Transforming the Medical Imaging Workflow:

How Mac systems and open source software combine to make full-featured diagnostic imaging solutions affordable for today's radiologist.

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Executive Summary

Today more than ever, the healthcare industry is reaping the benefits of advances in diagnostic medical imaging. Dramatic breakthroughs in higher-resolution CT, MRI, ultrasound, and interventional technologies have enabled healthcare providers to deliver more informed diagnoses, pursue more effective treatments, collaborate more easily with colleagues, and communicate more clearly with patients. Indeed, diagnostic medical imaging has undergone nothing short of a revolution.

But with these advances have come challenges. The healthcare industry's reliance on imaging may be intensifying, but so is the pressure on radiology operations to accomplish more with fewer resources. In the United States, well-meaning federal lawmakers have inadvertently put enormous cost burdens on many imaging centers and private radiology practices. The Deficit Reduction Act will impose cuts of up to $6 billion in previously allowable Medicare and Medicaid fees for radiology services over the next five years.

As if that wasn't enough, these organizations—along with radiology departments in hospitals and clinics—are also facing a veritable avalanche of imaging data. Most radiology environments have all but given up on film, opting instead for the flexibility and ease of digital images. This trend has dramatically increased the need for ever more powerful image processing workstations and storage systems. Meanwhile, the latest image capture devices can produce studies that are up to 1000 times more detailed than previous generations.

Processing, viewing, and interacting with all this image data has traditionally required an investment in a DICOM viewer provided by the scanning equipment vendor. These systems are typically Microsoft Windows–based workstations and can cost $50,000 or more—a price tag that, in today's environment, is proving too much to bear.

All of these pressures are causing radiology organizations to seek more efficient and cost-effective solutions for their imaging infrastructures.

This white paper, authored by a radiology industry expert and consultant, is written for radiologists and other medical professionals who view and manage DICOM images. It aims to illustrate how Apple's Mac systems, coupled with the OsiriX[1] open source application and Mac OS X, offer a more affordable alternative to today's Windows-based image review platforms—without sacrificing features or performance. A growing number of radiology facilities have embraced this option with much success.

The paper provides an overview of how a Mac OS X–based solution can interoperate within an existing Microsoft Windows–based medical imaging workflow, covering such key components as Picture Archiving and Communication Systems (PACS), Radiology and Hospital Information Systems, and collaborative teleradiology environments.

It also details some key steps necessary to incorporate a Mac OS X–based solution into a modern imaging infrastructure, including:

- Leveraging low-cost Apple Xserve systems and Apple-qualified RAID systems for image storage and retrieval
- Using cost-effective Mac computers and open source OsiriX software to build an imaging workstation environment
- Enabling the imaging workflow
- Collaborating beyond the office with OsiriX software

The new reality of today's medical imaging environment has forced radiologists to consider new, more cost-effective approaches to provisioning their IT infrastructures. For many, integrating an open source OsiriX environment on Mac systems running Mac OS X is becoming a compelling alternative—one budget-strapped facilities can adopt with relative ease and at substantially lower cost.

The New Realities of Medical Imaging

DRA: Beyond Medicare
The allowable fees for imaging and radiology services charged through Medicare are shrinking, the result of massive cuts mandated by the Deficit Reduction Act, which went into effect January 1, 2007. Naturally, hardest hit will be facilities dominated by Medicare patients. But because many insurance companies and HMOs match their payment schedules to Medicare's allowable charges, private practitioners and imaging centers may be left vulnerable to waning revenues triggered by the DRA. And as aging baby boomers dramatically increase the population of Medicare patients, imaging centers must look for ways to cut costs now.

We are witnessing a defining moment in the history of medical diagnostic imaging. It's a moment in which several trends are converging at once to present enormous opportunities for improvements in diagnoses, treatments, and patient care—along with unprecedented financial pressures.

For many radiologists and imaging centers operating in the United States, those financial pressures have been intensifying for years, as budgets have grown tighter and workloads have increased. But they came into even sharper relief on January 1, 2007, when the Deficit Reduction Act (DRA) went into effect. Passed by Congress two years before, the law was intended to shrink the record U.S. budget deficit in part by cutting back on Medicare and Medicaid spending. But the cuts inadvertently—and many say unfairly—home in on industry-standard charges for technical and professional radiology services. Of the $11 billion the DRA hopes to save in Medicare and Medicaid costs over five years, $2.8 billion is coming from Medicare reimbursement for imaging services. That's more than a quarter of all the cost reductions targeted for the two programs. Even worse, the American College of Radiology estimates that the cuts will more likely amount to $6 billion over the next five years.

Though many government-sponsored facilities will escape the reach of the DRA, the new law will, for many imaging centers and radiologists in private practice, slash reimbursement for a range of services, and some reductions are especially extensive. As of 2007, for instance, the DRA calls for a 50 percent decrease in reimbursements for the technical portion of MR, CT, and ultrasound exams on contiguous body parts in the same session.

For many radiologists and imaging professionals in private practice or in U.S. imaging centers, the DRA cuts place a new and sudden urgency on efforts already underway to streamline medical imaging workflows.

The Digital Data Explosion

The DRA is only part of the rapidly changing face of medical imaging. In the past decade, nearly all medical fields have been transformed by technological advances in CT and MRI technology, and by the rise of minimally invasive image-guided procedures. These advances have provided cost-effective alternatives to open surgical intervention. At the same time, many radiology and cardiology imaging practices have stopped printing images to film altogether, relying instead on digital software systems to meet their imaging needs.

Adoption of digital imaging has led to significant efficiencies in imaging workflow. The shift from hard-copy images printed on film to digital archives has streamlined radiology file room processes, significantly reduced the problems caused by misplaced

radiographs, and trimmed the capital costs of film development and storage. Digital acquisition has also fostered many advanced processing techniques that enhance the quality of care.

Still, the imaging revolution has come with certain costs. One of these is an avalanche of image data. As physicians replace film with digital images, the number of images for each study has also steadily increased. New scanning and measurement devices capture up to 1000 times more data than previous generations. And as baby boomers age, more patients are requiring diagnostic imaging examinations. So not only are physicians reviewing more exams, the exams they're reviewing contain vastly more data than ever before.

The Rise of Imaging Workstations

To take full advantage of the cost savings and improved care made possible by imaging breakthroughs, radiologists and imaging centers have had to adopt powerful viewing and post-processing workstations.

These systems have become essential to radiology practices because they integrate with central Picture Archiving and Communications Systems (PACS). Depending on where they fall in the medical imaging workflow, the systems are known by different names:

- **Diagnostic imaging workstations**, used in dedicated imaging departments, have features that are tailored to interpret images accurately and allow imaging professionals to efficiently generate official reports to assist in patient management.
- **Clinical review workstations**, located in hospital wards, are tailored to enable simple image review and access to the imaging report.
- **Dedicated 3D viewing workstations**, used to review advanced, volumetric multi-detector CT and MRI data, are equipped with powerful 3D graphics processors, workflow guided measurements, and specialized applications.

A Cost Conundrum

The benefits of viewing both 2D and 3D image data have come at considerable cost. Dedicated 3D viewing workstations from vendors like TeraRecon, Vital Images, and GE are commonly priced at more than $50,000. Add a few special features, and the price tag easily soars to more than $100,000. Yet despite the costs, radiology groups, hospitals, and even physicians in private practice continue to invest in them. They offer image-viewing features that solutions from most PACS vendors don't, such as the capability to review and process advanced MRI and multi-detector CT data. And while PACS vendors sell plug-ins to provide increased functionality, their performance and features rarely match those of dedicated workstations.

In the new reality wrought by the DRA and other factors, those high costs create a conundrum for professionals forced to operate under ever-tightening budgets.

Some hospitals have responded by funding internal development of workstation solutions. Their efforts resulted in well-known systems such as eFilm and Stentor iSite.

- *eFilm Workstation/PACS*, now owned by Merge, is one of the more affordable commercial systems. Many radiologists and clinicians are familiar with eFilm because they receive the free version of eFilm Workstation software on CDs from hospital and outpatient radiology departments. Merge also produces a retail version with additional functionality for those who don't need the complete function of a PACS. The cost of an eFilm Workstation including hardware is approximately 30 to 50 percent more than a Mac-based workstation.

- *Stentor iSite*, now owned by Philips Medical Systems, is popular due to its workflow enhancements (the system was designed by a radiologist) and its proprietary image transmission technology, which is helpful in teleradiology. However, the cost of the iSite system remains well out of reach of many departments and radiologic private practices.

  Like many PACS, eFilm and iSite focus on the traditional path of soft-copy image review, requiring additional funds to purchase commercial 3D workstations to perform higher-level tasks.

A Compelling Alternative: The Mac and OsiriX Workstation

Most healthcare and medical imaging applications run on Microsoft Windows–based PCs—a fact that has kept other platforms, including Apple's Mac OS X-based systems, from making inroads into imaging centers and radiology suites. Many in the radiology and imaging field have not considered the Mac a platform that could handle the escalating demands of medical imaging. The belief that Mac systems are difficult, if not impossible, to operate alongside Windows PCs has helped fuel this belief. The default assumption has been that only Windows PCs or proprietary commercial DICOM workstations belong in radiologic environments.

That assumption is proving to be incorrect. In recent years, new generations of Mac OS X–based systems have been adopted in more medical imaging environments, thanks in large part to their inclusion of multicore Intel processors, high-end graphics accelerators, and professional-quality display technologies.

OsiriX: Full-Featured, Open Source

At the same time, open source developers have dedicated themselves to creating a medical imaging workstation application expressly designed for the Mac OS X operating system. Called OsiriX, this open source application is available only for computers running Mac OS X. The software gives physicians and technologists access to most of the common features of radiological imaging and commercial DICOM workstations, including:

- Support for virtually all modality types and features
- DICOM networking functions
- Advanced image organization tools
- 2D, 3D, and 4D reconstruction tools
- Multiplanar, surface-shaded, and volume-rendering algorithms
- Sophisticated image fusion methods
- 4D imaging, required for gated cardiac MRI or CT
- Support for third-party plug-ins to customize the environment
- Complete PACS and workflow integration capabilities
- Complete support of digital angiography, including subtraction, pixel shifting, and high-speed fluoro loops. (See Apple Profile: Hartford Hospital Stroke Clinic.[2])

OsiriX benefits from its genesis in the open source community, allowing it to mature quickly into one of the most complete and feature-rich radiological software solutions available. Numerous open source developers from around the world regularly incorporate new features at the request of end users. Although free radiology-oriented software projects exist for other operating systems, including Linux and Microsoft Windows, none can equal the features and performance of OsiriX. Similarly, it is difficult for any single medical imaging vendor to match the rapid pace of innovation that this open source project enjoys.

Building on an open source foundation
In early 2003, physicians at UCLA and the University of Geneva noticed that most components required to develop a powerful medical imaging workstation were available under open source licenses. Using Apple development tools, the team at the Department of Radiology, University Hospital of Geneva, led by Drs. Osman Ratib and Antoine Rosset, produced the OsiriX DICOM Viewer. This software viewer takes advantage of many core features of Mac OS X and was released for distribution under the GNU public license.

Also released was the source code—or software building blocks—of the OsiriX open source application. Access to OsiriX source code presented a unique opportunity to visionary commercial developers who saw the advantages of building OsiriX-based solutions available via a traditional commercial licensing model, complete with certification, bug fixes, and technical support.

From this initial effort, more solutions have emerged:

- **aycan workstation OsiriX^{PRO}.** This workstation is a modified version of OsiriX from aycan (www.aycanus.com, www.aycan.de). The software has earned 510(k) clearance by the United States Food and Drug Administration, and it has a CE certificate for use throughout the European Economic Community and Turkey. Available commercially, aycan workstation OsiriX^{PRO} incorporates bug fixes and validated and exclusive plug-ins. Furthermore, the software comes with a comprehensive user manual, a computer-based training CD, and various training and service options.
- **SecureRAD OsiriX management and support.** SecureRAD (www.securerad.net) provides a variety of OsiriX workstation management, integration, and support services for healthcare organizations.
- **iRIS.** Also from SecureRAD, iRIS is a flexible web-enabled Radiology Information System.

Mac OS X and Mac Systems

OsiriX is developed for Mac OS X for a reason. Mac OS X is frequently regarded as the most advanced operating system available, combining the powerful and security-aware technologies of UNIX systems with the friendly user interface for which Mac OS X is known. Through modern programming techniques such as Objective-C and the Cocoa framework, Mac OS X supports new generations of highly stable and scalable tools for use in professional environments. Mac OS X runs on all Mac systems, from MacBook notebooks to high-end Mac Pro workstations. With Mac Pro workstations, users can, with relative ease, meet the more rigorous requirements of a high-performance radiological workstation: a standard Mac Pro workstation has eight Intel Xeon processor cores, up to 32GB of memory, as much as 4TB of internal disk storage, and a choice of three available graphics card options, one of which offers stereo viewing capability. The standard graphics card configuration available for Mac Pro workstations can drive two 30-inch Apple Cinema Displays in portrait mode to give users up to 8 megapixels of screen resolution. By adding additional inexpensive video cards, users can drive up to eight 30-inch Apple Cinema Displays with a single Mac Pro system.

A New Solution for a New Reality

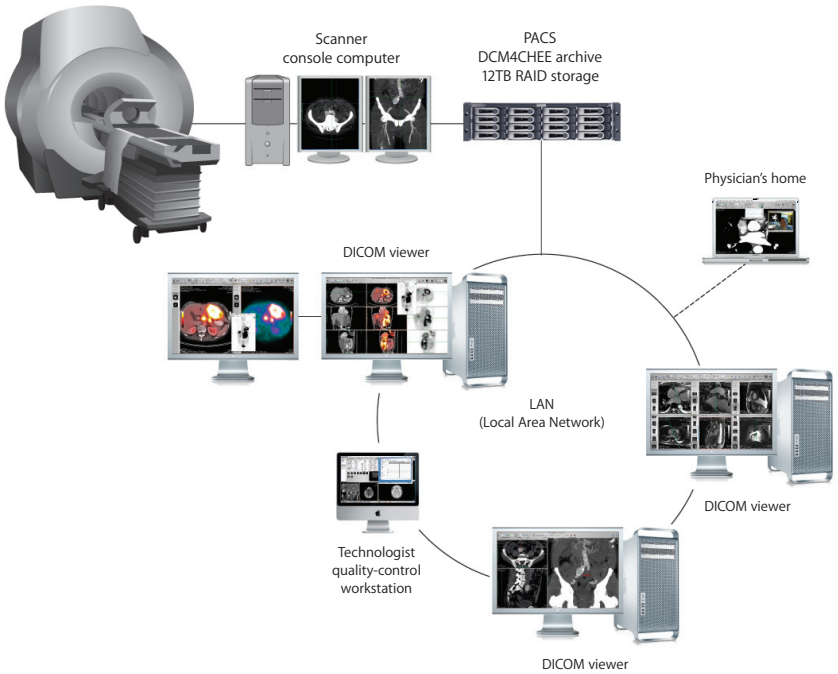
Written for radiology professionals and practitioners, this white paper is designed to show how the Mac platform, coupled with open source OsiriX and low-cost plug-ins, can offer practical digital imaging solutions to individual physicians and imaging practices of any size. These solutions offer not only improved imaging workflow, but in an increasingly difficult operating environment, they significantly lower the barrier to entry to medical imaging review.

Mac Systems and OsiriX in the Radiology Workflow

First-hand experience has shown that it isn't difficult to integrate Mac OS X systems and OsiriX into an existing radiology workflow—even those built around PCs running Microsoft Windows. With Apple software tools and the interoperability of OsiriX software and third-party plug-ins, radiologists can deploy Mac-based imaging workstations that conform to the tightest technology budgets.

Imaging workflows in a private radiology practice may differ from how a teaching hospital workflow operates. But all imaging workflows share some key components:

- Scanner or other image generation equipment
- Picture Archiving and Communications System (PACS)
- Storage system
- PACS server system
- PACS archive software
- Imaging workstation environment
- Displays
- Hospital Information Systems and Radiology Information Systems
- Collaboration environments



Understanding how Mac-based imaging systems and OsiriX software combine to integrate with these components is key to transforming medical imaging workflows.

Image Generation Equipment

Whether located onsite or at remote facilities, patient image studies from MRI, CT, PET, ultrasound, and other scanning devices define the typical entry point to the radiologic workflow. With OsiriX software, Mac-based imaging workstations support all common modalities.

Picture Archiving and Communications Systems (PACS)

PACS manage the storage and retrieval of patient data and images. Image data is stored in standard DICOM file format, which supports digital images generated by the various imaging modalities.

PACS systems also can be programmed to distribute DICOM data based on queries of a patient's name, the date of the study, or the study type. Images can be sent directly to workstations for soft-copy image review, or they can be stored in the PACS for later retrieval or for output to tape or DVD. The networking technologies within OsiriX are DICOM-compliant which allows the software to integrate seamlessly into a PACS architecture.

For users accustomed to working in high-performance environments, it's natural to question whether Mac workstations and servers have what it takes to manage image distribution throughout an enterprise. Mac systems utilize 64-bit memory addressing and the latest multicore Intel processors, ensuring they meet or exceed the demands of today's radiologic environments.

Creating a PACS Archive with OsiriX

Most established imaging environments already maintain a PACS archive using traditional commercial software. For new facilities or those looking to add new locations, OsiriX may provide a compelling alternative to commercial PACS.

Through the use of easily administered OsiriX software and Mac OS X, Apple's Xserve system can function as a powerful, yet inexpensive PACS archive. This is true even though the creators of OsiriX intended for the software to function as a DICOM viewer. Whereas a PACS archive is a repository of all examinations performed at a facility, a DICOM viewer is designed to store, retrieve, and view only a subset of those cases—usually one week to one month's worth of studies. They are kept on the local DICOM viewer system for efficient access and manipulation and to ensure optimal performance.

OsiriX is flexible enough to serve both as a DICOM viewer and as a PACS archive. For instance, when OsiriX is launched and then used as a DICOM viewer, imaging professionals can view the full database of local examinations. Using OsiriX in this way enables radiologists to review examinations that were "pushed" from the modality to the local database or obtained from CD. (See Figure 1.) And with OsiriX serving as a PACS archive, users can leverage the application's built-in database and DICOM server to act as the central repository of DICOM images. Then any DICOM-compliant viewer or workstation can "pull" the datasets from the archive as needed. (See Figures 2 and 3.)

OsiriX does differ from other PACS archive options in two major ways. First, OsiriX lacks web management functions, so interaction with the archive occurs either through a monitor connected directly to the server or via a remote management application such as Apple Remote Desktop. (Apple Remote Desktop software sends a live, interactive view of a remote computer's screen and allows power users to modify installed software or use command line instructions to delve into the UNIX underpinnings of Mac OS X.) Second, OsiriX allows users to manage only one PACS archive at a time (see Figure 4), whereas dedicated solutions support multiple PACS archives.

Other PACS archive options
Many options are available to enable an Xserve system to function as a powerful, inexpensive PACS archive. In addition to OsiriX itself, the options include two web-managed PACS tools: DCM4CHEE and CD Medic.

Like OsiriX, both DCM4CHEE and CD Medic have built-in databases and DICOM servers. These features allow them to accept data from radiographic modalities, along with queries from other devices requiring access to the data. Unlike OsiriX, however, these tools can support multiple, separate PACS archives.

For more information on DCM4CHEE and CD Medic, visit www.osirix-viewer.com/PACS.html.

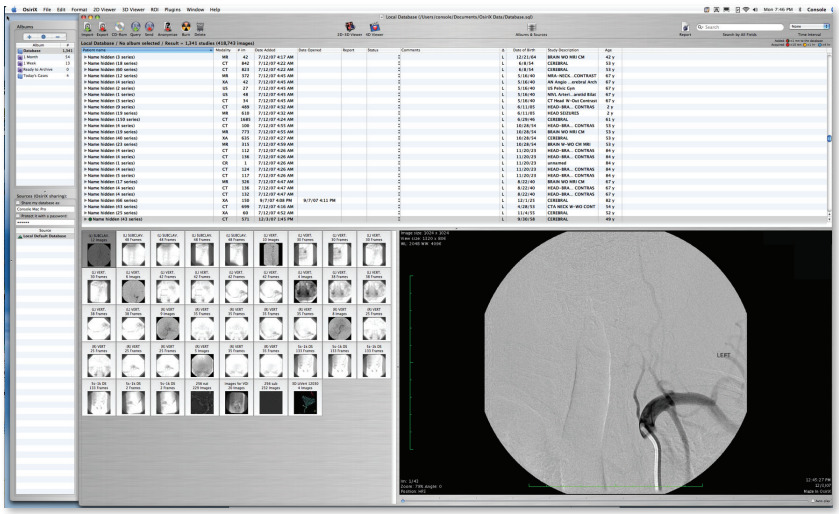


Figure 1: OsiriX is a flexible and powerful DICOM viewer. The database shown has 1341 studies and 419,000 images representing approximately 1.5TB of local data. It contains numerous, large multiframe digital angiography files of up to 700MB in size. A database this size takes approximately 8 seconds to load and is instantaneously searchable using Spotlight in Mac OS X. The ability to handle so much data locally and at this pace puts OsiriX on Apple hardware in a class of its own.

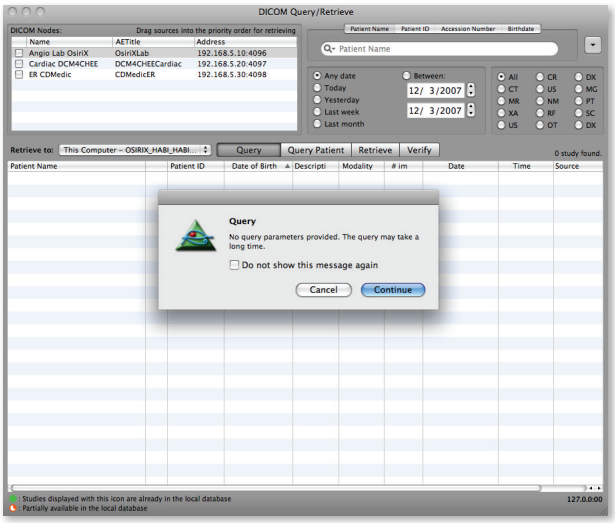


Figure 2: The OsiriX DICOM Query/Retrieve window is a key interface when using OsiriX as a DICOM viewer. Note that three different PACS archives are present in the DICOM Nodes box, with each representing a separate area within the hospital or office. These archives can be queried individually or all at once by checking the appropriate boxes to the left. As with commercial PACS archives, providing query parameters in OsiriX will narrow the query and provide results sooner. The Query dialog in this image reminds the user that because no parameters were provided, the query will produce a list of the entire data repository. Restricting queries as much as possible speeds the search process. OsiriX also allows the user to move studies from one archive to another by changing the selection in the "Retrieve to" pop-up menu.

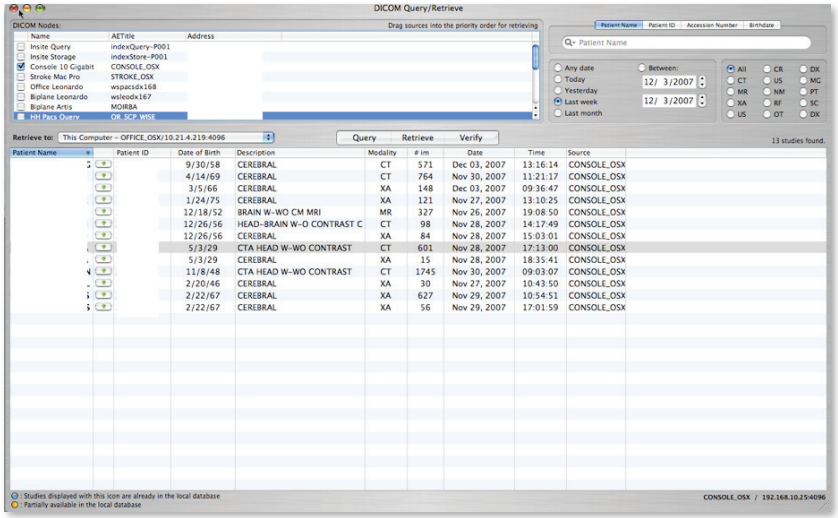


Figure 3: Here, an OsiriX DICOM Query/Retrieve window shows an active query to an OsiriX PACS archive. The query has searched the selected archive for all cases performed within the past week. The query is nearly instantaneous, and any file can be retrieved to the local archive with ease.

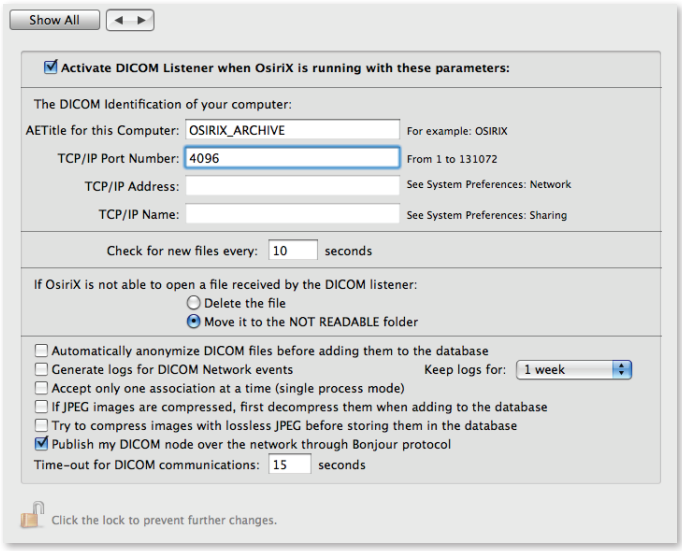


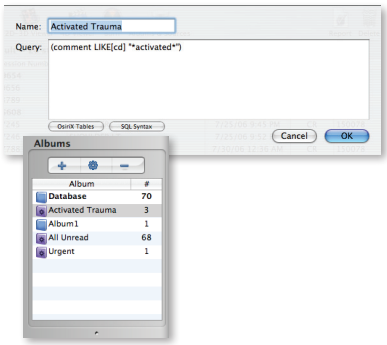
Figure 4: One benefit of using OsiriX as the PACS archive is that OsiriX is very simple to install and manage.

Sharing OsiriX databases with Bonjour
OsiriX uses these advantages in Apple's Bonjour technology to enable full database sharing:

- Clicking a single checkbox sets up sharing.
- Users can password-protect the database.
- Multiple users on the same subnetwork can access the same database, though multiple subnetworks can also gain access.
- On a Gigabit network, image delivery is nearly as fast as local viewing on an OsiriX workstation.
- Smart Albums (below) enable easy collaboration between residents or attending physicians seeking a second opinion.
- Collaboration can help equalize workloads when one department is overloaded but another is slow.

Databases featuring fewer than 300 examinations are recommended for best performance. Bonjour sharing is not recommended for large angiography studies.

Spotlight/Smart Albums
Spotlight, Apple's search technology, is integrated throughout Mac OS X. Based on industry-standard SQLite database technology, Spotlight searching is fast and allows complex queries to be made that search the entire computer. OsiriX has incorporated the same database technology, which allows real-time searching for patients using numerous fields such as name, accession number, or various dates. A feature called Smart Albums, analogous to Smart Folders, improves workflow by allowing the user to maintain customized folders that are automatically populated with cases based on a requested query. Smart Albums, such as the one below, can be created to separate urgent and trauma cases from all cases that are unread for the day. These queries can be helpful for triaging patients, adding teaching file cases, or sorting cases by time of acquisition.



Database Sharing and Autorouting

OsiriX also eases PACS administration by letting users share databases and automatically route images and data.

Database sharing. Mac-based image archives can use Bonjour, Apple's technology for zero-configuration networking. Bonjour enables computers to discover and connect to other computers and peripherals over a network. (See sidebar.) This technology has powered file sharing across everything from home and enterprise networks to wireless devices.

Autorouting. Using the same search technology found in Smart Albums, a feature of Mac OS X that organizes images by multiple useful criteria, OsiriX can be configured as an autorouting workstation. This allows a facility to efficiently manage the distribution of data to various departments. Adding an autorouting system into the workflow allows a technologist to send all studies to one location—an Xserve, which relays cases to the appropriate workstations. The Xserve may also be configured as the long-term PACS archive. Consolidating services in this way lowers expenses and makes system management and upgrades easier. Complex queries are also possible since searches can be conducted based on the date and time of the study, the referring physician, the reading physician, modality, and other parameters. The ability to conduct these complex searches, often found in dedicated solutions costing thousands of dollars, regularly saves valuable time for radiology technologists.

By implementing OsiriX as the PACS archive, radiologists can benefit from minimal configuration networking through Apple's Bonjour implementation and a bundled autorouting system—all at significant cost savings.

Storage System

If there are three words to describe the most necessary features of storage systems in a PACS environment, they would be *performance, scalability,* and *reliability*. This is because the volume of imaging data being generated continues to grow, and that data needs to be available for patient care around the clock and with minimal load time.

When evaluating storage solutions for the office, a 3D processing lab, or individual departments, radiology professionals will face a staggering number of options—and staggering price tags from "name vendors." In fact, storage is traditionally one of the most costly components of the imaging workflow, and selling storage solutions to hospitals and imaging practices has long been a reliable profit center for companies like EMC, IBM, and Sun Microsystems.

Historically, Apple's Xserve RAID solutions have been price competitive, as illustrated in Figure 5. The author's hands-on experience with these units showed that they performed exceedingly well and were very reliable.

In early 2008, Apple announced plans to transition the Xserve RAID line to an Apple-qualified RAID system from Promise Technologies.[3] Promise has a long history of producing excellent RAID products. That Apple has qualified Promise RAID products for use with Mac OS X client and server and Xsan 2 storage area network[4] environments speaks volumes about the quality and reliability of these solutions. In addition, it's evident from Figure 5 that the Promise RAID system offers the lowest price per gigabyte of all comparably configured systems, including Apple's Xserve RAID and storage arrays from Dell, IBM, and Sun.

Even with such competitive pricing per gigabyte, the Promise RAID features increased read/write performance (megabytes per second), scalability (supporting up to 24TB of raw storage), and reliability (with redundant RAID controllers). For details, visit www.apple.com/server/storage/.[5]

	Promise RAID	Xserve RAID	Dell AX4-5F	IBM DX-4200	Sun 2540 FC
Capacity	12TB 24TB*	10.5TB	9TB	12TB	10T
Size	3U 6U*	3U	4U	3U	6U
Price	$14,999 $26,999*	$13,799	$22,438	$33,498	$24,885
Price per GB	$1.24 $1.13*	$1.31	$2.49	$2.79	$2.49

Figure 5: As the need for more storage capacity inevitably increases, so does the total cost of the storage subsystem. By choosing the Apple-qualified Promise RAID system, users can minimize storage costs without sacrificing performance or functionality. To that end, it's advisable to understand the total scalability of a specific solution. Apple's Xsan storage area network, for instance, provides access to up to 2 petabytes of data per volume.

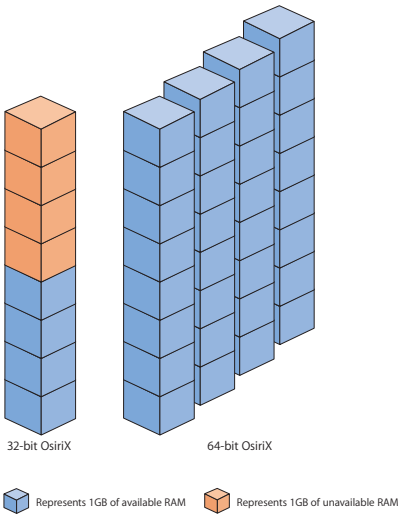
* With expansion chassis. Configurations vary. Prices based on similar components as of February 21, 2008.

Many IT departments consolidate storage into data centers and then distribute this storage over existing TCP/IP Ethernet networks via the iSCSI protocol. iSCSI can be supported using third-party hardware bridges, such as the ATTO iPBridge or DNF StorMacX products. However, much faster access to massive data volumes is available on the Promise RAID system, which features dual 4Gb per second Fibre Channel ports per controller.

Since any storage solution—from Promise, Dell, or the rest—will support a PACS environment, it's wise to understand what extra features, if any, come with higher prices.

Building an Imaging Workstation Environment with OsiriX

The 64-bit OsiriX Advantage



The chart above illustrates the benefits of a true 64-bit operating system, which can run both 32-bit and 64-bit applications simultaneously. Whereas the 32-bit version of OsiriX can access only 4GB of RAM, the 64-bit OsiriX environment can access all of a system's memory—up to 32GB on Mac Pro workstations. This means multiple 3D models can be manipulated at the same time, and up to eight times the amount of system memory is available for imaging data. This ensures that OsiriX with Mac OS X can handle today's radiological image tasks, with plenty of headroom for tomorrow's larger datasets.[6]

As described earlier, three types of workstations are common in radiological facilities: workstations for diagnostic imaging, clinical review, and dedicated 3D viewing. In traditional environments, these are often entirely separate systems that feature disparate commercial solutions designed to serve only one workstation role.

OsiriX is different. This single application provides the functionality of all three workstations on the Mac platform. The breadth of OsiriX features is perhaps easiest to examine in the context of how those features take advantage of Mac systems and Mac OS X.

Working with Large Datasets

Five years ago, a CT scan featured 100 to 200 images. Today it incorporates close to 1000, and some cardiac CTA exams have up to 5000 images. That explosive growth in image data volumes is leading to larger data sets, which in turn increases the demand on imaging workstations. For that reason, from today forward, imaging workstations must be built on a 64-bit architecture that makes all of the system memory available for imaging tasks.

All Mac systems are powered by 64-bit Intel microprocessors. To take full advantage of the benefits of these processors, Mac OS X is sold in only a single version: a 64-bit operating system offering full compatibility with 32-bit applications. (This is in contrast to Windows Vista 64-bit, available only as a $200 upgrade from the standard 32-bit version.) The 64-bit architecture allows for faster OsiriX operation, data manipulation, and 3D processing. This is especially true in a server environment where multiple users are independently loading gigabytes of data and require fast access to that data.

For instance, a general rule of thumb holds that 1GB of RAM is required to load 1000 MDCT images into the 2D viewer. Another 1GB is required to load this data into the 3D volume-rendering viewer. Since 32-bit OsiriX systems can access no more than 4GB of RAM, and 64-bit OsiriX on a Mac Pro system can access up to 32GB, the 64-bit advantage quickly becomes evident. (See sidebar.)

A 64-bit OsiriX environment is recommended when viewing more than 2000-image MDCT, 4D, or CT Fusion studies with 3D. For these environments, a minimum of 8GB of RAM is recommended. If virtualization or dictation software is also being used, even more memory is advisable.

Supporting Medical-Quality Displays

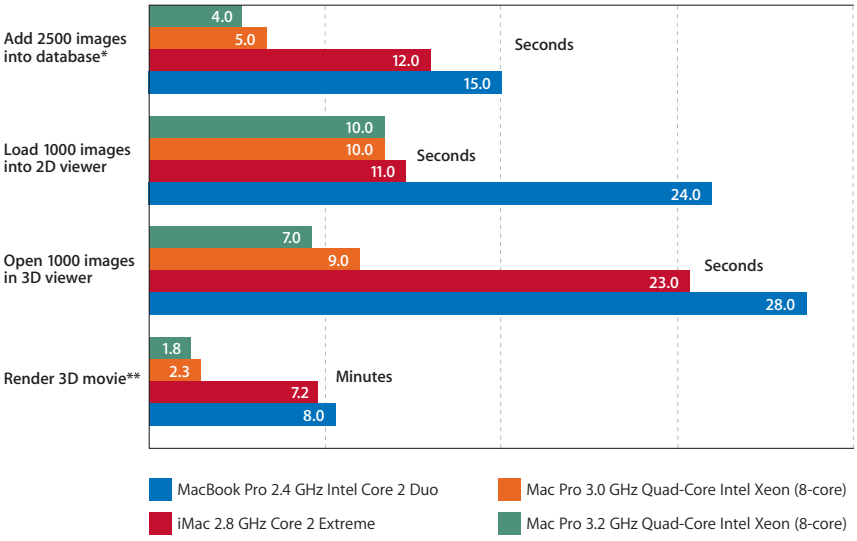
As described in the Apple white paper "Integrating Mac Systems into a Medical IT Infrastructure," Apple Cinema Displays perform admirably and meet all prescribed medical imaging standards, including requirements for grayscale presentation. For Computed Radiography, Digital Radiography, and mammography, however, some physicians prefer to use dedicated high-brightness grayscale monitors.

Resolution independence is an important element of Mac OS X. It addresses a problem common with high-resolution monitors, whose large, detailed fields inevitably shrink user interface elements to a size that becomes difficult to see and use. Mac OS X supports automatic resizing of elements such as application menus, toolbars, and pop-up menus.

Requirements for High-Performance Processors

By making the switch in 2006 from PowerPC processors to the industry-standard 64-bit Intel processors, Apple addressed the concerns of many users—among them radiologists—about the competitiveness of Mac system performance versus that of Windows PCs.

Now the entire Mac product line—from servers and desktops to notebooks and even the Mac mini—is driven by multicore Intel processors. As shown in the chart below, multiplying the number of processor cores applied to a data-intensive problem can dramatically reduce the time required to complete common imaging tasks. With more cores at their disposal, for instance, imaging professionals can trim the time required to render a 3D movie from eight minutes to less than two.



Desktop machines configured with 4GB RAM, 7200 RPM 750 GB HD. MacBook Pro configured with 4GB RAM, 5400 RPM 160 GB HD.

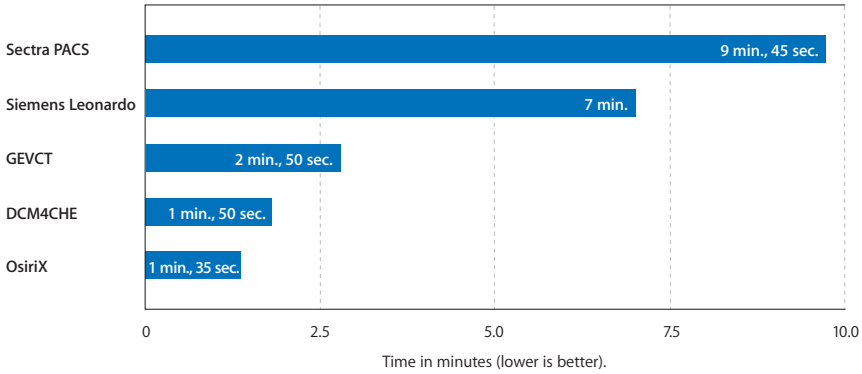
* Time represents raw SQL Lite performance. Additional loading time depends on hard disk performance.[5]

** 1009 image data set 768 x 768 output size. 100 frames at best quality (0.8). 360 degree rotation.

This bodes well not only for primary OsiriX workstations, but also for systems used remotely. With OsiriX on Mac systems, working from home or attending an out-of-town conference won't prevent radiologists from engaging in the same type of image reviews conducted every day at work. This capability is enormously valuable, and previously could not have been done.

Accelerating Image Retrieval

With so much data being generated in imaging centers, it seems reasonable to expect that the major equipment manufacturers would have pushed for more efficient implementations of DICOM networking to route the images from the modalities to a PACS or workstation. This, unfortunately, has not been the case, and a common complaint from users is that it takes too much time to transfer cases. OsiriX developers addressed this problem by focusing on using the most efficient DICOM networking libraries. The graph below shows how much faster OsiriX DICOM networking performs compared to expensive commercial workstations and PACS.



OsiriX DICOM retrieve of a 2880 image (1.5 GB) cardiac CTA data set. All systems were connected via Gigabit Ethernet.

OsiriX users experience minimal wait time when viewing studies while connected to a DCM4CHEE PACS, efficient commercial DICOM software, or other OsiriX entity in the workgroup. Whether using OsiriX as a DICOM viewer attached to a single modality or as the front end to a larger PACS, users can be confident OsiriX will not create a bottleneck in transferring even the largest studies.

Enabling the Imaging Workflow

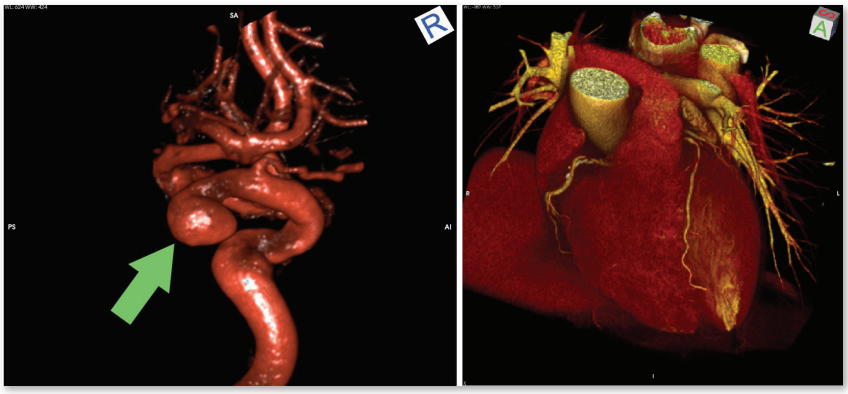
All the components of a radiologic environment exist to enable one thing: an imaging workflow that meets an organization's unique requirements. Earlier in this paper, we discussed how OsiriX and Mac systems can interoperate with, or in some cases, supplant resources that are already in place. We've also covered how OsiriX can be set up to accept images.

The next step is to incorporate the application into the workflow. For radiologists, this workflow could include using hanging protocols based on modality, using advanced visualization, or creating a new series with the results of an image review and sending that series to the PACS archive. For a clinician, the workflow may involve only viewing the images and showing them to the patient. OsiriX was developed to handle either workflow or some combination that leverages elements of both.

Options for Advanced Visualization

The demands of 3D-image viewing and manipulation are unique. OsiriX users have two sets of options for advanced visualization:

1. *Use the built-in OsiriX 3D engine.* This built-in 3D engine is based on an open source toolkit called the Visualization ToolKit (VTK), which supports most of the commonly used processing techniques, such as MPR, MIP, curved-Planar reformat, and volume rendering. In some cases, the 3D quality and performance of VTK on a Mac Pro workstation approaches the quality and performance found on commercially available dedicated workstations. As discussed previously, the cost of those workstations can easily exceed $50,000, making the bundled 3D engine in OsiriX an attractive value. Producing 3D images out of 2D slices, known as volume rendering, is highly complex and requires significant computing resources. OsiriX's built-in volume-rendering engine has two modes, one that taps CPU power and the other that relies on the graphics processing unit (GPU), or graphics card. The performance of CPU-based volume rendering consistently outpaces GPU-based rendering, however, thanks to advances in multicore Intel processor design and the availability of up to 32GB of fast main memory in high-end Mac systems.



Examples of the quality of OsiriX's built-in volume rendering. The image at left shows an unruptured 8.5 mm left posterior communicating artery aneurysm rendered from a 250 image rotational angiography dataset. The image at right shows a cardiac CTA examination, with the right coronary and left anterior descending arteries clearly visualized.

2. *Purchase a third-party plug-in to improve the advanced visualization quality and performance of OsiriX.* For 3D quality and performance that rivals or surpasses performance on dedicated workstations, there are two types of third-party volume-rendering options to consider: dedicated hardware-based solutions and software-based solutions.

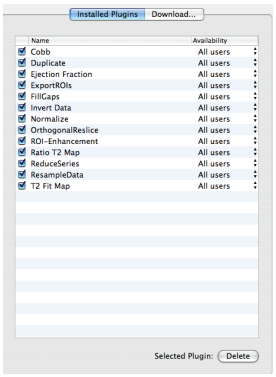
   Dedicated hardware-based solutions. OsiriX users looking for additional quality and performance may opt for a third-party hardware accelerator for volumetric ray casting, such as VolumePro, distributed by TeraRecon. While hardware accelerators can certainly boost the quality and performance of 3D processing, those considering a hardware acceleration card should carefully weigh the following trade-offs:

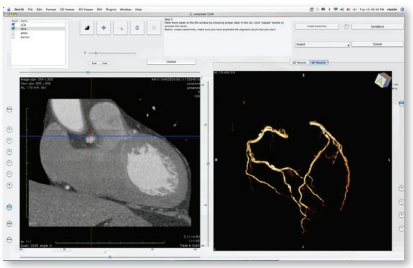
- Hardware accelerators may have significant memory constraints that limit the size of the datasets they can render.
- Adding new features and functionality often requires the purchase and installation of a new hardware accelerator to replace the existing one.
- Bug fixes and maintenance releases are often done via software "workarounds," potentially decreasing a hardware accelerator's advantages.
- Although the "final" quality generated by today's hardware accelerators is quite good, the "interactive" quality still exhibits zero-fill or "zebra" artifacts typically associated with undersampling.
- Hardware accelerators do not capitalize on the rapid multicore advancement made in off-the-shelf CPU performance, and therefore such accelerators become obsolete much faster than software solutions.
- Many laptops cannot physically accommodate hardware accelerators, thereby eliminating an important and growing market segment.

   Software-based solutions. The industry's highest quality 3D renderings are typically done with software, but the computational power necessary for such renderings requires server farms or other capital-intensive equipment that likely are impractical for an OsiriX user.

   Responding to the need for improved software-based 3D rendering algorithms, Fovia, Inc., (www.fovia.com) developed its High Definition Volume Rendering® (HDVR™) engine to take full advantage of multicore processors and 64-bit architectures. Fovia's software only OsiriX plug-in, expected to be available in the third quarter of 2008, enables interactive rendering of the largest datasets generated by today's medical imaging equipment. HDVR offers better interactive image quality, performance, and memory utilization than other products currently available—including expensive, hard-

Using plug-ins to expand OsiriX features
Some users or workflows demand advanced functionality that the current version of open source OsiriX doesn't include. Fortunately, OsiriX developers anticipated this and created a robust plug-in architecture, allowing independent scientists and physicians to create custom solutions to enhance workflows and processes. Some plug-ins, developed in response to requests posted to the OsiriX user newsgroup, are included in the standard installation of OsiriX. The largest plug-in to date is a complete cardiac CTA package developed by the University of Linköping in Sweden. Pictured here, this free plug-in includes interactive vessel segmentation, curved planar reformatting, and segmental volume rendering. To download this or other plug-ins, OsiriX users need only go to the Plug-ins Menu and click the Plug-ins Manager.





ware-based solutions. The superior quality and performance of HDVR is the result of volumetric ray-tracing implemented via proprietary algorithms that provide interactive rendering with high supersampling quality. Fovia's HDVR engine takes full advantage of Mac OS X.

The advantages of Fovia's OsiriX plug-in include:

- Performance and HDVR quality rival that of costlier dedicated workstations
- Interactive HDVR on Intel-based Mac systems
- The ability to interactively render the largest datasets that scanners can generate—and to do so at high supersampling rates
- No preprocessing
- Excellent scalability with larger datasets, larger rendering planes, and multicore CPUs
- A suite of advanced features, including: instant segmentation; instant and "clean" free-hand cut; multiple classifications; the ability to interactively modify correspondent transfer functions, advanced lighting, and 3D shadowing; on-the-fly auto-navigation for fly-through; sub-voxel precision for measurement; and tools to easily make and export movies made with Fovia's HDVR engine

Fovia provides an OsiriX software plug-in whose performance and High Definition Volume Rendering-quality that rival costlier dedicated workstations. (Image courtesy of Fovia, Inc.)

Starting and Sending a New DICOM Series to PACS

When reviewing a case, it's easy to take snapshots and save them as a new DICOM series. It is essentially a matter of choosing the correct image format and entering a series name. Separate series can be created using a different series name. Sending to a PACS is as simple as clicking the Send button in the toolbar.

Emailing and Printing Images

OsiriX also supports two other commonly requested functions that help streamline workflow: emailing images to colleagues and printing images for review with patients and others.

Email. OsiriX has built-in integration with Apple's Mail client program, which ships free with Mac OS X, via simple one-click export to a new mail window. Mail supports digital signing and encryption of email using standard security certificates. Helpful instructions on the use of this feature can be found at www.joar.com/certificates/.

Printing. By virtue of its tight integration with Mac OS X, OsiriX enables users to output DICOM images to industry-standard laser and injket printers and to DICOM printers. The DICOM printer functionality was added to OsiriX by aycan, creators of aycan workstation OsiriX^{PRO}. (See sidebar.) DICOM printers are usually film-based printers, such as the Sony FilmStation or Fuji DryPix. And because Mac OS X provides native support for PDF files, OsiriX can print a DICOM image or series of images to a PDF file. That file can then be saved to disk, sent as an email attachment, or printed to any industry-standard printer. Users can also create encrypted PDF documents with PDF Workflows in Mac OS X to protect sensitive content from unauthorized viewing. Many institutions are also attaching scanned documents directly to patient exams for easy review by technologists, radiologists and billing personnel. DICOMDonkey, a new inexpensive application developed by SecureRad and Lance Pysher, M.D., a developer of OsiriX, offers a simple and intuitive way to incorporate this feature into an OsiriX workflow. To learn more, visit www.dicomdonkey.com.

Windows virtualization applications for Mac OS X

- **Parallels Desktop for Mac.** Allows users to run Windows, Linux, and more side by side with Mac OS X on any Intel-powered Mac—without rebooting. Visit www.parallels.com/en/products/desktop/ for more information.
- **VMWare Fusion virtualization products.** Allows enterprise-level virtualization, security, system management, and more. Visit www.vmware.com/products/enterprise_desktop.html for more information.

Integrating with Hospital and Radiology Information Systems

Many hospitals and practices have already invested in Hospital Information Systems (HIS) and Radiology Information Systems (RIS), which are used for electronically entering orders or medical records and for centrally storing examination notes and reports. A handful of these solutions are Mac-based, but most were developed for Microsoft Windows PCs.

Consolidating resources through virtualization. For budget-strapped organizations looking to incorporate OsiriX imaging workstations within their workflow, it's preferable to pursue a cost-effective consolidation strategy—one that doesn't replicate existing software, but allows administrators to use what they have, even on an entirely different platform.

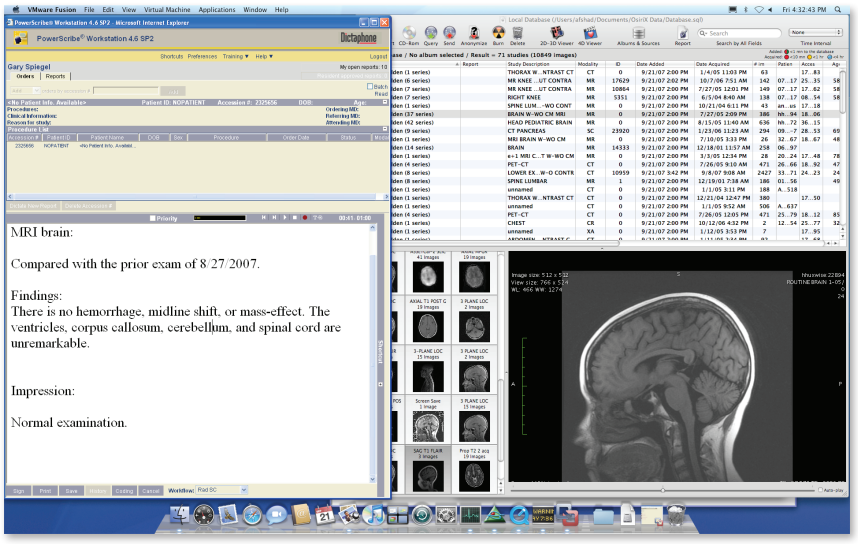
This is possible with "virtualization," which allows Intel -based Mac systems to run nearly all Windows applications alongside OsiriX and any other application written for Mac OS X.

Two popular virtualization products, Parallels Desktop for Mac and VMWare, have been tested with many applications, including RIS, HIS, medical dictation, EMR, and productivity suites like Microsoft Office, with very good results. In fact, most common radiology applications written for Microsoft Windows PCs operate seamlessly on Mac systems with the help of virtualization software. (See sidebars.)

Digital dictation and voice recognition

A key element in a radiology workflow is the ability to efficiently dictate results and transmit them to the hospital and/or radiology information systems for distribution to the referring clinician. Voice recognition technology has improved significantly over the last five years and now provides a way for groups to decrease the capital costs of a dedicated transcription department.

The section at right explains how through virtualization, RIS and HIS applications written for Windows can operate seamlessly on Mac systems. Similarly, dictation systems such as Nuance Powerscribe, Dragon Naturally Speaking, and Philips SpeechMagic have been tested at various institutions. Both the Philips Speechmike and Nuance Dictaphone Powermic drivers are completely functional with VMWare, which is the recommended virtualization environment for these applications. (USB functionality issues prevent adequate operation under Parallels Desktop).



With the help of virtualization software such as VMWare Fusion (above), most common radiology applications written for Microsoft Windows PCs operate seamlessly on Mac systems.

Exploring Alternatives to Windows RIS Systems

Although virtualization software can enable Mac-based imaging workstations to access the RIS, imaging centers can trim costs even further by exploring alternatives to expensive RIS solutions. SecureRAD's iRIS Core is one of these. The iRIS Core framework drives the radiology workflow by providing patient management, scheduling, report generation, digital document storage, patient notes, insurance management, radiology work lists, and integration with HL7-compatible devices and systems. The application runs on Apple's Xserve hardware and can be completely integrated to work with OsiriX. To extend iRIS Core, iRIS Stream offers referring physicians access to images and patient reports stored in iRIS Core via a web-enabled portal. iRIS Stream also provides simple imaging reviews through a web browser and through an iPhone.

Another alternative is MacPractice MD, a comprehensive practice management solution with integrated Electronic Medical Records (EMR) and medical imaging. MacPractice features patient accounting with sophisticated electronic insurance submission and automated posting of payments via ERA (Electronic Remittance Advice). Multi-user, multi-resource scheduling permits registration and posting from the calendar, and the MacPractice iPhone interface gives doctors live access to their office schedule. The solution also features an extensive battery of practice management reports. Radiologists can open DICOM images in MacPractice Imaging or in OsiriX from within MacPractice Imaging. Using MacSpeech, radiologists can dictate directly into a patient file in MacPractice. The integration of MacPractice Notes, Imaging, Attachments (documents and images) and EMR creates a powerful, low-cost RIS option.

Collaborating Beyond the Office with OsiriX

Sometimes the imaging workflow incorporates external resources—those located beyond the secure perimeter of the office, imaging center, or hospital. Teleradiology, or the ability to conduct remote visualizations of imaging studies, is enormously helpful when radiologists are away from the office or hospital, or when colleagues must view images at night, on weekends, or during holidays.

For OsiriX users, teleradiology requires a secure network, the ability for authorized remote users to visualize the OsiriX workstation environment, and tools that enable easy, interactive communication between consulting professionals.

Virtual Private Networks

In these teleradiology environments, ensuring the security of patient data is an absolute priority. Many organizations rely on a Virtual Private Network (VPN) to encrypt data sent over the Internet between a hospital server and a remote computer. Mac OS X supports many corporate VPNs out of the box using the PPTP or L2TP over IPSec standards. Some corporate VPNs, like the Nortel VPN Router, require an additional software client on the remote computer. These are low cost and easy to install.

As VPNs grow increasingly popular, more companies are switching to "clientless" VPNs that do not require installation or configuration of a remote client. These use the Secure Sockets Layer to safely exchange data with the VPN server. Users typically access these networks via a web browser, which upon successful login installs a simple Java application to manage the secure data transfer.

Applications that require the use of Microsoft's ActiveX technology can operate through the virtualization solutions covered earlier. In this case, all the Windows-based VPN access protocols are also available.

An abundance of VPN devices are available, so it's best to discuss setup with the IT manager of the hospital or practice.

Remote Visualization via Apple Remote Desktop

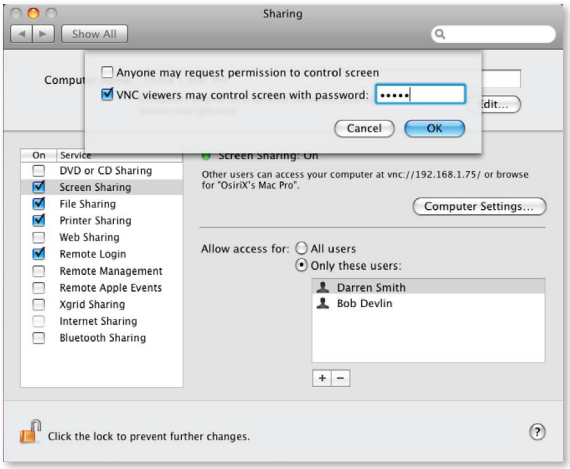
Once a VPN connection is established, the next step is to enable remote visualization of OsiriX. Apple Remote Desktop, the desktop management software for Mac OS X, is an enhanced version of the popular Virtual Network Computer server developed by Olivetti, Oracle, and AT&T. With its reliance on lossless compression of data, Apple Remote Desktop ensures that images viewed remotely are exactly the same as those viewed locally.

The Apple Remote Desktop client's suggested retail price begins at $299 and must be installed on each computer requiring teleradiology access.[7] Apple Remote Desktop also offers external authorized users access to the full array of programs used by the organization, including Windows programs running via VMWare or Parallels.

In addition to using Apple Remote Desktop for remote viewing of OsiriX systems, users can rely on it to maintain and manage Mac OS X systems. Users can conduct operations such as ensuring all computers are running the latest version of Mac OS X, perform application updates, remotely configure systems, and run reports on hardware and software profiles.

For collaboration and remote visualization, screen sharing is essential. With Mac OS X, Apple includes a subset of the screen sharing capabilities in Apple Remote Desktop. Users can take advantage of this capability in two ways:

- In a client computer's Finder window, computers that have Screen Sharing enabled will automatically show a share screen button that users can click to connect with others.
- Using iChat, users can share their screens with a colleague or ask permission to take control of a colleague's computer.



To enable Screen Sharing on the host Mac via Screen Sharing or Apple Remote Desktop, users can go to the Sharing System Preference pane, select Screen Sharing (or the Remote Management button for Apple Remote Desktop), and then click the Computer Settings button. This launches a dialog where users can check "VNC viewers may control screen with password." Then, with a third-party client such as TightVNC, PC users can view an OsiriX session on a remote Mac system.

Citrix/Windows Terminal Services

Another cost-saving practice gaining traction in healthcare is outsourcing the facility's IT infrastructure. Here, an Application Service Provider (ASP) uses its own servers and technical resources to host key applications, thus reducing the complexity and burden for small to medium-size organizations to maintain their own infrastructure. ASPs offer "on-demand software" or "software as a service." The software may operate through a web browser, though it more commonly will utilize the Citrix Presentation Server or Windows Terminal Services to remotely serve applications to many users simultaneously. This works best with applications that are not graphics intensive.

Mac users can connect to these services using applications written for Mac OS X and distributed by Microsoft (Remote Desktop Connection Client) and Citrix (Macintosh ICA Client). These applications provide the same access to enterprise on-demand resources as does Microsoft Windows XP or Vista. Citrix also has a Java-based client that can operate using Mac OS X without prior download or installation.

Teleradiology Collaboration

Communicating results to referring clinicians efficiently and effectively is an increasingly essential aspect of imaging. Modern medicine is too fast-paced to always afford clinicians the time to physically visit a radiology department to discuss patients. For a growing number of radiologists and clinicians, teleradiology is the answer.

Despite its importance, too many radiologic environments treat this vital function as an afterthought. That's a mistake, particularly as truly "connected" organizations are taking advantage of multiple time zones by establishing remote night-reading offices in places such as France, Australia, or Hawaii. Radiology practices willing to expand internally in this way can compete against commercial entities without incurring significant capital costs.

iChat and iChat Theater

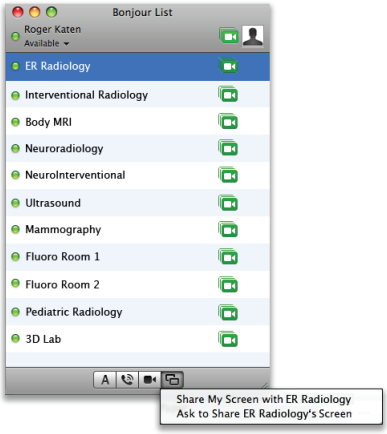
Mac systems provide an easy teleradiology solution: iChat, Apple's popular instant messaging and video conferencing solution. In Mac OS X, iChat Theater is an extension of this technology and allows not only video conferencing, but desktop file and application conferencing as well.

A surgeon in the operating room or a physician in a clinic can access iChat Theater and in real time, view OsiriX 2D and 3D images, see the radiologist, and discuss a patient's case simultaneously. iChat Theater provides two-way video conferencing, enabling real-time interaction and discussion between colleagues. Participants can also share Keynote and PowerPoint presentations and PDF files.

iChat can be used to manage a one-way interactive session from a remote computer running OsiriX. Even users who do not have OsiriX installed on their systems can view shared content as a live pointer alerts the viewer's attention to important findings. Remote interactions like this can save valuable time and increase productivity, leading to improved, focused patient care.

Users can also take advantage of iChat's screen sharing feature for real-time, two-way collaboration. It's important to recognize that only a live screen capture—not the entire DICOM examination—is securely transmitted over the network. This effectively eliminates time spent waiting for a study to transfer or be retrieved.

Although iChat is not available for PC users, Apple does employ standard Virtual Network Computing (VNC) protocols to enable screen sharing. Selecting this function via the Sharing System Preference pane allows PC users to view an OsiriX session on a remote Mac system with a third-party client such as TightVNC. While other VNC clients for PC or Linux users are available, they do not support Apple's Adaptive Quality setting, so PC viewing is best kept to the fast local network.



Collaborating with iChat
Using iChat, users can coordinate video conferencing with instant messaging and conduct screen-to-screen collaboration with colleagues. While non-OsiriX users cannot manipulate a DICOM study via iChat, they can view study images shared by OsiriX users. Such features are ideal for securing second opinions, consulting with surgeons, or facilitating resident teaching.

Retrieving lost data with Time Machine
Suffering hard drive failures and accidentally deleting important files is a constant worry, especially in small office environments. But data backups tend to be complicated and time-consuming.

Apple solves this in Mac OS X with Time Machine. Time Machine automatically backs up system files, applications, images, patient data, and documents. And unlike other backup applications, Time Machine not only keeps a spare copy of every file, it remembers how a system looked on a given day—so the user can revisit that workstation as it appeared in the past.

If at any time a user needs a file that he deleted in error, he can launch the Time Machine interface and search for the file. By viewing a series of Finder windows, he'll be able to see how his file changed over time. He merely picks the version he wants.

If a hard drive fails, the user replaces the drive and installs Mac OS X. During the installation process, he'll be asked to migrate a Time Machine volume. In less than an hour, the new drive will be ready to use.

Because Time Machine is included in Mac OS X, the only additional cost is an additional internal or external drive for backups. Alternatively, users can consolidate backups onto a network based shared drive using an Xserve system in their organization's computer closet.

With iChat and iChat Theater, radiologists and other medical imaging professionals can consult with colleagues, no matter where they are located. iChat supports remote viewing of images, audio and video recording of iChat sessions, multiple logins, and other helpful features.

Whether communicating with a colleague in another department or on another continent, radiologists have cost-effective and feature-rich options for achieving a true teleradiology environment with OsiriX running on Mac systems.

Conclusion

The field of diagnostic imaging has advanced rapidly, resulting in profound and dramatic improvements in healthcare delivery. Advances in CT, MRI, ultrasound, and interventional technology require computer systems that combine ease of use and processing ability with user-friendly ways to collaborate among healthcare providers.

And as pressure intensifies to contain operating and capital costs in imaging centers, private practices, and hospitals, many departments and users are searching for alternatives.

This white paper was written to show how Apple hardware, coupled with open source OsiriX software and the Mac OS X operating system, can provide significant value without sacrificing features or performance. Virtualization solutions allow Mac OS X and Microsoft Windows applications to run seamlessly together in a private practice or hospital setting. And advanced Mac OS X features such as iChat Theater enable productive, real-time collaboration between radiologists and surgeons located across town or around the world.

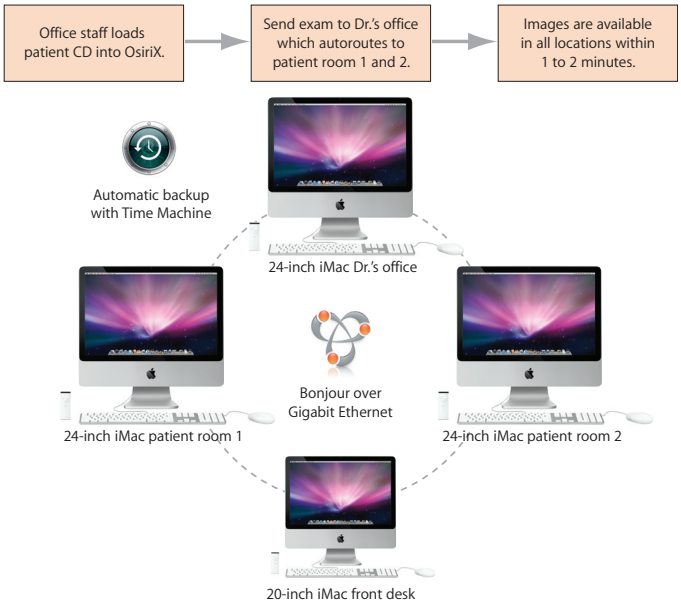
The solutions outlined here offer clinicians, surgeons, and radiologists a platform for image review that assists in patient management and breaks the tradition of high-priced medical imaging systems. The ability to scale their imaging solutions across the entire range of Mac systems—from MacBook notebooks and iMac desktops to Mac Pro workstations and Xserve server systems—means medical facilities can affordably grow their imaging infrastructure as their needs require.

About the Author

Roger Katen, M.D., is an imaging consultant with training in diagnostic radiology and computer engineering. He is a co-founder of the 3D medical imaging firm, Fovia, Inc. and was Vice President of Clinical Solutions for workstation developer TeraRecon, Inc. He lives in the Bay Area with his wife, Michele, a figurative painter.

A Closer Look: Clinician's Office Workflow

For studies performed in the office or brought from an external imaging department, clinicians can utilize an affordable iMac system. Databases can be shared among workstations via Bonjour, and backups using Time Machine ensure that valuable patient data remains secure and always retrievable. A complete office imaging system, which can also operate Windows or Mac-based clinical applications, can be purchased for less than $10,000.



Equipment	Cost
20-inch iMac[A]	$1199
Three 24-inch iMacs[B]	$7947
External backup drive	$400
Gigabit switch	$150
OsiriX software (32-bit)	Free
Total*	**$9696**

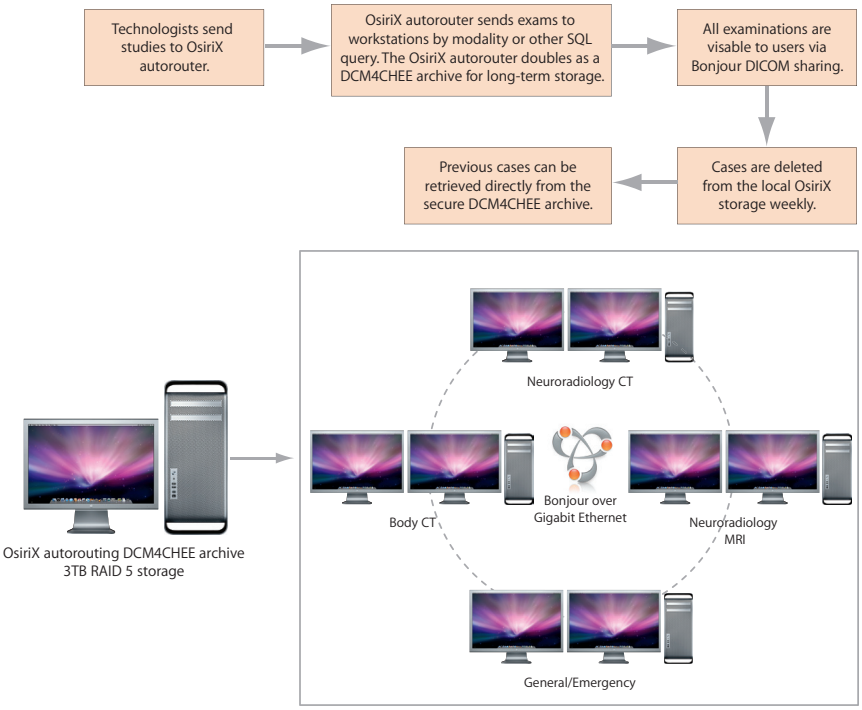
A: 20-inch iMac, 2.0GHz Intel Core 2 Duo, 1GB memory, 250GB Serial ATA Drive, ATI Radeon HD 2400 XT with 128MB memory

B: 24-inch iMac, 2.8GHz Intel Core 2 Extreme, 4GB memory, 500GB hard drive, ATI Radeon HD 2600 PRO with 256MB memory

*Approximate list pricing in U.S. dollars for hardware configurations shown at the time this paper was published (Spring 2008).

A Closer Look: Small Workgroup/Private Practice Workflow

For considerably less than the cost of a single commercial 3D viewing workstation, a small workgroup or private practice can be outfitted with Mac Pro workstations running OsiriX and Mac OS X. The autorouting function in OsiriX allows for efficient distribution of DICOM images via Bonjour database sharing technology.



Equipment	Scenario 1	Scenario 2
Autorouting Mac Pro and monitor[A]	$9500	$9500
Four Mac Pro workstations[B]	$22,600	$22,600
30-inch LCD monitors	Dual monitor per workstation $14,400	Single monitor per workstation $7200
Gigabit switch	$150	$150
OsiriX software (64-bit)	$299	$299
Total*	**$46,949**	**$39,749**

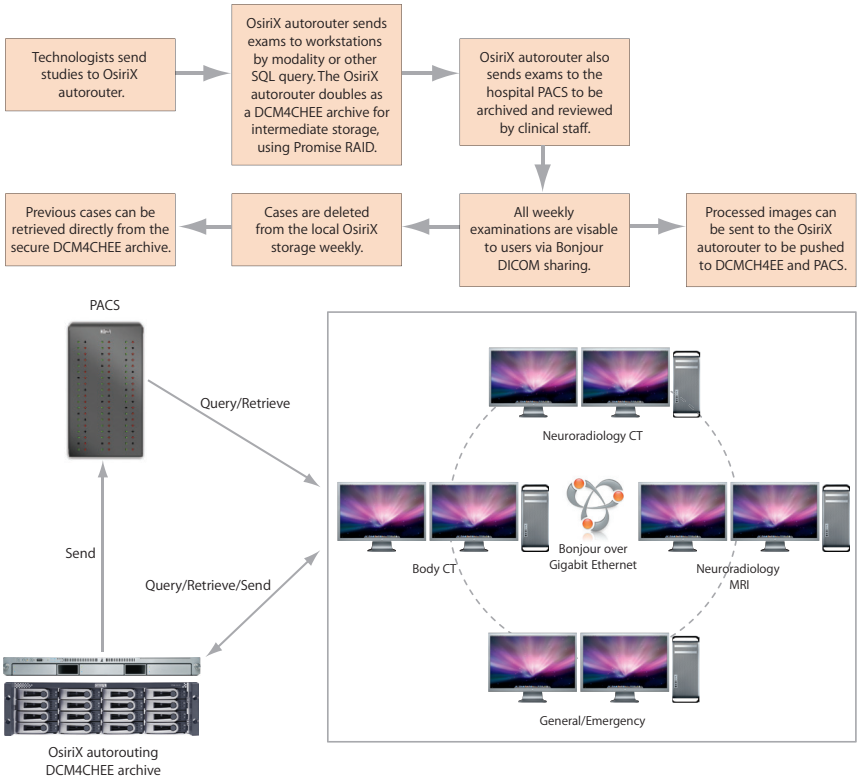
A: 3.2GHz Dual Quad-Core Intel Xeon, 8GB memory, Mac Pro RAID card, 4 1TB 7200 rpm Serial ATA drives, 20-inch Apple Cinema Display

B: 3.0GHz Dual Quad-Core Intel Xeon, 8GB memory, 1TB 7200 rpm Serial ATA drive, NVIDIA GeForce 8800GT 512MB

*Approximate list pricing in U.S. dollars for hardware configurations shown at the time this paper was published (Spring 2008).

A Closer Look: Imaging Office or Teaching Hospital

Utilizing Apple's Xserve as a PACS server and Mac Pro computers as diagnostic review workstations, organizations can create a scalable PACS. Included is fast, 3D functionality, replacing many of the functions of far more expensive workstations. Using Mac hardware and Xserve systems, costs average approximately $7000 to $10,000 per workstation and $3000 to $4000 per terabyte of storage. DICOM images are archived on an affordable Apple-qualified Promise Technologies RAID system.



Equipment	Scenario 1	Scenario 2
Xserve and Promise RAID[A,B]	6T (4.5T RAID 5) $21,000	12T (10.5T RAID 5) $24,000
Four Mac Pro workstations[C]	$22,600	$22,600
30-inch LCD monitors	Dual monitor per workstation $14,400	Single monitor per workstation $7200
Gigabit switch	$150	$150
OsiriX software (64-bit)	$299	$299
Total*	**$58,449**	**$54,249**

A: 3.0GHz Dual Quad-Core Intel Xeon, 8GB memory, 80GB 7200 rpm Serial ATA drive, On-Board SATA/SAS Controller, ATI Radeon X1300 64MB, Quad-Channel 4Gb FibreChannel card with PCI Express x16 riser, Promise VTrak E-Class 8 x 750 SATA RAID subsystem (6TB), Dual 750W power supplies, rack mounting kit

B: 3.0GHz Dual Quad-Core Intel Xeon, 8GB memory, 80GB 7200 rpm ATA ADM drive, On-Board SATA/SAS Controller, ATI Radeon X1300 64MB, Quad-Channel 4Gb FibreChannel card with PCI Express x16 riser, Promise VTrak E-Class 16 x 750 SATA RAID subsystem (12TB), Dual 750W power supplies, rack mounting

C: 3.0GHz Dual Quad-Core Intel Xeon, 8GB memory, 1TB 7200 rpm Serial ATA drive, NVIDIA GeForce 8800GT 512MB

*Approximate list pricing in U.S. dollars for hardware configurations shown at the time this paper was published (Spring 2008).

References

[1] OsiriX is available from www.osirix-viewer.com and through The OsiriX Foundation developers.

[2] Apple Profile: Hartford Hospital Stroke Clinic: www.apple.com/science/profiles/hartford/

[3] Promise Technologies: www.promise.com/apple

[4] Xsan storage area network from Apple: www.apple.com/xsan

[5] Apple website: www.apple.com/science

[6] OsiriX 64-bit is available as a moderately priced upgrade at $149 per individual license and $299 per site license from The OsiriX Foundation, http://www.osirix-viewer.com/Store.html.

[7] A $299 entry-level license allows administrators to manage fewer than 10 systems. For larger installations, a $499 license allows an unlimited number of managed systems.

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Black and White Design

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Version
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FILE NAME:	L369215A_Radiology_WP_rev.indd
Job Number:	4274
Part Number:	L369215A
Description:	White Paper
size:	8.5x11
Bindery:	n/a
Fonts:	Myriad Set

PRODUCTION NOTES:

- built @ 100%
- prints as PDF

Production: Mary E.
Editor: Robin K.
Project Mgr: Debi L.
Writer:
Printer: na

06/17/10
Date Revised

100
Laser %

06/17/10
Spellchecked

06/17/10
Disked/Posted

INKS: 4/4  CMYK

☐ Overall ☐ Spot

01/15/08