Model-Based Enterprise: An Innovative Technology-Enabled Contract Management Approach

BY MITZI S. WHITTENBURG

Introduction

Over the past few decades, product development has been moving toward a process called "Model-Based Enterprise" (MBE). This process relies on the 3D Solid Computer Aided Design (CAD) Model as its master rather than a traditional 2D drawing. By doing so, the master can be reused instead of being recreated many times throughout the life cycle of the product. In this way, many companies have used MBE to dramatically cut their time to market and overall cost. Unfortunately, the Department of Defense (DOD) has been very slow to address this fundamental shift in product development and remains, by and large, a drawings-based culture. However, with the current active conflicts requiring more and more sustainment along with new technology, DOD is acknowledging the need to acquire the technical data packages (TDPs) that define a product, along with the physical product itself. Yet, because of DOD's contractual reliance on drawings throughout its business model, this cannot be done quickly or efficiently, which, in turn, results in increased cost along with prolonged acquisition times. (See **FIGURE 1** on page 106.)

Because of this, the time has come for a new, innovative, technology-enabled contract management approach to be put into place for the U.S. government acquisition process. Employing technology to tie the disparate pieces of the acquisition environment together brings a more seamless approach to managing direct manufacturing contracts. Some of the components of this new technology-enhanced process discussed herein are 3D annotated models that have been validated for accuracy, the utilization of an e-sourcing tool to electronically distribute the models to the defense manufacturing supply chain, and adding a layer of electronic monitoring to machine tools in order to make sure the end product meets the original design. The result will make it easier for DOD and its suppliers to leverage the high-impact benefits of the MBE.

TDP

A *TDP* is defined as a technical description of an item adequate for supporting an acquisition strategy, production, engineering, and logistics support (e.g., engineering data for

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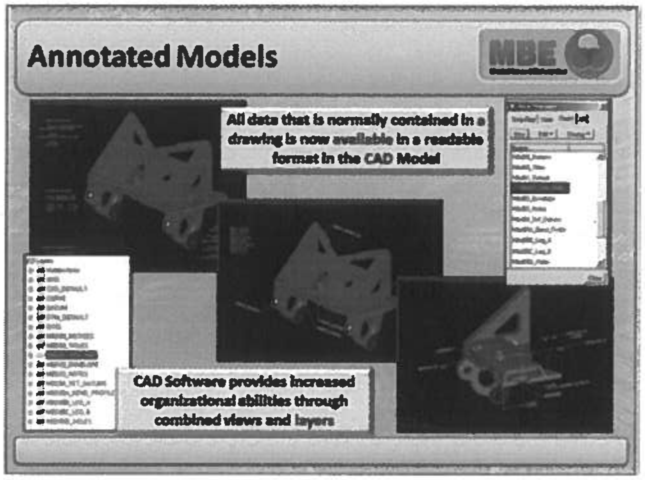


FIGURE 1.

provisioning, training, and technical manuals). The description defines the required design configuration or performance requirements and the procedures required to ensure adequacy of item performance. It consists of applicable technical data such as models, drawings, associated lists, specifications, standards, patterns, performance requirements, quality assurance provisions, software documentation, and packaging details. (See **FIGURE 2** on page 107.)

In the past, this TDP was based on 2D drawings; however, DOD is now pursuing data in the form of 3D annotated models along with associated detailed TDPs. The colloquial name for this new form of TDP is the "3D TDP." Its main purpose is to provide all downstream users a 3D data set they can reuse without remastering the data. The 3D TDP would be delivered in a PDF format ensuring a CAD agnostic solution. For suppliers, this means they will have the ability to drive their computer-aided manufacturing (CAM) software straight from the model along with numerous other processes. It also allows for increased collaboration between engineering, procurement, and suppliers and less ambiguity for suppliers when producing the product. (See **FIGURE 3** on page 107.)

In order to utilize the 3D TDP, some assurances must be made that the data quality is high enough to be usable by the procuring activity. Unfortunately, DOD currently has no standardized process defining model quality. Without this process, there is no way to contractually ensure that the 3D model data being received will work in downstream processes. Substantial time is lost throughout the product life cycle due to the need to rework low-quality models. One group stated that a single error caused by low quality models could take 30 to 90 days to correct; in the meantime work has stopped until the solution is presented. In response to this gap, a team associated with the Manufacturing Technology Program (ManTech) is working on 3D validation, defining a validated and verified 3D model and its derivatives. This team consists of representatives from multiple government agencies and industry and is being co-led by the National Institute of Standards and Technology (NIST). Wherever possible, the team has recommended leveraging the use of current industry best practices and the evaluation of existing off-the-shelf tools to solve the problem. The result of this activity will be a detailed guidebook providing both the validation process and possible contractual language to be used for enforcement.

MBE

In its most technical form, MBE is a fully integrated and collaborative environment founded on 3D product definition detail and shared across the enterprise with the intent to enable rapid, seamless, and affordable deployment of products from concept to disposal. The key component is the product definition. When working within an MBE, this core definition is referred to as the "model-based definition" (MBD). A formal definition of MBD is a 3D annotated model and its associated data elements that fully define the product definition in a manner that can be used effectively by all downstream customers in place of a traditional drawing.

The recurring theme in both of these definitions is the model, or more precisely the annotated model. In this case, we are referring to a 3D CAD model that uses both geometry and integrated text-like call outs to fully define the product. This has many advantages over the traditional drawing approach, including:

- The ability to extract information electronically for use by downstream users (e.g., manufacturing, procurement, logistics, etc.) verses remastering the data manually;
- Reduction of time and errors due to manual entry;
- More intuitive and easier-to-identify issues since it is 3D, thus not requiring the mind to convert a 2D image into something it can better understand; and
- Better configuration management and association with other data electronically when used with a product life cycle management (PLM) tool. (See **FIGURE 4** on page 108.)

ManTech Role

After weighing the benefits MBE has started to bring to the industrial base, DOD has been making a concentrated effort over the past seven years to update not only its infrastructure, but its processes. As a result, MBE has been a focus of many ManTech projects aimed at changing the culture from a drawing-based one to a true 3D-immersed environment. The DOD ManTech program has been DOD's investment mechanism for staying at the forefront of defense-essential manufacturing capability. The ManTech program develops technologies and processes for the affordable, timely production and sustainment of defense systems. The program impacts all phases of acquisition and aids in achieving reduced acquisition and total ownership costs by developing, maturing, and transitioning key manufacturing technologies. Ultimately, ManTech's overarching vision is to realize a responsive, world-class manufacturing capability to affordably meet the warfighter's needs throughout the defense system life cycle.

As a result of ManTech's role, many key MBE-related technologies have been advanced in the areas of CAD, computer-aided engineering, CAM, and PLM. However, technology is not the only piece that needs to be addressed for a successful MBE implementation. Standards and policies must also be updated or created to enable MBE. To this end, MIL-STD-31000, the standard defining DOD TDPs, is being updated to be compatible with a 3D MBD. MIL-STD-31000 places the TDP at the heart of the acquisition process.

MIL-STD-31000

As stated above, MIL-STD-31000 is being revised in an effort to assist in technology-enabled contract management. This standard prescribes the requirements for preparing a technical data package composed of one or more TDP elements and related TDP data management products. To ensure maximum participation and concurrence among stakeholders, over 60 subject matter experts from DOD, other government agencies, and industry participated in several workshops hosted at the NIST. The product of these workshops is the latest revision to MIL-STD-31000. Once the revision is finalized and published, this standard will address both traditional and model-based TDPs, thus enabling MBE to become a mainstream practice within DOD.

With the release of the revised MIL-STD-31000 providing the requirements language to be used by contracting officers for the acquisition of the 3D TDP, the next issue blocking MBE's adoption is proving that the data they receive from the contractor is usable. There are two approaches to address this, 1) defining a schema organizing this data and 2) defining requirements that check its quality. Again, the team of subject

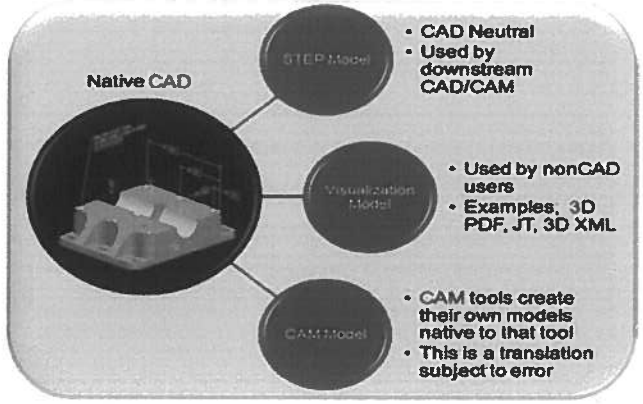


FIGURE 2.

matter experts has provided tools that can be called out contractually by adding appendixes or supplemental documents to the standard. The first is the model organization schema for annotated models, and the second is the model validation guidebook. Both will be released as companions to MIL-STD-31000 in the near future.

PLM and Other Repositories

Once a model is validated, the question becomes where is it stored? This leads to one of the key enablers of MBE, PLM. (See **FIGURE 5** on page 108.) This is both a process and a tool that enables the TDP to be electronically stored and configuration managed while allowing access to all of the users throughout the product's life cycle. Without this ability, the data quickly gets lost on a private drive or worse, potentially causing conflicting revisions of the same data to be sent to the supply chain. If implemented correctly, this technology allows for the master TDP to be stored and then distributed in a secure and controlled manner, once again reducing the risk of errors while allowing for direct access to the product definition.

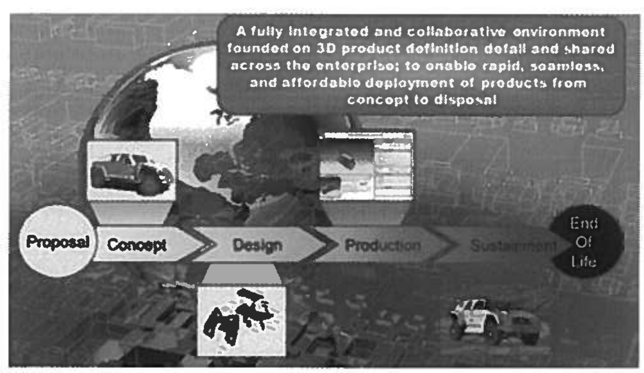


FIGURE 3.

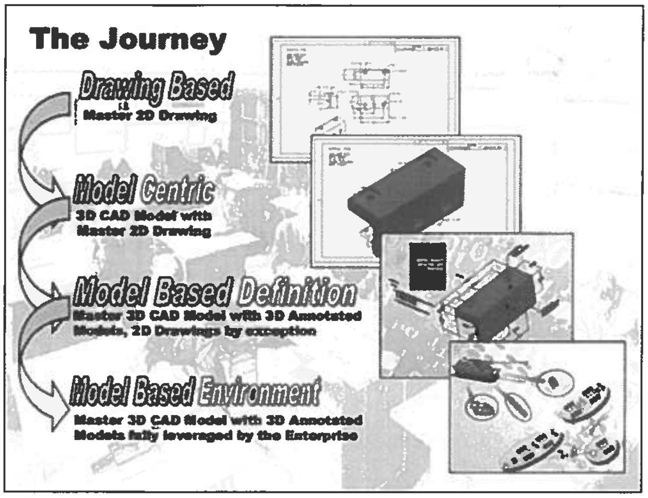


FIGURE 4.

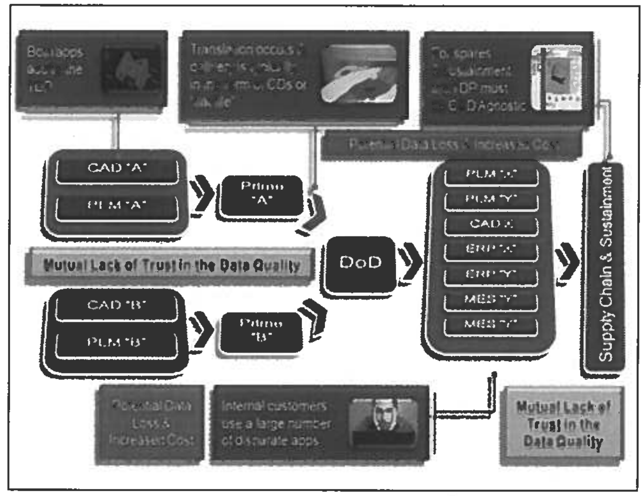


FIGURE 5.

PLM can also facilitate the efficient electronic delivery of the TDP from a contractor. By using an industry standard such as a product life cycle support (PLCS) for defining TDP delivery, the data can be seamlessly transferred from any PLM system to the government's PLM system. A PLCS is another neutral standard format that can be used to create a data exchange application. Current processes employ the use of these industry standard practices that result in a solution that is tool-independent. So, once again the government is leveraging existing best practices verses spending the time and money needed to create and sustain its own proprietary solution.

It should also be noted that PLM is not the only data repository used in MBE. It is only the one that manages the product definition. Others, such as the enterprise resource planning (ERP), material resource planning (MRP), and manufacturing execution systems (MES), all have a role in managing the process definition and financials. The optimum MBE approach would be to link these repositories together so that the relevant data is seamlessly passed from one area to the other without manual remastering anywhere along the way.

e-Sourcing Hub

As we continue to explore the concept of MBE, the 3D model moves into the procurement process. Whereas the decentralized nature of product design can be addressed through a PLM platform, the process breaks down in the sourcing phase. Buyers seldom have access to utilize PLM systems to view the designs in their native file formats. In addition, to provide technical design documents to the external supply base, buyers are typically forced to utilize inefficient e-mail or FTP delivery methods subject to network bandwidth and file size limitations. Large drawing files sent via e-mail or FTP may take several hours to download, downloaded files must be painstakingly organized into folders to relate the drawings back to specific parts, and uncompressed files must be printed out, often requiring several hours' effort. These methods for sharing documents also introduce the potential for intellectual property loss. One solution to this is the use of e-sourcing. (See **FIGURE 6** on page 109.)

E-sourcing is a suite of collaborative, Web-based tools that enable acquisition organizations and suppliers to conduct sourcing activities over the Internet. E-sourcing tools leverage the cloud model to extend enterprise systems such as PLM and ERP throughout the supply chain. The ERP system still maintains inventory and accounting transactions, while the e-sourcing tool enables a more collaborative and analytical sourcing process.

While product design still occurs in the PLM, the e-sourcing platform enables collaborators outside of the engineering function, external suppliers, and customers to review, annotate, and interact with the critical 3D data and associated specifications and requirements. For example, without access to the notes in the requirements on tolerances or the ability to "flatten" a drawing to calculate the volume of a key raw material such as the metal required to make a part, a supplier cannot accurately calculate a key cost driver such as the scrap rate—excess raw materials that will be eliminated in manufacturing the part, but which nevertheless represent a real cost that must be taken into account. Furthermore, the more sophisticated e-sourcing platforms use collaboration viewers and native file translators to enable neutral file viewing of the advanced 3D formats. All of these activities can then be accomplished without the need to acquire costly engineering viewing software or facilitate the risk of valuable intellectual property loss.

As noted, the sharing of TDPs is a crucial element of any successful collaborative e-sourcing system. At this point, the TDP can include a large amount and variety of data. Some examples are 2D drawings and 3D models for legacy programs, annotated models for new programs, technical specifications such as weights and finishes, product life cycle and usage data, as well as volume requirements, contract terms, and conditions. In addition to the TDP data, there are many additional data elements added to address the procurement requirements. Again, some examples are pricing, terms and conditions, lead time, and quantity. Each of these individual elements can come from different repositories and potentially different authors. In order to present the enterprise user with a single view of this data, the e-sourcing tool must act as an information hub that collects, organizes, and then securely distributes data to the proper recipient. A database of internal and external supplier capabilities can also be created inside of many e-sourcing tools. Because of this data fusion capability, the e-sourcing hub will enable better decision-making and establish a detailed knowledge database of capabilities and cost data.

The e-sourcing hub provides value because it is a template-driven, repeatable process to create a consistent and predictable program and project management framework to track milestones, workflows, program resources and commitments, and critical issue resolution. Enterprise-wide dashboard visibility ensures process compliance and communication of project status to customers. All project records are archived in a document repository creating a searchable knowledge management resource to enable a sustainable, superior sourcing experience.

Customizable templates provide a true picture of all price and non-price factors that aggregate to form the total costs of ownership—breaking down discrete cost elements such as raw materials, tooling, conversion costs (labor and overhead), or freight, summarized at the part or sub-assembly levels for side-by-side comparisons to other suppliers or should-cost standards. This structured process enables familiar, spreadsheet-like functionality for creating formulas or adding multiple rows of data without the inefficiencies and inaccuracies of spreadsheet-based methods. This means

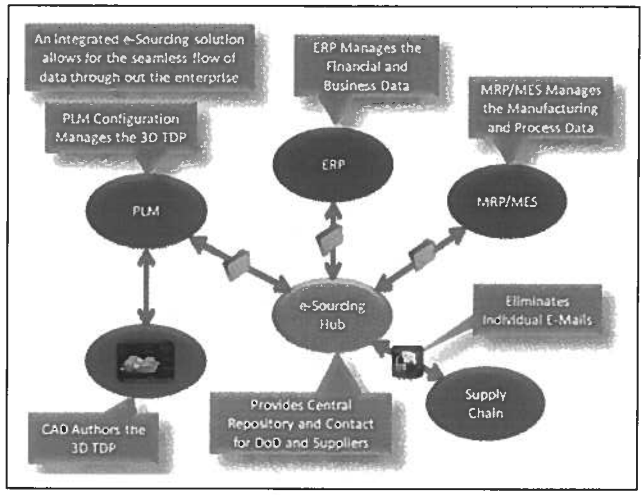


FIGURE 6.

that sourcing teams spend their time analyzing the best total cost values for validated total cost model calculations—not gathering data, fixing inaccuracies, and struggling to build a meaningful analysis and organization consensus.

This hub capability works for both the procurement agency and the supply chain, which means that the supply chain can also be given access to certain parts of the database in order to seamlessly collaborate throughout the procurement process. Suppliers are then able to freely view the TDP via the Internet, receive and reply to requests for information and quotations, resolve issues electronically, receive awards, and post status all within a secure cloud-based system. Suppliers are also able to ask questions in real time or suggest alternative materials or manufacturing processes to lower total cost, proposing, for instance, molded, plastic parts instead of a more expensive process to bend metal. Buyers have the discretion to disseminate questions and answers to all suppliers or select suppliers, and a discussion thread is maintained in the project record as an archive of the interaction.

An e-sourcing hub is a disciplined project management methodology that enables real-time rather than ad-hoc collaboration by leveraging a standardized process to establish permissions and roles, allocate collaboration tasks, establish project timelines and commitments, and track and monitor the project outcomes. It is more than just a secure means of document exchange, it enables collaborators to annotate, mark-up, and iterate on specifications and terms without any specialized software other than a Web browser and with a centrally archived audit trail of all interactions. The result of

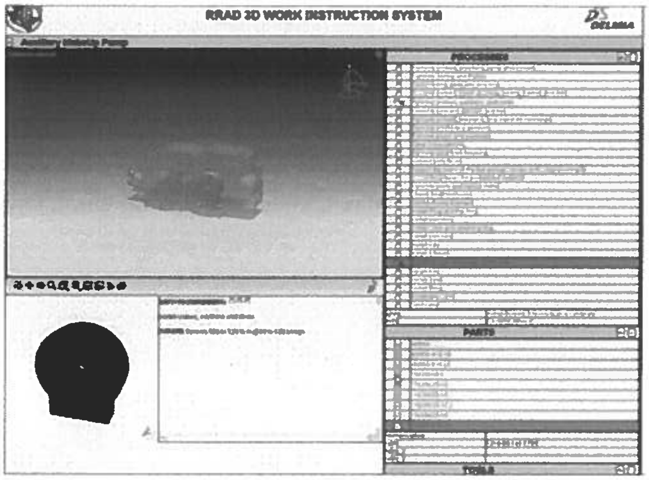


FIGURE 7.

this strategic use of technology is a fully enabled MBE that benefits everyone in the procurement process.

Technical Publications and Sustainment

While many would argue that both technical publications and sustainment are at the end of the product life cycle, they are some of the most important activities associated with it. Sustainment—meaning to keep in existence or maintain—is the single highest cost contributor in the extended life of a product because of the need for service parts after the initial production phase. Both of these areas are also perfect candidates for MBE and the potential benefits related to labor and cost savings are substantial. (See **FIGURE 7** above.)

Technical publications such as technical, maintenance, and training manuals use the product definition as their foundation. Traditionally, the TDP is remastered for use in illustrations and leveraged in the body of the document. Unfortunately, technical publications are the last recipients of changes to the TDP, potentially resulting in the documents being perpetually out of date as changes happen simultaneously and published updates lag. This fact is made even worse when observing the depot-level maintenance instructions created by the sustainment activity because they traditionally receive very little TDP data and must rely on receiving the first physical unit, breaking it down, and reassembling it, all while documenting the site-specific sustainment processes.

By providing a 3D TDP as early as possible to the technical publications and sustainment community, they can begin to reuse the models, thus helping to eliminate the cost and time of remastering. The models can be used for illustrations, imported into analysis software to simulate and optimize maintenance procedures, in addition to the creation of animations and interactive graphic-based technical manuals. Metadata and/or product manufacturing information can be programmatically extracted for use in the body of the text and used in ERP systems. Changes can be pushed electronically, allowing many of the illustrations and simulations to be updated automatically. The implementation of just a few of these areas can result in not only substantial cost savings, but perhaps more importantly to DOD, faster time to mission for the warfighter.

Another opportunity in this area is to use integration of several key tool suites such as manufacturing process planning and document management systems with both PLM and the e-sourcing hub. By connecting to the PLM tool, the end user has seamless access to the most current product definition and all of its change history. They can also see the design as it evolves, and thus move some of their work earlier in the life cycle. By accessing the e-sourcing hub, they not only get access to the ERP/MRP area but can start to create intelligent documents that allow the user to enter a purchase request while inside of the technical publication.

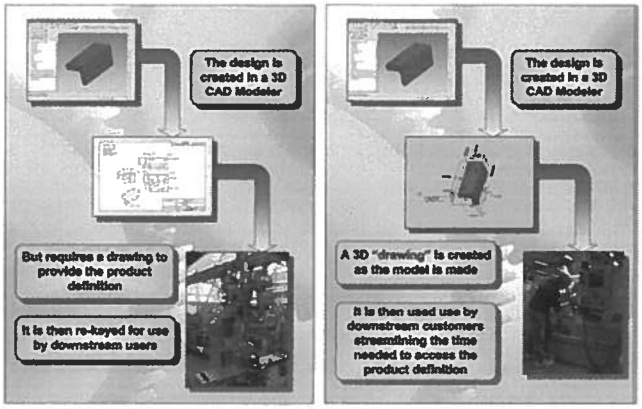
The Supply Chain

One of the most important aspects of acquiring any product is the extended supply chain. Any successful implementation of MBE must take this fact into consideration. To this end, we have talked about many tools that can aid the supply chain, but in order to utilize those tools, suppliers must not only be told about them, but trained on how to use them. An even better strategy is to partner with the supply chain as MBE is developed and deployed in order to learn from industry and provide training as needed. It also allows suppliers to have a stake in enjoying MBE success and ultimately drives their future success and productivity enhancements.

In the next few sections, we will review several projects that were aimed at enabling the partnership with the supply chain and aid in the cultural adoption of MBE. (See **FIGURE 8** on page 111.)

MBE Capabilities Assessment

One of the first things that need to be done when reaching out to the supply chain is to benchmark where they are in regards to MBE. Furthermore, the internal enterprise practices should be benchmarked as well. The problem was



Before After

FIGURE 8.

that there were no tools available to use as a foundation for this benchmark, so the subject matter expert team once again came into play to develop one: the "MBE Capability Index." This index is based on a scale from 0 to 6 and has requirements associated with not only each level, but each major organizational domain as well. It can be of use for the quick measurement and visualization of where an organization is on the MBE journey. The index can also be used to develop a roadmap and business case for where an organization wants to go. The MBE Capability Index is available at **http://model-based-enterprise.org** for those who are interested in knowing more.

The MBE website also illustrates how ManTech used a simplified version of this index (ranging from 1 to 5) as a base for a DOD supply chain assessment. Engaging the resources of the NIST Manufacturing Extension Program (MEP), an assessment was conducted that included onsite, telephone, and Web assessment tools. In total, 445 responses were received with the following results broken out by MBE capability level:

- Level 1: 142 companies,
- Level 2: 143 companies,
- Level 3: 156 companies,
- Level 4: 4 companies, and
- Level 5: 0 companies.

Each company that participated in the assessment was assigned an MBE rating by NIST MEP. It is important that these MBE capability levels not be thought of as an "MBE grade"—a Level 5 is not an "A" and, more importantly, a Level 1 is not an "F." There is an appropriate MBE level for every company based on their products, processes, and customer base—not every company needs to be, or should want to be, at an MBE Level 4 or Level 5. Companies should use available MBE information and resources to determine what MBE capabilities level makes sense for their business. That being said, given that a company must be at an MBE Level 2 in order to receive, consume, and send 3D data, the lowest level at which a company could be considered ready to operate in an MBE environment, in the most basic sense, is a Level 2.

Companies that rated a Level 1 showed no sign of using 3D models, very little computer-driven operations, and little or no electronic, cross-department integration and reuse of data. Of the 142 companies that were rated a Level 1, 66 were due to incomplete assessment information. On the contrary, Level 4 companies showed no indication of using 2D, drawing-based information—everything was based upon 3D data. Additionally, Level 4 companies showed significant cross-department, electronic reuse and integration of data with the assistance of software resource planning and data management systems. Companies at Levels 2 and 3 fell in between these two extremes. Level 5 is considered full MBE implementation, utilization, and cross-department reuse and integration—no company was rated at this level during the 2009 MBE capabilities assessment.

In order to ensure the validity of the results, the application of the MBE rating was performed by a subject matter expert from the NIST MEP project team and was done so blindly, looking at only the information relevant to the metric, not distinguishing company information. The rating process was repeated multiple times to ensure repeatability and accuracy. The full report is also available at **http://model-based-enterprise.org**.

Supplier Summits

ManTech also recognized the need to include the supply chain very early so they once again partnered with NIST's MEP to hold a series of summits intended to raise suppliers' MBE literacy across the country. The day-long summit was designed to increase the awareness and understanding of MBE technology and operations among domestic defense suppliers, as it communicated information about supply strategies and future directions relating to implementing MBE. Perhaps most importantly, the summits allowed DOD to get feedback from the suppliers on their perspective of MBE.

The agenda included presentation topics such as:

- "MBE and its Benefits: Perspectives from The Department of Defense;"

FIGURE 9.

- "Ongoing MBE Efforts within DOD and Specifically Army Programs;"
- "MBE Technical Data Package Development;"
- "The Implications and Opportunities of MBE for Small Business;"
- "MBE-Related Resources and Assistance Available to Suppliers, including via MEP;"
- "Certification As an Ultimate Goal;" and
- "Question and Answer Panels with Manufacturers and Government Experts in MBE." (See **FIGURE 9** above.)

Four summits were held around the United States, two of which were co-sponsored by NASA with approximately 125 companies participating, the majority of which were small businesses. Overall, the summits were successful in the fact that they were very interactive with many very good questions discussed with the most common one being: "MBE is a good idea but when are we going to see it?" While there is no definitive answer to that question from an enterprise level, there have been several new programs recently initiated including the requirement of a 3D TDP as a deliverable.

MBE Website

As previously mentioned, the subject matter expert team launched an MBE website (**http://model-based-enterprise.org**) that was intended to act as an information source for defense manufacturing suppliers. It contains assessment results, provides an information database for MBE, and it is a place to communicate with the supply chain. Also, the website includes an MBE discussion group available on Linked-In. It allows interested people to ask questions and get feedback from a large number of industry subject matter experts regarding various commercial practices and available resources. In short, the intent of this website is to act as a knowledge and communication portal for the MBE community.

What's Next?

While MBE has been around for a few years in industry, the government is still in its infancy as far as utilizing the potential since there are many more domains of opportunity that are waiting to be addressed. In fact, much of the work that has been done so far centers on infrastructure and mechanical components. Domains like electrical, systems engineering, composites, logistics, and many others have yet to be fully integrated into the MBE approach. Even infrastructure areas such as the ones supported by a program called "MT Connect," which addresses standard communication of computer controlled machine tools across a network, need to be further developed. Additional work is also underway in the standards community to ensure that the proper foundations exist to implement MBE consistently.

Perhaps the next biggest area of work is in the training and cultural adoption areas. Results will be suboptimal if training and a change in culture do not gain significant traction within the DOD enterprise. Why? Because quite simply it is an evolutionary step akin to moving from the drawing board to CAD or similar to the implementation of Lean manufacturing. Most of the current workforce does not understand the implications of such a change. They either take it for granted, or worse, actively oppose it without trying to learn its benefits. Until industry has a standard public business case along with a recommended implementation strategy, these cultural roadblocks will always remain.

Conclusion

After reviewing both the tools and activities DOD has undertaken in regards to MBE, there are several logical conclusions to be made:

- MBE represents an opportunity in these times of limited budgets and active conflicts to significantly cut both the overall life cycle cost of a weapon system and its time to mission,
- MBE can be used to create a digital thread representing the product that can be efficiently used throughout the life cycle by many different disciplines to reduce manual remastering and thus the errors and time it introduces, and

- MBE is being taken very seriously by DOD and many steps are being taken to enable it to be contractually required.

One final conclusion is that MBE appears to be well on its way to DOD and it would be prudent to be prepared for its arrival. The time has come for a new, innovative, technology-enabled contract management approach to be put into place for the government acquisition process. ***JCM***

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