

# An Enterprise Information Architecture: A Case Study for Decentralized Organizations

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## Abstract

*As enterprises become increasingly information based, making improvements in their information activities is a top priority to assure their continuing competitiveness. A key to achieving these improvements is developing an Enterprise Information Architecture (EIA). An EIA can be viewed as a structured set of multidimensional interrelated elements that support all information processes. The current ad hoc EIA in place within many enterprises can not meet an organization's future needs because it has an incoherent framework, incompatibilities, missing elements, few and poorly understood standards, uneven quality and unnecessary duplications.*

*This paper discusses the EIA developed at Lawrence Livermore National Laboratory as a case study, for other information based enterprises, particularly those with decentralized and autonomous organization structures and cultures. While the technical architecture is important, the organization and processes by which it is developed and sustained over time are equally important. This paper outlines the motivation for an EIA and discusses each of the interacting elements identified. It also presents an organization structure and processes for building a sustainable EIA activity.*

## 1. Introduction

Lawrence Livermore National Laboratory (LLNL) is an applied science laboratory whose primary missions are in national security, energy and environment, and bioscience and healthcare. Each of these involves many sub areas of interrelated science and technology. These activities and

the business processes that support them depend centrally on the use, creation, sharing and exchange of information. It is estimated that LLNL spends approximately one quarter of its billion dollar per year budget on computer, communications, and information activities. While many of these are world-class, improvements can provide strategic advantages, increase effectiveness, and reduce costs.

One key to achieving these improvements is developing an Enterprise Information Architecture (EIA). An EIA provides the framework for planning and implementing a rich, standards-based, digital information infrastructure with well-integrated services and activities fostering:

- Easier information sharing and exchange
- Improved security and privacy
- More effective response to customer requirements through easier and faster building of information services
- Increasingly effective matrix organization structure because of the use of common information services, resources, and tools
- Easier sharing with collaborators outside the Laboratory through wider use of industry standards
- Easier incorporation of outside vendors within chains of needed capabilities and better integration with the rest of the DOE Complex, academic community, and industry
- Lower overall institution-wide EIA-related costs.

Cook [2] points out that a prime purpose of an EIA is as a framework to develop standards and that resistance to developing and implementing an EIA and its associated

standards is to be expected. This resistance is particularly to be expected in a diverse decentralized organization, like LLNL, with a long history of autonomy among its major organizational elements. Therefore, as important as are the technical aspects of an EIA, close attention must also be paid to the organizational change and learning issues such as represented in references [1,2,4,6,10].

Kotter offers a concise list of issues (which we refer to in the paper as Kotter issue (x)) that need to be taken into account: (1) establish the urgency of the task, (2) create a guiding coalition, (3) develop a shared vision and strategy, (4) communicate the change vision, (5) empower employees for action, (6) generate short term wins, (7) consolidate the gains, and (8) anchor the new approach in the culture [6]. Senge adds that along with the vision one needs a clear understanding of the current state to provide the creative tension with the vision to drive the change [10]. We indicate below where the above issues are dealt with in our approach.

Another way to view the importance of an EIA is offered by Boynton et al, namely that it serves as a key framework to increase an organization's technology "absorptive capacity"[1]. An EIA is an effective organizing framework for acquiring, organizing, and prioritizing a wide range of technological knowledge and facilitates the ability to effectively and appropriately apply it.

When examining the current LLNL *ad hoc* EIA the Chief Information Officer (CIO) recognized the urgency (Kotter issue (1)) and obtained senior management commitment to deal with several critical challenges:

- There is no organization or process for creating and sustaining an EIA
- There are few standards
- There are no mechanisms to tap the laboratory's breadth and depth of knowledge and skills on which an EIA depends
- Changes in digital technology occur faster than our ability to bring new products and services to the workplace.

To develop the base EIA an Enterprise Information Architecture Committee (IAC), with senior staff and management representation from all major organizations, was established by the CIO, under the author's chairmanship as the guiding coalition (Kotter issue (2)), with four goals:

1. Develop an EIA model based on a shared vision and principles that can serve as the framework for EIA planning, communication and standards setting (Kotter issues (3) and (4)).
2. Describe (a) the current state of the Laboratory's *ad hoc* EIA, (b) the desired future EIA that meets the vision and principles, and (c) the gap between them (Senge's need for creative tension between vision and current state).
3. Recommend activities that can begin closing the gap, particularly those for achieving short term wins (Kotter issues (6) and (7)).
4. Recommend an EIA stewardship organization and process that implements the model, sustains its evolution across decades, and involves the Labwide community (Kotter issues (2), (5), and (8)).

### **1.1. The LLNL View of an Enterprise Information Architecture**

Developing an EIA is widely recognized as an important activity and numerous papers and other material have been published in print or on the Web. The few we found most useful are listed in the references, particularly [5,8]. A commonly recommended approach is to start by examining the enterprise's business goals, processes and information assets. In this approach one develops an EIA by first creating common enterprise business and data models [2,3,4,12]. After searching for and failing to find successful examples of applying this approach to comparable decentralized organizations we decided to take the approach described in this paper, which extends the work in [8]. Our resulting contributions are threefold: (1) developed a concise representation of the EIA requirements, (2) identified key EIA elements and developed a concise iconic representation of their relationships, and (3) developed an organization structure and processes that engages the enterprise as a whole. It is these that are the focus of this paper.

### **1.2. The Enterprise Information Architecture Requirements Represented as Vision, Principle and Strategic Objective Statements**

We collected an extensive set of requirements from all the Laboratory's organizations and then boiled them down

into concise, easy to communicate and understand forms we called vision, principle and strategic objective statements [7]. Several of these represent significant shifts from current practice.

**1.2.1. Vision Statement.** Easy access to the right information, for the right people, at the right time, in the right place, and at the right cost.

**1.2.2. Principles Statements.** The seven EIA Principles are:

1. Information is an institutional asset
2. The EIA is the preferred framework for doing business at the Laboratory
3. LLNL-wide access to information is the rule, not the exception
4. The EIA supports ease of use
5. Ownership and stewardship are well defined for all information
6. Information is safeguarded on a risk-defined basis
7. The Enterprise Information Architecture is an evolving framework.

**1.2.3. Strategic Objective Statements.** From the Principles, we derived EIA Strategic Objectives:

- All information assets will be integrated when appropriate.
- There will be only one official source for each asset.
- Information capture and validation will be done at its source.
- The information assets shall be readily accessible and available to the ultimate point of use.
- Dissemination, access and user self-service is supported for scholarly, scientific, engineering and business information.
- The safekeeping, storage, retrieval and preservation of our information assets are paramount.
- The extension of information services to the enterprise user's desktop supports the needs of all LLNL staff.

- The extension of information services to all our external customers and partners is desired, where appropriate.
- The continual planning, improvement, and innovation for reliability, availability, serviceability and performance of the information utility is supported institutionally.

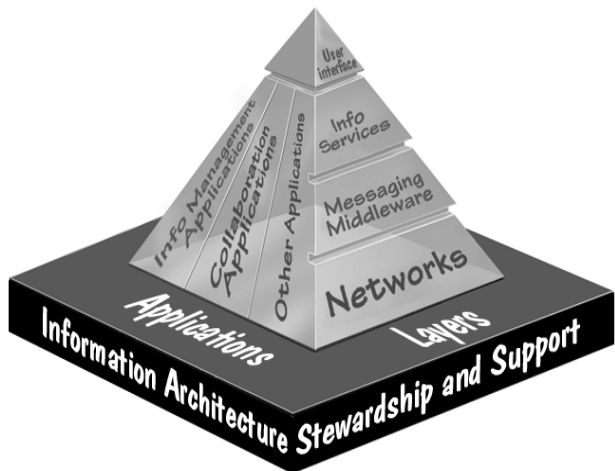
## 2. Overview of an Enterprise Information Architecture

### 2.1. Pyramid Representation

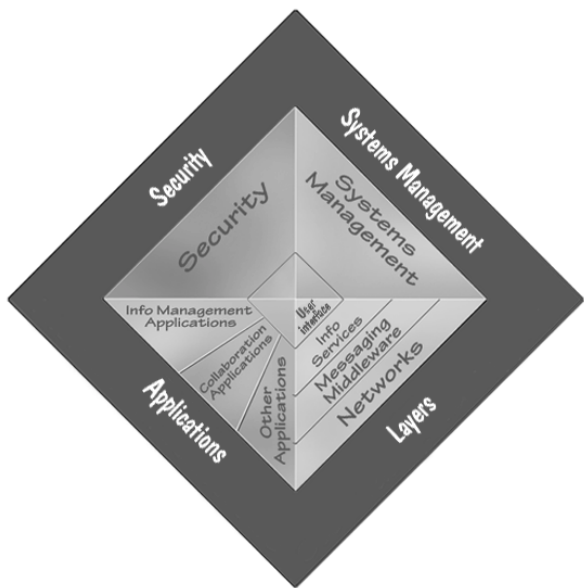
As the work of the IAC proceeded, it was critical to identify the key architectural elements and understand their relationship to each other. It was also important to represent them in a way that they could be easily communicated to and understood by LLNL management and staff. We also used this representation to organize into working groups for each element.

The EIA is viewed as a structured set of interrelated elements, represented as a pyramid, that support all information processes. The pyramid representation was chosen because four faces seemed as many as could be easily grasped, it allowed the main elements to be represented, the shape helped emphasize the projected relationships among the faces and layers, it emphasized the importance of the stewardship activities in the base, and pointed to the customer's desktop at the top. As the architecture is fleshed out, detailed requirements are being developed for the various elements. An example of going to the next level of detail is shown in fig. 2 for information management. The relationship of the elements to the ISO networking protocol stack is mentioned for each element [11] and excellent introduction to many of the elements is contained in [9].

**2.1.1. Layers.** Layers represent important elements that build on each other. Each of the application and infrastructure domains represented on the other three pyramid faces requires services from each of the layers: Network, Messaging and Middleware, Information Services, and the User Interface/Desktop.



**Figure 1 (a) . Interrelationships of EIA elements: Applications and Layers comprise two faces with EIA Stewardship and Support as the base on which the pyramid rests.**



**Figure 1(b) . Top view also shows the Security and System Management faces.**

**2.1.2. Network.** The first or network layer contains three sublayers, corresponding to ISO layers 1-4: (1) all

the wiring and fibers and their interconnection topology, (2) electronics for routing and other functions, and (3) the communication protocols necessary to transfer uninterpreted bytes of information between two or more computer systems or devices. This layer includes remote and local communications, including Internet access. Experience suggests that the first two sublayers are particularly important for network reliability, security, ease of maintenance and management, scalability of performance, and cost effectiveness. Network services can only deliver the reliability, security and performance that are provided by the physical infrastructure.

**2.1.3. Messaging and Middleware.** In any enterprise network, above the network transport (e.g., TCP/IP), and underneath any specific set of information services or desktop platforms, there is a layer we call the Message and Middleware (M/M) layer, corresponding to ISO layers 5,6 and lower portions of layer 7. M/M technologies are the glue that provides for transparent, secure information connectivity and integration at several levels of the infrastructure.

The M/M layer has three intimately related sublayers:

1. Information content formats for storage, display and exchange that are increasingly based on industry standards. Examples include HTML, PDF, RTF, JPEG, MPEG, GIF, MIME, netCDF, the emerging use of the XML/SGML formats, and others.
2. Session, presentation, and application layer protocols are based on industry standards. Examples include SMTP, POP3, and IMAP4 for e-mail, LDAP for directory services, NNTP for threaded newsgroup discussions, HTTP for Web interfaces, SNMP for network management, IIOP for remote service request and replies, X.509 for security using public key infrastructure, JDBC/ODBC for data management, and many more.
3. Common run-time services that support distributed applications, such as directory and naming services, transaction services, security services such as certificate authorities, and the object request brokers (e.g. of the CORBA model) for connecting components. These services are implemented software systems

providing general purpose common services to various applications.

**2.1.4. Information Services.** It is assumed in the EIA that both a standalone set of desktop services and a client/server architecture are supported. A server role provides services; a client role makes service requests of the servers. The Information Services layer of the architecture consists of the server side of applications (ISO layer 7). Examples of services at this layer of the architecture are the POP e-mail servers, HTTP-based Web servers, and Meeting Maker calendaring and scheduling servers, database and document servers, and servers that support business operations and programmatic applications. Two important Application Domains with broad Labwide use, Collaboration and Information Management—and the Information Services layer associated with them—are discussed below. Even though details of what is in this layer are driven by the other pyramid faces, its existence and the need for corresponding standards needs to be made explicit in the model.

**2.1.5. Desktop (User Interface).** The Desktop layer represents the user interface with the rest of the architecture (ISO layer 7). We broke the user interface discussion into general desktop support and Web issues (in general the Web technology spans all the layers). The Web-enabled desktop offers the potential for a standardized user interfaces for both scientific and business applications, whether the application is purchased or developed in-house. The desktop layer includes whatever system is most appropriate to access needed information services (e.g., laptops, mobile hand-held devices, or possibly a kiosk for users who do not normally work with computers).

**2.2. Application Domains**

The applications side of the pyramid represents all applications of interest. Important classes of intersecting applications include collaboration tools such as e-mail and calendaring and scheduling, information sharing tools such as document repositories or databases, and all the business and programmatic (scientific and engineering) applications. To understand how all the layers work together with the applications, consider two concrete examples: e-mail and online document access. Some of

the various clients, servers, and protocols of interest at each layer are shown in Table 1.

**Table 1. Standards in EIA layers for collaboration and information access applications.**

Layers	Applications	
	E-mail (Collaboration)	Online Access (Information sharing)
Desktop	Eudora Clients	Netscape Browsers
Information Services	Pop Servers, Ph servers	Online document repositories in TID
Messaging	SMTP, POP3, IMAP, MIME	HTTP, HTML, PDF
Network	TCP/IP, Internet and LabNet	

**2.2.1. Collaboration Applications Domain.** Computer-aided collaboration support, also called groupware, is the broad, somewhat fuzzy area consisting of computer systems that enable two or more individuals to work together more effectively.

Electronic mail is the most widely understood kind of groupware, but there are other groupware paradigms identified for future study shown in Table 2.

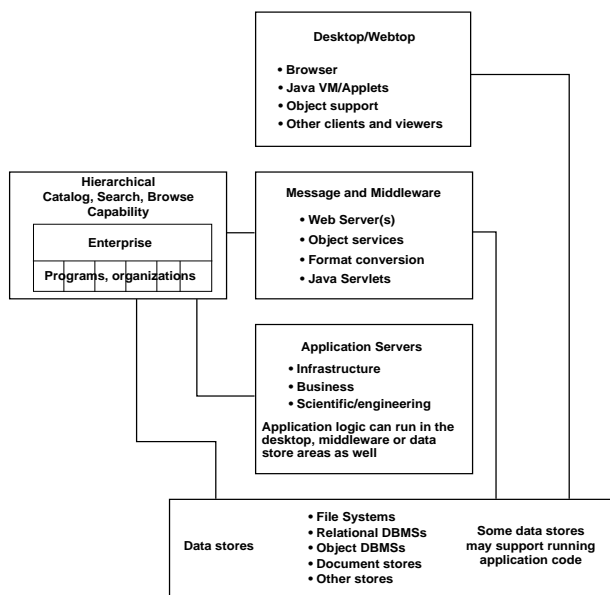
**Table 2. Groupware paradigms.**

	Same Place	Different Place
<b>Same Time (synchronous)</b>	Meeting Support Systems	Chat Shared Whiteboard Audio/Video Conferencing
<b>Different Time (asynchronous)</b>		Electronic Mail (e-mail) Calendaring and Scheduling Electronic Forums (discussion lists, newsgroups) Multiple Authorship Support Document Management, Electronic Library Workflow applications (e.g., purchasing)

**2.2.2. Information Management Application Domain.** The information management application domain is an important driver for an Enterprise

Information Architecture. AT LLNL we estimate that scientists spend 20–40% of their time searching for and gathering information and we expect the percentage is similar for those who work with business and other information. Clearly other applications need to leverage or connect to the capabilities for information management. We examined several information management systems both within and without the Laboratory and abstracted the high level model shown in Fig. 2 to focus standards activities.

With this model we identified areas in the desktop, information services (e.g., applications and datastores), M/M, and security areas where enterprise standards would be helpful. Of particular importance we identified (1) the need for an enterprise wide catalog system that allows other catalogs developed independently to be integrated, (2) the need for document management system standards, and (3) the need to develop an inventory of information assets [7].



**Figure 2. High-Level Information Management Model.**

**2.3. Unclassified Security**

At LLNL all classified information and associated processing and other resources are on a separate network, which is not connected to the outside world. The architecture considered here is for unclassified information.

The Security/Privacy side of the pyramid spans all the layers and interacts with the Applications and System Management sides. The architecture needs to provide perimeter defenses such as firewall systems, strong authentication and encrypted access from the outside; defenses in depth on local area networks and end systems, such as layers of intrusion detection and reaction procedures and mechanisms, and controlled system administration; and services to applications such as public key infrastructure, strong authorization, and encryption services.

**2.4 System Management**

The final face of the pyramid shown in Fig. 1(b), System Management, similarly requires services from the layers and interacts with the Applications and Security faces. It represents all the services needed to manage, troubleshoot, and debug applications as well as to maintain the services specific to a given layer. For example, consider automatic distribution services for keeping the software on the desktop up to date. This requires client mechanisms in the user interface, software repository and updating services, agreement on message formats, security mechanisms, and so forth. Within a given layer, such as the network layer, system management provides the facilities needed to detect and isolate the wiring and electronics faults, keep routing tables up to date, support the movement of staff to new office locations, and many others.

**2.5 Human Activities—the Base of the Pyramid**

The base of the pyramid, shown extended, represents the human activities required to support all aspects of the EIA, such as stewardship of its evolution, day-to-day operation of all its services, and its use. Setting up an organization and processes for enterprise wide interaction and stewardship issues is crucial for long term success and discuss this aspect in more detail below. It is here that

Kotter's issues outlined earlier must be carefully dealt with [6].

### 2.6. Data and Information—the Interior of the Pyramid

Data and information are required in order to support all aspects of effective and efficient use of information—generation, storage, access, presentation, sharing, manipulation and transformation, interchange, management/administration, and security. In terms of Fig. 1, we can visualize information as residing within the pyramid. System data and metadata is associated with every layer, while data and information the user directly cares about (such as e-mail, documents, or business/programmable information) are managed by the information services layer, created and interpreted by applications and accessed by the user interface/desktop layer. It is within this volume, associated with the appropriate layers and sides that various data architectures need to be developed. These will consist of standard data types, structures and models useful across the enterprise.

## 3. Enterprise Information Architecture Stewardship Organization and Processes

The EIA Stewardship process and organization shown in Fig. 3 are discussed below.

### 3.1. EIA Stewardship Organization

Because the EIA is a Laboratory-wide activity, there are a number of roles and organizations involved in its stewardship shown in Fig. 3. The organization names in the Line Organization, Working Group, and Special Interest Group boxes are representative of the types of groups involved. There are two main roles in standards stewardship: (1) stewardship of the standards themselves, which is the responsibility of the Stewardship Body, and (2) implementation and operational support, which is the responsibility of the line organizations.

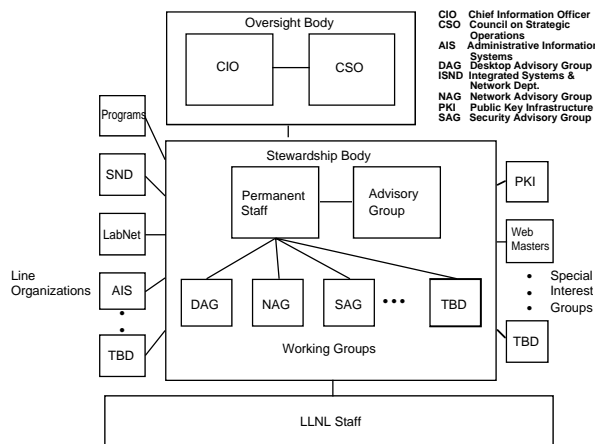


Figure 3. EIA Stewardship Organization.

**3.1.1. EIA Stewardship Body.** The Stewardship Body, the ongoing guiding coalition, consists of a small permanent staff (~4 people), an EIA Advisory Group representative of EIA stakeholders from across the Laboratory, and a set of permanent and temporary working and technical advisory groups responsible for EIA standards stewardship and special studies. The charter of the Stewardship Body is to provide the stewardship of EIA standards and process and manage the EIA activity on an ongoing basis.

The Stewardship Body:

- Assumes stewardship of the EIA Vision and Principles. Should these need updating in the future, the Stewardship Body coordinates that process with the Oversight Body and LLNL staff, and might utilize the RFC process before adopting modifications.
- Coordinates and drives the process of proposing, refining, and adopting the architecture and its associated body of standards as they evolve.
- Interacts with LLNL staff and management on a regular, ongoing basis to ensure the EIA is meeting business and programmatic needs; fosters the exchange of ideas and information in both directions; and coordinate tech watch activities, such as gathering information on emerging technologies or conducting limited-scale pilot/proof-of-concept projects.

- Interacts with LLNL's institutional information service providers who provide the day-to-day operational support of the EIA and related activities to ensure the exchange of ideas and information and to promote Labwide cooperation and leveraging of one another's activities.

When a standard or other EIA service is established, a working group needs to be identified or formed for its ongoing stewardship.

**3.1.2. Oversight Body.** The EIA Oversight Body depicted in Fig. 3 is composed of the CIO, and other senior Laboratory managers on the Council for Strategic Operations. The Laboratory CIO has the senior management responsibility for the EIA. This includes activities such as final concurrence or approval for all EIA standards, strategic direction, and budget. The Council for Strategic Operations provides an advise and consent role to the CIO on high level EIA policy, direction, and funding.

**3.1.3. LLNL Staff.** The LLNL staff is made up of all Laboratory employees. All members of the staff can participate in the Stewardship process by exchanging ideas with the Stewardship Body about any aspect of the architecture. Although a great deal of technical expertise resides in the Stewardship Body, particularly the working groups, we recognize that much real work in information systems development and utilization is performed in the Laboratory's organizations and projects. Customer perspective, customer needs, and appropriate input regarding cost effectiveness can only come from the staff at large.

**3.1.4. Line Organizations.** The implementation of the standards and other EIA services and their day-to-day support is the responsibility of line organizations such as those shown in Fig. 3. When a standard or other EIA service is established, one or more groups need to be identified and funded for its implementation and ongoing support.

**3.1.5. Special Interest Groups.** Special Interest Groups are constantly forming and dissolving to deal with issues around new areas of technology and share experiences. This process is encouraged. Because these groups are sources of expertise and suggestions for additions and modifications to the EIA and standards, the Stewardship Body works with such groups.

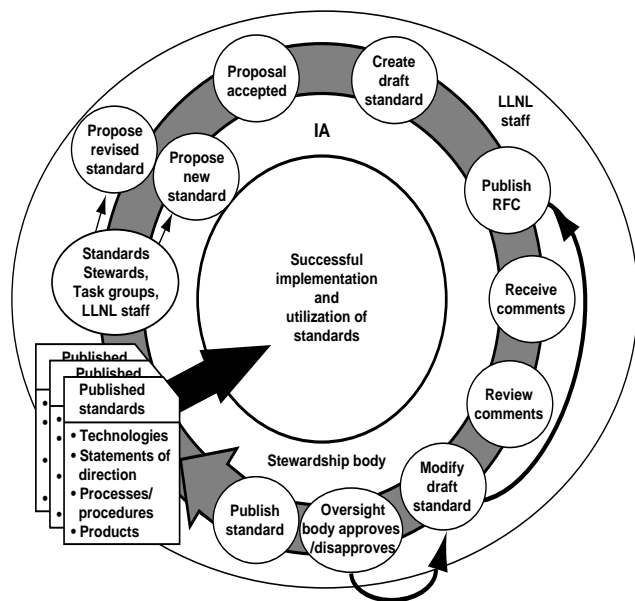
**3.1.6. The EIA Standards.** EIA Standards are of three main forms: (1) Statements of Direction provide institutional guidance toward a common goal; they are useful in procurements and system design and integration decisions, when it may still be too early to put technology or product standards in place; (2) technology and product standards that may include both industry and product standards; and (3) procedure or process standards. It is assumed that policies for security or other functions may also employ the processes of Fig. 4 if appropriate.

## 3.2. Standards Process

The EIA Standards Process depicted in Fig. 4 is a crucial element of the Enterprise Information Architecture. It is the means by which informed decisions are made and broad consensus reached on standards that drive Laboratory information practices. Standards emerge in two ways. First, there could be an exploratory phase in which ideas are exchanged, and experimental/prototype/technology demonstration activities are conducted. Alternatively, new or updated standards may be proposed through other mechanisms—the steward of a standard may put forth a revised version, or any staff member can propose a standard at any time. In any event, when a new or revised standard has been proposed, the Stewardship Body will examine it. The Stewardship Body can reject the proposal because it fails to meet one or more of the criteria for standards listed earlier.

If a proposed standard is judged worthy of further consideration, because it supports the vision, principle and strategic objective statements, it is passed through a Request for comments (RFC) process, used successfully for almost three decades in the Internet community. A formal RFC activity is conducted for each proposed standard (Fig. 4).





**Figure 4. The EIA Standards Development and Review Process.**

#### 4. Summary

We have described a high level framework for an EIA and the support organization and processes that we think are appropriate for many organizations, particularly for those with decentralized, autonomous cultures and organization structures. The three key elements include: (1) capturing the requirements in concise, easy to understand and communicate vision and principle statements, (2) identifying key EIA elements and their interrelationships and in an iconic diagram, and (3) specifying an enterprise-wide organization structure and processes for the EIA's development, implementation, support and ongoing evolution.

Our status is that: (1) the EIA has been widely discussed with staff and management (although much more is required); (2) strong management commitment has been obtained represented by the allocation of staff to the task and advisory groups and by the significant funding obtained to launch the Stewardship Organization; (3) active task and advisory groups, with widespread laboratory participation, have been established for the Desktop, Web, Network, Security elements; (4) initial explorations have been started in the information management area for catalog metadata and document

management standards; and Desktop, collaboration, Web and related M/M and Information Service standards have been put in place. Implementing the unclassified security architecture recommended by the Security Task Group has very high priority. Much work remains to be accomplished to realize the EIA described in this paper and [6]. We recognize that the funding, development, implementation and cultural change required is an ongoing multiyear process.

#### 5. Acknowledgements

The work reported here is the result of the contributions of over 60 people from across the Laboratory who participated in the IAC and the task groups associated with each element shown in Fig. 1. These people interacted with many more within their organizations. The chairs of the task groups deserve special mention for pulling together the current state, desired future state, gap and recommendations for each element: Dave Wiltzius, Networks and Stewardship processes; Rob Allen, Collaboration and Message/Middleware; Barbara Campbell, Desktop; Ted Michels, Web; Barry Howard, Security; Dave Seibel Vision and Principles. Carol Hunter played an important role as Cochair of the IAC until other priorities claimed her attention. We want to acknowledge our colleagues at Los Alamos National Laboratory (LANL) whose EIA work was of most influence on ours [8], particularly the helpful interactions with Diane Weir the LANL EIA project manager.

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