



Title:

**Evolution of the Model based Enterprise**

Authors:

Alex M. Miller, mille649@purdue.edu, Purdue University  
 Meagan N. Hughes, hughes72@purdue.edu, Purdue University  
 Nathan W. Hartman, nhartman@purdue.edu, Purdue University

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Introduction:

MBD is an emerging methodology for engineering enterprises. It utilizes a CAD model to drive engineering definition in place of the traditional engineering drawing [1],[6]. The transition to MBD from drawing based practices is quite challenging but offers significant cost savings. ITI stated in 2013 that “a savings of more than \$3M annually at a single naval facility will be generated by implementing MBD” along with “a 33 percent reduction in the development schedule of new items is expected” and “MBD shall also create a significant reduction in manufacturing errors, which should result in a decrease in the amount of rework, providing significant cost savings” [5]. The benefits of MBD are forcing industry to evolve and adopt MBD [2]. Because of this a new engineering enterprise is emerging. An enterprise which has adopted MBD is known as a Model Based Enterprise. MBE provides new opportunities, and challenges. For this reason, research is needed to help shape MBE, and better understand what a MBE should be.

Although MBD is a well understood practice, MBE does not share the same characteristic because MBE has been evolving. MBE has emerged as a broader business process methodology. MBE does not necessarily only refer to 3D-CAD models as it did when MBD was first defined, but now it refers to an organization which more widely adopts the use of models to carry information, regardless of model type [3]. Because of this there is significant debate between what paradigm should be adopted by a MBE. There is a need for research which analyzes and discusses the different potential MBE designs.

As stated previously, MBD no longer simply refers to 3D-CAD models, but encompasses the model-based approaches of disparate engineering activities. MBE advancement has different requirements than the original motivation behind MBD adoption. This leaves room for debate about how to create an advanced MBE. MBD experts will often discuss two main paradigms for a MBE. These paradigms are the master model and multiple model [4]. These paradigms alter the information structure within the organization, and they have different benefits and restrictions. Therefore, an understanding of the ramifications of each approach needs to be understood. This paper serves to clarify approaches to advanced MBE by illuminating the lack of clarity in current definitions, and methods.

Main Idea:

The complication of advancing MBE has led to different MBD paradigms. However, these paradigms are colloquial and subject to much interpretation. This is due to a lack formal research into MBE and insufficient definition of the paradigms. The paradigms which are most commonly discussed are master model and multiple model. Now although it is clear that these are intended to be different paradigms, when subject to interpretation they are inconsistent. A master model definition could be one model driving all other models in an enterprise, it is the master; or a master model is a single

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model which holds all information about an artifact. This is the type of misunderstanding that is common in colloquial MBE discussions. Furthermore, the paradigms definitions are commonly verbal, which leaves much room for interpretation. It is ironic that the MBE paradigms are verbal, when their roots were formed by the fact that models are a more sophisticated definition than drawings. The inconsistencies from interpretation lead to quite varied understandings of MBE paradigms and do little to provide an organization direction in improving as a MBE.

This paper seeks to provide formality to the paradigms which are commonly discussed, by illuminating the lack of clarity in their verbal definitions. The authors sought to understand the variety of MBE in literature and formalize their definitions through models. The paradigms can be better understood through their relationships within an organization. The reason that the relationships between the models, or model will be used is because it is what differentiates the paradigms. Instead of using verbal methods for definition, the paper seeks to employ entity relationship diagrams. Entity relationship diagrams allow the researchers and users to understand what is necessary to implement such a paradigm. Verbal definitions may be sufficient if properly constrained to define a paradigm, but it typically is not sufficient to understand the subtleties of implementation. The network models provide sufficient complexity to document the paradigms clearly, while also providing insight into the advantages of each. Furthermore, it provides consistency to the MBE field, using its own roots in defining the terminology.

### *Model*

An Entity Relationship (ER) diagram was used to model the MBD paradigms. The purpose of an ER diagram is to gain an understanding of the larger system by looking directly at the relationships between the entities within the model. This model was chosen for this research, because it focuses on capturing the relationships between models, which is what the researchers identified as the distinguishing factor in the different paradigms. This research uses both binary and unary relationships to model the MBE paradigms, and provide structure to their organization.

### *Proposition*

Organizations are stepping away from 2D drawing and implementing MBD, and the need to understand MBE is of great importance. More research needs to be completed to help shape MBE further, and better understand what an MBE should be.

The inconsistencies within the paradigms stems from their weak definitions. A master model paradigm can contain one model which contains all relevant information for the production of a product. The use of singular information source is the main attribute of a master model format, but there is not sufficient distinction in whether this master model drives other models, or is the singular model. Theoretically, it can be both. This contradiction is the essence of much debate within MBE paradigms. Often times, the master model paradigm is considered a singular model paradigm, when in actuality, it could also mean a multiple model format with a CAD model driving all subsequent activities. Considering this contradiction, the researchers recommend modification of terminology so that a master model format described by Figure 1 is called a Singular Model format. These models sufficiently document the contradictions that exist in the MBD, or MBE paradigms.

After discussing the first set of models with MBD practitioners, the complexity of the modeling relationships became clearer. The newer models represent the challenge of MBE paradigms, because there are often multiple models which describe a portion of a product. The relationships between these models increase cost and complexity of a product, and the less sophisticated the relationships within your network, the more expensive a structure becomes.

Figure 1 would be a representation of many MBD practitioners understanding of a Master Model format. It represents the idea that a single contains all necessary information to communicate a product. Looking at this structure one can see that a model would need to be capable of being interpreted by the various software which complete engineering activities within the organization. Furthermore, the model would need to be capable of carrying each software's information. This is a technologically infeasible structure, because the current models and software are not interoperable. For now, the singular model paradigm should be considered a future possibility.

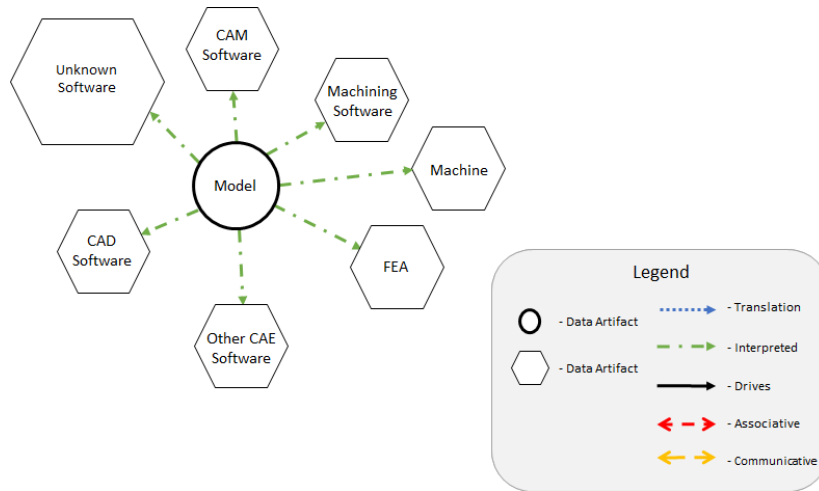


Fig. 1: Master Model, or Singular Model.

The master multiple model paradigm often understood, but not discussed. This format uses a Master model to ensure accuracy of all models, because all models are registered against the master. As stated previously, this is a master model paradigm, but also is multiple model paradigm, because the models each carry certain information which only they are capable of carrying. The entire dataset needed to describe the MBE paradigm is the entirety of Figure 2. This structure is not novel, or an advancement in MBE paradigms.

The master multiple model format is in all likelihood the equivalent to a drawing-based enterprise, but utilizes the model in place of the drawing. The model is created and then all subsequent information is registered against the released model, and as changes are made to the model, each slave is reregistered against the new model. This requires constant revision and maintenance to ensure that each model is reflecting the current master model. This format has been an effective method, but it takes little advantage of the capabilities of MBD.

The MBE paradigms defined discuss the future of what an MBE could be, but this does not aid an enterprise in navigating through the change. It is the responsibility of researchers to identify, and build the structures which organizations should utilize for MBE implementations now. Verbal definitions are insufficient in describing the paradigms, and often will allow critics to find shortcomings in the definition. Furthermore, too much information is left to interpretation. Clear and concise definition of MBE paradigms in the future is necessary.

Organizations are becoming model based enterprises using a master multiple model paradigm, which is a similar structure to a drawing-based enterprise. Exaptation can now occur; which will allow the MBE organization to evolve in ways that we could not have conceived prior. The initial savings brought on by utilizing MBD were significant, but taking advantage of the MBE process may provide even more. The following section will provide insight into the future, and possibility of research into MBE.

### Discussion

MBE research will become more important as organizations become more invested in its practice. As such, those behind the theory need to provide consistency and clarity in best practices for MBE use. An area of particular importance is MBE paradigms for an organization. Industry will soon begin to look for more sophisticated understandings of MBE, as they successfully adopt MBD. This is fast approaching, and the research into MBE paradigms and practice is insufficient. In this paper, the researchers sought to demonstrate the contradictions of the current MBE paradigms, multiple model and master model.

An important finding of this research was that all of the master MBE paradigms have a tendency to place authority on CAD and design, when many constraints stem from other aspects of an organization.

This may mean that a multiple model format would be a more effective implementation, but this is conjecture. Organizations emphasis on concurrent engineering and PLM methodologies demonstrates the need to alter how business is done. However, the authority placed by a master model paradigm on the master's owner will impede concurrent engineering and PLM. Therefore, the contradiction created by utilizing a master model paradigm, and PLM will need to be addressed. There is likely no single answer to this dilemma, but researchers need to provide answers to enterprises in order to move into the Digital Age competitively.

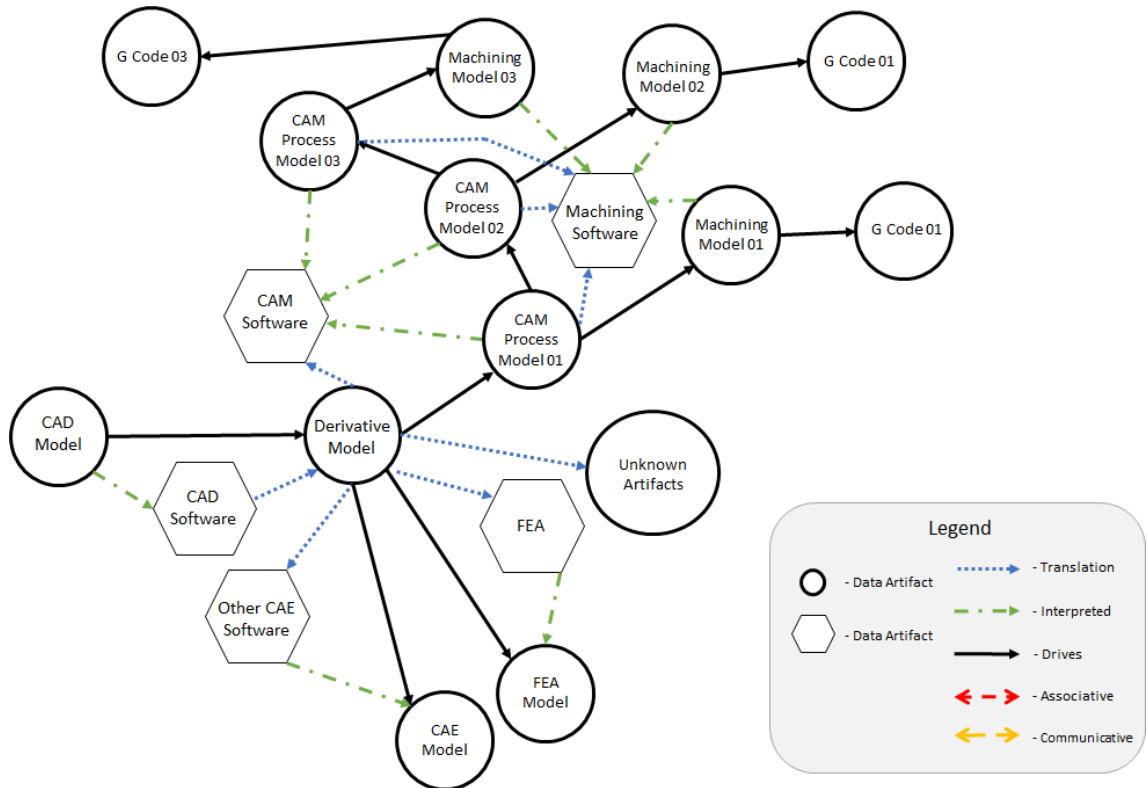


Fig. 2: Multiple Model Format, or Master Model.

Moving forward, the researchers believe that two research thrusts should be conducted to properly address two areas of research. First, that if one were to compare MBE paradigms of organizations, they would discover that all organizations have the multiple master model paradigm. Research should be done to corroborate this hypothesis, but considering the similarities between the master-multiple model paradigm and a drawing-based organization it is likely. Second, research should be conducted which models real MBD implementations, to determine the underlying MBE structure. The primary value of such research, would to put into literature a clear definition of the models that could be used in defining an engineering product. This information could then be used in structuring alternative MBE paradigms.

**Conclusions:**

The MBE paradigms defined discuss the future of what an MBE could be, but this does not aid an enterprise in navigating through the change. It is the responsibility of researchers to identify, and build the structures which organizations should utilize for MBE implementations now. Verbal definitions are insufficient in describing the paradigms. Furthermore, too much information is left to interpretation. Clear and concise definition of MBE paradigms in the future is necessary.

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