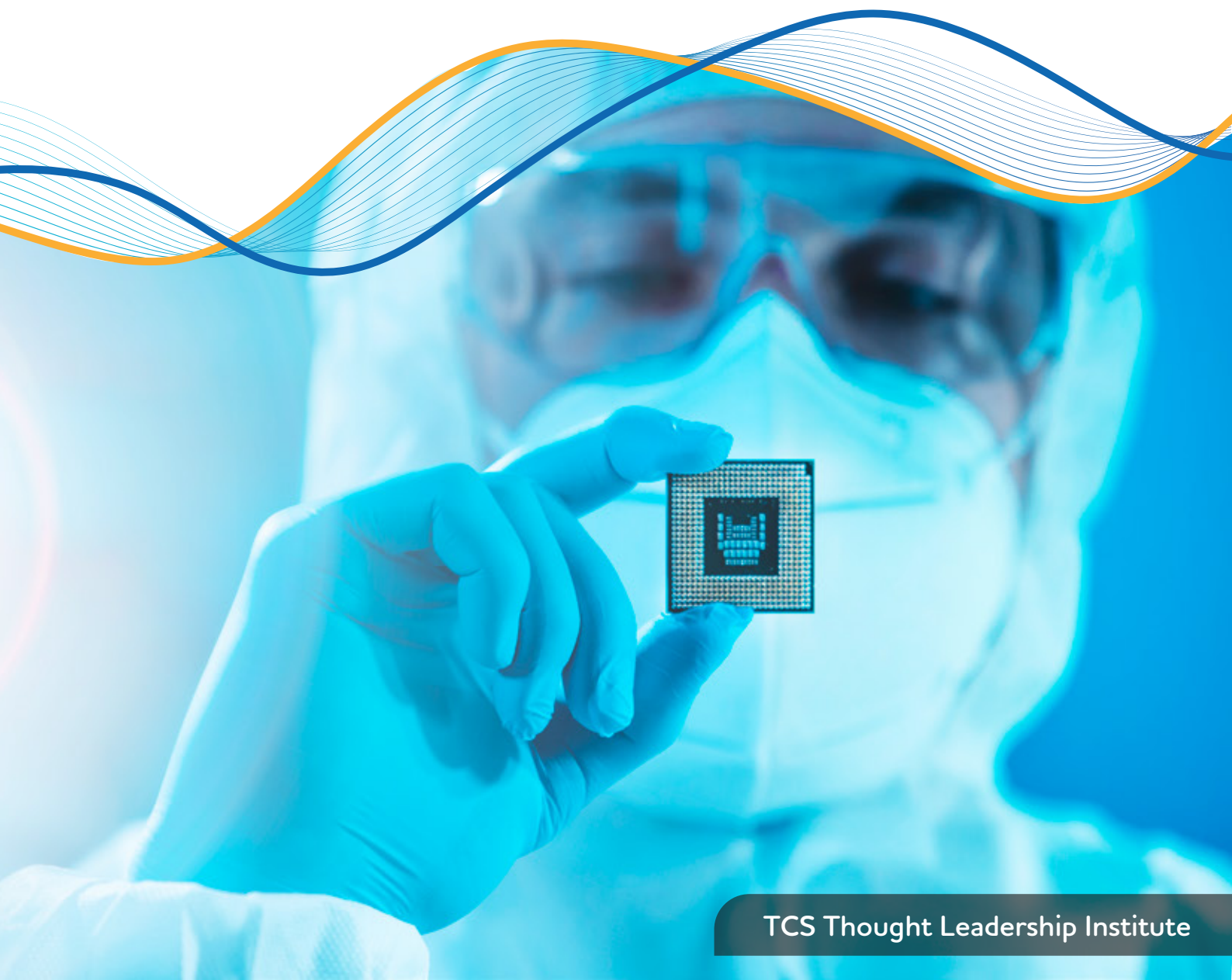
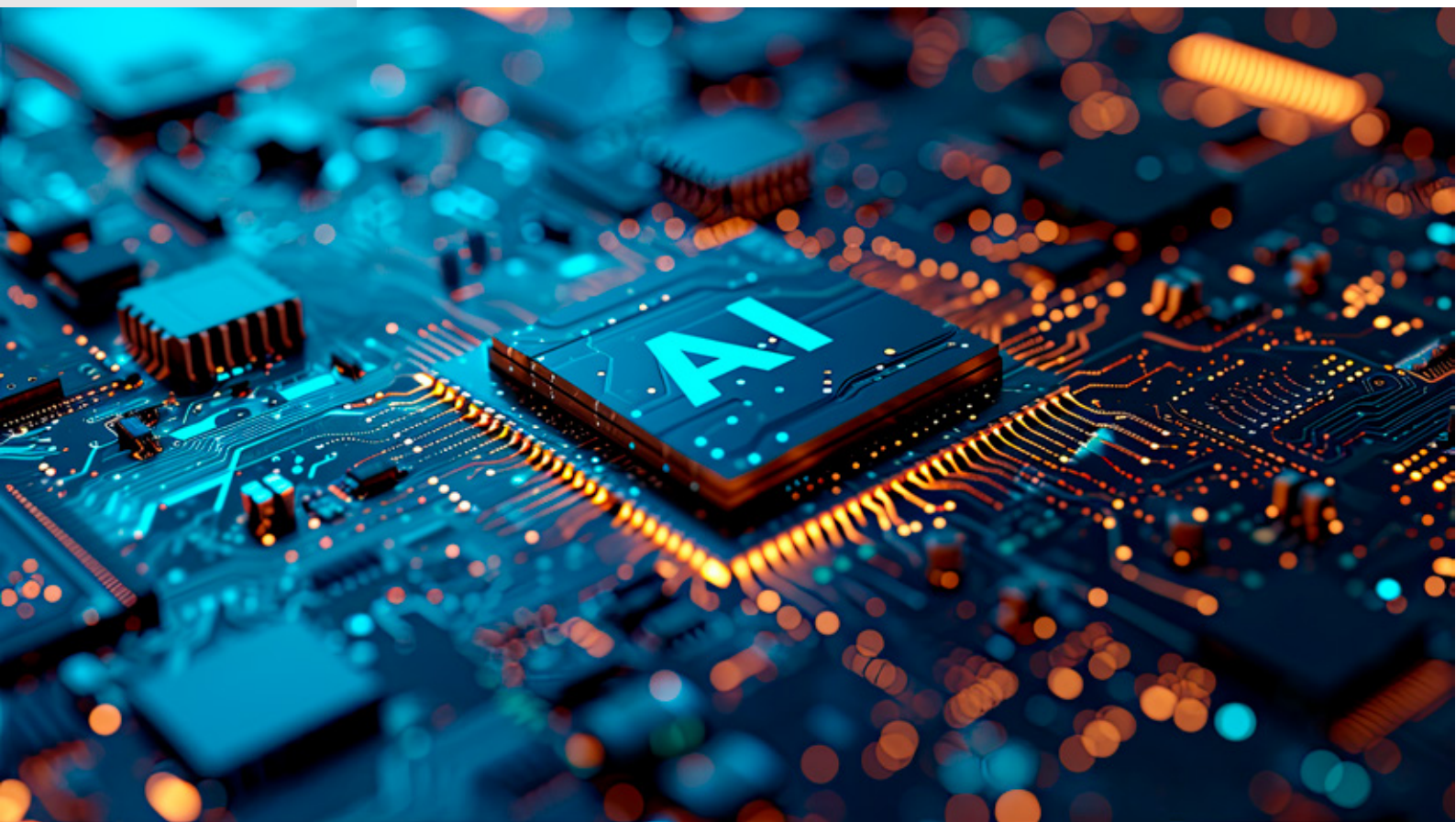


Next-generation semiconductors: Powered by generative AI



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Key takeaways

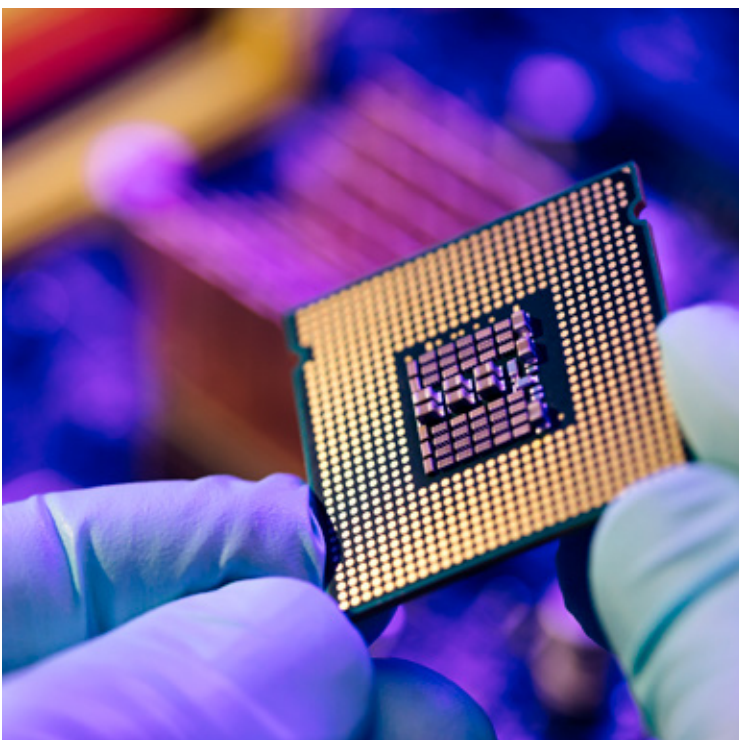
- The emergence of generative AI (GenAI) has the potential to reshape the semiconductor industry's value chains fundamentally.
- Merging reasoning and recognition intelligence into generative models allows for previously unimagined capabilities in quality control, product development, and support through accelerated innovation.
- Using their deep contextual knowledge, TCS designed a best practice approach to help semiconductor companies master the delicate balance of opportunity and risk to ensure successful GenAI outcomes.

Revolutionize

From tiny devices implanted in hearts to the sprawling infrastructure of large-scale factories, the semiconductor industry shapes nearly every aspect of modern life.

Now, with the emergence of generative artificial intelligence (GenAI), the industry has the potential to fundamentally reshape its own value chains.

Long plagued by skills and materials shortages, GenAI can help semiconductors improve chip layout designs, streamline production, optimize resources, and mitigate supply chain disruptions to meet continuing demand. In an industry where even the slightest delay can have far-reaching consequences, GenAI offers a new way forward.



AI: Then to now

Initially, AI focused on recognition tasks, like identifying objects in images. Its next iteration involved reasoning; analyzing what is happening, why it is happening, what the likely outcomes are, what we should do about it, and decision-making based on that understanding.

The most transformative shift happened with the advent of generative or operative capabilities, exemplified by large language models (LLMs) like generative pre-training transformer (GPT), language model for dialogue applications (LaMDA), and large language model meta AI (LLaMA). These models leverage predictions made during the reasoning stage and can make decisions and propose actions.

GenAI and large language models can potentially extract insights from unstructured content. Foundational models, such as GPT, LLaMA, and open-source alternatives, are 'world-wise,' able to integrate common knowledge that may exist offline, such as in books or in art. By combining such models with 'enterprise-wise' ones and traditional AI-ML techniques, semiconductors can create a knowledge superstructure.

Generative AI for semiconductors

Many semiconductor companies have already made a strong head start with artificial intelligence (AI) technologies that incorporate reasoning and recognition forms of intelligence.

Over the past few years, semiconductor businesses have increasingly used predictive analytics to forecast demand and reduce unplanned equipment downtime.

The merging of reasoning and recognition intelligence into generative models (see sidebar) marks the start of a transformative era for semiconductors. This integration allows for previously unimagined capabilities across the value chain covering quality control, product development, and support, including:

Research: At the outset, GenAI can analyze vast amounts of market data to determine optimal opportunities for resource allocation and competitive advantage. Proposals for novel equipment designs based on efficiency, size, cost, and initial circuit, or system schematics based on power, performance, and area parameters can shorten timelines and reduce costs.

Design: GenAI can accelerate development by translating research and development insights and specs into designs, and iteratively refine choices and chip layout designs based on human feedback. Real-time suggestions and design checks can help identify potential issues with power, performance, and area parameters for optimal production efficiency and yield.

Sourcing: Sourcing details require careful consideration, including quality, reliability, alternate pricing strategies, and sustainability checks. GenAI can streamline sourcing by offering rapid, ongoing evaluation of materials, suppliers, and components for human review. In addition, AI can help predict inventory needs based on production data, historical demand patterns, and lead times for more informed decision-making.

Production (test and assembly): Leveraging GenAI's transformative power can achieve faster, more accurate testing and simulations for design and implementation. With the ability to predict equipment failures, GenAI can help reduce downtime and accelerate time to market. In addition, rapid analysis of production line images can alert human operators to the need for closer inspection to detect errors.

Packaging: GenAI models trained on datasets of manufacturing defects can identify potential defects in real-time to ensure quality control. Designers can create multiple packaging scenarios, endlessly refining parameters for thermal performance, reliability, or cost to determine optimal configurations.

Distribution: GenAI models can create step-by-step intelligent troubleshooting guides based on reported issues and aid technicians with contextual knowledge. Additionally, GenAI can help supply chain and distribution analysts sift through changing market conditions and potential disruptions to ensure timely chip delivery at an optimal cost. GenAI intervention can also help in anomaly detection in supply chain plans and continuous adjustments in execution plans, such as material requirement planning, capacity requirement planning, and production scheduling, based on new demand and supply triggers.

Service and support: GenAI models can continuously analyze data to detect potential equipment failures and recommend comprehensive process improvements and upgrades. Natural language responses for routine customer inquiries for technical assistance, warranty service, returns and replacements can guide customers to accurate, customized responses and personalized assistance, enabling staff to focus on more complex inquiries.

In Figure 1, we list these seven value streams, along with relevant use cases of GenAI, where applicable. It is important to note that in most of these examples, intelligent technologies are a digital assistant for humans, not a replacement. AI will augment humans in their day-to-day work, empowering them to make consistently better decisions and truly innovate in a way that transforms the entire organization.

	Research	Design	Source	Make	Package	Distribute	Support
Semiconductor Equipment Manufacturer (SEM)	Designs semiconductor equipment for efficiency, cost and size	Refines equipment designs iteratively with human input	AI continuously optimizes supply chain for human review	Analyzes equipment data to predict failures, reducing downtime	Not Applicable	Generates troubleshooting guides for technicians to adapt	AI recommends process and equipment upgrades
Electronic Design and Automation (EDA)	Creates new schematics based on power, performance and area	Translating R&D insights into software solutions, from schematic capture to layout	Not Applicable	Not Applicable	Not Applicable	Personalized distribution, predictive deployment, intelligent licensing	Predictive maintenance prevent disruptions proactively.
Foundry	Predicts equipment maintenance to save time.	Provides real-time suggestions for optimal manufacturability	Rapidly evaluates suppliers for quality, reliability, sustainability	Rapidly analyzes production images to identify defects, alerting operators	Not Applicable	Ships finished chips globally, ensuring timely, cost-efficient delivery	Generates and Personalizes draft responses.
Fabless	Generating Marketing and Sales strategies	Generative AI offers real-time design optimizations	Not Applicable	Not Applicable	Not Applicable	Gen AI optimizes supply chain with real-time data	Generative AI Provides first-level technical support
Integrated Device Manufacturer (IDM)	AI predicts innovative materials with optimized Performance	Generative AI automates preliminary design checks	AI predicts disruptions, suggests alternative suppliers, enhances resilience	AI generates chip designs from specs for engineer approval	AI assists QA by highlighting potential defects in real-time	Gen AI recommends supply chain adjustments for changes	Technical Assistance, Warranty Service and Returns Management
Outsourced Semiconductor Assembly and Testing (OSAT)	AI Simulates Outcomes, reducing trial costs	Generative AI automates DRC for packaging designs	AI predicts inventory needs, informing SCM decisions	Not Applicable	Designers and AI optimize packaging for thermal performance, reliability, cost	AI forecasts demand, optimizing inventory and supply chain	Gen AI to generate draft responses for inquiries

Figure 1: GenAI focus areas for semiconductors

As an example, Figure 2 illustrates how GenAI infusion into the daily activities of a logistics manager helps solve pressing problems like troubleshooting and availability.

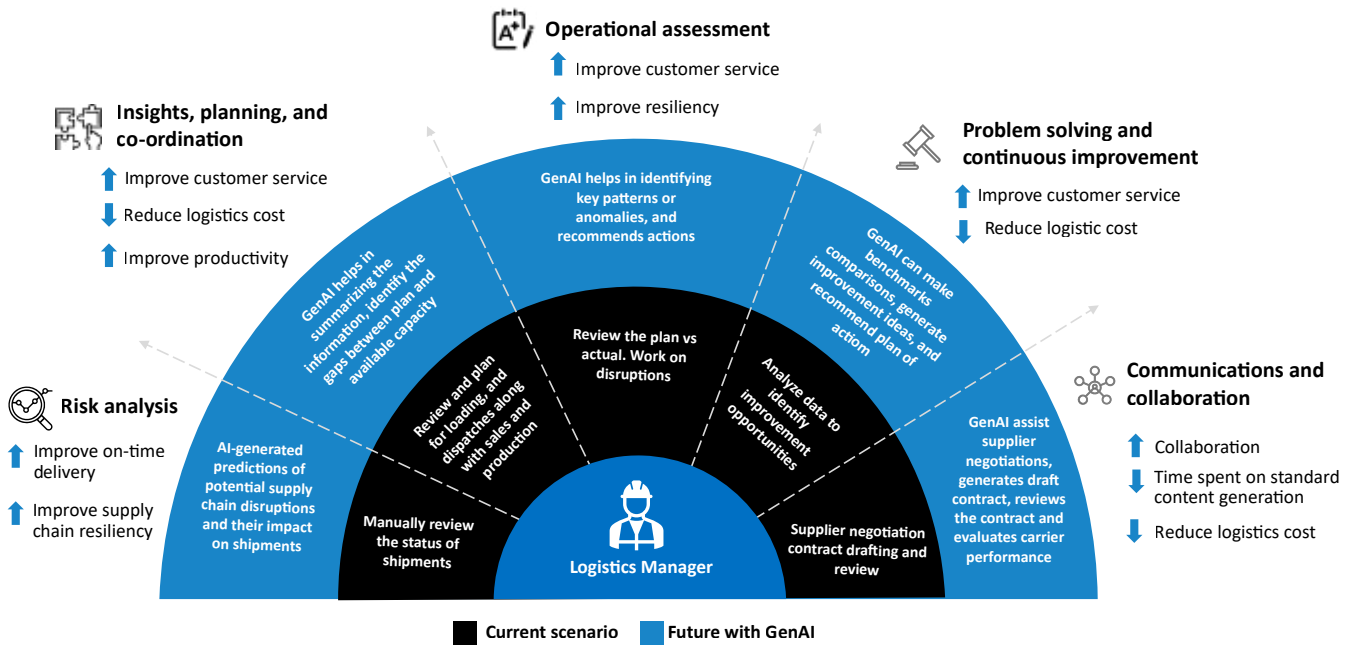


Figure 2: GenAI infusion into the daily activities of a logistics manager

Our GenAI vision

Transforming the potential of GenAI into sustained performance requires a tailored fit, not a one-size-fits-all solution.

The journey requires a multidimensional strategy and an enterprise architecture optimized for cost, quality, security, and privacy.

It can be complex, demanding meticulous preparation in terms of data, environment, and the potential creation of purposive agents tailored to specific tasks or activities. Choosing the right mix of intelligence, such as large language models or predictive AI, involves numerous decisions, making the solution-building process intricate.

Drawing on our extensive experience in working with hundreds of global organizations, we take a best practice approach to help semiconductor companies master the delicate balance of opportunity and risk to ensure successful outcomes. Built on the principles of an industry-led, data-fueled and ecosystem-enabled foundation, we offer an ‘enterprise-wise’ approach designed to make AI consumable for an enterprise-grade transformation (see Figure 3).

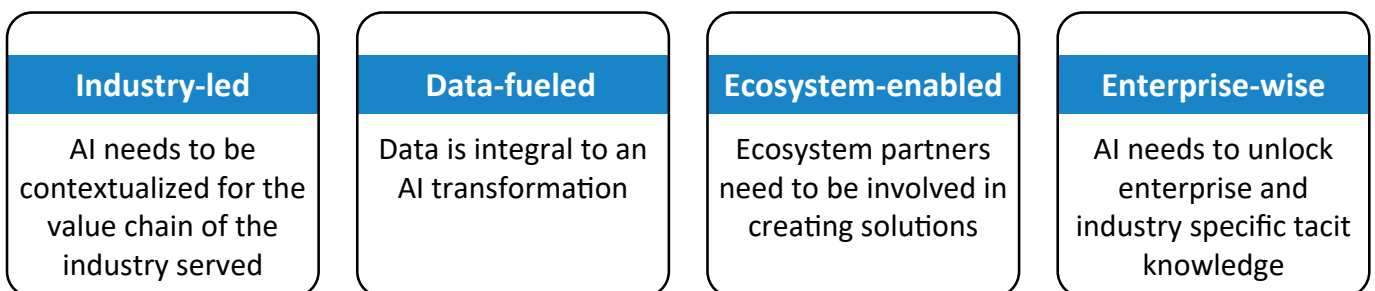


Figure 3: ‘Enterprise-wise’ AI adoption approach

These four principles underpin our approach to converting AI potential to performance, a continuum that builds upon and reinforces each stage: assist, augment, transform (see Figure 4).

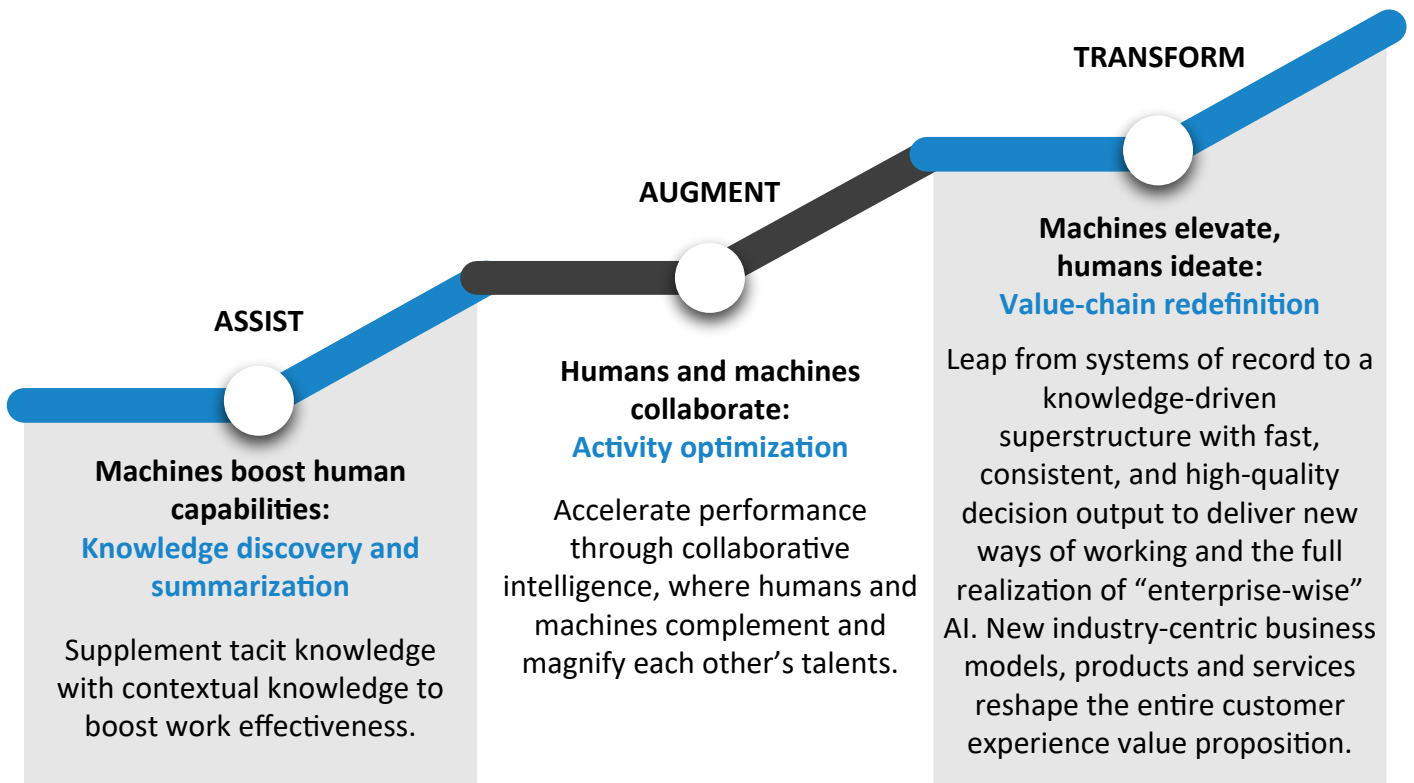
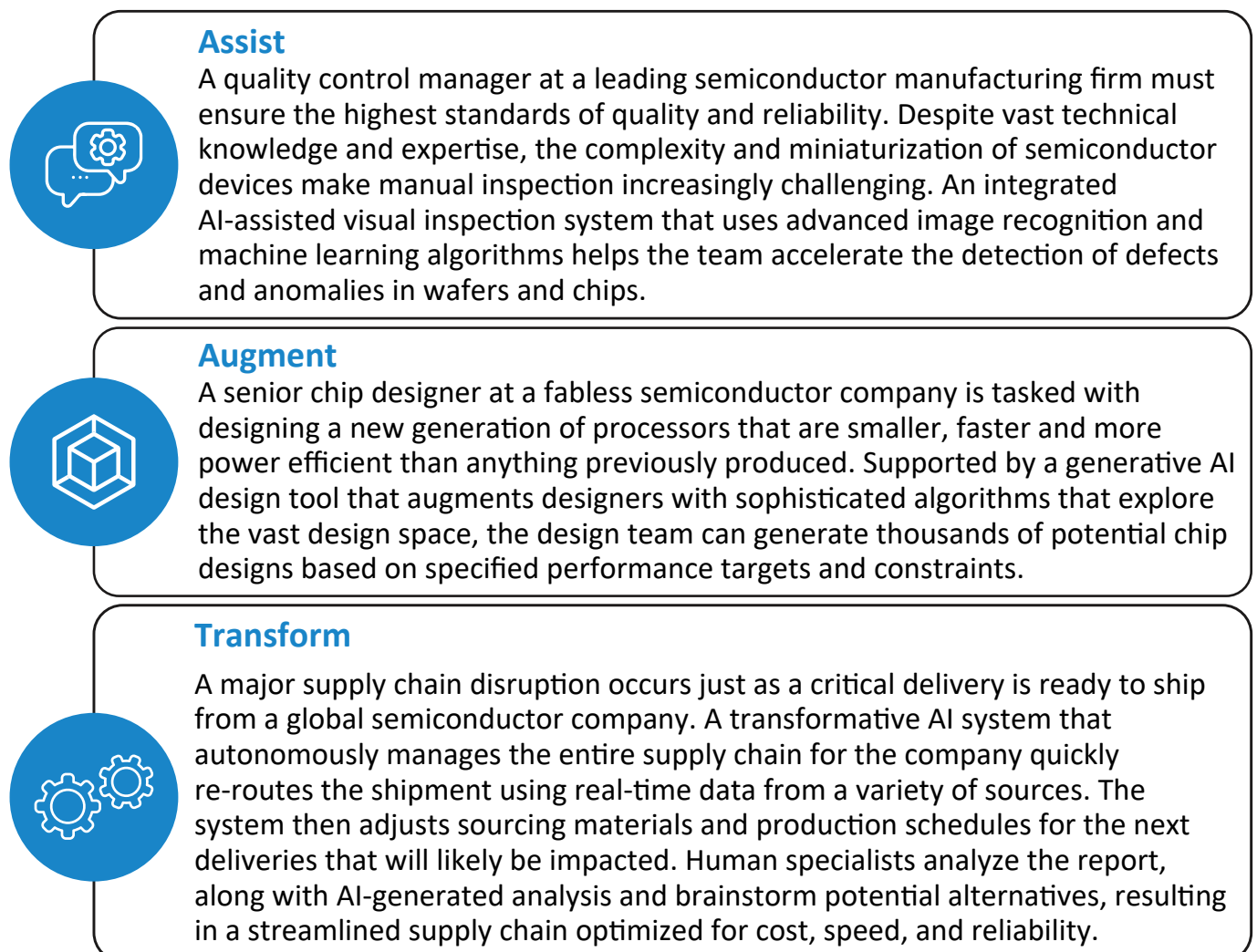


Figure 4: TCS AI continuum for semiconductors

An AI evolution in action



Navigating the complexity: A multi-layered approach

It can be challenging to develop a robust business case when it's difficult to quantify the business benefits and costs of AI. How can the semiconductor industry prepare for an AI evolution? Any AI solution must start with a value-augmentation opportunity for business; prioritizing use cases, rather than starting with technology adoption. For semiconductors to fully exploit the potential of AI, it is essential to have access to a multitier architecture and integration to enterprise systems.

Figure 5 shows the TCS enterprise architecture framework for semiconductors.

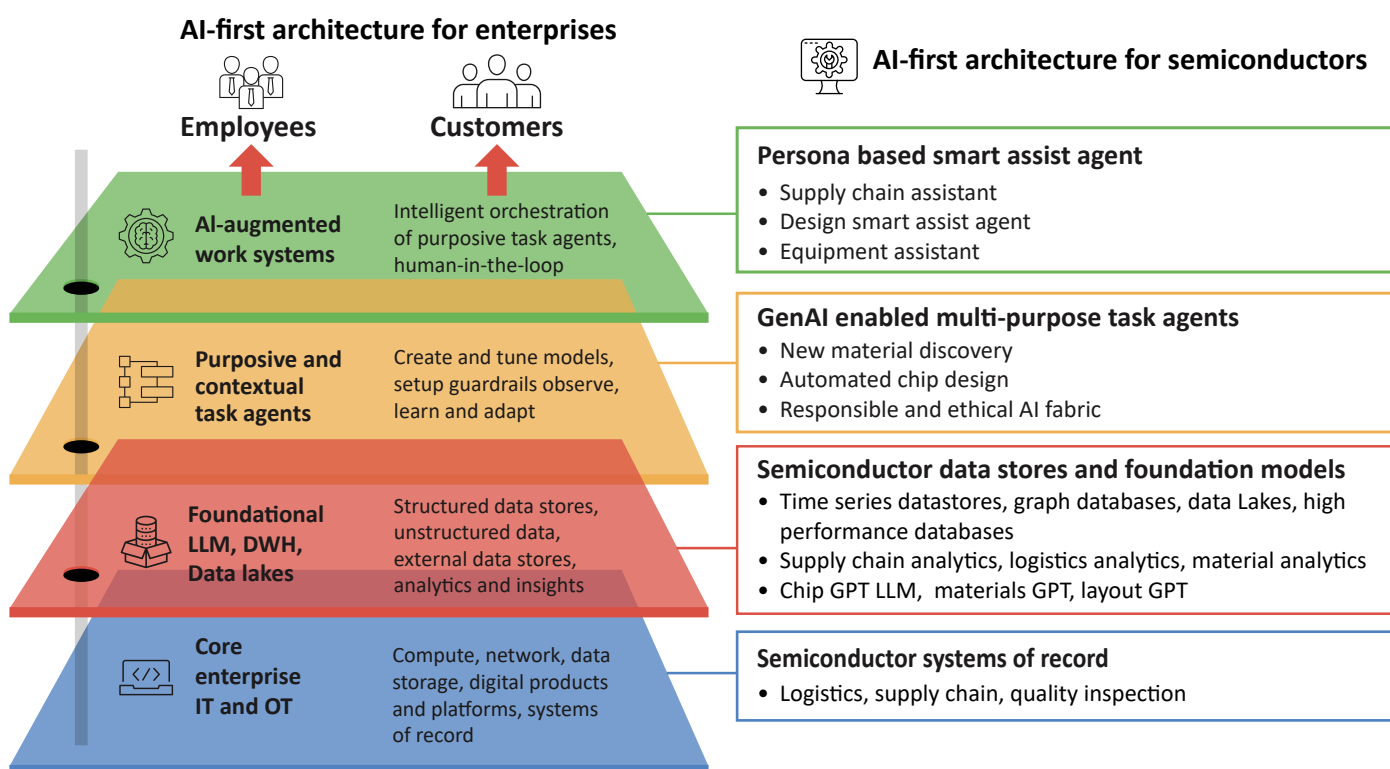


Figure 5: TCS AI architecture for semiconductors

- The bottom-most layer predominantly enables the compute, network and application as a foundation, and the existing enterprise IT and semiconductor systems of record such as logistics, supply chain and quality inspection systems.
- The layer above enables foundational LLMs for a variety of knowledge management use cases such as analytics for supply chains, logistics, and materials across semiconductor industry value-chain.
- The layer above that constitutes GenAI enabled purposive and contextual task agents to enable various moving parts of AI. For example, fine-tuning of AI models on an ongoing basis, establishing the necessary guardrails for responsible and ethical implementation of AI, and a strong machine learning (ML) and LLM operations capability for continuous learning by the models.
- The final layer comprises task agents that interact with each other within each stage of semiconductor value-chain in a seamless fashion with a human-in-the-loop for validation, verification, and disambiguation.

The TCS advantage

Our strong partnerships help semiconductors successfully navigate GenAI transformations to drive sustained performance.

Deep domain and contextual expertise:

Well-established enterprise knowledge and technological expertise across the semiconductor value chain for leading global semiconductors enable robust AI applications and ongoing support.

Cross-industry experience:

Working with customers across industries like manufacturing, transportation, retail and insurance brings an end-to-end holistic view of enterprise business functions and knowhow.

Partner ecosystems:

Scale and accelerate the path to value through a network of joint solutions, established hyperscaler partnerships, an extensive TCS CoIN™ network, co-innovation facilities such as TCS Pace Port™ and co-creation with TM Forum.

Enterprise AI at scale:

Our 3P strategy, patents, products, and platforms, and over 100,000 trained associates help us enable enterprise AI at scale.

Evolving capabilities:

TCS offers multiple areas of capabilities that infuse predictive and GenAI interventions to assist and augment the semiconductor value streams.



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A part of the Tata group, India's largest multinational business group, TCS has over 601,000 of the world's best-trained consultants in 55 countries. The company generated consolidated revenues of US \$29 billion in the fiscal year ended March 31, 2024 and is listed on the BSE and the NSE in India. TCS' proactive stance on climate change and award winning work with communities across the world have earned it a place in leading sustainability indices such as the MSCI Global Sustainability Index and the FTSE4Good Emerging Index. For more information, visit www.tcs.com

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