SIEMENS DIGITAL INDUSTRIES SOFTWARE

Integrating requirements with the entire product lifecycle

Accelerating product design with requirements management to deliver products that customers need

Executive summary

By enabling product developers to capture product requirements and tie these requirements to decision-making across every stage in the product lifecycle, Teamcenter® software facilitates a wide variety of business initiatives, including lean design, quality improvement, product test and integration, material management, regulatory compliance, design verification and strategic sourcing.

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Contents

Overview	3
Managing requirements to meet customer needs	3
The role of requirements management	3
Business issues	6
Value of connected requirements	8
Combining systems engineering with requirements management	10
Capturing and decomposing your requirements	11
Leveraging requirements for process improvement	13
Bottom-line benefits	15

Overview

In today's highly dispersed global economy, developing the next generation of autonomous, electric, connected, and shared vehicles that meet the needs of your customers is not easy. You may have to deliver products to global markets defined by ever-changing market demands, customer profiles, regulatory and homologation requirements, and consumer preferences. You may develop your products in an extended enterprise that spans multiple geographic, organizational, and technological borders. You may need to adjust your product designs mid-stream to account for new technology, changing regulations or rising market opportunities.

In a world like this, all product makers face the prospect of runaway costs, schedule delays, market-place failures, embarrassing errors and avoidable rework in every product development program.

When faced with so many design and development challenges, you need to adapt your processes. How can you accelerate your product design in a creative, secure, affordable, and efficient way and get it right first time to edge out the competition?

The role of requirements management has become more essential than ever before in determining the success of product development. Independent studies have repeatedly shown that a development process will not result in a successful product offering unless the products you deliver are rigorously aligned with up-to-date and accurate marketplace requirements and customer expectations.

Managing requirements to meet customer needs

Almost all of today's automotive manufacturers and their suppliers need an effective solution for enabling their products to satisfy customer and stockholders. Requirements management facilitates this business objective by providing the following basic benefits.

Cross-discipline communications Most companies implement their product development programs in enterprises that cross multiple disciplines, organizational boundaries, and geographical borders. Product requirements provide these diverse participants with a common language, a collaborative backbone, they can employ to determine what customers want. Equally important, requirements enable developers and other lifecycle participants to assess the entire vehicle as a single system to determine how to address trade-off issues (such as cost, quality, schedule, performance, and regulatory constraints) that typically arise during product development.

End-point definition Product requirements enable developers to determine "when they've arrived" at an optimal product design, manufacturing solution or serviceable product. In essence, requirements provide developers with a quantifiable means of determining what is "too much" or "too little" in terms of product content. Product requirements let developers establish "end points" for each stage in the product lifecycle.

Quality definitions According to internationally known quality experts like Philip Crosby, "quality" is defined as conformance to requirements. This gives rise to a simple and compelling question – how will you know if you have a quality product, if you don't understand your customers' requirements?

Overview

The role of requirements management

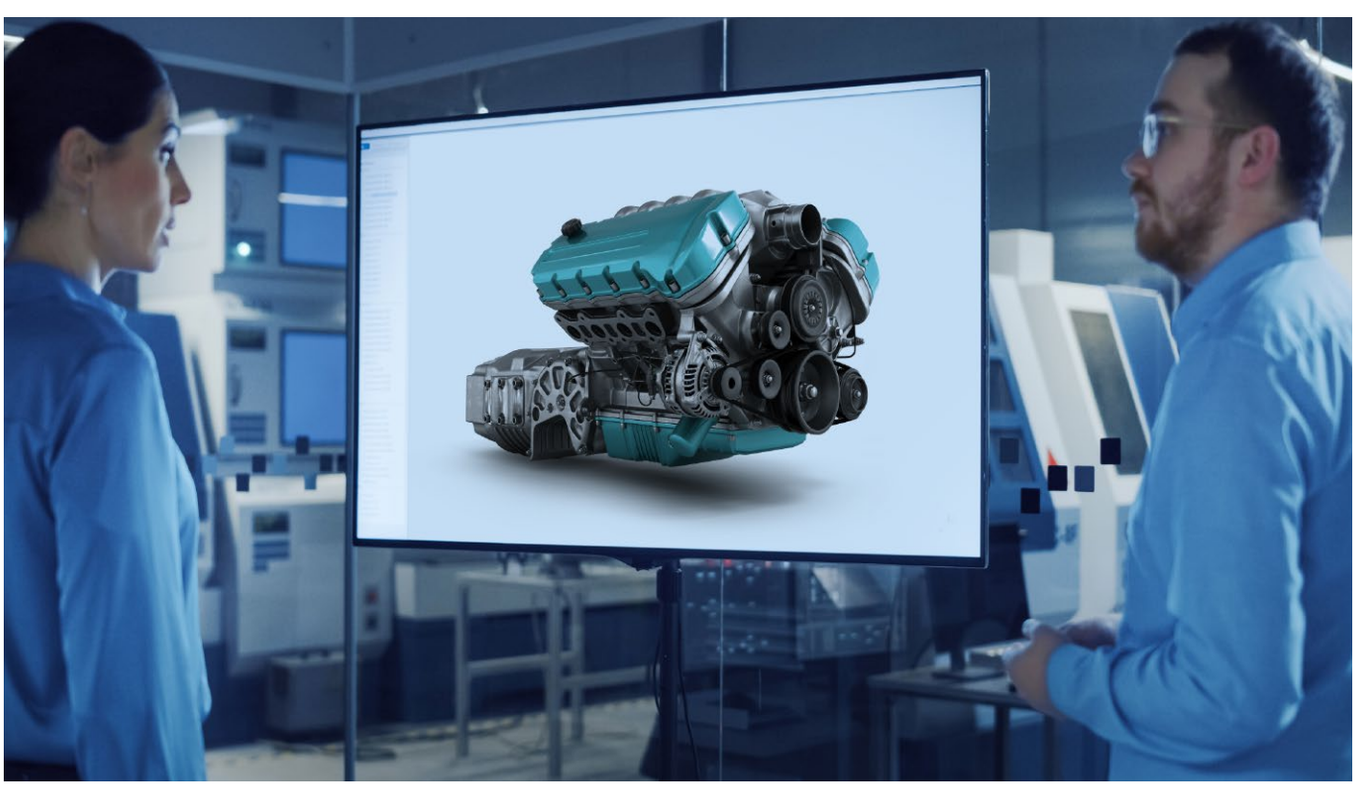
Given their importance, almost all organizations manage requirements in some way – Word documents, Excel spreadsheets being the most common or standalone requirements tools. Teamcenter also addresses your company's need to define, manage and leverage product requirements on a repeatable and rigorous basis by providing unsurpassed requirements management capabilities. Teamcenter Requirements goes beyond managing requirements to enabling requirements to drive product development by linking captured requirements directly into the product development cycle. As a result, Teamcenter enables global product development teams to fully understand how product requirements evolve across the product lifecycle and the impact that these changes will have on product design, as well as the impact that design changes will have on the product's requirements. It provides a connected, automated ecosystem that allows teams to identify and resolve design issues that do not comply with requirements, at every step of development. It is therefore possible to ensure the final product performs, reducing warranty and eliminating recalls.

Teamcenter facilitates customer needs management by meeting three key imperatives.

- Teamcenter enables your company to understand what its target market and customer base want in terms of documented expectations, preferences, standards, and regulations and allows your enterprise to capture this information from multiple sources as product requirements.

- Teamcenter allows you to link these requirements to fine-grain design elements that you can trace across the product configurations and definitions that describe a product's various lifecycle states.

- Teamcenter supports cross-discipline losed loop feedback by recognizing when your program constraints are in danger of being violated, when changes to your product requirements and design elements occur and what impact design change has on product requirements – as well as the impact of changed requirements on product design. This enables you to avoid issues during manufacturing, assembly, or in the field.



Overview

These basic Teamcenter capabilities enable requirements to flow throughout your product development process and function as a basis for decision-support that directly influences:

- Machine tool design and factory layout decisions
- Man-machine interface/ergonomic decisions
- Upgrade planning and product family management decisions
- Validation decisions (e.g., initiated by alarms triggered during CAE analysis)
- Schedule/resource decisions (e.g., by assessing impacts associated with proposed design / requirement changes)
- Configuration change decisions (e.g., by evaluating changes made against actual product models)

To optimize this decision-making, you can implement Teamcenter to support a variety of business initiatives including:

New product development and introduction, where companies focus on increasing the revenue potential of right-to-market products while validating new ideas against market opportunities. This focus facilitates product and service innovations that enable new products to hit the ground running ahead of their competitors, thereby improving the likelihood that customers will buy these products.

Global product development, where companies leverage global teaming to gain 24x7 product development efficiencies.

Lean design, where development teams are able to eliminate over-design by fully understanding what customers want for a price they are willing to pay and implementing end points for every stage in the product lifecycle.

Quality initiatives (such as Design for Six Sigma, ISO and QFD-driven programs), where the early definition of quality measures enables product developers to design-out defects and improve quality.

Product test/integration and design validation, where product developers link individual requirements directly into their test and integration processes so that test execution is able to verify product compliance.

Regulatory compliance and material management, where developers capture an array of regulatory requirements to ensure regulatory compliance and auditability (such as environmental regulations, technology mandates, extended producer responsibility legislation and end-of-life vehicle directives, as well as security, fiscal and financial and medical considerations) as the basis for analyzing products at the material, substance, part, assembly and rolled up BOM levels.

Strategic sourcing, where procurement teams inject component requirements and their related design definitions into automated bid processes, thereby enabling prospective suppliers to fully understand development needs and decision makers to effectively assess potential suppliers in terms of design capabilities, quality, and cost considerations.

Product family management, which enables enterprises to establish product platforms with connected requirements that can be managed, re-used, and optimized across whole families of similar product offerings. Product makers typically adopt these initiatives when they want to maximize their revenue by rapidly delivering product enhancements, derivatives, niche offerings and add-ons.

Business issues

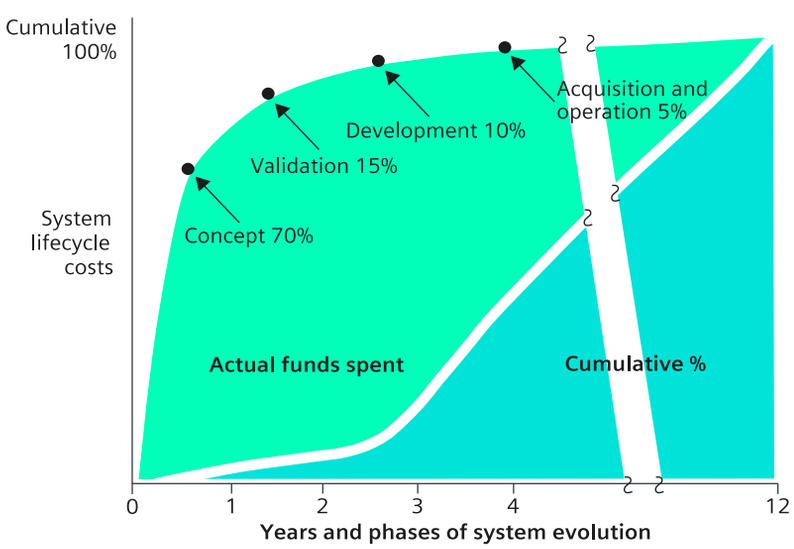
With requirements outside of Teamcenter, you have limited means to keep them synchronized as changes take place. The result is an isolated set of requirements maintained across multiple computers, in diverse documents that nobody reads, behind user interfaces that require lengthy learning curves, or in databases that don't reflect current product context or configuration. With parameters constantly changing, this lack of integration can lead to the late discovery of problems, design flaws and non-compliance, as changes in one domain impact another.

In the early 1990s, Texas Instruments conducted a landmark study that quantified this problem and its impact on business efficiency. The study found that the failure to capture, understand and keep up with project requirements results in runaway development costs 70 percent of the time. More specifically, seven in ten projects that failed to keep their requirements up to date resulted in programs that were either over budget, behind schedule or unable to accurately define their endpoint.

Symptoms of runaway development projects
Late cycle engineering change notices
Need for heroic integration efforts
Dubious quality (requirements misaligned with customer/market expectations)
Highly expensive documentation

Texas Instruments also discovered that even projects that employ some form of document management, database management or tracing tool have high run-away rates. In essence, this result showed that capturing requirements alone is not sufficient to ensure project success.

Texas Instruments concluded that requirements isolated from the product development cycle cannot effectively influence product design. What you need instead is a connected requirements environment that directly links product requirements to the digital ecosystem, providing a single source of up-to-date information for developers to design and validate your products.



Phases in the product lifecycle contrasted with actual funding spent.

Business issues

Phases in the product lifecycle contrasted with actual funding spent.

Approach to requirements	Runaway probability
Projects that ignore requirements	7 out of 10
Projects that capture requirements in document form	5 out of 10
Projects that capture requirements in a database	4 out of 10
Projects that capture requirements with a tracing tool	4 out of 10

As the seminal Texas Instrument study indicates, maintaining up-to-date product requirements is one thing; having them influence product design is another. Siemens Digital Industries Software's requirements management capabilities derive their power from Teamcenter and its ability to connect product requirements into the product development cycle. This connection enables an enterprise's continually updated requirements to influence design decisions while development is happening to accelerate product development.

Value of connected requirements

Connected requirements deliver an impressive array of benefits, including:

- **Increased marketplace success.** In today's highly competitive global economy, automakers cannot expect their products to financially succeed unless they comply with the requirements, regulations, standards, expectations, and preferences of their target markets. To ensure that products are aligned with today's marketplace demands, product developers – and everyone else who participates in the product lifecycle – need to tangibly understand how their decisions will impact a wide array of product requirements. Teamcenter enables developers to trace the impact of product decisions to fine-grain design items ensuring auditable traceability throughout the entire development process.

  Equally important, when requirements are captured and tracked in a Teamcenter-managed PLM environment (which supports a robust set of knowledge management, process management and collaboration capabilities), developers are able to leverage everyday tools that they already understand to assess the impact of their iterative product decisions. As a result, product developers are able to fully explore alternative design solutions with an eye to optimally satisfying a mix of customer/marketplace demands and cost/scheduling program constraints while avoiding performance problems and non-compliance.

- **Reduced development cost**, which occurs when enterprises are able to optimize the early stages of the product development, where the cost of your lifecycle is most dramatically affected, to identify and correct design flaws. For years, consulting companies have used the accompanying chart to explain the relationship between cost containment and cost realization. As the diagram on page 6 illustrates, nearly 90 percent of the cost of a project is fixed by the time a product reaches the development stage in its lifecycle. In essence, as valuable as your downstream cost efficiencies may be, they can only influence about 10 percent of your lifecycle cost. In contrast, the early stages of product development – where requirements are defined – provide you with the opportunity to realize your most significant cost savings potential.

  Teamcenter enables developers and downstream participants in your product lifecycle to understand your product requirements as early in the lifecycle as possible. The earlier these teams understand your requirements, the less rework they will have to perform. This saving is especially important when rework has to be performed late in the product lifecycle (e.g., after your manufacturing tools and production facilities have been built and need to be changed to accommodate unforeseen requirements).

Value of connected requirements

Connected requirements deliver an impressive array of benefits, including:

- **Accelerated time-to-market**. In today's global economy, product makers need to implement agile product development processes capable of repeatedly and systematically accommodating ever evolving product requirements to get designs right first time. Changing consumer preferences, new technological advances, and rising business opportunities require product developers to keep up to date with the competition. Teamcenter provides developers with continuous access to real-time feedback they can use to quickly understand changing requirements and their impact on product design to discover the configuration that best meets targets and requirements in the shortest time possible and quickly eliminate non-viable options. Teamcenter also enables developers to assess the fine-grain impact of changing requirements on specific parts and components – as well as the product definitions that support and sustain these design items. Teamcenter can be implemented so that developers are notified when design items and their related program constraints are at risk.

- **Shorter test and integration cycles**. Test and integration cycles often take up as much as 50 to 60 percent of a product's overall lifecycle. Teamcenter enables you to link requirements with your test cases and verify that product content meets your customer and market requirements. You can use Teamcenter to monitor and report on test results and establish complete traceability and audit trails for each requirement.

  Teamcenter can automatically generate test documents and specifications to describe conducted tests and their results. It also enables you to enforce a test methodology where tests are rerun automatically to verify that a re-designed product still is compliant. By allowing you to build requirements-related compliance into product test and integration, Teamcenter minimizes both the cost and cycle time required to perform this crucial process.

- **Optimum product quality**. Many companies invest millions of dollars implementing Six Sigma quality initiatives only to discover that they have hit the 4-Sigma quality wall. This shortfall is largely attributable to the fact that quality initiatives cannot reach their full potential simply by improving downstream stages in the product lifecycle (e.g., manufacturing-oriented processes). Teamcenter lets enterprises incorporate Six Sigma quality goals into early lifecycle stages, thereby designing-in quality, and designing-out defects. Industry analysts estimate that a 2-Sigma improvement reduces the cost of quality by as much as 25 percent of product sales.

Combining systems engineering with requirements management

Referring back to Texas Instruments' landmark study, the study's authors were surprised to discover many runaway projects where developers had implemented extensive design specifications and trace matrices but ended up designing to the wrong set of requirements. The study concluded that the only way to ensure that you have the right set of requirements is to map your requirements to the problem that you are trying to solve. Given that issue, it becomes extremely important to answer the following fundamental question:

How do you arrive at the correct set of requirements?
Siemens Digital Industries Software believes systems engineering is the answer to this question.

Systems engineering is an interdisciplinary approach to product realization that enables you to understand each of your products as a whole – and better architect the processes you use to plan, develop, manufacture, and sustain your products.

Companies leverage systems engineering to model / analyze the interactions between a product's requirements, subsystems, constraints, and components and optimize the tradeoffs that drive crucial decisions across the entire product lifecycle. System architects can use models, such as TRIZ, as a means of identifying alternative ways of accomplishing objective criteria and then designing these criteria as requirements that comprise the overall systems definition.

Development teams can implement a variety of Siemens Digital Industries Software capabilities to gain the whole product understanding that is essential to systems engineering.

- Teamcenter's Systems Modeling Workbench enables you to implement a systematic and repeatable approach to systems engineering in the planning stage of your product lifecycle. System Modeling enables you to assess and understand each product that you develop in its totality, including its high-level strategic roles – as well as the requirements, regulatory compliance, and program constraints that the product is expected to meet.
- Teamcenter's requirements management solution allows you to define each of your product development programs in terms of its captured requirements and then link these requirements to fine-grain design items. In addition, Teamcenter can manage, validate, update, and audit these linked requirements throughout every stage in the product lifecycle.
- NX™ WAVE for System Based Modeling uses managed top-down control structures to logically develop and manage interpart geometric dependencies that allow developers to understand how changing values buried deep within the part and assembly structure affect the final product model.
- NX Knowledge Fusion drives product designs up front by enabling developers to leverage external requirements and knowledge databases, as well as to embed knowledge rules inside existing designs for the purpose of encapsulating stimuli/results sequences.
- NX simulation, validation and optimization tools enable product developers to: 1) validate design alternatives against defined requirements during the early stages of concept design, 2) validate the design model against multiple CAE requirements during product test and validation and 3) check the design for compliance against corporate standards and processes.
- Teamcenter's environmental compliance solution allows product developers to validate product compliance with multiple environmental regulations – such as European Union directives on Restriction on the use of Hazardous Substance (RoHS) and Waste from Electrical and Electronic Equipment (WEEE), extended producer responsibility (EPR) legislation and end-of-life vehicle (ELV) requirements.

This white paper describes Teamcenter's ability to facilitate product development through the use of requirements capture and communication. Other white papers address Siemens Digital Industries Software's overall approach to systems engineering, NX solutions and Teamcenter's environmental compliance solution.

Capturing and decomposing your requirements

Requirements can originate from Teamcenter's own systems architecting application (System Modeling Workbench), as well as from documents, standards, problem reporting databases, competitive intelligence, customer meetings, focus groups and assessments provided by field service/support groups.

Teamcenter's requirements management solution supports all of these sources by enabling you to:

- Capture/import documents and spreadsheets, usually using Microsoft Word or Excel as the standard import mechanism
- Leverage a fully exposed web-based API to deposit requirements directly into the Teamcenter database
- Leverage various requirement exchange standards including RIF, ReqIF and others

Once you have captured a product's requirements in Teamcenter, you can use its robust knowledge management, process management and collaboration capabilities for a wide variety of purposes (as indicated by the accompanying table).

Teamcenter function	Business value
Requirements traceability	Teamcenter enables you to establish a complete set of product requirements that are traceable back to their sources. This capability is especially valuable for supporting regulatory compliance, where product makers need to be able to show regulators how their products – and substances, materials and components that comprise them – meet specific compliance thresholds at multiple levels, from concept through production.
Web application	The web-centric nature of Teamcenter's requirements management capabilities allows all entitled users continuous access to product requirements, specifications, and feedback through standard Internet browsers. The groupware nature of these capabilities ensures that all team members work from the same set of requirements with access to reports and Teamcenter's viewing and editing capabilities in real-time. Since each requirement, function, property, and relationship in your hierarchical Teamcenter product view has a unique web address, you can create web-based processes to leverage every product requirement, implant these references in documents and emails, and directly respond to routed review documents and change requests.

Once you have captured a product's requirements in Teamcenter, you can use its robust knowledge management, process management and collaboration capabilities for a wide variety of purposes (as indicated by the accompanying table). (continued)

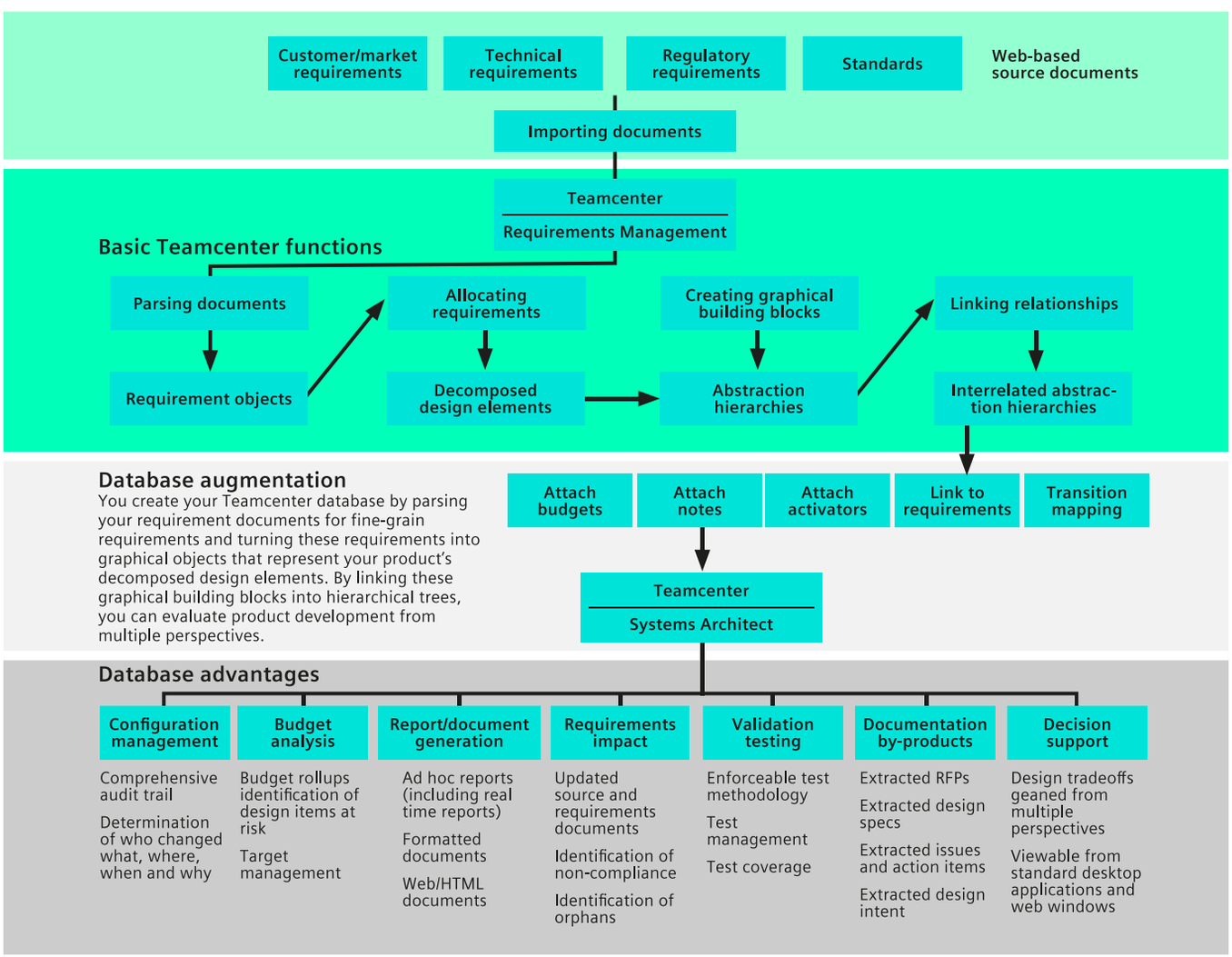
Teamcenter function	Business value
Windows desktop interface	Teamcenter's requirements management capabilities are fully integrated with common Windows desktop applications, including Microsoft Word and Excel. As a result, users are able to understand and leverage your product requirements through desktop applications they already understand. Similarly, you can expose Teamcenter-managed requirements into a real-time Teamcenter community collaboration environment available through standard web browsers so that invited team members can navigate your requirement documents, edit these requirements, and use your community's discussion threads, routing facilities and action item lists to support requirements-related tasks and assignments.
Connected requirements	Teamcenter enables you to leverage its knowledge management capabilities to decompose your product requirements to the fine-grain design elements that comprise your product configurations and their related definitions. Equally important, Teamcenter enables you to deliver these connected requirements to everyone in your extended enterprise at the point of decision.
Quality documentation	Teamcenter can generate documentation as a by-product of your systems architecture and requirements capture processes. This enables you to produce documents of known quality with complete traceability. Along these lines, you can use Teamcenter to trigger report generation when design-related events or API calls occur. You can incorporate up-to-date requirements information into these reports in user-defined formats, including spreadsheet and document-specific formats. This capability is especially valuable for users who want to produce "live" spreadsheets for direct editing of the requirements database. Users can define the requirements-related information they want to generate into their documents, as well as produce those documents in any standard Microsoft format. They also can associate a format or template with a report and generate documents directly from the requirements database. These documents provide "live" windows into the database (i.e., changing the document also changes the source document in the database). Since documents can be emailed or posted, users who open these documents and change their content actually change the database.

Leveraging requirements for process improvement

When you manage your requirements in a Teamcenter-enabled PLM environment, you can leverage these requirements throughout your entire product lifecycle. Eventually, you can use this integration to establish bills of materials that evolve across your as-required, as-designed, as-planned, as-built, and as-maintained lifecycle states.

The Teamcenter tool that you employ for requirements management uses the same database linkages that other Teamcenter solutions employ. As a result, your enterprise is able to leverage a single source of requirements, product and process information across your entire product lifecycle.

Teamcenter enables product requirements to flow throughout the development cycle so design teams can make decisions that comply with the product's most up-to-date and compelling parameters, constraints, and requirements. Because your requirements are linked to Teamcenter-managed design elements, your development teams can proactively understand the impact of product requirements on design content – as well as the impact of design changes on product requirements to get the design right first time.



Once requirements are integrated into your Teamcenter-based PLM environment, your enterprise is positioned to "push" impact-related information into a wide variety of processes that facilitate product development speed and improvement, including:

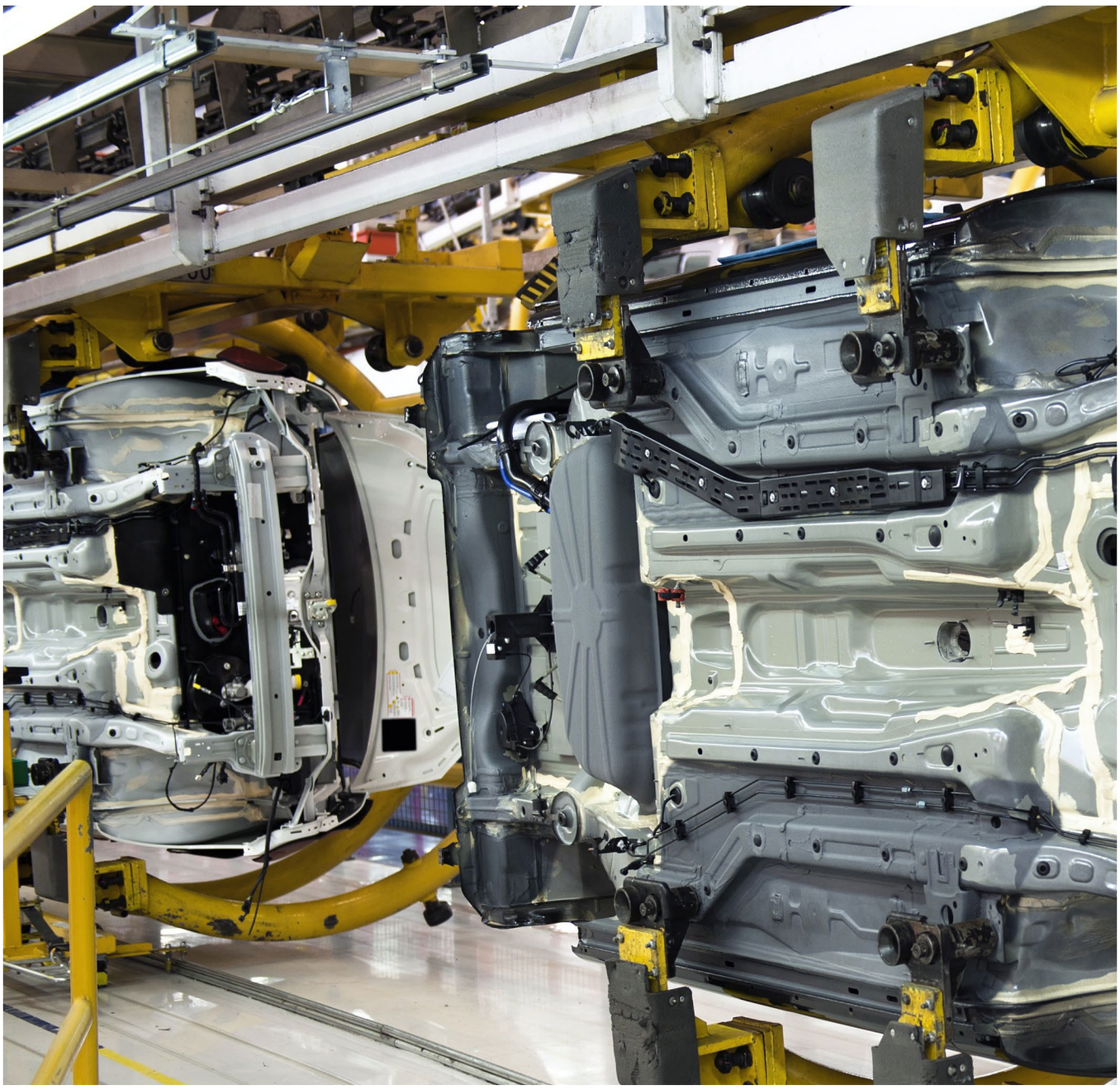
Your test and integration process You can leverage Teamcenter to link individual product requirements directly into your product test and integration procedures. This ambitious approach enables product requirements to drive your test procedures so that the execution of specific tests verifies that a product complies with high-level and fine-grain requirements. Since many development projects are in flux up to the last moment, test and integration almost always appear on the project's critical path. Connecting product design and test/integration provides management and product developers with unimpeded visibility to the impact of test results on product change – as well as providing your test/integration groups with visibility to the requirements they need to verify.

Your project and program management controls Teamcenter-managed requirements can be integrated with project and program management solutions (such as Teamcenter's program execution management solution) to determine the impact that requirement changes will have on project schedules and resource plans. Conversely, the linkage between requirements and your resource/scheduling data enables you to study the impact that changing resource allocations have on product requirements.

Your material management/regulatory compliance processes You can apply Teamcenter to your process for making materials decisions. Recent European Union and U.S. regulatory rules require that manufacturers assume responsibility for product disposal. By enabling companies to evaluate and account for these regulatory requirements when materials decisions are being made, developers can design compliance into their product offerings early in the product lifecycle – thereby ensuring regulatory compliance while minimizing disposal costs. The recent experience of a leading electronics manufacturer demonstrates these savings. In this instance, the manufacturer's products were held on its docks for two months until the company could prove compliance – a delay that resulted in an estimated loss of EUR 110 million.

Your design verification process You can leverage Teamcenter to establish automated processes that verify that product designs are compliant with critical requirements. In CAD-driven design processes, this level of implementation enables development teams to verify that features, materials, clearances, dimensions, and other design factors meet criteria established by your
Teamcenter-managed requirements. These solutions can highlight non-compliant conditions by using 3D product models to visualize requirement-related design violations and assess the impact of specific design/requirement changes across domains.

Your strategic sourcing process You can introduce Teamcenter-managed requirements into your strategic sourcing initiatives so that you can be assured that components procured from your suppliers meet your product requirements at the best possible overall cost. Teamcenter enables you to deliver requirements to suppliers early enough in the product lifecycle to allow them to adjust their components or suggest alternative approaches that will meet your requirements while simultaneously satisfying your cost objectives. A major Teamcenter customer recently implemented this approach and secured a 25 percent savings in bottom-line product cost as a result.



Bottom-line benefits

Implementing a requirements management solution does not, in and of itself, result in substantive product lifecycle improvement. But connecting requirements into your development processes does deliver the break-through benefits that you have come to expect from product lifecycle management. Teamcenter provides a collaborative data backbone to connect requirements to your design elements so that your development teams can understand the impact of changing designs/requirements by using tools and processes they already understand.

By marrying the advantages of Teamcenter's requirements management capabilities with your PLM infrastructure, you can repeatedly and systematically implement automated processes across every stage in your product lifecycle to accelerate product development – as well as re-use these processes in new product programs and continuous improvement initiatives.

To learn more about Siemens' requirements management capabilities,
contact your Siemens Digital Industries Software sales representative today.

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For additional numbers, click here.

About Siemens Digital Industries Software

Siemens Digital Industries Software is driving transformation to enable a digital enterprise where engineering, manufacturing and electronics design meet tomorrow. Xcelerator, the comprehensive and integrated portfolio of software and services from Siemens Digital Industries Software, helps companies of all sizes create and leverage a comprehensive digital twin that provides organizations with new insights, opportunities and levels of automation to drive innovation.

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