

Computer Systems Services for a Diverse Service Organization

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Providing computer systems services for a diverse service organization such as APL's Technical Services Department (TSD) is a challenge. Although all four TSD "business units" have unique missions and thus unique needs in terms of computer systems, it would be inefficient to provide each independently with computer support. Neither would it be practical to consider their needs as being identical. The challenge for the Department's Computer Systems Services Group is to focus on the common functions of the four units and then establish a computer systems infrastructure that provides the implementation flexibility to meet the needs of each. This article provides insight into the methodology for providing information technology support to TSD and describes how the challenge was met. Examples are given to demonstrate the concepts, but are not necessarily indicative of the state of the art (or even the current implementation), which is constantly evolving. (Keywords: Computer support, Information technology, UNIX, Windows NT.)

INFORMATION TECHNOLOGY BUSINESS UNITS

The Computer Systems Services Group (TSS) provides support for a diverse set of users—approximately 400 Technical Services Department (TSD) staff members organized into 8 groups—and more than 800 network-attached computing resources. Rather than considering each TSD group as an organizationally unique entity, the Department adopted a "business unit" approach to meeting TSD needs (Fig. 1). The term business unit, although not commonly used at APL, is often applied when addressing information technology and computer systems support. Instead of

looking at the "product" or "service" provided by an organizational unit, the focus is on the "process" that underlies the functioning of the unit. It is this process that is growing more and more dependent on the use of computer systems and more clearly defines the implementation and infrastructure requirements.

The Plant Construction (TSC), Plant Operations (TSF), and General Maintenance (TSG) groups of TSD comprise a business unit also designated the Plant Engineering Services Area. With the broadly stated mission of maintaining and enhancing APL facilities,

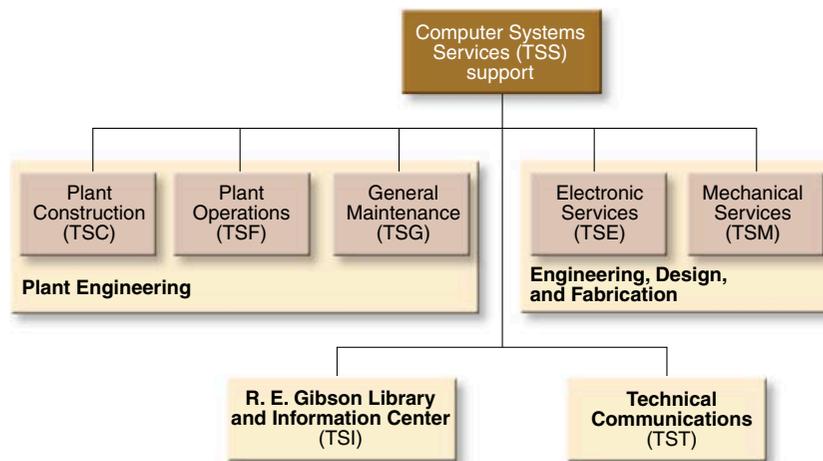


Figure 1. TSD groups viewed as four information technology business units.

the process focus of this unit is on work management and work tracking. This includes fiscal accountability, particularly important and unique to “chargeback” for TSD services associated with the Laboratory’s work programs other than facilities work programs.

The Engineering, Design, and Fabrication (EDF) Service Area and business unit consists of the Electronic Services (TSE) and Mechanical Services (TSM) groups. As its name implies, this business unit provides services ranging from engineering through design and hardware fabrication. It functions in a fashion that encompasses many of the processes that are common throughout APL and other technical organizations. The focus here spans the engineering design process (often involving project and program management functioning), and includes work management and tracking at the hardware fabrication end of the spectrum.

The R. E. Gibson Library and Information Center (TSI) is a business unit unto itself. Its business is information technology as it relates to information access and distribution and often encompasses the challenge of the “library of the future” (see the article by Gresehover et al., this issue). The vision continues to be for a highly connected environment, with computer systems operation at its core. The Internet and APL intranet are important parts of the existing and future functioning of this business environment.

Technical Communications (TST) is also a single group functioning as a business unit. (TST and TSI are considered to be a single Information Services Area; when viewed as information technology business units, however, they are significantly different.) Evolving from the paper-based world of publications, TST has changed to a near 100% utilization of computer tools for the creation of the final product. Even the nature of the deliverable media has evolved from paper-based products to include World Wide Web-based products and is expanding to direct display

in the form of video and multimedia products (see Pullin et al., this issue).

Common Points

The next step in meeting the computer support challenge is to determine the areas in which the business units are alike. Although differences exist, there is a great deal of commonality as well. Focusing on, leveraging, and taking advantage of the “critical mass” of common ground toward an information technology architecture has been the goal and results in an efficient and effective implementation.

One might begin this step by looking at relevant examples of Laboratory-wide common ground such as business systems applications. In this case an architecture is needed that provides access to applications developed and supported by APL’s Business and Information Systems Department (BISD). These applications include the APS for procurement, WyeTAS for time-keeping, SA and FPB for budget development and tracking, PEMS for property management, and the APL Data Warehouse System for information distribution. Extending the needed architecture to include more general-purpose systems such as e-mail, Web access, a common suite of general-purpose applications, etc., is a tougher challenge. However, to maintain uniformity with the rest of the Laboratory, TSD decided to use APL-wide resources for e-mail post office services (Microsoft Exchange servers as provided and supported by BISD). The Department has also extended the definition of the required architecture to include BISD-supported applications within the Microsoft Office suite (MS Word, MS Excel, and MS PowerPoint).

Uncommon Points

Considering only the similarities among the business units is not enough; areas in which they differ must also be examined. The obvious areas of divergence are those that involve imbedded systems and those that are tightly coupled to “legacy” systems. For example, the EDF has acquired a great deal of automated fabrication equipment over the years. These are often computer-based systems and have moved from unique digital logic-based hardware controllers to machines making use of off-the-shelf hardware and PCs. In addition, existing Microsoft DOS-based controllers and similar implementations may be associated with machines that have a useful life extending into

the future. Although not as prevalent, the same is true in the Plant Engineering area (e.g., the APL fire alarm system).

Support for these unique systems is generally best handled by a combination of service contracts and on-site trained staff. Often, however, additional software development or systems hardware troubleshooting expertise is needed. TSS often provides that expertise.

An interesting example of unique computer systems support requirements within TSD is TSE's wire-wrap electronic fabrication capability.¹ As a brief overview, wire-wrap technology extends back to the 1960s and began as a quick and easy way for engineers to create and work with electrical designs as breadboards. Component interconnects are accomplished by wrapping wires around long square posts with special, yet simple, hand-held tools, making it easy for technicians and engineers to build and test electronic prototypes. APL found the technology to be very valuable and even extendable into deliverable products! The gas-tight nature of the connections proved highly reliable. Therefore the Laboratory began incorporating wire-wrap circuitry in several spacecraft and space system designs in the early 1980s, beginning with the GPSPAC system. Although the technology does not support today's high-frequency designs, TSD customers still consider it viable. At present, nine wire-wrap circuit boards (evaluation or prototype versions) are planned as part of the APL Space Department's CONTOUR Program for NASA.

In response to the need for supporting wire-wrap technology, TSE procured a semi-automatic wire-wrap machine in the late 1970s. The original software for driving the system was a mainframe application obtained from Westinghouse called WestWire. Continued support of the TSE wire-wrap capability has evolved over the years through multiple iterations and migrations from the original application. It has progressed from the mainframe application using FORTRAN and assembly language, to a UNIX workstation-based application with "C" language code replacing portions of the original mainframe assembly code, and even through an upgrade from FORTRAN77 (no longer supported) to FORTRAN90.² Over the years various translators have been written to enable the processing of data from engineering software tools including Computer Vision, Mentor Graphics, Daisy, Valid, PCAD, and OrCAD. The system has gone through other changes as well in terms of hardware (which at one time incorporated an early IBM PC) and media (starting with the use of 8-in. floppy disks).

The most recent concern with the system involved Y2K compliance. TSS and TSE decided to address the issue by setting the clock back to 1972 rather than undertaking a major software development effort. (The year 1972 has the same dates and days as the year 2000!)

Keeping the wire-wrap system operational is but one example of the unanticipated software maintenance support provided by TSS to meet requirements that were unique to a particular TSD business unit. By meeting this challenge, TSS was able to preserve the utility of a still-viable legacy system.

Points In-Between

The extreme points of similarities and differences are always easy to see. For example, it would not be reasonable for each TSD business unit to use its own unique purchasing system; rather, all TSD units and the entire Laboratory benefit from using the same system. Thus the APL Purchasing System is an obvious common point. On the other extreme, forcing the wire-wrap machine into a current-day configuration may not be possible, would certainly not be practical, and must be considered a unique and uncommon requirement. Those areas between the extremes are where difficulties exist and where most of the work must be done to define an efficient and effective infrastructure. The challenge, then, is to determine where to draw the line between (1) a common solution that is implemented and supported uniformly among TSD's business units and (2) unique user (business unit, group, or even individual) requirements that call for unique support.

THE TSD COMPUTING INFRASTRUCTURE

Given the business unit viewpoint and the further assessment of each unit's common and unique needs, the next step in meeting the challenge of providing computer support is to maximize the efficiencies by specifying an infrastructure that is centered around the points in common. After evaluation, TSD management chose to identify a common computer hardware architecture and computer operating system and directed that a common solution be specified to meet the needs of all four business units. In November 1996, the Department issues the *TSD Workstation Standards*,³ which identified Microsoft Windows NT as the operating system of choice for desktop operations.³ (Windows NT, or NT, includes the Microsoft Windows 2000 operating system for purposes of this article. Also, although the terms "desktop" and "workstation" are sometimes used interchangeably, they have precise meanings as used here. Desktop refers to what have commonly been called PCs, WINTEL boxes, or IBM compatibles. It also includes Apple machines, or more specifically, Macintosh machines or Macs. Workstation, a term that will be seen later, is used to imply a more powerful machine. Today it is most commonly a hardware platform implementing the UNIX operating system and is placed in the end-user's office as opposed to being a "server-only" machine in a computer room.)

The *Standards* also specified that “our Department position will be to utilize applications that are either a Laboratory standard or embrace the largest user community within the Laboratory.” Further clarification noted that “exceptions to the standard will be made on a case-by-case basis for documented technical requirements.” Previously the TSD infrastructure was not focused or uniform in any recognizable form. At the desktop systems level, a mixed bag of Microsoft operating systems and Macs was in place. At the network operating system level, TSD was using Novell (as were a small number of other areas in the Laboratory). The decision to move toward a Microsoft NT approach was more than a decision for guidance for new procurements. It represented both a change in direction for desktop systems and, more importantly, the beginning of a commitment by the Department to a more uniform, TSD-wide implementation.

Figure 2 shows a 1 January 2000 breakdown of computer systems in use in TSD (Mac, Win95/98, and NT are desktop systems; UNIX is a workstation). At first glance this may seem to indicate a less-than-glowing endorsement of the intent of the *Standards*. However, the breakdown warrants a significantly different interpretation. While the movement toward NT as the desktop operating system was very specifically stated, the establishment of an NT networking infrastructure was only implied. Migration from the Novell operating system was a steady process that could only be fully accomplished with the discontinuance of legacy applications that were Novell based (one of the last being the CHIEF computer-aided maintenance management system used in Plant Engineering, which was in operation until December 1999). While Fig. 2 shows that not all desktop systems are NT, all TSD desktops (NT and otherwise) are network-connected to an NT infrastructure using the BSD-provided JHUAPL Domain for user authentication. In addition, they all use the BSD Microsoft Exchange e-mail server for e-mail and the Microsoft Office suite, both of which were identified in the *Standards* as the systems of choice. (See the UNIX section later in this article for details on how compatibility is addressed with the TSD UNIX systems.)

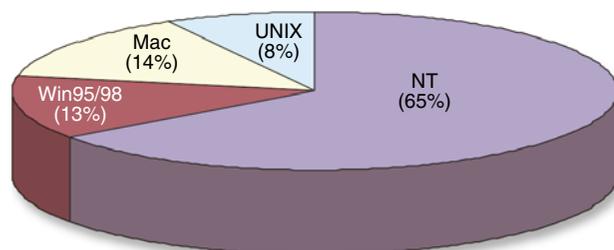


Figure 2. The distribution of TSD computer systems.

The Macintosh Exception

No discussion of desktop operating systems is complete without considering the Macintosh platform and the Intel-based Windows platform, and this is true for TSD as well. While a significant reduction in the use of Macintosh systems has resulted in the numbers shown in Fig. 2, there remains a stronghold principally in one area, the creation and manipulation of graphics. TST, and more specifically its Publications, Presentations, and Exhibit Services Section (TST-3), had used Macs long before the Department NT decision was made. An assessment of TST-3's operation resulted in identifying that area as one of the allowed exceptions. This remains an ongoing and regularly reviewed decision between TST and the Department Office (TSO), with TSS and others aiding in the evaluation. However, although Macintosh use is an allowed exception, the spirit and intent of the decision to use common systems throughout TSD was still addressed to the extent practical. Despite this exception, TST shares with other business units in the Department the use of the Microsoft Office98 suite (the Macintosh version of the NT Office97 suite included on NT desktops) and an e-mail client connecting to the Microsoft Exchange e-mail server. This provides a common e-mail system and the ability to read attached files throughout TSD.

Everything Else

Another segment of Fig. 2 is the non-NT Microsoft systems (Win95/98), which should be labeled more generically as “other desktops.” Although some isolated machine controllers are part of this segment, there are two more focused groups, the first being associated with laptop computer systems. Even though it was originally intended that laptop systems would use the NT operation system, an exception was found to be wise. Experience has shown, within both TSD and the general user community, that while NT 4.0 can generally be used on laptops, the benefits do not outweigh the added complexity associated with installing and supporting this configuration.

The second part of this segment is the electrical engineering hardware design function within TSE. An exception was granted here since the desktop hardware may also be the targeted design hardware for deliverable designs. In many cases capabilities that have not been fully implemented in the NT 4.0 architecture are available in other operating systems using Intel (or Intel-compatible) architectures such as Windows95 or Windows98 (or even a further dilution of this category to include LINUX!). Constraining this segment of the engineering community to NT was not consistent with the business unit's needs, thus resulting in the exception.

UNIX Component

Although the 1996 *Standards* did not focus on UNIX systems, it did note the importance of addressing the UNIX workstations that were the primary (and hopefully only) computers in some workplaces: "An application is under development to provide access to the Department standard application software in a UNIX operating environment...."³ Without a vision for consistency and compatibility that could be implemented across all needed TSD systems, which necessarily included UNIX, the decision to standardize would not have been made.

The computer was being used to support engineering work long before the PC era. However, in the early 1980s (considered the beginning of the era), the engineering and design elements of what is now TSD began hands-on use of computer-aided tools for engineering, design, and manufacturing (CAE, CAD, CAM). Since then, this business unit function has migrated through numerous computer infrastructure incarnations but has found its way to the UNIX environment as the most prevalent platform. UNIX remains the dominant choice for "high-end" computer needs. As a stable, scalable, and well-engineered environment, it continues to be challenged by the Microsoft NT world.

While portions of UNIX's previous dominance continue to erode, it was not practical or desirable in 1996 (and will not be for the immediate future) to discontinue its use. However, it was also not seen as practical or desirable for the "islands of technology" nature of its use to continue.³ Some offices had two machines in place, a UNIX box and a PC or Mac, "bridged" by the user and a few simple interface tools (the common FTP application for file transfers, the common telnet application for remote operation, and other similar applications). Not only did this require additional office space, higher hardware costs, and more user training, but also a much broader range of support and thus higher support costs per user. In the late 1990s the resulting high costs were no longer acceptable.

The application referred to above as being under development in the *Standards* was the Citrix (and more recently Microsoft Terminal Server) thin client architecture. As implemented, it enabled a UNIX workstation to open a window (with the X-Windows protocol), and in that window run Microsoft NT on a dedicated server. In that environment e-mail access and desktop suite applications were usable in an exact implementation of Department standards in those areas. It thus became practical for a business unit to adhere to TSD standards and also meet its (customer-driven) needs, which ultimately meant using UNIX.

CAE and UNIX in Its Own Right

UNIX deserves far more discussion than its compatibility with the NT environment. Although UNIX is

a part of the previously described "uncommon points," computer systems support in TSD continues to entail the strong need for UNIX.

Since TSD first began using CAE tools, an effort was made to extend their availability to the APL engineering community at large. As the EDF business unit has moved to a 100% utilization of computer tools for "front-ending" the fabrication process, the functionality has continued to expand. TSD engineers and engineering customers from outside the Department have realized smoother design cycles and faster hardware implementation as a result of the focus on compatibility of the tools, which have been predominantly UNIX based.

Within the broad category of electronic design automation (EDA) applications, the Mentor Graphics Corporation applications have dominated, although others also exist. Providing support to TSD users has evolved to ensuring the maximum amount of compatibility and utility to the Laboratory-wide EDA user community. Support includes providing application tools that are solely focused on engineering functions and on maintaining an electronic library of parts. The part library may contain data for VHDL design support and schematic representation, as well as physical data on the part. (VHDL is an advanced language for the design of high-speed electronic systems.) To perform this service, TSS offers oversight and administration support for EDA applications, including application engineering. Our engineers play a highly visible role in this area, even beyond APL, by participating in the Mentor User's Group, a several-thousand-member international organization.

We not only focus on engineering support, but also on a cost-effective approach to software licensing, hardware procurement, and software maintenance. TSS has taken action to reduce total costs and has even identified areas in which self-funded "time and material" maintenance approaches, as opposed to vendor-proposed maintenance contracts, have resulted in significant net savings.

The Server-Side of UNIX

UNIX purists do not like the term "server" to describe a unique hardware implementation, since the UNIX environment often finds a UNIX box functioning as server and workstation simultaneously. However, UNIX continues to dominate the server end of the marketplace. (This is true in the percentage of server/marketplace dollars going toward UNIX, although no longer true in terms of the number of servers.) In the late 1980s and early 1990s, client/server-based applications were coming into use within TSD business areas, with a projected growing need for additional systems. After analysis it was considered practical and cost-effective to

consolidate support and development expertise into a single relational database management (RDBM) product and operating system infrastructure. This analysis resulted in further identifying Oracle RDBM running in the UNIX operating system as the implementation of choice (see the article by Moore et al., this issue).

The TSD intranet and Web presence has been supported by UNIX servers as well. Presently using the Apache Web Server application, Web resources have evolved from an experimental era that saw multiple instances of Web servers and varying degrees of support. TSD's Web presence has become a "production" environment and has been appropriately supported. UNIX has proven to perform well in this capacity, but the Microsoft Internet Information Server (IIS) is beginning to balance out the spectrum. This environment is expected to evolve to include both UNIX and NT resources.

An even more interesting UNIX server evolution is taking place, however. While the Citrix/Windows Terminal Server thin client infrastructure has brought NT applications to the UNIX workstation, the reverse has also occurred. The X-Windows client/server architecture has made it possible to run UNIX applications from an X-Windows session on an NT (or other) desktop system. This cross-platform approach now makes it practical for an engineer using a desktop system (running an X-Windows client application) to use a UNIX-based CAE application.

Although connectivity across platforms has always existed (telnet and FTP only in the early days), the increased capabilities of desktop systems and the affordability of large, high-resolution displays have made X-Windows into a UNIX application from a desktop system the implementation of choice in a surprisingly large number of cases. In fact, the 8% UNIX share shown in Fig. 2 would double to 16% if it were to represent UNIX users rather than UNIX hardware systems. In this architecture, the UNIX application is being run on a central resource (server), which some might find reminiscent of the old "mainframe" days! These UNIX application servers are characterized by high-end and often multiprocessor CPUs and the memory capability to support multiple sessions. They also include access to high-volume shared storage capability. In fact the growth of data storage, backup, and archiving needs across all platform architectures has resulted in a new focus, i.e., storage area network (SAN) architectures and network attached storage (NAS) devices. TSS is migrating toward this approach to address UNIX storage needs, with an ongoing effort to extend the implementation into the NT world.

Connectivity

As has been described, much of the computational capabilities being drawn on by TSD and Laboratory-wide users is not being realized solely because of the

power of the workstation or individual desktop system. Connectivity, and more importantly high-speed connectivity, is a vital component. The Ethernet physical layer implementation of TCP/IP networking has grown from sharing a 10-Mbit/s network segment to dedicated use of a connection with switched technology. The bit rate has since gone to 100 and 1000 Mbits/s ("Fast-Ethernet" and "Gigabit Ethernet," respectively). In concert with the BIRD Enterprise Communications Group (BIX), TSD's connectivity to the desktop and workstation is almost entirely switched Fast-Ethernet. Building on the realization by BIX of a gigabit Ethernet backbone, server connectivity with dual ports of Gigabit Ethernet has been implemented in some instances.

As can be seen by the number of types of computer resources needed in TSD, all in place to meet the needs of the customer-driven business units, the Department does, indeed, have a diverse computing environment.⁴

MANAGING COMPUTER RESOURCES

Managing computer resources in a diverse environment becomes a critical success factor. At the heart of the decision-making process is the business unit. Each business unit answers to Department management. Computer systems decisions are no exception. TSS serves a unique role in the Department: it answers to Department management, but its predominant customers are the four TSD business units. And it is clearly the business units that "own" the desktop (or workstation). TSS's role thus becomes one of service and support for the business unit, but under the direction of Department (and Laboratory) management.

Key to establishing a support plan within TSD has been an organizational structure that includes the TSD User's Group (TUG) as a vital element. (The term "user's group," however, may be considered a misnomer for the functioning of this organization.) TUG was established in 1997 as an advisory and oversight body for all topics relating to computer resources within TSD. A strong "consensus forming" objective was built into its charter. TUG was initiated to work in concert with the TSD Management Committee (composed of TSD group supervisors, Department management, and key Department staff), with oversight from the TSD Executive Committee (the TSD management team). While computer support initiatives and policy proposals often originate from TSS, they also come from other TSD groups. Any decisions that have an impact across multiple business units within the Department have been brought to TUG for review. They have either resulted in a consensus at that level or have required Executive Committee involvement and concurrence.

With this approach, computer support decisions and computer-related policies have been based on sound technical knowledge and also have been independently

reviewed for compatibility with each business unit's needs. TUG remained in operation until early 2000, when it was determined that a stable operating environment had evolved. At that time the independent functioning of TUG had served its purpose of establishing the policies and direction for computer systems support in TSD.

THE SUPPORT STRUCTURE

The question of "who does what?" in terms of providing computer support was one of the first issues addressed by TUG. TSS championed a "Tiered Support" model⁵ for this purpose. With TUG overseeing the refinement of the concept, it has been successfully applied to the NT portion of TSD's computer systems support.

Tiered Support

The Tiered Support concept is a user support model that attempts to leverage naturally occurring peer-to-peer support. "PCs" have, from the beginning, been an environment in which the individual user has far more involvement with the computer system than ever before. Users find their own level of comfort and thus knowledge of the system. For some, the level may be limited to being able to accomplish a few tasks. However, for many, the computer represents a new challenge and opportunities, for example, to share their knowledge with their peers. In almost all work environments, one or more people will emerge as the more knowledgeable and interested desktop system users. Some even take off on a new career direction. Simply put, Tiered Support builds on this naturally occurring environment and focuses on giving the user community a "standardized" system implementation that, once learned and understood, can be uniformly and efficiently supported.

As implemented in TSD, the tiers reflect three functional levels. Tier 3 is the Laboratory-wide level, which includes the Computer Systems Policy Advisory Committee (CSPAC), the Department Software Coordinator's Committee (DSCC), the PC Hardware Coordinator's Committee (PCHCC), and two BISD groups (BIX and BIZ). Tier 2 is the TSD-wide level, which is provided by TSS, external subcontractors, the Computer Resource Center (CRC, the APL-wide help desk), and BISD's Support Level Agreements (SLAs). Tier 1 is the TSD business unit or group level (Fig. 3). Tier 3 staffing is a Laboratory and BISD decision; Tier 1 staffing is a group decision. A group may meet its Tier 1 support needs through a BISD SLA, through outsourcing, or by identifying one or more group members (either part-time for several staff members or full-time, depending on the size of the organization and the desires of the supervisor and staff). TSS group staffing includes both Tier 1 and Tier 2 activities. Activities for

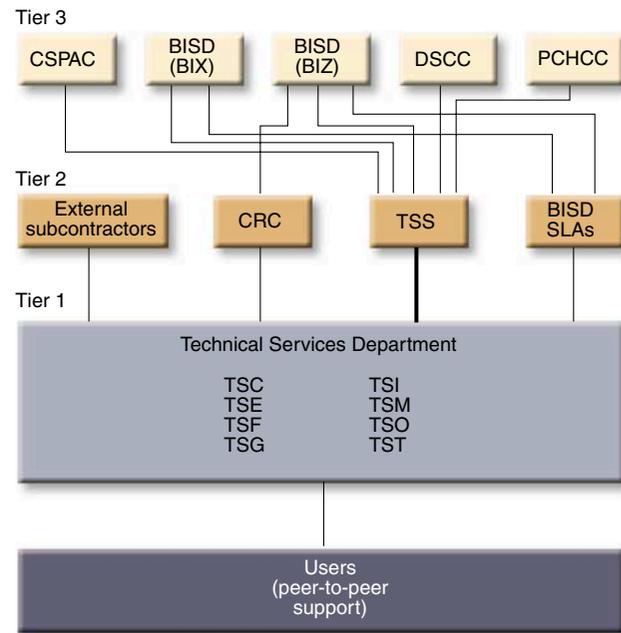


Figure 3. The TSD Tiered Support model.

the former focus on internal support for TSS and also have been expanded to include Tier 1 support for TSO. Table 1 provides examples of Tier 1 and Tier 2 support to illustrate the concept and contrast the nature of the technical involvement and thus expertise needed for each.

UNIX Support

Although the Tiered Support model has been applied to the NT area, it is seen by some as not applicable in the UNIX arena owing to the focused nature of the UNIX environment and its size. From another perspective, TSS can be described as providing Tier 1, Tier 2, and Tier 3 support for the TSD UNIX environment. It is interesting to note that while support in the Microsoft world is a highly visible and vocal topic, in the UNIX world it seems to be assumed and accepted as being left in the hands of the TSS UNIX professionals.

Support in the Printing Environment

Printing services can provide some interesting insight into the ways in which this environment responds to a computer support need. Printing is a critical service and often a very visible support issue. Procurement decisions, e.g., whether a desktop system would be best supported with a directly attached printer or whether a networked printer is a better business decision, are left up to group management. In this case, trade-offs must be considered between the cost of multiple printers and the procurement of a more expensive (and capable), shared (networked) printer.

Table 1. Sample breakdown of Tier 1 and Tier 2 tasks.

Tier 1: Desktop/user support	Tier 2: System integrity and function support
Provide "first call" user support	Provide support for "system" and repeating problems
Set up printers	Install print servers and print queues
Install software	Develop installation procedures (train Tier 1)
Place vendor, offsite, external (non-TSD) calls	Place vendor, offsite, external (non-TSD) calls
Handle non-network problems	Handle network problems
Perform "triage" for non-resolvable problems	Help Tier 1 with complex problems
Familiarize users, one-on-one	Facilitate training (predominantly third-party)

TSD continually makes such decisions, each time with the emphasis on the needs of the business units, but not always with the same result. However, for the more expensive (e.g., special-purpose color and large-format) machines, the decision generally falls toward a networked resource. In that case, the configuration needed for network access often includes both UNIX and NT, for which network print server and print queue support must be ensured. For these somewhat special printers (or plotters), as well as the more general-purpose printers, the support decision always includes a focus on the reliability and availability of the resource. The inability to print can cause a significant and unacceptable hardship. Does this mean that 24/7 printer availability is a requirement? How can 24/7 support (or a reasonable facsimile) be provided? The answer is a combination of a well-engineered network infrastructure design and built-in redundancy (in function if not in fact). For desktop users it may mean that each machine has at least two printer drivers installed, which are not only physically different but are supported from a different print server.

Putting in place the printing portion of the architecture is but one example of the support that exists "behind the scenes" to provide a full complement of computer systems services, meeting a common need across a diverse environment.

CONCLUSION

Within the TSD environment, it is possible for a user to be accessing a Laboratory-wide application such as the Data Warehouse System (through an NT-based Microsoft Excel application) at a UNIX workstation. From a computer infrastructure perspective,

this means accessing multiple operating system environments (UNIX, NT, and even the Digital Equipment Corporation VMS operating system for the Data Warehouse System). Also being used is the client/server architecture (X-Windows protocol and Oracle database with the SQL*Net connectivity application), and even the thin client architecture (Citrix Corporation applications for Microsoft Windows Terminal Server access). Multiple levels and links of network connectivity are required for this session, including the local area network and the Laboratory backbone. These are all required to give the user a fully functioning, reliable, and efficient implementation.

While supporting a single business unit might mean selecting an appropriate architecture, such a decision has not been possible or practical for a TSD-wide solution. At the same time, the role that computer resources plays in the success of TSD has grown increasingly more vital and visible. Providing this service in a cost-effective and efficient manner has been the challenge met by TSS.

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