White Paper

Improving Workflows with Visual Area Networking

Interactive and Collaborative Visualization of Large Data Sets in Distributed Environments

Table of Contents

1.0 Visual Area Networking—Business Challenges and Opportunities

Today's leading organizations face complex challenges driven by ever-increasing global competition and the search for competitive advantage. Some organizations need to maximize product quality and minimize time to market while maintaining or reducing IT budgets. Others find their organizations growing more global and more virtual in a competitive struggle to increase revenue and margin.

To many, these appear to be unsolvable challenges with four opposing characteristics.

- First, products need to be developed more quickly and with higher quality, while exploration and production need to achieve greater efficiencies. These goals drive a need for more High-Performance Computing (HPC) simulation, vastly increased data sets, and a way to visualize them.

- Second, business-driven increases in data size actually slow development cycles because time is lost copying data between centralized HPC systems, file servers, and desktop systems. Operational results cannot be achieved unless the storage, processing, visualization, and collaboration bottlenecks associated with these rapidly increasing amounts of data are eliminated.

- Third, many organizations are highly distributed with subteams distributed across a campus, a country, or the entire globe. Distributed decision making is time-consuming and laborious because key experts cannot be in several places at once and wide area networks magnify data access bottlenecks. Global workforces need to access huge amounts of data and processing capabilities to drive real-time decisions and dramatically improve business results.

- Fourth, today's desktop workstations cannot scale to enable analysis, visualization, and detailed understanding of large-scale simulations. IT budgets would increase significantly if all scientists or engineers were given their own advanced visualization systems.

Visual Area Networking (VAN) solves these challenges by integrating scalable storage, high-productivity computing, visualization, and networking technologies that make it easier to bring people together with the visual information they need to do their jobs effectively. VAN not only allows individuals and groups to solve complex problems while drawing on the company's best experts. Furthermore, it delivers these capabilities directly to the end users or groups, wherever they may be, so shared visualization becomes part of a user's standard environment. As a result, users are free to focus on creativity and insight in a collaborative setting rather than on the technical details of computing, visualization, and data management.

SGI® VAN solutions are highly scalable and flexible and can easily be deployed at the group, department, or enterprise level within an organization. At each level, VAN solutions can be used to both streamline IT infrastructure and deliver analytical and visual capabilities that are 10 to 1,000 times more powerful than those available with traditional desktop solutions. Organizations can start out by emphasizing increased problem-solving capabilities, reduced IT spending, distributed teamwork, or any combination of these three. They can then change their emphasis as technical requirements and budgetary constraints evolve. Table 1 describes some of the benefits achievable with SGI VAN solutions.

Visual Area Networking Benefit	Description
Immediate increase in problem-solving capabilities	SGI advanced visualization systems can deliver 10 to 1,000 times the capabilities of traditional desktops. Standard off-the-shelf applications are used without modification, so an organization can immediately use VAN to deliver increased capabilities.
Available to any user, anywhere, and at any time	VAN allows virtually any desktop, laptop, or wireless system to access increased capabilities so users receive the benefits without leaving their offices (or their current location) and without interruption to their workflow.
More timely analysis of HPC simulations and observational results	By eliminating network data copies, results are available for analysis 100 to 10,000 times more quickly. VAN can shave days off individual tasks and months off overall schedules.
Faster decision making with distributed teams	VAN solutions support fully interactive application sharing using existing, unmodified applications. This increases the impact of domain experts by allowing them to work with multiple remote teams during a single day. It also increases efficiency by allowing decision makers to review the progress of distributed teams without time-consuming travel.
Streamlined data management	Data and applications reside in one location, so configuration management, version control, and security issues are simplified. In distributed organizations, VAN can significantly reduce storage purchase and management costs.
Reduced IT spending	VAN solutions deliver high levels of computing, I/O, and visualization capabilities to end-user desktops when end users need them. Since the average user only needs peak capabilities for a fraction of each day, a single VAN server can support many users during the day and its scalable computing capability allows it to act as an HPC server at other times. This enables organizations to reduce the number of systems on each user's desktop and the costs associated with managing them.
Real-time analysis of distributed data	VAN solutions are the backbone of storing, computing, analyzing, and sharing real-time data across the distributed technical computing enterprise. This ability streamlines work and provides distributed decision-making teams the most current information to manage their operations or product development
The virtual company	VAN solutions help global companies manage their presence in a global economy in a global way. In effect, VAN matches the business, data, and personnel aspects of a global enterprise by allowing experts to collaborate on decisions using state-of-the-art equipment independent of the location of specific individuals or data. This reduces the inefficiencies associated with travel as well as the replication of data, computing, and personnel.

Table 1. Visual Area Networking Benefits

More detailed examples of VAN deployments, usage scenarios, and associated benefits are provided in case studies found in Section 3.

2.0 Technical Computing Workflow Challenges

Workflow is critical for all organizations. It defines how individuals do their jobs, how groups work together, and how final decisions are made. Much progress has been made over the past decade in version control for CAD data and automated document tracking and sign-off. However, because most of these applications transfer or manipulate small amounts of data at a time, little attention has been paid to the dataflow and collaborative aspects of technical computing applications that involve gigabytes or terabytes of data.

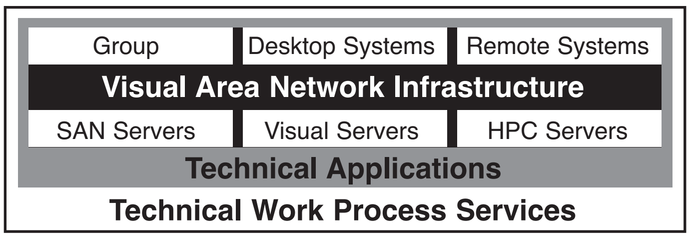

Fig. 1. Integrated technical work processes and infrastructure in a global enterprise

New technologies can fundamentally change the way people work, but unless they fit seamlessly into existing infrastructures and software portfolios and enhance the substantial investments that companies have already made, they will not have the intended impact. As shown in figure 1, SGI Visual Area Networking solutions are designed to use existing infrastructure and software portfolios. VAN solutions improve the way people work by augmenting their current capabilities, not by replacing them.

2.1 Increasing Problem Size

In technical computing environments, the management and migration of data between network file servers, HPC simulation systems, and individual desktops is becoming a critical bottleneck. Table 2 outlines the current size of data sets in many manufacturing companies and data requirements expected in one to three years. Given the growth in affordable HPC environments, the issue has become not whether a company can generate these results, but whether they derive any value from them.

As shown in figure 2, results in many high-end HPC environments are generated on an HPC server such as an SGI® Origin® 3000 or SGI® Altix™ system and transferred over a single Gigabit Ethernet to a network-attached storage system like a NetApp® F800 Series Enterprise Filer. Once HPC results are copied to the file server, a workstation accesses the data over a 100Base-TX switched network. With today's data sets, copying 56GB of data from the HPC system to the file server takes 12 minutes and copying the results to the desktop workstation takes about two hours. Unfortunately, these are synchronous processes, so the end users cannot start analyzing the data until all of it is copied to their desktop systems—assuming that the desktop systems can actually process and analyze 56GB of data at a reasonable rate. However, anticipated growth over the next one to three years would mean that it would take one day to copy 8TB of data from the HPC system to the file server and another eight days of dedicated time to copy it to the workstation. Even if the workstation could do something with 8TB of data, which it can't, a delay of nine days to access the data would be unproductive.

Manufacturing Industry Engineering Analysis Problem Sizes	CY2002 Requirements	CY2003–CY2005 Requirements
Number of cells per model	1 million	5 million
Number of attributes per cell	7	12
Number of time steps	1,000	2,000
Bytes per attribute	8	8
Total data per simulation	56GB	1TB
Number of concurrent MDO simulations per design iteration	1	8
Total data per iteration	56GB	8TB

Table 2. Manufacturing Industry Data Growth Trends

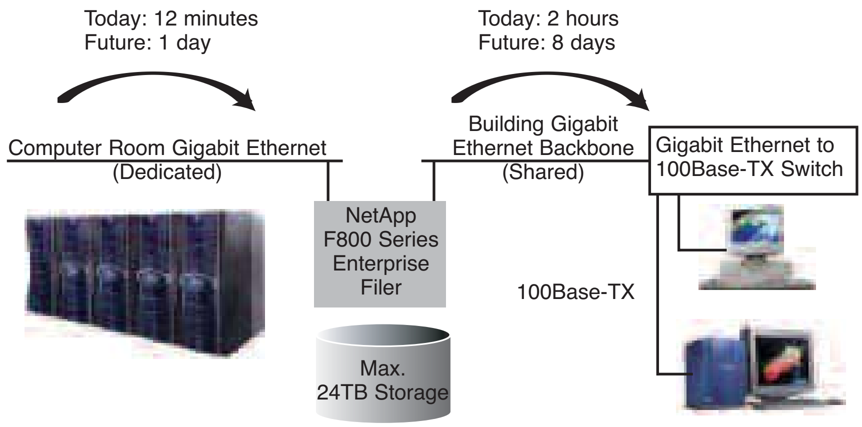

Fig. 2. Technical computing dataflow scenario without Visual Area Networking

To maintain or accelerate analysis of HPC data, organizations must increase the apparent access rates to large amounts of data by between 200 and 1,000 times while maintaining the interactive feel of a desktop environment. As described in the case studies in Section 3, Visual Area Networking can easily meet these requirements and offer instantaneous visual access to large data sets while at the same time improve the management of multi-terabyte data sets.

2.2 Data Access in Distributed Organizations

Organizations naturally want to expand market share, tap into key experts in remote locations, increase operational efficiencies, and solve new research challenges. These desires lead to growth through expansion, acquisition, or partnering. The resulting meta-organization is inevitably distributed and develops a need to provide each part of the organization equal access to the same data and problem-solving capabilities.

Historically, there are two distinct ways to deliver equal access and capabilities: replicate or centralize.

When data sizes and the required computing infrastructure are small, replication provides valuable efficiencies. If data consistency and configuration management issues can be worked out, it doesn't take much time to copy data or much equipment to manage and process it. However, as data sizes become large and organizations span more and more sites, replication becomes impossible or prohibitively expensive. (It takes three days to copy a single 50GB file over a T1 wide area network to a single site. A medium bandwidth OC12 network to four sites costs over $1 million per year and still requires high-end visualization capabilities at each site.)

The problem with data replication is high-lighted in the energy industry where data sizes have already exceeded the level at which they can easily be transferred to multiple sites. Energy exploration companies and consulting firms continuously fly structural geologists and other domain experts to sites around the world where they can review the latest seismic data and drilling results. As high-quality expertise becomes increasingly distributed and scarce, it becomes a business necessity to create a virtual company where each expert consulting session lasts four hours instead of four days including travel time.

Without Visual Area Networking, the alternative to data replication, complete centralization, is still inadequate because it is unable to provide fast and affordable data access. Centralized data repositories require that visualization systems be located with the data and that only people who are colocated with those resources can visualize and interact with that data. This creates islands of computing and visualization where only local people can see results, a serious limitation that undermines the expansion of the organization and its ability to address new opportunities. Many government and academic supercomputing centers experience this problem when remote scientists must fly to the center for one or two weeks every quarter just to analyze their data.

Neither replication nor centralization is satisfactory without VAN since neither can help integrate an organization or provide equal access across a distributed organization.

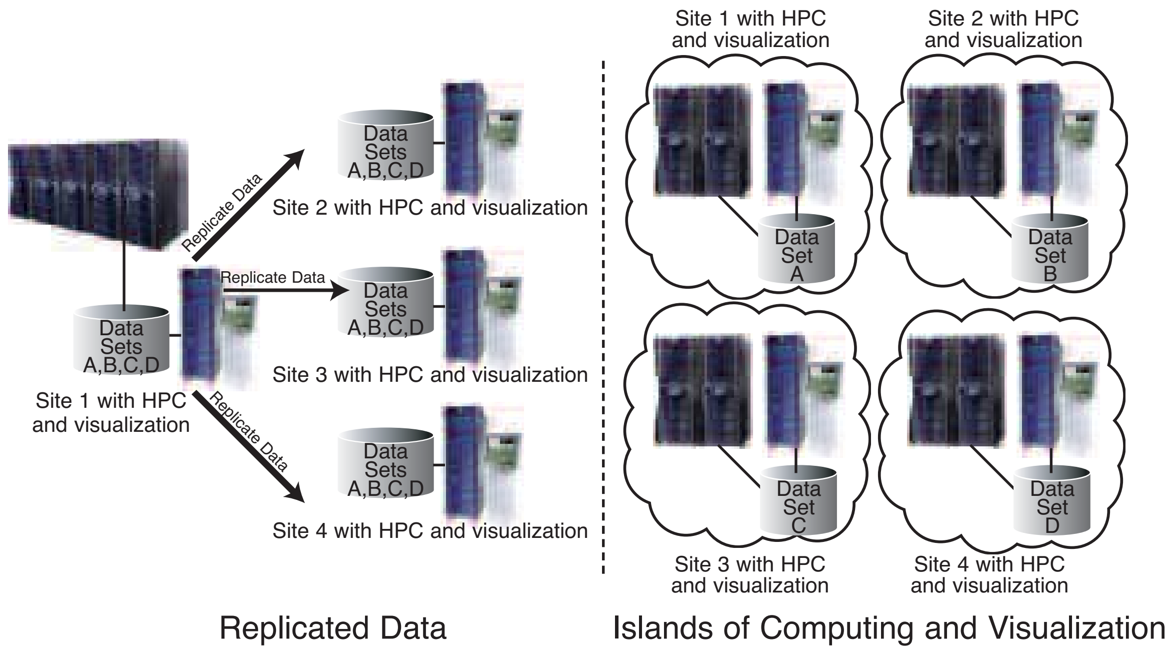

Fig. 3. Two data access challenges for distributed organizations

Visual Area Networking allows organizations to visually share information with either a fully distributed infrastructure, where each site has the data, computing, and visualization capabilities that their local work requires, or a fully centralized approach where all high-end resources are located at a single site. It can also provide a middle ground, where some resources are distributed to specific organizations, and other peak capabilities are centralized. As described in the case studies in Section 3, VAN solutions deliver uniform access, increase the value of remote experts, speed group decision making, and support the deployment of grid computing solutions.

2.3 Limited Desktop Capabilities

As data sizes grow, the ability of scientists and engineers to understand these results is limited by the capabilities of their desktop systems.

We have already seen how both LAN- and WAN-based data transfers limit the productivity of individuals by forcing them to wait before starting their interactive work. However as shown in Table 3, the greatest productivity constraint is often imposed by the user's desktop systems.

Desktop Limitation	Effect on Individual Users
Small local storage	Must segment the problem and reassemble mentally
Slow I/O subsystems	Must wait a second or third time while data is loaded into the system
Insufficient memory	Must segment the problem and reassemble mentally
Slow CPUs and memory subsystems	Cannot interactively explore results, which leads to lower-quality decisions

Table 3. Productivity limitations imposed by the limitation of desktop systems.

The result of these limitations is that users typically work with only part of a problem at a time or, in some cases, don't even attempt to solve large problems. Forcing a technical professional to work around desktop limitations can lead to errors and significant delays in the processing of large data sets. In the energy industry, one estimate suggests that the interactive analysis of 10 times the data takes only twice the time. Put another way, by significantly increasing the capabilities available to your analysts, their productivity can be increased up to five-fold.

Similarly, current-generation medical scanners generate three to five times more data than radiologists have the time or energy to analyze. By moving away from the limits of embedded workstations and traditional 2D slice visualization, visualizations can be generated using the entire high-resolution data set resulting in high-quality, pinpoint diagnoses.

2.4 Distributed Teamwork and Collaboration

As organizations grow and problems become more complex, different parts of an organization need to work together and domain experts need to consult with multiple project teams. When everyone is in a single location, experts can walk between meetings and readily consult with different groups. Ad hoc, cross-group problem-solving meetings can take place at anyone's desktop. These small organizations are very dynamic and productive because physical and organizational barriers do not get in the way.

As organizations spread over large buildings and then campuses, experts can still have a high level of impact, but it becomes increasingly difficult to get teams together for ad hoc problem-solving sessions and scheduled face-to-face meetings. As organizations extend to multiple sites, these issues are magnified, data transfer and consistency issues arise, and the cost of implementing high-end analysis solutions for each group escalates. As a result, organizations lose much of their real-time problem-solving capability, and development cycles are lengthened.

Characteristic	Desktop	VAN Server	Usage	VAN Advantage
Problem size	2GB	20GB+	N/A	Up to 10x or more
Load model	20MB/sec	2GB to 5GB/sec	10%	Up to 100x to 250x
Analyze model	1 to 2 old CPUs	8+ new CPUs	40%	Up to 10x or more
View model	6M triangles/sec	17M triangles/sec	40%	3x
Store results	20MB/sec	2GB–5GB/sec	10%	Up to 100x to 250x
Total			100%	Up to 25x or more

Table 4. VAN advantages when augmenting existing desktop capabilities.

Table 4 shows that a typical three-year-old desktop system has 10% of the compute power, 5% of the memory, and 1% of the I/O bandwidth available in many Visual Area Networking environments, so it is easy to see how the use of VAN solutions can increase individual productivity. Individuals and groups using older desktop systems can continue to use them for small tasks and desktop applications, accessing the integrated power of VAN servers when data-, computation-, visualization-, or collaboration-intensive tasks arise. As described in more detail in the case studies in Section 3, VAN solutions increase productivity and organizational flexibility while maintaining or reducing overall IT expenditures.

In order to retain the creative spark present in small organizations and to minimize product development cycles, companies need to establish real-time, interactive problem solving as an explicit goal and invest in solutions that make it possible. Creating what amounts to a virtual company ties together large organizations and enables experts to efficiently consult on multiple projects at the same time. Table 5 lists the group interaction

	Local Organization	Campus Organization	Wide Area Organization	VAN-Enabled Organization
Need to work together	High	High	High	High
Regular meeting method	Face-to-face	Face-to-face	Tele- or video-conference	Application sharing plus tele- or video-conference
Frequency of ad hoc meetings	High	Low	None	High
Quality of visual interaction	High	High	Low	High
Data access	Fast	Slow	Very slow	Very fast
Networking cost	Low	Medium	High	Medium
Total cost of interactive, large-problem analysis	Medium	High	High	Low
Number of collaborative applications	All	Few	Few	All

Table 5. Characteristics of group integration in Non-VAN and VAN enabled organizations.

changes that occur as organization grow and how Visual Area Networking solutions address problem areas. As described in the case studies in Section 3, SGI VAN solutions provide unique capabilities that allow existing applications to be used in network-based collaborative environments.

3.0 Case Studies

The best way to understand the benefits of Visual Area Networking is to examine the following examples. While in no way an exhaustive description of the potential applications of Visual Area Networking, these case studies do provide some insight into its vast power and potential benefits.

3.1 Accelerating Data Access for Remote HPC Users

Many technical computing environments are driven by the need to simulate complex problems and analyze nonintuitive results. As businesses adopt HPC as a simulation tool, the size and frequency of problems that are solved increase. While many HPC solutions are deployed directly where people use them, the largest of these resources are, by necessity, centralized. The centralization of these resources inevitably makes it difficult for individuals to access and understand the results of the centralized simulations.

As outlined in Sections 2.1 and 2.2, typical HPC environments have difficulty transferring data between HPC systems, data management systems, and visualization desktops. Organizations with remote users face the added challenge of accessing that data over relatively low-bandwidth networks.

For example, an engineer at a major aerospace manufacturer needs to optimize the lift and drag generated by a new wingtip design. The HPC simulation of the design takes up to 24 hours on a server located in a different part of the country and generates up to 100GB of data. The engineer is connected to the supercomputing center via a T1-based wide area network, so it takes almost a week for the data to be copied to the end user's location. Because the engineer has a midrange visualization system that was purchased to analyze 10GB data sets, she cannot view the entire set of data at once and must use a combination of reduced-resolution results and segmented high-resolution results to analyze the data—a task that takes five days. As a result, it takes almost two weeks per design iteration and over four months to complete the 10 iterations typically required for a design of this complexity.

If the aerospace company were using Visual Area Networking, it would eliminate six days otherwise lost to data copying for each iteration. In addition, the analysis phase could be shortened from five days to three through the use of a more powerful system that can manipulate and visualize the entire set of results in real time. Each design iteration is therefore cut from two weeks to as little as four days, and 10 iterations would take less than two months—a reduction of 58% in time to completion.

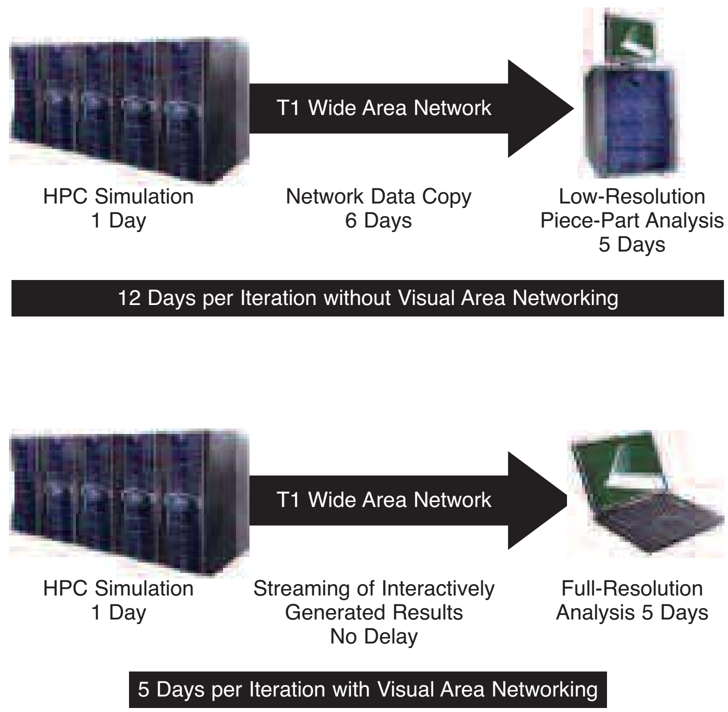

Fig. 4. Savings of 58% in time to completion by eliminating data copying for remote HPC users and by accelerating data analysis using full-resolution models in a VAN environment.

3.2 Increasing Individual Capability and Reducing Departmental Costs

When solving complex problems, scientists and engineers are often unable to follow through on their most innovative ideas because their desktop systems don't provide adequate capabilities. Budget constraints, data access limitations (see case study 3.1), and data and system management issues make it impractical to give each user a dedicated advanced visualization system.

In a departmental setting, Visual Area Networking leverages the fact that most users only need peak advanced visualization capabilities for one or two hours per day (figure 5). Since different users will have their peak needs at different times of the day, a single system can be used to support an entire department through coarse-grained resource sharing.

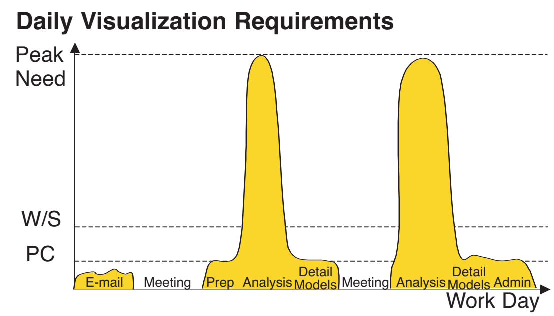

Fig. 5. Typical daily workload requirements for an engineer as a function of the time of day

Consider a 16-person engineering department as shown in figure 6. The department is trying to increase peak individual capabilities by 10 times and peak organizational capabilities by 40 times when compared with performance enabled by it's three-year-old Sun™ workstations.

To accomplish this, a Team configuration of the Silicon Graphics Prism™ system with 16 CPUs, 23 GB of memory, 2 GB per second of I/O, and four graphics pipes can be added to the department's computer room. VAN allows four users to simultaneously access this power from their Sun workstations or from standardized PCs when the existing workstations go off lease. VAN delivers between 3 times and 100 times the users' current problem-solving capability directly to their desktops in a way that integrates easily with their daily routines.

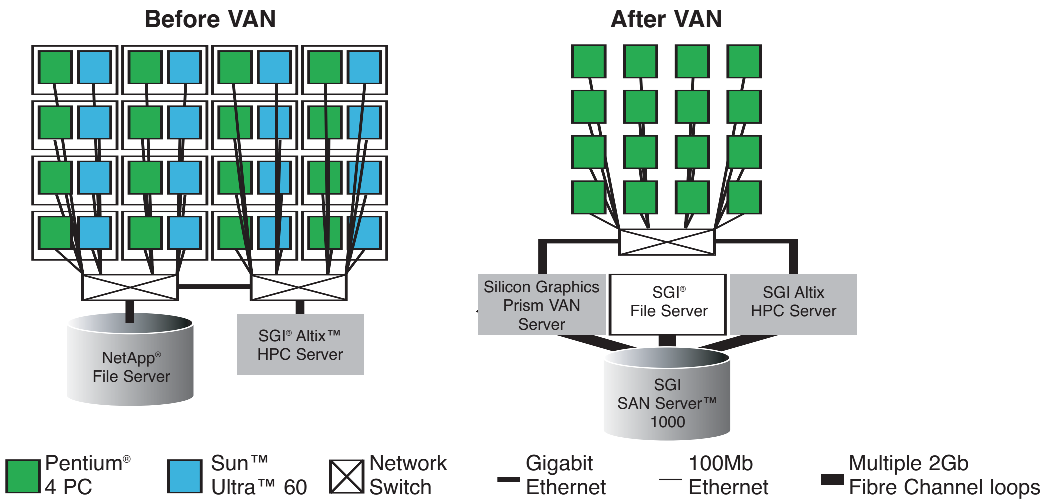

Fig. 6. 16-person engineering analysis department, before and after the installation of an SGI VAN solution.

On average, each user has access to eight CPUs, 8GB of memory, one graphics pipe, and the full 2GB-per-second I/O bandwidth of the system for two hours per day. However, usage patterns can be configured on the fly if some team members need dedicated access for four to eight hours per day during a critical portion of a project.

Further problem-solving advantages are obtained when short-term business needs dictate that problem sizes must increase without an associated increase in budget. Table 6 shows how SGI VAN solution can transparently adapt to the needs of the department by solving fewer large problems at a time or by devoting the entire system to solve a single "organizational peak" problem. These decisions can be made dynamically without any additional expense to the department.

	Prior to VAN Solution	**Individual Peak with VAN**	**Organizational Peak with VAN**
System type	Sun Ultra 60 Model 2450	Dell® PC plus 25% of Silicon Graphics Prism	Dell PC plus 100% of Silicon Graphics Prism
I/O bandwidth	20MB/sec	2000MB/sec	2000MB/sec
Local data storage	30GB	100GB to 1,000,000GB	1000GB to 1,000,000GB
Compute power	1x	8x	31x
Memory size	0.5GB	8GB	32GB
Graphics power	6M triangles/sec 54M pixels/sec	17M triangles/sec 484M pixels/sec	17M triangles/sec 484M pixels/sec

Table 6. Single user and departmental capabilities before and after the installation of a VAN solution.

Increasing Engineer Productivity at MSX International

MSX International, a leading supplier of engineering services for automotive and other engineering-intensive industries, immediately recognized the advantages of visual area networking for its operations. MSXI has been using the OpenGL Vizserver™ computing solution as part of a Visual Area Network in its MCAE group for several years, bringing the power of advanced visualization to its engineers' desktops. "With OpenGL Vizserver, we can bring the compute and visualization power of our Onyx 3000 systems directly to our engineers' desktops," said Iain Gibb, CAE manager at one of MSXI's U.K. sites. "Our engineers no longer require expensive desktop systems to do their work, and the quality of OpenGL Vizserver output even on a laptop system is sufficient to allow us to use visualization regularly in meetings and design reviews, improving productivity." MSXI will soon be using Visual Area Networking to improve collaboration between sites in the U.K. and ultimately to improve collaboration worldwide.

From a functionality perspective, this department can now solve problems that are more complex. It is also in a position to eliminate UNIX® OS-based workstations from everyone's desktop and reduce the system management expenses associated with those systems. By streamlining desktop IT resources, this department achieves additional savings that more than offset the cost of the SGI VAN solution.

Furthermore, the department can benefit from significant incremental HPC capabilities or additional savings by using the VAN server as an HPC resource at night and on weekends. Since this system is built using the SGI® NUMAflex™ architecture, all of the computing resources can easily be applied to HPC simulations when they are not being used for visualization. Because an average workweek is under 50 hours (only about 30% of the calendar week's 168-hour total), the engineering department has the equivalent of a 24-CPU compute server "for free" and is able to reduce its expenditures for future dedicated HPC resources by a similar amount.

While the benefits to any given department will depend on its particular needs and usage patterns, the combination of desktop and HPC cost savings achieved by this department exceeds 20% when compared to non-VAN, business-as-usual scenarios with multiple desktops and independent HPC systems.

3.3 Increasing Impact with Remote Experts

Every company has a few individuals who are indispensable, and in some industries the number of available experts in the marketplace at large is decreasing annually. In order to leverage their expertise across multiple projects, these experts often spend as much time traveling between locations as they do working. Not only is this travel tremendously expensive, it is an unproductive use of the expert's time, increases the time to quality decisions, often results in decision teams not consulting the best experts, and can lead to expert burnout.

Visual Area Networking enables experts to be consulted remotely while allowing them to see and manipulate the same visual data as the team with which they are collaborating. Experts can be consulted on critical issues on short notice, regardless of their location. Decisions can be made faster because the expertise needed for the decision is more readily available. At the same time, experts are more productive, since they are traveling less often.

The real value of using VAN with experts is that it allows them to consult on multiple projects simultaneously and allows them to provide immediate input so that decisions need not wait until they visit in person. Continuous expert input of one hour per day or one-half day per week can keep projects on track, shave months off development cycles, save millions of dollars per year, and significantly increase the value of the resultant project. These savings and value enhancements are usually not achievable without hands-on attention to detail since faxes, voice mail, e-mail, and even screen shots of critical issues do not allow the immediate and unambiguous solution of problems.

Leveraging Expertise at Ford

At Ford Motor Company, design and styling for new automobile models is going on continuously at numerous locations around the world. Leveraging the expertise of leading designers is a continual challenge, a challenge ideally suited to Visual Area Networking. According to Clive Johnson, supervisor, design systems (Europe) at Ford, "Our top designer always seems to be in the wrong design studio at the wrong time, just when critical design and styling decisions have to be made. The SGI concept of Visual Area Networking would solve this problem and allow him to review any design, at anytime, anywhere. In more general terms, it will allow immediate involvement of experts in the decision-making process, regardless of time and location."

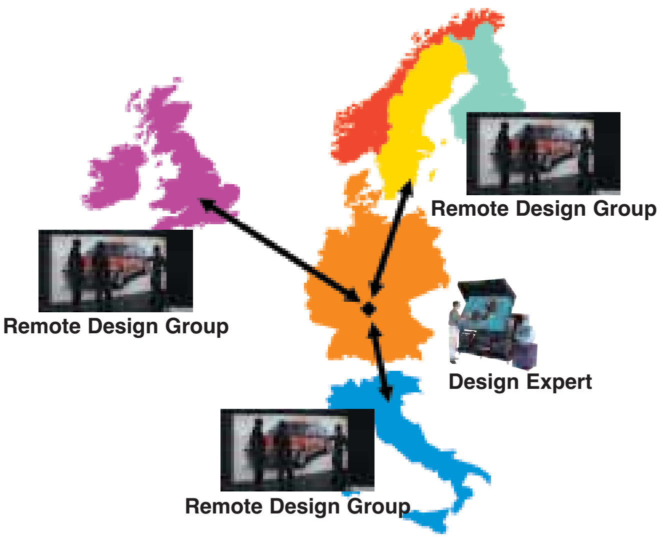

Fig. 7. Using Visual Area Networking with OpenGL Vizserver, a design expert working in Germany can consult with teams in the U.K., Sweden, and Italy on important decisions without ever leaving the office.

3.4 Shortening Design Cycles with Desktop Collaboration

The previous section focused on leveraging the expertise of a remote expert accessing large data sets on a powerful Visual Area Networking server. However, VAN can facilitate collaboration in a wide variety of circumstances. It allows individuals in the same or different departments to work together effectively using only their desktop systems and without leaving their offices.

For example, designing a new computer system may require a team of engineers with expertise in different disciplines such as ASIC design, board layout, system packaging, and power. An individual working on the design of a heat sink for a new chip in the system might perform some of the 2D- and simplified 3D-design work on his or her desktop system. More advanced work such as a full 3D simulation and visualization requiring the integration of other system components, including the airflow modeling for thermal analysis, might leverage a departmental VAN server as described in Section 3.1. After each simulation of heat transfer in the overall system, the heat sink engineer needs to consult with the designer of the system enclosure and cooling to ensure that there is adequate airflow over the new heat sink.

As seen in figure 8, VAN simplifies this collaboration by allowing both users to remain in their respective offices, using their own copies of the relevant data and software. The engineer requiring assistance need only contact the other team member by phone and use VAN to share the analysis. The two developers can interactively modify both designs to achieve maximum cooling efficiency and minimize noise. The fact that this collaboration takes place on an ad hoc basis using existing visualization software means that problems can be identified and solutions defined earlier in the design process, ultimately resulting in a better product and decreased time to market.

Using traditional design methods, issues like this might not be resolved until a late-phase design review, requiring another iteration of the design and increasing the time to completion for the project. Networked collaboration that brings the power of advanced visualization to multiple desktops can greatly enhance any process in which a team of individuals is working toward a common goal.

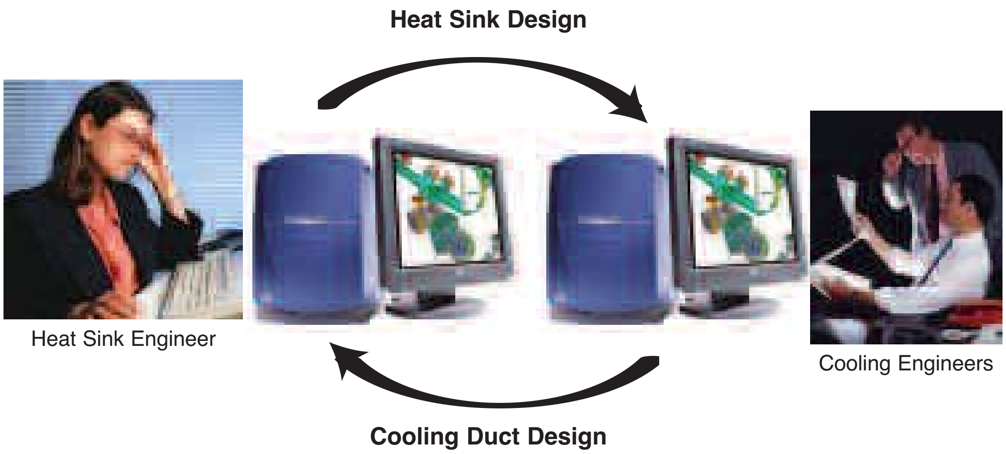

Fig. 8. Networked collaboration using OpenGL Vizserver: Two engineers in different locations share visual information while talking on the phone to speed the design process.

3.5 Multisite Group Collaboration

Powerful forms of collaboration can be achieved with the combination of Visual Area Networking and SGI® Reality Center® environments. Reality Center environments combine the advanced visualization capabilities of Silicon Graphics Prism family visualization systems with immersive displays in which teams can gather to make decisions. When discipline-specific or cross-functional teams are surrounded by all of their data, visualization becomes a common language, bridging training and cultural differences that can derail analysis and decision-making efforts.

As shown in figure 9, Reality Center facilities come in various shapes and sizes that are tailored to the needs of specific organizations. Because of the proven benefits of immersive visualization, Reality Center environments are being deployed in many industries to shorten decision cycles and increase return on investment. Reality Center environments are used in the manufacturing industry for design review and engineering analysis; in the energy industry for seismic analysis, real-time well placement, and reservoir management; in the pharmaceutical industry for evaluating new drug candidates; and anywhere else where the visualization of large amounts of data is beneficial.

Fully Immersive "Room" Environments — **"Wall" Environments for Large Models and Group Decision Making** — **"Desk" Environments for Single Users and Small Groups**

Fig. 9. Three SGI Reality Center environments, supporting fully immersive, semi-immersive, and team decision-making environments (Images courtesy of Fakespace systems and Dream Team)

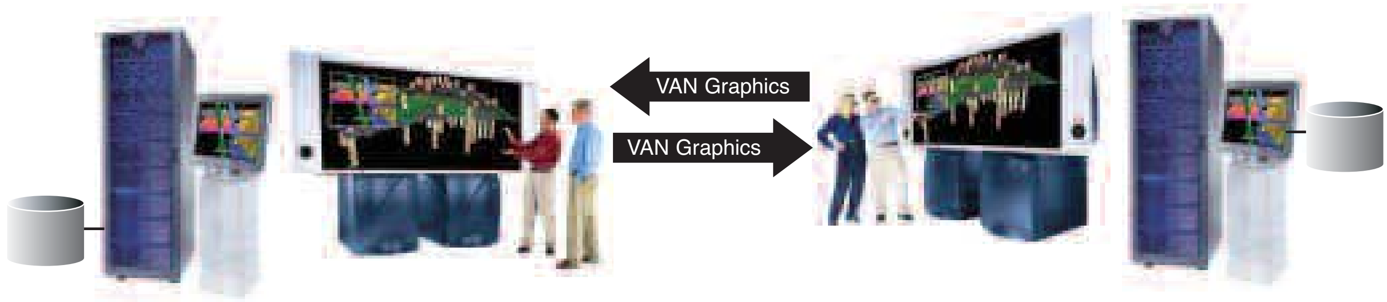

Fig. 10. Collaboration and data integration using VAN teams working in separate visualization facilities view their own data set locally and receive data from other facilities via VAN. Thus, both teams have the same integrated view of two different applications. (Screen images courtesy of Landmark Graphics Corporation and Austin GeoModeling, Inc.)

VAN adds another dimension to Reality Center environments by enabling large-scale, immersive displays at multiple sites to visualize the same information and work on the same large data sets as illustrated in figure 10. Now, organizations with groups at more than one site can see the same high-quality visuals, run the same applications, and manipulate exactly the same information without having to fly everyone to a single site or resort to low-quality video teleconferencing. Because everyone sees the same data and understands where someone from the remote group is pointing, critical decisions can be made efficiently and quickly.

For example, in oil and gas exploration, it is common to deploy teams near areas with important resources, such as the Gulf of Mexico or the North Sea. Each team has its own Reality Center facility to evaluate local assets because it is tremendously complex and expensive to drill in these areas. VAN allows these teams to work together in a shared immersive environment without waiting days or weeks for multi-terabyte data sets to be copied to each site. It also allows them to interact in real time with drilling operations in remote locations in order to precisely position these expensive wells.

One company has used VAN based drilling methodology to save more than $20 million in operational costs and realize over $300 million in increased recoverable petroleum reserves in a single field. These drilling decisions were made more quickly, with greater and more current data, and with greater veracity because the company's best experts could work together on a complex problem and take full advantage of the resources at the main office. In an industry where making the right decision is valued in the billions of dollars, making the best decision is critical.

In an alternative scenario, VAN is used as a data fusion tool for executive decision making. Visual information generated from large data sets residing on Silicon Graphics Prism visualization systems or Silicon Graphics® workstations located at different sites can be funneled into a single Reality Center where a team of executives can evaluate all the information at once. This executive decision-making environment does not have to have all of the various applications installed on, or large data copied to the central system so new data sources can be added at any time. High-quality multisite video conferencing can also be integrated into the environment for key personal interactions whenever they are required.

One example of an executive decision-making center is a crisis management center for civilian agency response. As shown in figure 11, the majority of compute and data storage infrastructure in a crisis management facility is concentrated at a large-scale operations and training center. Satellite facilities from other agencies or departments can join in visualization and collaboration with the central crisis management center as a VAN client. Remote centers can also visually share their information with the crisis management center, allowing for a review of current events.

All these forms of collaboration improve decision making by engaging the best people from different disciplines and maximizing the utilization of intellectual property. Because decisions can be made without the need for either data movement or travel, the total time needed to reach important decisions is greatly reduced.

Fig. 11. Collaboration between multiple remote sites and an executive decision-making center

3.6 Command-and-Control Environments

Distribution of and collaboration on battlefield information are essential due to the nature of modern, joint-forces warfare. Real-time information comes to a theater commander from a number of sources, including:

- Satellites feeding specifically tasked collection data
- Unmanned aerial vehicles collecting visual and sensor information
- Manned intelligence, surveillance, and Reconnaissance
- Orbiting airborne C2 assets
- Naval C2 assets

Figure 12 illustrates the complex dependencies and data routes for a typical joint-forces theater of engagement. Although each element may have unique data and processing requirements, there is a large amount of data commonality and therefore a need for data consistency at the lowest levels. Visual Area Networking ensures that the unique requirements for exchanging current information and collaborating with joint and forward elements are met.

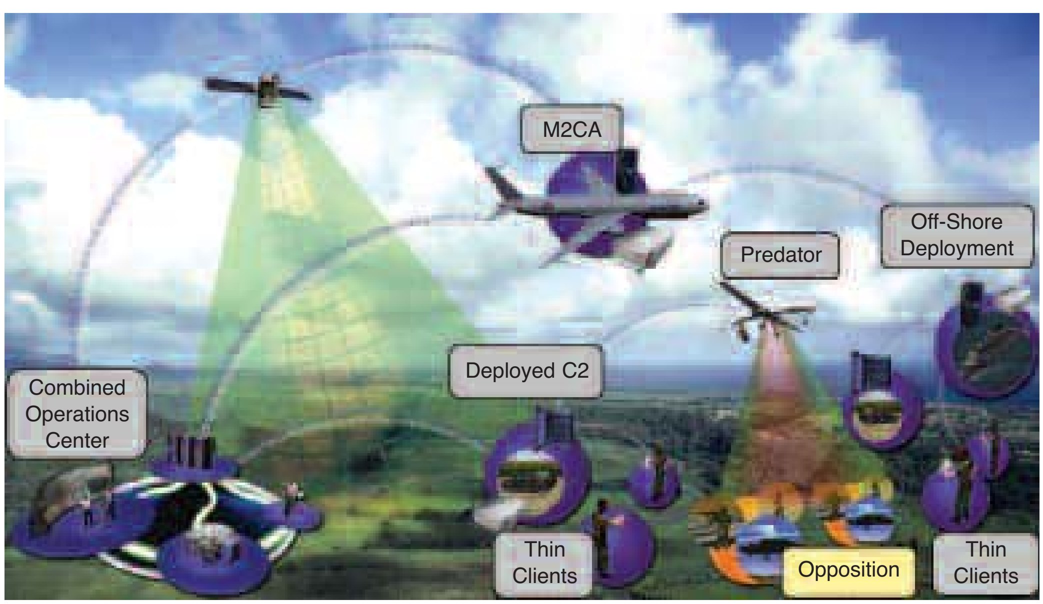

Fig. 12. VAN enabling collaboration between forward command-and-control elements and fixed combined operations centers

The visual information requirements for an engagement theater can be broken down into two categories: forward or deployed assets and fixed-operations centers.

Forward command-and-control assets and deployed assets require rapid response, and some need continuous mobility. VAN technology plays a crucial role in creating a foundation for deployed forces that enables forward collaboration while maintaining hundreds of gigabytes per day of sensitive information in a consistent form and in a controlled environments.

Using VAN, a simple, ruggedized client such as a laptop can interactively update and modify visual information generated in a mobile command-and-control or fixed-operations center. Field personnel can leverage graphics supercomputers and large, high-speed storage arrays. Furthermore, since forward-deployed VAN clients work on visualization generated at the operations center and not by the client, none of the physical data resides on the forward client, mitigating many information security concerns.

Fixed-operations centers are the nerve centers for command and control and typically contain a broad array of compute and storage components. VAN enables fixed-operations centers to streamline the exchange and collaboration of visual data with other theater elements in order to coordinate field feedback, maximize the efficiency of resources, and provide flexible, redundant capabilities. And, since VAN resources can be virtualized, forward commanders are not dependent on the availability of any single fixed-operations center to provide current information, but can draw on the resources of any available center.

Personnel at a fixed-operations center can quickly process and integrate multiple information streams into forms that can be reused by a broad array of consumers. The forward command-and-control centers and the fixed-operations center work together to create a complex information-processing environment where results can be generated and shared with other centers. Building a theater information infrastructure using VAN ensures that the visual data sent to the farthest reaches of a unit's deployment is consistent with that of the fixed-operations center, since it is the exact data being visualized at the fixed center.

3.7 Visualizing HPC Results in Grid Environments

The goal of grid computing is to enhance users' ability to solve difficult problems, collaborate across organizations, and increase the utilization of expensive resources—regardless of the location of those resources. Today's grid environments have made great strides toward providing transparent access to remote computational resources and are beginning to tackle the issues associated with shared access to numerical data. However, even if there were gigabit networks connecting every research desktop in the world, remote data access would remain a bottleneck, and every grid user would need a powerful large-data visualization system at his desktop. (See Section 2.1 for more details on this challenge.)

Today's grid environments do not adequately support remote visualization of data or the sharing of data analysis results with members of a distributed research team. The result is that once a set of data-intensive simulations or observations is completed, the grid user still faces the problem of understanding the data that resides on some faceless disk drive in some unknown location.

Visual Area Networking addresses the remote access and team collaboration issues of grid computing by delivering high-quality visualization to any research desktop that is connected to any grid, anywhere in the world.

For instance, a computational chemist in Maryland could submit a simulation to a molecular modeling grid with compute and data-storage resources in Texas, Florida, Japan, and Germany. The grid decides that the node in Germany can best handle the chemist's task, so the relatively small input data set is migrated to that site and the simulation completed in 48 hours. The simulation produces 300GB of data covering 10,000 time steps, and the results are stored on a SAN that is connected to the HPC server and a VAN server.

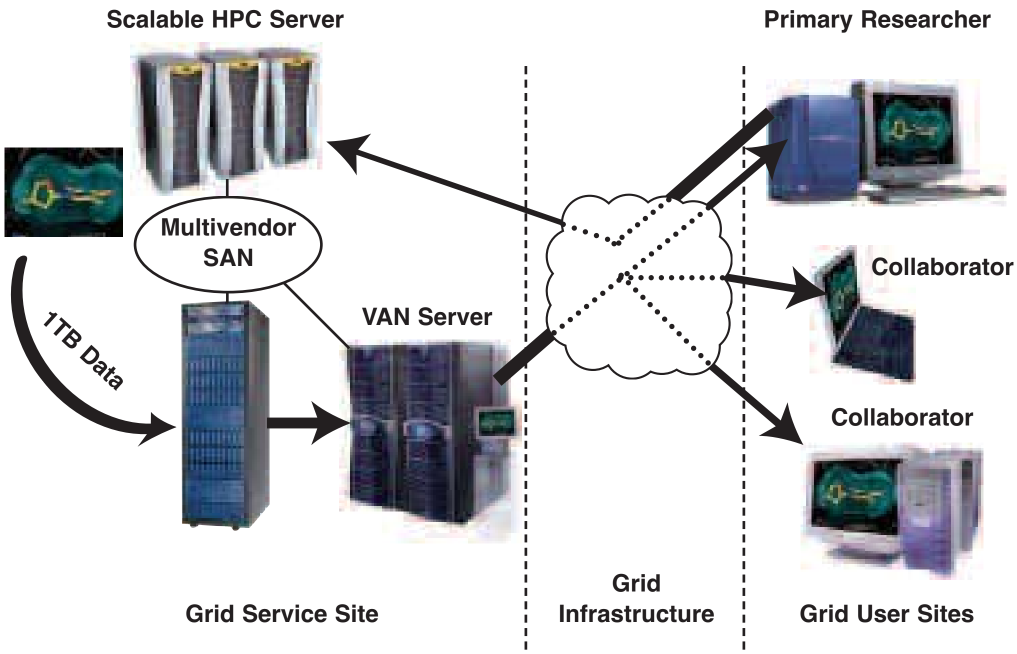

Fig. 13. Computational chemistry grid with multiple service sites (one showing) and multiple client sites collaborating on the visual analysis of a single problem (Molecule image courtesy of Janssen Pharmaceuticals)

Because the chemist wants to visualize the entire data set, not just a few snapshots, the VAN server directly accesses the data, generates the visual results, and sends them across the Atlantic using a 5Mb portion of a high-bandwidth Internet connection. The research scientist discovers a potential breakthrough in the results and immediately asks colleagues in France and California to join the analysis session and verify his interpretation. Though their interpretations differ slightly, the scientists agree that this is a potential for breakthrough, and together they design four additional simulations to clarify the original results and submit them to the grid with high priority. This time, the computational chemistry grid determines that it is best to run the four simulations concurrently—one simulation in Germany, two in Texas, and one in Japan. The four simulations are completed 24 hours later, and the three research scientists use VAN to simultaneously review the four results visually. Each scientist can see each result and interact with the visualization system, even though the group is manipulating more than 1.2TB of data spread over three continents.

Using a computational grid and VAN, the entire process—from start of the initial simulation to review of the follow-up results—takes less than 72 hours. This is over 100 times faster than using local Maryland computing and visualization environments and depending on typical, noninteractive team collaboration (e-mails, screen captures, telephone calls, and eventually several face-to-face meetings)—a process that might have come to the same conclusion, but would have taken from six months to one year.

Generalizing this scenario, VAN acts like the eyes of grid computing. Any computational grid can benefit from the addition of VAN servers to its computational nodes to increase both individual and team insight and productivity.

Using a Grid and OpenGL Vizserver to Bring Advanced Visualization to the OR

SGI is collaborating with the Manchester Visualization Centre (MVC) at the University of Manchester in the U.K. to bring interactive visualization to the operating room over a visualization grid. Most operating rooms don't have the visualization equipment necessary to view the results of CT MRI scans in 3D, although the ability to do so would greatly simplify the surgeon's job. Because visualization equipment would be both too bulky and too expensive for the operating rooms at most hospitals, surgeons continue to rely on traditional 2D x-ray films.

Manchester has developed a specialized OpenGL® visualization application for surgeons called Op3D and tested the use of OpenGL Vizserver to bring visualization to the OR. An SGI® Onyx® 300 system acts as a visualization server, providing interactive 3D graphics to a laptop system in the OR. This laptop system is connected to a video projector—allowing the surgical team a larger view of the image. The surgeon controls the application with a joystick. According to Dr. Nigel John of the MVC, "The advantage of OpenGL Vizserver is that it brings the full capabilities of our Onyx family visualization system to the operating room. A surgeon can interactively manipulate the view in real time, rotating and slicing the image in any way necessary. Since the laptop in the OR merely displays the pre-rendered images and passes control information back to the server, it requires no special graphics capabilities."

The team is working to enhance the Op3D application for voice-controlled, hands-free operation. Visualization access will be made available to other hospitals in Manchester, creating a visualization grid. Ultimately, this functionality can be replicated to bring visualization to operating rooms around the world.

4.0 Implementing Visual Area Networks

Visual Area Networking solutions are highly flexible and can be constructed to meet the needs of a small workgroup on a LAN or to meet the needs of a global enterprise encompassing many LANs and multiple locations connected by wide area links. A visual area network is composed of eight elements:

· Visualization server(s): The visualization system can be a Silicon Graphics Prism or SGI Onyx family visualization system. These systems combine high-performance graphics, multiple CPUs, large amounts of memory, and exceptional I/O bandwidth to compute and visualize problems far beyond the capabilities of typical desktop systems. When desktop-to-desktop collaboration is the goal, Silicon Graphics® Octane2™ or Silicon Graphics Fuel™ workstations can be used as visualization servers. The server is the core of a Visual Area Network, since the application and data reside on the server and all rendering is performed using the full 3D capabilities of the server. Rendered images are compressed in real time before delivery to the client.

· Visualization client(s): The client receives and displays rendered images from the application running on the server. Because the client simply displays images rendered by the server, accelerated graphics capabilities are not required. The client has full control of the application running on the server (or shared control during a collaborative session). SGI VAN solutions support a variety of UNIX, Linux®, and Windows® operating system clients. Because VAN places so little stress on the client, most users will find that existing desktop systems work well, so no new investment is needed.

· Storage area networks with CXFS™: Efficient and high-bandwidth storage, management, and delivery of data across an extended enterprise are key to quality collaborative decision making. As decisions become real time in nature (battlefield operations and oilfield operations, for example), the flow of data from sensors to storage to computational engines to visualization engines and through collaborative infrastructures is key to success. CXFS and SAN technologies from SGI are designed to handle the tremendous data size, data management, and data movement required to facilitate an efficient VAN environment. They accelerate dataflows across an enterprise by allowing a single data file to be shared by a large number of heterogeneous systems and users across storage interconnects with multiple gigabytes per second of bandwidth. As a result, SGI VAN solutions accelerate both local and remote data access.

· High-performance computing: Raw data must be transformed into meaningful analysis before visualization is meaningful. The integration of high-performance computing into VAN environments is crucial to streamlining the transformation of data into operational decisions. The combination of industry-leading families of scalable IRIX® OS-based and Linux OS-based computational servers with SGI SAN and VAN technologies make it possible to process real-time inputs and increase the value of timely information.

· Existing network infrastructure. SGI VAN solutions are designed to operate over existing network infrastructures, again minimizing the need for additional investments. OpenGL Vizserver adapts to almost any network environment because of built-in features such as compression and frame spoiling. On LANs, optimal performance is achieved with 100Base-TX or with connections of similar or greater bandwidth. Legacy 10Base-TX connections, however, can also be used, particularly with applications that take advantage of the incremental compression capabilities available with OpenGL Vizserver. For wide area connections, T3 (44.736Mb per second) or higher bandwidth is ideal, though T1 (1.544Mb per second) connections can be used with excellent results.

· OpenGL Vizserver software: OpenGL Vizserver is the core software that enables VAN solutions. OpenGL Vizserver implements a client/server architecture that is similar in concept to a Web server–Web browser combination. Just like Web browsers, the OpenGL Vizserver client is a lightweight program that is freely downloadable from the www.sgi.com Web site. The main difference between VAN and the Web is that VAN gives remote users and collaborative teams complete interactive access to existing applications, while the Web allows one user at a time to view static information.

OpenGL Vizserver works in a high-performance, application-transparent way by allowing applications to run natively on the OpenGL Vizserver "server" and complete their rendering using 3D graphics hardware on the server. Once each frame is completed on the server, OpenGL Vizserver reads the results from the active OpenGL window back into system memory, compresses the image, and sends the compressed results over a network to the OpenGL Vizserver clients. The clients decompress the image, display the image, and send mouse and keyboard control information back to the server. Table 7 lists key OpenGL Vizserver features.

· Existing OpenGL applications: Since existing OpenGL applications are used without modification for both remote access and interactive collaboration sessions, organizations can immediately get up and running.

· Services: SGI Technology Services offers insights into the specification, management, and growth of a company's Visual Area Networking infrastructure. Visual Area Network solutions start as focused pilots and their effectiveness will rapidly grow to enterprise proportions, in many cases enveloping a global technical computing infrastructure. Growth strategies must be intelligently planned to optimize the implementation, installation, and upgrades to the Visual Area Network. SGI Technology Services is uniquely qualified to tune these systems to their most efficient levels, giving customers unprecedented value from their SGI investments.

Visual Area Networking solutions are designed to immediately and significantly enhance existing technical computing infrastructure and operational processes, allowing an organization to evolve at its own speed into a fully enhanced VAN enterprise. Different organizations will initiate their VAN installations from different technical directions, leveraging the strengths of their most advanced investments—whether it is a global SAN, an HPC center, or an advanced visualization system.

OpenGL Vizserver Features	
Supported visual servers	Silicon Graphics® Onyx2®, SGI Onyx 300 and SGI Onyx 3000 family systems can be used as multi-pipe and multi-session visual servers; Silicon Graphics Prism, Silicon Graphics Octane®, Octane2™, or Silicon Graphics Fuel workstations with VPro™ graphics can be used as visual servers for personal collaboration
Supported clients	Silicon Graphics workstations (IRIX® 6.5.5+), Sun workstations (Solaris™ 2.6+), workstations with Intel® Pentium® III (or better) and Red Hat® Linux® 6.2, Microsoft® Windows NT® 4.0, Windows® 2000, or Windows® XP and Windows® XP Tablet PC operating system
Application transparent	Existing OpenGL applications run without modification for both remote users and collaborative teams.
Networked collaboration	Allows multiple independent users to share control of existing, unmodified OpenGL applications
Group environments	Silicon Graphics Prism support multipipe environments for connections between remote SGI Reality Center environments. SGI Onyx and Silicon Graphics workstation clients support remote stereo viewing for immersive collaboration.
Compression	4:1, 8:1, 16:1, 32:1 incremental compression and a compression API for creating custom compressors
Frame spoiling	Maximizes both local and remote performance
Authentication	Validates user login—including time of day, day of week, and resources they are allowed to use
Web-based reservation system and reservation API	Users can reserve time on visualization server. API allows integration with existing calendar systems.
Integrated management and accounting capabilities	Graphical system management interface simplifies setup and administration of users, authorized usage times, and the dynamic allocation of graphical resources. A full per-user usage log is available for planning, billing, etc.
Performance-monitoring tools	Detailed per-session and per-system real-time monitoring and logging of performance information

Table 7. Key features of OpenGL Vizserver

One of the major benefits from VAN is the multiple benefits available to users of scalable advanced visualization systems. Organizations that already have a Silicon Graphics Prism system to support power users or SGI Reality Center environments can enhance these installations by turning them into VAN environments simply by adding OpenGL Vizserver software. The impact of these environments is both immediate and significant, because most sites will be able to fully leverage existing desktop clients and networks. Once existing environments have been VAN enabled, their value to the extended enterprise can be further enhanced by using SGI SAN solutions to link high-value data management and multivendor high-productivity computing solutions into a single integrated VAN environment.

As the preceding sections suggest, a VAN can make dramatic improvements to decision making and workflow. Implementing a visualization server or servers allows applications and data to be more centralized, or virtualized, with less need for copying data. This means that critical data is more secure and more accessible and lessens the administrative burden associated with managing widely dispersed data and application software.

Instead of wasting valuable time copying data where it is needed and addressing complex data consistency issues between sites, a Visual Area Network user can begin accessing visual data immediately and manipulating that data with the full compute and visualization capabilities of an Silicon Graphics Prism platform. OpenGL Vizserver brings the power of visualization where and when it is needed, enabling people to focus on creativity and insight rather than on the technical intricacies of computing, visualization, and data management.

5.0 For More Information

More industry-specific and product-specific information, additional white papers, customer success stories, and recent press releases are available through the Visual Area Networking Web site at *www.sgi.com/visualization/van/*.

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