High Speed, Low Cost Itanium® 2-based Clusters Accelerate Development of Formula One at Toyota Motorsport

Solution Summary

Challenge	As an ambitious new entrant in Formula One racing, Toyota Motorsport needs continuously to improve car aerodynamics, boosting speed and road-holding power. Re-designs must happen quickly – during the season, 15 per cent of chassis specifications may change within two weeks. Toyota needed affordable high performance computers that could simulate complex full-scale design modifications overnight, rather than in several days as with existing systems. It was also seeking powerful, cost-effective platforms for enterprise applications and mobility needs.
Solution	Toyota Motorsport is accelerating its product development cycle with a cluster of 160 servers based on 2-way Intel® Itanium® 2 processors, and by the end of 2004 expects to add another 100 Itanium 2-based servers. Intel Solution Services contributed leadership and expertise that streamlined the implementation. For enterprise applications including SAP R/3*, the company is lowering compute costs and enhancing business flexibility by moving from a proprietary RISC platform running Unix towards servers based on the Intel® Xeon™ and Itanium 2 processors with Red Hat Linux and Oracle 9i* Real Application Clusters (RAC). For mobile applications such as trackside data collection and analysis, Toyota Motorsport uses more than 300 Panasonic Toughbook* notebooks, increasingly based on Intel® Centrino™ mobile technology.
Business value	During the 2004 season, Toyota was able to make extensive changes to its TF104B Formula One car resulting in performance improvements that would previously have taken much longer to achieve. Calculation speed is three or four times faster, and analyses of data sets, or meshes," can be 10 to 15 times larger giving engineers a more accurate understanding of their designs and allowing them to examine more design options. Overall, virtual tests are 100 times faster and development speed is up by a factor of ten. These gains are achieved at relatively low cost and are mirrored by similar price/performance advantages on enterprise and notebook applications running on Intel architecture. Toyota Motorsport is now making rapid and effective progress in an extremely demanding environment.
Technology	• 160 servers based on 2-way Intel Itanium 2 processors • Servers based on the Intel Xeon processors with Red Hat Linux and Oracle 9i* (RAC) • 300 Panasonic Toughbook* notebooks, increasingly based on Intel Centrino mobile technology.

Challenge

The Pinnacle of Motor Sports

Formula One, or Grand Prix racing, is widely regarded as the pinnacle of motor sports – high in risks as well as returns. It is the world's most expensive sport, with average annual team budgets in the hundreds of millions of dollars. For global awareness, it is rivalled only by football, the Olympic Games and the World Athletic Championships. Toyota Motor Corporation entered Formula One in 2002 via its subsidiary Toyota Motorsport, and created its entire venture from scratch, including team, car, engine and chassis. "We started with a blank sheet of paper and have done everything ourselves," says Waldemar Klemm, Senior IT Manager.

Formula One design, engineering and testing take place at Toyota Motorsport's purpose built factory in Cologne. The plant incorporates a 1/50th scale wind tunnel and an innovative layout that facilitates collaboration and team-working among engineers, designers and technicians. Only Toyota and Ferrari currently develop their whole racing car under one roof.

Speed On and Off the Track

A modern Formula One car has almost as much in common with a jet fighter as it does with a conventional road vehicle. Aerodynamic design is crucial to success, both in pushing the car's tyres onto the track to improve cornering, and in minimising the drag caused by turbulence. Every surface of a Formula One car is analysed in this way, from the shape of the suspension links to the driver's helmet.

Toyota needs to be able to gather data from cars during testing and on the race track to produce design modifications and enhancements as quickly as possible. "The business is about speed on and off the track," says Toshiro Kurusu, Vice President of Toyota Motorsport. During the racing season, the team typically wants to change 15 per cent of chassis specifications between races, which can be as little as two weeks.

In the past, aerodynamic analysis required expensive wind tunnels. But much faster results are now achieved by conducting airflow tests on computers using computational fluid dynamics (CFD) simulation software. Wind tunnels are still necessary, but CFD allows many more ideas to be explored in virtual space before building prototypes. This vastly speeds up design-to-manufacture. "In this competitive sport the most important thing is time. CFD enables us to predict behaviour, to define a computer version of what we have in mind," says Klemm.

CFD also saves money, according to Kurusu. "We can use simulation for the development of vehicle dynamics, engines and aerodynamics," he says. "It allows us to make more efficient use of a finite resource such as our wind tunnel."

High-Performance Computers Perform Complex Tasks

Traditionally CFD required supercomputers based on high-performance, complex and expensive Unix processors. But advanced technology from Intel has overcome this barrier. After evaluating the market for a suitable CFD platform, Toyota chose the Intel® Itanium® 2 processor for its breakthrough performance, which increases calculation speed and the ability to handle complexity.

For Toyota's engineers, CFD running on the Intel platform provides a flexible, scalable and cost-effective solution without compromise. "In one word, our core business here is performance," says John Howett, President of Toyota Motorsport. "That's really why we are so excited about our future partnership with Intel and the Intel Itanium 2 processor.

Thanks to the Itanium 2 cluster, we were able to make constant and rapid improvements to our TF104B Formula One car during the 2004 season. Without ultra high performance processing from the Itanium 2, such speeds would be impossible."

Toyota Motorsport also reviewed its enterprise software platform previously based on IBM RISC. Given the significant price/performance advantages of the Intel® Xeon™ and Itanium 2 processors, Toyota decided to make Intel® architecture the platform for its future enterprise applications strategy.

In notebook and wireless technology, Toyota Motorsport is also committed to Intel architecture. More than 300 Intel processor-based notebooks are currently used across the business, from trackside data analysis to administration. "The whole business depends on IT," says Klemm. "You can't even start a car without a notebook computer." From October 2004, Toyota began introducing laptops based on Intel® Centrino™ mobile technology[1] for further flexibility and wireless communications.

Solution

Rapid Implementation Exceeds Expectations

For help implementing the Itanium 2 cluster, Toyota turned to Intel® Solution Services, whose expertise in this area made it possible to troubleshoot system problems expediently, resulting in quicker system deployment. "The whole implementation was much faster than expected," says Klemm. "The Intel Solution Services team was brilliant – their just-in-time approach helped resolve problems quickly and effectively."

During the first quarter of 2003, eighty "number crunching" nodes were installed, each with dual Itanium 2 processors and 4GB RAM running Adapco STAR-CD* and the Linux operating system. Each node has two communication adapters to ensure very high throughput – Ethernet for general communication with the control station and Myrinet for very fast communication between number-crunching nodes. The control station has two hard disks and is connected to an external hard disk drive array.

The cluster quickly fulfilled the team's hopes. "Our evaluation in 2003 proved that the Itanium 2 processor delivered a significant performance increase at less cost," says Thomas Schiller, IT Manager. The processor's extended memory addressability and features such as the EPIC instruction set improve parallel instruction throughput, parallel processing, and efficiency, Schiller says. "In addition, we found we could count on the platform's reliability," he observes. "That gave us the confidence to move a massive amount of our calculation to the Itanium 2 processor, which meets our needs of being perfectly precise for accurate real-time data." During the first quarter of 2004, Toyota doubled the number of nodes to 160. "This dramatically increased our calculation power," says Schiller. "Previously we needed three days for a CFD calculation. With our Itanium 2 based cluster, we can get a result every morning."

"Thanks to the Itanium® 2 cluster, we were able to make constant and rapid improvements to our TF104B Formula One car during the 2004 season. Without ultra high performance processing from the Itanium 2, such speeds would be impossible."

John Howett,
President of Toyota Motorsport

Toyota Motorsport's cluster offers the ability to expand the system conveniently and cost-effectively. The company plans to add another 100 Itanium 2-based servers by the end of 2004, giving even more power to accelerate the development cycle and improve both the speed and accuracy of its designs.

The team has been delighted with the increase in the number and complexity of aerodynamic calculations it can perform. "Using Itanium 2 processors, calculation speed is three or four times faster," Klemm says. "Also we can analyse data sets, or "meshes", that are 10-15 times larger. The combination of these two factors means we can do virtual tests in one per cent of the time previously required and speed up development by a factor of ten. In addition, our strategies on how to utilise the accuracy of the high performance cluster were more effective than expected, and it took less time than anticipated to decide how many points to calculate in a mesh."

During 2004, the team was able to put the Itanium 2 cluster to powerful effect in designing modifications for the TF104. At an early stage, it realised that the standard TF104 lacked aerodynamic downforce, resulting in poor grip levels for some circuits. Thanks to the Itanium 2 clusters, the team was able to run intensive aerodynamic and weight reduction modelling tests, resulting in a narrower nose cone, smaller exhaust chimneys, lower aero extensions on the sidepod, and the introduction of cooling chimneys rather than the traditional "shark fins." The back end of the engine cover was also given an overhaul to aid the airflow over the car. "Previously it would have been impossible to introduce so many innovations so quickly," Klemm says. Avoiding the need for extra wind tunnels also delivers huge financial benefits. "The Itanium 2 clusters are a substitute for two or three wind tunnels so that is a huge cash- and time-saving. A wind tunnel would cost around €40m and take two years to build."

Migrating Corporate Infrastructure to Improve Business Efficiency

Toyota Motorsports is also deploying Intel architecture across its corporate infrastructure for enterprise applications previously on RISC platforms. The old platforms are gradually being replaced with servers and clusters based on Intel Xeon processors, running SAP R/3* and Oracle9*i**. The result will be faster performance, speeding up applications and improving response times to streamline business processes and drive up efficiency.

Toyota is also testing Oracle's Real Application Clusters* (RAC), which increases flexibility, uptime and cost-effectiveness by allowing massive Oracle enterprise databases to be spread across several clusters. "With the RAC option of Oracle9*i* one gains a highly available and flexible solution in addition to scalable load-balancing and easy maintenance," says Klemm. If one server needs to be removed for maintenance, others in the cluster take on its work.

The company plans to deploy one or two dozen servers based on the Itanium 2 processor for enterprise applications during the next five years. "This will deliver a huge increase in performance, with important advantages such as addressability of memory, speed and I/O functionality," says Klemm.

Mobile Enhances Trackside Flexibilty

Toyota Motorsport is keen to benefit from the flexibility and high performance of Intel architecture-based notebook computers. "Notebooks are very important for our business on the trackside during qualifying and dozens of test events," says Klemm. "We use them to collect telemetry data on the behaviour of the car itself including information such as oil temperature, downforce, and the heat of brakes." The data is downloaded from the car's black box at the trackside and analysed by the notebooks.

In future, engineers will increasingly use laptops based on Intel Centrino mobile technology because of its lightweight design, extended battery life and wireless functionality. "Engineers will be able to take their notebooks with them to work at hotels in the evening performing tasks for which they haven't had time on the track-side," Klemm says. "This is crucial during the racing season when we need to be able to get results really fast."

Deploying Intel Architecture for Competitive Advantage

Toyota Motorsport is confident that Intel technology can enhance its competitiveness in Formula One racing. “We are delighted to welcome Intel as one of our partners,” Howett says. “From our side we gain huge opportunities in terms of the advice we receive from Intel and of course the massive computing power offered by the Itanium 2 processor. This will not only help us develop the car we are running this year but of course future generations of car which will give us – we are absolutely confident – a competitive advantage on the track.”

The plan is to expand the Itanium 2 cluster so that the number of calculation points can be increased and the meshes become bigger and more complex. “The net result of this will be the ability to perform bigger and more complex calculations,” says Klemm. In 2005, the team wants to expand its use of these tools beyond chassis aerodynamics to engine design improvements. Meanwhile, it is also evaluating more powerful CFD programs including Cosmos* which was developed in-house for airflow analysis.

Toyota Motorsport is delighted it chose Intel architecture for its Formula One venture. Kurusu sums up: “With Itanium 2 we have the best available price/performance ratio because all the other technologies are hugely expensive or not available. We are very fortunate that Intel developed its 64-bit processor.”

Lessons Learned

- **Deploy IT to achieve competitive advantage.** In a technically demanding and highly competitive business such as Formula One racing, success requires access to state-of-the-art technology at every level. Toyota realised from the beginning that it needed to equip engineers, designers, technicians and even administrative and marketing staff with high-performance computers to win.
- **Benefit from expert services.** Leading edge technology needs to be implemented quickly and well to realise the full benefits. Toyota was delighted with the rapid and effective just-in-time service provided by Intel Solution Services.
- **Achieve massive performance gains and minimise costs with the Intel® Itanium® 2 processor.** An in-depth review of the market for suitable platforms to run its computational fluid dynamics (CFD) software convinced Toyota that Itanium 2 offered the best price performance ratio by far. For enterprise applications too, Toyota found servers based on the Intel® Xeon™ and Itanium® 2 are ideal for its challenging environments.
- **Utilise mobile and wireless notebooks to enhance productivity.** Mobility is a fundamental requirement of Formula One where crucial data needs to be collected and analysed at the trackside and overnight by engineers on location. Toyota has 300 notebook users and is adopting laptops based on Intel® Centrino™ mobile technology for staff on the move.

Find out more about a business solution that is right for your company by contacting your Intel representative, or visit the Intel® Business/Enterprise Web site at intel.com/business or its industry solutions specific sites at intel.com/business/bss/industry/

More Information
www.intel.com/eBusiness
www.toyota-f1.com

Solution provided by:

Part Number: CS18-2004/E
12/06/2004