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Title: Weapon Systems Engineering Material Database Requirements

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Weapon Systems Engineering Material Database Requirements

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1 Introduction

The Weapon Systems Engineering Material Database, often called 'Granta'[1] but referred to in this document as 'the database', stores and distributes material information to W-division at Los Alamos National Laboratory (LANL). The database is constantly evolving as data is imported and methods of retrieving data are developed. Because limited resources necessitate prioritization of data to be imported and retrieval method development, a definition is needed of how the database is to be used, both currently and in the future. This document, to be used by the database developers, is intended to provide that definition in the form of requirements for the database.

The requirements for the database are a function of the intended use of the database. Thus, this document presents the requirements in the context of the *use cases* (UCs) that describe how people use (or, in some cases, *will* use) the database. Each UC is discussed in Section 2. A list of engineering material database requirements (EMDRs) that are either required or recommended for successful accomplishment of the UCs will be given in Section 3. It is expected that this document will be updated as new UCs, and thus new requirements, are identified.

[1] Due to the use of Granta MI software by Granta Design.

2 Use Case Descriptions

This section lists and describes the UCs for the database. Each UC is constructed considering the role(s) of the user and the task they need to accomplish with the database. The EMDRs necessary to support these use cases are listed in Section 3.

UC1: Material Model Pedigree Tracking

Role: Engineering analysts - primarily, but not limited to, W-13 analysts

Description: A structural and/or thermal engineering model may contain dozens of material models. Typically the analyst will not retain knowledge of the sources of each material parameter but will occasionally need to trace the origin of a particular parameter. For example, if the analyst discovers a model to be sensitive to a particular parameter then he/she may deem it important to establish that the parameter reflects data that is appropriate to the situation being modeled. Or he/she may find it necessary to consult the original source documents to estimate the variability of the parameter.

Note that the engineering analysis baseline models (EABMs) *require* that the material properties be of good pedigree, and the EABM requirements document[2] recommends use of the material database for tracking model pedigree.

An example workflow for this UC might be as follows: the analyst obtains his/her material models from a list exported directly from the database. The materials could be assigned to parts in an EABM using the material specification document number, which could be part of the material record, as well as written on the part drawing. Then, when the analyst needs to trace the pedigree of a parameter, he/she would locate the appropriate record in the database. This database record would contain the pedigree information.

Multiple weapon systems may contain identical materials. For example, two systems may contain 6061-T6 aluminum parts with identical material specification. In this case, both EABMs will need to use the same material model. The user will not need to make sure that materials are consistent between systems; he/she will just assign materials according to the specification given in drawings.

UC2: Support for Material Model Development

Role: Material model developer

Description: Developing, calibrating, and validating a material model requires test data. The material modeler needs access to all available and relevant test data on weapon-specific materials. He/she needs to be able to easily

[2] W-13-TR-0056U

find, compare, and export test data. The export may be performed one record at a time, or it may be performed for multiple sets of data in a way that is organized and thus can be used by the modeler's own calibration/validation scripts, which may be written using common tools such as Python, Matlab, or Excel.

The material modeler may then create the database record in which the material model is stored. The material modeler might include documents and/or calculations to support the verification and validation of the material model, which would help a future material model user decide whether the material model was applicable to his/her situation.

UC3: Summary of Material History and Use

Role: W-division system engineer

Description: When issues arise with a material currently in use, or when a substitute material needs to be developed, a system engineer needs to be able to find all available information about that material. This includes information about the material development history (for example, Bendix reports), material processing, weapon assembly procedures (including procedure changes relevant to the material), and surveillance information. Currently, much of this information resides in PDMLink, but the information is not linked in such a way that finding one document leads the user to other related documents.

UC4: Identification of Material Physical Properties

Role: W-division system engineer, designer, or engineering analyst

Description: The engineer, designer, or analyst needs to be able to easily find physical properties, like density, specific heat, etc, of parts in a weapon system. Since these users, while assumed to be knowledgeable about the weapon system and its parts, may not be frequent database users or material experts, they expect to see a view of the database that easily leads them to the basic physical properties they need. Each different type of user expects to see the same properties, even though their views of the database may differ.

UC5: Material Property Comparison

Role: W-division system engineer or designer

Description: The engineer or designer may need to use a material that is not necessarily a current weapon material; for example, a designer may be designing a test fixture or an engineer may need to choose a surrogate material for a system test. The user would like to compare physical, mechanical, and thermal properties for many common engineering materials. Furthermore, these users are likely not to be frequent users or material

experts, so they should be able to accomplish their task with minimal experience using the database.

UC6: Assignment of Materials to Parts

Role: W-division designer

Description: It is the responsibility of the designer to assign materials to parts (i.e. to create the bill of materials) in solid models, drawings, and product structure. The designer will assign the materials from the database so that the properties are shared with other database users (for example, analysts) and the sources of the properties are traceable. Having the database accessible, and the correct materials easy to locate, from within the drafting software would reduce the chances of inadvertently assigning the wrong material or property.

UC7: Association of Materials with Parts

Role: Engineering analysts - primarily, but not limited to, W-13 analysts

Description: It is the responsibility of the engineering analyst to associate the correct material, and thus the correct material properties, to each part in an engineering model. The analyst will assign materials from the database so that the properties are shared with other database users (for example, designers) and the sources of the properties are traceable. Depending on the preferred workflow of the analyst the database may be accessed from within the analysis software or from scripts that create the engineering analysis model.

UC8: Material Test Data Archive

Role: Test engineer/scientist (e.g., MST-division)

Description: Much test data is generated at LANL that characterizes the behavior of materials in environments of interest to engineers. Test engineers/scientists need a central location to store this test data so that the data is not lost when the engineer/scientist leaves their organization.

UC9: Highlight New Test Data Needs

Role: Funding/project manager

Description: The funding manager or project manager needs to know which data has already been collected and how it is related so they can plan new tests. For this, they need a view of the data that shows them, for a given material or material type, what data exists, what data is missing, and how data sets are related.

3 Material Database Requirements

This section lists the EMDRs that, if satisfied, will allow the database to fulfill the UCs described above. Note that some of the language used (for example 'reasonably', 'easily', 'casual', 'effective', etc) is intentionally ambiguous. This is to allow for flexible interpretation of the requirements based on non-fixed constraints such as computer resources and user knowledge/experience. Strict requirements are indicated by use of the word "shall", while strong recommendations are indicated by use of the word "should".

EMDR-1 The database shall store all properties and material model parameters for the EABMs.

EMDR-2 The database shall store metadata (for example, material pedigree and applicable temperatures and strain rates), associated with properties and material model parameters, sufficient to allow the user to determine whether the properties and parameters are applicable to the user's environment of interest.

EMDR-3 The database should provide information to direct the user to subject matter experts or points of contact for each material, particularly weapon-specific materials.

EMDR-4 The database shall output all properties and material model parameters for the EABMs in such a way that they can be easily imported into the EABMs and traced back to their parent records (including version) in the database.

> **Comment:** The export format will depend on the workflow used by the EABM analysts. For example, for EABMs that are built from a script, a text file of material 'cards' that can be 'included' in the scripted model may be preferred. However, if an EABM resides directly in the modeling software (e.g. Abaqus/CAE) then the preferred method of outputting material models from the database may be to allow direct access to the database through the modeling software.

EMDR-5 It should be easy to identify the correct record.

> **Comment:** This might be accomplished, for example, by ensuring that the names of records are adequately descriptive or by providing warnings to users when there is more than one similar material.

EMDR-6 The database shall store all available material-level test data for weapon materials at environments relevant to the stockpile-to-target sequence (STS) with sufficient metadata such that (a) the user can establish how representative the tested material is of the actual war reserve (WR) material, and (b) the independent parameters (e.g. temperature, strain rate, porosity) in the related material models are well characterized.

EMDR-7 The database shall output test data, for single records and (in a reasonably automated way) for multiple records, in such a way that it can be analyzed by third-party software such as Matlab, Python, Excel, etc.

Comment: At a minimum, it must be possible to create text files with all record information. It is preferred that all attached files and documents can also be exported.

Comment: This requirement may be accomplished by providing an interface for third-party software to extract the data.

EMDR-8 For all materials modeled in EABMs, the database shall store or link to all available documents that contain (a) source data and/or pedigree information about properties or material model parameters, (b) information (e.g., drawings and procedures) defining in what part or assembly a material is used, and (c) test reports and related documentation.

Comment: Many relevant documents are stored in W-division's PDMLink database. For any such document, a link to its record in PDMLink will be provided, and a local copy, which may not be the most recent version, may be stored in the material database for convenience.

EMDR-9 Every property, material model, testing, and document record shall be version controlled such that (a) previous versions of the record are easily accessible, and (b) the changes to the record, and the reasons for those changes, can be documented.

EMDR-10 The database should have the ability to convey to users the quality of the information in a record in a simple way.

EMDR-11 Users should be notified when records they are interested in are changed.

EMDR-12 The database should show the relationships between related records and allow the user to navigate among related records.

Comment: This requirement could be satisfied, for example, by establishing web-links among related records.

EMDR-13 It should be possible to create different views of the database, including views that summarize the data, properties, or material models available for particular weapon systems, material types, organizations, etc. This capability should be flexible enough to create views of the database that have as yet not been defined.

EMDR-14 The database shall have an intuitive and effective search capability.

EMDR-15 The database should have the ability to graphically display data, both for a single record (e.g., a stress-strain curve) or for multiple records (e.g., displaying yield stress versus toughness for multiple materials).

EMDR-16 At a minimum, the database shall have the ability to store the following types of data, each with associated metadata: single-valued real number data, parameterized data (e.g. stress versus strain), range data (e.g., minimum and maximum yield strength), documents (e.g. pdfs, spreadsheets, images, text files), and text.

EMDR-17 Casual use of the database shall not require training assuming the user is familiar with common computer web-based databases such as Wikipedia or Matweb.

EMDR-18 A user shall be able to create a record and import data into the database with minimal training (for example, a short 'how-to' guide document).

EMDR-19 To ensure peer review and adequate population of the database it shall be available to as many users as possible, including, but not limited to, engineers, designers, test engineers/scientists, material modelers, and program managers.

EMDR-20 The database software shall include a capability that allows application of institutional access control policy to the data in the database.