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White Paper

Employing SGI® Pixel Fusion Technology to Streamline and Improve Critical QA Processes

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1.0 Executive Summary

This paper provides an overview of how high-performance computing and network technology (both current and under development) can be employed to streamline highly complex, real-world customer workflow processes. At Supercomputing 2005, The Boeing Company, SGI, Inc., and Intel Corporation have created a live scenario that demonstrates how a real-world, collaborative problem-solving situation is facilitated. SGI® Pixel Fusion technology plays a key role in establishing a shared, collaborative workspace. Sharing the workspace at a distance is essential to maintaining communication between the problem solvers. SGI Pixel Fusion technology integrates large data visualization, video, audio, and existing Boeing applications in a way that is comfortable for the participants as they address the challenges at hand.

In this technology demonstration, communication and the ability to share a workspace despite geographic distance are essential in diagnosing two simulated problems in the assembly of the Boeing 777. A Quality Assurance (QA) analyst finds the problems and works directly with a Boeing liaison engineer who is at a different site. Each team member is able to both control his own applications and participate in a collaborative review of complex data sources with the other team members.

The enabling SGI Pixe Fusion technology is expected to be introduced in Spring 2006. Currently available products are also key to this capability, including the Silicon Graphics Prism™ visualization system with its scalable shared memory, compute, and multipipe graphics architecture, SGI® OpenGL Vizserver™, Manta open source ray-tracing visualization software, IG2 software from inSORS, and high-resolution displays from Christie Digital Systems, Inc. The result is an expansion of collaborative workflow and immersive visualization capabilities in a complex product assembly environment.

2.0 Operational Challenges

Today, Boeing is distributing the design and assembly of major product subsections across the world. Computing and communications systems are mandatory, and huge amounts of data must be integrated and managed. This has direct impact on diagnosing assembly problems on the factory floor.

Boeing led the industry in the complete 3D digital design of the Boeing 777. The fact that the engineering design for the 777 is 3D leads to significant potential to use that data outside the design/engineering process. It is possible for a broader set of individuals to review the 3D data and use the images. There are numerous additional considerations and challenges, however, in the implementation of more broadly distributed 3D data. Just the storage and retrieval of this large dataset present serious challenges; a more pronounced challenge occurs when people actually have to interpret the information. Humans have a finite ability to comprehend complexity, and understanding how to display the data in a meaningful way requires extensive work. Using visual cues to help users interpret massive quantities of 3D data is an area that is just starting to be addressed.

In the workflow simulation, the QA analyst has the task of communicating about problems with the 777 nose landing gear to a liaison engineering consultant. The use of new computing technology adds two significant pieces to the existing set of computing tools. First, the QA analyst can share full-resolution real-time video and audio with the liaison engineer. The liaison engineer doesn't have to be in the same location to see the problem. Second, the use of the complete 777 3D visual dataset lets the liaison engineer and the QA analyst compare the landing gear "as built" to the landing gear "as designed" to determine how to fix the problems and meet the design intent. The QA analyst and the liaison engineer need to be able to review design details of particular parts and make sure that they are communicating clearly about what they are seeing, despite the distance between them. Full access to existing Boeing applications lets them simulate complete problem scenarios.

3.0 Technical Challenges

Key technical challenges for this workflow are:

- The interactive visualization of the 350 million triangle Boeing 777 dataset so that each part can be viewed in detail
- The need for close collaboration and troubleshooting among team members in different locations using real-time audio and video
- Making the solution appear seamless to the users in spite of the use of multiple computing systems

One of the technical challenges is the sheer size of the 777 data that must be visualized. Today's commodity graphics cards are phenomenally effective at rendering polygonal datasets, however they aren't well suited for very large datasets. The graphics cards themselves have a local memory capacity of 256 or 512 megabytes. Peak performance is only achieved when the model fits into this onboard cache of graphics memory. Models composed of tens or hundreds of millions of polygons imply many gigabytes of data and very long rendering times with conventional graphics solutions. 32-bit addressing limits can also be a concern with large datasets, as many current software packages are completely unable to handle models greater than a couple of gigabytes in size.

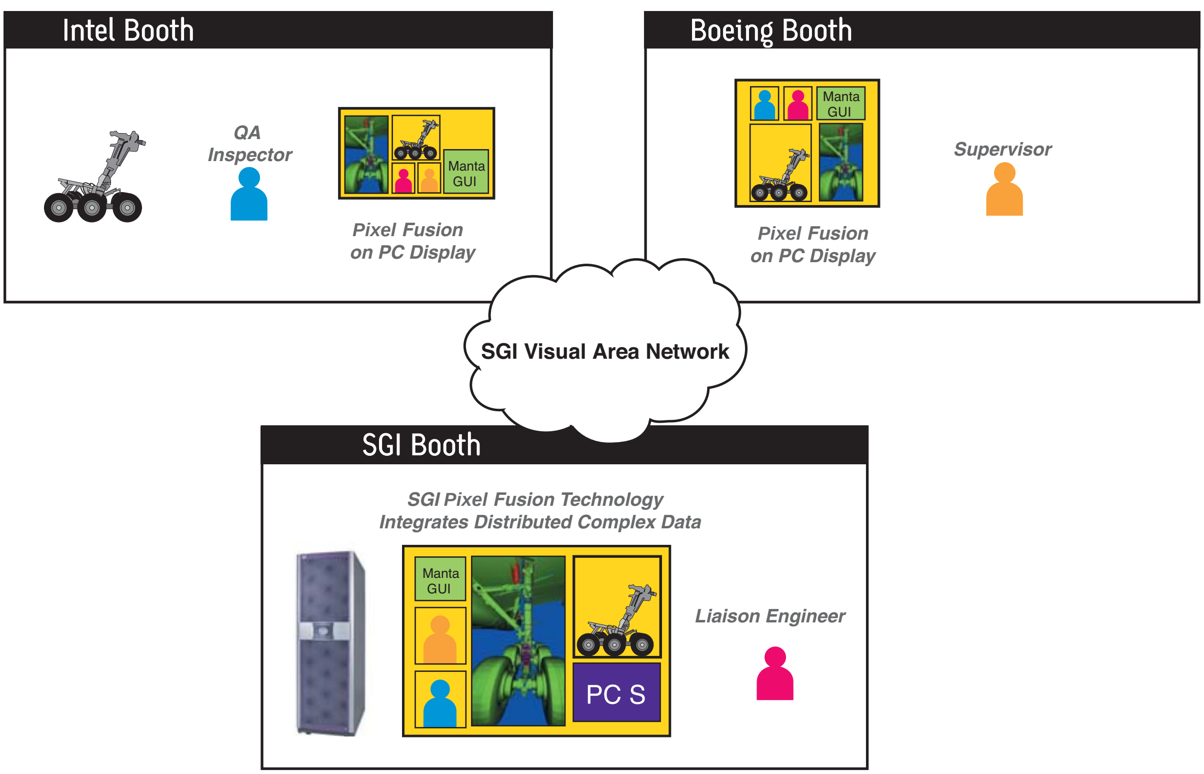
CPU-based rendering techniques on scalable 64-bit platforms have been successfully employed to address these limitations. In this simulation, SGI uses a ray-tracing algorithm rather than z-buffer-based rendering techniques. This CPU-based approach is not limited by the local memory limits of graphics cards; it can take advantage of the larger system memory, which can be hundreds of gigabytes or more on today's largest shared memory machines. In addition, ray-tracing solutions utilize 3D acceleration structures that allow them to handle very large models at roughly logarithmic complexity. This is in contrast to the zbuffer algorithms that require each triangle in the model be rendered for each frame drawn. For small model sizes, the zbuffer technique is faster, but the larger the model, the more attractive the ray-tracing solution. For models with hundreds of million of triangles, like the 777 model, the ray-tracer is a very effective solution.

In addition to interactively rendering this detailed 3D dataset of the Boeing 777, the challenge is to provide easy access to any of the other supporting applications required by this team, a common viewpoint for discussing the various data sources, and a clear understanding of what is being communicated despite the geographic distance between team members. OpenGL Vizserver and the inSORS Grid IG2 software for video conferencing are employed.

4.0 QA Workflow Solution Overview

The demonstration is focused on a collaborative session between two Boeing staff members and a monitor/dispatch station manned by a supervisor. The task is to troubleshoot a potential quality problem in a 777 final assembly and assist in a change in the assembly process. A QA analyst is inspecting the assembled 777 landing gear at the Intel booth and spots a potential problem. The QA analyst is equipped with a mobile computer and a camera so that he has freedom of movement to focus on the actual part. The liaison engineer at the SGI booth must help diagnose and solve the problem. The interaction is being monitored by a supervisor at a monitor/dispatch station in the Boeing booth. Once the problem is solved, all documents relating to the lifecycle of the product must be updated for use by ongoing and future assembly teams. The same general process applies to training simulation in the demonstration scenario, where a mechanic has a question about a new assembly process.

4.1 Overview Diagram of the Workflow Scenario



4.2 Collaborative Troubleshooting

Use of interactive 3D visualization between the QA analyst and the liaison engineer to show the as-designed configuration and remote cameras to show the physical assembly is critical to a timely solution. Access to different Boeing applications during the collaborative session is critical to troubleshooting, documenting, and solving the problem. Because all three locations have different application needs, they have independent access to the Boeing Intranet to access the required materials. Each participant has access to a desktop PC and all of them are connected by an inter-booth 10GiGE fiber optic network.

There are three basic connections:

- The InSORS private IG2 Grid for video conferencing between the three locations
- Silicon Graphics Prism visualization system with Pixel Fusion technology for seamless integration of multiple assets in a 3D workspace including
  - shared interactive 3D visualization of a complete 777 model
  - access to associated Boeing applications
  - video conferencing feeds
- VPN to gain access to the Boeing Intranet

The computer system at the heart of the solution is the Silicon Graphics Prism visualization system. It is a 128 Intel® Itanium® 2 processor system with six graphics pipes and performs three key functions: first as a compute server for interactive ray-tracing, second as a visualization engine for the Pixel Fusion technology, third as visual servers for the PCs in the Boeing and Intel booths.

The interactive ray-tracing of the 777 model at a resolution of 1K x 1K is accomplished through the use of the Manta application developed at the University of Utah. As detailed in the Technical Challenges section, ray-tracing provides photorealistic interactivity with this 350 million triangle dataset that would not be achievable with z-buffer rendering techniques. The Manta viewer shown in the demo allows interactive roaming of the entire model, along with support for arbitrary cutting planes and several options for controlling the quality of the rendering. This 777 application data is ingested into the Pixel Fusion technology within the shared memory architecture of the Silicon Graphics Prism system along with other data sources such as the video conferencing feeds from each booth, and the video streams from each of the PCs with Boeing in-house applications from the Boeing Intranet. The diverse data types are fused into a seamless 3D workspace that is unique to each team member and that each can independently control.

4.3 Creating the Private Grid

The audio/video conference between the QA analyst, the liaison engineer, and the supervisor at the monitor/dispatch station is facilitated by using the IG2 Grid software from InSORS (http://www.insors.com). A PC with a camera and microphone attached to it serves as the IG2 collaboration node for each location. Each node runs IGMeeting client software locally. Each conference view is ingested and fused with the Pixel Fusion technology on the Silicon Graphics Prism in the SGI booth. This adds a new dimension of seamlessly integrating the live video conference with other user applications and manipulating it in a 3D workspace.

In the SGI booth the fused image is rendered across multiple graphics pipes of the Silicon Graphics Prism system and displayed on a 2 X 2 powerwall of Christie DLP cube displays. The liaison engineer in the SGI booth interacts with the fused environment locally. This image is also intermittently routed to the projection system in the main theater located centrally in the SGI booth.

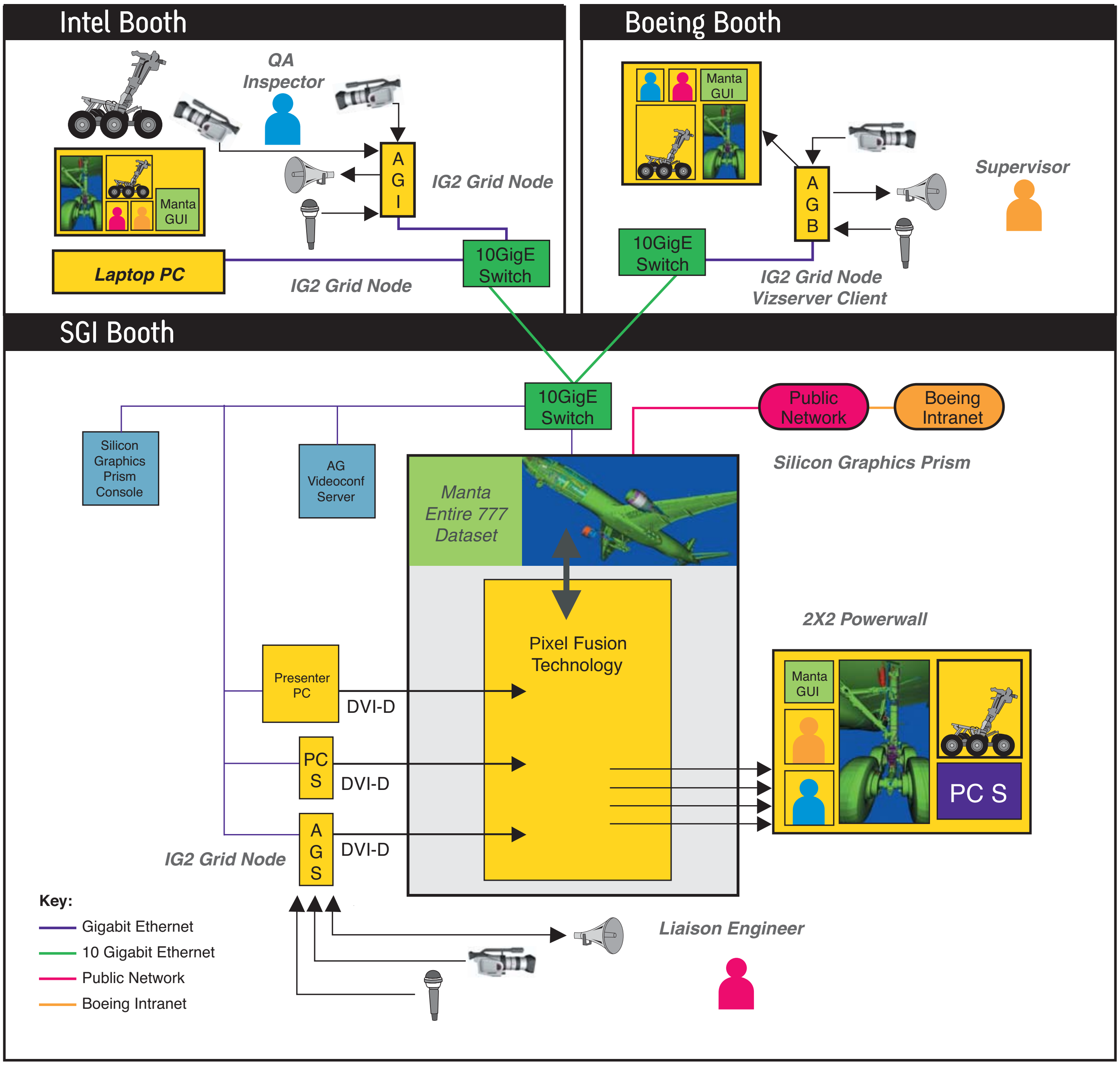
4.4 Leveraging OpenGL Vizserver

Fused images from the same Silicon Graphics Prism system in the SGI booth are also served out over the Visual Area Network (VAN) using SGI OpenGL Vizserver to the two remote collaborators in the Intel booth and the Boeing booth.

The PCs in the Boeing and Intel booths act as Vizserver clients, receiving the image streams from the Silicon Graphics Prism. This allows the QA analyst and the supervisor at the monitor/dispatch station to see the shared view of the 777 model, the camera view of the landing gear, the videoconference streams, and their own PC desktops. They can independently and interactively control their respective views of the fused, virtual 3D environment as well as the applications that are running within the desktop. They are sharing some data and some data (e.g., their desktop view with control of their applications) is unique to their session.

Thus each team member is able to participate in the collaborative review of the actual landing gear as compared to a shared view of the part as designed with his team members, while maintaining control of his workspace and supporting applications. This flexible workflow capability streamlines the team's ability to create a shared mental model for quickly solving the problem at hand.

4.5 Solution Implementation Diagram



4.6 Ray-tracing for Large Data Visualization

The 777 model is rendered using the Manta open source ray-tracing software, which includes large-model visualization capabilities contributed by SGI. Dr. Steve Parker of the University of Utah (http://software.sci.utah.edu/), one of the pioneers in the field of interactive ray-tracing, initiated the Manta project as a second generation follow-on project to the RTRT ray-tracer originally developed at Utah during the late 1990s. Manta relies on a shared memory programming model and explicit control of execution threads to deliver a highly scalable rendering solution. The polygonal renderer used in this demonstration has been tested on machine configurations as large as 512 processors with a terabyte of main memory.

For this particular application, the 777 model of 350 million triangles along with the companion acceleration data structure for real-time rendering occupies 66 gigabytes of memory on the 128-processor Silicon Graphics Prism system. The same model can be rendered on much smaller configurations, by using a less-efficient acceleration structure and rendering to a smaller window on the screen. Ray-tracing is an "output-sensitive" algorithm, meaning that more pixels in the final image directly imply more computational resources to generate the image. To generate the high-resolution images for this demonstration, 112 of the Intel® Itanium® 2 processors are used for the ray-tracing computations. The large 256 gigabyte shared memory footprint of the Silicon Graphics Prism also allows the aggressive generation of an acceleration structure.

The input data consists of 14+ gigabytes of data in the form of over 13,000 ".obj" files that represent the visual version of the 777 CAD data. These individual files were preprocessed on an SGI® Altix®, producing the 21 gigabyte kdtree acceleration structure. The Manta viewer along with the rendering code is available from the University of Utah at https://code.sci.utah.edu/svn/Manta/ under an MIT style open source license.

5.0 Pixel Fusion Technology as Applied in this Demonstration

The Pixel Fusion technology that is used in this demonstration will be employed in SGI® Reality Center® facilities. Pixel Fusion technology is used to provide the collaborative and communications infrastructure between the different applications, systems, display devices, users, and the three booth locations involved.

SGI Pixel Fusion technology is designed to provide an intuitive workspace that enables fluid integration of multiple local and distributed resources for seamless collaboration. It is designed to enable accelerated workflow, superior insight into complex data, enhanced decision making, and improved communications and collaboration.

In this demonstration, the Pixel Fusion technology, which is a software infrastructure layer running on the Silicon Graphics Prism visualization system hardware, enables data from a number of devices and applications to be ingested into the shared memory architecture of the Silicon Graphics Prism system.

The Silicon Graphics Prism system performs a number of parallel functions simultaneously. It renders the ray-traced imagery into shared memory, where it is ingested by the Pixel Fusion technology. It also ingests the external media and device data into shared memory via peripheral hardware and the networks. It renders the Pixel Fusion workspace for the SGI booth using four of its six graphics pipelines to drive a high-resolution 2x2 cube wall display. It is also acting as OpenGL Vizserver servers to each of the two remote Pixel Fusion workspace views in the Boeing and Intel booths.

The power of the Pixel Fusion technology is in the ability to rapidly build a collaborative framework that delivers easy access to distributed complex visual data. Local and remote team members have seamless access and control of their critical data in a collaborative 3D workspace that enables them to break comprehension barriers with ease.

6.0 Other Areas of Applicability for Pixel Fusion Technology

There are a large number of people who are removed from the data creation and analysis process, yet rely on the digital product definition for their own job tasks. For example, giving sales, fabrication, assembly, certification, maintenance, and product operation team members the ability to access and collaborate with the large design datasets as shown in this demonstration can clearly improve their productivity.

Access to a shared memory system such as the Silicon Graphics Prism, which can display large, detailed data models interactively, along with Pixel Fusion technology for efficient collaboration has enormous benefit to these teams.

Pixel Fusion technology is an extremely versatile and flexible framework for providing the next-generation of collaborative and immersive environments. Expected applications of this technology in SGI® Reality Center® facilities include:

- Manufacturing
  - Design Review
  - Global Decision Support Centers for collaborative working
  - Corporate Communications facilities
- Oil and Gas
  - Remote Operations facilities, e.g. Onshore Control Centers
  - Team Rooms
  - Connected Immersive Visualization facilities
- Medical
  - Realistic views of scanned datasets
  - Medical training
  - Surgical planning
- Defense and Intelligence
  - Decision Support Centers
  - Monitoring and Surveillance facilities
  - Command and Control centers
- Civil and Government
  - Urban monitoring and surveillance
  - Crisis Management and Disaster Recovery facilities
  - Facility monitoring and control
- Sciences
  - Rapid prototyping environment for research into immersive environments
  - Collaborative sharing and review of data and applications
  - Visual data sharing and interaction on the GRID
  - Public understanding of Science environments such as science theaters and museums
- Media
  - Collaborative review of program planning and production
  - Asset review
  - Live on air news

7.0 Conclusion: Virtual Collaboration Streamlines the QA Process

SGI Pixel Fusion technology helps humans do what they do best (gain insight, intuitively deduce, decide, collaborate) while leveraging what computers do best (analyze, manage complexity, organize and present).

The power of the Pixel Fusion technology is in the ability to rapidly build a collaborative framework that delivers easy access to distributed complex visual data. Local and remote team members have seamless access and control of their critical data in a collaborative 3D workspace that enables them to break comprehension barriers with ease.

The Boeing team has demonstrated that the computationally-intense virtual collaboration demonstrated with SGI Pixel Fusion technology enhances Boeing's ability to envision and realize high-technology products.

For more information about currently available products: Silicon Graphics Prism and OpenGL Vizserver, see www.sgi.com. For more information about Pixel Fusion technology, which is currently under development by SGI, contact your local SGI sales representative.

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