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CONF-860607--90

LA-UR -86-2032

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LA-UR--86-2032

DE86 012371

AUTHOR(S): R. C. Bearse, R. J. Thomas, S. P. Henslee, B. G. Jackson, D. B. Tracy, and D. M. Pace

SUBMITTED TO: 27th Annual Meeting of the Institute of Nuclear Materials Management, New Orleans, Louisiana, June 22-25, 1986

Los Alamos

Los Alamos National Laboratory
Los Alamos, New Mexico 87545

A MATERIALS ACCOUNTING SYSTEM FOR AN IBM PC*

R. C. Bearse, Consultant**
Los Alamos National Laboratory, Safeguards Systems Group
Los Alamos, NM 87545

R. J. Thomas, S. P. Henslee, B. G. Jackson, D. B. Tracy, and D. M. Pace
Argonne National Laboratory
Idaho Falls, Idaho 83403

ABSTRACT

We have adapted the Los Alamos MASS[1] accounting system for use on an IBM PC/AT† at the Fuels Manufacturing Facility (FMF) at Argonne National Laboratory-West (ANL-WEST) in Idaho Falls, Idaho. Cost of hardware and proprietary software was less than $10,000 per station. The system consists of three stations between which accounting information is transferred using floppy disks accompanying special nuclear material shipments.

The programs were implemented in dBASEIII†† and were compiled using the proprietary software CLIPPER.§ Modifications to the inventory can be posted in just a few minutes, and operator/computer interaction is nearly instantaneous. After the records are built by the user, it takes 4-5 seconds to post the results to the database files.

A version of this system was specially adapted and is currently in use at the FMF facility at Argonne National Laboratory in Idaho Falls. Initial satisfaction is adequate and software and hardware problems are minimal.

INTRODUCTION

In the ~10 or so years subsequent to the adoption of on-line computer systems for material accounting, significant progress has been made in developing user friendly and effective systems. At Los Alamos, for instance, 50 man-years of effort by Ferman Kelso et al. has culminated in the current MASS system for tracking Los Alamos special nuclear material (SNM). This computer system, running on equipment originally valued at about $750,000, can keep track of tens of thousands of inventory items involved in 20,000 or more changes per month.

Paralleling these developments has been a trend to ever more powerful, compact, and inexpensive personal computers with a wide array of efficient and effective software for data handling tasks. In particular, the IBM PC and its clones have led to a standardization in both hardware and software in this size niche.

There has been, and is, a need for small materials control systems that can keep track of several hundred inventory items undergoing 500 to 1000 alterations per month. Moreover, there is a need for intelligent terminals for the larger machines that can relieve the big machines of the chores of data entry and verification.

We set out to determine if an IBM PC/AT, valued at about $8000, could be used as a small-system central computer in a materials accounting system. It can.

HARDWARE

Early tests on an IBM PC/XT convinced us that the project was possible. The XT, though capable, was slow enough to annoy a nimble-fingered typist. We thus believed that a more capable and faster computer would provide a more acceptable product.

We chose to implement the accounting package on an IBM PC/AT. We configured the system with a 30 MB hard disk, 2MB of RAM memory, two floppy drives (standard and high density), and an interface board. The latter is used to connect the computer directly to a digital balance so that weighings may be read directly by the computer. A system was also purchased with two Bernoulli* drives in lieu of the hard disk. This system, which has removable media, has the advantage of allowing sensitive information to be easily secured when not in use. The cost of the latter system was $7200.

*Work supported by the U.S. Department of Energy, Office of Safeguards and Security.

**University of Kansas, Lawrence, KS 66045.

†Trademark of IBM, Inc.

††Trademark of Ashton-Tate, 10150 West Jefferson Blvd., Culver City, CA 90230.

§Trademark of Nantucket, Inc., 5995 Sepulveda Blvd., Culver City, CA 90230.

*Trademark of IOMEGA Corporation, 1821 West 4000 South, Roy, Utah 84067.

SOFTWARE

We chose to use dBASEIII as the major implementation language because it is a highly competent and widely respected product. Other similar systems are now on the market that should be considered for any new PC based systems. dBASEIII is a relational-like database system. The language can be used interactively, or procedure files (programs) can be written.

Compilers are available for this language that promise higher operating speeds and more security. With just the compiled code available in the computer, it is less easy to modify the data files without use of the intended code with its internal checks, balances and audit trails.

We tried the Winter 1985 version of Clipper by Nantucket Software systems and found it effective and easy to use. The compiled code ran significantly faster than the interpretive version. As an example, the most annoying delay in posting a change to the database occurred during the writing of the transaction information to a floppy disk. This operation averaged 9.2 seconds for 20 separately invoked write operations. The same test with the compiled version gave a 2.6 second average. This is 3.5 times faster. Other time savings are not as remarkable but were not needed in the first place. The overall time for posting a typical single update has dropped from about 10-12 seconds for the interpretive version to 4-5 seconds for the compiled version.

THE FUELS MANUFACTURING FACILITY

The Fuels Manufacturing Facility (FMF) produces metal fuel assemblies primarily for the test reactor EBRII. Pins are cast from alloys of uranium and sometimes plutonium. These pins are encapsulated in jackets to become elements, and these in turn are combined into fuel subassemblies.

Special nuclear material (SNM) is received from the Special Materials Department (SPM) of ANL-WEST. This material is alloyed with other materials, induction-melted, and injection-cast into glass molds.

The as-cast fuel pins are removed from their molds, sheared to length, and then sent to another unit for autoradiography and other tests. The scrap materials remaining are incorporated into a materials balance.

The acceptable pins are placed into sodium-filled, stainless-steel jackets and welded shut. These elements are then transferred to SPM where they are stored for later use. The elements are eventually returned to the FMF where they are incorporated into fuel assemblies. On occasion, rejected elements are disassembled for recovery.

The current accounting system involves generation of paper reports for entry into the ANL-wide SPM system. This system has proved more than adequate for global accounting purposes. It does not, however, provide the detailed reporting at the workbench level that is desirable for closer accountability and for better production and criticality control.

MASS SYSTEM

We chose to adapt the MASS system to our PC needs rather than start over. As stated earlier, the MASS system represents 50 man-years of design, programming, and testing. It has gained acceptance in a highly complex production environment. We thus secured permission from its architect, Ferman Kelso, to adapt it for our use. He also kindly supplied listings and machine readable copies of the current implementation.

As a development approach or design philosophy, Kelso reduced all possible operations that the MASS system was to perform to their least common denominator, thus generic operations. There are a limited number of generic operations necessary to maintain an inventory in a batch-oriented environment. Each of these generic operations is called a transaction and is listed below.

1. Items need to be moved (MOVE).

2. Items need to be split into two or more sub items (SPLIT).

3. Material from one existing item needs to be added to an already existing item (COMBINE INTO EXISTING).

4. Material from two or more items needs to be combined to create a new item (COMBINE INTO NEW).

5. Non essential information in an inventory record needs to be changed, perhaps for a correction to other transactions (MODIFY).

These five basic operations, and some slight variations are all that is needed to handle most production environments.

RECORD OF TRANSACTIONS

The use or application of these generic operations is known as a transaction. All transactions are recorded in the following manner. The record of the transaction contains three parts, called images. The FROM image contains the affected inventory record as it will appear after modification. The TO image contains the inventory record as it will appear after modification. The XN image contains information about the nature and amount of the change. These three parts taken together constitute the transaction record itself.

The transaction record is saved to a file of transaction records, and machinery in the program then uses this record to update the inventory file itself.

All computer transactions proceed similarly.

(A) One or two inventory items are selected and found.

(B) The records are copied to the appropriate images.

(C) The computer asks for and records the amount of material transferred.

(D) The TO and FROM images are adjusted accordingly.

(E) Additional changes to the TO item are requested and posted to the image.

(F) The XN image is constructed.

(G) The three images are posted to the transaction file.

(H) The images are used to update the inventory files.

ADAPTIONS TO MASS FOR ANL USE

Several changes were made to adapt the MASS system for ANL-WEST use. The MASS system uses a separate record for each component of SNM in an item. Thus an item that contains both uranium and plutonium will be represented by two separate records, and machinery in the MASS code assures that when one record is affected, the other is also affected.

This complication is necessary in a facility where a dozen or more types of SNM may be encountered on a regular basis. ANL-WEST, on the other hand, uses only uranium and plutonium. Because file size was not a limitation in this application, we elected to incorporate separate fields in the records to keep track of uranium, Uranium-235, plutonium, and plutonium isotopics.

The MASS system requires that an individual user enter a password at the beginning of a work session. He or she is then able to execute as many transactions as desired. The user then is expected to log off to prevent another user from deliberately or inadvertently using the system under the first person's authority.

We elected to require that a six-character password be entered as the first step in executing any transaction. After the password is entered, the computer checks its files to determine who the individual is and whether this individual is allowed to execute that transaction. This may become an annoyance to operators but provides what we believe is an extra necessary level of control over users.

The original MASS system as implemented at Los Alamos does not yet provide an ability to deal with collections—items that are associated with other items in some kind of assembly or subassembly. Fortunately, Kelso had finished the initial design work for adding this feature and was generous in helping us adapt his techniques to the present application.

Basically, we handle collections using two files—the regular INVENTORY file and a second file called COLLECTIONS. The records in both have exactly the same structure and include a field containing the collection name. When a collection is first created, a new inventory record is created with a non-blank collection name field. The item just added to this collection is removed from INVENTORY and added to COLLECTIONS after adding the collection name to the collection name field. Its SNM content is added to the record in INVENTORY that represents the collection.

When new items are added to the collection, their SNM content is added to the record of the collection maintained in INVENTORY. The inventory record of the item is deleted from INVENTORY and added to COLLECTIONS, again with the name of the collection inserted.

Thus, an examination of INVENTORY will show two kinds of items: those with no collection names and those with collection names. A collection name will appear only once in INVENTORY. The items without a collection name are individual, discrete items not associated with a collection. The items with a collection name are indeed collections, and the SNM content of the record reflects the total SNM content of the constituent pieces. COLLECTIONS then has the individual records for the individual items making up this collection. These can easily be accessed for any purpose.

The MASS system allows material to be transferred between accounts and subaccounts. This is possible because one computer is keeping track of all material, and users in each area have access to the same computer.

The FMF process areas are not currently contiguous, and it was not considered reasonable to string coaxial cable between these areas. We thus developed a system that relies on floppy disks, which accompany each transfer, to carry the information needed to update one computer with information from another.

Fortunately, the administrative system at ANL-WEST has, for many years, required that when SNM is moved from one area to another, the materials balance area (MBA) custodian physically inspect the transferred material and provide approval on a form accompanying the material. It is thus easy to have a floppy disk accompany these forms and to have the MBA custodian read this information into his computer at the time he inspects the transfer. In this way, his computer is as current as the last transfer made. Because transfers take place several times a day, he remains quite current. In addition, the transfer of data by disk rather than by wire appears to be a benefit with respect to physical security.

This approach also provides some programming simplification. In a system where everyone has access to the same files, techniques have to be incorporated that prevent one person from acting on a record while another person is doing so. Updating of the computer may not take place as the work is accomplished, and a second processing step may be reported to the computer before the first has been posted. Our approach automatically prevents these problems from occurring without needing software to prevent it.

The MASS system assumes that splits and combines will involve only a few to a dozen items to be combined or split at a time. FMF, however, has a key processing step where as many as a hundred pins may be created from a single batch. To create each of these items using the original MASS machinery would be too time consuming.

We elected therefore to violate the principle of genericness of the MASS system to provide a specialized transaction package that allows one item to be more automatically split into many items. The operator enters a minimum amount of information before database update occurs, and then the 100 or so transactions are run without operator intervention, freeing him or her for other activities. Even at 5 seconds per update, 100 updates represents nearly 10 minutes of computing.

Similar programs have been developed for putting fuel pins in jackets and recording test information on pins and elements. The modular nature of the original MASS system design made these adaptations easy to perform. Where MASS has a routine that identifies and locates a single record, we have had only to develop a routine that seeks out and copies a group of records. Then, instead of a single pass with the transaction building and posting machinery, we perform the operations repeatedly until each record has been handled.

ANL-PC/DYMAC DESIGN STRUCTURE

ANL-PC/DYMAC is structured into three levels of locations. The primary location (called SUBFAC in files and m_subfac in a memory variable) varies with major changes in administrative responsibility. In versions below 2.0, subfac is constant and is 'FMF'.

The secondary location is called ROOM in files and m_room in memory variables.

The STATION location is the glove box or workbench level of designation. It is assumed to be equivalent to the zones that have been specified at ANL-WEST for criticality control.

A file LOCATIONS keeps track of the allowable combinations of subfac, room and station. Information is also maintained on total plutonium and uranium content as well as criticality limits and total SNM. The latter is calculated using U-235 + 4*Pu.

In the ANL-DYMAC system, the birdcage, box, or storage drum is handled as an object with a seven-letter designator that can be moved from location to location. A file CONTAINER keeps track of the location, seal, and seal date as well as the contents and limits. A field in the CONTAINER file, called moveable, indicates whether or not the user may move the cage or drum. Each inventory item contains a container field that is blank if an item is not in a cage or drum but contains the container designator if the item is in a cage or drum.

Whenever a transaction is executed, the LOCATIONS and CONTAINER files are updated for plutonium, uranium, and SNM content and piece count. The number of cages in a location is also maintained. Criticality safety is then verified for limits on these values.

All users are assumed to have access to all stations within any room for which they have permission; that is, access is controlled by room. This control is vested in the password file, which keeps a list of each room for which a bona fide user has access.

Inventory control is on serial number. New values are determined by the computer.

The inventory item in ANL-DYMAC contains both plutonium and uranium fields and fields for their isotopic amounts. This is in contrast to MASS, which allows only one SNM type per inventory item, and hence two or more inventory records per blended item. We calculate new enrichments for an inventory item after determining the amount of uranium and U-235, and the amounts of plutonium and Pu-iso in the new item. Enrichment-235 = 100*U - 235/U and Enrichment - Pu = 100*Pu-iso/Pu. All values are carried in gram units and rounded to the nearest one-hundredth.

Each item has associated with it a batch-no. This batch-no ties the item to an isotopic and chemical analysis maintained in the file ANALYSES. If two items with different batch numbers are combined, the computer forces the user to designate a new batch name and calculates the batch analysis for it by performing a mixing calculation. The results are recorded in the ANALYSES file.

The AMOUNT subroutine is used to obtain weight values from the user or from instruments coupled to the instrument. The AMOUNT subroutine must be designed to return the following fields in public variables:

m_tarex	= tared weight of container if measured
m_uran	= the amount of uranium transferred
m_pux	= the amount of plutonium transferred
m_u235x	= the amount of U-235 transferred
m_puisox	= the amount of plutonium isotopics transferred
m_alloyx	= the amount of alloy transferred
m_calcnum	= the calculation option used to determine the above
m_mescod	= the designation of the safeguards instrument used.

This program is not used for A3SPLITPINS. Rather the subroutine PINS.PRG interacts with the user to create a file (pins) of information that is later used by the A3 option to update the database.

The DYMAC user is presented with a number of possible options, via displayed menus, designated by the letters A, B, C, D, Q, and S. The list of options is as follows:

A MENU
(1) Modify a single item
(2) Move a single item
(3) Make individual pins from a set
(4) Split a casting batch into several major parts (SPLIT)
(5) Add to a casting batch (COMBEX)
(6) Create a casting batch (COMBNEW)
(7) Post status of pins
(8) Post results of a chemical analysis
(9) Put pins into jackets

B MENU
(1) Put items in a container
(2) Take items out of a container
(3) Move a container to a different zone
(4) Ship a container to a different room
(5) Receive a container from a different room
(6) Post receipt for a shipped container
(7) Ship a small item to a different room
(8) Receive a small item from a different room
(9) Post receipt for a small item

C MENU
(1) Create a new collection
(2) Add to a pre-existing collection
(3) Remove items from a collection
(4) Put pins into jackets
(5) Post status of elements

D MENU
(1) Receive an item from outside FMF
(2) Send container and its items outside FMF
(3) Create a new container record
(4) Post transactions from another computer
(5) Enter an analysis record
(6) Place a seal on a single item
(7) Place a seal on a container
(8) Force move an item
(9) Force move a container

Q MENU
(1) Look up an inventory item
(2) List container items
(3) List collection items
(4) List inventory for station
(5) Look up batch analysis
(6) List all items in a batch

***S MENU ***
(1) Fix up a password record
(2) Fix up a location record
(3) Create a new PHD item
(4) Modify an item

Note, that operations involving items by themselves are in Menu A. Operations involving containers are in Menu B. Operations involving adding and removing items from collections are in Menu C. Menu D is not accessible to most operators. It contains the operations restricted to the MBA custodian. Menu S is used only by the system manager to initialize the system and to correct problems that develop. The existence of this menu is not even indicated to the regular user. Menu Q provides the opportunity to ask questions of the databases and to prepare reports and forms.

Each transaction has its own routine. This program gathers data from the user, any interfaced instruments, and the database to prepare three single record files: XNIMAGE, FRIMAGE, TOIMAGE.

XNIMAGE contains the information about what changes are occurring. The FRIMAGE shows how the item from which material was taken will look after the transaction is complete. Similarly, TOIMAGE shows how the item to which material is being sent will look after the transaction takes place.

Once these records are prepared, the menu option program calls the routine DBUP. This routine adds further information to XNIMAGE and then updates the databases by calling a series of further subroutines. WRITETRAN records the transaction in the TRANSACTION file. LOCNACCT updates the location inventory and checks for criticality safety violations. CONTACCT does the same thing for containers. MIXBATCH calculates the new elemental and isotopic analysis for the batch and updates the batch record in the ANALYSES file. DBUP1 is then called twice to update the INVENTORY, HISTORY, and COLLECTIONS files for both the TO item and the FROM item. The menu is then displayed so that the operator may make a new choice.

SHIPPING BETWEEN ROOMS

The shipping, receiving and receipting operations require some explanation. When a set of items is shipped, it must be in a container. The B4 option prepares a floppy disk that has on it all the INVENTORY records contained in the container and the associated ANALYSES. It also adds to the floppy a list of all transactions that have been made subsequent to the last shipment made from the sending computer. The INVENTORY records are adjusted in the sending computer to indicate that the items have been sent to a different location, but the records are not yet deleted.

This floppy is carried with the container to the MBA custodian. He or she uses this floppy to run D4, which posts the transactions to this central computer and prepares the floppy to be read by the receiving computer.

The floppy and container are then sent on to the receiving computer, which runs option B5 to receive the items. This program adds the records of the items to its INVENTORY file and updates its other appropriate files. It also prepares a receipt file on a floppy disk. At this point, each inventory record in the shipped container exists in both the sender's and receiver's computer.

The floppy is now returned to the MBA custodian's computer for option L and then the sender's computer, where option B6 is run to post the receipts. The shipped items are now deleted from the INVENTORY file of the sender.

IMPLEMENTATION

Many attempts to develop good on-line accounting systems have failed to recognize the need for close cooperation between the developers and users of software systems. The principals of this project were well aware of this pitfall and worked carefully to circumvent such difficulties arising here.

This is being accomplished in several ways. Overall management of the project has been in the hands of ANL-WEST. They have specified the timing of the project and have secured the resources in hardware, software, and personnel. The first designs were made by Los Alamos but served only as a draft for ANL to modify.

Once the final design was decided upon, ANL assigned a programmer to work with Los Alamos staff with particular responsibility for the Q menu query options. Successful preparation of a query requires a thorough understanding of the databases structure and program philosophy. Report generation, however, is completely separate from data acquisition once a design has been agreed to. Thus, the programmer developing queries can learn the system at his or her pace without delaying the initially more knowledgeable staff working on the remainder of the code. The same individual also provided training for the other ANL staff who are to use the system and translated their suggestions and criticisms back to Los Alamos for fine tuning of the code.

ANL also assigned a process supervisor to work with Los Alamos in adapting the FMF Operating Procedures manual to reflect the steps taken by the technicians to put the necessary data in the computer. The interaction of the Los Alamos programmers and the process supervisor greatly clarified reality for both parties.

The care taken in close coordination has paid good dividends. Implementation is going smoothly and complaints and disaffected parties are at a minimum.

REFERENCES

1. N. J. Roberts, B. H. Erkkila, and H. F. Kelso, "Materials Accountability and Safeguards Systems at Los Alamos," Nucl. Mater. Manage. XIV(3), 425 (1985).