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ABSTRACT

As part of the Fuel Cycle Facility (FCF) of Argonne National Laboratory's Integral Fast Reactor (IFR) demonstration, a computer-based Mass-Tracking (MTG) System has been developed. The MTG System collects, stores, retrieves and processes data on all operations which directly affect the flow of process material through FCF and supports such activities as process modeling, compliance with operating limits (e.g., criticality safety), material control and accountability and operational information services. Its architecture is client/server, with input and output connections to operator's equipment-control stations on the floor of FCF as well as to terminal sessions. Its heterogeneous database includes a relational-database manager as well as both binary and ASCII data files. The design of the database, and the software that supports it, is based on a model of discrete accountable items distributed in space and time and constitutes a complete historical record of the material processed in FCF. Although still under development, much of the MTG System has been qualified and is in production use.

INTRODUCTION

Since 1964 Argonne National Laboratory (ANL) has been operating a liquid-metal-cooled experimental reactor, EBR-II, at its Idaho site. The present design of a typical driver fuel subassembly consists of 61 fuel elements, each element being made up of a metal-alloy fuel pin inside of a stainless-steel jacket (clad) with a sodium thermal bond between the clad and fuel. Approximately 300 subassemblies have been removed from the core and are currently awaiting transfer to FCF.

When the Facility comes on-line, the spent fuel will be processed in a series of operations:

(1) The fuel elements will be chopped into small (1/4" inch) segments. Fuel-element structural material will be removed as a separate waste stream.

(2) The remaining heavy metal in the chopped segments will be separated from most of the fission products and the sodium bond by means of an electrorefining process. The product of this operation is an ingot containing the heavy metal.

(3) The ingots may be cast into pins in an injection-casting operation and the pins inserted into new structural hardware for return to the reactor.

All operations are conducted inside of a hot cell containing an Argon atmosphere. Most process equipment (e.g. the chopping apparatus, the refining equipment and the casting furnace) are operated by Programmable Logic Controllers (PLCs). The PLCs are, in turn, controlled by operators working through Operator Control Stations (OCSs), which are 486 PCs running control system software. Manual operations are performed using manipulators controlled from outside the cell. At frequent stages in the process, weights are measured by means of balances controlled by the Mass Tracking computer through the OCSs.

FUNCTIONS

The primary function of the MTG System is to track, in as near-real-time as possible, the movement and current location of materials inside FCF. It supports Materials Control and Accountability (MC&A) activities as well as provides data and information to assist FCF operations personnel in process control and in complying with facility operating limits (e.g. criticality safety).

For purposes of criticality safety, the FCF is divided into zones with limits on the amount and type of material allowed within each zone. Control of transfers of process material, either between zones in the cell or between containers, follow procedures that normally require weight measurements and proper authorization. Containers of process material are weighed in zone-to-zone transfers as part of the identification process and in container-to-container transfers to establish the mass and composition of new, accountable items. The MTG System collects, checks and reports data entered through the OCS and measured weights at all stages of the transfers.

A variety of criticality safety rules apply to FCF operations. There are rules on the overall amounts of fissionable material that may be present in a zone or a particular type of container. In addition there are rules governing the number and type of containers that can be present in a zone. Both kinds of rules may be operation dependent; for example, the rules may change for each of the several stages of a casting operation. The MTG System assists operations by applying these rules for proposed transfers and returning information to the OCSs to support operations review and approval of the transfer. However, the MTG System does not grant approval; that function is performed by operations personnel and includes any independent verification required.

As material is processed through the FCF equipment, its form, composition, and location change. Also, the material produced may have to be moved to a new location before weight measurements or analytical chemistry are available. For these operations, the MTG System tasks provide modelling to establish the new masses and compositions. As measurements are taken, these modeled compositions and masses are replaced by better known numbers.

When analytical chemistry results are available, and if the composition of the material from which the sample was taken is modified, the MTG System is able to "replay" subsequent operations to propagate the new compositions up to the current time.

SOFTWARE ARCHITECTURE

The MTG System runs on one or more Sun SPARC workstations under a conventional, vendor-supplied UNIX operating system.

The MTG System is made up of a number of different types of programs:

(1) Servers. The MTG System Servers are programs which manage communications between other software in the system and between OCSs and the MTG System. The Servers are running at all times, although most of the time they are simply looking for work to do.

(2) Tasks. MTG System Tasks are the pieces of software that do the work of (a) collecting and checking input data from the OCSs, other tasks or terminal sessions, (b) performing the modeling calculations, (c) storing and retrieving data to/from the database and other files, and (d) passing information back to operations personnel at the OCSs or terminal sessions.

(3) Terminal Sessions. Although most of the input to the MTG System comes from OCSs, some data entry is done from ASCII terminal sessions.

Figure 1 shows a schematic diagram of the flow of information between the various components of the MTG System.

On the right are the three types of interfaces between users (represented by circles) and the MTG System. OCSs and terminal sessions were mentioned earlier; the third mechanism, a mail-back server is not currently being used for routine operations. Although the three mechanisms are entirely different from the users' perspective, they all communicate with the rest of the MTG System in the same manner; all write communications

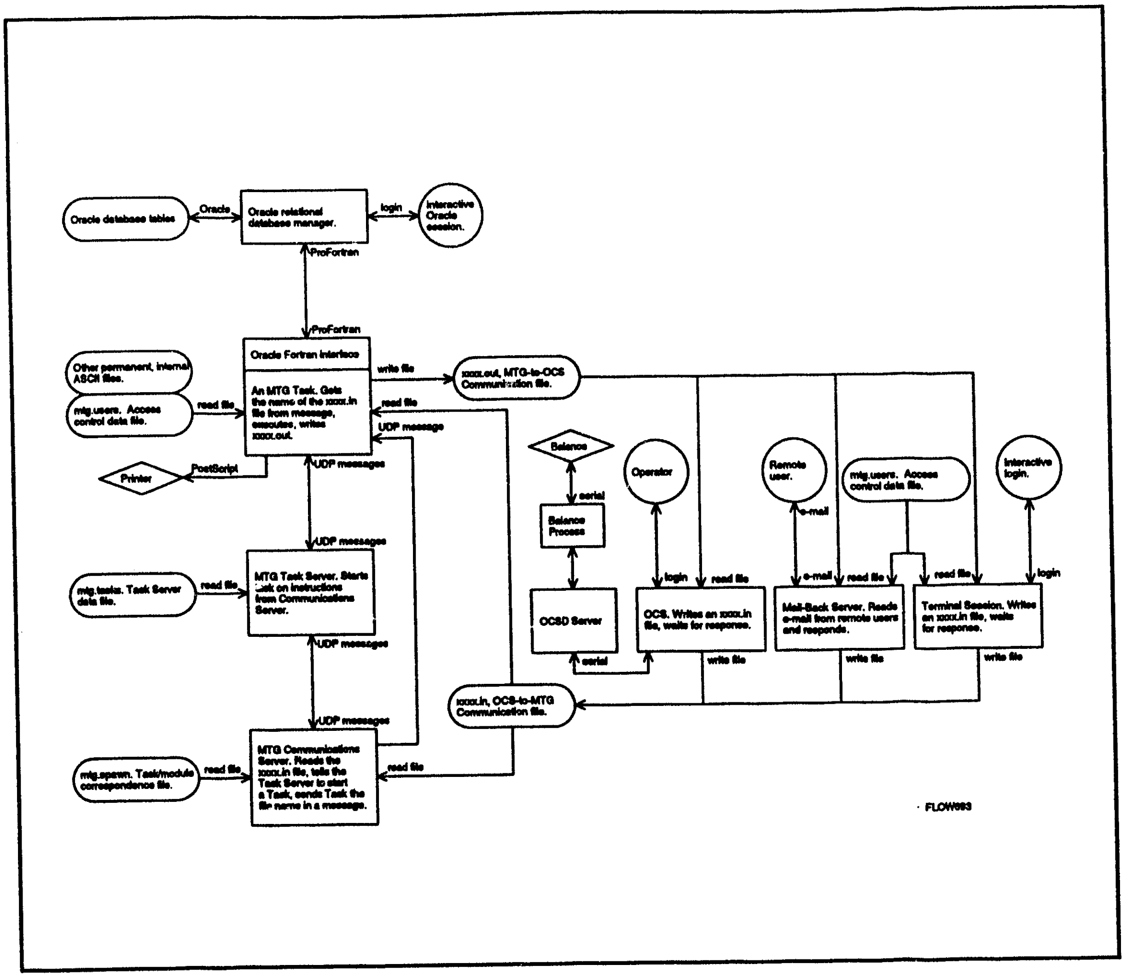

Figure 1. The flow of information within the MTG System.

files which are sent to the Communications Server. Communcations between the OCS and the MTG System computers is managed by the TCP/IP FTP protocol; communications between terminal sessions and the MTG System is managed by ordinary UNIX file copy.

The Communications Server identifies the nature of the communication file from the file's header record and commands the Task Server (by TCP/IP UDP messages) to start the appropriate Task. Any data needed by the Servers (e.g. names of executables) are contained in ASCII data files, permitting the addition and replacement of executables during operations and without the need of relinking code.

This kind of protocol permits several Tasks to be running simultaneously, and in principal on a distributed set of computers. In practice, the CPU load and frequency of interactions is not so great that the system requires more than a single host.

The MTG Tasks are the only pieces of software that read from and write into the Oracle database. This convention is followed to facilitate input error checking, event logging and backup/recovery procedures. There is no direct access to the database during routine operations; interactive Oracle sessions are only used occasionally, and then only to repair the database when errors are detected.

DATABASE DESIGN

The discrete nature of the processes in FCF leads naturally to discrete modeling of the accountable items in the Facility, and the accounting system fits naturally into a database format.

The data accumulated during operations are maintained in a number of forms.

1. A set of relational-database tables, managed by Oracle Relational Database Management System (RDMS), contains basic information on every accountable item that is, or ever has been, in FCF. These database tables also contain all weight data taken during operations and during the calibration and checking of the balances.

2. Files defining the composition of items being tracked are written as standard, IEEE-format binary datasets. These data are not maintained by the RDMS because of their volume (they include a considerable volume of data on fission product inventories) and because they are always read and written sequentially; only the names of the files are contained in the relational database.

3. ASCII files containing historical data on the details of all batch operations. These files include sufficient detail to permit the "replay" of each batch operation. The ASCII format is used to make the files readable with ordinary editors and portable to other, arbitrary computer systems.

The convention followed in designing the relational database tables was, with few exceptions, to always add (not modify) entries as events take place.

Unique timestamps assigned by the Task Server are used to logically connect generations of accountable items. Timestamps in the "Item" table define creation and termination times of accountable items. Timestamps in the "Location" table define the arrival and departure times of items in specific locations within FCF. When a new entry is created in a table, its creation time is the same as the termination time of its predecessor, thus establishing the parent-child connection in the database.

Process material, containers, equipment and even work zones within FCF are treated similarly as items in the database. In the same way that they are used to associate parent and child items, the timestamps are used to establish a space-time map of the contents of the Facility.

OPERATOR INTERACTIONS

Real-time interactions with operators are largely used to record weights and log events. When a weight measurement is taken by an operator, it is recorded in the database automatically; the balances used in FCF communicate directly with the OCSs, which, in turn, communicate with the MTG System. Events (e.g. the several stages of transfers between zones or between containers) are logged in by operators at the same OCS that they are using to take weight measurements and to control process equipment.

For reasons of both process control and MC&A, all operations conclude with a "closeout" procedure to determine that all material is accounted for properly. Also compositions of new items are established and approvals are collected. These closeouts are performed from the OCSs, with the support of hardcopy reports printed near the stations.

Hardcopy reports from process operations are printed automatically at closeouts. Transfer forms are printed at the beginning of each zone-to-zone transfer both as an aid to operations and for signature approvals. Mass-balance and MC&A inventories are triggered from a terminal session.

In most cases, operations do not have to be interrupted if the MTG computers are not available. The MTG System is not a safety system; responsibility for compliance with criticality safety and other Facility rules lies primarily with the operators. Operations can continue with the required data being collected off-line on forms provided for this purpose. When the MTG System is again available, UNIX scripts and the manual forms provide a means to "catch up" by entering data after the actual events.

MODELING

At several points in the process, calculations are used to model parts or all of an accountable item.

1. The initial estimates of fission product inventories are computed from burnup calculations

and are, for the most part, carried throughout the entire process.

2. Before weights are available, calculational models of certain operations provide masses that are used to assure compliance with criticality safety rules.

3. After weight data become available, compositions at closeouts are adjusted to reflect the measured weights. In some of these instances, chemical or physical models are part of the adjustment algorithms.

CONCLUSIONS

Parts of the MTG System (the Servers, certain Tasks, and many of the terminal session screens) have been tested, qualified and are currently supporting production work at FCF. The remaining parts of the system are in testing and are expected to be on-line in the fall of 1994.

REFERENCES

1. Y. Orechwa, C. H. Adams and A. M. White, "Mass Tracking and Material Accounting in the Integral Fast Reactor (IFR)", INMM 32nd Annual Proceedings, July 1991, Vol. XX, pp. 937-947.

2. Y. Orechwa and R. G. Bucher, "Measurement Control Design and Performance Assessment in the Integral Fast Reactor Fuel Cycle", these Proceedings.

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