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Assistant Secretary for Human Resources and Administration
Deputy Assistant Secretary for Information Management

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U.S. Department of Energy

Information Architecture Volume III

Guidance

April 1997

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Assistant Secretary for Human Resources and Administration
Deputy Assistant Secretary for Information Management

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Message from the Chief Information Officer

Since the summer of 1994, we have been on a journey to develop and define an information architecture for the Department. The journey has been longer than anyone, including me, expected. Notwithstanding this fact, this Department is leading other Federal Agencies, serving as an example, in accomplishing the now-mandated Clinger-Cohen Act implementation of an information technology architecture. Our architecture program is a major accomplishment and something in which all the past and current participants of the Information Management Planning and Architecture Coordinating Team (IMPACT) should take pride.

With publication of the Information Architecture, Volume III, Guidance, and the Volume IV, Vision Architecture (before the end of the fiscal year), we are completing the initial phase of the information architecture program and are transitioning to a new phase. This new phase will focus on extending the work accomplished during the initial phase and integrating the architecture with information management decision making and processes.

The Office of Management and Budget (OMB), the General Accounting Office, and other Agencies are keenly aware of our efforts and progress. These organizations will continue to watch as we apply the Departmental information architecture, accelerating improvements to the ways we do business. The oversight agencies increasingly expect that major initiatives will be clearly defined, be cost effectively managed, demonstrate returns on investments, and link to not only Departmental information architecture but also architectures at the program and site levels. The Guidance document explains what must be done to make this linkage a reality.

This document and the previous information architecture volumes, together with Volume IV, when completed, will be valuable references for your use. They will help you tie major projects and initiatives using information technology to the Departmental information architecture. These relationships are critical in order for the projects and initiatives to receive continued support and funding. Relating them to various aspects of the defined architecture in terms of how each embodies the 8 guiding principles or addresses any of the 14 focal areas, how they align to the minimal design characteristics, how they use and apply the architectural standards, and how they fit in the future vision architecture is important. The IM Capital Investment Planning and decision making process, OMB and Congress are requiring answers to these questions. As the Departmental Chief Information Officer, I am required by law to ensure that major information technology initiatives are aligned with the Departmental, programmatic, and site architectures. If they are, I can support them. If they are not, we need to work together to ensure they will be.

As its Champion, I am as supportive of and committed to the Departmental information architecture effort as I was when we started it just under 3 years ago. I am pleased with how the information management, program and field elements, and especially the laboratories, have pulled together to define the architecture. I am proud of what we have accomplished, not only because it is receiving nationwide, even international, attention and acclaim but also because of the way we have done it through the consensus-based, collaborative partnering that has been the earmark of the team known as IMPACT. I thank each person who has contributed to the Department of Energy leading the Federal Government in the evolution of an information architecture program that is not only innovative, but cutting edge.

A handwritten signature in black ink, appearing to read "S.W. Hall, Jr.", with a stylized flourish at the end.

S.W. Hall, Jr.
Chief Information Officer

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1. Introduction

1.1 Purpose

The purpose of this document, as presented in Volume I, The Foundations, is to assist the Department of Energy (DOE) in developing and promulgating information architecture guidance. This guidance is aimed at increasing the development of information architecture as a Departmentwide management best practice. This document describes Departmental information architecture principles and minimum design characteristics for systems and infrastructures within the DOE Information Architecture Conceptual Model, and establishes a Departmentwide standards-based architecture program. The publication of this document fulfills the commitment to address guiding principles, promote standard architectural practices, and provide technical guidance. This document guides the transition from the baseline or de facto Departmental architecture through approved information management program plans and budgets to the future vision architecture. This document also represents another major step toward establishing a well-organized, logical foundation for the DOE information architecture.

Information technology planners refer to abstract technical descriptions of systems as architecture. System architecture is conceptually based and may not always include the level of detail needed for construction. Information architecture is similar to a conceptual map of a transportation system. Transportation planners do not need to know all routes, specific construction technologies, forms of vehicles, and exact usage patterns to create such a map. They assume broad, reasonably well-defined parameters of physical dimensions and performance and rely on established construction standards. Similarly, information architecture planners do not need to know every possible use for its routes and information-carrying vehicles to think about the types of foundations and support systems it requires.

Architecture is an abstract, yet meaningful, description of a large Departmental system; various implementations could meet the architecture's specified principles and goals. An architecture consists of rules, guidelines, practices, and standards that flexibly and cost-effectively bind information system components into a single, complex, evolving Departmentwide engineering product that has continuing management value. The architecture exists and evolves independently of specific vendor products and various detailed implementations, yet it impacts both. Specific products and vendor capabilities can implement some or many architectural capabilities, depending on investment and transition plans. The Departmental architecture provides a basic framework and characteristics, and stewards the creation, movement, distribution, use, and management of information. This document focuses on the "whats" and "whys" of the Departmental architecture and leaves details of "how" and "where" to those responsible for developing, operating, and maintaining distributed architectures.

This document provides a vocabulary and context for the Departmental architecture, identifies fundamental components and services, and examines ways to expand and evolve the architecture's infrastructure. The Departmental architectural framework allows process owners, communications and computer staffs, information stewards, application developers, and users to work independently while implementing elements of a common architecture. The Departmental vision architecture, presented in Volume IV, Vision, is consistent with all previous volumes and interim and adopted Departmental standards as identified in appendix A, Information Architecture References.

Information Architecture, Volume III, Guidance, consists of six chapters and several appendixes, as follows.

- ☐ Chapter 1, *Introduction*. Provides the purpose of DOE information architecture guidance and its applicability to the Departmental information architecture program. This chapter also provides a generic list of technology categories addressed in this document.
- ☐ Chapter 2, *Principles*. Identifies the principles to be used in evaluating effective design and performance of internal or external information management initiatives that impact the Departmental information architecture.
- ☐ Chapter 3, *Minimal Design Characteristics*. Identifies the characteristics of information technology designs and development approaches to be used for Departmental information management. Characteristics of business systems and applications, as well as the supporting infrastructure and the relationships of the DOE infrastructure with that of the National Information Infrastructure (NII) are described.
- ☐ Chapter 4, *Information Architecture Program Guidelines*. Provides the purpose of the information architecture program; identifies the roles of the Chief Information Officer (CIO) and staff and field organizations within the architecture program; describes the DOE Information Architecture Conceptual Model; and identifies the models and methodologies suitable for use in architectural designs and evolutions.
- ☐ Chapter 5, *Information Architecture Standards*. Describes the Departmental approach to information architecture using adopted and de facto standards in the design, acquisition, and implementation of the nested organizational architectures.
- ☐ Chapter 6, *Summary*. Provides a short summary of the benefits of Departmentwide guidance.
- ☐ Appendix A, *Information Architecture References*. Provides statutes, Directives, and other applicable references.
- ☐ Appendix B, *Architecture Configuration Scales*. Describes several architecture configuration levels and presents a basic set of architectural configuration guidelines.

- ❑ Appendix C, *Recommended Readings*. Provides a bibliography of selected texts and articles used in the development of this document.

The key icon highlights information that has a significant effect on achieving the Departmental architecture objectives.

1.2 Applicability

1.2.1 Guidance Reference

The codes, laws, Orders, memorandums, Directives, and documents that establish the justification or rationale for and directly relate to the implementation of DOE internal information architectures are provided in appendix A, Information Architecture References. These references and guidelines apply to DOE Federal and contractor information technology activities and are useful references for Departmental entities developing and maintaining information architectures. Also, these guidelines are a valuable reference for DOE partners and stakeholders who have interest in the success of the Departmental information architecture.

1.2.2 Technology Scope

The information technology (IT) families used within the Departmental architecture and to which this guidance is applicable are presented in table 1-1, Information Technology Related Categories. The table includes examples of fundamental technologies, such as telephony, applications services (e.g., facsimile transfer), and other representative samples of the diverse Departmentwide capabilities used within the architecture.

Table 1-1, Information Technology Related Categories	
Facilities	Owned, rented, or contracted data centers, local area networks (LANs), telecommunications centers, and typical office sites
Wireless	High Frequency (HF), Infrared (IR), Ultra High Frequency (UHF), and Very High Frequency (VHF); microwave; satellite relays; radio frequency spectrum resources; paging systems (secure and unclassified); and other wireless communications
Telephone	Dedicated, dialup, cellular, facsimile, telex, teletypewriter exchange (TWX), telecopier, data, voice, and voice-mail systems (secure and unclassified)

Table 1-1, Information Technology Related Categories	
Networks	Data, video, local and wide area networks (LAN/WAN), land line, external commercial services, twisted pair, coaxial, fiber distributed data interface (FDDI), dedicated use, and public use systems (secure and unclassified)
Computing Platforms	Central processing, client/server, distributed processing, and standalone desktop processing systems (secure and unclassified)
Information Processing	Desktop, graphical user interfaces, servers/processors, data storage and retrieval devices, electronic mail (E-Mail) (secure and unclassified), electronic commerce/electronic data interchange, electronic document publication and distribution, and scientific computing simulation and visualization
Applications	System and user commercial-off-the-shelf (COTS) software, custom-developed, integrated, standalone, office automation, E-Mail, antivirus, and add-in and add-on third-party software
Database Management	Structured Query Language (SQL), relational, flat, object-oriented, standalone, application-oriented, and systems included in COTS or used within applications
Graphics Generation	Drawing, drafting, computer-aided design (CAD) databases, data visualization, plotting, technical, scientific, and engineering graphics
Video	Broadcast, desktop, and multipoint and point-to-point teleconferencing
Operating System Infrastructure	Infrastructure operating systems software, tools, and utilities
System Development	Tools and utilities
Physical Information Distribution	United States mail, Federal Express, United Parcel Service (UPS), courier (including physical document transfer to archives), and file storage

These categories define the technological envelope within which DOE provides information support to customers in response to business events requiring delivery of information products and services. These technologies are brought together in different configurations and design patterns at different locations within the architecture to provide flexible and affordable solutions to Departmental business needs.

1.2.3 Architecture Configuration Scales

Except as described below, DOE information architecture guidance is applicable to all system and infrastructure designs within the architecture. Differentiation of systems by scale and geographic dispersion provides a basis for establishing a Departmental Corporate Systems Architecture (DCSA). The information architecture guidance uses the terms system, corporate system, and Departmental corporate system as described below.

A **system** is a connected or related set of assemblages or combination of parts forming a complex or unitary whole that works toward a planned result. For the purpose of this document, it consists of at least one application, two or more processors or servers, and a communications link. De facto DOE corporate systems, other business systems, and infrastructure network systems identified in Volume II, Baseline Analysis, must be considered in the evolution of the Departmental information architecture.

A **corporate system** is a design and implementation to satisfy a subset of the enterprise's total business (and information) needs. Such systems can be partitioned across separate business areas, organizations, or processes to integrate both functional processes and technological capabilities. Corporate systems support business functions that meet the following criteria.

- ☐ Support business functions that exist in the majority of DOE organizations
- ☐ Required by laws, regulations, or generally recognized sound management practices
- ☐ Considered vitally important by DOE top-level executive management and support accomplishment of the business functions for which they are responsible
- ☐ Highly institutionalized and operate continuously and routinely

Such systems perform and support day-to-day business functions so vital that without them the organization would either no longer be legally viable or could not effectively accomplish its assigned mission or both. Many Departmental corporate systems are owned and operated by business units or programs. Corporate systems may be comprised of smaller systems or be part of a design subset within a DCSA. Typically, larger corporate systems use system-unique, as well as infrastructure or Departmental corporate systems resources, to transfer and manage information. This includes preparation, collection, transport, retrieval, storage, access, presentation, and transformation of information (e.g., voice, graphics, text, video, and images).

The DCSA includes corporate systems consisting of numerous heterogeneous processors, applications, and communications capabilities that may be geographically distributed. These systems integrate corporate and other business systems. A Departmental corporate system contains enterprisewide and related business unit capabilities that achieve collective purposes. The information technology infrastructure with the DOE Business Network (DOEBN) is an

example of a corporate system component having strategic configuration and business implications.

1.2.4 Exclusions

Certain implementations and uses of information technology are excluded from Departmental Information Architecture Guidance. For instance, unless DOE information architecture infrastructure capabilities are employed, research and experimental computing, storage, display, and transmission systems architectures within a business or program area are excluded. System-specific and program area-specific architectures within a business or program area, as well as site-specific architectural designs and local implementations, are similarly excluded. Also excluded are weapons embedded systems; commercial-off-the-shelf production, test measurement, and diagnostic equipment; and externally owned and configuration-controlled architectures, except for interfaces to DOE information architecture.

The Departmental infrastructure resources accessed and employed by excluded uses are included in these guidelines when they necessitate architectural changes or when performance and maintainability issues are involved. While excluded, voluntary use and application of architectural methods and approaches within these areas are not prohibited but encouraged.

2. Principles

This chapter describes the eight principles of the information architecture summarized in Volume I, The Foundations. These principles are high-level statements of the Department of Energy (DOE) philosophy of information architecture expressed in terms of business and engineering goals and objectives. The principles are intended to endure and provide a basis for standards and information management policies. The principles are expressed using criteria by which the needs of the user-centric and corporate business views are woven into a unified, user-centric system with sufficient flexibility to adapt to business and technology changes. In the descriptions that follow, each principle is expanded to provide links to other parts of the architecture and other sections of this guidance.

For Departmental purposes, order of these principles is not hierarchical. Each principle has relatively equal ranking within the Departmental enterprise architecture. Depending on the organization, site, business area, and particular need, a relative importance for related sets of principles may be established for local architectural designs. The following set of eight principles does not preclude the adoption of additional sound principles or corollaries for local information architectures, but it does provide the Departmental technology implementation envelope within which other possible principles reasonably fit. This flexibility is intended to maintain the overall coherence of the Departmental information architecture.

Principle #1 DOE information products and services are user-centric and customer-driven.

To be successful, information products and services must meet user requirements and enable effective decision making to increase productivity and efficiency. The architecture must support a diverse business environment and provide numerous technological opportunities and services. A wide range of users, their experience, and the purposes for which they employ technology to achieve business objectives require that architecture, design, and support requirements be viewed from an appropriate perspective. Access to information in a user-friendly manner from many sources helps achieve this goal. Information products and services critical to business process reengineering, system development, and evolution must also be considered.

Information products and services can be made available from various locations, but should be available to all users in an integrated, transparent, and seamless fashion.

DOEwide connectivity for both internal and external users is required through high-speed communications networks. Support for this connectivity on multiple desktops (e.g., personal computer (PC), Macintosh, Sun or Texas Instruments UNIX-based workstations, etc.)¹ will continue. Standards for these desktops support the ability to customize the work environment, but not compromise basic interoperability or capabilities to provide services. The diversity of future capabilities and the types of users to be supported are shown in figure 2-1, User-Centric Architecture Support Characteristics. This figure portrays the variety and diversity of supporting requirements through multiple sets of user-driven characteristics. Although not comprehensive, this graphic illustrates the complexity inherent in this principle.

Figure 2-1, User-Centric Architecture Support Characteristics

¹ Product names are illustrative only and do not imply DOE endorsement.

As illustrated in figure 2-1, User-Centric Architecture Support Characteristics, a laptop user from any organization will be able to access information or participate in workgroup activities from any geographical location. Architected, planned, and implemented access enables any user, regardless of experience level, authorized purpose, or role in the Department, to have valid and defined support needs satisfied. The diversity of roles, expressed as categories of users, requires that support needs be transparently and seamlessly satisfied so that all users can be productive and efficient.

Principle #2 DOE Information Architecture is based on modular components.

Modular architecture supports organizational changes. It is resistant to obsolescence, since antiquated and inefficient modules can be replaced with minimal adverse impact and maximum benefits to the overall architecture. Use of modular components improves the ability of systems to adapt to changing requirements. Changes can be isolated to affected modules. For both hardware and software components, this adaptability extends the useful life of the business system and has a favorable impact on return-on-investment decisions.

Modular architecture can also be made more reliable and operationally resilient by incorporating backup and concurrency designs and containing unpredictable failures to the component or immediate locale. For example, failures in a voice network or desktop video capability will not be propagated to data communications networks and their file servers. A highly integrated, multisite business structure, such as DOE, must continue operations regardless of component failure, and users should be advised, preferably in advance, if system resources are unavailable.

Modularity provides risk reduction by avoiding or isolating custom-designed components. Acquisition strategies can be used for scalable and tested pilot projects, simulations, or prototype implementations before deploying a full-scale capability. Modularity also enhances the ability to implement architectural changes in phased segments to narrow project scope, permits demonstration of measurable net benefits as part of overall mission needs, and reduces the overall time between need identification and deployment.

Finally, modularity provides system designers with significant opportunities for aligning their systems with customer and management requirements for partitioning components and information assets within well-ordered structural designs. While shared resources are expected to be the rule, the use of modular components within the Departmental architecture will simplify the overall design and increase flexibility. Modular designs and implementations are now an Office of Management and Budget (OMB) requirement for any significant information management initiatives considered within the Departmental Capital Information Technology Investment planning process.

Principle #3 *Information architecture is based on an open systems approach.*

With an open systems approach, software applications and information can be migrated easily to a variety of interoperable computers. Vendor-neutral internal machine architectures provide long-term potential cost savings through enhanced competition in the marketplace. DOEwide architecture strongly advocates use of commonly available, vendor-neutral standards but does not mandate an implementation strategy or specific products. DOE organizations can select their own products and use unique standards as long as the information can be transferred effectively among organizations without additional conversion efforts. DOE will continue to encourage vendors to provide products based on open systems standards.

As computing environments become more portable, people become more adaptable (i.e., applicable to different computing environments allowing resources, information, and software applications to become increasingly shared).

When supplemented with open systems capabilities, the architecture can accommodate the large inventory of legacy systems previously built on proprietary components. Short-term functionality, based on proprietary solutions, should be sacrificed only for long-term interoperability. The use of proprietary business solutions should be the exception.

Easy-to-use standard data formats and search and retrieval tools must be able to accommodate some older formats and media and adjust to meet emerging multimedia technologies.

Lifecycle costs can be reduced, although significant cost savings from implementing a standards-based information architecture are achieved incrementally and increasingly over a 5-year period.

While Department open systems standards are defined for the architecture, an open component is generally more integratable in an architectural framework. Proprietary components are considered major barriers to satisfying interoperability requirements. This may be because unnecessary, inefficient, or cumbersome translations add steps (e.g., to create or operate an interface) in information access and use. Departmental standards and standards-compliant components within a well-structured architecture help preclude the need for inflexible workarounds and inefficient additional steps.

Principle #4 Security is designed into all architectural elements, balancing accessibility and ease of use with protection of data.

Security, at all levels, must be designed into architectural elements and plans from the beginning.

Existing laws, acts, and regulations require safeguarding national security and sensitive data (mission essential, Privacy Act, proprietary, etc.). Existing information protection-related Directives, manuals, and guidelines apply and prescribe adherence approaches and best business practices.

Information sharing must be balanced against integrity, availability, and confidentiality considerations, privacy laws, and the proprietary aspects of scientific data. Both internal and external users continue to require increased access to DOE information. Consistent with Departmental openness policies, the right-to-know has priority over the need-to-know, unless strong reasons for protecting the information exist or are established. DOE data, products, and services will continue to reside in an environment characterized by multiple levels of sensitivity. Increasing numbers of industrial partnerships with DOE require a wider variety of information protection methods that do not overly restrict access and use of Departmental information.

To provide open access and maintain information protection, security must be implemented at the data level rather than the application level. This change in process requires a culture shift within the Department.

A DOEwide solution for secure access to multiple networks is necessary. The information architecture advocates and promotes uniform implementation of appropriate business-driven computer security practices Departmentwide, including contractor sites.

Principle #5 Information is not only a Departmental asset but also a national asset for which DOE staff is the steward.

The availability of timely and accurate information is a key ingredient of sound decision making. As such, information and data are vital assets that necessitate a high level of management. One goal of the Federal Government is to make quality information available to every citizen in a timely fashion. Treating information as a Departmental asset is necessary to accomplish this goal.

The need for sharing information complexwide necessitates and justifies the following types of actions.

- ☐ Establishment of consistent data definitions (at the corporate level with extensions within and across programs and sites).
- ☐ Establishment of standard data interchange formats.
- ☐ Establishment of business, technology, and investment management approaches commensurate with the decision making value of the information. Business process owners are essential participants in business alignment and information processing decisions.
- ☐ Establishment of an information locator capability as part of a meta-data repository.
- ☐ Identification of information stewards responsible for the definition, integrity, and timeliness of the information within their domain or business areas.
- ☐ Resolution of operational issues related to the physical implementation of a shared information environment.
- ☐ Establishment of a partnership between process owners, information stewards, and information technology providers.

Initiatives for many of these massive efforts are already underway at individual sites and within several Departmental business areas. Complexwide participation is imperative in fulfilling this principle and supporting efforts.

Process ownership, information, and stewardship enable the Department to be flexible in providing diverse business products and services. Stewardship, rather than ownership, encourages information use without sacrificing security or data integrity.

Information and data stewards are responsible for data, applications, and infrastructure. Information management ensures the integrity, timeliness, protection, and sharing of information.

Principle #6 DOEwide access to information is the rule rather than the exception.

Technology can be deployed to distribute information and make it available electronically, while allowing access in new ways across the entire complex. Productivity, decision making, and customer service benefit from easy, direct, consistent, and timely availability of information. The business necessity of sharing information should be established within each organization. For optimal decision making, DOE staff and contractors must access the broadest range of information possible within the constraints of Departmental policies and applicable laws. An example of integrated business and corporate systems that use diverse business techniques is shown in figure 2-2, Business Systems Technology Integration. Figure 2-2 depicts how the business needs (events) drive down through the other subarchitectural layers. Conscious design is required to ensure alignment from the business event driver through the information, application, and data subarchitectures for the chosen technology. This illustration also demonstrates the role of collaborative workgroups and distributed designs in the future architecture in providing ease of access to authorized users from fully integrated user desktop platforms.

Groupware products are being used in figure 2-2 as part of a business process workflow to provide an information product or service. In this depiction, electronic commerce capabilities in the technology subarchitecture are used within a larger, corporate-system framework. From the desktop, applications and data throughout the architecture are employed to deliver the required energy-related products and services for a particular business area. The architecture integrates the business subarchitecture with its supporting information, application, data, and technology subarchitectures Departmentwide to enable increased information accessibility and related business process enhancement.

Timeliness is an important information quality indicator. User and system developer time is often wasted in the quest for quality information. User and decision maker response times to business needs are often the most precious of resources. Efficient allocation of these resources is paramount as processes are improved through major redesign and operations reengineering.

For unclassified information, the right-to-know should be presumed unless policy or law specifies otherwise. Sensitive unclassified and classified information must not be accidentally released or compromised and must be protected according to current DOE Directives, Orders, and National Policies.

Figure 2-2, Business Systems Technology Integration

Principle #7 The information architecture incorporates a robust interface that optimizes the nature, efficiency, and effectiveness of the human operator.

The importance of human factor engineering is increased in a user-centric architecture. Human and computer interactions are interdisciplinary fields with roots in ergonomics, cognitive science, and human factors. The benefits for work process improvement are significant. Human factor engineering pays off in cost effectiveness, quality, and efficiency.

Deployment of productivity-enhancing systems (hardware and software) requires engineering of human and technological capabilities across all levels of the DOE architecture. The effectiveness of information delivery systems must support the full range of users, including the public. Successful workgroup collaboration, using networked computers, for example, requires knowledge of the human and computer interaction issues and the conversion of that knowledge into easy-to-use capabilities.

Human and computer interactions are complex domains often requiring more than the use of a graphical user interface (GUI). The use of human and computer interaction knowledge in all aspects of system development will be stressed to information technology development stakeholders. Incorporating informed human and computer interaction knowledge into DOE systems development within architectural frameworks is strongly encouraged.

Principle #8 DOE will have an information technology infrastructure that links offices, programs, facilities, and field locations together seamlessly.

The information technology infrastructure is aimed at increasing interoperability and the use of standards to support sharing of resources such as data, information, applications, telecommunications and video infrastructures, and computers. Artificial barriers to accomplishing Departmental missions can result from the lack of a consistent, fully interoperable, and robust information technology infrastructure. The degree of interoperability is reflected in figure 2-3, Service Integration, which shows a seamless view of information presentation and applications capabilities that transparently tap local and remote resources. Interoperability is a well-defined corporate requirement within and across various business areas. Guidelines for the creation of seamless systems and the ways in which transparency can be engineered into system designs are provided in chapter 3, Minimal Design Characteristics.

Figure 2-3, Service Integration

Figure 2-3, Service Integration, illustrates user-centric capabilities and views (as depicted in figure 2-2, Business Systems Technology Integration) expanded to and through several backend technologies. While integration of these technologies is transparent to users, these technologies are critical to the virtual offices of the future. This figure also shows the relative complexity of these portions of the transparent infrastructures. Complexity can be reduced by using common standards, protocols, middleware, and hardware components.

The infrastructure at sites throughout the Department can be centrally coordinated and decentrally implemented. Coordination ensures that nonvalue-added, redundant efforts and implementation gaps are identified and addressed, especially for Departmental networks.

A seamless information technology infrastructure facilitates Departmentwide sharing of information and other resources. The information technology infrastructure may include some common databases and applications with commonly available standards-based access mechanisms.

Information technology infrastructure planning and implementation require active participation from organizational elements. Centralized leadership, facilitation, and funding may be required for specific Departmental and local partnership initiatives that provide Departmentwide infrastructure consistency. When central funding cannot be provided, creative and cooperative funding may be required. Either way, for partnerships to occur, strong, architecturally-based business cases addressing the OMB Capital Information Technology Investment planning criteria must be documented and presented.

All DOE organizations must realize that a trade-off of autonomy for data subarchitecture integrity and consistency may be necessary for successful intersite interoperability to be established at the corporate layer and in business areas that cross programs.

In addition to improving overall interoperability, acquisition strategies may be employed to appropriately allocate risks between DOE and its contractors, effectively use competition, tie contract payments to accomplishments, and take maximum advantage of commercial technology. Acquisition strategies should also support core or priority mission functions, which must be performed by the Federal Government, or demonstrate that an alternative private sector or Government source can efficiently support those functions.

The DOEwide network capability that allows the exchange of sensitive unclassified data is a major component of this infrastructure. Security policy issues must be managed at the Departmental level or higher (Governmentwide). Increasingly, the DOE infrastructure, especially wide area networks, will be replaced with services provided externally through contracts.

3. Minimal Design Characteristics

This chapter describes design characteristics for business systems and Departmental infrastructure information architectures. These characteristics provide an engineering basis for requirements determination, analyses of alternatives, design alternatives, and delivery of business benefits. In the description of each characteristic, essential behaviors are identified. These Departmental architecture design characteristics are provided to guide the evolution of the future vision architecture. (The Information Architecture, Volume IV, Vision, is under development.) This chapter also clarifies guidelines identifying conditions (and examples) when replication is acceptable and redundancy should not be perpetuated.

Flexibility describes the Department's future information architecture system, application, and infrastructure environments. Flexibility is advantageous as statutes, Directives, missions, and revised or new business policies occur; partners and stakeholders or their interests change; business resource investments and expenditure levels fluctuate; strategic plans and relative priorities evolve; and redesigns of business operations occur. The Department of Energy (DOE) architectural flexibility is enhanced by the ability of business units to adapt their nested architecture components and designs to increase Departmentwide interoperability. The Departmental information technology infrastructure is an important means of positioning future capabilities to meet the changing needs of all business areas and sites. The transparent interoperation of connected infrastructures and business systems is essential for meeting the full range of information product and service delivery requirements Departmentwide.

The design of the DOE architecture, including the architectures of individual organizations, should allow for ease of change in rapid response to business, customer, and evolving information technologies. Based on decentralized information architecture management, the effectiveness of the Departmental information architecture is tied to its ability to adapt in usage growth and contraction periods without delays in redesign, acquisition, or redevelopment of altered technology components and designs.

The characteristics of the architecture can be viewed from two perspectives, as shown in figure 3-1, Major Architecture Perspectives. The user and business areas perspective on the left is oriented toward satisfying needs of specific business units and customers. The technologies and infrastructures perspective on the right shows that business needs are satisfied for component systems in a cost-effective, responsive manner. A fully aligned architecture successfully integrates business solutions from both perspectives.

Figure 3-1, Major Architectural Perspectives

<i>Business Driven</i>	<i>Technology Driven</i>
Business Goals Business Processes System and Application Oriented User-Centric Customer Satisfaction	Business Goals Business Process Support Wholesale Information Movement Multi-System Support Wholesale Technology Service Provider Network-to-Network Services Customer Satisfaction

3.1 *Business System and Application Design Characteristics*

The quality of architectural flexibility is enhanced by designing business system and corporate applications architectures with the following unprioritized characteristics. The characteristics are not prioritized for the Departmental level and can be applied depending on the needs of each system. At the Departmental level, flexibility results from the design characteristics being realized, with special emphasis on interoperability and DOE standards-compliant systems for all business areas, offices, applications, and subsystems. Priority can be attributed to the design characteristics to meet local business objectives; however, interoperability of DOE standards-compliant systems across business and technical boundaries made possible by the Departmental infrastructure must be ensured under future configurations.

- ❑ **Maintainability** is the ease of repairing the architecture components.

Modularity is the ability to add, modify, and remove or redesign components of the physical architecture.

Scalability is the ability to revise the capacity of the physical architecture (i.e., by the dimensions of transaction volume, data storage volume, concurrent users, system load types, or total users).

- ☐ **Adaptability** is the ease of changing information forms (e.g., data and text, graphics, imaging and animation, sound, voice, multimedia, and video) or functional characteristics (e.g., preparation, presentation, collection, display, transmission, storage, and processing).
 - ☐ **Portability** is the ability to move applications across the entire business system and application architecture and change architecture capabilities transparently from one location to another. Portability is a design, product, and network performance-based architecture characteristic. The ease of portability is influenced by the standards, platform characteristics, and configuration designs adopted at each site and among multiple interoperating sites. Also, some applications, typically commercial-off-the-shelf (COTS) application products and middleware, have greater portability than other similar products. Finally, the underlying telecommunication capabilities supporting the architecture enable the implementation or relocation of business system and application capabilities when and where needed.
-

Departmental standards compliance is the adherence of the physical components to selected Departmental standards. Departmental standards selected for use within DOE are identified in appendix A, Information Architecture References.

- ☐ **Autonomy** is the ability of each part of the architecture to function independently and as part of the whole regardless of physical location or resource owner. This could include, for example, multiple users operating on the same data element without mutual interference.
- ☐ **Data Accessibility** is the ability to access decoupled data (i.e., data separated from the applications and proprietary operating systems) locally or remotely and use copies of data within accepted limits of age, accuracy, or precision. At a minimum, data accessibility can require standards-based tools for access. This ability enables information to be assembled on demand as compared to current time, place, subject, and owner arrangements.

- ❑ **Interoperability** is the ability to work cooperatively among multiple heterogeneous networks, processors, and databases. Departmental and business area corporate systems should allow effortless exchange of information and services. Generally, the ability to interoperate is on a pass/fail level of performance with limited, if any, information about the cause of failure, including when and where it occurred.
- ❑ **Appliance Connectivity** is the ability for a wide variety of information appliances (e.g., desktop or portable platforms, personal digital assistants, fax machines, credit or smartcard devices, paging and other wireless devices, imaging devices, and printers) with a versatile set of graphical user interfaces (GUIs) to attach to and be disconnected from the business system, application, or infrastructure architecture.
- ❑ **Transparency** is concealment of the physical separation of the user's capabilities and application so business systems, applications, and infrastructure are perceived as functioning wholes, rather than as a collection of independent components. Transparency allows local and remote capabilities to be accessed using identical or similar access operations. In seamless architecture, applied technology provides transparent interoperability of all components to all users. Engineering for transparency across diverse architectural resources can be achieved using one or more of the design approaches listed below.
 - **Distribution Transparency** is achieved by providing a unified interface to computing resources using the same names and operations regardless of physical location or resource ownership. Some replication of resources and components is required; however, this replication is not considered unnecessary redundancy or duplication.
 - **Location Transparency** is achieved by providing consistent appearance and behavior independent of the location of stored data, processors, and other mechanisms.
 - **Access Transparency** is provided by accessing local and remote objects and services using identical access operations from any authorized user in the architecture.
 - **Failure Transparency** is provided by concealing faults and recovery activities from the user by performing system self-corrective actions without human intervention. When potential high-failure conditions are detected, the user is given as much prior notice as possible. For continuity of operations and needed reliability of service levels, duplication of architecture components and capabilities is not unnecessary redundancy or duplication.
 - **Scaling Transparency** is provided by allowing performance characteristics to be maintained despite changes in system and application loads and resource mixes.
 - **Replication Transparency** is achieved by ensuring that viewing and operating characteristics of copied data are consistent with the original data.

- **Migration Transparency** is achieved by allowing business and information entities, files, and services to change locations without disruption to authorized users. The ability to flexibly relocate assets and capabilities is enhanced by adopting common standards and domain-dependent global names for platforms, servers, users, files, distribution lists, access control groups, networks, and system services throughout the architecture.
 - **Concurrent Use Transparency** is provided by allowing multiple users to work in the same database without mutual interference.
- ❑ **Security** consists of preplanned, appropriate integrated protection for data, information, and technology capabilities. This protection requires cooperative interoperability among the systems, applications, and the Departmental infrastructure. Security sometimes takes precedence or priority over other design considerations.

Careful selection of approaches, designs, and components results in a demonstrated project return on investment equal to or better than alternative uses of available public resources. Applications and systems demonstrating these characteristics are consistent with Federal and Departmental architectures that integrate work processes and achieve Year 2000 compliance and required information flows.

3.2 Infrastructure Design Characteristics

The Department's diverse and geographically dispersed business systems and applications users depend on the technology infrastructure to satisfy their information and communication needs.

According to Webster's *Tenth New Collegiate Dictionary*, infrastructure is "the underlying foundation or basic framework (as of a system or organization)." Communications, telecommunications, computer processing, software and middleware, telephone systems, and videoconferencing systems are examples of Departmental infrastructure components. Specific strategic infrastructure capabilities include the DOE Business Network (DOEBN), videoconferencing systems, technology supported learning capabilities, national security communications systems, and electronic commerce/electronic data interchange business processes.

The DOE infrastructure exists within and contributes to a larger evolving Federal configuration, the National Information Infrastructure (NII). The Department's business entity architectures nested within the DOE architecture and their relationship to the NII and the growing Federal Information Architecture are shown in figure 3-2, Departmental Infrastructure Concept. The business systems and applications characteristics, described above, use the DOE infrastructure to interchange information among DOE, public, and other Federal users. The Departmental interoperability standards and protocols represented in figure 3-2, are identified in appendix A,

Information Architecture References. Use of these common standards enables DOE and Federal information architectures to serve their intended purposes through their respective enterprise level infrastructures. The nested DOE business architectures, with their locally developed extensions to the DOE infrastructure, interoperate with the NII independent of geography and technology vintage.

Figure 3-2, Departmental Infrastructure Concept

Like the NII, the Departmental infrastructure is evolving as user demands for capabilities and services are determined. The evolution of computing and information technology suggests that the architecture will concurrently support a great diversity of uses and users. For this to continue, the Departmental architecture and infrastructure must be flexible, with many levels of functionalities and capabilities, many applications and robust services that providers and users can select according to their needs and resources. The Department business needs will evolve as new technology and business service offerings become available.

The Departmental computing resources and communications networks currently make up a complex information infrastructure. Some parts of it, such as the voice telephone network, are well-integrated. Other parts, such as electronic mail systems or videoconferencing, are not as integrated. Similarly, document processing, accounting, and database software currently have limited data-exchange capabilities; therefore, it is often difficult to combine capabilities so they interact efficiently and spontaneously within systems and applications, or with new technologies. DOE intends to evolve a useful, well-planned business system infrastructure that exhibits, in varying degrees, the following characteristics.

- ☐ **Cost effectiveness** - The infrastructure value must be consistent with cost and service considerations. While not strictly an architectural issue, cost effectiveness is a fundamental requirement that will be reflected in the Capital Information Technology Investment planning process.
- ☐ **Flexibility** - The Vision infrastructure must evolve from current resources. The envisioned architecture can be brought about promptly and cost effectively by evolving today's infrastructure by adding new capabilities in an economically sound basis.
- ☐ **Standards** - The basic infrastructure elements and their interrelationships are clearly defined and documented. As increased interoperability and connectivity are accomplished, information management and its infrastructure will become increasingly stable with the support of the Departmental standards.
- ☐ **Accessibility** - The Departmental infrastructure is available to all authorized users. As a corollary, secured data and related supporting infrastructure components will be protected with appropriately limited access.
- ☐ **Scalability** - Common resources offer economies of scale for procurement and process scaling, minimized redundant efforts, and if appropriately organized, identification of competing innovative business and technology solutions. The Departmental infrastructure must be scalable to support multiple corporate systems and technologies. Capacity and performance must grow flexibly as needs increase and systems are extended to thousands of simultaneous users each work day. Further, it should not be overly constrained by specific assumptions of applications or transmission loads, but will instead provide a flexible

structure that can meet, or can evolve to meet, all Departmental needs responsively and cost-effectively.

- ❑ **Ubiquity** - All potential users, regardless of geographical location or device, can readily take advantage of the capabilities and information infrastructure provides. The use of a wide range of appliances permits access to unlimited information sources. Users must be able to change physical locations, terminal types, applications, or service providers while retaining key attributes (e.g., network identity). Users should experience no significant loss in capability beyond those imposed by the constraints of differing network and computational environments (e.g., bandwidth differences between wireless and optical fiber access). In addition, users, as required, should have wireless access to their information, as well as continuous access when mobile. The need for selected capabilities to be available cost-effectively from various locations or means will be supported by analyses and business case justifications.
- ❑ **Integrity** - The infrastructure must operate at such a high level of manageability and reliability that it will be noticeable only when it ceases to function effectively. It must provide high-dependability, high-integrity performance and sufficient integrity, resiliency, replication, and fault detection and isolation capabilities to provide highly dependable operations despite the potential for equipment failures, natural disasters, acts of sabotage, periods of unusual emergency conditions, and high-volume demands. Users may require, and will have available to them, different levels of reliability in accessing and using the infrastructure.
- ❑ **Ease of use** - There should be logical and consistent (preferably intuitive) rules and procedures for Departmental infrastructure use to serve all authorized users. The infrastructure must be easy-to-use, with intuitive and consistent GUIs and should provide a variety of capabilities supporting diverse user communities. Its internal complexities should be hidden from most users.
- ❑ **Interoperability** - The architecture, including its infrastructure, must promote increased interoperability and standards consistent with the DOE information architecture standards adoption and retirement process. The infrastructure must seamlessly link multiple Departmental business areas and the public with other Governmental networks. Like the World Wide Web and the Internet, the Departmental infrastructure will be based upon a concept of network of networks interconnecting numerous public and private networks. Infrastructure users will be best served, if and when, these specific vision networks are linked providing seamless access to all available services.
- ❑ **High-Quality, High-Capability, Modern Services** - The infrastructure must enable and integrate mission-critical systems applications and services that combine audio, video, still image, and other data formats. It should support a full-range of information types and

user-selectable quality levels. For example, these could include delivery of audio from telephone-quality voice to compact disc-quality, motion video from slow-scan through high-definition formats, still images from low- to very high-resolution, and data from simple transfer to telemetry, high-rate transfer of high-performance and scientific computing data, and enable use of large volumes of data in high-performance distributed systems and applications simulations. The Departmental infrastructure should also be able to incorporate new technologies as they become available and permit prototyping of new services and capabilities.

3.3 Replication, Duplication, and Redundancy

Replication is the deliberate use of the same or equivalent patterns, designs, and resources to achieve predetermined business and architectural objectives. The use of replication techniques is often essential to achieve performance and transparency characteristics. Replication of processes, systems capabilities, and infrastructure will be based on design, performance, and cost trade-offs. Operation and support of duplicate and redundant systems and applications, those that are not essential to meet just-in-case conditions, or provide other ways to obtain or provide information services, are unsound and not acceptable.

Architectural replication can be expressed in two ways: logical or virtual descriptions and physical duplication of technology (refer to table 3-1, Architectural Replication Guidelines). Replication can be described as either essential or non-essential depending on whether there is prior analytical support for the duplication.

Table 3-1, Architectural Replication Guidelines			
ARCHITECTURE AND BUSINESS NEED		ESSENTIAL REPLICATION*	NON-ESSENTIAL REPLICATION**
REPRESENTATION	LOGICAL AND VIRTUAL	Architectural documentation and business process descriptions occurring in more than one design	Business process representations and/or design information are unnecessarily complex; may duplicate other more useful architecture representations
	PHYSICAL	Replication based on prior design, performance, and process and investment analyses	Redundancy not acceptable
* Based on prior analysis, design, performance, and investment considerations ** Not supported by evidence of need			

- ❑ **Logical duplication** may exist when the same physical resources, such as the Internet, are portrayed in documentation for several logical systems. Logical duplication, when held to a minimum, contributes to understanding the business functionality being delivered by architectural designs and resources. Re-use of successful designs and sharing of architectural resources are encouraged.
- ❑ **Physical replication** may exist when multiple instances of a particular resource or process are incorporated into a single configuration design. A single instance of a physical resource (e.g., the Internet or the NII) may also exist in two or more logical designs such as those for different business areas or sites. As stated above, a physical duplication design approach is much more expensive to own and maintain and should be based on prior analysis and careful design preparations.

Replication of physical resources and business processes not based upon prior analysis and design activities will not infer essentiality of the resource and will not ensure that the redundant capability will be financially supported.

Replication may sometimes be imposed on the architecture from external sources, which become continuing business considerations and constraints having architectural importance. For example, an organization, user, or business process may be prohibited either by Federal statute, policy, law, or external interconnectivity considerations from accessing or fully utilizing a particular Departmental architectural capability or resource. In such cases (e.g., Energy Sciences Network), the replicated design and functional capability are not redundant even though they may be logically and physically duplicated. Other examples are expected to occur as DOE adapts to the wireless and frequency spectrum change requirements in the Telecommunications Act of 1996. A list of frequently encountered conditions and examples of replication derived from the results presented in the Information Architecture, Volume II, Part 1, Baseline Analysis Summary, is provided in table 3-2, Frequent Replication Conditions and Examples.

Table 3-2, Frequent Replication Conditions and Examples	
CONDITION	EXAMPLE
A capability or component is required for information security or privacy.	Access and password applications
A capability is mandated or directed by the U.S. Government or DOE.	FTS2000 and DOE Business Network (DOEBN)
A capability required by a DOE partner or customer (a non-DOE entity) requires an additional capability other than the choice adopted by others <u>within</u> the baseline.	Wide area networks (WANs), office automation and scientific and engineering applications, and videoconferencing capabilities
A capability is required for non-DOE users because it is essential for public access.	Firewall devices
A capability or component is required when access to a DOE remote location is otherwise limited.	Internet service providers, dial-up access capabilities, and file transfer software
The capability or component is required for intentional backup or continuity of operations.	Storage and communications devices, alternative network capabilities, duplicate instances of database management systems (DBMSs) and other applications, and operational spare desktop platform replacements
An essential duplicate or alternative network is required to provide the needed bandwidth and the total costs of the combined bandwidth are, on the surface and without further analysis, apparently cost-effective.	Data, voice, and video circuits; LANs and WANs; and routers
Capabilities or components that have been approved as part of a pilot project or pending information management solution evaluation.	World Wide Web (WWW) applications, parallel processors, data warehousing devices, commercial off-the-shelf (COTS) workgroup applications, and WWW authoring applications
Capabilities or components that are being replaced, pending management decisions, designs, and deployment plans.	Capabilities or components

4. Information Architecture Program Guidelines

For guidance purposes, the term, information technology architecture, or its shorter reference, information architecture, as used in section 5002, subparagraph (3), and section 5125, subparagraph (d), of the Information Technology Management Reform Act (ITMRA) is an integrated framework for evolving or maintaining existing information technology and acquiring new information technology to achieve the Department's strategic mission goals concurrently with information resources management goals.

The goal of the Department of Energy (DOE) information architecture program is to provide the framework to support Departmentwide information sharing and informed decision making that will result in process improvements and efficiencies and reduce ownership costs. This framework links Departmental and programmatic missions, goals, and objectives and provides increasingly detailed mappings of the information required to support and manage them. It defines the components required at various layers of the architecture model to attain these objectives and relates missions to requirements through the subarchitecture layers to the supporting technology implementations. The framework provides the blueprint for structuring information, applications, organizational, and technological components; their relationships; and the principles and guidelines governing their design and logical evolution. It also forms the basis for planning, budgeting, organizing, and implementing information systems. The DOE information architecture program, the supporting and defining information architecture documents, and this guidance are the formal means to fulfill these purposes.

The remainder of this chapter establishes program guidelines for specific architecture process areas and activities.

4.1 Roles and Responsibilities

The information architecture program continues to achieve consensus that permits coordinated deployment of economical technologies and systems consistent with decentralized organizational business needs. The DOE Chief Information Officer (CIO) leads in facilitating the consensus process by providing vendor-neutral performance assessment, independent trusted data about architecture performance, and neutral forums for the resolution of Departmental architectural issues.

With respect to both technology and its application, consensus may address engineering and business practices, performance characteristics of components or systems, or specifications for

components and technology operations. Agreements can be achieved most effectively where contending ideas, technologies, people, and organizations share broad agreement on the architecture (i.e., the overall plan for systems), guidelines, rules, and standards. While not an easy task to achieve, the Departmental information architecture program continues to support the openness and collaborative efforts of this consensus-based approach.

4.1.1 Information Architecture Program Elements

Decentralized architects must have a common basis and understanding for evolving their local architectures toward achieving Departmentwide benefits and capabilities. The effects of implementing the Departmentwide information architecture on local applications may require program and field sites to create their own architecture. A comprehensive business area or site architecture program for these organizations should include the following components and criteria.

- ☐ Architecture program guidance document
- ☐ Documented baseline and analysis (with periodic updates)
- ☐ Documented architecture vision (with periodic updates)
- ☐ Documented architecture standards
- ☐ An architecture training and awareness program that covers the following aspects.
 - Enterprise business and technology alignment
 - Use of business process redesign methodologies and tool suites by process owners
 - Enterprise architecture planning and development tool suites
 - Architecture proposal and business capital investments
 - Architecture transition/migration plans
 - Technology investment risk measurement and mitigation approaches
 - Architectural configuration management
- ☐ A documented performance measurement program that includes the following.
 - Business and architectural benchmarks and performance measures
 - Investment and technical risk mitigation results
 - Investment performance management
- ☐ A current architecture meta-data repository that identifies the following.
 - Business processes and supporting mission essential systems
 - Information types and data definitions
 - Benchmarks and performance measures (adopted and achieved)
 - Configurations of logical and physical architecture resources and performance requirements

- Business and systems subject matter experts for organizational core competencies
- Indications that future approved system modification activities and work packages have been reconciled with current modification activities

These indicators provide visibility of results for both the direction of architectural changes and the speed or momentum required by the enterprise. They reflect the organization consistency of purpose and success in meeting alignment goals over time.

Distribution and sharing of decentralized architectural information among organizations are essential to maximizing the benefits of common design and implementation opportunities. For sharing purposes, business areas and sites should furnish the CIO with electronic or paper copies of developing architectures, plans, processes, efforts, activities, lessons learned, and information architecture products. The DOE CIO is the focal point for and champion of the information architecture program. CIO responsibilities are formally identified in the ITMRA and DOE Order O 200.1, Information Management Program. Links between site information architecture program pages and the DOE information architecture home page is another way to stimulate information sharing.

Use of formal and structured information architecture approaches is strongly encouraged, though not mandated, to improve interoperability, increase information architecture component integration and reuse, improve data sharing, and reduce the time and cost of delivering updated capabilities. These approaches should integrate business and information models with information technology architectures, budgets and other financial management activities, information strategic planning, management of information technology assets, security of Government telecommunications capabilities, and information security.

The Departmental information architecture development approach recommends decentralized design activities and responsibilities within programmatic areas and sites and allows program offices and field sites wide latitude and autonomy in meeting business needs.

To provide policy direction, the information architecture program is integrated with other established management structures, most importantly the Executive Committee for Information Management (ECIM), the Information Management (IM) Council, and the Information Management Corporate Guidance Group.

4.1.2 Information Architecture Business Process Ownership and Data Stewardship

Information architecture will be driven and shaped by business process owners through the decision-making and governing processes provided by the information architecture program, the ECIM, and the IM Council to ensure that the architecture meets Departmental business needs.

Data stewards may be data administrators, database administrators, or other variations of information librarians. They are responsible for the day-to-day capabilities of obtaining, offering, and sharing information and data in support of these processes. The data stewards will perform major roles in the formulation of architectures that achieve high levels of conformance with the guiding principles. These stewards will exchange business models and rules, information and data models, data definitions and dictionaries, and other data access information upon request from authorized users, process owners, and other DOE data stewards.

4.1.3 DOE Information Architecture Program Phases

The Departmental information architecture program, under the leadership of the CIO, is moving out of the initial phase (illustrated in figure 4-1, DOE Information Architecture Program Phases) toward full institutionalization by 1999. Information Architecture, Volume III, Guidance, should be used with the DOE Information Technology Standards Program Guide to establish and coordinate a comprehensive standards-based Vision architecture.

Figure 4-1, DOE Information Architecture Program Phases

4.2 Framework

The Department has adopted the five-layered framework based on the National Institute of Standards and Technology (NIST) pyramidal architectural representation for illustrating the relationships between business, information, applications, data, and technology environments. The relationship of the information architecture to the business needs of the enterprise is described as the business purpose and contributes to organizational and information technology alignment. The DOE Information Architecture Conceptual Model consists of five interrelated and aligned subarchitectures. The subarchitectures provide a means for organizing, planning, and building an integrated information technology architecture. Figure 4-2 illustrates the Departmental Information Architecture Conceptual Model.

Figure 4-2, Departmental Information Architecture Conceptual Model

The five subarchitectures (or layers) within the Departmental information architecture are described below. Each layer is described individually and has numerous interrelationships with or links to the other layers depending on the individual system or capability being considered.

- ❑ The **Business** layer defines the core business processes of an enterprise or business unit entity at the level necessary to provide the requirements for any and all information management initiatives to support the missions of the enterprise. This layer drives the information subarchitecture. It provides a top-level framework within which business policies and information systems, and other kinds of systems and processes can be placed in context. This layer includes a model of business entities and relationships shown by exchanges of products and services among DOE users and external entities. This layer provides the strategy for beneficial, affordable, and timely information technology solutions and investments. The representatives of this layer include management and business process owners responsible for positioning the enterprise and its information technologies to meet future needs and respond to business events described in the Information layer.
- ❑ The **Information** layer identifies the subject matter that triggers some business event or decision. This layer contains two strata: business information and information management related information.

The business information stratum represents the mission aspects of the business and the information architectural features designed to satisfy the needs of the enterprise. The information that supports external and internal customer requirements is driven by externally originated business events usually documented within the business subarchitecture layer. A business event may be an information request, information product, or service request that requires coordinated actions throughout the information architecture to provide a suitable response. Events may originate from DOE business partners, DOE stakeholders, regulatory and oversight organizations, or vendors and subcontractors. Information, consisting of facts, analyses, and documents or reports, is a critical corporate asset because it enables the Department to provide suitable and timely business responses to its customers and partners.

The information management stratum contains current and future system designs, architecture and business performances, adopted information management best practices, standards, benchmarks, meta- and high-level data, and strategic configurations and Departmental corporate systems architectures.

The evaluations of the timeliness, quality, and cost of DOE business-driven responses include value-added measures to guide investment and development within the information architecture framework. The information subarchitecture components, including standards, are used to collect and organize information, knowledge, and data; influence processing, consolidation, storage, summarization, interpretation, presentation, communication, and distribution; and define and employ applications. The representatives of this layer include

business process owners and users or knowledge workers. The Information subarchitecture drives the Applications, Data, and Technology subarchitectures.

- ❑ The **Applications** layer translates the requirements for information into an automated set of system applications, data processes, and standards that provide direct support to business processes (e.g., software and system design, development, operation, deployment, and follow-on support).

The applications subarchitecture contains at least three substrata: business applications, information management applications, and middleware applications. Business applications, including the systems of which they may be a part, fulfill automated requirements of business events using architectural components and standards. Application logic includes process-decision logic and the application of business subarchitecture policies. Business applications are separated, where possible, from the data and meta-data used in a business process. The separation of logic and data and the recognition that applications encapsulate the use of business policies can assist architectural planners and designers in achieving architecture objectives and minimal design characteristics. This separation also helps fulfill the ITMRA capital investment package time-phasing requirements for investment planning and subsequent implementation.

The information management application stratum contains the applications and utilities needed to design, develop, test, secure, measure, maintain, enhance, and operate the architectural components, especially those in the Departmental architectural infrastructure.

The middleware application stratum provides higher-level functions and services used by multiple architecture components. These higher-level functions include browsers and file system support, authentication and other security functions, tools for coordinating multisite applications, and directory services for storage repositories, name servers, and networks. Middleware provides common services and interfaces between the applications and technology subarchitectures across the Department. The Departmental architecture infrastructure is the primary means of linking geographically separated users. Use of middleware also increases the opportunities for modular applications development and more architectural flexibility. The representatives of this layer include process owners, users or knowledge workers, and information systems staffs.

- ❑ The **Data** layer identifies the structure, definitions, standards, and storage needs of the business entities and elements. It ensures integrity and security of Departmental data and supports the processing of data into useful information. Data is the basis of DOE corporate knowledge and is an essential architectural component that enables the Departmental missions to be performed. This subarchitecture layer contains the business and information management data strata necessary to the ongoing enterprise performance. One example of information management data is the destinations and data/applications server identification

tables needed for data telecommunications. The representatives of this layer include system and application developers, data administrators, and data stewards.

- ❑ The **Technology** layer describes the physical attributes and components of the infrastructure required to support the processing of data into usable information. It consists of computing platforms, infrastructure, standards, special hardware, software, diagnostic and troubleshooting devices, and user and system interfaces. This layer contains five substrata.
 - **Carrier/Transport** substratum, which integrates applications middleware
 - **Telecommunications Network Technology** substratum, which contains the physical telecommunications media including wireless, wire, fiber optic cable, and copper lines upon which logical networks are designed and operated
 - **Network Technology** substratum, which includes software, firmware, and software utilities in efficient design patterns or configurations to make information movement and management possible
 - **Processor Platform Operating System**
 - **Processing Platform** substratum, including servers and satellites, physical routing, switching, and amplifying devices

When integrated, these substrata provide the capability to secure, prepare, transport, process, store, and retrieve business product and service requests and provide the intended business response across highly changeable business, functional, organizational, and geographic boundaries. The representatives of this layer include users and information systems staffs, especially configuration management, system operators, and their supporting contractors.

4.3 Architectural Program Guidelines

4.3.1 Methodologies

The information architecture development methodologies should be appropriate for the level of organizational and information architecture complexities and the scope of the total information management investments. The variations in methodology and analytical scopes are shown in the table below.

Table 4-1, Departmental Methodology Preferences				
ANALYSIS SCOPE		STRONG ANALYSIS (VERY HIGHLY STRUCTURED)	LIMITED ANALYSIS (GENERALLY OR SEMI-STRUCTURED)	NO ANALYSIS (UNSTRUCTURED)
METHODOLOGY	FORMAL	Highly Preferred	Acceptable	Not Applicable
	INFORMAL	Acceptable	Acceptable, But Not Encouraged	Not Recommended
	NONE	Not Acceptable	Not Recommended	Strongly Not Recommended

The use of formal, structured systematic architecture analysis methodologies and techniques is preferred. Informal or less structured architecture analysis methodologies and techniques, are preferred to the absence of applying architecture analysis and development activities. Leaving the detailed system requirements to the individual design phases of each implementation is not a sound architectural approach. Structured approaches that provide the benefits of analyses are the preferred means to change the architecture.

As a supplement to this guidance, another detailed reference entitled Department of Energy Information Architectural Methodology Guide resides in draft form on the Information Architecture Team (IAT) home page. This document currently describes a method for creating an architecture; future versions will also present best business architecture practices, methods, and references.

Larger and more experienced sites and organizations are strongly encouraged to make their information architecture core competencies available to tenant organizations and smaller, more remote sites.

DOE sites and organizations are strongly encouraged to develop information architectures that improve the Department's ability to conduct business among sites and organizations and with

external information customers and business partners. Such efforts can be fully comprehensive or address a single system, program area, business unit, project, or even specific technology using an expanding oil spot approach as illustrated in figure 4-3, Incremental Information Architecture Expansion.

In certain structures, standards, protocols or system parameter settings and subarchitecture components may conflict. If so, conflict resolution should first, ensure the integrity of the DOE infrastructure, and second, recommend suitable changes to the DOE information architecture proponent.

Because of the complexity of the many Departmental business processes, a single, top-down, one-size-fits-all architectural approach is not feasible or even advisable. For this reason, a more difficult, flexible, layered Departmental information architectural approach has been chosen. This approach is championed by the CIO and supported by all Departmental components as a best business architecture process.

The use of formal, structured architectural methodologies is strongly recommended for all Departmental components, complexes, and sites developing an architecture consistent this guidance and the Departmental information architecture.

Although use of analytical tools is encouraged, no single information architecture methodology or tools suite is required or recommended to achieve the goals of this guidance document. An appropriate test of the ultimate worth of candidate methodologies and tools is the ability of the user organization and sponsors to exchange information models, data models (with associated meta-data), network communications and protocol information, and similar information architecture descriptions with customers, partners, and stakeholders.

Figure 4-3, Incremental Information Architecture Expansion

The guidelines in this document are applicable to all business areas, programs, offices, complexes, and sites. They advocate the use of a formal methodological approach to developing information architectures. Departmental components must recognize the need to architect their business areas, enabling them to ensure proper information technology support and solutions. In designing an information architecture, each component, as a best business practice, should ensure compatibility and consistency with the published Departmental information architecture and information architectures of business partners, especially those within the Department. In this manner, information architectures can increase the effective utilization, availability, and potential for using information to support business processes. As architectures are implemented, the CIO can monitor and facilitate inconsistencies or conflicts that may occur. In an iterative and structured manner, current barriers to interoperability within at the technology layer and at sites will be improved, removed, or avoided.

4.3.2 Design Approaches

Information architectures and related activities result in a design approach or living blueprint for structuring information, applications, organizational components (and their interrelationships), and the principles and guidelines governing initial designs and future growth.

The design framework for Departmental information architecture can be expressed in a three-tier model consisting of a user platform tier, a server tier, and a processor platform tier. These are the essential building blocks to which functionality can be allocated to achieve design and performance objectives. The three-tier model can be viewed from two opposing perspectives. The first is the bottom-up, knowledge worker view, which is useful for envisioning user-level capabilities and system transparency opportunities. The second is the top-down, DOE enterprise structural view, which can be used to examine system integration and alternative technology use opportunities. Both perspectives, as described in chapter 3, Minimal Design Characteristics, are essential for the design and evolution of a functional Departmental information architecture.

Both perspectives may also benefit from the use of architectural design patterns. An architectural design pattern is a reusable, tailorable design of relatively uniform configurations and components, with relationships described by standards and protocols. Architectural patterns provide the following benefits.

- ☐ Proven ability to reproduce the intended result at other times and locations
- ☐ Proven value of designs to be reused thereby reducing
 - Development risk
 - Development time
 - Performance failure risk
 - Maintenance effort and cost

Patterns provide a Departmental basis for interoperable global and local architecture evolution and a mechanism for reducing information technology investment risks.

4.3.3 Flexibility

The combined impact of recent and continuing external events and forces requires improvement of Departmental capacity to flexibly provide information for operations and decisions support and enable the Departmental information architecture to evolve or migrate through system lifecycle phases, including the following.

- ☐ New systems, technologies, and techniques for sharing and using information based on business case development and process and technology requirements analyses.
- ☐ Re-engineered business processes, such as through application of the Strategic Information Management (SIM) process, and systems that have been revamped using structured methodologies to increase value-added merit and leverage technologies and prior investments.
- ☐ Adapted legacy systems that are isolated or rendered more interoperable, so that future replacement is easier and less disruptive. This openness includes improved opportunities for resolution of Year 2000 challenges.
- ☐ Ongoing enhancements to the installed base, which exploit new technology offerings or make existing systems more productive or effective with the business and technology subarchitectures.

4.3.4 Implementation

The information architecture is implemented across the five layers shown in figure 4-2, Departmental Information Architecture Conceptual Model, in the following major Departmental architectural configurations.

The **Departmental infrastructure** consisting of sites within various types of gateways and communications service access capabilities and Departmentwide services (e.g., telecommunications, communications servers, service provider capabilities, consolidated information management procurements, information architecture management, strategic information management planning, policy and program integration, standards management, technology assessment, Departmental system development and support, and similar enterprisewide processes). These infrastructure capabilities provide backbone capabilities to support the entire Department.

The **Departmental systems** supporting corporate business needs between Headquarters, field sites, and customers and partners, such as executive information and tracking systems; financial, facilities, and personnel management; science and technology information collection and distribution; environmental safety and health; common user authorization resources; and security.

The **local business unit systems** at sites or within programs support local business needs, strategic and otherwise, but are not recognized Departmental, corporate, or other enterprisewide systems. These systems, even if they provide corporate data, can still be considered local, except in instances where a corporate module is used. In this instance, the module is a part of a Departmental system, even if locally implemented.

Customer and partnership systems may require configurations and standards that are not directly controlled by DOE business units. Examples include electronic commerce, electronic grants management, videoconferencing, secure voice and message transfer with Department of Defense (DoD) and other Federal Agencies, U.S. Treasury systems, and Departmental contractor information systems.

Local applications in support of business and information resource management and technology processes can serve multiple sites, share information among business and programmatic areas, and require the capabilities enabled by Departmental corporate systems and local business unit systems. Local applications can be used to exchange information and data with other sites, business and program areas, and open systems products and commonly used protocols.

Data repositories (warehouses) providing primary and backup storage and archival functions for Departmental, infrastructure, and local and remote or replicated information management systems and applications. These repositories warehouse data structures, business rules, architecture designs and models, meta-data, and data for diverse functions and processes.

4.3.5 Levels of Technology Maturity

Information resources can also be described by their technological maturity. In some cases (e.g., multiple parallel processors and very large scale storage devices), the Department's technological maturity assignment may be on the vanguard of industry or other Federal Agencies. At the other end of the spectrum, the Department lags behind the marketplace in deploying technologies. Innovation requires adherence to a baseline and selective freedom from overly rigid information technology standards. This crucial balance, when abused in either direction, can result in waste, inefficiency, and lowered infrastructural interoperabilities. The technology maturity levels used as benchmarks within the architecture are defined in the following paragraphs.

- ❑ **Experimental** - This level of maturity is reserved for initial technology examination, proof-of-principle pilot projects, and exploration of business benefits for possible future architectural capability. This level is not to be confused with program responsibility for scientific computing, which is often experimental by nature. While experimental projects can require temporary and quickly reversible infrastructure alterations, these local modifications are not regarded as permanent changes of Departmental architecture. This type of project allows for examination of new or innovative technologies without a permanent alteration of

the Departmental or business unit architectures or commitments to full-scale deployments. The usefulness of the technology within the business areas rather than return on investment or adherence to standards, indicates the merit of further implementation. Current examples could include object-oriented software technologies, voice-activated computing, smartcards, and digital authentication/digital signature capabilities.

- ☐ **Adoption and Expansion** - This level of maturity is reserved for planned architecture project implementations and development that add to or replace existing baseline capabilities. Multisite deployments, training activities, procured and leased investments, and changes to established data, applications, or technology subarchitectures are included in this level. At this level, baseline capabilities and standards evolve concurrently, and merit is determined by the usefulness of the technology and the return on investment or other acceptable business case evaluators. Examples include data centers and client/server conversions.
- ☐ **Formalization** - This level of maturity is reserved for planned architecture projects that continue to add or replace baseline capabilities. It is usually marked by an increasing number of multisite deployments, more intensive and advanced training activities, additional procured and leased investments, and widespread changes to established data, applications, and technology subarchitectures. Examples include Internet usage, CD-ROM libraries, and videoconferencing.
- ☐ **Mature** - This level is reserved for planned architecture projects and other initiatives that continue to provide established and proven baseline capabilities. It is marked by decreasing rate of multisite deployments; reduced skill-sustainment training activities and procured and leased investments; and widespread changes to established data, applications, and technology subarchitectures. Examples include e-mail usage and integrated office automation packages.
- ☐ **Obsolete** - This maturity level is reserved for technologies and capabilities within the baseline, which are or should be considered for elimination or replacement. It is marked by an absence of multisite deployments; low skill-sustainment training activities; reduced or halted investments; and no further enhancements to established data, applications, and technology subarchitectures. Examples include key punch machine capabilities, Intel-based and other desktop platforms (at less than 100 MHz) and earlier computer platforms, slow-speed modems (below 9600 baud), much of the DOS-based and non-Windows-based software, and proprietary database management software applications, which are no longer vendor-supported.

4.3.6 Modeling

Any acceptable means can be used for modeling business processes and information flows. A single structured or semi-structured analysis approach may result in using a family of models to analyze, evaluate, develop, and deploy a system design within an architectural framework. The use of models ensures that quality is incorporated into architecture evolution, processes can be repeated, design instances can be replicated changes are managed, and investment alternatives described. A business model for the sponsoring organization plus other typical representations as shown in table 4-2, Architectural Models and Representations, may be part of the process.

Table 4-2, Architectural Models and Representations	
SUBARCHITECTURE (LAYER)	MODELS AND REPRESENTATIONS
Business	Entity-relationship diagrams (ERD), business relationship models, business products and services corresponding to processes, value-added chain models, business performance models, and similar information representations
Information*	Best practices being employed, adopted standards, subject area experts, physical configurations with overlaid logical or virtual design mappings, design structure charts, access control mechanisms, data definitions, data naming conventions, data structure and control charts, server and domain naming conventions, network structure diagrams or tables, failure/recovery information, business rules, benchmarks, architectural plans and strategies, and simulation models
Application	Logic flow diagrams, applications structure tables or charts, logical and physical descriptions of applications within a business or system context, and distributed logic charts and tables
Data*	Data flow diagrams (DFD), tables, or charts and replication diagrams
Technology	Network structure flow diagrams or tables, access path diagrams, transition diagrams, processor, network, server, hardware appliances such as videoconferencing, printers, scanners, smartcards and similar devices, digital assistants, storage devices, wiring diagrams of circuits and segments, configuration designs, wireless frequency tables, and processor and network device transaction timing diagrams
*There are obvious relationships between these layers and many would debate the inclusion or exclusion of one or more of the potential models/references and where they are described. This chart points out the most relevant models; many of those listed were implied throughout chapter 3, Minimal Design Characteristics.	

These models and representations are the result of business processes and technology requirements that have been analyzed to provide architecture and standards-based solutions. In addition to their value to system designers, these models and representations enable organizations

to describe how business needs are or will be satisfied. They aid in transferring sound solutions across the Department.

The use of architectural tools and models is strongly recommended. The selection of a useful set of tools is left to the discretion of the sponsoring organization, subject to their ability to achieve the Department's architecture principles and objectives. Information systems architects should also provide hard-copy, electronic copies, or the home page address for architecture products to the DOE CIO for sharing, Department outreach assistance, and possible re-use.

Creation of an information architecture is not a one-time activity nor should it result in a static and unchangeable representation. It is a programmed method for performing information management. The information architecture, as described in this document, must be periodically revisited and updated so that it continues to be an effective business resource and tool.

Since no single set of modeling systems and architectures has been identified for use within DOE or the Government, Departmental organizations can use suitable tool suites, such as commercial Computer Aided Software Engineering (CASE) tools; Integration Definition for Function Modeling (IDEFO), Federal Information Processing Standards Publications (FIPS PUB) 183; Integration Definition for Information Modeling (IDEFIX), FIPS PUB 184; and Information Engineering Facility (IEF). Among other considerations, the sophistication of tools used should be based on prior experience with information modeling, project size and strategic importance, prior investments, and re-use of analytical products, meta-data, data structures, and generated code. Developing and documenting information architecture designs with tools are preferred to intuitive or academic alternatives. Use of object-oriented tools is preferred to entity-relationship modeling, which provides less insight into meta-data needed by other users or organizations. Entity-relationship modeling is preferred to the absence of modeling.

4.3.7 System Design and Development

System design and development activities should be guided by a lifecycle model and methodologies suitable to the business unit needs, the scale and complexity of the technology development effort, and the sophistication of the designing activity. A highly recommended approach is presented in the DOE Software Engineering Methodology, dated March 1996. Across the Department, diverse lifecycle models, such as a waterfall system development life cycle model (SDLCM), spiral life cycle models, rapid applications prototyping and development (RAD), joint applications development (JAD) approaches, are used for full and partial systems development and maintenance. There is no preferred model or methodology, but all applications and systems designs, enhancements, and information resource planning activities should be guided by an appropriate system development lifecycle and model.

4.3.8 Measurement

An effective architecture program requires measurement of important business activities and information systems services prior to and after initial investments are made. Measuring information resource services and information technology performance is essential to evaluating costs, benefits, and effectiveness. Business units and programmatic areas are strongly encouraged to establish and maintain information resource measurement capabilities and periodically review information architecture usage patterns. They are also strongly encouraged to adopt measurement approaches and indicators that enable comparisons to other Departmental business units, Federal and State Agencies, and the experience of leaders in the commercial sector. The Departmental approach to information architecture measurement contains three aspects.

- ❑ **Business Products** - Delivery of business information products and services is the basic goal of all information management activities. The extent to which business objectives are supported by the architecture is measurable. Measurements should be based, in part, upon the business purposes for which a service or capability is provided. For example, useful units of measure can include the number of business processes or operations reengineered; the number of simple or complex documents produced; the number of documents distributed to customers; the number of business staff supported with e-mail; the number of e-mail messages with and without attachments; the number of downloads at a Departmental Intranet server; the volume and growth rate of storage space used for publicly available information; the return on investment for planned capabilities; and organizations with similar business-related entities, benchmarks, and measures. When related to investment and operational cost factors, measurements can provide decision makers with knowledge to evaluate return on investment decisions. Relating business product value (benefits) to these cost factors allows decision makers to compare expected returns with actual expenditures and assess the results of productivity improvement and cost reduction activities.

- ❑ **Architecture Capabilities** - The architecture is an essential capability delivering business products and services. Architecturally oriented measurement systems are based, in part, upon supporting information architecture capabilities, such as the following.
 - Size of e-mail messages with attachments sent or stored over a period of time
 - Amount of staff time required to redesign and deploy new systems and applications
 - Utilization rate of local area networks (LANs) and Departmental service provider gateways
 - Response times and reliability levels experienced

- Corporate or other system development/design/program activities in terms of function points
 - Extent to which capabilities are delivering anticipated benefits
 - Extent to which the entire site or program architecture is mapped
 - Extent to which proprietary standards are replaced within standard operational capabilities, utilization of standards references in acquisitions, and similar measures
- ❑ **Resource Usage and Usage Rate Changes** - Measurement and supporting systems should guide and enable decisions regarding changes in operations or to the architecture that identify new capability levels, reallocate existing capabilities, or dispose of unneeded capabilities to meet business and infrastructure demand changes. This aspect of the measurement system ensures that the indicators of information resource capability facilitate and enable continued realignment with business needs and resources.

Measurements derived from the information architecture require a structural approach and conscious linkage of cause and effect or input and output. While there are no universal sets of factors, products, or processes to be measured or preferred measurement methodologies or tools available, these are growing assessment areas. For example, the areas of increased flexibility and lowered risks are receiving increased attention as architectural measures. In addition, greater attention to measurement and new approaches are being furthered within the software engineering discipline, including faster quality development, the ISO 9000-9004 standards, the Software Engineering Institute capability maturity levels, and other total quality management practices.

5. Information Architecture Standards

The evolution to a flexible, open, and interoperable architecture requires that system designs be implemented using Departmentwide standards. Over time, interoperability problems will be resolved through the widespread use of an increasingly limited set of agreed-upon standards.

5.1 Architecture Standards Program Framework

The Departmental information technology candidate standards presents guidance for achieving interoperability within the Department of Energy (DOE) community and with business partners and stakeholders. While not mandatory, requiring these standards should be enforced for contracts that use Departmentwide technology implementations (e.g., Telecommunications Integrator Service (TELIS) contract). The DOE Chief Information Officer (CIO) will measure architecture implementations using these standards to assess the extent to which these contracts contribute to the Department's investment returns. DOE Information Technology standards must be carefully considered whenever more than one business area, program, business function, or site are involved and supported by technical information system solutions.

Without adoption of common standards as guidance, achieving higher degrees of interoperability throughout the Department is unlikely. Standards are an important pillar in the Departmental information architecture, and they must be advocated and stewarded by the CIO to benefit the Department.

Within the scope of approved Departmental standards, business areas and organizational components should evolve and implement standards that support their information architectures. Whenever a Departmental standard should change or be retired, the organizational component or affinity group, by way of its information management, should notify the CIO and, when appropriate, to nominate a replacement standard.

5.2 Standards Adoption Processes

To further the standards-based open systems approach, the Department established an information architecture standards adoption and retirement process and, with substantial Departmentwide contributions, an initial set of proposed standards. After a full review and approval process in fiscal year (FY) 97, these standards will supplement the architectural principles and add a significant building block to the Departmental information architecture. The Departmental standards adoption and retirement process is described in the DOE Information

Architecture Standards Adoption and Retirement Process Service Action Plan and the DOE Information Technology Standards Program Guide.

The baseline consists of selected standards from the Government and other standards bodies. Departmental policy will comply with all mandatory Federal standards and specifications. Federal standards (e.g., Federal Information Processing Standards Publications) and DOE policies that specify standards were identified for 10 standard service areas. Additional de facto standards may be identified when the baseline analysis update is completed.

The success of this architecture is tied to establishment and implementation of a successful DOEwide standards process. Industry, standards bodies, and DOE are developing a methodology for identifying, defining, and communicating standards and their level of adoption. DOE is establishing a process for continued review of DOEwide and subsidiary programmatic, sitewide architectures. A library of terms, definitions, access rules, characteristics, and interrelationships of each standard component will be developed to support dialog on corporatewide requirements.

Current stovepipe systems are being replaced by integrated subsystems. Standalone systems (i.e., commercial-off-the-shelf (COTS) products) acquired for use by DOE from external organizations and partnerships must be integrated as subsystems depending on their data, processes, or need for telecommunications and security services. Increasingly, DOEwide acquisitions will be aligned with approved Departmental standards. Other acquisitions will be measured and viewed in light of specification to standards.

Achieving the information architecture vision for DOE information resources requires greater Departmentwide interoperability than exists today. The adoption of DOEwide standards, protocols, and best practices will enhance information exchange. The standards-setting process must meet the needs of the entire DOE community and be dynamic enough to change as the information technology base changes. Adopted standards are analogous to building codes. They form a fundamental set of requirements that ensure the DOE information architecture is a sound, practical, and solid set of structures. The architectural infrastructure must interface safely and effectively with infrastructural components, such as applications and networks, and allow owners to optimize their work processes according to business drivers and needs.

5.3 Standards Scope, Use, and Applicability

The Department will strive to use open systems standards throughout architectural implementations as described in Volume I, The Foundations, and other standards references. Use and applicability of specific DOE-adopted standards is not mandatory; however, when and where possible, adopted standards are strongly advocated. When they do not apply, exemption should be documented. Other voluntary or Federal standards can be locally adopted if they do not impair or otherwise render the DOE information architecture less flexible, interoperable, or capable.

Interoperability among business areas, sites, and customers, as well as the ability to collaborate on a Departmentwide and global basis, requires Departmentwide use of consistent and compatible standards. When local standards, products, or services are employed that are not consistent and compatible with corporate standards that organization will not be given additional support to overcome interoperability and collaboration problems. Choice to use other than DOE-established standards and protocols requires these organizations to assume the training, conversion, and adaptation costs without shifting these adverse effects to other compliant DOE organizations and customers.

In addition, the CIO will periodically review various implementations, designs, and acquisitions to determine if Departmental information architecture principles and standards have been followed. Exceptions will be challenged and reported. In extreme cases, system development or implementation cancellation could occur and/or funding withdrawal or reduction recommendations may be pursued.

Lastly, the Office of Management and Budget, through recent Federal CIO Council activities and guidance, requires that all CIOs mandate a minimal set of standards to establish increased levels of interoperability throughout the Federal Government. While DOE has resisted mandatory standards because of its consensus-based standards approval process, the issue of mandated standards could be revisited, if it is determined that the current approach is not working.

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6. Summary

Application of guidance and adherence to the architecture goals, principles, and approaches will enable decision makers, process owners, partners, and users to realize the benefits of increasing interoperability and easing of current architectural and design restrictions. System developers, operations staffs, contractors, and others will be able to better assess and describe the contributions of technologies new to Department of Energy (DOE) business areas. Based on these efforts, a coordinated and pervasive vision architecture of increased interoperability will be established Departmentwide.

The DOE information architecture will be characterized as providing transparent, reliable, non-redundant reach to diverse computing appliances providing access to the wealth of Departmental information, and to maximize enterprise capabilities in a flexible, adaptable, and affordable manner. Finally, application of these guidelines will ensure that the business needs and technology capabilities become closely aligned at all levels of the architecture.

This Guidance is in effect as of the date on the cover and will periodically be supplemented or changed as needed to ensure appropriateness and usability. Additional Office of Management and Budget or other guidance will be posted as available to the Information Architecture home page at www-it.hr.doe.gov/iat.

Appendix A

Information Architecture References

1. Title 5, United States Code 552, The Freedom of Information Act (Public Law 89-487), as amended, which establishes the right of citizens to request information from Federal Agencies and establishes a framework of procedures to implement this right.
2. Title 5, United States Code 552a, Privacy Act of 1974 (Public Law 93-549), as amended, which establishes requirements for the collection, maintenance, and dissemination of personal information by Federal Agencies.
3. Title 5, United States Code, Section 306, Strategic Plans, establishes that no later than September 30, 1997, the head of each Agency shall submit to the Director of the Office of Management and Budget and to the Congress a strategic plan for program activities.
4. Title 5, United States Code, Section 5315, Positions at Level IV of the Executive Schedule, lists the positions for which the annual rate of basic pay is the rate determined with respect to Chapter 11, Citizens' Commission on Public Service and Compensation, Title 2, United States Code.
5. Title 31, United States Code, Chapter 11, The Budget and Fiscal, Budget, and Program Information.
6. Title 44, United States Code, Chapter 33, Disposal of Records, specifies the functions and responsibilities for managing Federal records and the procedures that must be followed to obtain approval for their disposition.
7. Title 44, United States Code, Section 3506, Federal Agency Responsibilities, establishes Agency responsibility for carrying out information management activities, complying with information policies, principles, standards, and guidelines prescribed by the Director, and designating a senior official to carry out the responsibilities of the Agency under this chapter (Chapter 35, Coordination of Federal Information Policy).
8. Public Law 104-104, Telecommunications Act of 1996, promotes competition and reduces regulation in order to secure lower prices and higher quality services for American telecommunications customers and encourages rapid deployment of new telecommunications technologies.
9. Public Law 104-106, Information Technology Management Reform Act (ITMRA) of 1995, authorizes military activities appropriations for fiscal year 1996 and effective August 8, 1996, rescinds the Federal Information Resources Management Regulations (FIRMR) and establishes the Chief Information Officer (CIO) functions.

10. Public Law 104-113, National Technology Transfer and Advancement Act of 1995 amends the Stevenson-Wydler Technology Innovation Act of 1980 with respect to inventions made under cooperative research and development agreements, and for other purposes.
11. Public Law 104-13, Paperwork Reduction Act of 1995, as amended, and its predecessor Public Law 96-511, Paperwork Reduction Act of 1980, establishes a broad mandate for Federal Agencies to perform information activities in an efficient, effective, and economical manner, and specifically recognizes the General Service Administration's role in the acquisition and management of computing resources.
12. Public Law 103-62, Government Performance and Results Act of 1993, requires agencies develop strategic plans and performance measures. It starts with a series of pilot programs and allows waivers of regulations for some of the pilots.
13. Public Law 100-235, Computer Security Act of 1987, provides for a computer standards program within the National Institute of Standards and Technology (NIST) for Governmentwide security and training in security matters of persons who are involved in the management, operation, and use of Federal computer systems and for establishing minimum acceptable security practices for protection of sensitive information.
14. National Performance Review (NPR) has a total of 384 recommendations, encompassing approximately 1,200 individual actions. To date, approximately 49 percent of NPR recommendations involve legislative action; 25 percent of all actions involve legislative activity.
15. National Security Decision Directive 42, dated 7-5-90, establishes initial objectives, policies, and organizational structures to guide the conduct of activities to secure national security systems from exploitation.
16. National Security Decision Directive 97 (unclassified version), National Security Telecommunications Policy, dated 8-3-83, establishes the policy for integrating the Nation's telecommunications resources essential to national survival.
17. Executive Order 12862, Setting Customer Service Standards, dated 9-11-93, requires that Agencies serving the public define who their customers are and develop and post service standards that are the best in the business. They must benchmark standards, survey their customers, provide alternative choices, and provide means for redress. This is intended to change the current orientation of agency service delivery.

18. Executive Order 12861, Elimination of One-Half of Executive Branch Internal Regulations, dated 9-11-93, requires that Agencies reduce half of their internal regulations within 3 years. This is intended to help streamline the headquarters bureaucracy and empower line managers to focus on results and customers, rather than mere compliance with rules.
19. Presidential Memorandum, Implementing Management Reform in the Executive Branch, dated 10-1-93, directs all Agency heads to designate someone as chief operating officer and creates the President's Management Council—comprised of chief operating officers—to help lead reinvention efforts across the government. This is intended to serve as the main nerve center for the culture change and overall reform implementation efforts.
20. Presidential Memorandum, Streamlining Procurement Through Electronic Commerce, dated 10-26-93, encourages the exchange of procurement information, such as invoices, electronically between the Federal Government and private sector. It also provides small businesses with greater access to Federal procurement opportunities and simplifies access via standardized formats, using existing networks where possible.
21. Office of Management and Budget Memorandum, Funding Information Systems Investments, dated 10-25-96.
22. Office of Management and Budget Memorandum, Government Performance and Results Act, dated 10-8-93.
23. Office of Management and Budget Circular A-11, provides detailed instructions and guidance on the preparation and submission of agency budget requests and related material for the 1998 budget. Part 2 of the Circular provides specific instructions on the preparation and submission of agency strategic plans required by the Government Performance and Results Act of 1993.
24. Office of Management and Budget Circular A-130, Management of Federal Information Resources, dated 2-8-96, establishes policy for the management of Federal information resources.
25. DOE Order O 200.1, Information Management Program (the consolidated information management Order for the Department).
26. Department of Energy Strategic Plan.
27. Department of Energy Information Management Strategic Plan.

28. Department of Energy Information Architecture, Volume I, The Foundations, March 1995.
29. Department of Energy Information Architecture Standards Adoption and Retirement Process - Service Action Plan, December 1996.
30. Department of Energy Information Architecture Profile of Adopted Standards (Draft), April 1997.
31. Department of Energy Information Architecture, Volume II, Part 1, Baseline Analysis Summary, December 1996.
32. Department of Energy Information Architecture, Volume II, Part 2, Baseline Analysis, December 1996.
33. Department of Energy Information Architecture, Volume II, Part 3, Reference Data, December 1996.
34. Department of Energy Information Architectural Methodology Guide (no date).
35. Department of Energy Management Standards Program and Process Guide, September 1997.

Appendix B

Architecture Configuration Scales

This appendix is intended to introduce and describe the several scales of architectures included within the Departmental information architecture and for those external architectures with which the Department of Energy (DOE) must interoperate.

Foundations Contribution

In Information Architecture, Volume I, The Foundations, the concept of interrelated architectures within the Department was presented. The various terms used to describe these relationships included interoperable, nested, and integrated. The links between the five layers of the DOE model were initially defined as interconnected. Other documents, such as Volume II, Baseline Analysis; Volume III, Guidance; Volume IV, Vision; and Standards further elaborate on these ideas. The concept of a user-centric architecture reoccurred and was elaborated on in different ways.

Baseline Analysis Contribution

Information Architecture, Volume II, Baseline Analysis, identified 13 categories of information technologies used in DOE; described the business subarchitecture by organization types; and discussed the uses of technologies for mission achievement by the implied design patterns, standards, and protocols, and for impacts on focal areas of continuing management interest.

The baseline was analyzed for the eight principles. The information products and services delivered varied widely due to differences in business processes, the age of legacy components and designs, and the scale of information technology at each location. The architecture was viewed and described in different and often mutually exclusive ways, depending on the configuration language used at each site or business area. Description was difficult because virtual or logical designs were intertwined with physical descriptions and component designs. The Baseline Analysis suggested that the various architecture scales required a new approach to classifying the complexity of architectural designs and information service organizations Departmentwide.

Standards Contribution

The Departmental information architecture standards program identified an initial set of candidate standards toward which the Department would migrate as business processes were redesigned and architectures modified. The standards adoption and retirement process will enable the Department's diverse information management capabilities to evolve toward a more interoperable architecture. In doing so, many of the problems (and strengths) identified in Volume II, Baseline Analysis, will be appropriately addressed. The adopted standards will provide the rules and glue referred to in chapter 1, Introduction, of Volume III, Guidance.

Vision Contribution

In preparing the Information Architecture, Volume IV, Vision, many information technologies were viewed as either user-centric support or, from the other end of the spectrum, wholesale capabilities of numerous types of technologies. Technologies were expected to be efficient, cost effective, or sound investments that could deliver capabilities across business areas, program areas, and sites. Broadband communications, massive data warehousing, electronic commerce, technology supported learning, and intranet capabilities provided means for satisfying a wide range of user demands; therefore, the user-centric view needed to be supplemented (not replaced) by a technology-centric view. This view required that the special information management services provided by large sites, business areas, and complexes deserved architectural notice because they operated on very much larger information movement and management scales. One or two gigabits of operational functionality at the desktop inevitably cascaded into Very Large Databases (VLDB) requiring massive amounts of real-time telecommunications bandwidth and processor power.

Guidance Contribution

Different scales of architectures are implied when one examines desktop environments, business system environments, and infrastructures. The baseline infrastructure should provide major opportunities for improved efficiencies of scale, improved costs of ownership and operation through data center consolidation, and increased procurement savings over the life of an information architecture project. The possible improvements were achievable at some sites for some technologies, business areas, and types of business events. Since the baseline had different scales of infrastructures within it, the need to describe them emerged. Improvements should be aimed at the portion of the architecture where their effects can be measured and managed.

In chapter 3, Minimal Design Characteristics, a distinction between business systems and the infrastructure was presented. Business systems and applications represent a user-centric view of information management technologies within the architecture. The infrastructure, through wholesale movement and management of information, provides the connectivity between geographically and chronologically dispersed users in different business systems. Neither is dominant; both are required. One represents the enterprise and the other serves as the enterprise's machinery to do productive and cost-effective work. Just as there are different sizes of organizations to do the Department's business, there are different sizes of technology aggregations in different locations to support them.

Table B-1, Architectural Configuration Scales, provides an information technology guideline for three scales of business systems and infrastructures applicable to the Department's architecture: desktop, system, and infrastructure levels. While architecture rules for very large scale information systems have yet to be formulated, the use of entity-relationship approaches employing entity cardinality (many-to-one, one-to-many, many-to-many, etc.) appears promising.

The table presents an initial attempt to describe DOE architectural objects, the “whats,” and their cardinality in useful terms. The units of measure become more inclusive of diverse but finer measures as the scale of architectures increases. Portions of copper pennies, ounces of precious metals, and assets that cover the full-range of value (currencies, debts, real estate, stocks, bonds, etc.) are represented in the units of measure provided. A sample of the driving considerations affecting the Department’s architecture at each of these levels is provided. User-centricity and responsiveness at the lowest levels should be supplemented by wholesale measures of technology and investment soundness at the most concentrated or higher levels. The system level can be seen as providing many applications and users with the capability to interoperate with many other sites using many other technologies. Systems interoperate with other systems and infrastructures. At the higher levels, business event satisfaction occurs as the architectural designs, components, and invoked standards are integrated into capabilities driven by desired information architecture system events and processes. Linkage between applications, business systems, and infrastructures has, until now, caused large-scale architecture operation, maintenance, and performance improvement to be elusive to investment and performance-oriented decision makers.

This description of Departmental architecture levels has another value in providing the framework for identifying how business-driven processes and technologies become integrated with larger systems and infrastructure capabilities. It also provides a reverse view; that is, technology-driven solutions developed for new or more cost effective enterprise information management processes, primarily within the infrastructures and in larger business systems, inevitably lead to impacts in and on the user-centric desktop environment. Finally, as some powerful technologies, such as client/server computing designs become the core of a business system, the impacts radiate outward into both the user level and the infrastructures. These paths to architecture and business change at specific levels of the architecture, from whatever source, provide a more complete description of the cooperative and integrative implications represented in the oil spot diagram (refer to figure 4-3, Incremental Information Architecture Expansion).

Table B-1, Architecture Configuration Scales			
Architectural Level	Meta-Object Relationship	Analogous Unit of Measure	Driving Considerations Affecting the Departmental Architecture
User Level		\$Currency	
Desktop/Distributed Applications	Many Users to Many Desktops or Local Applications	1/5 Cent (One Million)	Business event completion, user accessibility, user interfaces, transaction volume and size, connectivity to other users, and systems capabilities
System Level		Weights of Precious Metals	
Business System	Two or More Mission-Essential Applications to a System	One Ounce of Gold	Business event process complexity and diversity, transaction merger, storage, reporting, and history
Information Management System	One or More Mission-Essential Applications to a System	One Pound of Platinum	System event and capability management for multiple technologies and designs
Infrastructure Level		Banking	
Office within Buildings	Many Applications in Two or More Systems to One Local Site Infrastructure	ATM Machine Assets	Business event product and service creation, coordination, and distribution; system event and capability management for multiple technologies and designs
Building (Standalone)	Many Applications in Two or More Systems and Zero to Many Corporate Systems to One Local Site Infrastructure	Local Bank With Drive-In and ATM Assets	Business event product and service creation, coordination, and distribution; system event and capability management for multiple technologies and designs; merged transaction processing and reporting requiring higher volume throughput and acceptable response times for all users
Buildings within a Single Facility	Two or More Systems and Zero to Many Corporate Systems to One Local Site Infrastructure	Local Bank Chain Assets	Business event product and service workload merger, routing, and distribution from limited geographically separated locations; system event and capability management for multiple technologies and designs for numerous business systems; merged transaction processing and reporting requiring even higher volume throughput, reliability, and acceptable response times for all users consistent with investment benefit and cost considerations

Table B-1, Architecture Configuration Scales

Architectural Level	Meta-Object Relationship	Analogous Unit of Measure	Driving Considerations Affecting the Departmental Architecture
Campus/Complex of Buildings	Many Systems and Zero to Many Departmental Corporate Systems to One Local Site Infrastructure	Metropolitan Area Bank Assets	Business event product and service workload merger, routing, and distribution from wider geographically separated local locations; system event and capability management for multiple technologies and designs for numerous business systems; merged transaction processing and reporting from other similar organizations and requiring even higher volume throughput, reliability, and acceptable response times for all users consistent with investment benefit and cost considerations
Business Area or Program Area (Geographically Distributed)	Many Systems and Zero to Many Corporate Systems and One Infrastructure Per Site to a Business or Program Area	Regional Bank System Assets	Business event product and service workload merger, routing, and distribution from widely geographically separated local locations; system event and capability management for multiple technologies and designs for numerous business systems existing at this and other locations; highly merged transaction processing and reporting from other similar organizations and requiring even higher volume throughput, reliability, and acceptable response times for all users consistent with investment benefit and cost considerations
Departmental	Many Users to One Departmental Infrastructure; Many Business Area Infrastructures to One Departmental Infrastructure; Many Site Infrastructures to One Departmental Infrastructure; Many Departmental and Corporate Systems to One Departmental Infrastructure	National Bank System Assets	Business event product and service workload merger, routing, and distribution from very widely geographically separated locations having a large degree of information technology diversity, design, and system performance complexity; system event and capability management for multiple technologies and designs for numerous business systems existing at all locations specified by the business subarchitecture; very highly merged transaction processing and reporting from other similar and subordinate organizations and requiring even higher volume throughput, reliability, and acceptable response times for all users consistent with investment benefit and cost considerations

Table B-1, Architecture Configuration Scales

Architectural Level	Meta-Object Relationship	Analogous Unit of Measure	Driving Considerations Affecting the Departmental Architecture
National Information Infrastructure (NII)	Many Departmental, Government Agency, Commercial, and Academic/Non-Profit Infrastructures to One NII	Federal Reserve Bank System Assets	Federal business event product and service workload merger, routing, and distribution from very widely geographically separated locations (at home and abroad) having a large degree of information technology diversity, design and system performance complexity, and information content variety; system event and capability management for multiple technologies and designs for numerous Federal business systems existing at all locations specified by the Federal business and technology subarchitectures; very highly merged transaction processing and reporting from other similar and subordinate organizations and requiring even higher volume throughput, reliability, and acceptable response times for all users consistent with investment benefit, cost considerations, and industry capabilities
World Wide Web (WWW)	Many NII and Other Organizations to One WWW Infrastructure	International Monetary Fund Transfer System Assets	Massive volumes of information requiring the greatest amount of bandwidth and alternative routing means available to support the most heterogenous and complex designs existing in the global infrastructure

Appendix C

Recommended Readings

This appendix provides an annotated bibliography of selected texts and articles used in developing this document. These recommended readings provide forward-looking concepts and sound approaches that are useful for evolving legacy architectures and systems for DOE Vision Architecture. The readings include recent texts and journal articles that provide concepts, approaches, and methodologies that are useful for the Department's widely heterogeneous business and technology environments. The inclusion of the readings on this list does not imply that the texts, authors, or organizations are preferred or given precedence. Where appropriate, DOE subarchitectures associated with an approach or concept are identified for increased understanding of the composition of the DOE Information Architecture Concept Model (refer to figure 4-2, Departmental Information Architecture Conceptual Model).

Vision and Alignment

Boar, Bernard H., Practical Steps for Aligning Information Technology With Business Strategies, ISBN 0-471-07637-6, John Wiley and Sons Inc., New York, NY, 1994. This reference describes the author's approach to examining strategic ways to achieve improved reach, range, and maneuverability for an architecture. The presentation is appropriate for medium to large offices and entire programs and business areas. Mr. Boar's presentations about the role of middleware, the measures of goodness for distributed processing, and the firm as an economy are particularly insightful. While his primary focus is on ways in which technology can increase competitiveness, technologists will find his discussions about issues of interest to Chief Information Officers in a Government and nonprofit environment. His emphasis on the role of middleware as a means of passing telecommunications service messages provided a basis for examining the intertwined issues of hybrid architectures containing serial (or concurrent) and parallel architectures, heterogeneous architectures consisting of object-oriented and traditional applications languages, and the integration of workflow and groupware in a widely geographically distributed collaborative business or scientific computing environment. Mr. Boar was a guest speaker describing how to think strategically about architectures at the DOE Information Management Planning and Coordination Team (IMPACT) IV meeting in Santa Fe, NM, in May 1996.

Boar, Bernard H., The Art of Strategic Planning For Information Technology, ISBN 0-471-59918-2, John Wiley and Sons Inc., New York, NY, 1993. This text is an extended presentation of strategic thinking in accordance with the principles of historic figures such as Sun Tzu and others. It is particularly useful to those interested in evolving their technical understanding from an object's perspective to objectives and outcomes.

Darnton, Geoffery, and Giacoletto, Sergio, Information In The Enterprise - It Is More Than Technology, ISBN 1-55558-091-2, Digital Press, 1992. This text describes the authors' experience developing an information architecture for DEC's European operations over a 10-year period. It describes how they employed an incremental approach in which small strategic advances were made in an opportunistic manner and the nature of the resultant increases in flexibility and benefits.

Eccles, Robert G., and Nohria, Nitin, Beyond The Hype - Rediscovering The Essence of Management, ISBN 0-87584-331-X, Harvard Business School Press, 1992. This reference presents useful case studies of executives developing and employing visions of their enterprises and explains why these visions must be slightly ambiguous and yet be compellingly stated. The ambiguity, required to exploit unanticipated opportunities and alter the plans being implemented, helps to explain why large-scale business and infrastructural systems must be designed for flexibility. This text also offers the reader a wide range of perspectives about the business subarchitecture, the motivations and intent of the executives in it, and the users of information. The section describing the critical components of a Vision and the implied measures of goodness are especially useful for new architecture initiatives.

Kouzes, Richard T.; Myers, James D.; and Wulf, William A., "Collaboratories: Doing Science On The Internet," IEEE Computer, August 1996, pages 40-46. This article, co-written by Myers of Pacific Northwest National Laboratory and Wulf, describes how state-of-the-art instrumentation for complex scientific investigations can bring geographically dispersed individuals from multiple institutions together for achieving scientific objectives. This project was performed for the Department of Energy. Like wall-less libraries, this view of ongoing information sharing is a good example of laboratories without walls. The Guidance document assumes that boundary-less capabilities from applications, data, and technology subarchitectures can be extended to business subarchitecture needs, such as electronic commerce, technology-assisted learning, desktop videoconferencing, and similar extensions of architecture furnished boundary eliminating capabilities.

Ramos, Lisandro R., "Case Study: Los Alamos National Laboratory, A Network Long Overdue," LAN Magazine, Volume 10, Number 9, September 1995, pages 149-153. This article describes the laboratory's use of CD-ROM networking technology to create a digital library without walls in support of high-performance computing and scientific collaboration. While the purpose of this operational capability is to obtain access to journals in science, engineering, physics, chemistry, business, mathematics, geology, medicine, and other online databases (contents of DOE information and data subarchitectures), it provides a visionary solution for other boundary-less business needs, such as electronic commerce and electronic collaboration.

Enterprise Architectures and Process Redesign

Bogan, Christopher E., and English, Michael J., Benchmarking For Best Practices - Winning Through Innovative Adaptation, ISBN 0-07-006375-3, McGraw-Hill, New York, NY, 1994. The text provides approaches for identifying useful benchmarks, integrating them into normal business activities and motivating change through benchmarking and change management. The chapters describing benchmarking in the public sector and managing best practice knowledge are particularly relevant to the executives and organizations in the DOE business subarchitecture.

Cipolla, Emil T., "Data Warehousing Technologies: Data Warehouse Implementation Considerations," Enterprise Systems Journal, Volume 11, Number 8, June 1996, pages 22-28. This article presents a set of typical user characteristics and the relative strengths of hardware and software platforms for consideration in data warehousing applications. These characteristics were expanded and tailored for use by DOE architects in the Guidance document.

Cook, Melissa A., Building Enterprise Information Architectures - Engineering Information Systems, ISBN 0-13-440256-1, Prentice-Hall, Upper Saddle River, NJ, 1996. This text describes and applies the Zachman framework for enterprise architecture approaches and is useful for design and development activities requiring a schema for abstracting levels of system functionality for the several perspectives that must exist in every development team.

Curtice, Robert M., Strategic Value Analysis, ISBN 0-13-851452-6, Prentice-Hall, Englewood Cliffs, NJ, 1987. This reference, primarily treating the application and data subarchitectures, is useful for examining the strategic value of information and the associated strategic value meta-model within an architecture of any size.

Dickinson, Brian, Risk-Free Business Re-Engineering, ISBN 0-9629276-2-7, LCI Press, Kings Beach, CA, 1996. This reference is particularly useful for conducting enterprise architecture efforts where the overall project scope is limited, well-defined, and requires business operations redesign and information architecture development. The descriptions of business events and stimuli and business responses and ways to separate interwoven processes from applications and data sets are particularly noteworthy. While the use of the term risk-free is not altogether appropriate, the suggested methodology does provide a way to demonstrate that the architecture is tied to the missions and objectives of the business subarchitecture. The author's principle of analysis and engineering precedes use of computer-aided engineering and software development tools is fully consistent with DOE objectives. The Guidance document authors adapted his business event and response concepts to describe the top two layers of the Departmental Information Architecture Conceptual Model (figure 4-2) and link them to the three technology subarchitectures (applications, data, and technology).

Grimshaw, Andrew; Wulf, William; and The Legion Team, "The Legion Vision of a Worldwide Virtual Computer," Association of Computing Machinery, Communications of the ACM, Volume 40, Number 1, January 1997. The work in this article was jointly funded by the National Science Foundation and the Department of Energy, Office of Energy Research program under a Sandia National Laboratories grant. This article describes a large-scale, multisite, network-intensive architecture in which design objectives include parallel processing of massive amounts of data and concurrent support to over one million workstations. This article presents many design principles or variations contained in the Guidance document. This architecture, expected to further evolve as systems tools and system management techniques become more robust over the next 10 years, is of particular interest to those concerned with scientific computing. The Guidance document authors view the material presented in this article as developed independent of IMPACT efforts yet is fully consistent and compatible with a subset of the overall DOE architectural requirements.

Saiedian, Hossein, "An Invitation To Formal Methods," IEEE Computer, Volume 29, Number 4, February 1997, pages 16-30. This article describes several contributing presentations by Carnegie and Mellon, NASA Research Center, and SRI International authors, among others, in which the decision whether or not to use formal methods, formal methods already in use, criteria for when rigorous formal methods should be considered, and use of formal identification of the elements for a less rigorous or lightweight approach are presented. The Guidance document authors adapted these considerations in development of this document.

Sowa, J.F., and Zachman, J.A., "Extending and Formalizing the Framework for Information Systems Architecture," IBM Systems Business Journal, Volume 31, Number 3, 1992. This article, the work upon which many others have advanced notions of what, how, where, who, and why in analyzing legacy systems and for developing new applications, is considered must reading for those dealing with architectural issues. The approach assumes that the business subarchitecture goals and needs have already been identified using systems analyses or business operations re-design techniques. The value of this approach was demonstrated during the IMPACT IV meeting in Santa Fe, NM, in May 1996, when it was used to develop an initial outline of the DOE Vision architecture. It is also a fundamental concept used by Spewak, Dickinson, Grimshaw, and Blumenthal.

Spewak, Steven H., Enterprise Architecture Planning, ISBN 0-471-599859, John Wiley and Sons, Inc., New York, NY, 1992. This reference provides a detailed sequence of activities, objectives, deliverables, and considerations for conducting an enterprise architecture effort. It is particularly suited for large or complex activities, especially those in which business operations re-design activities have been completed. Mr. Spewak was a guest speaker describing how to perform architecture planning at the DOE IMPACT IV meeting in Santa Fe, NM, in May 1996.

Welch, Lonnie; Farr, William; and Uehara, Minoru, "Challenges in Metrics and Measurement for Computer-Based Systems," IEEE Computer, Volume 30, Number 1, January 1997, pages 88-89. This short article is useful for benchmarking several performance measures of computing systems.

White, Thomas, E., and Fischer, Layla, New Tools For New Times: The Workflow Paradigm, ISBN 0-9640233-0-X, Future Strategies, Inc., Alameda, CA, 1994. This edited collection of articles by other authors presents an action view of business process reengineering, workflow and groupware capabilities, and the emerging technologies to deliver efficient and user-friendly capabilities. Information from this text was used to assist in articulating the differences in workflows (a process view) and groupware (an application-oriented view) within an electronic commerce or collaborative computing setting in the Guidance document. The discussion of integrated (but not necessarily open-systems-compliant) products, such as Lotus Notes and the case study about George Mason University's experience are useful to system designers and process redesign teams.

The Corporation for National Research Initiatives (CNRI), in Reston, VA, sponsors the Cross-Industry Working Team (XIWT) Home Page (<http://www.cnri.reston.va.us>). This industry group posts numerous useful white papers on National Information Infrastructure (NII). Several recent white papers addressed telecommunications infrastructure, electronic commerce, and numerous scenarios similar to those presented in *Information Architecture, Volume I, The Foundations*, for conveying how emerging technology solutions might be applied to solve practical problems for consumers. The characteristics of an infrastructure presented by XIWT have been adapted for DOE use in chapter 3, *Minimal Design Characteristics*, and chapter 4, *Information Architecture Program Guidelines*.

Architecture Design Principles

Bic, Lubomir F.; Fukuda, Munehiro; and Dillencourt, Michael B., "Distributed Computing Using Autonomous Objects," IEEE Computer, Volume 29, Number 8, August 1996, pages 55-61. This article describes the eight classes of distributed systems that may use smart messages in which the functions of an application can be modified after the application has begun. Using the concept of autonomous objects to activate roving programs, invoke intelligent E-mail entities, activate intelligent browsers, and operate or control simulations, the authors provide a view of emerging capabilities in a wide area network environment. This concept could also enable computer processes to operate concurrently in either scientific or corporate systems applications. Architects using this concept would require their designs to be compatible with other designs, such as parallel processing, and non-object-oriented technology components, such as those expected to evolve within DOE's heterogeneous computing and business environments.

Blumenthal, Marjory, "Unpredictable Uncertainty: The Internet and the Information Structure," IEEE Computer, Volume 30, Number 1, January 1997, pages 50-56. This short article describes the anticipated change in Internet usage patterns, but it is more notable to the Guidance document authors for its description of the substrata within two of the Department's information architecture model layers. This approach allowed the DOE architecture model to be further defined in terms that reflect the contributions of the many families of technologies identified in Volume II, Baseline Analysis, and Volume IV, Vision.

Boar, Bernard H., Implementing Client/Server Computing, ISBN 0-07-006215-3, McGraw Hill, New York, NY, 1992. This text established the author's basic tenets for his subsequent works. It is useful for developing measures of goodness by which client/server architecture designs can be described to the business subarchitecture process owners.

Boar, Bernard H., Cost-Effective Strategies for Client/Server Systems, ISBN 0-471-12846-5, John Wiley and Sons, New York, NY, 1996. This reference provides a more current description of the author's approach to strategic design and employment of large scale architectures.

Ganti, Narsim, and Brayman, William, The Transition of Legacy Systems to a Distributed Architecture, ISBN 0-471-06080-1, John H. Wiley and Sons, New York, NY, 1995. This user-oriented reference provided the Guidance document authors with two essential concepts: the problem of abstraction levels, which Ganti and Brayman related to the Zachman framework and tailored a useful developer's variation as further articulated by Ms. Cook; and the ways that transparency in a user-centric architecture can be engineered in an application architecture or corporate system and achieve strategic information technology characteristics described by Boar and others. The Guidance document authors adapted these concepts in the current Guidance document in the section concerning minimal design characteristics and the principles related primarily to users.

Jones, Caper, "Strategies for Managing Requirements Creep," IEEE Computer, Volume 29, Number 6, June 1996, pages 92-94. This journal article describes an approach for isolating stimuli for requirements changes, relating changes to function point metrics, and how these changes can be managed to increase the rate of change deployment. The discussion outlines how the rate of creep can be measured and possibilities for either reducing the rate or increasing the pace of change.