WHITE Paper

AUGUST 2003

DWP-080301

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THE VALUE OF HIGH-PERFORMANCE TECHNICAL COMPUTING REFERENCE ARCHITECTURE FOR ADVANCED DIGITAL SIMULATION IN THE AEROSPACE INDUSTRY: THE AIRBUS UK STORY

Aerospace manufacturers are increasingly employing CAE tools to curb the mammoth costs associated with the building and destruction of physical prototypes...

...while also compressing schedules and maximizing product performance, quality and safety.

Current economic conditions have intensified longstanding technical computing infrastructure challenges involved in engineering and manufacturing aircraft. Faced with tight budgetary controls, and schedule pressures, aerospace manufacturers are finding it more critical than ever to employ CAE tools to reduce the mammoth costs of building and testing physical prototypes, while also compressing schedules and maximizing product performance, quality and safety. But for these initiatives to succeed, manufacturers must ensure that their computing infrastructure can effectively support this increased use of CAE as well as manage and maintain their wealth of proprietary processes and mathematical codes developed over the years.

With their current and future competitiveness at stake, aircraft manufacturers require a high-performance technical computing (HPTC) plat-

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...Fortunately, commodity 64-bit high-performance technical computing architectures are now emerging to address these challenges.

form that will scale to their computational requirements. At the same time, these companies place a high premium not only on performance but also on compute stability, longevity and affordability. With aircraft lifespans measured in decades — many fly for at least thirty years — manufacturers seek cost-effective alternatives to maintaining specialized, high-cost supercomputers to run CAE codes on legacy models. Fortunately, commodity 64-bit high-performance technical computing architectures are now emerging to address these challenges.

A key benefit of HPTC reference architectures is that they let manufacturers match their computing systems to the needs of various software applications and math codes for optimum performance, without introducing undue system integration complexity. The resulting ease of integration and system administration reduces the overall total cost of hardware and software ownership. Today, the emergence of the affordable and powerful Itanium-based processors, together with robust operating systems built to complement Itanium, have brought new levels of computational stability and caused many companies to revisit their HPTC architectures. This paper explores how Airbus, one of the premier aerospace manufacturers in the world, is employing HPTC reference architecture at one of its UK sites to successfully address its computing challenges.

The Airbus UK Story

Airbus is a leading aircraft manufacturer with one of the most modern and comprehensive family of airliners on the market, ranging in capacity from 100 to more than 500 seats. The company has delivered over 3,100 aircraft to more than 180 customers world-wide since it first entered the market in the early seventies, and boasts a healthy order book of more than 1,500 aircraft for delivery over the coming years. With an annual turnover of 19.4 billion Euro in 2002, Airbus is a global company, employing some 46,000 people in design and manufacturing facilities in France, Germany, the UK, and Spain, as well as subsidiaries in the U.S., China and Japan. Airbus also operates spare parts and training centers in Europe, the U.S. and Asia, and provides round-the-clock support services to all Airbus operators, helping them enhance the profitability of their fleets. Headquartered in Toulouse, France, Airbus is an EADS joint company with BAE SYSTEMS.

The wing structure and fuel systems for all Airbus aircraft are designed and analyzed at Airbus' Filton site, near Bristol in the UK. Airbus's wing design activities at Filton are the primary focus of this paper.

Airbus, like other aerospace manufacturers, faces a number of challenges and urgent priorities: reducing program costs and compressing product development schedules while producing lighter aircraft which in turn reduce fuel requirements and costs, optimizing payload, and maintaining and enhancing performance. In addition, manufacturers must maintain up-to-date records, meet strict Federal Aviation Authority (FAA) and Joint Aviation Authority (JAA) regulations and, above all, guarantee safety.

A company the size of Airbus cannot rely on a single hardware supplier for its HPTC environment...

Airbus UK's use of HPTC solutions highlights the challenges facing aerospace manufacturers, and how these can be addressed by implementing an open HPTC reference architecture to optimize their use of digital simulation technology. Airbus UK uses high-performance technical computing systems from Hewlett-Packard Company and other IT vendors to reduce engineering and test costs while improving engineering and analysis productivity in order to bring to market better aircraft at a lower total cost of hardware ownership to Airbus UK.

...Airbus uses hardware from several commercial IT providers to reduce engineering and test cost...

Airbus UK uses a heterogeneous high-performance computing environment with hardware from HP, Cray, Fujitsu, Hitachi, IBM, NEC, SGI and Sun. The HP-UX 11i operating system from HP powers 70% of the CPUs in this environment, and provides an open and flexible environment for Airbus UK to integrate its high-performance technical computing infrastructure to efficiently run and maintain its CAE applications.

...The HP-UX 11i operating system from HP powers 70% of the CPUs in this environment...

According to Nigel Barry, IT Architect at Airbus' Filton site near Bristol in the UK, Itanium-based high-performance technical computing technology has helped Airbus UK save costs by speeding simulation runs and reducing the amount of software optimization maintenance required. In the past, the amount of time required to run simulations was often very long and costly for Airbus UK. Indeed, many simulation routines could take weeks to run. "The cost associated with analysis is not in buying the hardware — it is in running the software," explains Barry. "What HPTC means is that we can now run simulations faster. We could always run them, but we could not afford the time it would take to run the big simulations, because some of them would take many weeks to run. Now we can do 20 to 30 a night, and we can look for an optimum solution. We've probably got two or three orders of magnitude more computing power than we had ten years ago."

...and provides an open and flexible environment for Airbus to integrate its high-performance technical computing infrastructure...

The value of an Itanium reference architecture lies not just in the design phase, but extends throughout the life of the aircraft. If a plane

built twenty years ago requires service, the manufacturer must be able to rerun the analysis code exactly as it was performed twenty years ago to ensure an identical response. A manufacturer's ability to react quickly to maintenance problems that spring up is an important measuring stick for the airlines, and reliable HPTC solutions can help ensure positive customer perception.

...to efficiently run and maintain its CAE applications.

Another crucial area in which HPTC reference architecture reduces the total cost of ownership is software maintenance and optimization. Airbus UK estimates it has some 10,000 software applications in use, and of those, only about 20 are from commercial software developers. The rest are internally developed proprietary codes. Of the 10,000 applications, the majority are CAE or digital simulation applications, including applications for computational fluid dynamics (CFD), finite element analysis (FEA), aerodynamics, control systems and structural analysis.

For Airbus, the cost of quality assurance averages $10,000 per application for each platform...

According to Barry, the cost of quality assurance, maintenance and porting these applications to multiple hardware platforms averages $10,000 per application for each platform. Thus, the total cost of QA for Airbus UK's 10,000 applications will exceed $100 million. "But some software applications must be updated and optimized to run on the latest hardware platform in order to achieve maximum efficiency, accuracy and speed," said Barry. "Using a standard, open HPTC environment is very important, because we spend a lot of time and money optimizing this software for the hardware. A common high-performance computing platform reduces our software maintenance and porting costs, which lowers our total cost of ownership."

...making the total cost of QA for its 10,000 applications over $100 million.

The Importance of Digital Simulation in Producing More Advanced Wing Designs

The use of simulations has effectively revolutionized the wing design process — allowing for thousands more designs to be produced and analyzed and resulting in the most effective wing design — all in reduced time-scales. Digital simulations have also been very helpful in confirming Airbus UK designers' estimates of an aircraft-wing's weight.

"A common, high performance computing platform reduces our software maintenance and porting costs," said Nigel Barry of Airbus...

In the aerospace domain, physical testing of aircraft components is always necessary. However having the ability to digitally simulate wing designs earlier in the development process reduces the testing costs for the manufacturer. Said Barry: "We need to make sure we've got the wing design right the first time. Airbus pays close attention to costs and

we can't afford to cut metal for a whole series of prototypes which may never see production."

"...which lowers our total cost of ownership."

Over the last few years, Airbus UK has upgraded its servers from Convex, IBM MVS and DEC VAX to HP V-Class and Superdome 64-bit PA-RISC servers, and now, to new Itanium 2-based servers. The robust HP-UX compilers and development environment have allowed the company to port CAE applications from multiple hardware platforms to the Itanium-based servers. While the cost of porting the software to run on the Itanium platform was not insignificant, Airbus UK believes that the computing power and the standardization of Itanium-based servers ensures it will not have to move to a new CAE infrastructure anytime soon.

The use of simulations has effectively revolutionized the wing design process...

This HPTC infrastructure has enabled Airbus UK to dispense with physical test altogether in some areas, and to dramatically reduce physical testing in others. An example of the progress Airbus UK has made by combining the high-performance Itanium reference architecture with its digital simulation applications is illustrated in the development stages of the A340-600 and A380 aircraft. In the recent past Airbus UK would have built not only full wing test rigs, but also a large number of component and sub-assembly test rigs. The ability to carry out detailed digital simulations has increased the company's confidence that many of these preliminary tests are no longer required. Said Barry, "We wouldn't ever want to rely solely on digital simulations and we will be continuing with our very thorough wing testing procedures. It's fair to say though that we have moved a long way from testing every individual component, then working up through the sub-assemblies to the final assembly."

...allowing for thousands more designs to be produced and analyzed and resulting in the most effective wing design — all in reduced time-scales.

In some areas, Airbus UK carries out analysis using digital methods where testing is impracticable. In other areas, physical testing is being considerably reduced. In this, the goal is to move beyond simulating individual components, which Airbus UK has accomplished, to simulating subassemblies and assemblies — which it is doing today — to ultimately simulating every aspect of the aircraft wholly digitally.

Digital simulations have also been very helpful in confirming Airbus UK designers' estimates of an aircraft-wing's weight.

Airbus UK must simulate all possible items that may have any possibility of a design flaw, and it's often necessary to perform multiple simulations in order to derive the same information as from a single physical test. "With HPTC, we are now fairly high up on simulating subassemblies, thereby working to remove subassembly testing altogether. But we're not there yet. Now it's a question of moving up to larger

"We need to make sure we've got the wing design right the first time," said Barry...

assemblies, to remove more time and risks from the project. The testing of these larger subassemblies occurs towards the end of the project, near first flight, so we need to be able to simulate them sooner to avoid any design or structural flaw that may cause problems."

Barry further explained, "Take an optimization loop, for example. If I optimize a component, I must optimize that component assuming there is no effect on the interaction with all the other components it's bolted or attached to. Obviously, as soon as I alter that component, I do in fact alter all the attachment modes. So then I've got to optimize the components it is attached to, and that affects its loading."

"...We can't afford to cut metal for a whole series of prototypes which may never see production."

"If I can optimize the component and all the components it is attached to, and I can do it all in one loop, it becomes a much faster process. But obviously I need a much bigger, much faster computer so I can actually do that. The bigger and faster the computer, the more components I can perform an optimization on in one pass, and the more accurate that optimization is because of the fewer assumptions I have to make about my interaction modes." Describing Airbus UK's ultimate objective, Barry concluded, "If I can do aerodynamics, structures, systems layout and all the other things at once in one big optimization loop, I can produce a perfect aircraft."

99 Years

Airbus UK needed a company with not only vision, but the history, people, and technological capability to make it happen.

Airbus UK requires that its information technology solution providers maintain the manner in which its CAE applications are run for 99 years. Airbus UK needed a company with not only vision, but the history, people, and technological capability to make it happen. Why 99 years? The ability to reproduce calculations must be maintained for the life of the family, for example, the highly successful Airbus wide bodied family, from the first design calculation to 6 years after the flight of its last derivative. Said Barry, "We needed a stable company and partner that would enable backward and upward compatibility for 99 years, so that we can run the applications in 99 years and know that the math libraries will be compatible and consistent so we won't get different numerical results. We need a consistent high-performance computing reference architecture that will enable us to do so, and HP provides us that."

The HP-Airbus UK Partnership

The ability to reproduce calculations must be maintained for the life of the aircraft family.

Airbus UK looks for specific qualities in an IT solution provider. Among them are competitiveness and continuing improvement, flexibility, strict

adherence to schedules, effective supply chain management, proactive support, innovation to provide competitive advantage, customer services and solutions, a continuing drive to improve product support and customer service, and a commitment to efficient communication and operations, including e-business.

Tangible productivity gains are an essential benefit of an effective HPTC strategy. There are four concrete ways, according to Barry, to achieve better productivity. One is to make the hardware faster; two is to modify the software; three is to do a bit of both; and four is to change the method entirely. Airbus UK and HP take the third approach to HPTC.

Said Barry, "HP modifies the hardware, and we work with the math team at HP to do mathematical libraries, which changes the performance of the software applications — and sometimes even changes the method by which the application achieves an answer — in order to get the answer more efficiently."

HP has a development and integration lab in Toulouse, France with dedicated resources and specialists onsite to work with Airbus UK to help integrate their products not only with HP platforms but also with other platforms. HP and Airbus UK have a close partnership, which Barry described. "First, since most of our software is internal and not third-party, we have to do a lot of optimization ourselves, and therefore have to work closely with the hardware vendors. Second, because our software is internal, we have to work with the hardware vendors to determine what specific hardware we need to run our software optimally."

HP's partnership with Airbus UK has spanned many years, and it was with Airbus UK's collaboration that the HP-UX 11 operating system was first introduced. An important aspect of the partnership is that Airbus UK, as well as other manufacturers with advanced technical computing demands, can influence the actual design of the hardware and operating system.

Barry believes Airbus UK's relationship with HP is built on a high level of trust. "I think we've reached the point now that if someone wanted to change how a major piece of software worked in HP, or a piece of hardware, Airbus would be one of the companies HP asks first, 'Do you want this to happen? Will you want it to be done differently?' And we're happy to oblige."

"This obviously impacts our cost of ownership of hardware," he notes, "because we can get our costs down faster by carrying out those OS

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This close collaboration helps keep HP at the cutting edge of computer technology...

changes in the sequence that benefits us best, or has the least impact on our operating environment."

This partnership is not one-sided. Roughly 80% of HP's server technology is sold into commercial markets, including banks and insurance companies, for instance, while the other 20% is technical, including large aerospace and automotive manufacturers, among others. It is widely held that the requirements of the technical servers hold a three-year lead-time over the requirements of commercial servers. So in this way, HP's partnership with Airbus UK helps keep it ahead of the requirements of 80% of its customer base and the hardware and software improves for all. And in many ways, Airbus UK is helping HP to define architecture, which can then be applied to other technical as well as commercial server solutions.

...and at the same time enables Airbus UK to run highly advanced yet commodity-based computer technology.

This close collaboration helps keep HP at the cutting edge of computer technology, and at the same time enables Airbus UK to run highly advanced yet commodity-based computer technology. Said Barry, "We want to run a commodity computer infrastructure — the very top end of the commodity — but a commodity computer system nonetheless. So the fact that other companies run the same computer for different purposes is a great benefit to us. It is not cost-effective to run a unique and very expensive computer. Itanium 2 is the next step in commodity computing."

"We want to run a commodity computer infrastructure—the very top end of the commodity..."

Benefit of an Itanium-Based Reference Solution Architecture for CAE Applications

Digital simulation poses many computational challenges. Some applications are so large and complex that memory throughput and CPU performance become problems. Itanium-based processors have made advances in this area, in Airbus UK's experience. "Itaniums have exceptionally large memory bandwidth and are very good at parallel processing," says Barry, "and it is that balance that makes Itanium better than a lot of other processors. And because Intel's volume is high, they're much more affordable. They actually perform better and they're lower cost. That's unique in 64-bit computing." In addition, the Itaniums are more highly scaleable, according to Barry, providing Airbus UK with much sought-after operational flexibility to run multiple applications at once.

"...but a commodity computer system nonetheless," said Barry.

"This gets back to the necessity of having standard HPTC reference architecture. We want an architecture with a very long life, so by using

HP-UX 11i and Itanium in the beginning, we hope to optimize those key applications to move forward so they do last a long time. Performance won't be an issue in 60 years — it will be an issue of whether or not they will be able to run the applications." Airbus UK is banking on the combination of a standard, Itanium-based reference architecture and the reliability of the HP-UX 11i operating system to enable it to do so.

The scalability of Itanium provides Airbus with much sought after operational flexibility to run multiple applications at once.

Barry believes Itanium holds another advantage over competing architectures as well. "A lot of the applications we run internally depend upon BLAS libraries, or algebra libraries, which are standard HPTC libraries all vendors supply. The libraries for Itanium are particularly fast, probably two or three times faster than most other architectures. That eases the optimization work we have to do on our own internal applications."

"Itaniums have exceptionally large memory bandwidth and are very good at parallel processing..."

Operating System Reliability

Barry counts HP-UX 11i's reliability among its greatest strengths. When a failure occurs with the operating system, the resulting downtime can be very costly for Airbus UK. Certain long-term optimization routines can take two to three weeks to complete, and an OS failure in the middle of a long run may set Airbus UK back weeks. Said Barry, "If we have a one-second outage, we could lose two to three weeks worth of work. People in our industry talk about check-pointing and restarting, but the aircraft applications we use don't perform check-point and restart. The overhead of this task is greater than the benefit when running on a highly available system like HP's. Software upgrades to fix system deficiencies are an equally big problem."

"...and it is that balance that makes Itanium better than a lot of other processors," said Barry.

"So Airbus UK requires a stable operating system, one that doesn't need fixing that often. That obviously creates more uptime. HP-UX 11i is quite reliable. It can handle temporary failures of the application without crashing the machine. That's one of the problems with Linux- you do tend to lose the machine if you have a crash on an application."

An Itanium-based reference architecture for digital simulation and analysis...

Another benefit of HP, according to Airbus UK, is its strong ISV support team. "When it comes to the third-party ISV applications that we do run, like NASTRAN and ABAQUS for instance, we rely on the vendor to optimize the application to run as fast as possible on their hardware," said Barry. "HP has a very good ISV support team."

...can speed simulation performance, reduce software maintenance costs and help to significantly reduce the number of physical tests performed.

Airbus's success documents why today's HPTC environments based on commodity reference architecture merit close investigation...

...by aerospace manufacturers seeking new solutions in hardware price/performance, CAE software cost savings...

...and long-term protection of their high-performance technical computing investments.

Conclusion

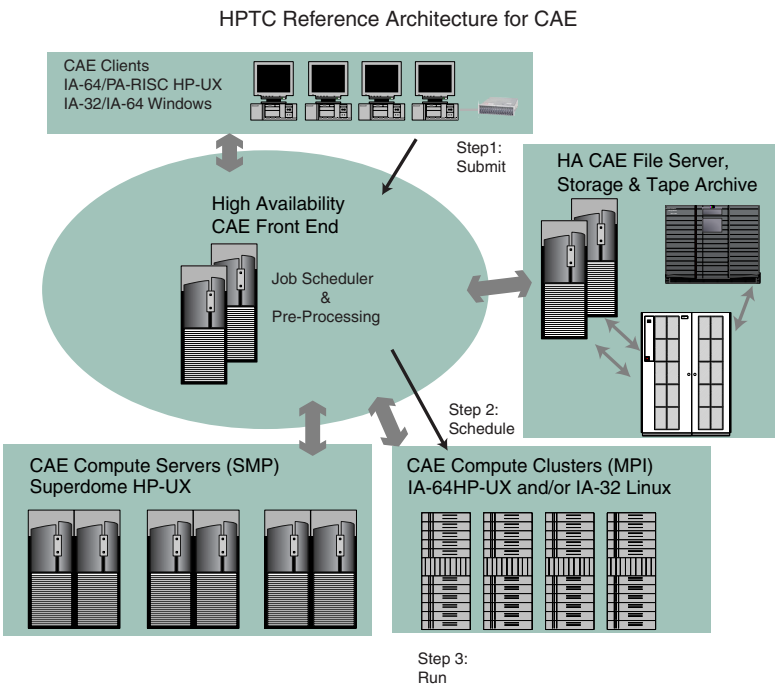
Airbus UK's achievements dramatize how the most urgent business challenges facing aerospace manufacturers today — reducing the cost and time required for aircraft design and validation while improving performance, quality, safety and operating efficiency — can be successfully addressed with CAE and digital simulation strategies based on a high-performance technical computing (HPTC) commodity reference architecture.

Because physical prototypes are expensive and time-consuming to build — aircraft manufacturers today are more focused than ever on reducing reliance on physical testing through increased use of CAE and digital simulation. However, this requires massive amounts of computational power, for which many practitioners still rely on costly supercomputers and special-purpose IT infrastructures. Prohibitively expensive to implement, support and maintain, these specialty computing environments have the added drawback of driving up CAE software costs due to high porting expenses, multi-platform customization costs, and the burdens of software maintenance and quality assurance.

Fortunately, help is available. Airbus UK's experience shows that today, abundant computational power at breakthrough price/performance levels is available from a new class of solution — HPTC reference environments based on commodity architecture.

Not only can such solutions help aerospace manufacturers dramatically lower their hardware and IT infrastructure costs; the stability and commonality afforded by adopting a commodity reference architecture can also substantially reduce software expenses by minimizing the work of porting, customizing and maintaining software across multiple platforms and technology generations. Further, for aircraft manufacturers, the forward compatibility and stability of a commodity HPTC reference architecture can be a boon.

In all, Airbus UK's success documents why today's HPTC environments based on commodity reference architecture merit close investigation by aerospace manufacturers seeking new solutions in hardware price/performance, CAE software cost savings, and long-term protection of their high-performance technical computing investments.



CAE job flow:

Step 1: Client submits job, specifying # CPUs requested (e.g.) CFD

Step 2: Front End Server finds available resource (CFD cluster) and queues job.

Step 3: CFD Solver run on Cluster