MBD (Model-Based Definition): 2021 Edition

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What is MBD (model-based definition)?

MBD is the process of using an annotated 3D CAD model that includes semantic PMI (product manufacturing information a.k.a. manufacturing data for building & measuring) to be the definitive authority downstream throughout the product lifecycle.

It is a unifying aspect for design, manufacturing, quality, and other disciplines to move away from traditional 2D drawing-based workflows to a 3D CAD model-based workflow with geometry, manufacturing data, and other data all contained in one digital file- a.k.a. the "single source of truth."

The 3D model with PMI would include any of the following data:

1. GD&T (geometric dimensioning and tolerancing)
2. Bill of materials (BOM)
3. Surface finish
4. Weld symbols
5. Manufacturing or measurement process plan data
6. Metadata & notes
7. History of engineering change orders
8. Legal/proprietary/export control notices
9. And other definitive digital data

The most important takeaway about MBD is that data is interoperable and CAD/CAM/CAE agnostic; therefore, is essential to the digital transformation of manufacturing and factories known as Industry 4.0 or model-based enterprise.

Another key point about MBD is that the 3D CAD model with semantic PMI should be **both human and machine readable:** interpretable by humans and consumable by computers and their software with full

traceability to the authority model.

Why is MBD important?

MBD is important, because it increases the speed, accuracy, and efficiency of manufacturing complex parts while also reducing the cost of through automation and time-savings.

MBD enables engineers to model, measure, test, and refine in a more collaborative setting than in silos, resulting in faster feedback loops, better decisions, and faster-to-market products.

Let's take a deeper dive:

Process & automation

Although we're reaching the end of the first quarter of the 21st century, there is a disconnect between design and manufacturing processes.

Designers develop in 3D CAD using tools like CATIA, Creo, Inventor, NX, SOLDWORKS, and others, however, their product and process information is then projected down into 2D drawings--some on literal paper--which is not machine readable.

Thus it takes the manufacturing or quality control engineer to MANUALLY enter the GD&T and other vital details into their CMM (coordinate-measuring machine), CAM (computer aided manufacturing), or CAI (computer aided inspection) software.

Traditional Approach	MBD Approach
3D model with 2D drawing containing GD&T / PMI.	3D model with embedded GD&T / PMI.
Human-readable.	Human-readable and machine-readable.
Reliance on personnel & interpretation.	Reliance on process & data.
Labor intensive, especially revisions & rework.	Reduction of labor time because of upfront encoded knowledge.
Multiple, propriety data formats.	Universally accessible data.
Not mapped to a "single source of truth."	Data mapped to design model.

And in the new age of the internet and digitalization, this manual action needs upgrading.

Manual transcription & interpretation increases cost, time, and risk to the manufacturing process, especially as the complexity of the 3D model increases and the number of disconnected documents pile up from different revisions, departments, and personnel working together.

Having an engineer do manual transcription leads to the weak link of the whole manufacturing workflow: an ambiguous process that is encoded in "tribal knowledge" that is not repeatable, not rigorous, not automated, and more prone to errors.

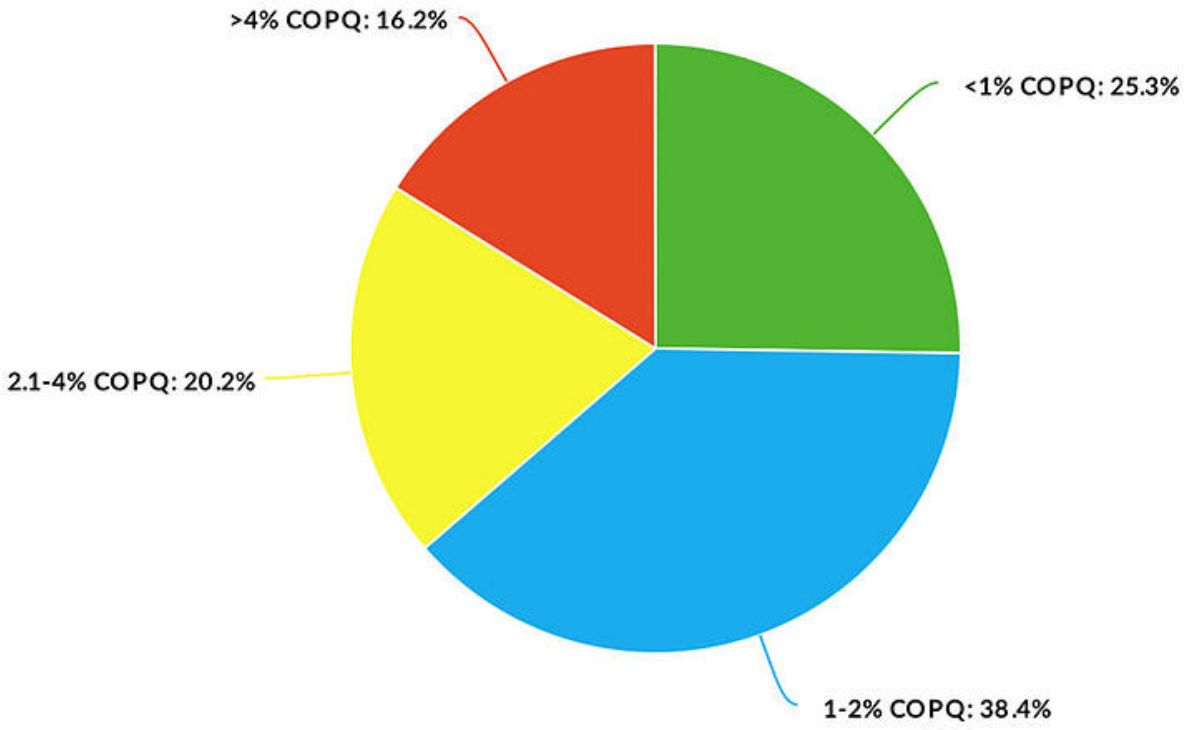
People quit, retire, or move on to the competition taking that knowledge with them, and leaving the next engineer to figure it out. MBD ensures for less errors, more time saved, and most importantly, **company-encoded standard knowledge** to be performed faster with quality repeatability.

Prevention & root cause

The Cost of Poor Quality (COPQ) measures costs associated with process failures like scrap, rework, retesting, recalls and more. It's estimated that 16% of manufacturers have a COPQ of 4% or higher with only 25% of manufacturers with a COPQ of less than 1% (top-performers).

With an industry average hovering around 1.2%, this means over 36% of manufacturers are below average in their COPQ score (2% or higher). To put that into perspective, the average revenue of the top 5 aerospace and defense companies is around $59.2 billion. In this example, a top-performing company will have scrap and rework costs around $59 million while a low-performing company will have scrap and rework costs around $2.95 billion.

That's money (a lot if it) being left on the table.



Manufacturing scrap, rework, and recalls happen because of human errors when either transcribing or interpreting, design changes not mentioned, and/or poor implementation of design & manufacturing. It all spawns defective products & processes.

MBD helps catch errors earlier in the product lifecycle which reduces cost by 7-10X when corrective action is made in the design phase compared to testing phase.

As the timeless saying goes, "An ounce of prevention is worth a pound of cure."

Data & analytics

Industry 4.0, digital twin, digital thread, advanced manufacturing, and model-based enterprise.

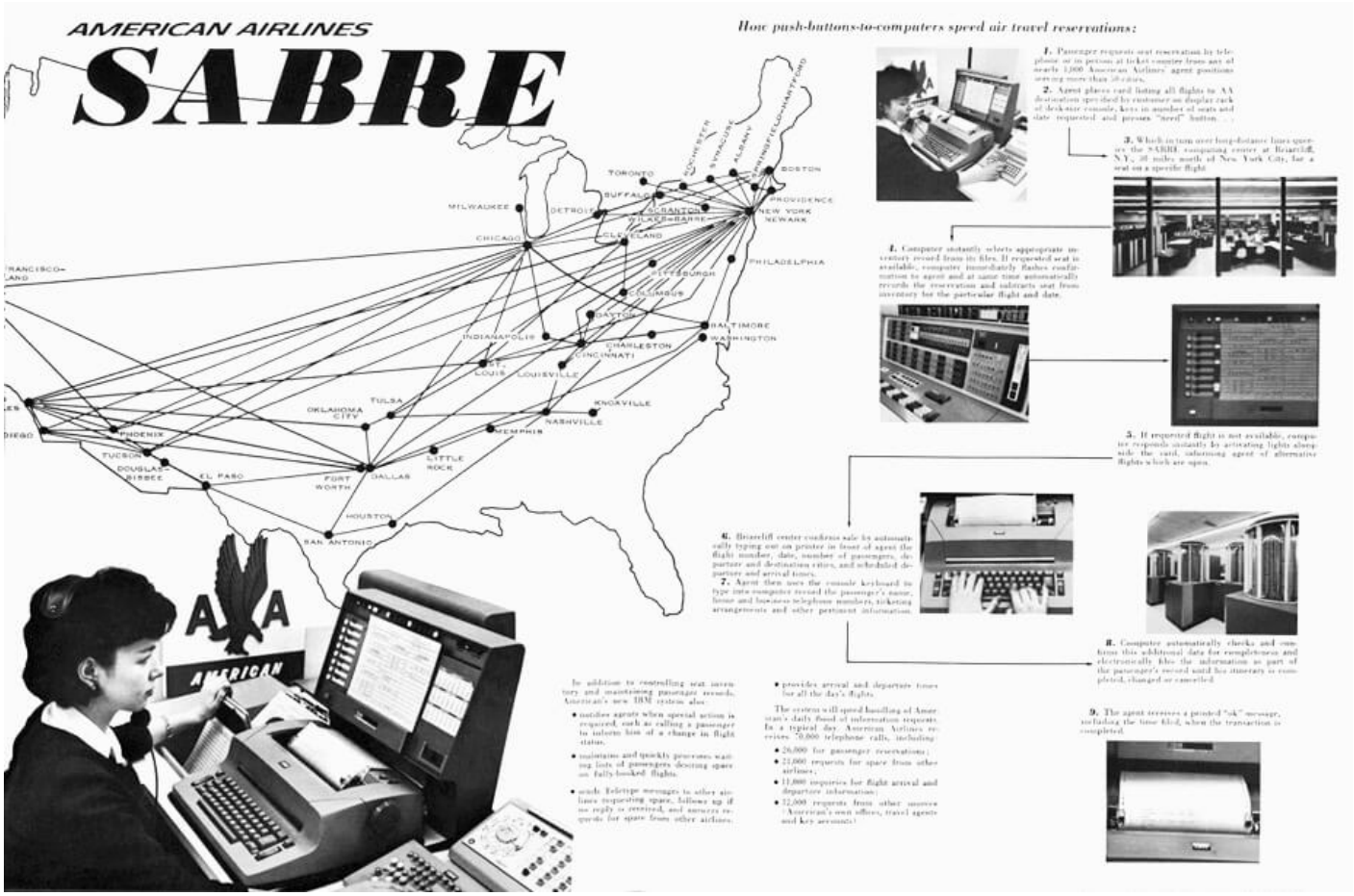
These terms and MBD are about **using good quality data to solve business problems or improve business products**.

Unfortunately for most manufacturers, that data is being unused.

Quality and inspection departments carry out the validation of products coming out the shop floor, measuring parts and coming with pass or fail decisions. However, that data is rarely reintroduced back to ecosystem and often discarded despite being highly valuable.

MBD ensures having data tied to the model for improved designs (a.k.a. digital twin for manufacturing), improved parts, improved operations, and most importantly, improved business decisions.

Although future use cases with data from inspection are still being discovered, a similar comparison can be made with digital transformation in the airline industry when American Airlines was one of the first airlines to transition from manual paper-based reservations to computerized in the 1960s.



Although the goal was to make booking faster--which it did-- one big benefit was having granular data to analyze on flights, cities, seasons, hours, and demand, helping the company adjust ticket prices and making more profit for the company.

Best yet, their reservation system became its own business when it was used as the backbone for other nationwide travel agent reservation systems, allowing American Airlines to recommend their own flights first, gain exclusive insights on competitors, and receive licensing fees from travel agents.

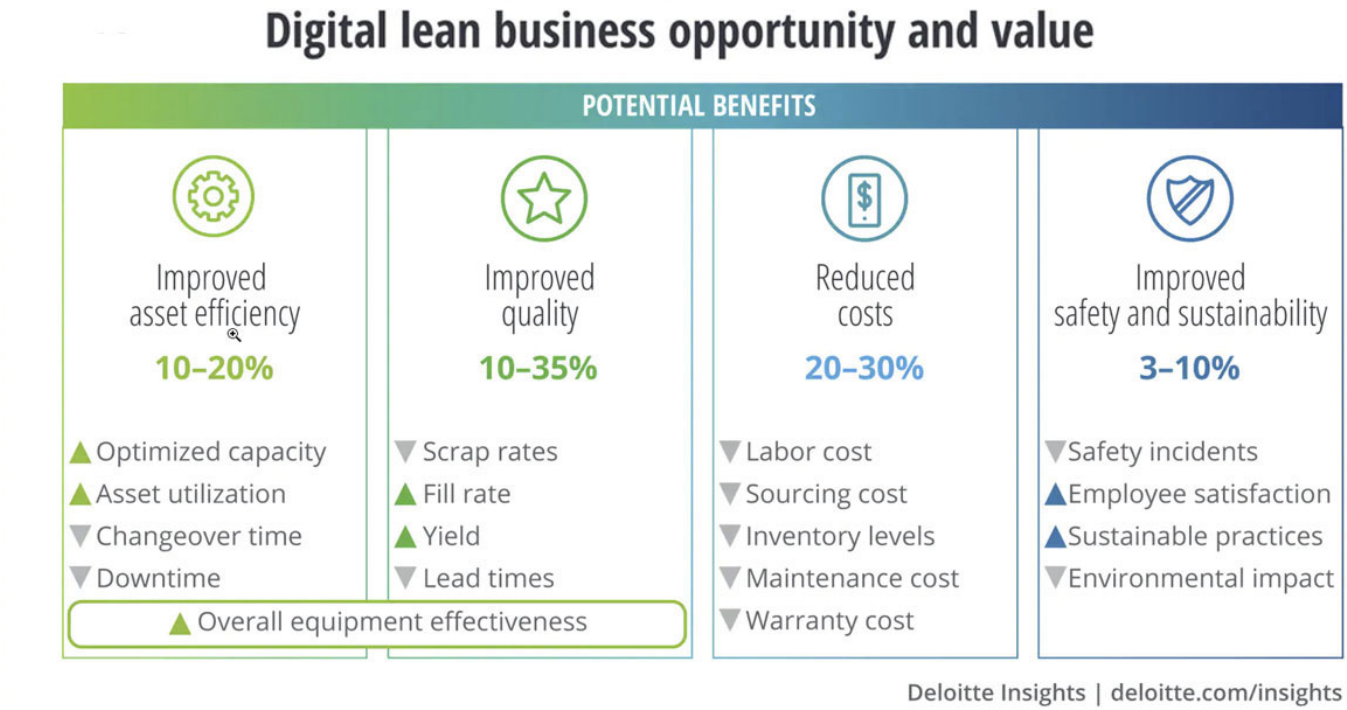
It's the same with data derived from MBD. For now, MBD is a time-saving, cost-saving function. But insights derived from data will be much more valuable as it impacts business and even create new ones.

Bottom line impact

Traditional practices, processes, and tools are about stability & repeatability. **In the manufacturing world, it's crucial to maintain what works.**

However, the complexity of today's dynamic business environment means change is inevitable and getting into MBD is about staying relevant and profitable in a world of change.

According to a Deloitte study on digital manufacturing , the leading manufacturers in digital transformation initiatives see improved quality up to 35% while reducing cost from 20 to 30%.



According to a Bain study, companies that truly understand the impact of digital manufacturing boost efficiency by 15-20% compared to the 2-4% of traditional continuous improvement programs.

MBD is beyond buzzwords and theory. It impacts the bottom line.

MBD benefits & advantages for engineers

Time savings for higher-level work

The biggest elephant in the room is the number of man hours wasted by design and manufacturing engineers.

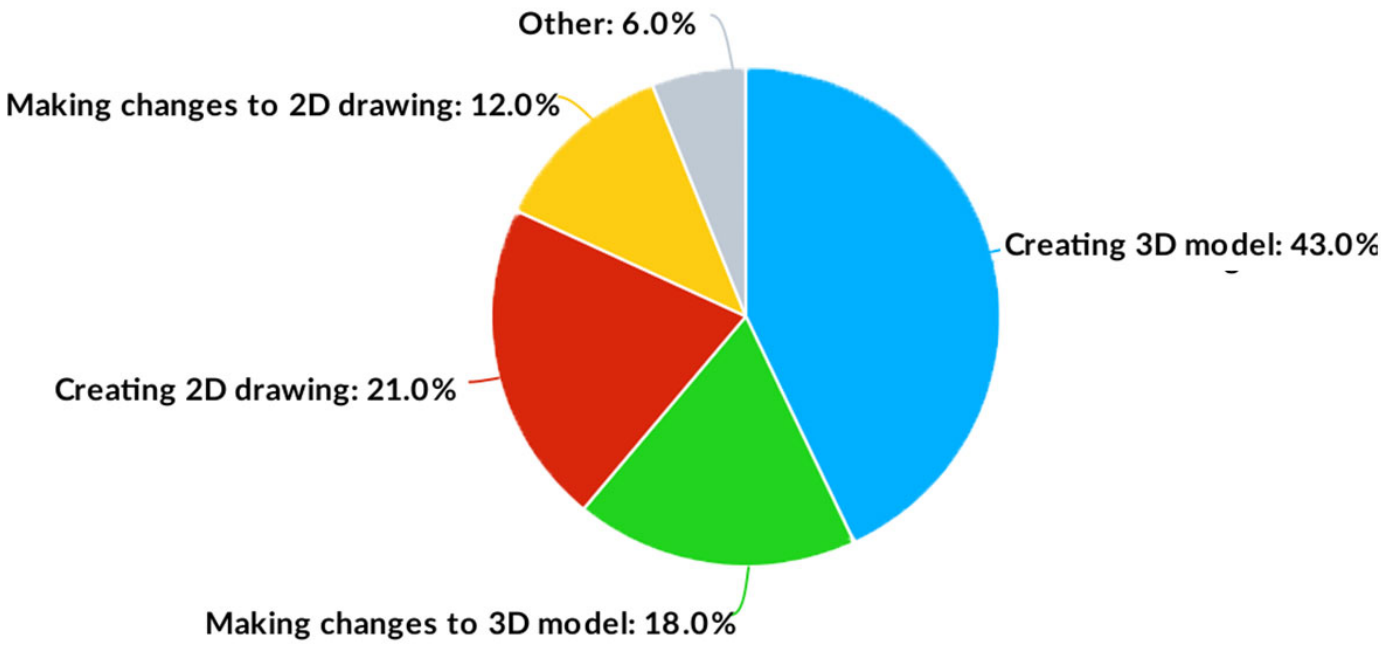
Designers spend up to 33% of their time on creating and modifying 2D drawings.

It's common for programming a CMM for a specific part with thousands of features to take months depending on the complexity of the part.

Manufacturing engineers usually sit side by side with the 2D drawing(s) on a second screen or even printed sheets of paper. They oscillate back and forth between the 2D drawing and CMM/CAM to read tolerance and surface finishes, and validate all information while manually entering in the requirements into their software.

The drawing-centric approach is an unnecessary complexity, introducing potential human reading, interpretation, and typing errors, wastes time on engineering documentation, increases hours for validation and manufacturing, and adds burden to the process.

Engineers freed from this manual task could focus on other important, value-add work.



An MBD workflow (or model-centric approach) using a 3D model with PMI is machine-readable and has all necessary manufacturing information embedded in the 3D model.

MBD ensures the design intent and final product align throughout its product development cycle: one authority source, one single truth that everyone can depend on.

This leads to automation, resolves human error, provides cost-savings, and speeds up the entire manufacturing process & iteration.

MBD has proven to save up to 80% of hours spent in annotating, machine, and inspection and reduce CMM workflow up to 81%.

It's simple math considering the benefits of MBD.

Multiply the hours saved per manufactured part **X** the number of parts produced **X** the number of plants = an incredible number of cost-savings in time.

More time for engineers to tackle higher-level opportunities than work on menial tasks creates a stronger company.

Being on the same page (digitally)

Using 2D drawings is nearly a century-old practice that has served well.

However, as parts get more complex and revisions upon revisions are requested, the room for error such as interpretation, duplication, ambiguity, and revision error also increase.

Engineers design in 3D and should include annotations in 3D. Having a single interoperable digital file removes complications, especially in industries like aerospace and defense when thousands of parts and

hundreds of engineers spread across different countries using different CAD/CAM/CAE software work together.

The Airbus A380 is a $6.1 billion example when design inconsistencies and mismatched calculations could have been avoided with MBD.

Leveled-up, skilled, and relevant worker

According to a LinkedIn Workplace Learning Report, 94% of employees say that would stay at a company longer if the company invested in their learning and development.

Companies need more skilled workers to stay competitive and employees want to strengthen their skills and abilities.

In an industry that lionizes agile management, six sigma, and kaizen, this one is an easy decision.

However, it's a bit of a chicken and egg problem in manufacturing: companies need skilled workers to do the job and workers need training & direction to perform well on the job.

MBD through streamlined and accessible processes and working in collaboration instead of in silos promotes growth for the worker and the team.

Innovative company

Stability and repeatability are a cornerstone of the manufacturing world.

Unknown technology and ideas bring unknown risks.

However, risk also coincides with the rewards of innovation. **Innovation is RISK. Innovation is disruptive.**

The biggest companies today stay relevant by leaning into the future and adopting an innovation mindset.

Avoiding risk, especially avoiding innovation has a long history of agile innovators taking down once-great market leaders:

1. Kodak (Canon, Nikon)
2. Blockbuster (Netflix)
3. Nokia & Blackberry (Apple, Samsung)
4. Yahoo (Google, Facebook)
5. Xerox (Microsoft, Apple)

If you have any questions about MBD, ask away:

We're MBD nerds. From tools to pilots to processes, we're all things MBD and are glad to help or point you in the right direction.

Top 15 reasons you should go MBD

People

1. Man hours saved: up to 80% total process hours saved compared to drawing-centric approach.
2. Frees up engineering time for improving design and products: innovation.
3. From skilled worker to smart worker: working on data & generating insights.
4. Digital links between design and makers: digital twin.
5. Next generation of engineers see and design in 3D.

Process

6. Reduces human error through typing or interpretation.
7. Machine-readable 3D CAD & PMI for automation.
8. Removes the “middle man” or engineering drawings.
9. More feature-rich data for better instructions for the end user.
10. More iteration and process breakthrough improvement.
11. Higher quality inspections with measurement optimization algorithms
12. Transparency and interoperability along the entire process

Product

13. Better products, better pricing, better margins.
14. Shorter product development cycles, faster time to market.
15. Staying competitive, first-mover advantage.

MBD disadvantages

Though the concept of MBD has been around since the early 2000s, adoption has been slow. Here are some of the reasons:

MBD is disruptive

Doing MBD is completely different from 2D drawings requiring design engineers to do more upfront work for a bigger impact downstream which they don't get to see.

It also requires manufacturing engineers and suppliers to have the capability to receive MBD data and validate their models against the authority model in case there's a difference in CAD software.

So it does require learning new or adjacent skills, processes, and tools to get MBD started.

Resistance & lack of skill

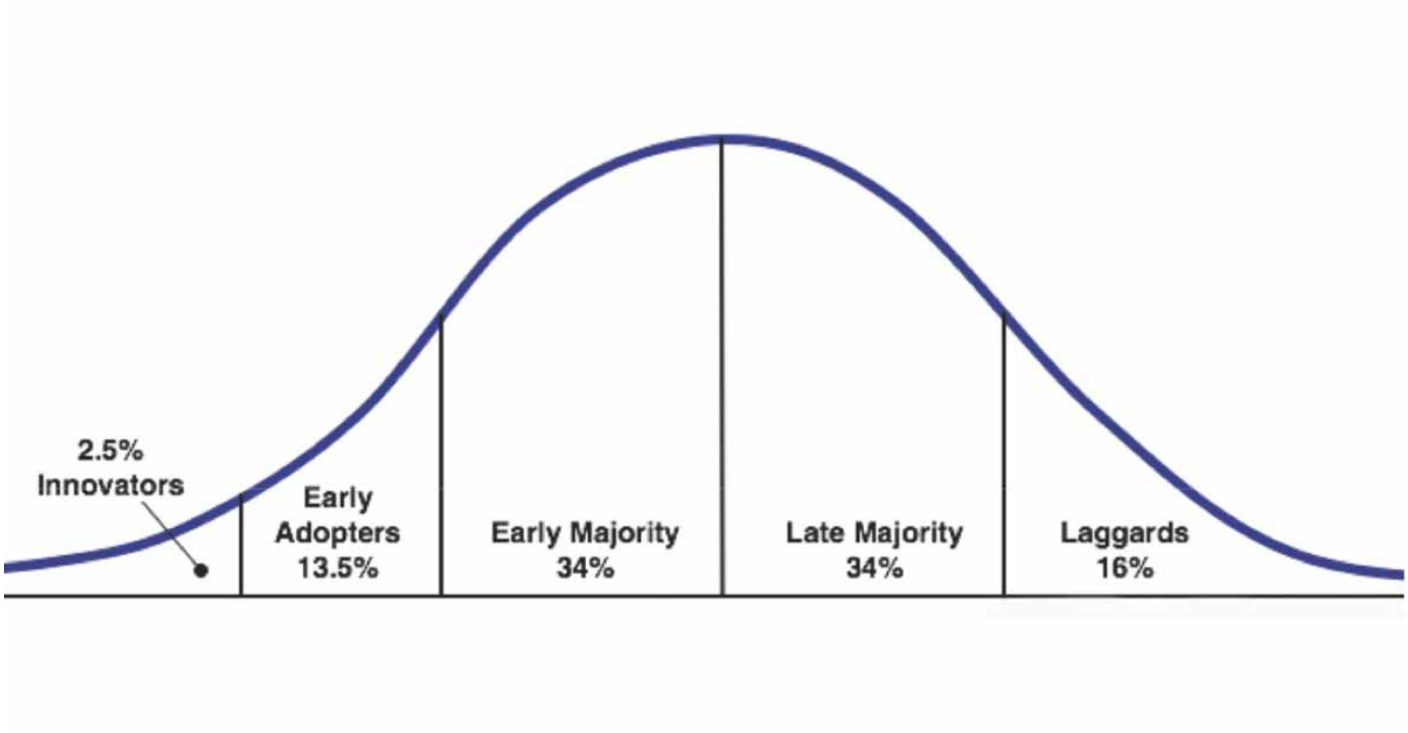
Manufacturing processes is about repeatability and stability. In short, if it ain't broke, don't fix it.

Change is hard and resistance to it is natural and encouraged.

Engineers do have to learn new skills and new ways to complement the MBD process.

Until there's a clear directive or event in the horizon, learning new things to get the "same" results isn't worth the effort.

Lack of maturity & strategy



In general, MBD is still in the early adoption phase while needing a few more years to reach early majority.

The innovators of MBD, especially the ones who have succeeded, aren't publicly sharing their results to protect their "secret sauce" and maintain a competitive edge.

This leads to a lack of definitive & concrete information, misconceptions of MBD, slower adoption, which effects the advancement of MBD software tools.

Therefore, MBD will continue to move slowly forward until companies find out what their top competitors are doing.

Another roadblock is a lack of management buy-in.

Current and immediate MBD ROI is focused on time-savings and faster processes, but lacks the value-add punch that most senior-level executives and decision makers need to change business process.

MBD does produce the bottom-line impact, but meaningful double-digital ROI can take up 5 to 10 years depending on the size of the company and speed to execution from case study to pilot project to company-wide implementation.

Think compound interest.

How to implement MBD

All downstream organizations: quality, inspection, manufacturing, assembly, procurement, service, suppliers, and others benefit using MBD since it cuts through the complexity of today's system to reduce time, cost, and risk.

But how does one start the process of MBD?

It can be overwhelming; however, starting small is the best method since it begins with a focus on benefits that are more immediate and obvious:

1. **Define the stakeholders:** who uses 2D drawings and how are those drawings used within the company.
2. **Infrastructure:** Document current practices, data exchange, and technologies.
3. **Opportunity:** Identify a current process that can be improved. Begin a pilot project to test MBD.
4. **Reporting:** Track progress during downstream handoff.
5. **Bottom-line Value:** Measure ROI with MBD with either time or cost savings.
6. **Expansion:** Continuously expand into other MBD projects in slow and sure manner while building up the education level of MBD users.

Recommended MBD pilot projects / process-specific improvements

Automated FAI (first article inspection) & inspection reports

Though an MBD approach, the 3D CAD with PMI can drive the FAI report, bill of materials, notes, engineering change orders, and more for automatic tasks.

Instead of relying on 2D drawings and manual transcription, auto-generated ballooning and data is sorted into an organized Bill of Characteristics for Excel or Net-Inspect export, reducing FAIR creation up to 80%.

Example of automated FAI workflow:

1. Identify measurement tasks a.k.a. Bill of Characteristics.
2. Store information in MBD model to generate FAI (first article inspection) or PPAP (production part approval process) documents.
3. Assign measurement plan.
4. Generate inspection program for CMM.
5. Gather results.
6. Carry out statistical analysis.
7. Tie back to MBD model for single source of truth.

Automated ballooning definition

With MBD, by defining the output (Bill of Characteristics) on the model, it bypasses the extra work of the engineer to make up his/her own way of output naming conventions and sorting measurement results.

This allows for an organized and unified naming convention.

Automated CMM program generation

Current state of CMM programming is labor intensive, requiring a skilled CMM technician to manually enter GD&T from a 2D drawing into their CMM software. Also, if given to five different engineers, there's a possibility for five different CMM programs because of different decisions made in the process, different interpretations of GD&T data, and transcription errors.

An MBD approach puts the GD&T embedded into the 3D CAD model and is directly imported by the CMM software like Calypso, Checkmate, PC-DMIS, and more, which allows for a consistent process to be applied to measurement.

Current State of CMM	MBD approach to CMM
Manual transcription of GD&T / PMI.	Encoded design knowledge.
Translation and interpretation errors.	Transcription errors eliminated.
Requires skilled CMM technician.	Frees up skilled engineer's time.
Personnel and machine dependent.	Reliance on process over personnel.
Labor intensive	Drastic reduction of labor time.
Multiple, propriety data formats.	Universally accessible data.
Not mapped to a "single source of truth."	Data mapped to design model.

Future use cases for automation

The possibilities are limitless. But MBD processes currently being test are welding, visual inspection, and non-destructive testing.

MBD-ready CAD formats

The heart of MBD is interoperability.

Proprietary formats from CAD programs such as Creo, CATIA, SOLIDWORKS, NX, Inventor, and others cannot be read nor converted directly to another proprietary format.

However, universal neutral CAD formats are interoperable between different CAD, CAM, and CAE programs.

MBD-ready CAD files like QIF and STEP AP242 are ISO-standard machine-readable file formats, which can be opened and examined by human engineers and unambiguously imported by software tools.

FAQ:

Q: Which industries are most mature in MBD?
A: Aerospace & defense and automotive are the leading the charge for MBD. Boeing requires MBD with their suppliers.

Q: What does a successful MBD pilot project look like?
A: It has to be a S.M.A.R.T. (specific, measurable, achievable, relevant, and timebound) project. Starting small like FAI or CMM generation provides the lowest hanging fruit.

Q: What metrics can we gather on our current process, so that we can compare them to an MBD-based process?
A: First, labor time reduced. It's the easiest to capture and easiest to calculate. Second, reduction in delays and the cost benefits of getting the product into the market. Third, availability of better data and intangible ROI which can be used to fuel smart manufacturing insights.

Q: How does MBD help OEMs? How about small businesses and suppliers?
A: For manufacturers, MBD keeps cost down because of automation, preventative or corrective action earlier in the product lifecycle. For small businesses and suppliers, no more ambiguous designs and data to build and measure the part.

MBD resources:

MBD standards:

1. ASME Y14.5 and ISO GPS (Geometrical Product Specifications): These standards govern the use of geometric dimensioning and tolerancing — GD&T. Having a solid understanding of the principles of GD&T will help to ensure that your MBD-based processes are well-defined, efficient, and stable.
2. ASME Y14.41: This standard provides guidelines for how to go about creating your digital product definition in 3D.
3. ASME Y14.47: This standard provides schemas for organizing CAD models.

MBD maturity index:

NSE MBE Maturity Index: assessment tool for companies to find their level of MBD/MBE-readiness. Download presentation slides.

MBD conferences

These conferences are entirely dedicated to MBD or have good tracks related to MBD.

1. Model-Based Enterprise Summit
2. 3DCIC (3D Collaboration & Interoperability Congress)
3. GPDIS (Global Product Data Interoperability Summit)

Need more information about MBD workflows or starting points?

Contact us and we'll glad to help or point you in the right direction.

Additional Reading

- What is PMI (Product Manufacturing Information)?
- QIF (Quality Information Framework): Definitive Guide
- 3D CAD Translation: Importing & Exporting The Right Format
- Digital Product Definition: Getting to Yes
- Best STEP File to Use: AP203 vs AP214 vs AP242