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Model-Based Engineering

A strategy for RRW and future weapons programs

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Abstract

To meet Sandia's engineering challenges it is crucial that we shorten the product realization process. The challenge of RRW is to produce exceptional high quality designs and respond to changes quickly. Computer aided design models are an important element in realizing these objectives. Advances in the use of three dimensional geometric models on the Reliable Robust Warhead (RRW) activity have resulted in business advantage. This approach is directly applicable to other programs within the Laboratories. This paper describes the RRW approach and rationale. Keys to this approach are defined operational states that indicate a pathway for greater model-based realization and responsive infrastructure.

Introduction

An important element in the engineering lifecycle of any product is the Design Definition. In today's environment Computer Aided Design (CAD) tools are core to this Design Definition. To date, these CAD tools have provided great value for visualization, design layout, geometry checks, and quick drawing generation. Other value includes the re-use of this information for other engineering functions such as analysis of a fully defined product and rough machining. Underlying all of these functions is the three dimensional geometric solid model which forms an important foundation for mechanical engineering design. We advocate that this foundation model be the source for the functions listed above and often the source for downstream applications like analysis and tool path generation. At the same time, we recognize that due to the design process other foundational models may be necessary to support conceptual analysis and concurrent engineering.

The term "model-based" has been associated within the use of these geometric solid models applied in a variety of value added activities throughout the product realization lifecycle. For all of these reasons, the leveraged use of the solid model has proven successful in increasing quality and minimizing cost which has driven the "model-based" focus within the mechanical design industry.

While "model-based" is a familiar term, it is used inconsistently. The purpose of this paper is to define the term "model-based" and the RRW approach to realizing the associated benefits. Throughout this paper the term Design Definition refers to the information provided to companies tasked with building and verifying product.

Motivation for a model-based description

We are in the midst of significant business process changes driven by increased use of three dimensional solid models. With technical capability comes opportunity. Capitalizing on this opportunity requires a thoughtful strategy and careful implementation. The excitement of a paperless, "drawingless" environment must be balanced with other business realities including current technologies, infrastructure limitations and constraints from partners. Consequently, we leverage technology while accommodating business partners who currently operate at various capabilities of model use.

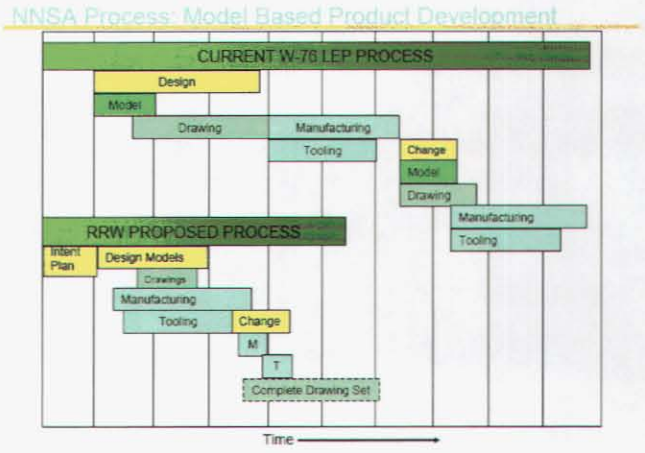
Since the term "model-based" is not well defined, miscommunication occurs. Some view a model-based environment as one without drawings. Some visualize a single model used for drawing creation, numerical controlled (NC) machining and analysis. Others believe that there are a suite of models tailored for specific purposes – all with a common core. It is evident that while these perspectives have similarities they have the potential for vastly different interpretations and implementations.

We believe model-based means "Creation, management and re-use of appropriately featured 3D solid models." It is clear that there can be various models established to meet immediate and downstream needs. We believe that the most robust path along this model-based journey starts with a strategy and includes explicit pre-defined states regarding the use of models within the Design Definition. These states are defined in the context of model-based maturity and harmonize the various elements within the Design Definition.

Drawings – an element of model-based

Many manufacturing facilities use models to generate NC tool paths and otherwise control machines. During this process, it is common to see drawings laying on the bench-top of the machinist. These drawings are used as a reference for the machinist. This is because people can understand complex and inter-related information and views quicker using printed drawings. In one glance a machinist can see Geometric Dimensional and Tolerance (GD&T) callouts and also important cross section views. In this environment the machinist typically has a computer capable of displaying and manipulating the solid model. However, even in the hands of the most accomplished CAD user, this computing power is no match for the speed of reading a well organized D size drawing layout.

Another virtue of the engineering drawings comes within the peer review process. The process of verifying the details of a design often requires quickly flipping from one view to another. Reviewing these details is done quickest and easiest using paper drawings. It should also be noted that peer reviews also include verification of assemblies, mass properties and features – which are best done using models.



Another use of engineering drawings concerns the archiving of design definition. There is presently no ability to predict whether electronic models created today will be readable by tomorrow's software tools. Interchange formats such as STEP, while predictably readable, do not contain vital model information such as datums, coordinate systems, etc. For these reasons, we believe that drawings will continue to be an important part of the Design Definition. It is important to note that drawings do include a maintenance liability which is minimized by creating drawings only when needed and as late in the design process as possible. In addition, when drawings support models, sparsely dimensioned drawings should be considered to further minimize drawing creation time. This approach ensures

that inevitable engineering change is conducted efficiently in the model without need for unnecessary wasteful drawing updates.

At present, the modeling tools do not provide a high confidence path for archiving models. Therefore, we recommend that drawings defining end product are generated and saved for permanent archive.

Objective for RRW model-based

- We will create drawings when needed and as late in the design process as possible to reduce the burden caused by engineering change and to ensure permanent archiving of design.

Common CAD tool

We are beginning to see that the benefit derived from three dimensional geometric models is related to the detail contained in them. Models that are built to construction standards provide greater benefit to NC programmers because they require less change. Models that include accurate mass properties information and comply with analysis-ready modeling standards provide greater value to analysts. Increased care will be needed to define and construct features to align with downstream processes. This re-use of feature information is not possible when users export and import geometry from multiple CAD systems. As our engineering processes become more information driven, the use and value of models will increase. This reuse of information will drive the desire for higher fidelity information sharing and drive the need to use the same CAD software. In addition, we are increasingly being asked to reduce cycle time in all aspects of engineering. For these reasons, including our need for speed, our corporate standard Pro/ENGINEER should be used to the maximum extent possible.

Objective for RRW model-based

- We will maximize information sharing and re-use by using our corporate standard CAD solution Pro/ENGINEER to the maximum extent possible.

Models used in manufacturing

Three dimensional models of RRW and other weapons systems contain classified information. To maintain speed in the product realization process, the complete set of classified models will be shared with our manufacturing partners. Currently, many of our manufacturing partners are not prepared to handle complete classified models. Therefore, we currently dissect classified associative models into singular part models and drawings. Many of these drawings contain only unclassified information and are label unclassified after verification through the Derivative Classifier (DC) process. While this approach supports our current manufacturing partners, we have broken the model-based chain.

Business goals are increasingly requiring design options to be considered much more rapidly. We also have a need for speed in the manufacturing process. This need for speed has driven industry to fully leverage models in the generation of manufacturing tool paths. We have demonstrated at Sandia that parts built directly from the models are built quicker and often of higher quality. This use of models enables initial responsiveness and rapid accommodation of changes. To achieve this responsive environment, classified manufacturing is required.

When fully classified manufacturing capabilities are not available at the manufacturing site, our strategy requires the manufacturer to create manufacturing drawings. The manufacturer will be responsible for processing these drawings through the DC process to establish drawing classification. Some drawings will be classified and others will be unclassified. These supporting drawings should be generated in a semi-automated fashion without the need for Drawing Requirements Manual (DRM)-type perfection so long as the necessary content is included. At this point, the model-based chain has been broken. No longer can the manufacturing entity fully leverage the detail and information contained within the model. Should design changes be made, the post model-based activity must be re-done adding time and cost. At this point, we are no longer responsive.

Objectives for RRW model-based

- Complete set of models will be provided to the manufacturing organization.
- Manufacturing will be done directly from the model, if possible.
- If unclassified manufacturing is required, necessary supporting drawings will be created from the model and processed through an DC process to be deemed unclassified.
- Supporting drawings required will be semi-automatically generated and should include only necessary information.

Inspection

Significant research is occurring within the area of model-based inspection. Technology limitations currently require inspection facilities to depend heavily on drawings as a basis for their inspection process. Our current strategy is to provide the drawings and supporting models for inspection.

Objective for RRW model-based

- Models and supporting drawings will be provided for inspection purposes.

Concurrent Engineering

Model-based design provides the opportunity for significant contribution in realizing organizational responsiveness. Configuration management is a vital enabler to managing the information in a mode-based environment – models, drawings and other

electronic documents. While drawings can be electronically accessed or printed and shared, models must be electronically accessed. Drawings can be electronically accessed outside of their design context while comprehensive models must be electronically accessed within their context due to the parametric association with other models. This illustrates that the benefits of model-based design come at a cost of increased configuration management infrastructure complexity.

The RRW design environment requires sharing of component and system design information in an efficient manner. This information not only includes three dimensional solid models, but also process documents and analysis results all organized in a manner that preserves the entities relationships within context. Each site maintains a sophisticated configuration management capability established to best manage their models and other product data. While some visualize a single shared "NWC system", the RRW activity proposes access to site systems by team members regardless of their site. This method allows designers at Los Alamos National Laboratory (LANL) to directly access Sandia's most current designs and vise versa. While our direct access approach requires discipline to ensure proper occasional manual synchronization of models, the location of the record copy is clearly known and available to any team member when needed. The RRW (Sandia) approach to sharing this information is documented in the RRW Configuration Management Plan and the existing Engineering Authorization infrastructure is used to capture formal documentation regarding model and drawing sharing.

Objectives for RRW model-based

- Direct access to site-configuration-managed models by team members across sites
- Engineering change documentation within context

Pathway to NWC model-based responsiveness

While the benefits of model-based design are clear, achieving these benefits must be realized through careful implementation of a comprehensive strategy. A method for defining goals and measuring success in the model-based journey is described in the next section. While we strive for model-based State 3 on the RRW activity, we advocate state model-based State 2 for NWC planning. We believe that this is a pragmatic approach allowing the NWC to realize significant advantage within the current state of technically dissimilar site capability.

Model-based operational states

Our strategy for achieving increased model-based business benefit is to advance through specific defined states. These states provide an effective basis for measuring progress.

Model-based State 1:

In this state, models are used primarily as a pathway to generating drawings. Two dimensional drawings form the official basis for Design Definition and are solely trusted for manufacturing and inspection. Models are also used to directly generate rapid prototyping parts, visual aids, and numerical controlled machining instructions.

Key Characteristics of model-based State 1:

- Drawings are the sole element of Design Definition and configuration managed.
- Traceability of drawings is maintained within current engineering information tools and electronically available within the NWC.
- Drawings are typically generated from models.
- Models exist but are not part of the Design Definition.
- Tool paths are often generated from models however official validation is done using drawings.
- Inspection is based on Design Definition drawings.
- Models are unofficially shared to support drawing changes and the creation of manufacturing models. In some cases, engineering authorizations are documented; however, configuration management and traceability of models with drawings is not conducted.

Model-based State 2:

In this environment, models are managed and used to evaluate design options, assist in the generation of analysis models, generate drawings, and support NC machining. The model is inextricably associated with the Design Definition and is properly controlled and considered an element of the Design Definition set. Drawings still form the basis for official Design Definition. Drawings are used to validate NC tool paths even though models are normally used to generate them.

Key Characteristics of model-based State 2:

- Drawings form the basis of Design Definition.
- Drawings are generated from models when created or updated.
- Models are a supporting element of the Design Definition set.
- Drawings are generated from models.
- Tool paths are normally generated from models; however, official validation is done using Product Defining drawings.
- Inspection is based on Product Defining drawings.
- Models and other entities are configuration managed as a set and retrievable for any given date or event.
- Traceability of drawings is maintained within current engineering information tools and electronically available within the NWC.

Model-based State 3:

In this environment, models and other product defining documents are defined and managed as a configuration managed set. Models are used to evaluate design options, analysis models are derived from models, analysis results are traceable to models, drawings are generated from models, and NC machining is conducted from the model. The model is the product defining element. While drawings exist, they are established late in the design process and are recognized as a support element of the Design Definition. These drawings do not necessarily conform to strict ANSI Y14.5 drawing standards in form but are accurate and consistent with the models. NC tool paths are validated from the model. Inspection processes are derived from the model.

Key Characteristics of model-based State 3:

- Models are the official Design Definition.
- Drawings are generated from models and are added to the Design Definition set late in the product realization process.
- Tool paths are generated from models and validation is done using the model
- Inspection processes are driven by drawings.
- Sets of information are configuration managed with established corporate tools.
- Traceability of models, drawings and other artifacts is maintained within engineering information tools. Electronic access within the NWC granted to team members.

Model-based State 4:

In this environment, models and other product defining documents are defined and managed as a configuration managed set. Models are used to evaluate design options, analysis models are derived from models, analysis results are traceable to models, drawings if needed are generated from models, and NC machining is conducted from the model. The model is the product defining element. While drawings can exist, they are established late in the design process and are recognized as a support element of the Design Definition. These drawings do not conform to ANSI Y14.5 drawing standards but are accurate and consistent with the models. NC tool paths are validated from the model. Inspection processes are derived from the model.

Key Characteristics of model-based State 4:

- Models are the official Design Definition.
- Drawings are generated from models and are added to the Design Definition set late in the product realization process.
- Tool paths are generated from models and validation is done using the model.
- Inspection processes are often established from the model.

Conclusion

The RRW model-based approach addresses concurrent engineering needs recognizing the need for solutions to fit the logically different aspects of the product realization process such as design and manufacturing. Our working strategy, model-based State 3, effectively leverages the three dimensional solid model for design, analysis and manufacturing while maintaining the drawings as the Design Definition. Drawings are created when needed and as late as possible. While this approach was used for RRW, it can be used for any future engineering activity.

Within Sandia and the NWC, we use models as described in State 1. While the future states promise to further reduce design and drafting cost and time, complications of moving away from drawing-based manufacturing and acceptance represent too great of an obstacle to overcome in the short term. Business benefit can be realized from achieving State 2. This state requires the use of a Design Definition set containing product defining drawings and supporting models. Implementation of this "next step" will provide great value to our customers and advance us in information driven engineering.

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