COMPREHENSIVE SILICON LIFECYCLE MANAGEMENT

FROM DESIGN OPTIMIZATION TO PREDICTIVE ANALYTICS IN THE FIELD, THE BENEFITS OF MANAGING THE LIFECYCLE OF SILICON PLATFORMS ARE COMPELLING

SUMMARY

While the global semiconductor industry has matured on many fronts, producing faster, cheaper and more power-efficient devices in vast quantities, lifecycle management for silicon remains lacking. Until now, there has been little thought given to the need for and benefits of an end-to-end, data-centric solution. Hopefully, this situation is about to change.

According to global industry organization SEMI, semiconductor providers created some 11 billion square inches of silicon in 2019, excluding wafers used in solar panels.[1] Silicon devices are ubiquitous and, of course, critical to business, entertainment, communication, health, safety, autonomous vehicles and security. With that in mind, it is surprising that management throughout a chip's lifecycle remains largely ad hoc or even non-existent. Consequently, the semiconductor industry lacks the data and closed-loop feedback processes that could optimize designs, speed time-to-market, predict failures in the field and increase device longevity. The latter is increasingly critical to safety and security in applications such as automotive development and 5G infrastructure, where lifespans can extend well beyond a decade.

Monitoring and maintaining high-value semiconductors' performance and reliability through a lifecycle management solution could yield significant benefits for critical applications such as autonomous transportation and cloud data centers. The outcome of such a solution could provide access to device health data across a device's lifecycle, addressing quality and security challenges through hardware-based electronic maintenance. Detailed visibility and control of semiconductor devices can help improve performance, safety and security. Some semiconductor design service firms are beginning to offer solutions that chip designers can use as a start, and more comprehensive platforms remain under development. This research paper will examine the concept and benefits of silicon lifecycle management (SLM) and explore one company's efforts to deliver a complete SLM platform.

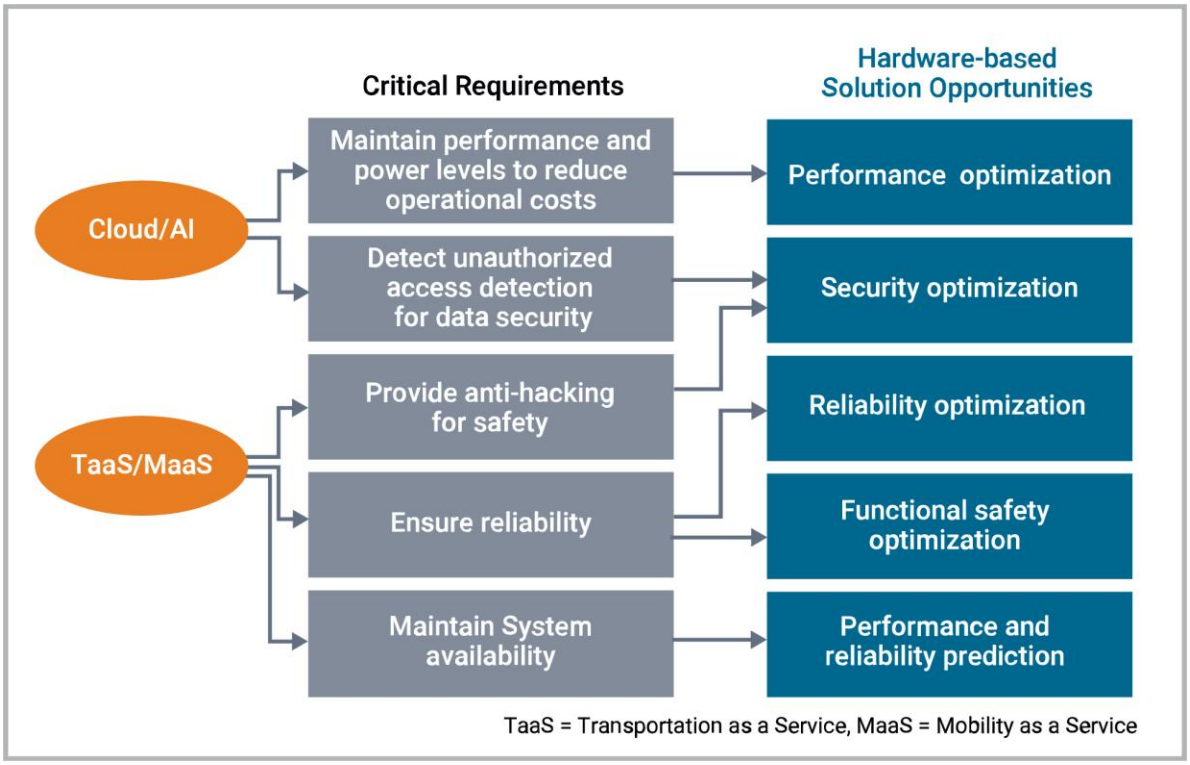
[1] https://www.semi.org/en/news-resources/press/2019-global-silicon-shipments

AN INTRODUCTION TO SILICON LIFECYCLE MANAGEMENT (SLM)

Product lifecycle management (PLM) has been in place for many years, helping businesses in many industries create closed-loop monitoring and feedback into products' engineering and operational lifespans. Led by software providers such as Dassault, Autodesk, Siemens, SAP and others, this practice is relatively mature. It depends on maintaining databases of product lifecycle events such as delivery, service calls and repairs.

Conversely, SLM capabilities are just emerging, enabled by on-chip data collection and monitoring and coupled with offline data repositories and analytics. The full vision of SLM spans development and deployment phases, starting with design and continuing through manufacturing, testing, bring-up and deployment in the field. Each step of the lifecycle adds information such as power, process, performance, temperature and error logs to a comprehensive database, which supports analytics that can improve the product in each subsequent phase.

FIGURE 1: KEY MARKET REQUIREMENTS AND SOLUTIONS



(Source: Moor Insights & Strategy)

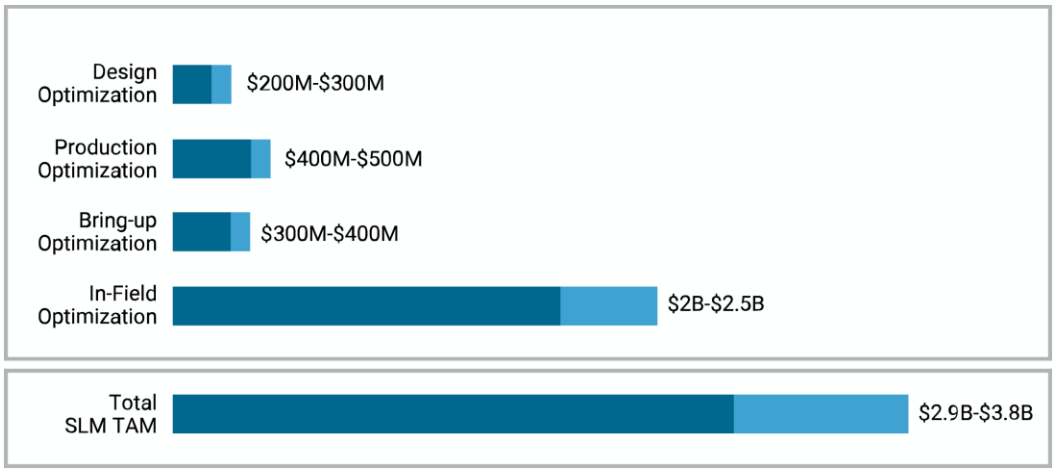
An SLM platform delivers two capabilities to enable the ongoing management of devices: data collection and detailed analytics. As device data feeds, test systems,

engineering teams and customers populate the SLM database, the analytics calibrate the design, identify yield limiters, evaluate and improve product quality and provide predictive maintenance in the field. The in-field phase will likely deliver the most significant benefit to providers and users alike.

The data journey begins when designers integrate targeted sensors and monitors into their chips. While individual sensors such as PVT (process, voltage and temperature) have long been around for real-time circuit calibration, these and other sensors and monitors can now provide input to an SLM database for off-chip analytics. An initial focus for SLM is on high-value devices where the returns justify the investment in logic and analytics. The system on a chip (SoC) designer is critical to successful implementations as they must embed the initial sensors and monitors into the chip. The die area required is typically small and inconsequential from a Power Performance Area (PPA) standpoint.

For example, data centers require performance and power optimization to manage total ownership costs and meet service-level agreements. Intrusion detection and security management are also vital to data center operators. Other high-value segments, such as advanced driver-assistance systems (ADAS) and autonomous vehicles, require extreme safety, security and reliability levels. In these environments, predictive maintenance and performance monitoring can provide tremendous value to the silicon provider, silicon customer and end-user.

FIGURE 2: SLM MARKET SIZE ESTIMATES



Estimated industry-wide annual revenue for SLM technology and services
(Source: Synopsys)

Synopsys, a leading provider of electronic design automation (EDA) software and services, has introduced the most comprehensive SLM platform we have seen and has provided us with its internal market size projections. We think these projections may be conservative, depending on the timeframe. In-field service and optimization analytics, especially valuable to data centers and automotive suppliers, represent the largest market opportunity for Electronic Design Automation vendors and their clients.The estimates in Figure 2 represent Synopsys' views on what each SLM product/technology category could generate on an annual basis, with in-field optimization by far the largest segment.

FIGURE 3: SILICON MANAGEMENT VALUE CHAIN

	Design	Manufacturing	Test	Debug/Bring-up	Deploy and Use
User(s)	Design engineers	Manufacturing engineers Product/yield engineers	Test, product/yield, quality, assembly engineers	Silicon, software & system designers	Product or service end-users
Resources	Sensors (PVT, ...) Monitors (DFT, structural and functional) Calibration analytics	Sensors and monitors Yield ramp analytics	Sensors and monitors Test and quality analytics	Sensors and monitors Embedded analytics	Sensors and monitors Predictive maintenance analytics
Metrics	PPA Resilience Security Time to Market	Yield Quality / resilience Excursion frequency	Specification gaps DPPM Test time OEE	Performance Power TTM	Performance, power, resilience, safety, security
Benefits	Tighter timing Calibrated design models TTM/ fewer iterations Closed loop understanding of SoC performance	Faster yield ramp Improved yields Customer delivery Excursion detection /prediction	Test time reduction Improved quality Fast excursion detection	Improvements in power & performance Faster TTM	Improvements in performance, power, resilience, safety, security
Costs	Engineering time Minimal die area Data storage	Minimal die area Data storage Data integration Data management Engineering time	Minimal die area Data storage Data integration Data management Engineering time	Minimal die area Data storage Data integration Data management Engineering time	Minimal die area Data storage

(Source: Moor Insights & Strategy)

POTENTIAL BENEFITS OF SLM

Figure 3 outlines the users and benefits across the value chain of a high-value semiconductor's lifecycle. Analytics can improve design calibration, accelerate yield improvements, reduce testing time and time to market and, most importantly, predict failures or deterioration in the field. The need for in-field quality assurance and maintenance increases demand for SLM. These needs are evolving beyond predictive failure analysis, especially in the quest for ongoing optimization via firmware and software updates that can keep the product within specifications and even improve those specifications, based on monitoring across a fleet or datacenter of devices.

Effects of device aging and new security threats are identified at the hardware level and resolved in the field without replacing the silicon device.

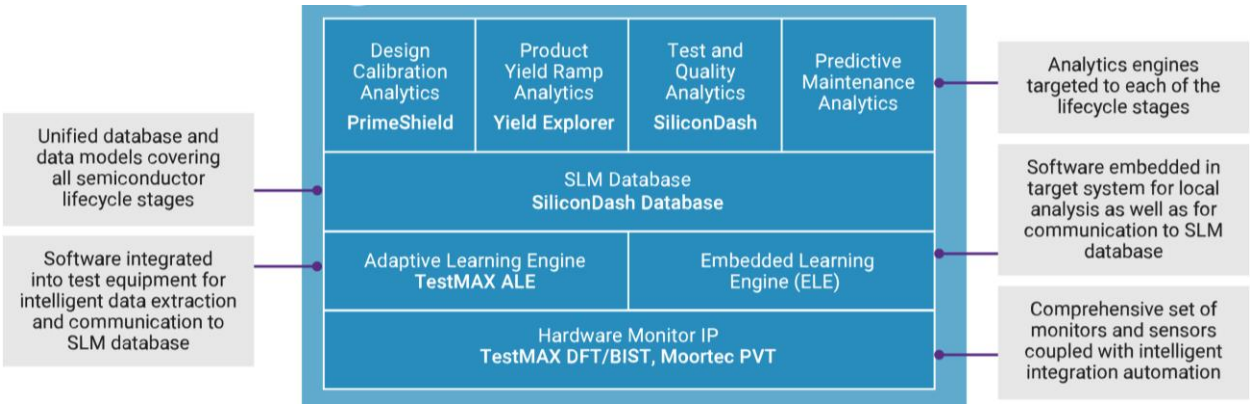
To realize these potential benefits, system architects, SoC architects and their management must take leadership positions, embrace the SLM vision for products and define the services needed by the end-users. The typical SoC mantra of "Performance, Power and Area" should be augmented with "Manageability," and the team must drive that concept through the entire product's lifecycle.

THE SYNOPSYS SLM PLATFORM

Having established SLM's requirements and benefits, let's look at how one company delivers on the promise. Synopsys has decided that the time is right to enable this journey with an SLM platform that spans the value chain. The company points to a decreasing tolerance for in-field device failure as data centers and transportation segments depend on reliable silicon for safe and secure operations.

Figure 4 outlines the Synopsys SLM Platform. The foundation provides the sensors and monitors which feed the database and analytics platforms. Synopsys recently acquired Moortec, a leading provider of in-chip monitoring technology specializing in PVT sensors, to accelerate SLM development.

FIGURE 4: SYNOPSYS SILICON LIFECYCLE MANAGEMENT PLATFORM



The Synopsys SLM platform includes hardware monitors, learning engines, a product database and four analytic engines, three of which are currently available.

(Source: Synopsys)

Sensors and monitors feed two adaptive learning engines. The first is TestMAX ALE for test equipment and is currently available; the second will be an embedded learning engine that target system software can use to provide in-situ analysis at a system level.

These two engines feed the SLM database, informing four analytic engines targeting different product lifecycle phases. Three of these analytic engines are now available for design, manufacturing and testing. The fourth, the predictive maintenance engine, is currently under development. In our opinion, the existing modules provide significant value, which the availability of predictive maintenance will only enhance.

The Synopsys SLM database is extensible, enabling users to add proprietary IP, technology and methods to deliver customized value. As one should expect, the SLM database contents remain the developer's property and need not be shared with Synopsys.

It is important to note that design teams need to think about and plan for SLM before starting the design phase, specifying the goals and tactics needed to enable management across the lifecycle phases. Senior management buy-in to the SLM concept is critical to achieving alignment across the teams and ensuring success.

Although Synopsys SLM seems to be one of the most comprehensive offerings we have seen, the company is not alone. Other platforms are available that provide specific features for specific challenges. For example, ProteanTecs focuses on design optimization, while Mentor/Siemens acquired UltraSoC earlier this year to add embedded functional monitoring and analysis technology to its Tessent product suite.

CONCLUSIONS AND RECOMMENDATIONS

SLM can lay a new foundation for improving quality and maintenance across the semiconductor lifecycle, from design through deployment. Closing the silicon loop by analyzing on-chip monitor and sensor data to optimize all the silicon lifecycle phases creates a new chip design process and maintenance model.

Awareness of the value, benefits and techniques of the SLM concept should help IC industry leadership instill a sense of urgency in design teams to embrace SLM in product design. EDA vendors are the logical torchbearers for SLM as these firms can provide the required expertise, data collectors, analytics and monitors. We anticipate that other EDA providers will follow Synopsys and develop comparable SLM solutions, which will increase the visibility and appeal of SLM across the landscape and help early adopters forge ahead.

The future of SLM is taking shape. Proactive management and design teams are beginning to embrace the concept, with early adopters benefiting first from SLM applications. While SLM platforms remain a work-in-progress, the time to start is now;

the fundamental building blocks are already in place and analytic platforms are taking shape. We conclude that SLM adoption will quickly become a significant industry trend in high-value silicon devices.

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