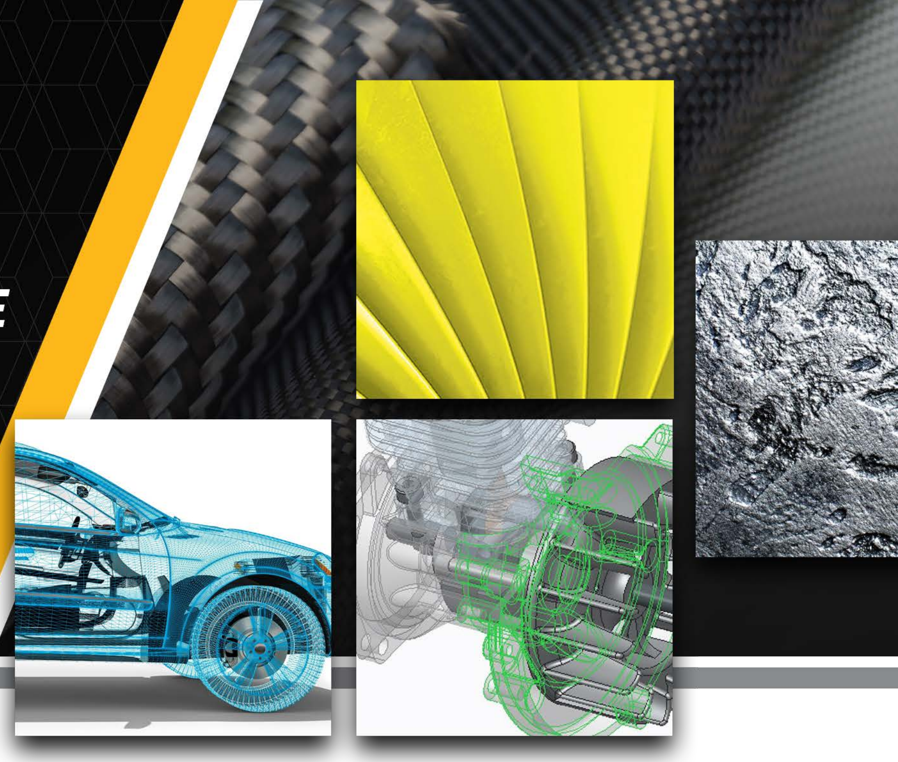
MATERIAL INTELLIGENCE for CAD, PLM and INDUSTRY 4.0

Arthur Fairfull, Stuart Baker,
Stephen Warde, Peter Cherns



Materials information is important. Your company needs to invest in managing this information. And it needs to integrate that managed information with enterprise CAD and PLM systems.

Why? Because materials are one of the four fundamental factors (together with function, shape, and manufacturing processes) in design decisions for every product. The choice of material(s) has a profound impact on reliability, manufacturability, cost and environmental impact.

Making such a choice is difficult because materials information is complex. A material is defined by hundreds of attributes, many highly-specialized and with their own lifecycles, which evolve independently of any related product lifecycles. But materials information management has matured. We cite multiple case studies, such as **Rolls-Royce quoting multi million dollar annual savings** from projects in this area.

A primary challenge is that success depends on collaboration between different disciplines – materials, design/CAD, product engineering, PLM and process engineering/improvement, and IT. Materials in particular has historically had limited systematic integration with the others. We present:

- An overview of the importance and complexities of materials information management, for PLM community readers.
- An overview of the evolution and vision of PLM and associated concepts such as the digital thread and Industry 4.0, for materials community readers.
- A “deeper dive” into the use cases that depend on the interaction between these capabilities, and the benefits obtainable.
- Assessments of best practices, checklists at the end of each section to help you consider your own company’s requirements, and an experience-based “how-to” approach to implementation.

We will demonstrate how to obtain maximum benefit from business-critical use case categories, including:

- Materials assignment, updating, and change management – ensuring consistent, accurate descriptions of materials in the product representations in CAD and/or PLM, and in calculations based on material properties.
- What to assign? Selecting the right materials, first time, in line with corporate strategies — cutting design cycles while enhancing quality and opportunities for innovation.
- Version control, traceability and materials-enabling the digital thread — critical if product designs are to be successfully audited, analyzed, and optimized.
- Understanding where materials are used in the product portfolio.
- Compliance analytics — e.g., managing restricted substance risks that can have enormous cost, reputation, and liability implications, including through the supply chain.

We conclude by describing the integration options and detailing implementation considerations. In different companies and industries, specific implementations of CAD and PLM technologies are at different levels of maturity and follow different strategies. We will therefore show how to deliver productivity, traceability, and time-to-market benefits today — while preparing to support tomorrow’s more visionary digital transformation and Industry 4.0 concepts.

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1. Introduction

1.1. Materials and the product lifecycle

There are four fundamental factors to consider in designing a new product. Firstly, obviously, is the function that the product needs to achieve. Then, we must consider the design factors that will determine how the product achieves that function — the shape ('geometry') of each part, the manufacturing process(es) by which the parts are made, and the material(s) from which they will be made (Figure 1).

The choice of material(s) has profound impact on the ability of the part/product to fulfill its functional requirements reliably, cost-effectively, and with minimum environmental impact. Material choice also interacts with the other variables to determine the viability and cost-effectiveness of manufacture — especially now when choosing between "traditional" and additive manufacturing options.

In this paper, we present best practices in the management and use of business-critical materials information, in the context of the product definition process — specifically through optimizing interaction with enterprise computer-aided design (CAD) and product lifecycle management (PLM). We will demonstrate how to obtain maximum benefit from the primary use case categories:

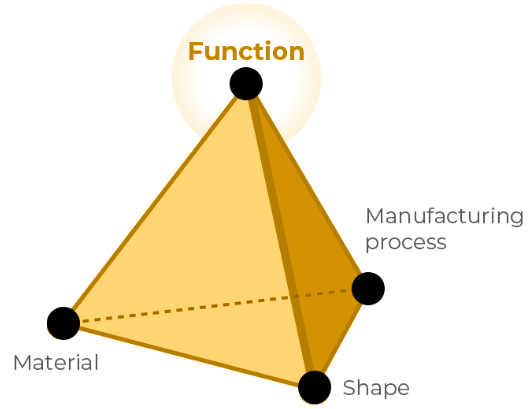


Figure 1. Design variables to achieve product function issues, legislation compliance implications, or other factors.

1. The core upstream **materials information management** which derives and supplies the approved, traceable, information for enterprise-wide use in design and product engineering —including consideration of supply chain processes and controlled propagation of data updates.
2. Use of that approved information in the **assignment of selected materials** to the CAD design and/or PLM product structure, thus completing the engineering definition and building out the bill of materials (BoM). Assignment completes the systematic workflow from requirements, through material/spec selection guidance, to product definition.
3. The ability then to run **analytics and reporting** on these assignments, enabling design optimization and risk avoidance by advising on cost or weight.

In different companies and industries, specific implementations of CAD and PLM technologies are at different levels of maturity and follow different strategies. We will therefore show how to deliver productivity, traceability, and time-to-market benefits today — while preparing to support tomorrow's more visionary digital transformation and industry 4.0 concepts.

1.2 Materials information management – what and why?

Materials are also one of the highest costs for a manufacturing enterprise, after personnel. Yet, while most businesses, rightly, invest in organizations and IT to manage human resources, investment in managing materials intellectual property has been small by comparison. Why?

The primary reason is that older generic database approaches struggled to support the required use cases, due to the **complexity** of materials information. A material may be defined by several hundred properties or 'attributes', many highly specialized in their nature and in how they are measured and recorded. Many of these attributes also have their own lifecycles, evolving with new test results, in-service information or analyses, or external factors such as legislation or price volatility. This makes managing materials information a very different proposition to managing HR or financial data — or even CAD data, which has relatively few attributes despite the large file sizes.

Our separate white paper The Business Case for Materials Information Technology [1] discusses the many motivations for managing corporate materials information. These include: reducing risks associated with uncontrolled data, removing the costs associated with finding approved materials information and maximizing the potential for innovation using materials knowledge.

Rolls-Royce have spoken of the multi million dollar annual savings from managing materials information

Materials information technology has advanced significantly over the last decade. Many forward-looking enterprises now have established materials information management systems in place and are reaping the benefits. Rolls-Royce, for example, have spoken [2] of the multi million dollar annual savings that they attribute to their materials information management program. For more case studies, see Section 2.4.

To understand how this significant corporate asset of materials knowledge can be fully leveraged in product definition, specifically in interaction with enterprise CAD and PLM, we first consider what we mean by PLM.

1.3 PLM – what and why?

Industry analysts such as CIMdata [3] and Gartner [4] describe PLM in terms such as "[PLM is] a strategic business approach applying a consistent set of business solutions to support collaborative creation, management, dissemination, and use of product definition information," and "[PLM involves] integrating people, processes, business systems, and information," and "[PLM is] a philosophy, process and discipline supported by software for managing products through the stages of their life cycles, from concept through retirement."

Note that none of these definitions refers to PLM as a single software system. Indeed, CIMdata says: "It is important to note that PLM is not a definition of a piece, or pieces, of technology." That said, we are all familiar with software environments such as Teamcenter® [5], Windchill® [6], ENOVIA® [7], and Aras Innovator® [8] being referred to as PLM systems. Differing perspectives notwithstanding, we can at least be clear on the **core objectives for PLM**:

1. Universal, secure, managed access and use of the [digital representation of] product definition information.
2. Maintaining the integrity of that definition and related information through the product's life.
3. Managing and maintaining business processes used to create, manage, disseminate, share and use the information.

Search the internet and you will quickly find any number of images illustrating the collection of technologies and software required to fulfill these criteria. We compiled Figure 2 from some typical PLM software product illustrations. Note that very few of these illustrations call out the digital representation of engineering materials — the critical component addressed by the technologies and strategies described in this white paper.

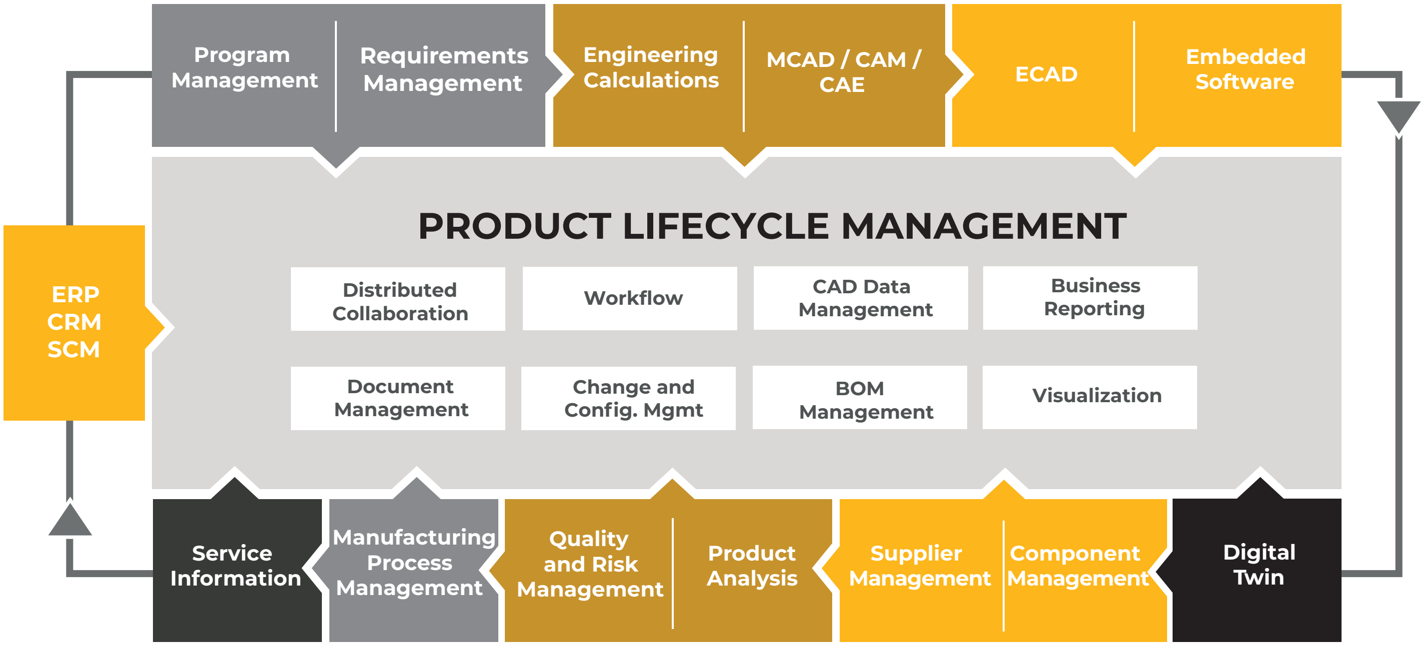


Figure 2. A typical software-centric illustration of PLM.

Meanwhile, the very latest thinking on PLM, as part of digital transformation and Industry 4.0 initiatives, brings high visibility to the **traceability** of data objects via **Digital threads**. We shall consider the evolution of PLM methodologies in Section 3, and show how to ensure materials support for whatever level of technology your company is implementing.

1.4 Bridging the disciplines: materials information in product lifecycle context

So materials data is highly specialized. A material may have hundreds of properties, each with its own supporting web of data and its own lifecycle. Creating information structures to capture and manage this richness is inherently complex. Meanwhile, a spectrum of product definition approaches are in use across different companies, ranging from basic CAD through the latest visions of PLM and the digital enterprise — but in all cases, the materials knowledge from the company and its supply chain must be made available in a controlled way for application to the digital product representation. We will show how to ensure support of the required use cases by optimizing the “touch points” and synchronization between these different and complementary information lifecycles and technologies.

2. In more depth – materials information management

2.1 The complexity of materials information

Materials property information is remarkably rich, and the data types required to represent it are varied. The simplest is a list of single-point numerical values, but even these need to have appropriate engineering units and numerical precision. Moving then to ‘multi-point’ values, these represent the variability of material properties with parameters such as temperature, pressure, or strain rate. This may be accomplished via sequences of data values, by coefficients of functions or equations, by a combination of data points and superimposed functions, or by curve definitions including logical operators (e.g., “use one set of coefficients below strain value X, then different coefficients above that value”).

Other materials data types include text and notes, images, documents, media files, and discrete or logical values such as the flammability rating sequence of HB, V-2, V-1, and V-0. Link relationships between multiple records can also be a powerful tool, such as one record describing a material and one describing a coating used with that material, where the coating thickness is an attribute on the link, in turn drawn from a specification held in another data table.

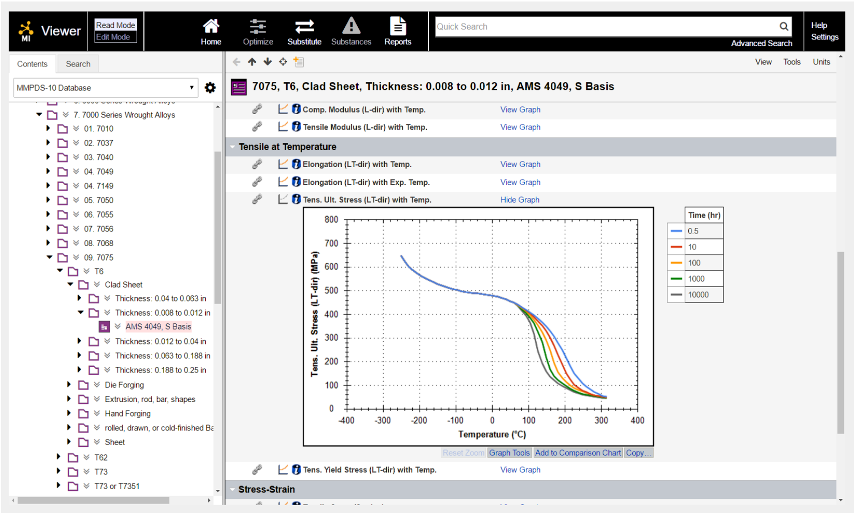


Figure 3. Typical materials information (for an aerospace alloy) including multi-parameter curve data.

Creating the **structure** to efficiently store, manage and represent all of these data types is a challenging requirement. Being able to search them effectively is another. A user request might be “Which aluminum forging alloys, available in our plant in Europe, have a fatigue strength of at least 300 MPa at 100,000 cycles at room temperature?” A dedicated materials software approach is required.

2.2 Every property has a lifecycle

A further complexity comes from the fact that materials information is not static – rather it "lives" and is subject to regular updates (Figure 4). Different attributes of the same material can have different, independent lifecycles. Few of these **property lifecycles** relate to the lifecycles of the products to which the materials are assigned.

Materials information is not static. It "lives." Properties have their own individual lifecycles.

Examples include:

- Engineering properties that are updated when additional test results are available; behind any number used in design may lie a web of hundreds of connected pieces of test data and analysis.
- Properties that are updated when a supplier or processor is changed.
- Pricing information, which is market-driven.
- Legislation information, updated frequently by government agencies and environmental bodies.

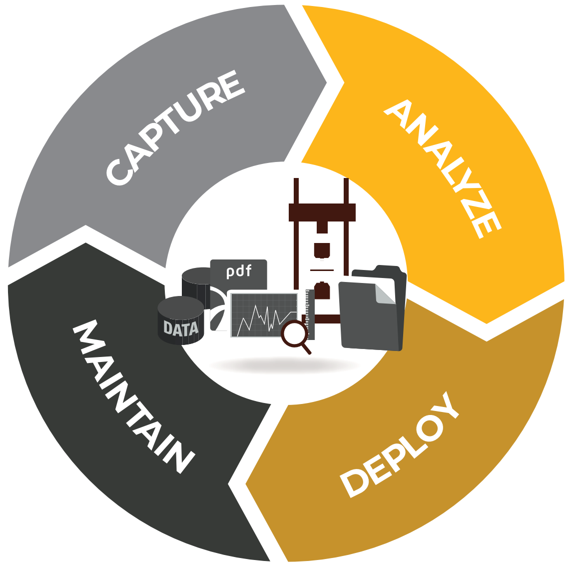


Figure 3. Typical materials information (for an aerospace alloy) including multi-parameter curve data.

2.3 Defining best practice: the MDMC

The **Material Data Management Consortium** [9] is a collaborative project that pioneered best practices in management of materials information.

Early in its existence, the project identified the importance of the materials information lifecycle illustrated in Figure 4 – the need to think about the **capture** of materials data, its **analysis** to create useful information, the **deployment** of that information where it is needed, and **maintenance** of that information leading to ongoing iterations.

The software embodiment of the work of MDMC members is **Granta MI™** [10], the leading system for materials information management in engineering enterprises. By implementing this software, applying it, sharing the knowledge gained, and providing review and input over many years, members have not only contributed to development of a system aligned with industry needs, but have developed best practices according to the requirements of each phase of the materials information lifecycle.

Most successful materials information management projects have met the requirements outlined above through implementation of specialist commercial off-the-shelf software. In-house developed systems, while achieving some initial successes, have tended to be replaced sooner or later due to the high costs of on-going year-on-year maintenance and upgrade.

Aerojet Rocketdyne	Fokker Aerostructures	Lawrence Livermore NL	Rolls-Royce
Airbus Helicopters	GE – Aviation	Lockheed Martin	SAFRAN
ASM International	GKN Aerospace	Los Alamos National Lab	Sandia National Labs
AWE	Honeywell Aerospace	NASA	Sulzer
Boeing	IHI Corporation	Northrop Grumman	United Technologies Corp
Embraer	Kansas City Plant	Raytheon	US Army Research Labs

Table 1. Members of the MDMC, June 2019.

2.4 Case studies of materials information management

More information on these case studies and webinars can be found at the Ansys and Granta websites [11]

- **PSA Peugeot Citroën** is using materials information technology to manage the data required for their simulation activities.
- **A global automotive OEM** is implementing a program of 'Materials Lifecycle Management' including integration with their enterprise PLM.
- **A leading supplier** of electrical and electronic components has built a system to manage material data for CAE and other applications, rolling it out to 1,400 engineers enterprise-wide.
- **Aerojet Rocketdyne** presented at an Ansys webinar on the business value of materials data management.
- **Ansaldo Energia**, spoke at an Ansys webinar on the value of materials data management to ensure error-free component design.
- **Embraer** discussed their implementation of a system to manage restricted substance reach at an Ansys webinar.
- **A leading medical device manufacturer** has created a single "gold source" for corporate materials information, including support for answering vital "patient on the table" questions relating to their medical devices.

Section 2 CHECKLIST!

Don't currently have a materials information management system? Review **www.grantadesign.com/industry/success-stories** and **www.grantadesign.com/mdmc** to learn about successful active systems in your industry sector.

3. In more depth – materials in your PLM strategy

There is no need to repeat here the ample coverage in the literature of the evolution of PLM. It is, however, relevant to note key trends, and the role of materials information in the different scenarios. Given the broad spectrum of possibilities, it is important to understand both the current approach and future PLM vision in your specific company — as this will determine how best to optimize materials integration to ensure support of the required use cases.

1970s

Traditional drawing-based design. When products were defined by drawings, materials were specified in a 'box' on that drawing—directly, or as specifications defining the materials and related processing or finishing. There would also be numbered notes, specific to the product design.

1980s

CAD-based design. The advent of CAD brought various flavors of computerized drafting, solid modeling, parametric modeling, and 3D design. Although 2D drawings remained a primary output, the focus became attributes of the 3D model. These included materials information, with materials assigned to CAD parts, and associated information written to parameters and notes to appear on drawings.

1990s

Product Data Management (PDM). As CAD workflows grew more sophisticated, PDM evolved with it as a means of managing CAD design files and their versions/configurations. With time, PDM began to manage a limited number of additional attributes 'attached' to those files. Many companies using 'PLM systems' today are still primarily in this mode of PDM/CAD data management. It is still fundamentally CAD structure-centric.

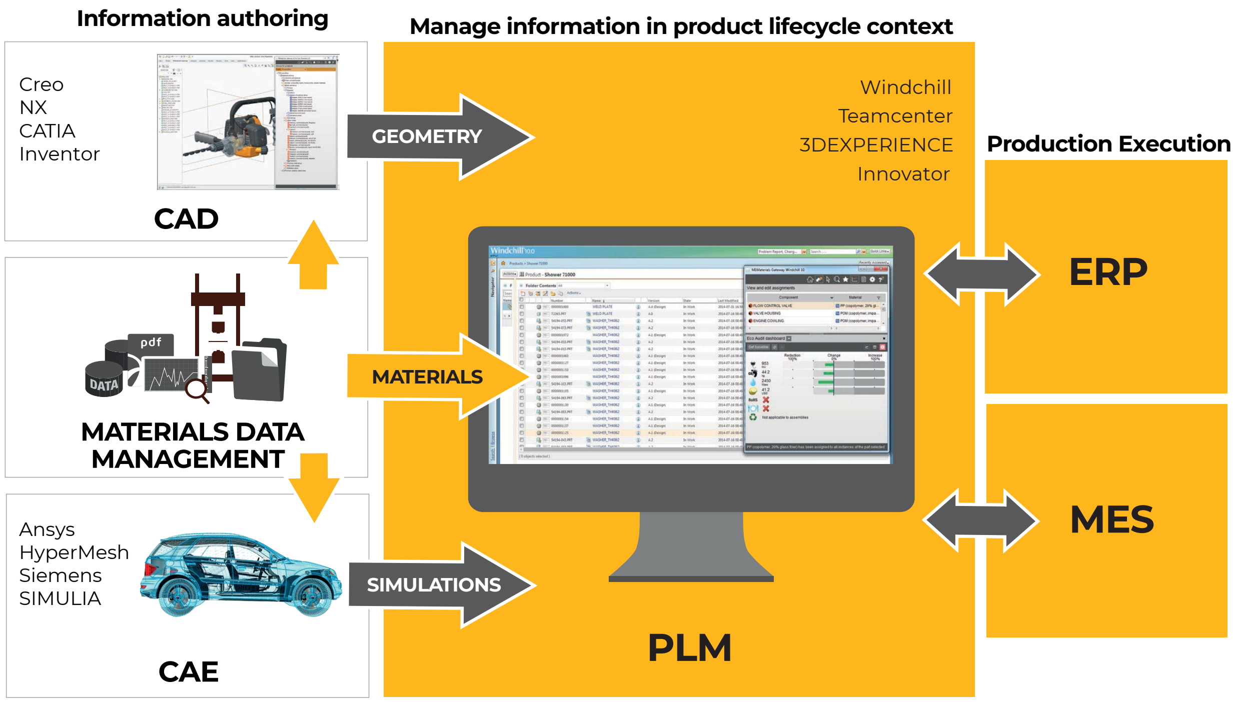


Figure 5. The materials information management system fulfills a similar role to CAD or CAE, authoring specialist data into the PLM product definition.

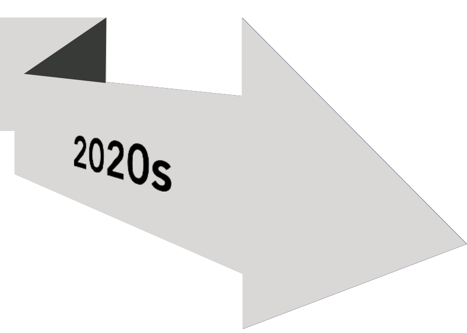
/ 3.1 From drawings to fully-integrated PLM

The timeline below shows the evolution of CAD and PLM approaches from managing technical drawings to the latest PLM-centric world. Across these different approaches, there remain two main means of authoring representations of materials into the digital product definition:

- **Assign materials in CAD**. Materials are assigned to attributes parameters on the CAD parts. PLM manages the resulting CAD documents, but may not be able to “see into” them to access information on the assigned materials.
- **Assign materials to the PLM product definition.** Materials are assigned directly to the PLM product definition, alongside the CAD geometry. This requires either:

  a. The PLM system itself to provide a native materials “first class object” and associated data structure, or

  b. A bespoke material object to be defined in PLM for/by the material authoring tool, to which the information can then be assigned.



PLM representation-centric. “True” PLM moves away from CAD-centric representations toward complete digital product structure representation, with CAD geometry being but one category of “object class” — and materials as another. The product definition here features a broader bill of materials (BoM) structure — including such aspects as paints and lubricants, electronic components, and even embedded software, none of which have geometry representations in CAD.

Digital thread, systems engineering, and model-based enterprise. The latest thinking seeks to pull together the benefits of CAD/configuration-centric and PLM-BoM/lifecycle-centric approaches into an enhanced and unified product structure, modeled at a systems level. Throughout the product lifecycle, the traceability of the data objects within this structure represents a digital thread.

Materials information management systems need to support both of these options—see Section 5.1, and Figure 5.

Manufacturers are at varying stages along the path of adoption of PLM approaches and technology. Smaller companies typically remain CAD-centric, perhaps using PDM/PLM for CAD data management. Larger enterprises are likely to have implemented enterprise CAD data management, with steps towards 'full' PLM. The most advanced have global PLM or model-based 'digital transformation' programs in place. Over time, we can expect to see on-going transition from CAD-centric to PLM-centric — with the speed of implementing cultural change a more dominant factor than the availability of the technology.

3.2 Real-world PLM: mixed environments

For the fully-integrated PLM vision, the primary vendors' solution suites provide comprehensive and highly capable functionality. But single-vendor environments for all of a company's CAD, CAE and PLM components are rare due to local preferences for specific functionality, requirements for suppliers to use the same tools and formats as the OEMs they supply, and legacy from mergers and acquisitions.

The existence of multiple **CAE** tools in particular is common, as different systems have complementary specializations.

For **CAD** software, the picture is different. Numbers are large (CAD users typically outnumber CAE users at least ten-to-one) and so for efficiency the ideal is for a single system. But this may not always be viable — in addition to the effect of mergers and acquisitions, it is still common (neutral data formats such as ISO 10303 STEP [12] notwithstanding) for OEMs to require suppliers to use a specific version of a specific CAD tool on their projects.

For **PLM** software, the challenge is the substantial investment and IP built into typical deployments — in proprietary data model customizations, workflows, complex application integrations, and data revision and synchronization procedures. Legacy systems resulting from mergers and acquisitions (or from different original strategies for PLM and ERP) may coexist for decades.

> ***Materials information management needs to support real-life mixed CAD, CAE and PLM environments.***

Reality at most manufacturers is therefore a **variety of tools from different vendors**, with varying degrees of success in integration and automation between them. Materials information management needs to support and fit into these real-life mixed environments and their evolution.

3.3 Native materials models in PLM

We saw above that materials information systems could either write relevant data to a native PLM "materials object," or could define and populate a custom object. But, until recently, PLM systems have not provided native materials object models out-of-the-box. The **Integrated Material Management (IMM)** module for Siemens Teamcenter [13] was the first specifically-targeted capability of this type, while the **3DEXPERIENCE** platform from Dassault Systèmes [14] now features a first version of a materials model with support for CAD and simulation.

As native data model objects, these materials models can take direct advantage of the parent PLM infrastructure — including concepts such as revisioning, classification and sub-types. Nonetheless, information to be used directly in calculations — whether in CAD, CAE, or downstream systems such as ERP — still needs to be in a format understandable by that system. Again, where all tools are from a single vendor, this associativity can come "out of the box" but for mixed environments as discussed above, the data translation still needs to be done somewhere in the process, whether by the material authoring tool or otherwise. Overall, however, these developments are progressively advancing product definition technology, making materials information easier to apply and the concept of a full digital product representation more complete.

3.4 Other considerations – cloud, access rights

In considering touch points between a materials system and PLM, there are two additional practical factors to bear in mind:

Much is currently being made of **cloud-hosted** PLM capabilities. As a broad generalization, cloud PLM solutions tend to be more oriented toward logistics, process management, and task automation, rather than in-depth design data management and data processing involving direct interaction with CAD geometry. This may influence supported use cases, but is unlikely to affect interaction with materials information technology. Web-based systems such as Granta MI, with underlying web-services API's, can in principle equally readily support on-premise or cloud-hosted interaction.

Regarding categories of system user, every CAD user typically has **access rights** (i.e., a log-in) to the PLM environment, in its function as CAD-data manager. But the reverse is often not true. Product stewards, EH&S, commodities, and senior management can get significant value from consulting PLM on the implications of material choices in products, but are not CAD users. So "smart" interaction with engineering CAD data must be successfully managed 'behind the scenes' by the materials system, to present PLM management reports and analytics on the implications of materials choices.

Section 3 CHECKLIST!

- New to PLM? Considering the options outlined in this section, find out about the PLM initiatives that your company currently has in place, and its future vision.
- Keywords to look out for include Industry 4.0 and digital transformation. Such projects could have budgets to which your materials project could be attached!

4. Materials integration with CAD and PLM – the key use cases

4.1 Materials assignment and change management

The fundamental link to the design process occurs when a user identifies a material in the company database and **assigns it to a part** in a CAD model or PLM product definition. Data associated with that material then becomes available within the CAD or PLM system, so it can be used by subsequent calculations and tools. The value of this is substantial — all the designers, managers, analysts, engineers, purchasing agents, etc. that interact with this information will then know that they are analyzing or specifying the same approved material. Further benefits follow where the assignment brings with it property data — for example, density for accurate mass roll-ups, CAE models for simulation, or environmental properties for risk analysis.

Figure 6. Simply ensuring use of approved materials in Design, and automatically designating them on drawings has substantial consistency benefits.

Beneath this apparently simple requirement, however, lurk many challenges, including:

- **Helping users to find the right material** — this requires robust, intuitive browsing and searching tools (which enable engineers to find materials in the way they would expect; for example, by searching for a spec, a pre-approved shortlist, or a particular combination of properties).
- **What data is transferred?** It's unlikely to be efficient to transfer all of the many properties that might be associated with a material to CAD or PLM when, typically, just a handful are needed. So assignment tools need to be configurable to transfer the required data (e.g., density, color, selected mechanical properties) for the task in hand, while retaining a "live link" so that further properties can be accessed on-demand.
- **Transforming data** — there may not be a simple match between specific attributes needed in an engineering tool and those produced by materials tests. (CAE material models are a good example, as they must be expressed in precise, system-specific formats known as material "cards.") Assignment tools therefore need to be able to transform data from one format to the other and, again, must be configurable for a company's specific models.
- **Change management, version control, and updating data** — how do we preserve a "live link" and version information from assignments in CAD or PLM, enabling designers to be notified if materials they have specified have since been updated, so they can choose whether to apply later versions.
- **Materials variants** — what if a designer can't find a material that meets their needs? Rather than using the wrong material, or finding uncontrolled data outside the company, they should be able to trigger a request to their materials team to investigate or approve suitable variants.

Three key themes are **traceability**, the need to **manage the specifics** of materials information, and the need for **configurability** to real engineering environments and workflows.

> ***Key themes are: traceability, managing the specifics of materials information and configurability***

Best-in-class capability in addressing these requirements embeds an app in the host CAD system, as shown in Figure 7, that provides a view from within CAD, CAE or PLM into the corporate materials knowledgebase. The user searches or browses for a material, then simply clicks to assign it to a part. Relevant property data is copied across automatically, together with unique identifiers enabling the host system to reconnect to the corporate materials database at any point to find additional, new or updated data for that material.

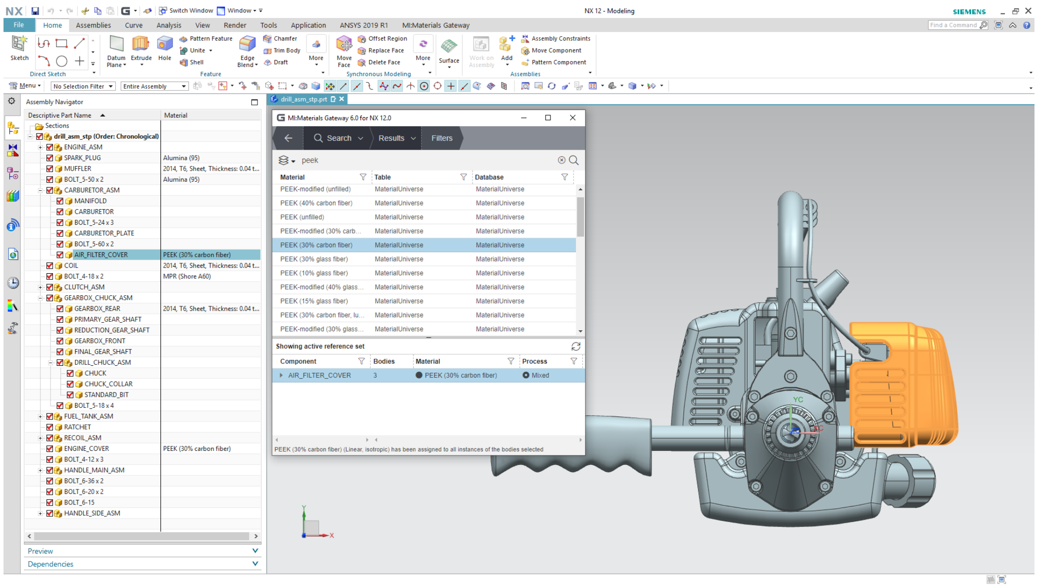


Figure 7. MI:Materials Gateway [15] embedded within a host CAD system, in this case NX.

4.2 What to assign? Materials selection guidance

While assigning a material can be achieved with a single click, identifying what that material should be can involve significant data-processing and knowledge access — especially, as is often the case, when the expertise embodying company rules for choosing materials lies elsewhere in the organization. We may therefore wish to formalize provision of “material intelligence” to guide designers in the choice or use of materials or to deploy corporate procurement or substitution strategies. We may want, for example, to classify materials with designations such as ‘preferred’, ‘acceptable’, ‘do not use’, or ‘obsolete’. Or perhaps the initial choice for one specific application may not necessarily be the best choice for the enterprise because it conflicts with strategic objectives such as rationalizing the number of material suppliers.

> ***Designers can be helped to align their individual materials choices more closely with company materials strategy.***

Overall, building-in such guidance via integration with CAD and PLM helps ensure individual design decisions are aligned with company materials strategy.

4.3 Change control, traceability, and the digital thread

Traceability is the essence of the digital thread, itself a fundamental tenet of PLM. If a company cannot trace a piece of information attached to a product back to its source, including "unpacking" any previous versions, it cannot truly be said to have control over the whole lifecycle. Furthermore, opportunities could be missed to improve product performance or minimize risk by redesign; to ensure fast, effective failure analysis; or to enable fast response to customer or regulatory requirements. Efficient integration of materials information has a fundamental role in supporting this traceability objective.

Further, when considering materials in product context, we find that **the definition of a material itself evolves** during the progression from design to manufacturing (Figure 8). In conceptual design, a material may be referred to as glass-filled nylon, or even simply "strong stiff plastic", whereas at the end of the design process, the material specified for procurement is a specific grade. How the material is defined between these points varies. In some cases, a specific definition is used early: The material in the engineering bill-of-materials (EBoM) emerging from the design process may already be the specific version subsequently called out in the 'manufacturing bill-of-materials' (MBoM). Elsewhere, a CAD designer may simply specify 'aluminum'; then, following guidance from CAE, a materials authority will update that assignment via PLM to specify Alloy 7075 in T6 condition. Different manufacturing locations or supply chains may also specify different materials. The result can be one-to-many relationships at each of the process handovers in Figure 8.

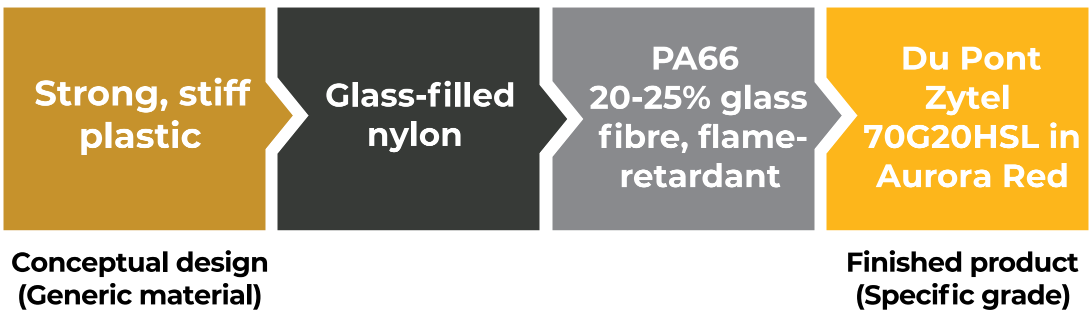


Figure 8. Evolution of the material definition through the product lifecycle.

The materials integration with CAD and PLM must therefore support relating the specific material(s) in the MBoM back to the less tightly defined material in the EBoM and potentially back to the generic representation in conceptual design.

4.4 'Where used?'

"Where is this material used?" is a deceptively simple sounding question with multiple scenarios in which the answer can be crucial.

When considering a plastic for a new product, for example, a designer may want to know where else in the company's product portfolio that grade has been used, so that knowledge from earlier applications can help to optimize the design of the new product or to avoid risks. If a material has been rendered obsolete by a new regulation or through supply problems, the company needs to find out quickly which of its products use that material to enable mitigation strategies. Where a material substitution has proved successful in one product, the development team will want to find out where else they could benefit.

Answering the "Where used?" question requires systematic management of materials information, to ensure consistency in the description of the material. And it requires this material representation in the product definition, such that we can easily search for it in PLM. We should also think about who typically wants to answer such questions. Often, these users may not be familiar with the detailed operation of either the materials or PLM systems, so they need intuitive apps to understand materials implications (Figure 9).

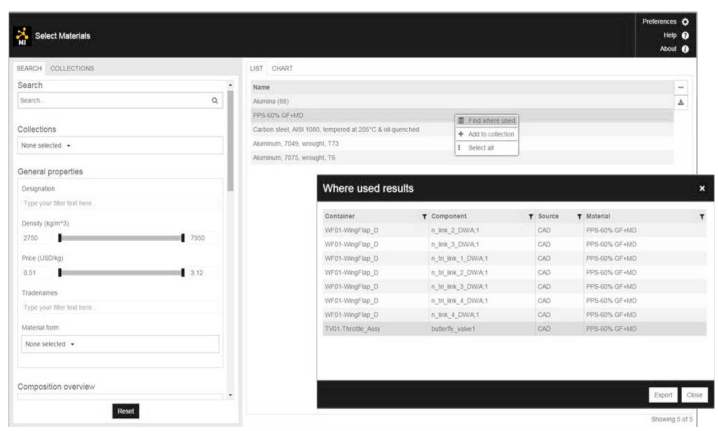


Figure 9. A "Where used?" app providing a simple interface for a query that combines data from the materials information management and PLM systems.

4.5 Compliance analytics

Combining material and product data through an efficient assignment process also enables development and application of quantitative "product intelligence". A high-value example concerns the challenge associated with restricted substance regulations such as REACH. These have multi million-dollar implications in key materials becoming obsolete, disruptions to supply, or simply large amounts of time handling customer and regulatory enquiries.

Most approaches to meeting this challenge focus on time-consuming data-gathering exercises designed for analyzing finished products. But these break down where the availability of primary data is limited. And it is also greatly preferable to be able to quickly analyze likely regulatory impact during early-stage design, **before** most of the costs have been committed, i.e., to enable design for compliance, rather than reporting after the fact. As it happens, the key decisions are those on materials or processing.

The solution is to connect bills of materials (whether these originate in PLM, in other legacy data stores, or are constructed as part of a conceptual design process) with materials records in the corporate materials information system [16]. If those materials records can in turn be linked to reliable reference data that is regularly updated on at-risk substances and the regulations that impact them, then we can easily run compliance analytics (Figure 10) based on this data to, for example, understand whether a design may incur a restricted substance risk, or whether a new regulation impacts existing products.

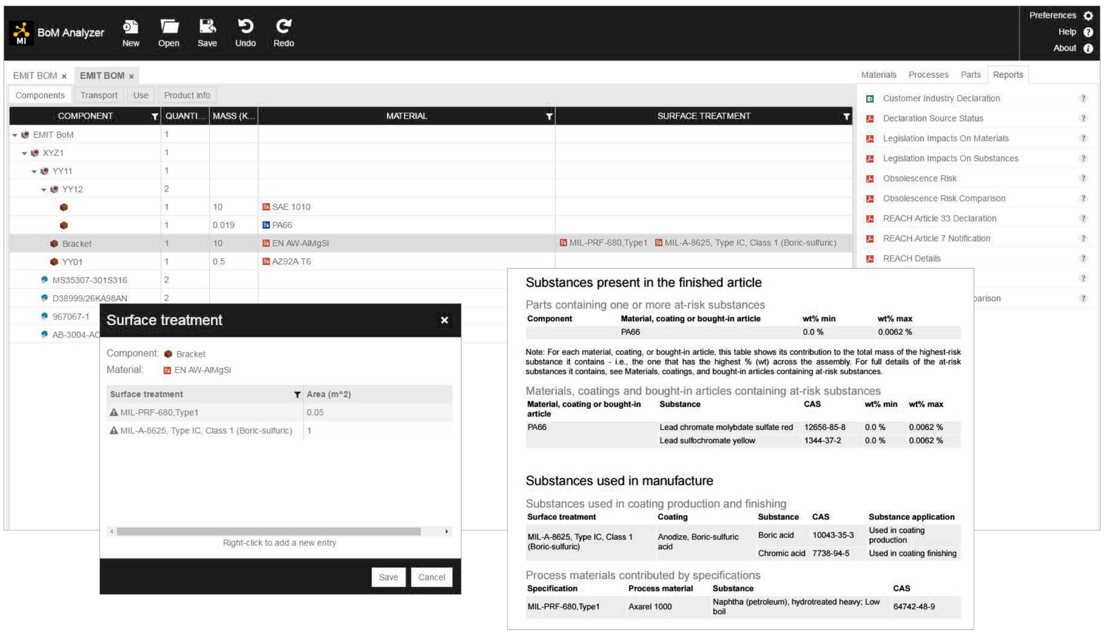


Figure 10. Analyzing compliance for a product by connecting material and surface treatment data in Granta MI to bill of materials data from PLM.

Section 4 CHECKLIST!

- If you're hearing "We need materials to be in our PLM environment," then this is the section to help you determine what that might mean.
- Study and use Appendix I to help get an initial overview of your company's requirements and key potential use cases.
- Discuss with data producers (materials dept, supply chain), data consumers (design teams, product engineering, etc,) and other key stakeholders (IT, process improvement).

5. Structured implementation

5.1 PLM/CAD connectivity

What technologies enable enterprises to meet the use cases outlined above? Here we discuss four technology options for achieving this integration. The appropriate option, or mix of options, will depend on specific IT environment, systems, and use cases.

- **Embedded apps** running within the host CAD or PLM system and connecting to the corporate materials database. These can enable materials to be assigned as attributes or parameters on a CAD part, enable them to be directly assigned into the PLM product definition, or enable a combination with assignments being synchronized between the CAD and PLM models. See Section 5.2.
- **PLM data model integration** gives you the ability to author approved Design subset(s) of the data collated and managed by the corporate materials database into the PLM system's own materials data model. See Section 5.3.
- **Stand-alone apps** created using federated services within the corporate materials database enable applications to communicate and exchange data with both your corporate materials database and third party software. (This technology was used to develop the "Where used?" app in Figure 9).
- **Formatted data export/import** is an option for design or simulation tools not yet supported by the options above.

5.2 A case study of an embedded app

At the time of writing this updated version of this white paper (March 2020), **Granta MI:Materials Gateway** is at version 6.

Key capabilities include:

- Searching and browsing your materials databases; assigning materials (and related processes) to parts in CAD or PLM; assign materials models within CAE.
- Access control to ensure users see only data for which they are authorized.
- Configurability so that you can map properties in your materials database to your CAD and PLM system, and decide what data is transferred with a material.
- The ability to tramsform data into the CAE models required by simulation tools.
- Access to dashboards and reports provide product intelligence analytics within CAD and PLM.
- Full traceability for materials, and associated data transferred to the host system.
- Notification when a newer version of data becomes available in the database.

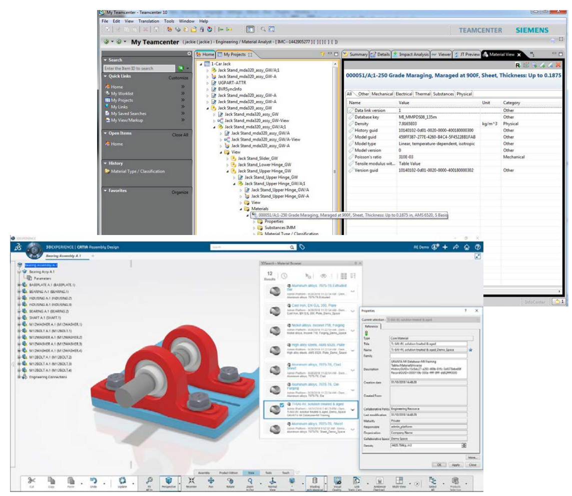


Figure 11. Materials data in the Teamcenter and 3DEXPERIENCE PLM systems. In Teamcenter (left) you can see the 'GUID' live link traceability attributes.

A key point here is the ability that this brings to support the type of heterogeneous engineering software environment typically found in today's corporations, as outlined in Section 3.2.

5.3 A case study of PLM synchronization

A second technology example is provided by a partnership between Siemens PLM and Granta to support Teamcenter Integrated Materials Management (IMM) [14] shown above in Figure 11. While employing the full power of Granta MI to manage the complex lifecycle of materials information for every material and property of interest, this option **enables the deploying company to author into PLM** the subsets of data approved for design, from where they can be assigned and used by Teamcenter tools and workflows. The "live link" to the Granta MI source is retained, providing traceability, and supporting updates as data changes. This also enables Granta analytics tools to operate on the resulting assignments, even though in this instance these assignments were made by Teamcenter. The integration maintains synchronization between the enterprise Granta MI and Teamcenter databases, in line with the materials version control and updating criteria specified by the materials authority administrator.

The MI:Enterprise Connect technology has also been proven in the context of the 3DEXPERIENCE platform from Dassault Systemes.

/ 5.4 Proven implementation project approach

Effective delivery of materials information management and its integration into your enterprise CAD and/or PLM environment can be a significant project, demanding careful planning and the appropriate implementation experience. A typical project (Fig 12, overleaf) would involve working with key data-producing, data-consuming and IT stakeholders in a proven structured implementation approach — with example categories of work including:

Analysis – defining the "as-is" and "to-be," and the resulting implementation plan:

- Sources of data, how data needs to be processed and updated, and any access control restrictions such as ITAR, or projects for different OEMs.
- Usage of data, including the categories of users, their software tools and workflows, and the data formats and interface mechanisms of 'downstream' systems such as ERP that will require particular data on each material.

Implementation

- Refine the resulting database structure (or 'schema') to capture the required data and its formatting.
- Configure importer technology for data upload.
- Implement tools to support: data cleaning, linking of related data (e.g., materials to substances), and mapping between different descriptions of a material.
- Arrange initial population of the database(s), such as by converting the data formats from existing legacy systems.
- Configure integration technologies to enable assignment from the corporate materials system into CAD and PLM, and/or establish protocols to populate PLM with material intelligence, e.g., preferred materials lists.
- Configure additional apps, e.g., for 'Where used?' or restricted substance reporting.
- Arrange interfaces with other systems, as required.

Deployment

- Server and client software installations.
- Training.
- Progressive roll-out from development to test to production environments.

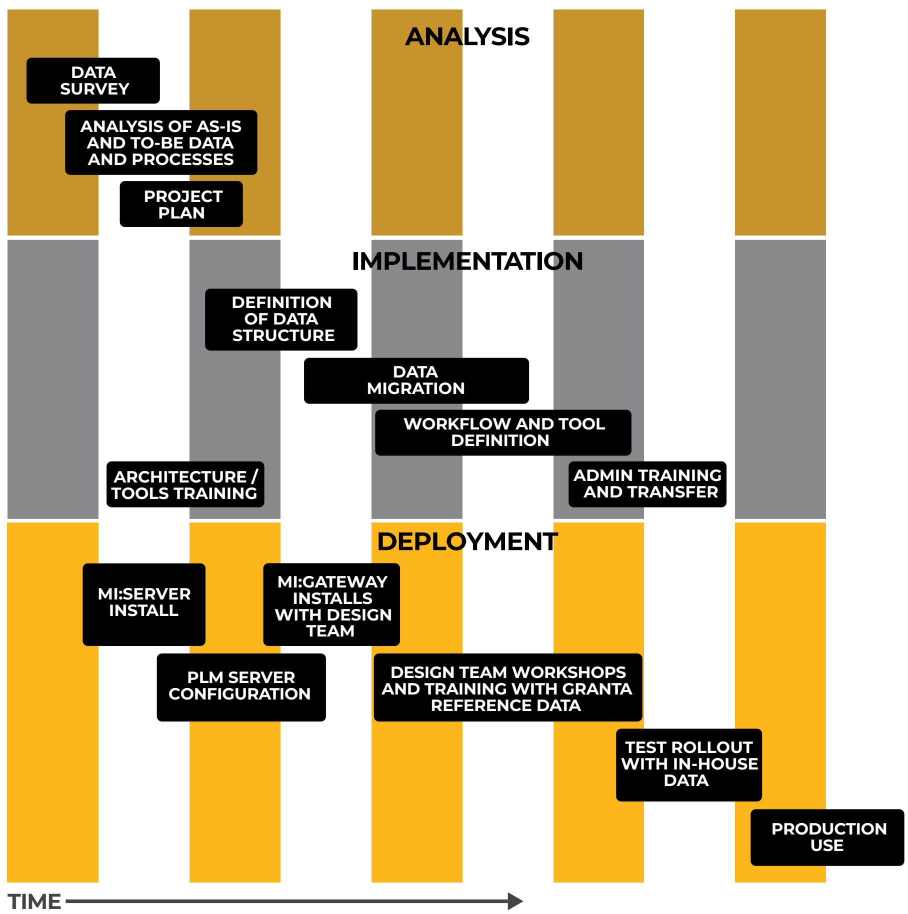


Figure 12. A typical implementation process.

Section 5
CHECKLIST!

- Contact Ansys Granta to discuss your requirements, experience of similar implementations, and an outline of the likely project steps.
- Study and use Appendix II to get an initial overview of your company's requirements and key potential use cases.

6. Conclusions

In this paper, we summarized the value of materials information, citing examples where managing this valuable corporate asset has provided multi-million dollar returns to engineering enterprises.

We have explained that even greater benefits are available through the effective integration of this information with key processes and technologies that drive overall product definition — particularly enterprise CAD and PLM. In different companies and industries, specific implementations of CAD and PLM technologies are at different levels of maturity, and follow different strategies. Use of a best practice materials information management system **complements and integrates with any or all of these options** — delivering productivity, traceability, and time-to-market benefits today, while supporting tomorrow's more visionary PLM and Industry 4.0 concepts when you're ready to deploy those.

We, of course, advocate the Granta MI system, which meets all of these requirements and, as the leading commercial off-the-shelf system, benefits from significant on-going investment in development and maintenance, in partnership with an established worldwide user-base and customer consortia.

Whatever your approach, based on our experience summarized in this paper, we suggest that assessment of your requirements should include consideration of the questions in Appendix I. The answers to these questions can have a significant impact on the design of your solution architecture, the phasing of your implementation project, and thus the schedule by which the benefits will become available.

Appendix I. Top 20 considerations for planning materials integration with CAD and PLM

1. Where and how are materials decisions implemented in your company, and by whom? What content and format of information do these personnel need? What information do they produce? What are the implications of using inaccurate or inconsistent material data?

2. Can you draw a diagram of the desired flow of material data through your company's systems? Start with where the information is authored, then where it is assigned (to product definitions), and where else it may be used ('consumed'). What are the interfaces?

3. Does your product definition process involve materials, specifications, or both? What level of specifications do you require your system to handle — materials, surface treatment processing, others?

4. Do you need to implement best-practice materials information management

   (a) in new product development going forward,

   (b) in analyzing knowledge and experience from existing product designs,

   (c) in both?

5. In creating digital product representations, does your company need to assign materials to the CAD design model, the PLM part model, or both? Is this expected to change with any next generation PLM plans or visions? Is product configuration done in PLM or elsewhere, and how is this related to engineering product representations?

6. Do you need to build the business case for systematic materials information management — a pre requisite for effective deployment of materials information to CAD and PLM — or have project experiences/issues already highlighted the need ? Which of the more fundamental requirements listed in Appendix I of this paper are most applicable? (See also our separate white paper, specifically on business benefits [1].)

7. What are the criteria by which you will determine the data published to design? Will this include centrally-defined guidance such as preferred materials categorization, and if so, will such guidance be company-wide or product-specific?

8. Are there one or more legacy materials databases in your company, perhaps owned by other departments or due to a company merger, that you'd like to import into the new system? Are there common materials across these systems, or do they cover different areas?

9. Do you need to include materials data provisions from your supply chain, and if so will the suppliers need direct access to your system — for example to reference your materials standards, to provide batch testing data or to make declarations?

10. Are there other external third-party materials data sources that you need, or would like, in your overall materials system?

11. Do you need assistance (for example from best practice developed by peer organizations) in optimum structuring of data on "new" materials and processes – notably additive manufacturing and/or composite materials?

12. Determine if your company has active initiatives (and project budgets) in any of the following. If so, discuss the key role of materials information use cases with the respective director(s) – digital thread, digital twin, Industry 4.0, digital transformation, MBSE, process Improvement/Six Sigma, sustainability.

13. What are the most dynamic aspects of materials that you use — color, texture, engineering properties, price, legislative impact? How often do you need these aspects to be updated (a) for/by your materials specialists, and (b) for the approved information published to design? How should this synchronize with data revisioning in PLM?

14. Consider the process of assigning and updating materials, and which users have write-access. Do materials specialists using PLM need to update materials assignments in CAD? Are there requirements for materials updates in CAD to be propagated to PLM? How are materials requirements made at the conceptual/design studio stage propagated?

15. List the Styling, CAD, CAE, CAM, PLM, ERP, etc. tools that will access your managed materials data. In each case, what is the version currently in production use, the roadmap for upgrades and the specific materials information required to support the desired use cases? Do you have a heterogeneous CAD environment, and/or different PLM and CAD suppliers?

16. Who are the users of each of these Styling, CAD, CAE, CAM, PLM, ERP tools? In particular, what reporting and analytics on materials implications (such as mass roll-up, costs, substance content, etc.) are required by non design personnel consulting or using these systems?

17. Outside direct use in the CAD, PLM, and other software environments, what materials information "deliverables" do you need from your system — e.g., designations and surface treatment specifications to go on drawings; risk assessment reports for management; material names, spec numbers and colors for ERP; material assignments to 3D models for your website?

18. What other aspects of "material intelligence" would you like to introduce to your product design process via CAD and PLM. e.g., enabling designers to request and define variant materials, providing guidance on trade-offs between engineering, cost and environmental implications?

19. Specifically, do you need a solution for analyzing environmental impact and regulatory (restricted substance) risk? Does this solution need to support design risk assessment (i.e., DfE), product compliance verification reporting, or both? Who currently produces these assessments, and are they related to accurate 3D design data or estimated?

20. Determine how your company's cloud strategy relates to PLM. What data will be stored remotely, how will materials information interact with this, and what are the processes and system interfaces you will need to consider?

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ANSYS, Inc.
Southpointe
2600 Ansys Drive
Canonsburg, PA 15317
U.S.A.
724.746.3304
ansysinfo@ansys.com