Reducing the Cost Impact of Engineering Errors, Changes and Escapes for 3D Product Data

Much can go wrong between the “as designed” and “as built” stages of any manufacturing effort. Seven recommendations for identifying and documenting engineering escapes are presented here.

- James Flerlage, EVP
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Introduction

The origin of quality issues for 3D product data often start with the discovery of engineering “escapes” buried in a complex system of inefficient engineering change processes that create functional gaps and labor redundancies. The problem is exacerbated by reliance on outdated methods and procedures for exchanging product data with partners throughout the supply chain. The findings revealed in this white paper coalesce years of experience based on customer consulting engagements, product and program studies, government research projects, and 3D CAD validation projects – all] conducted by International TechneGroup Incorporated (ITI).

An engineering “error” is defined as unintended content additions or variations to 3D product data that stem from software issues. An engineering “change” is defined as an intentional revision of the 3D product definition. An engineering “escape” is defined as an unidentified or undocumented quality issue in the upstream 3D product data that leads to negative consequences in downstream manufacturing processes. The negative consequences caused by “escapes” may include – but are not limited to – labor waste, material and part scrap, assembly errors, program delays, environmental impacts, product safety issues, warranty/recalls and mission failure.

Readers should note that this work is not a comprehensive collection of recommendations but a starting point for their own initiatives. (Protecting proprietary client information is a core ITI business value, and as such, comprehensive results from client projects cannot be published.) The formulas, strategy points, insights, and recommendations presented in this paper will help engineering and manufacturing leaders develop a strategy and action plan for mitigating the cost of engineering errors, changes, and escapes for 3D product data.

In this paper, the following seven recommendations are discussed:

1. Troubleshoot 3D product data in the context of a design factory
2. Trace production issues back to engineering escapes
3. Discover how downstream users track and communicate 3D product data changes
4. Extend your engineering change user studies to the supply chain
5. Establish an approved list of metrics and formulas for measuring ROI
6. Identify engineering errors in 3D product data early in the product lifecycle
7. Use a feedback loop to document and communicate change

> ***“ECOs consume one-third to one-half of engineering capacity and represent 20-50% of tool costs, which can easily account for over US $100M in large development projects…”***
>
> - Terwiesch and Loch

1. Troubleshoot 3D product data in the context of a design factory

In “Managing the Design Factory,” [7, p. 11], Donald Reinersten posits that product design centers can be compared to factories. “The purpose of a design process is to generate information. It is the difference between making food and making recipes. The manufacturing factory creates food for people to eat. The design factory creates recipes. Our designs will only make money if we create recipes to turn material, labor and overhead into valuable functionality better than our competitors do.”

Figure 1.1 – 3D MBD designs become the container integrating both the picture and the recipe.

Applying Reinersten's premise to product design extends this analogy to 3D MBD (model-based definition). With 3D MBD, the 3D design becomes a container that integrates both the picture and an embedded recipe, known as product manufacturing information (PMI). Ed Lopategui, in his blog post titled, "Engineering Drawings Are Dead" [5], explores this concept.

"No longer does product definition need to be limited by the communication medium. In other words, 3D objects can now be defined and controlled in 3D. We all think and understand 3D, because that's how we perceive the universe. But the intended value behind PMI is beyond just adding a dimension, but rather taking what was once a picture and evolving the process. Not a mere snapshot with annotations, PMI brings a persistent overlay of metadata that is queried and utilized with the model."

As organizations continue to adopt 3D MBD, engineering and manufacturing processes will become increasingly dependent on having quality product-data from the design factory. The ability to ensure that both the "picture" and the "recipe" are intact, is critical to improving upstream 3D product data quality and eliminating downstream engineering escape costs. To find the exposures that exist in your processes, first initiate a discovery project that locates key points in the product lifecycle where unidentified engineering changes to 3D product data are introduced and to quantify the cost impact to downstream manufacturing processes.

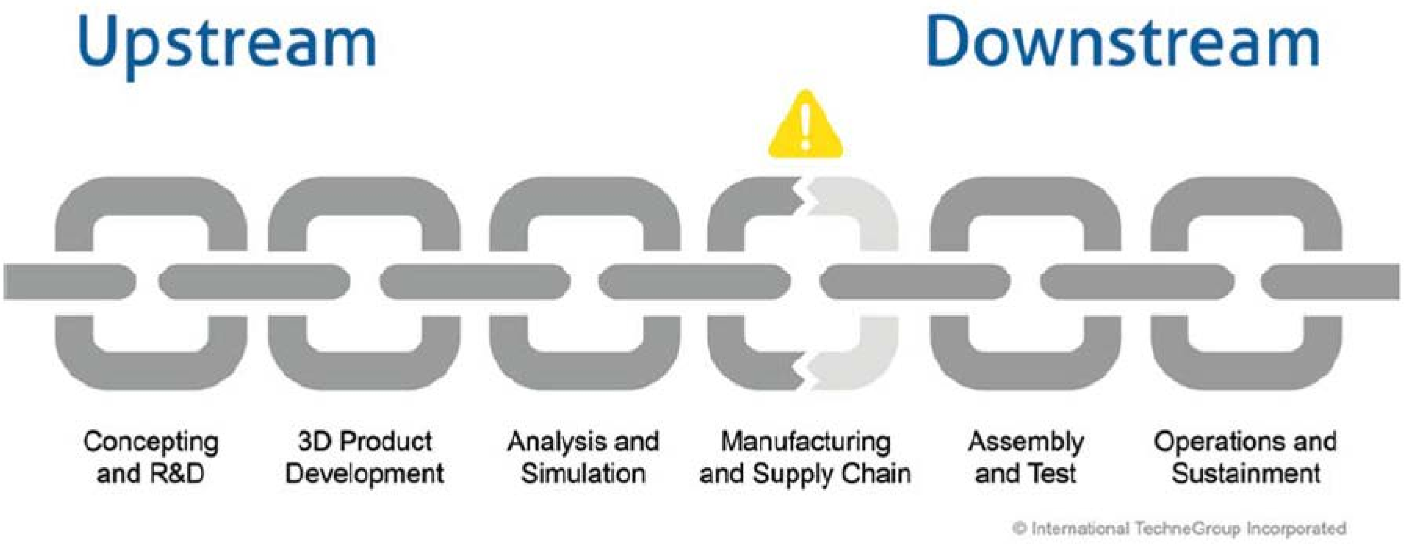

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Figure 1.2 – Unidentified engineering changes to 3D product data often occur in the manufacturing and supply chain points of the product lifecycle, which is why most discovery projects start here.

> ***"In a design process, the cost of making changes early is exceptionally low, whereas the cost of late changes is very high. Exponentially rising costs make it critically important to drive changes into the upstream portion of the design process where such changes are hundreds of times cheaper to make."***
>
> \- Donald Reinersten

2. *Trace production issues back to engineering escapes*

Given that today's organizational and manufacturing culture values product quality, and if management is willing to hold engineering accountable to 3D product-data standards, then the next step must identify a proactive process for tracing production issues back to engineering escapes.

The first step is to assemble a project team that is focused on process and operational excellence, and then to establish the business requirements, justification, and budget needed to execute the work statement. Depending on the size and scope of the initiative, a project can span between three and twelve months, and in some cases, longer. Once the preliminary project team is assembled, launch a formal 3D product-data-quality improvement program. It is best to use a phased approach, leveraging the following recommendations:

> Identify an executive sponsor with funding and select a program that will not only benefit from the study but can also afford minor disruptions.

> Select a project leader that possesses excellent finance, operations, and interpersonal skills.

> Ensure that the project team has adequate representation and relationships across engineering, manufacturing, IT, supply chain management, and maintenance/sustainment.

> Select team members who are comfortable with management and have a blend of technical, communication, and business skills (these types of projects often gain executive visibility).

After obtaining funding and assembling the team, the project lead must develop a project plan. At a high level, the team can begin to define an approach by incorporating the following criteria:

CRITERIA FOR 3D PRODUCT DATA QUALITY IMPROVEMENT PROGRAM

Determine where the product data is stored/located and how information flows; the producers and consumers of engineering and technical content changes; change documentation methods and any factors that stimulate 3D product-data rework.

Evaluate engineering changes based on frequency, the impact of the occurrence, the ability to detect change, and the effort required to interpret change documentation. Identify decision points that cause engineering and manufacturing stakeholders to change the 3D models. Note the types of variation caused by actual product-data changes versus process mistakes or software errors.

Assess how 3D model changes are communicated throughout the product development lifecycle. Start with 3D design and follow the models, step by step, through the value chain. Document how functions within the product lifecycle use or transform the 3D model and whether the model is referenced or re-created. Periodically compare the differences between asdesigned "released" 3D models and those being used in manufacturing.

Analyze change processes that affect manufacturing rates; relate non-value-added cost – such as model re-creation, rework, and revisions, part scrap, assembly issues, and inconsistent technical documentation – to organizational metrics and/or key performance indicators (KPIs).

3. Discover how users track and communicate 3D product data changes

In his text “Engineering Documentation Control Handbook” [10, p. 325] Frank Watts asks, “Given a revision D drawing and a revision E drawing, is not your first question going to be ‘What is different?’”

Counter to the intuition that modern technology simplifies work, this question is often easier to answer for drawing-centric environments versus 3D MBD.

The 3D product data model (particularly in the case of 3D MBD) contains multiple elements such as geometry, topology, specification trees, and product manufacturing information (PMI). Combine the complexity of all these data elements with multi-CAD scenarios and supply-chain collaboration requirements, and stakeholders will uncover a proliferation of engineering changes and 3D data-quality escapes stemming from poor product data. This is where precise 3D product-data validation becomes extremely critical. It is particularly important to mitigate the risk of unidentified or undocumented engineering changes for the following scenarios:

1. Converting 3D product data from one CAD system to another
2. Translating 3D product data into a neutral CAD format (such as STEP) or a visualization format (such as JT or PDF)
3. Transforming 3D product data for downstream use in simulation, analysis or manufacturing
4. Re-mastering legacy 3D product data for use in a new CAD system
5. Migrating 3D product data from the original PDM or PLM system to a new system
6. Outsourcing 3D product design authority to a third-party but owning the overall product liability
7. Collaborating with partners and suppliers on 3D product data but owning the design authority

Early in the process, it is important to learn the way in which each engineering and manufacturing function interprets, transforms, or changes the 3D models; to discover what new 3D product data is being created; and to determine if the changes are communicated upstream. The team should be interviewing key resources, and in a parallel activity, should physically follow the 3D product data through each stage of the product lifecycle, documenting the various tools, responsibilities, decision criteria and work processes.

Below is a sample list of questions to help the team build a relevant questionnaire:

WHO?	Who distributes the changed 3D models and who receives them?
WHAT?	What and/or who initiates changes to 3D product data?
WHEN?	When users/consumers receive model changes with information about the changes, do they trust that the information is complete and accurate?
HOW?	How are changes communicated to users/consumers when a user/consumer receives a changed model? How do users/consumers who receive model changes and the information about the changes need to transform or modify the data for input into a subsequent system or process? How do users/consumers translate 3D models to other formats for downstream use?

As is evidenced by the questions above, an increasing area of concern for engineering and manufacturing leaders is data re-creation, whereby downstream 3D product-data consumers are reluctant to trust changes to the original 3D design and thus choose to re-design the 3D model instead. In many cases, users do not document or track these 3D product-data changes downstream, nor do they communicate the changes back to design. This creates an environment that perpetuates quality risks to the manufacturing process and the physical product, which then leads to material/part scrap, program delays, and acute increases in labor costs.

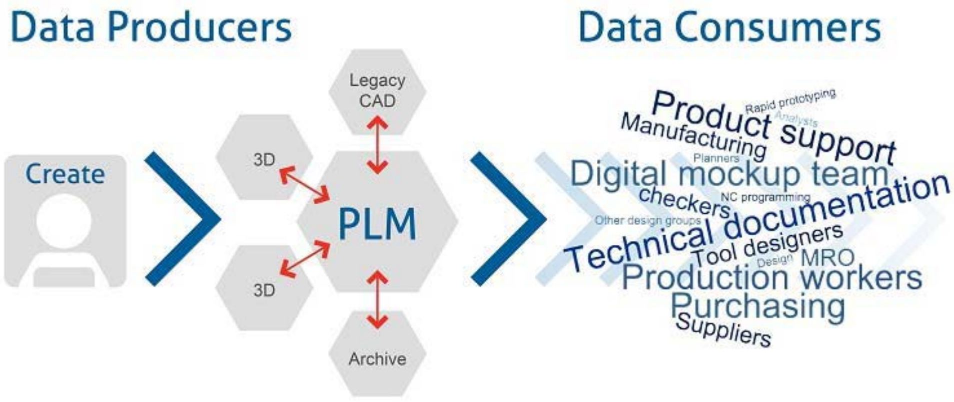


Figure 3.1 – In the producer-consumer PLM ecosystem, the potential for 3D product data quality escapes increases as the data is re-used and re-purposed throughout the value chain.

Donald Reinersten states in his book, “The Principles of Product Development Flow,” [8, p.86]: “Product development creates economic value by producing the recipes for products, information, not creating physical products. If we create the same recipe twice, we’ve created no new information, and consequently, no economic value.” ITI has proven that manufacturers who prevent the re-creation of 3D product data for a significant percentage of their models and assemblies, net annual labor savings of $5M to $30M and higher.

An increasing area of concern for engineering and manufacturing leaders is data re-creation, whereby downstream 3D product data consumers are reluctant to trust changes to the original 3D design and choose to re-design the 3D model.

By viewing engineering change processes as a burden or cost center, engineering and manufacturing leaders miss the chance to potentially improve profitability by reducing labor costs. For instance, in a paper authored by C. Terwiesch and C.H. Loch, entitled, *Managing the Process of Engineering Orders: The Case of the Climate Control System of Automobile Development [4]*, the authors suggest that engineering change processes are too often treated as cost centers, rather than opportunities for cost reduction. Such an approach represents an important but often missed opportunity for improving program profitability.

ITI has proven that manufacturers who prevent the re-creation of 3D product data for a significant percentage of their models and assemblies, net annual labor savings of $5M to $30M and higher.

“The negative impact of engineering change orders (ECOs) has been reported in a number of studies. ECOs consume one-third to one-half of engineering capacity and represent 20-50% of tool costs, which can easily account for over US $100M in large development projects. However, the management of ECOs is not well understood, despite this importance. In the past, both practitioners and researchers have tended to view ECO-related problems more as a tragedy than as a sign of a process management issue. In particular, the support process for administering ECOs has received little attention, although it has been identified as one of the root causes of ECO costs.”

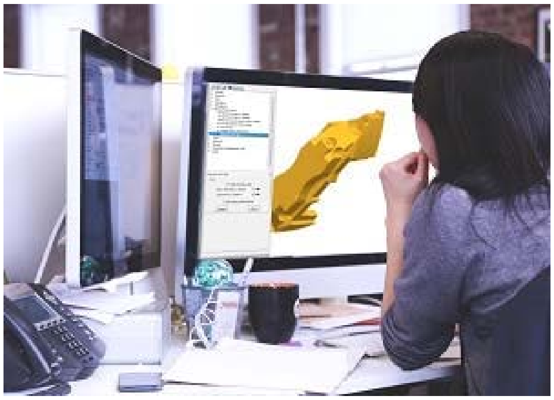
4. *Extend your engineering change user studies to the supply chain*

Tracking, documenting, and interpreting internal changes is a complex undertaking for any large manufacturer, but once the 3D product data is released from the design factory, intentional and unintentional changes could be introduced in virtually dozens of places within the value chain. After the team has followed the 3D model through each stage of its internal product lifecycle, be prepared to follow the 3D product data as they are released from the organization to the supply chain and product lifecycle support organizations, such as maintenance, field support, and warranty.

In “Engineering Documentation Control Handbook” [10, p. 323], author Frank Watts states, “The supply chain requires the right document, at the right place, and by the right process.” Do your suppliers receive quality, 3D product data at the right place, by right process? To answer this question, observe how the 3D datasets are packaged and sent to the supplier. When the supplier receives the 3D data package, document how the model is distributed and how it moves between functions and users. If a change request was submitted back to the organization, record the path of the 3D product data, any changes that may have happened during the process, and document response times.

It is also important to note the amount of time the users at a supplier will wait for verification of a change or of data accuracy before they begin to look for workarounds. Observe the solution they choose, if the 3D model was changed in the process, and determine if the 3D model that the supplier sends back is different than the one they received. Watts [10, p. 325] also states that “customers will spend a lot more time if changes are not precisely described – and make errors which come back in the form of bad parts or higher prices.”

The longer it takes to execute engineering changes to 3D product data, the greater the risk to data quality. By the time 3D data consumers receive the change, labor may have been wasted on out-of-date or out-of-compliance product data. **Finding and remedying the differences between “as-designed” models and “as-built” components is critical to establishing the data integrity of a product or program that relies on 3D product data.**



How long will suppliers wait before they begin to look for work-arounds?

5. *Establish an approved list of metrics and formulas for measuring ROI*

In “The Principles of Product Development Flow” [8, p.109], Reinersten emphasizes that, “When thinking about variability, it is important to focus on the cost of variability instead of just worrying about the amount of variability.” By discovering measurable findings regarding the frequency of 3D product-data escapes, project teams correlate 3D product data issues to engineering escapes and determine a quantifiable cost impact.

Establishing trustworthy metrics is a critical piece to determining the cost impact of 3D product-data variability on the return on investment (ROI) for subsequent projects and/or technologies required to correct any issues. This section reviews the types of metrics teams can collect and measure, and provides a formula that can be used to calculate labor savings. Do not forget to include a list of questions for collecting quantitative information. This will enable the team to measure the cost impact of labor redundancies within engineering change processes. The items below include a partial list of recommended metrics that should be collected during the investigative process:

METRICS FOR MEASURING ROI

> Minimum/maximum number of 3D model changes per month, by group and function
> Total number of 3D model changes, program-wide or enterprise-wide
> Minimum/maximum number of hours teams spends interpreting change documentation
> Total number of hours all groups and functions spend interpreting engineering changes
> Total number of engineering escapes per month
> Total cost per escape per shipment
> Minimum/maximum cost to incorporate 3D model changes by third parties or suppliers
> Number of pre-release cycles and check/fix cycles
> Minimum/maximum number of hours required to document changes to 3D product data
> Average labor rates by group, function, contract or job title
> Escapes and changes per year cost translated into 1/3/5-year cost impact forecast

The information below contains an example of a cost-estimation formula for measuring labor costs for geometry changes related to engineering escapes.

Formula for estimating total monthly labor cost in order to understand and document geometry changes and correlating engineering escapes

Monthly Estimate = [A*(D*B) + A*C]*E + [F*G*H]

A = Number of changes per month
B = Time to understand the change
C = Time to document the change
D = Number of check cycles
E = Labor rate
F = Number of escapes per month
G = Cost per escape per shipment
H = Number of shipments per month

Example calculation using the above formula

Monthly Estimate = [100*(3*10) + 100*5]*$100 + [2*$500*10]

100 = Number of changes per month
10 = Time to understand the change
5 = Time to document the change
3 = Number of check cycles
$100 = Labor rate
2 = Number of escapes per month
$500 = Cost per escape per shipment
10 = Number of shipments per month

Monthly labor savings estimate = $360,000
Annual labor savings estimate = $4,320,000

6. *Identify engineering errors in 3D product data early in the product lifecycle*

In order to gain early visibility, engineering and manufacturing stakeholders need to analyze and communicate engineering changes to 3D product data upstream – before changes become engineering escapes.

Doug Cheney, an expert on 3D product data variation and validation from International TechneGroup Incorporated (ITI) in Milford, Ohio [2], believes that 3D MBD and PLM initiatives could be more profitable by minimizing downstream 3D CAD model variation. “If you expect downstream users to rely on the model to make decisions that not only affect their function, but also their livelihoods, then you have to consistently produce CAD models that are reliable. The engineers I know don’t want to make mistakes; a proven, automated, non-disruptive solution for identifying 3D CAD model variation and communicating change upstream is essential to winning user trust and eliminating unprofitable work processes.”

Discovering undesirable design changes early in the product lifecycle mitigates the cost impact of engineering errors and escapes. As Reinersten notes in “Managing the Design Factory” [7, p.14]: “The cost of making changes during product development rises exponentially throughout the design process. This is quite different from the manufacturing process, where value-added rises more linearly through the process. In a design process, the cost of making changes early is exceptionally low, whereas the cost of late changes is very high. Exponentially rising costs make it critically important to drive changes into the upstream portion of the design process where such changes are hundreds of times cheaper to make.”

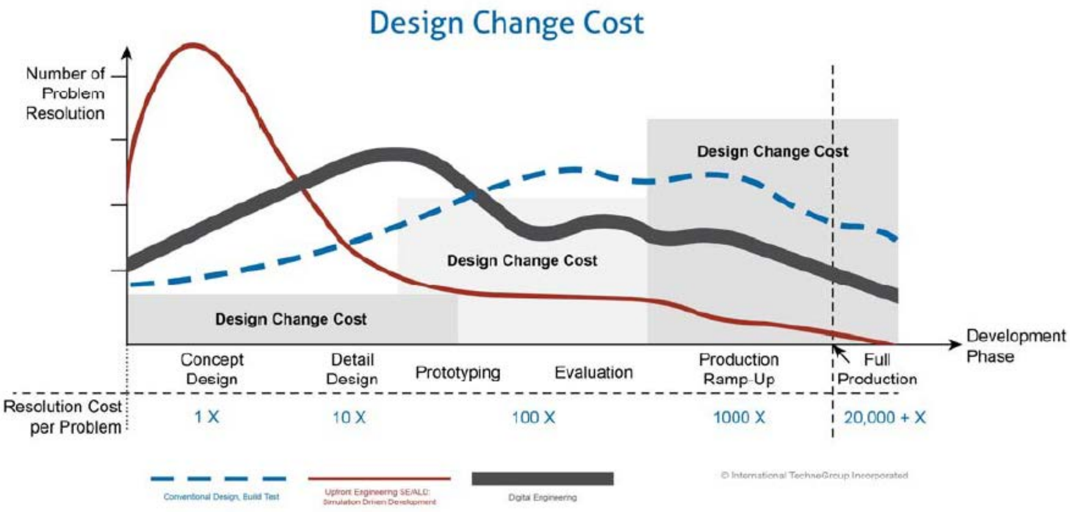
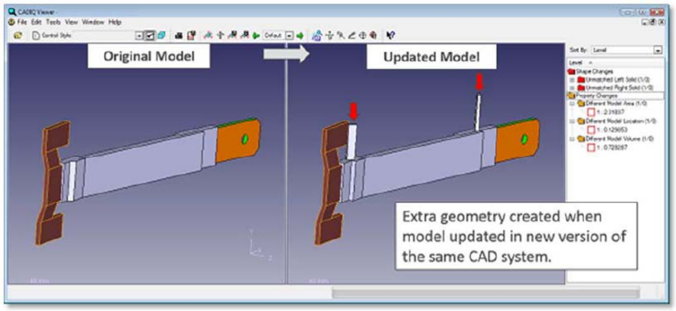


Figure 6.1 – Created by ITI founder Dr. Jack Lemon, this chart illustrates that design costs stemming from design changes are an order of magnitude cheaper to absorb if the changes are made earlier in the product lifecycle.

In product development organizations that use only one CAD environment, the most common sources of unidentified or undocumented change are related to the following four conditions:

1. CAD version upgrades across a point release

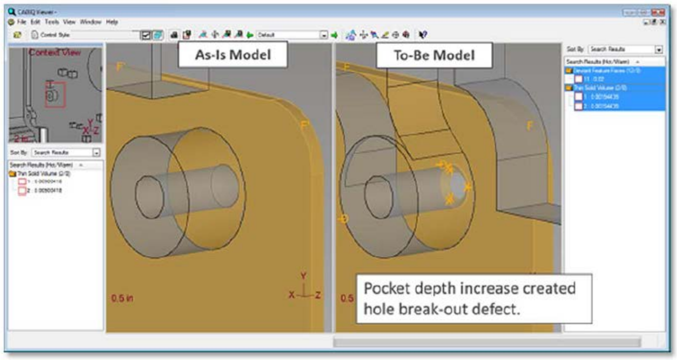
CAD version upgrades (e.g. CATIA V5 R24 to R25, Siemens NX10 to NX11, Pro/ENGINEER Wildfire 4 to Creo 2) or multiple releases (e.g. ProENGINEER Wildfire 4 to Creo 2) can lead to changes.



Extra geometry created when model updated in new version of the same CAD system.

2. Inadequate engineering change processes, communication and/or training

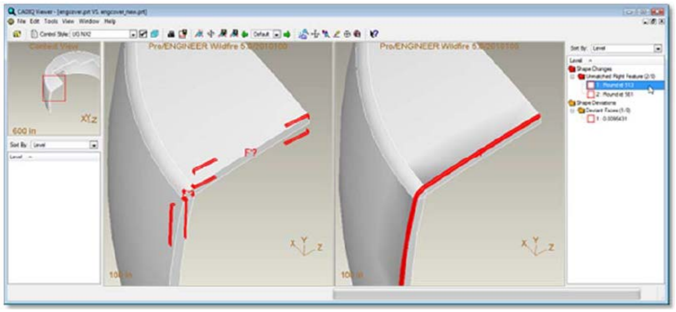
Organizations that deploy 3D MBD but lack adequate engineering change processes, communication workflows and/or training for downstream 3D product data (for both data consumers and suppliers) risk engineering escapes.



Pocket depth increase created hole break-out defect.

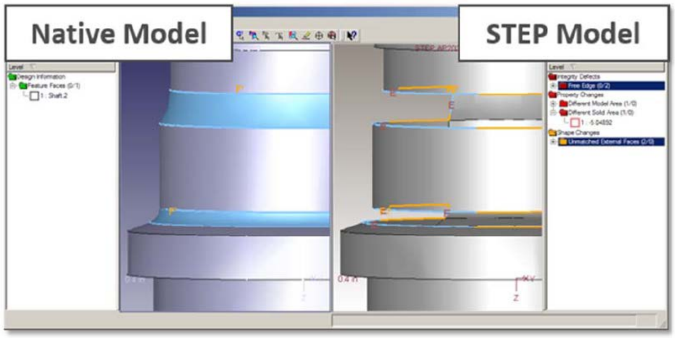
3. Poor modeling practices

Non-producible conditions can be introduced into the 3D model through poor modeling practices; manufacturing engineers then change the model to fit downstream manufacturing capabilities.



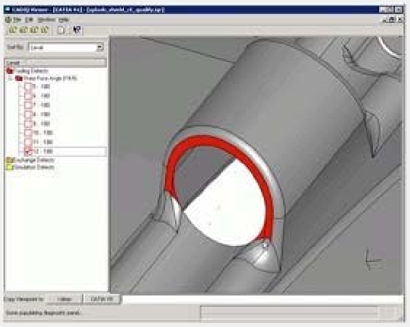
4. Long-term archival workflows

Long-term archival workflows, where the 3D product data is converted to a neutral format and/or a visualization format, can lead to the derivative format output not matching the native source data.



Example

Consider one scenario, in which a large motor-vehicle manufacturer struggled to identify the source of its part failures. After the simulation group approved the model, the manufacturing team discovered that all of the associated parts failed during final testing.



Unbeknownst to the simulation and manufacturing groups, the parts failure was the result of an undetected “thin” condition introduced into the 3D model upstream. This single failure resulted in unscheduled production delays, a major retooling effort, and wasted labor and material costs.

An automated software application for 3D product data validation, architected on the application programming interface (API) of the corporate CAD system, detected a zero-thickness condition inside the 3D model. This undetected condition resulted in testing failures for dozens of parts because the molded fender was missing material, which made the fender crack during final assembly. In addition to this example, hundreds of documented cases exist where the graphical representation of the data, along with the precise geometric representation, contained non-producible conditions that could not be detected by the designer, design checking tools, or manual checkers.

For some industries (such as aerospace, defense, and medical devices), the adoption of 3D MBD, PLM, and digital manufacturing technologies requires an unprecedented level of 3D product data precision and accuracy. In the book "Coordinate Measuring Machines and Systems," [1, p. 408], Dean Beutel and Paulo Pereira state that "In general, high cost or high risk components (luxury items, airplanes, and medical devices) have small margins for errors. In those cases, the producer must make sure defective items are not shipped. The producer's cost is also a factor, as zero defects can be costly if manufacturing processes are not properly designed and maintained."

For some industries such as aerospace, defense, and medical devices, the adoption of 3D Model Based Definition (MBD), PLM, and digital manufacturing technologies requires an unprecedented level of 3D product data precision and accuracy.

Augmenting product development processes in a way that automates the inspection and validation of 3D product data is a critical step to reducing cost. For the most precise and accurate interrogation, ensure that the software solution uses the API of the CAD system to conduct its analysis. Once the automation routine is implemented, configure system settings to look for confusing structures (such as changes to PMI, blocked holes, cracks, and more), inconsistent data, especially unrealistic features. In many cases, unrealistic (or ambiguous) features are left open to interpretation by downstream users and suppliers. This often results in the 3D product data variation that affects part quality, and this variation is unlikely to be communicated either upstream or downstream or incorporated back into the 3D master model.

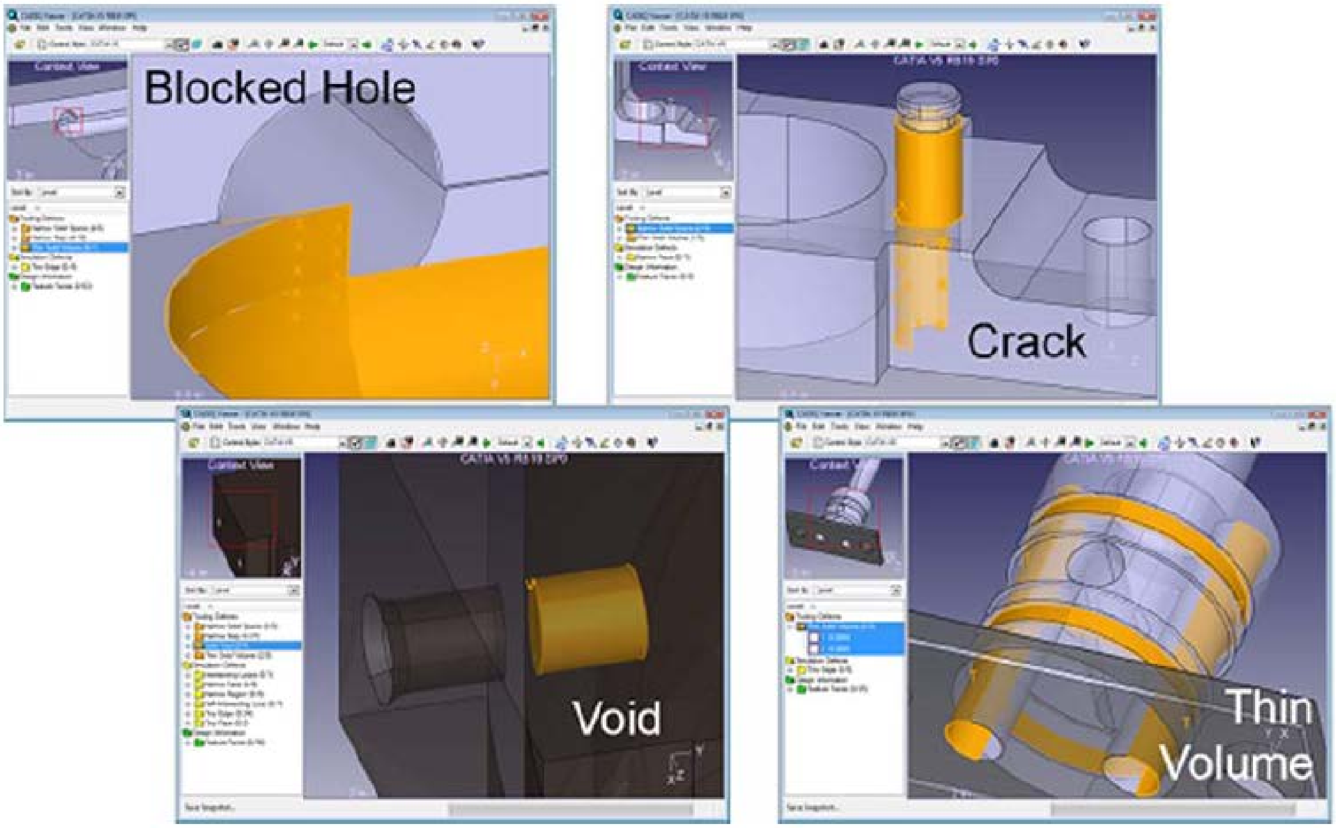


Figure 6.3 – Ambiguous features, such as blocked holes, cracks, voids, and thin volumes are nonproducible manufacturing conditions that may lead to model re-work and undocumented changes.

With the standards and practices governing PMI open to interpretation, large enterprises struggle to enforce 3D modeling standards consistently, and a lack of consistency leads to both poor upstream 3D data quality and downstream rework.

For organizations adopting model-based definition (MBD) and model-based manufacturing (MBM), an API-based software validation solution is preferred because the semantic representation of product manufacturing information (PMI) can be interrogated precisely. Precision is a critical component to upstream data quality because downstream processes for tooling, machining, and robotics require accurate, usable product data.

With the standards and practices governing PMI open to interpretation, large enterprises struggle to enforce 3D modeling standards consistently, and a lack of consistency leads to both poor upstream 3D product data quality and downstream rework. Thus, any automated software application used to identify engineering changes to PMI should detect the following:

PMI CHANGES TO DETECT

> Missing and overlapping annotations
> Collapsed dimension graphics
> Missing extension lines
> Implied annotation patterns
> Unassociated dimensions, datum targets, and annotations
> Missing datum references
> Undefined datum features
> Large or unrealistic tolerance zones
> Changed annotations (rounded up or down)

7. Use a feedback loop to document and communicate change

In their paper titled, A Comparative Study of Engineering Change Management in Three Swedish Engineering Companies, [6] authors Peter Pikosz and Johan Malmqvist state a simple but often overlooked premise. “If an undesired design decision has been made, the product data has to be changed in a controlled fashion. The impact of the change has to be investigated and all documents related to the error have to be identified and changed.”

Identifying and tracking engineering changes that lead to escapes is a step. Communicating these changes to upstream producers is just as critical. In Reinersten’s book, “The Principles of Product Development Flow: Second Generation Lean Product Development” [8, p. 241], he states that, “Feedback is several orders of magnitude more important in product development than it is in manufacturing. Tight feedback loops can become an explicit organizational focus.”

Typical feedback loops used for engineering change range from casual shop floor conversations to documents, spreadsheets, and embedded workflows within the PLM systems. Unfortunately, many of these solutions do not provide a visual representation of the changes that occurred in the 3D product data, nor are there ways to track or document said changes. An automated CAD-validation solution should offer a tightly integrated feedback loop that includes a pictorial reporting mechanism highlighting the 3D product data changes and including technical notes and commentary.

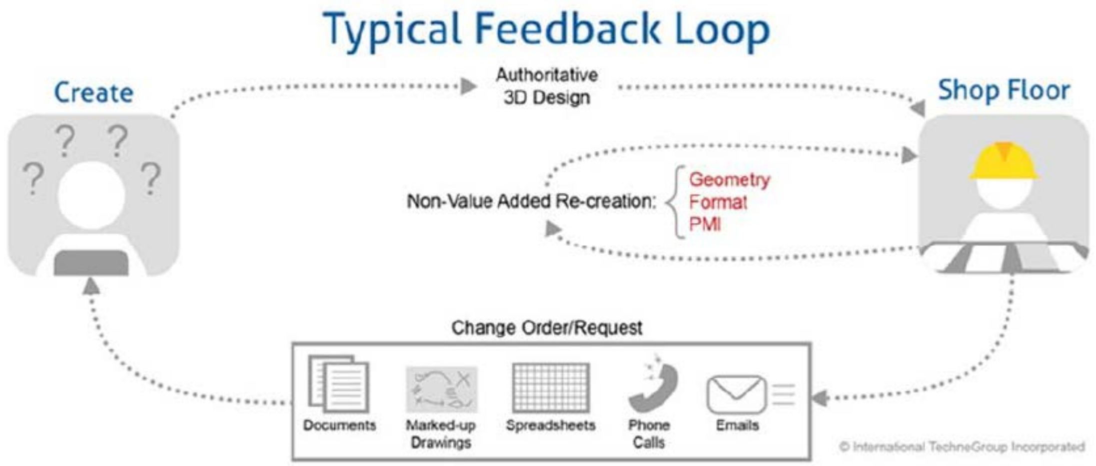


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Figure 7.1 – Typical engineering change feedback loops include casual shop floor conversations, documents, spreadsheets and embedded PLM workflows, plus non-value-added re-work such as the re-creation of 3D product data geometry, formats, and PMI. This new information is often undocumented or not communicated upstream.

As Paulo Pereira and Dean Beutel state in “Coordinate Measuring Machines and Systems,” [1, p. 401]: “One of the greatest advantages of CAD-based programming is pictorial reporting. Pictorial reporting can save time in decision-making because an operator can look at the CAD rendering of a part with the measured deviations included. Pictorial rendering relays part deviations without having to use numerical results so that people from different disciplines can more readily understand them.”

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Figure 7.2 – Pictorial reporting can save time and improve communication, while ensuring that the as-designed component serves as the digital twin to the as-built component.

Asa Trainer, Vice President of Product Operations at ITI, in Milford, Ohio, [9], spent more than 20 years on the shop floors of the world’s largest aerospace and defense manufacturers. In his previous role at The Boeing Company and Parametric Technology Corporation (PTC), Trainer has helped several companies understand the impact of poorly designed processes on 3D engineering change and escapes. His concern is that many companies are losing profits not because they lack engineering change processes, but because the processes are often based on outdated approaches that aren’t congruent with the present state or technical capabilities of 3D design.

"In my experience, many companies base their engineering change processes on some derivative of a 2D (drawing)-oriented process. However, with 3D, especially MBD, you're talking about a significantly complex product development environment that is handling more data and more consumers. It's a scenario that increases the likelihood of engineering changes, coupled with a lot of human interpretation in between. Companies should look for ways to lean out these processes and automate them, to make identifying and communicating 3D design changes easier."

Conclusion

With the evolution of product design, 3D MBD initiatives, and supply chain complexity, the integrity of 3D product data moving through the product lifecycle is absolutely critical to the success of any complex manufacturing program. This white paper explained the origins and realities of 3D product data engineering changes and offered organizational insights and initial steps to minimize the escapes in 3D product data that compromise product data quality. As organizations explore whether or not addressing "engineering escapes" is worthy of time or resources, perspective must shift. Detecting escapes is not just an opportunity to reduce costs; it is a legitimate profit center that proactively adds to the bottom line.

Minimizing engineering escapes result in dramatic cost benefits. When organizations that produce complex products across global supply chains identify and document changes to 3D product data, they can develop and implement processes that eliminate or minimize engineering escapes. Managing an effective change process requires quality 3D product data through each step in the "design factory," and ensures that the 3D MBD datasets contain accurate and detailed product definition throughout the entire lifecycle to avoid engineering escapes. In fact, preventing the added step of re-creating 3D product data can result in significant annual labor savings alone, ranging from $5M to $100M and higher.

Over the past fifteen years, ITI consulting projects revealed that engineering changes throughout the product lifecycle result in engineering escapes, or "unidentified changes to 3D product data that lead to a negative economic consequence." Escapes occur as a result of routine 3D product data exchange throughout the lifecycle and across the supply chain. Typically very costly in terms of labor waste, material, and part scrap, assembly errors, and manufacturing delays, escapes are often not thoroughly or accurately identified and measured. Until these issues are addressed, escapes signify lost revenue.

For companies looking at the bottom line in the manufacturing process while ensuring the "as-built" matches the "as-designed," managing engineering escapes may present a hidden opportunity to do both. Manufacturers must view the engineering change process as a potential profit center rather than accept that such losses are a natural part of the product development process. By applying the seven recommendations detailed in this white paper, organizations can start to identify potential risks, create a process, and reduce escapes in 3D product data.

About ITI, a Wipro company

ITI is the global leader providing reliable interoperability, validation, and migration solutions for product data and related systems. ITI solves complex product data interoperability problems so the world's leading manufacturers can focus on making great products. ITI is a wholly owned US-based subsidiary of Wipro, Ltd, and exists within the Wipro Engineering business. Wipro Engineering provides customers with a platform to innovate and engineer the next generation of products and platforms at scale.

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