# Reshaping the Enterprise through an Information Architecture and Process Reengineering

*"The architecture provides the blueprint for developing an integrated set of information services, processes, and technologies ... "*

*by Nicholas C. Laudato and Dennis J. DeSantis*

***This article describes the University of Pittsburgh's unique approach to designing an enterprise-wide information architecture and a framework for engaging the University community in business process reengineering. That approach included building consensus on a general philosophy for information systems, utilizing pattern-based abstraction techniques, applying data modeling and application prototyping, and tightly coupling the information architecture with efforts to reengineer the workplace.***

A team of faculty and staff at the University of Pittsburgh has completed the design of an enterprise-wide information architecture and a framework for engaging the University community in business process reengineering. The architecture provides the blueprint for developing an integrated set of information services, processes, and technologies, enabling significant efficiencies in business and service processes, and facilitating informed decisions concerning information technology expenditures and acquisitions. This article describes the University's unique approach to this undertaking.

**Background**

The University of Pittsburgh, founded in 1787, is an independent, nonsectarian, coeducational, public research institution, with a Fall 1994 headcount of 32,519 students at its five campuses. The University has a central-site information system configuration, relying heavily on an IBM 3090-400J mainframe dedicated to administrative computing applications. Most of the University's financial, student, library, and personnel systems run in this environment. The Administrative Information Systems (AIS) group within the Computing and Information Services division is charged with supporting the administrative computing needs of the University. AIS is staffed by approximately 75 personnel skilled in creating and supporting batch and character-based interactive systems developed in COBOL and MANTIS.

Like many other large institutions, the University is permeated with islands of automation in

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the form of thousands of microcomputers and hundreds of local area networks. These systems are considered by the owning units to be an integral part of the information services provided to end users. Many of them support business applications that complement or duplicate some of the functionality of the central systems. This duplication is quite costly in terms of personnel, hardware, and software. But a more critical issue is the timeliness and accuracy of the information on these local systems as compared to the central site systems, and the difficulty of integrating and reconciling data from multiple systems and platforms.

**Project mission and goals**

Like many of its peer institutions, the University finds itself in an economic, social, and political climate that demands the ability to respond to local, regional, national, and international changes in a timely and relevant manner. To accomplish this, University leaders must be able to access and utilize information about all aspects of the enterprise and must change the way its people plan, make decisions, and perform work. In short, the University must transform itself into a modern organization where information is viewed as an asset and used to strategic advantage.

As an initial step in this transformation, the newly-appointed senior vice chancellor for business and finance conceived an approach in August 1992, and selected a senior faculty member from the Department of Information Sciences to design and direct a special project. The project director initiated the Information Architecture and Process Innovation Project in February 1993, with four individuals selected because of their background, knowledge, and experience with varied components of the University. These individuals were relieved of their normal responsibilities for the duration of the project and physically relocated to private office space in the School of Library and Information Science. The project team defined the following mission:

- design an architecture for the University Information System (UIS) that will provide a framework for making decisions about information systems and for improving the UIS in the future;
- establish a methodology for business process reengineering using the UIS; and
- develop a plan for migrating from the current systems to the envisioned UIS.

The architecture provides an overall, high-level design for the UIS, identifying scope, direction, components, relationships, and behaviors. Understanding and intelligently deploying information technology in compliance with the architecture will, in turn, play a crucial role in successfully reengineering the University's business processes.

**Information architecture philosophy and principles**

The project began with the articulation of a philosophy and set of architectural principles. The creation of a University Information System philosophy statement directly involved over 100 faculty and staff. The statement was debated in three formal focus groups that were specifically configured to represent all constituencies in the University. It was also published in the *University Times* and on several electronic bulletin boards. Through this process, the philosophy statement was refined to reflect the desired goals and directions of the entire University community.

The philosophy and related principles (see sidebar on page 37) have provided a framework for the information architecture by articulating the objectives and quality characteristics that the architecture should follow. These, in turn, are intended to guide the analysis, design, and decisions made relative to all aspects of information systems and processes at the University. They determine the technological approach taken in defining components of the architecture and how they must operate, and are meant to provide a set of guidelines by which information system design decisions can be made.

*"… the information processing technology empowers users and customers to reengineer business processes, and the reengineered processes determine the need and cost justification for the information technology."*

**Implementation strategy**

The Information Architecture and Process Innovation Project employed a methodology that combined information engineering with business process reengineering. These two components have a symbiotic relationship—the information processing technology empowers users and customers to reengineer business processes, and the reengineered processes determine the need and cost justification for the information technology.

Because of the broad scope of the envisioned University Information System, it became clear that its implementation would have to be phased in over several years. Consequently, when choosing an implementation strategy, the project team eschewed the traditional master plan in favor of a pattern-based approach to building the information architecture. This methodology was inspired by the Oregon Experiment,[1] a highly successful approach used over the past thirty years in designing and building the University of Oregon campus.

*(continued on page 36)*

[1] Christopher Alexander, *The Oregon Experiment* (New York: Oxford University Press, 1975).

# Reshaping ...

*(continued from page 31)*

In the Oregon approach, a set of six core principles serve to guide the building process through the use of a pattern language. The pattern language describes the detailed patterns for towns and neighborhoods, houses, gardens, and rooms.[2] The project team's methodology recognized many parallels between the architecture of towns and buildings and that of information systems. The following set of project principles is modeled after those articulated in the Oregon Experiment:

> *"In a pattern-based approach, the architecture is documented in a set of patterns, or information processing principles."*

- *Organic order:* The planning and implementation of the UIS will be guided by a process that allows the whole to emerge gradually from local implementations, guided by the information system philosophy and structure.
- *Participation:* Decisions about what will be built, and how it should behave, will be in the hands of the users at various levels. This is based on the assumption that users help shape the environment, know their needs best, and can define the qualities of the information system required to satisfy their needs.
- *Piecemeal growth:* Piecemeal growth hinges on dynamic and continuous growth. Therefore, funds should be distributed for small, intermediate, and large projects. Funds must be made available without an overwhelming amount of specific, low-level details, since resources consumed attempting to determine such details could be better spent on implementation.
- *Patterns:* All design and implementation will be guided by a collection of communally adopted design principles, called information processing patterns.
- *Diagnosis/evaluation:* The well being of the architecture and the envisioned information system will be protected by an annual diagnosis/evaluation system that will identify and explain, in detail, which information processing patterns are alive and which are dead, at any given moment in the history of the system.
- *Coordination:* The slow emergence of organic order in the whole will be assured by a funding process that regulates the stream of individual projects put forth by users. The use of a standard template to fund projects, describe projects, describe patterns of information processing, perform diagnosis, and estimate costs will aid in prioritizing projects.

In a pattern-based approach, the architecture is documented in a set of patterns, or information processing principles. Decisions about developing, modifying, or acquiring components of the architecture are made by evaluating proposals based on their adherence to the specified patterns. The patterns are subject to ongoing review and refinement to ensure that they incorporate advancing technology and continue to meet the needs for which they were designed. The information architecture will evolve as more and more projects are implemented that comply with its specifications.

The patterns must be communally designed and adopted, and will guide the design of everything in the University Information System. Patterns can be both very large and general, and very small and specific. Some general patterns deal with the behavior of computer interfaces, some with the distribution of data, some with hardware configurations, some with network protocols, and others with data access methods. More specific patterns deal with report formats, application-specific functions, ordering of data on displays, etc.

The use of a pattern-based approach prevented the project staff from being overwhelmed by the volume of small details necessary to implement a specific task for a specific function for a specific application. Such details are better addressed using prototyping techniques at design time, not at the architectural phase of an information system. The project team, therefore, developed a set of common information processing tasks based upon a series of interviews and an analysis of user requirements. The architecture is a response to these patterns of information use across all University activities and related processes which are found in every application.

**Prototype applications**

The team preferred to recommend guidelines that could be implemented using state-of-the-practice technology and reasonably cost-efficient methods. For this reason, many of the principles espoused in the architecture statement were illustrated through a set of prototype applications that would serve as "proof of concept" and validate the premises put forth in the philosophy statement.

The team completed four major prototypes during the life of the project. The first of these, the Course Inventory Prototype, illustrated several key patterns. For example, a *finder*, is used to identify an object in the database that the user wishes to view. A finder prompts the user for information that could either uniquely identify the desired object, or identify a list of objects. If the search results in more than one object, the prototype would generate a *browser*. A browser provides a list of objects, with enough informa-

[2] Christopher Alexander, *A Pattern Language* (New York: Oxford University Press, 1977).

tion to allow the user to select the exact object to be viewed. A *viewer* displays the object. The viewer is typically segmented into pages or scrolling sections to allow all attributes associated with the object to be viewed without invoking additional transactions. Viewers also provide "hot button" links to other associated viewers and functions. Finally, a *view-before-update* pattern specifies that you must view the attributes associated with an object before entering a mode that allows you to modify them.

One of the premises of the architecture is that these patterns, among many others, would repeat over and over again in different applications, with only the specific data elements changing from application to application. For example, a finder will always look familiar and behave consistently, regardless of whether it is designed to find a student record, course section, purchase order, or research account. If all of the University's business applications were constructed from such recurring patterns, it would be easier for users to master the interface and seamlessly move from one application to another.

The finder/browser/viewer paradigm designed in the first prototype was replicated in a series of six smaller prototypes developed by Information Science graduate students. These student prototypes involved a wide variety of topics, including a classroom scheduling package, a car dealership program, a real estate program, and a purchasing system. This set of prototypes helped verify the team's assertion that the patterns being developed were flexible and generalizable.

Based on the experience of advising the graduate students in using the patterns to create additional prototypes consistent with the architecture, the team developed a second major prototype, the Application Builder Prototype. Twelve of the fifteen code modules created for the first prototype were generalized so they could be completely driven by metadata (instead of hardcoding the association between a database field and its display field in a window, the application used metadata, stored in a relational table, to link all display fields to the database). The remaining three modules could then be tailored to create a unique application with a finder, browser, and viewer. This allows a programmer to generate a new application simply by creating the metadata and laying out fields on the viewer window. The Application Builder Prototype thus illustrates the possibility of creating an application software library containing reusable software components that embodied the identified patterns.

### UIS Philosophy and Related Principles

- Regard and manage information, information technology, and infrastructure as University assets.
- Capture data one time, at their source.
- Enable organizational units and individuals to share information by making data and documents visible via seamless interconnections and adherence to database standards.
- Assure the quality of information (timeliness, reliability, and accuracy) via a centralized data and document administration function with established data ownership and stewardship policies.
- Reduce the manual effort and paper required to perform information processing activities.
- Facilitate flexibility and ease of adapting to changes in policy, to incremental improvements in processes, to specific needs of local units, and to advances in technology.
- Guarantee choice via a systems environment that is open technologically, operationally, and commercially.
- Utilize the client/server model as the basic paradigm for applications in the UIS.
- Implement a common graphical user interface (GUI) for all business applications. The common GUI will provide a consistent look and feel across all applications, be easy to learn and use, be intuitive and consistent with the standards relative to its particular platform, and enable easy transferability of skill from one application to the next, facilitating substitutability of personnel across applications.
- Ensure effective use of information technology via education and training.

The final two prototypes demonstrated the feasibility of developing applications using the client/server paradigm and of retrofitting a legacy application into the envisioned architecture. The last of these, the Registration/Advisement Prototype, evolved into a production application that is currently deployed on approximately ninety desktops across the University.

**Architectural view**

To its users, the UIS will appear as a single set of applications automating the information processing activities the user performs. All activities will involve a familiar set of information processing tasks, each with a standard interface. The system will create the illusion that all data are stored and processed at the user's location.

The UIS architecture will be distributed and layered (see Table 1). Eventually, all applications will be constructed and integrated using foundation software, including a data management system, common utilities, a user interface library, and network services. Each will conform with

**Table 1: Architectural layers**

<table>
<tr><td rowspan="5">Philosophy and Principles</td><td>DESKTOP/CLIENT INTERFACE LAYER<br>The desktop/client interface layer allows applications to obtain interactive input and present interactive output through routines in the user-interface library, standardizing the look and feel across UIS applications.</td><td rowspan="5">Organizational Structure and Responsibility Model</td></tr>
<tr><td>APPLICATION LAYER<br>The application layer provides a set of common utilities for use by all UIS applications, standardizing the way users perceive and perform activities, and reducing the effort required to create and integrate applications.</td></tr>
<tr><td>DATA AND DOCUMENT MANAGEMENT LAYER<br>The data and document management layer standardizes the description, storage, and retrieval of all UIS data and documents. All applications will access data through services provided by this system.</td></tr>
<tr><td>SYSTEM AND NETWORK MANAGEMENT LAYER<br>The system and network management layer facilitates the management of the configuration of computer processors, networks, software, access devices, data storage devices, and other devices, like any other assets within the University.</td></tr>
<tr><td>PLATFORM LAYER<br>The platform layer addresses the hardware, system software, and networking components of the architecture that support applications and user access to information system resources.</td></tr>
</table>

emerging industry standards for distributed information systems. Such standards facilitate the use of common tools such as spreadsheets and statistical packages, facilitate electronic data interchange with organizations outside the University, and promote independence from individual vendors.

Until the architecture is fully implemented, existing systems and commercial packages will be evaluated on their ability to meet functional needs, their compatibility with UIS data management and network standards, and the ease of integrating them with the UIS interface library and common utilities.

## Process view

The University's work activities are currently organized around functional units, and the organization can be viewed as a series of vertical organizational structures. All activities are based upon this set of vertical compartments. Current information systems are also organized in this manner, as is all the information technology used to support the work of the University. This traditional organizational structure is not unlike organizational structures found in industry. Work activities organized around such functional organizational structures are commonly characterized by inflexibility, unresponsiveness, the absence of customer focus, an obsession with activity rather than result, bureaucratic paralysis, lack of innovation, and high overhead.

Current processes, such as the campus procurement process, are long, convoluted assembly lines that are plagued by inefficiencies, delays, excessive paper, multiple levels of authorizations, errors, lack of access to information, and customer dissatisfaction. Personnel are specialized, lack adequate access to electronic information, and spend too much of their time on work flow and paper flow issues. Processes are badly in need of significant reductions to the costs of delivering services and radical improvements to the quality of the services delivered.

One of the ways to begin addressing these characteristics is by viewing the organization as a set of processes instead of individual functions. Once natural processes are identified, the focus can shift to how well all activities in the process support the process outcome and how well the process outcome helps the University to achieve its goals and objectives. Morris and Brandon[3] state that processes can be viewed as the essence of business. Not only is most work accomplished through processes, but a great deal of what differentiates organizations from each other is inherent in their individual work processes. This seems perfectly reasonable, since the same raw materials and human capital are available to every organization. Process is therefore one of the most important factors contributing to competitive advantage. However, despite the importance of process, it seems to have been largely ignored by management theorists and managers themselves.

A process is a logical and finite set of observable, interrelated (or hierarchical), work activities utilizing *input*, that when performed in a predefined series produce *output(s)*. Processes have internal and external customers, and are independent of an organization's functional boundaries. Output is generated by a *transformation* of the input(s). As displayed in Figure 1, activities are limited by the resources available to work activities, and the constraints imposed by mandates (policy, laws, and regulations).

The Information Architecture and Process Innovation Project identified four general clusters of processes (shown in Figure 2) and defined the processes and components related to each

[3] Daniel Morris and Joel Brandon, *Re-engineering Your Business* (New York: McGraw-Hill, Inc., 1993), p. 3.

cluster. The flow through a process represents the data and documents that enter into and exit from the activities of a process. Each of the processes have many sub-processes that act as threads of inter-related activities. These process clusters represent the workflow of the University and the services provided by administrative systems to support the mission of the University. The focal point of these processes is the set of customers that the process is intended to support. The data and document processing required to provide service to customers must be supported by the information architecture.

In their seminal work, Hammer and Champy[4] define reengineering as "the fundamental rethinking and radical redesign of business processes to achieve dramatic improvements in critical, contemporary measures of performance, such as cost, quality, service and speed." In order to make dramatic and meaningful improvements, an organization must identify and take a fresh look at natural "beginning-to-end" processes. Reengineering means starting over and asking why we do what we do. The purpose of process reengineering is to make the processes as streamlined as possible and provide a high level of service to customers. Part of the streamlining requires the use of information technology to permit sharing of data, parallel activities, increased responsiveness and improved quality.

Based on its research into business process reengineering literature, and on discussions with representatives from corporations who had successfully deployed BPR projects (Bell Atlantic, DEC, IBM, Xerox, and Deloitte & Touche), the project team developed a BPR methodology and proceeded to select a pilot BPR effort to test the newly developed methodology. The team first identified all business processes in the enterprise. Using their knowledge of the structure, policies, procedures, and processes, the team performed a "process dump," then analyzed and organized the resultant activities and processes into categories. These categories were reviewed with individual end users and further refined. The team then selected one of the high-level processes that was in a state of disrepair, the procurement process, for a pilot reengineering effort.

The project team commissioned a core reengineering team, composed of a representative cross section of faculty, staff, and others, including vendor representatives from IBM, Xerox, and DEC. This team, facilitated by two members of the original project team and led by the director of purchasing (the designated process owner), was supplemented by a standing resource team and by several other individual

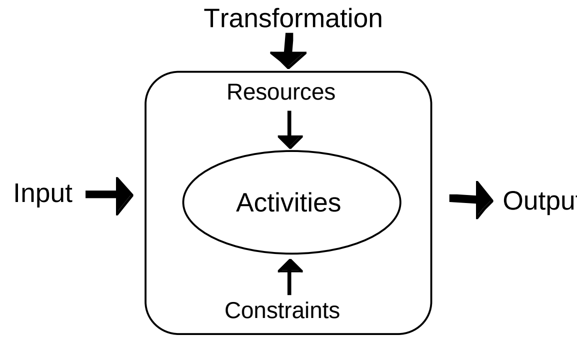


**Figure 1: General components of a process**

users and administrators throughout the University. The team investigated, but rejected, the use of specialized software packages to assist the reengineering effort, deciding instead to use general flowcharting software to map existing and envisioned process chains. After eight months of deliberation, the reengineering team completed and documented its new procurement process.

**Transforming the University of Pittsburgh**

The project team proposed that three organizational units should play a prominent role in the implementation of the proposed architecture and process innovation initiatives: (1) an advisory committee to provide overall guidance, direction, and priority setting; (2) an advanced technology group to investigate and implement emerging technologies, as well as to develop the technical capabilities for staff in Administrative Information Systems (AIS); and (3) AIS, through assuming the ongoing responsibilities of the Information Architecture and Process Innovation Project, to ensure that the architecture evolves and grows with changing technology and that the process reengineering efforts are related and refined.

*Advisory committee role*

The basic organizational structure proposed for policy formation and implementation of the information architecture centers around the creation of the University Information System Advisory Committee (UISAC). The UISAC, formed in September 1995, is composed of senior administrators and faculty members and will be chaired on a rotating basis by the senior vice chancellor for business and finance and the provost. The UISAC is composed of representatives from the University community, including academic units, administrative units, and the regional campuses.

The UISAC has been given responsibility for creating an enterprise-wide business and information system strategy, and for making policy

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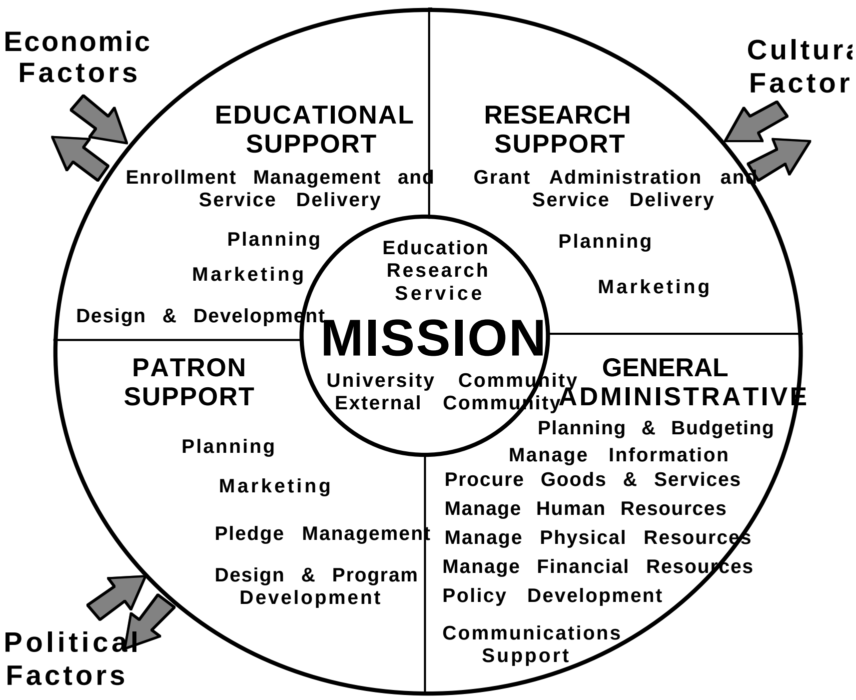
[4] Michael Hammer and James Champy, *Reengineering the Corporation: A Manifesto for Business Revolution* (New York: Harper Business, 1993), p. 32.

**Figure 2: Process clusters**




and funding recommendations for information system and reengineering projects proposed by academic and administrative unit design teams and by AIS. The rationale behind the formation of the UISAC is the strongly felt need for a consistent and coordinated approach to (1) the University's administrative information systems and information technology infrastructure, (2) the policies, tools, and techniques required for development, and (3) the implementation of the information architecture and business process reengineering initiatives. The focus must be on technology supporting business and its customers. The UISAC will be a major agent of change and, as such, needs to create an environment of trust and demonstrate effective planning and committed leadership.

*Advanced technology group*

One of the critical elements for any information systems organization in this age of rapid technological development is to develop and retain a staff trained in the use of new and productive technologies and techniques. The recommended approach to this issue is to form an advanced technology group whose function is to develop applications using the newest technologies and techniques available on a prototype scale. This group could attract faculty and advanced students to work with AIS personnel on projects that are developmental in nature but have a potential payoff for the University. Such a group could also begin to attract external funding as well as become a beta site for hardware and software vendors.

*Project approach*

The information architecture will be implemented through a project approach. Projects will be proposed by project design teams that are formed within the administrative and educational units of the University. The design teams for projects may be reengineering teams, or they may be smaller incremental improvement project teams. The teams will propose projects in accordance with detailed guidelines that ensure they will be aligned with the information architecture. This project approach is preferred over a master plan approach in order to avoid the problem of plan obsolescence typically associated with large master plan implementations.

The design team concept takes advantage of the expertise available across the University and permits multiple views of the information system project, consistent with the notion that partnerships produce a better design in a more cost-effective manner than if any one of the team components attempted to implement the project alone. It also leverages the knowledge of the unit's needs, the specific knowledge of the local unit's information system, and the knowledge that AIS personnel have of the University's central systems.

The project design teams will present their project proposals to the UISAC, which will review the proposed projects and recommend revisions as necessary. Project proposals submitted for funding will be described using a pattern language and will contain an environment section, a functional section, a performance section, and a budgetary section.

All proposals must indicate what University and other standards are being utilized as part of the project. If proprietary products are being proposed that do not adhere to an open systems architecture, then a rationale must be provided. The decision to fund projects will be based largely on their adherence to the architectural patterns.

To date, six major projects have been proposed by business units and four have been approved by the UISAC:

- Following up on the successful business process reengineering pilot for procurement, the University issued an RFP for a procurement system, and ultimately selected Oracle Financials. Because of their close relationships, the general ledger and accounts payable components are also being implemented. The phased implementation will begin in 1996 and proceed through 1998.

- To begin building the infrastructure necessary to support the other projects, AIS initiated an ad hoc committee to evaluate and select database management systems. In addition, AIS formed a set of ten working groups, patterned after those proposed in the architecture statement, to advise the procurement project team on the technical issues related to hardware and software selection and acquisition. This activity culminated in the purchase of a site license for Oracle database and development tools.
- Based on the success of the fourth application prototype, the Registration/Advisement Prototype, a registration project was initiated to investigate ways to improve the registration process. This project followed the University's BPR methodology, except for one fundamental point—it did not start from scratch, but rather assumed that the legacy student system would not be significantly changed. The project plan calls for further deployment of the Registration/Advisement Prototype, as well as the creation of new capabilities for the related processes of course scheduling and academic advisement. Implementation will be phased in over three years, culminating in student self-registration via client/server technology and telephone.
- A second major BPR effort was initiated in the human resources area.

*Roles and responsibilities defined*

A need was identified to define the roles and responsibilities of AIS personnel, IS owners and IS coordinators, local unit technical personnel, end users, and management. For example:

- Managers have the responsibility to assemble design teams for projects and to provide release time for design team members to work on the information system projects being proposed.
- End users have the responsibility to make requirements for information system services, products, and features known to the design team in a timely manner and in a form and format that is understandable to them.
- Local unit technical personnel, IS owners, and IS coordinators act as information system design team members, local system implementors, local system managers, local application developers, and local end user consultants and trainers.
- AIS personnel act as technical consultants and design team members for implementing information system projects. AIS may also act as application developers for both the client and server sides, as well as act as IS suppliers and IS operators.

*Project work documented*

The work of the project team has been documented in a series of internal publications. First, a forty-page summary document, written for the average user, explains the fundamentals of the architecture. A more detailed 200-page document explains the background, philosophy, architectural layers, and recommended organizational changes. This document is supported by a 300-page technical supplement that provides

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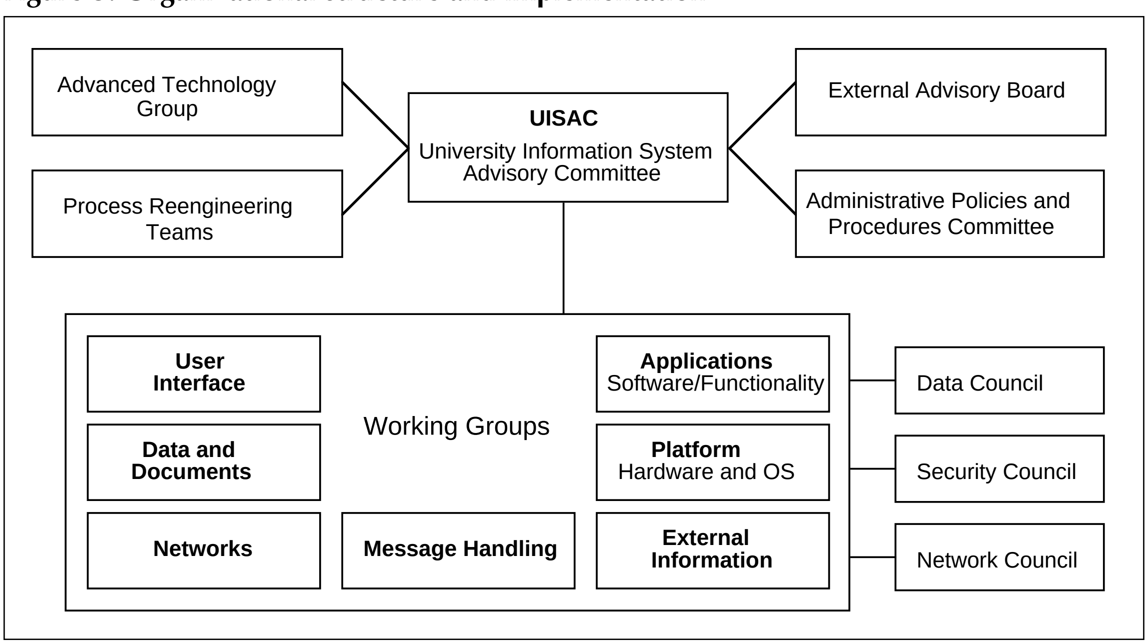
**Figure 3: Organizational structure and implementation**



details on the architectural layers, the prototypes, and the process reengineering efforts. This work was reviewed and approved, first by the senior vice chancellor's executive staff, and subsequently by a sixteen-member committee of academic and administrative leaders.

**Summary**

The Information Architecture and Process Innovation Project determined that the current University administrative process environment can benefit from drastic improvements in quality and efficiency by employing the methods available through process reengineering. The project also determined that modern information processing technologies and systems are required to support the flexibility, rapid response time, and information access requirements needed by end users to perform their work, deliver quality services, and make informed decisions.

*"… these new system implementation projects must be balanced with projects to improve access to information using the current systems."*

The implementation strategy is being driven by business process reengineering projects, but, at the same time, these new system implementation projects must be balanced with projects to improve access to information using the current systems. The implementation strategy is based upon process owners, system owners, and end user initiatives for projects that follow the architectural principles and the natural relationships between activities of a process and the interrelationships between and among processes. C/E