SOFTWARE THAT REALLY WORKS

A consortium of forward-thinking corporations and government agencies in the aerospace, defense, and energy sectors has worked for three years to help create the first software system tailor-made for materials engineers.

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After three years of collaborative effort, the Material Data Management Consortium (MDMC) has achieved its initial objective: the first version of a true *materials* information management system. The software is tailor-made to address the requirements of materials engineering, comprising a comprehensive set of specialist tools capable of managing workflow throughout an organization. Granta MI is the first commercial release of that software system, launched by Granta Design in April 2005.

The architecture of the system is relatively simple. With its initial focus on requirements of the aerospace, defense, and energy sectors, quality and traceability of materials information are treated as paramount. Engineers can access the information in two ways, characterized by the "intensity" of access required.

• **Higher-intensity** tasks usually involve significant quantities of information and use a client application installed on the engineer's computer. An example would be loading results from a testing program into the system, or calculating an MMPDS typical stress-strain curve. The library of data reduction modules or specific tests, developed within the MDMC, can be found here.

• **For lower-intensity** tasks, such as searching and retrieving data, or comparing two or more materials on a graph, a browser application would suffice. This application does not require any software to be installed on the engineer's computer other than a standard web browser, saving valuable IT time and resources.

From the theoretical to the real: software design

The Consortium has worked to specify in detail the software system now known as Granta MI. The basic theoretical design of the software was loosely based on the concept of a "lifetime" of materials data, split into three phases for convenience: Data consolidation, data analysis, and data distribution.

Phase 1: Data Consolidation

The consolidation phase is primarily concerned with testing. It focuses on aspects of efficient data capture and the analysis of experimental data from single tests, along with the effective gathering and storage of the associated pictorial and text information needed to build up the necessary pedigree.

This phase is generally associated with research into new materials and the characterization of existing materials. The challenge for a software system is to provide for easy assimilation of raw data into the system and its effective reduction to usable engineering quantities. Because the personnel most involved with these issues are materials scientists and they are well represented within the Consortium, it is not surprising that significant effort was focused here.

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Materials Data Management Consortium

The Materials Data Management Consortium (MDMC) was founded in 2002 as a collaboration between materials-oriented corporations and government agencies in the U.S. aerospace, defense, and energy industries to develop a software system for managing materials information. The overall objective of the MDMC is to increase the return on investment for materials research and development. Member organizations cooperate to apply their requirements, experience, and technical expertise to the detailed specification of the new software system.

ASM International manages the Consortium, which is chaired by Dr. Steven Arnold of the Life Prediction Branch at NASA Glenn Research Center. The members are all materials-oriented organizations and government agencies in the U.S. aerospace, defense, and energy sectors. The members of the Consortium include:

Alcan Aerospace
ASM International
Concurrent Technologies Corporation
Granta Design
Los Alamos National Laboratory (MST6)
Los Alamos National Laboratory (ESA)
NASA-Glenn Research Center
NASA-Marshall Space Flight Center
Naval Surface Warfare Center
Pechiney Rolled Products
Rolls Royce Corporation
Secat Inc.
Westmoreland Mechanical Testing
Williams International

Data from materials tests are produced in a variety of file types and formats. As discussed above, specification from the Consortium rather than a single organization made it possible to cover a wide range, especially with regard to formats of data within text files.

Tensile data is a useful example. Modern test equipment often creates a pair of ASCII files or a single binary file and may contain data from one or more specimens. For each specimen, raw and reduced data are available, along with other information about pedigree (in the form of an identifier, e.g. batch number) which may be used to link to all relevant information. Other mechanical test machines provide a single ASCII file containing two columns of numbers with units of volts.

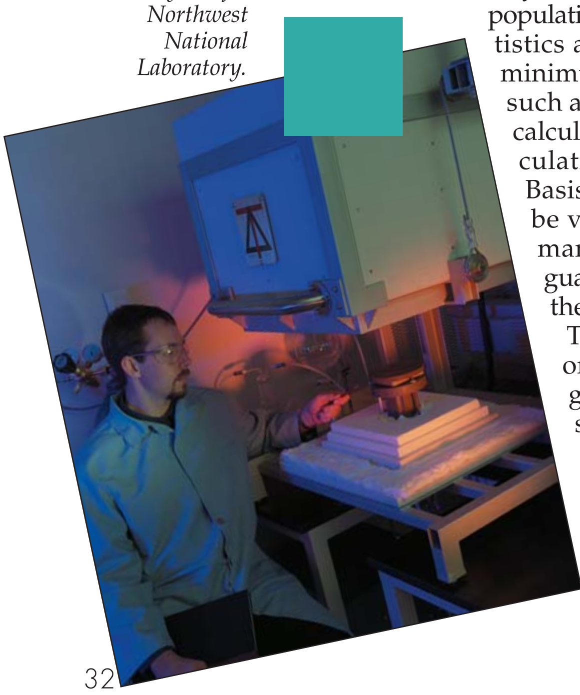
As might be imagined, the handling of these two types of data for the same test type is very different, yet neither is superior when it comes to data quality. Therefore, each must be managed in the appropriate way to maximize the efficiency and quality of the data that is retained in the system. One requires more manual intervention, but both data types are handled with full traceability to their original data.

Phase 2: Data Analysis

The analysis phase concentrates on the manipulation and/or examination of data from groups of tests. Materials are tested for many reasons. However, the true value of test results is only realized when they are combined to form a population that can be analyzed for some specific purpose. Analysis techniques have many different results, but generally they examine either a single characteristic in order to derive a statistically valid value (at one extreme) or assess the effect of changes in a variable on a characteristic (at the other extreme). It should be noted that these calculations vary in complexity. Some examples illustrate the point:

The statistical analysis of a single property in a population can be easy if the statistics are simple. The mean, minimum, and maximum for such a population are easily calculated. However, the calculation of an "A" or "B" Basis design allowable can be very complex, and has many requirements to guarantee the suitability of the final value.

The effect of a variable on a property is at first glance more complex, such as changing R-ratio of fatigue life or fatigue crack growth. However, the changes of production property against time (in order to assess the effects of, for example, changing production techniques on a material) should be relatively easy to assess, and it is, provided the data is available!



A Pacific Northwest National Laboratory researcher prepares to test a solid oxide fuel cell stack. The Laboratory uses materials science and modeling resources to develop improved materials and stack designs for SOFCs. Image courtesy Pacific Northwest National Laboratory.

The software situation is further complicated by the secrecy that surrounds materials information in the aerospace and defense sectors. This is a direct result of the expense of materials qualification, and the competitive advantage possible by the use of innovative materials. This secrecy often extends to software manufacturers creating analysis and reduction modules of materials data. The MDMC members recognized this limitation, and therefore specified a suitably flexible structure so that their proprietary models or statistical treatments can be accommodated, while the algorithms are kept confidential.

Phase 3: Data Distribution

The distribution phase covers the tools and tasks associated with publication. Valuable information must be made available to the appropriate audience, yet often must be prohibited for other audiences.

When materials and test records can be linked to information describing other aspects of their use and pedigree, the value of an integrated system stretches far beyond the confines of the Materials and Process department. It has relevance in all aspects of an organization's engineering function. However, the type of data suitable for different audiences inside the same organization varies widely. Both ease of access and a failsafe access control system are required.

For Consortium member organizations and for others, it can be important to avoid the possibility that some types of information may fall into the wrong hands. ITAR-restricted data is a case in point. Several effective access control mechanisms were built into Granta MI to enable failsafe control of data distribution.

Ease of access for those who need the information is also vital. The audience for the data derived in the consolidation and analysis phases usually consists of the internal and external engineering functions. The requirements of this audience are pretty straightforward and may be characterized by the maxim: *"What I want: when I want it: in the format I want."*

No matter how superior the quality of information on a new system, if an engineer is required to take more time than usual or enter a totally unmemorable twenty-character alphanumeric password, chances are that neither the engineer nor the organization will benefit. Best quality data may be ignored when the engineer goes instead to a directory of out-of-date text files on a shared drive or some incomplete spreadsheets hidden on a local drive.

The goal, therefore, is to provide easy access for all engineers in the organization to a controlled proportion of a single, consistent set of qualified materials information. The obvious solution is to allow access to the system through a web browser. This does not mean that the information is available to all Internet users; just that web technology can be used to distribute the information around an organization, inside its firewall, via the most up-to-date technology.

In Granta MI, engineers are given a set of user-friendly tools that allow them to find quickly the data they need. These include Boolean characters (AND, OR , NOT etc.) and wildcards (e.g. alumin* to find different spellings of aluminum/aluminium). Once the data has been located, the engineer can choose from a variety of tabular and graphical tools to compare selected sets of data. If the data is for a CAD or FE package, exporters are available, and others are easily created in-house.

Challenges and successes of collaboration

The Consortium members are clearly motivated to work through individual concerns to achieve successful solutions, and they share the same interest in the promise of materials information management. Working towards consensus has informed a number of important developments in the software. Three key topics provide examples: Choice of data for storage, confidentiality, and data compatibility.

• **Choice of data for storage:** Achieving consensus between parties on choice of data for storage is notoriously difficult. The Consortium proved the exception. The level of background information and the exact types of raw data stored had developed independently and over many years in each of the member organizations.

Therefore, a group of members decided to focus on the problem, and a surprisingly straightforward solution emerged. They concluded that it was possible to create a common relational database schema for holding ALL raw, reduced, pedigree, and statistical data. This was achieved within a single session based on representative sets of information, by analyzing members experiences with the data and their "war stories" about the effects of missing information.

• **Confidentiality:** This presented another challenge to collaboration. Most organizations, and many represented within the MDMC, develop confidential algorithms for analyzing materials behavior. Careful and constructive discussions allowed these different techniques to be assessed, and resulted in the specification of a system architecture that could accommodate all necessary technologies, while protecting the confidentiality of proprietary algorithms.

• **Data compatibility:** The issue of data compatibility, also an inherent challenge to collaboration, was similarly addressed by the new system's architecture. Nearly all member organizations have legacy codes for curve fitting and for other applications that require very different techniques and run in different software environments. The solution was found in specifying the necessary flexibility in the tools and associated data structures to allow all proprietary models or statistical treatments within the software.

Next steps for the MDMC will depend in part on inspiration provided by new members, since MDMC membership is still open. Faithful to its original mission, the MDMC plans to continue pushing the boundaries of materials data management, creating new demands for software that really works for materials engineers.

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The U.S. Navy has selected the Lockheed Martin US101 for a new fleet of "Marine One" helicopters for the President of the United States. Materials selection will be an important task for the designers of the helicopter. Image courtesy Lockheed Martin.

Granta MI Windows applications

A summary of Granta MI's architecture and capabilities is shown here.

MI:Admin is for database administration tasks

- Schema building
- Bulk data processing
- Population
- Access control system construction
- Access control system maintenance and settings population

MI:Lab is for bulk data processing and analysis

- Text file importer
- Spreadsheet importer

The library of analysis modules includes

Test Modules

- Tensile
- Compression
- Creep
- Stress Relaxation
- LCF / Cyclic Deformation
- Fatigue Crack Growth
- Fracture modules:
- E399 Fracture Toughness
- E561 Fracture Toughness
- E1820 Fracture

Statistical Modules

- Tensile
- Cyclic Deformation
- Creep
- Fatigue

Granta MI browser features

Search

Select

Report

- Compare table
- Compare chart
- Record reformat for export (e.g., to an FE code)

Enter new data

Edit existing data

Add/edit/copy/move existing records

Update access control settings on individual data and/or records