Database and World Wide Web Infrastructure for Application Development

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The Computer Systems Services Group (TSS) of the Technical Services Department (TSD) provides an infrastructure of database servers, World Wide Web servers, and applications. This infrastructure supports the business, administrative, and technology needs of TSD and its staff and serves as a resource to other APL departments. By applying data administration and programming skills, Computer Systems Services staff have integrated the pieces—Web and application programming, Web server administration, and database administration—to provide customers with customized data systems and access to information residing in various databases. This article describes TSD's database and Web server infrastructure and highlights a number of applications developed by the Department in support of its customers. (Keywords: Application development, Database, Web.)

INTRODUCTION

The Technical Services Department (TSD) provides a diverse set of services to APL including engineering and drafting design and fabrication, library services, plant facilities maintenance and construction, and publication services. To provide these services, the Department has established an infrastructure of computers, networks, databases, Web servers, and software applications. As is true elsewhere, information and data system technology has become more important to all aspects of the Laboratory's business. This article focuses on the application development environment in TSD, including the database systems, Web servers, and software tools in place to support the growing need for custom applications that provide easy data access. In a

number of cases, TSD has procured commercial software systems to help manage an expanding workload. These systems have often required customization either because they were designed to be customized by the users or because there were interfaces or features that needed to be added to the commercial product.

The World Wide Web has brought about an unprecedented explosion of readily accessible information. Its use has grown within TSD as it has in the rest of the world. The availability of Web browsers on essentially every APL desktop system has provided a "standard" application interface for all users of any new custom application. This makes distribution of an intranet application across a group or a department much more

straightforward. Web application development is one area where TSD's infrastructure support extends to other APL departments. We present a number of examples of custom intranet applications developed by TSD's Computer Systems Services Group (TSS) that are making information available using the Web browser as the user interface.

To support these customized applications, TSD maintains a database environment with an infrastructure based on the Oracle RDBMS. As the Department creates or procures new applications that use Oracle, the established hardware and software base, as well as staff resources, can be focused on efficiently supporting this single database environment. (See the glossary for terms used in this article.)

DATABASE ENVIRONMENT

We have used the Oracle RDBMS to support both applications developed within TSD and third-party applications used by the Department. Within TSD, Oracle installations are presently hosted on UNIX platforms. Two Hewlett Packard HP-9000/810/D380 (HP-D380) computers currently support six production Oracle databases. A third HP-D380 supports an additional seven preproduction test and development databases, and is available in whole or in parts to replace either of the production machines in case of hardware failure (Table 1). A RAID system and a tape backup unit (DLT) provide storage, backup, and archiving for each production system. A fourth system—an HP-C180—is a development machine that allows database

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GLOSSARY

CFML: Markup language for ColdFusion.

CGI (Common Gateway Interface): A standard that allows programs to generate dynamic Web pages. CGI scripts can be written in many languages including (but not limited to) "C", Java, and PERL.

CMM (Computerized Maintenance Management): Any computerized system that helps manage data related to a company's business.

ColdFusion: Web application server from Allaire Corp. that allows for display of dynamic database-driven Web pages.

CSS (Cascading Style Sheet): A file that tells the Web browser how to format the display of the HTML page.

DataEase: RDBMS with a graphical user interface from Sapphire International, Inc.

DLT (Digital Linear Tape): High-performance, high-capacity streaming cartridge tape for use with DLT drives.

DMCS (Data Management and Control System): A PDM product that served as the precursor to the current Metaphase implementation from SDRC.

FTP (File Transfer Protocol): The mechanism for transferring files across the Internet.

HTML (HyperText Markup Language): Platform-independent language used to create Web documents.

JavaScript: A scripting language that enables Web authors to develop interactive Web sites.

MAXIMO: Enterprise Asset Maintenance Software from PSDI.

Metaphase: Enterprise-wide PDM package from SDRC.

Microsoft Access: RDBMS product from Microsoft Corp.

Netscape Enterprise Server: Enterprise-level Web server software from Netscape Communications Corp.

NFS (Network File System): Distributed file system that allows users to access files and directories located on remote computers and treat those files and directories as if they were local.

ODBC (Open DataBase Connectivity): A standard for accessing different database systems.

OFA (Optimal Flexible Architecture): A set of configuration guidelines facilitating faster, more reliable Oracle databases that are easier to maintain.

Oracle: RDBMS product from Oracle Corp.

PDM (Product Data Management): System used to control, configure, and archive product-related information supporting the product life cycle.

PeopleSoft: Client/server software for human resources, finance, materials management, distribution, and manufacturing in enterprise environments from PeopleSoft, Inc.

PERL (Practical Extraction and Report Language): Shell script language designed as a tool for writing programs in the UNIX environment.

RAID (Redundant Array of Independent Disks): A system of disks organized to provide redundancy and fault tolerance.

RDBMS (Relational Database Management System): A type of database that stores data in the form of related tables, thereby allowing the data to be viewed in several different ways.

SAFER (Safety and Fitness Electronic Records System): System for monitoring intrastate and interstate commercial vehicle traffic.

SDRC (Structural Dynamics Research Corp.): Vendor supplying the Metaphase PDM product and DMCS.

Solaris: Sun Microsystems UNIX operating system environment.

SQL (Structured Query Language): Standard language for commercial RDBMS.

SQL*Net: Remote data access software product enabling client/server and server/server network database communications from Oracle Corp.

UNIX: Multi-user multitasking operating system developed at Bell Labs.

VISUAL Manufacturing: Work management system from Lilly Software Associates.

Table 1. TSD Oracle servers.

Environment	Server	Memory (MB)	Disk (GB)	RAID (GB)	Databases hosted	Dedicated tape unit (for backup)
Production	*tholos 1* (HP-D380)	512	19	38	pdm vmfg appl73 aplref	Yes
	tholos 2 (HP-D380)	512	18	24	maxprod maxloc	Yes
Preproduction	*iceberg* (HP-D380)	512	20		maxtest maxtrial maxdemo maxdev dvmfg pvmfg tsinfo	Yes
TSS development	*raven* (HP-C180)	256	16		eval7 eval8	No

volume/directory names and structures. The OFA implementation also provides a measure of failure protection in that multiple copies of critical files are written to different disks. Some performance improvements are also achieved by ensuring that heavily accessed files are on disks and controllers of their own. To the extent that the hardware has been available to allow the independent disk volumes to be created, TSS has adhered to the OFA.

The Oracle database infrastructure was designed to support the requirements of multiple projects within the TSD area of responsibility. Figure 1 shows the growth in number and size of the TSD databases. Each colored band in the graph represents an individual database instance, and the thickness of the band indicates the relative size. The labels at the right show the project areas (some of which are described elsewhere in this article) supported by the individual databases.

Computer Systems Services uses a combination of operating system file backups, Oracle archive logging, and logical database backups (database exports) as part of an overall database backup and recovery plan. These backups overlap in content to provide some redundancy in coverage for the range of failures that have been considered. Database backup files are archived to tape on a regular schedule and kept for future retrieval. The

evaluations and version updates to be tried outside the production and preproduction environments.

Computer Systems Services also maintains a Sun SPARCserver 1000 as its production Web server. Although no Oracle databases are installed on this server, database connectivity for the many Web documents that interact with Oracle is achieved by the installation and configuration of Oracle's SQL*Net and client tools on the SPARCserver.

TSD's Oracle clients gain access to the databases via Oracle client tools installed either on the user's PC or shared network file server, direct or NFS-mount connection to a UNIX database server, software application interface, ODBC, or Web interfaces. For PC clients, wherever possible, client-side SQL*Net is installed on a network file server and shared out, which minimizes the administrative burden of having to visit individual client machines whenever modifications or updates are made to the system.

With multiple databases on a single server, TSD needs a systematic approach to configuring them, both for ease of maintenance and performance. To this end, Oracle's OFA[1] standard has been adopted, which defines an approach to configuring Oracle databases for low maintenance and high performance. The standard includes specific file naming conventions as well as disk
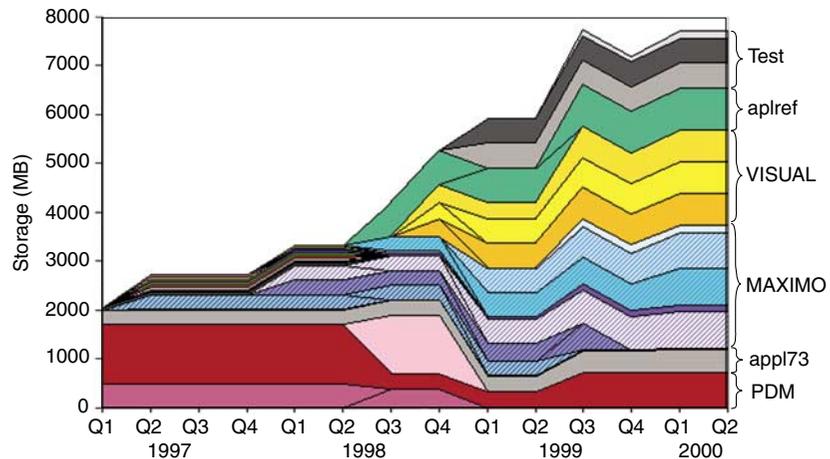

Figure 1. Oracle database growth. Each horizontal "band" is an individual database; vertical height represents size. A break in a band indicates that the database was moved from one server to another.

most recent week's worth of backup files is also kept on disk for quick access, even after being archived to tape. Failures considered in designing the plan include accidental table deletion, corruption or loss of a database file, or much more seriously, media failure such as a disk crash. Recoveries from these failures require human intervention and make use of one or more of the different types of backup data.

THE WEB

TSD is involved with the Web in two principal areas: maintenance of a Web server environment to support our presence on the APL intranet, and development of Web-based applications both for TSD and other APL departments.

Web Server

We became involved with the Web in early 1994 when a curious staff member downloaded a National Center for Supercomputing Applications (NCSA) Web server and began experimenting with HTML and CGI program development using PERL. One of those experiments produced a dynamic report built by extracting a formatted list of drawings from the PDM, a drawing release and electronic vault system. From this example, several staff members were quick to grasp the value of a Web browser as a universal client to view reports from TSD's engineering databases. This type of dynamic reporting application was unusual in 1994, when nearly all the published Web pages at APL contained static information.

In 1995 additional database-enabled applications were generated for customers in TSD and other Laboratory departments. For example, we provided tree and release information from the PDM, a prototype of the SAFER project that kept track of trucking company safety records for a customer in the Strategic Systems Department, and a prototype of the APS (APL Procurement System) Requisition Status search page for the Business and Information Services Department.

An unanticipated side effect of these activities was the creation of a TSD Web presence throughout the Laboratory. The need for an official TSD Web presence was recognized in mid-1995, and the top-level HTML pages were completely redesigned to describe the Department's organization and services. Database reporting via Web pages has continued to be a major feature requested by TSD customers. For example, in 1996 the Electronic Services Group (TSE) Work Tracking System was released, in 1997 the PDM reporting pages were revised and expanded, and earlier this year, time card applications for MAXIMO and VISUAL Manufacturing were created.

Today, the TSD production Web environment consists of the Netscape Enterprise Server software hosted on a Sun UNIX workstation running the Solaris operating system with a ColdFusion Web Application Server toolkit. ColdFusion has become our tool of choice for developing custom database-driven applications for the Web. TSD began using the toolkit in 1998 to increase productivity and has built many applications using it (Table 2). Among other features, it provides easy connection to databases, allows validation of field entries in Web forms, and includes security features to provide some level of access control to developed applications.

Many of the Web pages developed by TSD, and in particular TSS, access data in Oracle databases. Some of the major software applications that we support (e.g., Metaphase on which the PDM is built) have their own procedures for extracting and presenting the database data on the Web; for others, we had to write query and display routines. In earlier projects, the method used to extract the data was a combination of PERL programs, UNIX shell scripts, and embedded SQL calls. Now, ColdFusion provides more straightforward connectivity with TSD's Oracle databases for those applications that require database access.

TSD-Developed Web Applications

Table 2 lists some of the Web applications developed for our customers. Two of these applications are described in more detail next to illustrate the functionality that has been implemented in these and similar applications.

APL Online Employment System

Before the APL Online Employment System was implemented in March 1997, people responded to ads in various newspapers and journals or at college campuses, usually with a letter of application and a resume. APL would then either send the applicant an application or schedule an interview.

With the TSD-developed online system, positions open at APL could be viewed on the Laboratory's external Web site.[2] When visitors to the page found a position of interest (Fig. 2), they could request an application by mail or send e-mail directly to the recruiter of the position along with their resume. The positions were broken down by specific skill level (entry level, experienced, support staff, or business/administration) and skill category (e.g., Aeronautics, Information Science, Digital Hardware Design, etc.).

We also created the scripts that provided an interface to the Laboratory's PeopleSoft System to break down the text files into the skill levels and categories mentioned previously. In the 3 years of its existence, APL averaged over 2500 unique visitors a month to its

Table 2. Web applications developed by TSD's Computer Systems Services.

Application	Function	Language(s)	Additional tool	Database
4th & 5th Research and Development Symposium*	Enter/update/track papers and posters for APL-sponsored symposium	HTML, PERL		Oracle
Aegis Symposium*	Register online	HTML, PERL		Standard e-mail messaging and text files
APL Online Employment System**	View all job openings at APL; submit resume; request job application	HTML, PERL		Standard e-mail messaging and text files
APL Phonebook/Locator	Display phone, location, and organizational information for employee	HTML, PERL		Text files
APL Supervisory Feedback Process	Allow supervisors to select APL staff for evaluation	CFML, HTML	ColdFusion	Microsoft Access
Computer-Based Training System	Download courses from a database of classes	HTML, PERL		Proprietary files
HFC-SDK Download	Track and report licensed users for APL-generated software package	HTML, PERL		Text files
Individual Country Threat Levels (ICTL)	List all countries designated to have terrorist threat possibilities	HTML, PERL		Text files
IRAD Project Evaluations	Enter/update/report project evaluations for APL's IR&D funds	CFML, HTML	ColdFusion	Oracle
Laboratory Construction	Check schedules, floor plans; list FAQs; show live webcam images of construction progress	HTML		
MAXIMO WyeTAS and Chargeback Applications	Create and upload business-necessary files from the TSD MAXIMO System	CFML, HTML	ColdFusion	Oracle
NEAR Mathilde Encounter and NEAR Earth Flyby*	Simulate deep space activities of NEAR spacecraft	HTML, PERL		Text files
Patents Search System	Load and search APL patents database	HTML, PERL		Text files
PDM Queries	Query the Metaphase PDM System	CFML		Oracle
Plant Facilities Work Request (PFWR) System Reporting	Report status and funds expended for plant facilities work	CFML, HTML, CSS	ColdFusion	DataEase
Property Management System (PEMS)	List all surplus and pending transfer property	HTML, PERL		Text files
R. E. Gibson Library Order System**	Order books, periodicals, etc.	HTML, PERL, JavaScript		Microsoft Access
Reproduction Copier Tracking	Track APL copier readings and maintenance contracts	CFML, HTML	ColdFusion	Oracle
Reproduction Copy Requests	Order copy services	CFML, HTML, JavaScript	ColdFusion	Standard e-mail messaging
SIGNAGE	Generate room signs	HTML, CSS		Oracle
Standard Naval Distribution List	Look up naval installation addresses around the world	HTML, PERL		Oracle
Stockroom Catalog System	Search stockroom inventory	HTML		Text files
Johns Hopkins APL Technical Digest	Manage work flow for *Digest* production	CFML, HTML, JavaScript	ColdFusion	Oracle
TSD Help Desk**	Enter/track customer-reported hardware and software problems	HTML, PERL, JavaScript		Oracle
TSD Work Tracking System	Search for work status of customers' tasks	HTML, PERL		Oracle
VISUAL Manufacturing Work Tracking System	Report status of work orders	CFML	ColdFusion	Oracle

Note: All applications are in operation, except those created for a special purpose/function* or when superceded**.
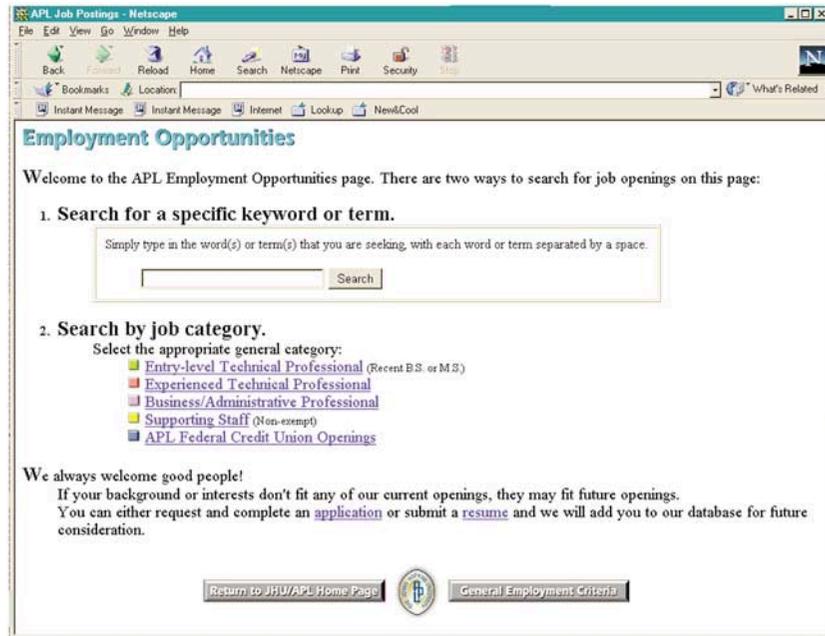
Figure 2. APL Online Employment Application.

external postings site and 1000 unique visitors a month to its internal site. Visitors to the external site included people from the United States as well as 63 other countries worldwide. Approximately 100 resumes a month were submitted via the Web interface.

PDM *Queries*

The combination of a Web browser, application code, and database access offers the user a dynamic interface for retrieving data. Web pages are no longer used as references of static data; they are live extractions from online data. Many of the Web applications developed by TSD provide data dynamically by querying a database at the time the page is requested. The user sees, via the Web application, the very latest information that is available from online data storage. By following a series of dynamically generated links in each successive page displayed, the user can drill down into more detail in the live data. Another twist of this technique is the ability to build the Web page pick lists from direct queries in real time.

An example of this from the PDM query page is shown in Fig. 3. The list of projects presented to the user for selection is extracted from the database to populate the pick list. Building the pick lists dynamically minimizes the amount of ongoing maintenance for these pages in that the HTML code for the page does not have to be manually changed when a new entry is required in the pick box. We use this technique wherever possible to provide Web pages that are always up to date while minimizing the maintenance required.

THIRD-PARTY APPLICATIONS

In addition to supporting the Web applications already described, the infrastructure elements have been put in place to support three major commercial applications used by TSD personnel to manage and monitor their work: Metaphase, MAXIMO, and VISU-AL Manufacturing. These multiuser (20–100) server-based systems all use an Oracle database for storing application data and require networked access from the user's desktop computer.

The Oracle databases reside on an HP UNIX server, which is shared with other supported applications. The executables for MAXIMO and VISUAL Manufacturing, as well as the SQL*Net Oracle database access software, are on dedicated NT servers. Each client workstation that runs these third-party applications connects to the NT server by mapping a directory on the server as a local drive on the client. For Metaphase, the executables are installed on a single UNIX workstation. With more than 100 workstations spread over the APL campus accessing these applications, this approach greatly reduces the effort required for updates and modifications, as only the single copy on the server needs to be maintained.

In addition to providing this infrastructure, TSS has customized Metaphase and MAXIMO to work in the TSD environment. Both are large, enterprise-class applications that require modification to suit the organization using them. Screens, forms, reports, the underlying database, and basic work flow elements have all been tailored to customer needs. VISUAL Manufacturing has similar infrastructure requirements but was not customized by TSS.

Metaphase

TSD began using a PDM software system in April 1994 to serve as an electronic vault and to control the configuration and release of formal APL engineering drawings. The system used DMCS 6.0 software from SDRC, which was customized by TSS personnel specifically to handle the drawing release and configuration processes of the Laboratory. The Engineering, Design, and Fabrication groups in TSD incorporated the PDM into their standard practices for drawing release and change control, replacing the previous all-paper drawing book and configuration control system.
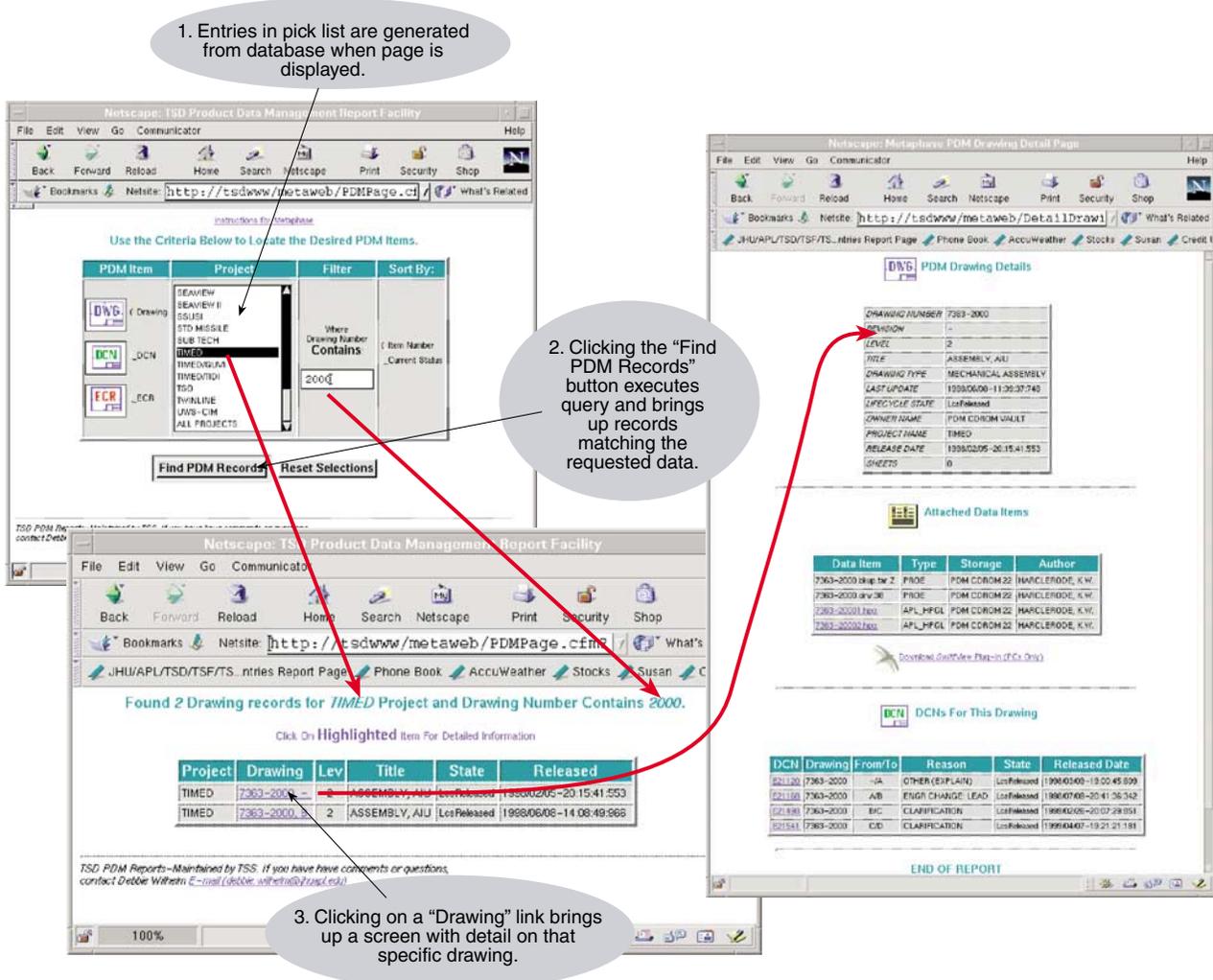
Figure 3. Dynamic Web page.

In September 1997, a product upgrade to the original DMCS software—now called Metaphase—was implemented. The upgrade was neeeded because the original DMCS software was no longer supported by SDRC and would not run with newer versions of Oracle or the server hardware and software that was coming online. Again, this version required extensive customization for use in the TSD business environment. Since the product was so different from its predecessor, none of the customization done previously was applicable.

The PDM handles the actual computer-aided engineering/computer-aided design (CAE/CAD) files that represent the design. These files, some of which are as large as 650 MB, are "checked into" the PDM, which then controls access and modifications to them and provides a single electronic repository which can be backed up and archived as needed.

As already mentioned, Metaphase stores all of the data about the files it manages in an Oracle database hosted on one of our UNIX servers. We elected to host the Metaphase application itself from a single HP UNIX platform and have users do a remote login and execute from the centralized server. This allows users the flexibility to access the application from diverse computing platforms without having to support a large variety of application installations. Users can also access information about a drawing in the system (e.g., release status, designer's name) through Web applications that query the underlying Oracle database directly.

With its growing file storage needs, Metaphase continues to drive the technology being deployed within TSD. Computer Systems Services has added a RAID storage system to enhance the system reliability and ensure that we can recover and restore files, even after single disk failures. For data files that are "released" in the configuration system, and therefore will not change, we use CD-ROMs as the storage medium. A CD-ROM jukebox that can hold 99 CDs has been added to allow data to be archived in permanent storage and still be available for on-demand loading.

MAXIMO

MAXIMO is a CMM system used by the Plant Engineering groups in TSD to plan and track their work. This comprehensive software system handles work orders, inventory, preventive maintenance, equipment, locations, timekeeping, and other items associated with the maintenance of APL facilities. We put the first piece, a preventive maintenance module, in pilot production in April 1998. The remainder of the system was put into production in October 1999. MAXIMO replaces several smaller computer applications that were previously used to monitor and track work. It extends these capabilities in a number of ways (e.g., by providing the preventive maintenance module with its stored maintenance cycles). It also forms an integrated system that ties together applications that in the previous system did not talk to one another and were labor-intensive to use and maintain.

MAXIMO is integrated with other data systems in the Laboratory to minimize the amount of manual data entry and reentry. To achieve this integration, TSD created interfaces to APL's spending authorization, data warehouse, and timekeeping systems, and customized screens and database fields within the MAXIMO application itself. As with the customizations of the PDM discussed previously, these changes were needed to better fit the MAXIMO system into the way TSD and the Laboratory do business.

VISUAL Manufacturing

A third major work management application, VISUAL Manufacturing, was put into production in March 1999. This manufacturing-oriented system, as its name implies, is used by TSD's Engineering, Design, and Fabrication groups to help plan and track all of their work. VISUAL Manufacturing also has bar code and data collection modules that provide for easy entry of status data right on the shop floor.

No major customization is planned for this application. Some interfaces to APL fiscal systems—specifically the data warehouse—have been implemented, and Web-accessed reports are being generated. Its database and storage requirements are similar to MAXIMO, and other than database expansion from the continuing transactions associated with operations of the system, no extraordinary storage growth is anticipated.

FUTURE DIRECTIONS

TSD's Computing Systems Services is seeing an increased demand for application development—particularly in the Web area—in support of customers in the Department and the rest of the Laboratory. The Web applications we are being asked to develop or support are becoming more complex as users see what can be done with this technology. To support this demand, we are currently evaluating software configuration management and Web site content management tools to help manage these development efforts. In addition, TSS is upgrading the TSD databases to Oracle 8 and is restructuring the TSD Web environment with new server hardware and software. We expect the number of Web applications on the TSD servers to continue to grow and also anticipate that TSD staff will increasingly use the APL intranet to do their daily work. This will make the growth and continued support of the production Oracle and Web server environments in TSD even more critical.

REFERENCE AND NOTE

[1]Millsap, C. V., *The OFA Standard—Oracle 7 for Open Systems*, Oracle System Performance Group Technical Paper (24 Sep 1995).
[2]This online employment system has since been supplanted. However, APL employment opportunities can still be accessed through the Laboratory's external home page at http://www.jhuapl.edu.

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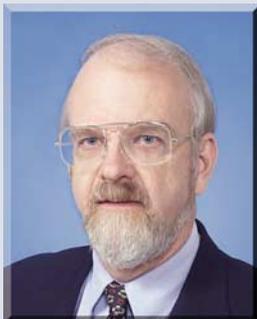
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