research reactors (Loeber 2001), and, more germane to the issues of nuclear material management, DOE initiated the Excess Materials Determination in order to manage the large quantities of nuclear materials, reserves, and stockpiles that had accumulated in these facilities over the course of cold war nuclear proliferation.

Requirements were necessary to direct nuclear materials management activities in the DOE complex, and DOE Order 5660.1B, *Management of Nuclear Materials* (effective May 26, 1994) was developed. To further define requirements, several other nuclear materials management projects were also initiated in the pre-1998 time period including:

- Defense Programs Nuclear Materials Management Recommendations (1995)
- Materials-in-Inventory (1995-96)
- Materials and Assets Management (1996)
- Nuclear Materials Inventory Systems (1996)
- Mission redeployment to field (1997).

SNL's role in nuclear materials management in this pre-1998 time period included the Material Technology Development Redbox project (so-called protected money in classified work). The SNL budget for domestic DNMS programs was on the order of $24 million. Project thrusts included making available the technical advisor to the US Trilateral Agreement on actual weapon dismantlement and disposition, in which it was intended the nuclear components of weapons and warheads would be made into reactor fuel. Other nonproliferation thrust areas included transportation security, robotics, remote monitoring (using the T-1 sensor platform system), container development, technology demonstrations, and U.S./Russian interactions.

3.2 Period 1998-1999

During the 1998-1999 period of time, it became clear that DOE requirements were broad in scope, affected many sites and programs, and interactions at different sites were linked. To assure compliance and coordination, several DOE-complex wide efforts were undertaken including establishment of:

- Nuclear Materials Working Group
- Tri-Lab Global Nuclear Materials Mgmt
- Office of Field Management chartered to lead effort to disposition excess property
- Tri-Lab White Paper.

One of SNL's roles in the Weapon Material Stewardship (WMS) Program was to engage Russia in physical protection of nuclear facilities and arms control verification activities. The SNL project budget for this time period was on the order of $20 million (with $10 million directed toward the Russian work alone). These activities took place under SNL's Nuclear Weapons Division 5000.[1] The cognizant Center Director advocated certain technologies which supported these activities, including Strategic Engagements and Awareness (SE&A) Program, WMTP, and SE&A – Russian Technical Exchange.

3.3 Period 1999-2000

During the 1998-1999 period of time, the SNL Vice Presidency under which WMS programs were administered changed hands to a new Vice President. The SNL project budget for this time period was on the order of $17 million. Under a new Center Director, some reorganization occurred along with concomitant reprioritization toward international program activities. During this period of time, portions of WMS were split between two managers, and eventually WMS transitioned to DNMS (with a new focus from weapons work). In addition, the SE&A program was transferred to a different Center under a new Center Director.

Relevant DNMS efforts were undertaken during this time period external to SNL activities. Most significantly, the Nuclear Material Stewardship Initiative—Strategic Information Management (NMSI SIM) was established in December 1999 (DOE 1999), after the recommendation put forth in the Nuclear Materials Working Group white paper (June 1999), the FMC support of implementation of NMSI, and the Office of Policy (PO-4) and the CIO signed the memorandum of agreement (MOA) to establish NMSI SIM

[1] Division 5000, in SNL organizational hierarchy, is comprised of a number of Centers. Each Center will have 150 to 200 personnel assigned.

in December 1999. The SIM process was a General Accounting Office sanctioned methodology using an eight-step approach (including developing alternatives and cost/risk/benefits for each alternative) to produce a business case. During 1999, the SIM Program conducted several projects, but the SIM process for a business case for the Enterprise Network Infrastructure (ENI) was not coupled with the NMSI SIM process.

Other key milestones in the 1999-2000 period included:
- NMSI implementation assigned to PO-4 (October 1999)
- NMSI SIM Core Planning Team kickoff meeting (December 1999)
- PO-4 and the Office of Plutonium, Uranium, and Special Nuclear Materials Inventory sign MOA delineating NMSI SIM and NMMSS Upgrade activities coordination (January 2000).

3.4 Period 2000-2002

During this period of time, the NNSA was formed under DOE. The development of an advanced inventory information and analysis system was initiated to address the requirements stipulated in Materials Readiness Campaign, MTE-4: *Enabling Processes, Technology, and Analytical Tools*. Specifically, this document stated a requirement to "... evaluate and employ database and mathematical tools to develop models necessary for the assessment, forecasting and efficient management of the materials needed for national security." Another requirement stated the need for a process to provide NNSA/NA-125.3 with the "… assessment, forecasting and planning tools to support" accurate and timely decisions necessary for the "… efficient management of nuclear and special non-nuclear materials." A summary of the Legal and regulatory requirements that govern Nuclear Material Management over all periods (Newton 2000) and a timeline for activities (Figure 1) are as follows:
- Atomic Energy Act of 1954, as amended
- DOE Order 5660.1B Management of Nuclear Materials
- DOE Order 410.X (Draft)
- Presidential Decision Directive (PDD) 13, 42DOE Order 474.1.A
- DOE Manual 474.1-1A
- DOE Manual 474.1-2
- 10 CFR 835, 10 CFR 830 Parts A and BDOE Orders 435.1 and 5400.5
- DOE Manual 434.1-1, DOE/I0093
- 40 CFR Part 191, OSR-29-90 (for waste requirements)
- Waste Isolation Pilot Plant Land Withdrawal Act (Public Law 102-579) Environmental Protection Agency (EPA) regulations and state laws
- Compliance agreements/consent orders
- 10 CFR 71 (for requirements governing containers)
- 49 CFR (DOT)
- E.O. 12958 "Classified National Security Information."

Also during this period of time, DOE HQ perceived the nuclear weapons complex as being "awash" in large quantities of nuclear materials, and there would be no difficulties in providing nuclear materials for any program or project. This perception was offset when individual sites revealed much of the nuclear material was apparently not useable, since it did not meet design specifications or requirements. To better manage these inherent demands on utilization, supply/demand material forecast modeling was initiated.

The SNL project budget for DNMS in 2000 was on the order of $14 million, and by 2002 it had become $10 million. Moreover, the funding structure for DWS (LEPs) was changed to Campaigns (SNL Project #7940 MRC), and RTBF (SNL Project #7963 DNMS). SNL line management changes also occurred during this period of time, and included the former head of WMTP under SE&A becoming the direct line manager of DNMS activities. NA-117 funding from SE&A and DNMS were grouped to form one collective of RTBF moneys, and Material Readiness Campaign activity funds from NA-12 was used to support directed stockpile work. The first in a small series of publications on modernization of nuclear materials management was presented at the 42nd INMM Annual Meeting (DeLand 2001).

3.5 Period 2002-2003

As NMSI SIM was wrapping up, some of the key conclusions that the team made were addressed in more detail by the business process reengineering (BPR) group that was formed as an outgrowth of NMSI SIM. The BPR included a small group of active analysts from multiple sites who were trained in nuclear material management issues, and conducted interviews at a number of sites.

The Standardization Task Team (STT) was a still-smaller multi-site organization of active analysts who addressed a subset of the issues identified by the BPR. Four white papers were generated by the STT. The NNSA Materials Management Division (NA-125.3) requested the STT to develop a unique item identifier as a data field in the NMIA. This unique item identifier would allow tracking a nuclear material item as it was transferred from one site to another. Currently, items have a site-specific unique identifier, which is changed when the item is transferred to another site. Therefore, item history is actually lost in the course of transfers across site boundaries. Four separate STT white papers were drawn up to provide some architectural foundation for the IIIMS effort and specifically addressed concepts of the unique item identifier, item history, project code, and characterization data.

A listing of the white papers, publications, and products germane to the subject of nuclear materials management which were issued during this period include:

- Project Code White Paper (STT 2002a)
- DOE Standardization Task Team paper issued to NA125.3, NA-26, NA-3, SO-62, EM, SC, CR (STT 2002b)
- Defense Programs Materials Program Strategy (Rev. 0, 5/15/2002)
- Unique Record Identifier White Paper DOE Standardization Task Team (STT) paper issued to NA125.3, NA-26, NA-3, SO-11, EM, sites (STT 2002c)
- *The Integrated Inventory Information Management System for Nuclear Materials Tracking, Forecasting and Planning* (Thompson 2002)
- NM Data Tool and Modifications (Watts 2002)
- Standardization of Data Characterization Draft White Paper (STT 2002d)
- IIIMS Prototype Requirements Document - DRAFT (Bray 2003)
- Y-12 HEU Forecasting model (Jenkin 2003).

SNL was eventually directed to develop IIIMS with sponsorship from NNSA's Office of NA-125.3, Office of Defense Programs (DP), Materials Management Division. Concurrence on the IIIMS concepts was to come from field and area offices including NNSA/OAK, NNSA/AL, and YAO. NA-125.3 gave specific direction to develop and operate IIIMS to meet the requirements of DOE 5660.1B, and subsequent DOE directives (i.e., the draft DOE 410.X) were accommodated in the conceptual design of IIIMS to the extent possible. While some operational issues were considered, they were not a major focus for this initial exploratory work. During this period of time the DNMS budget was reduced to approximately $8 million, and SNL line management changes also occurred at this time.

Despite the progress being made, the 2002-2003 period was also the time when material readiness money was withdrawn throughout the DOE/NNSA complex, except at Y-12. In March 2003, formal notice from SNL's Program Director's Leadership Team announced termination of SNL's defense nuclear materials stewardship program (SNL 2003). Independently, the NNSA Office of Strategic Materials and Transportation was realigned and in May 2003, NA-125.2 was disestablished with its functions transferred to NA-124 along with reassignment of staff to NA-12.

4. General IIIMS Objective and Scope

The objective of the DNMS IIIMS was to modernize nuclear materials management information systems at the Enterprise DOE/NNSA level, and to create true electronic connectivity directly with each of the DOE/NNSA sites. The scope of IIIMS was broken into two distinct parts: 1) broad enterprise-oriented materials management; and 2) materials forecasting. Specific requirements, while not derived directly from DOE Orders were advanced from different funding sources, over several years during the life of the project (Figure 4-1).

- Edward Reynolds, DP-22, September 3, 1999. *Material Readiness Campaign Guidance* "… provide modern materials management and inventory information systems …" by FY05.
- Edward Reynolds, DP-22, October 29, 1999. *Material Readiness Campaign Gap Analysis Guidance* provide "… new, state-of-the-art technologies and improved material inventory management system …" by FY05.
- John W. Newton/Nancy Buschman, Materials and Logistics Management Division, NA-125.2, August 1, 2002. *Combined Plan for Materials Stewardship Program* "Materials Information Systems WBS 3.7" with activities to 2QFY07
- Diane Bird/Michael Thompson, NA-11, March 19, 2003. *Readiness in Technical Base and Facilities FY03 Implementation Plan Data Sheet* "Develop implementation plan for integrating Y-12 inventory information into the SNL Integrated Inventory Information Management System (IIIMS)" 4Q milestone

Figure 4-1. IIIMS Requirements

In the long term, the DOE/NNSA e-Government initiative will probably address the broad concepts of IIIMS or at least include ideas currently part of IIIMS, whether or not IIIMS is the genesis of those concepts. It is likely an understanding of IIIMS decision-making processes and workflows would ease the e-Government transition to an enterprise endeavor. However, fixed requirements, which cannot change or can only be changed with difficulty such as new or revised DOE orders, manuals, or guidelines, impose some inflexibility in the enterprise. These requirements must be separated from clear solutions to workflow difficulties, which may be relatively easy to change as long as they continue to meet the requirements and there is enterprise agreement on the changes.

During the 2002-2003 period of time, a third intermediate focus was added to IIIMS. This involved consolidating NMIA reporting by NNSA sites (SNL, LANL, Y-12, LLNL, and Pantex). Based on its work with the Y-12 NMIA reporting, Haselwood Enterprises, Inc. developed a data reporting tool, funded in part through anticipated SNL RTBF moneys. SNL, LANL, Pantex, and Y-12 used the tool for their FY2002 NMIA reporting, but the multi-site consolidated reporting did not occur.

The rest of this section summarizes the activities that have occurred in each of the three focus areas – the Enterprise perspective, material forecasting, and NMIA consolidation and reporting.

4.1 IIIMS Enterprise Perspective

IIIMS and the enterprise perspective has been the least well defined part of nuclear materials management. The DOE/NNSA leadership, its vision, and the complex-wide nuclear materials information needs *in toto* are less clearly understood than are the missions for each DOE/NNSA site. From a complex-wide materials management perspective (the enterprise), there are many nuclear material management decisions that need to be made and many distinct questions (and associated analyses) to support those decisions. In an esoteric sense, some decisions may be supported by existing or planned systems, others may be addressed by specific systems at individual sites, and still others are not adequately addressed anywhere and may or may not be within the scope of IIIMS. In order for the initiatives to progress, the requirements in this area must be brought from the esoteric realm and identified in the same level of detail as materials forecasting and NMIA consolidation and reporting areas, and likely requires a revision of DOE Orders. The IIIMS prototype was intended to help explore these needs. The e-Government initiative for nuclear materials management should likewise explore and define needs.

Determining universal requirements and specifications was a most difficult challenge of IIIMS system development. The foremost reasons for the challenge were the many different stakeholders with different requirements at different sites, managed by different contractors. The stakeholders for IIIMS include the NNSA site offices, the NNSA Program Integration Office, NNSA HQ, and the sites themselves. A critical development issue was shifting the focus from a set of totally independent systems to a federation of systems that collectively provided a complex-wide perspective for nuclear materials management.

This section describes a prototype in use as both a proof of concept and a tool to further explore and refine the requirements. A team, including nuclear materials managers from multiple sites and NNSA offices and information systems people, has been working to define the needs to support materials management at the complex level. A nuclear material STT also identified several issues and proposed solutions. The STT issues included the need for a permanent, complex-wide unique item/record identifier, a stable project code, and a standard for characterization data. The prototype started with the NMIA reporting requirements. The STT solutions and several other requirements were added. The database design was extended to satisfy these new requirements and can be further extended as additional needs are identified. The remainder of Sections 4.1.1 through 4.1.4 focus on the requirements the prototype addresses, the prototype itself, the benefits if the requirements are satisfied, the data structure to support them, and several queries or scenarios. Section 4.1.5 focuses on the IIIMS architecture itself.

4.1.1 Unique Item/Record Identifier

<u>Requirements</u>
A major requirement is for a permanent, complex-wide unique identifier, without which many of the potential enterprise-level benefits will not be achievable. Currently, when an item is shipped from one site to another, its identifier changes because each site has its own identifiers, which are only unique within a site. This lack of a permanent, complex-wide unique identifier creates two problems. First, characterization data is lost when an item is transferred to another site and is given a new identifier for that site. The problem is not that the item is given a new site-specific identifier, which may be needed for site systems, but rather that it has no permanent identifier. Sometimes the characterization data can be recovered, but only through a labor-intensive, manual process. In other cases, expensive characterization tests must be repeated. Lastly, it is very difficult or nearly impossible to track an item's history and movement through the complex.

<u>Prototype Approach and Benefits</u>
A unique identifier can be easily generated using the current site identifier. This unique identifier is stored and linked to the current site unique identifier. Items do not have to be relabeled with a new identifier unless or until they are shipped to another site. However, the receiving site can still apply its own identifier, which can be linked to the complex-wide identifier. Since the local site applications use the

local site identifier, retaining it allows the local applications to remain unchanged. However, any queries or updates across sites would be done using the complex-wide identifier rather than the site identifier. These unique identifiers are needed at both the item and the record level.

An item is a physically distinct part, subsystem, system, or container. It includes one or more reportable materials that must be tracked. The item identifier consists of two parts. First, there is the site identifier, which should be the NMIA (Nuclear Materials Inventory Assessment) RIS (Reporting Identification Symbol) code. All sites have an RIS code and there is a well-defined mechanism to maintain and update (i.e. add new and delete expired) RIS codes. There are two RIS codes, program and location or P and L. The location or LRIS should be used since the item is in that site's physical inventory and has been given an identifier unique to that site. The second part of the unique item identifier is the site unique identifier for the item. This part of the identifier is unique to the site. Therefore, by appending a site code it becomes unique for the complex. These complex-wide, unique item identifiers can be automatically generated for all of the items in the database.

Data Structure and Queries

For each item there can be one or more records for each reportable material in the item. These records are currently numbered sequentially within the item. This approach can be maintained, using the unique item identifier instead of the site-specific identifier. In this approach, like the item identifier, the record identifier for each material in the item is a permanently unique identifier across the complex. If an item characterization history is needed, each record for the item can be time stamped for when they were created and when they became inactive or invalid.

There is a special case involving bulk materials. Bulk materials, such as oxide powder or fuel pellets, have no unique item identifier (e.g., a serial number), but they still need to be considered as items and reported, since this material can be characterized. Bulk materials are stored in containers, so the containers become the items that can be identified. The material in a container can be measured and characterized like the material in any other item. Therefore, bulk material is not an anomaly. It can be identified by its container and characterized like any other material.

4.1.2 Item History Using the Unique Identifier

Requirements

A permanent, complex-wide, unique identifier provides the capability to track an item's movement through the complex. It also provides the capability to track an item's history as the item changes or is grouped with or removed from other items. Currently, with site-specific identifiers, this can be done only while an item remains at a site.

Only the unique item identifier is required for item history, not the individual records for each material (i.e., its characterization). These records remain associated with the items, so they are available, but they are not required for tracking item history.

Prototype Approach and Benefits

There are five specific cases. First, items may be combined with other items in a way that still maintains their identity (e.g., an item is put in a container, which is another item). Second, any removed items resume their identity (e.g., an item is removed from a container and maintains its original identity). Third, two combined items lose their previous separate identity (e.g., two or more items are melted or blended together to create a new item); although these items no longer exist, they remain in the database to maintain their history so their identifiers cannot be reused. Fourth, an item can be created or a new container arrives and is given an identifier. Fifth, an item can be destroyed or removed from the enterprise inventory, but its data remains in the database.

Data Structure and Queries

A simple history record (see Table 2-1) captures and maintains this information in four fields. Item X_1 is the "superitem" that contains Item Y_1. The operation specifies the operation on Item X_1 or the relationship that was created between Item X_1 and Item Y_1. Item X_1 may have been created or destroyed. Item Y_1 may have been placed in or removed from Item X_1. Finally, Item Y_1 may have been combined with Item X_1 in such as way that it ceases to exist as distinct item (e.g., melted or blended into Item X_1).

If multiple items are combined, then there would be multiple records, one for each item. The date/time specifies when the operation occurred. If ten items were packed into a container, there would be ten history records – one showing each item being placed in the container. Note that if any additional

Table 4-1. Item History Data Structure

Item1 Identifier	Item2 Identifier	Operation	Date/time
X_1	Y_1	A	dd/mm/yyyy/hh:mm
X_2	Y_2	B	dd/mm/yyyy/hh:mm
X_3	Y_3	C	dd/mm/yyyy/hh:mm
…	…	…	…
X_n	Y_n	Z	dd/mm/yyyy/hh:mm

information (such as who performed the operation) is needed for the item history, additional fields can be added to this record format. As an example, assume a container (Item X_1) was loaded with Items Y_1 and Y_2, shipped to another site where Item Y_2 was removed. Later item Y_3 was added and the container was shipped to a third site. Depending on when it was queried, item X_1 would contain Items Y_1 and Y_2, Item Y_1, or Items Y_1 and Y_3.

The following three examples show queries using this history tracking capability:
1. (1) What are the current contents of container (item X_1)?
2. (2) List all of the items that have been in container (item X_1), and when?
3. (3) What containers has Item Y_1 been stored in and when?

4.1.3 Project code

<u>Requirements</u>
Currently, the NMIA project code is a 10-character field with embedded information about site, usage, and B&R financial codes. This creates two problems. First, the size of the project code is determined by the amount of information to be captured, not by the number of projects. To capture additional information about projects would require expanding the size of the project code. Second, since many project codes change each year (in part due to B&R code changes), there is an updating problem. Every item record includes a project code, so project code changes can impact tens or hundreds of thousands of records.

<u>Prototype Approach and Benefits</u>
The recommendations given in one of the STT white papers was to use a nine-digit project identifier. This field is only an identifier and contains no information about the project. All project information is included in a separate table (a project information table) that can be accessed using the project identifier.

<u>Data Structure and Queries</u>
This approach allows any amount of additional project information to be added just by adding fields to the project information table. It limits the size of the project identifier—a nine-digit field would allow a billion projects. Finally, it reduces the maintenance problem when project information changes. Only the project record in the project information table changes, not all of the project codes in every item record. If needed, versioning would allow the history of project information changes to be tracked. While this change simplifies the database structure and its maintenance, it does not have to be visible to the users of the data for their current queries. If users still want to see the current project code, the system can automatically reconstruct and print it.

4.1.4 Characterization data

Requirements

There are really two distinct characterization issues. First, should there be a set of standard ways to characterize materials for disposition or any other uses? Second, should there be a standard way to store and report characterization data for these materials? The two major objectives are to determine what characterization data to collect for a specific material and how to store and report this data. The first objective is beyond the scope of IIIMS project. However, how to accomplish the second objective is addressed below.

Consider the current characterization process. During an item's active life cycle, it is characterized in a number of ways, depending on how it is going to be used. These characterizations determine whether or not the item can be used in certain ways or for certain processes. Since there is not currently a common, permanent item identifier, when an item is moved to another site it is given a new identifier. Since the characterization done at the shipping site is related to its identifier for the item, this characterization data is lost when the item gets a new identifier. Sometimes a time-consuming manual process can recover the data, if the shipping site kept it. However, if the data cannot be recovered, then the item may have to be re-characterized. When the item is no longer needed, additional characterization data may be needed to determine whether or not it can be stored locally and whether or not it meets the requirements for a disposition path.

The shipping site needs to know the characterization requirements of the receiving site so it knows what tests to perform on the item prior to shipping. Sometimes the shipping site does not know the characterization requirements of the receiving site, while in other cases, the receiving site may not have determined all of the characterization data it needs. In other cases, it is hard to find all of the characterization data for an item to determine whether or not additional tests are needed. This means that any process to capture, store, and retrieve characterization data must be very flexible.

The required characterization data varies depending on both the type of material and on the target process. For example, the required plutonium (Pu) characterization data is different depending on whether the Pu is being dispositioned as mixed oxide fuel (MOX) or immobilized. The characterization requirements may also change as the disposition process requirements become better known, and as the process its characterization data requirements change over time. This means the way the data is stored and reported must be flexible enough to allow for these changes. The site having the material may not know what characterization data is required until the disposition or target process is specified. Over its life cycle, this material may have been tested and characterized multiple times, sometimes for different assays or examinations or because either the previous data can longer be found or it went out of date. Therefore, the material already has some characterization data, but possibly not all of the required characterization data. It is difficult to track down all of this characterization data, especially if the material has been shipped among the sites, because of the changing item identifier. However, with a unique record identifier, this historic characterization data would be much more easily available.

Prototype Approach and Benefits

The approach includes fields to capture the characterization variable name, the acceptable lower and upper limits for the variable, and the measurement units. Additional data, such as a specific methodology or type of instrument, could also be added, if needed. Tables 4-2 and 4-3 show how to address the needs for data flexibility. Table 4-2 provides a way to specify what characterization data is needed for any given material and process combination.

Table 4-2. Material-Process Characterization Requirements Data Structure

Material	Process	Characterization Variable Name	Lower limit	Upper limit	Units	Other data

Table 4-2 provides a template for tracking what characterization data is needed for what material-process combinations. If a material-process combination needs five types of characterization data, then there would be five record fields - one for each type of characterization data. This approach reduces the maintenance problem. Adding new material-process combinations only requires adding new data records, not restructuring the database, which would create a maintenance problem. Similarly, adding new types of characterization data or tests also only requires adding new data records, and not restructuring.

Table 4-3. Item Material Characterization Data Structure

Item/record	Material	Process	Characterization Variable Name	Characterization Variable Value	Data Time	Other data

Data Structure and Queries

Table 4-2 indicates what characterization data is needed. Table Table 4-3 provides an effective way to actually store the characterization data about each item. Each row/record in Table 4-3 contains one data characterization variable and its value. Additional information can easily be added to this table organization. For example, one could add a date for the characterization. Adding new characterization data for an item only adds another data record or row to Table 4-3.

The following are a set of queries that involve characterization data. Note that some of these queries can be applied by a site to its own data. These queries can probably be addressed by internal site systems, although they may not use this approach to characterization data. However, many of these queries would also be useful across sites and these should be addressed in the prototype.

- Find items with characterization X.
- What are the characteristics of Item X?
- What characterization data is needed for disposition Path X?
- What additional characterization is needed to determine if Item X can use disposition Path Y?

4.1.5 IIIMS Architecture

This section describes the software architecture alternatives for IIIMS by identifying the methodology for meeting a given set of requirements. In this case discussing the pros and cons of the various alternatives can help clarify some of the requirements issues. This section describes four basic architectural alternatives, with variations of some of the alternatives, and their implications for a later implementation.

In addition, this section describes and discusses the benefits, constraints, and issues with the four basic architectural approaches described – the current approach, the approach used with the NMIA Data Analysis Tool (also discussed independently in Section 4.3), a distributed system with direct access to each site's operational databases (which is probably not a viable approach, but is useful for comparisons), and a data warehouse approach with a number of variations.

Current Architecture

The current architecture for nuclear materials management information is completely decentralized. Each site has individual requirements and has developed site-specific systems to meet those requirements. Most of the information sharing across sites and/or with headquarters is done an on *ad hoc* basis to satisfy specific reporting requirements or guidance. Much of this data sharing involves predefined reports in hardcopy or electronic form. It does not involve direct access to a site's data or often not even an electronic copy of the data in a form that can be easily manipulated. In fact, for quality control (and safeguards) purposes the sites often do not want the recipients to be able to independently manipulate the data they receive.

The problem with this approach is that it does not support site-to-site and/or site-to-headquarters data sharing. Existing site systems can accommodate some data sharing needs, but this data-sharing is difficult to support. Also there may be an issue of mapping disparate data values to a common set of values in order that the shared data is meaningful and interpreted by or across multiple sites.

Three potential exceptions to this description are noted. The first system, LANMAS, is a materials accountability system that is currently used by a number of sites (Section 2.2). It was developed at a single site, but with the intention of being used by multiple sites, and is being maintained for the multiple user sites. However, while versions of LANMAS are being used by multiple sites (it is customized for its user), it is still a single-site system, since the data that is collected and maintained is not directly shared beyond the particular single site. The second system is NMMSS, which is a national reporting system (Section 2.1). NMMSS provides summary nuclear material inventory reporting data for national and international reporting. It also captures summary transaction data on material movement to update its inventory. However, NMMSS involves reporting requirements that are satisfied by extracting reporting data from the site operational systems. Individual sites do not run the same software or share data directly with NMMSS, in part for safeguard and security reasons.

The third system is NMIA, which is a more detailed inventory report that is provided by the sites to NNSA/HQ in response to annual guidance. Again, each site extracts the data required by NMIA from its operational data systems and provides this snapshot to HQ in an NMIA report format (either hardcopy or electronically). HQ then enters site data and uses it in the HQ reporting systems. NMIA data is not shared among the sites, and even though the data is shared with HQ, it is information at only one point in time. HQ does not have direct access to the sites' data nor does it have access to continuously updated data. One problem this approach creates is that there are now two sets of summary inventory data (NMMSS and NMIA), which must now be reconciled in a labor-intensive process. Despite reconciliation, neither of these data sets are the data of record, which is the operational data at each individual site.

Architecturally, the approach used by the NMIA Data Analysis Tool represented an improvement in data sharing. Although it was still a snapshot, it did provide a limited mechanism for sites to share data with NNSA/HQ and with each other, and the protocol provided an authorization mechanism. This sharing was in read-only mode, but it was a step in the direction of modernization, and distributed or Enterprise systems. Since use of the data tool was designed to support and satisfy the NMIA guidance, it involved an annual snapshot of data in part because of the labor-intensive data cleaning required for NMIA. It is worth noting that much of this data cleaning appears to involve reconciliation with NMMSS data. To the extent that the data cleaning and processing could be automated, more frequent snapshots would be possible for data sharing of more current data among the sites, if that were desirable. The NMIA Data Tool approach involved a data "push" from the sites when the data was "good enough" to submit, rather than a data "pull" in which case the data receiver rather than the data sender would drive the process.

<u>Direct access to site systems</u>

A different architectural approach allows direct access to a single, sometimes centralized, copy of the data. However, for DOE/NNSA and the nuclear materials management data, there is no single centralized copy, and the only single copy of the data is distributed among the sites with each site maintaining the copy of record of the data for its nuclear materials inventory. Distributed approaches are conceivable that would allow direct access to this single distributed copy of the data. However, given the rigorous security requirements as well as DOE/NNSA culture (i.e. each site being independently operated by different contractors), any approach allowing direct access to sites' operational data is unsound and is not considered further.

<u>Data Warehouse</u>

Data warehouse architectures are also possible alternative architectures for IIIMS. Data sharing is a common feature of all data warehousing architectures, but data sharing does not involve direct, real-time sharing of operational data. First, the data warehouse involves a snapshot of the data at a certain point in time. Second, the data warehouse involves sharing all of the operational data. The data warehouse usually contains only a subset of the total operational data, and the data is usually preprocessed into various statistical summaries for multi-dimensional analysis and on-line analytical processing. IIIMS would only involve nuclear materials management data (i.e., a functional subset of a site's total stock inventory data).

The basic concept for data warehousing is to organize data depending on how it is to be used. Data can be organized to support fast query and for updating detailed transactional data in a traditional relational database structure. In addition, data can be organized to support elaborate categorization for more complex analyses such as a data warehouse to support on-line analytical processing and reporting. Most of the IIIMS data sharing involves reporting and analysis functions on summary data instead of transaction processing of detailed site operational data. Subset and summary data warehousing also provides a security benefit for IIIMS, since sites share only very limited views of their data.

Data warehousing is performed on a fixed schedule, and only periodically when the data supplier (the site) pushes the data from the operational system into the data warehouse and not by the data warehouse user pulling the data into the data warehouse. Scheduled periodic updating of the data warehouse is important because the process involves data selection, cleaning, refinement, categorization, analysis, and summarization before the data is moved into the data warehouse. This is analogous to the process for creating the NMIA and other reports, which are currently used for data sharing beyond the local site.

Options for the physical placement of the data warehouse hardware include centralized or distributed arrangements. A centralized nuclear materials data warehouse would have a simple structure and would be easy to work with and maintain. Only summarized, rather than raw, data would be included in the data warehouse in this configuration, and rigorous controls can be layered on top of the data warehouse to address security concerns. This approach would also be different from the current culture of the DOE/NNSA complex where each site is relatively isolated and operates independently. An alternative architecture would be a distributed data warehouse system with the data for each site remaining locally at the site, giving each site more direct control of their part of the data warehouse. However, the use of a data warehouse in any form implies that a decision has been made to share, at some level, the data in the warehouse.

4.1.6 IIIMS Prototype

The IIIMS prototype was developed to allow the multiple participating user groups to explore nuclear material requirements and needs in detail. The IIIMS prototype was developed with SQL Server with an Inxight VizServer™ user interface. VizServer is a scalable enterprise solution for visualizing and exploring large data collections. VizServer creates graphical data visualizations and is deployed from a web browser.

VizServer is designed to speed and simplify the exploration and understanding of large information collections. VizServer presents complex and large hierarchies of documents in a branching tree-like map view with associated nodes that represent different levels of data (Figure 4-2 and Figure 4-3), to enable users to navigate and quickly locate what they are looking for, such as a data mining operation. The IIIMS prototype's VizServer imports data from relational databases, text files, and the like, provides integration between unstructured and structured data, and provides comprehensive information management. VizServer's Categorizer™ function would be used to filter and classify data for delivery to authorized users and including DOE/NNSA headquarters. The program's SmartDiscovery™ 3.0 function allows for automated data integration, manipulation, and document management from multiple and different languages including MS-Office files, intranet pages, and email if that requirement becomes necessary for data inclusion.

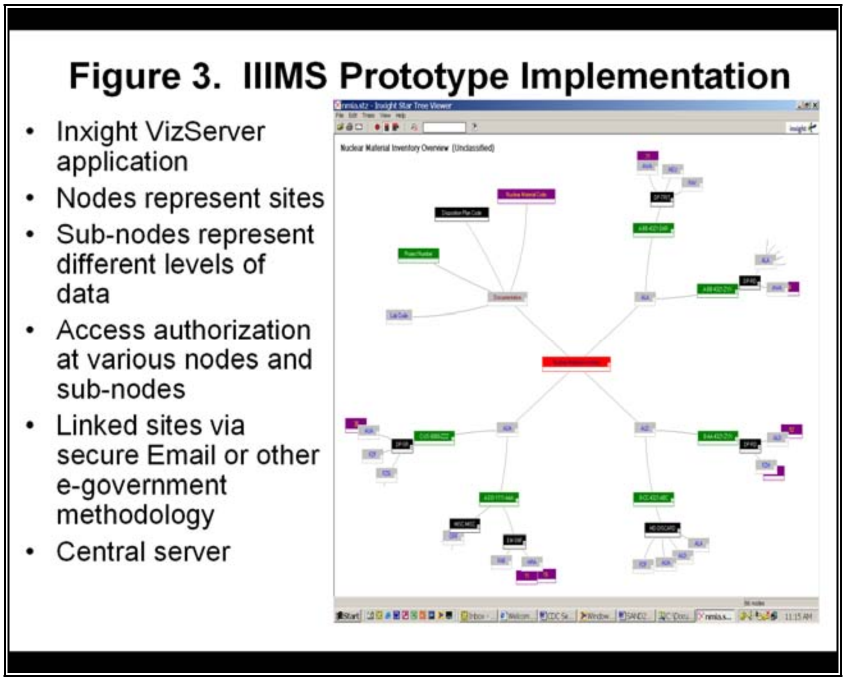


Figure 4-2. IIIMS Prototype Implementation

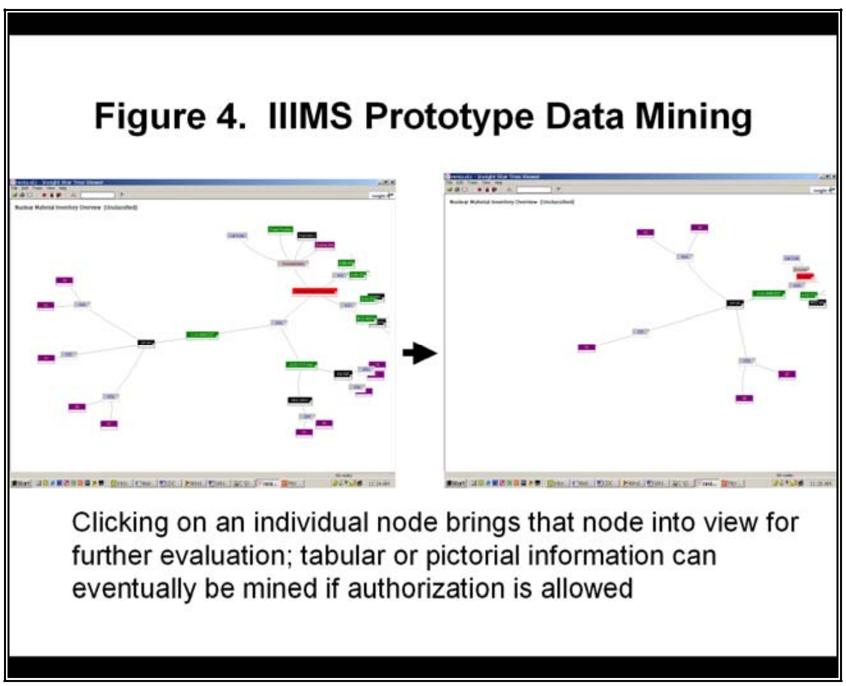


Figure 4-3. IIIMS Prototype Data Mining

Drill-down, or data mining capability exists for every node on the map view. Unlike in a typical relational database, the data does not have to be presented in a tabular format. Data is presented in a visual format that can display dependencies and relationships in unique ways. Various tools can also be used to display the data presented in any node. In Figure 4-4 and Figure 4-5, IIIMS Prototype screen shots represent selection of a particular node which then executes a dynamic HTML query to the database containing the item history. In this particular example, the complete set of sample complex-wide data is displayed when the node is selected. In addition to opening an HTML report, this linkage function can be used to open any MS-Office data, run third-party software tools (such as a reporting tool), or run a statistical analysis package.

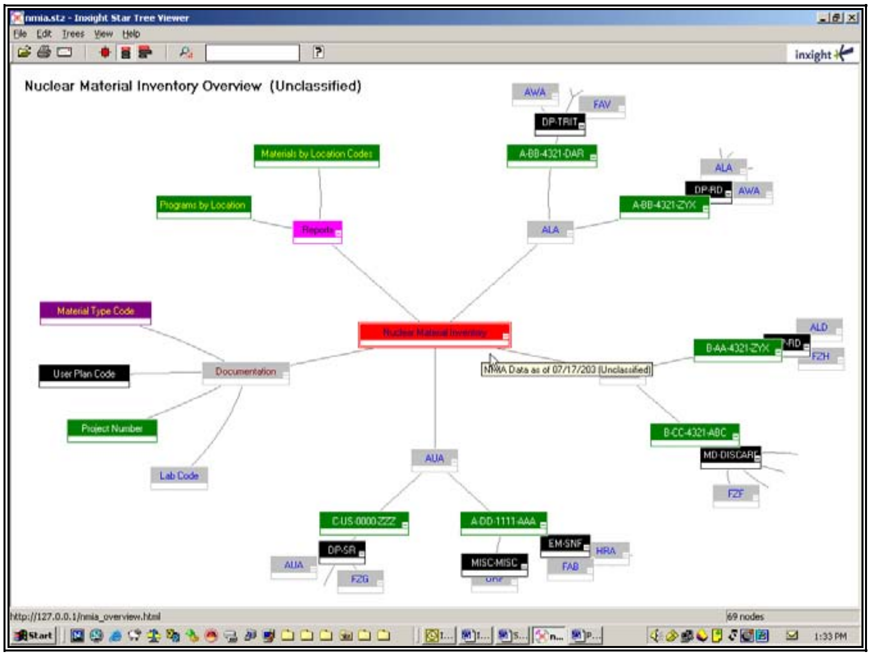
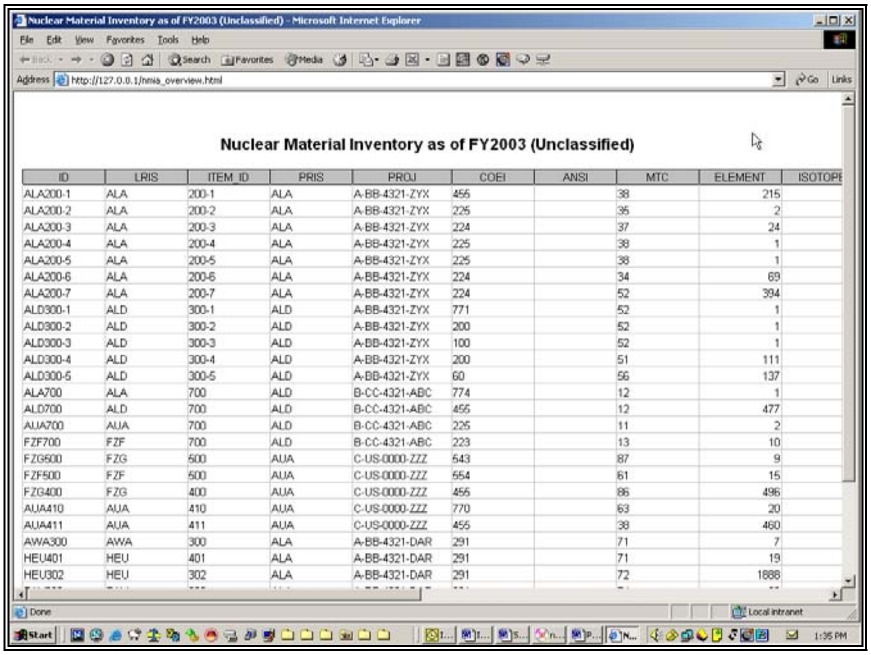


Figure 4-4. IIIMS Prototype node hyperlink used to jump to a dynamic HTML report



Nuclear Material Inventory as of FY2003 (Unclassified)

ID	LRIS	ITEM_ID	PRIS	PROJ	COEI	ANSI	MTC	ELEMENT	ISOTOPE
ALA200-1	ALA	200-1	ALA	A-BB-4321-ZYX	456		38	215	
ALA200-2	ALA	200-2	ALA	A-BB-4321-ZYX	225		35	2	
ALA200-3	ALA	200-3	ALA	A-BB-4321-ZYX	224		37	24	
ALA200-4	ALA	200-4	ALA	A-BB-4321-ZYX	225		38	1	
ALA200-5	ALA	200-5	ALA	A-BB-4321-ZYX	225		38	1	
ALA200-6	ALA	200-6	ALA	A-BB-4321-ZYX	224		34	69	
ALA200-7	ALA	200-7	ALA	A-BB-4321-ZYX	224		52	394	
ALD300-1	ALD	300-1	ALD	A-BB-4321-ZYX	771		52	1	
ALD300-2	ALD	300-2	ALD	A-BB-4321-ZYX	200		52	1	
ALD300-3	ALD	300-3	ALD	A-BB-4321-ZYX	100		52	1	
ALD300-4	ALD	300-4	ALD	A-BB-4321-ZYX	200		51	111	
ALD300-5	ALD	300-5	ALD	A-BB-4321-ZYX	60		56	137	
ALA700	ALA	700	ALD	B-CC-4321-ABC	774		12	1	
ALD700	ALD	700	ALD	B-CC-4321-ABC	455		12	477	
AUA700	AUA	700	ALD	B-CC-4321-ABC	225		11	2	
FZF700	FZF	700	ALD	B-CC-4321-ABC	223		13	10	
FZG500	FZG	500	AUA	C-US-0000-ZZZ	543		87	9	
FZF500	FZF	500	AUA	C-US-0000-ZZZ	554		61	15	
FZG400	FZG	400	AUA	C-US-0000-ZZZ	456		86	496	
AUA410	AUA	410	AUA	C-US-0000-ZZZ	770		63	20	
AUA411	AUA	411	AUA	C-US-0000-ZZZ	455		38	460	
AWA300	AWA	300	ALA	A-BB-4321-DAR	291		71	7	
HEU401	HEU	401	ALA	A-BB-4321-DAR	291		71	19	
HEU302	HEU	302	ALA	A-BB-4321-DAR	291		72	1888	

Figure 4-5. IIIMS Prototype dynamic report using a centralized data warehouse

The nodes on the IIIMS prototype map are color coded to aid the user of the program to determine the type of data that the node contains without having to open or otherwise examine the node. In addition, "fly-over" help (balloons with explanatory text appear automatically when the cursor resides over a node) is built in to provide more functionality and usability (Figure 4-6).

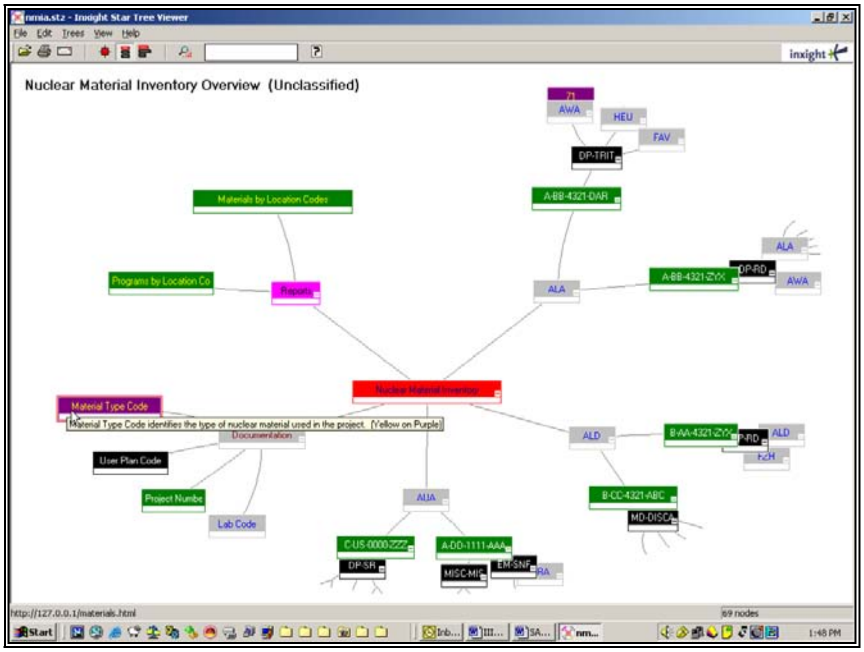
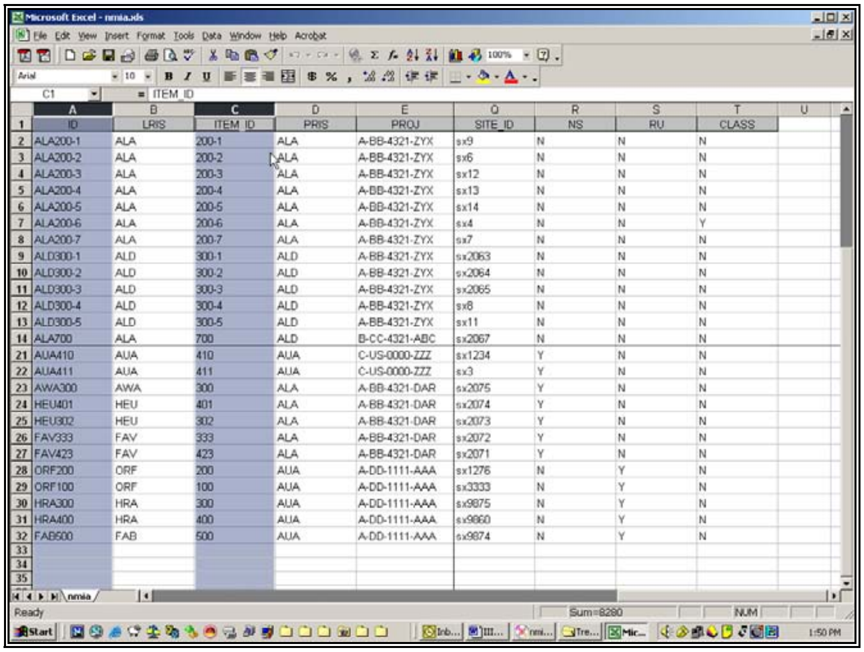


Figure 4-6. IIIMS Prototype color coded nodes and fly-over help

For the purposes of the IIIMS prototype, the data used was a spreadsheet created from two unclassified databases having example data with the same field characteristics as real (controlled or classified) data. One database contained information about the material gathered from a hypothetical site, while the second database created a unique key based on the material from the site and site name (Figure 4-7).



	ID	LRIS	ITEM_ID	PRIS	PROJ	SITE_ID	NS	RU	CLASS
2	ALA200-1	ALA	200-1	ALA	A-BB-4321-ZYX	sx9	N	N	N
3	ALA200-2	ALA	200-2	ALA	A-BB-4321-ZYX	sx6	N	N	N
4	ALA200-3	ALA	200-3	ALA	A-BB-4321-ZYX	sx12	N	N	N
5	ALA200-4	ALA	200-4	ALA	A-BB-4321-ZYX	sx13	N	N	N
6	ALA200-5	ALA	200-5	ALA	A-BB-4321-ZYX	sx14	N	N	N
7	ALA200-6	ALA	200-6	ALA	A-BB-4321-ZYX	sx4	N	N	Y
8	ALA200-7	ALA	200-7	ALA	A-BB-4321-ZYX	sx7	N	N	N
9	ALD300-1	ALD	300-1	ALD	A-BB-4321-ZYX	sx2063	N	N	N
10	ALD300-2	ALD	300-2	ALD	A-BB-4321-ZYX	sx2064	N	N	N
11	ALD300-3	ALD	300-3	ALD	A-BB-4321-ZYX	sx2065	N	N	N
12	ALD300-4	ALD	300-4	ALD	A-BB-4321-ZYX	sx8	N	N	N
13	ALD300-5	ALD	300-5	ALD	A-BB-4321-ZYX	sx11	N	N	N
14	ALA700	ALA	700	ALD	B-CC-4321-ABC	sx2067	N	N	N
21	AUA410	AUA	410	AUA	C-US-0000-ZZZ	sx1234	Y	N	N
22	AUA411	AUA	411	AUA	C-US-0000-ZZZ	sx3	Y	N	N
23	AWA300	AWA	300	ALA	A-BB-4321-DAR	sx2075	Y	N	N
24	HEU401	HEU	401	ALA	A-BB-4321-DAR	sx2074	Y	N	N
25	HEU302	HEU	302	ALA	A-BB-4321-DAR	sx2073	Y	N	N
26	FAV333	FAV	333	ALA	A-BB-4321-DAR	sx2072	Y	N	N
27	FAV423	FAV	423	ALA	A-BB-4321-DAR	sx2071	Y	N	N
28	ORF200	ORF	200	AUA	A-DD-1111-AAA	sx1276	N	Y	N
29	ORF100	ORF	100	AUA	A-DD-1111-AAA	sx3333	N	Y	N
30	HRA300	HRA	300	AUA	A-DD-1111-AAA	sx9875	N	Y	N
31	HRA400	HRA	400	AUA	A-DD-1111-AAA	sx9860	N	Y	N
32	FAB500	FAB	500	AUA	A-DD-1111-AAA	sx9874	N	Y	N

Figure 4-7. IIIMS Prototype data combined from hypothetical Site and Central Data

4.2 Material Forecasting

The purpose of material forecasting was to determine nuclear material availability over a 10 to 15 year period in light of the dynamic nature of nuclear materials management. Existing internal site systems plan current detailed operations schedules. The material forecasting work described here was driven by site's needs since enterprise-level requirements have not been defined. Currently, the forecasting tool includes linked Excel spreadsheets that manipulate material availability at the Y-12 National Security Complex. The Forecasting Model is based on algorithms that reduce Y-12 process flow and plant knowledge to material balance supply and demand equations. The next logical step would be to link these site-specific spreadsheets with spreadsheet models developed for other sites in order to forecast material availability across the enterprise, but this was not performed for this exercise.

The premises of the Forecasting Model should be stated. If there is enough material of all of the types needed for DSW, campaigns, and RTBF projects, then the forecasting is complete. If there is not enough material, the forecasting model/tool will not generate possible solution alternatives, and a negative result will flag the problem. Varying the input values to the Forecasting Model may provide insights into generating possible solution alternatives, and in that sense the model is interactive. Users, including program managers, material managers, and manufacturing process experts, would generate scenarios and their alternatives. The manager, through the use of the forecasting model/tool, would ensure that the tool actually provides a realistic solution that analyzes the alternatives. To help with the interpretation, tabular and visual representations of forecast material modeling results are automatically provided by the model.

Material forecasting work to-date has its greatest focus on highly enriched uranium (HEU) for the Y-12 facility, and specifically to generate quarterly reports. Future extensions would cover more material types (for example material flow models for depleted uranium and lithium-6 materials) and more sites when clear requirements are provided. This activity is relatively straightforward for a range of other nuclear materials and at the other DOE NNSA sites. Data collection for the forecasting model will eventually be linked to the internal Y-12 Dynamic Special Nuclear Material Control and Accountability System (DYMCAS) MC&A system to reduce manual data entry.

4.2.1 Supply and Demand Models

Forecasting for materials management activities can be viewed as calculating long-term supply and demand (i.e., sources and requirements) for critical nuclear and non-nuclear materials at Y-12 site. Forecasting was not designed to address short term operational planning to manage Y-12 site internal operations. Supply and demand functions are typically associated with economic modeling. The generalized economic supply and demand concepts, from which IIIMS forecasting is built, is the relationship between the quantity that producers wish to sell at various prices and the quantity of a commodity that consumers wish to buy. In this case however, the demand curve does not have a monetary component, but is driven by the DSW, Campaigns, and RTBF projects which are required to support specific missions, activities, weapon systems, weapon types, line item deliverables, or nuclear weapons information demonstration requirements. The total demand for all the specific nuclear material by all segments identified by Y-12, for example, determines the aggregate materials needed by Y-12; materials thus depend on availability, and a circular relationship exists between production, inflow, and final demand.

<u>Generalized Forecasting</u>

An example of a conceptual Y-12 HEU supply-and-demand block diagram can be illustrated by Figure 4-8. Selected portions of inventory stock HEU, as well as process stock HEU are needed to fill the "buckets" of raw materials (B1, B2, B3) needed for processing steps in plant production lines. The buckets of HEU material (with different specifications such as purity or enrichment) feed manufacturing processes that support campaigns and stockpile readiness/material demands (SR/MD), or stockpile lifetime extension programs (SLEP) in this example. Some byproduct materials are wasted during manufacture. In this example for HEU, byproducts or waste may include metal castings that are left as residues in a mold, flashings on the casting itself, or machining waste.

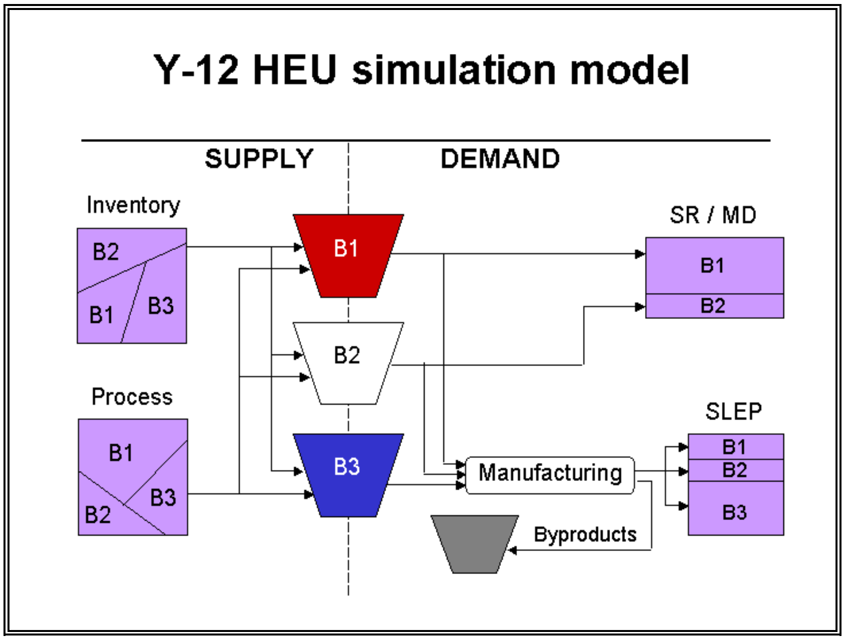


Figure 4-8. Y-12 HEU Supply and Demand Block Diagram

The initial Y-12 forecasting model Excel spreadsheets were consistent with generalized process flows for HEU, DU, and Li materials at Y-12 (Figure 4-8, Figure 4-8, and Figure 4-10, respectively). It can be seen that process-flow supply and demand may have segments that are external to Y-12 and that material possessed by Y-12 is required for operations at other DOE/NNSA sites. Supply and demand also has a component internal to Y-12, when materials are consumed in manufacturing processes, are assayed using destructive methods, or become unusable due to aging or obsolescence.

Forecasting Use

DOE/NNSA HQ assessments of nuclear material inventories indicate that the DOE/NNSA complex, and certain sites in particular, appear to be “awash in materials” (Alspaugh, 2003). The sites store large quantities of nuclear materials, however these materials may not meet supply and demand design specifications, and out-of-spec materials appear to inflate the total usable site inventory. Therefore, the broad HQ appraisal of excesses of materials is frequently disputed by sites, and sites have historically identified the potential for significant shortages in materials for specific programs. The IIIMS Forecasting Model can be applied toward resolving differences in HQ and site perspectives of nuclear material availability.

The forecasting model allows users to explore the solution space and balance the list of demands with the available supplies of materials that meet the specification. The forecasting model provides two benefits over conventional methods of projecting material requirements. First, the model captures the limited and vanishing expertise of some of the material managers explicitly, and therefore can aid in succession management. Second, it automates and makes aspects of materials management analysis easier, freeing managers to explore alternatives more deeply, perform sensitivity analyses, and visualize supply and demand requirements of the future. Possible enhancements might focus on analysis of the output by generating and recommending possible alternatives or solutions.

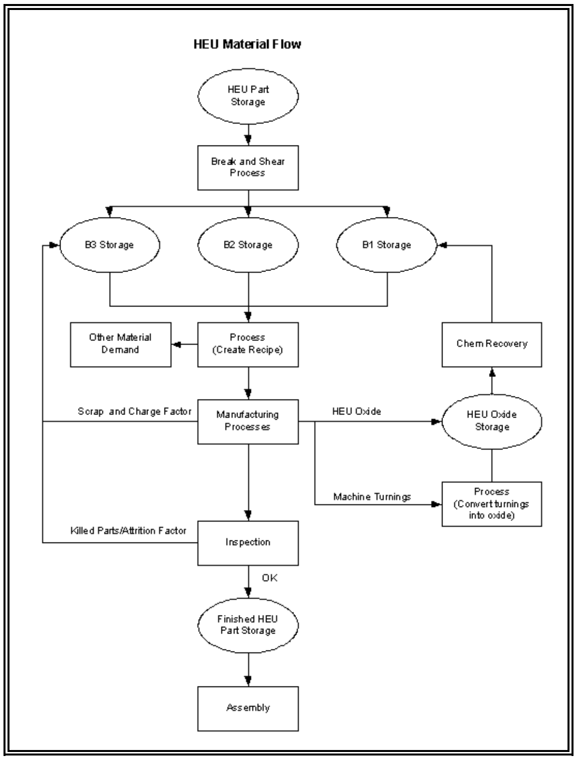


Figure 4-9. Y-12 HEU Material Flow Process

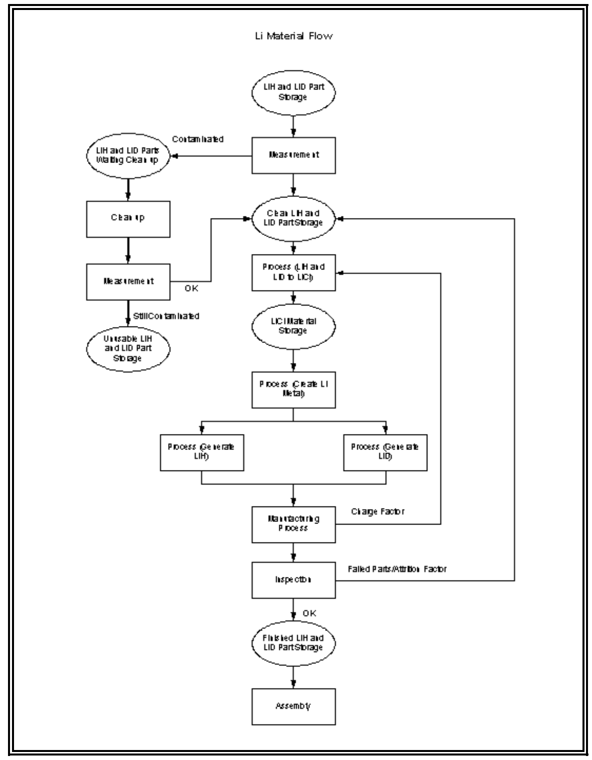


Figure 4-11. Y-12 Lithium Material Flow Process

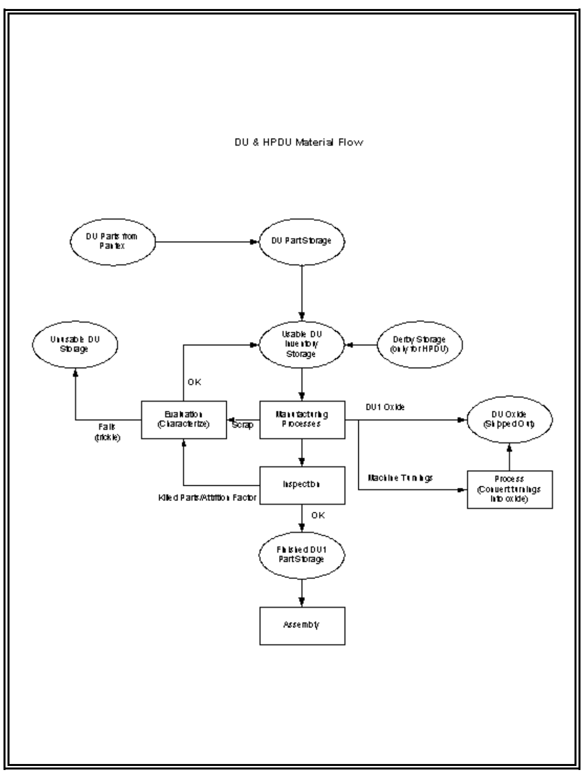


Figure 4-10. Y-12 DU Material Flow Process

Both the starting inventory of the critical materials and a schedule of the requirements for various weapons systems and other programmatic demands are identified as inputs to the model. The forecasting model algorithms convert the number of units needed to the amount of material needed to produce those units. The result may show no material gaps or there may be gaps in one or more materials in certain years as a negative balance in a particular material. Displayed are the years in which gaps appear, the size (amount or quantity) of the gaps for each year, and the programs (Campaigns, LEPs, SLEPs, DSW, or RTBF) for which the material with a gap appears (Figure 4-12). Materials needed to meet demands are represented by colored lines ("buckets" labeled B1, B2, and B3 in the figure). In this example, the supply of B2 will be negative after one year, and demand for that material will not be met. At this point, the material manager must evaluate options to produce the needed material and adjust the inventories for the material to be produced along with input material (if that is appropriate), and the model could be re-run to determine if the modifications eliminate the gaps.

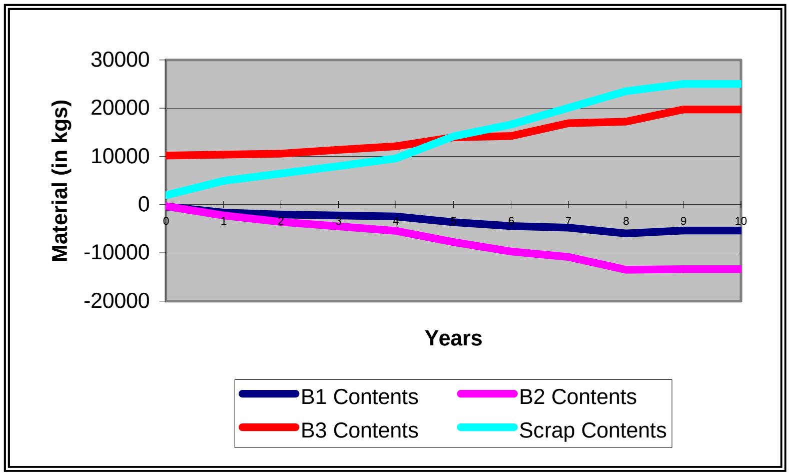


Figure 4-12. Y-12 HEU 10-Year Supply and Demand Simulation Example

4.2.2 Forecasting Methodology

The IIIMS Forecasting Models were initially developed using a simulation modeling tool, Extend (licensed by Imagine That, Inc., 2004). Extend is a flexible, extendable simulation tool which has an interactive and graphical architecture that is combined with a robust development environment. Extend is used to create dynamic models from building blocks, explore the processes involved, and see how they relate. Blocks, which represent parts of the IIIMS Forecasting Model, are the basic model-building components (Figure 4-13). Blocks contained unique procedural information and were grouped into libraries according to function. The forecasting model was built by dragging blocks from a library onto a worksheet, connecting the blocks, and then entering the appropriate data in the dialog for each block. Once the model accurately represented material forecasting, sensitivity analyses was performed to explore alternatives by changing data, by adding or removing blocks, or by using a built-in optimizer to maximize or minimize important variables.

The Extend tool was effective for initial development work with site material managers, and ensured that the basic forecasting model captured the correct processes and material flows. However, for implementation this simulation tool appeared to be over-designed, and was expensive to procure and maintain. The forecasting work continued by utilizing linked Excel spreadsheets, and had the added benefit that excel was a tool most material managers were already familiar with (Excel visual basic source code for the HEU Forecasting Model is provided in Appendix 1). The data was first manually loaded into the forecasting tool, and later automated linkages between the Y-12 HEU forecasting model and the Y-12 internal inventory system (referred to as DYMCAS) were developed.

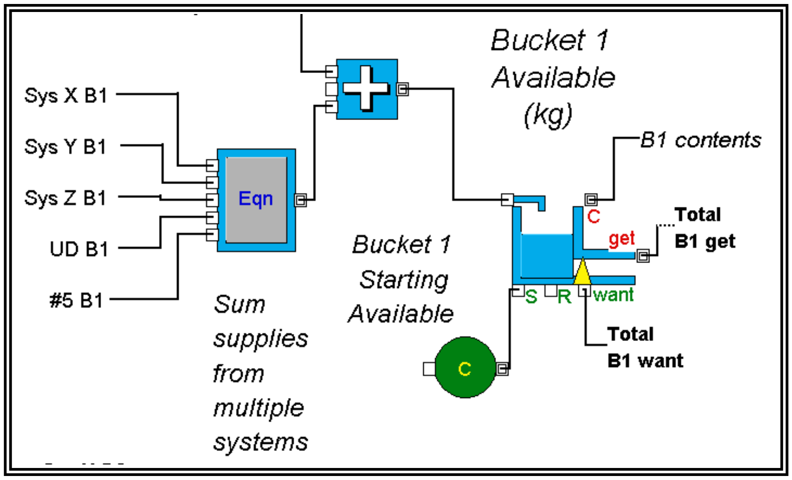


Figure 4-13. Basic IIIMS Conceptual Extend Forecasting Model for Material Supply and Demand

IIIMS forecasting was designed to address only critical nuclear and non-nuclear materials listed in the NA-125.3 Strategic Plan. Cost details were not built into the model, and production scheduling and operational information was not identified. Initially, the forecasting model would only address material availability from inventory, material processing, transformation, and manufacturing processes, but the extending it to include constraints due to storage and transportation capacities is possible.

4.2.3 IIIMS Forecasting Model Data Requirements

The IIIMS Forecasting Model uses site item-level inventory information, dismantlement schedules, manufacturing and ship schedules, and material processing options in its calculations. Specific data requirements for the forecasting model include:

- Material demand for each program
- Bill of materials for each system or component including only the critical materials being forecasted
- Information about manufacturing processes, including the amount of input material that is used (which is always greater than the amount of material shipped in a unit), how much of that material becomes scrap, and how much can be recycled, assuming there is a recycling process available
- Information about any conversion processes, including input and output material specifications, the amount of each input material needed to produce one unit of output, and the capacity of the process
- Any bulk material demand
- Material inventory for each critical material-by-material specification.

<u>Supply inputs</u>
Supply information comes from the sites that have material inventory on hand and/or can process material from unusable forms to usable forms. Where appropriate, supply information may come from commercial vendor forecasts of availability and capacity. The supplies are characterized in the following ways:

- Available (usable or in right form) and unavailable inventory on hand
- Programmatic owner
- Location of inventory on hand within the enterprise (aggregated at site level)
- Material quality (additional characterization such as assay may be needed before a site can determine whether or not it can use the material)
- External supplies (if relevant).

Demand inputs
Demand information comes from DOE/NNSA, DoD, and Work for Others programmatic decision makers and stakeholders. Material demand requirements are identified by NA-122; NA-125; NA-20, NA-30; DOE Offices of Nuclear Energy, Science and Technology, and Naval Reactors; and the United Kingdom. Demands are quantified by the number of unit systems, parts, or the quantity of bulk material needed. For systems or parts, the bill of material (or product structure) specifies the total quantity of material needed for production, as well as the material specifications for each critical material in the system or part. For bulk material, only material specifications are provided.

The forecasting model also incorporates process information in order to provide paths for transforming material from unusable forms to usable forms. For example, a process to produce some blend of raw materials would be characterized by the quantity of input materials or units required to produce one unit of the needed output material. The model will calculate the effects of these processes on the material inventory. The user specifies which processes to use. The next generation models/tools may have incorporated measurement, transportation, and storage processes to explore a broader solution space.

Model Outputs
The IIIMS Forecasting Model provides a set of forecasting reports. The reports contain graphical information and data tables on supplies and demands for each critical material. Reports include inventory category quantity per year and demand and available supply per inventory category per year. More specifically, Table 4-4 provides an unclassified mapping of all possible graphical output reports (charts) for the Y-12 HEU Forecasting model. Actual unclassified graphic output corresponding to this table is provided in Appendix 2.

To more easily support sensitivity analysis and scenario-based, what-if planning, versions of the input and output data sets may be considered as a future enhancement. For each output, the source data would have been identified, including the date of forecast and the date/version of the data set (inventory data set, demand, site-level processes); the input and output data sets would then be saved for subsequent analysis.

4.3 NMIA Consolidation and Reporting

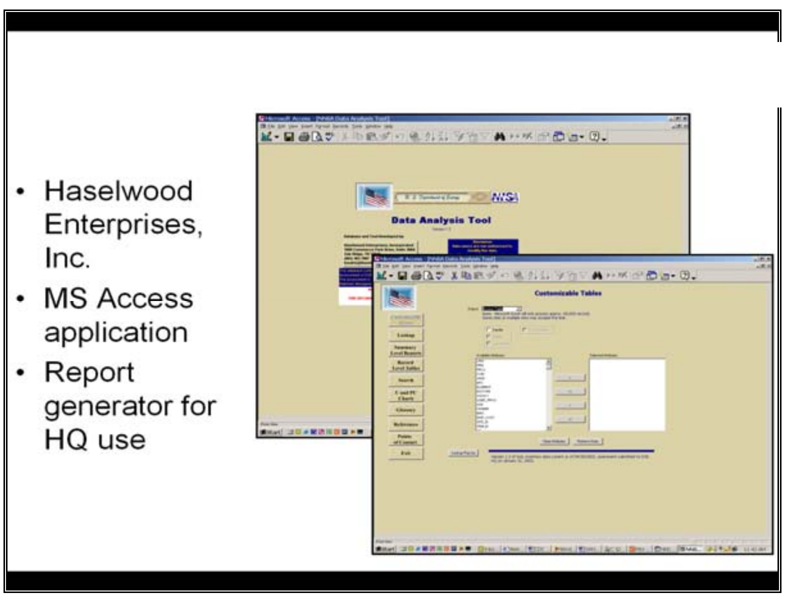
NMIA consolidation and reporting also seems to be a relatively straightforward task, and has largely been defined and addressed by the NNSA Data Analysis Tool (Haselwood Data Tool). The NNSA guidance defines the requirements of NMIA reports. The NMIA data from the five NNSA sites can be collected centrally, loaded into the Haselwood Data Tool, and submitted to NNSA as a consolidated report or database. In addition, a set of standard queries that had been defined to run against the database for users with the appropriate authorizations is possible. In some cases, *ad hoc* queries can also be created, as long as each site approves the use of its data and authorizes the requestor to see the data. Microsoft Office 2000 Professional must be installed on the desktop computer being used to update the Haselwood Data Tool. A set of protocols to control access to, and use of, the NMIA data has also been developed.

Key users of the NMIA data include NNSA, site users who may use it to access their own site data, and coordinating groups that need to analyze data from multiple sites. An example of the latter would the cross-site quarterly coordinating group, if it were reinstituted as has been discussed. Figure 4-14 provides screen shots of the NMIA Data Analysis Tool. The logical continuation of this work is uncertain given the sites' decisions not to submit consolidated reports.

The Haselwood Data Tool was developed using simulated data and is initially unclassified until populated with classified data. Because actual inventory (classified) site data was not available to verify the functions of the Haselwood Data Tool, each site runs independent queries and checks the results once actual the software is populated with actual site data. The graphical user interface exhibits appropriate security notices. The Data Specification for FY 2002 is found in Table 4-6, and Project Table Attributes are found in Table 4-6.

Table 4-4. Unclassified Mapping Graphical Output Reports For The Y-12 HEU Forecasting Model

Output Selection	Charts Generated				
All Categories Charts	FY Carryover	Sources	Requirements Out the Door (OTD[2])	Totals	-
Category A Charts	Category A	Category A Sources	Category A Requirements OTD	Category A Totals	Category A (two views)
Category B Charts	Category B	Category B Sources	Category B Requirements OTD	Category B Totals	Category B (two views)
Category C Charts	Category C	Category C Sources	Category C Requirements OTD	Category C Totals	Category C (two views)
Category D Charts	Category D	Category D Sources	Category D Requirements OTD	Category D Totals	Category D (two views)
Category E Charts	Category E	Category E Sources	Category E Requirements OTD	Category E Totals	Category E (two views)
Category F Charts	Category F	Category F Sources	Category F Requirements OTD	Category F Totals	Category F (two views)
Category Other Charts	Category Other	Category Other Sources	Category Other Requirements OTD	Category Other Totals	Category Other (two views)
Source	Sources	Category A Sources	Category B Sources	Category C … F Sources	Category Other Sources
Requirements	Requirements OTD	Category A Requirements OTD	Category B Requirements OTD	Category C … F Requirements OTD	Category Other Requirements OTD
Materials	Totals	Category A Totals	Category B Totals	Category C … F Totals	Category Other Totals
OTD / Sources / In the Pan (ITP[3])	Category A (two views)	Category B (two views)	Category C (two views)	Category D … F (two views)	Category Other (two views)



2 OTD – "Out the Door"—jargon used by Y-12 to identify what material is actually shipped out the door as a machined part or as a bulk material demand. OTD appears on the bill of materials.

3 ITP – "In the Pan" —also called "Kg Throughput," used by Y-12 to identify the total amount of material that is pulled in order to meet a demand actually on the shop floor being processed. ITP includes charge and attrition factors.

Figure 4-14. Relevant Screen Shots of the NMIA Data Analysis Tool

Table 4-5. NMIA Data Specification for FY 2002

Field	Type	Length	Format
LRIS	Character	4	XXXX
PRIS	Character	4	XXXX
PROJ	Character	13	X-XX-XXXX-XXX
COEI	Character	3	XXX
ANSI	Character	3	XXX
MTC	Character	2	XX
ELEMENT	Number/Double	14	9999999999.999
ISOTOPE	Number/Double	14	9999999999.999
ASSAY	Number/Double	6	999.99
ITEM_ID	Site-specific	Site-specific	Site-specific
USER_PROG	Character	10	DP-XXXXXXX MD-XXXXXXX Etc.
NS	Character	1	X
USE	Character	1	X
OWNER	Character	1	X
RU	Character	1	X
CLASS	Character	1	X
IDES	Character	6	XXXXXX
SITE_FORM	Site-specific	Site-specific	Site-specific
NMI_MAPID	Number	5	Map-specific
Weapon Type	Character	Site-specific	Site-specific
Component Type	Character	Site-specific	Site-specific
SURPLUS	Character	1	X
DISP_COST	Character	1	X
SITE_ID	Site-specific	Site-specific	Site-specific

Table 4-6. Project Table Attributes

Field Name	Data Type	Description
ID	Auto/Number	Text
Project Number	Text	Text
Project Title	Text	Text
DOE Manager Code	Text	Text
DOE Program Code	Text	Text
RIS	Text	Text
Number	Text	Text
Name	Text	Text
Qty	Text	Text
Allotment Code	Text	Text

5. Conclusions

5.1 Lessons Learned

Formal enterprise-level requirements (i.e., DOE Orders) were never issued. DOE HQ also did not identify the fundamental motivating concepts in the course of IIIMS development work from 1998 to 2004. Verbal direction by NNSA/NA-125.3, and later the DOE/NNSA CIO, to shift the responsibility of modernizing materials management information systems to the sites de-coupled the site's efforts at producing unified solutions (even though IIIMS was expected to provide tools for individual sites within a context of later supporting the enterprise). One lesson learned is that without direct and relevant development of an IIIMS or unified information systems regulation in the form of one or more DOE Directives (official communications of policies, requirements, and procedures) from DOE/NNSA HQ level, any attempt at developing an enterprise-wide IIIMS will fail. The second lesson learned is that without structured requirements, the constant change of responsible personnel in authority positions at DOE/NNSA HQ, despite anyone's best efforts and intent, will thwart the long-term efforts of even the best-organized operation.

Therefore, only a knowledgeable, responsible, and accountable team, whose members are facile in managing nuclear materials and include one high-level DOE/NNSA official who will champion the effort and distribute funding, must be constituted to produce the requisite directive(s). Leveraging off the e-Government IDEA initiative on Nuclear Materials Accountability, as well as DOE Strategic Planning[4] (DOE 1993) is vital to initiating efforts and infusing funds are required for any next stage of planning. Any new development effort for a IIIMS team will have to overcome a whole litany of challenges including lack of timely coordination between HQ and the sites, the change of potential sponsors and champions, and the energy to overcome the *status quo* material management operations at DOE HQ.

5.2 Systems Requirements for IIIMS

As identified in previous sections, the initial purpose of the IIIMS project was to develop a modern nuclear materials management information system at the enterprise level of DOE/NNSA headquarters. This effort would be attended by collaboration with the DOE/NNSA nuclear weapon sites, predominantly LLNL, LANL, Y-12 National Security Complex, Pantex, and SNL. The new system would address numerous HQ and site missions and roles within the nuclear weapons complex, and (hopefully) consolidate numerous nuclear material management information systems that support local operations.

A top-down approach to IIIMS requirements would first necessitate inclusion of the reporting functions provided by NMMSS to provide the same output reports which facilities and US government offices use to manage and safeguard nuclear materials. The migration of NMMSS to the XML for increased capability and integration, as well as Sun Microsystems or PC servers and PC-based desktop computing, may also be important requirements. In most cases, a new NMMSS supporting the enterprise would have elements of the old NMMSS. For example, production of COEI reports for each facility would be necessary, as would NRC licensee and DOE contractor reports detailing semiannual material balance data. Transaction data for transfers, foreign retransfers, operating losses, inventory differences, burnup, contract reclassifications, origin swaps, project number changes, shipper/receiver data comparisons, and other changes affecting inventory data must be included in NMMSS reporting as well. Finally, an NMMSS data comparison capability to support nuclear nonproliferation initiatives is required.

[4] Defense Strategic Goal: To protect our national security by applying advanced science and nuclear technology to the Nation's defense, specifically Nuclear Weapons Stewardship to ensure that our nuclear weapons continue to serve their essential deterrence role by maintaining and enhancing the safety, security, and reliability of the U.S. nuclear weapons stockpile.

Enterprise-wide IIIMS would incorporate site requirements. LANMAS, the NMIA data Tool, and IIIMS are not mutually exclusive and the best elements of these systems must be retained. LANMAS and the NMIA Data Analysis Tool were customized and built for site-specific needs. The experience of implementing LANMAS and the NMIA Data Tool and their everyday use, are important for a truly functional enterprise system. Therefore, LANMAS and the NMIA Data Tool are not mutually exclusive of IIIMS, and the IIIMS concepts previously presented in this paper (including the Forecasting Model) would provide the functional mechanics of integration and the robustness needed for the overall system.

Optimum (minimum) cost is not necessarily an appropriate goal. The US government is willing to pay a premium for safeguards and security systems. IIIMS requirements should be structured to provide high confidence levels that significant, slight, or indicator discrepancies are detected, while divulging classified information to unauthorized entities does not occur. The hardware and software to support IIIMS are already available today, or require only minimal reconfiguration. Multiple MC&A systems are in place to provide data (quantity, status, and location) for all materials at all DOE/NNSA and NRC sites, although these are not integrated. Given the specific requirement(s), hardware/software resources, and manpower, an enterprise-wide and integrated system can be instituted which automatically or semi-automatically compiles DOE/NNSA and NRC data. Therefore, developing a modern, integrated system would require coordinating multiple organizations and paying for immediate hardware and software solutions. The alternative is paying out proportionately lesser sums over a long period (and paying more in total) for the manpower within each of the disparate systems to generate the required accountancy data

5.3 Possible Next Steps

5.3.1 Leverage New Efforts on Past Initiatives

Duplicating or reengineering the efforts of activities from 1999 to the present (NMSI SIM, BPR, and a broad concept of the enterprise) is unnecessary, and in fact future initiatives can build on the previous work summarized in the sections above. To provide initial impetus to a development program, Energy Secretary Spencer Abraham recently indicated the need for new initiative to develop security technology, specifically “to move the weapons complex to a computer-based ‘diskless environment’ within five years” (Monitor 2004). This plan could presumably leverage an enterprise-wide IIIMS materials management concept with all the necessary security as well as with the requisite technology.

In addition, the adoption of the Additional Protocol of the Nonproliferation Treaty compels the United States to seek a safeguards system that is effective, efficient, and flexible. A key part of the U.S. plan is to retain nuclear material accountancy as a safeguards measure of fundamental importance (Cherry, *et al.* 2004). There is no better argument for a modern IIIMS than enhanced national security and requisite transparency that would come with IIIMS.

Stimulus for developing an IIIMS program can be found in past efforts at DOE. In FY2000, an initiative to “Develop and Revise Department Orders” and institutionalize changes in management practice was identified. The multi year agenda for this effort called for a “nuclear materials information management and inventory accountability system and upgrade and integrate to the degree possible.” The need for a new requirement was identified and could probably be resurrected to:

> “… include developing a new Departmental Order on Management of Nuclear Materials (Department Policy and Order 5660.1B) … [which] would identify the scope and requirements of a comprehensive, integrated Departmental nuclear material stewardship program and assign and describe the responsibilities of each program support element, including an NMSI coordinating function.” (DOE 2000b)

Finally, the DOE Information Architecture Program (DOE 2003) was initiated to improve the Department's information management processes. The Program defined the foundations, baseline, guidance, standards, and vision for the development and implementation of an architecture-based process for making IT investment decisions. A primary tenet of the DOE information architecture methodology was that business needs drive the need for applications and technology, not the other way around. The architecture would be used to assess legacy and development systems for alignment with key business, technical, and operational criteria. It is possible that IIIMS implementation would fulfill this concept. Specifically the DOE Information Architecture Program included four thrusts:

- Implement a Department-wide enterprise architecture (EA) to support the acquisition and maintenance of information technology investments per the requirements of OMB Circular A-130 and other guidance
- Make common, reliable data available for sharing Department-wide and minimize redundant and duplicative systems
- Complete, refine, and execute the Corporate Systems Information Architecture
- Provide leadership, education, and support to EA efforts.

5.3.2 Model Systems Based on Successful Programs

Some examples of government successes in the area of integrated, enterprise-wide materials management systems already exist, and can be used as overall models to base IIIMS implementation concepts upon. These systems are identified and described below:

- The Compliance Monitoring and Tracking System (CMTS) national-level inactive weapon stockpile reporting for START (and other treaties) by the U.S. Air Force Treaties and Agreements Branch (USAF/XONP)[5]
- The Defense Threat Reduction Agency's (DTRA) Nuclear Weapon Information Tracking Systems (Department of Defense 1999) which integrate the Nuclear Management Information System (NUMIS), the Special Weapons Information Management System (SWIM), Defense Integration and Management of Nuclear Data Services (DIAMONDS), and the Nuclear Weapons Contingency Operations Module (NWCOM) to provide DoD with the ability to track the location of all active nuclear weapons and components from cradle-to-grave.[6]

START accountancy is initiated at so-called Nodes (which are analogous to DOE/NNSA sites), with dedicated terminals on the Secret Internet Protocol Router Network (SIPRNET) at each facility. The compliance software verifies that data being sent from the United States to the other parties in START is in compliance with all START rules and agreements. Data are transmitted to the Nuclear Risk Reduction Center (NRRC), which is a centralized Department of State Operations Center, located in Washington, DC, responsible for transmitting treaty notifications to the other Parties. For example, an update from any Node back to the Central Node and the NRRC is required when the status of a reportable item changes.

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[5] Compliance software (developed in C using embedded Structured Query Language - SQL) resides on a Sun SPARC Station 20 server and uses an Ingres database to track U.S. assets that are Treaty Accountable Items (TAIs) and to verify that actions reported via the CMTS Windows PC client software do not violate START rules.

[6] NUMIS/NWCOM consists of two classified Sun Microsystems, Incorporated, SPARCserver 2000 production servers, and two unclassified developmental SPARCserver 1000 and 5500 servers. The servers are located at two separate locations for purposes of 100% redundancy. The NUMIS/NWCOM production servers use Solaris 2.5.1 as the operating system and Oracle 7.3.2.3 as the database server software. NUMIS, NWCOM, and SWIM communicate via the Automatic Digital Network and Secret Internet Protocol Router Network (SIPRNET). SWIM data is transmitted via the DoD Components Communications Center over the Automatic Digital Network. SWIM sends data to NUMIS or NWCOM but does not receive data from them. NUMIS and NWCOM receive messages via the Automatic Digital Network, Message Distribution Terminal, and the Multifunctional Secure Gateway System. Message traffic is passed over the Automatic Digital Network and received via the Message Distribution Terminal for routing or distribution. Messages can be designated for the NUMIS or NWCOM system. The messages are routed to, then through, the Multifunctional Secure Gateway System. In addition, NUMIS sends messages to NWCOM using the reverse process.

Formats (a report or form for use at each Node terminal) define specific reporting requirements, and this report is filled in and transmitted.

Logically, any one of the sites in the nuclear weapons complex could develop the computerized database IIIMS system(s) in conjunction and/or collaboration with the Defense Programs Nuclear Materials Working Group, made up of representatives from five NNSA sites. There is an expectation among many participants of the Defense Programs Nuclear Materials Working Group that SNL would maintain and operate the IIIMS system and the computer server network(s) required for implementation.

In the end, the IIIMS enterprise ideal will only come to fruition when a commitment is made by headquarters and site information management business practices are changed. HQ must support re-issue of requirements documents and provide the funding necessary for programmatic change and organizational change.

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Appendix 1
MS Excel Visual Basic Source Code for High Enriched Uranium Forecasting Model

```
Option Explicit

Public CurrentWB As Workbook           'Name of the initial workbook
Public FirstTimeThrough As Boolean
Public InitialOpening As Boolean
Public Chart_Data(15) As Range
Public Chart_Type(15) As Variant
Public Chart_Title(15) As String * 30
Public NumSeries(15) As Integer
Public RowOffset(15) As Integer
Public iChart As Integer
Public NumChart As Integer

Dim co As ChartObject

Sub ChartTheData()
   Dim C As ChartObject
   Dim K As Integer
   Dim I As Integer

   Set CurrentWB = ThisWorkbook
   CurrentWB.Worksheets("Charts").Activate
   Range("B2").Select
   PleaseWait          'Display PleaseWait message

   'Remove any charts currently on the page
   For Each C In Worksheets("Charts").ChartObjects
      C.Activate
      'C.Select
      C.Visible = False
      C.Delete
   Next C

   Application.ScreenUpdating = True
   Range("B2").Select
   Application.ScreenUpdating = False


   '***Setup the requested chart type***

   If ActiveSheet.btnAllCategories.Value Then
      'All Categories Charts
      AllCategoriesCharts
   End If

  If ActiveSheet.btnCategoryA.Value Then
      'Category A Charts
      CategoryACharts
   End If

   If ActiveSheet.btnCategoryB.Value Then
      'Category B Charts
      CategoryBCharts
   End If

   If ActiveSheet.btnCategoryC.Value Then
      'Category C Charts
      CategoryCCharts
   End If

   If ActiveSheet.btnCategoryD.Value Then
      'Category D Charts
```

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```
      CategoryDCharts
   End If

   If ActiveSheet.btnCategoryE.Value Then
      'Category E Charts
      CategoryECharts
   End If

   If ActiveSheet.btnCategoryF.Value Then
      'Category F Charts
      CategoryFCharts
   End If

   If ActiveSheet.btnCategoryOther.Value Then
      'Category Other Charts
      CategoryOtherCharts
   End If

   If ActiveSheet.btnSource.Value Then
      'Source Charts
      SourceCharts
   End If

   If ActiveSheet.btnRequirements.Value Then
      'Requirements Charts
      RequirementsCharts
   End If

   If ActiveSheet.btnMaterial.Value Then
      'Materials Totals Charts
      MaterialCharts
   End If

   If ActiveSheet.btnOTDSourcesITP.Value Then
      'OTD/Sources/ITP Charts
      OTDSourcesITPCharts
   End If

   'Generate the requested charts
   Call GenerateChart(iChart, NumChart)

   'Reposition the buttons and menu items on the Charts worksheet
   ChartPosition
   Application.ScreenUpdating = False

   CurrentWB.Worksheets("Charts").Activate
   Range("B2").Select
   PleaseWaitClear            'Clear Please Wait message
   Application.Goto Range("A1"), Scroll:=True 'Position to the first chart
   Range("A1").Activate
End Sub

Sub AllCategoriesCharts()
   Dim C As ChartObject
   Dim K As Integer
   Dim I As Integer

   iChart = 1
   NumChart = 4    'Number of charts to be generated

   'Setup the First chart
   K = 1
```

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```
    Set Chart_Data(K) = Worksheets("Output Data").Range("FY_Carryover").CurrentRegion
    Chart_Type(K) = "xlLine"
    NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be charted
    RowOffset(K) = 0
    Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

    'Setup the Second chart
    K = 2
    Set Chart_Data(K) = Sheets("Output Data").Range("Source").CurrentRegion
    Chart_Type(K) = "xlColumnStacked"
    NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be charted
    RowOffset(K) = 0
    Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

    'Setup the Third chart
    K = 3
    Set Chart_Data(K) = Sheets("Output Data").Range("Requirements_OTD").CurrentRegion
    Chart_Type(K) = "xlColumnStacked"
    NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be charted
    RowOffset(K) = 0
    Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

    'Setup the Fourth chart
    K = 4
    Set Chart_Data(K) = Sheets("Output Data").Range("Totals").CurrentRegion
    Chart_Type(K) = "custom"
    NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be charted
    RowOffset(K) = 0
    Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

End Sub

Sub CategoryACharts()
    Dim C As ChartObject
    Dim K As Integer
    Dim I As Integer

    iChart = 2
    NumChart = 6

    'Setup the First chart
    K = 1
    Set Chart_Data(K) = Sheets("Output Data").Range("FY_Carryover").CurrentRegion
    Chart_Type(K) = "xlLine"
    NumSeries(K) = 1 'Number of series to be charted
    RowOffset(K) = 1 'Data is in first row of table
    Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

    'Setup the Second chart
    K = 2
    Set Chart_Data(K) = Sheets("Output Data").Range("Category_A_Sources").CurrentRegion
    Chart_Type(K) = "xlColumnStacked"
    NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be charted
    RowOffset(K) = 0
    Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

    'Setup the Third chart
    K = 3
    Set Chart_Data(K) = Sheets("Output Data").Range("Category_A_Requirements_OTD").CurrentRegion
    Chart_Type(K) = "xlColumnStacked"
    NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be charted
```

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```
    RowOffset(K) = 0
    Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

    'Setup the Fourth chart
    K = 4
    Set Chart_Data(K) = Sheets("Output Data").Range("Category_A_Totals").CurrentRegion
    Chart_Type(K) = "custom"
    NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be charted
    RowOffset(K) = 0
    Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

    'Category A OTD/Sources/ITP xlColumnClustered
    K = 5
    Set Chart_Data(K) = Sheets("Output Data").Range("Category_A").CurrentRegion
    Chart_Type(K) = "xlColumnClustered"
    NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be charted
    RowOffset(K) = 0
    Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

    'Category A OTD/Sources/ITP xlLineMarkers
    K = 6
    Set Chart_Data(K) = Sheets("Output Data").Range("Category_A").CurrentRegion
    Chart_Type(K) = "xlLineMarkers"
    NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be charted
    RowOffset(K) = 0
    Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value
End Sub

Sub CategoryBCharts()
    Dim C As ChartObject
    Dim K As Integer
    Dim I As Integer

    iChart = 3
    NumChart = 6

    'Setup the First chart
    K = 1
    Set Chart_Data(K) = Sheets("Output Data").Range("FY_Carryover").CurrentRegion
    Chart_Type(K) = "xlLine"
    NumSeries(K) = 1 'Number of series to be charted
    RowOffset(K) = 2 'Data is in second row of table
    Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

    'Setup the Second chart
    K = 2
    Set Chart_Data(K) = Sheets("Output Data").Range("Category_B_Sources").CurrentRegion
    Chart_Type(K) = "xlColumnStacked"
    NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be charted
    RowOffset(K) = 0
    Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

    'Setup the Third chart
    K = 3
    Set Chart_Data(K) = Sheets("Output Data").Range("Category_B_Requirements_OTD").CurrentRegion
    Chart_Type(K) = "xlColumnStacked"
    NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number
charted
    RowOffset(K) = 0
    Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

    'Setup the Fourth chart
```

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```
   K = 4
   Set Chart_Data(K) = Sheets("Output Data").Range("Category_B_Totals").CurrentRegion
   Chart_Type(K) = "custom"
   NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be charted
   RowOffset(K) = 0
   Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

   'Category B OTD/Sources/ITP xlColumnClustered
   K = 5
   Set Chart_Data(K) = Sheets("Output Data").Range("Category_B").CurrentRegion
   Chart_Type(K) = "xlColumnClustered"
   NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be charted
   RowOffset(K) = 0
   Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

   'Category B OTD/Sources/ITP xlLineMarkers
   K = 6
   Set Chart_Data(K) = Sheets("Output Data").Range("Category_B").CurrentRegion
   Chart_Type(K) = "xlLineMarkers"
   NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be charted
   RowOffset(K) = 0
   Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value
End Sub
Sub CategoryCCharts()
   Dim C As ChartObject
   Dim K As Integer
   Dim I As Integer

   iChart = 4
   NumChart = 6

   'Setup the First chart
   K = 1
   Set Chart_Data(K) = Sheets("Output Data").Range("FY_Carryover").CurrentRegion
   Chart_Type(K) = "xlLine"
   NumSeries(K) = 1 'Number of series to be charted
   RowOffset(K) = 3 'Data is in third row of table
   Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

   'Setup the Second chart
   K = 2
   Set Chart_Data(K) = Sheets("Output Data").Range("Category_C_Sources").CurrentRegion
   Chart_Type(K) = "xlColumnStacked"
   NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be charted
   RowOffset(K) = 0
   Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

   'Setup the Third chart
   K = 3
   Set Chart_Data(K) = Sheets("Output Data").Range("Category_C_Requirements_OTD").CurrentRegion
   Chart_Type(K) = "xlColumnStacked"
   NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be charted
   RowOffset(K) = 0
   Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).
```

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```

   'Setup the Fourth chart
   K = 4
   Set Chart_Data(K) = Sheets("Output Data").Range("Category_C_Totals").CurrentRegion
   Chart_Type(K) = "custom"
   NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be charted
```

```
   RowOffset(K) = 0
   Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

   'Category C OTD/Sources/ITP xlColumnClustered
   K = 5
   Set Chart_Data(K) = Sheets("Output Data").Range("Category_C").CurrentRegion
   Chart_Type(K) = "xlColumnClustered"
   NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be charted
   RowOffset(K) = 0
   Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

   'Category C OTD/Sources/ITP xlLineMarkers
   K = 6
   Set Chart_Data(K) = Sheets("Output Data").Range("Category_C").CurrentRegion
   Chart_Type(K) = "xlLineMarkers"
   NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be charted
   RowOffset(K) = 0
   Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

End Sub

Sub CategoryDCharts()
   Dim C As ChartObject
   Dim K As Integer
   Dim I As Integer

   iChart = 5
   NumChart = 6

   'Setup the First chart
   K = 1
   Set Chart_Data(K) = Sheets("Output Data").Range("FY_Carryover").CurrentRegion
   Chart_Type(K) = "xlLine"
   NumSeries(K) = 1 'Number of series to be charted
   RowOffset(K) = 4 'Data is in fourth row of table
   Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

   'Setup the Second chart
   K = 2
   Set Chart_Data(K) = Sheets("Output Data").Range("Category_D_Sources").CurrentRegion
   Chart_Type(K) = "xlColumnStacked"
   NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be charted
   RowOffset(K) = 0
   Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

   'Setup the Third chart
   K = 3
   Set Chart_Data(K) = Sheets("Output Data").Range("Category_D_Requirements_OTD").CurrentRegion
   Chart_Type(K) = "xlColumnStacked"
   NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be charted
   RowOffset(K) = 0
   Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

   'Setup the Fourth chart
```

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```
   K = 4
   Set Chart_Data(K) = Sheets("Output Data").Range("Category_D_Totals").CurrentRegion
   Chart_Type(K) = "custom"
   NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be charted
   RowOffset(K) = 0
   Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

```

```
    'Category D OTD/Sources/ITP xlColumnClustered
    K = 5
    Set Chart_Data(K) = Sheets("Output Data").Range("Category_D").CurrentRegion
    Chart_Type(K) = "xlColumnClustered"
    NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be charted
    RowOffset(K) = 0
    Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

    'Category D OTD/Sources/ITP xlLineMarkers
    K = 6
    Set Chart_Data(K) = Sheets("Output Data").Range("Category_D").CurrentRegion
    Chart_Type(K) = "xlLineMarkers"
    NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be charted
    RowOffset(K) = 0
    Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

End Sub
Sub CategoryECharts()
    Dim C As ChartObject
    Dim K As Integer
    Dim I As Integer

    iChart = 5
    NumChart = 6

    'Setup the First chart
    K = 1
    Set Chart_Data(K) = Sheets("Output Data").Range("FY_Carryover").CurrentRegion
    Chart_Type(K) = "xlLine"
    NumSeries(K) = 1 'Number of series to be charted
    RowOffset(K) = 5 'Data is in fifth row of table
    Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

    'Setup the Second chart
    K = 2
    Set Chart_Data(K) = Sheets("Output Data").Range("Category_E_Sources").CurrentRegion
    Chart_Type(K) = "xlColumnStacked"
    NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be charted
    RowOffset(K) = 0
    Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

    'Setup the Third chart
    K = 3
    Set Chart_Data(K) = Sheets("Output Data").Range("Category_E_Requirements_OTD").CurrentRegion
    Chart_Type(K) = "xlColumnStacked"
    NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be charted
    RowOffset(K) = 0
    Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

    'Setup the Fourth chart
    K = 4
    Set Chart_Data(K) = Sheets("Output Data").Range("Category_E_Totals").CurrentRegion
    Chart_Type(K) = "custom"
    NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be charted
    RowOffset(K) = 0
    Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

    'Category E OTD/Sources/ITP xlColumnClustered
    K = 5
    Set Chart_Data(K) = Sheets("Output Data").Range("Category_E").CurrentRegion
```

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```
    Chart_Type(K) = "xlColumnClustered"
    NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be charted
    RowOffset(K) = 0
    Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

    'Category E OTD/Sources/ITP xlLineMarkers
    K = 6
    Set Chart_Data(K) = Sheets("Output Data").Range("Category_E").CurrentRegion
    Chart_Type(K) = "xlLineMarkers"
    NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be charted
    RowOffset(K) = 0
    Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

End Sub
Sub CategoryFCharts()
    Dim C As ChartObject
    Dim K As Integer
    Dim I As Integer

    iChart = 5
    NumChart = 6

    'Setup the First chart
    K = 1
    Set Chart_Data(K) = Sheets("Output Data").Range("FY_Carryover").CurrentRegion
    Chart_Type(K) = "xlLine"
    NumSeries(K) = 1 'Number of series to be charted
    RowOffset(K) = 6 'Data is in sixth row of table
    Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

    'Setup the Second chart
    K = 2
    Set Chart_Data(K) = Sheets("Output Data").Range("Category_F_Sources").CurrentRegion
    Chart_Type(K) = "xlColumnStacked"
    NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be charted
    RowOffset(K) = 0
    Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

    'Setup the Third chart
    K = 3
    Set Chart_Data(K) = Sheets("Output Data").Range("Category_F_Requirements_OTD").CurrentRegion
    Chart_Type(K) = "xlColumnStacked"
    NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be charted
    RowOffset(K) = 0
    Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

    'Setup the Fourth chart
    K = 4
    Set Chart_Data(K) = Sheets("Output Data").Range("Category_F_Totals").CurrentRegion
    Chart_Type(K) = "custom"
    NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number
charted
    RowOffset(K) = 0
    Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

    'Category F OTD/Sources/ITP xlColumnClustered
    K = 5
    Set Chart_Data(K) = Sheets("Output Data").Range("Category_F").CurrentRegion
    Chart_Type(K) = "xlColumnClustered"
    NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be charted
    RowOffset(K) = 0
```

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```
    Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

    'Category F OTD/Sources/ITP xlLineMarkers
    K = 6
    Set Chart_Data(K) = Sheets("Output Data").Range("Category_F").CurrentRegion
    Chart_Type(K) = "xlLineMarkers"
    NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be charted
    RowOffset(K) = 0
    Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

End Sub
Sub CategoryOtherCharts()
    Dim C As ChartObject
    Dim K As Integer
    Dim I As Integer

    iChart = 5
    NumChart = 6

    'Setup the First chart
    K = 1
    Set Chart_Data(K) = Sheets("Output Data").Range("FY_Carryover").CurrentRegion
    Chart_Type(K) = "xlLine"
    NumSeries(K) = 1 'Number of series to be charted
    RowOffset(K) = 7 'Data is in seventh row of table
    Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

    'Setup the Second chart
    K = 2
    Set Chart_Data(K) = Sheets("Output Data").Range("Category_Other_Sources").CurrentRegion
    Chart_Type(K) = "xlColumnStacked"
    NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be charted
    RowOffset(K) = 0
    Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

    'Setup the Third chart
    K = 3
    Set Chart_Data(K) = Sheets("Output Data").Range("Category_Other_Requirements_OTD").CurrentRegion
    Chart_Type(K) = "xlColumnStacked"
    NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be charted
    RowOffset(K) = 0
    Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

    'Setup the Fourth chart
    K = 4
    Set Chart_Data(K) = Sheets("Output Data").Range("Category_Other_Totals").CurrentRegion
    Chart_Type(K) = "custom"
    NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be charted
    RowOffset(K) = 0
    Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).
```

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```

    'Category Other OTD/Sources/ITP xlColumnClustered
    K = 5
    Set Chart_Data(K) = Sheets("Output Data").Range("Category_Other").CurrentRegion
    Chart_Type(K) = "xlColumnClustered"
    NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be charted
    RowOffset(K) = 0
    Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

    'Category Other OTD/Sources/ITP xlLineMarkers
    K = 6
    Set Chart_Data(K) = Sheets("Output Data").Range("Category_Other").CurrentRegion
    Chart_Type(K) = "xlLineMarkers"
    NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be charted
    RowOffset(K) = 0
    Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

End Sub
Sub SourceCharts()
    Dim C As ChartObject
    Dim K As Integer
    Dim I As Integer

    iChart = 9
    NumChart = 8

    'Setup the First chart
    K = 1
    Set Chart_Data(K) = Sheets("Output Data").Range("Source").CurrentRegion
    Chart_Type(K) = "xlColumnStacked"
    NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be charted
    RowOffset(K) = 0
    Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

    'Setup the Second chart
    K = 2
    Set Chart_Data(K) = Sheets("Output Data").Range("Category_A_Sources").CurrentRegion
    Chart_Type(K) = "xlColumnStacked"
    NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be charted
    RowOffset(K) = 0
    Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

    'Setup the Third chart
    K = 3
    Set Chart_Data(K) = Sheets("Output Data").Range("Category_B_Sources").CurrentRegion
    Chart_Type(K) = "xlColumnStacked"
    NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be charted
    RowOffset(K) = 0
    Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

    'Setup the Fourth chart
    K = 4
    Set Chart_Data(K) = Sheets("Output Data").Range("Category_C_Sources").CurrentRegion
    Chart_Type(K) = "xlColumnStacked"
    NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be charted
    RowOffset(K) = 0
    Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

    'Setup the Fifth chart
    K = 5
```

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```
    Set Chart_Data(K) = Sheets("Output Data").Range("Category_D_Sources").CurrentRegion
    Chart_Type(K) = "xlColumnStacked"
    NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be charted
    RowOffset(K) = 0
    Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

    'Setup the Sixth chart
    K = 6
    Set Chart_Data(K) = Sheets("Output Data").Range("Category_E_Sources").CurrentRegion
    Chart_Type(K) = "xlColumnStacked"
    NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be charted
```

```
    RowOffset(K) = 0
    Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

    'Setup the Seventh chart
    K = 7
    Set Chart_Data(K) = Sheets("Output Data").Range("Category_F_Sources").CurrentRegion
    Chart_Type(K) = "xlColumnStacked"
    NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be charted
    RowOffset(K) = 0
    Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

    'Setup the Eighth chart
    K = 8
    Set Chart_Data(K) = Sheets("Output Data").Range("Category_Other_Sources").CurrentRegion
    Chart_Type(K) = "xlColumnStacked"
    NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be charted
    RowOffset(K) = 0
    Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value



End Sub

Sub RequirementsCharts()
    Dim C As ChartObject
    Dim K As Integer
    Dim I As Integer

    iChart = 10
    NumChart = 8

    'Setup the First chart
    K = 1
    Set Chart_Data(K) = Sheets("Output Data").Range("Requirements_OTD").CurrentRegion
    Chart_Type(K) = "xlColumnStacked"
    NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be charted
    RowOffset(K) = 0
    Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

    'Setup the Second chart
    K = 2
    Set Chart_Data(K) = Sheets("Output Data").Range("Category_A_Requirements_OTD").CurrentRegion
    Chart_Type(K) = "xlColumnStacked"
    NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be charted
    RowOffset(K) = 0
    Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

    'Setup the Third chart
    K = 3
    Set Chart_Data(K) = Sheets("Output Data").Range("Category_B_Requirements_OTD").CurrentRegion
    Chart_Type(K) = "xlColumnStacked"
    NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be charted
    RowOffset(K) = 0
    Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

    'Setup the Fourth chart
    K = 4
    Set Chart_Data(K) = Sheets("Output Data").Range("Category_C_Requirements_OTD").CurrentRegion
    Chart_Type(K) = "xlColumnStacked"
    NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be charted
```

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```
    RowOffset(K) = 0
    Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

    'Setup the Fifth chart
    K = 5
    Set Chart_Data(K) = Sheets("Output Data").Range("Category_D_Requirements_OTD").CurrentRegion
    Chart_Type(K) = "xlColumnStacked"
    NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be charted
    RowOffset(K) = 0
    Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

    'Setup the Sixth chart
    K = 6
    Set Chart_Data(K) = Sheets("Output Data").Range("Category_E_Requirements_OTD").CurrentRegion
    Chart_Type(K) = "xlColumnStacked"
    NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be charted
    RowOffset(K) = 0
    Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

    'Setup the Seventh chart
    K = 7
    Set Chart_Data(K) = Sheets("Output Data").Range("Category_F_Requirements_OTD").CurrentRegion
    Chart_Type(K) = "xlColumnStacked"
    NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be charted
    RowOffset(K) = 0
    Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

    'Setup the Eighth chart
    K = 8
    Set Chart_Data(K) = Sheets("Output Data").Range("Category_Other_Requirements_OTD").CurrentRegion
    Chart_Type(K) = "xlColumnStacked"
    NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be charted
    RowOffset(K) = 0
    Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value
End Sub
Sub MaterialCharts()
    Dim C As ChartObject
    Dim K As Integer
    Dim I As Integer

    iChart = 11
    NumChart = 8

    'Setup the First chart
    K = 1
    Set Chart_Data(K) = Sheets("Output Data").Range("Totals").CurrentRegion
    Chart_Type(K) = "custom"
    NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Num charted
    RowOffset(K) = 0
    Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

    'Setup the Second chart
    K = 2
    Set Chart_Data(K) = Sheets("Output Data").Range("Category_A_Totals").CurrentRegion
    Chart_Type(K) = "custom"
    NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be charted
    RowOffset(K) = 0
    Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

    'Setup the Third chart
    K = 3
```

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```
   Set Chart_Data(K) = Sheets("Output
Data").Range("Category_B_Totals").CurrentRegion
   Chart_Type(K) = "custom"
   NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be
charted
   RowOffset(K) = 0
   Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

   'Setup the Fourth chart
   K = 4
   Set Chart_Data(K) = Sheets("Output
Data").Range("Category_C_Totals").CurrentRegion
   Chart_Type(K) = "custom"
   NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be
charted
   RowOffset(K) = 0
   Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

   'Setup the Fifth chart
   K = 5
   Set Chart_Data(K) = Sheets("Output
Data").Range("Category_D_Totals").CurrentRegion
   Chart_Type(K) = "custom"
   NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be
charted
   RowOffset(K) = 0
   Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

   'Setup the Sixth chart
   K = 6
   Set Chart_Data(K) = Sheets("Output
Data").Range("Category_E_Totals").CurrentRegion
   Chart_Type(K) = "custom"
   NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be
charted
   RowOffset(K) = 0
   Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

   'Setup the Seventh chart
   K = 7
   Set Chart_Data(K) = Sheets("Output
Data").Range("Category_F_Totals").CurrentRegion
   Chart_Type(K) = "custom"
   NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be
charted
   RowOffset(K) = 0
   Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

   'Setup the Eighth chart
   K = 8
   Set Chart_Data(K) = Sheets("Output
Data").Range("Category_Other_Totals").CurrentRegion
   Chart_Type(K) = "custom"
   NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Num
charted
```

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```
   RowOffset(K) = 0
   Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value
End Sub

Sub OTDSourcesITPCharts()
   Dim C As ChartObject
   Dim K As Integer
   Dim I As Integer

   iChart = 12
   NumChart = 14

   '***First set of charts are Clustered Columns***
   'Setup the First chart
   K = 1
   Set Chart_Data(K) = Sheets("Output
Data").Range("Category_A").CurrentRegion
   Chart_Type(K) = "xlColumnClustered"
   NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be
charted
   RowOffset(K) = 0
   Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

   'Setup the Second chart
   K = 2
   Set Chart_Data(K) = Sheets("Output
Data").Range("Category_B").CurrentRegion
   Chart_Type(K) = "xlColumnClustered"
   NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be
charted
   RowOffset(K) = 0
   Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

   'Setup the Third chart
   K = 3
   Set Chart_Data(K) = Sheets("Output
Data").Range("Category_C").CurrentRegion
   Chart_Type(K) = "xlColumnClustered"
   NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be
charted
   RowOffset(K) = 0
   Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

   'Setup the Fourth chart
   K = 4
   Set Chart_Data(K) = Sheets("Output
Data").Range("Category_D").CurrentRegion
   Chart_Type(K) = "xlColumnClustered"
   NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be
charted
   RowOffset(K) = 0
   Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

   'Setup the Fifth chart
   K = 5
   Set Chart_Data(K) = Sheets("Output
Data").Range("Category_E").CurrentRegion
   Chart_Type(K) = "xlColumnClustered"
   NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be
charted
   RowOffset(K) = 0
   Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

   'Setup the Sixth chart
   K = 6
   Set Chart_Data(K) = Sheets("Output
Data").Range("Category_F").CurrentRegion
   Chart_Type(K) = "xlColumnClustered"
   NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Num
charted
```

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```
   RowOffset(K) = 0
   Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

   'Setup the Seventh chart
   K = 7
   Set Chart_Data(K) = Sheets("Output
Data").Range("Category_Other").CurrentRegion
   Chart_Type(K) = "xlColumnClustered"
   NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be
charted
   RowOffset(K) = 0
   Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

   '***Second set of charts are Line charts***
   'Setup the Eighth chart
   K = 8
   Set Chart_Data(K) = Sheets("Output
Data").Range("Category_A").CurrentRegion
   Chart_Type(K) = "xlLineMarkers"
   NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be
charted
```

```
    RowOffset(K) = 0
    Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

    'Setup the Ninth chart
    K = 9
    Set Chart_Data(K) = Sheets("Output Data").Range("Category_B").CurrentRegion
    Chart_Type(K) = "xlLineMarkers"
    NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be charted
    RowOffset(K) = 0
    Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

    'Setup the Tenth chart
    K = 10
    Set Chart_Data(K) = Sheets("Output Data").Range("Category_C").CurrentRegion
    Chart_Type(K) = "xlLineMarkers"
    NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be charted
    RowOffset(K) = 0
    Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

    'Setup the Eleventh chart
    K = 11
    Set Chart_Data(K) = Sheets("Output Data").Range("Category_D").CurrentRegion
    Chart_Type(K) = "xlLineMarkers"
    NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be charted
    RowOffset(K) = 0
    Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

    'Setup the Twelfth chart
    K = 12
    Set Chart_Data(K) = Sheets("Output Data").Range("Category_E").CurrentRegion
    Chart_Type(K) = "xlLineMarkers"
    NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be charted
    RowOffset(K) = 0
    Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

    'Setup the Thirteenth chart
    K = 13
    Set Chart_Data(K) = Sheets("Output Data").Range("Category_F").CurrentRegion
    Chart_Type(K) = "xlLineMarkers"
    NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Num
charted
    RowOffset(K) = 0
    Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

    'Setup the Fourteenth chart
    K = 14
    Set Chart_Data(K) = Sheets("Output Data").Range("Category_Other").CurrentRegion
    Chart_Type(K) = "xlLineMarkers"
    NumSeries(K) = Chart_Data(K).Rows.Count - 1 'Number of series to be charted
    RowOffset(K) = 0
    Chart_Title(K) = Chart_Data(K).Offset(RowOffset(K), 0).Resize(1, 1).Value

End Sub




Sub GenerateChart(iChart As Integer, NumChart As Integer)

    Dim I As Integer
    Dim J As Integer
```

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```
    Dim DataTable As Range
    Dim NumRow As Integer
    Dim NumCol As Integer
    Dim NumRowOffset As Integer
    Dim iLeft As Long
    Dim iTop As Long
    Dim iWidth As Long
    Dim iHeight As Long

    'Define position parameters for initial chart
    iLeft = 250
    iWidth = 460
    iHeight = 258

For I = 1 To NumChart
    iTop = 75 + 300 * (I - 1)
    Set co = Sheets("Charts").ChartObjects.Add(iLeft, iTop, iWidth, iHeight)
    'co.Chart.Location Where:=xlLocationAsObject, Name:="Charts"
    'co.Chart.Select
    co.Chart.SetSourceData Source:=Chart_Data(I).Resize(2, 1), PlotBy:=xlRows
    co.Chart.SeriesCollection(1).Delete

    Select Case Trim(Chart_Type(I))
        Case "custom"
            co.Chart.ApplyCustomType ChartType:=xlBuiltIn, TypeName:="Line - Column"
            'co.Chart.ApplyCustomType ChartType:=xlUserDefined, TypeName:="LineBar"
        Case "xlLine"
            co.Chart.ChartType = xlLine
        Case "xlLineMarkers"
            co.Chart.ChartType = xlLineMarkers
        Case "xlColumnStacked"
            co.Chart.ChartType = xlColumnStacked
        Case "xlColumnClustered"
            co.Chart.ChartType = xlColumnClustered
        Case Else
            MsgBox ("An undefined chart type: " + Chart_Type(I))
    End Select

    'The data to be charted is located in range Chart_Data(I)
    'MsgBox (Chart_Data(I).Address)
    NumRow = Chart_Data(I).Rows.Count      'Number of rows including 1 header row
    NumCol = Chart_Data(I).Columns.Count   'Number of columns of data in the table

    'Add series to the chart
    NumRowOffset = RowOffset(I)
    For J = 1 To NumSeries(I)
        If RowOffset(I) = 0 Then NumRowOffset = J
        Call NewChartSeries(I, Chart_Data(I), NumRow, NumCol, J, NumRowOffset)
    Next J

    With co.Chart
        .HasTitle = True
        .ChartTitle.Characters.Text = Chart_Title(I)
        .Axes(xlCategory, xlPrimary).HasTitle = False
        .Axes(xlValue, xlPrimary).HasTitle = True
        .Axes(xlValue, xlPrimary).AxisTitle.Characters.Text = "Kgs"
    End With
    With co.Chart.Axes(xlValue)
        .HasMajorGridlines = True
        .HasMinorGridlines = False
    End With
    co.Chart.HasLegend = True
    co.Chart.Legend.Position = xlRight

    co.Chart.ChartTitle.AutoScaleFont = True
    With co.Chart.ChartTitle.Font
```

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```
        .Name = "Arial"
        .FontStyle = "Bold"
        .Size = 12
    End With

    'For some reason, we need to redefine the custom chart here.
    If Trim(Chart_Type(I)) = "custom" Then
        co.Chart.ApplyCustomType ChartType:=xlBuiltIn, TypeName:="Line - Column"
        'co.Chart.ApplyCustomType ChartType:=xlUserDefined, TypeName:="LineBar"
        With co.Chart
            .HasTitle = True
            .ChartTitle.Characters.Text = Chart_Title(I)
            .Axes(xlValue, xlPrimary).HasTitle = True
            .Axes(xlValue, xlPrimary).AxisTitle.Characters.Text = "Kgs"
        End With
        co.Chart.ChartTitle.AutoScaleFont = True
        With co.Chart.ChartTitle.Font
            .Name = "Arial"
            .FontStyle = "Bold"
            .Size = 12
        End With
    End If
Next I

End Sub

Sub NewChartSeries(I, DataTable, NumRow, NumCol, SeriesNumber, RowOffset)
    Dim XNameRange As Range
    Dim XLabelRange As Range
    Dim XValueRange As Range

    co.Chart.SeriesCollection.NewSeries
    'Set range of x-axis labels
    Set XLabelRange = DataTable.Offset(0, 1).Resize(1, NumCol - 1)
    co.Chart.SeriesCollection(SeriesNumber).XValues = XLabelRange
    'MsgBox (XLabelRange.Address)

    'Set range of values to be charted
    Set XValueRange = DataTable.Offset(RowOffset, 1).Resize(1, NumCol - 1)
    co.Chart.SeriesCollection(SeriesNumber).Values = XValueRange
    'MsgBox (XValueRange.Address)
```

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```
    'Set range location for name of values
    Set XNameRange = DataTable.Offset(RowOffset, 0).Resize(1, 1)
    co.Chart.SeriesCollection(SeriesNumber).Name = XNameRange
    'MsgBox (XNameRange.Address)

End Sub

Sub ChartPosition()
' Routine used to reposition the buttons and menu items
' on the Charts worksheet.

Worksheets("Charts").Activate

ActiveSheet.btnAllCategories.Top = 54
ActiveSheet.btnAllCategories.Left = 16.5
ActiveSheet.btnAllCategories.Width = 150
ActiveSheet.btnAllCategories.Height = 18

ActiveSheet.btnCategoryA.Top = 72
ActiveSheet.btnCategoryA.Left = 16.5
ActiveSheet.btnCategoryA.Width = 150
ActiveSheet.btnCategoryA.Height = 18

ActiveSheet.btnCategoryB.Top = 90
ActiveSheet.btnCategoryB.Left = 16.5
ActiveSheet.btnCategoryB.Width = 150
ActiveSheet.btnCategoryB.Height = 18

ActiveSheet.btnCategoryC.Top = 108
ActiveSheet.btnCategoryC.Left = 16.5
ActiveSheet.btnCategoryC.Width = 150
ActiveSheet.btnCategoryC.Height = 18

ActiveSheet.btnCategoryD.Top = 126
ActiveSheet.btnCategoryD.Left = 16.5
ActiveSheet.btnCategoryD.Width = 150
ActiveSheet.btnCategoryD.Height = 18

ActiveSheet.btnCategoryE.Top = 144
ActiveSheet.btnCategoryE.Left = 16.5
ActiveSheet.btnCategoryE.Width = 150
ActiveSheet.btnCategoryE.Height = 18

ActiveSheet.btnCategoryF.Top = 162
ActiveSheet.btnCategoryF.Left = 16.5
ActiveSheet.btnCategoryF.Width = 150
ActiveSheet.btnCategoryF.Height = 18

ActiveSheet.btnCategoryOther.Top = 180
ActiveSheet.btnCategoryOther.Left = 16.5
ActiveSheet.btnCategoryOther.Width = 150
ActiveSheet.btnCategoryOther.Height = 18

ActiveSheet.btnSource.Top = 198
ActiveSheet.btnSource.Left = 16.5
ActiveSheet.btnSource.Width = 150
ActiveSheet.btnSource.Height = 18

ActiveSheet.btnRequirements.Top = 216
ActiveSheet.btnRequirements.Left = 16.5
ActiveSheet.btnRequirements.Width = 150
ActiveSheet.btnRequirements.Height = 18

ActiveSheet.btnMaterial.Top = 234
ActiveSheet.btnMaterial.Left = 16.5
ActiveSheet.btnMaterial.Width = 150
ActiveSheet.btnMaterial.Height = 18
```

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```
ActiveSheet.btnOTDSourcesITP.Top = 252
ActiveSheet.btnOTDSourcesITP.Left = 16.5
ActiveSheet.btnOTDSourcesITP.Width = 150
ActiveSheet.btnOTDSourcesITP.Height = 18

ActiveSheet.CommandButton1.Top = 285
ActiveSheet.CommandButton1.Left = 16.5
ActiveSheet.CommandButton1.Width = 150
ActiveSheet.CommandButton1.Height = 23.25

ActiveSheet.Label1.Top = 33.75
ActiveSheet.Label1.Left = 41.25
ActiveSheet.Label1.Width = 84
ActiveSheet.Label1.Height = 16.5

'ActiveSheet.PrintButton.Top = 2.25
'ActiveSheet.PrintButton.Left = 770.25
'ActiveSheet.PrintButton.Left = 860.25

Application.Goto Range("A1"), Scroll:=True

End Sub


Sub PleaseWait()
    InitialOpening = True
```

```
    Selection.Font.ColorIndex = 1       'Black Font
    Selection.Interior.ColorIndex = 2   'White Interior
    Application.ScreenUpdating = True
    ActiveCell.Value = "Please Wait"
    Application.ScreenUpdating = False
End Sub

Sub PleaseWaitClear()
    InitialOpening = True
    Selection.ClearContents
    Selection.Font.ColorIndex = 1              'Automatic Font Color
    Selection.Interior.ColorIndex = 47         'Purple Interior
End Sub
```

Appendix 2
Unclassified HEU Forecasting Model Graphic Output Examples

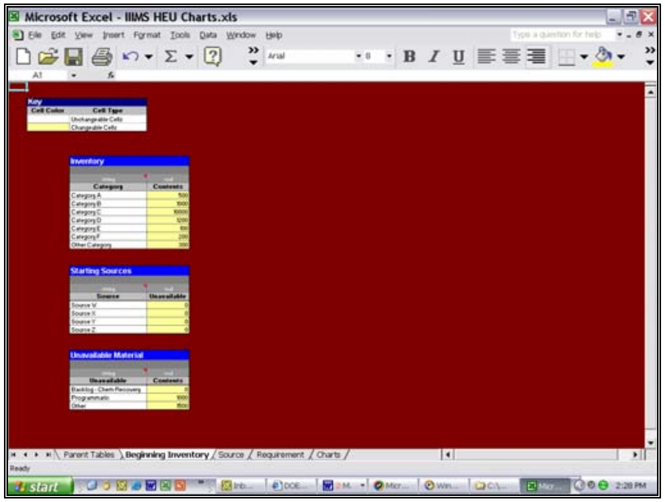

Figure A 2- 1. Beginning Inventory Tables

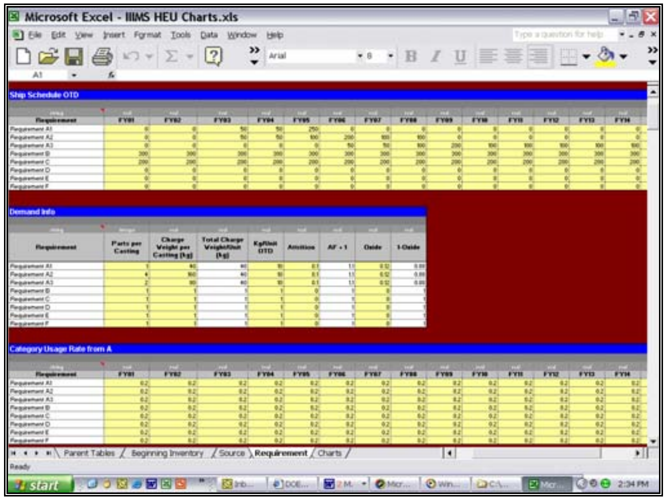

Figure A 2- 3. Requirement Tables

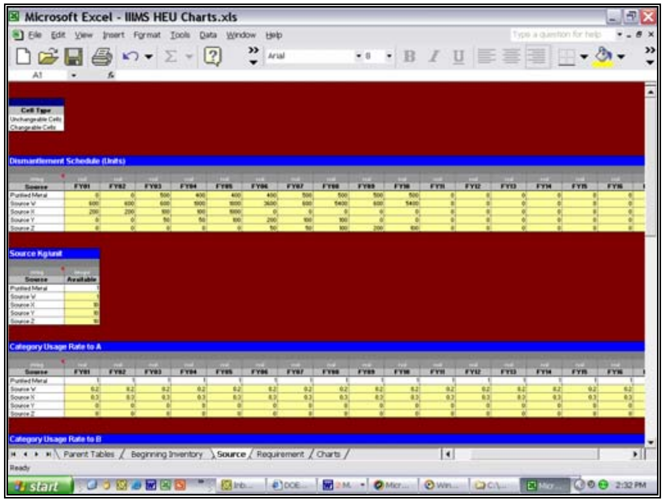

Figure A 2- 2. Source Tables

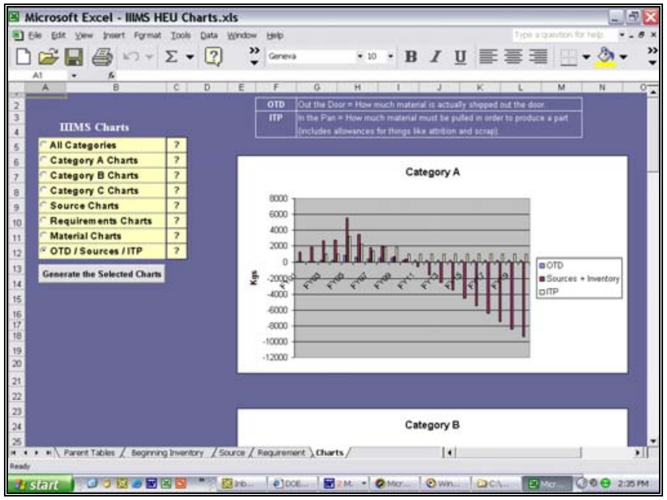

Figure A 2- 4. Charts Tables

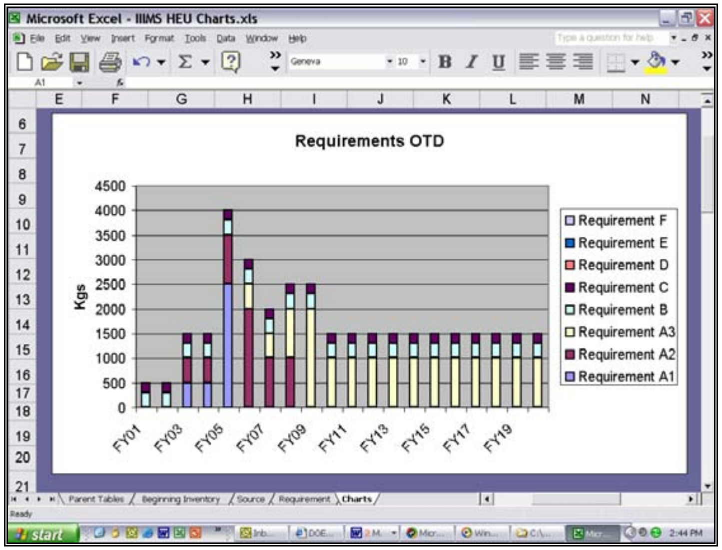

Figure A 2- 5. Requirements OTD Totals

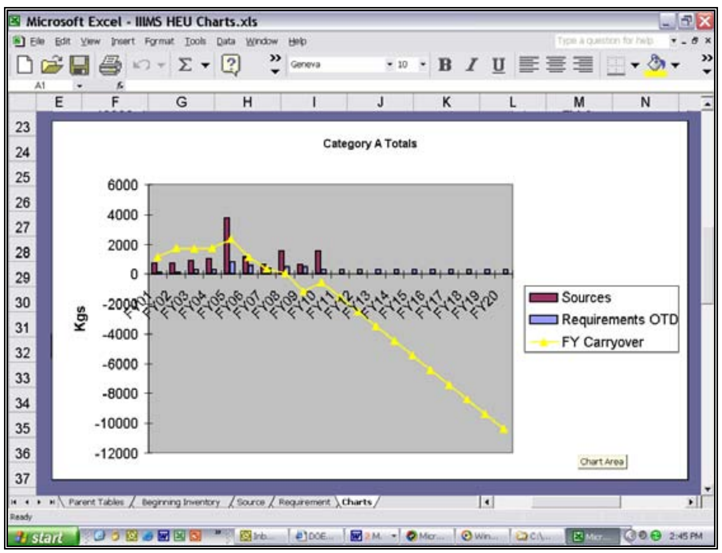

Figure A 2- 6. Category A Materials Totals

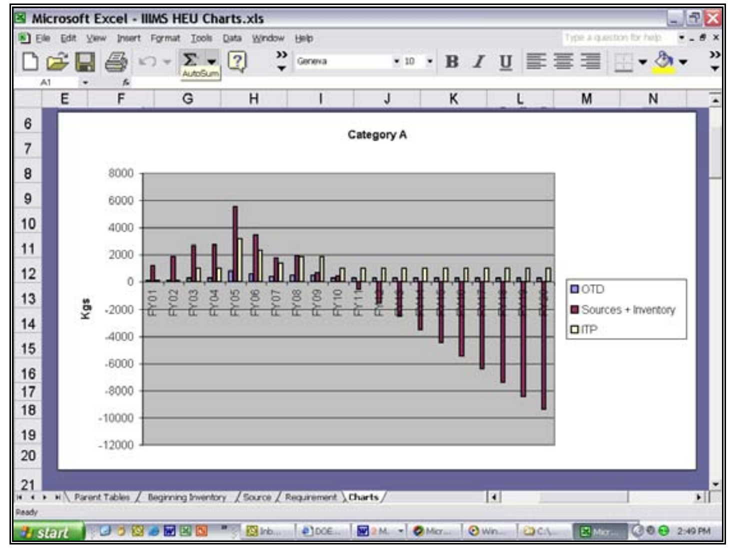

Figure A 2- 7. OTD/Sources/ITP Category A

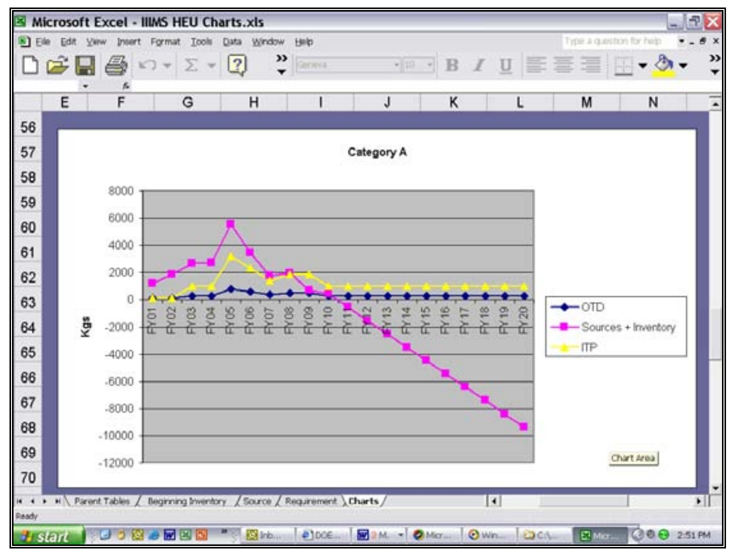

Figure A 2- 8. OTD/Sources/ITP Category A

Distribution

2	MS 1371	Christopher A. Aas, 6926
1	MS 1374	Robert M. Huelskamp, 6926
1	MS 1217	Ricardo A. Contreras, 5925
1	MS 1207	Olin H. Bray, 5923
1	MS 1138	Christina L. Jenkin, 6222
1	MS 9018	Central Technical Files, 8945-1
2	MS 0899	Technical Library, 9616
2	NA-124	Dale R. Dunsworth
2	NA-125.2	John W. (Bill) Newton