Crossing the Innovation Chasm

How to Unlock the Business Value of Systems Engineering

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> "When innovative ideas are captured, there are assumptions about the underlying requirements, the consumers, the service provider, the end user, and so on. As design is undertaken, those assumptions are often lost in over-the-wall communications. Oracle's PLM Cloud solutions are focused upon eliminating those disconnects first and foremost by assuring that the defining data is carried cleanly and consistently through each communication boundary."
>
> **CIMDATA**
>
> ORACLE'S PLM CLOUD CONNECTS PRODUCT MASTER DATA FROM IDEATION TO COMMERCIALIZATION, 2016

Executive Summary

» In our increasingly digital world, how quickly organizations can uptake new product design and development competencies, such as systems engineering, dramatically impacts market success. The innovation and development of today's products can be significantly impacted by the efficiency and effectiveness of systems engineering capabilities available to design and development organizations. A survey of systems engineering effectiveness, sponsored by the National Defense Industries Association (NDIA) and conducted by the Software Engineering Institute, proved 'project performance' to be significantly higher when systems engineering (SE) capability is moderate or high compared to projects with lower SE Capabilities. Systems engineering capabilities describe a broad range of processes and best practices and are focused around requirements management (RM), test management (TM) and system architecture (SA) for this treatise.

Project Performance vs. Systems Engineering Capability

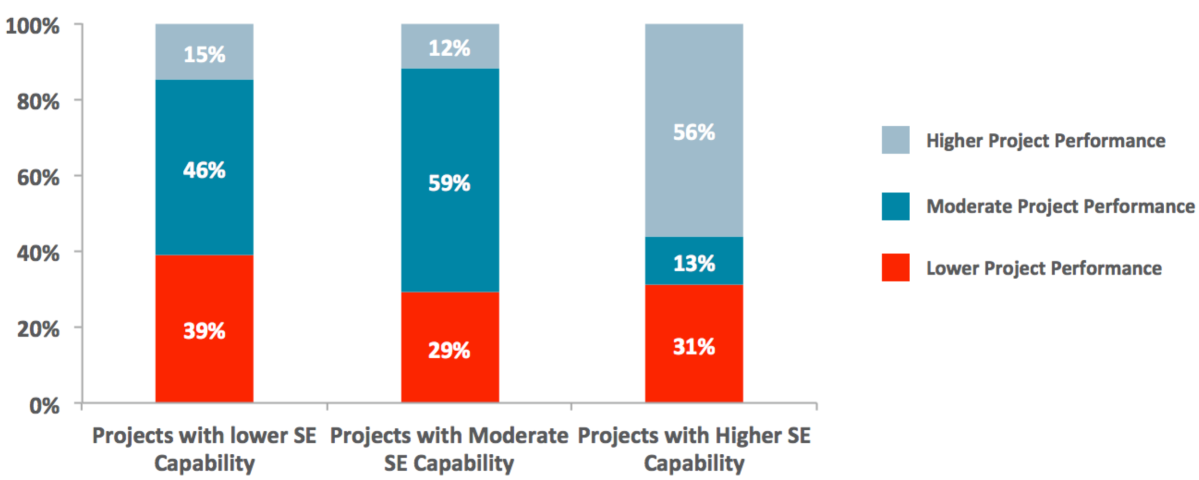

Figure 1: Project Performance versus Systems Engineering Capability, Software Engineering Institute, 2012, "A Survey of Systems Engineering Effectiveness"

Product and service companies engaged in the challenging process of keeping pace with and/or leading innovation, whether complex mechatronics (e.g. high-tech electronics), life sciences (e.g. medical device, bio-pharma), or information technology focused (e.g. software development) are all driven by business needs and enabled by best practices. Best practices are in turn embodied and instituted in software solutions like Oracle's PLM Cloud which directly connect requirements definition and system engineering processes with the product development record. The application of the best practices described herein leads directly to concrete benefits, as illustrated in Figure 2, typically resulting in greater revenue/income margin, decreased cost of goods sold (COGS), increased productivity and risk avoidance. More efficient innovation through greater systems engineering capability directly enables achievement of growth and profitability goals.

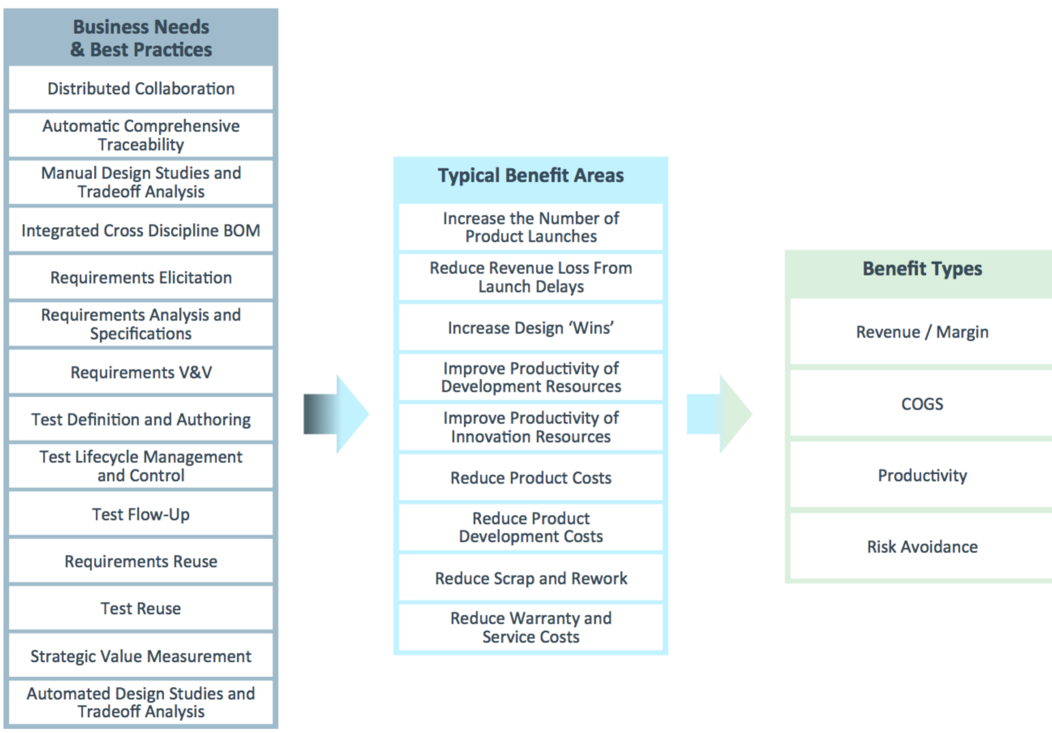

Figure 2: Systems Engineering Capabilities that Deliver Benefits to the Value Chain

This paper outlines Oracle's PLM Cloud solution leveraging the best business practice approach to yield favorable impact on design and development efficiencies resulting in higher systems engineering capability. The examination of this methodology includes:

- **Challenges that Characterize Lower Maturity Systems Engineering**
- **Benefits Areas of Systems Engineering that Contribute to Innovation**
- **Strategies to Increase Systems Engineering Maturity**
- **Best Practices Explained**

Challenges that Characterize Lower Maturity Systems Engineering

As a company endeavors to improve areas of the business that impact the innovation process, challenges from legacy systems, processes and practices inevitably emerge. These challenges must be specifically addressed in order to achieve the greatest value improvements from higher SE capability. The challenges can be summarized as:

Lack of Connectivity

- **Manual processes** – includes widespread legacy use of email, spreadsheets, document vaults, etc. for managing requirements, test, and system architecture in a highly manual and one-off type method. These manual processes are highly document centric as well as 'one-off' type exercises fraught with manual error and difficulty in keeping pace with change
- **Difficulty in facilitating design and trade studies** – includes heavily manual processes whereby design and trade studies, make/buy decisions, impact analyses and other SE intensive practices are primarily manual in execution and require extensive RM / TM / SA history to execute
- **Disparate systems for hardware and software design / development** – includes the use of disparate mechanical (CAD / CAM), electrical (eCAD / eCAM) and software systems that have little formal relationship or traceability between requirements management, test management and system architecture / design elements
- **Lack of integration to downstream systems (e.g. PPM, PLM, ERP)** – includes lack of integration between design and development activities and their eventual embodiment in program and project management (PPM) design systems of record like product lifecycle management (PLM) and enterprise resource planning (ERP)
- **Disconnected collaboration internally and externally** – includes the extension of design, development, assembly, integration and test not only among internal organizations within one company, but also among the extended design teams among vendors, contractors, sub-contractors and customers in the value chain
- **Limited reuse of design elements (requirements, test architecture)** –includes the normal 'one-off' challenges described above and minimal or inefficient reuse of requirements, test and system architectural elements

Requirements Drift

Market research indicates roughly 72% of companies' requirements management practice suffers requirements 'drift' exacerbated by highly manual processes for requirements management, test management, traceability and the design details necessary to depict system architecture. Companies at lower maturity levels are characterized by not only storing most design elements in the document domain (e.g. PDM), but also by requiring extensive manual efforts to produce and communicate relevant development documents across the entire product development cycle and supply chain. Typically, a large, manually based effort is required for:

- **Design / development reviews** (e.g. Sprint / Release, PDR / CDR / FDR, et al)
- **Validation** (e.g. requirements authoring, decomposition, analysis and flow down into design elements HW, EE, SW)
- **Verification** (e.g. test case flow up to requirements)
- **Communication / Coordination** of these activities to both internal groups and across the extended supply / value chain. Emails, phone calls, and document vault check in / check out are daily inefficient activities for the teams involved in such

Limited Traceability

Requirements traceability is the critical process of connecting product hardware, software and electrical engineering requirements to test cases that ensure the correct product is verified and validated. Traceability is typically achieved in a highly manual fashion with either references around document naming conventions and numbers, or embedded spreadsheets subsequently cross-referenced.

- **Difficulty in facilitating design trade studies**– primarily a heavily manual process whereby design and trade studies, make / buy decisions, impact analyses and other SE intense practices are collaborative in execution but often lack connected data and analytics to make the best decisions

» **Manual processes**- includes widespread legacy use of spreadsheets, email, and document vaulting for managing requirements, test cases and system architecture in a highly manual and one-off type method. These manual processes produce 'one-off' type exercises (e.g. Sprint / Release / PDR package) subject to manual error and dependent on legacy organizational / tribal knowledge

Benefit Areas of Systems Engineering that Contribute to Innovation

The application of Oracle PLM Cloud best practices directly addresses the business needs derived from systems engineering. The ability to enable the best practices described below quantitatively contributes to increased innovation efficiencies and effectiveness in processes utilizing systems engineering. Typical benefits areas include:

» **Increase the number of successful product launches** – more efficient requirements and test management best practices allow greater focus on products that are most likely to succeed in addressing market needs

» **Reduce revenue loss from launch delays** – good change control review and approval processes combined with superior test management best practices directly impact release readiness metrics, a key to accurate launch dates

» **Increase design 'wins'** – more efficient translation of ideas into technical requirements increases the probability of describing a winning design

» **Improve productivity of development resources** – increasing systems engineering efficiencies directly contributes to improving development resource utilization to projects most likely to succeed, and fail or iterate faster those that aren't

» **Reduce product costs** – tight integration of systems engineering best practices with PLM processes result in delivering the best design and a smooth transfer through to lean production and commercialization processes resulting in lower product costs

» **Reduce product development cost** - systems engineering best practices backed up with a modicum of process discipline lead directly to leaner and more efficient design, development and commercialization

» **Reduce scrap and rework** – more efficient requirements and test management enable lean engineering disciplines where impact analysis and trade studies help minimize mistakes that lead to scrap and rework

» **Reduce warranty and service costs** – better knowledge of systems architecture, as designed, as built and as deployed reduce downstream maintenance and repair

Strategies to Increase Systems Engineering Maturity

» Increasing systems engineering maturity is characterized by the application of process discipline that enables the automation of many formerly manual and one-off processes, focused around requirements management (RM), test management (TM) and system architecture (SA) and when applicable, reuse of all three in parallel

» More mature companies are characterized by increased automation in storing and reusing most design elements in a single-solution architecture. They no longer require nor want extensive manual efforts to produce and communicate relevant documents across the product development cycle, including the extended supply chain

» Traceability is typically achieved in an automated fashion by utilizing the drag and drop capabilities of Oracle's PLM Cloud. Document and spreadsheet export / import is enabled, but the primary design and development elements are items within Oracle's PLM Cloud. Traceability occurs automatically as designs progress across the various stages of systems engineering maturity

Best Practices Explained

Oracle's PLM Cloud service enables best practices around requirements (RM), test (TM) and system architecture (SA):

Requirements Management

» **Requirements Elicitation / Authoring -** Authoring and capturing all requirements from internal and external sources including requirements imported from other systems. Provide a rich and flexible user-friendly environment to capture graphics, tables, text, video, requirement attribution, etc. in order to fully describe and then validate requirement intent

» **Requirement Analysis and Specification** – Establishing a methodology for determining total scope / level of effort and if any stated requirements are unclear, incomplete, ambiguous, or contradictory, and tracking the resolution of these issues while capturing decision collaboration artifacts

» **Requirements Verification and Validation** – Capturing test requirements which enable verification and validation methods at each level of decomposition in the system design. Providing systematic analysis to ensure requirements have been met by the design

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Oracle PLM Cloud provides a modern innovation platform to help businesses transform product development for competitive differentiation and rapid growth. Requirements Management, Test Management and System Architecture are embedded across the entire product lifecycle and supported by the Oracle PLM Cloud. Starting as early as the ideation process and continuing through concept, design, development, commercialization, sustainment and end-of-life, Oracle PLM Cloud improves operational efficiency, compliance integrity, enterprise collaboration and comprehensive change management. Key systems engineering capabilities include: 1. A single collaborative solution to define, manage, verify and validate requirements, 2. Real-time visibility into the completeness / fulfillment of product requirements, 3. Ability to assess product requirements' feasibility instantaneously, 4. Ability to establish, maintain traceability and assess change impact across ideas, requirements, concepts, designs and test cases, 5. Integration of requirements within Oracle PLM Cloud and / or on premise solutions.

Figure 3 Illustrates a characteristic view of requirements within Oracle's PLM Cloud solution illustrating RM best practices. Requirements are authored, captured and analyzed into a specification, while views of real time verification and validation status are summarized in analytical dashboards. Of the 626 total requirements, segregated by priority, 84% have been fulfilled as an indication of release readiness.

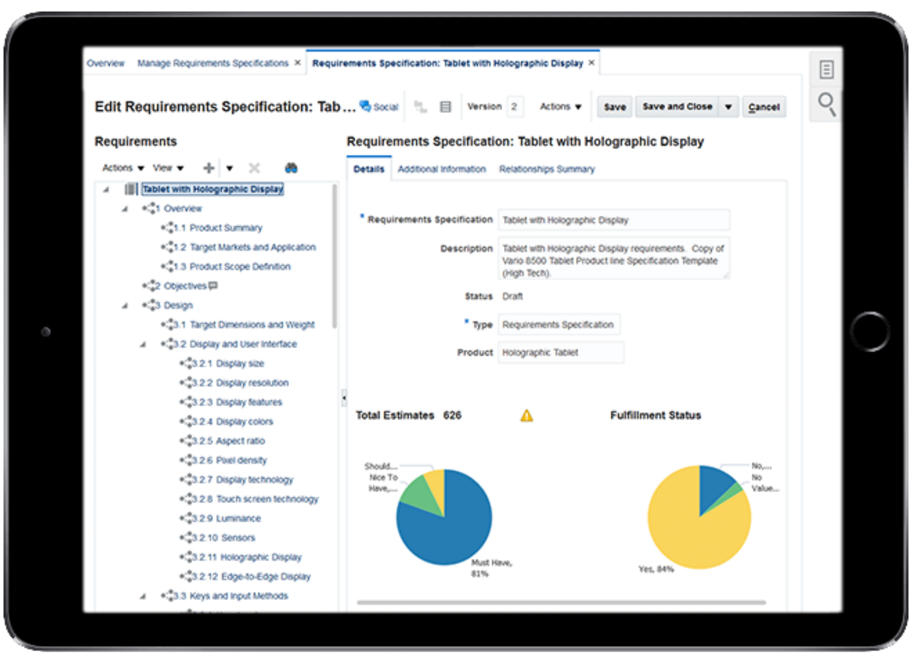


Figure 3: RM Best Practices

Test Management (TM)

- » **Test Definition / Authoring -** Authoring and capturing all test cases and plans. Providing a rich and flexible user environment for handling graphics, tables, text, etc. in order to fully capture the test's intent
- » **Test Flowup** – Establishing traceability between requirements, associated technical specifications/designs, and test. Ensure that all tests are allocated to requirements and capture verdicts
- » **Test Lifecycle Management and Control** – Manage and control individual test definitions and specification approval throughout the lifecycle

Figure 4 illustrates a view of test within Oracle's PLM Cloud solution illustrating TM best practices. Test cases are defined and authored, as well as flowed up to requirements and verified.

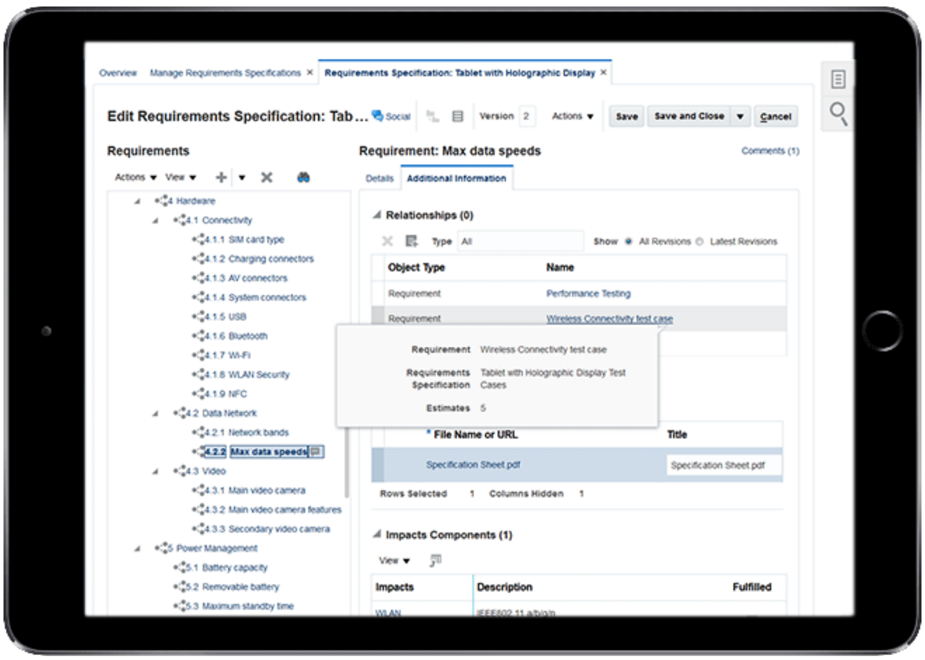
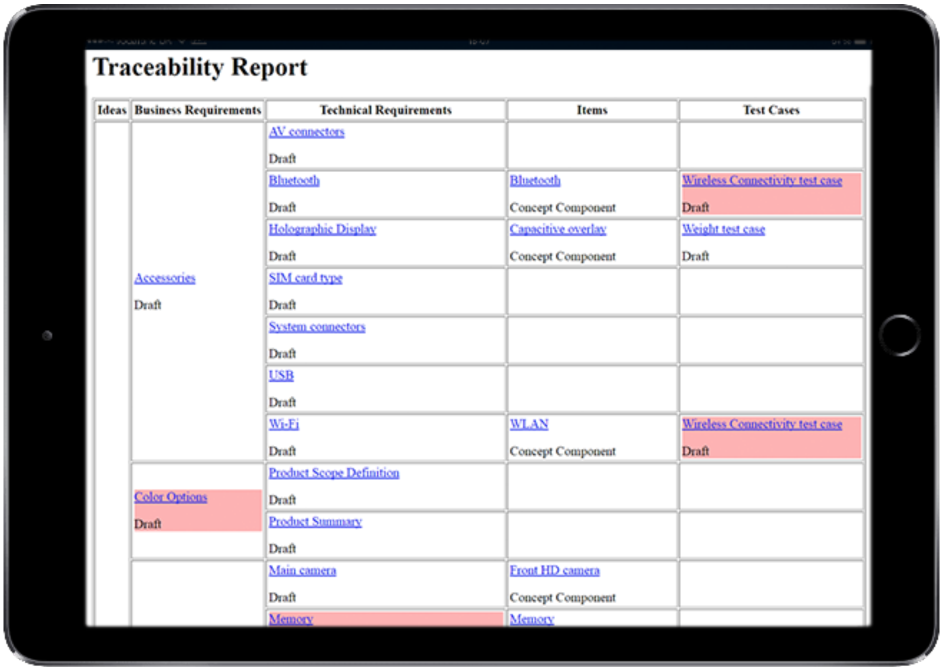


Figure 4: Traceability Report Demonstrating TM / RM Best Practice

Figure 5 shows a requirements traceability matrix (RTM) comprised of requirements and test views giving comprehensive insights into the traceability of all product items including color coding of real time design outputs. The matrices also facilitate rapid identification and analysis of impacts with fully verified and validated links of not only requirements and test but also the 'as designed,' 'as built' and 'as deployed' product records.



Traceability Report

Ideas	Business Requirements	Technical Requirements	Items	Test Cases
		AV connectors Draft		
		Bluetooth Draft	Bluetooth Concept Component	Wireless Connectivity test case Draft
		Holographic Display Draft	Capacitive overlay Concept Component	Weight test case Draft
	Accessories Draft	SIM card type Draft		
		System connectors Draft		
		USB Draft		
		Wi-Fi Draft	WLAN Concept Component	Wireless Connectivity test case Draft
	Color Options Draft	Product Scope Definition Draft		
		Product Summary Draft		
		Main camera Draft	Front HD camera Concept Component	
		Memory	Memory	

Figure 5: Requirements Traceability Matrix (RTM)

System Architecture (SA)

- **» Distributed Collaboration -** Enabling and capturing collaboration artifacts on work-in-process design / development data. Sharing product information across cross-functional, key stakeholders in order to facilitate front-end ideation, concept development, and design refinement
- **» Integrated Cross Discipline BOM** – Manage and relate cross-discipline product information (e.g., mechanical, electrical, software, firmware) in a single product structure. Establish a single, synchronized source, integrated with product data to capture the correct hardware and software product configuration
- **» Design Studies and Tradeoff Analysis** – Perform design sensitivity and trade studies to establish performance envelopes and manage risk
- **» Automatic Traceability** – Comprehensive indications of relationships between items in requirements, test and system architecture to enable complex systems engineering processes including verification, validation, impact analysis, trade studies and others

Figure 6 Illustrates how we graphically navigate the product while filtering the system architecture by requirement, test, design element, relationship, and / or other traceability relationships.

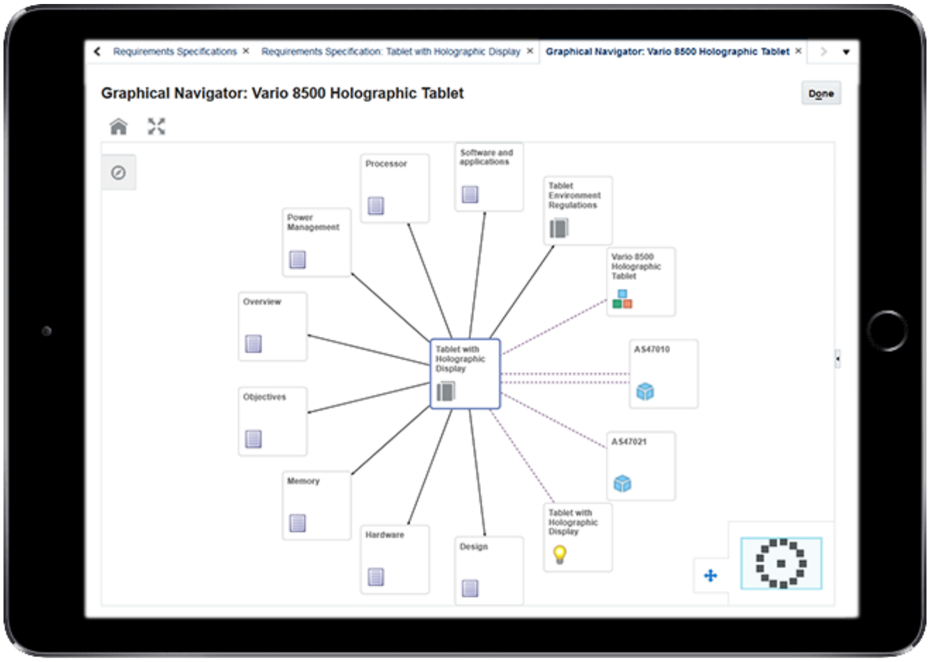


Figure 6: Systems Architecture Overview

Figure 7 Illustrates a summary view of release readiness, based on the verification and validation levels obtained in requirements and test management best practices.

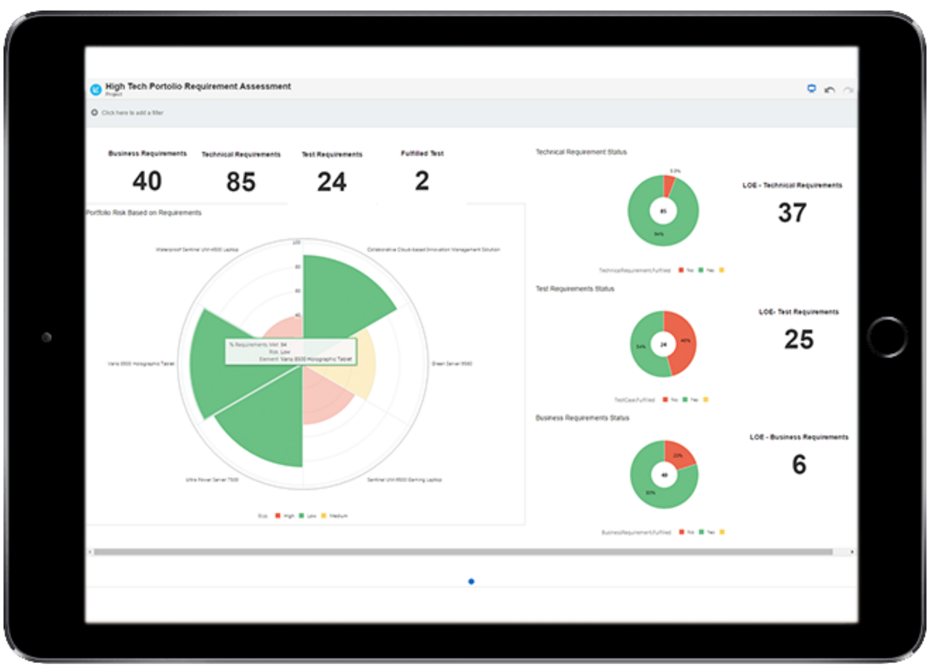


Figure 7: Release Readiness Summary

The best practices can then be leveraged in a complementary and symbiotic fashion with other Oracle PLM Cloud services, adding additional value around schedule, project, portfolio, enterprise planning and lifecycle / change management.

Conclusions and Recommendations

The application of systems engineering capabilities across requirements management, test management and system architecture, provided by Oracle's Cloud PLM, as well as the broader suite of Oracle Cloud services, enables product companies to cross the innovation chasm by tying market demand to supply chain execution as an integrated continuous process. High-level marketing and business requirements can be directly traced to those that define the technical design expediently and effectively. This nexus of systems engineering capabilities results in higher return on investment by addressing the typical challenges associated with improving design and development performance. Increasing systems engineering maturity directly improves the business's ability to more reliably and predictably achieve growth and profitability objectives.

ABOUT THE AUTHOR

Kurt Brock is a classically trained systems engineer whose career spans a number of complex systems engineering disciplines (e.g. satellites / rockets) combined with extensive practice in software development lifecycle management (SDLC), application lifecycle management (ALM) and product lifecycle management (PLM). In addition to being a Certified Systems Engineering Professional (CSEP / INCOSE) Kurt is a certified scrum master, master scrum master, and Scaled Agile Framework (SAFe) practitioner and instructor. Kurt has published more than a dozen papers for various academic and engineering journals, holds 4 issued and 6 pending patents, as well as a BS in Mechanical Engineering from the University of California, Berkeley, and an MS in Astronautical Engineering from Stanford University.

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