IAIMS at Columbia–Presbyterian Medical Center: accomplishments and challenges*

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The concept of "one-stop information shopping" is becoming a reality at Columbia–Presbyterian Medical Center. Our goal is to provide access from a single workstation to clinical, research, and library resources; university and hospital administrative systems; and utility functions such as word processing and mail. We have created new organizational units and installed a network of workstations that can access a variety of resources and systems on any of seventy-two different host computers/servers. In November 1991, 2,600 different individuals used the clinical information system, 700 different individuals used the library resources, and 900 different individuals used hospital administrative systems via the network. Over the past four years, our efforts have cost the equivalent of $23 million or approximately 0.5% of the total medical center budget. Even small improvements in productivity and in the quality of work of individuals who use the system could justify these expenditures. The challenges we still face include the provision of additional easy-to-use applications and development of equitable methods for financial support.

When the National Library of Medicine (NLM) announced the Integrated Academic Information Management System (IAIMS) program in 1983 [1], Columbia University and Presbyterian Hospital‡ began to plan for a network that would allow a user with appropriate credentials to access administrative, research, clinical, and scholarly information resources from a single workstation [2–5]. In addition, the user would be able to access utility functions such as electronic mail, spread sheets, and word processing from the same workstation [6]. At the end of 1988, NLM awarded Columbia–Presbyterian Medical Center (CPMC) Phase III funding to begin implementing these objectives throughout the medical center. In a separate paper, Hendrickson et al. described the organizational and logistical approaches used to construct this environment [7]. The purpose of this paper is to list accomplishments to date, to review costs, to survey the benefits, and to discuss the remaining tasks and challenges.

ACCOMPLISHMENTS TO DATE

Organizational impact

IAIMS already has had a significant impact on information management at CPMC, especially in terms of leadership and infrastructure. We have brought the information management activities of Presbyterian Hospital and Columbia University more closely together by providing a common network for delivery

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and access. Within the University Health Sciences Division, we also have provided a more centralized focus for all computing activities. Meanwhile, IAIMS activities are in full swing. There is wide use of system resources and applications, particularly clinical and library information, and this activity will increase as we continue to provide additional, reliable applications and as we expand from 1,000 workstations to the projected 3,000 to 5,000.

Our organizational model is one of coordination rather than control, perhaps best exemplified by the use of the term *information architect,* rather than *information czar,* for the leadership of IAIMS and its related activities. Because the scope of IAIMS is so broad, multiple individuals and groups are responsible for the various resources available over the network. Control of the network gives the IAIMS leadership enough leverage to foster cooperation among resource providers.

As a result of IAIMS, five new organizational units have been created, and the role of the library has been expanded significantly. The first new unit was an academic Center for Medical Informatics (CMI), which essentially serves as the research arm of IAIMS. The center brings together personnel with expertise in key areas (networking systems, natural language processing, vocabulary control, medical decision making, library science). Organized in 1987, the center now is staffed by 11 faculty members (4 Ph.D.'s, 5 M.D.'s, 2 M.L.S.'s) and has trained 4 fellows. Nine of these faculty members serve as the leaders in Presbyterian Hospital's Department of Clinical Information Services (CIS), another new unit. This department, also formed in 1987, provides clinical information for both the hospital and the university. The overlapping of CMI and CIS, modeled on the dual role of clinical departments within a medical center, creates a structured relationship for a common architecture linking the organizationally distinct entities.

As a result of IAIMS and other converging efforts, the University Health Sciences Division has established a group that is responsible for implementing administrative systems on the health sciences campus and for interacting with the university-wide administrative system. The fourth unit formed was the core resources group, which serves the hospital and university by managing the common network and linking up new users and resources. Finally, a joint security task force was created involving Columbia University, its Health Sciences Division, and Presbyterian Hospital. This task force is one of very few policy-making groups that span these three organizations, and its presence suggests that information policies will be developed on a more centralized basis.

The development of library applications, or the scholarly information systems (SIS) component of IAIMS, has been managed by the Columbia University Health Sciences Library (HSL) rather than by a new organizational unit. While the library staff was expanded to handle these efforts, SIS development is seen as a natural extension of existing library services and thus has been integrated gradually into ongoing library operations. In turn, the expanded HSL has developed close ties with the CMI, leading to joint projects and other beneficial interactions.

Network

Our current network links eighteen buildings at seven separate locations. On the CPMC campus, redundant token ring backbones connect thirteen buildings; one is a fiber-optic cable running a 16mb token ring and the other is copper running a 4mb token ring. The fiber is currently activated in seven buildings. In addition, coaxial-based ethernet goes into nine buildings. Expansion of the ethernet is underway, using existing fiber-optic cable. Forty-two additional token rings connect to the backbones via bridges, and three AppleTalk local area networks connect to the backbones via gateways. Network components (gateways, routers, LANACS, and terminal servers) permit connections among different networks and devices. The network is extended via microwave and T1 phone lines (1.54 mb/sec) to Columbia University's Morningside campus, the Allen Pavilion (a 300-bed community hospital three miles north of the CPMC campus), and the off-site data center located thirty-seven miles north of the CPMC campus. Split bridges and leased telephone lines (9600 baud) extend the network to three remote clinics and practice sites. Physicians also can access the system by dial-back modem. Several CPMC buildings are not yet connected to the network.

The network encompasses three mainframe hosts, 32 minicomputers, 37 servers (Novell, Unix, and 05/2), 875 DOS-based personal computers (PCs), and approximately 150 Macintosh computers. Using terminal emulation, most workstations on the network can access any of the hosts or servers; all can reach the major resources. In addition, an unknown number of dumb terminals are hardwired to various minicomputers. Many of these terminals communicate with mainframe resources via host-to-host gateways. The network simultaneously supports TCP/IP, IPX, and SNA protocols, which send tokens or packets over the single physical network in an intermingled fashion. We hope to move all network traffic gradually to the TCP/IP suite of protocols.

Applications

Our first was a DOS-based scripting program that transparently connects and disconnects a PC user and

Table 1
IAIMS resources and applications at Columbia–Presbyterian Medical Center

Clinical results reporting	
laboratory	
pathology	radiology
operative reports	discharge summaries
obstetrics	neurophysiology
admit–discharge history cardiology	labor and delivery
head and neck	
GI endoscopy	demographic profile
clinical profile (physician data entry and review)	
Clinical decision making	
Surgery scheduling	
Medical records DRG coding	
Medical records	
Chart tracking/chart deficiencies	
Scholarly information systems	
Galen MEDLINE	
Columbia Textbook of Medicine	
Columbia Library Information Online	
Concise Electronic Encyclopedia	
Anatomy Textbook	
Physician's Desk Reference	
NIH Clinical Trials Alerts	
Other	
Mail	
Phone directory	
Word processing/spreadsheets	
Grants and contracts newsletter	
Hospital and university administrative systems	
Laboratory-supported research initiatives	

a host resource using terminal emulation. We used commercial products as platforms for these scripts. Extensive care was taken to ensure that all initial states for the PCs and all exit points in the various applications were taken into account. Resources and applications developed as a result of the IAIMS effort that are available from IAIMS network workstations are listed in Table 1.

The clinical results applications were made possible by gathering data from existing or newly implemented local resources. We upload these data elements into our comprehensive patient-oriented clinical database [8–9] using HL-7 protocols [10] and review them using a common results-review utility. Thus far we have concentrated on providing information to health care workers and have not asked them to enter data. A single program that allows physicians to enter clinic visit notes is used by a small number of enthusiastic physicians [11]. We are using a rule-evaluation monitor to scrutinize new data added to the patient database and to generate patient specific alerts, suggestions, or warnings as appropriate [12].

We provide online access to the most recent five years of MEDLINE (Galen MEDLINE), including abstracts, using locally mounted BRS search software. The Columbia Textbook of Medicine and the Anatomy Textbook are examples of resources developed elsewhere within the medical center and brought onto the network, while CLIO, Columbia's library catalog, and the Columbia Electronic Encyclopedia come from the Columbia University Libraries and Academic Information Services, respectively. Most of these resources would have existed even in the absence of an IAIMS initiative.

The university and hospital administrative systems and the research computers in individual laboratories are accessible from the IAIMS network.

Training and support

Among our goals in developing the IAIMS network and its menu of applications was to provide a consistent, easy-to-use interface so that most users would require neither training nor printed instructions. We did anticipate a need for online instruction and tutorials and have provided modest amounts of online help.

The key factor in training and support of the IAIMS network and its applications is the Core Resources Unit. This group installs and maintains the network, installs and maintains the system menus, and advises individuals and departments throughout CPMC on issues ranging from how to join the network to how to take advantage of individual applications. A help desk operation (four full-time positions) provides twenty-four-hour telephone information on system availability and use, as well as assistance with all hardware and software problems and other questions. To date, we have found that the Core Resources Unit requires about one staff person for every 200 workstations on the network.

When the network was first installed, we provided some initial training. Training sessions were scheduled and the systems development team spent time on-site providing individual instruction and responding to questions. But interest in scheduled training sessions was minimal. Subsequent network expansions have been accompanied by less initial instruction.

There seems to be greater interest in training related to specific applications of the network, and we have provided sessions on the use of e-mail and MEDLINE. The library provides twice-weekly demonstrations on using Galen MEDLINE, which are well attended, and plans additional demonstrations of other scholarly information components and e-mail. A pocket card provides introductory information on the use of Galen MEDLINE. Regular issues of *Information News,* the IAIMS newsletter, provide brief descriptions of the network applications.

Levels of use

The clinical results review system began operation in July 1988. Currently, the system has more than 2,700

active users, and utilization has more than doubled over the past twelve months. On an average weekday, there are more than 2,500 log-ons and more than 7,000 data inquiries, and these numbers are increasing each month. Although requests for laboratory data are by far the most frequent (70% of all inquiries), demand is strong and growing for narrative text reports in radiology, pathology, cardiology, and other areas. Approximately 70% of all house officers use the system regularly, as do 60% of attending physicians who have hospitalized patients. Nurses account for 20% of system utilization, and medical students 7%. The system also is used regularly by hospital staff in fifty different departments.

The surgery scheduling system, implemented in 1989, is used by the admitting department to schedule 30,000 procedures each year. The system also is used by numerous other clinical departments, clinics, and physicians' private offices to review surgery information.

The patient-abstracting and DRG (Diagnostic-Related Group) coding system, installed in 1988, is used by medical records and utilization review staff, and less by quality assurance and patient accounts. The system is in use sixteen hours daily, with an average of twenty-five continuously active users each weekday. More than 850 patient abstracts are created or updated each week.

The chart tracking system, implemented in 1991, is being phased in gradually. Of the one million-plus CPMC charts, more than 200,000 have been loaded into the new tracking system, and new charts are added as they are used or created. During the day shift, more than 100 medical records and ancillary staff use the system, with another 40 to 50 using the system during the evening and night hours. The system supports approximately 5,700 transactions each weekday.

Galen MEDLINE was one of the earliest resources linked to the network. While it still accounts for only a small percentage of the total use of the IAIMS system, MEDLINE searching has become commonplace at CPMC. Not all MEDLINE searching at the campus is done through Galen; searches continue to be done via NLM's MEDLARS system, other online MEDLINE vendors, and the Cambridge MEDLINE compact disk system housed in the library.

Levels of online searching at CPMC have increased significantly over the last five years, as in-house access was introduced. In 1985–1986, for example, all MEDLINE searching was done through outside vendors, and we estimate that about 3,300 searches were made throughout the institution. After the 1987 introduction of Cambridge MEDLINE and CLIO MEDLINE (mounted as a part of the library catalog), there were about 35,000 searches in 1988–1989. Galen MEDLINE now averages about 160 log-ons per weekday. During an average month, 700 different individuals use Galen MEDLINE. For the 1990–1991 academic year, this amounted to about 41,000 searches, or 70% of the 58,000 total MEDLINE searches done within the institution.

The increased usage has been accompanied by considerable change in the purposes of searches. About half of the current Galen MEDLINE searching is done from hospital workstations, reflecting, we believe a major upturn in clinical usage. Student use of MEDLINE also has increased significantly, as a result of the availability of Galen and the free systems in the library.

Since the mail package was made available six months ago, 700 different individuals have signed up. This package is used for communication within and outside CPMC, not only between individuals but also, increasingly, to distribute campuswide information on meetings, etc.

In summary, on an average day, 1,045 individuals use one or more of these IAIMS systems. In November 1991, 3,177 different individuals used at least one system.

Costs

Although we know that costs would be substantially different in other institutions, we want to provide some sense of our expenditures. These estimates are necessary for a cost-benefit evaluation and comparison with overall budgets.

CPMC uses established administrative computing systems, which have been augmented only recently by clinical and library applications. Costs for connection to the IAIMS backbone network have been calculated in the same way regardless of workstation location or function, whether clinical, administrative, research, or library. The costs we consider in the IAIMS context are the incremental expenses above and beyond ongoing expenditures for central university and hospital administrative computing activities and all grant-funded research activities outside of the IAIMS initiative.

We have spent the equivalent of $23 million in the past four years: $9.8 million for personnel, including salaries, fringes, overhead, and indirect costs; $3.9 million for the network; $7.4 million for resources and applications; and $2.1 million for workstations. Forty percent of this total came from Presbyterian Hospital operating and construction funds, 10% from Columbia University, and the remaining half from external sources (some of the external support comes in the form of products). This level of expenditures is in line with our initial planning estimate of $34 million for implementation of the IAIMS concept at CPMC [13].

Using methods described elsewhere [14], we esti-

mated that our annual amortized costs (capital and operations) are $550,000 for the network, $430,000 for PCs/workstations, and $1.8 million for IAIMS-related resources and applications. Thus, our total annual IAIMS-related costs are $2.8 million. This annual cost is 0.3% of the total annual medical center budget of $950 million. Dividing the annual cost by 365 results in a daily cost of $8,000. Given the utilization of major systems described earlier, this breaks down to approximately $7 per day per individual user, $3 per log-on, and $0.60 per inquiry. CPMC's actual out-of-pocket costs are only half these amounts, due to external support.

The costs of integration are small compared to the costs of applications. Two thirds of our costs are attributable to applications, and as we expand our selection, this proportion will increase.

The incremental expenses of network connectivity and integration appear well justified, especially when the costs associated with point-to-point wiring are considered. The total cost for wiring two new hospital buildings—a total of 1,050 beds and one or more network connections in each room, for a total of 2,968 outlet jacks—was $1,079 million, or $364 per node. By comparison, the typical cost of installing horizontal wiring from a central wiring closet to an office is approximately $600.

To connect to the network a user provides a personal computer and network access card and pays a one-time installation charge of $200 and an annual maintenance and support charge of $240.

Benefits

In our opinion, the main value of the IAIMS effort at CPMC to date has been convenient access to information that would otherwise be unavailable or would require substantial effort to obtain. An example is a patient record. The paper-based chart can only be in one location at a time; this location may be unknown to a potential user, and even when the chart can be located it requires manual retrieval and delivery. The clinical information system, which can provide much of the information found in paper charts, is the vehicle that makes possible many popular applications that by themselves might not have justified an institution-wide network.

Personnel action forms, purchase orders, and scholarly journals are other paper-based records that can be provided more conveniently over the network. Once high-level commitments were made and early IAIMS efforts appeared to generate sufficient credibility, nearly everyone saw new ways in which the integrated information system could be useful.

We expect that this expanded access to all types of information will improve the efficiency and quality of our patient care, research, and education. However, it is difficult to gauge any increases in research productivity, reductions in malpractice claims, improvement to student learning, or actual time saved that can be attributed to enhanced access to patient information, for example, or literature. Although the need for access to the literature is documented [15–16], no one has yet measured the value of access to the system. We note, however, that overall IAIMS expenditures would be justified if each of the 1,045 daily individual users (assuming average salary plus fringe of $50,000) saved approximately 20 minutes per day and benefited in no other way.

In the area of patient care, information systems can improve quality and efficiency in four ways, by

- enhancing access to accurate facts about the patient or institution (laboratory results, surgery schedule, etc.);
- providing immediate, focused access to the literature;
- facilitating critiques of provider actions or lack thereof; and
- facilitating analysis of the way medical care is provided.

We have been able to identify examples of each of these types of benefits.

At CPMC, where occupancy rates are high and elective admission waiting lists are long, a shorter average length of stay would translate directly into increased admissions. If improved access to information could reduce the average stay by even 1%, that could mean an additional 450 admissions per year, or an increase in annual net revenue of $3.15 million. This revenue alone would more than compensate for the annual expense of the IAIMS initiative.

Another important facet of patient care is decision making by physicians. Leape et al. [17] have shown that there is substantial negligence in such information-intensive activities as prescribing drugs. Gardner [18], McDonald [19], Evans [20] and others have attributed substantial cost benefits to critiquing systems. A significant fraction of our application development costs have been spent on attaining the present level of online decision-making capability [21].

We are beginning to see special instances where the benefits of the IAIMS system could be substantial. We have, for example, installed a utility that uses one rule to provide alerts about rapid deterioration of renal function. We did not make the alert available to physicians or nurses but we observed that, in twelve days, the single rule led to alerts on eighty-seven different patients. A review of the eighty-seven charts showed that, in the majority of instances (seventy-five patients), physicians recognized immediately what was happening. In three cases, however, it was at least two days before care providers realized what was happening and adjusted therapy. One patient

transfer to the intensive care unit might have been avoided had a potassium supplement been discontinued earlier.

The availability of MEDLINE has had obvious benefits. For example, an attending physician, while discussing a patient's sudden deterioration with a resident, wondered if it might be due to a drug interaction. They ran a MEDLINE search from the nursing station, saw that their patient fit the reaction profile described in the literature, and changed drugs. In another case, a family was pressing a physician to provide a folk medicine therapy to a patient. At the prompting of the risk management office, the physician ran a MEDLINE search at the nursing station. The output enabled the physician to show the family the results of rigorous trials indicating that the questionable practice provided no benefits and in some instances was harmful. The family acquiesced to the physician's recommended course of therapy.

The network also facilitates research. Several research teams looking for patients who fit their subject criteria have written Medical Logic Modules, which evaluate patient data as they are acquired and alert researchers by e-mail whenever there is a match. The patient yield and labor savings are tremendous compared to traditional methods of finding subjects.

An additional benefit of IAIMS, which is obvious to the development team, is the ease and rapidity with which new applications can be introduced. No longer must every desirable resource or database be written or purchased to run on one mainframe host to which terminals are hardwired. By focusing on relatively inexpensive microprocessor-based servers, we are able to offer many applications that would be impossible or prohibitively expensive in the mainframe environment. We feel strongly, but cannot document, that this ability to overcome the applications backlog through parallel development more than justifies the cost of the system.

In summary, the costs of integration are small compared to the costs of implementing and maintaining applications. In the absence of definitive data on time saved or improvements in quality and efficiency of care, the only data-based standard for judging our success is network utilization. We hypothesize that bright, extremely busy individuals who want to provide efficient, quality health care and to pursue research and educational activities use the system because it provides useful information more conveniently and effectively than traditional alternatives.

CHALLENGES

We are pleased, in general, with our accomplishments to date, but there are many continuing challenges. The major issues we can identify at this point are pricing, security, computer platforms, applications priorities, standardized software, and linkages.

Pricing

With a combination of funding sources, we have been able to install and provide the levels of network services previously described. Because much of the initial funding came from Presbyterian Hospital, hospital workstations have not been assessed individual charges. Recently, we established a policy of charging university workstations an annual fee for network access. As network services grow and become an integral part of CPMC operations, however, we will need to develop and rationalize a more comprehensive scheme for recovering network costs.

Our evolving philosophy is that central funding should cover network installation and maintenance to the point of wiring closets on each floor in CPMC. Beyond that point, departments or individuals should pay for wiring and equipment, installation and setup, and ongoing access. Access charges will be collected to support personnel in the Core Resources Unit, which manages the network, and also to support campuswide information resources.

Because applications are developed by a variety of units within CPMC, maintenance generally will not be covered by network access fees. The hospital directly supports the operation of the clinical information systems and hospital administrative systems and pays for servicing of its share of the network. We do not yet know how operation of university administrative systems available over IAIMS will be funded. Servicing of the scholarly information system has been funded to date by a combination of library and grant funds; because this tends to be a campuswide resource, we anticipate that future support will come from a combination of library funds and access fees. Other network resources, such as e-mail and the phone directory, are regarded as campuswide services appropriately supported by a combination of access fees and central funds provided by the relevant administrative unit (university or hospital).

Significantly, this evolving funding scheme focuses on a combination of central, departmental, and workstation charges, but avoids charging on any per-use basis. The emphasis, we feel, will be on workstation charges, using the model of basic telephone service.

Security

From the earliest stages of planning for IAIMS, important questions related to security have been raised. For example, what are the security policies and requirements of the University's Health Sciences Division and Presbyterian Hospital, the two units cooperating to develop IAIMS? Who should be allowed

to use the system? What resources, and which data within particular resources, should be accessible to which users? Who owns the data and has a right to make policies concerning those data? How might users be authenticated? How could existing data policies be applied to new automated applications, or would changes be required? How would data be protected in the system? Are different levels of protection appropriate for different systems and types of data—say, patient information versus library systems? Are different levels of security appropriate for different types of users? What are the legal and ethical implications of security policies and decisions? Who would manage security activities? How would users be informed of security policies? Who would develop security policy?

The IAIMS project emphasized security issues across the two institutions and clearly called for new policies based on dramatic increases in data access. In 1990, twelve subcommittees addressing different aspects of computer security (user authentication, physical security, access control to system resources, data ownership, data protection, building security into systems, hard copy security, systems integrity, user profiles, legal and liability issues, problem identification resolution issues, and network security) were convened and developed reports. A consulting firm worked with us to prepare the agenda for each group and moderate the meeting discussions. We identified more than sixty security issues, and each of the eighty-five individuals participating in one or more of the subgroups was asked to rank the issues from the perspectives of urgency and exposure.

The number one issue identified was the lack of a way to deal with security issues across the three institutions, i.e. Columbia University, its Health Sciences Division, and Presbyterian Hospital. From this it was clear that a separate policy for each institution would be counterproductive, so interested parties from all three were assembled as the Joint Columbia University–Presbyterian Hospital Committee on Data Security. This committee, which meets regularly, develops data security policies that will cover all types of users of IAIMS and other network university networked systems and provide for individual treatment of diverse types of data.

In 1991, CPMC and the Digital Equipment Corporation began a joint project to investigate use of the Kerberos authentication protocol from Massachusetts Institute of Technology's project Athena [22]. The goal is to set up one common, reliable server to contain a file that securely delineates a user's access privileges. This server will communicate transparently with network resources so an individual will have to log on to the system only once.

Joint university–hospital efforts on security issues have provided a starting point for development of other comprehensive information policies. We have begun discussions on basic network services, the definition of core information services for all employees and students, and policies on charging for information services. Informal discussion among information systems personnel also may lead to parallel development within the three units of local policies on hardware, software, applications, user support, and so on.

Computing platforms

From the beginning, we have realized that our hardware environment would be heterogeneous. The hospital might control the type of workstations purchased with central funds, but physicians with private office systems, university departments, and individuals funded by grants would choose a variety of workstations and hosts as prices dropped, new products emerged, and personal tastes came into play. Given this reality, we chose to think that heterogeneity was good. It is impossible to predict what kinds of machines and operating systems will be available in five years, so forced uniformity would be impractical and probably would lead to obsolescence.

Both DOS and Macintosh microprocessor workstations can get to the major host machines using terminal emulation software. But certain PC resources are written for proprietary environments (e.g. the Anatomy Textbook uses Windows), which do not allow a Macintosh user access. The reverse situation is also true. UNIX workstations can access files on any of our Novell but cannot run the applications on those servers.

We feel the UNIX operating system is currently the best common platform for transporting applications across the machines of various manufacturers. For the same reason, we see as desirable the presentation-level graphical user interfaces, which are based upon X-Windows/Motif libraries. However, we realize that character-based terminal emulation applications may continue to exist long after our favored presentation standards and operating systems have been superseded by the next round of software advances. Heterogeneity is likely to continue to be a fact of life.

Selecting application priorities

Input from users is an important factor in our choice of resources and applications. In the initial IAIMS planning process, a User Needs Committee laid out the general categories of needs and discussed the expected differences among researchers, clinicians, educators, and students. We decided to begin by meeting the information needs of practicing clinicians. Our first major offering was the clinical results review. Many hospitals begin with order entry, but we

did not hear physicians complaining that they could not order tests via the computer. We felt our success would hinge on meeting real needs in ways that saved time. The resounding success of the clinical results review gave us a strong platform upon which to anchor additional options.

Also important in the early stages, we felt, were some resources that would be useful to nearly everyone. So we set about mounting the MEDLINE database and the phone book and installing an e-mail package. Given this platform, many groups have begun to select priority applications within their particular domains. As we proceed, we will continue to add applications developed through CPMC and to implement other resources requested by our users. Where possible, we will supplement the offerings now targeted to researchers, educators, and students.

Standardized interface/software

Our overall development philosophy has been to take advantage of existing resources wherever possible. The workstation is the integration glue because it provides transparent access enabling a wide variety of applications running on the seventy-two host machines and servers. Beyond the workstation, however, integration crumbles as the user encounters disparate interface philosophies associated with the panopoly of applications.

Thus, when an individual uses one of our four text search engines (TOPIC, used for the Textbook of Medicine; FOLIO, used for the phone directory; National Institutes of Health Clinical Trial Alerts and nurse care plans; BRS, used for Galen MEDLINE; or the Concise Electronic Encyclopedia), he or she will experience a multitude of user interface conventions. This situation highlights the dilemma faced by system architects: both extreme alternatives—designing all applications internally or using whatever is available on the market—involve significant disadvantages. The former alternative presents many difficulties, especially given the time required and the speed at which hardware and software environments become obsolete.

Our approach has been to achieve functionality in a rapid manner and to modify software when the user interface is not intuitively clear. This approach is based on our need for quick start-up and our conviction that user interface standards and presentation still are evolving rapidly compared to a decade ago, when character-based terminals were the only option. When possible, as was the case with the Physician's Desk Reference, we use software designed for other applications (in this case, FOLIO).

Considering the range of resources and applications listed in Table 1, our situation could be likened to the tower of Babel. And yet, we have had surprisingly few complaints from users. Nonetheless, we feel certain they would use a wider range of applications if there were a common appearance and "feel" and we look forward to moving in this direction.

Linkages

In the original planning for IAIMS, we proposed not only "one-step information shopping," or access to a wide range of resources and services from a single workstation, but also easy movement among the various options as required by the user's task. An author, for example, might want to consult the library, communicate with a colleague, and use word-processing software in a single session. Thus, the user should be able to move quickly among these options, and also be able to transfer information from one to another. At our current level of development, the first goal has been accomplished; a user can perform these tasks on DOS workstations in a serial fashion. We have operational prototypes of multitask workstations (UNIX, OS/2) that allow for multiple concurrent applications.

Regarding the second goal, we hypothesized that users would benefit from more direct links among particular applications. If a clinical information systems user received an alert, for example, and wanted to comment on it, the system should allow e-mail communication by the press of a key. This type of capability has been implemented on a limited basis by hard coding. But the general capability does not exist today.

Of particular interest to us is the provision of links between the clinical and scholarly information components of IAIMS. Such links would depend on the intellectual content of both resources and would require consideration of the respective vocabularies. Our first projected user target is the physician who is reviewing a patient record and wishes to consult the scholarly literature. As a contractor to NLM's Unified Medical Language System project, we are experimenting with defining standard queries that would allow us to process the patient information, propose possible questions to the user, and then provide MEDLINE search results based on the user's choice of one or more questions [23]. We also would like to enable the recipient of a computer-generated alert to gain immediate access to the electronic textbook or MEDLINE abstracts. Such attempts to support clinicians' use of the scholarly literature could have, we hypothesize, a significant impact on the quality of patient care.

CONCLUSIONS

Although we have made significant gains in providing information to users, we still have much to ac-

complish. University and hospital purchase orders, personnel appointments and credential forms, and payroll sheets still are typed on multipart forms and entered offline in a batch environment. Physicians still write orders and progress notes in patient charts and the ward order book. Nurses still record patients' vital signs on sheets of paper, which become part of each patient's chart. Users cannot yet access a sufficient range of scholarly databases, and we do not yet provide electronic ordering of documents. Many administrative applications remain to be offered via the network. Finally, the majority of private faculty offices and many of the hospital administrators and support staff are not yet connected to the network.

What we do have is substantial institutional credibility and recognition of our accomplishments to date. The infrastructure is in place, users and developers are enthusiastic about our current and planned applications, and costs are reasonable. With two years remaining of Phase III funding, we are confident that our original goal of one-stop information shopping will become a reality at CPMC.

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