TRANSURANIC WASTE INFORMATION PROCESSING LESSONS LEARNED

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ABSTRACT

The massive amount of data required for characterizing, certifying, and transporting Contact-Handled Transuranic (CH-TRU) waste to the Waste Isolation Pilot Plant (WIPP) necessitated development of an integrated system to meet production rates associated with the accelerated schedules. Creating and maintaining an information system through the continually changing requirements was a challenge. The Idaho National Engineering and Environmental Laboratory (INEEL) developed an information processing system that was essential in meeting the 3,100m^3 milestone which supported seventeen shipments a week, at times and more than ten shipments a week sustained.

This paper discusses lessons learned for four key areas that were essential for successful TRU waste information processing during six years of production TRU waste data processing. Factors that contributed to our success were establishing goals and objectives, using digital signatures, adhering to the information model and using a reference data driven design.

INTRODUCTION

The signing of the state of Idaho's Settlement Agreement [1] with the U.S. Department of Energy (DOE) on October 16, 1995 committed INEEL to ship 3,100 cubic meters of transuranic (TRU) waste out of Idaho by December 31, 2002. The use of a paper-based system to gather, organize, review, and approve this data would have been extremely time consuming, cumbersome, and unmanageable when attempting to meet the accelerated shipment goals. The 3,100m^3 milestone was met six weeks ahead of schedule and under budget. The Transuranic Reporting, Inventory and Processing System (TRIPS) application and development team was essential in meeting this milestone.

The INEEL developed the TRIPS application to speed up the data collection and approval process. The TRIPS application is a customized computer database tool to effectively manage the data generation, modification, and review processes. The application is a passive, electronic system that provides near-paperless processing for container tracking, characterization, data validation, certification, and transportation. Major factors for the success of TRIPS included:

- Establishing of goals and objectives for the project and developing an infrastructure to support the goals and objectives,
- Using digital signatures for a near-paperless data flow,
- Adhering to the information model to store and manage the data once and
- Using a reference data driven design to reduce software changes.

Background

The TRIPS timeline began with the signing of the letter requesting an information system - February 1996, and ended with the 3,100m^3 records close-out activities supported by the TRIPS team - April 2003. The following architecture and operations sections will provide a background to understand the impact of the continually changing requirements.

Architecture
TRIPS is a client/server configuration consisting of an Oracle™ database resident on a Sun™ computer server along with a front-end personal computer (PC) system to allow the user to view the data in the database. TRIPS architecture consisted of three Sun Solaris™ boxes and multiple PCs running Microsoft Windows 95™, Windows NT™ or Windows 2000™. The development tool used was a product from Compuware called Uniface™. The information model was duplicated in the Uniface™ product and the end user screens were developed in Uniface™. Users with signing permissions had a Litronic Netsign 210™ smart card reader attached to their PC. They were also assigned a Schlumberger Crytpoflex™ smart card for creating digital signatures. The project used Symbol™ barcode readers and Intermec™ wireless barcode readers for the waste container inventory subsystem of TRIPS.

24/7 Operations
When the 3100m^3 initiated a 24 hours a day 7 days a week shift, the database needed to be up 24 hours a day. This left no time for required daily database backups. A standby database was created on another Unix server located 50 miles from the main production server. This allowed the production database to be copied approximately every 20 minutes to the standby database. If the production database went down for any reason, the TRIPS process could point the users to the other server within one operating shift. The TRIPS application was in production for over six years (two of those years supporting 24/7 operations), supporting up to 400 users under continually changing requirements to support this critical INEEL mission.

Figure 1 shows a summary of the subsystems and functions supported by the TRIPS application.

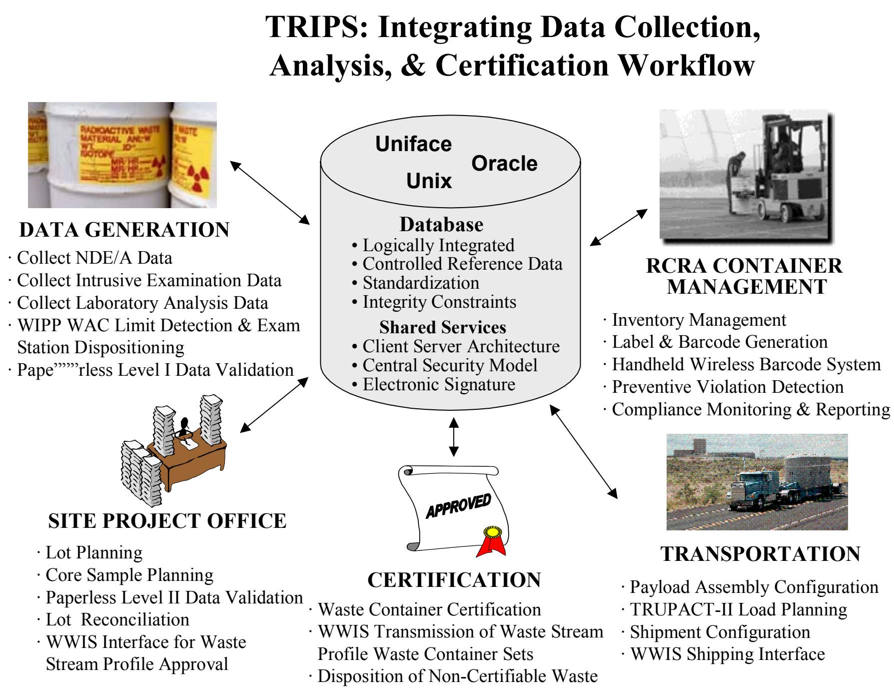

Fig. 1. TRIPS functions

Goals and Objectives

Defining a clear and obtainable goal allowed the development team to maintain focus. As documented in the System Requirements Specification [2] (SRS) the TRIPS goal was:

> TRIPS will be an integrated data collection, analysis and management system to support characterization, certification, and transportation processes needed to ship contact handled TRU waste to WIPP.

This goal was written in 1997. Six objectives that supported the TRIPS goal were written in the SRS. The objectives included: container management, characterization, certification, report automation, transportation, and integration. All of these objectives were met.

Scope Creep

Keeping focused goals and objectives allowed the development team to say no to the customer to reduce scope creep. Not long after TRIPS began collecting characterization data, management requested additional functionality beyond that identified in the original scope. The requested management data - to aid in determining the production rates - were not signed quality records in TRIPS, data structures. Another application developed by another group of developers (the Information Resource Management personnel) provided the management tracking reports by querying the TRIPS database. This was a good example of controlling scope creep by allowing another reporting tool to interface with the TRIPS data structures.

Methodology - Spiral Development/Phased Implementation

An infrastructure to support the goals and objectives was needed. A methodology that would be flexible enough to handle the continually changing requirements and aggressive schedules was selected. Identifying the source and impact of changes and documenting those changes was an important part of change management. The TRIPS design effort identified cross-cutting development rules to allow for the changes of how data will be used during the life cycle. Very few of the simplest processes were operating at production rates needed to support shipment of 3,100 m^3 of waste within the mandated timeframe. Due to the requirements constantly changing and the aggressive schedule, a modified spiral approach was used for development that provided for controlled design decisions to be implemented after software coding was initiated. From a high-level perspective, TRIPS development included the same activities as the traditional waterfall method (analysis, design, implementation and testing). However, the complexities of this system and of the requirements precluded following the strict, single path sequence defined in the waterfall method. The TRIPS application was the integrating agent for an entire spectrum of processes that were involved in the certification of waste for shipment to WIPP. These processes were geographically and organizationally dispersed.

A development technique has been successfully used at the INEEL that provides recognition that the big picture of a design affects its details and the details often affects the big picture. This development technique was Round-Trip Gestalt design [3] with incremental implementation. It was a style of design that emphasized the incremental and iterative development of a system through the refinement of different yet consistent logical and physical views of the system as a whole. Using this technique, we developed a preliminary, high-level view of a system (or requirements, design or implementation) as we proceeded forward with the individual component development cycles. That preliminary view of the system (or requirements, design or implementation) needed to be modified as more detail was defined. Several components were developed in parallel, while ensuring that the development remained consistent with the integrated effort. With the high level requirements set, the subsystems were identified and their requirements documented with customer signed off documents through the use of iterative user evaluations. The TRIPS subsystems interaction was defined in the Integrated Design Document [4] (IDD).

Using the spiral development and incremental implementation, we were able to work on the requirements for one subsystem, while testing a precursor subsystem. The Radioactive Waste Management Complex's (RWMC) need for a container tracking system replacement drove the decision to release the Resource Conservation and Recovery Act (RCRA) compliant container tracking subsystem in Release 2.0. Data collection, digital signatures, and data validation were released in Release 3.0. The final major Release 4.0 included WIPP's Waste Information System (WWIS) transfer, certification, and transportation. The ability to work on code while working on the next iteration of requirements was essential because requirement change was constant. In addition, the time expended to refine requirements to functions that were not scheduled to be released until the next year would have been wasted due to further changes that would occur during that year.

Change Is Constant

The continual changes during the development of TRIPS, was the number one challenge of the development team. Changing requirements came from many sources. The driving requirements from the DOE / Carlsbad Field Office (CBFO) would change, management personnel changed for the 3,100 m^3 project, the maintenance, and operations contractor changed for the INEEL and finally the process changed when more efficient ways to increase production rates were used. The changing requirements from CBFO were the most visible.

The CBFO requirements at the time of start up were:

1. Department of Energy Carlsbad Area Office Waste Acceptance Criteria [5] (WAC) Revision 5,

2. Quality Assurance Project Plan [6] (QAPP) Revision 0,

3. TRansuranic Waste Authorized Methods for PAyload Control (TRAMPAC) [7] Revision 12., the transportation document, U.S. Department of Energy Carlsbad Area Office (DOE-CAO) and

4. Quality Assurance Program Description [8] (QAPD), CAO-94-1012, Revision 1, April 1996.

By the end of the project, the WAC had two major revisions prior to being changed to the Contact-Handled WAC Revision 0, totaling 3 major revisions.

The QAPP was abandoned and the RWMC HWMA/RCRA Permit [9], #ID4890008952, effective date November 13, 1999 (RWMC RCRA Part B permit) also known as the Waste Analysis Plan (WAP) changed requirements again by moving the non-destructive assay out of the quality controlling documents and into an appendix of the WAC.

The TRAMPAC underwent seven major revisions. These changed the transportation requirements from only allowing alpha-numeric shipping categories to numeric shipping categories, adding the alternative method, matrix depletion, and flammability index allowing for the mixing of shipping categories in a TRUPACT-II shipment.

The QAPD underwent three major revisions, causing a ripple effect to the other driving documents.
Other changes were as substantial, but less visible, since the driving documents had an effective date in which the processing had to match to meet the requirements.

With a methodology in place to manage these changes, now the tasks of processing, and documenting the changes were needed.

Requirement Change Management

The TRIPS team documented requirements in several methods during its life cycle. The Functional and Operational Requirements [10] (F&OR) document was released initially in July 1996 and re-released in January 1997 in conjunction with the System Requirements Specification (SRS). The Integrated Design Document (IDD) was released April 1997. These documents were essential to understand the big picture of the application, but the refinement of requirements and processes were not yet defined. Development of subsystem components resulted in Component Design Documents [11], and later, the Business Process Requirements[12] (BPR). The requirements in the F&OR and SRS were matrixed to the test cases.

The F&OR effort was accomplished during large meetings with the subject matter experts (SMEs. The SMEs went through previous efforts for an information system to identify requirements and processes. The F&OR was updated after the SRS and IDD were nearing a major design review. The operational concepts were presented in the IDD and in a design review with the SMEs. The presentation of the operational concepts was a turning point in the relationship between the SMEs and the TRIPS analysts. A close working relationship between the SMEs and TRIPS analysts evolved while addressing the SMEs' comments.

Changes to the TRIPS application can be summarized into four categories: CBFO driving requirements changes, process improvements, shippable inventory increases and RWMC operations capacity increases. These changes had to be documented to meet the Quality Assurance Program Requirements for Nuclear Facilities [13] (NQA-1) compliance.

Documenting Requirement Changes

With the requirements continually changing, INEEL needed a way to document the requirements without continually updating the base line documentation. The base-line documentation, such as the F&OR, was approved by the customers and was valid at the time of signing of the requirements. Due to extensive changes to the base-line documents, the effort to have these documents continually signed again and again did not fit into our development methodology. Instead, smaller sections of functionality were documented outside of the baseline documentation and approved by the SMEs in Business Process Requirements (BPR).

To handle the changes to code in production we used a web database application called Razor™. This commercial off–the-shelf (COTS) product was used for our configuration control, work-load, status tracking and most importantly for the TRIPS Change Requests (TCR) and the formal review and processing of changes to an NQA-1 compliant system. Razor™ provided scripts to customize the process implementation in terms of TCR states, automated email notification, permission controls on state changes and web based summary reports. The version control information for a specific software component modified and testing to address the change required could also be linked.

A TCR could be entered by almost anyone (e.g., developer, tester, user) that went through the review and approval process required by NQA-1. At any point of time, the status of the submitted change request could be seen. Only the head of the change control board could move a TCR from review to approval for implementation. The technical leads would use this system to manage workload and status development for the system builds. Approval states on the TCR controlled whether a software component could be patched into testing, or production. We provided auditors access to the TCR system to review the changes that occurred. The ability to share this data across user groups, managers, testers, and developers without paper accelerated change incorporation.

For example, new requirements from New Mexico Environmental Department (NMED), such as the WAP, required our analysts to review the document with the SMEs, provide an impact analysis to the existing system, and to document the changes in a TCR. For the analysis effort during the elimination of the QAPP and the start of the WAP, at least 13 TCRs were created. After additional analyses, four of those TCRs were rejected.

The application had to have the underlying structure to support these changes. Several key pillars to the software architecture proved to be resilient and robust in the face of these changes.

Event Paradigm
With the lack of an end-to-end production operation at RWMC, the processing appeared to be in the experimental phase. For this reason an exam/event-based paradigm was used.. An event is an experiment/process result that cannot be changed without knowing who changed the outcome, when the outcome was changed and why. Creating the information model structures to fulfill this paradigm and layering the other quality aspects on top such as batch processing proved to be robust in dealing with future requirement changes from multiple sources.

Centralized Database
A centralized database was chosen due to the issues with the current stove-piped systems at the INEEL's RWMC and the Site Project Office (SPO). The centralized database design appeared to be more stable and reliable than a replicated distributed database. The synchronization of data between geographically distant databases appeared to be risky. The centralized database also allowed for the storage of data in one place, one field, and in one table. The normalization of the database was required for the complexity and size of the data managed. The centralized database eliminated the issues with data replication and time sensitivities of changes occurring to the same data at the same time.

Minimize Hard-Coded Values
Since changes to requirements were frequent, the team decided early in the project, that all values that could possibly change, and would be managed in the information model database structures and not be hard-coded. We called these values reference data. For example, reference data items included WIPP WAC limits, container types, and checklist questions.

Focused Team
The team that designed, developed, and maintained the TRIPS application remained intact allowing for continuity of these design goals and objectives. This continuity is rare in a long-term development environment. This allowed for the main architecture to remain intact over the years of requirements changes.

Digital Signatures

Each waste container would require hundreds of paper records to ensure the integrity of the container's characterization, certification, transportation data process, and validation of those data records prior to the TRIPS application. An analysis of the amount of paper records was done and it was estimated that a nominal figure of 900,000 pages of quality records would be generated each year for five years. In order to reduce paperwork TRIPS produced an electronic signature that would store the signatures in a light duty application protocol (LDAP) database.

Implementation
An electronic signature data link library was created in-house by the TRIPS developers to store the signature and cross verify the signature with current data in the database. It used Public Key Cryptography Standards© (PKCS). PKCS uses a public and private key method. Each user with signing

privileges was given a Schlumberge Cryptoflex™ smart card. The private key was stored on this card. The users picked a personal identification number (PIN) that would allow them to access the private key. The public key was stored in a "Certificate Authority". TRIPS used XCERT™ as our "Certificate Authority" product.

When the user signed data by activating a button on the TRIPS screen that required a signature, a window would request their PIN number. The data was gathered by a SQL procedure (SQL is a language to extract data from databases) that would reflect the data shown on the screen. This data was then hashed with a timestamp to produce a time-dependent cryptographic hash representation of the data called a "message digest". This digest was then combined with the user's private key using the RSA™ (Rivest, Samara and Adleman) cryptography algorithm. The combination of all the information was called a snapshot. This snapshot was stored in the LDAP database and used in the cross-verification process.

TRIPS digital signature was a unique set of bits which: represented the signer's identity and the data signed. Algorithmically, a digital signature was the result of encrypting a one-way hash of the data being signed (plus date-time) with the private key of the signer. The hash ensures that data has not changed. Encrypting the hash with a private key (to produce a "signature") binds the user's identity to that signature and prevents tampering with the hash. The encrypted hash or snapshot was stored in an LDAP database running on Netscape Suitespot™.

TRIPS Digital Signature Key Points

Non-Reputable: Authenticity of both data and signer of data was not questionable. This differs from other types of electronics approvals (e.g. user ID capture, digitized capture of handwritten signature) in that the integrity of data being signed was verifiable since it was an integral part of the digital signature algorithms.

Private Key: The private key created the signature and the key was held privately by the signer on the smart card unlocked with a PIN on each signing. This provided two-factor authentication of the signer:

- "what you know" (TRIPS user ID/password, smart card and PIN) and
- "what you have" (smart card).

The smart cards contain a cryptographic processor that performs the entire digital signature algorithm and store the keys in an encrypted fashion. During signing, the private key never leaves the smart card and is therefore never stored clear-text on the client PC's memory where it could be compromised. A copy of the signers "digital certificate" issued by the Certification Authority is also stored on the smart card.

Public Key: The public key verifies the signature and was "valid" and "certified". Public-private key cryptography algorithms are set-up so one key encrypts (or signs) and the other key decrypts (verifies). Knowledge of the public key does not compromise the private key and one, and only one, public key mathematically corresponds to one private key. The public key can continue to verify past signatures even after the private key expires (time limit just like passwords) or is revoked by the certificate authority (signing privileges removed). Some digital signature packages like Pretty Good Privacy (PGP), distribute public keys directly to the users; others use a "Certification Authority" that keeps the public keys within a "digital certificate" for a users.

Certificate Authority: The Certificate Authority provides control over who is issued new private/public key pairs and actually digitally signs the entire digital certificate to authenticate the public key to software modules that can verify the signature of the Certificate Authority. The TRIPS process for issuing new smart cards and digital certificates was a "face-to-face" verification of the user's with a DOE badge, who choose their own PIN when the smart card / key pairs are initialized. TRIPS maintained it's own Certificate Authority using RSA's XCERT package for long-term control of certificate archives.

Carlsbad Approval: The TRIPS digital signatures were approved by the TRU Program through CBFO [14] in June 1997 based on submitted TRIPS design documents, and again on March 19, 1998 in a memo [15] to DOE-ID. The type of digital signatures used in TRIPS were also approved nationally by the states of Idaho and New Mexico. The national ESIGN act [16] of 2001 also provided full legal weight to digital signatures so long as all parties approve the process.

Savings and Awards: There are 378 to 1008 signatures (variation depends on solids analysis or visual exam processing) on every 42-drum shipment to WIPP. Based on the estimates of RWMC continuous operations processing approximately 5000 drums per year, the TRIPS digital signatures replaced approximately 1,000,000 pages of paper and approximately 40,000 black ink signatures per year. Based on this paper and time processing savings the patent pending TRIPS digital signature won two national awards.

- The White House's "2001 Closing the Circle'" award recognized the TRIPS team for developing a digital signature technology.

- DOE 2001 National P2 Pollution Prevention Award recognized the TRIPS team effort to reduce paper for the TRU waste program.

Cross-Verification of Data

Besides the existence of the digital signature, a process of cross-verification checked the Oracle™ data structures. Prior to activities being preformed on a data set, the digital signature would be re-created and verified against the signature in the LDAP database. Only a cross-verification process, that recreates the previous signature from the native Oracle™ structures, and compares it to the signature in the LDAP database, ensures the data was the same as the previous signer of the data. For example, at the start of a TRIPS session an independent reviewer would start reviewing a Non-Destructive Examination (NDE) batch. Upon selection of the NDE batch to review, the entire batch would be cross-verified. This cross-verification process would insure the data under review was the same data seen and signed by the operator. Any changes to the data, by SQL activity on the database or other mechanism that could have changed the data, would be identified by a failure for the data to cross-verify. This same process occurred at every processing step. Managing hashed message digests in a LDAP database does not ensure the data in the native Oracle™ database structures was the same as the data signed.

During close-out activities, more than 250,000 signatures were cross-verified. Only 24 waste containers had signatures that would not cross verify. All of those data anomalies were documented in existing TCRs. This provides a testament of the data integrity and quality change control processes for TRIPS data.

TRIPS processing was not totally paperless. The Department of Transportation and the transportation departments for each state through which the waste shipments would travel would have to agree on the digital signature. Early in the process a decision was made not to attempt to get DOT approvals for federal and the six states involved. Each 42-drum shipment had approximately 130 pages of paper dealing with transportation records. The TRIPS application did not include the data generator level processing at the laboratories. So, all of their records were paper up to the point of the interface with TRIPS. The laboratories normally interfaced with TRIPS at the data generator approved level. Operational notebooks and conduct of operations records were also not included in TRIPS. Eliminating of laboratories at the data collection level and other factors led to a lot of paper for the TRU waste program to process for long-term storage.

During the close out activities, 1,400 cubic feet of records were processed for long-term storage. Forty full time employees worked for five months to process this paper. Without TRIPS digital signature and electronic master copy, it was estimated that this processing would have been multiplied by a factor of four.

True Benefit

The true benefit of digital signatures and cross-verification is the speed of data processing. Process modeling to determine the production rates rarely adequately represents the data processing times. One can time the assay scans with a stopwatch but one needs a calendar to time the paper-based data validation and processing. Conflict between reviewers could be resolved by a phone call, followed by the demotion, and promotion of a batch within minutes without question regarding the version of data, software or another master record of the data. With a paper-based system, the paper could not be located in minutes, let alone routed to the appropriate reviewers for data modifications and signatures.

Information Model

The vital requirements, to handle a large amount of data spread across numerous data collection events, to integrate legacy data systems, to ensure data integrity, and error prevention and to protect transaction data all demand a strong information model. At the end of the project there were over 2200 database objects. There are over 380 tables in the system with 140 reference or system reference tables. There are over 700 database triggers and over 170 database procedures, packages and functions. There are numerous sequence generators, synonyms, views, indexes, database links, and thousands of unique data attributes and millions of records stored in TRIPS.

Multiple Masters

Without a controlled normalized database with auditing and version control of the data or software, the management of data is nearly impossible. Multiple masters of data are normal in non-integrated systems and was the state of records prior to the TRIPS application. The key to the normalized database and digital signatures was the concept of one master for the data. Even with integration of the data processing, users would create multiple masters of data by printing data periodically and then have to review the on-line master information to ensure correct information was being used. As soon as information was printed out of TRIPS, that data on paper could not be the master (with the exception of shipping documents which were not integrated into TRIPS).

Key Information Model Elements

Database Architecture – The Relational Database Management System (RDBMS) selected was from Oracle™ Corporation. At the beginning of the project the version used was 7.3. During the project, the system was migrated to Oracle™ 8i. Oracle's RDBMS was selected due to it's prevalence at the INEEL, it's ability to handle large volumes of complex data, it's robust capabilities and strength in the market.

Batch and Event Orientation – The system was designed around the WIPP requirements, which focused on the data collection and quality processes that were used to characterize, certify and ship the waste containers. The database design reflected that approach rather than having everything center on the container itself. This allowed greater independence and a more natural handling of events and batches, particularly since the batch data was not tied to any one container. This worked well with the digital signatures since the person was signing off on the data being captured rather than on the characteristics of a waste container at some point in time. While the overall design supported the idea of independent events and batches, several tables were created to facilitate easy retrieval of container-specific data. These tables were "copy" tables and were refreshed regularly, either in an overall batch process or on a triggering event. They contained no original data, but existed only to bring together data into a convenient location.

Table Normalization – The database was designed with a strong emphasis on referential integrity and on "normalizing" the table structures. Put simply, this means that a piece of data was found in only one place in the system. There are some copy tables as mentioned above and views that organize how the information was presented, but they are never treated as the source. Due to the database complexity and low transaction demands, the TRIPS model design favors normalized tables over performance compromises with the aim of being understood and resilient over the life of the project.

Full Integration –. Replication was established in Release 2.0 between TRIPS and the Transuranic Waste Management Information System (TWMIS), but this went away when TWMIS data was moved and the application was taken off-line. The TRIPS application was designed as a single, fully integrated system residing in one database instance, with a redundant, mirrored instance for fail-over support and backups. Had this not been integrated, there would have been extraordinary problems in keeping everything in sync across multiple servers and instances. There were functional subsystems that were broken out in the Uniface™ model and in the diagrams. However, in the database itself, there were no artificial boundaries.

Auditing Features – In order to preserve information on all actions in the database, audit tables were created for all tables in the system. The auditing features allowed for knowing by whom, when and why the data was changed.
With few exceptions, a history of the state of the data in each table could be viewed at any time with the reason for the change. Because the design excluded the ability to delete records, other than for specific interim planning functions or temporary operations, no information has been lost.

Security and Access Control – The design included a data-driven method of controlling users and access to Oracle™ tables. Reference tables were created that managed users and their assigned roles. The roles translated into Oracle™ database roles, which controlled table permissions. Dynamic SQL was used to update the table permissions based on the records in the reference tables. The reference tables also controlled what navigation was available in the interface depending on the assigned roles. Login to the system was controlled at the interface and database level.

Digital Signature Design in the Database – Tables were built to handle versioning of procedures, linking to the signature and indexing of the data that was captured in the signature file. Because of the strict adherence to the design, signatures of data from years ago can be verified exactly as to what they were at the time of the original signature event, even though structures have changed and new TRIPS releases, (both major and minor) have been implemented.

Integration with Other Systems – TRIPS was developed to provide data to the WWIS application in CBFO. As this system was understood prior to the design, a special effort was put forth to make the data move easily into their structures. Attention was given to data types and sizes and to their schema. Because several waste management systems existed at the INEEL prior to TRIPS, it was also necessary to incorporate data from earlier systems, which held original generator data and examination results. Special tables were created to store this data so that it could be used without affecting the records found in the rest of the database.

Data Integrity

The use of the event paradigm, normalized structures with referential integrity and full audit capabilities allowed for a solid base to build the TRIPS application.. The continual changes did not impact the overall structures for data maintenance. The ability to cross-verify all data at the end of the project with no unresolved issues is a testament to the model's worth in maintaining data integrity.

Reference Data

All limits in the WAC, WAP or TRAMPAC applicable to INEEL shippable waste were entered into reference data tables and managed to revisions along with values from other sources.

Coding Standards

As a coding standard, no hard-coded values were allowed. This was one way to pre-identify any value that could possiby change without anticipating the precise future change. Any code from a requirements driving document was placed in reference data. Any code a developer created to identify a shipping configuration or some other entity was managed in reference data structures. Any cross-walk type of code used for an interface to an external system was placed in the reference data structures. User names, roles, permissions and start up forms were managed in reference data structures. The procedures followed for a data collection or validation event were managed in reference data structures. The numerous checklists used in data validation were all reference data driven down to the order of the question and expected response. Even the unit of measurement values and conversions were managed in reference data structures.

Reference Data Structures

Data structures were created to manage the reference data. Simplistic application screens were developed to allow end users with knowledge of the data to manage the reference data. These reference data structures include the ability to obsolete any item. Due to the time sensitivity of the characterization and certification processing a waste container not approved for shipment under the earlier revisions may now be shippable. To manage these changes, older limits were obsolete and not deleted. No data was deleted in the TRIPS application. Retaining old data allowed historical information about the certification of a waste container to be understood along with the latest limit changing allowing for more shippable inventory. The majority of the limit changes were less restrictive allowing for more shippable inventory. If the limit change was in the other direction (more restrictive) special disposition house-keeping processes would be run to identify affected waste containers without changing the waste containers already certified. Lastly, all reference data was associated with a source note to identify the source of the limit or reference data to be managed. The quality engineers and auditors appreciated these source notes in the reference data.

Managing Reference Data

The task of managing the reference data was not trivial. The reference data had to be managed by one person who understood the TRIPS application or by many people who were SMEs in the area of the reference data to be changed. The TRIPS team normally used one person who understood the TRIPS application. By the end of the project, another role was added to manage the multiple procedure changes required to handle the unique processing at the end of the available inventory.

Electronically Track Reference Data Changes

The TRIPS Data Change Request (TDCR) was implemented for this purpose. The Razor™ application) was used as a tracking tool for changes. This system was used to submit data changes and document the status of the change requests in electronic format. It also allowed the requester and QA personnel access to view and add comments to the process and status of the desired results. Complete quality assurance (QA) validation of data entry in the reference data database was performed when changes were made in TRIPS. This QA process supplied assurance that data was correct and that all necessary changes to all tables within TRIPS were managed correctly.

Allowing Quick Changes

By using the Reference Data database (a separate instance of an Oracle™ database to handle large reference data changes) TRIPS was able to make substantial changes required by the source requirements in a minimal amount of time, requiring little or no programming changes. One example of this type of change was provided when the change from alpha-numeric shipping categories to numeric only shipping categories was done. With the use of the Reference Data database, this change was easily made to the integrated data in TRIPS.

The reference data changes required for the numeric shipping category took approximately one month and involved several thousand changes to the Reference Data database that were all QA verified. The time was spent analyzing, entering the new shipping codes and validating those codes. At the conclusion of the Reference Data changes there was no rework required. All aspects of these changes were transparent to the user and the changes were made ahead of schedule with little to no impact to production. The use of reference data requires more analysis time and less coding time.

Managed Reference Data

TRIPS provided the applications to support inventory control as well as the characterization, certification and transportation of waste containers. The adding and editing of containers and storage facilities allowed for the constant tracking of all containers located at RWMC. This contingency allowed for constant accountability of characterized containers, combining of containers and virtual payload construction prior to physical construction of TRUPACT payloads, or Standard Waste Box payloads. All locations that a waste container could be located at were entered into reference data with rules on segregation areas as well. This allowed for reconfiguration of the storage modules as needed. All limits associated with processing waste for WIPP shipment were entered into reference data (e.g. dose rate). Default processing plans and their default statuses were managed by reference data (e.g., Required - Non-Destructive Assay, Not Required - Gas Generation Testing). Numerous system codes designed by the developers were managed in reference data (e.g. P/G WWIS translation of PAN/Gamma). Checklist items (e.g. Did the replicate scan pass verification?, Was the field blank clean?) were also managed in reference data.

CONCLUSION

The TRIPS application was essential for the amount and speed of data processing necessary to meet the 3,100m^3 milestone. The extensive up-front requirements and design analysis led to the definition of the goal and objectives and a solid information model. The goal and objectives reduced scope creep. The solid information model provided the data integrity needed for managing one single master record of data. Digital signatures were necessary for allowing the data processing to occur at the required production rates, eliminating the volumes of paper records. The reference data driven design was essential to handle the continual changes without huge reprogramming efforts for every approved change. Figure 2 shows the essential parts of the TRIPS application that were needed to meet the schedules and maintains data integrity.

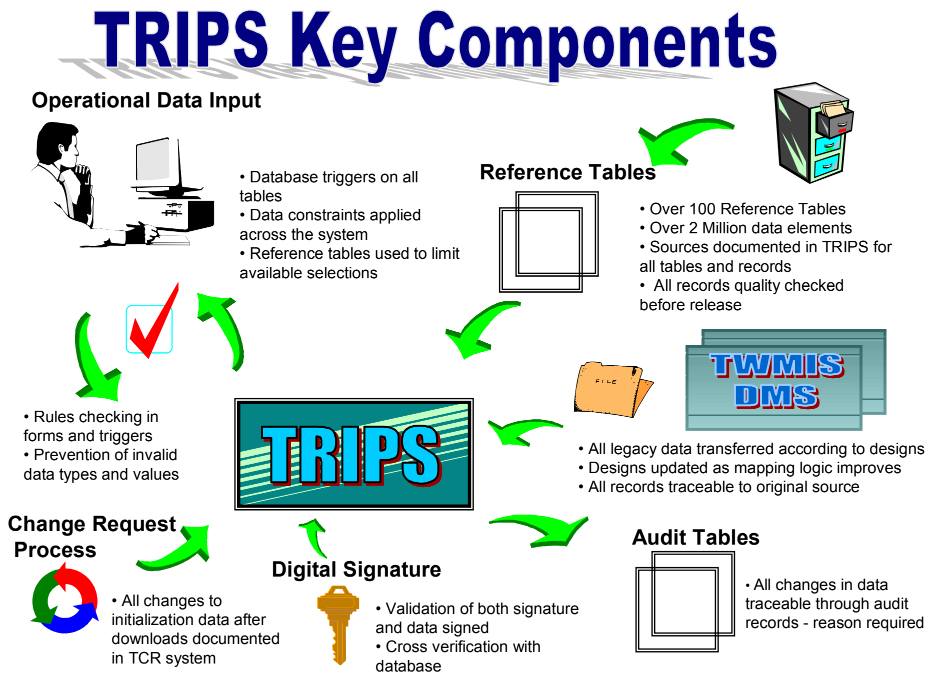

Fig. 2 TRIPS key components

After six years in production, faced with the continual changes, the main architecture, and infrastructure in place from the inception has allowed these changes to occur without degradation of the application. The data integrity of the system is still in-tact. This is evident by the massive cross-verification of data done during the close-out activities with NO undocumented changes to the data identified.

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