半导体企业的全面创新管理：

领先的实践、功能和工具

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创新观点

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执行概要

半导体企业致力于不断促进有意义的创新发展，但很少有企业真正为实践这个承诺做好了准备。

如果没有清晰的创新战略与路线图，这些企业与负责企业业绩的这些人员必然会遭遇失败。

本白皮书分析了半导体行业的一流企业采用哪些先进的实践与工具来保持业界领先地位，积极应对全面创新管理这一关键要求。

2009年，Kalypso发布了题为《半导体产品全生命周期管理：产业应用、收益和未来趋势》的白皮书。该白皮书重点分析行业领先的半导体企业采用产品全生命周期管理(PLM)工具的趋势，特别是如何采用半导体产品数据管理 (PDM)，以加速产品开发，提高产品质量并降低成本。业内PLM/PDM技术的早期实施方能将成本节约多达40%，通过结合更出色的方法来高效支持产品团队。该白皮书发布的近几年以来，领先的半导体企业采用了一系列更高级的流程、工具和实践来满足全面创新流程，加速向市场推出更低成本的新产品，同时满足增长目标的要求。

创新进展态势良好，但对于大多数企业来说，目前所使用的工具和流程还不足以推进新技术创新，也无法满足未来半导体产品更高的复杂性要求。为了实现真正的创新转型，所有的半导体企业都必须超越PDM，确保首次设计就能成功进行投产，更加重视高效的产品导入与制造灵活性。

这就需要一系列具体的改进创新功能，包括：

- 统一的产品数据模型不仅记录现有的产品，还应能支持开发和创新流程的所有阶段；
- 产品组合与多项目管理工具及实践可将工程开发团队与企业战略和客户需求完美整合在一起；
- 客户需求管理功能可协调工程与开发团队以及客户要求与规范，从而在设计周期的早期阶段就发现并解决问题。

这种更全面的方法所带来的效益包括降低开发成本，改进产品质量，最大化研发投资回报等。这些改进不仅能促进成本节约和提高收益，同时也能推动公司开始步入全面创新管理之路。

日益复杂的行业环境中企业面临规模与协作挑战

为保持市场领先地位，半导体企业需要保持敏捷与快速反应的能力，高度关注创新与执行力。半导体企业如今拥有现成的工具和流程来管理创新，而芯片的复杂性不断提升，产品开发进度越来越紧，资源要求日益紧张。因此企业必须建立起创新流程、全球制造和设计中心、知识产权(IP)的增加流程或许可机制，并在技术能力和功能之间找到正确的平衡，以紧跟最新技术发展趋势。

图1给出了随着新工艺节点上新产品的推出而带来的日益增长的设计复杂性。以往的产品仅包含15 – 30个应用块(Application Blocks)，而现在则超过150个应用块；过去的设计团队仅有50名工程师，而现在需要200多名工程师全球化协同工作。就28 nm片上系统(SOC)而言，开发库、IP生成和芯片设计的成本超过3.5亿美元，而且随着每一项新技术节点的推进这一成本还将不断提升。2

由于晶体管与单元数量的增加，从而造成设计成本的提升，也进一步要求尽量缩短产品上市时间，并最大限度地延长上市产品的生命周期，进而将新技术的价值实现最大化。如果设计反复修改并出现瑕疵，就会延迟产品发布，缩短新产品的营收寿命，甚至会让竞争对手有机可乘。为应对成本和复杂性的不断提升，半导体企业必须采用高效的设计流程，大规模商用新技术，不仅要确保产品的成功流片，还要确保及时的成功交付客户并实现盈利。

支持新产品、新技术的工艺和技术能力实现快速商业化，这是未来成功的关键。

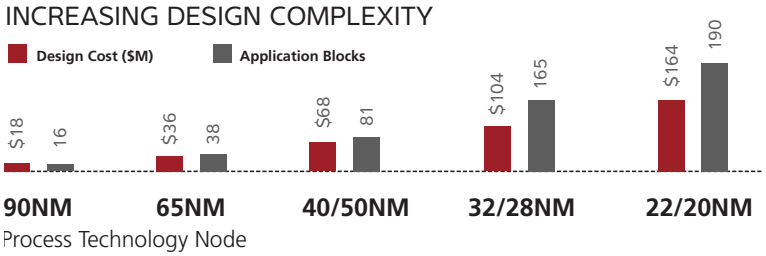

Figure 1 Design Complexity[1]

Figure 1 shows the increasing design complexity as new products are introduced

1 Source: International Business Strategies

2 Kay, Roger (2012, March 16), Rising Stakes In Semiconductor Game Squeeze Out All But A Few, Forbes Magazine

Equally important to NPI execution and in-market lifespan is ensuring that resources are being used to develop the right products that customers want. Better visibility to the product portfolio enables maximum alignment with customer needs and their own financial performance.

The need for visibility and constant collaboration has never been greater. To ensure that global and regional customer needs are met, typical semiconductor NPI efforts require several hardware and software design teams, along with applications, product, reliability, test, and production engineering teams across the globe working in concert with global sales and marketing teams. Internal manufacturing, external foundries, internal and external final manufacturing, wafer probe, and test locations need instant visibility into qualified processes, tools, vendors and engineering teams to get parts quickly to the end customers. Product, test and reliability teams each use their own systems, Design Automation/CAD platforms, in-house tools, and processes. Efficient collaboration is essential to the NPI process and can lower development costs, increase IP reuse, compress development schedules, and improve product quality.

Despite the challenges that the industry faces today, leading semiconductor companies can maintain an innovative edge in a complex industry with enhanced practices and tools to handle the increasing design complexity, manage portfolio decisions, and to increase global collaboration throughout the NPI process.

Three New Leading Practices for Innovation

At Kalypso, we suggest an innovation results transformation approach, supported by leading new product introduction practices, processes and tools. We have found that leaders in the semiconductor industry all have enhanced tools and capabilities built around improving the same basic priorities to overcome industry challenges. These priorities can be summarized in three leading practices.

1. First Pass Design Success

The most successful semiconductor companies possess a relentless focus on first pass success for new Integrated Circuit (IC) designs and product solutions. A successful first pass design minimizes time to market and development costs, and maximizes the revenue life of a new product. Design re-spins and software kit updates massively increase development costs and lengthen the time-to-market for new products, frustrating customers. Low quality first pass designs also produce unacceptable yields which drive up cost, decrease profitability and increase the final release and qualification requirements. One semiconductor company recently had to delay the launch of their flagship processor because of multiple design re-spins and low production yields. This resulted in angry customers and third party developers, and ultimately a loss in market share and stock price for the company.

Producing and taping out high quality designs with technologies ranging from 20nm to 90nm is very challenging. Companies with enhanced processes and tools designed to enable innovation and collaboration dramatically improve the quality of their designs, leading to higher first pass design success, lower overall development costs, faster time-to-market, and increased product margins.

2. Efficient New Product Introductions

With expanding product portfolios and limited resources, semiconductor companies constantly have to do more with less. Executives at leading semiconductor companies have visibility into NPI projects in all phases from ideation to execution. Looking at the development pipeline from two perspectives - current resource load and future projects to be launched - ensures that both the monetary and human resources are allocated correctly, customer requirements are met, and changes are made quickly enough to respond to an evolving industry landscape.

Senior managers in development and NPI teams need to make quick decisions based on current information from engineering teams, customers, and the market. Executives

also need traceability into both future and past projects, and should use benchmarks from prior product development projects to improve new product selection and refine NPI processes and success rates. Summary product and technology reliability data should also be available for executives to review in order to assess the readiness of product development and reliability benchmarks. Detailed quality data should be easily accessed for quality and product engineering teams to enable further quality improvements.

This alignment of resources to strategy and data ensures that the right products are being developed while organizational waste is minimized. This can only happen when decision makers have comprehensive and current information available through collaborative portfolio tools.

3. Improved Manufacturing Flexibility

Continuing advancements in wafer process technology, packaging technology, and testing demands require a flexible and robust manufacturing plan for new product introductions. Leading semiconductor companies can quickly adapt to natural disasters, regulatory changes, labor cost changes, and supply chain disruptions that can wreak havoc on companies that are not prepared.

The 2011 Tohoku earthquake and tsunami in Japan severely disrupted the supply chain for semiconductor wafer manufacturing, final assembly, testing, and component suppliers [3]. Several large semiconductor companies had wafer fabrication plants partially or completely destroyed. Some of these companies were unable to meet customer demand for months while they scrambled to qualify new manufacturing locations and suppliers to fill customer orders. Customer shipments and deadlines were missed as new factories and equipment were qualified and damaged factories were eventually reopened.

The companies that had a flexible manufacturing plan already incorporated into their customer qualification criteria were able to quickly reallocate capacity and maintain supply to meet customer demand. This kind of flexibility requires tools and processes to enable global collaboration, a single source of product data, and comprehensive management of custom systems and manual processes.

3 http://www.semi.org/en/sites/semi.org/files/files/FINAL_JAPAN_spreadsheet.pdf

Enhanced Capabilities and Tools to Support Leading Practices

In order to support these leading practices and move towards more comprehensive innovation management capabilities, semiconductor companies must adopt new enhanced tools and capabilities. Basic PLM/PDM tools focused on managing the product data record used to be sufficient to drive innovation in the semiconductor industry. These tools provided a single, centralized data record for part numbers, shop orders, and bill of materials. However, given the new challenges and complexities of the industry, true innovation results transformation comes from moving beyond PDM and placing more emphasis on first pass design success, efficient product introductions, and manufacturing flexibility.

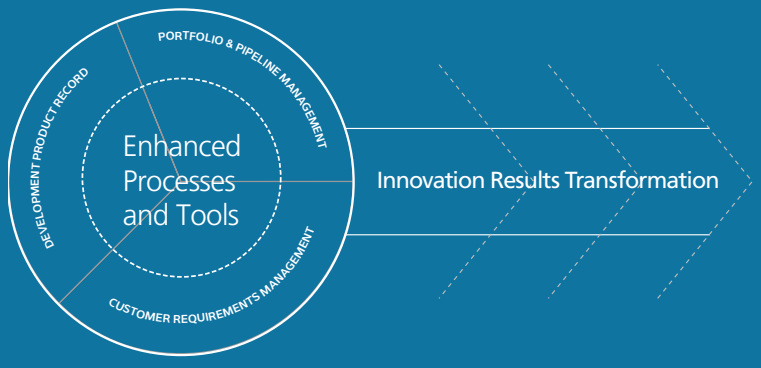

Figure 2: Enhanced Processes and Tools Drive Innovation Results Transformation

Special tools and practices are needed to drive these capabilities. Innovation leaders use three enhanced processes and tools to boost collaboration, link resources with priorities, and align requirements with design output, including:

- **A development product record** that goes beyond existing product data record capabilities with a product data model that supports all phases of the development and innovation process
- **Portfolio and pipeline management** tools and practices to unite engineering and development teams with corporate strategy and customer demand
- **Customer requirements management** capabilities to align engineering and development teams with customer requirements and specifications, and to identify and fix problems early in the design cycle

Together, these processes and tools enable the capabilities that drive towards true innovation results transformation, helping companies realize dramatic improvements in development schedules, cost, quality, and customer satisfaction.

The Development Product Record

The first capability is an enhanced development product record and technical infrastructure to support strategic design, data management, software development, and supply chain processes throughout the development process. Semiconductor companies have widely adopted basic PLM/PDM tools for product data management systems that include part numbers, bill of materials, and shop orders. The development product record goes beyond basic product data management capabilities and supports a broad set of PLM capabilities throughout the innovation process, shown in Figure 3 below.

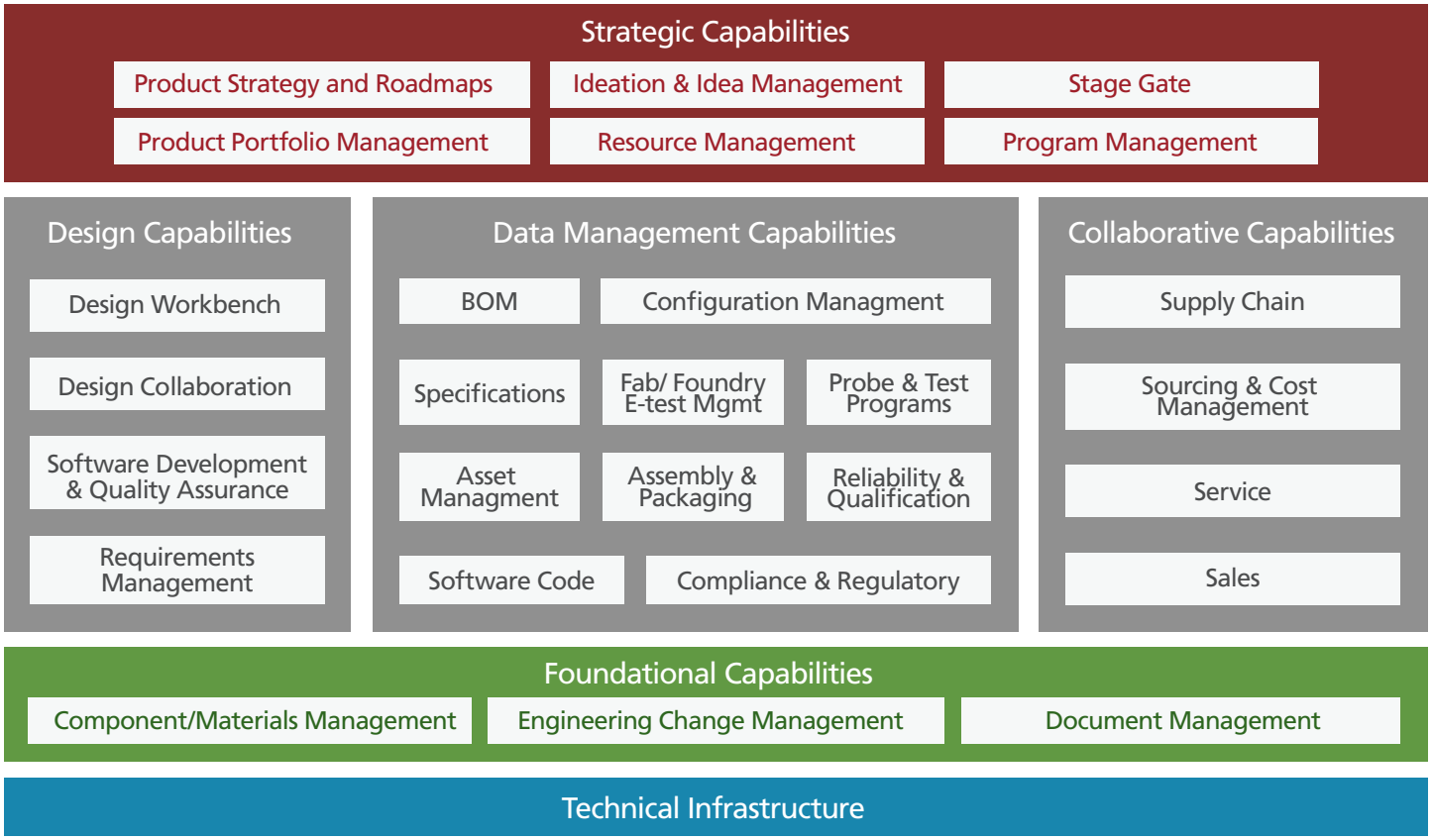

Figure 3 Semiconductor Development Product Record PLM Capabilities Framework

Strategic Capabilities enable program management for product development processes and launch programs, as well as product portfolio management. More advanced solutions enable product and technology road mapping, and support for idea management and ideation processes. This can either be done within a single PLM solution to address these

portfolio needs or a with a more specialized PPM (Portfolio and Pipeline Management) solution.

Design Capabilities of a PLM solution start with basic customer needs definition and extend to the decomposition of specific product requirements. The design capabilities will allow a user to link customer requirements in the system to features and design teams, providing a record of the linkages and changes throughout the development process. The design collaboration enables geographically dispersed, cross-functional teams to work together in digital form across EDA/CAD platforms.

IP management enables both re-use and protection of purchased and invented technology. Leveraging PLM capabilities to manage IP also enables a design manager or engineer to quickly gain access to existing IP that may be re-used in a design. PLM facilitates access to the correct version of IP and builds the relationships and linkages to enable the reusable IP owners to support the design, even if that IP originates from various cross-functional organizations or groups. This can drastically reduce time to market and design timelines as well as improve the quality of the IP/design.

Data Management Capabilities are often seen as the foundation for an effective PLM system and this comprises the main semiconductor product record. The functionality for this product record can be used to logically link all information related to a product and manage changes to that information over time, providing a single version of the truth across the global value chain of customers, employees, partners, and suppliers. It includes requirements, technical specifications, design definitions, production schedules, test reports, sourcing plans, and quality inspections that are tied to critical processes and tasks.

Software Capabilities give companies a way to manage source code, which is an integral, but often omitted, component of a comprehensive PLM solution. Many semiconductor companies now have software solutions embedded as firmware or through a design reference kit. This requires integration of the IC hardware with the software, and the versioning and revision control required to meet the customer needs and the profitability demands. Additionally, many semiconductor companies that embrace leading practices find that integrating bug tracking and issue management in their PLM solution offers them a much more powerful way to resolve design issues identified during testing or in production. PLM is a vehicle for bridging the two disciplines of IC and software. This is critical given the financial impact when companies do not have commonality, intersection points, or guidance around how to control changes or requirements in the IC design that impact the software, and vice versa. Today, many IC bugs or issues can be corrected via the software stack.

Supply Chain Capabilities are integral to development process and an important part of

a comprehensive solution. PLM, particularly as it relates to the semiconductor industry, should almost always be considered a multi-enterprise system. Outsourcing foundry operations and the backend operations of test and assembly functions at PAT (Probe, Assembly & Test) subcontractors means that the design, product, and test engineering teams need a secure way of collaborating on new product launches and an efficient way to communicate timely changes to existing product specifications.

Given the varied facets of each component in a comprehensive PLM solution, these components are almost never implemented all at once. Rather, most companies find that the best approach to a PLM implementation is to define a strategy based on a commercially available platform, and create a roadmap that integrates additional new capabilities over time.

The development product record and PLM tools must be viewed as a transformational initiative rather than a one-time innovation installation. As firms grow and change through acquisitions and divestures, more due diligence to maintaining the development product record and evolving and expanding PLM capabilities is a must. Without intelligent business processes built around maintaining these tools through changing business environments and new priorities, semiconductor companies cannot take full advantage of the innovative capabilities that PLM tools can offer.

CASE STUDY

A **$2.5B fabless semiconductor company** recently embraced PLM as a transformational initiative, choosing to implement PLM with a development product record. Like many companies, they were using systems developed in-house including a simple spreadsheet repository and a database client with a web interface. With no standardized tool or process to manage the product record, they had no way to efficiently collaborate with external suppliers, foundries, contractors, and manufacturing partners.

Product data was migrated to new comprehensive PLM tools and they now have a robust enterprise solution that includes all product groups and development teams, and integrates with all external suppliers, foundries, contractors, and manufacturing partners. There is a single source of truth for all product and development data.

This company has seen a 15% reduction in development costs and a 50% cycle time reduction in validations of change order requirements as a result of their PLM and development product record tool adaption.

Portfolio & Pipeline Management

The second enhanced capability is the use of PPM process and tools to align innovation strategy with business strategy to drive the new product development process. Semiconductor companies often ask themselves, "Am I building things right?" They should actually ask themselves, "Am I building the right things?" Without a clear picture of innovation investments and the expected return and ranking of these potential projects, companies can't be confident that products will win in the market, and they won't know if their teams are working on winning or losing projects.

To drive growth, leadership teams must be able to tie development work to business strategy, and this can only happen with pipeline transparency and access to the right data.

PPM tools help semiconductor companies align new product investments with business strategy. Three processes make a closed loop cycle that promotes innovation success (See Figure 4).

- Early Phase Portfolio Management fills the pipeline with promising ideas.
- Project Portfolio Management ensures that strategy enables development projects.
- Product Portfolio Management links market need and reaction to the front end of innovation

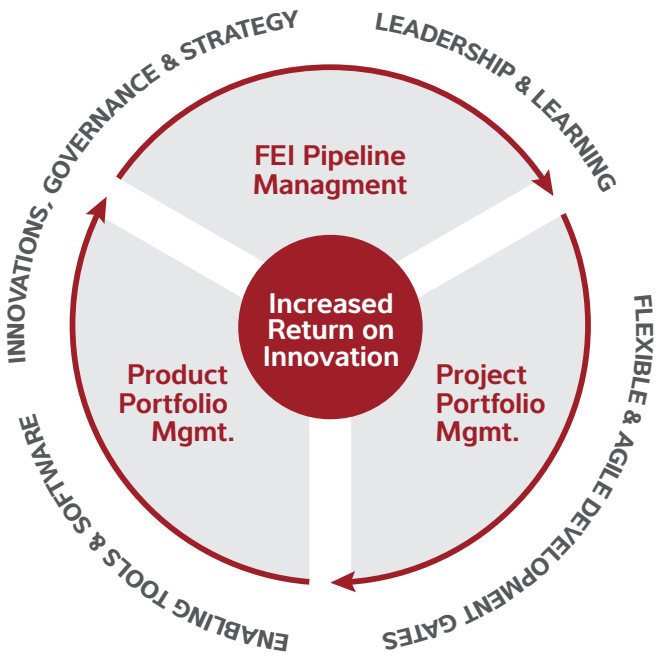

Figure 4
Early Phase Portfolio Management

Companies that embrace PPM gain visibility into development activities which allows them to make informed decisions on investment mix, efficiently reuse IP, and allocate resources into critical projects. Leading semiconductor companies have processes and tools that help provide scalable phase-gate execution, informed investment plans, intelligent resources allocations, and regular data updates. These tools allow executives to track product ideas, proposals, requirements, and market success to efficiently link resources with the projects that have the highest potential success.

CASE STUDY

A **$1B division of a global fabless semiconductor company** was struggling with poor new product portfolio decisions. Product development and pipeline management was splintered with no ownership or clear decision chain. The most outspoken middle managers would often get resources and funding for projects, regardless of how those projects fit into the strategy of the company or the needs of their customers.

With new PPM processes and a supporting solution with a clear phase-gate portfolio pipeline process, development projects that previously had no executive approval or link to strategy are now approved through a defined process visible to all decision makers. Development projects are now aligned to corporate strategy initiatives and customer priorities. The result is better deployment of limited innovation resources and increased visibility to company priorities and projects. This company realized a 20% improvement in NPI release time, and a 30% improvement in project phase review efficiency.

The most effective semiconductor PPM tools also help companies manage enabling technologies. In 2012, the semiconductor industry spent $53 Billion[4] on research and development on enabling technologies, such as wafer fab manufacturing nodes, assembly and packaging roadmaps, and test technologies and software. Transparency into the development of these technologies as the foundation for successful product development is critical in enabling the right products to be developed in the pipeline.

In addition, semiconductor companies must be able to appraise product lines and determine if they need to develop or acquire additional product lines, or divest themselves of certain product lines for strategic reasons. PPM tools help executives value and appraise the monetary impact of product lines and plan merger and acquisitions or divestitures to match their product strategy.

4 Source: IC Insights

Requirements Management

The third required capability is design requirements management, sometimes called customer requirements management for development. Increasing complexity forces companies to create multiple design and development environments, each using disparate tools and engineering teams. Design requirements management enables all of these environments, teams, and locations to work together to ensure that the comprehensive design meets customer requirements, and is optimized for reliability and performance.

Companies that use a requirements management tool to centrally manage design, validation, and verification create a collaborative and traceable design environment, and are able to get higher quality designs out the door faster. With requirements management:

- Disparate tool outputs are integrated into a single platform
- Complex designs are easily managed, even when developed by multiple teams & tools
- Interdependent modules and processes are collectively managed
- Interdependent input parameters are verified and optimized
- Design outputs are verified to end-customer requirements
- Comprehensive Design of Experiments (DOE) can be enabled for robust information gathering across emulation, simulation and physical test comprising verification and validation
- Integrated data and process management can enable cross functional decision making

When the entire design flow can be managed against requirements, the input and process parameters can be modeled and simulated to determine what can be modified to optimize yield, manufacturability, and quality. Early visibility into design parameters and Monte Carlo simulations can identify critical parameters and allow global design teams to optimize their design process around them. This is only possible if all outputs from all systems can be modeled simultaneously.

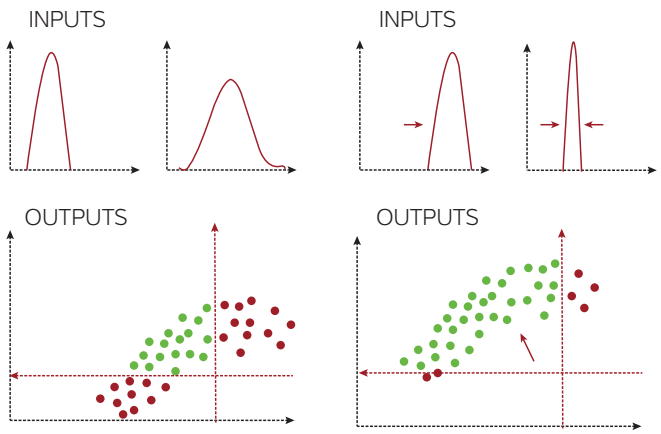

Figure 5 Output Simulation

Figure 5 shows how an enhanced requirements management tool can simulate the impact of various parameters customer requirements, allowing design teams to collaboratively improve customer outputs, improving performance and yield. If designers can model critical outputs based on multiple design inputs - even if those inputs come from disparate design platforms and outputs, different global design centers, or various design revisions - those outputs can be designed for optimal manufacturability, quality, and testability.

Key Benefits Achieved

Leading companies that implement managed capabilities and solutions for the full innovation process, including the development product record, portfolio and pipeline management, and customer requirements management have seen substantial improvements in cost, schedule, and quality metrics. Figure 6 shows the ranges of the average improvement that companies are realizing through an integrated approach throughout their development cycle[5].

BUSINESS IMPACT	AVERAGE % IMPROVEMENT
Productivity Improvements	40-45%
Design Engineering Time Saved	45-50%
Multi-site Design Projects	70-75%
IP Re-use	40-45%
Product and Manufacturing Schedules	20-25%
Manufacturing Cost Savings	20-25%
Design/Product Quality	30-35%

Figure 6 Innovation Improvement Ranges

Semiconductor companies are facing real innovation challenges, and the tools and processes being used today are not sufficient to drive innovation in the future. Leading companies are adopting enhanced tools to help achieve first pass design success, an efficient NPI process, and flexible manufacturing plans. These enhanced tools include a comprehensive development product record, portfolio and pipeline management tools, and customer requirements management tools. With tools and process built around the full innovation process, leading companies are staying ahead in the market as judged by their product offerings and growth in the marketplace.

We recommend a comprehensive and honest assessment of current capabilities around the development product record, portfolio and pipeline management tools, and customer requirements management tools. Once companies know what their deficiencies are they can then formulate a plan to correct those deficiencies. A smart plan that incrementally builds capabilities with the right tools based on innovation successes is the best way to start. Adopting these leading practices and supporting tools is the first step in the future success of their innovation results transformation.

5 Source: Gantry Group Study

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