SPEC INNOVATIONS
DEVELOPERS OF INNOSLATE

WHITEPAPER

OPTIMIZING SEMICONDUCTOR MANUFACTURING WITH INNOSLATE AND LML

Chris Howard | chris.howard@specinnovations.com

About SPEC Innovations

Systems and Proposal Engineering Company, dba SPEC Innovations was founded in 1993 by Dr. Steven Dam. The company has worked on significant architecture and systems engineering projects for the DoD, DOE, and other government and commercial organizations. Learn more at www.specinnovations.com.

We began the development of Innoslate in 2010 when we found it challenging to do the work we needed to do with the limited tools available at the time. Innoslate was first released in 2012 on the cloud and is currently in version 4.7 as a full lifecycle tool, with integrated Systems Engineering and Program Management capabilities. It uses the open standard, Lifecycle Modeling Language (LML), as its open ontology.

Innoslate currently supports users around the world and is also available on NIPRNET, SIPRNET, and C2S, as well as behind your own firewalls. You can learn more about Innoslate by going to our website, www.specinnovations.com/innoslate.

Executive Summary

Introduction

“Are your semiconductor yields driving profits or draining your resources?”

In the cutthroat world of semiconductor manufacturing, chip yield isn’t just a technical metric—it’s the difference between thriving and merely surviving. With the industry’s rapid growth fueled by the demand for advanced electronics, Artificial Intelligence (AI), and Internet of Things (IoT) devices, maintaining high chip yields has never been more crucial. Yet, many companies grapple with low yields, resulting in substantial financial losses and competitive disadvantages. This whitepaper aims to explore these challenges and present a robust solution to enhance chip yields and secure profitability.

Author’s Credentials

As a computer engineering student with a keen interest in semiconductor manufacturing, a fresh, innovative perspective is brought to this critical issue. Partnering with seasoned professional systems engineers, academic insight is combined with practical industry experience. This unique collaboration enables the development and presentation of cutting-edge solutions that are both theoretically sound and practically viable. The whitepaper stands out by blending rigorous academic research with real-world applications, offering semiconductor companies actionable strategies to boost yields and drive profitability.

Methodology and Key Findings

Industry reports, case studies, and historical data were analyzed using advanced simulation tools to model yield improvements. Key findings include:

- Revenue Impact: High yield rates correlate with significantly higher revenues.

- Cost Reduction: Decreasing yield loss can reduce per-unit production costs by up to 20%.
- Efficiency: Targeted strategies can cut production times by 15%.

Conclusion

Optimizing chip yield is crucial for financial and competitive success in the semiconductor industry. This whitepaper demonstrates how using Model-Based Systems Engineering (MBSE) with Innoslate software can transform yield challenges into growth opportunities. Implementing these strategies will enhance profitability and position companies as industry leaders.

"Optimizing chip yield isn't just a technical goal—it's the key to unlocking significant revenue growth and achieving a competitive edge in the semiconductor industry."

Project Context

Maximizing chip yield is a critical concern in the highly competitive semiconductor industry. Low chip yield translates to significant financial losses, reduced reliability, and competitive disadvantage. This problem is particularly relevant to stakeholders in chip manufacturing, where increasing yield is synonymous with higher profitability and enhanced product reliability.

Current Market Scenario

Today, the semiconductor market is witnessing rapid growth driven by increasing demand for advanced electronics, AI, and IoT devices. However, this growth is accompanied by intense competition and shrinking profit margins. According to industry reports, Taiwan Semiconductor Manufacturing Company (TSMC) leads the market with the highest revenue, demonstrating the direct correlation between high yield rates and financial success.

Historical Context

Historically, the semiconductor industry has faced the challenge of improving chip yield due to the intricate and precise nature of chip manufacturing. Technological advancements have gradually improved yields, but the process remains fraught with difficulties. The transition from planar transistors to Fin field-effect (FinFET) technology, for example, introduced new manufacturing complexities that initially impacted yields negatively before stabilization and improvement.

Current Struggles and Pain Points

Companies in the semiconductor industry struggle with several issues that impact chip yield:

- **Manufacturing Precision:** Even minor deviations in the manufacturing process can lead to significant yield losses.
- **Material Quality:** Variations in raw material quality can affect the overall yield.
- **Technological Complexity:** As chip designs become more advanced, maintaining high yield rates becomes increasingly challenging.

These challenges are compounded by the need to maintain stringent quality standards and meet the growing demand for advanced chips.

Supporting Data

- **Financial Impact:** Lower yields lead to higher per-unit costs and reduced profitability. TSMC's financial success is largely attributed to its high yield rates, which enhance both profit margins and market reliability.
- **Time and Resource Wastage:** Low yields result in wasted materials and extended production times, impacting overall efficiency & profitability.
- **Business Growth:** Companies with lower yields struggleto scale operations and meet market demand, hampering growth prospects.

Frameworks for Understanding

- **Yield Learning Curve:** Figure 1 below illustrates how yield improves over time with process optimization and experience.

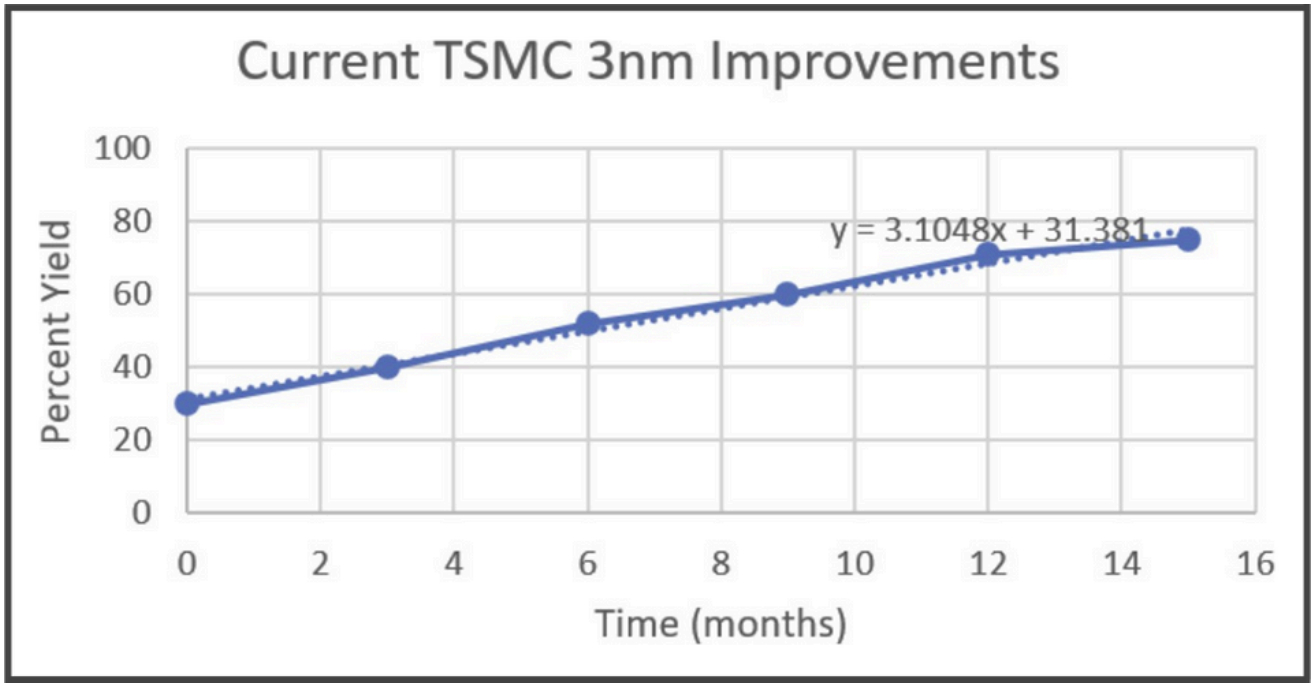

Figure 1: 2021 - 2023 TSMC 3nm Yield Estimate

Benefits of Solving Yield Problems

Addressing yield issues offers numerous benefits:

- **Increased Profitability:** Higher yields reduce per-unit costs and enhance profit margins.
- **Improved Reliability:** Consistently high yields indicate a stable and reliable manufacturing process, boosting customer trust.
- **Competitive Advantage:** Companies with higher yields can produce more chips at lower costs, gaining a competitive edge in the market.

"Increasing chip yield is not just about boosting numbers; it's about enhancing profitability, reliability, and maintaining a competitive edge in a fast-evolving market."

As seen in Figure 2, and stated in the initial problem description, TSMC has a high yield rate. This directly correlates to their high revenue in 2022, and points to reliability in the future for their products. In order to compete with the industry leader, strict guidelines must be implemented to achieve their profitability heights.

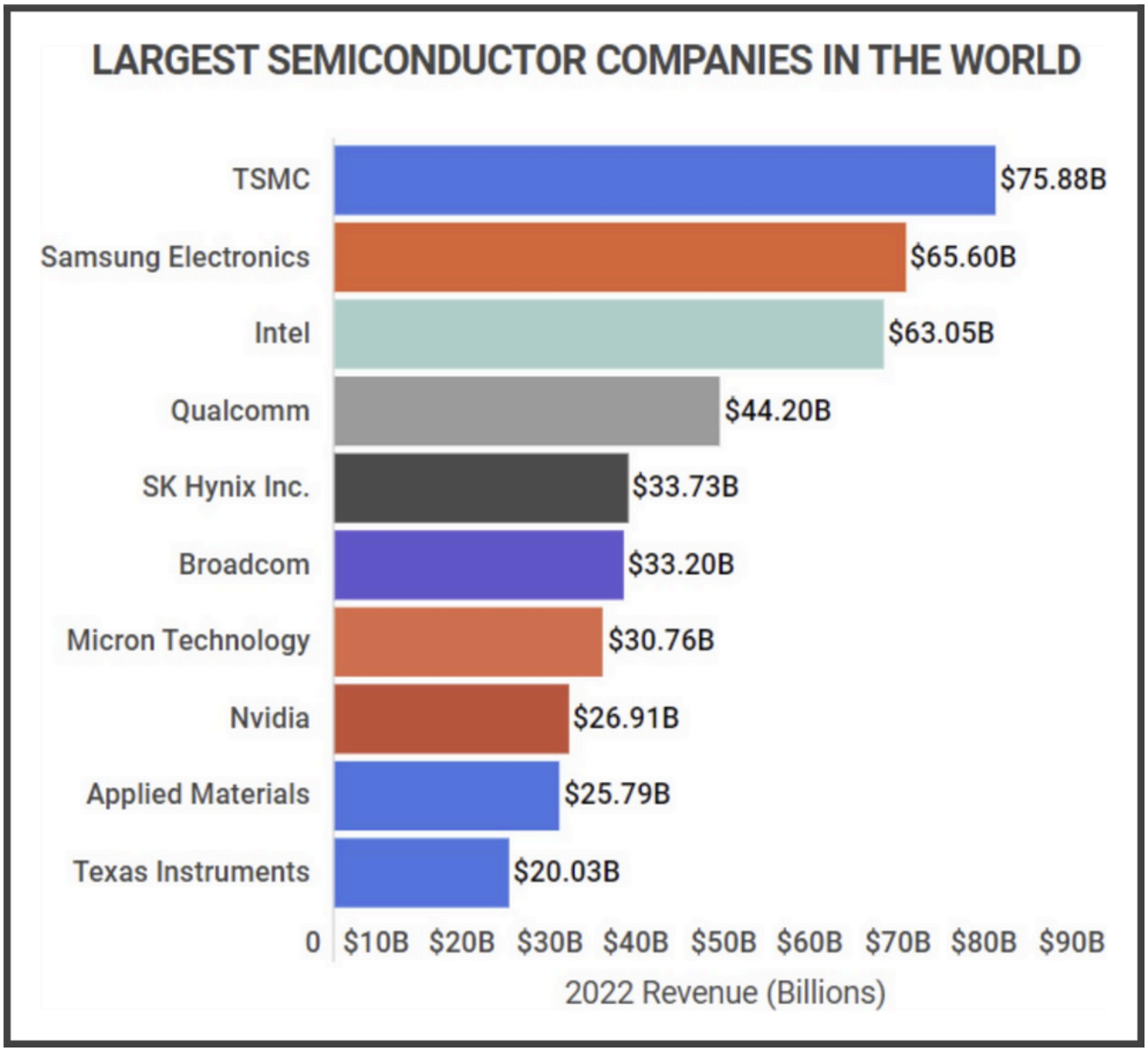

Figure 2: Company Revenue

Project Implementation

Solution: Enhancing Chip Yield with Innoslate MBSE Software

Introducing the Solution

To address the critical issue of low chip yield, leveraging Innoslate's Model-Based Systems Engineering (MBSE) software is proposed. This solution addresses the previously discussed pain points of manufacturing precision, material quality, and technological complexity by providing a robust framework for process optimization and quality assurance.

Step-by-Step Plan of Action

1. Define Requirements and Objectives

- **Identify Key Metrics:** Establish clear yield targets and quality standards. Within Innoslate, this can easily be done by creating requirement documents.
- **Set Baselines:** Use historical data to set benchmarks for improvement, and implement them into test cases.

2. Implement Innoslate for Process Optimization

- **Action Diagrams:** Innoslate is employed to create detailed process maps, defining existing, new, and coming manufacturing sections where yield may be impacted.
    - **Visuals:** Action diagrams illustrate the process of manufacturing for any given project. In Figure 3 below, the user is designing a simple diagram for chip mfg.

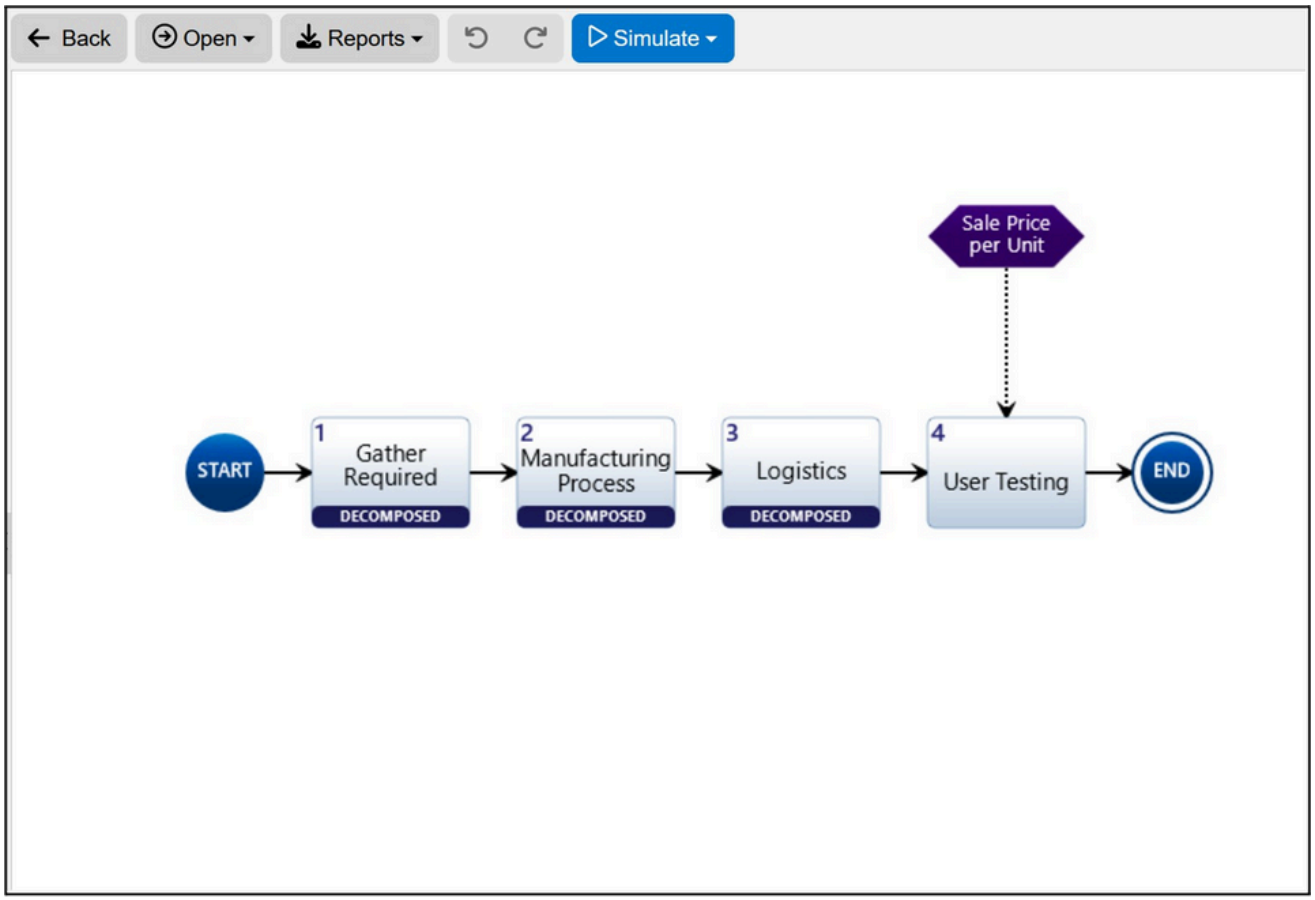

Figure 3: Action Diagram

- Discrete Event Simulation: Action diagrams can be used to simulate resources, time, and other assets. This view can be used to estimate the cost of manufacturing.

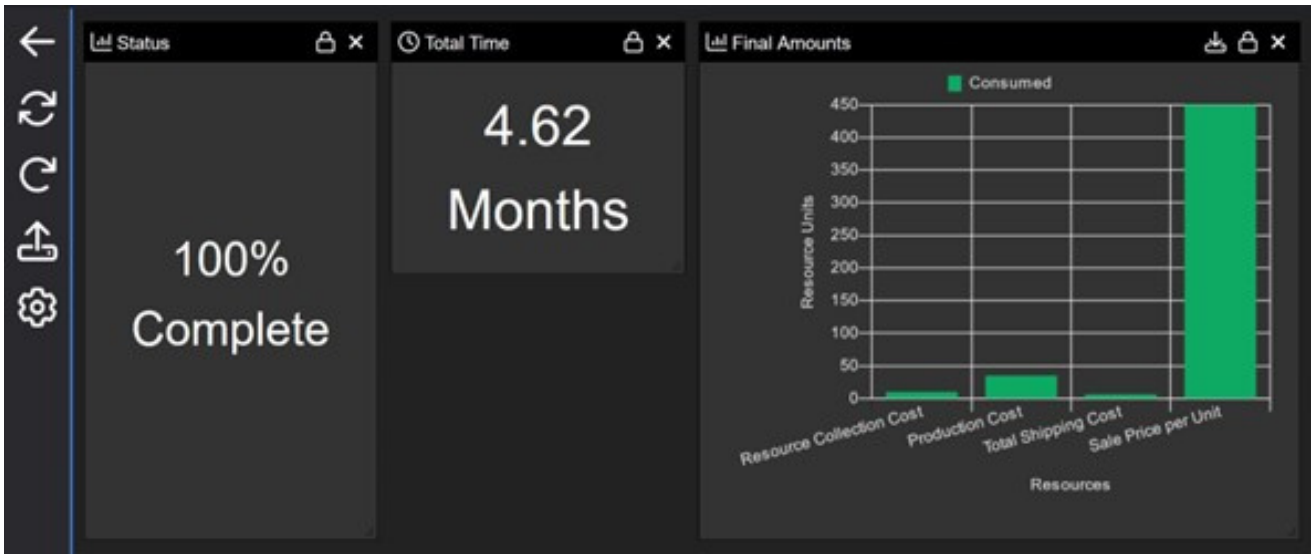

Figure 4: Discrete Event Simulation

3. Conduct Rigorous Testing and Safety Protocols

- **Design Tests:** Develop and implement tests that align with safety protocols to verify each requirement. This can be done within Innoslate's Test Center.
- **Monitor and Adjust:** Use real-time data from tests to adjust and refine manufacturing processes.
- **Traceability Matrix:** Link each process step to specific requirements and test cases to ensure comprehensive coverage and accountability.
    - **Visuals:** As seen in Figure 5 below, traceability matrices can be employed to showcase the relationship between requirements and test cases.

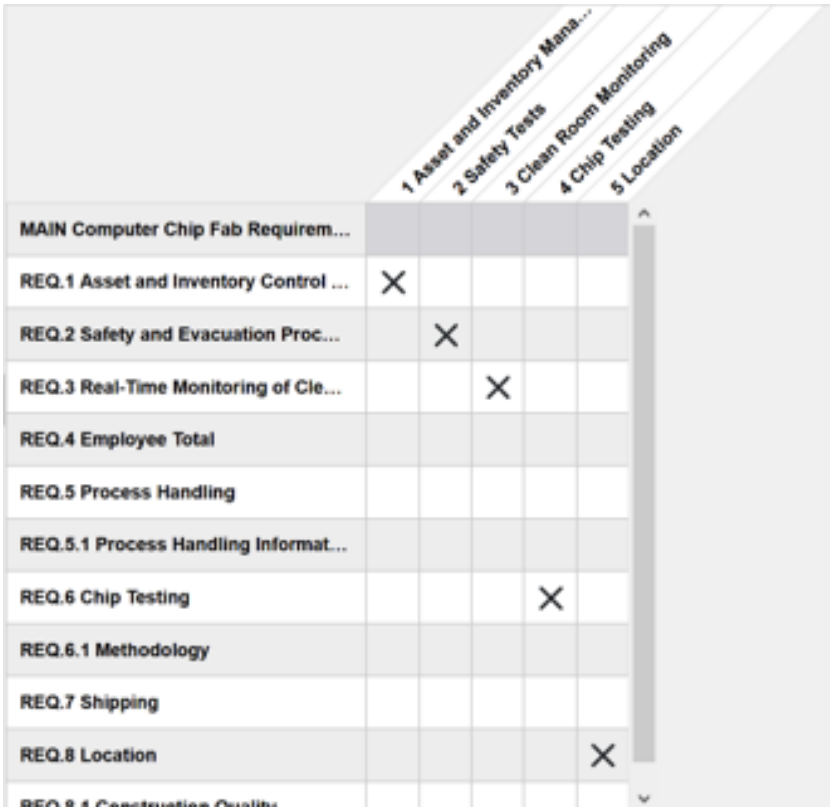

Figure 5: Traceability Matrix

4. Enhance Supply Chain Resilience

- **Inventory Management:** Use Innoslate to track and manage inventory, ensuring materials are always available to prevent production delays. Much like controlling any resource, when an action is completed within a simulation, resources can be either added or removed, allowing the user to accurately measure their supplies.

- **Supply Chain Mapping:** Map out the supply chain to identify potential disruptions and plan contingencies.

5. Collaboration and Continuous Improvement

- **Real-Time Communication:** Utilize Innoslate's collaboration tools to maintain clear and consistent communication among all stakeholders.
- **Feedback Loops:** Implement continuous feedback loops (defined in the glossary) to identify areas for improvement and ensure ongoing optimization.
    - **Visuals:** View the following screenshots to highlight the potential of Innoslate as an all-in-one solution for communication within a project.
    - **AI Tools:** Innoslate help and AI assistant utilize chatGPT to assist the user.

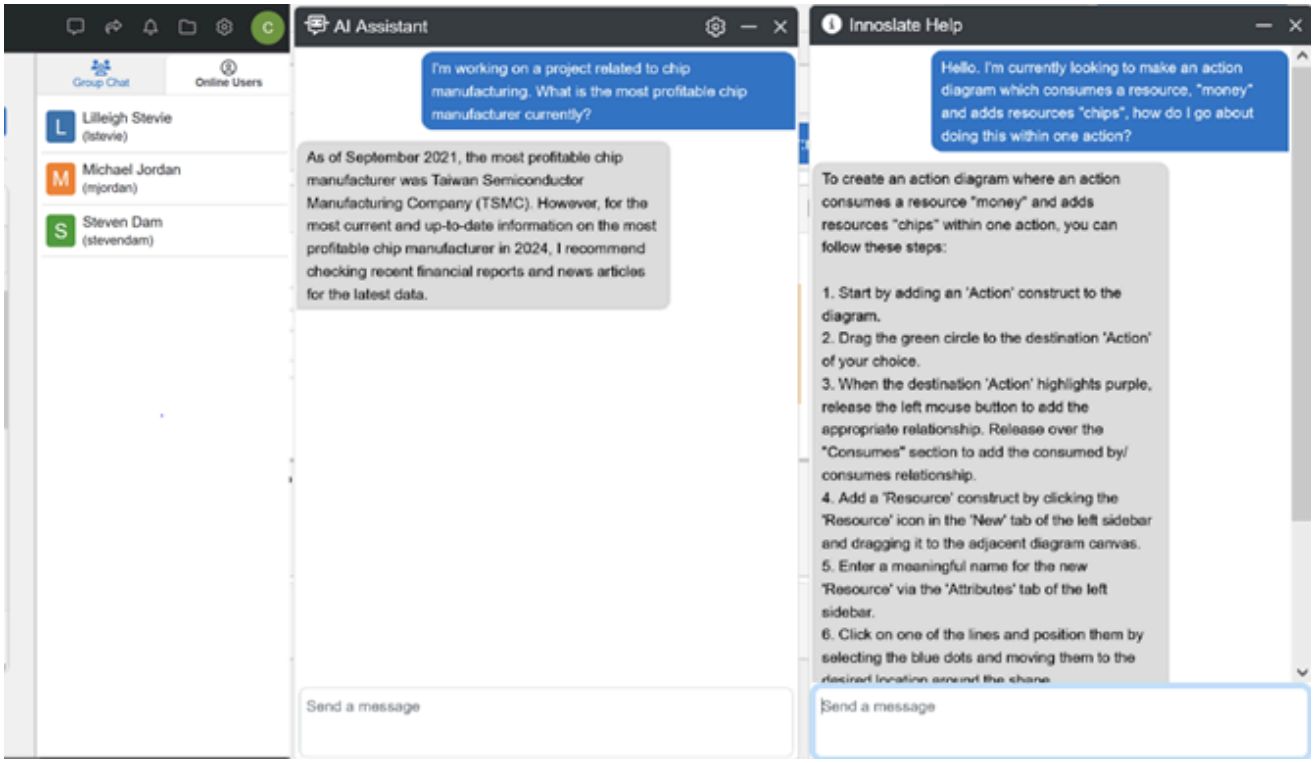

Figure 6: Collaboration & AI Tools

6. Project Management Capabilities

- **Dashboard:** Utilizing the project management dashboard, all upcoming deadlines and events within the project are easily visible.

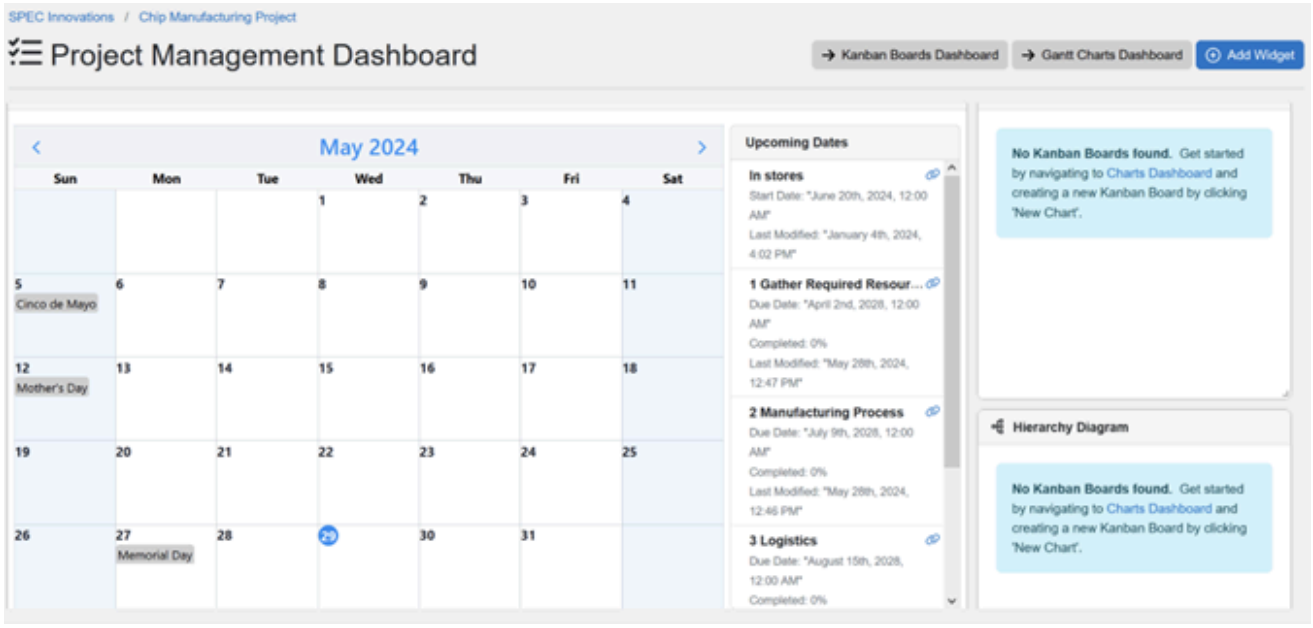

Figure 7: Project Management Dashboard

Benefits of the Solution

1. Increased Profitability

Higher yields reduce per-unit costs, directly enhancing profit margins.

2. Improved Reliability

Consistently high yields indicate a stable and reliable manufacturing process, boosting customer trust.

3. Competitive Advantage

Companies with higher yields can produce more chips at lower costs, gaining a competitive edge in the market.

Real-World Examples

TSMC's Success

- **Example:** TSMC has achieved high yield rates through meticulous process optimization and stringent quality control, resulting in its position as the market leader with the highest revenue (Rieff, 2024).

Startup Semiconductor Company

- **Example:** A hypothetical startup could leverage Innoslate to quickly identify yield-impacting processes, streamline operations, and compete with established players by achieving higher yields and reducing production costs.

Existing Semiconductor Company

- **Example:** A hypothetical implementation for an existing company is similar to that of startups. As Innoslate can be employed to optimize requirements, test cases, and cost estimation in a similar manner, it will improve upon the foundation of the company's current policies.

Concession Statement

While there are various approaches to improving chip yield, some may argue that traditional methods suffice. However, integrating MBSE software like Innoslate offers a comprehensive, modern solution that not only addresses yield issues but also enhances overall process efficiency and reliability, making it a superior choice in the long run.

Conclusion

In the highly competitive semiconductor industry, the challenge of improving chip yield is paramount. Low chip yields result in significant financial losses, reduced reliability, and a competitive disadvantage. This whitepaper has highlighted these critical issues and introduced a comprehensive solution leveraging Innoslate's Model-Based Systems Engineering (MBSE) software to address them effectively.

Review of the Problem

The semiconductor market faces substantial hurdles in maintaining high chip yields due to the intricate and precise nature of manufacturing processes. Companies

struggle with manufacturing precision, material quality, and the increasing complexity of chip designs. These challenges lead to lower yields, higher production costs, and reduced profitability.

Recap of the Solution

The proposed solution involves using Innoslate MBSE software to enhance chip yield through:

- **Action Diagrams:** Detailed process maps to identify and address yield-impacting steps.
- **Traceability Matrix:** Linking requirements to test cases to ensure comprehensive process coverage.
- **Rigorous Testing:** Implementing tests aligned with safety protocols and real-time monitoring for adjustments.
- **Supply Chain Management:** Tracking and managing inventory to prevent production delays.
- **Collaboration Tools:** Facilitating clear communication and continuous improvement among stakeholders.

Re-emphasis on Benefits

Implementing Innoslate MBSE software offers numerous benefits, including increased profitability through higher yields, improved reliability of manufacturing processes, and a competitive edge in the market. These improvements lead to reduced per-unit costs, enhanced customer trust, and the ability to meet growing market demand more effectively.

Final Statement

By addressing the critical issue of low chip yield through the innovative use of

Innoslate MBSE software, semiconductor manufacturers can achieve significant enhancements in efficiency, reliability, and profitability. This approach not only solves the immediate challenges but also positions companies for sustained growth and success in the dynamic semiconductor industry. For more information and resources on implementing these solutions, visit SPEC Innovations and explore further capabilities of Innoslate MBSE software.

Yield Improvement Impact Table. By implementing MBSE into chip manufacturing, higher yield is achieved in an equal amount of time, pointing to increased profits.

Figure 8: Ideal Yield Improvement (15 months)

Glossary

Term	Definition
AI	Artificial Intelligence
Chip Yield	Chip yield refers to the proportion of functional semiconductor chips produced from a single wafer, expressed as a percentage of the total number of chips. It indicates the efficiency and quality of the manufacturing process.
Feedback Loops	Output data goes back into the input data for the next iteration of a program. This allows the data the program is working with to be up to date constantly and is useful for things such as inventory and cost management.
FinFET Technology	A type of non-planar or 3D transistor used in modern semiconductor devices
IoT	Internet of Things
MBSE	Model-Based Systems Engineering
TSMC	Taiwan Semiconductor Manufacturing Company
Yield Learning Curve	A graph that shows how yield improves with increased production and process optimization.

References

Reiff, N. (2024, February 15). *10 biggest semiconductor companies.* Investopedia. https://www.investopedia.com/articles/markets/012216/worlds-top-10-semiconductor-com panies-tsmintc.asp