Case Study
Digital Twin Technology
Manufacturing IT

Intel and Sony Semiconductor Corporation Solutions Advance Digital Twin Technology for Manufacturing

How two world leaders in semiconductor manufacturing collaborated to optimize high-performance factory technology

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Table of Contents

Overview

Other than electricity itself, no technology has changed the world as much as semiconductors. As the essential components of the continuing computer evolution, they are responsible for dramatic changes in virtually every area of modern life. As semiconductors have evolved into a wide variety of forms—including but not limited to microprocessors, memory chips, and integrated circuits—they have become the enabling technology behind a broad array of devices, from our ubiquitous PCs, laptops, and smartphones to cameras, home appliances, automobiles, laser-powered devices, and innumerable specialty systems for business, industry, healthcare, transportation, aerospace, defense, and more.

Sony Semiconductor Manufacturing Corporation (SCK, a subsidiary of Sony Semiconductor Solution Corporation) is a world leader in the semiconductor industry. Headquartered in Kumamoto, Japan, SCK produces and markets image sensors, integrated circuits, and a variety of components for use in the devices mentioned above.

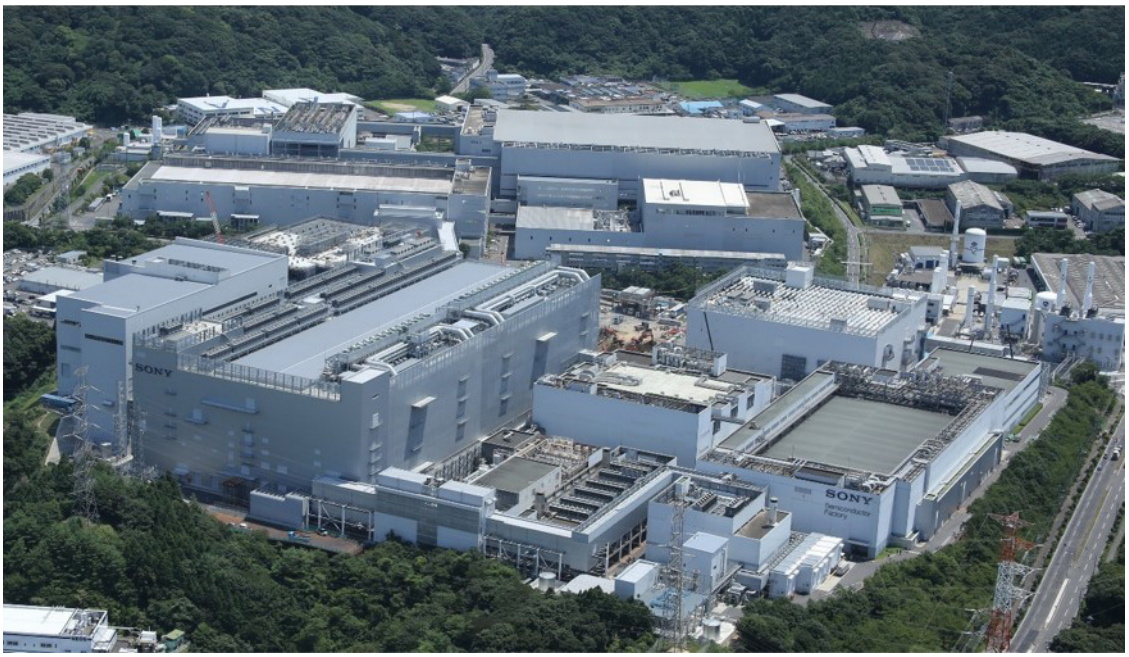
The manufacturing of semiconductors is complex, demanding, and expensive. Cutting corners isn't an option, as meeting the highest standards of quality is critical to maintaining industry leadership. Balancing process efficiency while delivering that quality (all while maintaining the margins required for overall profitability) is a never-ending job.

To help meet these challenges, SCK joined forces with Intel Corporation, a leading innovator in the microprocessor industry for many years. With over fifty years of experience in successfully manufacturing semiconductors, Intel was uniquely positioned to team up with SCK. This paper details the progress—and success—of that partnership.

The Challenge

In general, semiconductor manufacturing can be segmented into *front-end manufacturing*, consisting of Fabrication (Fab) and Sort processes, and *back-end manufacturing*, where assembly, testing, and finishing processes take place. Of these, the fab processes are the most complex and require the most manufacturing time. As a result, optimizing any steps in fab manufacturing can translate into significant bottom-line savings and increased product margins.

In 2020, SCK was dealing with specific long-term fab issues. Their Nagasaki manufacturing complex (known in industry terms as a "fab") was home to several separate factory buildings. Coordinating workflow through these separate operations was a campus-wide Automated Materials Handling System (AMHS), but the complexity and isolation of the different facilities was hampering efficiency and effectiveness. Exacerbating the materials



SCK Nagasaki Technology Center

handling situation, SCK had begun adding new fab floors in addition to the ones already in operation. These new facilities would need to be supported by the already-overburdened AMHS—a huge obstacle to overcome. SCK was facing the prospect of spending millions of dollars to upgrade the AMHS system and install additional process equipment to handle the expansion.

This is where Intel comes into the picture. In 2020, SCK met with Intel to discuss possible strategic approaches to their situation. During these meetings, it became clear that Digital Twin technology held great promise for enabling a long-term solution to the challenges they were facing.

Digital Twins: The Key to Automated Manufacturing

Just what are Digital Twins? In simplest terms, Digital Twins are models built of data. While similar to physical models of objects, they can contain much more information, so they can be significantly more comprehensive and robust. For a long time, the development of Digital Twins was restricted because they often required a prohibitive level of processor performance. Today, that obstacle has been surmounted: the ever-increasing technological capabilities of computers equipped with Intel® Xeon® Scalable processors mean developers can effectively digitize the concept of modeling, raising it to new, dynamic levels. Now, instead of simple physical replicas, Digital Twin data sets can simulate not only the physical attributes of entities (such as shape, color, and size) but also more abstract characteristics (such as strength, elasticity, conductivity, and many more). Plus, once created, Digital Twins of different objects can be combined into Digital Twin systems with behaviors mimicking those of their real-world counterparts. That behavior can be recorded, analyzed, tested, and revised cyclically.

In recent years, the use of Digital Twins has expanded into a wide variety of industries, with manufacturing being one of the most fruitful. The ability to digitally represent

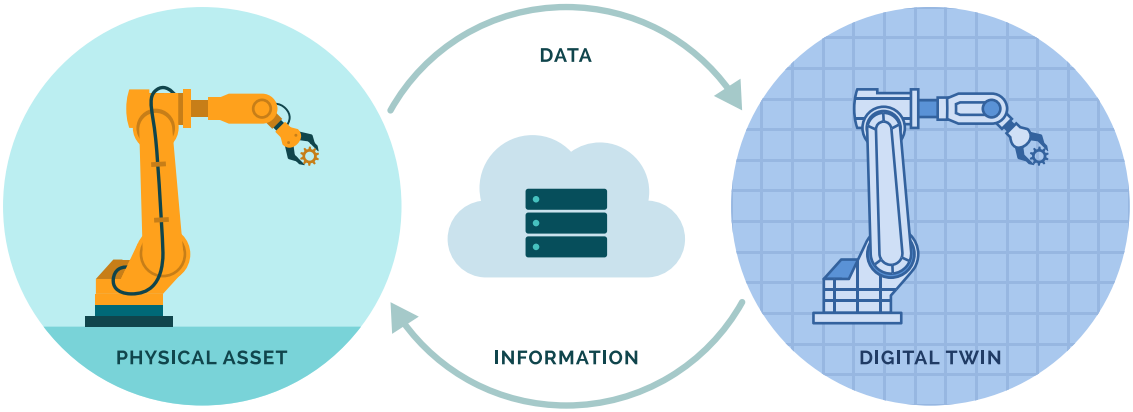


Figure 1. The flow of data in a Digital Twin configuration.

objects and functions has opened an enormous range of possibilities for manufacturing engineers and technicians, who can now simulate a wide variety of operations quickly and without risk of damage or disruption of operations. Digital Twins have proved invaluable in a wide range of manufacturing environments, including discreet manufacturing (individual items such as cars, planes, semiconductor wafers, and processors), process manufacturing (chemicals, petroleum, pharmaceuticals, etc.), and more.

Working Toward a Solution

Having determined that Digital Twin technology was the key to the required solution, the SCK-Intel team set out to create a framework for moving ahead. Based on a carefully engineered engagement process that Intel had developed, the framework was designed to deliver transparency throughout this first-time software partnership, as well as to reduce risk for SCK.

They agreed on a win-win engagement process. The first step was a structured peer-to-peer information exchange, where SCK would provide technical details about their product flow and AMHS situation (and the problems they were experiencing), and Intel would share knowledge of comparable Intel processes and (importantly) software solutions they had developed to improve these processes.

After this information exchange, the second step was for Intel engineers (working remotely due to COVID-19 restrictions) to collaborate with SCK staff to plan, develop, and test Proof of Concept (POC) software projects. At the heart of the solution were two Intel software products, Intel® Factory Pathfinder and Intel® Factory Recon. Using these powerful tools, prototypes were implemented using obfuscated data as a series of NRE (Non-Recurring Engineering) tasks, the goals of which were to comprehensively exercise new approaches and confirm that they would deliver the improved production results the team was aiming for.

These development cycles involved intensive testing, interspersed with iterative code modifications and retesting loops. Given the importance of the process, quality assurance was rigorous.

Intel engineers worked closely with their SCK counterparts during all project phases, from conception to launch. The goal was to enable discrete event simulation to optimize the SCK production line, integrated in near real-time with the dispatching system. The prototypes passed all performance and reliability goals, and the initial phase of the project went live in April, 2022.

In parallel with the adoption of Intel Factory Pathfinder, SCK also implemented Intel Factory Recon. A Digital Twin visualization mapping tool, Intel Factory Recon enables SCK to clearly visualize all fab floors and all AMHS lanes, including vehicle location and status, tool operation status, and more. This powerful Intel tool means that SCK can remotely monitor the entire fab, check wafer movement, control lane congestion, and verify equipment and error status in real time. Intel Factory Recon can visually "play back" events in SCK fabs, enabling staff to quickly troubleshoot problems that would have been difficult or impossible to isolate previously. In addition, managers can visually simulate future transfers, allowing them to confirm fab floor changes or tool relocation activities before making the actual physical moves.

Sony Semiconductor Solutions Group

SCK produces a variety of products that power the modern world. Image Sensors, SCK's flagship products, serve as the "electronic eyes" of myriad modern devices, enabling the preservation of images, entertainment, and information.

" We firmly believe that our imaging and sensing technology will be increasingly responsible for developments in society as the technological advancement accelerates changes in the world. This will necessitate us to collaborate with various partners and create open innovations."

Terushi Shimizu, Representative Director, President and CEO

Other SCK products include:

- Edge AI Sensing Platforms
- Large Scale Integration Modules
- Integrated Circuit Modules
- Microdisplays for AR headsets
- Boards, diodes, and more...

Results

In developing software tools for factories, Intel leveraged decades of experience in optimizing and streamlining semiconductor manufacturing processes. Intel engineers' and programmers' long history in the creation and refinement of algorithms running in Intel fabs have delivered significant benefits to Intel manufacturing facilities around the world—including major reductions in inter-fab transfers by up to 50%*. In this project, the goal was to provide equivalent benefits for SCK. Let's look at what happened.

SCK completed the integration of the Intel tools in June, 2022. While implementation is still in the introductory phase, with six months of live operation at the time of this writing, results have been overwhelmingly positive. SCK

has achieved a 25% reduction in the transport traffic on the interconnects between fabs—while maintaining previous levels of manufacturing output. This strong result is directly attributable to the introduction of Intel Factory Pathfinder and the implementation of physical and logical production control capabilities made possible by the SCK-Intel team collaboration. For instance, the team jointly optimized the Intel Factory Pathfinder simulation parameters for SCK fabs, further enhancing results.

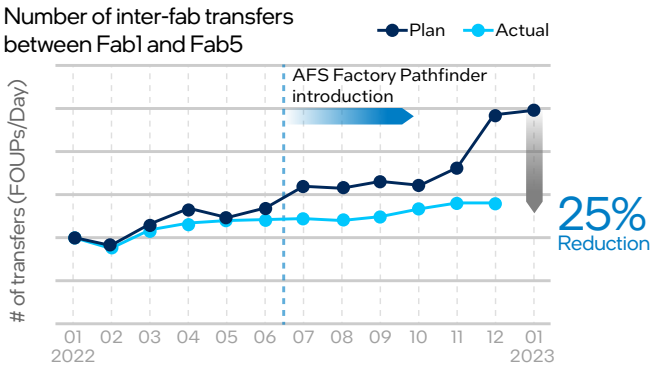
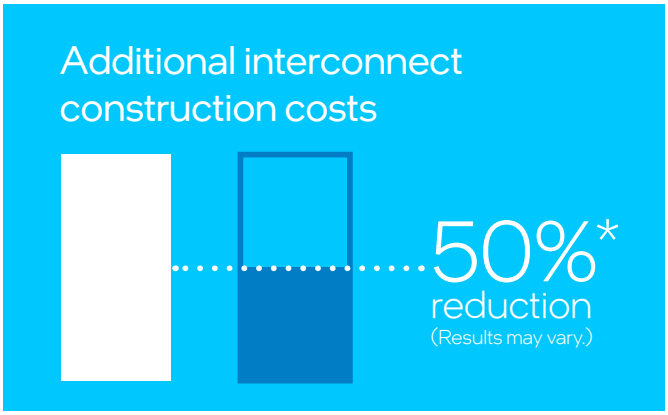


Figure 2. Fab transfer history*. (Fewer transfers are better. Results may vary.)

In addition to the capabilities and customizability of Intel Factory Pathfinder, SCK found that the simulation speed of operations was *200 times* faster than the prior industry-leading solution they had been using*. This was one of the decisive factors SCK considered when finalizing adoption of the Intel software. Using these simulation capabilities, SCK ran thousands of simulations, drilling down to the best cases. Intel Factory Pathfinder enabled truly significant improvements, with materials delivered to the most suitable process equipment, whether in the same manufacturing facility or a different fab. By adopting Intel Factory Pathfinder, SCK reduced the cost of additional scale-out inter-fab transfer capacity by 50% compared to operations before the project*.



In addition, with Intel Factory Recon, SCK engineers can now view rich visualizations of the Digital Twin of the multi-fab, campus-wide AMHS via their computer displays. This enables them to monitor the AMHS's traffic behavior in real time, trace materials, view historical events, and create and analyze future "what-if" cases. As a result, the SCK implementation of Intel Factory Recon has enabled better transfer management, more efficient manufacturing, and increased overall fab efficiency. As illustrated in Figure 3, Intel Factory Recon enables more efficient mean time to repair (MTTR).

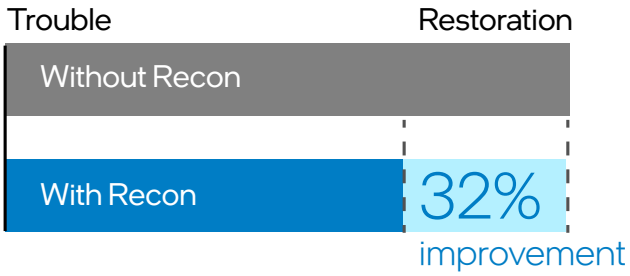


Figure 3. The Recon effect*. (Greater improvement/less trouble is better. Results may vary.)

What SCK engineers said after implementing Intel Factory Recon:

"By viewing what is happening on another floor on one screen, we can grasp the impact of a problem."

"Looking back on the restoration work and clarifying the reasons for mistakes and work that took time, we can use Intel Factory Recon to provide feedback for troubleshooting."

"By sharing the situation at that time with the manufacturing team, it is possible to have them understand the situation well."

"We can see in playback mode how the anomaly happened and how the deadlock happened."

Intel Tools for Semiconductor Manufacturers

Let's look more closely at what Intel brought to the table for SCK.

All the Digital Twin capabilities we've covered so far are highly relevant to Intel's experience in the semiconductor industry. Their transformation to digital manufacturing started over forty years ago, in the 1980s. In that era of chip manufacturing, workers in Intel processor fabrication plants tracked materials on paper, and a lot of tool-to-tool silicon handling was performed manually. Over the years, chip manufacturing steadily increased in complexity, and of course, demand for chips exploded exponentially, both of which drove the evolution of processor fabrication toward increased digitization.

Starting in the 90s, Intel massively digitized wafer production by implementing highly integrated factory systems, including tool controllers, manufacturing execution systems, advanced process control, and automated material handling systems. In the early 2000s, fabs saw further steps toward digitization by introducing remote operations centers that enabled a fab to be monitored and managed off-site. With the introduction of Industry 4.0, Intel quickly adopted many of the strategies inherent in this revolutionary development to help meet the challenges of increasingly complex microprocessors and other components. These efforts have proved highly successful: harnessing the power of Digital Twins has been a true game-changer, streamlining processes and reducing costs. As a result, Intel has significantly increased per-person productivity and reduced unit throughput time while maintaining outstanding product quality, even as microprocessor manufacturing procedures have exponentially increased in complexity.

Intel® Automated Factory Solutions (Intel® AFS)

With the promise of Digital Twins firmly established, Intel formed the Automated Factory Solutions team in 2019. Its mission is to leverage Intel's hard-earned expertise in manufacturing automation software like Digital Twin technology and provide it as commercial products for other manufacturers around the world.

Intel® AFS Digital Twin software inspired by solutions implemented in Intel fabs has provided tremendous benefits. Now these solutions are available for use by other discrete manufacturing companies.

Intel® Factory Pathfinder – Implemented at SCK Nagasaki Technology Center

Intel® Factory Pathfinder delivers advanced simulation and scheduling capabilities for manufacturing. It uses Digital Twin technology to provide manufacturers with critical capabilities designed to improve processes, increase efficiency, and reduce costs. As a simulation-based system, Intel Factory Pathfinder can digitally model the entire factory floor, including machines and infrastructure, and can recreate the flow of materials through the system, as well as the many processes involved in turning raw materials into finished product. Intel Factory Pathfinder can even help manage product handling in multi-factory environments (as is the case with SCK), optimizing the movement of products within and across facilities to help reduce the cycle time of each individual product through the manufacturing process.

With Intel Factory Pathfinder, companies can turn disorganized and wasteful processes into organized systems, reducing "ping pong" problems and increasing productivity, as shown in Figure 4.

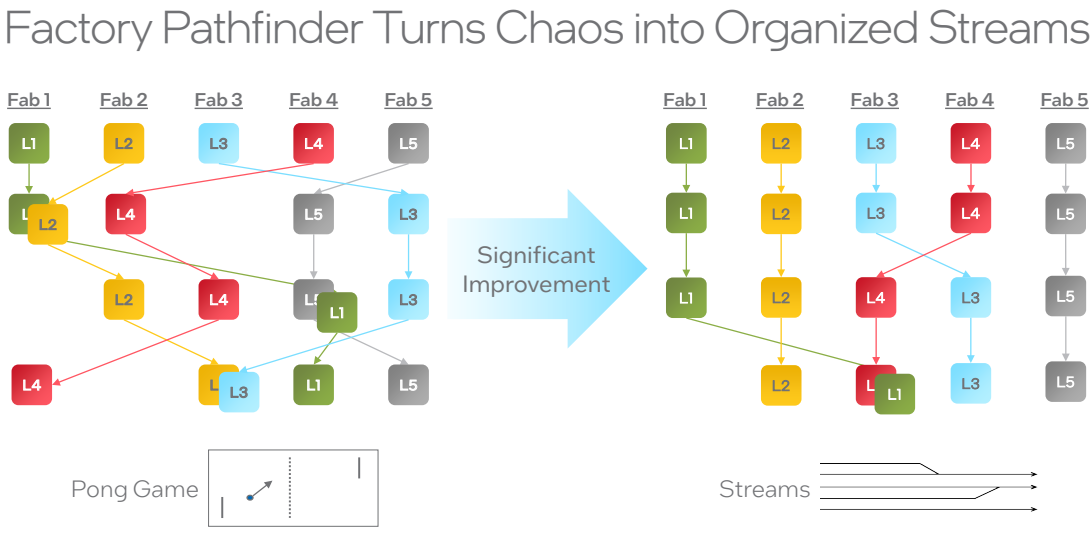
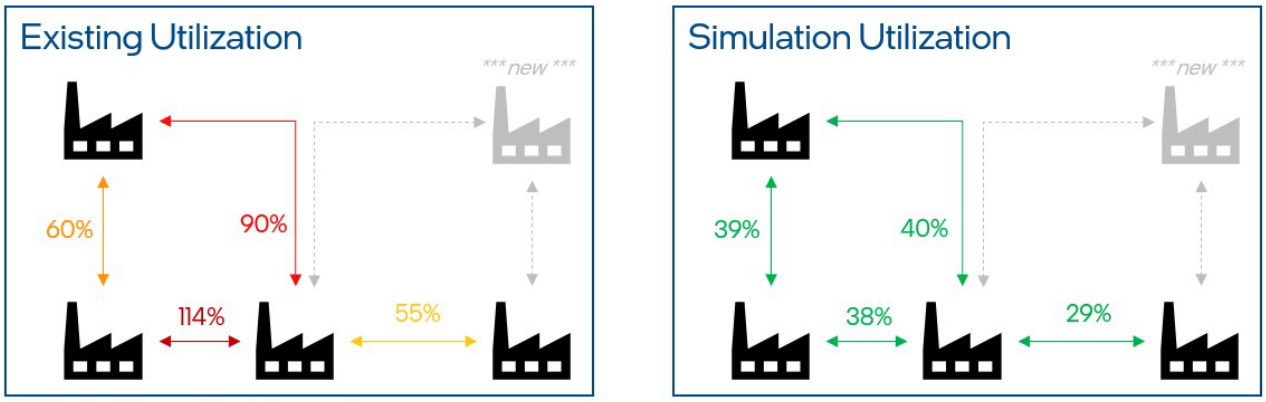


Figure 4. Streamlining materials handling by simulating forward and making better decisions.

- Problem: Multi-factory campus Automated Material Handling System (AMHS) building link capacity is stressed ahead of expansion.
- Solution: Intel Pathfinder greatly reduces product movement, saving tens of millions of dollars (and more).



*Utilization/Capacity is measured in product moves per day.

Figure 5. Greatly optimized product movement observed from simulation results.

And, as shown in Figure 5, through simulation, Intel Factory Pathfinder can significantly optimize product movement between separate manufacturing facilities, removing wasteful AMHS building transfers while maintaining production levels.

Intel® Factory Recon – Implemented at SCK Nagasaki Technology Center

Intel Factory Recon enables manufacturers to use game-like, immersive graphics capabilities to instantly visualize their operations better than ever before—how they're running now, how they ran in the past, and how they might run in the future. Thanks to this enhanced visibility into their operations, companies can dramatically reduce Mean Time to Repair (MTTR) for factory incidents. Intel Factory Recon not only serves as a factory incident detective system to investigate problems, but also as a flexible simulation application for modeling "what-if" scenarios.

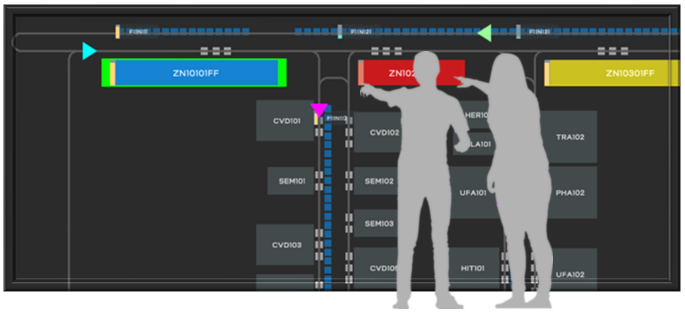


Figure 6. Intel® Factory Recon Graphical User Interface (GUI).

Intel Factory Recon works in several modes:

Live Mode
Presents AMHS information in a single panel view, so managers can quickly view the entire factory operation, including AMHS, production equipment status, error alerts, and more. Problems can be discovered more quickly, mitigating cascading impacts to other areas in the plant. Plus, managers have quick access to detailed status reports.

Playback Mode
Think of this as a rewind button for manufacturing activity: managers can quickly load data and run playback for specific windows of time. They can visually inspect process steps, run detailed analyses, and collect data and metrics automatically. This can be a game-changing tool, often reducing problem resolution times from days or weeks to minutes or seconds.

Simulation Mode
"What-if" scenarios are valuable tools for planning the physical movements of materials and equipment. Using this mode, engineers can dial in specific conditions to understand their effects on production throughput, then analyze the results in detail before finalizing often-expensive modifications to equipment or procedures. For example, will reconfiguring equipment in a specific location in the factory result in a traffic jam within the AMHS? Use Intel Factory Recon simulation mode to find out.

Figure 7. Intel® Factory Recon display of factory floor.

The Complete Set of Intel Factory Automation Solutions

The full set of Intel Factory Automation tools is shown here.

Intel Automated Factory Solutions	
Intel® Factory Pathfinder (running at SCK)	High-speed discrete event simulator for factory optimization.
Intel® Factory Recon (running at SCK)	Full graphical Digital Twin of factory production equipment and automated material handling system.
Intel® Factory Optimizer	An AI-based control layer for Intel Factory Pathfinder.
Intel® Factory Adapter	Adapting the factory process to the environment in two specific ways: (1) Automated measurement step-skipping and job parameter processing engine with decisions based on quality or other relevant data. (2) Dynamic equipment process job customization necessary to meet specific process rules in the factory.
Intel® Factory Pathfinder for Enterprise	Moving Intel Factory Pathfinder simulations into the enterprise layer to enable rapid product allocation and customer order response times.

Powering Digital Twin Technology

As we've seen, Digital Twin technology includes powerful, specialized software tools. As such, they demand high-performance hardware. Intel provides the processors manufacturers need to power the groundbreaking factories of today and tomorrow.

Intel® Xeon® Scalable processors offer a balanced architecture with built-in acceleration and advanced security capabilities, designed over decades of innovation for the most in-demand workload requirements—all with consistent, open, and proven Intel architecture. In addition, Intel Xeon Scalable processors come with built-in accelerators to deliver the levels of server performance needed for demanding manufacturing environments.

	Intel® Factory Pathfinder App Virtual Servers	Intel® Factory Recon App Virtual Servers	Data Loader Servers	Database
CPU	Intel® Xeon® Gold 6242 @ 2.80GHz	Intel® Xeon® Gold 6242 @ 2.80GHz	Intel® Xeon® Silver 4215R 6242 @ 3.20GHz	Oracle RAC on Linux
Threads/cores	8 threads	12 threads	16 Cores, 32 threads	N/A
Memory	128GB	128GB	128GB	N/A

Into the Future

Complex manufacturing challenges require sophisticated solutions. With its success in the semiconductor market driving a move to expand production, SCK was searching for new manufacturing methods with the power and capabilities to enable increased production, improved manageability, a lower total cost of ownership, and a better bottom line.

Intel proved the ideal partner to meet these challenges, and the results were truly win-win…

Win for SCK: An exemplary, effective, and transparent collaboration with Intel that enabled millions of dollars of savings in the Nagasaki fab in the short term, and that promises increased savings in the future. Over time, SCK plans to increase the silicon wafer input, production capacity, and inter-fab transfer capabilities. When the new fab floors are fully on-line, they will take advantage of Intel Factory Pathfinder to continue optimizing production by tuning maximum production output while minimizing interconnect wafer transfers.

Win for Intel: Extending benefits gained from efficiencies in Intel fabs and successfully demonstrating the maturity of Intel Automated Factory Solutions software suite for solving critical, real-life factory issues.

With the successful introduction of Intel software into the SCK fab, the two companies are in the early planning stages for the potential implementation of up to three additional Intel Automated Factory Solutions products.

Bottom line

Intel Automated Factory Solutions Digital Twin software has provided tremendous benefits to one of the world's largest companies. These same tools are available for purchase by other discrete manufacturing companies. Intel follows a proven engagement process that helps minimize operational risk to the partners through careful investigative testing, extensive data collection before presenting a prototype, the development of an integration plan, and ultimately the deployment of a working software solution.

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