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DEVELOPMENT AND TRIAL OPERATION OF A SITE-WIDE COMPUTERIZED MATERIAL ACCOUNTING SYSTEM AT KURCHATOV INSTITUTE

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ABSTRACT

Since August 1994 Kurchatov Institute in cooperation with several US Department of Energy Laboratories has been developing a site-wide computerized material accounting system for nuclear materials. In 1994 a prototype system was put into trial operation at two Kurchatov facilities. Evaluation of this prototype led to the development of a new computerized material accounting system named KI-MACS, which has been operational since 1996. This system is a site-wide local secure computer network with centralized database capable of dealing with strictly confidential data and performing near-real time accountancy. It utilizes a Microsoft Windows NT operating system with SQL Server and Visual Basic, and has a 'star'-like network architecture. KI-MACS is capable of dealing with materials in itemized and bulk form, and can perform statistical evaluations of measurements and material balance. KI-MACS is fully integrated with bar code equipment, electronic scales, gamma-ray spectrometers and an Active Well Coincidence Counter, thus providing almost on-line evaluation and utilization of results of measurements, item identification and accounting. At present KI-MACS is being used in Physical Inventory Taking at the Kurchatov Central Storage Facility, and by the end of 1997 will be installed at twelve Kurchatov nuclear facilities.

1. INTRODUCTION

The "Kurchatov Institute" Russian Research Center (KI) in Moscow is one of the largest Russian nuclear R&D enterprises. It currently possesses 30 operating nuclear facilities, about half of which use nuclear material in bulk or semi-bulk form. In 1991 KI became the first State nuclear R&D enterprise directly subordinated to the Russian Government only. Due to socio-political changes which have occurred in Russia since 1991, the development of improved material protection, control, and accountability (MPC&A) systems for the Russian nuclear complex in general and for KI in particular has became an urgent necessity. The KI management recognized the scale of this problem and in 1992 initiated R&D to evaluate the current MPC&A

system and to search for ways to improve and bring it in line with current international safeguards.

The MC&A system which existed in the USSR and is still used in Russia is based on principles of book-keeping financial accounting which are different from the principles of accounting for and control of nuclear material inventory and material balances in Material Balance Areas (MBA) used at many U.S. facilities. In 1993 KI specialists developed the Technical Specifications for the "Model Automated System of Nuclear Materials Accounting, Control and Safeguards for Complex Nuclear Facilities (NUMACS system)", which are based on the concept of MBAs and measured material balance (1). This design was developed almost two years ahead of introduction of a new Law on use of Atomic Energy in Russia which was put into force at the end 1995. This Law introduces the principle of measured material balance in nuclear material accounting and obliges the Russian Government to develop a new State System for accounting for and control (SSAC) of nuclear materials, radioactive substances and radioactive wastes.

2. HISTORY OF DEVELOPMENT

Since August of 1994 KI specialists in cooperation with staff from Los Alamos National Laboratory (LANL) have worked to develop a site-wide CMAS capable to perform near-real time accounting on a facility level. Accounting reporting for the future SSAC is considered as a 'by-product' of nuclear material accounting at the facility level. By the end of 1994 a prototype system as a local network with the Client-Server architecture was put into trial operation at two Kurchatov critical facilities and was used for a Physical Inventory Taking (2). Thus from the very beginning of its implementation the KI CMAS has been tested under real operating conditions.

Using the experience gained in the trial operation of the prototype system, the KI CMAS was then fully redesigned. In a course of this redesign the functionality and main design features of the Core Material Accountability System (CoreMAS) developed at LANL, was analyzed and taken into account. As a result of this redesign, a new site-wide computerized material accounting system named KI-MACS was developed and was put into trial operation in July 1996. This system, a secure local network with Client-Server architecture and 'star'-like topology, has been deployed at three separate KI buildings, including the KI Central Storage Facility (CSF). KI-MACS has been fully integrated with bar code equipment providing a possibility for convenient item accounting and identification. Other equipment provided by US National Laboratories and used for measurements of nuclear materials at KI, includes electronic balances, gamma-ray spectrometers of InSpector type and an Active Well Coincidence Counter (AWCC) (3). By the end of October 1996, all available measurement equipment had been integrated into KI-MACS permitting the direct input of results of measurements into the system database and utilization of these results for material accounting and verification. Thus KI-MACS has become an unique computerized material accounting system which is fully integrated with various measurement equipment.

However, as a result of further trial operations it has become clear that data protection and system security features of the integrated KI-MACS must be additionally enhanced in order to satisfy Russian State security certification requirements. The required enhancement of KI-MACS security features has been performed within few months. As of July 1997 KI-MACS is under trial operation and is passing through the Russian State security certification procedure, being performed by the State authorized organization, and which is planned to be completed in a few weeks in order to start KI-MACS trial operation with utilization of strictly confidential nuclear material accounting data.

3. KI-MACS MAIN FEATURES

Up until now there have been no Russian State regulations concerning implementation of the main provisions of the mentioned Law on use of Atomic Energy in Russia. There are no approved list of categories of materials to be accounted for, no list of accounting events to be reported to the SSAC, no accounting report formats and so on. All such regulations are under development. Current accounting and control are performed in accordance with the still valid principles of book-keeping financial accounting. The transition period from the current system to the future one may last for a number of years. Therefore KI specialists have developed a computerized nuclear material accounting system which should be adequate for practically any future requirements which shall be developed in accordance with Russian law. This led to development of KI-MACS with certain built-in redundancy. The main design features of KI-MACS such as a list of material accounting categories, a list of reporting accounting events, a list of material description codes and some others has been defined as a result of evaluation of accounting rules, requirements and regulations applied in the US domestic Safeguards, as well as in International Safeguards of IAEA and Euratom. All these lists are expandable. The development of structure of MBA which would be established at KI facilities, has been performed in collaboration with LANL and with wide utilization of the Graded Safeguards approach developed and introduced by the US Department of Energy.

Thus KI-MACS has been developed as a site-wide computerized material accounting system assigned to perform a near-real time accounting and verification of nuclear inventory and balance on a level of a facility and group of facilities. It has been developed to satisfy the Russian State security certification requirements related to computerized treatment of confidential data. KI-MACS is assigned to provide a relatively smooth transition from the current book-keeping financial accounting system to the system which is using principles of measured and verified material balance introduced by the Law on use of Atomic Energy in Russia in 1995.

3.1. Functionality

KI-MACS simultaneously supports three nuclear material accounting systems: the current system of book-keeping financial accounting on a level of an enterprise, operated by the enterprise central material accounting office, the current system of book-keeping accounting on a facility level, operated by the facility custodians, and a measured material balance and verification system on a facility level, operated by facility custodians. All systems run in parallel and provide capabilities for cross-check between various sources of data. The second and third accounting systems provide near-real time accounting of materials currently used at the facility and are under the responsibility of the facility custodian(s). The first system performs a computerized treatment of all currently used accounting documents in a form of invoices, inventory sheets, ledgers and other forms. The second system performs a computerized treatment of accounting data routinely used by the facility custodians. The third system performs a computerized treatment of experimental data, its statistical evaluation, and development of resulting data used for evaluation of measured material balance.

KI-MACS operates with multiple structures of Material Balance Areas (MBAs). Each facility may be a part of some global MBA, may be considered as a single MBA, or may be subdivided into a number of MBAs. Total number of structures of MBAs which may be established for the same facility is currently limited by 21. Facility custodians may be completely unaware about the complexity of MBA structure being established by a specific Supervisory Body. KI-MACS detects all accounting events which are in its list of accounting events, and records them in a specific internal format for each established MBA. This information forms a basis for accounting reporting to a specific Supervisory Body. KI-MACS is capable to provide automatic generation of accounting reports in a format and timing to be prescribed by a specific Supervisory Body. There are more than 30 reporting accounting events detected by KI-MACS in a course of routine treatment of nuclear material by a facility custodian, including transfer of materials inside facility premises and between facilities, renaming of an accounting Batch or Item, grouping and

regrouping of accounting Items, blending, measured write-offs, etc. List of accounting events, detected and recorded by KI-MACS, may be expanded upon needs to incorporate some additional accounting events to be reported to a supervisory body - National, International or, for instance, Bilateral Safeguards Body. Current reporting capacities of KI-MACS are limited by a number of accounting reports routinely generated for book-keeping financial accounting system, for use by facility custodians (for instance, current allocation of materials inside facility premises, current book-keeping and measured material balance, list of material in transit from one facility to another, etc.).

3.2. Topology and Architecture

KI-MACS is developed as a local secure network with the Client-Server architecture and "star"-like topology. The main features of the network are as follows.

The main network standard is the Ethernet (IEEE 802.3). The network consists of a "central" and a number of "local" segments. The main topology for the local network "segments" inside each building housing nuclear facilities, is the "star"-like topology with use of local concentrators (intellectual hubs) installed there, and with the main concentrator installed inside the "central" building which is the CSF. This topology provides the highest reliability of the network as a whole thus permitting to localize and restore any failed segment of the network without interruption of operations of the other segments. Moreover this topology permits to use it with all high transmission rate standards such as FDDI, Fast Ethernet, ATM, without the need to change the network topology.

Connection of local "star"-like networks between buildings with the "central" one is provided with use of fiber cable without intermediate amplifiers (up to a distance of about 2000 m) which provides required secure data transmission between buildings located inside the guarded perimeter. Connections between Clients, Servers and a concentrator inside each building is provided with use of twisted pair. This minimizes the cost of networking equipment (network adapters and concentrators) as well as warranties the transfer to the high speed networking standards without needs to change the cables inside the building. There is no connection of the local secure network with any other network at the site.

The main concentrator is provided by modules supporting the standard 10 BASE-T (twisted pair) for connections with the Servers and Clients located in the same "central" building, and by modules supporting the standard 10 BASE-FL (fiber) for connection with concentrators installed inside other buildings. The Clients installed inside other buildings are connected with their corresponding concentrators by twisted pairs. If the number of Clients exceeds 30 and number of Servers exceeds 2, then the network may be subdivided into a number of "independent" segments being integrated into an unique network by the Switch Concentrator, the use of which seems the most cost effective tool to increase the transmission rate of the Ethernet networks.

3.3. Operating Software

The operating environment of the Server includes the following basic software components: Operating System Microsoft Windows NT Server, Data Base Management System Microsoft SQL Server for Windows NT, network operating system Microsoft System Management Server, application programming languages Microsoft Visual Basic as a main tool and Microsoft Visual C++ as a supplementary tool. The operating environment of Clients includes: Operating System Microsoft Windows NT Workstation and components of Microsoft Visual Basic and Microsoft Visual C++ for executing application programs.

3.4. Application Software

Application software consists of the following three components:

A "core" component which is responsible for interaction with SQL Server Database. This "core" component is written on Transact SQL and perform all operations with the Database connected with data loading and evaluation. The "core" components resides on the Server only.

An "end-user" application interface component which is responsible for interaction of an end-user with the "core" component. This component is written mostly on Visual Basic. Part of this component is written on Visual C++. The "end-user" application interface component resides on Clients.

An "equipment" interface component which is responsible for interaction of an end-user with measurement and identification equipment. This component consists of parts written on Visual Basic, Visual C++ and some other languages applied for interaction with measurement equipment through NTFS - Windows NT File System. This component resides on Clients and on the computers which are associated with the measurement systems.

4. KI-MACS SECURITY RELATED FEATURES

Among the factors influencing the system design, data protection and security features are the key factors. These factors predetermine the selection of system topology and architecture, operating software tools, Database structure, and even structure and functionality of application software. As a result of joint evaluation of the prototype system the operating environment for KI-MACS was changed to the Windows NT, SQL Server with data manipulation language Transact SQL, Visual Basic, and Visual C++.

At the same time KI specialists came to the conclusion that all operations with the SQL Database must be performed by Transact SQL stored procedures only. No direct access to the Database should be allowed from application software residing on Clients. All calls from Client application software to the Database must be checked on a level of stored procedures against an end-user authorization list. Almost all quality control of incoming data should be performed on the Server by means of appropriate stored procedures. Flow of data required to perform some quality control on Clients should be restricted as much as possible. Any direct access of software used in PC being a part of measurement system, to the Database, should be prevented. All communications between measurement systems and the Database should be performed through Clients with utilization of Windows NT security mechanism and file system, and so on.

As a result of such considerations all data elements in the Database were grouped into 12 functional groups each of which was developed with observation of security related functional requirements. End-user access to relational tables (RT) in each specific data group is checked against an authority RT being a part of the Database and providing each end-user by an explicit list of rights to call stored procedures dealing with requested set of data, to deal with data for a specific facility, and to deal with data with level of security not exceeding a level granted for this end-user. This check mechanism was incorporated into all stored procedures (about 400) assigned to load and retrieve data to/from the Database. At the same time any possibilities for direct calls to the Database from the application software residing on Clients, were suppressed by utilization of SQL Server security features and by administrative procedures providing assurance that Clients do not contain any software which may be used for direct calls to the Database. All data evaluation procedures (evaluation of measured data, material balance, etc.) are carried out by Transact SQL stored procedures only and resulting data in a form of various reports are loaded into a number of specifically designed "resulting" RT of the Database. These reports are available for reviewing by an authorized end-user but may be reproduced in a form of hard-copies on dedicated printers with recording of such event into system log.

The current version of KI-MACS, version 3.3.1, contains 58 relational tables and a system dictionary which maintains description of currently defined 392 data elements with 1014 values of coded variables. The list of error and warning diagnostic messages includes about 200 response codes and its description.

5. PRESENT STATUS OF DESIGN AND IMPLEMENTATION

The functionality and performance of KI-MACS has been tested from the beginning of its design under real operating conditions through a number of physical inventory takings and several other tests and demonstrations at various KI nuclear facilities. Almost all nuclear material used in a course of these activities has been in the most difficult, from an accounting point of view, bulk or semi-bulk form that requires statistical evaluation of measured data and sophisticated measurement control programs. All these materials are not classified. Trial operation of KI-MACS during quite lengthy period of time has permitted to perform an overall test of software and hardware and eliminate detected deficiencies and software bugs. But the majority of nuclear materials used at KI are still considered as classified. Therefore it is reasonable to expect some software related problems due to quite probable bugs not yet discovered due to relatively small amount of treated data. It means that the current version of KI-MACS is to be considered as a beta-version which is to be in trial operation for certain period of time being comparable with duration of time required to perform physical inventory taking for a majority of materials.

In accordance with Russian State regulations all computerized systems assigned to treat classified information must be certified by State security organizations licensed to perform such certification. At the present time KI-MACS application software is successfully passing through certification procedure performed by an assigned State security organization. Upon completion of this phase of certification KI-MACS will be put into trial operation with classified data for about half a year. This will permit KI to complete the on-going physical inventory taking at CSF performed in cooperation with Brookhaven National Laboratory, to put into production mode of operation all measurement and identification systems provided by Oak Ridge, Lawrence Livermore, Pacific Northwest and Los Alamos National Laboratories, and to begin deployment of the next section of a site-wide KI computerized material accounting system. By the end of 1997 this system will provide computerized near-real time accounting at 12 KI facilities with the most attractive nuclear materials.

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